ENVIRONMENTAL ASSESSMENT REPORT

Oil Search

PNG BIOMASS

VOLUME 1:
MAIN REPORT

PNG BIOMASS
MARKHAM VALLEY

MARCH 2017
Report No. 01183B_2_v2

ERIAS GROUP

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Markham Valley Biomass Limited

PNG Biomass Markham Valley

Environmental Assessment Report

Volume 1 – Main Report

ERIAS GROUP

March 2017
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Executive Summary

1. Introduction

Oil Search Limited (Oil Search/OSL), through its wholly-owned subsidiary Markham Valley Biomass Limited (MVB)[1], proposes to develop the PNG Biomass Markham Valley project (hereafter referred to as 'the Project') in Morobe Province, Papua New Guinea (PNG). The Project area (also referred to as Area A) is located in the Markham Valley, about 50 km west-northwest of the provincial capital Lae (Figure ES1).

The Project is a response to a call from PNG Power Ltd (PPL) for an Independent Power Producer (IPP) to generate 30 to 40 MW of power near Lae, and reflects the requirements of a 25-year Power Purchase Agreement (PPA) that was executed with PPL on 15 December 2015. The Project will address, at least partially, the current inability of the Ramu grid to provide reliable power, and the PNG Government's long-term objective of increasing the availability of reliable and sustainable power supply at a reasonable cost. Power generated by the Project will provide reliable baseload power to households, industries and resource projects on the Ramu grid, which runs from Lae and Madang in the east to Mt Hagen and Mendi in the west.

The Conservation and Environment Protection Authority (CEPA) advised MVB that the Project would be classified as a Level 2 (Subcategory 10.2) activity. Subcategory 10 relates to energy production, specifically:

> 10.2. Operation of fuel burning power stations with a capacity of more than 5 MW, but not including emergency generators.

As such, and in accordance with the relevant CEPA operational procedure, the Project prepared the following:

- Environmental assessment (EA) report, reflecting the findings of baseline environmental and social studies, and impact assessment.
- Environmental management plan (EMP), developed on the basis of the environmental risks posed to the identified environmental values, as well as mitigation and management measures required to minimise those risks.

Other associated and subsidiary Project activities also classified as Level 2, including the plantations, will be permitted under the umbrella of the approvals pursued for the main Level 2 activity.

[1] The entity name of Markham Valley Biomass Limited (MVB) will be changed to PNG Biomass Limited. However, for the purposes of this report, the former will be used. This EA report applies to the activities of both MVB and its subsidiary Markham Valley Power Limited (MVP).

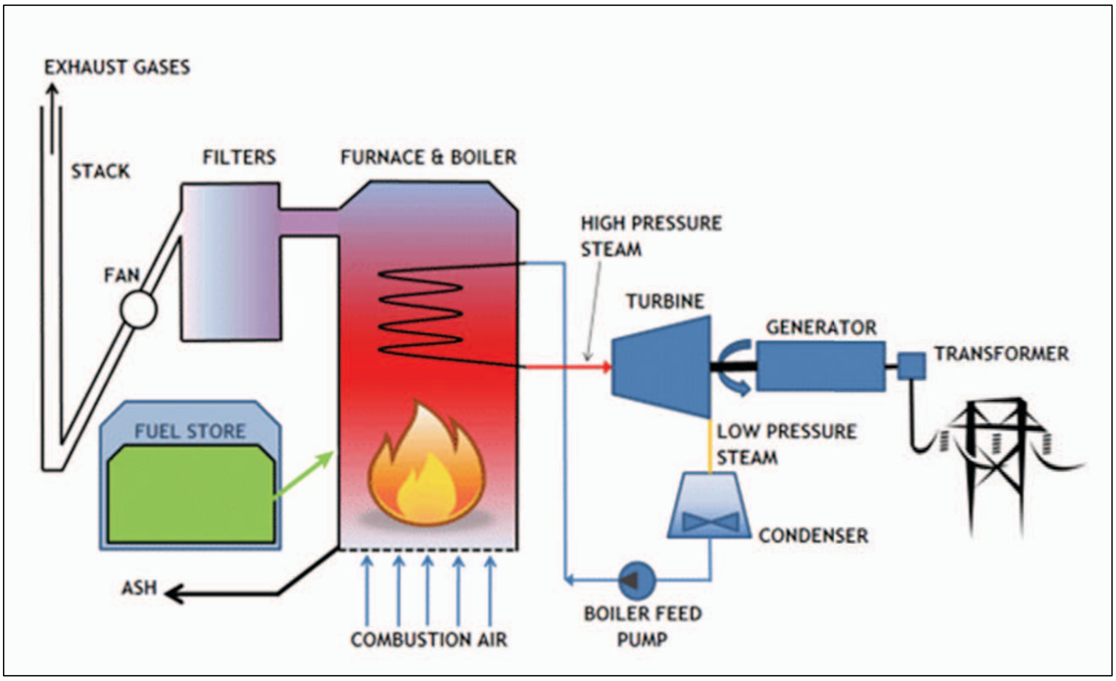
Figure ES1 – Project Area Location

2. Project Description

The Project has two components: the establishment of up to 16,000 ha of sustainably managed eucalypt plantations, and a biomass-fuelled power plant consisting of two 15 MW units, with the preferred power plant site being located in the southeast of the Project area (see Figure ES1). Construction of the power plant and related infrastructure, and development of the plantations, will occur over several years. Plantation development will be supported by road upgrades and/or construction, and a development of a large plant nursery. Plantations will be harvested every 7 to 9 years to provide about 175,300 BDMt/yr (bone dry metric tonnes of biomass (wood) per year).

The combustion of dry biomass, i.e., woodchips supplied from the dedicated plantations, will generate steam from water sourced from bores or, if required, the Markham River. This steam will drive steam turbine generators (Plate ES1), thereby generating electricity that will be transferred directly to the nearby high voltage Ramu grid transmission system.

Plate ES1 – Biomass Power Plant Schematic



Source: AEL, 2016d.

3. Project Schedule

Key dates in the Project's schedule are:

- Power Purchase Agreement (PPA) finalised – Q4 2015.
- Environmental assessment (EA) report and environmental management plan (EMP) submitted to CEPA – Q1 2017.
- Environment permit issued by CEPA – Q3 2017.
- Initial 3,000 ha of plantation established – Q4 2017.
- Power plant commissioning (first 15 MW unit) – Q4 2019.

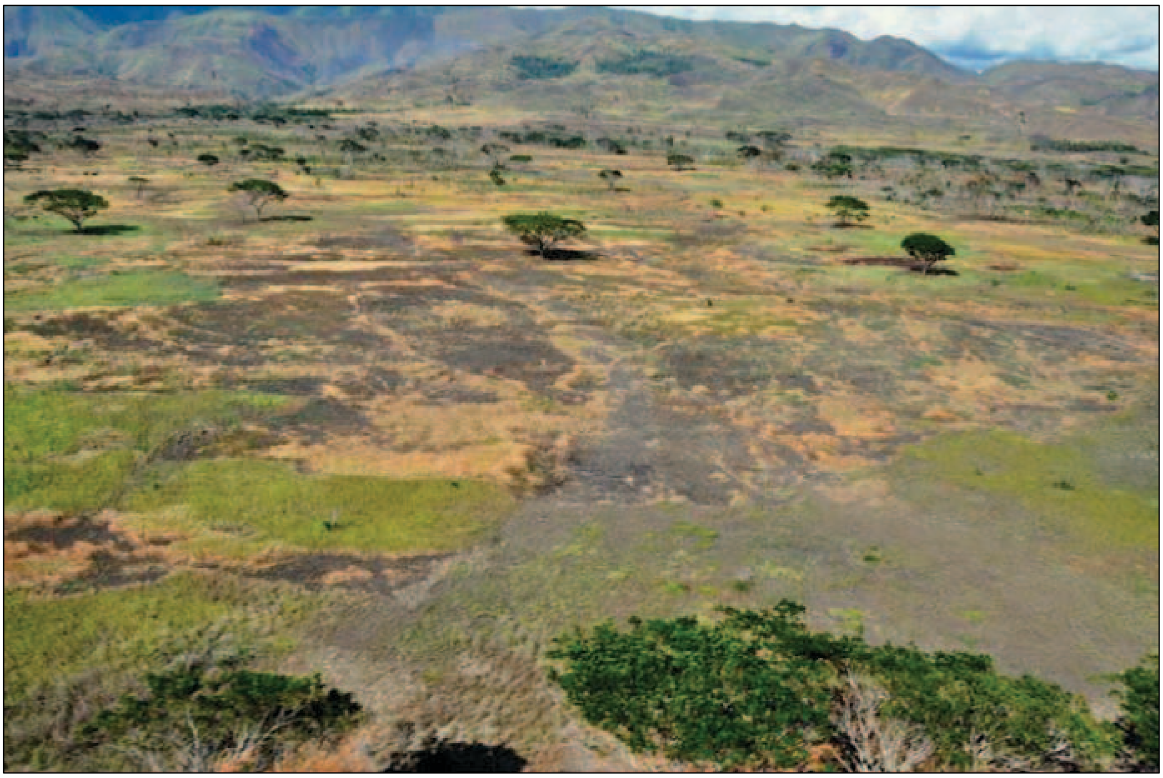
4. Project Setting

4.1 Physical Environment

The Project area is situated on broad, flat alluvial plains (Plate ES2) associated with the Markham River and its tributaries, where the river flows in a generally west to east direction and forms the area's southern border (see Figure ES1). The area itself straddles the northern floodplain of the Markham River between Leron and Nadzab, and encompasses the Leron, Erap, Rumu and Maralumi sub-catchments.

The geology of the Project area is relatively young, deep Quaternary alluvial fan deposits, consisting of rounded coarse gravels, sand and silt laid down during both the Pleistocene and Holocene periods. The area is seismically active.

Plate ES2 – Flat Plains of the Markham Valley Backed by the Saruwaged Range



Source: Pöyry, 2012.

Soils vary across the Project area but are generally deep alluvial deposits consisting of well to imperfectly drained, undifferentiated soils subject to seasonal moisture stress due to low water holding capacity.

The Project area has a tropical climate with distinct wet (October to April) and dry (June to August) seasons. Annual rainfall, which is in the range of 1,200 to 1,400 mm, varies considerably between years and between different locations within the Markham Valley. Mean annual maximum temperature in the Project area is around 31°C, with the coolest months being June to September. Wind speeds are generally light to moderate, most frequently from the east and associated with the southeast trade winds from May to October.

The Markham River is braided along its entire length, with the braids, islands and bars of the river channel continually changing. The four sub-catchments in the Project area consist of very steep headwaters, draining onto flat alluvial fans, which is indicative of very high sediment loads. However, in addition to sediment-rich and turbid waterways, a number of smaller clearwater streams appear to originate downslope of the fans produced by the high-energy headwater streams.

Water quality in the Project area is generally consistent with similar watercourses elsewhere in Papua New Guinea, i.e., generally good quality water in terms of maintaining aquatic ecosystems and providing drinking water for local communities, but with elevated suspended solids concentrations in some rivers and elevated faecal coliform levels at most sites. Similarly, sediment quality is consistent with other similar watercourses in Papua New Guinea, and is indicative of generally good sediment quality in terms of maintaining aquatic ecosystems.

Groundwater in the area comprises two main types, i.e., deep (4 to 70 m) and shallow (0 to 3 m). The water table fluctuates seasonally and reflects rainfall patterns with a delayed response time, with recent data indicating a maximum increase in groundwater depth during the dry season of a little more than 2 m. Groundwater quality is 'fresh', i.e., total dissolved solids (TDS) levels are less than 500 mg/L, with generally alkaline or near-neutral pH values. Hardness is variable, ranging from soft through to very hard, with the latter being more common.

Background air quality is expected to be generally good with negligible concentrations of gaseous pollutants. Potential particulate matter air pollutants are expected to be low, although not negligible. The ambient background noise levels are expected to be consistent with insects, heavy rain, birds, domestic animals, wind noise in foliage, and typical village domestic activities.

4.2 Biological Environment

The Project area is dominated by vegetation in a degraded, highly modified condition, with natural vegetation being an extremely limited component of the landscape. No intact vegetation was recorded during a terrestrial ecology survey of the area. No Kunai grassland habitats within the Project area are considered to be in a natural condition due to the importance of anthropogenic influences in the origin and maintenance of such grasslands. No critically endangered or endangered flora species have been detected and none are considered likely to occur. Furthermore, no habitat areas of significant importance to endemic or restricted-range species were identified and there is no evidence to suggest that habitats support key evolutionary processes, most of which have been substantially modified by repetitive anthropogenic disturbance. No forest in the Project area qualifies as High Conservation Value Forest.

The Project area has four main terrestrial fauna habitat types: alluvial forest and woodland; grassland; watercourses and wetlands; and highly disturbed anthropogenic habitats. A field survey recorded a total of 89 terrestrial vertebrate fauna species, and discussions with local informants identified at least a further 10 mammal species, eight bird species and five reptile species that are likely to occur in the Project area. Anabat detectors identified the presence of eight microbat species. However, no threatened or near-threatened terrestrial vertebrate fauna species have been detected and no threatened or near-threatened species are considered likely to occur in the area. Two introduced fauna pest species, the giant African snail (*Achatina fulica*) and cane toad (*Bufo marinus*), were common throughout the area surveyed and were the only fauna species trapped.

Four broad aquatic habitat types have been characterised within and near the Project area that reflect factors including watercourse bed structure, sediment loads and hydrology. Fish species are characteristic of lowland rivers and tributaries in northern Papua New Guinea, with fish species richness (16 species total) being within the range recorded in previous surveys in the Lower Watut and Markham rivers (11 to 21 species). The generally reduced diversity of in-stream and off-river habitats, and the turbid and semi-ephemeral nature of streams in the Project area (Plate ES3), are expected to limit fish species diversity, although it should be noted that the clearwater streams (Plate ES4) had a higher diversity of aquatic fauna and are considered 'sensitive areas' at the scale of the Project area.

Plate ES3 – Rumu River

Source: Appendix 7.

Plate ES4 – Klin Wara

Source: Appendix 7.

Introduced fish species dominated at a number of sites, and introduced exotic and translocated fish species represent a major stressor on the system.

4.3 Socio-economic Environment

The Markham Valley, within which the Project is located, runs through the centre of Morobe Province. The province is one of the three most populated provinces in Papua New Guinea and contains almost 9.3% of the country's total population (674,810 persons in the 2011 census), and is headquartered in Lae. The Project is located within the Wampar Rural Local-level Government (LLG) area of the Huon Gulf District. The Highlands Highway connects the Project area and Lae, and has a network of smaller feeder roads. The proposed power plant site is located about 10 km west of Lae Nadzab Airport.

The Project area includes five communities – Chivasing, Tararan, Bampu, Kokok and Nowa – and is inhabited by a single ethnic group, Wampar, with a language group of the same name. Wampar social organisation is based around membership of clan (*sagaseg*) and patrilineal lineage groupings, dictating land ownership and use rights. Nine clans have been identified in the Project area, although each Wampar village has a multi-clan composition. Houses within the communities are primarily constructed of traditional materials and the majority of people cook with wood fires.

Most Wampar people maintain gardens that supply food for their families (Plate ES5); sago is the most important staple food not grown in garden plots. In addition, extensive use of other natural resources occurs, with activities including foraging, hunting and fishing. Village chickens and pigs are kept for sale and self-consumption (particularly on special occasions), and some families raise cattle (for meat) and horses (for riding). Processed foods are also purchased.

Communities rely on the sale of agricultural products and trade store ownership as their main sources of income. Cash income levels in the study area are generally high to very high by rural PNG standards, although disparities occur between communities due to their proximity to key trade markets (Plate ES6) and other services, as well as within communities where disparities reflect different levels of access to agricultural land. Commercial activities relating to agribusiness/capital agriculture are constrained by the fact that most land within the Project area has low agricultural potential caused by poor soils, low (within the PNG context) average annual rainfall, a long dry season, and frequent inundation in floodplain areas. Few people participate in formal employment activities and financial literacy rates are low.

Plate ES5 – Mixed Garden Crops and House in Bampu

Source: SIMP, 2017.

Plate ES6 – 40 Mile Market

Source: SIMP, 2017.

Health concerns are consistent with other areas of rural Papua New Guinea. Health-related infrastructure is available within the Project area and these services adequately support communities with more-serious cases treated in Lae. A number of elementary schools are located within the Project area, as well as five primary schools and a national high school. Formal education levels are similar to the PNG average, although female attendance in later years is higher than the national average. Other services that concern matters such as law and order, banking and various urban facilities are available to varying degrees either in the Project area or in Lae.

As a result of over a century's exposure to mission activity, many of the Wampar are converts to various denominations, although traditional beliefs in malicious spirits and agencies (*masalai*) persist, as do traditional beliefs about sorcery and angry ancestral spirits as the source of sickness and death. Sixty two cultural heritage (oral tradition) and archaeological sites have been identified in the Project area, including spirit sites, former settlement sites, burial/cemetery sites, skull house sites, historic sites and archaeological (pottery) sites (Plates ES7 and ES8). None were associated with the proposed power plant site.

Plate ES7 – Historic Heritage

Source: SIMP, 2017.

Plate ES8 – Clay Pot

Source: SIMP, 2017.

5. Potential Issues

The main concerns relating to the potential impacts of the Project include:

- Project physical presence and land alienation.
- Altered land use and changes in vegetation and habitats associated with the conversion of a modified grassland environment into broad scale tree plantations, with consequent changes in local biodiversity.
- Air emissions from operating machinery and equipment, where these can include dust, combustion emissions (from wood and diesel fuel), volatile fuels, particulates from fires and other fugitive emissions, as well as power plant stack emissions.
- Soil erosion and sedimentation from power plant construction, establishing plantations, access roads (including watercourse crossings), laydown areas, walking tracks and other areas of vegetation clearing and ground disturbance.
- Disturbance of cultural heritage and/or archaeological sites due to vegetation clearing and ground disturbance.
- Noise (and light spill) from construction works and from operating miscellaneous items of machinery and equipment.
- Use of hydrocarbons (e.g., fuels, oils) and chemicals (e.g., solvents, herbicides).
- Generation of non-hazardous waste.
- Use of surface water and/or groundwater during construction and operations, and related wastewater discharges (e.g., from the holding pond) and runoff of turbid water.
- Introduction of invasive alien species (including introduced pests and pathogens) through personnel and equipment movements, and plantation establishment.
- Major accidental event (e.g., oil spillage, vehicle collision).

Socio-economic impacts associated with the above also require consideration, as do the positive socio-economic outcomes that will result from Project development.

6. Predicted Impacts of the Project Activity

6.1 Physical Environment Impacts

Air quality and noise impacts have been evaluated by comparison of predicted (modelled) concentrations of gaseous pollutants or particulates with relevant guidelines such as those from the International Finance Corporation (IFC) or World Health Organization (WHO), or by comparison with recommended buffer distances. The results indicate that sensitive receptors, i.e., people living in the general vicinity of the power plant, will generally be unaffected. Possible exceptions are night-time noise levels at the two settlement outbuildings located less than 800 m from the site boundary, although the predicted levels will typically be similar to background noise levels. Residents in Ganef may be affected by construction traffic, but this will be minimised by trucks having to slow down to turn off the Highlands Highway. Construction activities in plantation areas, e.g., access road construction, may have some affects on villages should the separation distances be less than 350 m, in which case additional mitigation measures will be considered.

From a high level (and national) perspective, the Project itself can be viewed as a mitigation measure in terms of power generation and associated greenhouse gas emissions that are often associated with power sources. Development of the Project is estimated to avoid 145 kt CO_2 per year of emissions from an alternative diesel/heavy fuel oil power development, through carbon displacement. The actual CO_2 emissions from the Project will either be negligible with respect to national emissions or, given that some carbon from the plantations may be permanently stored in veneer and sawlogs, the impact may be positive.

Given the location of the power plant site near Lae Nadzab Airport, the possible effects of the stack plumes on aircraft were assessed. The modelling results show that, even under worst-case meteorological conditions, the plumes will have no significant effect on aircraft landing or taking off from Lae Nadzab Airport.

Changes in sediment loads to nearby surface watercourses, or changes to the form of the channels themselves, due the Project are expected to be either negligible or low. However, as noted above, the Project area contains some clearwater streams in addition to the more common turbid rivers. Protection of these streams is a priority for MVB and hence no plantations will be developed in their source areas until additional information has been obtained that will inform future management options. Other impacts on surface water quality are similarly expected to be negligible or low, due to treatment of the power plant holding pond discharge prior to release (to meet IFC effluent guidelines) and the low volume of this discharge (0.012 m^3/s) compared with flows in the Markham River (conservative low flow (10^{th} percentile) estimate of 3.38 m^3/s, mean of 236 m^3/s). Papua New Guinea ambient and drinking water quality standards in the Markham River will be easily met after the Project discharge has fully mixed with the Markham River, as will WHO drinking water guidelines. Most of the Australian freshwater guideline values will also be met, a notional exception being Cr, although the exceedance is small and, in practice, unlikely to be detectable. Bed sediment quality in the Markham River and other rivers that drain the Project area is also highly unlikely to be impacted by Project activities.

Modelling was undertaken to describe the catchment water balance and the potential effects of the plantations, taking into account a range of factors including rainfall, evapotranspiration, catchment storage and crop factors. The results suggest that in 60% of years the change in seasonal fluctuation in groundwater level will be between 0 and 2 m, with the maximum likely increase being 4.5 m, and these changes will diminish to zero within 50 m of the edge of plantations. As the study concluded, there is little cause for concern that the plantation will result in a trend of continuous decline in the groundwater, given rainfall within the historical range. However, the modelling indicated a less than optimum requirement for bore location (assuming that all of the power plant water is sourced from groundwater rather than the Markham River). The existing groundwater data will therefore be subject to additional analysis prior to construction and, if required, further investigation will be undertaken, e.g., groundwater level monitoring during construction and operation of the first 15 MW unit and updated modelling predictions. Continued focus will also be placed on flood risk in relation to the power plant, given its location on a floodplain.

Considering other possible Project-related impacts, the impact significance in relation to matters such as changes in surface hydrology, land contamination (which includes consideration of hazardous and non-hazardous material and waste), soils and visual amenity are all negligible or low (with fertiliser and fly ash additions possibly having a positive impact on soils). This is based on the successful implementation of the proposed management or mitigation measures.

6.2 Biological Impacts

Impact assessment in relation to terrestrial ecology focused on the effects of the Project on a number of key values, where these effects are primarily due to the altered land use and associated changes in vegetation and habitat. Taking into account the proposed management and mitigation measures, it was found that the Project will have negligible impacts on two plants of conservation significance (*Intsia bijuga* [Kwila] and *Cycas schumanniana*, respectively listed as vulnerable and near threatened by the IUCN Red List), and on the natural habitats in the study area that are already degraded and fragmented.

From the perspective of aquatic systems in the Project area (as well terrestrial systems), the Project is to be developed in a non-pristine area. Existing (non-Project) factors affecting these systems include introduced exotic fish species, riparian vegetation removal, agricultural land use practices (current and historical), and aggregate extraction practices in river channels. Project-related impacts, assuming the implementation of measures such as riparian buffer zones (which are integral to Project planning), are expected to be negligible with respect to the Markham River and high energy, high sediment load (i.e., turbid) streams, and low for clearwater tributaries (with due focus on the sources of these tributaries as flagged above).

6.3 Socio-economic Impacts

Assessment of socio-economic impacts that may result from the bio-physical and biological impacts of the activity is presented in the previous section in terms of, for example, degradation in air and water quality, increased noise levels, or land contamination. Impacts on ecosystem services have also been assessed, particularly in relation to provisioning services such as food from hunting, crop cultivation, fishing and foraging, as well as biomass fuel, animal products, natural medicines, building materials and water supply.

The residual impacts in relation to all of these matters, i.e., the impacts that are predicted to occur after the successful implementation of management and mitigation measures, are either negligible, low or, at worst, moderate. No impacts have a significance rating of high or major.

Socio-economic impacts associated with these environmental impacts are also predicted to be low.

Notwithstanding these findings, some consideration has also been given to other socio-economic impacts (both positive and negative).

Beneficial socio-economic impacts expected from the Project relate to increased income levels through Project employment, plantation-land cropshare and annual land rentals, intercropping (Plate ES9), and the establishment of local business enterprises. In addition, improvements to road access and infrastructure are likely, as well as an increase in education and training opportunities, including financial literacy.

Plate ES9 – Intercropping in a Project Area Trial Plot

Most of the negative potential socio-economic impacts relate to the key resource of land, including loss of land used for subsistence and cash income, possible inequitable distribution of plantation-land cropshare, land rentals and access to intercropping opportunities and benefits, as well as the potential for poorly-established business entities managing the land leasing, leading to land conflict within clans and across generations.

Potential health impacts will be largely reduced as a result of the predicted low levels of Project-induced in-migration, a lack of construction camps and proposed management measures. Despite only a minimal increase to road traffic predicted along the Highlands Highway, prevention of traffic-related accidents and injuries will be an ongoing focus of MVB. The residual impacts of congestion to the Highlands Highway, Lae Port and Lae Nadzab Airport are expected to be low.

There will be no impact from construction of the proposed power plant on any of the cultural heritage and archaeological sites identified during the surveys and database reviews. The implementation of management measures will reduce the residual impact on all identified sites and those that may be identified in the future.

All residual impacts relating to gender (e.g., inequitable share in income, loss of land use rights and important land resources, increased burdens on younger females) are predicted to be low, and the majority of those relating to human rights are also expected to be low or non-existent. The two exceptions to this concern a potential increase in both gender-based violence and family and sexual violence, and a limited ability for women and other socially-vulnerable groups to express opinions and/or obtain information.

7. Environmental Management, Monitoring and Reporting

An environmental management plan (EMP) that applies to the power plant construction and plantation development activities has been prepared for the Project. The EMP will guide the MVB workforce in identifying and managing potential environmental impacts that may result from these activities. In so doing, the document describes the environmental management framework that is required to identify and assess risks, implement appropriate mitigation measures, and monitor and evaluate their success to facilitate continual improvement.

All MVB personnel and contractors must comply with the EMP.

The EMP will sit within the framework of the Integrated Management System (IMS) that is currently being developed. The IMS will ultimately encompass all Project activities, from office-based work through to plantation establishment and harvesting and power plant operation. From an environmental perspective, the IMS will also be consistent with Oil Search's policies, statutory obligations and commitments made as part of the environmental assessment (EA) process in accordance with the requirements of the PNG *Environment Act 2000*.

The IMS will be developed in line with the principles of relevant international standards such as ISO 9000 (quality and loss control), ISO 14000 (environment) and OHSAS 18000 (occupational health and safety), and will incorporate all aspects of MVB's documentation including policies, planning procedures, standard operating procedures (SOPs) and management prescriptions. The environmental aspects will be consistent with ISO 14001:2015, as reflected in the Australian and New Zealand equivalent, i.e., AS/NZS ISO 14001:2016. This standard specifies that an environmental management system should consist of the following, which are tailored specifically to the activities of the business: leadership, planning, support and operation, performance evaluation, and improvement.

These elements as they relate to the Project are addressed within the EMP, which also contains a number of procedures that reflect the various environmental concerns and issues:

- Cultural heritage and archaeology.
- Vegetation clearing, earthworks, topsoil management and rehabilitation.
- General waste management.
- Hydrocarbons, chemical and hazardous waste management.
- Noise management.
- Air emissions and air quality management.
- Invasive alien species management.
- Surface water and groundwater management.
- Watercourse crossing management.
- Environmental incident and non-compliance reporting.
- Emergency response plans and drills.
- Environmental auditing.

These procedures each describe their purpose and context, specific management and mitigation measures relevant to the topic, and monitoring and reporting requirements.

The construction phase of the Project involves the use of only conventional practices in a generally non-sensitive environment. The adoption of well-established industry norms, international best practices and established SOPs will therefore minimise risks and potential adverse impacts, both in construction and continuing through operations. This also applies to plantation development, where environmental management procedures will be supported by documents such as 'Management Prescriptions', which describe what Project foresters need to do, and 'Best Operating Practices' (BOPs) that provide instructions for workers.

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1. Introduction

This section should include brief description of the following –
- *proposed activity and its objectives.*
- *potential bio-physical impacts.*
- *potential socio-economic impacts (direct results of bio-physical impacts).*
- *potential benefits of the activity.*

(Excerpt from 'Information Requirements for Permit Applications and Registration of Intention to Carry Out Preparatory Work', DEC Operational Procedure, Schedule 3, General Guidelines on the Additional Information Required to Support a Permit Application for a Level 2B Activity)

1.1 Project Proponent and Context

Oil Search Limited (Oil Search/OSL), through its wholly-owned subsidiary Markham Valley Biomass Limited (MVB)[1], proposes to develop the PNG Biomass Markham Valley project (hereafter referred to as 'the Project') in Morobe Province, Papua New Guinea (PNG). The Project area (also referred to as Area A) is located in the Markham Valley, about 50 km west-northwest of the provincial capital Lae (Figure 1.1).

The Project is a response to a call from PNG Power Ltd (PPL) for an Independent Power Producer (IPP) to generate 30 to 40 MW of power near Lae, and reflects the requirements of a 25-year Power Purchase Agreement (PPA) that was executed with PPL on 15 December 2015. The Project will address, at least partially, the current inability of the Ramu grid to provide reliable power, and the PNG Government's long-term objective of increasing the availability of reliable and sustainable power supply at a reasonable cost. Power generated by the Project will provide reliable baseload power to households, industries, and resource projects on the Ramu grid.

An application for an environment permit was submitted to the Conservation and Environment Protection Authority (CEPA) in late 2015. As subsequently advised by CEPA in early 2016, the Project is a Level 2 (Sub-category 10.2) activity under the Environment (Prescribed Activities) Regulation 2002, the relevant requirement being the operation of fuel burning power stations with a capacity of more than 5 MW. This requires submission of an environmental assessment report (i.e., this document) and an environmental management plan (appended).

Additional discussion about the Project's regulatory and policy framework is provided in Chapter 2, while Chapter 3 contains further information about the Project proponent and context.

The remainder of this chapter briefly addresses the project description and schedule, objectives, potential impacts and benefits, and report structure, with further detail being provided in subsequent chapters.

[1] The entity name of Markham Valley Biomass Limited (MVB) will be changed to PNG Biomass Limited. However, for the purposes of this report, the former will be used. This assessment reflects activities by both MVB and its subsidiary Markham Valley Power Limited (MVP).

PROJECT AREA LOCATION

PNG Biomass Markham Valley I Environmental Assessment Report

FIGURE 1.1

Image Source: Google Earth.

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1.2 Proposed Activity

1.2.1 Project Summary

The Project has two components: the establishment of up to 16,000 ha of sustainably managed eucalypt plantations, and a biomass-fuelled power plant consisting of two 15 MW units, with the preferred power plant site being located in the southeast of the Project area (see Figure 1.1). Construction of the power plant and related infrastructure, and development of the plantations, will take place over several years. Plantation development will be supported by road upgrades and/or construction, and a development of a large plant nursery. Plantations will be harvested every 7 to 9 years to provide about 175,300 BDMt/yr (bone dry metric tonnes of biomass (wood) per year).

The combustion of dry biomass will generate steam from water sourced from bores or the Markham River. This steam will drive steam turbine generators, thereby generating electricity that will be transferred directly to the nearby high voltage Ramu grid transmission system, which runs from Lae and Madang in the east to Mt Hagen and Mendi in the west. The power will be distributed to supply energy to major industries, households and rural communities.

1.2.2 Project Schedule

Key dates in the Project's schedule are:

- Power Purchase Agreement (PPA) finalised – Q4 2015.
- Environmental assessment (EA) report and environmental management plan (EMP) submitted to CEPA – Q1 2017.
- Environment permit issued by CEPA – Q3 2017.
- Initial 3,000 ha of plantation established – Q4 2017.
- Power plant commissioning (first 15 MW unit) – Q3 2019.

1.3 Project Objectives

The primary objective of the Project is to implement a profitable renewable energy project that meets all international sustainability criteria, enhances Papua New Guinea’s reputation and international standing, and contributes to the wellbeing of local communities, without compromising environmental values. More specifically, the Project aims to meet the need for electricity in the Lae region (and further afield in the remainder of the Ramu grid) with a more environmentally sustainable and socially beneficial energy option than that provided by fossil fuel power. A secondary objective is to sell timber products when biomass supply exceeds power plant requirements.

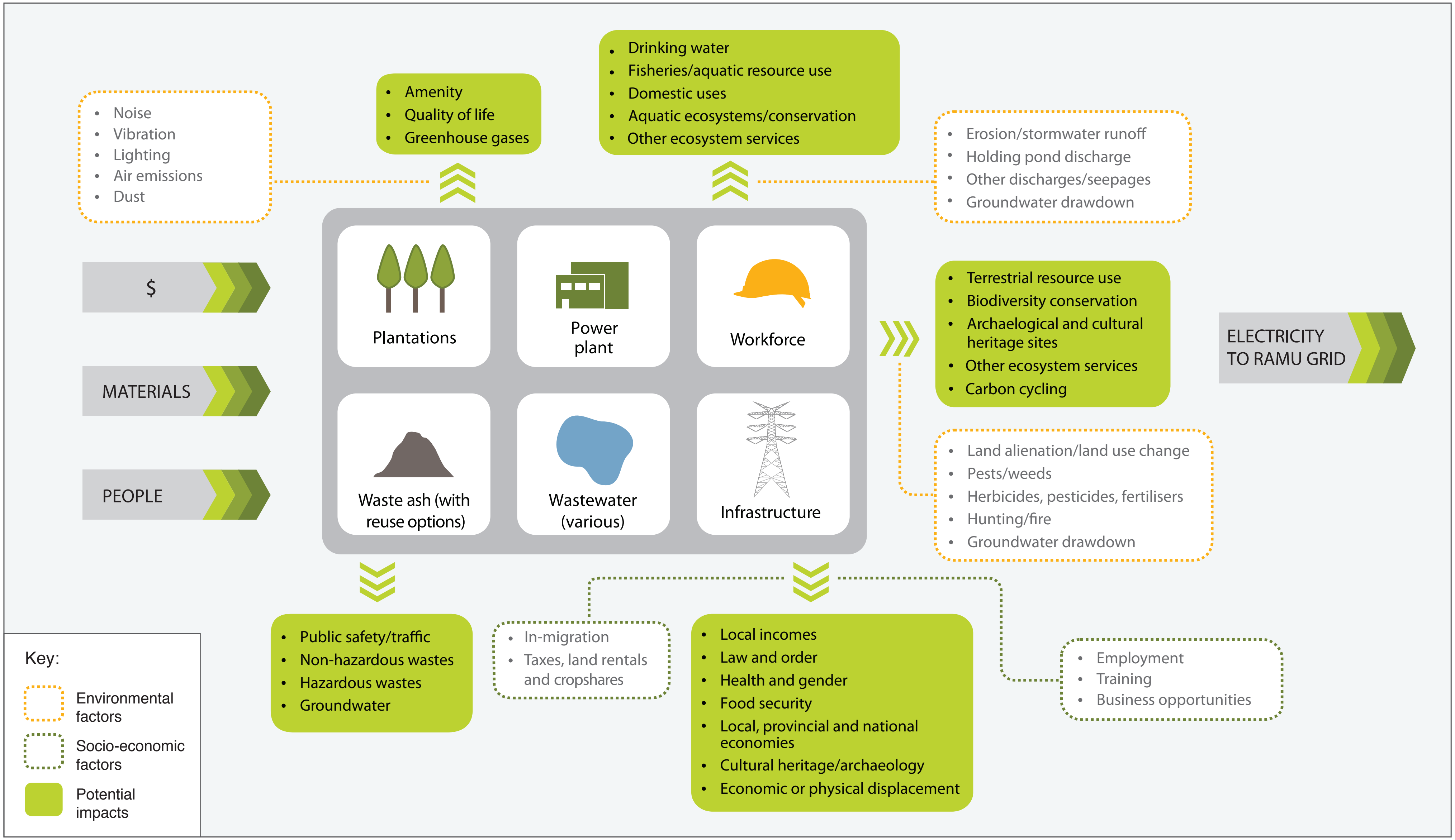
1.4 Potential Impacts and Benefits

A conceptual model of potential impacts and benefits associated with the Project is shown in Figure 1.2.

SIMPLIFIED CONCEPTUAL MODEL OF POTENTIAL IMPACTS AND BENEFITS

PNG Biomass Markham Valley I Environmental Assessment Report

FIGURE 1.2



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The Project will have some unavoidable impacts associated with conversion of a modified grassland environment into broad scale tree plantations. This has the potential to impact the biophysical environment due primarily to the change in vegetation, and will generate both positive and negative social impacts, particularly relating to resource use by local communities and 'provisioning' ecosystem services. Impacts will also result from air emissions and wastewater discharges, and changes to the local socio-economic context with respect to matters such as income.

Benefits associated with the Project include sustainable financial income streams for landowners and substantial new local employment and business development opportunities, as well as increased power supply for the region. Growing demand for electricity in Morobe Province has resulted from industrial development, modernisation, and population growth. Increased energy generation capacity is required and non-fossil fuel options such as biomass provide both commercial and environmental benefits, with the latter relating particularly to a 'closed carbon cycle' whereby Project carbon emissions (primarily from power generation) are offset by carbon absorbed into biomass by growing tree plantations (as shown schematically in Figure 1.3).

1.5 The Environmental Assessment Report

1.5.1 Report Structure

The structure of the environmental assessment (EA) report (this document) reflects CEPA's general guidelines for additional information to support an environment permit application for a Level 2B activity (DEC, 2013). The report commences with introductory chapters that describe the proponent and the Project objectives, purpose, viability, schedule and site selection rationale. These chapters are then followed by a description of the existing environment, Project activities and assessment of impacts, where the latter identifies the predicted physical environment, biological, and socio-economic impacts taking into account factors such as the impact magnitude and the sensitivity of the value that is affected. Cumulative impacts are also assessed where the Project may interact with impacts arising from the actions of third parties.

Specialist studies that supported the assessment are listed in Table 1.1.

Table 1.1 – PNG Biomass Markham Valley Specialist Studies

Appendix	Specialist Study Topic	Author
1	Hydrology and sediment transport	Hydrobiology Pty Ltd
2	Hydrogeology	Whitegum Forest and Natural Resources Pty Ltd/ HydroEnviro Scientific Solutions Pty Ltd
3	Air quality	SLR Consulting Australia Pty Ltd
4	Noise	SLR Consulting Australia Pty Ltd
5	Water and sediment quality	ERIAS Group Pty Ltd
6	Terrestrial ecosystems	BAAM (Biodiversity Assessment and Management Pty Ltd)
7	Aquatic ecosystems	Fathom Pacific Pty Ltd/Hydrobiology Pty Ltd
8	Plume rise assessment	SLR Consulting Australia Pty Ltd
9	Environmental management plan	ERIAS Group Pty Ltd

FIGURE 1.3


Carbon dioxide is released back into the atmosphere
Forests absorb carbon dioxide through photosynthesis
Biomass can be converted into heat and power
Forests can be harvested sustainably to produce biomass

1.5.2 Report Conventions

A number of conventions have been adopted in the preparation of this report, the most significant being as follows:

- Although the Project and related activities is a development proposal, the use of 'will' rather than 'would' has been adopted for this report.
- The Project will be developed primarily as described herein. However, MVB reserves the right to alter aspects of the Project as additional information (engineering, environmental, social or other) becomes available. Major changes, if they occur, will be communicated to CEPA and other relevant authorities, and appropriate actions in terms of regulatory requirements determined in conjunction with CEPA and those other authorities.
- The environmental assessment is based on impacts that are realistic and credible, and the timely implementation of management measures that will be feasible and effective in terms of minimising adverse impacts and enhancing benefits.

1.5.3 Spatial Boundaries

This report discusses the issues and impacts associated with the Project in a range of spatial contexts, predominantly referring to the Project area within the Markham Valley and the Project surrounds. Where appropriate, the discussion also addresses aspects relevant to Papua New Guinea on a regional, national and international scale.

2. Purpose of the Activity

This section should include brief description of the following –

- *objectives of the activity,*
- *description on whether the proposed development is compatible with National, Provincial, and Local Level Government development goals and planning strategies,*
- *description of benefits to the Nation, Province, District and to the local community.*

(Excerpt from 'Information Requirements for Permit Applications and Registration of Intention to Carry Out Preparatory Work', DEC Operational Procedure, Schedule 3, General Guidelines on the Additional Information Required to Support a Permit Application for a Level 2B Activity)

2.1 Objectives

Further to the Project objectives outlined in Chapter 1, the overarching environmental and social goals of the Project are to ensure implementation is in accordance with PNG regulatory requirements (as defined by the *Environment Act 2000*), good industry practice, and MVB environmental and socio-economic corporate policies (see Section 2.4.5). In particular, the Project will be consistent with the Equator Principles and associated International Finance Corporation (IFC) Environmental and Social Performance Standards 2012 (IFC, 2012), as well as the principles of the Forest Stewardship Council (FSC) National Forest Management Standards for Papua New Guinea (FSC, 2010; 2016).

2.2 Compatibility with Government Development Goals and Planning Strategies

2.2.1 Constitutional Goals and Directives

As described in Chapter 1, the Project involves developing short-rotation tree plantations to fuel a power plant, with consequent economic and social benefits to the region. Potential exists for future expansion of plantation areas and power plant capacity, depending on successful operation of the initial phase of the Project, markets for electricity and timber, and further plantation area appraisal.

The development of the power plant will diversify the electricity supply industry in Papua New Guinea, which is currently dominated by hydropower, oil (diesel) and gas. The Project is consistent with the PNG Government's initiatives and policies to provide a long-term energy solution that provides secure, sustainable, base-load power. Biomass power generation is a widely used power source around the world, and biomass power plants are operational in more than 40 countries. Worldwide biomass power capacity is increasing, with an estimated 93 GW (93,000 MW) installed by the end of 2014 (REN21, 2015). Further context is provided in Chapter 3.

The Project is consistent with the constitutional goals and directives of Papua New Guinea, which promote the development of its resources through various policies aimed at encouraging investment. While encouraging foreign investors, a priority of the PNG Government is that the people of Papua New Guinea must benefit from any such development.

As outlined in the Constitution of Papua New Guinea, key relevant aspirations and principles for the development of the nation are presented in Goals 2, 3 and 4:

> We declare our second goal to be for all citizens to have an equal opportunity to participate in, and benefit from, the development of our country.
>
> We declare our third goal to be for Papua New Guinea to be politically and economically independent, and our economy basically self-reliant.
>
> We declare our fourth goal to be for Papua New Guinea's natural resources and environment to be conserved and used for the collective benefit of us all, and be replenished for the benefit of future generations.

Markham Valley Biomass will ensure that local skills and resources are maximised to provide opportunities for PNG citizens to participate in, and benefit from, the Project. In developing the plantations and power plant, the Project will provide significant employment opportunities during construction and operation, and will enhance the capacity of the local and/or regional workforce and infrastructure to support future development projects. This in turn will also contribute to the economy, employment opportunities and longer-term improvements in infrastructure and services. Furthermore, the Project will create employment in a region distant from conventional energy resources, in a manner that creates social, environmental and development opportunities for PNG citizens.

During the Project's lifecycle, the PNG economy will benefit from the payment of cropshare and land rental, along with direct and indirect taxation, thus contributing to the nation's economic independence. Payment of wages with flow-on effects to local and regional businesses will also contribute to the local, provincial and national economies.

Markham Valley Biomass proposes to develop the Project through public participation and has initiated consultation with relevant landowner groups. This participatory process is focussed on engaging local communities in culturally appropriate ways to build trust and to identify issues relevant to Project planning and implementation. With this process MVB endeavours to ensure that the Project's socio-economic and environmental objectives are met. Adverse effects on local communities, their resources and the environment will be minimised, and benefits (including employment opportunities and sustainable development) will be maximised.

2.2.2 Strategic Plans and Policies

In 2009, the PNG Government, through the National Strategic Plan Taskforce (NSPT), released 'Vision 2050' (NSPT, 2009). This describes the country's long-term strategy and reflects the aspirations of Papua New Guineans, with the goal that Papua New Guinea will be ranked in the top 50 countries in the United Nations Human Development Index by 2050 (NSPT, 2009). The NSPT (2009) lists seven strategic areas, of which the development of the Project particularly aligns with the following:

- 1: Human Capital Development, Gender, Youth and People Empowerment:

  - The Project will provide employment-related training, which will increase the skills base of the local and/or regional communities.

- 2: Wealth Creation:

  - The Project will strengthen and support a productive regional economy, with landowner participation, and will present a potential new source of wealth and growth for Papua New Guinea.

- 5: Environmental Sustainability and Climate Change:

  - The Project will capture carbon in cyclically growing plantations, and will provide a more sustainable source of electricity with lower greenhouse gas emissions than alternatives.

In addition, the Project is consistent with the Papua New Guinea Development Strategic Plan (PNGDSP) 2010-2030 (DNPM, 2010), which states that the nation's long-term goal for energy development is that:

> All households have access to a reliable and affordable energy supply, and sufficient power is generated and distributed to meet future energy requirements and demands.

The PNGDSP has a stated goal that by 2030, at least 70% of PNG households will have access to electricity, and around 25% of the nation's generation capacity will be renewable energy other than hydroelectricity. It also states that 'in partnership with the private sector, energy development from renewable sources will be pursued, including biomass'. The Project is consistent with this goal.

A forecast in 2010, as part of the PNGDSP, estimated that Papua New Guinea's demand for energy was likely to exceed supply by 2014/2015. As such, the development of new electricity generation capacity in the next few years (and in particular, renewable energy) is aligned with the Government's development strategy.

The PNGDSP states that the nation's long-term goal with regard to climate change is to 'contribute to global efforts to abate greenhouse gas emissions' (DNPM, 2010). A biomass power plant will have significantly less greenhouse gas emissions than a diesel or heavy fuel oil (HFO) power plant, while the replacement of grasslands with tree plantations will contribute to increased absorption of carbon from the atmosphere. Therefore, the Project is in alignment with the PNGDSP and, more specifically, the PNG National Climate Compatible Development Management Policy, which promotes renewable energy sources (OCCD, 2014).

The PNGDSP also has a stated goal for Papua New Guinea to 'build a forestry sector that is sustainable and highly profitable' (DNPM, 2010). In relation to this, the PNG Department of National Planning and Monitoring (DNPM) has set a 2030 target of a 'substantial increase in plantation forests'. The PNG Forest Authority has a related target of reaching 150,000 ha of plantation forests in Papua New Guinea by 2025 (PNGFA, 2013). The Project will contribute to these targets.

Further to the PNGDSP, the DNPM has developed shorter-term initiatives in the form of medium-term development plans that have goals stemming from Vision 2050, aim to implement the PNGDSP, and are the benchmark for all sectoral, provincial, district and local level government plans. The Papua New Guinea Medium Term Development Plan 2016-2017 (DNPM, 2015) defines forestry assets as strategic and states that:

> …government investment will focus on developing and strategically positioning these assets to meet the needs of current as well as future generations of Papua New Guineans.

The Project also directly addresses a number of relevant PNG Electricity Industry Policy (PNG Government, 2011) objectives, particularly with regards to:

- Actively seeking landowner participation, and establishing arrangements with landowners.
- Using technologies for electricity generation that are environmentally and socially sound (i.e., biomass power as opposed to fossil fuels).
- Emissions reduction (as discussed above), which qualifies the Project under the Kyoto Clean Development Mechanism or similar international emissions reduction schemes.

2.3 Benefits and Impacts

Potential impacts and benefits as a result of the implementation of the Project have been considered in the environmental assessment. The main benefits include providing competitively priced, sustainable and reliable power capable of supporting everyday needs and creating employment and local business opportunities for PNG citizens. In particular, the Project's emission of carbon dioxide (CO_2) to the atmosphere is significantly lower than if the same amount of power was generated by HFO or other fossil fuels.

Further information relating to energy supply and how the Project aligns with the electrification of the Markham Valley and surrounds is discussed in Chapter 3.

The Project will promote significant social advancement in the Markham Valley region, primarily via sizeable ongoing employment (over 480 full-time equivalent direct ongoing jobs during operations, and approximately 4,000 indirect jobs) and landowner business development opportunities (e.g., plantations and support services businesses). The Project will also support education of young people with the objective of introducing them to more specifically qualified jobs in agriculture, forestry, engineering and business, and it will implement a Community Partnerships and Sponsorships program which will target specific community needs.

Changes in local land use due to the conversion of modified grassland into broad scale tree plantations have the potential to impact the biophysical environment due largely to altered land use. These impacts will relate primarily to resource use by local communities and ecosystem services rather than biodiversity conservation (as discussed in Chapter 8).

Some level of impact will also result from factors such as stack emissions, wastewater discharges, traffic fumes and dust, and the potential for herbicides, pesticides and fertiliser to cause contaminated runoff.

Potential Project benefits and impacts are discussed further in Chapter 8 of this report.

2.4 Regulatory and Policy Framework

2.4.1 Introduction

The PNG development goals and planning strategies outlined in Section 2.2 are supported by a legislative framework that ensures that approved developments assess, mitigate and manage residual environmental and social impacts, so that these impacts are as low as reasonably practicable.

The following sections describe the key environmental and socio-economic legislation and agreements that are relevant to the Project, along with international standards and principles that the Project has adopted. While minor aspects of many other acts and regulations will be relevant to the Project, such acts and regulations have only been listed rather than specifically discussed, as they do not relate directly to environmental project approvals or necessarily require a specific action.

2.4.2 Environmental Legislation

The *Environment Act 2000* (the Act) prescribes requirements for proponents seeking environmental approvals for new developments or changes to existing developments, and is administered by CEPA. Despite being amended in 2012 and 2014, the PNG Government has not enacted all of the amendments to the Act and, as such, ongoing consultation with CEPA is required by Project proponents. The related Environment (Prescribed Activities) Regulation 2002 (the Regulation) lists the types of approvals required for different levels of activities under the Act.

On 4 September 2015, MVB submitted to CEPA an application for an environment permit and notification of intention to carry out preparatory work. Subsequently, CEPA formally advised (by letter dated 8 March 2016) that the Project would be classified as a Level 2 (Subcategory 10.2) activity. Subcategory 10 relates to energy production, specifically:

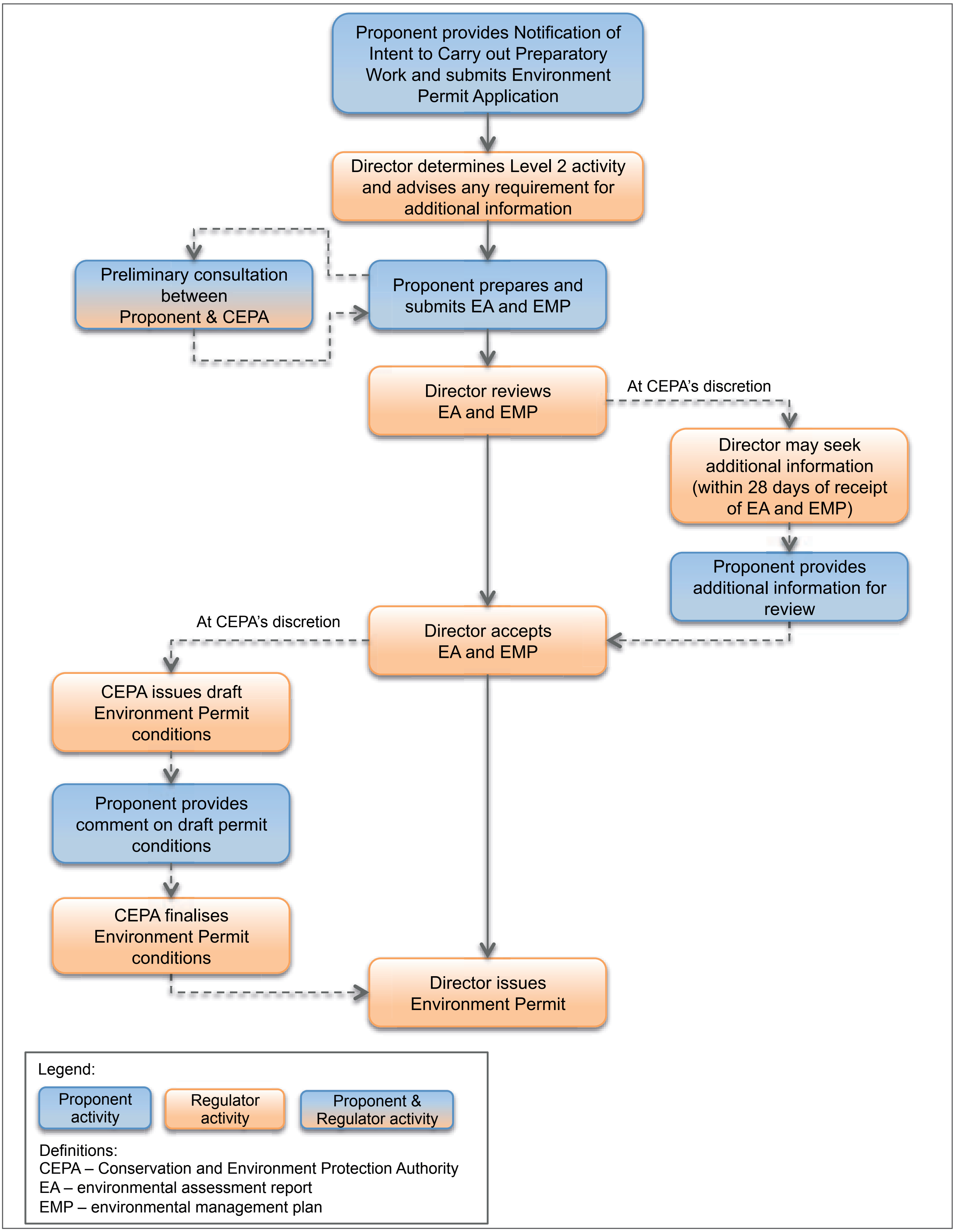
> 10.2. Operation of fuel burning power stations with a capacity of more than 5 MW, but not including emergency generators.

As such, and in accordance with the Department of Environment and Conservation (DEC) Operational Procedure – Information Requirements for Permit Applications and Registration of Intention to Carry Out Preparatory Work (DEC, 2013) prepared in accordance with the Act (s.132), the Project is required to prepare the following:

- Environmental assessment (EA) report, reflecting the findings of baseline environmental and social studies.
- Environmental management plan (EMP), developed on the basis of the environmental risks posed to the identified environmental values, as well as mitigation and management measures required to minimise those risks.

Figure 2.1 shows the approvals process for the Project as stipulated by the Act, its associated regulations and instructions, and consultation with CEPA.

FIGURE 2.1


Proponent provides Notification of Intent to Carry out Preparatory Work and submits Environment Permit Application
Director determines Level 2 activity and advises any requirement for additional information
Preliminary consultation between Proponent & CEPA
Proponent prepares and submits EA and EMP
Director reviews EA and EMP
At CEPA's discretion
Director may seek additional information (within 28 days of receipt of EA and EMP)
Proponent provides additional information for review
At CEPA's discretion
Director accepts EA and EMP
CEPA issues draft Environment Permit conditions
Proponent provides comment on draft permit conditions
CEPA finalises Environment Permit conditions
Director issues Environment Permit
Legend:
Proponent activity
Regulator activity
Proponent & Regulator activity
Definitions:
CEPA – Conservation and Environment Protection Authority
EA – environmental assessment report
EMP – environmental management plan

Other associated and subsidiary Project activities also classified as Level 2, including the eucalypt plantations, will be permitted under the umbrella of the approvals pursued for the main Level 2 activity. The Project EA report and EMP will need to be consistent with Schedule 3 – General Guidelines on the Additional Information Required to Support a Permit Application for a Level 2 Activity (DEC, 2013).

Part VII of the Act provides for permits for the use of water resources in Papua New Guinea, including dams and diversions, discharges of wastes and/or contaminants, water investigations and the taking of water resources via specific conditions in an environment permit.

2.4.3 Forestry Legislation

The *Forestry Act 1991* (Forestry Act) (and its amendments from 1993, 1996, 2000 and 2005) is the primary piece of legislation governing the management, protection and use of forests and forest resources in Papua New Guinea. The Forestry Act is administered by the Papua New Guinea Forest Authority (PNGFA) and is supported by the Forest Regulation 1992 and the Forestry Regulation 1998 (in operation from January 1996).

Under the Forestry Act (Part IV), to engage in forest industry activities involving harvesting, chipping and selling of the finished timber product, MVB must be registered as a Forest Industry Participant (FIP). This FIP registration does not relate to the planting of the eucalypt plantations.

A Forest Clearing Authority (FCA) (s.90B of the Forestry Act) will also be required and MVB will apply for this prior to harvesting of the plantation trees.

2.4.4 Other Relevant Legislation

In addition to the legislation discussed in Sections 2.4.2 and 2.4.3, the legislation, industry codes and plans listed in Table 2.1 are also relevant to the Project.

In addition to the items listed in Table 2.1, a number of other acts and regulations may be of relevance to the Project in relation to matters such as public and workforce health and safety, and commercial and professional matters. These matters are outside the scope of this assessment.

Table 2.1 – Other Legislation, Industry Codes and Plans Applicable to the Project

Environment
♦ *Conservation Areas Act 1978 and Conservation Areas (Amendment) Act 2014* ♦ Environment (Council's Procedures) Regulation 2002 ♦ Environment (Fees and Charges) Regulation 2002 ♦ Environment (Water Quality Criteria) Regulation 2002 ♦ Environment (Permits) Regulation 2002 ♦ *Fauna (Protection and Control) Act 1966, Fauna (Protection and Control) Act 1974 (Chapter 154)* and *Fauna (Protection and Control) (Amendment) Act 2014* ♦ *International Trade (Fauna and Flora) Act 1979 (Chapter 391)* and *International Trade (Fauna and Flora) (Amendment) Act 2014* ♦ *Plant Disease and Control Act 1953 (Chapter 220)* ♦ Public Health (Drinking Water) Regulation 1984 (Chapter 226)

Table 2.1 – Other Legislation, Industry Codes and Plans Applicable to the Project (cont'd)

Forestry
♦ *Forestry (Amendment) Act 1993* ♦ Forest Regulation No. 15 1992 ♦ Forestry Regulations 1996 ♦ *Forest (Timber Permits Validation) Act 2007* ♦ National Forest Policy 1991 ♦ National Forest Development Guidelines of 1993 ♦ National Forest Plan 1996
Protection and Preservation of Sites and Features of Archaeological and Cultural Heritage Significance
♦ *National Cultural Property (Preservation) Act 1965* and *National Cultural Property (Preservation) Regulation 1965* ♦ *National Museum and Art Gallery Act 1992*
Land Acquisition and Compensation
♦ *Business Groups Act 1965* ♦ *Land Act 1996* ♦ *Land Dispute Settlement Act 1975* ♦ *Land Groups Incorporation Act 1974* and *Land Groups Incorporation (Amendment) Act 2009* ♦ Land Groups Incorporation Regulation 1974 ♦ *Land (Ownership of Freeholds) Act 1976* ♦ *Land Registration Act 1999* and *Land Registration (Amendment) Act 2009* ♦ Land Registration Regulation 1999 ♦ *Land Registration (Customary Land—Amendment) Act 2009* ♦ Land Regulation 1999 ♦ *Valuation Act (Chapter 327) 1967*
Power Generation, Transmission and Distribution
♦ *Electricity Industry Act (Chapter 76) 2002* ♦ Electricity Code ♦ Third Party Access Code ♦ Grid Code
Power Station Construction
♦ *Physical Planning Act 1989* ♦ Physical Planning Regulation 2007 ♦ *Building Act (Chapter 301) 1971* ♦ Building Regulations 1994

2.4.5 International Standards, Agreements and Guidelines

2.4.5.1 International Financing Standards and Guidelines

As the Project may seek financing by international finance institutions (also known as 'lenders'), the EA report has been prepared so as to satisfy both PNG regulatory requirements and the requirements of the Equator Principles.

The Equator Principles provide a risk management framework that is adopted by financial institutions for determining, assessing and managing environmental and social risk in projects. The principles refer to the International Finance Corporation (IFC) Performance Standards as well as the World Bank Group Environmental, Health and Safety Guidelines.

The IFC Performance Standards (IFC, 2012) are directed towards project proponents and provide guidance on how to identify and manage environmental and social risks and impacts. They also establish the standards that proponents are to meet throughout the life of an investment by the IFC. Specifically (IFC, 2012):

> They are designed to help avoid, mitigate, and manage risks and impacts as a way of doing business in a sustainable way, including stakeholder engagement and disclosure obligations of the client in relation to project-level activities. In the case of its direct investments (including project and corporate finance provided through financial intermediaries), IFC requires its clients to apply the Performance Standards to manage environmental and social risks and impacts so that development opportunities are enhanced.

The eight IFC Performance Standards are:

- Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts.
- Performance Standard 2: Labor and Working Conditions.
- Performance Standard 3: Resource Efficiency and Pollution Prevention.
- Performance Standard 4: Community Health, Safety, and Security.
- Performance Standard 5: Land Acquisition and Involuntary Resettlement.
- Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources.
- Performance Standard 7: Indigenous Peoples.
- Performance Standard 8: Cultural Heritage.

The World Bank Group’s Environmental, Health and Safety (EHS) Guidelines are technical reference documents that are specifically referred to in the Performance Standards and provide general and industry-specific examples of good industry practice. The general EHS guidelines provide guidance to users on common EHS issues that are potentially applicable to all industry sectors (IFC, 2007) and should be used in conjunction with the relevant industry sector guidelines. Although the Project's generating capacity of 30 MW is less than the 50 MW minimum specified in the thermal power plants guideline (IFC, 2008), MVB has decided to use that document for guidance during Project planning and development.

Additional IFC documents (e.g., the Good Practice Handbook for Cumulative Impact Assessment and Management (IFC, 2013)) have been referred to as appropriate in later chapters.

2.4.5.2 Forestry Stewardship Council

The Forest Stewardship Council (FSC) is an independent, not for profit, non-government organisation. Its vision is that (FSC, 2017):

> The world’s forests meet the social, ecological, and economic rights and needs of the present generation without compromising those of future generations.

The FSC Principles and Criteria (P&C) describe the essential elements or rules to support environmentally appropriate, socially beneficial, and economically viable management of the world's forests. There are ten principles, each supported by several criteria that provide a way of judging whether the principle has been met in practice. All ten principles and criteria apply to all forest types and to all areas within the management unit included in the scope of the certificate, and must be applied to any forest management unit before it can receive FSC certification. The P&C are not specific to any particular country or region; they are applicable worldwide and are relevant to forest areas and different ecosystems, as well as cultural, political and legal systems.

The FSC's 2010 National Forest Management Standards for Papua New Guinea (FSC, 2010) is an adaptation of the FSC P&C (FSC's International Standard) in relation to the specific conditions in Papua New Guinea. The National Forest Management Standards for Papua New Guinea set the principles, criteria, indicators and verifiers by which all forest operations in the country can be judged, and are tailored to reflect the country's unique social, economic and environmental situation.

The ten principles of the National Forest Management Standards for Papua New Guinea – including requirements to conserve environmental values, maintain high conservation forests, and manage plantations in a manner that complements sustainable management of natural forests – have been taken into account by the Project.

The 2010 version of the standards is currently under review and a 2016 draft version has been released for public consultation (FSC, 2016). Finalisation of the document will occur in the first half of 2017, and subsequent approval by FSC is likely to occur in Q4 2017 (Dam, pers. com., 2017). Given the Project's development timeline and the forthcoming approval of the revised version, the content of the 2016 draft version has been taken into account for this environmental assessment.

The FSC's position on plantations is described in FSC (2014) as follows:

> FSC supports the responsible use of plantations as a strategy to complement conservation and the sustainable use of natural forests. While plantations cannot replace the richness, stability and beauty of natural forests or the complexity of the services they provide, applying the FSC standards to them ensures that their management is defined by transparency and fairness and minimizes negative environmental and social effects.

This allows for plantation certification, apart from any plantation that was established as a result of forest conversion after 1994, and efforts have been made by FSC over the past decade to better integrate its requirements for plantation management into those that apply to all types of forests.

2.4.5.3 International Conventions, Treaties and Protocols

Relevant international treaties, conventions and protocols that the PNG Government has signed, ratified or acceded to, are shown in Table 2.2.

Table 2.2 – Applicable International Conventions, Treaties and Protocols

Title	Summary/Objective
Kyoto Protocol to United Nations Framework Convention on Climate Change (1997)	♦ Stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system ♦ Places onus on industrialised (Annex 1) countries to reduce emissions; developing countries such as Papua New Guinea are exempt from this requirement
Vienna Convention for the Protection of the Ozone Layer (the Vienna Convention) (1993) and the Montreal Protocol on Substances that Deplete the Ozone Layer (1992)	♦ Protect the ozone layer
Convention to Ban the Importation into Forum Island Countries of Hazardous Wastes and Radioactive Wastes and to Control the Transboundary Movement and Management of Hazardous Wastes Within the South Pacific (Waigani Convention) (2001)	♦ Reduce and eliminate transboundary movements of hazardous and radioactive waste, to minimise the production of hazardous and toxic wastes in the Pacific region and to ensure that disposal of wastes in the Convention area is completed in an environmentally sound manner
Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (Basel Convention), 1989	♦ Protect human health and the environment against the adverse effects of hazardous wastes
Stockholm Convention on Persistent Organic Pollutants (POPs) (2004)	♦ Protect human health and the environment from chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of humans and wildlife, and have harmful impacts on human health or on the environment)
International Tropical Timber Agreement (ITTA, Geneva), 2006	♦ Promote the expansion and diversification of international trade in tropical timber from sustainably managed and legally harvested forests and to promote the sustainable management of tropical timber producing forests ♦ This replaces the International Tropical Timber Agreement, 1994
Convention on Biological Diversity (1993)	♦ Preserve and sustain biological diversity, sustainable use of its components and the fair and equitable sharing of benefits from genetic resources
Convention on Wetlands of International Importance Especially as Waterfowl Habitat (RAMSAR Convention), 1971 and the international regime for the 'conservation and wise use' of wetlands and waterfowl populations	♦ Halt the worldwide loss of wetlands and promote the conservation and wise use of all wetlands through cooperative management
Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora (1975)	♦ Ensure that international trade in specimens of wild animals and plants does not threaten their survival
International Plant Protection Convention (Rome), 1951 (revised 1997)	♦ Prevent and control the introduction of pests of plants and plant products

Table 2.2 – Applicable International Conventions, Treaties and Protocols (cont'd)

Title	Summary/Objective
Convention for the Safeguarding of Intangible Cultural Heritage (UNESCO) (2003)	♦ Safeguard intangible cultural heritage, ensure respect for the intangible cultural heritage of the communities, groups and individuals, and raise awareness at the local, national and international levels of the importance of intangible cultural heritage
Convention Concerning the Protection of World Cultural Heritage and Natural Heritage (1972)	♦ Identify, protect and conserve cultural and natural heritage

2.4.5.4 Industry Standards and Codes of Practice

The standards and guidelines adopted by the Project follow the hierarchical approach of:

- Applicable Papua New Guinea acts, regulations and standards.
- International standards and guidelines.

The Papua New Guinea Logging Code of Practice (PNGFA/DEC, 1996) and, where appropriate, the Forest Practices Code developed by Tasmania's Forest Practices Authority (FPA, 2015) will be used by the Project.

Additional sector-specific PNG environmental codes of practice are addressed in the relevant sections of Chapter 8 of this report.

In the absence of PNG standards, or where additional assessment is warranted alongside the use of PNG standards, internationally recognised standards and guidelines will be applied including, for example, those developed by the Australian and New Zealand Environment and Conservation Council/Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ), the World Health Organization (WHO) and the IFC. This is further detailed in the relevant sections of Chapter 8.

2.4.6 Company Policies and Standards

Markham Valley Biomass is committed to operating the Project in a manner that meets the environmental and social sustainability principles that Oil Search (as the owner of MVB) has developed through its Health, Safety, Environment and Security Policy (Box 2.1) and its Social Responsibility Policy (Box 2.2).

Box 2.1 – Oil Search Health, Safety, Environment & Security Policy

Oil Search

Health, Safety, Environment & Security Policy

Oil Search is committed to achieving incident free operations through the provision of effective Health, Safety, Environmental and Security (HSES) Management across all of its operations and worksites that benefit employees, contractors and the community.

The Company is committed to:

- Promoting HSES objectives, leadership, responsibilities and behaviour as an integral part of the duties of management and all employees;
- Complying with applicable laws and other obligations and requirements that the company subscribes to, and where adequate laws do not exist, adopting and applying standards that reflect Oil Search's commitment to HSES outlined in this policy;
- Reporting and evaluating risks, threats, hazards and impacts to company operations that have the potential to adversely affect the environment or the health and safety of employees, contractors or the community;
- Implementing appropriate control and contingency measures to prevent pollution and minimise and manage these risks, threats, hazards and impacts to an acceptable level;
- Establishing and ensuring that standards are followed and effective practices promoted to ensure that the environment, people, property and information are protected from harm;
- Selecting and engaging contractors whose management systems are acceptable to Oil Search and whose commitment to this policy is clearly and continuously demonstrated;
- Providing competent human resources to manage relevant aspects of health, safety, environment or security;
- Communicating openly with all stakeholders on HSES related issues;
- Providing training, instruction and supervision to personnel to enable them to attain the knowledge and skill levels necessary to perform their work incident free;
- Maintaining appropriate contingency arrangements;
- Continually monitoring, reviewing and improving HSES performance and associated management systems so that our activities can continue without interruption and;
- Ensuring that oversight of accident, incident and near miss investigations is assumed by the appropriate executive manager and that those investigations are conducted to a level of detail that is appropriate to the event's actual and potential severity.
- A consistent and equitable approach to the prevention of HIV among employees, families and their communities; the management of the consequences of HIV including the care and support of employees and their families; and protecting the rights of employees living with HIV from discrimination, victimisation or harassment.

Every employee and contractor working for the Company has a responsibility to promote a culture whereby their actions and those of their colleagues are consistent with this Policy.

Richard Lee
Chairman

Peter Botten
Managing Director

EMS-PRO-000006

Updated: 7 December 2015

ERIAS GROUP

Box 2.2 – Oil Search Social Responsibility Policy

–

Oil Search

Social Responsibility Policy

With operations in environmentally, culturally and socially sensitive locations, Oil Search's commitment to social responsibility stems from a culture that strives for the highest ethical, social and moral values and a desire to be recognised as delivering "excellence in socially responsible oil and gas exploration and production".. We set ourselves apart from our peers by our sustainable development approach and our ability to contribute positively and creatively to the growth and development of communities in which we operate.

The Company is committed to:

- Operating with integrity at all times as well as adopting and advocating for principles, practices and standards that respect diversity, local culture, human rights, labour rights, women's protection and empowerment, and the environment, and which contribute towards combatting corruption;
- Generating shared value by ensuring positive, sustainable outcomes for the communities in which we operate, while at the same time ensuring secure and continued operations and being mindful of our responsibility to shareholders and other stakeholders;
- Maintaining and enhancing our social license to operate through high levels of stakeholder engagement; establishing and maintaining strong and mutually beneficial community relationships; leaving a long-term positive social development legacy; and monitoring the impact of our activities on our project area communities;
- Continuous performance improvement by continuing to grow and leverage our social responsibility capability; seeking ways to enhance our approach; and improving measurement and reporting of performance.
- Seek ways to manage natural resources responsibly by minimising our environmental impact and operating in an environmentally sustainable way by adoption of the precautionary principle and giving consideration to effective and efficient use and re-use of resources and;
- Upholding the Ten Principles of the UN Global Compact, the Voluntary Principles for Security & Human Rights, and contributing to the progress of the Sustainable Development Goals in its countries of operation.

To achieve this commitment, Oil Search will:

- Ensure governance systems are in place to oversee, monitor, measure, report and drive social responsibility performance and decision making including social responsibility objectives and leadership responsibilities.
- Comply with all social and environmental laws, regulations and obligations and, where these do not exist adopt and apply standards that are in alignment with the intent of this policy and internationally accepted norms of behaviour.
- Proactively identify, evaluate, transparently report and manage any risks, threats or impacts related to our operating context that have the potential to adversely affect the environment, the well-being of the local community or our social license to operate. Appropriate control and contingency measures will be adopted to minimise and manage concerns and opportunities.
- Use our sphere of influence to advocate for the commitments contained in this policy, including but not limited to our supply chain and local content.

Every employee and contractor working for the Company has a responsibility to promote a culture whereby their actions and those of their colleagues are consistent with this Policy.

Richard Lee
Chairman

Peter Botten
Managing Director

EMS-POL-000009

Approved: 7 December 2015

3. Viability of the Activity

This section should include brief description of the following –

- *information on the capital cost associated with the development,*
- *financing arrangement,*
- *proponent's technological expertise and resources,*
- *results of any feasibility investigations that has (sic) been conducted.*
- *information on landowner and/or resource owner support, including a copy of the formal written approval of their consent to the activity.*

(Excerpt from 'Information Requirements for Permit Applications and Registration of Intention to Carry Out Preparatory Work', DEC Operational Procedure, Schedule 3, General Guidelines on the Additional Information Required to Support a Permit Application for a Level 2B Activity)

3.1 Capital Cost and Financing

The currently forecast total expenditure of the Project (power plant and plantation) development is provided in Table 3.1. Costs are based on benchmark costs, field costs observed to date, proposals received from contractors and estimates from third party reviews. Project financing options are currently being evaluated, and it is expected that the required funds will be provided from a range of sources that may include the required equity (cash) contribution from Oil Search, possible additional equity from new partners who may participate in the project, and debt financing from a range of sources.

Table 3.1 – Project Capital Costs and Establishment Costs

US$ Million, MOTD*	1 x 15 MW Unit	2 x 15 MW Units (Second Unit 2022)
FEED	19.8	19.8
Total Capital and Establishment Costs from FID		
IPP and Infrastructure including owners costs	66.5	124.5
Plantation establishment (to end 2021)	46.9	46.1
Working capital/securities	5.0	5.0
Capex from FID (with all plantation costs)	118.4	175.6
Plantation Establishment		
Before first revenue	24.4	24.3
After first revenue	22.5	21.9

* Money of the Day.

3.2 Proponent's Technological Expertise and Resources

As previously outlined in Section 1.1, Oil Search, through Markham Valley Biomass Limited, has 100% ownership of the Project. Aligned Energy (PNG) Limited (Aligned Energy) is responsible for the initial Project planning[2], while Pöyry has been chosen to fill the Early Contractor Involvement

[2] Project planning and implementation responsibilities will transfer from Aligned Energy to MVB by Q2 2017.

(ECI) role and to undertake the Front End Engineering Design (FEED) study for the power plant as part of the ECI process. The credentials of all three companies are relevant to demonstrating the Project's viability.

3.2.1 Oil Search Limited

Oil Search is an oil and gas exploration and development company that has been operating in Papua New Guinea since 1929 (OSL, 2016a). The company is the country's largest oil and gas producer and has interests in all of the nation's producing oil and gas fields. While biomass-to-energy is a new business sector for Oil Search, it has a long history of developing large-scale greenfield projects in Papua New Guinea, with extensive in-country experience.

The company's involvement in the Project is, in part, related to its sustainable development program (OSL, 2016b). Oil Search is committed to operating the Project to meet the environmental and social sustainability principles that it has developed through its Health, Safety, Environment and Security Policy (see Box 2.1) and its Social Responsibility Policy (see Box 2.2), as well as those of the Papua New Guinea Government.

Oil Search has a corporate commitment to promoting positive social change in Papua New Guinea. In 2016, the company joined leading global companies in support of the United Nations Sustainable Development Goals (SDGs) and currently contributes directly or indirectly to 13 of the 17 SDGs, including:

- SDG#3: Ensure healthy lives and promote well-being at all ages – Oil Search currently operates within government systems in Papua New Guinea to deliver on targets such as immunisations, improved nutrition, malaria control, prevention and treatment of HIV, and strengthening of health systems.
- SDG#5: Achieve gender equality and empower all women and girls – Oil Search collaborates with PNG communities and other businesses to deliver culturally appropriate initiatives that help to change attitudes that hinder the advancement of women.
- SDG#7: Ensure access to affordable, reliable, sustainable and modern energy – Oil Search is working closely with the PNG Government and key power agencies to significantly increase the percentage of the population with access to electricity. In particular, the PNG Biomass Markham Valley project aims to provide reliable, sustainable power to the Ramu grid by 2030.

Other corporate commitments to social change include employment opportunities, improved livelihoods, and local enterprise development. Oil Search supports the creation of economically independent communities by providing employment opportunities and access to supply chains. This has several benefits including improving supply chain reliability, supporting Oil Search's social licence to operate, helping to mitigate landowner related issues, building strong local businesses, and facilitating community economic development.

In 2015, the company made an estimated US$466 million contribution to Papua New Guinea's socio-economic development (OSL, 2015).

3.2.2 PNG Biomass Project Team

The PNG Biomass Project team incorporates internationally experienced energy, biomass, forestry, and project management personnel to provide competitive renewable energy solutions, with appropriate technology and biomass production methods. The Project management team has a combined 100 years of experience working in developing countries, the energy sector, plantation development and management. The team develops sustainable energy projects by integrating biomass production, water and nutrient management, and energy conversion in a manner that is cost effective and environmentally beneficial (AEL, 2016a).

The policy or 'pillars' of sustainable production under which the Project team operates are:

- Development of plantations in areas that are less suitable for food production.
- Appropriate plantation water management in areas with adequate rainfall, to reduce water resource use.
- Appropriate management of environmental impacts, energy use and carbon emissions.
- Equitable social and economic benefits for communities in areas of company operations.

The technological expertise of the team is best demonstrated by summarising the experience of key personnel who are, and will be, involved in the Project. The incumbents in senior roles within the organisation have over 20 to 30 years of international forestry experience and/or technical experience in the energy industry, as well as in energy conversion and integrated energy projects. Specific expertise that will be brought to the Project in these roles includes:

- Plantation management for short-rotation fibre or biomass crops and longer-rotation solid log crops, and tropical forestry.
- Fibre harvesting, fibre transport, timber utilisation, and biomass production and utilisation.
- Electrical manufacturing, engineering consulting and power utilities management and project development.
- Technical and commercial management and issue resolution in energy projects.

3.2.3 Pöyry

Pöyry is an international consulting and engineering firm founded in 1958 that has a global market across the energy and industrial sectors and provides engineering services in its core markets. The company's focus sectors are power generation, transmission and distribution, forest industry, chemicals and bio-refining, mining and metals, transportation and water.

Pöyry's biomass fuel experience includes forest harvesting residues, the by-products of the pulp and paper industry (e.g., black liquor, bark, sawdust, sludge, wood waste) and crops (e.g., rice husk, bagasse, nut shells, cereal straw, rape seed and reed canary grass), as well as biogas produced from various biodegradable wastes. The company delivers over 10,000 projects annually; examples of some engineering, procurement and construction (EPC) or engineering, procurement and construction management (EPCM) projects, design and build projects and thermal power projects are provided in Table 3.2.

Table 3.2 – Pöyry EPC/Design and Build and Thermal Power Projects

Client and Country	Project	Scope of Services	Years
EPC/EPCM/Design-Build Projects			
PRG Granary Co., Ltd. Thailand	Upgrade of existing mill facility in Pathumthani Province. The project entailed the installation of a biomass 9.24 MW cogeneration plant using rice husks as the primary fuel	Overall project management, detailed design, process engineering and technical integration	2001 to 2002
A.T. Biopower Co., Ltd. Thailand	Construction of 20 MW rice husk-fuelled power plant, located in Pichit Province	Overall project management, detailed design, civil, structural and architectural works, procurement, erection and installation	2003 to 2005
UPM-Kymmene (UK) Ltd Wales	Shotton Paper Biofuel Boiler plant.	Complete basic and implementation engineering and procurement services	2005 to 2006
United Pulp and Paper Co., Inc Philippines	Balance-of-plant works to new circulating fluidized bed boiler	Erection works, engineering procurement and construction, electrical works, start-up, performance test and operations and maintenance	2004 to 2005
Stora Enso Langerbrugge Paper mill Belgium	12 MWe backpressure steam turbine plant bubbling fluidized bed boiler	Procurement, commissioning and installation, design and optimisation	2002 to 2003
Salmi Voima Oy Finland	15 MWe district heating steam turbine plant (fuels: milled peat, sawdust, wood waste, bark)	Complete design, tender documents and evaluation, contracting, detailed procurement and performance tests	2001 to 2002
Thermal Power Plants			
Confidential Myanmar	Shwe Taung 70 MW IPP Project	Preparation of conceptual design and EPC documentation	2015
Petro Vietnam Power Corporation Vietnam	Nhom Trach 2 CCPP, comprising one block of 800 MW (multi-shaft), direct river water cooled condenser	Engineering support and long-term maintenance agreement Evaluation of tender documents	2008
Energie AG Oberosterreich Austria	Timelkam (Linz) 400 MW combined cycle power plant with 100 MWth steam extraction for district heating	Conceptual and basic design and preparation for international tender	2005 to 2006
Singapore Power International Korea	Kusan 52 MW CHP Plant	Review of EPC and construction and O&M cost assumptions	2002

Pöyry has previously worked closely with Blake McBurney on a number of biomass projects, with the latter providing expertise in relation to the detailed design of boiler plants, and this relationship will continue through the design and implementation of the Project.

3.3 Feasibility Investigations

3.3.1 Project Context

Papua New Guinea has one of the lowest per capita consumption rates of electricity in the world. Access to electricity is minimal, with less than 10% of the population connected to public power supply, which reflects constraints from both the rugged PNG topography and the fact that most of the population is dispersed in rural areas that are not served by electricity. Papua New Guinea is therefore an ideal candidate for distributed generation and small-scale (domestic or village level) power, as reflected in the various PNG Government development goals and planning strategies described in Chapter 2.

The Power Sector Development Plan Project (ADB, 2009) has a long-term objective of increasing the availability of reliable and sustainable power supply in Papua New Guinea at a reasonable cost. Focusing on existing technology for providing local level electricity, the use of biomass is considered to be highly feasible.

Currently, the total installed power generation capacity in Papua New Guinea is approximately 800 MW (excluding power generation relating to the PNG LNG Project), of which half is on-grid generation supplied by PPL and several smaller Independent Power Producers (IPPs). These IPPs operate under Power Purchase Agreements (PPAs), with PPL as the buyer.

The Ramu grid extends from Lae and Madang in the east to Mt Hagen and Mendi in the west (Figure 3.1), with a 132 kvA transmission line running along the Markham Valley near the Highlands Highway. It is currently Papua New Guinea's largest and fastest growing grid, and is located in the most populous area of the country. Although options such as a transmission line to connect the Port Moresby area to the Ramu grid have been raised, these are unlikely to occur given factors such as the terrain, high costs and seismic issues. Therefore, the Ramu grid is, and will likely remain, the largest separated grid, which also has the greatest opportunity to significantly increase electricity connection rates from a very low baseline level.

However, the reliability of the Ramu grid’s supply network is variable. Current generation supply is primarily from PPL, which owns the Ramu Hydro Power Stations with installed capacity of 77 MW. The power stations are supplemented by intermittent power supply from primary diesel and HFO generators (owned by PPL and other smaller IPPs). The demand is driven primarily by commercial, industrial and mining customers, which make up approximately 86% of sales. Low residential sales indicate the present lack of household connections, which is forecast to drive significant growth in the future.

Lae, which is the second largest city in Papua New Guinea, is the country's largest industrial centre. The nearby highland provinces have the highest population density in the country and the Project area in the Markham Valley is a significant agricultural hub. Many companies have had to install stand-by and/or off-grid diesel generation because of the lack of reliable supply via the grid. Based on forecast power requirements, it is estimated that the required latent and self-generating

PAPUA NEW GUINEA'S CURRENT ELECTRICITY INFRASTRUCTURE

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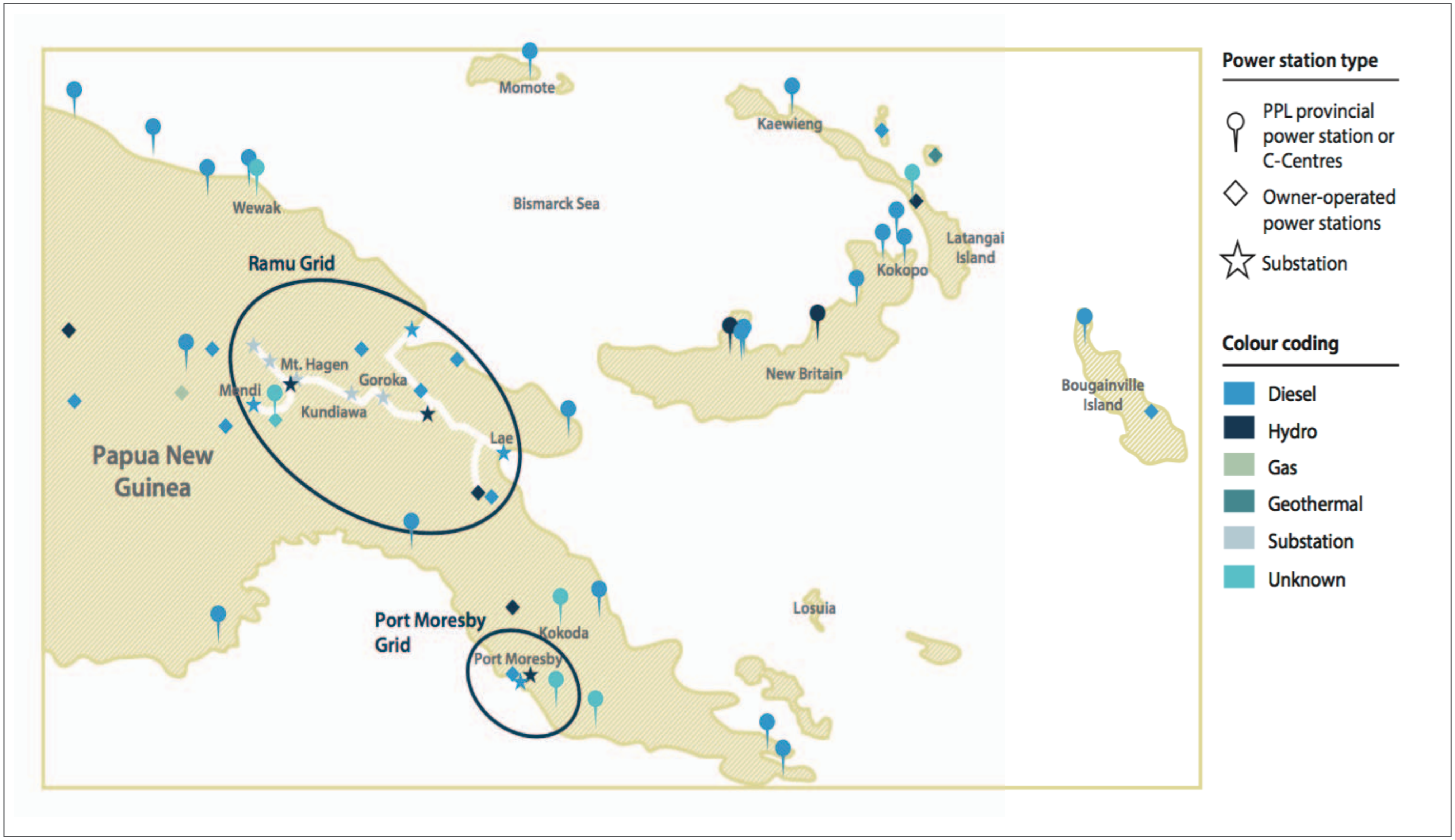
FIGURE 3.1



Source: PJPL, 2015.

industrial (baseload) power is 20 to 30 MW in Lae, and this will largely be met by existing hydro-electricity dispatch and the PNG Biomass Markham Valley IPP units (which are the subject of this assessment). In addition, new industrial and other loads are being added to the system, and PNG Biomass Markham Valley will provide the ability to meet this demand[3].

3.3.2 Project Feasibility

Given the context described in the preceding section, the Project proponents assessed a number of renewable power options to determine if any of these would be appropriate for Papua New Guinea, and to quantify the benefits of renewable IPPs.

In 2009, it was clear that a biomass power project[4], if feasible in Papua New Guinea, would offer environmental, electricity access, employment and social benefits which would not be associated with further HFO or diesel power generation. Project planning therefore progressed to an initial country-wide feasibility study in 2010 which included detailed geographic information system (GIS) data mapping and field studies, and assessment of potential Project areas based on the following criteria:

- Relatively flat land available for plantations which was not cleared native forests and was underutilised.
- The need for more than 10 MW of baseload power generation.
- Adequate rainfall to support biomass production.
- Appropriate soil types for large-scale biomass (wood) plantations.
- A nearby power grid and market, which required power in a three to five year time frame.
- Water sources for a biomass boiler and steam turbine generator power plant.

The GIS mapping collected extensive data on land use, population distribution, rainfall and soils to develop high yield biomass suitability maps. Field studies were conducted in seven regions over an area of 2,500 km^2 and focused on soil analysis, remediation and program design for large-scale pilot testing. The conclusion of these studies (which cost more than US$1 million) was that areas located in the Markham Valley close to sections of the Ramu grid were considered to be most suitable for further investigation. These areas were initially named Project Areas, A, B and C.

A Memorandum of Understanding (MOU) was signed with PPL to conduct a specific feasibility study aimed at the Markham Valley with intent to move to a PPA.

[3] These estimates are independent of large forecast resource loads expected upon the Ramu grid, which would result in a call for the Project's second 15 MW unit when the resource projects are forecast to possibly add to the requirements.
[4] Biomass is renewable plant material that includes wood and other cellulosic plant fibres, with wood being favoured as a biomass fuel due to low ash and a relatively constant heating value. Combustion and combined heat and power (CHP) plants burn biomass in a boiler and generate power using a steam turbine in dedicated power plants, typically for smaller plants (5 to 100 MW capacity levels). There are more than 4,200 generation units in nearly 2,900 biomass power plants and over 320 biomass co-incinerators worldwide, in over 40 countries.

The Project's history from 2010 can be summarised as follows:

- May 2010 – February 2011: initial PNG-wide feasibility study for biomass power.
- August 2011: Markham Valley determined to be the preferred site; first trees planted.
- January 2012: initial landowner agreements, trial plantations and services agreement with PNG Forestry Research Institute in Lae.
- May 2012: MOU signed with PPL to conduct a feasibility study.
- December 2012: PPL commenced an open tender process.
- December 2012: PPL competitive tender process commenced.
- December 2015: 2.5 years of negotiation with PPL: PPA signed.
- September 2016: front end engineering and design (FEED) commenced.

3.4 Landowner Support

In recent decades, the people of the Markham Valley have been involved with agri-industry developments and are aware of the requirements for land lease and dealing with developers. Since completion of the feasibility study (see above), Project staff have undertaken consistent efforts to engender community support. As a result, there has been good support for the Project to date from communities, with some clans having signed MOUs to commit their land to the Project (see above).

In response to a recent (October 2016) household survey in the Project area that was undertaken as part of the SIA to support the EA and EMP, 73% of those surveyed responded that they would like to see the Project proceed, with another 12% being unsure (SIMP, 2017). Although a large majority, this is less than the support for petroleum projects such as the P'nyang Gas Project (98% (Goldman, 2016)) or the PNG LNG Project (91% (Goldman, 2009)) at the same stage of development. The majority of survey respondents (62%) similarly expressed the view that their life would be better if the Project were to be developed, with 26% being unsure. It is possible that these figures reflect the alternative commercial options (e.g., palm oil, cattle farming and agribusiness) that Markham Valley landowners have in respect to land use, with such options not being readily available to the survey respondents in the other project areas.

Formal written confirmation of landowner support for the Project cannot be obtained until the negotiations concerning land access have been completed.

3.5 Stakeholder Consultation

A preliminary social mapping and landowner identification (SMLI) study that was conducted for the Project identified the communities that were likely to be affected by Project field activities, primarily the establishment of tree plantations. The potential positive and negative impacts of Project construction and operation on the landowner communities in Area A (which is the focus of this assessment) are described in more detail in Chapter 8.

The main stakeholder groups that the Project interacts with have been identified and are defined in Table 3.3, together with additional comment about the nature of the relationships between the Project and these groups. The extent of communication with stakeholders to ensure that all have been appropriately engaged on the Project activities will vary depending on the stakeholder involved, with the engagement program being consistent with free, prior and informed consent (FPIC) requirements (FPIC is discussed in detail in SIMP (2017)).

Table 3.3 – Identified Stakeholders

Description	Comment
Affected Landowners	
Traditional landowners of land required for plantations and other Project facilities	Interaction in the field will consist of community visits. Field studies will engage communities during the EA/EMP/RAP development and preparation process. These interactions will be recorded in the CA (community affairs) database A group of community/village liaison officers (CLOs/VLOs) from key local villages will be recruited as more local communities are affected by Project activities. These CLOs will be responsible for the two-way transmission of information regarding Project progress details and community concerns
Landowners of Surrounding Communities in the Markham Valley	
Neighbouring communities in the Project area who may be related to affected landowners	Non-directly affected landowners will be engaged similarly to directly affected landowners
Wampar and Umi Atzera Local Level Governments (LLGs)	
The local level authorities within whose boundaries Area A is located	As a result of regular extension visits to the Huon Gulf District, a good relationship exists between Project field staff and the councillors of the directly affected wards. Regular meetings with the LLGs, ward councillors and staff of district level administration will continue
Morobe Provincial Government	
Provider of community services, promoter of sustainable rural development	The Provincial Governor has supported the Project by letters written to PPL and other parties. Presentations have been made to the provincial heads and Project engagement with the provincial lands administration staff will expand as Project development progresses
National Government Departments, Agencies and Statutory Bodies	
Regulatory bodies whose regulations the Project or associated landowner representative entities have to comply with	A number of national regulatory departments and agencies are required to be informed of Project progress, especially in regard to formal submissions, e.g., CEPA on environmental matters. These agencies will be informed on an ongoing basis at appropriate stages of Project development
National and International Non-government Organisations	
Organisations that Markham Valley Biomass may cooperate with and who will be kept informed of Project progress	The Project may interact with a number of NGOs with regard to improving the health and livelihoods of the communities associated with the Project
International and Development Agencies	
Agencies that may provide specific assistance to the Project, such as Forest Stewardship Council (FSC), International Finance Corporation (IFC) and International Renewable Energy Agency (IRENA)	Markham Valley Biomass currently maintains relationships with selected international and development agencies to keep them informed of the Project's progress and this will continue throughout Project development. For example, the Project will comply with FSC guidelines with assistance from FSC representatives in Papua New Guinea

Table 3.3 – Identified Stakeholders (cont'd)

Description	Comment
PNG Corporations and Businesses	
Local companies that the Project is working with in some manner	Markham Valley Biomass currently maintains relationships with selected PNG corporations, and this will continue throughout Project development. For example, an MOU has been signed with South Pacific Brewery (SP) in regard to the promotion of growing cassava in the Markham Valley for use in beer production and to promote associated social and economic development in the area
Media Organisations	
Mainstream and social media bodies that the Project will keep informed of development progress and the achievement of any notable, newsworthy milestones	The Project has received little media attention as activities during the feasibility stages have been of a trial nature. Markham Valley Biomass will manage its own media interactions but will collaborate with the OSL public affairs personnel

Specific communication mechanisms that have been used to date include:

- Maintaining Village Liaison Committees, which currently consist of 14 representatives of 7 clans from Area A and are convened on a monthly basis. Details of discussion topics at these meetings have been recorded in the CA database, with minutes being circulated and signed off by the Leadership Group.
- Running town hall meetings, which are currently held on a quarterly basis.
- Participating in local market days, which are irregularly used as an opportunity to further raise local community awareness about the Project.
- Having a stand at the annual Morobe Show to present information on the Project and distribute 'Tok Save' information leaflets.
- Having a stall at the Trukai Agricultural Field Day held annually at the Trukai Erap Estate.
- Having regular meetings with LLGs, ward councillors and staff of district level administration, provincial government personnel, and national government agencies and statutory authorities.
- Maintaining relationships with various private companies and non-government organisations to keep them informed of the Project's process.
- Maintaining a website and Facebook page, and issuing press releases to various media outlets during operations.

These mechanisms will be reviewed and modified as the Project develops to ensure that transparent, open and pro-active communication and cooperation between Markham Valley Biomass and stakeholders is maintained.

4. Development Timetable

This section should include details of the project schedule that includes timeframes for site preparation, commissioning, commencement of operation, decommissioning, closure, etc as well as expected dates on which other relevant statutory approvals (if applicable) will be secured. A Flow chart, Gantt or PERT chart should be attached where appropriate.

(Excerpt from 'Information Requirements for Permit Applications and Registration of Intention to Carry Out Preparatory Work', DEC Operational Procedure, Schedule 3, General Guidelines on the Additional Information Required to Support a Permit Application for a Level 2B Activity)

The proposed timetable for the Project, including environmental approvals and Project execution, is summarised in Table 4.1 and shown schematically in Figure 4.1.

Table 4.1 – Timetable for Approvals and Development

Notional Date	Activity/Milestone
Feasibility and Engineering Studies	
Complete Pre-Feasibility and Feasibility Studies	2010 to 2015
FEED starts	1 September 2016
FID	Q3 2017
Environmental Studies and Approvals	
Submit Application for Environment Permit and Notification of Intention to Carry Out Preparatory Work to CEPA	4 September 2015
Finalised Power Purchase Agreement	Q4 2015
Final (revised) response from CEPA	8 March 2016
Environmental and social characterisation field studies	August 2016 to January 2017
Other environmental and social supporting studies	November 2016 to February 2017
EA/EMP submission	10 March 2017
Draft environment permit (CEPA)	27 June 2017
Final environment permit (CEPA)	27 July 2017
Project Execution	
Nursery construction	2017 to Q4 2018
Power plant (first 15 MW unit) EPC*	Q4 2017 to Q3 2019
3,000 ha of plantations planted	Q4 2017
6,000 ha of plantations planted	Q4 2018
Power plant commissioning (first 15 MW unit); electricity output commences	Q4 2019
10,000 ha of plantations planted	Q4 2019
16,000 ha of plantations planted	Q4 2020
Power plant (second 15 MW unit) EPC*	Q1 2020 to Q3 2022 (to be confirmed)
Power plant commissioning (second 15 MW unit); electricity output from second unit commences	Q2 2022 (to be confirmed)

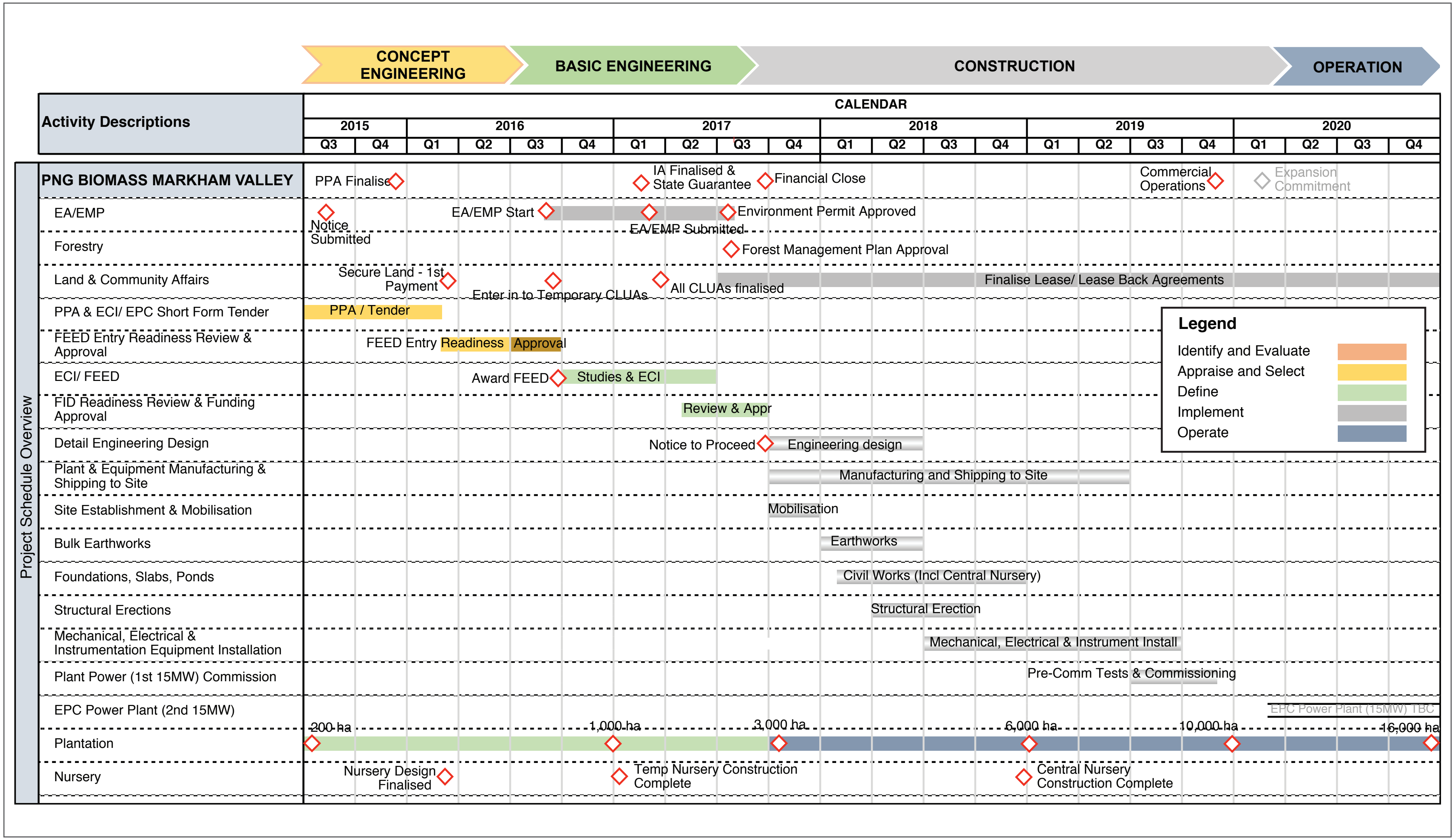
* Engineering procurement and construction.

ERIAS GROUP

PROJECT DELIVERY TIMELINE

PNG Biomass Markham Valley I Environmental Assessment Report

FIGURE 4.1



Source: AEL, 2017.

In parallel with the environmental and social studies, ongoing landowner negotiations and consultation with PPL will be pursued, as well as consultation with other stakeholders. The outcomes of these discussions, as well as the investment decision on the Project by Oil Search, may result in changes to the proposed development schedule.

In accordance with the *Forestry Act 1991*, prior to commencement of harvesting Oil Search will register machinery for wood chipping and will apply for a Forest Clearing Authority, as well as the various other regulatory requirements specified under that Act (see Section 2.4.3).

Other statutory approvals such as those described in Chapter 2 will also be obtained prior to construction of the power plant or commencement of harvesting.

The Project timetable does not include proposed dates for decommissioning or closure, since it is expected that both the power plant and the plantations will continue to operate well beyond the initial Project life of 25 years.

5. Site Selection

This section should provide details of the reasons for selection of the proposed site.

(Excerpt from 'Information Requirements for Permit Applications and Registration of Intention to Carry Out Preparatory Work', DEC Operational Procedure, Schedule 3, General Guidelines on the Additional Information Required to Support a Permit Application for a Level 2B Activity)

5.1 Rationale for Site Selection

From 2010 to 2015, Aligned Energy (who at that time was the Project proponent) completed a range of feasibility and conceptual development studies to select the optimum Project location and development concept. These studies included consideration of environmentally, socially and economically feasible geographical locations for the plantations and power plant.

The Markham Valley has been selected following extensive surveys across Papua New Guinea. Selection of this area in general, and the Project area/power plant site in particular, is based on a number of key factors including the following:

- The proposed plantation area is largely under-utilised, degraded anthropogenic grassland (which does not represent cleared native forest), along with some introduced raintrees. The raintrees also provide an initial source of biomass to fuel the power station during the first phase of plantation development.

- The proposed plantation area is characterised by relatively flat or low relief topography, good soil and adequate rainfall, all of which are preferred for plantation development (although the potential for some water stress due to the sandy nature of the soils is acknowledged and will be a specific focus of plantation development).

- A 132 kV transmission line (the Ramu grid) already exists along the length of the Markham Valley. This existing infrastructure will simplify the connection of the power plant to the regional electricity grid.

- The Project area has a low population density and a small number of clans and land groups, with landowners in the area being generally supportive of the Project. Markham Valley Biomass has entered into Memoranda of Understanding (MOU) and Land Use Agreements with landowners for the plantation trial and pilot studies.

- The Project area is close to a major port and engineering facilities. The Port of Lae is the largest cargo port in Papua New Guinea (PNG Ports, 2016) and has the required facilities for Project supply, construction and operation. Lae itself is the main industrial city in Papua New Guinea and has many of the required support services such as logistics and transport.

- There is easy access to the Highlands Highway and sealed roads between the power plant site and Lae. Road routes to, and within, the Project area currently exist (although these will require upgrading).

- The preferred power plant site is close to major hubs for electricity demand, including Lae and Morobe Mining Joint Ventures' existing and new developments (the Hidden Valley Mine is currently operational and connected from Erap by a 132 kV transmission line; the Wafi-Golpu Project (a proposed underground copper mine) is another major development in the final stages of planning).
- In terms of specific characteristics, the preferred power plant site:
  - Has 50 ha of flat land available to build 2 x 15 MW units and a fenced area for the Project nursery and central facilities.
  - Is composed of grassland (and introduced raintrees) that was previously used for grazing cattle.
  - Will provide adequate foundations to deal with seismic and other geotechnical factors.
  - Is appropriately located in terms of distance and direction from Lae Nadzab Airport and associated flight paths.
  - Is close to suitable water sources (either groundwater or the Markham River), thereby avoiding the need for lengthy pipelines for cooling water and nursery water supplies.
- Additional land areas suitable for plantations are located in the near vicinity of the Project area, if there is an opportunity to expand the Project and power plant capacity at a later date.

5.2 Alternatives

The factors outlined in Section 5.1 provide a rationale for the preferred location for both the plantations and power plant, with these two Project components being located close to each other for maximum efficiency. The following discussion outlines alternatives relating to both the Project itself, i.e., if the decision were made not to proceed with the Project, and specific aspects of Project design.

5.2.1 No Project

The Project will be the first biomass power development in Papua New Guinea and will provide a number of benefits including competitively priced, sustainable, reliable power, and employment and local business opportunities for PNG citizens (as detailed in Chapter 8).

As part of the Project's feasibility study, an analysis has been completed by MVB concerning the impact on the Ramu grid's power supply in the absence of the Project (and the findings are discussed further in Chapter 8). Using 2024 as an example, the Ramu grid is predicted to require an additional baseload and shoulder supply of 30 MW. Should the Project not proceed, this supply would have to be met by alternatives such as HFO with the associated CO_2 and other greenhouse gas emissions. It is assumed that, over the longer-term (i.e., after 10 years), hydro or lower intensity gas generation would be deployed to meet the requirements of large mining loads in need of additional sources of generation.

With HFO as the equivalent fuel source, there would be no carbon savings or sustainable benefits that are associated with a renewable power source. The Project is estimated to provide a reduction of 1.5 to 2.6 million barrels of oil equivalent that would otherwise be required over a 10-year period. Over the Project life it is expected that approximately 5,000,000 t of CO_2 credits may be available based on the displacement of diesel, HFO or hydrocarbon liquid generation. In addition, this fuel displacement would produce a substantial fuel purchase price saving to PPL. None of these benefits would occur if the Project were not to proceed (unless it were replaced by a similar development).

Other advantages of using plantation biomass (which is classified as a renewable power source by UNFCCC (2014a) over alternative fuel sources include:

- Lower costs and shorter time frame for construction (three to five years) than comparably sized hydropower and diesel/HFO alternatives.
- Significantly lower sulfur oxides (SO_x) and nitrogen oxides (NO_x) emissions than diesel and HFO.

These advantages/benefits would be lost if the Project were not to proceed and alternative fuel sources were used to meet the projected demand. Other renewable energy options such as large-scale solar or wind power are not considered feasible within the required timeframe due to factors such as unsuitable climate or technological challenges.

Although the main impact of the Project not proceeding is related to carbon emissions, additional consequences of the 'no Project' alternative include the ongoing widespread presence of the introduced raintree in the (degraded) Project area, and the absence of the environmental and social benefits and impacts that would otherwise become evident (as discussed in Chapter 8). In particular, it is unlikely that the social welfare of the local communities would change dramatically in a 5 to 10 year period (SIMP, 2017), with the direct and indirect economic and social benefits that would have been accrued by the farmers and their employees due to the Project being lost. The presently under-utilised grassland areas would probably either be given over to more cattle farming, used for oil palm or left unused.

5.2.2 Project Design Alternatives

5.2.2.1 Power Plant Site

The preferred power plant site is near Ganef, located in the southeast of the Project area and about 2 km from the Erap switching station (see Figure 1.1). Notwithstanding the rationale for the Project area that is described in the preceding section, three other nearby sites were also considered for the power plant. Final site selection was based predominantly on proximity to the Markham River and nearby power lines, geotechnical concerns, and negotiations with landowners.

The final selection of the power plant site is subject to technical studies that, at the time of preparing this assessment, are currently in progress. Should those studies indicate that the preferred site is unsuitable, other acceptable sites within close proximity that would not have a material impact on Project viability will be considered, and the appropriate authorities informed as required.

5.2.2.2 Power Plant Design

From a high-level perspective, several types and sizes of power units were considered for the power plant. PNG Power initially (in 2012) requested a proposal via a tender process for 30 to 40 MW of power at Lae. As the capital cost in $/MW reduces with size, the initial proposal to PPL was for a 36 MW dispatch unit, later modified to a 30 MW unit. However, it was evident during negotiations that the uncertain nature of demand growth and timing of resource project customers with loads in the 10 to 30 MW range required a power solution configuration with smaller units. This would minimise the cost to PPL for unused capacity and would have the attendant benefit of new units not exceeding the existing largest generation unit size on the Ramu grid (15 MW), which facilitates grid management.

In order to minimise the cost for power and to allow operational flexibility, MVB assessed the capital costs, fuel use and operation and maintenance costs for 10 MW and 15 MW units, to determine whether a 3 x 10 MW or 2 x 15 MW unit would provide an optimal solution. The outcome of this assessment was that a 1 x 15 MW unit with an option over a multi-year time period for PPL to take up a second 15 MW unit provided the best solution from a power price and network operation perspective.

As a consequence, the two units in the current Project design have been sized to match the next largest individual units currently on the Ramu grid, i.e., the 5 x 15 MW turbines of Ramu 1 (hydro), and meet PPL's preferred maximum 15 MW unit size and the terms of the PPA. Each 15 MW unit will be able to operate independently and provide power to the grid in the event that the other unit is offline for reasons such as maintenance.

At a more detailed and technical level, the design of the power plant has involved consideration of alternatives for the main plant components. These include:

- Fuel log delivery:
  - Debarking at the log storage facility rather than at the harvesting site.
  - Log storage options with, rather than without, stanchions.
- Fuel log storage, preparation and chip storage system:
  - Initially using a 100% capacity fuel train for the screen/hog and stacker conveyor system rather than a 200% system.
  - Having the chip storage area (partially) covered to prevent weather affecting chip quality.
- Fuel supply to boiler:
  - No alternatives to the preferred system.
- Boiler and auxiliary systems:
  - Start-up burner or manual ignition, given that the boiler will start only a few times per year.

  - Location of the ID fan before or after the electrostatic precipitator (ESP).
  - Installing a condensate preheater in the back end of the ESP to reduce the stack temperature by around 20°C, thereby further increasing the efficiency of the overall power plant and reduce the fuel consumption.
- Steam turbine generator and condenser systems:
  - Using an On Line Tube Cleaning System (OLTCS) or a ball cleaning system for the condenser.
- Cooling tower and cooling water systems:
  - Using auxiliary cooling water pumps that are designed as booster pumps on the discharge side of the pumps rather than having their own suction system.
- Raw water supply and water treatment system:
  - Rain water collection basin, well water or treated water from the raw water tank as sources of nursery water.
  - Sizing of the pre-treatment plant and the demineralise water plant.
- Wastewater system:
  - No alternatives to the preferred system.
- Electrical system:
  - Smaller transformers, switchgear and main distribution board.
  - Equipping the pumps and fans with a power consumption higher than 200 kW with 11 kV motors, with no auxiliary transformer and no 6.6 kV board.

In each case, evaluation of the alternatives has led to a preferred option based on consideration of engineering, financial, environmental and worker safety factors. These will be revisited and revised during FEED and detailed design as additional information becomes available.

5.2.2.3 Power Plant Construction

Planning the construction phase of the power plant has involved consideration of a range of alternatives, with perhaps the most significant being the adoption of a 'modularise and pre-assemble' philosophy as opposed to 'stick built' whereby construction occurs largely (or entirely) on site. Factors such as the power plant location and its proximity to Lae favour the optimisation of modularisation and pre-assembly, which is expected to save on costs and risk to time schedule, investment costs, site infrastructure requirements, coordination efforts, equipment and manpower requirements. Examples of equipment that may be delivered as modules or pre-assembled include pipe bridges, small bore piping, building floor and wall slabs, and various tanks and vessels.

5.2.2.4 Plantation Species

A key determinant of economic return for a biomass plantation project is the product yield and the time to mature harvest. During the Project development phase, demonstration plantations and progeny orchards were established to select the most productive, fast growing and adaptive species in the Markham Valley. The optimum species was identified as *Eucalyptus pellita*, a species that is native to the Western Province of Papua New Guinea (and elsewhere). This is a well-known commercial species that is often planted in large plantations because it develops rapidly, has a high density and is known to coppice. Demonstration plots and pilot plantations in the Project area have shown that *E. pellita* has an average growth height of approximately 4 m at twelve months.

Some sites in the Project area have been identified where conditions are more suitable to selected *Acacia* species (also native to Papua New Guinea). These species may therefore be planted in some areas as part of the final plantation design.

It is also worth noting that oil palm and biodiesel, while possible fuel sources, represent lower savings in terms of CO_2 emissions with increased technical complexity, hence the preference for *E. pellita* and similar trees as a fuel source. Cash crop residues, livestock waste or forestry residues (from harvesting and/or wood processing) are not viable options due to the quantities that would be required as well as the specific design of the boiler.

5.2.2.5 Plantation Design and Management

A number of alternatives were considered during the plantation design process, particularly in relation to factors such as the length of rotation (growing phase), tree planting density, use of seedlings, propagated cuttings and/or coppicing from first rotation rootstock, and other plantation establishment, maintenance and management requirements. The Project description provided in Chapter 7 reflects an optimised approach that is based on the objective of growing adequate biomass to fuel the power plant, combined with the proponent’s experience in plantation forestry and additional information obtained during plantation trials within the Project area. This approach will be further refined as additional information becomes available during plantation development.

6. Baseline Environmental Information

This section should provide environmental baseline data on environmental quality within the proposed project location that may be affected when the activity is carried out.

(Excerpt from 'Information Requirements for Permit Applications and Registration of Intention to Carry Out Preparatory Work', DEC Operational Procedure, Schedule 3, General Guidelines on the Additional Information Required to Support a Permit Application for a Level 2B Activity)

6.1 Physical Environment

6.1.1 Geomorphology, Topography and Landscape

6.1.1.1 Geomorphology and Topography

The Project area is situated on broad, flat alluvial plains associated with the Markham River and its tributaries, where the river flows in a generally west to east direction and forms the area's southern border (see Figure 1.1). To the river's north, the Markham Valley is generally flat from the river mouth at Lae in the southeast to the junction of the river's major tributaries (Maniang and Umi rivers) in the northwest, and the valley floor rises only 400 m in over 100 km. To the south of the river, parts of the valley are more constrained by hills and mountains, an exception being the area near the confluence of the Watut River with the Markham River (which is also near the Project area). The proposed plantation area is located in the broadest part (greater than 14 km) of the Markham Valley.

The alluvial fan of the Leron River (Plate 6.1), which is the largest of this type of landform in the general area, forms the western boundary of the Project area. The braided gravel channel of the Erap River forms the eastern boundary. Rivers and streambeds in this region are often highly mobile, altering course from year to year as a result of fluvial and hydrological processes, hence abandoned channels are common. The characteristics of rivers and streams in the Project area are discussed further in Section 6.1.5.

The Project area is positioned between about 40 m above sea level (asl) in its southeast corner and 300 m asl in the northwest near the steep Sawteeth Hills. The power plant site is located at approximately 58 m asl. Most of the proposed plantation area is flat to rolling land (less than 20% slope), with the northern and northeastern parts being more undulating. To the north are steep foothills and mountains of the Saruwaged Range more than 3,000 m high (see Figure 1.1 and Plate 6.2), which forms the northern boundary of the Project area. The Owen Stanley Range and the Central Range bound the Markham Valley to the south. The power plant and central nursery site, approximately 1 km to the southeast of Ganef, is on flat land 2.6 km north of the Markham River (Figure 6.1). Some 2.5 km southeast of the power plant site, Pyramid Hill is an isolated feature in the otherwise flat landscape that has a highest point of about 130 m asl.

Plate 6.1 – Alluvial Fan of the Leron River

Source: Pöyry, 2012.

Plate 6.2 – Flat Plains of the Markham Valley Backed by the Saruwaged Range

Source: Pöyry, 2012.

ELEVATION AND HYDROLOGY OF THE SOUTHEAST PART OF THE PROJECT AREA

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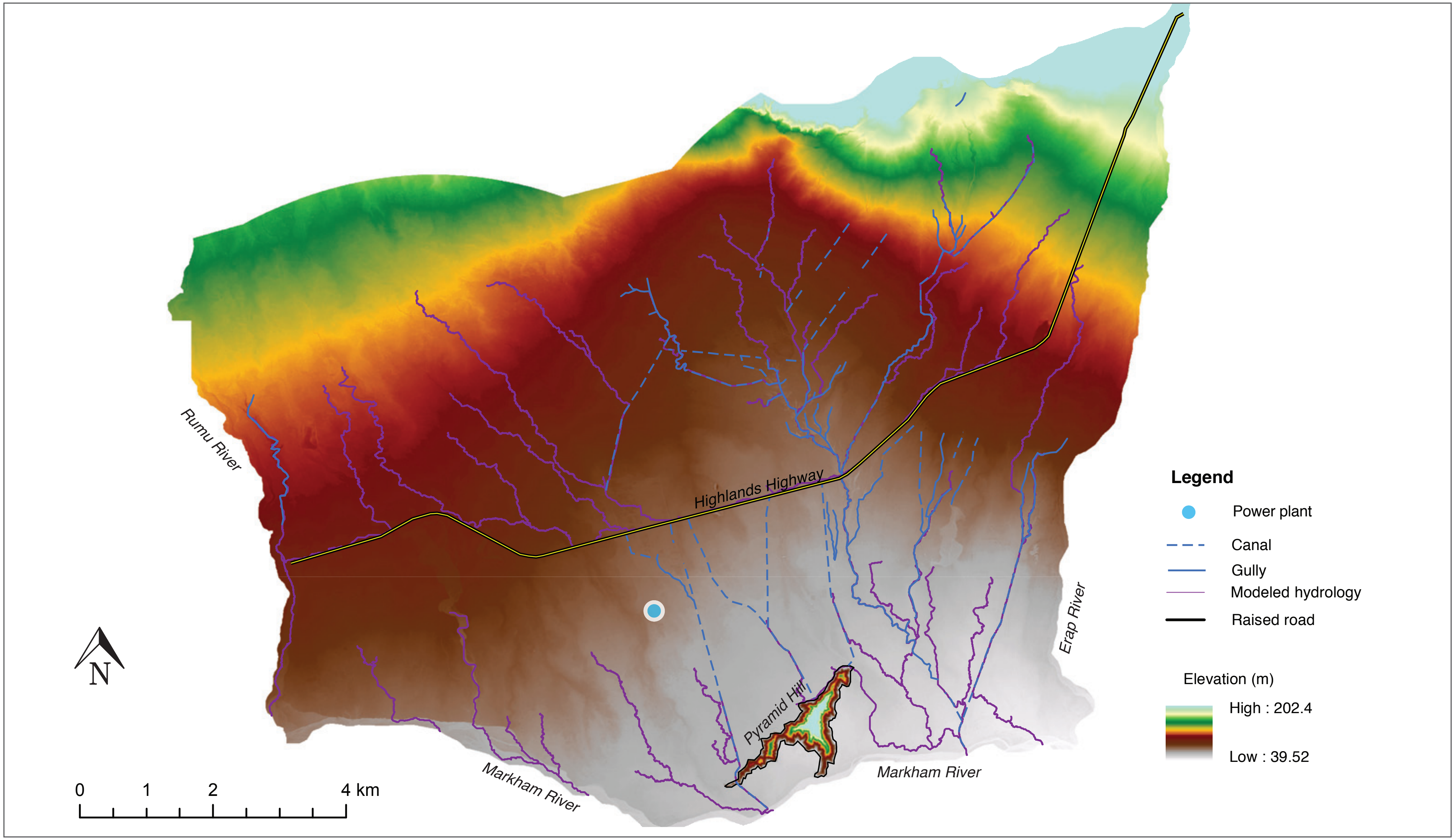
FIGURE 6.1



Source: Fugro, 2016.

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6.1.1.2 Landscape and Visual Amenity

In terms of the existing landscape character, most of the Project area can be described as extensive flat plains with minimal dissection or spatial definition, as shown in Plate 6.2 and Plate 6.3. In these areas, rivers and streams are located in shallow, indistinct valleys. The transition along parts of the northern Project area boundary from flat plains to steep hills is abrupt. This description is also applicable to other parts of the Markham Valley and surrounds, i.e., the visual character of the Project area is not distinctly different from that of the local region.

Plate 6.3 – Part of the Project Area with Plantation Trial Plot in Foreground

Source: AEL, 2015a

Vegetation within the landscape is anthropogenic grassland in over two thirds of the Project area, with most of the remainder being dominated by land uses including villages and gardens, agriculture, grazing and existing plantations, as well as areas of exotic (introduced) raintrees. Nearly 95% of vegetation within the Project area is degraded or highly degraded. The power plant site and the area between the site and the Highlands Highway is currently a mosaic of moderately degraded Kunai grassland and degraded open forest dominated by raintrees. Vegetation is discussed in more detail in Section 6.2.1 of this report.

From a visual landscape perspective, the Project area and the surrounding valley have been substantially modified from their natural condition by the various land uses described above. The Kunai grasslands form extensive areas of similar vegetation with few discernible patterns. Elsewhere, grasslands are interspersed by patches of raintree forest. Where existing land uses form a mosaic of vegetation colours and textures, these are often distinct, with sharp boundaries, geometric shapes and long straight lines, particularly where associated with existing coconut, sugar or oil palm plantations (Plates 6.4 and 6.5). Other vegetation and land use boundaries are more irregular and/or gradual, providing some visual interest but rarely being distinctive. Native vegetation is typically not evident, although raintrees may be seen as a positive focus of view.

Plate 6.4 – Sugar Cane in the Markham Valley

Source: Pöyry, 2012.

Plate 6.5 – Oil Palm Plantations in the Markham Valley

Source: Pöyry, 2012.

Landscape can be classified in terms of scenic quality based on naturalness, scenic variety and scenic prominence, uniqueness or distinctiveness, in the context of the visual character of the local region (FPB, 2006). Based on the above landscape characterisation, most of the Project area (i.e., the extensive flat plains) can be considered as having low scenic quality, apart from areas adjacent to major rivers and/or locations where there is more noticeable dissection of the landscape by watercourses, which may be considered as having moderate scenic quality.

Beyond the Project area to the north (visible in the background of Plates 6.1, 6.2, 6.3 and 6.4), the foothills and mountain ranges are of moderate to high scenic quality, and provide the key visual interest or focal point in the local area. This also applies to areas to the south and west of the Project area on the far (southern) side of the Markham River (Plate 6.6).

Plate 6.6 – Aerial View Looking West from the Markham-Watut Junction

Source: Matsui/Google Earth, 2014.

6.1.2 Geology and Soils

6.1.2.1 Geology

The geology of the Project area is relatively young, deep Quaternary alluvial fan deposits, consisting of rounded coarse gravels, sand and silt laid down during both the Pleistocene and Holocene periods (Fugro, 2016) (Figure 6.2). These geological materials have been, and continue to be, eroded from older materials in adjacent foothills and the more distant Finisterre and Saruwaged mountain ranges to the northwest and north, respectively. The nearest foothills are mapped as the 'Leron Formation' and consist of sandstone and conglomerate bedrock from the Pliocene period (Garrett-Jones, 1979). The geology of the northern mountain ranges is older again, including greywacke, sandstone, conglomerate and limestone from the upper Oligocene to mid Miocene periods. Geological materials continue to be actively eroded from these areas by rainfall and surface drainage, as well as landslides, before being deposited as alluvium in downstream areas, including the Project area.

Near the power plant site, Pyramid Hill (see Section 6.1.1) is an isolated outcrop of bedrock formed of Cretaceous-aged Owen Stanley metamorphic rocks including schist and/or greywacke, which are also found to the south of the Markham River.

GEOLOGY OF THE PROJECT AREA AND SURROUNDS

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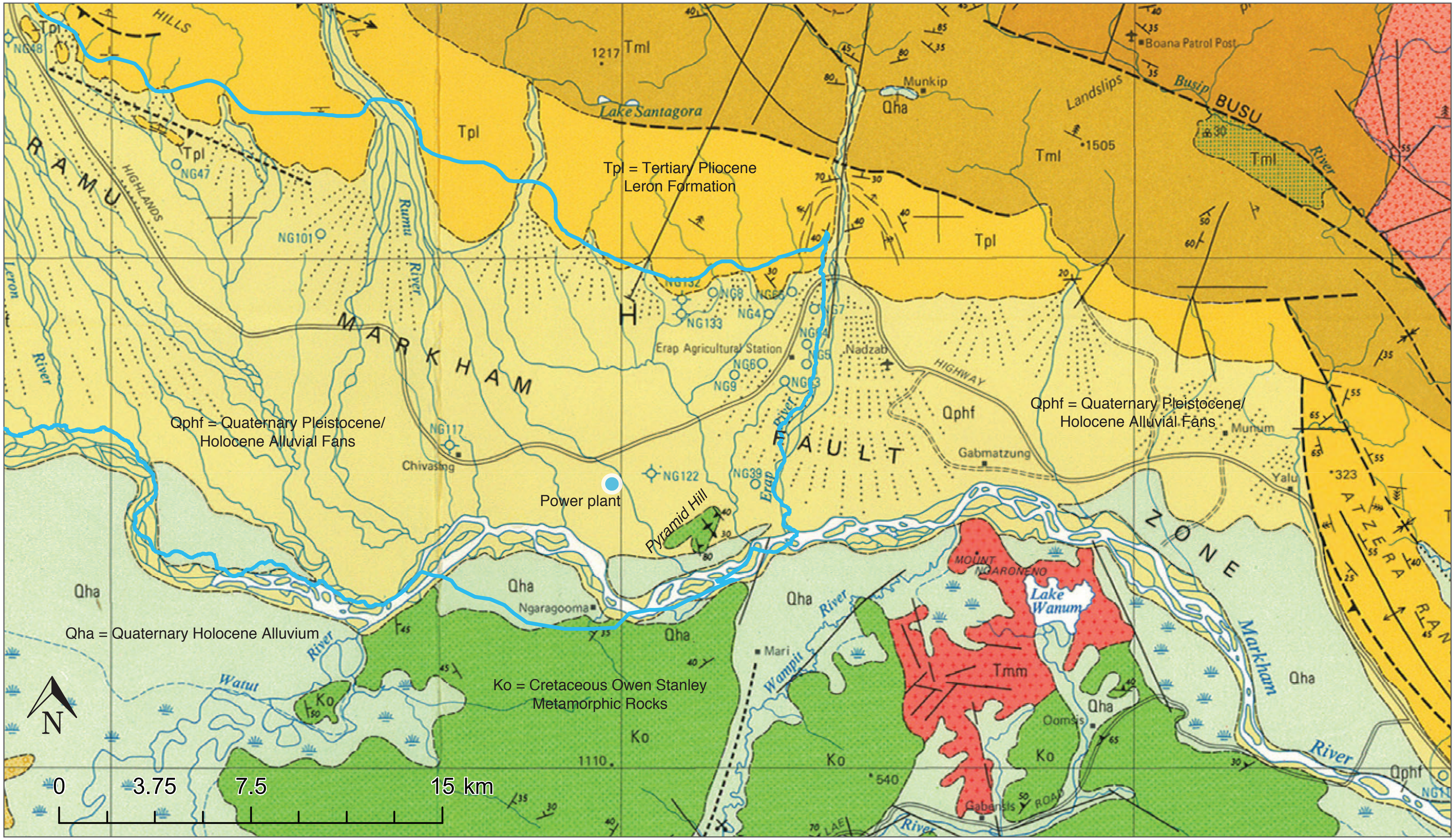
FIGURE 6.2



Source: Fugro, 2016.

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6.1.2.2 Soils

Soils vary across the Project area but are generally deep alluvial deposits (Plate 6.7) consisting of well to imperfectly drained, undifferentiated soils subject to seasonal moisture stress due to low water holding capacity. Soil sampling undertaken within the Project area (Table 6.1) found that topsoils are most commonly silt loams to approximately 30 cm depth, overlying coarse sands to a depth of 1 m or more (Plates 6.8 and 6.9). Less common are clay loam topsoils (Plate 6.10). Rounded (alluvial) gravels and pebbles are present in the subsoils of some sites, but bedrock is not encountered in areas of Quaternary deposits. Active or recent alluvial fans are typically composed of coarse granular material consisting of boulders, gravels, cobbles and sands with minor amounts of silts and clay. These sediments are usually deposited in lobes or lenses and are not uniform in thickness across the deposit (Fugro, 2016).

Plate 6.7 – Deep Alluvial Deposits Within the Project Area

Source: AEL, 2015b

Table 6.1 – Results of Project Area Soil Sampling – July 2015

Soil Horizon	Depth (cm)	Class	Colour	pH	EC (µS/cm)
Silt Loam – Ngaroraf D					
A	0-30	Silt loam	2.5Y 6/3	7.4	-
B	30-65	Sand	2.5Y 5/2	7.3	-
C	65-130+	Sand	2.5Y 2.5/1	7.5	-
Silt Loam – Orogawi					
A	0-30	Silt loam	2.5Y 5/3	7.2	86
B	30-70	Sand (coarse)	2.5Y 3.5/1	7.0	91
C	70-120+	Sand	5Y 2.5/2	7.2	90
Silt Loam – Motto					
A	0-20	Silt loam	5Y 3/2	7.4	87
B	20-35	Silt loam	2.5Y 3/2.5	7.6	88
C	35-45	Sand (coarse)	5Y 3/1	7.3	67
D	45-95+	Silt loam	5Y 3/2	8.3	90
Silt Loam – Nowa (Onga)					
A	0-20	Silt loam	2.5Y 4/2	7.3	87
B	20-35	Silt loam	2.5Y 4/3	7.3	88
C	35-100+	Sand (coarse)	5Y 3/2	8.3	116
Clay Loam – Ngaroraf E					
A	0-20	Clay loam	2.5Y 6/2	7.6	-
B	20-60	Clay	2.5Y 4/4	7.8	-
C	60-85	Silt/sand	2.5Y 2.5/1	7.9	-
D	85-105	Gravel/bedrock	2.5Y 2.5/1	7.6	-
Clay Loam – Ngaroraf F					
A	0-30	Clay loam	5Y 5/3	7.2	-
B	30-70	Sand (med)	5Y 4/4	7.5	-
C	70-140	Sand (coarse)	5Y 3/3	7.5	-
Clay Loam – Bampu					
A	0-15	Clay loam	2.5Y 3/1	7.6	98
B	15-45	Sandy clay	2.5Y 5/4	7.5	107
C	45-58	Sand (coarse)	2.5Y 5/1	7.3	64
D	58-90+	Loamy sand	2.5Y 4/2	8.3	93

Detailed soil mapping in the Erap-Leron area (which correlates closely with the Project area) by Zijsvelt and Legger (1971) shows the most common soils (33%) are deep, coarse loamy soils over gravels or sands, which tend to be well drained to imperfectly drained (Figure 6.3). Well-drained sandy soils (22%) and imperfectly to poorly drained deep fine loams or silts (21%) are next most common, with the latter often being situated further from the major rivers. Very shallow soils over gravel (15%), which are common in the northwest near the Sawteeth Hills, may be excessively well drained. Less shallow loams over gravel (7%) vary in their drainage capacity. Deep clay soils, which tend to be poorly drained, are least common (3%).

Plate 6.8 – Soil Pit at Nowa (Onga) with Silt Loam Topsoil and Coarse Sand Subsoil

Source: AEL, 2015c

Plate 6.9 – Silt Soils in a Riverbank Within the Project Area

Source: AEL, 2015b

Plate 6.10 – Soil Pit at Ngararaf with Clay Loam Topsoil over Silt/Sand and Gravel

Source: AEL, 2015c

Soil sampling undertaken in July 2015 in the Project area (see Table 6.1) found that soil pH is typically slightly alkaline, between pH 7.0 and 8.0 in topsoils. Knight (1973) indicates that most soils of the Markham Valley are lacking in some major plant nutrients as well as trace elements. In a PNG context, the absolute nitrogen contents in Markham Valley soils are comparatively low, although the thickness of the topsoils mitigates this. Bleeker (1983) confirms that topsoils developed on recent alluvial deposits in the lower rainfall parts of the Markham Valley have low average nitrogen of 0.13%, compared to typical nitrogen content in soils ranging between 0.02 and 0.4%. However, slightly to moderately weathered soils that show some horizon development (Mollisols) have consistently higher nitrogen contents than coarse-textured and very young soils in the valley (Entisols). Low nitrogen levels reflect the influence of a relatively low rainfall and high temperature climate on the area, as well as vegetation factors including, in some areas, regular burning of grasslands by local people.

Knight (1973) indicates that soil phosphate levels in the Markham Valley tend to be low, associated with the slightly alkaline soil pH. Soils in the vicinity of the Project area (i.e., with annual rainfall of about 1,400 mm and pH between 7.5 and 8.1) have between 11 and 33 mg/kg of phosphate (Bleeker, 1983). Both Knight (1973) and Bleeker (1983) state that potassium levels in the Markham Valley are generally high to very high.

With regard to potential soil erodibility, Knight (1973) states that:

> Most soils in the Markham Valley are regarded as unstable due to their youthfulness, high silt and sand fractions and low organic matter contents. Most surfaces would be subject to erosion in unprotected (bare soil) conditions but risks of topsoil loss increase with steeper slopes.

SOILS OF THE PROJECT AREA

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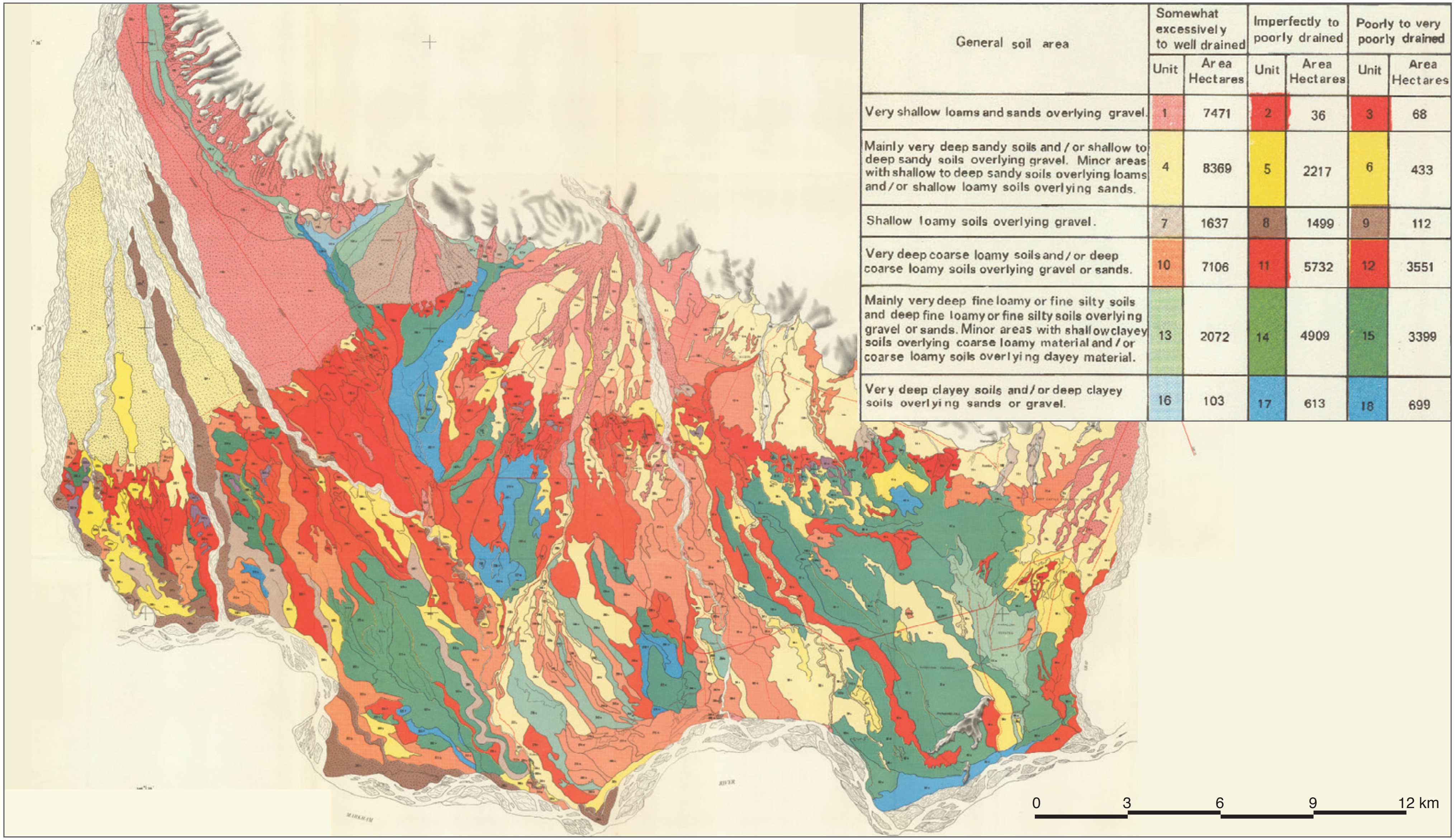
FIGURE 6.3



General soil area	Somewhat excessively to well drained		Imperfectly to poorly drained		Poorly to very poorly drained	
	Unit	Area Hectares	Unit	Area Hectares	Unit	Area Hectares
Very shallow loams and sands overlying gravel.	1	7471	2	36	3	68
Mainly very deep sandy soils and / or shallow to deep sandy soils overlying gravel. Minor areas with shallow to deep sandy soils overlying loams and / or shallow loamy soils overlying sands.	4	8369	5	2217	6	433
Shallow loamy soils overlying gravel.	7	1637	8	1499	9	112
Very deep coarse loamy soils and / or deep coarse loamy soils overlying gravel or sands.	10	7106	11	5732	12	3551
Mainly very deep fine loamy or fine silty soils and deep fine loamy or fine silty soils overlying gravel or sands. Minor areas with shallow clayey soils overlying coarse loamy material and / or coarse loamy soils overlying clayey material.	13	2072	14	4909	15	3399
Very deep clayey soils and / or deep clayey soils overlying sands or gravel.	16	103	17	613	18	699

Source: Zijsvelt and Legger, 1971.

However, given the moderate rainfall (within a PNG context) of the Project area (discussed in Section 6.1.4), water erosion will be lower than in nearby areas with higher rainfall, such as Lae on the coast or further inland at higher elevations. Landslide and flooding hazards are discussed in Section 6.1.3.

6.1.3 Natural or Induced Hazards

6.1.3.1 Introduction

A geohazard assessment has been undertaken by Fugro (2016), including review of potential seismic hazards, flooding and landslide hazards. The following summarises the findings of this assessment, which was limited to the southeast part of the Project area between the Rumu and Erap rivers, extending as far north as the Highlands Highway crossing of the latter (referred to as 'the study area' for the purposes of this section of the report). The proposed power plant site is located within this area.

6.1.3.2 Tectonic Setting and Regional Seismicity

The northern edge of the Markham Valley aligns with the Ramu-Markham Fault Zone, which is a northwest to southeast trending thrust fault that extends eastwards as a submarine canyon to join the deep New Britain trench in the Solomon Sea (Figure 6.4). This fault zone, which forms the boundary of the South Bismarck Plate and the New Guinea Highlands Deforming Zone, is 3 km northeast of the power plant site.

Remote sensing data was used to assess geomorphic features of the study area that were used as potential indicators of past faulting and of the likely hazard of surface fault rupture in the future. Two potential indicators of past surface displacement were identified:

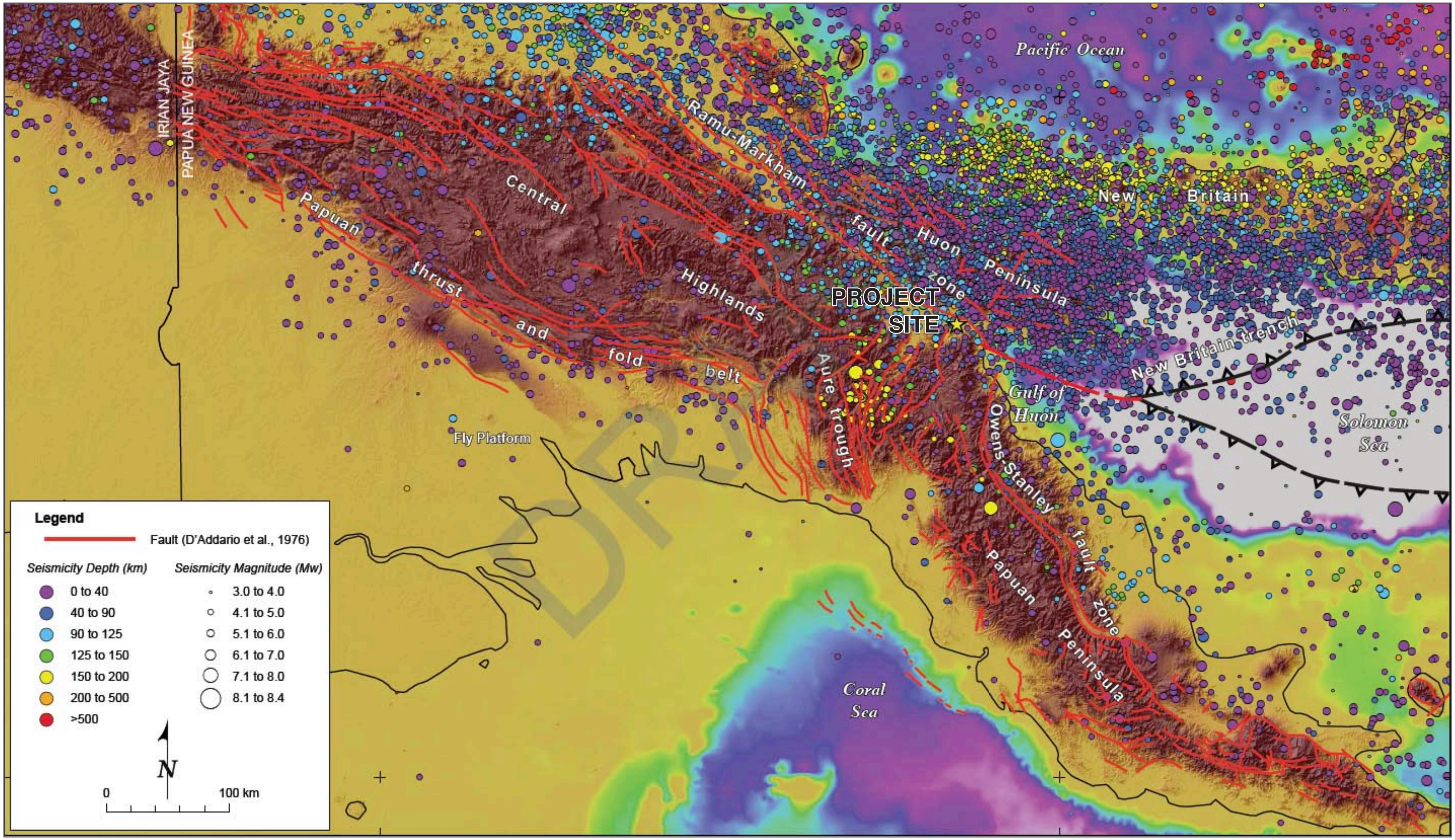
- Subtle east-west trending escarpments at the base of foothills in the northeast of the study area. These features may be tectonic or erosional in origin, but pose no risk to the power plant site.
- A slight leftwards deflection in abandoned stream channels approximately 3 km north-northwest of the power plant site. This feature is more likely to be the result of fluvial rather than tectonic processes.

Plate boundaries within the broader region of the Project area are associated with a concentration of seismicity, as shown in Figure 6.4. Shallow seismicity (0 to 40 km depth) is localised along the Ramu-Markham Fault Zone, with deeper seismicity also recorded. In terms of magnitude, seismicity of up to 7.0 M_W has been recorded along the northern margin of the Markham Valley (Fugro, 2016). The geographical seismic activity classification for Lae is 'Zone 2' (high seismic hazard region) in accordance with PNG Standard 1001-1982 General structural design and design loadings for buildings, Part 4 Earthquake loadings (Golder, 2017).

6.1.3.3 Landslides

Landslides can be triggered by ground movement caused by seismic activity (earthquakes) or may occur due to inherent slope instability with or without additional disturbance such as cut and fill works or watercourse diversion, particularly when high groundwater conditions exist in wetter months. Fugro (2016) assessed the landslide hazard within the study area in relation to evidence

FIGURE 6.4



Source: Fugro, 2016.

of past landslides combined with percent slope. Landslides are most likely to occur in areas where they have previously occurred, on slopes greater than 15% and on landslide-prone geologies.

As noted in Section 6.1.1, the vast majority of the Project area is relatively flat, with steeper slopes being confined to foothill areas and bedrock ridges in the north of the area. Within the southeastern study area, no landslide scarps were identified on the steeper slopes, nor were deposits of landslides identified downhill of these areas. Landslides are very unlikely to occur in the vicinity of the power plant, and are unlikely to occur in any but the steepest parts of the plantation area.

6.1.3.4 Flooding

A qualitative assessment of likely flooding hazard, undertaken by Fugro (2016) between the Rumu and Erap rivers, concluded that topography, mapped fluvial features and modelled drainage patterns indicate that surface water drains preferentially to the southeast corner of this area, near Pyramid Hill and the Erap switching station, to the east of the power plant site (see Figure 6.1). Multiple artificial channels occur in this vicinity, which Fugro (2016) suggests have been constructed to divert watercourses as well as sheet wash during major rainfall events, with the number of channels likely indicating a significant amount of surface runoff in this location. The above factors combined with low-lying topography in the vicinity of the switching station indicate a strong risk of flood hazard in this area during major rainfall and storm events.

The proposed power plant site is 2.5 km west of the Erap switching station, just outside the above-mentioned low-lying area with its numerous natural and artificial drainage channels. The site is also located slightly higher in the landscape at approximately 58 m asl. As such, the risk of flooding is lower than that for a previous site option that was adjacent to the switching station. However, the hydrological investigation undertaken to support this environmental assessment (and provided as Appendix 1 of this report) describes the currently proposed power plant site as being situated on the floodplains of the Markham, Erap and Maralumi rivers, and preliminary modelling indicates that this location (as well as parts of the plantation estate) requires further consideration of flooding risk. This is discussed further in Section 6.1.5.1.

Sites next to the numerous rivers and streams within the Project area may also be at risk of flooding/inundation, with potential for associated access restrictions, erosion and/or scour. This will be addressed in management planning for the power plant and plantations.

6.1.4 Climate

6.1.4.1 Rainfall and Temperature

The Project area has a tropical climate with distinct wet and dry seasons. The wettest months are October to April, with rainfall being over 120 mm/month on average, while the driest months are June to August, with less than 60 mm/month on average. Annual rainfall for the Project area is in the range of 1,200 to 1,400 mm. Rainfall varies considerably between years, and also between different locations within the Markham Valley. Annual rainfall in Lae is much higher, being approximately 4,400 mm (WMO, 2016).

As described by Garrett-Jones (1979), rainfall patterns in the Project area can be related primarily to the two patterns of atmospheric circulation that influence most of Papua New Guinea. From December to March, i.e., the 'northwest' or 'monsoon' season, low-pressure systems associated with the intertropical convergence zone (ITCZ) dominate atmospheric circulation. Between May and October, the ITCZ is located north of the equator and has no direct influence on the Project area. At this time, southeasterly winds, i.e., the ‘southeast trades’, dominate atmospheric circulation. Either circulation system may dominate during the shoulder months, when the ITCZ is moving across the region. Due to the significant variations in topography between the Markham Valley floor and the nearby Sarawaged Range, circulation patterns produced by anabatic and katabatic winds (i.e., winds heading up and down slopes, respectively, as a result of radiation effects on air temperature and density) along the valley margins have a significant effect on local rainfall.

Mean annual maximum temperature in the Project area is around 31°C, with the hottest months of January to March (mean monthly maximum 32.6°C for these months) coinciding with the peak of the wet season. The coolest months are June to September, with a mean monthly maximum of 29.2°C. Mean monthly minimum temperature is approximately 23°C.

The average daily total solar radiation in the Project area varies from around 15 MJ/day between May and July to around 30 MJ/day from November to February (see Appendix 2 of this report). Figure 6.5 shows Project area monthly average rainfall, maximum temperature and minimum temperature based on local records (average from Umi, Bampu, Nadzab, Chivasing and Leron weather stations in 2014), moderated by comparison with synthetic data from the University of East Anglia Climate Research Unit. This figure also shows daily solar radiation calculated for the Project area. Further detail is provided in Appendix 2.

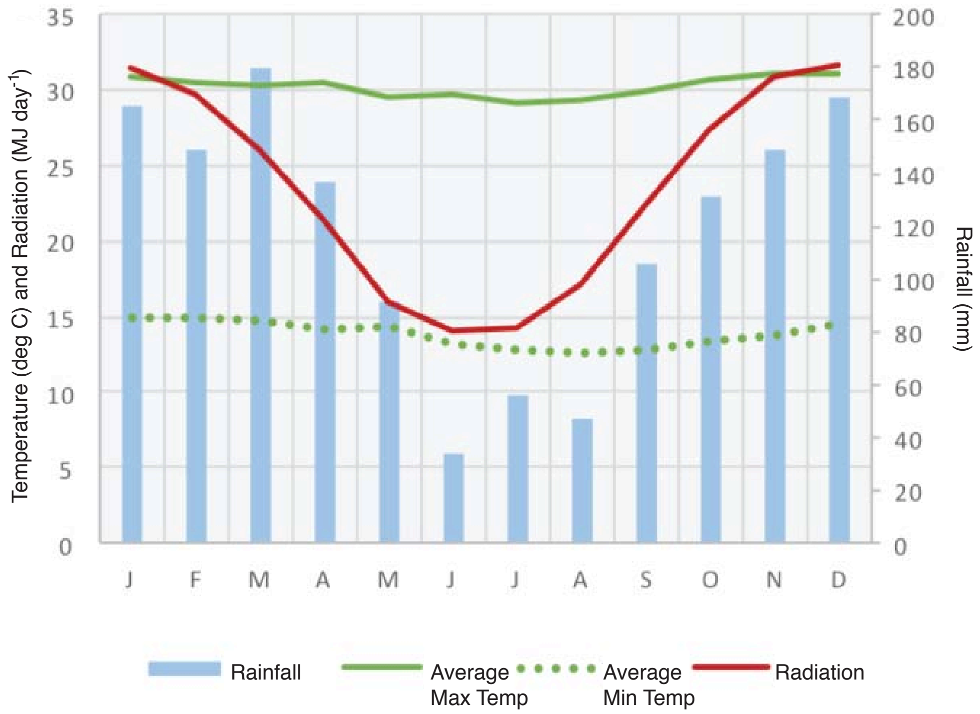
6.1.4.2 Wind Speed and Direction

Available meteorological data from Lae Nadzab Airport was used in conjunction with a CALMET meteorological model to assess expected typical wind speed and direction within the Project area. Wind speeds in the vicinity of the power plant site were found to be light to moderate, ranging between 0.5 m/s (1.8 km/h) and 8.0 m/s (28.8 km/h). Calm conditions occur 12% of the time, and winds are most often light at less than 6.0 m/s (21.6 km/h).

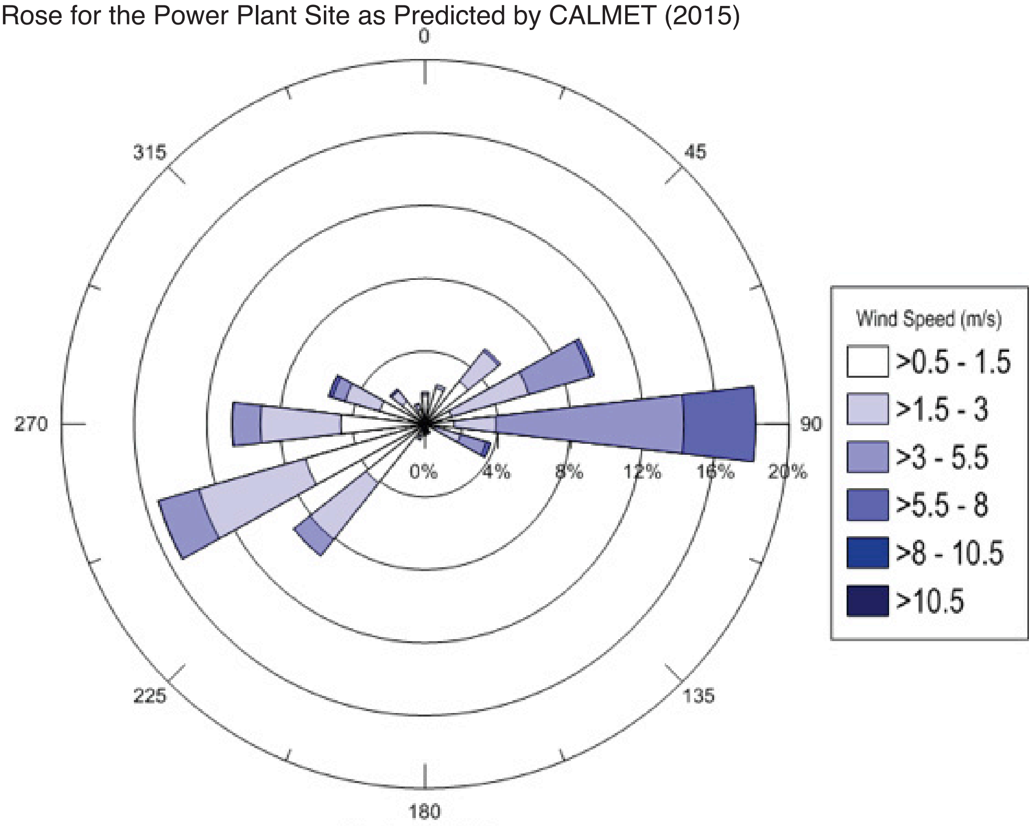
The prevailing winds are most frequently from the east, associated with the southeast trade winds from May to October (Figure 6.5). Winds from the west-southwest are slightly less frequent. Further details concerning wind speed and direction are provided in Appendices 3 and 4.

FIGURE 6.5

Climate of the Project Area



Annual Wind Rose for the Power Plant Site as Predicted by CALMET (2015)



Sources: Appendix 2; Appendix 8.

6.1.5 Surface Water

6.1.5.1 Hydrology

General

The following description of the surface hydrology of the Project area and surrounds is from a report prepared by Hydrobiology Pty Ltd and provided as Appendix 1. As described therein, the information presented below reflects both a literature review and the results of hydrological modelling that involved:

- Generating runoff estimates using several techniques to provide a range of values that would inform the assessment. The resulting hydrological statistics represent the upper and lower values that can be expected.
- Using these estimates to develop flow duration curves, plus additional methods to develop design peak discharges and flooding extents.

Flows

The location of the Project area within the Markham Valley, which is bounded to the northwest and north by the Finisterre and Saruwaged ranges (respectively) and to the south by the Owen Stanley Range and the Central Range, is shown in Figure 6.6. The Markham River itself is situated in the eastern part of the Markham-Ramu Graben which, in turn, forms part of the Sepik-Markham Depression, a major structural feature of Papua New Guinea and West Papua. Selected physical characteristics of the river, which is the fourth largest in Papua New Guinea are summarised in Table 6.2.

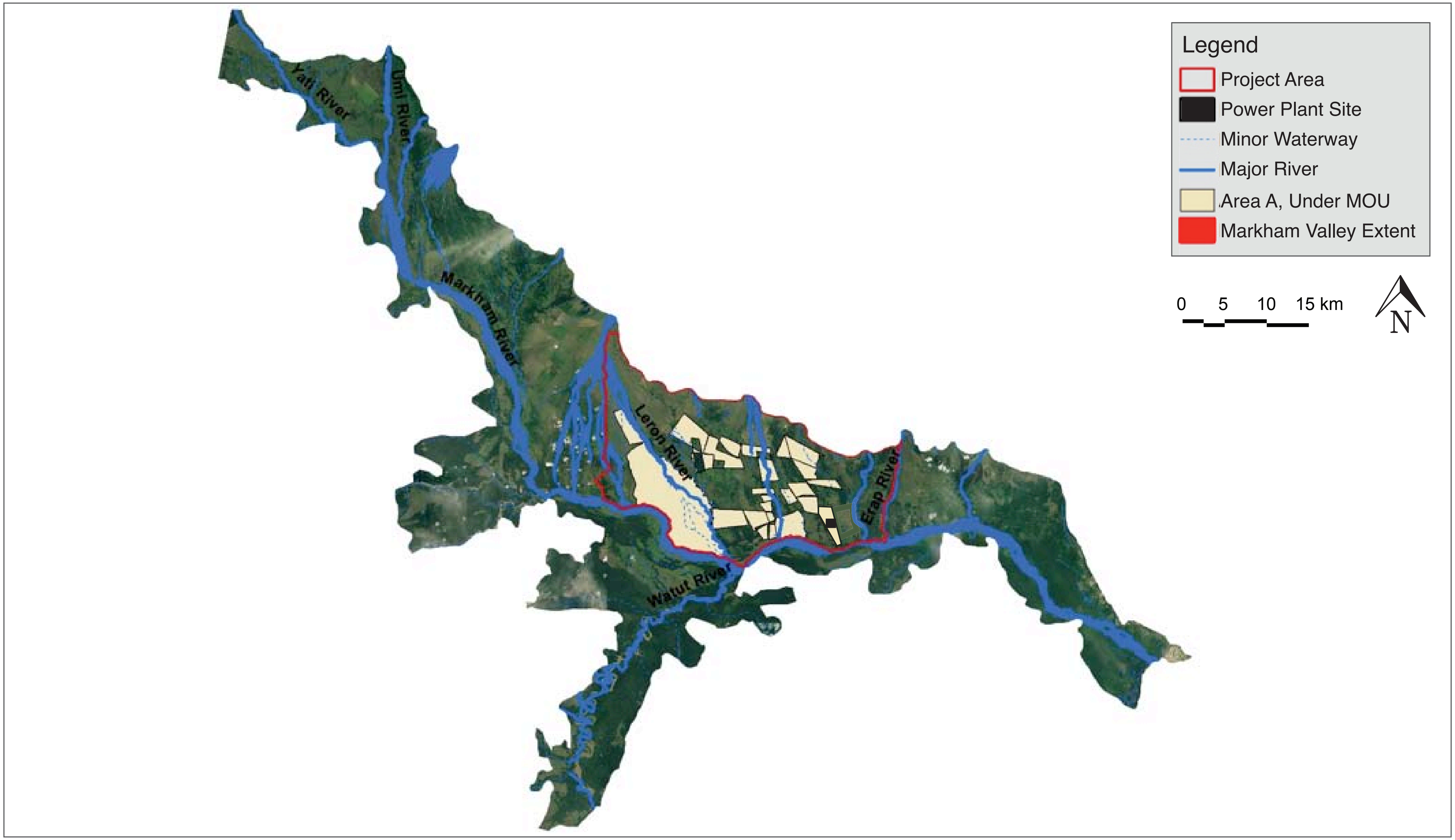
The main tributaries of the Markham River – the Umi, Maniang, Leron, Rumu and Erap rivers – flow from the northern ranges, while major tributaries on the south side include the Watut River and the Wampit River.

The Project area itself straddles the northern floodplain of the Markham River between Leron and Nadzab, and encompasses the Leron, Erap, Rumu and Maralumi sub-catchments (Figure 6.7). These four main waterways are all considered to be permanent, although it is likely that flows cease for short periods during very dry conditions in the smaller catchments. Many of the smaller distributary channels of the waterways would dry during the dry season, with only the main channel remaining 'wetted' during these periods.

Using the modelling approach described above, hydrological statistics for the various sub-catchments were determined and are summarised in Table 6.3. Flow duration curves for both model outputs the Rumu River is shown in Figure 6.8, which also shows the monthly mean daily flows for the four sub-catchments (excluding the Markham River) as determined using the Pickup model (see Appendix 1 for additional graphs and other model outputs). Examination of the data shows that the two models predicted similar low exceedance flows (higher magnitude values), maximum flows and 90th percentile flows (i.e., 10% probability of exceedance), with differences becoming more apparent at lower flows.

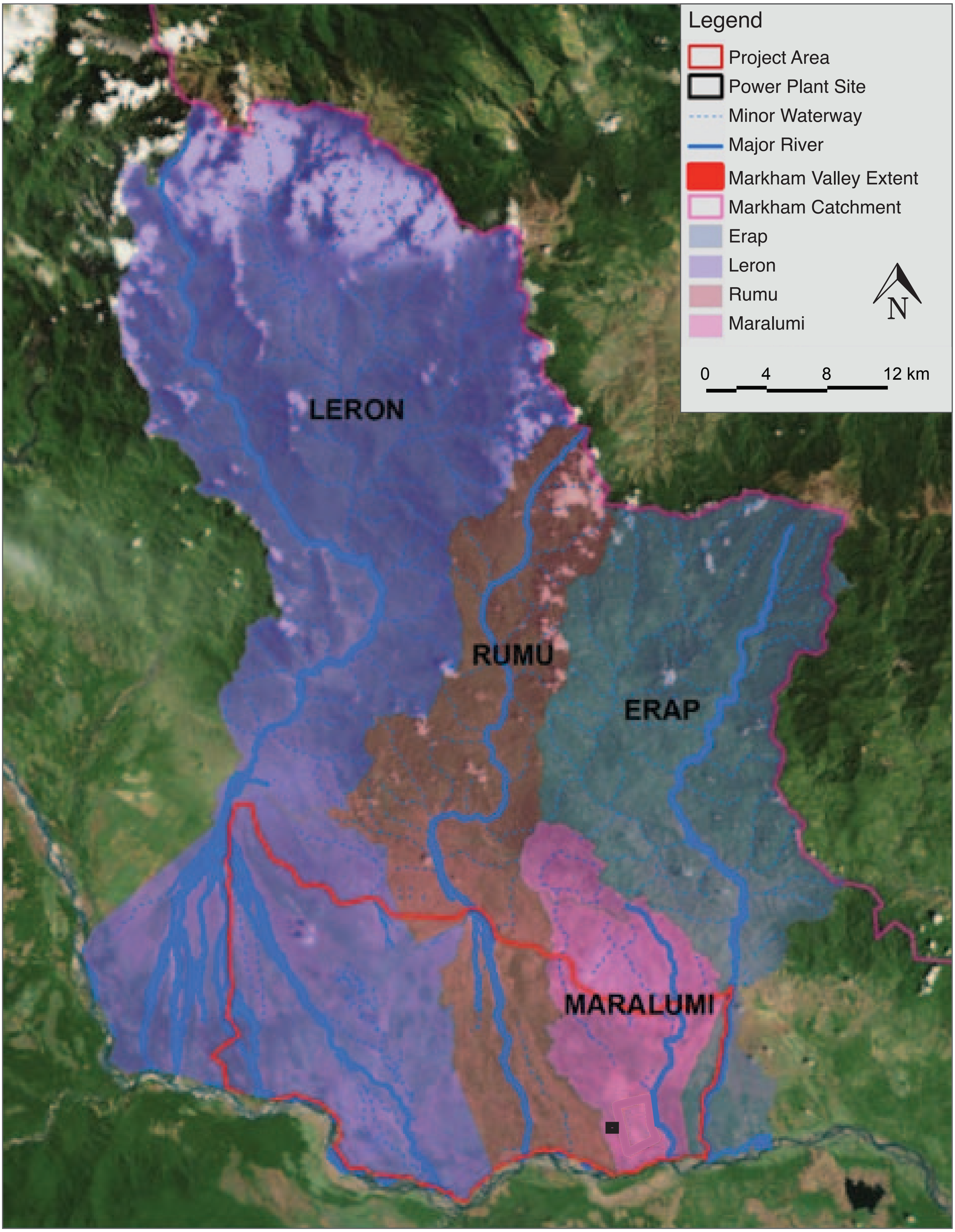
LOCATION OF THE PROJECT AREA WITHIN THE MARKHAM VALLEY

FIGURE 6.6



Source: Appendix 1.

FIGURE 6.7



Source: Appendix 1.

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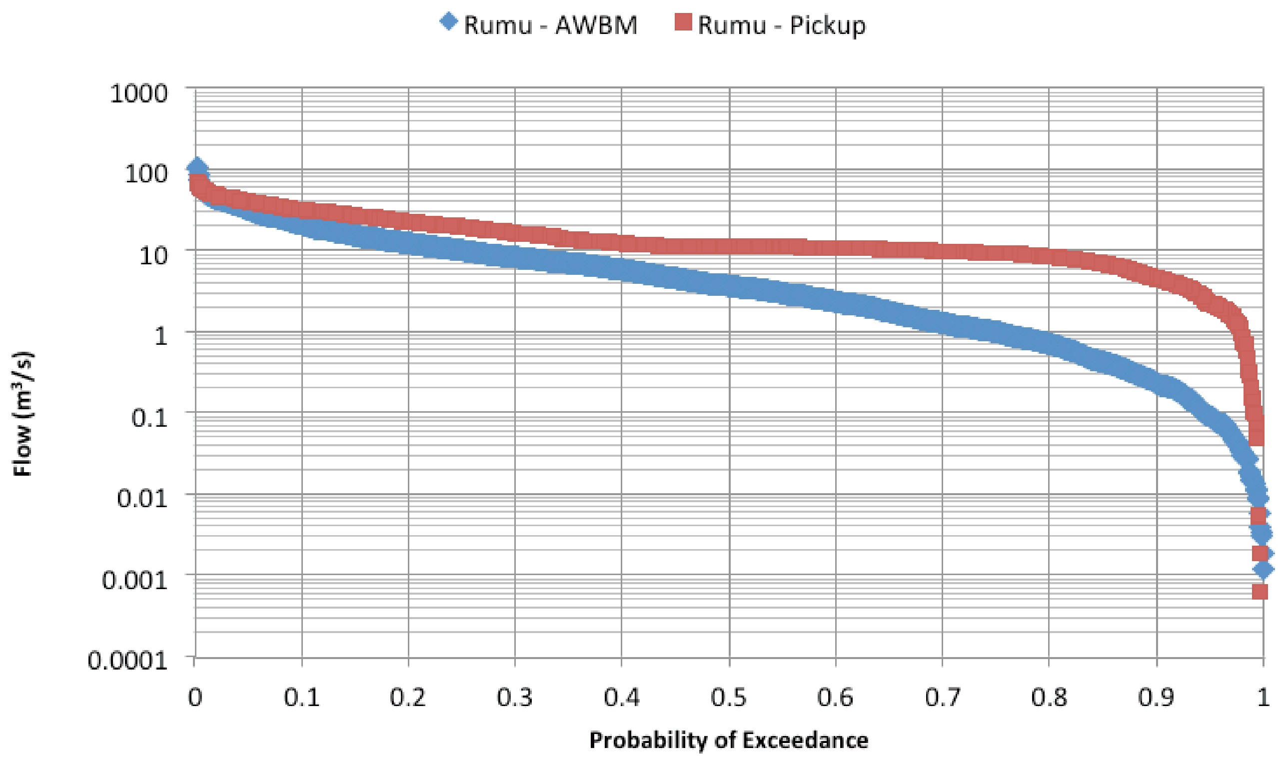
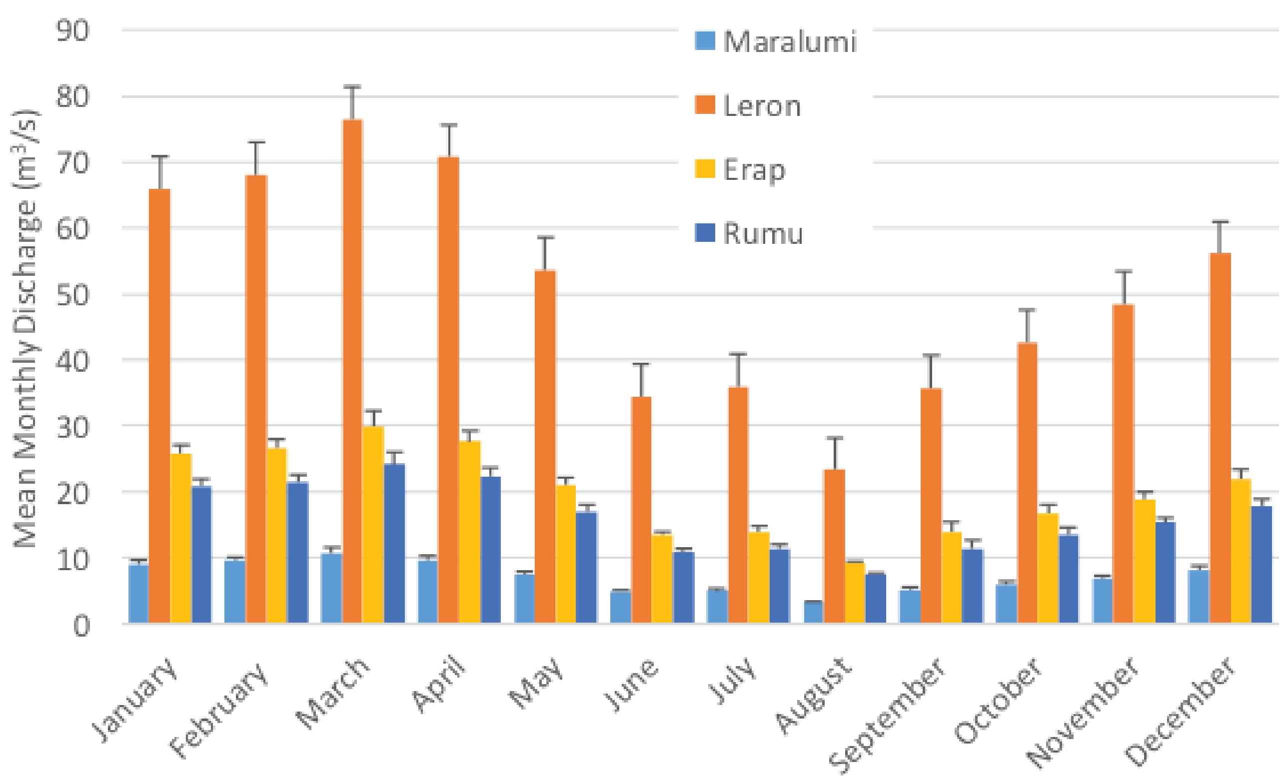
FIGURE 6.8

A. RUMU SUB-CATCHMENT FLOW DURATION CURVES FOR THE TWO MODELS



B. MONTHLY MEAN DAILY FLOWS FOR THE FOUR SUB-CATCHMENT (PICKUP MODEL)



Source: Appendix 1.

Table 6.2 – Selected Physical Characteristics of the Markham River

Parameter	Value/Comment
Catchment area (km^2)	12,000 to 13,000
Catchment mean annual rainfall (mm)	2,100
Mean annual discharge (m^3/s)	~350 to 450
Maximum recorded discharge (m^3/s)	3,087
Channel width (km)	0.5 to 2.0
Valley width (km)	3 to 8 (generally)
Maximum valley width (km)	22
Length (km)	140
Elevation at source (m)	450
Area of alluvial fan (km^2)	1,800
Gradient: min, max, average (m/m)	0.001, 0.006, 0.003
Morphology	Anastomosing*, shallow, wide, braided#
Planform†	Mostly straight, with some incipient meanders of very long wavelength
Sediment type	Variable (gravel-clay)
Floodplain sediment grade (bridge reach)	65% of material in upper 2 m has a median particle size (D50) of <0.075 mm
Channel sediment grade (Markham River mouth)	D50 ~ 19 mm in upper 0.5 m of bed
Channel sediment grade (Maus Markham)	Sandy gravel, gravelly sand, and boulders up to 50 cm diameter
Tributary stream types	Fans**, piedmonts##

* Watercourses comprising two or more interconnected channels, separated by semi-permanent banks formed of cohesive material.
# A waterway characterised by a network of interconnected converging and diverging channels. The intervening bars are exposed at low water and are highly mobile/transient.
† View from above.
** A fan- or cone-shaped mass of material (usually sand/gravel) deposited by a stream where it emerges from the constriction of a narrow valley at a mountain front and debouches onto a plain or into a wide trunk valley.
Used to describe the gentle slope leading down from the steep mountain slopes to the plains, including the bedrock (pediment) and the accumulated colluvial and alluvial material (bahada).

Notwithstanding the differences between models, it is evident that:

- All rivers display similarly low mean and median flows relative to their higher magnitude flows, and high variability.
- There is considerable hydrological seasonality (as shown by the considerable range between the 10th and 90th percentile values) (although this is partly an artefact of the modelling methods, rainfall records and the literature support this finding).
- In terms of mean and median flows, and excluding the Markham River, the Leron River is the largest, with the Rumu and Erap rivers having similar flows, while Maralumi River is the smallest of the main watercourses in the Project area.

Table 6.3 – General Hydrological Statistics for the Study Sub-catchments

	Maralumi Sub-catchment	Leron Sub-catchment	Rumu Sub-catchment	Erap Sub-catchment	Markham Sub-catchment
General Statistics (m^3/s)					
Percentile 10*	0.05–2.08	0.38–14.94	0.12–4.72	0.15–5.83	3.38–135
Percentile 90#	9.46–9.77	68.0–70.1	21.5–22.1	26.5–27.3	612–631
Maximum	204–237	1,464–1,699	463–537	571–663	13,184–15,300
Mean	3.64–7.10	26.2–50.9	8.26–16.1	10.2–19.9	236–458
Median†	0.83–5.22	5.99–37.4	1.89–11.8	2.34–14.6	53.9–337
Mean daily baseflow	0.82–3.88	5.88–27.8	1.86–8.78	2.30–10.8	53.0–250
Flood Frequency Peak Discharge (m^3/s)					
1 Year ARI	46.8–84.4	336–559	127–177	157–218	3,028–5,032
10 Year ARI	109–134	782–971	247–304	305–376	7,047–8,677
100 Year ARI	174–200	1,254–1,434	396–453	490–555	11,297–12,918

* The 10th percentile has a 90% probability of exceedance at any one time; Figure 6.8 uses 'probability of exceedance' rather than percentiles.
# The 90th percentile has a 10% probability of exceedance at any one time; Figure 6.8 uses 'probability of exceedance' rather than percentiles.
† The median flow (50th percentile) has a 50% probability of exceedance at any one time; Figure 6.8 uses 'probability of exceedance' rather than percentiles.

The extensive floodplain (both laterally and longitudinally) results in substantial areas of the valley being subject to inundation, with about 40% subject to flooding on a permanent/long-term basis and 36% subject to flooding periodically/seasonally. Only 24% of the valley is considered not subject to flooding (although this is not entirely consistent with anecdotal evidence). Overbank flows and groundwater levels during flooding of the major waterways influence the inundation of several low-lying wetlands within the Project area. These areas tend to occur upstream of the clearwater streams that are discussed further below (in Section 6.1.5.2) and are understood to be dry except during periods of high rainfall, i.e., they do not form permanent wetlands.

6.1.5.2 Sediment Transport

General

The following description of the sediment transport in the Project area and surrounds (including channel condition and behaviour) is from the Hydrobiology report that is provided as Appendix 1. As described therein, the information presented below reflects desktop data review, remote sensing methods, review of in situ photographs and descriptions, and catchment sediment budget modelling that involved:

- Considering the movement and storage of sediment throughout the contributing catchments as well as the theoretical transport capacity of the channel.
- Using a Monte Carlo (MC) framework[1] that allowed the uncertainty, variability and random nature of sediment generation and transport to be quantified using an iterative process that involved running model scenarios tens of thousands of times.

[1] This is a probability simulation that uses random samples of parameters to examine the behavior of a complex process.

Geomorphology

As noted in Appendix 1, the Markham River has been described as ‘quite unusual’ due to a braided form along its entire length and a longitudinal slope that is considerably higher than for any other plain stream of comparable discharge and catchment area within a PNG context. This is attributed primarily to the very high rates of sediment delivery from upland areas to lowland plains. This, in turn, reflects the combined effect of high rainfall and tectonic activity (i.e., frequent earthquakes that trigger landslides). The river's morphology throughout its length shows similarities to alluvial sediment runout fans, and the main river channel follows a relatively steep course before discharging to the Huon Gulf at Lae after traversing a highly energetic flood plain.

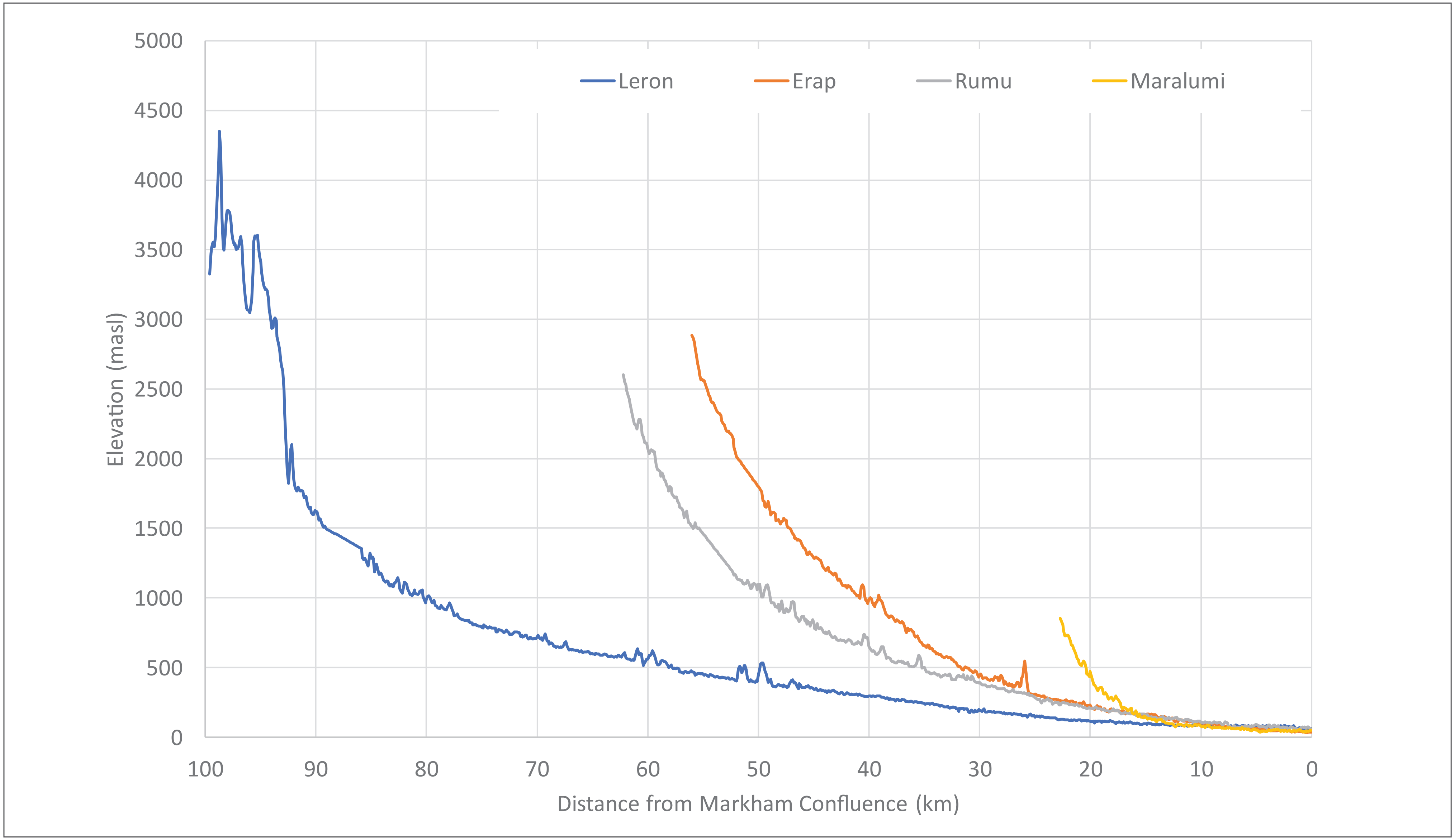
Of particular note is that landslide damming of rivers and subsequent dam breaching result in pulses of sediment being transported to the coast. For example, an 'event' in 1988 mobilised an estimated 1.8 km^3 of sediment within the Markham River catchment, which is probably still being transported through the river system, while temporary damming of the upper Leron River by debris (soil and rock) occurred as a result of earthquakes in the Finisterre Range in 1993.

Alluvial fans are a characteristic feature of the Markham Valley and an important sediment store and delivery mechanism. These features represent sediments deposited by river flows, and debris flows resulting from landslide activity typically triggered by ongoing uplift of the northern block and seismic activity. The fans contain alluvium to depths of up to 1,000 m with river channels incised up to 20 m below the fan surface. The largest fan is the Leron Fan, which forms the western boundary of the Project area; other notable fans include those of the Rumu and Erap rivers, with the latter forming the eastern boundary of the Project area. The active alluvial fan deposition in the northern part of the valley has forced the Markham River to flow against the valley's southern margin. The fans, and the rivers that flow over them, are highly mobile and continuously changing in form due to ongoing fluvial processes and intermittent tectonic activity. The general depth of floodplain alluvium is not known but is likely to be at least 50 m.

The Markham River bed is typically braided and up to 1.5 km wide in places. The braids, islands and bars of the river channel are continually changing, and the largest recent shift is a major avulsion between the Watut-Markham confluence and the Markham River bridge crossing that occurred in the mid-1990s.

As noted above, the Project area encompasses four sub-catchments. While channel length and catchment area vary considerably, all four sub-catchments consist of very steep headwaters, draining onto flat alluvial fans (Figure 6.9). The stream types are indicative of very high sediment loads, as demonstrated by the wide, flat beds composed of mostly sands and gravels, with sporadic cobbles and boulders. Widths of the Leron, Erap and Rumu rivers are several hundred metres in the most downstream reaches, and narrow in an upstream direction towards the foothills. In contrast, the Maralumi River channel width remains less than 100 m for its entire

FIGURE 6.9



Source: Appendix 1.

length. Floodplain widths are also highly variable, and are generally intersected by many smaller distributary channels and waterways, which vary between turbid waterways with coarse bed material and clearwater streams with finer bed material. The Markham, Leron, Erap and Rumu rivers, and turbid ephemeral waterways, are subject to major aggradation, bank instabilities and avulsions. Maralumi River and other clearwater waterways are generally stable, well-vegetated waterways that are less subject to channel instabilities.

While most of the major streams and their tributaries are mobile and subject to high sediment loads, several smaller, less mobile systems with much lower sediment loads are also evident. These appear to originate downslope of the fans produced by the high-energy headwater streams, i.e., due to the excess of sediments in the fans, flows are sub-surface during the dry season and only return to the surface at the origins of the clearwater streams some distance downstream. The downstream reaches of Maralumi River and Klin Wara (a Leron distributary) are good examples of this. The dissipation of energy and settlement of sediment loads within the fans appears to be contributing to clearwater conditions in subsequent outflows. During the monsoon, these waterways would probably be connected by surface flows and turbidity would be higher.

Sediment Delivery and Transport

A number of attempts have been made to estimate basin-wide erosion rates for the Markham River catchment, and these range from 1.5 to 1.6 t/ha/yr up to 21 t/ha/yr (which are generally comparable to estimates for elsewhere in Papua New Guinea). Similarly, estimates have also been made in relation to sediment transport, where these include (refer to Appendix 1):

- Long-term (Holocene average) total silt and clay (washload) delivered from the Markham River to the Huon Gulf averaging between 10 and 40 Mt/yr.
- Average bedload of about 2 Mt/yr and an estimated suspended load of 9 to 12 Mt/yr.

The model referred to above indicates that median coarse sediment yields (i.e., sediment which is transported partially to totally along the river bed) for the Leron, Erap, Rumu and Maralumi sub-catchments are, respectively: 1,654,000; 471,000; 518,000; and 132,000 m^3/yr. This ignores much of the washload (fines) and, although it would include particles down to the silt fraction at times, the results would generally apply only to sand particles or larger. Taking washload into account, where much of this material will end up in the Markham River and downstream or on the floodplain or ephemeral wetlands/clearwater tributaries, total sediment yields are calculated to be:

- Leron – 2,481,000 to 4,962,000 m^3/yr.
- Erap – 706,500 to 1,413,000 m^3/yr.
- Rumu – 777,000 to 1,554,000 m^3/yr.
- Maralumi – 198,000 to 396,000 m^3/yr.

The estimates compare well with whole-of-catchment estimates of Markham River sediment yield. The lower sediment yields for Maralumi River are consistent with the field observations of clearer water in this river, as well as results of water quality analysis, which can be attributed to the smaller sub-catchment area and higher proportion of lower sloping lands in this catchment. Much of the sediment carried by the Maralumi River is also thought to deposit within the alluvial fan reaches.

A further point to note about the model results is that they highlight catchment erosion processes (as opposed to channel erosion) as accounting for more than 90% of channel sediments for all the sub-catchments. Considerable deposition will occur during periods where the sediment supply from the catchment exceeds the transport capacity of the waterways, with this deposition probably occurring within the alluvial fan reaches.

6.1.5.3 Water and Bed Sediment Quality

General

The following description of the surface water and bed sediment quality in the Project area and surrounds is from a report prepared by ERIAS Group Pty Ltd and provided as Appendix 5 and primarily reflects a surface water sampling program undertaken during 2016, where samples were taken on three separate occasions from the Markham River, Rumu River (which reports to the Markham River) and two smaller tributaries of the Markham River that flow through the Project area (Maralumi River and Klin Wara). Sampling sites are shown in Figure 6.10. Samples were analysed for a wide range of water quality variables including:

- General water quality indicators.
- Nutrients, chlorophyll a and faecal coliforms.
- Metals (filtered and unfiltered).
- Total petroleum hydrocarbons, phenols, polynuclear aromatic hydrocarbons (PAHs), benzene/toluene/ethylbenzene/xylenes/naphthalene (BTEXN).

Two bed sediment samples were also analysed for glyphosate/aminomethylphosphonic acid (AMPA). Samples were analysed using standard (accredited) methods by ALS Environmental, a laboratory accredited by NATA (National Association of Testing Authorities, Australia) with proven relevant experience in their Australian laboratories.

Water Quality

Assessment of water quality data requires consideration of the relevant beneficial values of the water, such as its use as a drinking water source or for the maintenance or protection of the existing aquatic ecosystem. Different beneficial values may have varying water quality requirements, with the protection of aquatic ecosystems generally requiring the highest water quality of all beneficial values. Relevant beneficial values assumed for this report focus on (i) protection of aquatic ecosystems (which includes protection of fish and similar organisms), and (ii) use of watercourses as drinking water sources. Consideration was also given to other beneficial values such as recreation, where appropriate. Guidelines/standards used to evaluate the water quality data include PNG drinking water and environmental regulations, World Health Organization drinking water guidelines (WHO, 2011), and Australian and New Zealand water quality guidelines (ANZECC/ARMCANZ, 2000) (which supplement the PNG statutory requirements and provide a more conservative assessment framework).

WATER AND SEDIMENT SAMPLING SITES

PNG Biomass Markham Valley I Environmental Assessment Report

FIGURE 6.10

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Evaluation of the water quality data in terms of these guidelines/standards shows that water quality results at all sites within the Project area are generally consistent with data for other similar watercourses in Papua New Guinea. The results indicate generally good quality water in terms of maintaining aquatic ecosystems and potentially providing drinking water for local communities, albeit with elevated suspended solids concentrations in some rivers and elevated faecal coliform levels at most sites (which is also commonly found throughout Papua New Guinea).

From a more detailed perspective, the water at all sites is alkaline and dominated by calcium (and/or sodium at some sites, particularly the two smaller tributaries) and bicarbonate ions (Figure 6.11). This is consistent with the catchment geology containing substantial amounts of limestone or similar calcareous material, although the results also suggest some variability in the geological nature of the catchments. Suspended solids levels are significantly higher in the Markham and Rumu Rivers as opposed to the other tributaries, and are particularly low in Trib G-1 (as reflected in its local name of 'Klin Wara', meaning ‘clean water’).

Filtered metal concentrations are low at all sampling sites, and generally meet drinking water and aquatic ecosystem protection guidelines. The exception is filtered Cu which slightly exceeds Australian guideline value for ecosystem protection, but is well below the PNG standard and is not likely to be toxicologically significant. In contrast, unfiltered metal concentrations are more variable, with significantly higher concentrations of unfiltered Al, Fe and Mn recorded in the Markham and Rumu rivers compared to other tributaries. These metal concentrations are closely correlated with total suspended sediment concentrations (Figure 6.12) and reflect a major contribution of particulate-associated metals. From a toxicological perspective, guidelines or criteria for aquatic ecosystem protection generally acknowledge the higher bioavailability of dissolved toxicants and hence focus on filtered concentrations rather than unfiltered (total) concentrations.

Although some nutrient levels are elevated compared with guidelines for lowland rivers in tropical Australia, chlorophyll a levels are below the reporting limits at all sites, which suggests that primary productivity may not be correlated with nutrient levels and may be controlled by other factors such as turbidity (at least in rivers such as the Markham and Rumu).

As noted above, faecal coliform levels are significantly elevated at almost all sites (although the sampling regime did not allow direct comparison with a number of guidelines). Faecal coliforms are commonly found in human and animal faeces, and indicate the possible presence of pathogenic (disease-causing) organisms that also live in human and animal digestive systems.

Sediment Quality

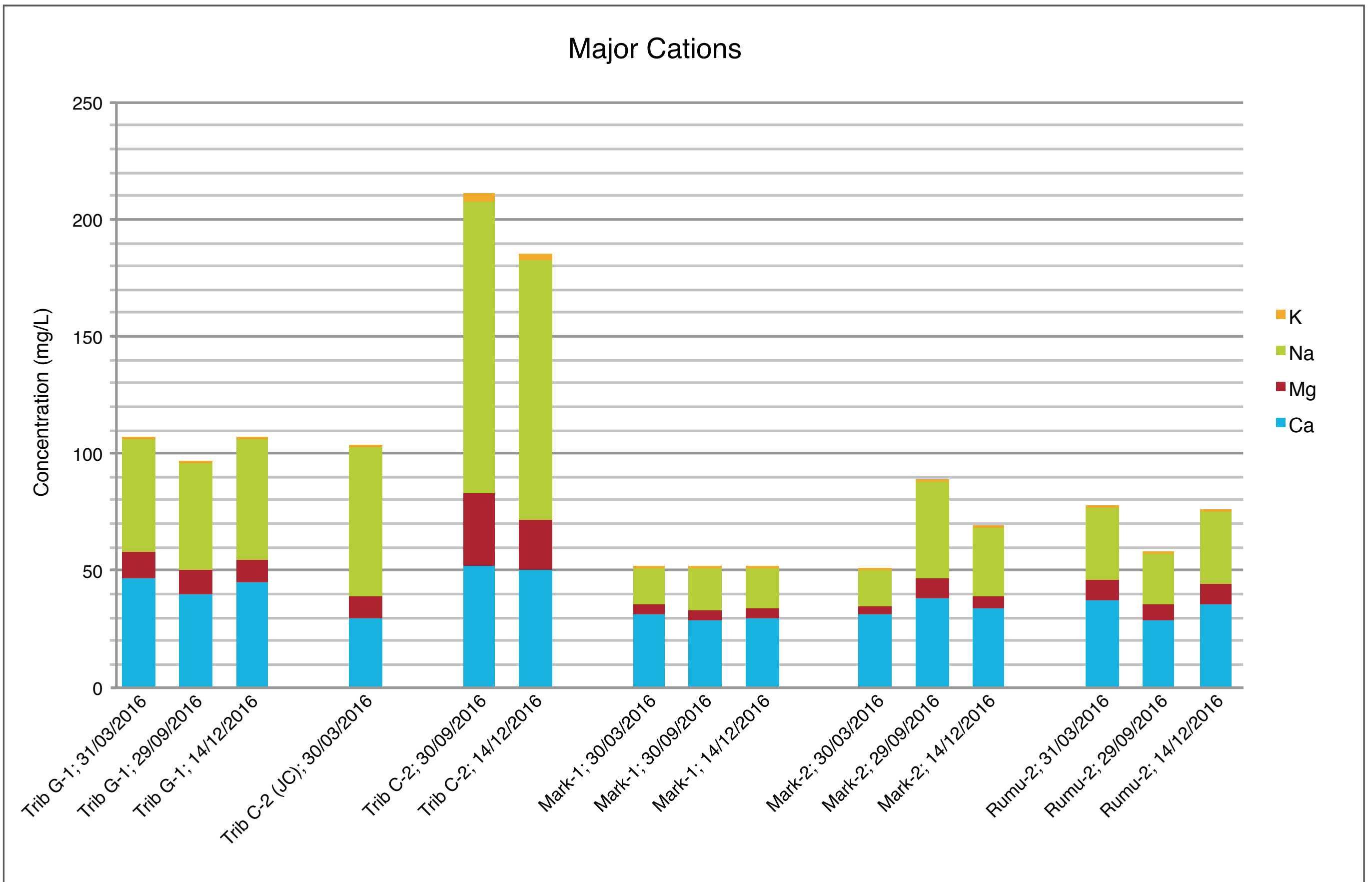
In the absence of PNG statutory requirements, sediment quality in streams has been assessed against the updated Australian and New Zealand sediment quality guidelines (Simpson et al., 2013).

The sediment data from the various sites shows that, as with the water quality data, sediment quality is consistent with other similar watercourses in Papua New Guinea, and is indicative of generally good sediment quality in terms of maintaining aquatic ecosystems. The river sediment samples are dominated by sand-sized and/or gravel-sized particles, which is consistent with a

SURFACE WATER MAJOR ION CONCENTRATIONS

PNG Biomass Markham Valley I Environmental Assessment Report

FIGURE 6.11



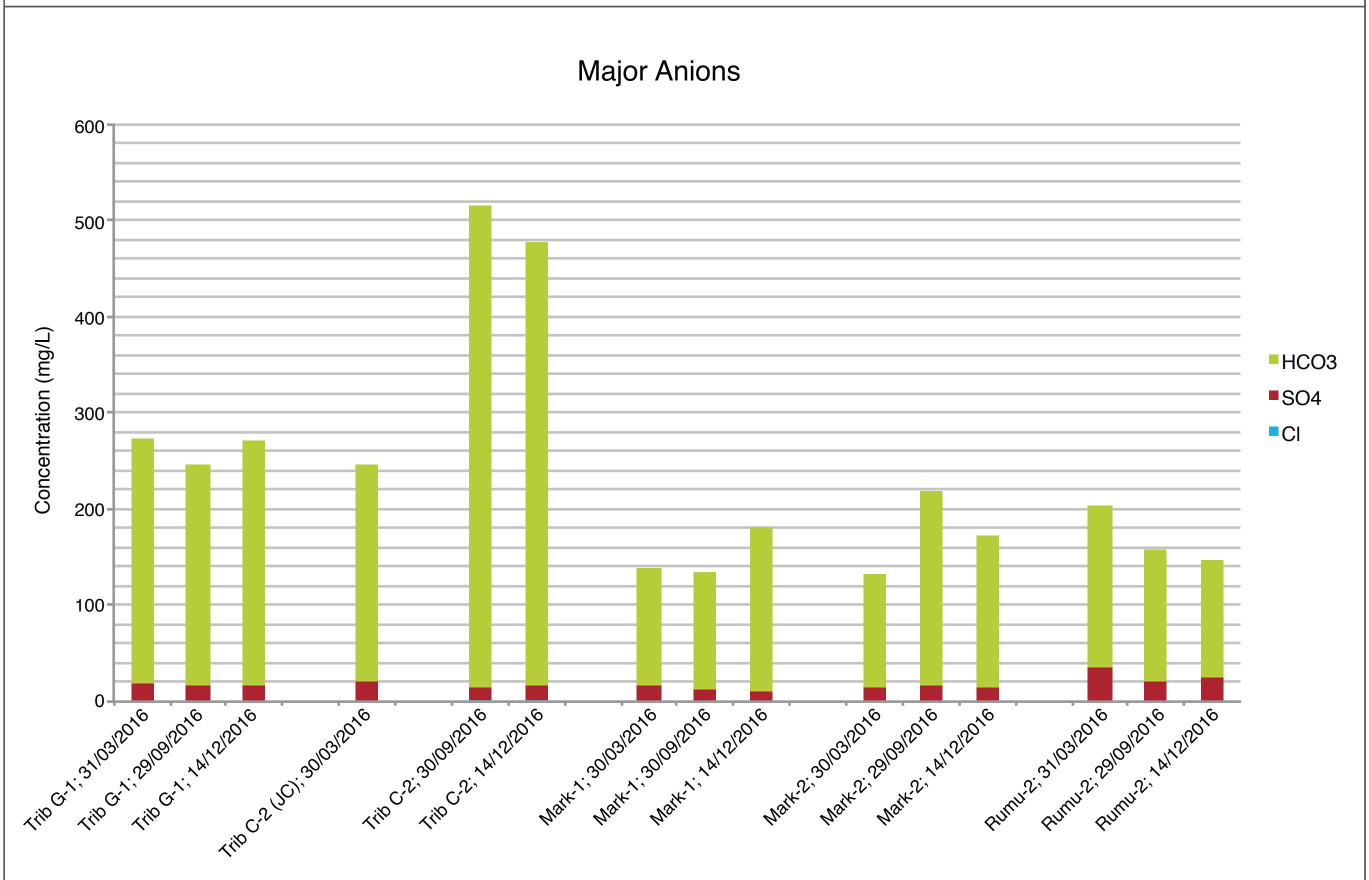
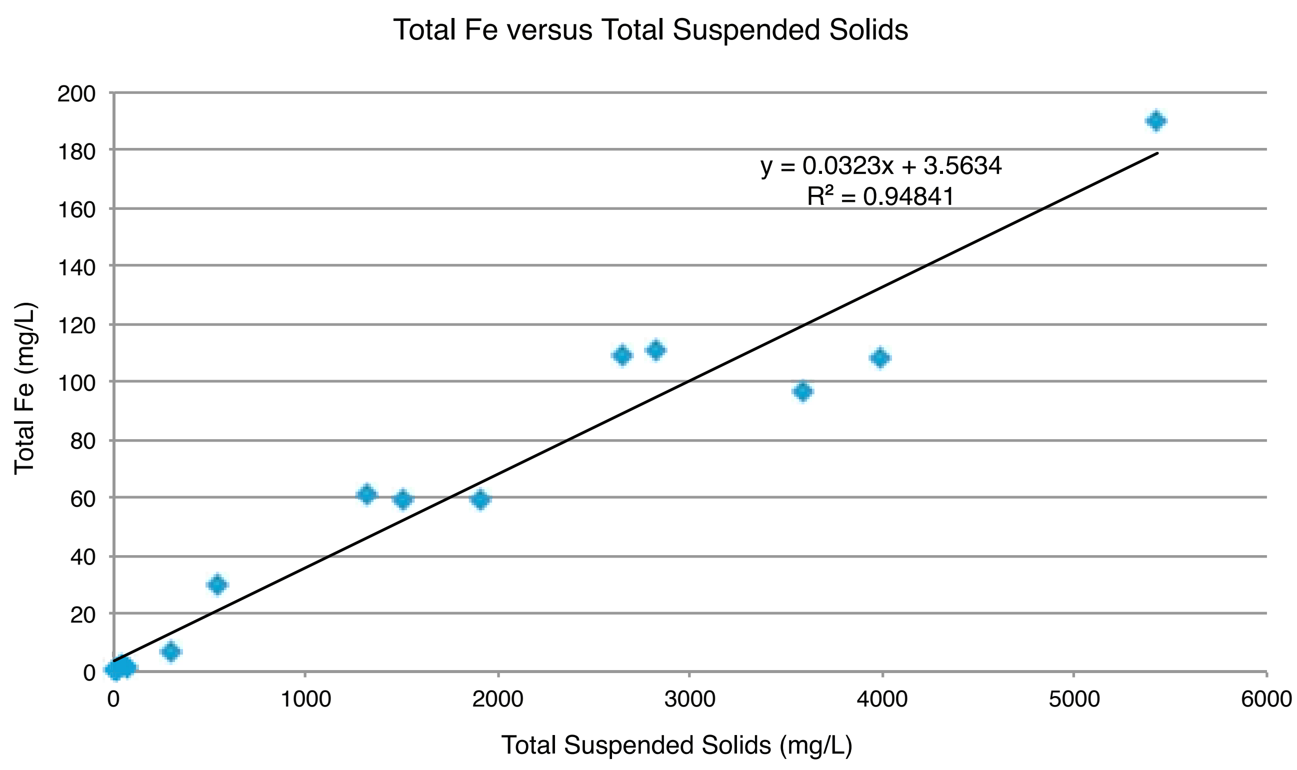
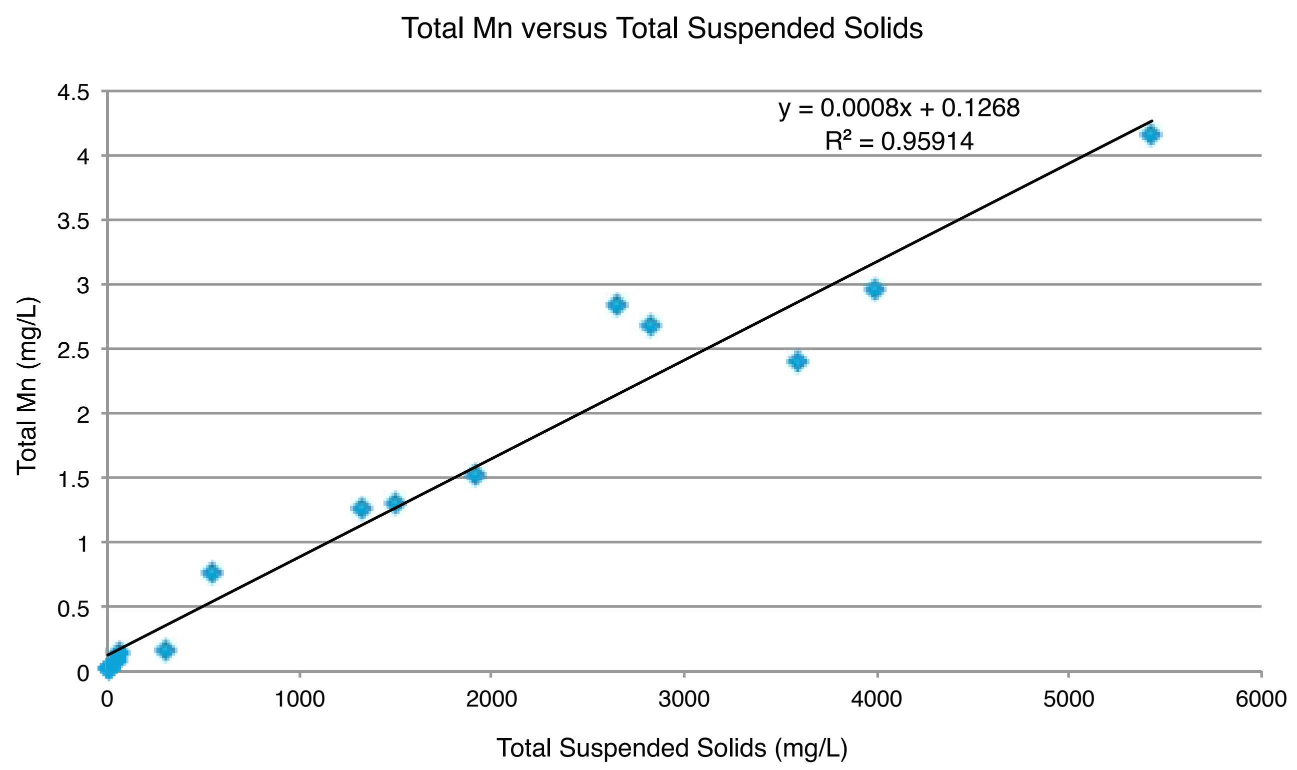


FIGURE 6.12


Total Fe versus Total Suspended Solids
y = 0.0323x + 3.5634
R² = 0.94841
Total Fe (mg/L)
200
180
160
140
120
100
80
60
40
20
0
0
1000
2000
3000
4000
5000
6000
Total Suspended Solids (mg/L)


Total Mn versus Total Suspended Solids
y = 0.0008x + 0.1268
R² = 0.95914
Total Mn (mg/L)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
1000
2000
3000
4000
5000
6000
Total Suspended Solids (mg/L)

high-energy environment and the information presented in Section 6.1.5.2. Total organic carbon (TOC) is low <0.5% in all sediment samples, while total inorganic carbon (TIC) (0.42 to 0.77%) is also relatively low. This may reflect a range of geological characteristics in the catchments rather than dominance by limestone or similar material. Nutrient concentrations are similar to, or lower than, those obtained for similar watercourses elsewhere in Papua New Guinea.

All metal concentrations in the <2,000 µm fractions are less than or equal to relevant criteria (where available), apart from Ni which is elevated compared with the sediment quality guideline value (SQGV)[2] at all sites. For those metals present at relatively elevated concentrations in the <2,000 µm fractions and for which criteria are not available, all are either less than or similar to mean crustal abundances or ranges in the earth's crust. Dilute acid extractable concentrations (which provide an indication of the potentially bioavailable metal) are below the guideline values for Ni in most samples, the exception being Trib G-1 (Klin Wara) (22.9 mg/kg in the <63 µm fraction compared with the SQGV of 21 mg/kg). Dilute acid extractable concentrations of other metals in both fractions are less than the guideline values.

Low concentrations of phenols, TPH/TRH, BTEXN and PAHs are evident in all sediment samples, with most results being less than the reporting limit. This was also the case for glyphosate and aminomethylphosphonic acid (AMPA) for two sediment samples taken in December 2016. Glyphosate is a broad-spectrum herbicide that is used in sectors such as agriculture and forestry, and will be used in the Project for weed control. Anecdotal evidence suggests that local communities in the Project area also use this chemical, although the extent of use is not known. Aminomethylphosphonic acid is glyphosate's principal degradation product. All results for glyphosate and AMPA in sediment were <0.05 mg/kg. Although the recommended sample storage time prior to analysis was exceeded, these results suggests that background levels in bed sediments in the Markham River (Mark-1) and one of its tributaries (Trib C-2) (Maralumi River) are low (although this preliminary finding requires validation by further sampling and analysis).

6.1.6 Groundwater

6.1.6.1 Hydrogeology

General

The following description of the hydrogeology of the Project area is from a report prepared by Whitegum Forest and Natural Resources Pty Ltd/HydroEnviro Pty Ltd and provided as Appendix 2, as well as a review of available literature.

Groundwater Aquifers and Levels

Although somewhat dated, the information presented in Knight (1973) provides a useful background concerning groundwater in the Markham Valley by categorising groundwater into two main types, i.e., deep (4 to 70 m) and shallow (0 to 3 m). Deep groundwater was investigated by drilling boreholes into a number of large alluvial fans (Leron Fan, Erap Fan, other fans) and piedmont. The mean depth to water intersection ranged from 18 to 34 m with flows in the order of 2,000 to 6,000 L/hr from depths of 10 to 15 m (and it was considered that flow rates were lower

[2] Biological effects are likely to be negligible if the contaminant concentration is less than the SQGV.

than what was actually available). The producing aquifer was described as being 'composed of sand and gravel overlain by clayey gravel aquicludes'. Using information from bore holes on Leron Plains, a general trend of lateral groundwater movement near the fan head to the southwest after initial recharge near the valley margin was observed. However, in the mid-fan area, movement changes direction to the southeast, parallel with the Markham River. This was interpreted as indicating that the deep groundwater movement is most closely related to the subsurface (three dimensional) sediment patterns and properties rather than to the surface topography and sediments, i.e., the groundwater flow direction is not related to the surface drainage. Vertical rises of groundwater were observed in most boreholes, i.e., the aquifers were artesian and the groundwater is confined under pressure by overlying aquitards or aquicludes. At the time of that report, i.e., the early 1970s, there was no record of flowing (at the ground surface) artesian bores, although ECO Care (2013) reports the existence of an aquifer beneath the Project area with artesian flow and groundwater was observed to flow from geotechnical investigation boreholes drilled at the power plant site in late 2016/early 2017.

Shallow groundwater in the Erap-Rumu Area reflected perched watertable zones fed by groundwater from near the Rumu Fan head. These watertables were generally discontinuous and had gradients that were either sub-parallel to, or slightly steeper than, the ground surface. The 'perching' is due to layers of sediments with low hydraulic conductivities, and Knight (1973) noted that during deep auguring it was not uncommon to observe a watertable one day that was absent the next day due to leakage to underlying permeable horizons. In contrast to the deep groundwater movement, the lateral movement of shallow groundwater was subject to both lithological and topographic controls.

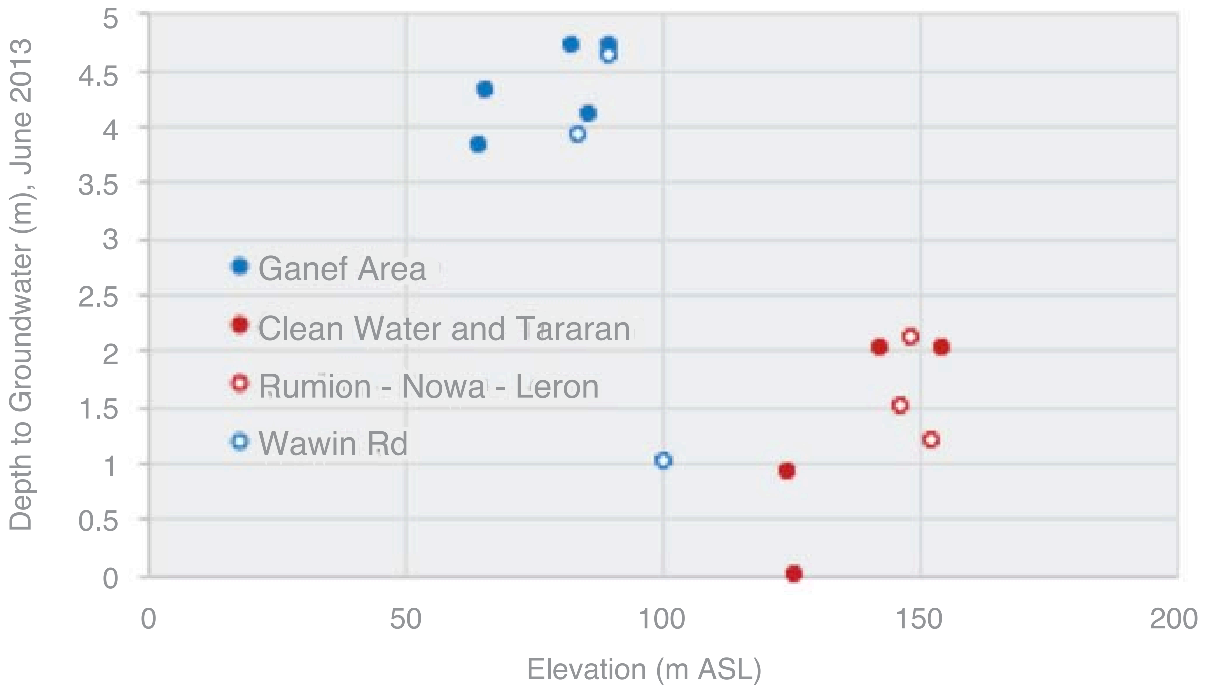
The surface of the soil watertable in the Erap-Leron area, where present, fluctuated seasonally. The major watertable fluctuations reflected rainfall patterns except that a delayed response time for the soil groundwater to rise towards the ground surface and then to begin receding to the dry season depth was observed. The fluctuations were considered to be due to a combination of direct precipitation (vertical percolation) and lateral groundwater movement from positions up-slope of the watertable site (Knight, 1973).

More recent information concerning watertable fluctuations is provided in Appendix 2. As noted in that appendix, depth to groundwater records, for a series of water supply wells within and outside the proposed plantation area, are available for the period June 2013 to February 2016. When considered within the context of four areas, the wells fall into two groups with respect to the relationship between height above sea level and depth to groundwater. The groundwater in the wells in June 2013 was 3.7 to 4.8 m below the surface in the Wawin Road and Ganef areas, which are between 60 and 100 m asl. The groundwater was about 2 m closer to the surface in the wells in the Cleanwater – Tararan and Rumion – Nowa areas (Figure 6.13), which are between 125 and 153 m asl. The Wawin Road and Ganef areas are further from the Leron River or any other major watercourses than either the Clearwater – Tararan or the Rumion – Nowa areas.

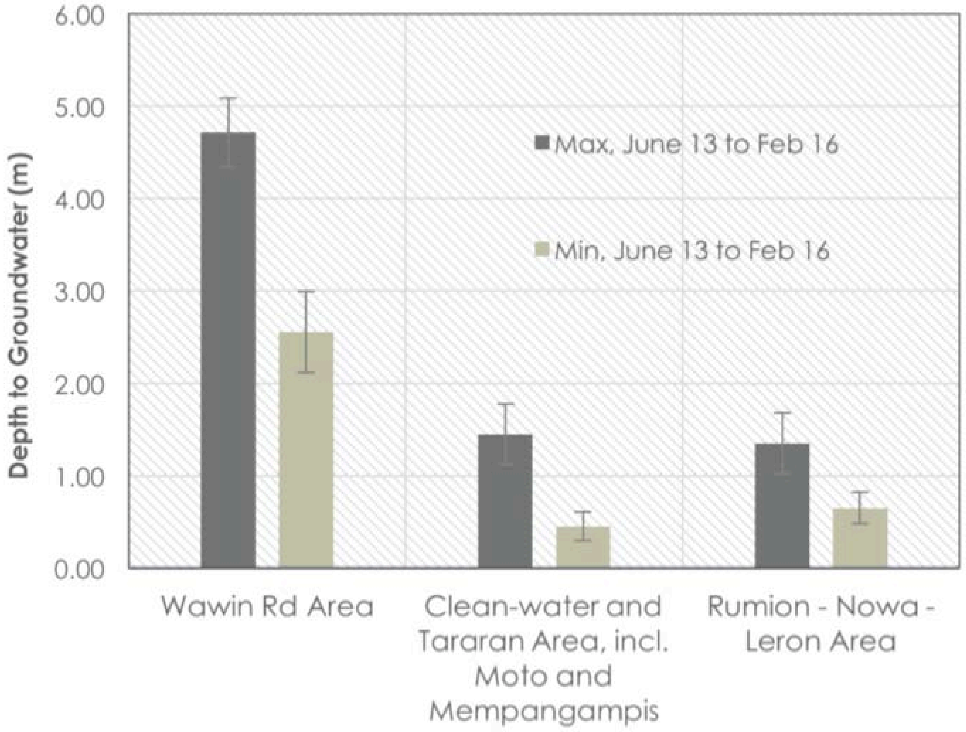
As noted in the hydrogeology report (Appendix 2), the small dataset precludes making conclusions about the effects of site characteristics (e.g., altitude, region, soil type or season) on groundwater depth. There is no clear trend of either an increase or decrease in depth to groundwater and the data sequence is too short to make conclusions about effects of rainfall or aquifer characteristics. However, it is worth noting that the maximum increase in groundwater

FIGURE 6.13

A. THE RELATIONSHIP BETWEEN HEIGHT ABOVE SEA LEVEL AND DEPTH TO GROUNDWATER



B. AVERAGE MAXIMUM AND MINIMUM DEPTH TO GROUNDWATER



Source: Appendix 2.

depth during the dry season of a little more than 2 m was observed in some wells in the Wawin Road area (see Figure 6.13). It is also possible that the very shallow wells reported above are in perched local groundwater that is not associated with the deep groundwater system.

6.1.6.2 Groundwater Quality

General

The following description of groundwater quality in the Project area is from data provided by MVB, supplemented by a review of available literature.

Water Quality

In addition to addressing groundwater movement in the Erap–Leron area, Knight (1973) examined the hydrochemistry of Markham Valley waters and reported that groundwater (as well as stream water) in the valley was known to contain significant concentrations of bicarbonate. That same document also noted that, in relation to the deeper groundwater resources in the valley, the water was a 'bicarbonate type' with total dissolved solids (TDS) values from 300 to 500 mg/L. Analysis of shallow groundwater samples 'had higher levels of TDS and bicarbonate (compared with stream waters flowing out of the ranges), with very low levels of chloride and sulfate in almost all case' (Knight, 1973). Conductivity values varied widely.

Groundwater data for samples taken in late 2015 and 2016 from the Project area and surrounds is shown in Table 6.4. These results show significant differences in groundwater quality between samples taken in the Project area close to the Markham River (i.e., 'Spring Water' and 'Markham Farms Groundwater'), those taken from the power plant site (i.e., 'BH-3', BH-6' and 'Main Water Bore') and that from Marawassa Spring which is close to the western border of Area B and well west of the Leron River (which effectively is the western border of the Project area). The groundwater from near the Markham River is alkaline and, in terms of cations and anions, is dominated by Na and HCO_3 (with significant Cl levels), with a hardness category of 'soft'. Metal concentrations are low, as are nutrients except for the NO_3 value of 2 mg/L in the Markham Farms sample. In contrast, the Marawassa Spring sample is slightly acidic and dominated by Ca (with significant Na levels) and HCO_3 (with significant SO_4 levels), and can be classified as 'very hard'. Although Cu and Zn concentrations are low, Mn and Fe levels are readily measurable and may be indicative of anoxic conditions, with these metals consequently being solubilised. The groundwater from the power plant site is only slightly alkaline, with substantially higher Mg concentrations than Ca levels, and low Cl and SO_4 concentrations. The calculated hardness values, based on the Ca and Mg results in Table 6.4, range from 304 to 317 as mg/L $CaCO_3$, hence these samples can also be classified as 'very hard'.

All samples for which TDS was determined are 'fresh', i.e., they have a TDS of less than 500 mg/L.

Comparison of the results with PNG drinking water regulations and WHO guidelines for drinking water quality indicates that water quality of groundwater in all samples, as determined by physicochemical parameters, is consistent with drinking water requirements.

Table 6.4 – Groundwater Quality in and Near the Project Area

Parameter	Sample Description					
	Spring Water	Markham Farms Groundwater	Marawassa Spring	BH – 3	BH – 6	Main Water Bore
pH	8.4	8.4	6.8	7.5	7.4	7.6
TDS (mg/L)	230	215	364	nd	nd	nd
EC (μS/cm)	330	330	560	nd	nd	nd
Alkalinity (as mg/L CaCO3)	141	138	331	250	464	362
Total hardness (as mg/L $CaCO_3$)	22	<1	240	nd	nd	nd
Ca	7	7	74	23	30	20
Mg	1	<1	13	60	59	52
K	2	1	1	nd	nd	nd
Na	67	67	26	nd	nd	nd
Cl	25	23	2	<0.1	<0.1	<0.1
SO_4	6	7	91	1.2	1.5	3.3
NO_3	Nd	2	<0.5	nd	nd	nd
NH_4	Nd	<0.5	<0.5	nd	nd	nd
PO_4	Nd	0.1	0.2	nd	nd	nd
Cu	Nd	0.001	0.001	nd	nd	nd
Zn	Nd	<0.001	<0.001	nd	nd	nd
Mn	Nd	0.001	0.041	nd	nd	nd
Fe	0.011	0.001	0.017	nd	nd	nd
B	0.124	0.098	<0.001	nd	nd	nd

Although microbiological parameters were not determined in the sampling program referred to above, ECO Care (2013) reported the presence of both faecal and total coliforms in a sample taken from a drinking water well in Bampu (a village located within the Project area) and noted that the findings were 'of concern'.

6.1.7 Air Quality and Greenhouse Gases

6.1.7.1 Air Quality

Baseline ambient air quality monitoring has not been undertaken to establish existing levels of air pollutants within the Project area. However, as described in Appendix 3, the ambient air quality is expected to be generally good with negligible concentrations of gaseous pollutants, reflecting the Project's location and the virtually complete absence of industrial sources. Potential particulate matter air pollutants are expected to be low, although not negligible, with sources including volcanic eruption (very rare, and significant on a regional level), bushfire (potentially significant on a regional or local level), and the release of particulate matter from local cooking fires, generators, the use of unsealed roads for forestry operations, agricultural activities and local grass burning. Expected background concentrations of particulate matter for the Project area are shown in Table 6.5.

Table 6.5 – Estimated Background Particulate Concentrations

Pollutant	Averaging Period	Assessment Criterion (µg/m^3)	Expected Range (µg/m^3)	Assumed Background Concentration (µg/m^3)
PM_{10}	24-hours	50	5 to 35	25
	Annual	20	10 to 20	15
$PM_{2.5}$	24-Hours	25	2 to 10	15
	Annual	10	5 to 10	8

Source: Appendix 3.

No data is available for background concentrations of volatile organic compounds (VOCs), although these will naturally occur in the area. The air quality assessment (as presented in Chapter 8) evaluated the potential VOC air emissions based on the worst-case assumption that all VOC emissions are in the form of benzene, which has the most rigorous ambient air quality criteria. However, background concentrations of benzene at the Project site can be assumed to be negligible, again primarily due to the absence of local industrial sources.

6.1.7.2 Greenhouse Gases

General

Greenhouse gases (GHG) are gases that trap heat inside the earth's atmosphere. Some GHGs are naturally occurring, e.g., carbon dioxide (CO_2) and methane (CH_4), although human-induced emissions have increased considerably with the use of fossil fuels thereby causing a global rise in temperatures.

The UNFCCC (United Nations Framework Convention on Climate Change) (UNFCCC, 2014b) defines a source as any process or activity that releases a greenhouse gas, an aerosol or a precursor of a greenhouse gas into the atmosphere. On a global scale, the key direct greenhouse gases emitted by human activities are (UNFCCC, 2014b):

- CO_2 – carbon dioxide: combustion of fossil fuel is the primary source of CO_2, although emissions can also occur through activities such as deforestation, land clearing for agriculture, soil degradation and disposal of waste products. Similarly, land can also remove CO_2 from the atmosphere through reforestation, soil improvement and other activities.
- CH_4 – methane: agricultural activities, waste management, energy use and biomass burning all contribute to CH_4 emissions.
- N_2O – nitrous oxide: agricultural activities, such as fertiliser use, are the primary source of N_2O emissions. Biomass burning also generates N_2O.
- PFCs – perfluorocarbons: a group of human-made chemicals composed of carbon and fluorine only. Perfluorocarbons are powerful greenhouse gases that were introduced as alternatives to ozone depleting substances.
- HFCs – hydrofluorocarbons: any of a class of partly chlorinated and fluorinated hydrocarbons, used as an alternative to CFCs (chlorofluorocarbon) in foam production, refrigeration and other processes.

- SF_6 – sulfur hexafluoride: an extremely potent greenhouse gas, used most commonly as an insulator, e.g., for glazed windows.

Indirect greenhouse gases include SO_2, NOx, CO and NMVOC.

Human-induced sources of GHG emissions are typically categorised into the following five sectors for global climate change reporting (UNFCCC, 2014c):

- Energy (includes fossil fuels).
- Industrial processes and product use.
- Agriculture.
- Land use, land-use change and forestry (LULUCF).
- Land waste.

Greenhouse Gas Emissions

UNFCCC 1994

Papua New Guinea's most recent submission to the UNFCCC GHG inventory on the sectors detailed above was in 1994. The inventory covered emissions of CO_2, CH_4 and N_2O, but addressed only four of the five categories of emission source categories defined above, i.e., energy, industrial processes, land use and agriculture. At the time of publication, limited data was available for emissions and removals (i.e., the process relating to carbon sinks) from land use change and forestry (LUCF) and waste, and hence they were excluded from the inventory. Table 6.6 provides a summary of the results of the GHG inventory for the four sources of GHG emissions.

Table 6.6 – Greenhouse Gas Inventory Summary for 1994 (t)

Greenhouse Gas Source/Sink Categories	CO_2 -e
All energy	947,570
Industrial processes	193,000
Agriculture	3,871,670
LUCF	-413,000
Total excluding LUCF	**5,012,240**
Total including LUCF	**4,599,240**

Source: UNFCCC, 1994.

The data reflects an underestimation of the emissions of GHGs in Papua New Guinea at that time. All energy sources were not accounted for in this inventory, which only covered liquid fuels (PNG Government, 2000), emissions from waste and solvents were not included, and agriculture emissions focused primarily on domestic livestock since no data was available concerning emissions from soil cultivation and burning of forests and grasslands.

Papua New Guinea's Climate Change and Development Authority (CCDA) and the PNG Forest Authority (PNGFA) are currently collating data for release this year as part of Papua New

Guinea's reporting requirements for the United Nations Convention for Climate Change (UNFCCC). However, this data is not yet available for public release.

Food and Agriculture Organization of the United Nations (FAO) 2014

Data collated by the Food and Agriculture Organization of the United Nations (FAO) is the most recent source of emissions information that includes emissions associated with LUCF. The total greenhouse gas (GHG) emissions for Papua New Guinea reported for 2013 (including LUCF) totalled 70.85 Mt CO_2-e; the corresponding value excluding LUCF totalled 16.43 Mt CO_2-e (FAO, 2014). The high total associated with the inclusion of LUCF provides an indication of the levels of emissions that are associated with forestry and agricultural activities, and are caused by factors such as deforestation[3] of primary or native forest, deforestation of secondary forest which regenerates where native forest has been cleared, and forest degradation through selective logging.

6.1.8 Noise

The existing noise conditions in the Project area have not been monitored. However, noise levels have been determined at other locations in Papua New Guinea, in rural areas where the character and the terrain of the surrounding environment are comparable to this Project. The ambient background noise levels at sensitive receptors (i.e., villages) is therefore expected to be as follows:

- Day (7.00 a.m. to 6.00 p.m.) – L_{A90} 30 to 43 dB.
- Evening (6.00 p.m. to 10.00 p.m.) – L_{A90} 40 to 49 dB.
- Night (10.00 p.m. to 7.00 a.m.) – L_{A90} 34 to 46 dB.

Previous noise monitoring has showed that insects, heavy rain, birds, domestic animals, wind noise in foliage, and typical village domestic activities dominated the ambient background noise (Appendix 4). High insect noise levels were a common feature of the ambient environment all year round.

6.2 Biological Environment

6.2.1 Terrestrial Ecosystems

The information presented in this section is based primarily on a terrestrial ecology assessment and report (and references cited therein) undertaken by BAAM and attached as Appendix 6. In the context of that report, the 'study area' is the area of assessment of terrestrial ecology values and the mapping of vegetation communities and habitat condition. The 'Project area' is a subset of the study area and comprises the areas under Memoranda of Understanding (MOU) with the

[3] Deforestation generates carbon emissions through the degradation, decay and burning of wood, debris, and organic soil matter. When deforestation is the result of commercial logging, approximately one-third of sequestered carbon is released into the atmosphere within five years, one-third is stored in the resulting wood products, and one-third is initially retained on the site. Emissions are more rapid when caused by land use activities that involve clear-cutting, for example agriculture or road-building. Deforestation, including contributions from countries such as Papua New Guinea, is the second leading cause of climate change behind fossil fuel combustion.

land owners, within which the plantations, power plant, plantation nursery and associated infrastructure will be developed.

6.2.1.2 Special Purpose and Protected Areas

Papua New Guinea has less than 2.8% of land under formal protected area status, with 80% of the protected areas consisting of only three sites on the mainland, and the remainder being small and fragmented. Wildlife Management Areas (i.e., provincial parks and local parks) are managed under local Land Use Management Plans for the management of specific wildlife and to prevent over-exploitation.

Three areas are formally protected as national parks, i.e., Lake Kutubu, Varirata National Park, and McAdam National Park. McAdam National Park is the only park located in Morobe Province, and is located at least 40 km from the study area in the upper reaches of the Watut River catchment. As the Project is unlikely to impact on this or any national park, no specific aspects of the *Conservation and Environment Protection Authority Act 2014* specific to national parks will be triggered.

Two Conservation Areas are located in Morobe Province, i.e., Labu Tali Conservation Area and Yus Conservation Area. The Labu Tali Turtle Conservation Area is located along several kilometres of sandy beach immediately south of the Markham River mouth and protects the nesting sites of Leatherback Turtles that visit between late November and early February to lay eggs. Yus Conservation Area is located on the Huon Peninsula, outside the zone of influence of the Project. As the Project is unlikely to impact on any conservation area, no specific aspects of the *Conservation Areas Act 1978* will be triggered.

The only Wildlife Management Area in Morobe Province is the Kamiali Wildlife Management Area located in the Salamaua District, about 80 km south along the coast from the city of Lae. The Project will not impact on any Wildlife Management Area and will therefore not trigger aspects of the *Fauna (Protection and Control) Act 1966* specific to such areas.

Papua New Guinea’s two wetlands listed under the Ramsar Convention, i.e., Lake Kutubu in the Southern Highlands and Tonda Wildlife Management Area in Western Province, are both remote from the study area. Project development will therefore have no implications for Papua New Guinea’s commitments under the Ramsar Convention.

6.2.1.3 Terrestrial Ecology Surveys

A single phase terrestrial ecology survey was conducted within the study area and encompassed the northern side of the Markham River between the Erap River in the east and the Leron River in the west, extending from the northern banks of the Markham River to the foothills of the Saruwaged Range in the north. Surveying occurred through the wet season over a period of five field days (4 to 8 September 2016). Further details are provided in Appendix 6.

6.2.1.4 Flora Surveys

Floristic Diversity

Floristic information was gathered at a total of 72 floristic survey sites distributed across the study area during the course of the field assessment. The locations of these survey sites and site data descriptions are provided in Appendix 6.

Terrestrial Flora of Conservation Significance

Although Papua New Guinea is a signatory to conventions such as the International Plant Protection Convention and Convention on Biological Diversity, there is no formalised system within national legislation that specifically addresses the protection of threatened or significant plant species, nor has any structured national system applying conservation status to flora species been devised or applied. The recognition of threatened species in this report is based on information provided in the IUCN Red List of Threatened Species. It should be stressed that this system has no legislative or legal significance within Papua New Guinea, other than to provide guidance to the relative conservation significance and/or rarity of any given plant species at a particular location. Reference to the IUCN database indicates 143 plant species within Papua New Guinea that are listed as threatened (vulnerable, endangered or critically endangered), 34 that are listed as near threatened, and a further 20 species that are listed as data deficient. Table 6.7 provides information relevant to the four threatened and near threatened species that are either known to occur based on the results of field survey (two species) or are considered likely to occur based on known distributions and habitat preferences. The following two significant flora species were detected during the field survey (see Figure 6.14 for locations):

- *Intsia bijuga* (Kwila) (IUCN: Vulnerable): Kwila is a valuable timber in Papua New Guinea and forms a large canopy tree in intact primary lowland rainforest on the southern side of the Markham River, outside the study area. The species was recorded at a single location within the study area, as a small regrowth tree associated with degraded gully line forest in foothills behind Dinsu Village, just outside the assessment area. Historical timber extraction and forest clearing is probably responsible for the current rarity of this species in the area.

- *Cycas schumanniana* (IUCN: Near Threatened): A common species in native grasslands (Plate 6.11) on hill foot-slopes throughout the study area with scattered individuals extending onto adjoining outwash plains. This species is associated with Kunai grassland on foot slopes and hill slopes in the study area. Figure 6.14 shows the locations of *Cycas schumanniana* populations at sites that were visited during the field survey. However, the species is highly likely to be more widely distributed than the limited sites surveyed hence the distribution of habitat suitable is also shown in this figure.

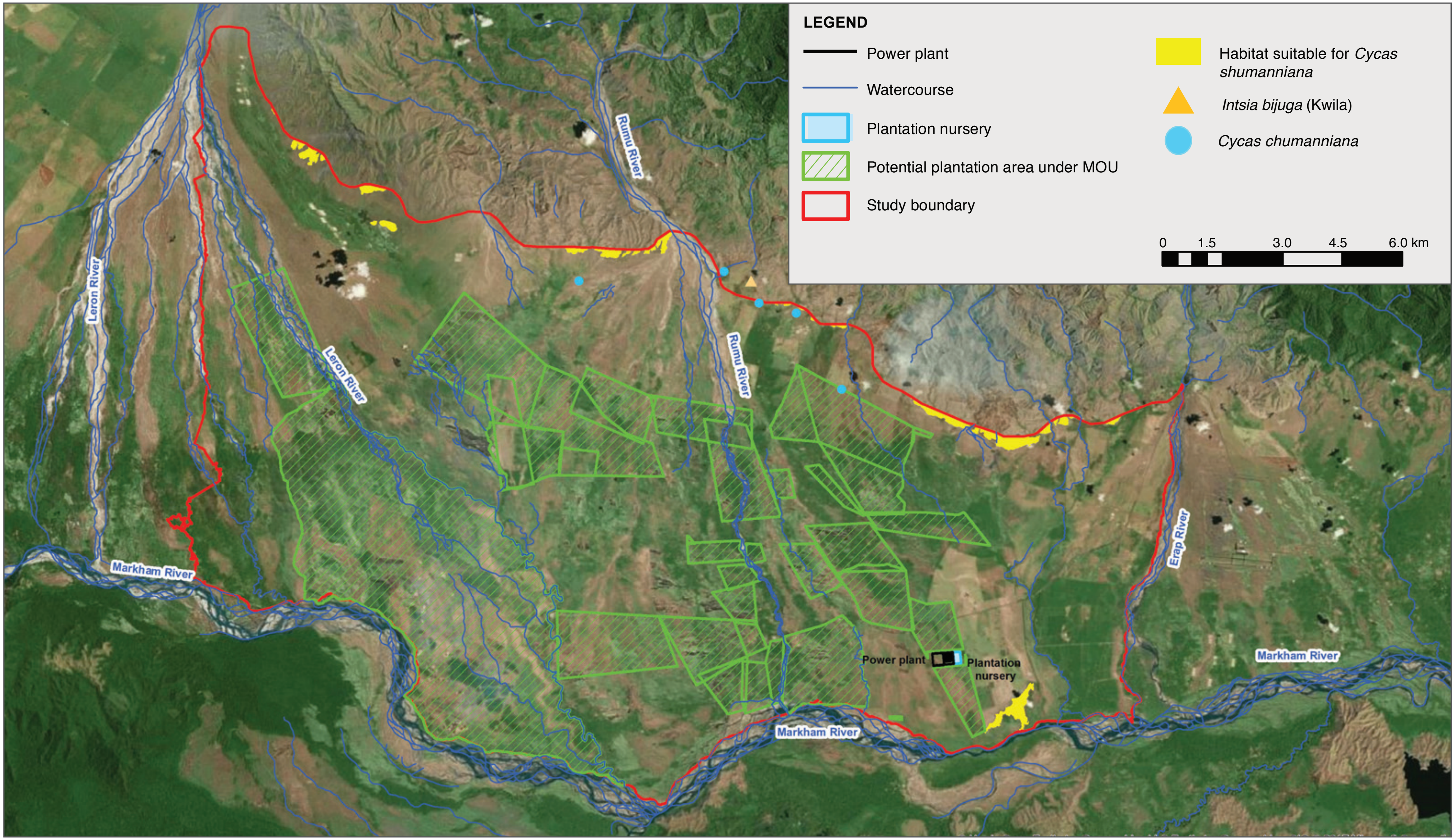
Table 6.7 – Conservation Significant Flora Species Within the Study Area

Species	Record Source	IUCN*	Habitat and Distribution	Comments on Records and Likelihood of Occurrence
Species Known to Occur in the Study Area – Recorded in 2016 Survey				
Intsia bijuga (Kwila)	Recorded during survey	VU	A pan tropical species of lowland rainforest distributed throughout southeast Asia and Melanesia, which produces one of the most valuable timbers of South East Asia	Recorded during survey as a single small regrowth tree associated with degraded gully line forest in foothills behind Dinsu Village (outside the assessment area). A relatively rare regrowth tree with no adult trees noted. Historical timber extraction and forest clearing is likely responsible for the current rarity of this species in the study area
Cycas schumanniana	Recorded during survey	NT	Endemic to Papua New Guinea occurring on the northern side of the island along the foothills of the Bismarck Range, predominantly in the valleys of the Markham and Ramu rivers extending south from Lae along the Bulolo River as far as Wau and Madang. Recorded from low to high elevations, up to 1,600 m asl in Kunai grassland habitats	A common species in native grasslands on hill foot-slopes throughout the study area with scattered individuals extending onto adjoining outwash plains. This species is associated with VC4b (Kunai grassland on foot slopes and hill slopes) in the study area
Species Possibly Occurring in Study Area – Historical Records				
Pterocarpus indicus (New Guinea Rosewood)	Not recorded although known from area	VU	A widespread tree found in lowland primary and some secondary forest, mainly along tidal creeks and rocky shores	Known from primary and secondary forests along the Watut and Markham rivers. A widespread tree that is likely to be associated with both intact and disturbed native forest (VC1a in particular), but historical timber extraction is likely to have removed all adult trees
Aglaia rimosa	Not recorded although known from area	LR – NT	A widespread tree that is generally associated with secondary forests near rivers and streams	Suitable habitat occurs in the study area, most likely in disturbed rainforest habitats (VC1a)

* IUCN status: LR- NT = Lower Risk – Near Threatened; NT = Near Threatened; VU = Vulnerable (facing a high risk of extinction in the wild in the medium-term future).

PROJECT FOOTPRINT IN RELATION TO SIGNIFICANT FLORA SPECIES

FIGURE 6.14



Source: Appendix 6.

Plate 6.11 – Native Grassland in Good Condition (Left), Native Grassland on Footslopes Dominated by Kangaroo Grass (Right)

Source: Appendix 6.

The majority of species listed under IUCN schedules are associated with intact habitats and hence are considered unlikely to occur in the study area. A full list of threatened species for Papua New Guinea, as per the IUCN Red List, together with a detailed assessment of their likelihood of occurrence within the study area is provided in Appendix 6. *Acacia crassicarpa*, listed as Vulnerable, is considered unlikely to occur in natural habitats within the study area; however, it has been planted as a plantation tree in some stands of Project test plantings.

In addition to the IUCN species list, 263 taxa are listed in the CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) Appendices for Papua New Guinea. The species presently listed include five species of *Cyathea*, 10 species of *Cycas*, five taxa in the fern family *Dicksoniaceae*, four pitcher plants (genus *Nepenthes*), and 149 species of orchid. The CITES listing of orchids is, however, incomplete (as noted in the database explanatory notes) and export of all orchids collected from the wild was banned in 1990. *Euphorbia spp.* are listed as protected under CITES. *Cycas schumanniana* is the only species recorded within the study area that is listed under the CITES Convention.

Invasive and Introduced Vascular Plant Species

One hundred and thirty-six exotic flora species, or 36% of the flora, were recorded within the study area during the field assessment. The highest number of weeds is represented by grasses (*Poaceae*) followed by legumes (*Fabaceae*) and herbs within *Asteraceae*. Disturbed roadsides, garden and village areas were found to support the highest number of weed species (124 species) although a number of these are cultivated plants. High numbers of exotic species are also recorded in regrowth and disturbed grassland habitats.

There are 30 species that are considered to pose considerable risk to the integrity and function of both native habitats and agricultural and plantation systems within the study area, details of which are provided in Appendix 6. This assessment does not include exotic garden food plants unless these spread readily into natural environments, nor a number of introduced species which are considered widespread and of low invasive potential. Nine species recorded in the study area listed in the '100 worst invasive alien species' have been attributed the highest risk of impact to natural habitat values.

Throughout the broader study area, a dominant proportion of the landscape has been pervasively altered by growth and infestation of exotic weed species. Many of these are widespread herbaceous species and are not considered highly invasive nor a significant threat to native vegetation or agricultural land. However, several highly invasive weeds do occur, and these are having significant landscape-scale impacts on the ecology of the area as well as reducing the productivity of grazing lands. These highly invasive weed species, which include Siam Weed (*Chromolaena odorata*), Leucaena (*Leucaena leucocephala*), Bamboo Piper (*Piper aduncum*), Giant Sensitive Plant (*Mimosa diplotricha*), Glyricidia (*Glyricidia sepium*), Cassia (*Senna spp.*), Neem Tree (*Azadirachta indica*) and Pigeon Bundle Flower (*Desmanthus pernambucanus*) plus the large woody Raintree (*Albizia saman*) (Plate 6.12), are creating major landscape-scale impacts to ecological values and land productivity. Other more aggressive species include Ceara Rubber (*Manihot glaviozi*), Bitter vine or Mile a Minute (*Mikania micrantha*), Belly Ache Bush (*Jatropha gossypiifolia*) and Castor Oil Bush (*Ricinus communis*).

Plate 6.12 – Typical Stand of Raintree Forest (Left), Mixed Exotic/Native Regrowth Forest (Right)

Source: Appendix 6.

The most significantly degraded areas are those that are, or have been, subject to heavy grazing regimes that have facilitated the spread of weeds throughout the landscape and diminished the potential for fire to act as an effective control agent. Riparian areas are almost universally impacted by monocultures of raintree and Leucaena that inhibit the regeneration of native forest tree species. Further determination of weed control priorities at the Project scale requires consideration of the potential significance of the impact of each weed present, the existing and future disturbance impacts to the local environment, and the feasibility of control.

Deleterious effects of exotic species may include direct displacement of native species through competition, smothering of canopy or ground layers or prevention or deflection of natural regeneration. They may also significantly impact agricultural productivity including orchard establishment and management as well as silviculture.

6.2.1.5 Vegetation Communities and Mapping

A hierarchical approach is applied to the classification of habitats, land and associated vegetation within this report using the three categories listed below:

- Broadest scale (global) – Terrestrial ecoregions. Ecoregions define distinct ecosystems that share broadly similar environmental conditions and natural communities, and are defined at 1:1,000,000 scale.
- National/regional scale – Forest Inventory Mapping System (FIM) vegetation types. Vegetation is described with reference to the national scale vegetation mapping produced at 1:250,000 scale, which provides context to the finer scale vegetation community mapping undertaken in this study.
- Local scale – Vegetation community mapping. Vegetation mapping produced specifically for the purpose of this study at a scale of 1:50,000. A vegetation community is best described as a unit of vegetation that demonstrates similarities in both structure and floristic composition. Vegetation communities are used to describe fine scale variation in floristic composition that may not be apparent at broader scale (global and national) mapping such as FIM.

A summary of vegetation communities identified in the study area is provided in Table 6.8, together with their equivalent FIM classifications.

Table 6.8 – Vegetation Communities Occurring Within the Study Area

Vegetation Community Code	Vegetation Community Description[1]	FIM Vegetation Type[2]	FIM Vegetation Type	Area (ha)	% of Total Area
Vegetation Communities with Minimal to Moderate Present-day Disturbance					
1a	Large to medium crowned forest (disturbed)	PL: Large to medium crowned forest on plains and fans <1000 m	Large to medium crowned forest	13.6	<0.1
2a	Small crowned forest/ regrowth forest	PS: Medium crowned forest/small crowned forest on plains and fans <1000 m	Medium crowned forest/Small crowned forest	102.5	0.2
3a	*Nauclea orientalis/Albizia procera* savannah	SA: Savannah	Savannah	53.8	0.1
4a	Kunai grassland on riverine alluvium	G: Grassland and herbland	Grassland	907.3	1.9
4b	Kunai grassland on footslopes and hillslopes	G: Grassland and herbland	Grassland	390.3	0.8
Vegetation Communities with Moderate to High Levels of Disturbance					
3b	*Nauclea orientalis/Albizia procera* savannah - moderately degraded	SA: Savannah	Savannah	937.7	2.0
4c	Kunai grassland on riverine alluvium - moderately/ patchily degraded with weeds	G: Grassland and herbland	Grassland	19,322.6	40.9
12a	Active river channels	O: Other non-vegetation and areas dominated by land use[3]	Lakes and larger rivers	1,072.3	2.3

Table 6.8 – Vegetation Communities Occurring Within the Study Area (cont'd)

Vegetation Community Code	Vegetation Community Description[1]	FIM Vegetation Type[2]	FIM Vegetation Type	Area (ha)	% of Total Area
Vegetation Communities that are Highly Degraded					
2b	Mixed native/exotic secondary forest	O: Non-vegetation and areas dominated by land use		1,148.5	2.4
3c	Native savannah woodland with severely degraded ground cover	SA: Savannah	Savannah	59.5	0.1
4d	Kunai grassland on riverine alluvium - heavily modified and degraded with weeds and pasture plants	G: Grassland and Herbland	Grassland	10,424.6	22.1
4e	Mixed native/exotic grassland, shrubland and woodland on river alluvium	G: Grassland and Herbland	Grassland	553.7	1.2
4f	*Saccharum robustum, Leucaena leucocephala* grassland/shrubland on recent river deposits	G: Grassland and Herbland	Grassland	469.2	1.0
5a	*Albizia saman* dominated savannah	G: Grassland and Herbland	Grassland	210.9	0.4
10a	Sago swamp - regrowth/ degraded forest	O: Non-vegetation and areas dominated by land use[3]		92.9	0.2
Vegetation Communities Resulting from Complete Habitat Modification					
5b	*Albizia saman* dominated open forest	O: Non-vegetation and areas dominated by land use[3]		7,430.2	15.7
6a	*Leucaena leucocephala, Albizia sp., Albizia saman* dominant shrubland	O: Non-vegetation and areas dominated by land use[3]		206.1	0.4
7a	Village Area	O: Non-vegetation and areas dominated by land use[3]		397.3	0.8
8a	Plantation areas/leucaena/palm oil	O: Non-vegetation and areas dominated by land use[3]		936.7	2.0
8b	Plantation areas: *Pinus* and *Araucaria*	O: Non-vegetation and areas dominated by land use[3]		25.8	0.1
9a	Former gardens/coconut plantations	O: Non-vegetation and areas dominated by land use[3]		2,115.4	4.6
11a	Garden areas with evidence of recent modification	O: Non-vegetation and areas dominated by land use[3]		294.1	0.6
Total				**47,205.0**	**100.0**

1 Description derived from Paijmans (1976), applied to natural vegetation communities only.
2 Classification derived from Hammermaster and Saunders (1995).
3 Referring to areas utilised by humans for agriculture, settlement or other industrial or extractive activity.

The distribution of the vegetation communities across the study area is mapped in Figure 6.15. The area subject to mapping assessment covers approximately 470 km^2 and is focused on the floodplain of the Markham River. The study area is suitably broad to provide context to the plantation areas as well as to accommodate future modifications to the plantation layout.

PROJECT FOOTPRINT IN RELATION TO VEGETATION COMMUNITIES

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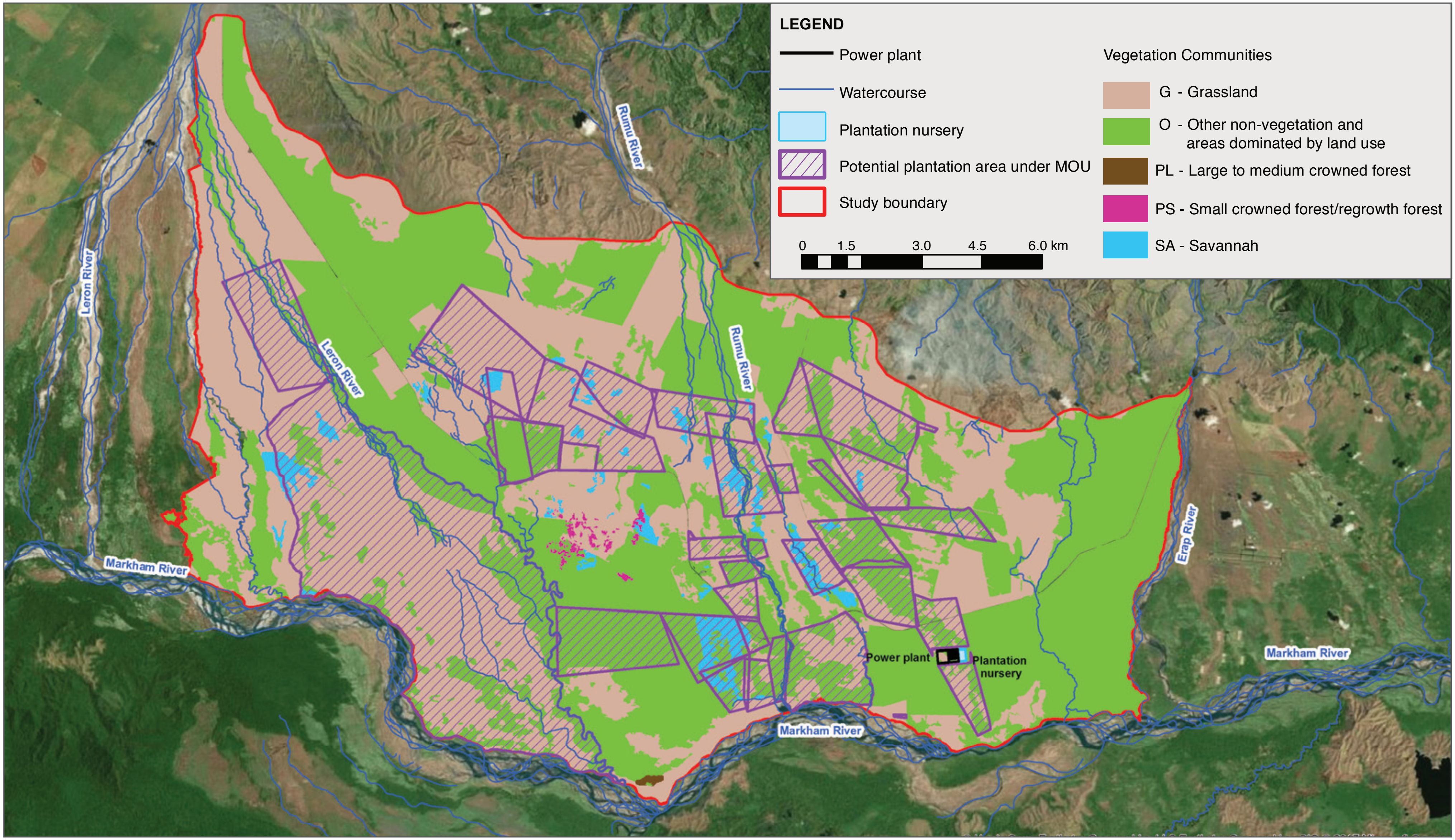
FIGURE 6.15



Source: Appencix 6.

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Structural and floristic descriptions of vegetation communities sampled in the field survey are presented in Appendix 6.

Condition of Vegetation Communities

The vegetation condition assessment identified different categories of vegetation condition based on the structural integrity of vegetation communities. The different categories of vegetation condition were then related to the IFC Performance Standard 6 habitat classifications, as well as the FSC Standard. The condition classification specifically aims to identify those habitats that have been subject to minimal human intervention, thereby demonstrating a high degree of 'intactness'. Additional categories identify varying levels of disturbance ranging from partial clearing or thinning of natural vegetation to complete clearing and/or vegetation dominated by planted gardens or invasive exotic species. The classification of vegetation condition used in this assessment is described in Table 6.9.

Table 6.9 – Habitat Condition Categories Applied to Vegetation Communities

Condition Category		Condition Description	IFC Performance Standard 6	FSC Standard*
1	Intact	The vegetation community exists in unmodified condition. No structural disturbance of canopy, sub-canopy or ground cover layers is evident. Some selective harvesting of poles or timber species may have occurred although this is minor in nature and has not compromised structural integrity of the vegetation community	Natural habitat	Natural forest
2a	Moderately disturbed: stable to declining	Vegetation in this category has been subject to structural modification, resulting in a general reduction in forest stature and complexity. A sub-set of the original floristic diversity is retained within the habitat and small vestiges of unmodified habitat may remain. Habitat is subject to ongoing degradation through weed invasion or continued thinning. Also includes river gravel beds subject to weedy degradation	Natural habitat	Natural forest
2b	Moderately disturbed: stable or regenerating	Areas of remnant vegetation providing good representation of natural savannah habitat in native condition, and regenerating regrowth rainforest habitats that are developing some of the structural complexity of the native forest ecosystems and are comprised predominantly of native flora species	Natural habitat	Natural forest
3	Modified (cultural)	Modified habitats composed of native species that have had long term stability through regular intervention by man (e.g., Kunai grasslands that represent rainforest transformed to grassland through a long history of regular burning). Differentiated from category 4 by the dominance of native species and absence of invasive exotic species	Modified habitat	-
4	Degraded	Secondary forest composed of a mix of native pioneer species and exotic trees in which the structure and floristic assemblage of the original forest has been modified through prior complete clearing or long-term continuous disturbance. Differentiated from category 3 by the presence of invasive exotic species that limit the potential for recovery of native species if the source disturbance was removed	Modified habitat	-

Table 6.9 – Habitat Condition Categories Applied to Vegetation Communities (cont'd)

Condition Category		Condition Description	IFC Performance Standard 6	FSC Standard*
5	Highly degraded	Highly degraded habitats generally comprising a mix of native and exotic food plants, garden plants and also weeds. Includes maintained and abandoned garden areas with large areas of the latter occupied by the invasive pest plants such as *Piper aduncum*	Modified habitat	-

* The FSC Standard is relevant to forest habitats only. Forests comprise vegetation where the tree layer has projective foliage cover greater than 30%.

The following trends are noted:

- No intact forest vegetation was identified within the study area. A single degraded (14 ha) patch of disturbed large to medium crowned forest (VC1a) (Plate 6.13) that remains on the river frontage was classified Moderately Disturbed (Stable to Declining) (Condition Category 2a).
- Vegetation Community 3a represents the best-preserved representation of savannah habitat in the study area, the habitat being largely free of exotic weeds and in a stable natural condition. Associated patches of rainforest (VC2a) are predominantly native and developing structural attributes of a natural forest. These habitats are of relatively minor extent within only 53 ha of VC3a and 102 ha of VC2a mapped across the assessment area. These habitats are assigned to the condition category of Moderately Disturbed (Stable or Regenerating) (Condition Category 2b).
- Regrowth vegetation comprising a mix of native pioneer and exotic trees and shrubs (VC2b) occupies 1,147 ha or 2.4% of the mapped assessment area. These are considered degraded forest patches (Condition Category 4) that are subject to decline in habitat condition through continued expansion of exotic species, notably raintree, on the forest margins and into forest canopy gaps.
- Highly degraded vegetation (Condition Category 5), represented by exotic forests dominated by raintree (VC5a and VC5b) form 7,641 ha or 16.1% of assessment area); severely degraded grasslands (VC4d, VC4e and VC4f) forming 11,448 ha and 24% of the assessment area; and other degraded areas including villages and plantation forming 11,922 ha, or 25% of the assessment area.

On a whole, the assessment area is dominated by vegetation in a degraded, highly modified condition with natural vegetation being an extremely limited component of the landscape (Table 6.10). The mapping of vegetation condition across the assessment area, according to the framework described above, is provided in Figure 6.16. No intact vegetation (Condition Category 1) was recorded. The moderately disturbed (stable or regenerating) Condition Category 2b represents habitats that have been subject to moderate levels of human disturbance but remain dominated by native species characteristic of the original natural state prior to human impacts. The limited extent of this condition class indicates the pervasiveness of exotic species that are symptomatic of habitat degradation throughout the majority of habitats in the Project area.

PROJECT FOOTPRINT IN RELATION TO VEGETATION CONDITION

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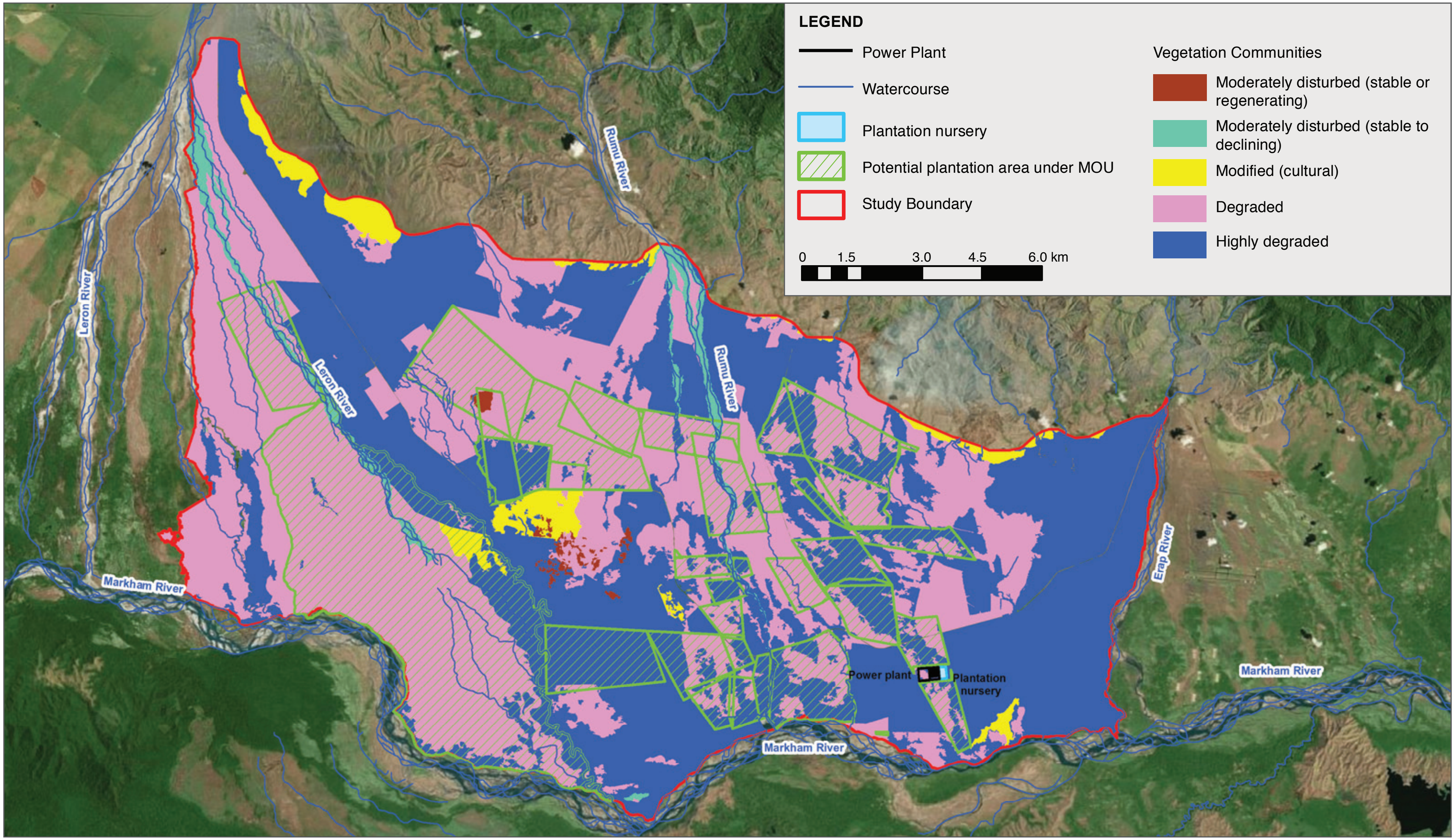
FIGURE 6.16



Source: Appendix 6.

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Plate 6.13 – Degraded Large to Medium Crowned Forest (Left), Native Regrowth Forest (Right)


Source: Appendix 6.

Table 6.10 – Spatial Extent of Vegetation Condition Classes Across the Project Area

Vegetation Condition Class	Vegetation Communities	Area (ha)*	% of Total Area
Moderately Disturbed (stable or regenerating) (Category 2b)	2a, 3a	156.2	0.3
Moderately Disturbed (stable to declining) (Category 2a)	1a, 12a	1,085.9	2.3
Modified (cultural) (Category 3)	4a, 4b	1,297.05	2.7
Degraded (Category 4)	10a, 2b, 3b, 4c, 4f	21,970.9	46.4
Highly Degraded (Category 5)	11a, 3c, 4d, 4e, 5a, 5b, 6a, 7a, 8a, 8b, 9a	22,694.4	48.2
Total (allowing for rounding)		**47,205.0**	**100.0**

* Sum of individual values before rounding.

IFC Flora Habitat Type Assessment

The classification of floristic habitats against IFC Performance Standard 6 has previously been provided in Table 6.9. In summary, three habitat types are recognised under the IFC framework:

- Modified habitat: areas that may contain a large proportion of plant and/or animal species of non-native origin, and/or where human activity has substantially modified an area's primary ecological functions and species composition.
- Natural habitat: areas composed of viable assemblages of plant and/or animal species of largely native origin, and/or where human activity has not essentially modified an area's primary ecological functions and species composition.
- Critical habitat: areas with especially high biodiversity value.

Mapping showing the distribution of habitat categories in accordance with the IFC framework across the Project area is shown in Figure 6.17.

Most floristic communities within the study area fit within the definition of modified habitat.

PROJECT FOOTPRINT IN RELATION TO IFC HABITAT CLASSIFICATION

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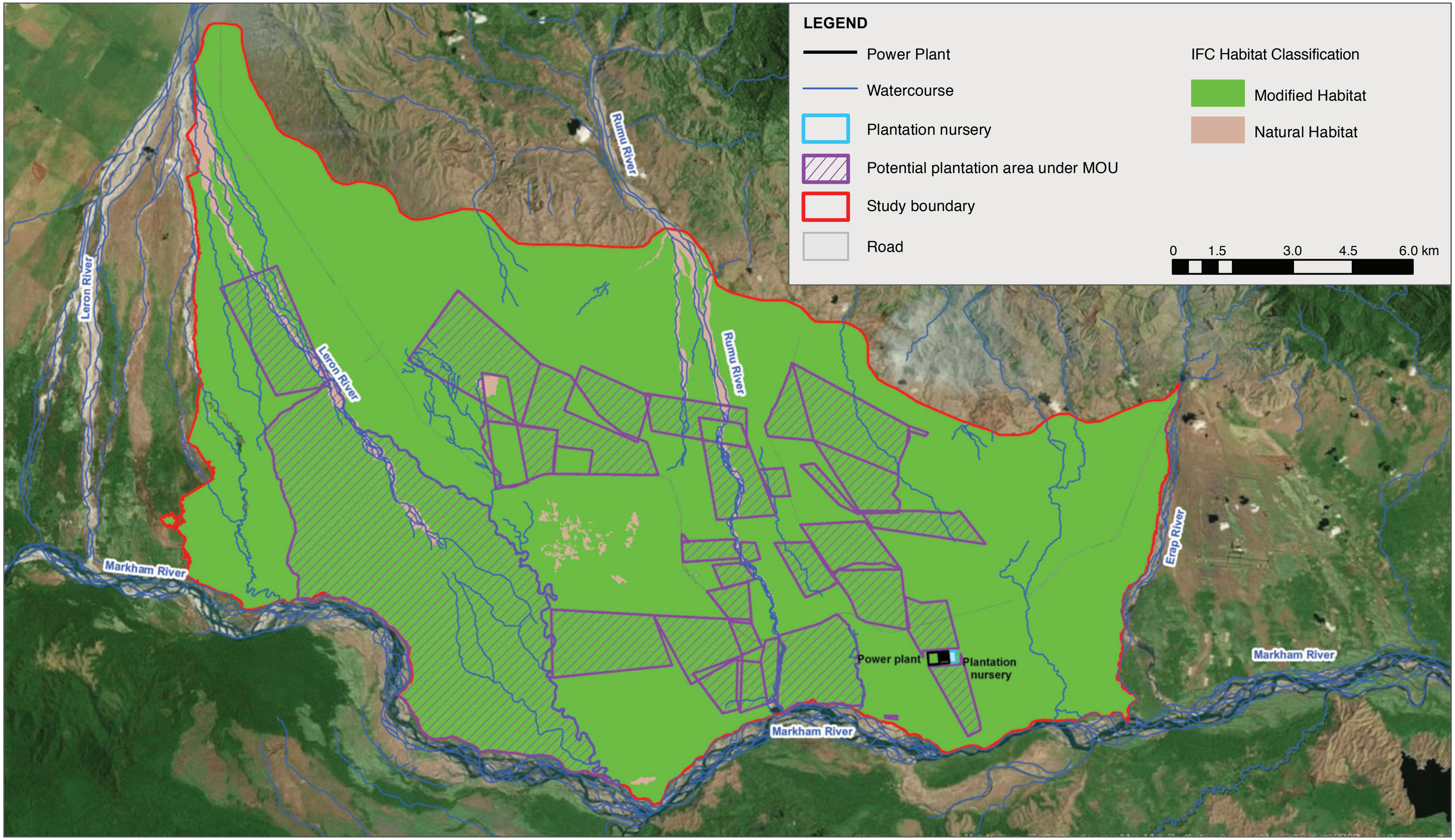
FIGURE 6.17



Source: Appendix 6.

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No habitats in the study area have escaped extensive anthropogenic influence. However, a few small habitat vestiges have nevertheless retained aspects of their original undisturbed vegetation structure, composition and their primary ecological function and are considered consistent with the definition of natural habitat.

For the purposes of this assessment, natural grassland is defined as grassland composed of species of native provenance whose structure and distribution is controlled by edaphic (produced by, or influenced by the soil) and climatic conditions and has developed outside any substantial anthropogenic influence. No Kunai grassland habitats within the Project area are considered to be in a natural condition due to the importance of anthropogenic influences in the origin and maintenance of Kunai grasslands. This concurs with descriptions from other studies that considered the extensive 'anthropogenic' grasslands within the Markham Valley as being derived through human modification.

No critically endangered or endangered flora species were detected within the study area, and none are considered likely to occur. Furthermore, no habitat areas of significant importance to endemic or restricted-range species were identified and no evidence was found to suggest that habitats support key evolutionary processes, most of which have been substantially modified by repetitive anthropogenic disturbance. There is little evidence to suggest that native savannah habitats (Plate 6.14) would qualify as a highly threatened or unique ecosystem due to the extensive, well-preserved representations of savannah woodland associated with the Fly River Delta in southwest of Papua New Guinea. There is evidence that large to medium-crowned forest in lowland localities is highly threatened, being subject to considerable anthropogenic pressure and extensive areas have been cleared for shifting cultivation and to develop commercial timber resources. Based on clearing rates for commercially accessible forest (1.41% between 1975 and 2002 increasing to 2.6% since 2002), large to medium crowned forest (1a) is predicted to have experienced >50% reduction in habitat extent between 1975 and 2015, qualifying it as endangered under IUCN criteria. However, the small area of this vegetation community within the study area is highly degraded and therefore does not have high biodiversity value. Consequently, the patch of large to medium crowned forest (Vegetation Community 1a) within the Project area does not meet requirements for recognition as critical habitat. In summary, there are no habitats within the study area that qualify as critical habitat under IFC Performance Standard 6.

Plate 6.14 – Severely Degraded Savannah Woodland (Left), Savannah Vegetation Where Tree Cover has been Thinned (Right)

Source: Appendix 6.

FSC Forest Type Assessment

The framework for assessment of habitat under the FSC National Forest Management Standard has been detailed in Appendix 6. This framework recognises two forest types of conservation significance:

- High Conservation Value Forests.
- Natural Forests.

Two natural forest types occur within the study area (Figure 6.18), namely:

- Large to medium crowned forest.
- Small crowned forest/regrowth forest.

Neither of these natural forest types qualifies as High Conservation Value Forest for the following reasons:

- No significant populations of endangered or endemic species occur within these forest types.
- Neither is considered a threatened forest type of high biodiversity value due to the extent of habitat degradation experienced by these patches of forest, as discussed in more detail in above.
- They do not provide any critical landscape function and contribute little to watershed protection or erosion control due to their landscape position, i.e., on an alluvial plain close to the coast.
- The forests do not provide for >50% of the basic needs of the local communities. Food resources are largely obtained from cultivated garden areas and natural forests do not provide dietary staples. Timber resources are also obtained from a range of habitat types with no particular reliance on the very limited extent of natural forest areas within the study area.
- There is no evidence that there is any particular cultural, ecological, economic or religious significance placed on these habitats by local communities.

Natural forests are fragmented and have limited coverage across the Project area. Total natural forest cover in the Project area is 116 ha, which constitutes just 0.2% of the study area.

Other high conservation values within the study area are restricted to the occurrences of two conservation significant plant species. The study area does not support significant concentrations of biological diversity, intact forest landscapes, other significant landscape-level ecosystems or critical ecosystem services.

Conservation Status of Vegetation Communities

There are few targeted floristic studies focusing on habitats in the Markham Valley, or New Guinea savannah landscapes in general. Studies within the lowland rainforests (below 400 m asl) of the Josephstaal Forest Management Agreement Area, approximately 250 km north of the study

PROJECT FOOTPRINT IN RELATION TO FSC FOREST TYPES

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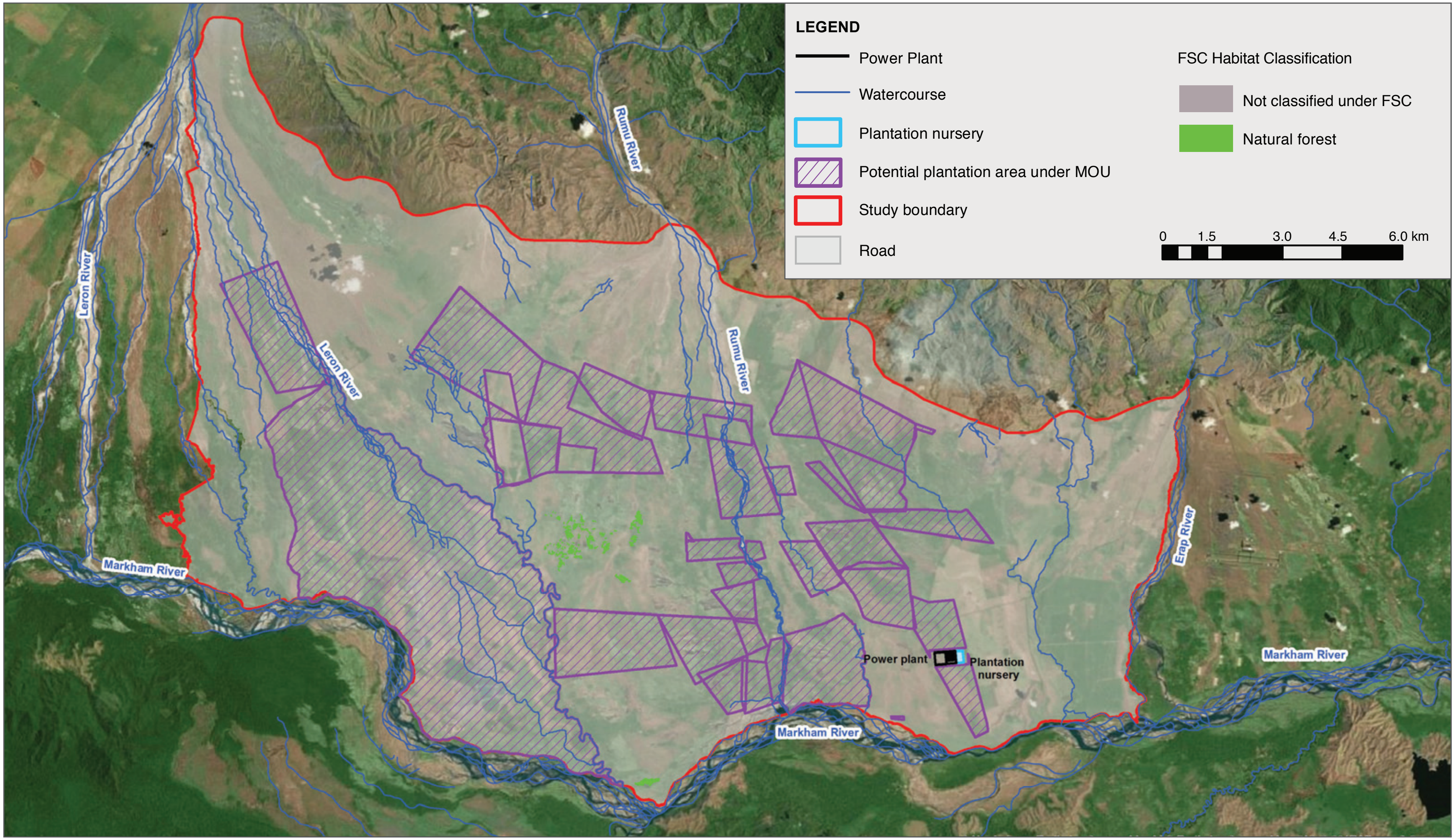
FIGURE 6.18



Source: Appendix 6.

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area, identified 139 families, 445 genera and 730 distinct morpho-species with an unaccounted proportion of the flora considered undocumented. However, due to the highly disturbed and degraded nature of the forests in the study area, coupled with the considerable extent of relatively homogenous grassland, floristic diversity is likely to be significantly diminished. The exception; however, is likely to be a considerable abundance of exotic species promoted by grazing and cultivation, with 36% of the species recorded in the study area considered to be of exotic origin. The high proportion of exotic flora is due to the land use history and extensive areas of highly disturbed and degraded vegetation.

The results of this survey, augmented with floristic records sourced from historic collections within the botanical database of the Queensland Herbarium, identified a flora of 370 species occurring within 85 families and 267 genera. This comprises 235 (64%) native species and an introduced/ exotic flora of 135 species (36% of the total flora). There are 11 ferns, one cycad, four gymnosperms and 354 flowering plants. One species is listed as significant under the IUCN and 150 (41%) of the flora are significant to the local landholders on account of traditional and/or current uses and value.

6.2.1.6 Fauna Surveys

Due to the large size of the indicative study area and the limited, rough access tracks, the selection of survey sites aimed to provide a survey of sites representative of the different fauna habitat types within the area. The fauna survey involved two phases:

- An initial reconnaissance of the study area via a guided driven tour of portions of the study area on 4 September.
- A general fauna trapping and observational survey over three nights and four days in the period 5 to 8 September 2016.

Methods used to survey fauna and information collated from the desktop assessment is detailed in Appendix 6 of this report.

Habitat Types

Four main terrestrial fauna habitat types were characterised within the study area: alluvial forest and woodland; grassland; watercourses and wetlands; and highly disturbed anthropogenic habitats. These broad habitat types and their characteristic terrestrial fauna assemblages are described in more detail in Appendix 6.

Faunal Diversity

The field survey recorded a total of 89 terrestrial vertebrate fauna species, including 68 bird species, eight mammal species, two reptile species and two frog species. Discussions with reliable local informants identified at least a further 10 mammal species, eight bird species and five reptile species that are likely to occur in the study area. Anabat detectors identified the presence of eight microbat species. No small mammals were trapped during a trapping survey; the only species captured by traps were two introduced fauna pest species: Giant African Snail (*Achatina fulica*); and Cane Toad (*Bufo marinus*). Remote cameras photographed New Guinea Scrubfowl (*Megapodius decollatus*) at two locations, and nest mounds of this species were detected at a number of locations. There was surprisingly little reptile activity, and few reptile species were detected in the Project area. As nocturnal surveys were not feasible, only two frog species were detected despite good rainfall falling during the survey period.

The field survey also focused on recording the presence of significant ecological features, including:

- Caves that might provide roosting and maternity sites for significant concentrations of cave-dwelling bats.
- Waterbird nesting colonies, where egrets, herons and other waterbirds gather together to nest.
- Megapode nest mounds. Two species of megapode bird occur in the study area, Collared Brush-Turkey and New Guinea Scrubfowl. The males of these species construct large mounds of leaf-litter and other decomposing vegetation mixed with loose soil. The females dig deep holes into the mounds in which they lay an egg every few days. Incubation of the eggs then occurs through the heat generated by the decomposing vegetation. Megapode eggs are large, weighing up to 200 g each, include a large proportion of nutritious yolk, and females may lay between 28 and 50 eggs each year. As the best quality mounds are large and energetically costly to build, they are maintained and used by the birds over many years. This combination of features means that megapode eggs are valued by local communities as an important source of food, with community members visiting mounds regularly to harvest freshly-laid eggs.

Conservation Priority Species

The desktop assessment identified nine threatened or near-threatened vertebrate fauna species with potential to occur in the study area, including three mammal species and five bird species (Table 6.11). No threatened or near-threatened terrestrial vertebrate fauna species were detected in the area during the field survey. Based on an assessment of habitat suitability and the nature of threatening processes at a broader landscape scale (i.e., relatively high human population density resulting in heavy hunting pressure and extensive rainforest habitat fragmentation and degradation), no threatened or near-threatened species are considered likely to occur in the study area (see Table 6.11 for details).

Table 6.11 – Threatened and Near-threatened Vertebrate Fauna Species Within the Study Area

Scientific Name	Common Name	Status[1]		Likelihood of Occurrence in the Study Area
		IUCN	PNG	
Mammals				
Dasyurus albopunctatus	New Guinea Quoll	NT		**Unlikely to occur**. The study area occurs within the historical range of the species. However, this species was not recognised by community interview participants. The forest-dwelling species is sensitive to habitat loss and hunting by dogs, so is likely to have been extirpated from the study area historically due to extensive habitat transformation and high hunting pressure

Table 6.11 –Threatened and Near-threatened Vertebrate Fauna Species Within the Study Area (cont'd)

Scientific Name	Common Name	Status[1]		Likelihood of Occurrence in the Study Area
		IUCN	PNG	
Mammals (cont'd)				
Thylogale browni	New Guinea Pademelon	VU		**Unlikely to occur.** New Guinea Pademelon inhabits primary and secondary tropical moist forest, with an apparent preference for disturbed areas. The main threat to the species is subsistence hunting by local people (hunting with dogs) for food; hunting has heavily depleted populations over parts of its range, where it is now restricted to remote mountainous interior areas. The study area occurs within the range of the species. However, community interview participants recognised the species and reported that while it used to occur in the area, it no longer occurs. This species is likely to have been extirpated by extensive habitat transformation and heavy hunting pressure
Spilocuscus rufoniger	Black-spotted Cuscus	CR	P	**Unlikely to occur**. This rare species has been extirpated from parts of its range through overhunting and its intolerance of human disturbance. Within the local region it is known only from mountainous rainforest areas north of Lae, and it was not recognised by community interview participants; therefore, it is unlikely to occur in the study area
Birds				
Psittrichas fulgidus	Pesquet's Parrot	VU	P	**Unlikely to occur**. This species is restricted to hill and lower montane forest, mostly at elevations of 500 to1,800 m asl. The species is sensitive to hunting pressure and has been historically and recently extirpated from large areas in Papua New Guinea. The species is therefore unlikely to occur in the study area due to the relatively low elevations, lack of hill forest and extensive forest fragmentation and degradation
Megatriorchis doriae	Doria's Goshawk	NT		**Unlikely to occur.** This unobtrusive and therefore cryptic species occurs only in the interiors of intact lowland forest and adjoining hill forest foothills. While it has been reported in lowland forest habitat northwest of Lae, it is unlikely to occur in the study area due to the absence of intact rainforest habitat and extensive forest fragmentation and degradation
Harpyopsis novaeguineae	Papuan Eagle	VU	P	**Unlikely to occur**. Papuan Eagle inhabits intact rainforest landscapes and is most common in undisturbed forest at elevations from sea level to 3,700 m. In suitable habitat of extensive, old growth forest, pairs occupy large home ranges that average 13 km^2. While the species is known to occur in extensive hill forest on the southern side of the Markham River, it is unlikely to occur in the study area due to the absence of intact rainforest habitat and extensive forest fragmentation and degradation
Aquila gurneyi	Gurney's Eagle	NT	R	**Unlikely to occur**. Gurney's Eagle inhabits a variety of rainforest habitats to 1,000 m elevation, but seems to prefer primary, relatively undisturbed rainforest. While the species is known to occur in extensive hill forest on the southern side of the Markham River, it is unlikely to occur in the study area due to the absence of intact rainforest habitat and extensive forest fragmentation and degradation

Table 6.11 –Threatened and Near-threatened Vertebrate Fauna Species Within the Study Area (cont'd)

Scientific Name	Common Name	Status[1]		Likelihood of Occurrence in the Study Area
		IUCN	PNG	
Birds (cont'd)				
Zonerodius heliosylus	Forest Bittern	NT		**Unlikely to occur**. Forest Bittern occurs in association with streams, pools and swamps in lowland alluvial and hill rainforest at elevations up to 1,430 m. It is unlikely to occur in the study area due to the absence of intact rainforest habitat and extensive forest fragmentation and degradation

[1] Extinction risk status under the IUCN Red List (IUCN) and protection status under the Papua New Guinea Fauna Act (PNG): CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; P = protected; R = restricted.

Species Protected Under the Papua New Guinea Fauna Act 1966

A total of four species declared protected (P) and a further two species declared restricted (R) under the PNG *Fauna Act 1966,* all of which are birds, have been recorded within the study area (Table 6.12). All of these species occupy wide ranges across Papua New Guinea and none is of particular conservation concern.

Table 6.12 – Protected or Restricted Terrestrial Vertebrate Species Within the Study Area

Scientific Name	Common Name	Status[1]	
		IUCN	PNG
Ardea alba	Great Egret	LC	P
Egretta intermedia	Intermediate Egret	LC	P
Aceros plicatus	Blyth's Hornbill	LC	P
Probosciger aterrimus	Palm Cockatoo	LC	P
Cacatua galerita	Sulfur-crested Cockatoo	LC	R
Circus spilothorax	Papuan Harrier	LC	R

[1] Conservation status under the IUCN Red List (IUCN) and Papua New Guinea Fauna Act (PNG): EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC= Least Concern; P = protected; R = restricted.

Exotic Fauna Species

Two introduced fauna pest species, the Giant African Snail (*Achatina fulica*) and Cane Toad (*Bufo marinus*), were common throughout the area surveyed and were the only fauna species trapped during the trapping survey. While local informants reported that feral pigs were still hunted in the area, no clear evidence of feral pig diggings was encountered during the field survey, suggesting that feral pigs probably occur at low density as a consequence of high hunting pressure.

6.2.2 Aquatic Ecosystems

The information presented in this section is based primarily on an investigation and report (and references cited therein) undertaken by Fathom Pacific and attached as Appendix 7.

6.2.2.1 Aquatic Ecology Background Information

The Markham Valley

As described in Section 6.1.5, the Markham Valley is characterised by broad alluvial deposits, with the headwaters of the Markham River and the major tributaries that originate in the surrounding ranges generally being high gradient, shallow, fast-flowing and turbid. Several major tributaries are highly braided (e.g., Erap River, Rumu River) and some create large low-gradient alluvial fans in the valley (e.g., Leron River). The Markham River mainstream is highly braided and subject to significant course alterations in sporadic high flow events. These characteristics influence the ecology of the various rivers and streams, as described below.

Aquatic Ecology in the Project Area

The freshwater fish fauna of northern Papua New Guinea is broadly separated from that of southern Papua New Guinea by the central dividing range. Only species with a marine life history phase occur in both northern and southern parts of the country, and most of the northern half is thought to represent a single zoogeographic zone with considerable uniformity between the Ramu and Markham systems. On a global scale, freshwater fish diversity in Papua New Guinea is comparatively low due to the absence of native primary freshwater fish species (i.e., species originally evolved in freshwater); the fauna belong in, or are recently derived from, marine families. Freshwater fish diversity in northern Papua New Guinea is further limited by the fact that, unlike the southern part of the country and northern Australia, northern Papua New Guinea lacks extensive estuaries. Therefore, some species that have a life history stage involving estuaries (e.g., barramundi) do not occur in the north, although several marine migratory species, notably mullet (family *Mugilidae*) and eels (family *Anguillidae*), do migrate into northern rivers. Freshwater prawns (*Macrobrachium* spp.) form a significant component of the diversity and biomass of aquatic fauna in the northern rivers.

In the fast flowing turbid rivers that typify the Markham Valley and the watercourses intersecting the Project area, high sediment loads and high flow conditions are important drivers of fauna composition, although fauna may take refuge in clearwater tributaries and similar during times of very high flow or sediment loading. Sediment and flow conditions are also key factors to foodweb functioning in these rivers. In general, allochthonous (i.e., external to the watercourse) sources of organic matter are more dominant than autochthonous (i.e., within the watercourse) production in high flow-high sediment load watercourses. Macroinvertebrates, dominated by the aquatic life stages of terrestrial insects, and prawns play a role in breaking down allochthonous organic matter, as well as providing prey for fishes.

Native Fish Communities of the Markham River System

A total of 38 native fish species have been recorded from previous sampling in the Markham River system (Table 6.13). Historic monitoring of fish populations in the catchment has been most intensive in the Watut River and this data, while representing generally higher altitude watercourses than those in the Project area, provides some basis for understanding diversity and impacts in the catchment. Fish communities in the upper Watut River declined severely in 2007 to 2009, probably as a result of sediment-related impacts, and have not recovered since that time. In contrast, communities in the Lower Watut and Markham rivers have remained relatively stable, although fish abundance appears to have decreased, potentially due to fishing pressure and localised landslips. Several species in the Watut River system are probably maintaining their populations in off-river habitats including floodplains, oxbow lakes, and tributary streams. Native species that are likely to occur in off-river water bodies include *Glossamia gjellerupii*, *Melanotaenia affinis* and *Mogurnda aurofodinae*.

One particular study sampled the Erap River, at the eastern boarder of the Project area, and a single *Chilatherina bulolo* was captured.

Table 6.13 – Fish Species Historically Recorded During Surveys in the Lower Watut and Markham Rivers

Species	Powell and Powell 2000	2007	2009	2010 a	2010 b	2010 c	2011	2012	IUCN Listed[1]
Ambassis interruptus						X			LC
Ambassis macrocanthus			X						ND
Anguilla megastoma			X				X		DD
Anguilla reinhardtii		X							ND
Anguilla sp.								X	ND
Awaous melanocephalus			X			X		X	ND
Chilatherina bulolo		X	X	X	X		X		DD
Chilatherina crassispinosa	X		X	X		X		X	ND
Chilatherina fasciata					X			X	ND
Cottapisttus praepostus			X						ND
Glossamia gjellerupi	X			X	X	X	X	X	ND
Glossogobius torrentis		X			X	X	X	X	ND
Glossolepis kabia					X	X	X	X	ND
Glossolepis sp.				X					ND
Hephaestus transmontanus	X	X						X	ND
Johnius amblycephalus			X		X				ND
Lamnostoma kampeni			X			X			ND
Lentipes watsoni		X	X				X	X	ND
Liza sp.			X						ND
Liza subviridis		X						X	ND
Liza tade			X						DD
Melanotaenia affinis	X	X	X		X	X	X	X	ND
Mesopristis cancellatus			X		X				ND
Microphis mento			X	X	X				LC
Mogurnda aurofodinae		X							ND
Mogurnda nesolepis		X			X	X	X		ND
Mugil sp.				X	X	X			ND
Mugil subviridis						X			ND
Neosilurus idenburgi	X				X			X	ND

Table 6.13 – Fish Species Historically Recorded During Surveys in the Lower Watut and Markham Rivers (cont'd)

Species	Powell and Powell 2000	2007	2009	2010 a	2010 b	2010 c	2011	2012	IUCN Listed[1]
Nibea sp.						X			ND
Ophieleotris aporos	X		X	X	X	X	X	X	ND
Bunaka gyrinoides	X	X	X		X			X	LC
Potamosilurus coatesi			X						ND
Potamosilurus velutinus	X			X	X	X	X	X	ND
Rhyacichthys aspro		X							DD
Schismatogobius sp. cf. insignus								X	ND
Stenogobius laterisquamatus			X						LC
Valamugil buchanani					X				ND
Native species richness	**8**	**11**	**18**	**8**	**16**	**14**	**10**	**16**	
Clarias batrachus					X			X	LC
Xiphophorus helleri	X		X	X	X	X	X	X	ND
Tor putitora					X	X	X	X	E
Cyprinus carpio	X			X	X		X	X	ND
Gambusia holbrooki			X		X	X		X	ND
Oreochromis mossambica	X		X	X	X	X	X	X	ND
Oreochromis niloticus								X	ND
Non native species richness	**3**	**0**	**3**	**3**	**6**	**4**	**4**	**6**	

[1] Conservation status under the IUCN Red List (IUCN) and Papua New Guinea Fauna Act (PNG): EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC= Least Concern; P = protected; R = restricted; ND = Not Determined.

Non-native Fish Species

Previous studies have reported three non-native species in the Lower Watut River and seven non-native species are known to occur in the Lower Watut and Markham rivers (see Table 6.13). On average, non-native species account for about 15% of total fish species diversity in the Lower Watut and Markham rivers, although some watercourses are almost completely dominated by non-natives.

At least three of the exotic fish species (*Tor putitora, Oreochromis niloticus* and *Clarias batrachus*) in the Watut and Markham rivers have the potential to negatively impact native fish communities, particularly in floodplain habitat. The introduced golden mahseer, *T. putitora*, is successfully breeding in the Watut River and continuing to disperse upstream. The dietary range of the species is likely to result in negative impacts on resident fish communities through resource competition and predation. The walking catfish, *C. batrachus*, can dominate small creeks and waterbodies and have a similar negative impact on native species. The GIFT (Genetically Improved Farmed Tilapia) is genetically 'improved' stock of the Nile tilapia, *O. niloticus*, which was originally introduced locally for aquaculture but has now entered open waters. This species, with wider ecological tolerances and more vigorous growth and preferring floodplain habitat, may also negatively impact resident communities through resource competition.

Exotic Fish Species

Since the 1950s, a number of freshwater fish species have been intentionally introduced to, or have migrated to, Papua New Guinea (Table 6.14).

Some of these species, such as tilapia (*Oreochromis mossambica*) and common carp (*Cyprinus carpio*), have become widespread and are common in most subsistence inland fisheries. Others are either too small to be eaten (e.g., guppy, swordtail and mosquitofish) or are not found in significant numbers in self-sustaining populations and therefore do not feature prominently in the diets of local communities. The ecological effects of these introductions and migrations are largely unquantified but, until about the 1990s, these introductions, migrations and translocations were considered to be so widespread and accepted by the culture that they have become part of the PNG fisheries identity (e.g., tilapia, common carp and trout) or were spatially limited and not of widespread ecological concern. However, in light of subsequent introductions, the cumulative effects of exotic species on the ecology of PNG freshwater systems are likely to now be significant. Additional information is provided in Appendix 7.

Table 6.14 – Freshwater Fish Species Intentionally Introduced or Naturally Migrated to Papua New Guinea

Common name	Species name	Location/Habitat	Potentially Occurs in Project Area or Downstream
Tilapia	*Oreochromis mossambica*	Nation-wide, most prevalent in off-river water bodies	Yes
Common carp	*Cyprinus carpio*	Widespread throughout Papua New Guinea	Yes
Snakehead	*Channa striata*	Apparently migrating or translocated from western borders	Yes
Walking catfish	*Clarius batrachus*	Introduced to Lake Sentani (West Papua) and now present throughout northern Papua New Guinea	Yes
Guppy	*Poecilia reticulata*	Nation-wide, most prevalent in off-river water bodies, temporary pools, or backwater edges of streams	Yes
Swordtail	*Xiphophorus helleri*	Nation-wide, most prevalent in off-river water bodies, temporary pools, or backwater edges of streams	Yes
Mosquitofish	*Gambusia affinis*	Nation-wide, most prevalent in off-river water bodies, temporary pools, or backwater edges of streams	Yes
Climbing perch	*Anabas testinudeus*	Western Province and possibly further east and south	Unlikely
Snakeskin gouramy	*Trichogaster pectoralis*	Western Highlands, Central and Gulf provinces. Self-sustaining populations uncertain. Also present in West Papua so translocations possible	Unlikely
Giant gourami	*Osphronemus goramy*	Introduced to off-river water bodies in a number of districts, unknown as to whether populations are self-sustaining	Unlikely
Threespot gourami	*Trichogaster trichopterus*	Apparently Central Province around National Capital District (NCD) only	Unlikely

Table 6.14 - Freshwater Fish Species Intentionally Introduced or Naturally Migrated to Papua New Guinea (cont'd)

Common name	Species name	Location/Habitat	Potentially Occurs in Project Area or Downstream
Brown trout	*Salmo trutta*	Upland streams generally >1,600 m altitude	No
Rainbow trout	*Oncorhynchus mykiss*	Upland streams generally >1,600 m altitude	No

Threatened Fish Species

A previous survey in the Watut River catchment recorded only one threatened native species listed on the IUCN Red List, i.e., the critically endangered freshwater sawfish *Pristis microdon*. The sawfish is generally found in shallow near-shore marine environments and estuaries, but also in large, turbid rivers. Adults breed in estuarine or marine conditions and use freshwater reaches as nursery grounds. The record was from the lower Watut River below its confluence with the Wafi River. This species was not recorded in numerous subsequent surveys undertaken between 2007 and 2012.

According to the IUCN Red List, the golden mahseer, *Tor putitora*, is endangered in its natural range. This species was introduced to Papua New Guinea from India in 1995 for fisheries enhancement. Its natural range extends across the Himalayan region and elsewhere in South Asia and Southeast Asia, ranging from Afghanistan to eastern Thailand. The IUCN conservation status is not deemed to apply to populations of this species outside of its natural range, i.e., it does not apply to this species in Papua New Guinea.

Four species recorded from the Lower Watut and Markham rivers are listed in the data deficient category of the IUCN Red List: *Anguilla megastoma*, *Chilatherina bulolo*, *Liza tade* and *Rhyacichthys aspro*. A further four species are in the 'of least concern' category: *Ambassis interruptus*, *Microphis mento*, *Bunaka gyrinoides* and *Clarias batrachus* (the latter species being non-native to Papua New Guinea).

Threatened Aquatic Reptiles

Threatened aquatic reptiles, which have previously been reported within the Project area, are:

- The New Guinea snapping turtle (*Elseya novaeguineae*), which has been recorded from off-river water bodies in the Markham River catchment. This species is listed in the lower risk/least concern category of the IUCN Red List.
- The New Guinea crocodile (*Crocodylus novaeguineae*), which is listed in the lower risk/least concern category of the IUCN Red List and may occur in the Markham River in the vicinity of the Project area.
- The saltwater crocodile (*Crocodylus porosus*), which is listed in the lower risk/least concern category of the IUCN Red List. If present in the Markham Valley, it is most likely restricted to the narrow estuarine zone of the Markham River mainstream near the mouth.

Fishes with Restricted Distributions

A native rainbow fish (*Glossolepsis kabia*) collected from an oxbow lake in the Uruf creek (a tributary of the Lower Watut River) was found to be genetically distinct from other populations in the Sepik and Ramu rivers. The population was classified as an evolutionarily significant unit, and represents a population in the process of becoming a new species, which, if its habitat remains isolated, will be endemic to the lower Watut-Markham catchment. The genetic differences suggest that the populations have been isolated for a reasonably long period prior to migration of the main channel and formation of the oxbow lakes.

While this water body is well outside the Project area, this finding elevates the importance of off-river water bodies such as floodplain swamps, oxbow lakes and other permanent pools as potential habitats of significance in the catchment. Indeed, such habitats are also commonly associated with sites of cultural significance (e.g., spiritual masalai sites).

Several species collected in the Watut-Markham catchment are understood to be endemic to northern New Guinea (i.e., north of the Central Range). These include *Hephaestus transmontanus*, *Glossamia gjellerupi*, *Glossogobius bulmeri*, *Mogurnda aurofodinae* and *Neosilurus novaeguineae*.

Species of Fisheries Significance

Most fish species, including small-bodied species, are important food species for local villagers in the Markham River catchment and people generally eat whatever is caught. As is the case in other areas in the country, the tilapia (*Oreochromis mossambica*) has become a key species for inland subsistence fisheries.

Approximately 300 active fish farms are thought to be located in the Morobe region. No detailed information on the farmed species is available, but carp, GIFT and rainbow trout, and to a lesser extent crocodiles, are commonly farmed in northern PNG catchments.

Several commercial significant freshwater species found elsewhere in Papua New Guinea, such as barramundi (*Lates calcarifer*) and Saratoga (*Scleropages jardinii*), do not occur in the Markham River catchment. Several eels (*Anguilla marmorata*, *Anguilla bicolor pacifica*) that form an important component of subsistence fisheries in Papua New Guinea have been recorded from the catchment, particularly in high altitude areas. Eels have also been the subject of aquaculture attempts in Papua New Guinea, albeit with apparently limited success.

Macrocrustacean Communities

Freshwater prawn communities in the Lower Watut-Markham rivers are diverse, although still not well documented taxonomically (see Appendix 7 for a table of all taxa). Five species have been recorded in the Watut-Markham system that are undescribed and possibly endemic to this area.

Prawns are detritivores and many species are tolerant of high levels of suspended sediments, while others prefer clear water conditions. However, lower abundance of prawns was recorded downstream from the junction of the Markham and Erap rivers at a time when the Erap River had a very heavy sediment load.

Macroinvertebrate Communities

Aquatic macroinvertebrate communities are dominated by the aquatic larval stages of terrestrial insects. A number of macroinvertebrate surveys have previously been carried out in the Watut River system, primarily in conjunction with the development and operation of the Hidden Valley Mine (located in the upper Watut catchment) and the Wafi-Golpu Project (an advanced exploration project that is expected to result in a large-scale underground copper mine in the lower Watut Valley). While the sites that were sampled are not necessarily analogous to those in the Project area, the data provides some context to the Project-specific survey results. In a healthy system, with good water quality and stable, diverse micro-habitats, a broad range of feeding guilds of macroinvertebrates may be present. Filter-feeders are particularly vulnerable to sediment-related water quality impacts.

The likely factors influencing the diversity and abundance of aquatic macroinvertebrates in the Watut River system are:

- Suspended sediment and sedimentation regimes. Sites sampled along the lower Watut River and the area from Tsili Tsili downstream are reported to be virtually devoid of aquatic macroinvertebrates, which may be due to severe sedimentation caused by land disturbance in the Upper Watut River.
- Flows and structural habitat conditions. Tributary streams can support higher levels of micro-habitat complexity compared to main river channel environments, thereby providing a broader range of niches for aquatic fauna.
- Biological processes and interactions. This includes differences in, for example, recruitment, competition and predation.

Further detail on the macroinvertebrates found in specific riffle and pool habitats is provided in Appendix 7 of this report.

6.2.2.2 Aquatic Ecology Survey

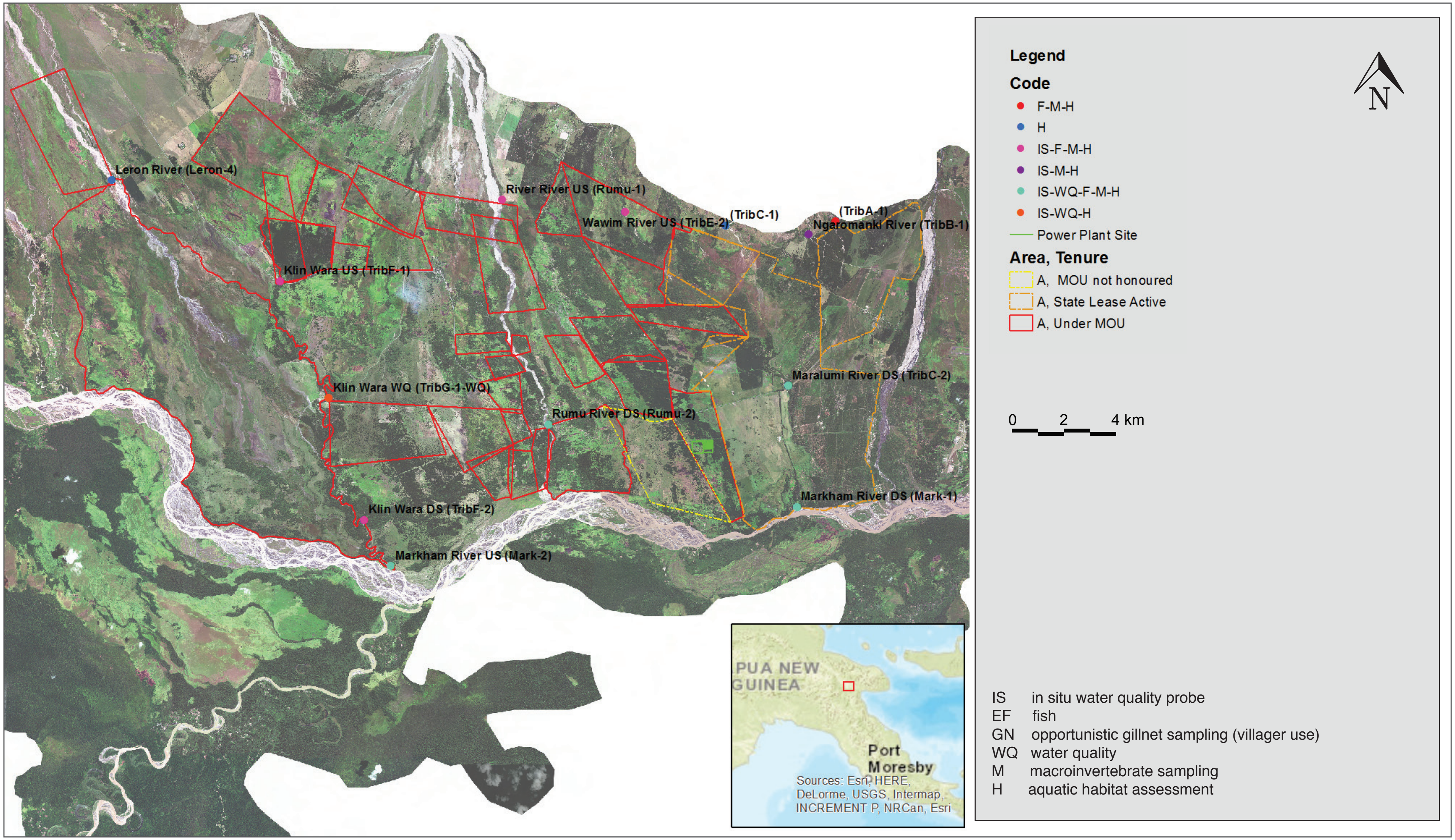
Fieldwork was completed in the Project area during the wet season from 25 September to 2 October 2016; sampling sites are shown in Figure 6.19. The survey included habitat assessments using in situ measurements, electrofishing and opportunistic villager gill net sampling, subsistence catch observations and macroinvertebrate sampling.

Previous sampling at sites upstream and downstream of the Markham River Bridge and along the Watut River provides the main basis of knowledge for the area, although most studies focused on fish and macrocrustaceans. Monitoring surveys were most frequent in the period 2007 to 2012 and included key publications that are detailed in Appendix 7.

AQUATIC ECOLOGY SAMPLING SITES

PNG Biomass Markham Valley I Environmental Assessment Report

FIGURE 6.19



Source: Appendix 7.

Habitat Types

The established broad habitat types of the Markham River observed during the survey are as follows (Plates 6.15 to 6.27):

- Type 1: Boulder-cobble-pebble dominated bed structure and moderate to high sediment loads with high gradient headwaters and ephemeral or episodic flows that dictate relatively low aquatic fauna diversity. Riparian vegetation is dominated by grasses. This class describes the aquatic habitats in much of the northern sector of the Project area bordering the foothills and the Leron River. These watercourses support aquatic fauna only when flowing and diversity of aquatic fauna is limited by sediment tolerances and habitat connectivity that enables movement of fishes and prawns into the area from perennial downstream reaches.

- Type 2: Perennial high flow energy, high sediment supply rivers with boulder-cobble-pebble bed structures and low diversity aquatic habitats. This class describes the Erap and Rumu rivers. Riparian vegetation is dominated by grasses and low shrubs, but some larger trees and canopy cover are evident. These watercourses support aquatic fauna at all times and diversity of aquatic fauna is limited by tolerances to sediment conditions and habitat availability (e.g., refugia from high flow).

- Type 3: Clearwater streams (Klin Wara and Maralumi River) that appear to originate in flat lowland areas that receive waters from high-energy streams draining the foothills of the Finisterre and Saruwaged ranges. These lowland flats/receiving areas may buffer potentially high sediment loads and contribute outflows in surface water, soil water and/or groundwater. The buffering of flow energy and settlement of sediment loads in these flats may contribute to clearwater conditions in Klin Wara and Maralumi River. The riparian vegetation has a relatively high diversity of vegetation structural forms including large trees. These streams support a relatively high diversity of aquatic species and, at downstream reaches, are likely to provide important refugia for populations of mobile species in the Markham River during times of high sediment conditions that exceed tolerances.

- Type 4**:** The Markham River, which has a high sediment supply and flow with moderate aquatic habitat diversity. The habitat has a moderate diversity of riparian vegetation with some intact forest, and supports a higher diversity of aquatic fauna as well as migratory species.

Survey sites classified into each of these four habitat categories are listed in Table 6.15 where US and DS relate to upstream and downstream, respectively. While these four habitat types appear to be morphologically distinct, macroinvertebrate assemblage data indicated that there was no differentiation between habitats 2 and 4.

Plate 6.15 – Wawin River: Trib E-2, Type 1 Habitat

Source: Appendix 7.

Plate 6.16 – Leron – 4: Trib E, Type 1 Habitat

Source: Appendix 7.

Plate 6.17 – Leron: Trib C-1, Type 1 Habitat

Source: Appendix 7.

Plate 6.18 – Leron: Trib A-1, Type 1 Habitat

Source: Appendix 7.

Plate 6.19 – Ngaromanki River: Trib B-1, Type 1 Habitat

Source: Appendix 7.

Plate 6.20 – Rumu River US: Rumu-1, Type 2 Habitat

Source: Appendix 7.

Plate 6.21 – Rumu River DS: Rumu-2, Type 2 Habitat

Source: Appendix 7.

Plate 6.22 – Klin Wara US: Trib F-1, Type 3 Habitat

Source: Appendix 7.

Plate 6.23 – Klin Wara Mid: Trib G-1-WQ, Type 3 Habitat

Source: Appendix 7.

Plate 6.24 – Klin Wara DS: Trib F-2, Type 3 Habitat

Source: Appendix 7.

Plate 6.25 – Maralumi River: Trib C-2, Type 3 Habitat

Source: Appendix 7.

Plate 6.26 – Markham River DS: Mark-2, Type 4 Habitat

Source: Appendix 7.

Plate 6.27 – Markham River US: Mark-1, Type 4 Habitat

Source: Appendix 7.

Table 6.15 – Sites Classified into Habitat Types

Site Code	Site Name	Habitat Type
Mark-1	Markham River DS	4
Mark-2	Markham River US	4
Rumu-1	Rumu River US	2
Rumu-2	Rumu River DS	2
Trib B-1#	Ngaromanki River	1
Trib A-1	Unnamed	1
Trib C-1*	Unnamed	1
Trib C-2	Maralumi River DS	3
Trib E-2	Wawim River US	1
Trib F-1	Klin Wara US	3
Trib F-2	Klin Wara DS	3
Trib G-1-WQ	Klin Wara Mid	3
Leron-4*	Leron River	1

* Watercourse completely dry at the time of sampling.
# Watercourse had running water at the sampling location, but villagers reported that the flow terminated a short distance downstream of the sampling site.

Habitat Comparisons

Macroinvertebrate taxa richness was approximately 40% higher in the clearwater tributaries of Klin Wara and Maralumi River (Habitat Type 3). PET richness (which refers to the number of families in a sample belonging to one of the three particularly sensitive orders of aquatic insects: Plecoptera (stoneflies), Ephemeroptera (mayflies) and Trichoptera (caddisflies)) also differed significantly among habitats, with PET richness in clearwater streams being significantly higher than that in other watercourses. Mean total abundance of macroinvertebrates showed the same pattern, with significantly higher abundance in clearwater streams compared to the other watercourses.

No significant differences in Shannon-Wiener diversity among habitats were evident, which takes into account both species richness and abundance. High abundances can reduce overall calculated diversity and, in this case, the high abundance in clearwater habitats is down-weighting the diversity index. There were no significant differences in weighted SIGNAL 2 scores (a scoring system for macroinvertebrates) among habitats.

Fish and Macrocrustacean Communities of the Project Area

Species Richness

Nine native and seven introduced or translocated fish species, and one native macrocrustacean species, were recorded during the survey (Table 6.16) (Plate 6.28). Raw data and photographic records of recorded species are presented in Appendix 7.

Plate 6.28 – Observed Villager Catches at Maralumi River (Trib C-2) (Left) and in the Markham River (Mark-1) (Right)

Source: Appendix 7.

Fish species recorded from the Project area are characteristic of lowland rivers and tributaries in northern Papua New Guinea. Fish species richness (16 species total) in the Project area is within the range of that recorded from previous surveys in the Lower Watut and Markham rivers (11 to 21 species). More extensive surveys in the Project area and sampling in other flow conditions may record additional species. However, the generally reduced diversity of in-stream and off-river habitats and the turbid and semi-ephemeral nature of streams in the Project area are expected to limit fish species diversity compared to that in the larger and more diverse Watut River system.

Table 6.16 – Fish and Macrocrustacean Species Sampled and Observed in the Project Area

Species Name	Common Name	Sampled by Electrofishing	Sampled by Gill Net	Sampled by Kick Net	Observed Villager catch
Native Fishes					
Anguilla bicolor pacifica	Short-finned eel	X			
Awaous melanocephalus	Largesnout goby	X			
Chilatherina bulolo	Bulolo rainbowfish	X			
Chilatheria crassispinosa	Silver rainbowfish	X			
Glossamia gjellerupi	Mouth almighty	X	X		

Table 6.16 – Fish and Macrocrustacean Species Sampled and Observed in the Project Area (cont'd)

Species Name	Common Name	Sampled by Electrofishing	Sampled by Gill Net	Sampled by Kick Net	Observed Villager Catch
Native Fishes (cont'd)					
Hephaestus transmontanus	Sepik grunter	X			
Kuhlia marginata	Spotted flagtail				X
Melanotaenia affinis	North New Guinea rainbowfish	X			X
Valamugil buchanani	Bluetail mullet	X	X		
Introduced/Translocated Fishes					
Clarius batrachus	Walking catfish	X			X
Cyprinus carpio	Common carp				X
Gambusia affinis	Mosquitofish	X			
Oreochromis mossambica	Tilapia	X	X		X
Tor putitora	Golden mahseer	X	X		X
Xiphophorus helleri	Swordtail	X			
Macrocrustacea					
Caridina sp. 1	Atyid prawn			X	
Macrobrachium australe	Freshwater prawn	X		X	
Palaemon sp. 1	Freshwater prawn			X	
Palaemonidae sp. 1	Freshwater prawn			X	
Palaemonidae sp. 2	Freshwater prawn			X	

Compared with fish species richness reported from the Lower Watut River and other areas of the Markham River catchment, the Project area showed:

- Reduced diversity of mullet species (family *Mullidae*) and other large-bodied marine/ estuarine migratory species (e.g., *Johnius amblycephalus, Nibea* sp. and *Mesopristis cancellatus*).
- Reduced diversity of rainbowfishes (family *Melanotaenidae*).
- Reduced diversity of goby species (family *Gobiidae*).
- Absence of *Mogurnda* species (family *Eleotridae*).
- Absence of fork-tailed catfishes (family *Ariidae*) and native eel-tailed catfishes (family *Plotosidae*).

It is possible that further sampling effort may lead to additional species being recorded from the Project area, or that the differences between these results and those from other studies in the region may be seasonal. However, some of these differences are likely to be related to three key environmental drivers in the Project area:

- Reduced diversity of suitable habitat and ephemeral status of some streams.
- Water quality (specifically, total suspended sediment concentrations and sedimentation regimes) in some streams (and this is particularly relevant for species that are clearwater species such as *Mogurnda* species and benthic species such as gobies).
- The potential adverse effects of an increasing dominance of exotic species.

Analysis of standardised electrofishing catches shows that species richness was highest in clearwater tributaries (Klin Wara and Maralumi River) (Figure 6.20). These rivers were also the watercourses with the greatest diversity in aquatic habitats. It should be noted that electrofishing results from the Markham River are not considered representative of the full species diversity of that river.

Introduced fish species dominated the total electrofished catch at Klin Wara US, Rumu River US and DS and at Wawim River US (Figure 6.21). The catch from gill net catches was dominated by introduced species at both sites sampled using this method (Figure 6.22). While not weighed in the field, opportunistic observations of villager catches from gill netting (Markham River tributary confluence) and poisoning (Maralumi River) (see Table 6.16) revealed a dominance of introduced species.

Macroinvertebrate Communities of the Project Area

Species Richness and Abundance

A total of 59 macroinvertebrate taxa were identified from 11 sites and 3 habitats. This is higher than total taxa richness recorded in previous surveys in the Lower Watut River catchment (maximum of 48 taxa). The table of macroinvertebrate taxa and raw data are presented in Appendix 7 of this report.

The site Markham River US yielded the highest number of taxa (30), consisting predominantly of two mayfly taxa Caenidae and Baetidae. Klin Wara DS (28) and Ngaromangki River (28) yielded slightly fewer taxa, though Klin Wara DS contained considerably more individuals (3,778). Markham River DS yielded the lowest number of taxa (9) and individuals (31), dominated by a single mayfly taxa Baetidae. The site Maralumi River DS yielded the highest number of individuals (7,065).

Macroinvertebrate taxa diversity recorded in the Project area is within the range recorded from previous surveys within the Lower Watut River. However, taxa richness per site (maximum of 30 taxa) in the Project area is higher than that recorded in the Lower Watut River and tributaries (maximum of 320 taxa).

FISH AND MACROCRUSTACEAN SPECIES RICHNESS FROM ELECTROFISHING CATCHES

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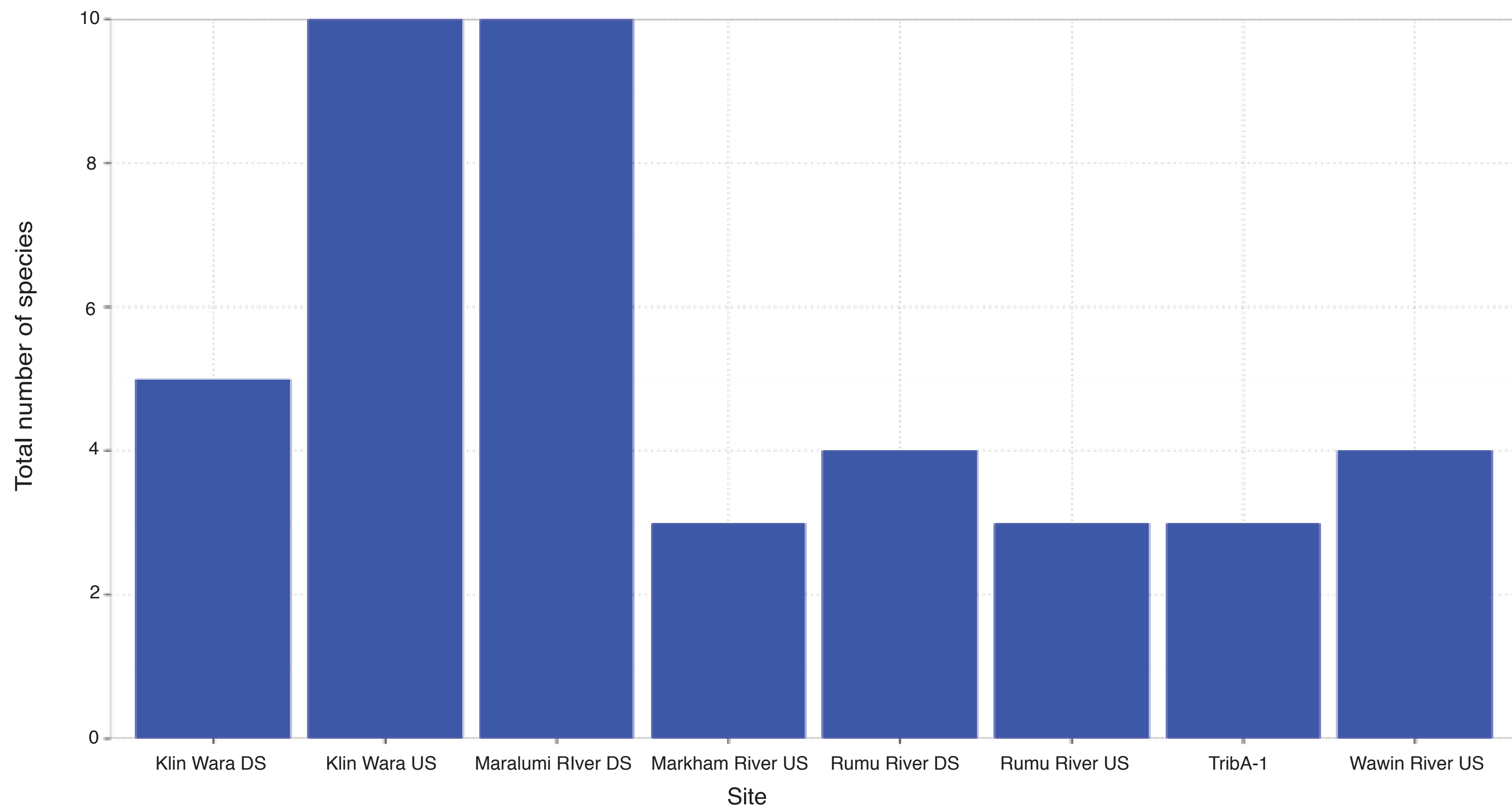
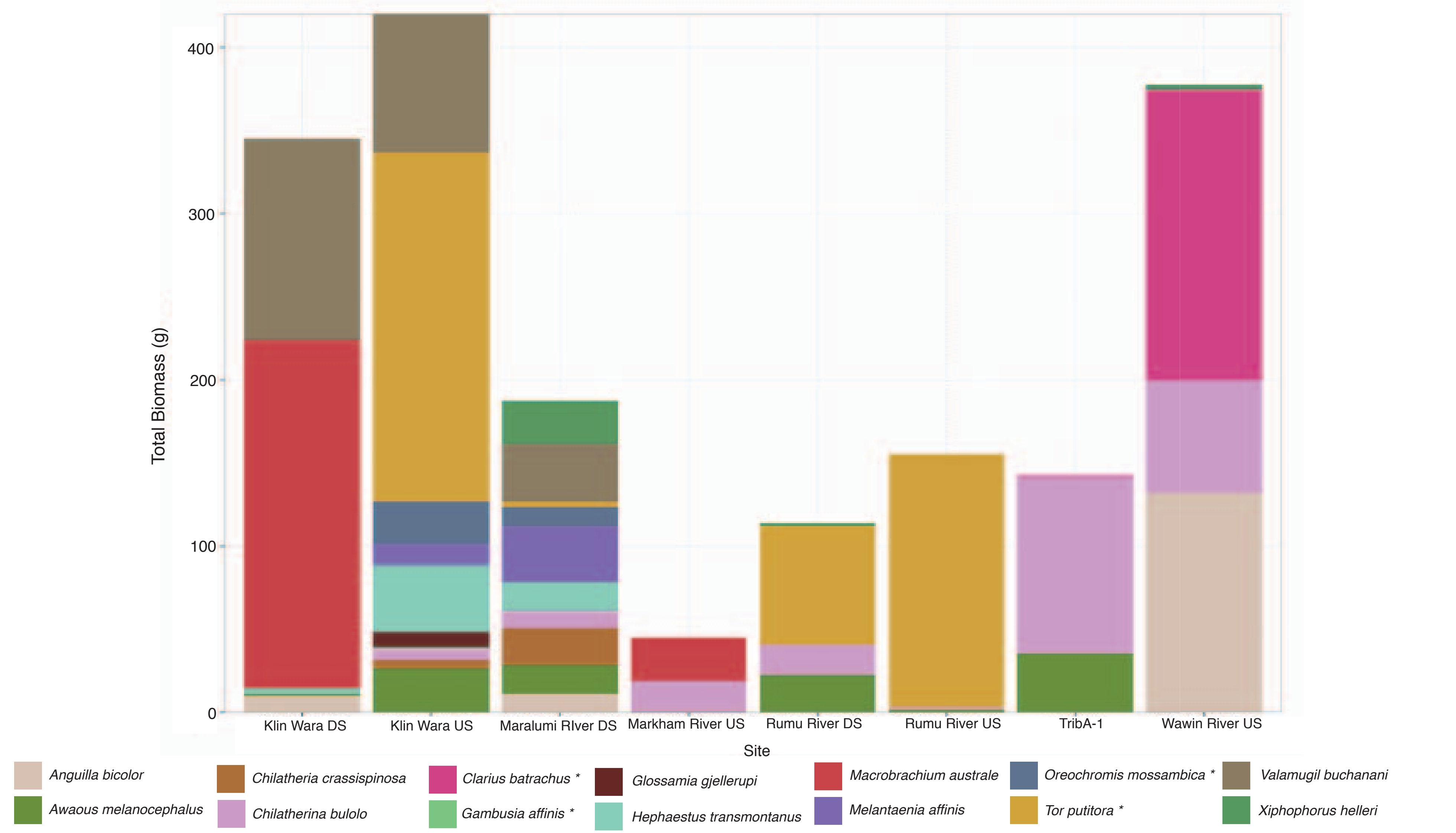
FIGURE 6.20



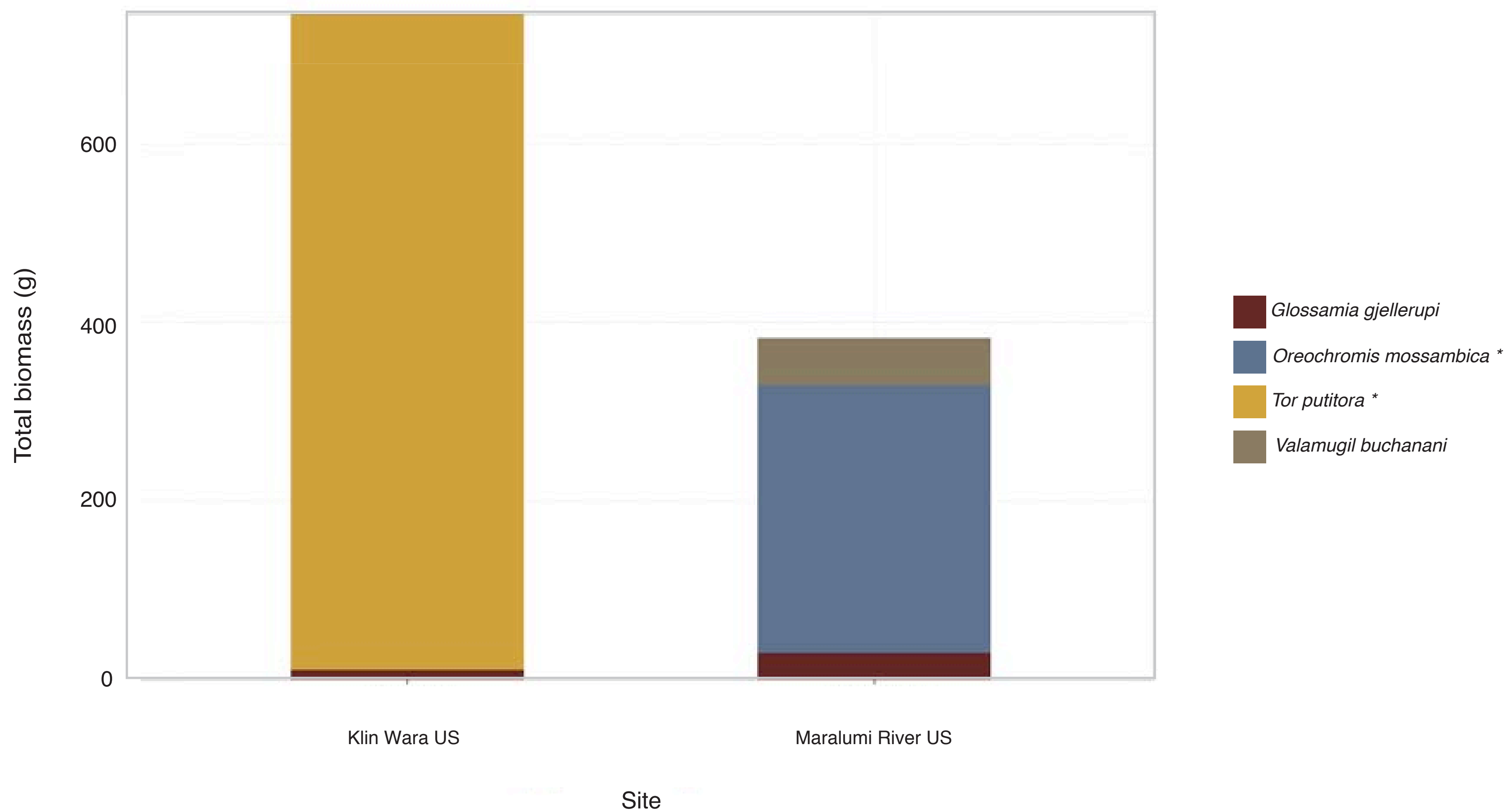
Source: Appendix 7.

FIGURE 6.21



Source: Appendix 7. *exotic species (migration/introduction).

FIGURE 6.22



Source: Appendix 7. *exotic species (migration/introduction).

Other historical surveys undertaken within the wider Markham River catchment for the Hidden Valley Mine recorded considerably lower macroinvertebrate richness. However, these surveys have only occurred in the Upper Watut catchment, which is at a higher altitude and not considered analogous to the watercourses sampled in the Project area. Lower species richness recorded in the Upper Watut catchment has also been attributed to the impacts from Hidden Valley Mine.

Aquatic Flora of the Project Area

No aquatic flora was observed at sites sampled in the Project area.

Aquatic Reptiles of the Project Area

No aquatic reptiles were recorded at sites sampled in the Project area and sampling methods did not target this fauna. Anecdotal evidence concerning the likely presence of crocodiles and highly unlikely presence of the New Guinea snapping turtle (*Elseya novaeguineae*) is discussed in Section 6.2.2.1.

Species of Conservation Significance

Three confirmed fish species that are listed in the IUCN Red List were recorded in the survey:

- Golden mahseer, *Tor putitora*. As noted previously, the status of this species is endangered in its natural range but the conservation status is not deemed to apply to populations of this species in Papua New Guinea. Development projects in Papua New Guinea are not required to make assessments as if this was a native endangered species.
- Bulolo rainbowfish, *Chilatherina bulolo*. The status of this species is data deficient. The species was originally described from collections made in the Erap River and was once considered to have a potentially restricted distribution. However, the species has since been recorded from multiple areas in the Ramu-Markham River system and is now known to be widespread. This species is considered one of the native species in streams of the Project area that is potentially under threat from the impacts of exotic species. While its formal conservation status is in need of updating, the threat of exotic species impinging on local populations suggests that this is a species of informal conservation significance at the scale of the Project area (although the threats of exotic species to this and other native species are beyond the control of the Project).
- The walking catfish, *Clarias batrachus*. This species is in the 'of least concern' category of the IUCN Red List. The fish has a wide native range across Asia and appears to have entered Papua New Guinea from Indonesia either by natural migration or via intentional translocation. The Red List categorisation does not apply to populations in Papua New Guinea and the adverse ecological effects of this species to native populations is unquantified. Its presence in the Project area signifies a rapid colonisation of the northern part of the country since its first recording in Western Province in 1995, if, indeed its expansion across that range has been natural. However, studies indicate that intentional introductions for aquaculture purposes may have contributed to this range expansion.

While unconfirmed, two reptile species of conservation significance potentially occur in the Project area:

- The New Guinea snapping turtle (*Elseya novaeguineae*) has been recorded from off-river water bodies in the Markham River catchment (P. Lloyd, Biodiversity Assessment and Management Pty Ltd, pers. comm.). This species is listed in the lower risk/least concern category of the IUCN Red List.
- The New Guinea crocodile (*Crocodylus novaeguineae*) is listed in the lower risk/least concern category of the IUCN Red List. As noted previously, this species may occur in the Markham River in the vicinity of the Project area.

No freshwater species are listed as 'protected' in the national *Fauna (Protection and Control) Act 1976*. This list requires revision but currently includes only brown trout and rainbow trout (both introduced species).

Sensitive Areas

Clearwater streams in the Project area had a higher diversity of aquatic fauna and are likely to be refugia for species that are intolerant of high sediment loads that may occur in other watercourses. Klin Wara and Maralumi River are therefore considered sensitive areas at the scale of the Project area due the following attributes:

- They are the only permanent clearwater streams in the Project area with diverse habitats.
- There is limited representation of these watercourse types in the Project area and in this mid-reach region of the Markham River more generally.
- They appear to support a range of ecosystem services.
- They are characterised by relatively high biodiversity, and have a predominance of taxa that are adapted to clearwater conditions.
- They appear to have a relationship with flat, lowland receiving areas that play a role in flood mitigation.

These watercourses appear to have their origins in broad flat areas that receive inflows from several streams draining the mountainous region to the north. At the scale of the Project area, these 'lowland flats/receiving areas' are considered sensitive. They are understood to be dry most of the time and do not form permanent swamps, but may have standing water temporarily during periods of high rainfall when they may attract aquatic and terrestrial species that use aquatic habitats (e.g., frogs, birds, turtles). The physicochemical properties of Maralumi River downstream of the receiving areas may be indicative of soil water or groundwater contributions.

The stand of intact secondary forest vegetation at the headwaters of Klin Wara appears to represent a habitat type that is not represented elsewhere in the Project area. This habitat may play a role in the buffering of inflows to Klin Wara and contribute to processes that interact with the receiving areas to maintain clearwater conditions. This vegetation stand is therefore also considered to be a sensitive area at the scale of the Project area.

6.2.2.3 Existing Stressors

Based on the information presented above, the four most significant existing stressors in the Project area in relation to aquatic ecosystems are considered to be:

- Ecological impacts of introduced exotic and translocated fish species.
- Potential water and sediment quality impacts associated with current and historical agricultural practice.
- Streambed and water quality impacts associated with aggregate extraction in river channels.
- Potential degradation of riparian habitat due to vegetation removal associated with existing and historical agriculture, settlements or other construction activities (and this is particularly relevant along the Highlands Highway).

6.3 Socio-economic Environment

This section describes the Project's existing socio-economic environment and has been based on SIMP (2017) and the references cited therein.

6.3.1 Introduction

6.3.1.1 Project Impact Area and Study Area

Identification of all individual landowners and communities who will eventually participate in the Project is still to be completed at this stage of Project development, as are full details of how cropshare and land rentals will be distributed. While the encompassing area will be the Markham Valley, the plantations are likely to evolve in a patchwork pattern across the region rather than a continuous landscape belt. The study area from a socio-economic perspective is therefore defined as the land within the designated Area A (Figure 6.23) that lies to the east of, and excludes, the areas within Markham District (i.e., it is focused only on the area within the Wampar Local-level Government (LLG) area, Huon Gulf District). Area A:

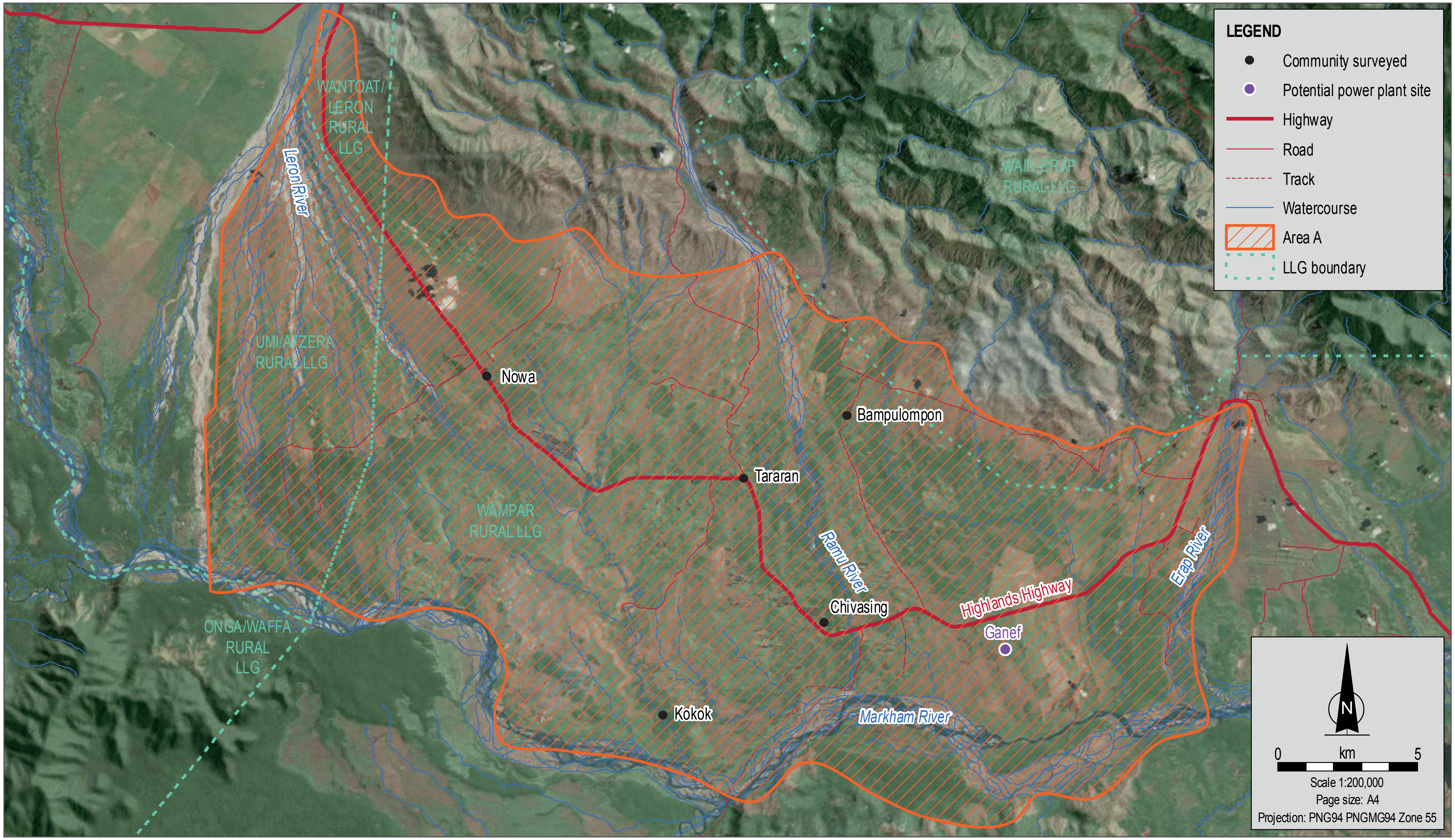
- Represents an area of interest within which the Project has and will concentrate its negotiation and stakeholder liaison efforts; it is represented by those communities (within Huon Gulf District) that opted for trial plantations, have existing MOU agreements, and have received ongoing stakeholder engagement.
- Is inclusive of five communities that are indicative of where the major Project social impacts are likely to be felt in the short-to-medium term, and representative of communities in the broader region.
- Encompasses both the IFC ‘area of influence’ and the World Resources Institute’s (WRI) ‘ecosystem services project area’.

STUDY AREA COMMUNITIES

PNG Biomass Markham Valley I Environmental Assessment Report

FIGURE 6.23

PNG BIOMASS Oil Search ERIAS GROUP



Source: SIMP, 2017.

ERIAS Group I 01183B_2_F6-23_v1

6.3.1.2 Study Tools and Methods

The following tools and methods were used to establish the social impact assessment (SIA) baseline:

- Review of available published social scientific literature, and secondary and primary data from and about the affected area.
- Review of early historical writings and previous archaeological documents and consultation with previous researchers in the region to create a site predictive model for the study area.
- Inspection and collation of sectoral data from:
  - The PNG National Museum and Art Gallery (NMAG) site register.
  - PNG agencies such as the Department of Education, Health, and Lands.
  - NGOs and mining developers (e.g., Wafi-Golpu Joint Venture) in Morobe Province.
- Review of relevant legislative regimes.
- Consultation and peer review by other researchers associated with the region.
- Field investigations that included:
  - Household, village, health, ecosystems, cultural heritage, water source, infrastructure and gender survey questionnaires (incorporating both quantitative and qualitative questions) throughout the study area.
  - Cultural heritage site and ground surveys to determine GPS centroids of cultural heritage sites and, where possible, site extent polygons delimiting site[4] areas.
  - Surveys of land and gardens areas, and fresh food prices in three key fresh food markets (Lae, 40 and 41 Mile markets).
  - Surveys of health authorities and infrastructure (e.g., health centres and aid posts).
  - Informant interviews (structured/unstructured, and random individual/focussed selective group) concerning significant sites, prioritising areas for clearance survey and general socio-cultural conditions and issues.

6.3.2 Administrative Setting

The Markham Valley, within which the Project is located, runs through the centre of Morobe Province, which is headquartered in Lae and occupies an area of 33,525 km^2. The province is one of the three most populated provinces in Papua New Guinea and contains almost 9.3% of the country's total population (674,810 persons in the 2011 census). The 2011 census results also

[4] 'Site' is defined as a discrete archaeological site where an object ('artefact'), feature or set of artefacts/features were separated by ≥15 m of culturally sterile ground from its nearest neighbouring archaeological site. Sites were recorded on standard site survey forms approved by NMAG and registered in the National Site File of cultural heritage sites along with site photography. No excavation or artefact collection was conducted; surface examination only was completed.

show that the province has a male to female ratio of 108:100 and 130,109 households with an average household size of 5.2 persons. It has 9 districts, 33 local-level government councils, 547 wards, and 827 census units. Those relevant to the study area are Chivasing, Tararan and Nowa wards in the Wampar Rural LLG, Huon Gulf District. Huon Gulf, which is the largest district in Morobe Province with an area of 7,401 km^2, is headquartered within Salamaua Rural LLG.

6.3.3 Socio-cultural Setting

6.3.3.1 Community Demographics

The study area is inclusive of five communities (see Figure 6.23): Chivasing, Tararan, Bampu (also known as Bampulompon), Kokok and Nowa (also known as Noa). Tararan and Chivasing are the largest communities in Area A, while Kokok and Bampu represent small satellite hamlets respectively of these two villages. Nowa is an outlier community composed of an immigrant enclave. Table 6.17 provides the 2011 census population data for these communities.

The male to female ratio for households in the study area is reasonably balanced at 52.3:47.7, which closely approximates the provincial average of 51.9:48.1. Household size is 5.6 persons per house, which compares well with the World Bank Group-reported figure of 6 persons per house, and the Wampar Rural LLG-reported figure of 4.6 persons per house (NSO, 2011). Figure 6.24 shows the population pyramid from the household composition survey.

Table 6.17 – Village Demography

Study Area Village	2011 Census	
	Population	Households
Chivasing	614	134
Tararan	548	124
Bampu (Bampulompon)	NA*	NA*
Kokok	303	53
Nowa (Noa)	479	102
Estimated totals	2059	426

* Statistics not available; Bampu figures were included under the Hangamap census and cannot be disaggregated.

A very low absentee rate (less than 5%) was recorded during the surveys, which is quite different to the higher rates of between 12 to 20% found in PNG highland societies. The proximity to Lae and job opportunities is expected to be a major explanatory factor.

6.3.3.2 Ethnic Groups and Linguistics

Two major ethnic groups are relevant to the Project:

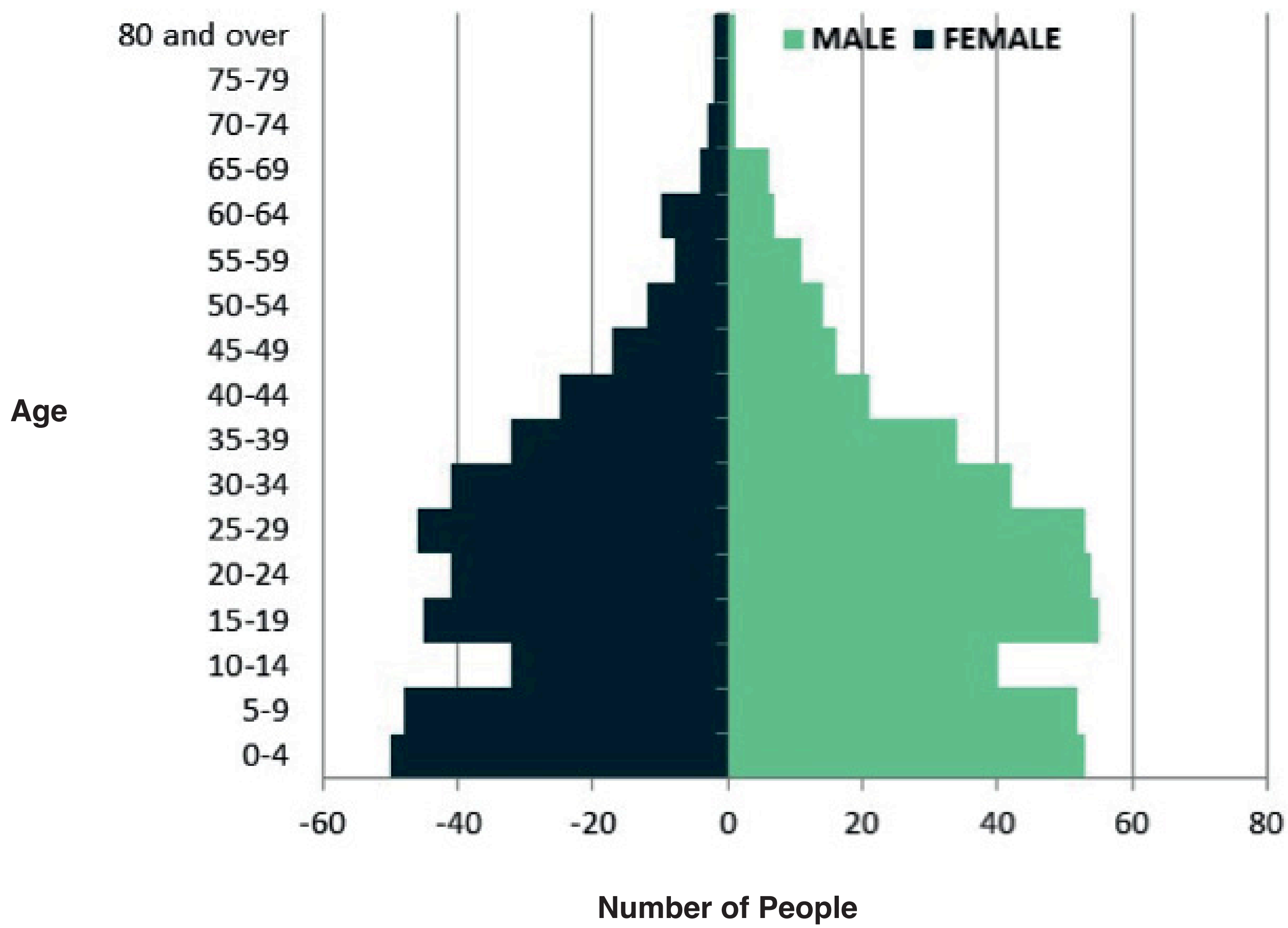
1. The Wampar (12,000 to 15,000) who occupy Area A and the study area.
2. The Adzera (30,000) who reside west of the Leron River in Area B (which is not part of this assessment).

These two groups, whose general locales are shown in Figure 6.25, constitute one culture area due to their cultural commonalities and long history of inter-ethnic trade, warfare and marriage.

STUDY AREA HOUSEHOLD POPULATION PYRAMID

PNG Biomass Markham Valley I Environmental Assessment Report

FIGURE 6.24

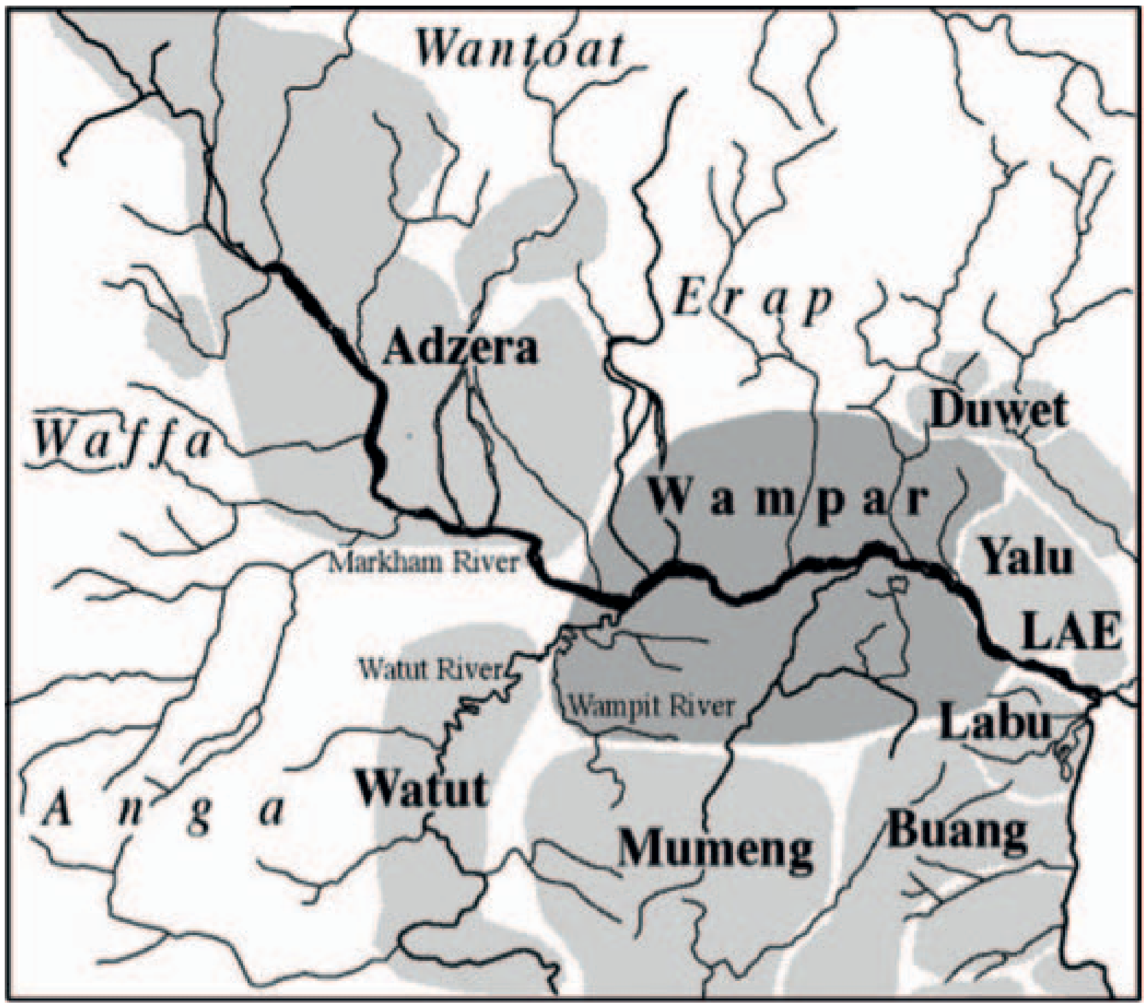


Source: SIMP, 2017.

WAMPAR AND ADZERA ETHNIC GROUP LOCATION

PNG Biomass Markham Valley I Environmental Assessment Report

FIGURE 6.25



Source: SIMP, 2017.

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The Rumu River (see Figure 6.23) has been previously noted as a 'natural border' between Wampar and Adzera; however, other literature sources, along with the cultural heritage interviews undertaken as part of the SIA, delineate the ethnic/language boundary between these two groups as further to the west and corresponding with the Leron River (i.e., the Leron River bridge of the Highlands Highway). This is supported by the identification of a number of Wampar cultural heritage sites west of the Rumu River, extending towards (but not beyond) the Leron River. Cultural heritage sites are discussed in Section 6.3.8. As the Adzera ethnic group reside outside the study area, they are not discussed further in this report.

The Wampar, often previously referred to as *Laewomba* or *Lahewomba*, self-reference as *Ngaing Wampar* ('Wampar people'), and their language as *Dzob Wampar* ('Wampar talk').

The Wampar ancestors originally occupied the lower Watut valley. Through warfare, the people of the lower Watut and lower Markham valleys, e.g., Nga Wari, Aribwaungg, Aribwatsa, Labu and Bukawa, were displaced. The Wampar language was still understood in the north Watut area by older men until quite recently. Genealogical evidence indicates that the movement into the Markham Valley occurred some 230 years ago and was still in progress at the time of first European contact in late 1890–1900s. Although very little is known of the prehistory of the Markham and Watut regions, archaeological sites on Huon Peninsula dated to 40,000 years before present indicates human settlement in these areas around that time. Early non-forest pollen taxa records suggest human firing and early agriculture.

The Wampar language falls under the Lower Markham subgroup and its relationship to other language groups is shown in Figure 6.26. Wampar-speakers, south of the Markham River speak a different dialect to those living north of the river (including those within the study area); they also identify as constituting a different sub-group of Wampar – the Wampar *Saab* (*saab* means 'flying-fox' in Wampar) – and refer to other Wampar to the north of the river as Wampar *Fofon*.

Additional languages spoken in the study area are Watut, Safeyoka (a Menyamya language), Adzera and Tok Pisin.

6.3.3.3 Social Organisation

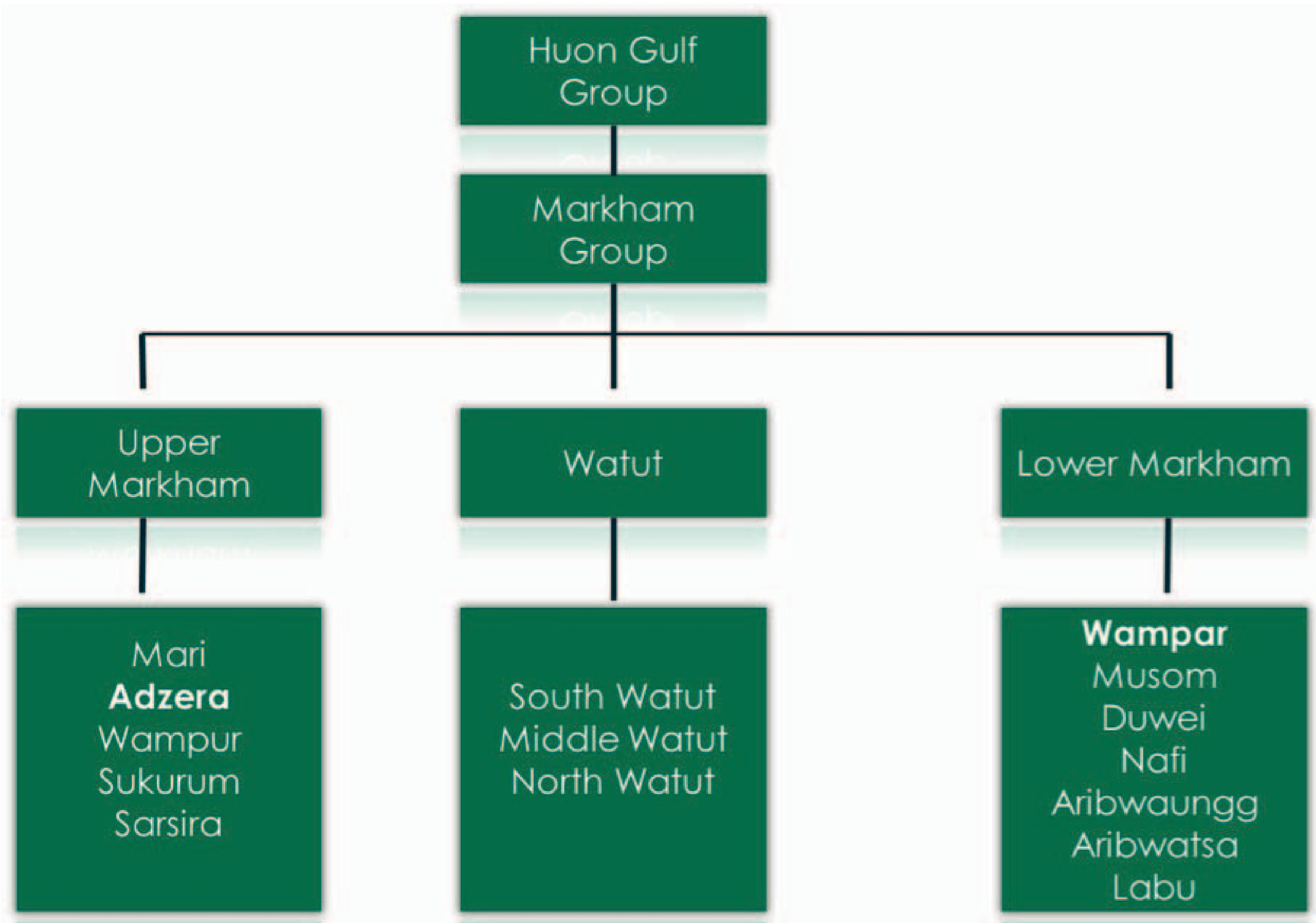
Wampar social organisation is based around membership of clan (*sagaseg*) and patrilineal[5] lineage groupings. The nine clans associated with the Wampar are: Feref, Muswarang, Oroganzon, Orogwangin, Owangrompon, Chuaif, Zeaganzon, Orogazog and Montar.

Each Wampar village has a multi-clan composition. Previously, these groups were physically demarcated within the settlement but today clans-people are intermixed residentially. Allied villages in the past would cooperate for fighting, exchange, ceremony and annual kunai burning.

[5] Relationships are traced through the father of a family.

LANGUAGE CLASSIFICATION OF WAMPAR AND ADZERA

FIGURE 6.26



Source: SIMP, 2017.

6.3.3.4 Marriage and Land Rights

Sister-exchange was previously the preferred marriage form for the Wampar within a village cluster, since these created alliances and sequential marriages between the groupings. Residence was patrivirilocal[6] and there were prevailing affinal name avoidances and other taboos.

Early inter-ethnic marriage was largely between Wampar and Adzera but from the 1960s onwards, men from more distant coastal and lowland areas were increasingly marrying in, while after the 1980s Wampar men were taking wives from other provinces.

The marital profile for the study area shows that just over 50% of people had never married, with just over 40% being currently married. The remainder of respondents were divorced, separated or widowed. This is comparable with data for PNG LNG Project greenfield communities[7] located in Port Moresby.

According to Wampar tradition, the first small group of men to cross the Markham River from the south (upper Watut) 'put' their names on stretches of grassland and bush areas. People who migrated later laid claim to such areas from these original namings and claims. Ownership of rights to particular areas of land and bush is vested in the descendants of the ancestor who was believed to have 'named' these areas. In the past, land could also be won through warfare.

Patrilineal lineage remains the main form of land inheritance. Male children normally inherit the rights to their father's land (including certain areas of grassland, bushland and forest), whereas daughters inherit land rights only if they have no brothers, stay unmarried, or their lineage is rich in land and they are married to landless Wampar or non-Wampar. In contrast, trees such as coconut palms are owned individually by those who planted them, regardless of whether they are on the planter's own land or not. In addition, land can never be permanently alienated from the clan group and decisions to lease still require group consent.

6.3.3.5 Leadership

There are multiple leadership roles in Wampar society based loosely on the 'big man' (i.e., achieved not ascribed) archetype found across Papua New Guinea. Since missionary contact and colonial administration in the early 1900s, the church appointed and trained people as church elders, pastors and teachers. In the 1960s, the early administrations also appointed village leaders such as *tutuls*, and *luluais*. Following independence in 1975, new leadership types were also introduced such as village court officials, and youth and women's leaders. Government personnel located in each of the five main communities in the study area are listed in Table 6.18.

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[6] Referring to the social system in which a married couple resides with or near the husband's parents.
[7] Greenfield' areas, in terms of the PNG LNG Project, were areas added to the project that had not been subject to previous petroleum development and included Juha and the Port Moresby villages of the Koita/Motu (Porebada, LeaLea, Boera and Papa).

Table 6.18 – Village Service Personnel in the Study Area

Personnel	Bampu	Chivasing	Kokok	Nowa	Tararan
Aid post orderly	No	Yes	No	No	No
Village birth attendant	Yes	Yes	No	No	Yes
Councillor	Yes	Yes	Yes	Yes	Yes
Village court magistrate	Yes	Yes	No	Yes	Yes
Land mediator	Yes	No	No	No	Yes
Village development coordinator	Yes	No	No	No	No
Ward development committee	Yes	No	No	No	Yes

6.3.3.6 Religion

As a result of over a century's exposure to mission activity, many of the Wampar are converts to various denominations, including Seventh Day Adventists (SDA), the Assemblies of God (AOG), the Lutheran Renewal and PNG Revival churches. Fifty-five per cent of interviewed households stated that they were members of a variety of religious denominations and the churches are well attended, particularly for up to three hours on Sundays. The churches provide predominantly spiritual rather than material assistance.

Despite this, traditional belief in malicious spirits and agencies (*masalai*) persist, with masalai believed to inhabit rivers, rocks and big trees. Further, traditional beliefs about sorcery and angry ancestral spirits as the source of sickness and death have not been completely erased, despite the advent of modern medical science. Further information related to cultural beliefs is presented in Section 6.3.8.

6.3.3.7 Organisational Affiliations

Twenty per cent of households interviewed belong to a women's group and 18% belong to 'other' groups such as youth groups. The churches run many of these groups.

A women's group operates as a mother's group that prays for those who are sick. Youth groups offer an occasional camp and organise community work for youngsters, but no organised sports or games – with these being offered by the school, where young people play rugby, basketball, soccer, volleyball, netball and tennis on an open grass space.

Membership to the three main types of 'landowner' entities – incorporated land groups (ILGs)[8], landowner companies (Lancos)[9] and landowner associations[10] – remains at very low levels (9.3, 7.4 and 5.6%, respectively) primarily because without a project catalyst there is little incentive to form such organisations.

[8] An ILG is a legally registered corporation for the management of land resources and distribution of cropshares and land rentals.
[9] Lancos are representative companies established in order to participate in commercial business opportunities associated with a particular development.
[10] Landowner associations are incorporated under the *Associations Incorporation Act 1966* to collectively represent landowners that may also have ILGs and are empowered to manage the use of land resources, mirroring traditional landownership clan and sub-clan structures; they represent landowners in negotiations that may affect their social and economic welfare.

6.3.3.8 House Construction, Utilities and Assets

Survey results show that more than 79% of houses constructed in the study area used traditional materials (Plate 6.29), while 14% were of semi-permanent materials and 6% were constructed from permanent materials. These levels reflect, in part, a measure of affordability rather than access to materials, but also in part 'choice/preference' given the extreme heat and dislike of metal roofs that increase temperatures inside the house.

More than 95% of households had metal cooking pots, blankets and mosquito nets, but ownership of radios, kerosene lamps and stoves averaged below 30%. Most people (94%) cooked with firewood and almost always outside the house; only 2% used electricity for cooking. The reliance rates for lighting were solar (40%), battery (27%), electricity (16%) and firewood (13%).

Plate 6.29 – Example of Village Housing in Chivasing (Left) and Tararan (Right)

Source: SIMP, 2017.

6.3.3.9 Economic Activity, Income and Expenditure

Economic activity in Morobe Province is dominated by a few key sectors. Early alluvial gold mining began in the 1920s and, more recently, the Hidden Valley Mine has had a significant effect on the provincial (and national) economy with its gold and silver mining (and this is expected to continue into the future). In addition, the Wafi-Golpu Project, once developed, will be one of the largest gold and copper mines in the world. In addition to these and other current and proposed mining projects, medium and small-scale artisanal gold miners (both registered and unregistered) are important in the regional and national economies.

Forestry is also significant for the economies of both Morobe Province and Papua New Guinea. The forestry sector provides significant employment in businesses that include round-log forestry operations and local wood processing operations involved in saw milling and furniture making.

Morobe Province is currently Papua New Guinea's most important beef-growing region, and most cattle in the province now belong to either Trukai Industries or Ramu Agri Industries. Rumion Limited operates Papua New Guinea's largest piggery, with 15,000 pigs, and 5,000 beef cattle in the Markham Valley. The two main chicken producers in Morobe Province are Niugini Tablebirds and Zenag Chicken; Niugini Tablebirds supplies 65% of Papua New Guinea's fresh and frozen chicken, and contracts 135 smallholders in the Wampar LLG to grow about 800,000 chickens each year.

Agricultural crops are also an important contributor to the economy in Morobe Province and Papua New Guinea. These include a significant domestic trade in coconuts in Lae and in the inter-provincial markets in the Highlands, cocoa production, coffee and betel nut. Other key contributors to the provincial economy include:

- The world largest saltwater crocodile farm, operated by Mainland Holdings in the Huon Gulf District, which houses approximately 40,000 crocodiles.
- Offshore fisheries, including tuna and mackerel, with Lae expected to become the South Pacific's largest fish processing centre.

Having established the broader provincial context above, the results of the field investigations and other tools described in Section 6.3.1.2 provide Project-specific information concerning economic activity. These results indicate that wide variation in income levels occurs across study area households. Respondent data indicated that sale of agricultural products and trade store ownership were the main sources of income (26% and 11%, respectively). Forty one per cent of respondents reported they also received income from relatives or friends receiving a wage, and 25% of these said on average they received money one day per month.

Cash income levels in the study area are generally high to very high by rural PNG standards, but vary depending on the proximity of communities to the Highlands Highway, the 40 and 41 Mile markets (Plates 6.30 and 6.31, respectively) and other key service centres such as Wawin National High School, and their cultural-linguistic affiliation. Disparities also occur within communities, where these reflect different levels of access to agricultural land, particularly for perennial tree or cash cropping activities.

Figure 6.27 shows the main source of income across households, based on annualisation of the recall of all income sources over the previous fortnight. As shown, only a relatively small percentage of respondents earned an income from employment, while 'business' (e.g., trade stall sales) or sale of various bush or farmed products was a more common source of household income. A primary use of cash income in the area is contribution towards socio-cultural payments such as bride price, compensation and certain funeral or mortuary rite costs. These expenses are generally shared among larger clan or sub-clan groupings and affiliations, and given the reciprocal basis still governing most traditional social relations, the money involved usually circulates within and among communities throughout the broader region.

The expenditure categories households in the study area reported and the average amounts they claim to have expended in a two-week period on these items are shown in Table 6.19. Based solely on this data, average monthly expenditure per household would be approximately PGK794. However, as is the case concerning income, this data is not necessarily a reliable guide to understanding yearly expenditures.

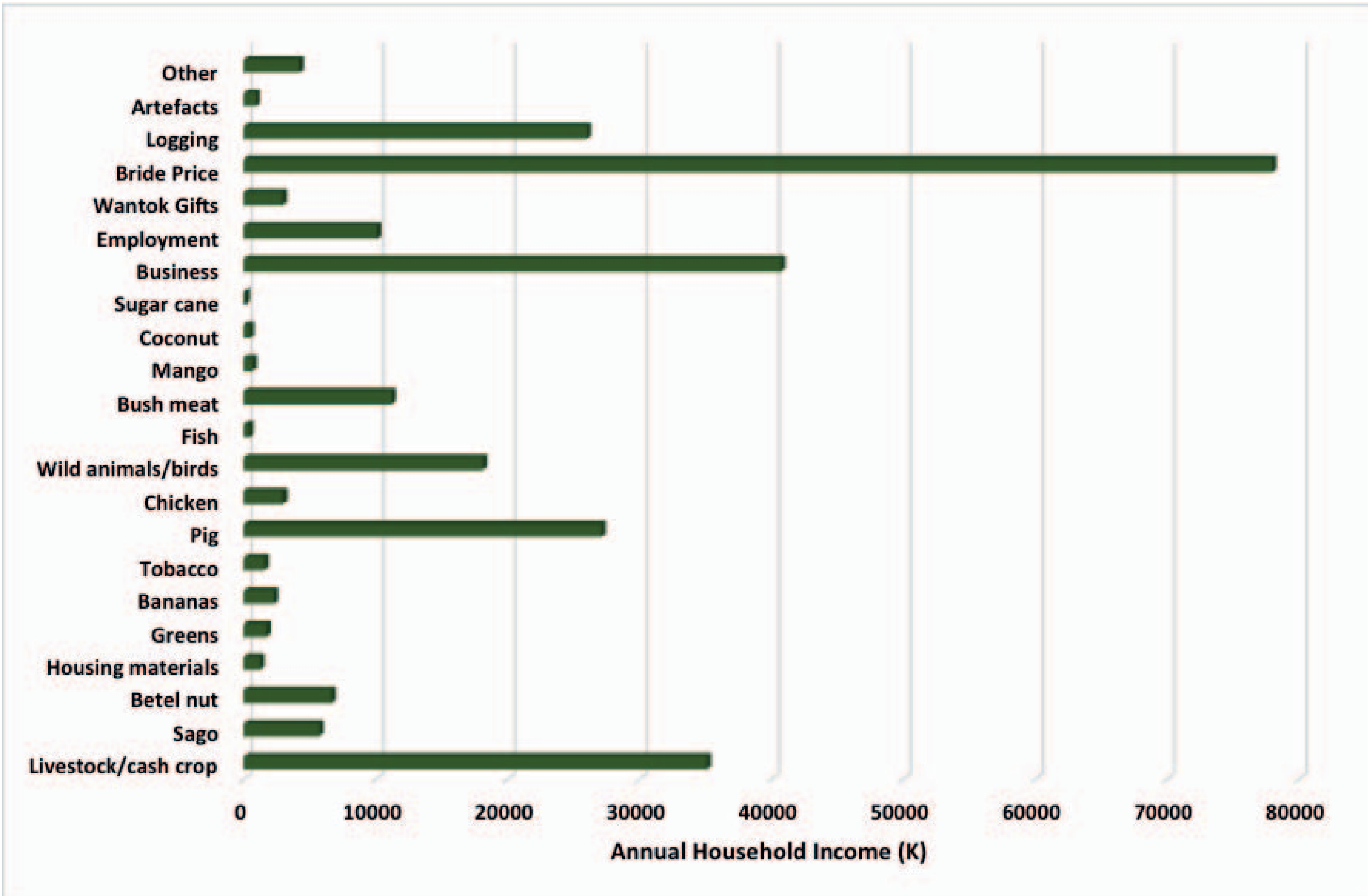
Plate 6.30 – 40 Mile Market

Source: SIMP, 2017.

Plate 6.31 – 41 Mile Market

Source: SIMP, 2017.

FIGURE 6.27



Source: SIMP, 2017.

Table 6.19 – Study Area Household Monthly Expenditure Patterns

Category	% of Households	PGK Average	Category	% of Households	PGK Average
Transport	66.0	46.7	Trade store items	65.3	96.0
Kerosene	16.7	12.6	Market goods	44.7	41.3
Other fuel	6.0	65.5	School fees	21.3	287
Bride price	5.3	499	Medical costs	40.7	54.2
Disputes	5.3	1,926	Church donations	44.0	33.6
Funeral	12.0	303	Fines	3.3	222

Wage labour employment across Morobe Province, when combined for full and part time wage labour, is approximately 12%, with disparities evident between male and females. Employment levels across the study area are below the 2011 provincial average, with less than 10% of either gender being in any paid job of any description. Of those employed, 29% worked for government agencies, 32% for the Project, and over 43% for various commercial enterprises such as Ela Motors and Guard Dog security.

Although men in Morobe Province are more likely to report savings account ownership than women, overall more than 40% of adults living in urban or township areas reported owning a savings account, primarily with EFTPOS and ATM capability. In rural areas, less than 10% of the adult population reported owning an account, whether card based or passbook based. In contrast, in the study area over 44% of individuals have a bank account, which is above the national average for a rural or semi-rural community, and this was split evenly across males and females (44% each). This is most likely due to the fact that Lae is only 30 km away and easily accessible by road.

The study area population is relatively advantaged compared to other more rural enclaves in that the various communities have some access to on-grid electricity and there is increasing use of solar off-grid appliances.

Almost 70% of respondents had travelled to Lae and travel was also recorded to more than nine other provinces, with Madang being the most frequently visited of these destinations. A small percentage of survey respondents had travelled overseas.

While consumer goods are easily available for purchase in Lae, including items such as video players, refrigerators, food goods, cooking utensils, cars and mobile phones, the local communities have a tendency to replace rather than repair such goods when they deteriorate, finances permitting. This trend is likely to continue in the short term. The risk of this consumerism is that people expend money on items that are quickly unserviceable because of lack of knowledge about care and use, and lack of back-up services, which is further fuelled by Papua New Guinea's lack of an adequate maintenance and repair infrastructure.

There seems to be little awareness or anticipation of the problems of consumerism that occur in developed economies of the West, and concepts of thrift, investment for the future, and weekly management of budgets have yet to become widespread.

6.3.3.10 In-migration and Urbanisation

Contemporary in-migration into the Lae area has been ongoing for a century and Morobe Province is above the national average in terms of its net-immigration percentage. In-migration comes from rural areas both within the province and from other provinces, and from people moving to the main urban centres such as Lae for commercial projects in agriculture (coffee, cocoa), livestock, poultry and mining. The construction of the Highlands Highway also had a significant impact on the intensification of rural-urban networks.

During the household surveys, 33% of respondents declared they had moved to their present locales from elsewhere. However, this figure is slightly misleading as many had moved a long time ago to Nowa and Kokok settlements and, once these are discounted, a true rate would be in the region of 15 to 20%. The predominant reason for relocating to the area was marriage (just under 50%), followed by family reasons, visitation and jobs (Figure 6.28).

Over the last five years, some Wampar groups have started to lease or sell plots of land to non-Wampar (*yaner*) people, with most of this land tending to be near the highway. Although highly controversial in Wampar society, this practice has led to an increase to the number of *yaner* living on Wampar land, including families who are not related in any way to Wampar.

The social-structural characteristic in Papua New Guinea that most limits unfettered movement is access to land and hence a subsistence base, since land is controlled by the clan system. The proximity of the study area to the country's second biggest urban hub, Lae, and the longevity of exposure to contact has meant there has always been a degree of influx into the area from surrounding provinces and rural enclaves. In fact, Wampar social networks have been influenced for more than a century by the links the population has had with the occupants of Lae, which has evolved from a trading post and mission staging-point firstly to a colonial town, and now to an industrial city. The entanglement of village and town life has become further intensified by the immediate exchange of information made possible by mobile telephones, which have increased communication and the capacity of separated individuals to maintain 'co-presence' with one another across regions and across the entire country.

It is also worth noting that operation of the Hidden Valley Mine in the headwaters of the Watut River, south of Wampar territory, and the Wafi-Golpu Project, in conjunction with other mineral exploration and mining activities, have intensified rural-urban ties and networks.

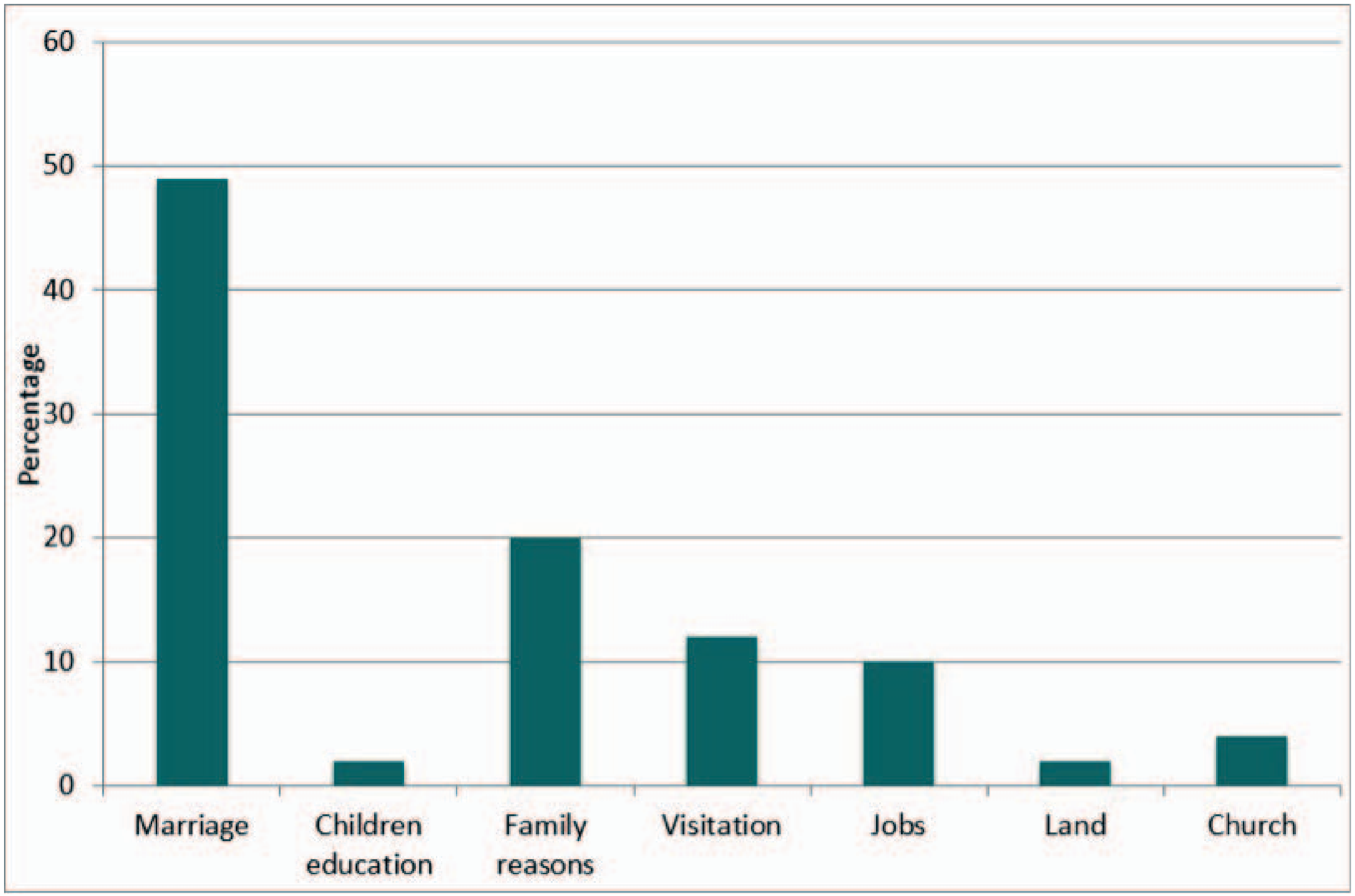
6.3.4 Economic Infrastructure

6.3.4.1 Transport and Traffic

Roads

The study area is north of the confluence of the Markham and Watut rivers, 50 km west-northwest of Lae and within 30 km of Lae Nadzab Airport. The Highlands Highway (Okuk Highway) connects the study area and Lae, and has a network of smaller feeder roads. Lae is the main logistical and distribution centre of Papua New Guinea, and the highway is the nation's busiest road and the dominant arterial route in the region, being used to transport goods and people from Lae to five highland provinces.

FIGURE 6.28



Source: SIMP, 2017.

In May 2014, a Visual Road Condition Survey was conducted across Papua New Guinea to assess road services and conditions. The resulting report (RAS, 2015) details the findings for the Highlands Highway section of that survey. Although the report contains the results for the highway from Lae Wharf to the Mendi Kiburu junction, a distance of 571.1 km, only road sections NR0007_010, NR0007_020 and (part of) NR0007_030 apply to the 50 km section from Lae to the study area.

The road survey results include traffic flows of the various sections of the Highlands Highway, e.g., the flow per hour and the estimated annual average daily traffic (AADT). The main findings that are relevant to the Project can be summarised as follows:

- While pedestrians walking alongside road sections and roadside markets are common, observed traffic flows for motorcycles and bicycles were extremely low, and assumed to make up 0% of the total vehicle flow.
- The 12.4 km section of NR0007_010 had a flow/hr of 333 and an estimated AADT of 5,378.
- The 26.4 km section of NR0007_020 had a flow/hr of 74 and an estimated AADT of 1,191.
- NR0007_030 (44.5 km) had a flow per hour of 24 and an AADT of 379. However, this road section extends farther than the 50 km from Lae to the study area and reflects the substantial decrease in traffic that occurs beyond Lae Nadzab Airport.

The highway is a two-lane, single carriageway with no divider between opposite lanes and generally a very rough surface from the wharf to the study area. Only 9 km of road from Lae to the Wau/Bulolo turnoff is sealed with 50 mm of asphaltic concrete, although further upgrades to the highway are reportedly under consideration by the government. Road safety is a major issue due to factors such as the lack of median between carriageways, a lack of speed limits, poor road safety awareness, and hazardous roadside objects. Very few pedestrian crossings occur on the highway, and only 1% of the entire route has dedicated pedestrian sidewalks. In the period 2009 to 2011, Morobe Province had an average of 51.3 deaths of vehicle occupants per year, with pedestrian deaths being 8.3 per year.

Water

Lae Port is the largest port in Papua New Guinea, handling approximately 3 million tonnes of cargo (which is almost half of all PNG’s cargo). The port serves as an export port for agricultural and mining industries in the Highlands and Markham/Ramu region, and a recent redevelopment project (the creation of a 700 x 400 m tidal basin, and a 200 x 40 m wharf) has resulted in an increased carrying capacity. The port is able to berth any type of cargo or vessel (Pöyry, 2016a) and is used for both international and domestic shipping, including both cargo and passenger services. About 300 shipping containers are handled per day, and 200 ships per month, although the capacity for heavy bulk shipments is limited. As of 2012, Lae Port had a TEU (twenty-foot equivalent units) of over 184,491 annually, while Port Moresby had an annual TEU of over 89,503 (PNG Ports, 2013).

At a more local level, villagers within the study area continue to use rafts and canoes to meet relatives and transport produce downstream to markets. Otherwise, there is little transport use in the waterways near the study area.

Air Transport

The regional airport, Lae Nadzab Airport, is located 32 km from Lae city and about 10 km east of the Project's power plant site. The airport is the second busiest airport in Papua New Guinea after Port Moresby, both in terms of flight movements and passenger throughput, and handles 60 flight movements per day.

The Papua New Guinea and Japanese governments have agreed to begin redeveloping the airport in 2018 to increase capacity to allow international flights.

6.3.4.2 Communications

Communities in Papua New Guinea have previously relied on radio and VHF systems for communication. These systems faced many difficulties in terms of their effectiveness, including low accessibility and poor reliability. Since the introduction of mobile phone and data company Digicel to the country in 2007, mobile phone and internet access and usage has increased substantially. As of 2012, 38% of the population had a mobile subscription, having risen from 0.16% in 2000. Nationwide, it is estimated that there are 150 mobile subscribers for every 1,000 people, and 3G and 4G services have been introduced in urban areas. However, rural areas still only have access to 2G service. Some 42.5% of rural households in Papua New Guinea contain one or more mobile phones, 1.4% contain a personal computer, and 2.3% have internet access. Despite the rise of mobile phone services, the country’s fixed phone network is still not well networked, with only 1.94% of the population subscribing to fixed phones.

In Morobe Province, all urban households have access to mobile phone based communications. Until relatively recently, such communications were limited to urban areas, although as of 2014, most of rural households were within a short walking distance of mobile phone access. The SIA survey found that more than 70% of respondents had mobile phones, with good mobile coverage in all Project area villages. Of the two service providers in Morobe Province, i.e., Digicel and B Mobile, Digicel has a wider spatial coverage and better coverage in rural areas. Although mobile phone based communications are rising, fixed phone networks and internet access are still very low in the Huon Gulf District. There are no known plans for additional communication investments in Morobe Province.

6.3.4.3 Energy

Most rural households in Papua New Guinea do not have access to electricity, mainly relying on wood fire and kerosene for cooking and lighting. Households that do have electricity may have small generators. The main source of power supply in Morobe Province is the Ramu grid, which is described in further detail in Section 3.3.1.

Details concerning energy sources for lighting and cooking in the study area are provided in Section 6.3.3.8. The *Huon Gulf District Integrated Development Plan* 2013-2017 has flagged an intention to increase rural electrification, recognising the lack of access to rural electricity within rural areas of the province.

6.3.4.4 Other Services

Law and Order

Police services in Papua New Guinea are mainly limited to urban areas, and only deal with issues in outside areas, such as rural locations, in the event of serious crimes. The village justice system, which has largely derived from traditional systems of law and order, is responsible for dealing with minor criminal activities, particularly in rural areas. Minor criminal activities include garden stealing, disputes, general bad behaviour and conflict between husbands and wives. Crimes that cannot be resolved under this village justice system, or are of a more serious nature, are referred to the police in urban centres like Lae. Due to rapid social change within the country, rural areas are now experiencing unprecedented criminal activities, and this is particularly significant in areas with road access, government stations and nearby mining operations.

General police infrastructure in the study area includes community-based police posts, rural police stations, police vehicles and village courts. In Huon Gulf District, there are two police stations, three village courts, no village courthouses and three village court circuits. The household survey completed as part of the SIA indicated that law and order was not considered to be a priority in the development of the area, although alcohol, drugs and domestic disputes were considered to be high priority.

Banking

There are 12 licensed banking institutions in Lae, with at least one bank in most provincial centres. However, there is a lack of informal banking services (that operate low-cost savings, credit, and other financial services), and a suitable regulatory framework for these informal institutions is still required. Overall, financial services in Papua New Guinea have failed to reach the majority of the population, and the country's financial services are underdeveloped. This is especially true in rural areas, with one of the major impediments being the lack of access to credit for small to medium sized enterprises. However, financial services in general are expanding across the country. For example, BSP has recently introduced phone banking, and the three major banks (BSP, ANZ and Westpac) all have branches in Lae City and numerous ATMs and EFTPOS outlets, as does Kina Bank and the National Development Bank (which specialises in small and large rural loans, microfinance loans and commercial lending). Micro-credit organisations such as PNG Microfinance Limited and MiBank also have offices in Lae, and MiBank and BSP have branches in Bulolo.

Most banking services in Morobe Province are located near Lae city, although some BSP EFTPOS outlets can be found along the Highlands Highway in the Markham Valley. The nearest banking facilities to the study area are in Lae, and access is not an issue due to the study area’s proximity to the city and the good level of accessibility. The SIA survey results indicate that only 34% of households have a bank account (44% of individuals), while considerable amounts of money were involved the exchange of gifts and cultural transactions such as bridal and funeral expenses, compensation and gifts, and that these costs were considered in household income and expenditure.

Urban Services

Due to its importance as a logistics and distribution hub (which reflects the port facilities and highway connections to the five highland provinces), Lae has developed into a major commercial and industrial centre. The city is also a manufacturing hub, with industries from metal work and engineering to fish processing and beer brewing (and 25% of Lae's formal workforce is employed by the manufacturing sector, which contributes 6 to12% of PNG's gross domestic product (GDP)). A number of major local manufacturers are located in Lae, as well as local subsidiaries of international companies such as Nestlé, Colgate, Coca-Cola Amatil and Heineken (SP Brewery). As such, a range of urban services is necessary to maintain the functioning of the city, and these include post offices, supermarkets, bakeries, fast food outliers, hardware stores, pharmacies, car dealerships, airline booking agencies, banks and hotels. Lae also has a golf course, several sports fields, an indoor sports centre, a gym, and a range of sporting and cultural events. The city's power, water, sewage and garbage collection services are all considered to be reliable, and are managed by the local council. However, Lae is supplied by bore water, and there are concerns over the sustainability of the city's water supply due to its growing population. There are a number of educational services, such as the University of Technology, teacher training and numerous other colleges. In settlements outside the city, residents often live in temporary and makeshift households, mostly without electricity, piped water, toilets and waste collection. There are intentions to establish postal services, and to increase water tanks in schools, in a number of LLGs.

6.3.5 Health

6.3.5.1 Introduction

The available information, including survey results, has been reviewed by means of the environmental health area (EHA) method published by the IFC (e.g., IFC, 2009) and oil/gas organisations such the International Petroleum Industry Environmental Conservation Association (IPIECA) (IPIECA/IOGP, 2016). Environmental health areas (Table 6.20) are a standard set of health effects categories that have been developed to capture a variety of determinants of health, where these reflect all of the biomedical and social concerns originally developed by key international health and development agencies, i.e., the WHO and the World Bank Group. In general, while each EHA may not be relevant for a given project, it is still important to systematically analyse the potential for Project-related impacts (positive, negative or neutral) across the various EHAs.

Table 6.20 – Environmental Health Areas

Environmental Health Areas (EHAs)	
1	**Health systems issues** – physical health infrastructure (e.g., capacity, equipment, staffing levels and competencies, future development plans); program management delivery systems (e.g., malaria-, tuberculosis-, HIV/AIDS-initiatives, maternal and child health)
2	**Respiratory-related communicable diseases** (generally linked to linked to housing) – transmission of communicable diseases (e.g., acute respiratory infections, pneumonia, tuberculosis, meningitis) that can be linked to inadequate housing design, overcrowding and housing inflation. Construction phase work camps are also considered.
3	**Vector-related diseases** – mosquito, fly, tick and lice-related diseases (e.g., malaria, dengue, yellow fever)

Table 6.20 – Environmental Health Areas (cont'd)

Environmental Health Areas (EHAs)	
4	**Sexually transmitted infections, including HIV/AIDS** – sexually transmitted infections such as syphilis, gonorrhoea, chlamydia, hepatitis B and, most importantly, HIV/AIDS
5	**Water, sanitation and hygiene related diseases** – diseases that are transmitted directly or indirectly through contaminated water, soil or non-hazardous waste (e.g., diarrhoeal diseases)
6	**Food- and nutrition-related issues including food security** – adverse health effects such as malnutrition, anaemia or micronutrient deficiencies due to, e.g., changes in agricultural and subsistence practices, or food inflation; gastroenteritis, food-borne trematodiases. This will also consider feeding behaviours and practices. Access to land plays a major role in developing subsistence farming contexts
7	**Non-communicable diseases** – e.g., cardiovascular diseases, cancer, diabetes, obesity
8	**Accidents/injuries** – road traffic or work-related accidents and injuries (home and project related)
9	**Exposure to potentially hazardous materials** – this includes exposure to pesticides, heavy metals, solvents or spills and releases from road traffic. Noise, water and air pollution (indoor and outdoor) as well as visual impacts are typically considered in the environmental impact assessment
10	**Social determinants of health** – including psychosocial stress (due to, e.g., resettlement, overcrowding, political or economic crisis, mental health, depression, gender issues, domestic violence. There is a significant overlap in the social impact assessment in this section
11	**Veterinary medicine and zoonotic diseases** – diseases affecting animals (e.g., bovine tuberculosis, swinepox, avian influenza) or that can be transmitted from animal to human (e.g., rabies, leptospirosis)
12	**Cultural health practices** – role of traditional medical providers, indigenous medicines, and unique cultural health practices

6.3.5.2 Study Limitations

The following limitations apply to the community health study:

- Occupational health concerns (e.g., physical hazards or environmental hazards encountered while working) have not been addressed. 'Inside the fence' issues are addressed by the Project itself, although 'cross-over' issues (e.g., health issues that arise as workers interact with local communities, such as roadway traffic) have been considered.

- Extensive, household-level biomonitoring was not conducted and is not considered to be necessary for the limited size and scale of this Project. Assessments are therefore limited by the information that is available and that was collected by: i) social teams, ii) through key informant interviews conducted by the field team, and iii) review of relevant health centre and aid post outpatient clinical data.

6.3.5.3 Health-related Services and Infrastructure

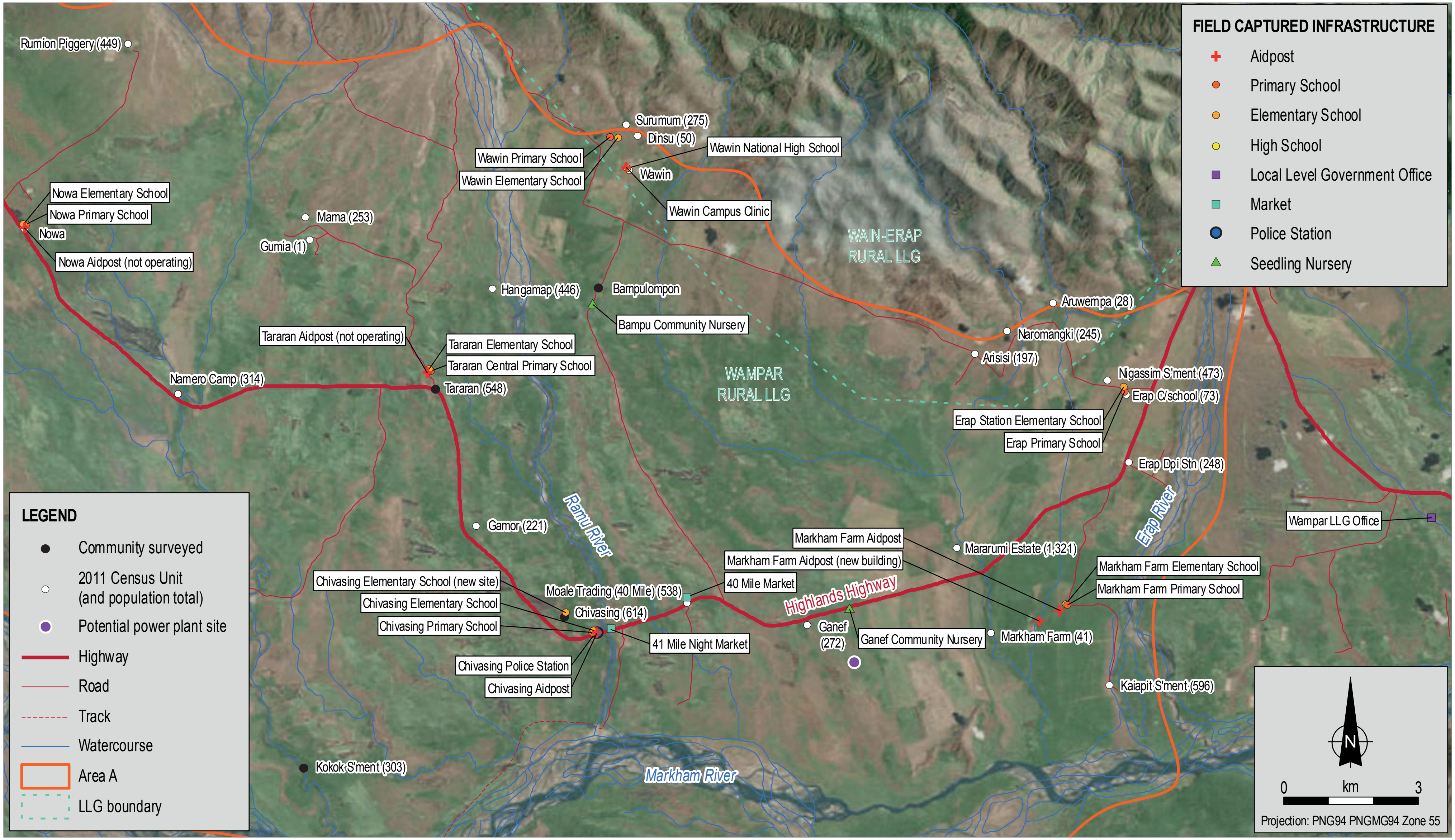
The location of health-related infrastructure within the study area is shown in Figure 6.29.

The Wampar (Nadzab) Health Centre (WHC) is the dominant health care provider for the local communities. Despite being located outside the study area, it is within the Markham Valley (on the Highlands Highway) and supplies significant health services in the Huon District and across the Wampar LLG (Plate 6.32), generally seeing more than 200 patients per day. The health centre is a large, fully functioning outpatient health facility, but with limited inpatient facilities; patients requiring acute care or labour and delivery are transferred to Lae (Angau Memorial Hospital).

INFRASTRUCTURE IN THE STUDY AREA

PNG Biomass Markham Valley I Environmental Assessment Report

FIGURE 6.29



Source: SIMP, 2017.

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The facility is well-staffed and is supplied with medications and testing equipment (Plates 6.33 and 6.34), the presence of which aligns with provincial data showing that less than 7% of functioning Morobe Province health facilities have supply shortages (SPAR, 2015). This is a significant improvement over the 2011 data, where 35% reported a shortage.

Plate 6.32 – Wampar Health Clinic Outpatient Waiting Area

Source: SIMP, 2017.

Plate 6.33 – Wampar Health Clinic Medication Stocks

Source: SIMP, 2017.

Plate 6.34 – Wampar Health Clinic Laboratory

Source: SIMP, 2017.

In addition to the WHC, three aid posts occur within the study area: Chivasing (Plate 6.35), Tararan and Nowa. Only Chivasing is staffed and functional at present (although it was temporarily closed due to staff absence at the time of the field surveys); the Tararan and Nowa aid posts are not currently functioning and have been converted into staff housing for local schools.

Plate 6.35 – Chivasing Aid Post

Source: SIMP, 2017.

The presence of non-functioning aid posts in the study area is not unexpected, and aligns with management performance data for Morobe Province that indicates the proportion of provincial health facilities that received at least one supervisory visit by provincial or district program/management staff during 2015 was only 14%. This is a fall in performance when compared to 65% in 2011. In turn, these provincial percentages mirror the national PNG percentages of 29% in 2015, compared to 62% in 2011.

6.3.5.4 Baseline Health Data

Outpatient morbidity data from 2015 (12 months) and 2016 (8 months) for all of WHC's reporting facilities (over 10 aid posts within the region, including Chivasing) are shown in Figure 6.30. As can be seen from these figures, respiratory infections are the dominant health issue for the region, with over 13,600 cases in 2016. This is followed by 'others'[11], while skin diseases, laboratory-proven malaria and diarrhoea are also significant. Antenatal, family planning and vaccination data are not included in these figures. The morbidity pattern seen is consistent with what is reported across rural Papua New Guinea.

The 2016 data from the Chivasing aid post is shown in Figure 6.31. A fairly similar burden of disease pattern is seen between Chivasing and the overall WHC data.

During household surveys, respondents in the study area reported that most visits to a health centre were due to 'illness' (35%), followed by 'other' (24%), which included baby clinic, fever, malaria, diarrhoea, immunisations, musculoskeletal and genital issues. Maternal issues (delivery, postnatal, and family planning) accounted for 20%, skin ulcers and check-ups were both around 9% and accidents accounted for 4%. Health care services were obtained primarily from an aid post or sub-health centre (35% each), followed by a hospital (15%), traditional practitioner (13%) and other means (3%).

Time taken to access health care services varied across the study area, although the average time was less than an hour, and less than 30 minutes for Chivasing (Table 6.21). Bampu and Kokok village access times averaged approximately 2.5 to 3 hours, which is consistent with the lack of functioning aid posts in these communities.

Table 6.21 – Time to Reach Health Care Services

Village	No. Cases	Average Time (Minutes)
Bampu	1	180
Chivasing	8	26
Kokok	3	133
Nowa	5	48
Tararan	10	40
Total	27	53

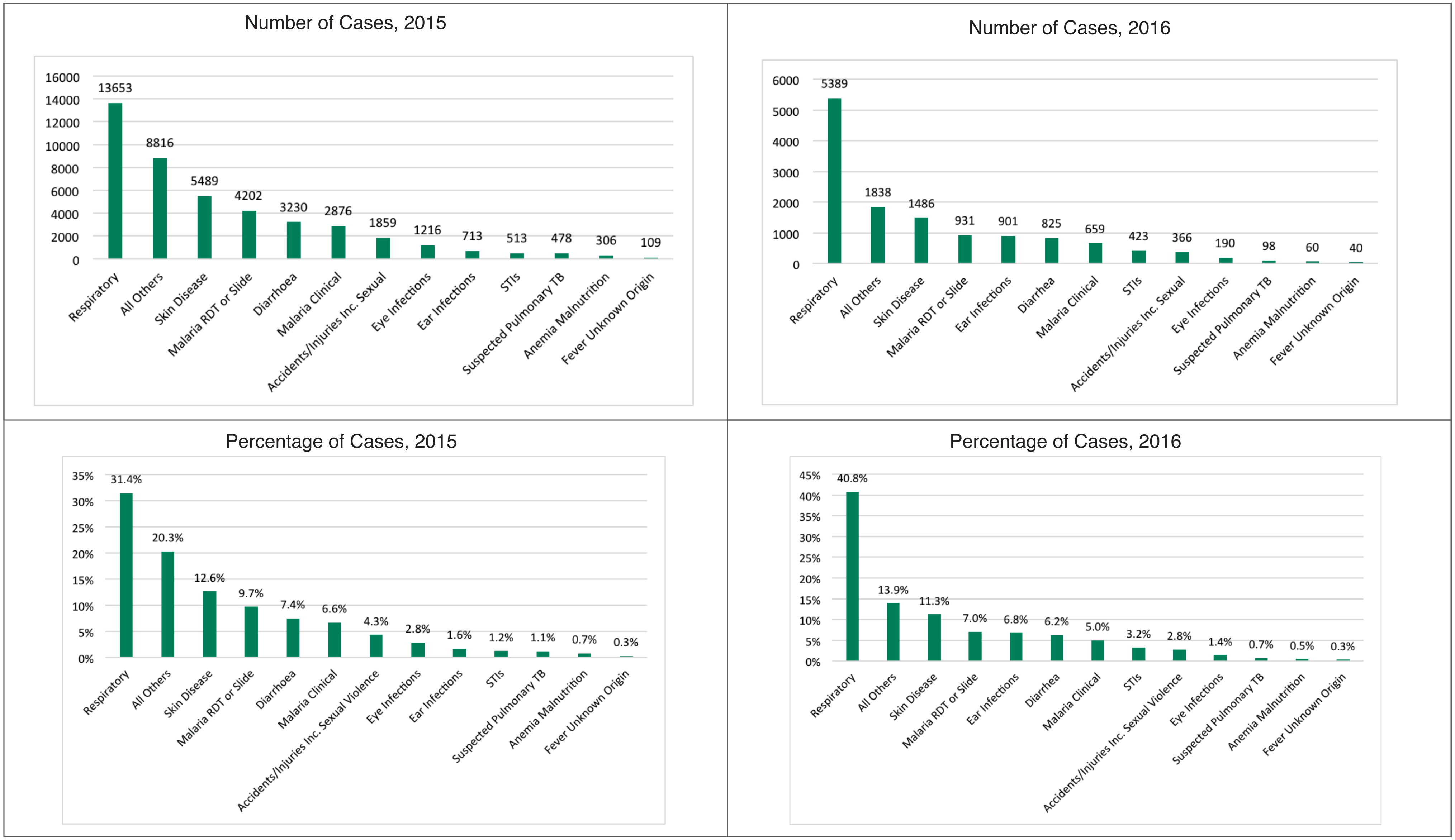
Half of the respondents travelled to health services by vehicle, while 44% walked and 3% were taken by ambulance and 3% by helicopter. Emergency medical cases are all transported to Lae, Angau Memorial Hospital.

Respirable Communicable Diseases

Communicable respiratory infections are a significant concern across Wampar LLG and the burden on the communities is likely to fully reflect the overall Wampar LLG data. Tuberculosis is a major issue and is probably underdiagnosed.

[11] 'Others' is a commonly reported category across all PNG health centres and aid posts.

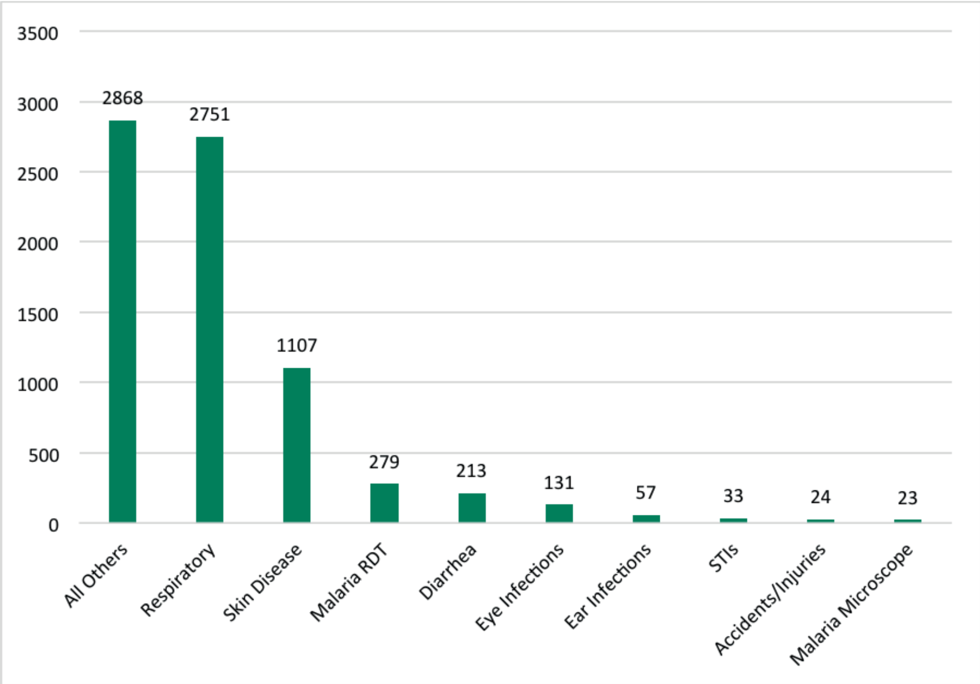
FIGURE 6.30



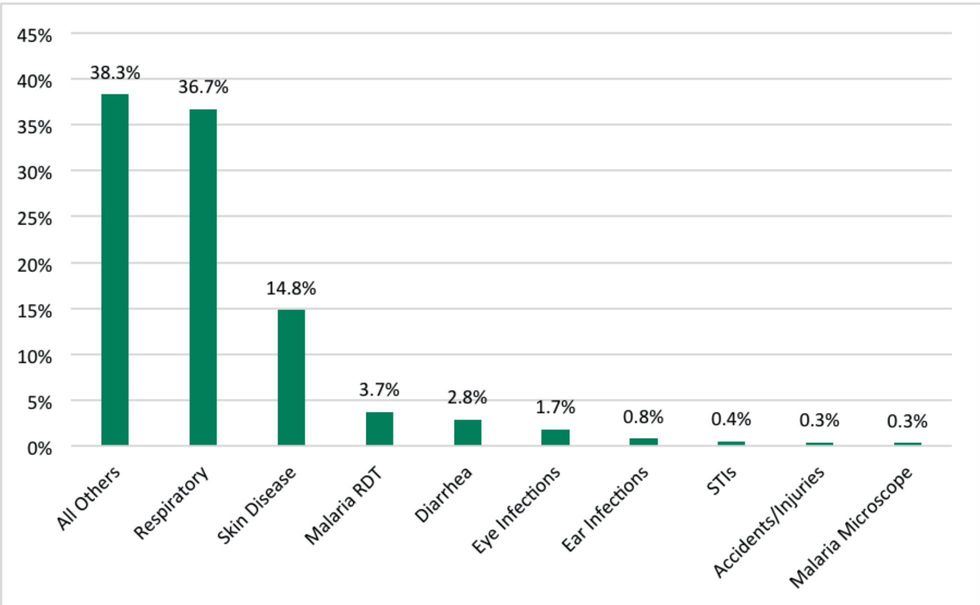
Source: SIMP, 2017.

FIGURE 6.31

Number of Cases, 2016



Percentage of Cases, 2016



Source: SIMP, 2017.

In addition, the percentage of children under the age of five diagnosed with pneumonia, relative to the total age-specific pool, is estimated to be 46% in the Wampar LLG. Even assuming over diagnosis, this calculation demonstrates that pneumonia is a significant issue. Historically, adult pneumonia in Papua New Guinea is also a major cause of morbidity and mortality.

Vector-borne Diseases

Malaria is a significant cause of morbidity in the Wampar LLG and is a significant issue in the study area. Its prevalence is likely to be highly location-dependent (i.e., due to variation in hydrology and vegetation type) and diagnosis is based on either clinical presentation, i.e., fever for three consecutive days, or clinical presentation plus laboratory confirmation using a rapid diagnostic test (RDT). However, malaria is not the only potential vector-borne disease (VBD), i.e., other significant diseases such as dengue and Chikungunya are present and are probably underdiagnosed. The level of other VBD in the study area, i.e., Japanese encephalitis and Ross River virus, is unknown.

Sexually Transmitted Infections including HIV

Papua New Guinea has among the highest prevalence of HIV, syphilis and other sexually transmitted infections (STIs) in the Asia-Pacific region. All reporting health centres and aid posts report STIs; however, experience elsewhere in the country indicates that these diseases are substantially under-reported. This is probably seen in the study area where the WHC data indicates 3.2% of the cases are STI related and Chivasing aid post indicates only 0.4% of cases are STI related. Rates of HIV are consistent with rural levels across the country.

Water Sanitation and Hygiene

Diarrhoeal disease in Papua New Guinea is one of the leading causes of morbidity and mortality, accounting for 8% of deaths among children aged less than 5 years. However, the burden of enteric illness in the country is not restricted to children. Outbreaks of cholera and shigellosis in the recent past highlight the risk to the broader population of enteric disease outbreaks, and endemic illnesses such as typhoid fever continue to cause illness.

Water access and available household water volumes can impact disease transmission via hygiene (e.g., hand washing). Microbiological testing of community/household water supplies is not available, but water and sanitation issues are present across the local communities, despite the documented morbidity burden of diarrhoea being relatively modest. Data from the WHC indicate that diarrhoea is a significant issue, accounting for 6.2% of the reported morbidity burden, while in Chivasing, the diarrhoea level was substantially lower at only 2.8%. The potential causes of the differences between the overall WHC and Chivasing diarrhoea burdens are uncertain.

Of the households surveyed, 13% reported either one or two persons were affected with diarrhoea in the past week. This level is higher than the health centre/aid post percentages and is probably related to severity, i.e., only more severe cases seek medical attention. Of those who experienced diarrhoea, 50% sought treatment at home, 37.5% at an aid post, and 12.5% at a sub-health centre.

Skin diseases are frequently related to hygiene (hand washing and bathing) and the presence or absence of sufficient volumes of water at the household level (hand washing). As previously noted, skin diseases are a significant cause of the observed morbidity across the WHC and reporting aid posts, including Chivasing – the overall skin morbidity burden for WHC was 11.3% (2016) and 14.8% in Chivasing. In addition, the household surveys show that skin ulcers are an extremely common problem and probably reflect poor overall hygiene.

The villages use a variety of sources for their water, and the water resources were used both for drinking and washing. Some areas of drinking water could not be accessed due to religious or cultural reasons. While 94% of respondents reported that their main source of water was available year round, an average of 10% of respondents reported ‘water supply’ as a critical problem facing both their family and the community.

All villages have bore wells but, while the water seemed clean, it was limited in quantity and pumps were generally broken and in need of repair. Sixty per cent of respondents said they obtained water from wells (easily accessed in an averaged return time of 10 minutes) while 45% also said they collected at streams (between 15 to 72 minutes for a return trip). Plastic containers and buckets (on average 3 per household) were used for water collection at streams and rivers, and most wells were accessed with a long string and container (Plate 6.36). Water tanks were not ubiquitous and only 6% of respondents said they had household tanks.

Plate 6.36 – Collecting Water at Tararan Village Well

Source: SIMP, 2017.

Less than 25% of respondents reported that they boiled the water for drinking and 97% said they never boiled water for washing.

Almost 59% of villagers use traditional pit latrines for their ablutions, which is typical of rural area communities. The remaining villagers used an improved pit (just under 15%) or used the bush/no facility (just over 25%). There are no composting practices and food scraps and rubbish were reported as being dumped in the bush or some metal/tin goods were buried in pits.

Non-communicable Diseases

Non-communicable diseases and associated risk factors such as smoking, excessive alcohol consumption, obesity, hypertension, abnormal cholesterol and lipid profiles, and physical inactivity currently account for a minor proportion of outpatient and inpatient admissions at the WHC. However, it is likely that many (if not most) forms of non-communicable diseases are undetected or untreated.

Accidents and Injuries

Accidents and injuries are reported by both community members and health workers. As presented in the morbidity overview, the WHC documented outpatient burden of disease for accidents/injuries is 2.8%, which is not too dissimilar form the overall Morobe Province data (3.4% injuries reported over the 2011 to 2015 time period). There is an existing emergency transportation system with local (but limited) ambulance services to Angau Memorial Hospital in Lae.

Exposure to Hazardous Materials

Potential exposures to hazardous materials are typically not a major issue in a rural subsistence agriculture environment and are, therefore, likely to be minimal.

Zoonotic Diseases

Knowledge regarding the burden of zoonotic disease transmission is a chronic problem in Papua New Guinea. Local health facilities lack the clinical and laboratory capability to accurately diagnose these diseases.

Cultural Health Practices

Based on local community and health center interviews, key concerns surrounding cultural health practices were not identified.

6.3.6 Education and Training

6.3.6.1 Overview

Substantial school infrastructure has been built and maintained in Morobe Province over the past decade. The quality of school infrastructure is only one of several factors that impact on education levels. Other factors include:

- The type and standard of teachers' houses.
- The capacity of teachers.
- The curricula and availability of teaching materials.

- Attitudes among children, their parents and the local community towards education.
- The budget for education support, and cash flow problems delaying access to funds which restricts the level of support providers to teachers and schools and limits supervision.
- The State's Tuition Free Policy, which provides an opportunity for many more parents to have their children attend school with consequent overcrowding and other problems as schools struggle to cope with higher numbers of students, boarders and often limited boarding and classroom facilities to manage these increased numbers.

6.3.6.2 Education Facilities and Enrolment

The Project area contains a number of elementary schools (Plate 6.37) that feed into five primary schools (see Figure 6.29). There is one national high school.

Plate 6.37 – Tararan Elementary School

Source: SIMP, 2017.

The characteristics of the five primary schools are detailed in Table 6.22. All primary schools in the Project area have almost a full complement of teaching staff and are well attended. School infrastructure varied. All have permanent material classrooms and most also have additional bush material buildings, although all head teachers stated that their main desire for the future was improved classrooms and teachers' houses, better water supplies and sanitation. A shortage of basic teaching materials was also cited as an issue at the five primary schools visited. These findings align with province-wide data that illustrates a desire for better infrastructure and more teacher housing.

Table 6.22 – Characteristics of Study Area Primary Schools

Parameter	Erap Primary	Markham Farm Primary	Wawin Primary	Chivasing/Zifasing Primary	Tararan Primary
School Level	Five	Four	Four	Five	Four
Students					
Total Male	407	183	97	283	84
Total Female	339	110	99	198	77
Gr 3 Male	43	34	25	76	12
Gr 3 Female	57	36	22	66	12
Gr 4 Male	67	33	18	42	22
Gr 4 Female	57	28	26	31	16
Gr 5 Male	66	32	14	47	12
Gr 5 Female	64	11	28	32	12
Gr 6 Male	68	32	12	36	11
Gr 6 Female	50	19	4	28	7
Gr 7 Male	76	30	18	35	14
Gr 7 Female	51	18	11	22	11
Gr 8 Male	66	22	10	47	14
Gr 8 Female	58	10	8	19	19
No. Teachers	19	9	7	16	6
Teacher vacancies	0	0	3	0	0
Classrooms					
Permanent	15	4	2	12	6
Bush material	0	4	3	0	0

Table 6.22 – Characteristics of Study Area Primary Schools (cont'd)

Parameter	Erap Primary	Markham Farm Primary	Wawin Primary	Chivasing/Zifasing Primary	Tararan Primary
Staff Housing					
Permanent	14	7	1	13	5
Bush material	0	0	3 (+1 under constr.)	0	0
Other Facilities	Library, basketball court, Incomplete computer facility, 2 typists	None, just grass playing fields	None, just grass playing fields	Library, playing fields ablution block	Library, playing fields
Water supply	Incomplete	None, walk to Markham Farm tank	Spring + gravity reticulation	Water tanks + 2 wells for washing only)	Tanks
PNG Power	Yes	Some	None (small generator for office)	Yes	Yes, u/s back up generator
Communications	Mobile phone	Mobile phone	Mobile phone	Mobile phone	Mobile phone
Health facilities	-	-	High school clinic or Chivasing aid post	Chivasing aid post in same compound	Chivasing aid post
Sanitation	Yes	None	None	Yes	Pit toilets
Student home villages	Nadzab, Arankop, Erap, Munkip, Naramangki, Trukai farm	Markham Farm, Bobong (mainly Atzera language)	Bampurampom, Dinsu, Sarampik, Surumin, Wawin station, Bismark Farm	Wawin, Ganef, Wawin junction, 40 Mile, 41 Mile, Chivasing, Kokop, Gamul	Mempang, Ampes, Fenof, Hangamap, Simbu compound, Clean Water, Tararan, Gabafi
Feeder Elementary schools	Erap Station, Mungkip, Naramangki, Nadzab Farm, Markham Farm	Bobong Elementary (6 teachers)	Wawin Elementary – 5 local village teachers, 1 staff house, total 160 students – 78 female and 82 male	Chivasing Elementary in same compound; 147 female students + 173 male students, 6 semi permanent c/rooms	Tararan and Fenof Elementary; Tararan – 76 male+ 67 female students, 5 teachers, no housing, 2 permanent + 2 bush material c/rooms
Other	Elementary school – 126 pupils	Elementary school (6 teachers, 2 perm+ 2 incomplete c/rooms)	Wampar and Nawae languages	Plan for 3 feeder elementary schools. Rental from Digicel tower	-

Table 6.22 – Characteristics of Study Area Primary Schools (cont'd)

Parameter	Erap Primary	Markham Farm Primary	Wawin Primary	Chivasing/Zifasing Primary	Tararan Primary
Future Plans in School Learning Improvement Plan	Raise to level 6 (+4 teachers)	Water supply, sanitation, c/rooms, housing, Raise status to level 5	Improved facilities + fence to keep out cattle	3 teachers houses, ablution block, complete fencing, more classrooms	Improve all facilities, fencing to keep out pigs

Wawin National High School currently has 408 students: 163 female and 245 male. The school has a capacity to take up to 550 to 600 students if the facilities are completed to allow this, although an additional four teachers would be required. There are 16 classrooms, four (currently non-equipped) laboratories, a library and 25 staff houses. Students are accommodated in six dormitories with ablutions. The school also has an electricity connection (to the PNG Power network), a back-up generator, two water bores with pumps and storage tanks, and incomplete basketball courts within large fenced grounds. Staffing includes 26 teachers, 3 administrative staff, 3 ground staff, 5 security staff and 4 cooks. Students come from all over the country to board at the school, although in practice about 70% of the intake is from secondary schools in Morobe Province. The school has a clinic that is staffed by a nurse supplied by Huon District Health, which also treats patients from nearby communities. An earlier installed VSAT communications system is non-operative so all communication is by mobile phones (Digicel).

While most students could walk to primary/elementary schools (averaged time between 2 and 20 minutes), the travel time to the nearest secondary school for some villagers could be up to 90 minutes for a one-way trip. Kokok was the most disadvantaged of the study area villages in respect to access to secondary schools, although children at Kokok, Bampu and Nowa required the use of vehicles to get to secondary school.

6.3.6.3 Education Status

In 2009-10, it was estimated that 35% of PNG's rural population aged 6 years and above had not been to school (males: 30%; females 41%). The most common reasons for not attending school were cited as:

- No interest (23%).
- Too young (15%).
- Not allowed (14%).
- Couldn't afford school fees (14%).
- School too far away (13%).

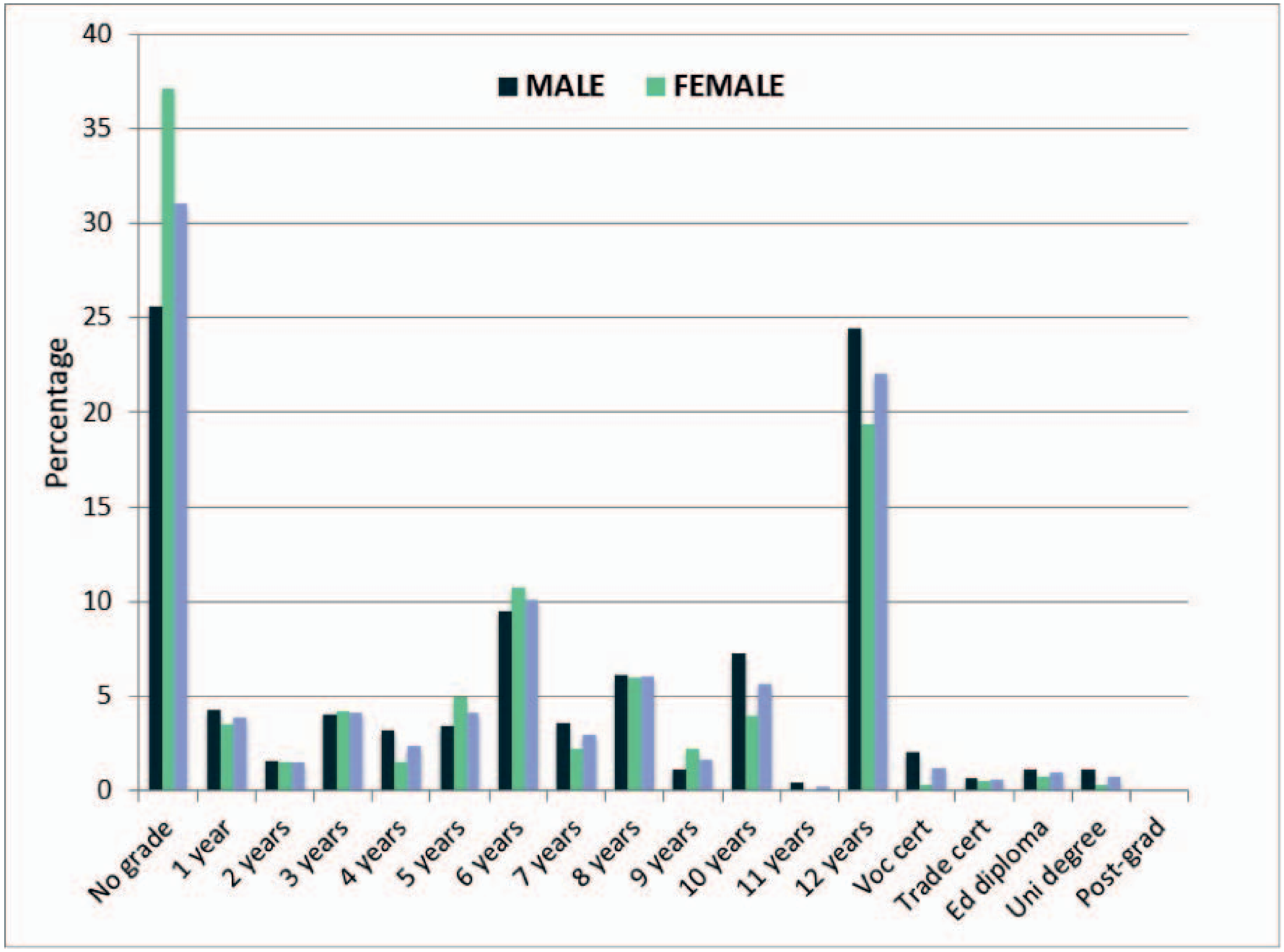
Results from the 2011 National Census indicate that the people of Morobe Province have education levels similar to that for the country, and literacy levels slightly above the national average.

Formal education levels in the study area are low; 25% of males and 37% of females aged 10 years and above have not had any formal education. As shown in Figure 6.32, only 7% of males and 4% of females aged 10 years and above had completed nine years of education, which is the basic education requirement in the current National Education Plan[12]. However, it should be noted that 24% of men and 19% of women in the households surveyed had attained Grade 12.

[12] Although a child would normally be 15 years of age before completing 9 years of education, the National Statistics Office presents education information for people aged 10 years and above. Information has been presented for the study area using the same age category to enable comparisons with provincial and national data.

HIGHEST FORMAL EDUCATION COMPLETED IN THE STUDY AREA

FIGURE 6.32



Source: SIMP, 2017.

At the time of survey, 28% of the present population of respondents were reported as attending school: males – 31%, females – 24%. This figure approximates the provincial average of 32%.

In the Project area, 28% of surveyed households indicated that they had a school-aged child who was *not* attending school, a total of 77 children (47 male and 30 female) in 134 households. This indicates, however, that 72% of school age children *are* attending school, which compares well with other rural areas of the country. In addition, the data from the study area shows that it goes against national trends that have in the past indicated attendance of females at school tends to drop off in years 9 to 12 as they take up more domestic duties or prepare for marriage. On the contrary, respondents in the study area reported that female attendance was actually marginally higher than that of males and their absentee rate, as reported above, was correspondingly lower than for males.

In response to the household survey question around the main reasons for each child not attending school, the most common answer was 'no interest/refused' (30%), followed by 'school fees' (26%).

6.3.6.4 Literacy

The National Statistics Office (NSO) defines 'literate' as the ability to speak and write in any language and it is up to the individual respondent to answer the question during the census (i.e., without testing).

Overall in Papua New Guinea, literacy in urban areas is estimated at 89% compared to 65% in rural areas (Figure 6.33). The findings of the household survey for the study area indicate that literacy levels for people aged over 10 years is slightly lower than the national and provincial estimations (Table 6.23). Further, literacy rates for females in the study area (and across the country) are lower than for males (see Figure 6.33). The gap was narrower in Chivasing than other study area villages, which may reflect the central-hub status this village occupies in the region. Comparison with the 2011 National Statistical Office data shows the study area survey findings to be close to the Provincial average.

Table 6.23 – Population Aged >10 who are Literate

Census Area	Males	Females
Papua New Guinea	71%	64%
Morobe Province	74%	66%
Study area	68%	56%

Source for PNG and Morobe data: NSO (2011); as cited in SIMP (2017).

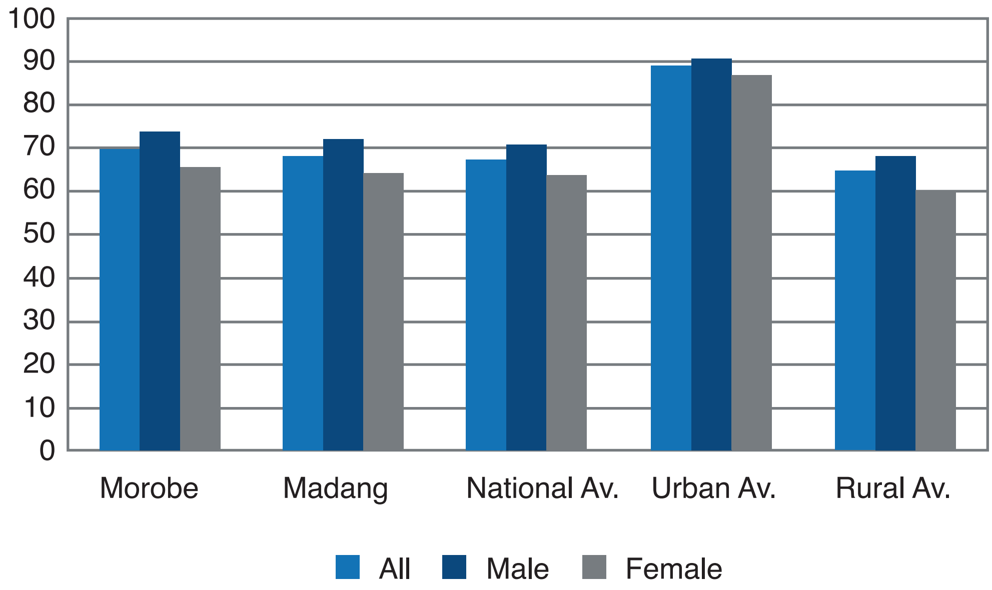
6.3.6.5 Formal Training Opportunities

Tertiary and Vocational Education

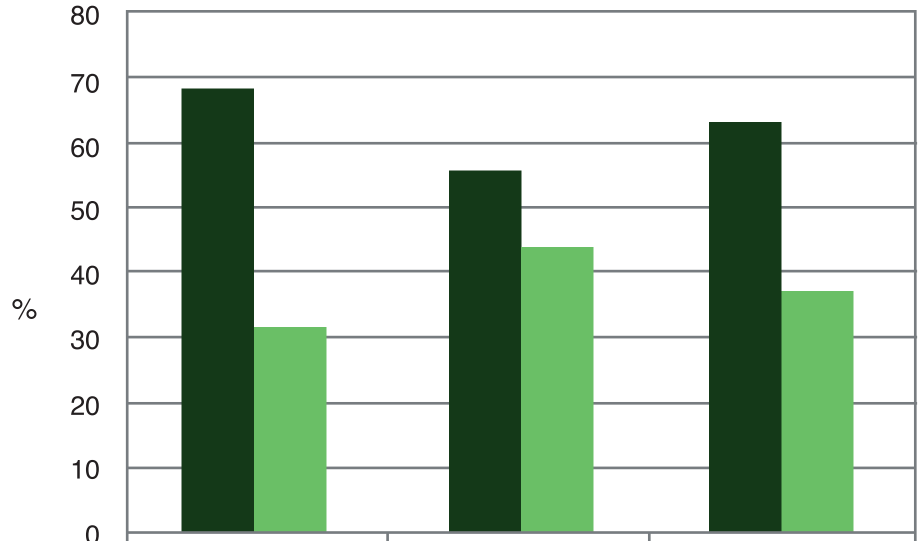
Morobe Province has a number of tertiary training institutions including the PNG University of Technology (UNITECH), Forest Research Institution (FRI), National Polytechnic Institute, Bulolo University College, Timber and Forestry Training College (TFTC), Lae Nursing College, Telikom Technical Training College, PNG Defence Force Academy and Balob Teachers College. The Department of Forestry also offers diplomas in forestry studies.

FIGURE 6.33

Provincial Literacy Rate



Study Area Literacy Rates by Gender



	Male	Female	Total
Literate	68.4	56.0	63.0
Non-literate	32.0	44.0	37.0

Source: SIMP, 2017.

A number of vocational schools also operate within the province, including the government-run Umi, Bulolo, Wau, Menyamya and Finchsafen vocational colleges and the Malahang Technical High School. In addition, the Catholic Church operates St. Joseph's Tech School, St. Therese Vocational Centre and the St. Francis Vocational Centre.

These vocational institutions cater for approximately 1,900 students in a wide range of practical and technical topics including carpentry, plumbing, metal fabrication, home economics, mechanics, agriculture, panel-beating, catering and secretarial studies. There are approximately 1,000 vocational training places available every year in Morobe Province, with 111 instructors to teach students.

Private Sector Training

There are only two private sector enterprises within Morobe Province that are large enough to consider training (in addition to their in-house technical and apprentice training) of employees, i.e., PNG Forest Products and the Hidden Valley Mine. The latter sponsors personal viability training for people from local villages and teacher training for those posted in nearby schools, and has an extensive program for a number of disciplines providing industrial training for final year university students.

6.3.7 Agriculture, Land and Natural Resource Use

This section describes village-based agriculture, land and natural resource use, and cash income related to subsistence livelihoods in the study area. The five selected communities (and their associated land holdings) also reflect the variability in land use types within the study area identified by the PNG Agricultural Systems Project illustrated in Figure 6.34, e.g., smallholder and capital agriculture.

6.3.7.1 Physical Environment for Agriculture and Land Use Patterns

Physical Environment

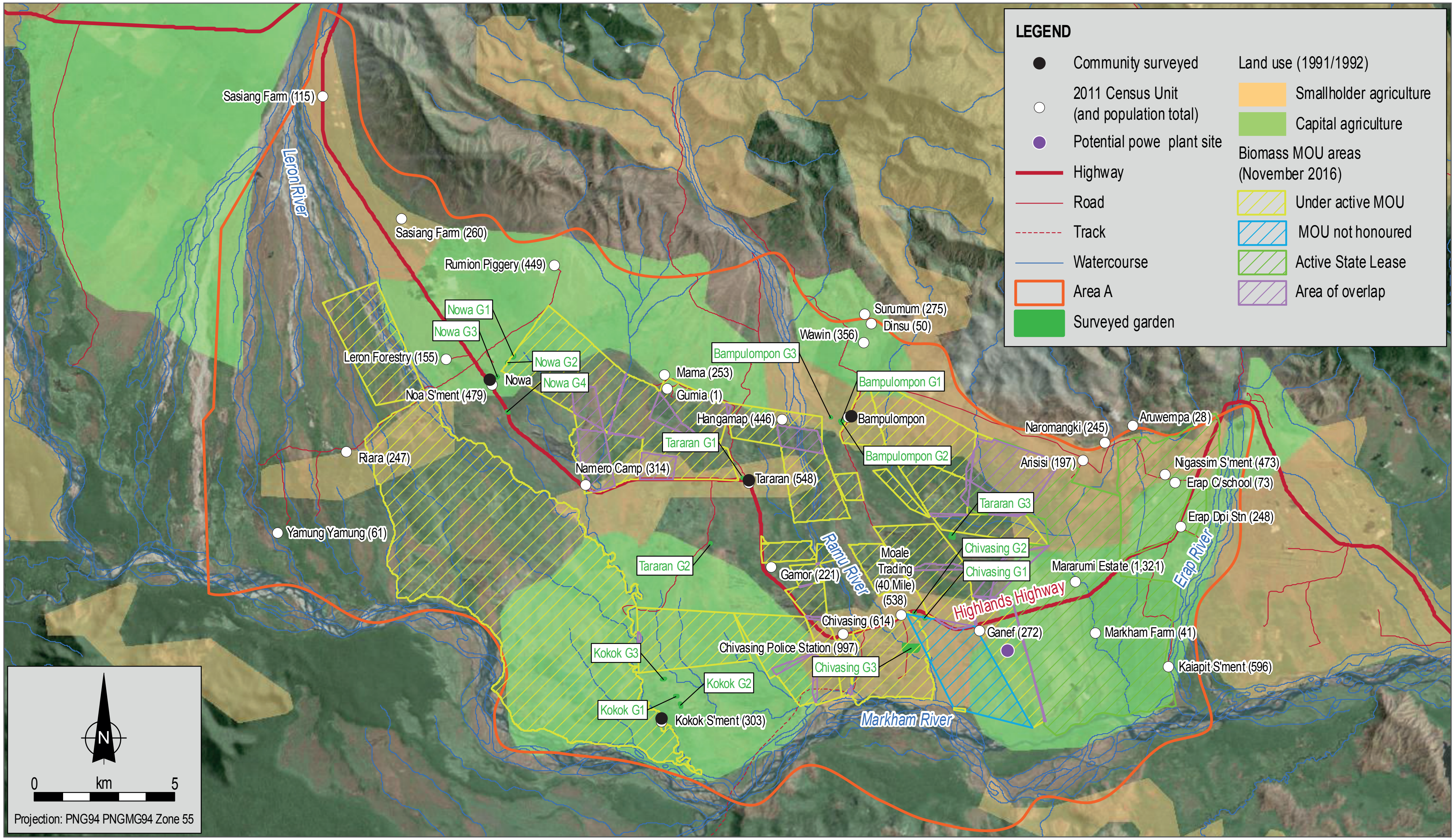
Most land within the study area has low agricultural potential caused by poor soils (on flat to gently sloping alluvial plains, terraces and fans), low average annual rainfall (1250 mm), a long dry season of eight months (April to November) limiting the planting period and growing season for most food crops, and frequent inundation in floodplain areas.

A comprehensive study of land resources and land use potential was conducted in the Markham Valley during the early 1970s. Over 40% of land between the Erap and Leron rivers was found to be inappropriate for food production, a further 40% was classified as low to very low suitability, and only 18% was regarded as having moderate to low suitability (Table 6.24). Figures for tree crops were even lower, though agricultural land potential could be improved through extensive reclamation (i.e., drainage, use of fertiliser, weed, pest and disease control, and protection against land movement/erosion).

CAPITAL AND SMALLHOLDER AGRICULTURE, GARDENS SURVEYED AND MOU AREAS

PNG Biomass Markham Valley I Environmental Assessment Report

FIGURE 6.34



Source: SIMP, 2017.

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Table 6.24 – Land Suitability between the Erap and Leron Rivers

Suitability Class	Arable (Food) Crops				Tree Crops			
	Without Improvement		With Full Improvement		Without Improvement		With Full Improvement*	
	Ha	%	Ha	%	Ha	%	Ha	%
Very high	Nil	0	Nil	0	Nil	0	Nil	0
High	Nil	0	9,460	19	Nil	0	Nil	0
Moderate to high	Nil	0	6,888	14	Nil	0	Nil	0
Moderate	5,321	10.5	12,606	25	Nil	0	13,238	26.5
Moderate to low	3,815	7.5	4,437	9	6,084	12	11,203	22.5
Low	4,807	10	61	0.1	6,619	13	13,352	27
Low to very low	1,691	3	1,110	2	6,153	12	4,591	9
Very low	13,439	27	5,702	11.5	7,720	16	273	0.5
Nil	20,855	42	9,664	19.5	23,352	47	7,271	14.5

Source: Tables 59, 60, 62 and 63 (Knight, 1973; as cited in SIMP, 2017)
* Full improvement includes drainage, use of fertiliser, weed, pest and disease control, and protection against land movement and erosion.

There is low- to moderate-intensity agricultural pressure in the region and despite population densities being low (1 to 20 persons/km2), with steady population increase and in-migration the area may become vulnerable to the effects of land degradation and declining crop yields. However, some of this can be offset by the adoption of land improvement practices, better access to markets and wage employment in and around Lae city.

Land Use

Three broad land use categories occur within the study area. While the boundaries of these systems were identified in the early 1990s and mapped at a broad scale (1:500,000), they provide a good representative overview of conditions in the region. These categories are:

- **Smallholder agriculture** (see Figure 6.34) – generally subject to the land use practices described in the following section (Section 6.3.7.2). Includes lands surrounding Chivasing and its eastern outliers, Tararan stretching west to the Leron River mouth, and between the Tararan outliers of Hangamap/Bampul and the Naromagki communities towards the Erap River in the east.
- **Capital agriculture** (see Figure 6.34) – refers to land engaged for large-scale/commercial agricultural and animal projects. Includes (in relation to the study area) the following:
  - To the east and southeast: (i) the Erap DPI Station used for various food, cash crop and animal husbandry trials; (ii) Trukai Farms where field assessments are similarly conducted on various stock feed options such as sorghum; and (iii) Markham Farm which was previously a cocoa and coconut plantation and is currently being converted to oil palm.
  - In the northern central region, an old cattle ranch now owned by the Morobe Provincial Government (part of which houses the Wawin National High School, Primary and Elementary schools) and includes communities from cultural-linguistic groups located further north.

  - To the southwest, another large former cattle ranch that now contains a mixed community of settlers from Chivasing, the north Watut and other provinces (particularly East Sepik). Land use in this area ranges from tall woody regrowth, and grassland fallows to short and medium-term food gardens and perennial tree cropping.
  - Further west, the former Melanesian Plantation (now a forestry station).
  - In the northwest, the extensive land holdings associated with Rumion Piggery that also encompasses communities from cultural-linguistic groups located further to the west (i.e., Adzera), north and south (in the Menyamya District).

- **Unused or 'no' agriculture** – primarily contains a mixture of forest, tall woody regrowth and grassland fallows. Includes the balance of the study area, however, short- and medium-term food gardens, and well-established perennial tree cropping was also noted in these areas during the surveys.

These findings emphasise that the grasslands in the study area have all been subject to subsistence or garden activity.

6.3.7.2 Subsistence Patterns and Purchased Foods

Food Gardens

Food gardens throughout the study area are generally made in one of two environments:

- Grasslands (for short-term, smaller intensive plots of commercial vegetable crops).
- Tall woody regrowth fallows (for larger plantings of mixed staples and vegetables, triploid bananas, perennial trees such as betel nut, cocoa and coconut).

House gardens are rare (except in Kokok) due to the potential for problems with domesticated pigs and a preference for clean, uncluttered living areas. Most people plant flowers and decorative shrubs (widely regarded as a sign of good character) as well as shade and some fruit trees close to their residences. Larger food gardens located some distance from settlements usually include temporary living quarters (Plate 6.38).

The dominant staple crop throughout the region is triploid banana (*kalapua* variety), a high yielding cultivar that tolerates poor and challenging growing conditions. Triploids are introduced to gardens four to six months after other important carbohydrate sources have become established. These gardens usually include sweet potato, taro and diploid banana (often inter-planted with corn, sugarcane and greens), as well as yam and cassava, which are generally planted separately. Chinese taro (another hardy staple species) is often planted beneath triploid banana and maintained there for several years, or as a mono-crop in other plots.

Plate 6.38 – Mixed Garden Crops and House in Bampu

Source: SIMP, 2017.

A number of other fruits and vegetables and perennial tree crops are commonly planted in gardens, and some are planted in older gardens, areas of woody regrowth and near residences in established settled areas. The dry seasonal environment is well suited to certain cash crops, particularly mango, and a large unsatisfied demand exists in both the highlands and Lae for good quality sweet fruit.

Marita pandanus is also grown; its fruit contain significant amounts of vegetable oil and the precursor to Vitamin A (beta carotene). Coconuts are an important source of vegetable oil, sterile drinking water and food (though none are processed into copra for sale), and the carbohydrate-rich seeds (but not the flesh) of breadfruit are also considered a significant food source. *Galip* (*Canarium*) nuts are commonly collected when in season, more usually gathered from self-sown (yet highly valued) trees in the secondary regrowth and more distant surrounding forest. Other planted nuts tree species are also grown.

Sago is the most important staple food not grown in garden plots. Most palms are planted along watercourses and in swampy or high water table areas, but some are self-sown. Field survey results show that respondents processed sago approximately 13 times per year, each involving a four-day absence from their community, and undertook this work predominantly (65%) as a family.

Several psychoactive substances (or stimulants) are grown and consumed in the study area, including tobacco, betel nut and betel pepper, and marijuana (although the latter is sold and consumed discreetly).

Field surveys provided an indication of current variability between specific cropping regimes, the areas of land involved and their geographic spread, and highlighted distinctions between the extensive longer-term activities of established landowners (such as those in Chivasing and Tararan) and more temporary intensive practices of settlers (for example, Kokok and Nowa).

Natural Resource Use

Several edible fruits and vegetables are still sourced from wild or self-sown plants on a semi-regular basis (and generally by women) in forested or secondary regrowth areas, including new leaves and seeds of the tulip tree (*Gnetum gnemon*), leaves of certain ferns, ginger (*Zingiber officinale*), *karakap* (*Solanum nodiflorum*), and a local fig (*Ficus copiosa*, or *kumu mosong* in Tok Pisin), bamboo shoots and fruit, watercress, *kangkong* (*Ipomoea aquatic*, an aquatic plant related to sweet potato), the growing tips of a number of palms, and various fungi and mushrooms. Self-sown yam tubers (*Dioscorea spp*) and the fruit of wild mango, pawpaw, passionfruit (yellow), guava and *yasi or gorgor* (*Amomum aculeatum*) are also commonly collected, particularly when new food gardens are being established away from settled areas. The surveys found that 92% of respondents spent six days per month collecting wild or self-sown materials including medicines.

During the surveys, people reported catching and consuming many types of introduced and native fish species, including trout, tilapia, catfish, carp, besta fish, sand fish, big fish, scale fish, crocodile, eel, shellfish, shrimp and tortoise.

The surveys found that 63% of respondents reported that they went fishing 8 days every month, using hook and line (33%), net (26%) and poison (10%), with approximately half the catch sold and the other half eaten. Fishing is more significant in those communities located close to waterways, popular when river levels are low or on weekends, and often regarded as women's work. Several problems were also reported with water quality due to upstream spoilage, and concerns were raised about its possible impact on aquatic food sources.

The respondents are divided as to whether there was less or about the same abundance of fish than before. For the respondents who felt there are less fish now, the most common reason stated for the driver of change was increased population (44%). Over-fishing and floods each accounted for 13% of the answers, although 19% of the respondents also blamed river pollution.

Fishponds were only recorded during surveys in 10 of 137 households surveyed, of which 6 are operational. All but one of the fish ponds are in Tararan village.

Hunting is undertaken by males who have appropriate dogs and a knowledge of the best locations, materials and techniques (i.e., traps, spears, and bows and arrows). Eighty-nine per cent of respondents hunt an average of seven days per month (ten at Kokok) and 44%of respondents prefer to hunt during the dry season near watercourses, in grasslands and forested areas. The significance of hunting in the communities is limited to a more specialised, recreational activity conducted on weekends or when living in garden or bush camps away from settled areas.

Bandicoot (34%) and wild pig (31%) are the most popular prey. Flying fox, bat, wild fowl (for their eggs and meat), cuscus, parrot, cockatoo, lizard, snake, various small bird species, rat, wild chicken and duck, wild cattle, buffalo and cassowary are still hunted for food. While primarily for self-consumption, some of this produce is occasionally sold, usually in cooked form, at local markets and canteens. As population increases and agricultural expansion cause greater disturbance throughout the region, game meat is becoming less popular and considered a more time consuming pursuit with prey becoming somewhat harder to find.

Women and children collect seasonal specialties including dry wood insects, sago grubs, grasshoppers, green frogs, Christmas beetles and cicadas. Women are also skilled at collecting many plants used for bush medicine, including for cuts and wounds, sickness and stomach aches, skin problems, malaria treatment, pain, and fever, nose and eye problems.

In addition, villagers collect many other products from the surrounding forest, grasslands and waterways for use in their daily lives. These include:

- Bark—for medicine (inhaled and topical), fine and course rope/string (binding and tying), string bags, baskets, fishing nets, material/cloth.
- Cane—for building construction (wall cladding and flooring), strong rope (binding and tying), fishing net frames, brooms.
- Clay—for pot manufacture (now rare).
- Flowers—for decoration (garden, house and personal), medicine, perfume, magic/poison.
- Grasses—for roofing material, netting, string, woven wall panels, indicator of swamps/land subject to waterlogging.
- Leaves—for medicine (ingested, inhaled and topical), perfume, poison, roofing material, baskets, matting, brooms, stretchers/carrying devices for children/the ill (now rare), wrapping the dead (now rare), body decoration, abrasive surface/sandpaper, wrapping food for cooking and storage, (toilet) paper.
- River stones—for medicine (heated and inhaled).
- Sap—for glue (manufacturing items and hunting/trapping), perfume, poison, medicine (topical), decoration (personal, tattoo ink ingredient).
- Seeds and fruits—for medicine (ingested), body decoration, jewellery, toys, hunting season/location indicator, fishing lure, ink, poison.
- Timbers—for building construction (wall cladding, framework, flooring, posts and rafters) tools and furniture (bows, chairs, paddles, rafts/canoes and tables), fencing, carvings, firewood, windbreaks, shade, hunting and gathering location indicator.
- Vines and stems—for strong rope (binding/construction and tying), hunting (catching bats and birds with spiny tendrils).

Domesticated Animals

Village chickens and pigs are the most common animals kept for sale and self-consumption (particularly on special occasions) in the study area; 39% of respondents reported an average of three pigs per household. Some families also raise cattle (for meat) (3% of households in Chivasing and Tararan) and horses (for riding).

Purchased Food

Households in the region buy only very small quantities of locally grown food as most people generate an adequate volume and range of nourishment for their own needs; markets are primarily used for convenience or ‘top-up’ purposes.

Processed foods are also purchased and can constitute between a third and one half of some families' diets, particularly rice, tin fish and meat, noodles, salt and cooking oil. Items are usually purchased in Lae to take advantage of cash flow opportunities (after selling other items of local produce), lower prices, wider range and prior transport arrangements, with local trade stores and canteens reserved for occasional impulse or last minute shopping.

The 40 Mile Market is the most important daytime fresh food market in the study area (see Plate 6.30). Other markets are either very small (e.g., Erap Bridge) or operate during the evenings/night-time (41 Mile, see Plate 6.31) and focus on providing a limited range of cooked and processed convenience foodstuffs for the passing Highlands Highway traffic.

6.3.7.3 Trade of Agricultural Products

As reported in Section 6.3.3.9, the sale of agricultural products was reported to be a major income stream in the study area. Most of the market-based income from sale of crops and other items (e.g., banana, pig, chicken, fish) was concentrated in the two major villages of Chivasing and Tararan.

Seventy-one per cent of survey respondents were growing cash crops at the time of the survey, including peanuts, cocoa, coconut, pineapples and watermelons, as well as betelnut and tobacco. Markets also provide an opportunity to sell most commercial poultry (live, cooked, eggs and occasionally ducks) and some pork (usually cooked and sometimes village or game varieties), while the sale of larger animals and volumes of commercial pigs generally involve transportation to Lae or the Highlands.

6.3.7.4 Labour Inputs

Labour inputs for food and cash crop production are generally gender based, i.e., certain tasks tend to be conducted by men and others by women (although there is increasing flexibility in these roles).

In low-intensity agricultural systems based on long-period tall woody regrowth fallows, which are common in this region, men and women contribute similar amounts of labour for agricultural production, although tasks are generally divided. Men are generally responsible for heavier work, including clearing large trees, digging drains and clearing paths, while women are responsible for lighter work, including clearing lighter fallow vegetation, weeding, and most planting and harvesting of crops.

Where land use is more regular (particularly at Nowa and in grassland areas), less labour input is needed to clear fallow vegetation and a greater burden for agricultural tasks tends to fall on women. However, in these areas men maintain a keen interest in the management and maintenance of cash cropping activities.

The division of labour according to gender is further discussed in Section 6.3.9.

6.3.7.5 Food Security

Food shortage is not a major issue for villagers in any of the communities surveyed, with people generally reporting surplus production and a ready market for most of their crops in Lae. Any disruption to their food supply is readily compensated by purchased food, particularly imported rice and flour.

Drought and flooding events have caused declines in food garden productivity and sago processing and/or loss of significant areas agricultural land. In these situations, communities have been able to take advantage of their strategic location along the Highlands Highway where they sold small quantities of fuel, trade store items, betel nut and other foodstuffs to the passing traffic.

There were several reports of minor production losses from pest and diseases. These comments indicated some occasional problems, however, the issues were not sufficient to seriously threaten food supply in any of the communities surveyed.

6.3.8 Cultural Heritage and Archaeology

The focus of this section is on tangible and immovable cultural heritage (i.e., cultural heritage *sites*); however, associated intangible cultural heritage sensitivities (e.g., songs and stories linked to particular sites) were also encountered during the cultural heritage and archaeological investigation.

6.3.8.1 Study Limitations

The cultural heritage fieldwork and assessment were constrained by several factors including:

- Site access was not always possible due to factors such as the rugged/remote locations or because appropriate permission could not be obtained.
- The assessment was based on three communities (Chivasing, Tararan and Bampu) within the study area.
- Landownership disputes were encountered that resulted, in one instance, in abandoning site recording. Intra-clan disputes (between sub-clans/families) were also encountered, with the group declining to conduct a pre-arranged interview.
- Limited female participation (only one woman) occurred in interviews and none in subsequent surveys.
- Limited archaeological site survey was conducted and ground surface visibility encountered was often minimal due to the density of vegetation.

6.3.8.2 Wampar Religion and Ontology

Pre-contact Wampar religion consisted mainly of beliefs in ancestor spirits (*mamafe*). *Mamafe* are everywhere, although they are thought to be concentrated in special places [termed *rop*]’. During cultural heritage interviews undertaken as part of the investigation with the Feref clan, a distinction was made between *ramazazeran* (spirit) and *mamafe* (spirit taken physical form). For example, in the context of sacred/spirit cultural heritage sites, clan members may consult with, or talk to, ‘the spirits’ (i.e., *ramazazeran*) upon approaching/visiting/exploiting a particular *rop* to avoid otherwise dangerous and potentially fatal active ancestral engagement such as being chased by a spirit snake (i.e., *mamafe*). While *mamafe* are often said to take the form of animals, they can also appear as people, and in some cases be physical forms yet amorphous.

A *rop* is a sacred/spirit site, generally associated with a particular drainage feature (i.e., river, creek, spring, pool, swamp) and/or vegetation type, particularly forest (*dau*) or sago (*montam*). Former settlement sites (*gabapik*) are almost always also regarded as spirit sites. Ancestral spirits are often associated with the outcomes of success or failure in warfare or hunting, and becoming sick, although the latter can also be linked to sorcery.

In Wampar tradition, early (or ‘first’) names given to areas are important, which is evident in clan cultural heritage sites. Often area and site names represent the name of the person (usually a male ancestor of the clan or partilineage) who first found/claimed/discovered the place or feature in question. Holzknecht reported that ‘true’ names of sacred Wampar sites (i.e., *rop*) can become taboo.

6.3.8.3 Pottery Traditions

In a regional historic context, only a limited number of Wampar pottery-making villages existed. Three centres of production are evident, each of which can be differentiated in terms of ware shape:

- Adzera pots: the smallest, with flatter bottoms and flattened, flared or ‘everted’ rim.
- Salamaua pots: larger, with pointed bases, a slight inward curve of the body near the rim, and commonly decorated with applied ‘nubbins’ in a line around the rim.
- Watut pots: including Lower Watut—‘which is very similar to Adzera and “extinct” Laewomba [Wampar] wares’—and Middle Watut—larger and deeper than Adzera ware, sharply pointed base, with a waisted ‘neck’ beneath the rim which is the focus of decoration.

Informants at Chiatz and Mare villages stated during 2012 surveys (not for this Project) that they often observe potsherds at former settlement sites and that ‘each Wampar clan had its own, distinctive, decorative style’. However, the pottery industry is now defunct and the Wampar obtain pottery from their neighbours to the west, the Adzera. While Wampar no longer manufacture clay pots, it is not uncommon to see such pots in use (or discarded) within villages and hamlets.

6.3.8.4 Totemic/Symbolic Affiliations of Clans

As discussed in Section 6.3.3.3, Wampar social organisation is based around clans (*sagaseg*). The Wampar practice of naming places after shade-trees was a catalyst for totemic associations with trees, birds and other animals. For example, the group of people who had taken to sitting under the shade of the Ngempang tree became Orogazog clan. Some clans also associated with elements or features of trees more generally (e.g., trees with holes or the twigs of trees).
Table 6.25 lists the names of these clans along with their totemic/symbolic affiliation, as identified during cultural heritage interviews for this investigation. A comparison/correlation of the survey findings with those of Dangerfield (1971) and Hitchcock (2012; both as cited in SIMP, 2017) shows that animals (e.g., crocodile) and particular terrain (e.g., flood zones) can also function as clan totems/symbols, and illustrates the complex nature of these kinds of social groupings as they are traced back in time and intersect with different local oral histories and settlement dynamics.

Table 6.25 – Wampar Clan Names and Totemic/Symbolic Affiliation Details

Clan	Clan Totem/Symbol Details			
	Wampar Name	Common Name	Species Name	Notes
Chuaif	Aif	Cotton tree kapok	(*Bombax ceiba var. leioclada*)	The shape of the Aif leaf was a characteristic decorative motif used in traditional Chuaif clan pottery manufacture
Feref	Sangra	Noni plum	(*Morinda citrifolia*)	This is the totem of the major Feref clan – Feref Pisangra. It is *tambu* for Feref clan members to eat the noni plum
Jeanganzon	Jeanganzon	Hollow pit-pit wild sugarcane	(*Saccharum spontaneum*)	The origin of Jeanganzon clan involves grouping beside a patch of hollow pit-pit at Ononaporon and the wind was blowing through the broken canes making musical notes like a flute. Wampar: *jeang* (cane) and *zon* (hole)
Muswarang	Mus/Mos	Tall coconut (Markham tall)	(*Cocus nucifera*)	Wampar: *warang* (very tall). This type of coconut is also commonly referred to as the Markham tall. Muswarang was also the name of a male ancestor who was extremely tall
Oroganzon	Oroganzon	Tree with hole	N/A (any tree with a hole)	Wampar: *orog* (tree) and *zon* (hole)
Orogazog	Ngempang (ripe fruit of)	Yellow cheesewood	(*Nauclea orientalis*)	In particular it is the ripe fruit of this tree which is the clan totem. Wampar: *orog* (tree) and *zog* (ripe fruit)
Orogwangin	Orogwangin	Tree twigs	N/A (twigs from any tree)	Wampar: *orog* (tree) and *wangin* (twig)
Owangrompon	Ngowang Owang	? ?	? ?	Wampar: *owang* (type of bird); *Ngowang* (type of tree). The name and call of the Owang bird sound the same (i.e., onomatopoeia); brown coloured bird with a long hooked beak. Ngowang is a fruiting tree; the Owang bird feeds on the fruit of this tree (also flying foxes)

6.3.8.5 Cultural Heritage and Archaeological Sites

Recorded Sites

A key differentiation can be made between oral tradition sites and archaeological sites, although the site classes are not mutually exclusive:

- Oral tradition sites (also termed cultural sites or cultural heritage sites) are those known to local communities. They are part of clan (or 'tribe') oral history and have contemporary significance.
- Archaeological sites include any place that has evidence of past human activity, whether it is known to local communities or not.

The site types referred to during the cultural heritage survey are: spirit, origin, clay source, former settlements, skull house, burial/cemetery, historic, warfare and archaeological.

In total, 62 cultural heritage and archaeological sites were identified during the Project-specific surveys, in prior studies and by review of NMAG data, of which 43 were located inside the study area. Table 6.26 presents a summary table of these sites, their distribution is presented in Figure 6.35, and some examples are shown in Plates 6.39, 6.40 and 6.41. No cultural heritage or archaeological sites were identified at the proposed Ganef power plant site during interviews or survey.

Eight previously recorded sites identified during the NMAG review could not be verified during the Project-specific surveys, probably as a result of a combination of two factors: 1) these site records are fragmentary and sometimes unclear, and 2) most of the cultural heritage site information appears to have come from villages/hamlets other than those included in the cultural heritage survey (e.g., Kokok). As a result, it was not feasible to assess their significance and potential duplication.

Plate 6.39 – Example of a Historic Site (Montar-4)

Source: SIMP, 2017.

Plate 6.40 – Example of a Spirit Site (KRQ)

Source: SIMP, 2017.

Plate 6.41 – Example of Material Culture (Clay Pots) Previously Recovered From a Settlement Site (KSE)

Source: SIMP, 2017.

Table 6.26 – Summary of Cultural Heritage and Archaeological Sites

Clan Site No.*	NMAG Code#	Site Name	Site Type	Date Recorded	Location Method†	Location Coordinates†
Chuaif-1	-	Manamen	Spirit (creek)	14-Oct-16	Map (indicative)	449013, 9264860
Chuaif-2	-	Ngarusi	Spirit (sago)	14-Oct-16	Map (indicative)	449013, 9264860
Chuaif-3	-	Tafin	Spirit + Campsite	14-Oct-16	Map (indicative)	449013, 9264860
Chuaif-4	-	Zaruzaru	Spirit (spring)	14-Oct-16	Map (indicative)	449013, 9264860
Chuaif-5	-	Zun Zanum	Settlement	14-Oct-16	Map (indicative)	449013, 9264860
Chuaif-6	-	Fanchun	Clay Source	14-Oct-16	Map (indicative)	449013, 9264860
Feref-1	-	Zowa	Spirit (forest)	22-Oct-16	GPS (equestrian survey)	457439, 9277690
Feref-2	-	Nowa Gagar	Spirit (forest)	22-Oct-16	GPS (equestrian survey)	457499, 9277819
Feref-3	-	Romed Antzoz	Spirit (sago) + Warfare + Burial	22-Oct-16	GPS (equestrian survey)	456062, 9277295
Feref-4	-	Afi Diritz	Spirit (sago) + Warfare	22-Oct-16	GPS (equestrian survey)	456257, 9277440
Feref-5	-	Kiamung (Fidifid)	Spirit (sago/spring/creek)	20-Oct-16	Map (indicative)	457113, 9277159
Feref-6	-	Gororop	Spirit (forest)	20-Oct-16	Map (indicative)	457313, 9277159
Feref-7	-	Moaen	Spirit (forest)	20-Oct-16	Map (indicative)	457313, 9277159
Feref-8	KRX	Apem	Spirit (sago)	22-Oct-16	GPS (ground survey)	454712, 9277983
Feref-9	-	Mazung Araran	Settlement + Spirit (forest)	22-Oct-16	GPS (equestrian survey)	456944, 9277696
Feref-10	-	Pamap	Settlement + Spirit (forest)	22-Oct-16	GPS (equestrian survey)	457011, 9277435
Jeanganzon-1	-	Roar	Spirit (forest/creek)	14-Oct-16	Map (indicative)	445113, 9265959
Jeanganzon-2	-	Mangkui	Spirit (forest/pond)	14-Oct-16	Map (indicative)	443613, 9263960
Jeanganzon-3	-	Sinamun	Spirit (forest)	14-Oct-16	Map (indicative)	445113, 9265959
Montar-1	-	Buzampungeran	Settlement + Spirit	18-Oct-16	Map (indicative)	436614, 9286659
Montar-2	-	Pomwai	Spirit (creek)	18-Oct-16	Map (indicative)	436614, 9286659
Montar-3	KRW	Suvi	Spirit (creek/sago) + Campsite	22-Oct-16	GPS (ground survey)	453689, 9277515
Montar-4	-	Yasi Naron Plane Crash Site	Historical (Plane Wreck)	22-Oct-16	GPS (equestrian survey)	457433, 9275924

Table 6.26 – Summary of Cultural Heritage and Archaeological Sites (cont'd)

Clan Site No.*	NMAG Code#	Site Name	Site Type	Date Recorded	Location Method†	Location Coordinates†
Montar-5	-	Watag Ampes	Spirit (sago/forest)	22-Oct-16	GPS (equestrian survey)	456837, 9276787
Montar-6	-	Ubit Ampes	Spirit (forest)	22-Oct-16	GPS (equestrian survey)	456781, 9276437
Muswarang-1	KRR	Saog (Renan)	Settlement + Spirit	21-Oct-16	GPS (ground survey)	460686, 9275097
Muswarang-2	KRQ	Ngarowantong	Spirit (creek)	21-Oct-16	GPS (ground survey)	459991, 9275103
Muswarang-3	KRP	Kiamung	Spirit (creek)	21-Oct-16	GPS (ground survey)	458601, 9275507
Muswarang-4	-	Zozazoz Ngaromimi	Spirit (creek/sago)	18-Oct-16	Map (indicative)	448613, 9264460
Muswarang-5	-	Taganeg	Spirit (creek/sago/forest)	18-Oct-16	Map (indicative)	448613, 9264460
Muswarang-6	-	Pipu	Settlement + Burial	18-Oct-16	Map (indicative)	448613, 9264460
Muswarang-7	-	Ngasano	Spirit (forest)	18-Oct-16	Map (indicative)	448613, 9264460
Muswarang-8	-	Boanzem	Spirit (creek)	18-Oct-16	Map (indicative)	448613, 9264460
Muswarang-9	-	Ganteb Amuteran	Spirit (creek)	18-Oct-16	Map (indicative)	448613, 9264460
Oroganzon-1	KRY	Ngarowagef	Settlement + Cemetery + Spirit	24-Oct-16	GPS (ground survey)	451699, 9278706
Oroganzon-2	KRZ	(Old) Tararan	Settlement + Cemetery + Spirit	24-Oct-16	GPS (ground survey)	451572, 9277595
Oroganzon-3	KSA	Kraferngam	Spirit (sago)	24-Oct-16	GPS (ground survey)	451598, 9275934
Oroganzon-4	KRT	Ngamifinang	Spirit (sago/forest)	24-Oct-16	GPS (ground survey)	451042, 9277771
Oroganzon-5	KRS	Posap	Spirit (creek)	24-Oct-16	GPS (ground survey)	450771, 9277066
Oroganzon-6	KSB	Ngamida Airr Azi Wogowag	Spirit (sago)	24-Oct-16	GPS (ground survey)	451719, 9277672
Oroganzon-7	KSC	Gengo	Spirit (pool)	24-Oct-16	GPS (ground survey)	451582, 9277739
Orogazog-1	KRO	Ondropovon	Settlement	20-Oct-16	GPS (ground survey)	443632, 9269124
Orogazog-2	KRU	Edzofonafi	Burial + Spirit	20-Oct-16	GPS (ground survey)	451892, 9270748
Orogazog-3	-	Ofagamag	Clay Source	14-Oct-16	Map (indicative)	456113, 9234660
Orogazog-4	KRM	Buvri	Historical (Plane Wreck)	20-Oct-16	GPS (ground survey)	451892, 9270748
Orogazog-5	KRN	Narogoan	Skull House	20-Oct-16	GPS (ground survey)	445100, 9271520

Table 6.26 – Summary of Cultural Heritage and Archaeological Sites (cont'd)

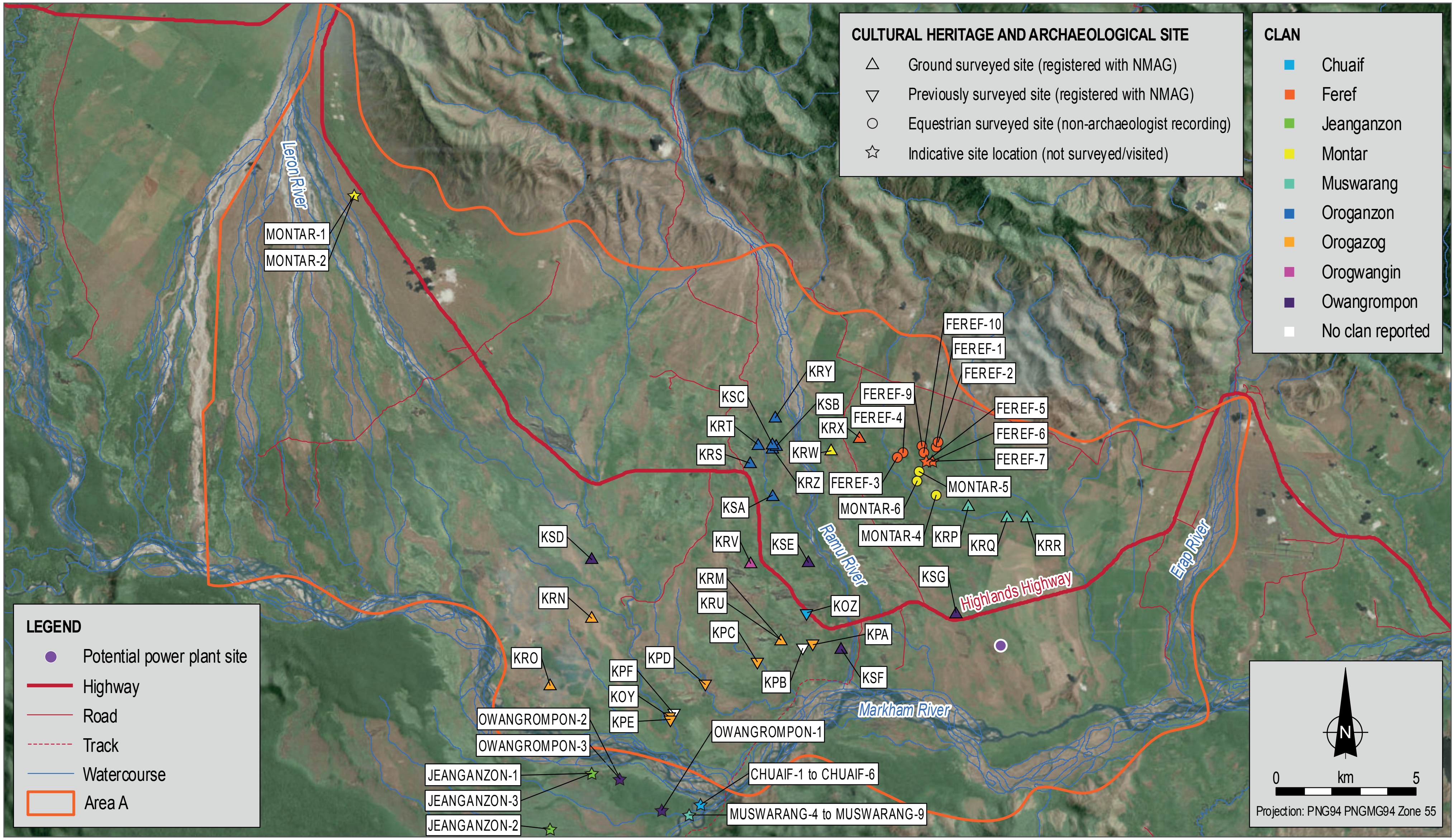
Clan Site No.*	NMAG Code#	Site Name	Site Type	Date Recorded	Location Method†	Location Coordinates†
Orogwangin-1	KRV	Gabamos	Settlement + Spirit	21-Oct-16	GPS (ground survey)	450800, 9273478
Owangrompon-1	-	Ngaromimi	Spirit (creek)	14-Oct-16	Map (indicative)	447613, 9264660
Owangrompon-2	-	Chuachi	Spirit (spring)	14-Oct-16	Map (indicative)	446113, 9265759
Owangrompon-3	-	Zung	Spirit (forest)	14-Oct-16	Map (indicative)	446113, 9265759
Owangrompon-4	KSD	Yadzub	Settlement + Spirit	25-Oct-16	GPS (ground survey)	445105, 9273617
Owangrompon-5	KSE	Ngampor	Settlement + Spirit	25-Oct-16	GPS (ground survey)	452881, 9273525
Owangrompon-6	KSF	Parag	Settlement + Spirit	25-Oct-16	GPS (ground survey)	454053, 9270389
Owangrompon-7	KSG	Furif	Archaeological (potsherds)	23-Oct-16	GPS (ground survey)	458151, 9271735
Chuaif	*KOZ*	*Gabraun*	*?*	*01-Nov-15*	*GPS (ground survey)*	*452834, 9271723*
Orogazog	*KPA*	*Yazu*	*Spirit + Historical*	*28-Oct-15*	*GPS (ground survey)*	*453035, 9270561*
?	*KPB*	*Wuruleanan*	*?*	*28-Oct-15*	*GPS (ground survey)*	*452679, 9270451*
Orogazog	*KPC*	*Wuruleanan/Bampulompon*	*?*	*27-Oct-15*	*GPS (ground survey)*	*451051, 9269970*
?	*KPD*	*Bampulompon*	*?*	*26-Oct-15*	*GPS (ground survey)*	*449187, 9269162*
Orogazog	*KPE*	*Mali Aki Amos*	*Settlement*	*26-Oct-15*	*GPS (ground survey)*	*447932, 9267901*
?	*KPF*	*?*	*?*	*27-Oct-15*	*GPS (ground survey)*	*448039, 9268137*
Orogazog	*KOY*	*Mali Aki Amos*	*Settlement*	*26-Oct-15*	*GPS (ground survey)*	*447896, 9268000***

Note, shaded sites are outside the study area; rows in italics are sites recorded within the study area prior to the Project-specific surveys.
* Information for the Montar clan is not available.
# Sites subsequently registered with NMAG on their National File have acquired a corresponding three-letter code; otherwise the site interview code is retained.
† Location data collected during ground/equestrian survey used a high-sensitivity handheld Garmin GPSMAP 60CSx. Coordinates are presented in Universal Transverse Mercator (UTM) and refer to WGS84 Zone 55S with the first coordinates representing the easting and the second the northing. Indicative coordinates were estimated during clan cultural heritage interviews using 1:100,000 scale topographic maps.
** A digit was missing from the location coordinates entered on this site record. Therefore, the northing was rounded/approximated (this site is also a potential duplicate of KPE).

CULTURAL HERITAGE AND ARCHAEOLOGICAL SITES

PNG Biomass Markham Valley I Environmental Assessment Report

FIGURE 6.35



Source: SIMP, 2017.

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Site Type Overview

Spirit sites were easily the most common site type recorded during the assessment (30 or 86% of the 35 sites within the study area), including multicomponent sites (e.g., spirit + settlement + burial). Wampar spirit sites were regarded as being of high significance to the identifying clan. These sites also have high educational significance in terms of educating the next generation of cultural heritage custodians. While these sites were routinely understood to have the potential to make trespassers/intruders disoriented and/or sick (potentially with fatal consequences), certain sites were singled-out as being particularly *tambu* (forbidden/dangerous), e.g., site KSA (the 'home of Goa').

After spirit sites, former settlements represent the most numerous site type identified within the study area (11 sites, 31%). These sites have a strong association with patches of secondary regrowth forest or *dau,* and are also invariably located close to a water source (often in the form of a confluence of two creeks). Former settlements have high scientific significance given their potential to provide information on human occupation in the local area, and the Markham Valley region more generally, especially in the absence of comparative archaeological studies in the region. These sites also have high cultural/social/political significance to local people, especially given their general association with burials and cemeteries, and also towards affirming clan and/or 'tribe' identity and history of land ownership.

Four sites were identified as having isolated burials (graves) associated with them, two of which relate to single burials spatially removed from former settlements, while the remaining two are linked to former settlements that were occupied for a relatively short period of time. These burial sites have high cultural/social/political significance to the identifying clans. Oral history records the name, sex and clan of these deceased individuals, although only approximate locations were known as the graves were not marked. In addition, two cemetery sites were identified and both were also directly associated with former settlement sites. These cemetery sites have high cultural/social/political significance to the local community and are considered part of the former settlement site.

A single skull house site was identified during the survey and has high cultural/social/political significance to the local community (particularly the wider Chivasing 'tribe') along with educational significance for the next generation of traditional custodians. The site has a ritual context that remains only partially documented due to its sensitive nature (i.e., linked to cannibalism). The site has suffered a high degree of disturbance in the past, but human skeletal material potentially remains in subsurface sediments.

Two historic sites were identified during the assessment – both U.S. Air Force WWII plane crash locations and wreck sites – and are of high historic significance. Furthermore, they have educational significance for local communities as places linked to a time of dramatic change.

Only one exclusively archaeological site was documented in the study area, i.e., this site is not directly tied to the oral traditions and histories of the local community. However, as discussed in 'Recorded Sites' (above), any site displaying physical evidence of past human activity can also be classified an archaeological site, whether that be in the form of durable material culture such as pottery and/or stone tools or in relation to the presence of ethnobotanic plant species. All archaeological sites in the study area have high scientific significance, however, the exclusively archaeological site appears to have low cultural/social significance. Collection of potsherds from this site did not warrant traditional mitigation measures (e.g., no ceremony or consultation with ancestral spirits appears to have been conducted in response to the find/collection); however, degrees of social/cultural/political significance are not necessarily static, and other groups may potentially consider such sites as being more significant.

A key finding in terms of the spatial distribution and significance of identified cultural heritage sites within the study area is that kunai grasslands (the preferred landscape for the Project plantations) appear to be the least significant vegetation community for cultural heritage sensitivities identified by clan landowners. Other vegetation communities (e.g., sago and regrowth forest areas) host the majority of known cultural heritage sites. However, dynamic landscape changes and (or potentially associated with) long-term human occupation in the region means that archaeological sites unknown to the local communities have the potential to be situated within subsurface sediments of grasslands, and rapid grassland development also has the potential to cover sites.

6.3.9 Gender and Human Rights

6.3.9.1 Papua New Guinea's Gender Context

In general, gender marks a primary form of social differentiation and inequality in Papua New Guinea. Women tend to be more adversely affected than men by development projects because most women often do not have the same material endowments as men, cannot take advantage of new economic opportunities, and lack access to and ownership of land, assets, and financial literacy. Some of these themes have been previously discussed in Section 6.3.3.

The United Nations Development Program’s Gender-related Development Index (UNDP GDI), based on the sex-disaggregated Human Development Index (HDI), is defined as a ratio of the female to the male HDI. It measures inequalities through health, education and command over economic resources. Papua New Guinea scores poorly on the UNDP GDI and its ranking in gender development continues to fall. In 2002, Papua New Guinea had a GDI of 0.536 (ranking 106), while in 2006 the country’s GDI had fallen to 0.529 (ranking 124).

In 2010, the Gender Inequality Index (GII) was introduced and reflects gender-based inequalities in three dimensions—reproductive health, empowerment, and economic activity. In the 2014 GII index, Papua New Guinea was attributed a value of 0.611, ranking it 140 out of 155 countries.

Across most cultures in the country, social behaviour and value are usually defined in respect to the principles of gender and age, and as such conventionally allocates a series of ‘male’ and ‘female’ defined jobs. Male are often seen as ‘head of the household, although their role within the household may be limited to earning cash income, while women tend to be restricted to the domestic domain, including the trading of agricultural produce. Some typical gender-specific tasks are listed in Table 6.27.

Table 6.27 – Household Roles Typically Assigned to Genders

Typical Roles for Men	Typical Roles for Women
♦ Clearing land for cultivation ♦ House building ♦ Hunting and warfare ♦ Political representation ♦ Competitive inter-group gift-giving ♦ Funerary contributions ♦ Compensation payments for the resolution of disputes	♦ Cooking, washing and cleaning ♦ Caring for elders, children and the disabled ♦ Gathering garden produce and subsistence foods ♦ Fishing ♦ Care for domestic animals and gardens (weeding) ♦ Collecting water and firewood ♦ Trade/marketing of agricultural produce ♦ Supporting the church and community

While these traditional divisions persist in contemporary society, modernisation has increased women's vulnerability and led to new forms of gender inequality and marginalisation, including access to, and equitable shares in, development benefits, and representation on decision-making business entities.

6.3.9.2 Gender, Kinship and Land

The current status of women in the Project area reflects familiar social characteristics of their gender roles found across Papua New Guinea. However, there are also cultural nuances specific to being a 'Wampar woman'.

As noted previously, the Wampar are a patrilineal society and bride price has traditionally represented the value of women to a kin group. However, not all Wampar pay bride price; it may be paid following a couple's production of one or more children or to demonstrate strength and wealth. With the demise of sibling-exchange marriage (potentially the basis for the first marriages of Wampar ancestors) and where some women have been raised in several different households, conflict is generated over entitlement to bride price, especially more recently, when Wampar women have married into ethnic groups prepared to pay large sums of money. Rising monetary bride price payments can compensate for the considerable costs of education. Informants during the surveys relayed that the present bride price level was three pigs and PGK30,000.

In Wampar culture, the practice of sharing one's name is also tied into bride price. The namesake of a woman receives a share of the bride price, while the namesake of a man is expected to contribute in the raising of the bride price.

Projects that direct compensation and revenue payment to male landowner groups are driving the purchase of young women (i.e., 13 to 14 years of age) as new wives and are leaving initial wives and children economically vulnerable with little or no income and family support. In most project developments, landowner women or daughters become targets for outsiders to marry as a perceived means to establish a foothold in the communities and access to income producing assets like land.

In Wampar, women (as producers of food) have access to clan land parcels for foraging and can, therefore, be considered to have 'use rights' to land. However, women rarely have decision-making powers with regard to land ownership, lease or commercial uses; their brothers are usually the custodians of the kin group's property, responsible for any political decision concerning it. It is this lack of agency in decision-making that renders them disadvantaged in development contexts where land resources and access to land are central.

The Constitution of Papua New Guinea provides for gender equity and equality, but customary law, recognised by the Constitution, discriminates against women in relation to rights and property; PNG law generally does not provide clear principles or guidance in terms of land or other rights in relation to marriage, divorce or on widowhood, thereby falling short of providing women with equal rights with men, especially in relation to property.

6.3.9.3 Gender and Education

The educational profiles for the study area have been previously described in Section 6.3.6. Key gender trends were as follows:

- Female literacy levels lagged behind those of their male counterparts, although the gap was narrower in Chivasing than other study area villages.
- Twenty-eight per cent of the present population of study area respondents were said to be attending school at the time of the survey: males 31% and females 24%.
- Female attendance for years 9 to 12 was marginally higher than that of males and their absentee rate was lower than males. Moreover, achievement of Year 12 was only marginally different between the genders. This is contrary to the national trend where attendance of females at school tends to drop off in years 9 to 12 as they take up more domestic duties or prepare for marriage.
- Anecdotally, there is a complete absence of women in post-secondary training or degree courses.

6.3.9.4 Gender-based Violence

The term ‘gender-based violence’ (GBV) is broadly defined as violence directed against a person due to his or her socially prescribed ‘gender’. It is an action that is undertaken using force, and the nature of this violence may be physical, psychological, emotional, economic or sexual in nature.

Family and sexual violence (FSV) often takes the form of sexual, physical and emotional abuse by spouses, partners, family members, friends, neighbours or others, and usually occurs in the place where a person should feel safest (e.g., their home or gardens).

Médecins Sans Frontières/Doctors Without Borders (MSF) previously operated a family support centre in the Angau Memorial Hospital in Lae that provided comprehensive treatment and psychosocial care, with a particular emphasis on victims of domestic and sexual violence. The team provided free, comprehensive medical and counselling services to an estimated 6,500 patients in 2012. This support centre has now been handed back to the hospital, however, MSF continue to provide technical support.

In all villages surveyed, women generally felt safe travelling around but the fear of spirits and/or *sanguma* is present. During the surveys, Wampar women reported the fear of meeting sorcerers when walking alone in the bush or working alone in their gardens. These fears are generally of men from their own or another village, who are entered by ‘evil spirits’ and then engage in physical and sexual assault. This generalised fear means that women do not need to focus on the potential wrongdoing of members of their own community.

Women reported that the main issues affecting themselves or their family were ‘alcohol and drugs’ (over 40%), which were also linked to concerns about increasing male promiscuity, while ‘domestic disputes’ (25%) was the second highest ranked response. These were over and above social services such as health and education that normally appear on concern profiles from most SIA surveys in rural areas. In contrast, males ranked ‘financial issues/income’ as their most prominent concern (33%), followed by ‘land disputes’ (15%) and ‘unemployment’ (12%).

The fact that women indicated ‘domestic disputes’ as a prime cause for concern is suggestive that some level of GBV is present, despite its attested absence. Male violence against women occurs, and is usually represented, in terms of ‘fights’ within households. Although the number of times women and men attended a local aid post or hospital for attention to wounds caused by domestic violence was not recorded by the health survey, MSF noted the high rates of violence against women in Lae prior to handing their family support program to the hospital.

6.3.9.5 Access to Employment and Economic Resources

Gender plays a role in access to employment and economic resources in Papua New Guinea. Women, by law, are prohibited from working in certain positions. When compared to men, women are less represented in the urban sectors (including public and private sectors) than in subsistence employment, and are less likely to be working in a registered business enterprise. Women also face difficulty in accessing finance to grow their business, or in access to the justice system to resolve commercial disputes. Low levels of education and literacy also impede their ability to operate profitable businesses.

Within the study area, no women had any experience in formalising a business. As discussed previously, many engage in small-scale trade in nearby markets but a lack of viable transport means that garden produce and food that has been hunted or fished can easily spoil before arrival. In addition, when women sell their own food, many are then ‘helped’ by their husband to make decisions about how it is spent.

6.3.9.6 Human Rights and Socially Vulnerable Groups

A basic concept underpinning human rights assessments is that human rights are held by individuals referred to as ‘rightsholders’, and rights analysis starts and ends with the individuals whose human rights are impacted. Only human beings (i.e., not corporations, governments, NGOs or other institutions) can be potential rightsholders.

The rightsholders relevant to a human rights impact assessment (HRIA) are a subset of a Project’s human stakeholders. The rightsholder group can be very large, including even those who have no direct interaction with the Project but who live close enough to feel the effects of Project impacts. Rightsholder groups included in the Project HRIA are:

- **Potential employees** at all levels, as well as female employees.
- **Contract workers** including transport contractors and security contractors, who have unique human rights risks.

- **Wampar people** including Wampar employees and contract workers, women of Wampar and mixed ethnic descent living in the Project area, children and various other sub-groups of the Wampar population.
- **Horticultural/nursery/plantation workers** predominantly from Wampar heritage.
- **Roadside residents** including Wampar populations on the Highlands Highway.
- **Potentially affected communities** inclusive of non-Wampar, as well as women and children of diverse ages and livelihoods, and vulnerable groups such as:
  - Refugees/internally displaced persons.
  - The elderly and ill.
  - Youths and children.
  - Female-headed households, particularly women who do not belong to the Wampar.
  - People with a disability.

6.3.10 Community Attitudes and Expectations

This final subsection is concerned with summarising community attitudes and expectations concerning the Project, based on information obtained from the Project-specific surveys described in Section 6.3.1.3.

6.3.10.1 Knowledge and Attitudes Toward the Project

As noted in Section 3.4, in response to the household survey question of ‘Do you want the Project to proceed?’, 73% of respondents supported the Project, 12% were unsure and 15% did not want the Project to proceed. While a significant majority, this support level is not as high as that reported for the PNG LNG Expansion Project or PNG LNG Project at the same stage of development, and this is probably due to range of the commercial options that Markham Valley landowners have in respect to land use.

Explanations for answers in the ‘unsure’ category were divided into two main types: 1) 71% wanted more participation and information/awareness; and 2) 41% had concerns about the environment. The predominant reason provided by respondents who did not want the Project to proceed was ‘environmental concerns’ (100% response rates for Chivasing, Nowa and Tararan villages), while ‘lack of progress’ and ‘fairness of payment concerns’ were equally the next most common explanations. Importantly, the concern about ‘environmental’ impacts is not about landscape aesthetics but rather relates to livelihood. The specific environmental issues that recurred are:

- Land degradation, loss of gardening and hunting land, and loss of plant and animal species (each 23%).
- Chemical pollution (15%).
- Soil and water erosion (7%).

- Water and air pollution (6%).
- Deforestation (4%).

In terms of potential community benefits and problems that respondents thought the Project would bring, employment income was uppermost in people's understanding of the immediate benefits, followed by infrastructure, and then cropshares and land rentals, and education/school fees (Figure 6.36).

A consistent pattern was evident across responses to these questions in that people from Chivasing were more vocal in expressing negativity and uncertainty than any of the other four study area villages that were surveyed.

6.3.10.2 Community Development Expectations

Community members reported that alcohol and drugs, and financial issues, were the main issues currently affecting personal/family life (Figure 6.37). However, when separated into gender, the concerns take on a different nature. For males, financial issues become more prominent (33%), followed by land disputes (15%) and unemployment (12%), whereas for women, alcohol and drugs were the principal concerns (40%), while domestic disputes (25%) was the second highest ranked response.

Development priorities recorded during the village surveys, in order of frequency, were water, health services, and transport. The proposed solutions were installation of pumps, more wells and reticulation by pipe to households, and better public motor vehicle (PMV) services.

There are a variety of entities or agreements that affected landowners could incorporate to represent their interests and also manage cropshare and land rentals arising from Project operation, including business groups, incorporated land groups (IGLs), landowner associations, clan agents, special agricultural business leases, landowner companies and other representative entities such as village liaison committees. As reported in Section 6.3.3.7, membership (albeit in low levels) of ILGs, Lancos and Landowner Associations already exists in the study area.

6.4 Ecosystem Services

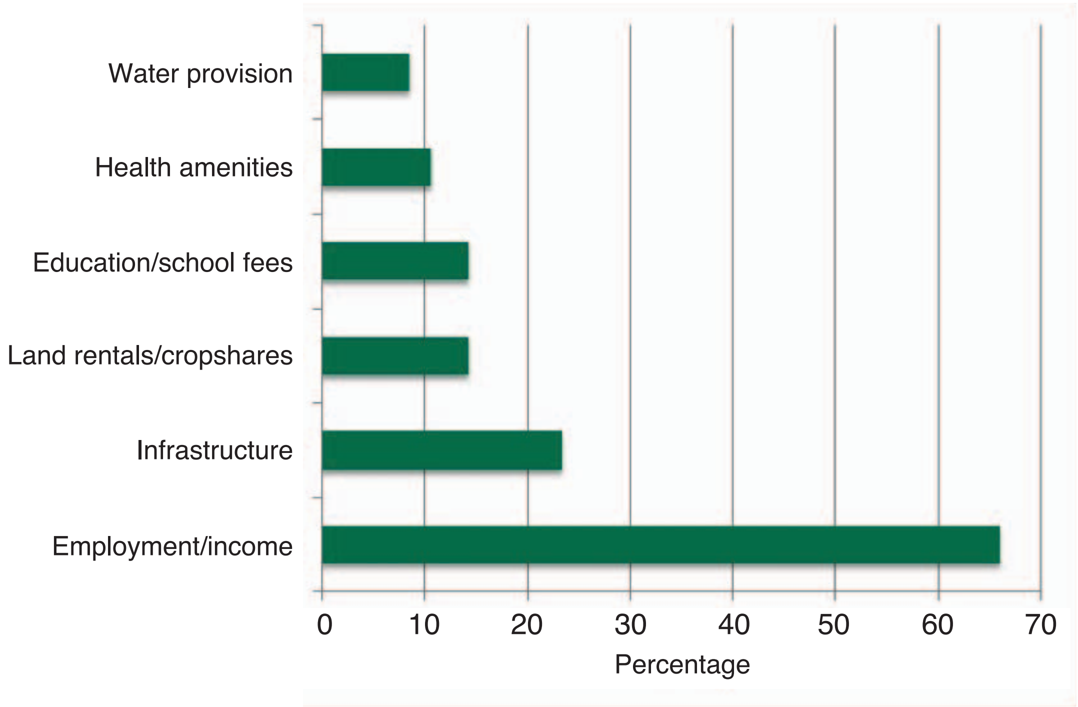
This section is based on information contained in reports that address socio-economic matters (SIMP, 2017), terrestrial ecology (Appendix 6 of this report) and aquatic ecology (Appendix 7 of this report), and the references therein, as well as other information obtained by review of relevant literature. Some of this has also been presented earlier in this chapter.

6.4.1 Background to Ecosystem Services

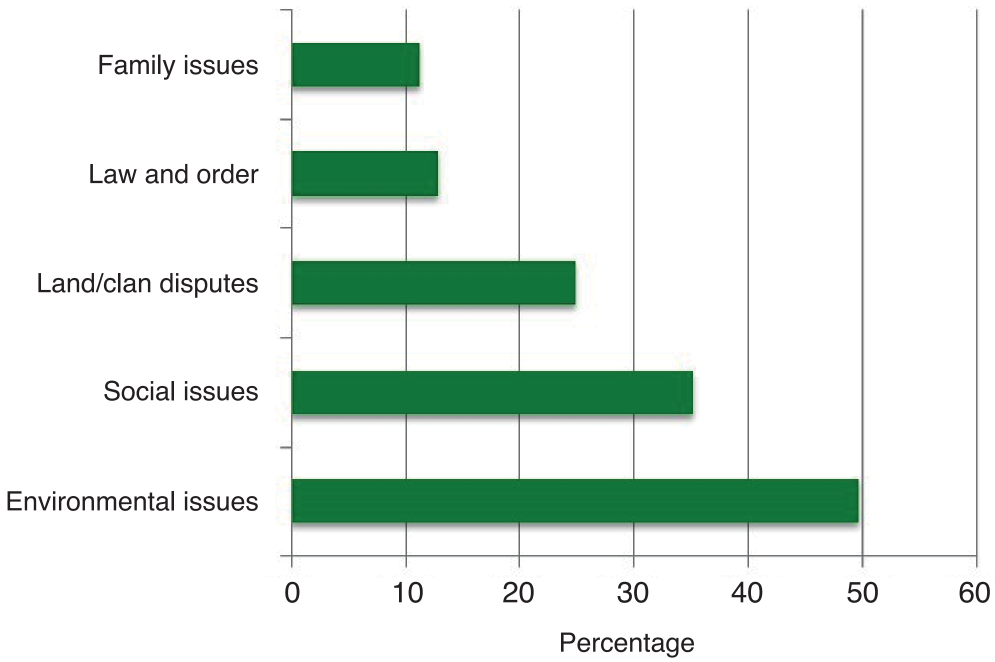
Ecosystem services are the direct (e.g., provision of food plants and animals) and indirect (e.g., through the functioning of ecosystem processes) benefits that people or businesses obtain from the environment. In Papua New Guinea, this concept is largely analogous to 'beneficial uses' or 'natural resource use', which historically has generally been addressed in environmental impact statements and assessments. The current *Environment Act 2000* does not refer explicitly to the term 'ecosystem services' but the concept is implicitly acknowledged by the following requirement of the Act:

FIGURE 6.36

Perceived Benefits



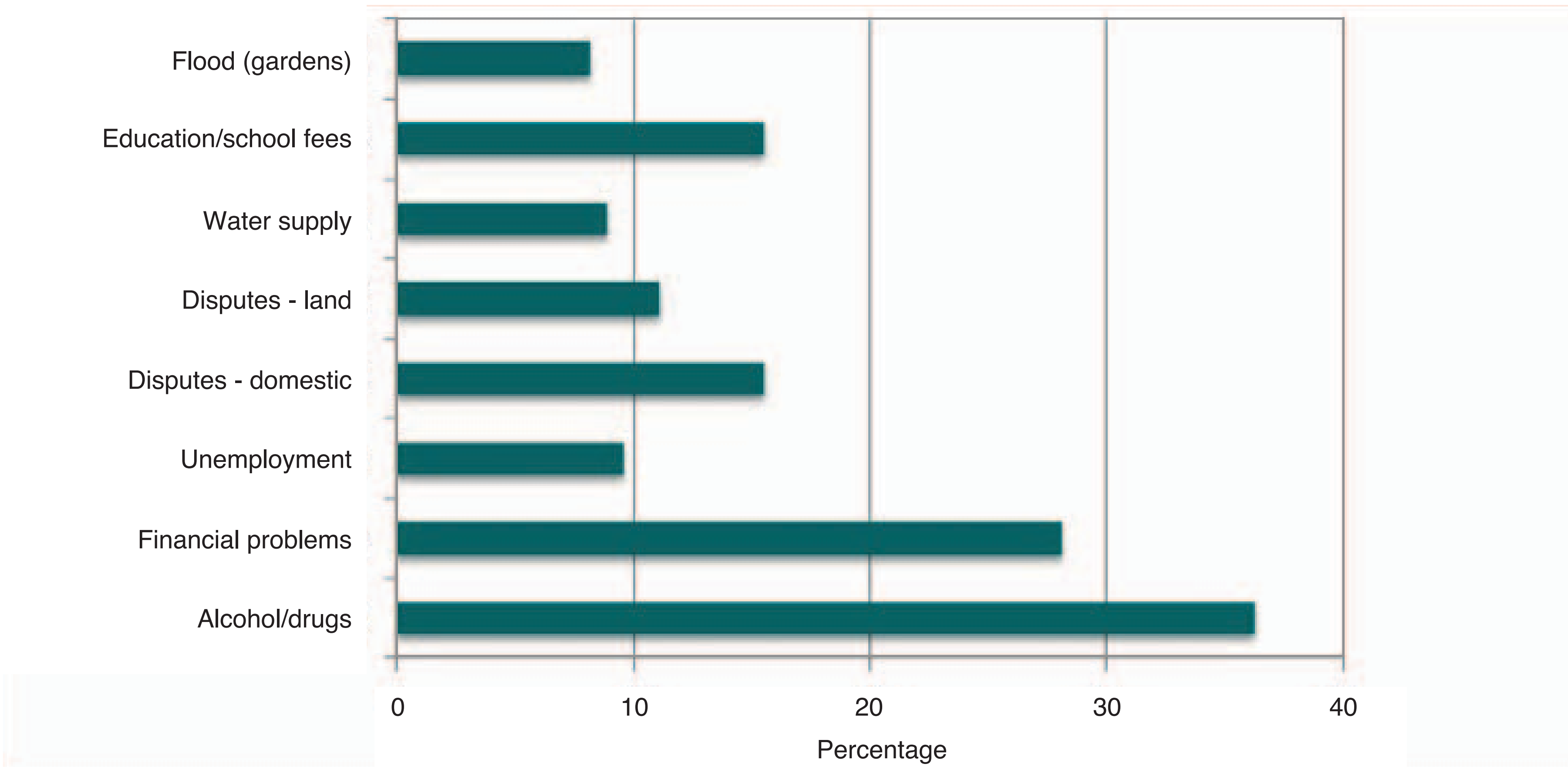
Perceived Problems



Source: SIMP, 2017.

PERCEPTIONS OF PRINCIPAL PERSONAL/FAMILY ISSUES

FIGURE 6.37



Source: SIMP, 2017.

> To regulate the environment impacts of development activities in order to promote sustainable development of the environment and the economic, social and physical well-being of people by safeguarding the life-supporting capacity of air, water, soil and ecosystems for present and future generations and avoiding, remedying and mitigating any adverse effects of activities on the environment.

The concept of ecosystem services is also integral to the IFC Performance Standards (IFC, 2012), particularly Performance Standard 6 – Biodiversity Conservation and Sustainable Management of Living Natural Resources. It has been promoted by organisations such as the WRI (WRI, 2013; as cited in SIMP, 2017, the International Petroleum Industry Environmental Conservation Association and the International Association of Oil & Gas Producers (IPIECA/OGP, 2011; as cited in SIMP, 2017).

Ecosystem services are typically organised into four categories or functions (WRI, 2013; as cited in SIMP, 2017):

- **Provisioning services**: the goods and products people obtain from terrestrial and aquatic ecosystems, such as food from agriculture or hunting/gathering, freshwater, timber, construction materials and medicinal plants.
- **Regulating services**: the benefits people obtain from the ecosystems' control of natural processes, such as climate and disease control, purification of water and air, control of pests, natural hazard mitigation and water flow regulation.
- **Cultural services**: the non-material benefits people obtain from ecosystems, such as spiritual wellbeing, sacred sites and aesthetic enjoyment.
- **Supporting services**: natural processes that maintain other ecosystem services, such as nutrient cycling, and primary and secondary production.

Natural ecosystems provide refuge, foraging and reproductive habitats to flora and fauna, and hence contribute to the conservation of biological diversity and evolutionary processes. A project's effects on biodiversity can therefore potentially affect the delivery of ecosystem services, with consequent community impacts.

Ecosystem services can also be considered in terms of the following two categories (WRI, 2013; as cited in SIMP, 2017):

- Type I: Provisioning, regulating, cultural and supporting ecosystem services over which a project proponent has direct management control or significant influence, and where impacts on such services may adversely affect communities.
- Type II: Provisioning, regulating, cultural and supporting ecosystem services, over which a project proponent has direct management control or significant influence, and where the project directly depends on such services for its operations.

6.4.2 Current Ecosystem Services

6.4.2.1 Overview

The main ecosystem services in the Project area that require consideration are summarised in Table 6.28. Further detail, particularly in terms of provisioning services and resource use, can be obtained from the documents referred to at the start of this section. The information presented in this table represents an initial prioritisation of the various ecosystem services in terms of potential Project-associated impacts, where the Project is viewed as a direct driver of ecosystem change due primarily to the associated change in land use and land cover.

Table 6.28 – Summary of Major Ecosystem Services in the Project Area

Ecosystem Service	Examples	Broad Habitats/Ecosystems Potentially Impacted
Provisioning		
Food – wild game	Boars, bandicoots, cuscus, birds, bats, possums	Woodland, woody grassland and open grassland
Food – crop cultivation	Subsistence and short-term commercial agriculture	Woodland, woody grassland and open grassland, and riverine swamps
Food – livestock	Animals raised for domestic or commercial consumption such as poultry or pigs	Woodland, woody grassland and open grassland
Food – forest produce	Fruits, vegetable, shoots, fungi, mushrooms	Secondary forest
Food – aquatic fauna	Fish, freshwater prawns	Rivers, streams, off-river waterbodies
Biological raw materials	Timber species used for construction or trade, kunai grass used for walls and roofs, poles, sago leaves, flooring, ropes, rafters	Secondary forest
Biomass fuel	Timber and charcoal for cooking and lighting	Secondary forest
Animal products	Tusks, bones, feathers used for self-decoration	Woodland, woody grassland and open grassland, forest
Natural medicine	Wild plants used for medicinal purposes	Woodland, woody grassland and open grassland, forest
Water supply	Water use for consumption, bathing, laundry	Rivers, streams, off-river waterbodies
Regulating		
Surface water and groundwater water regulation	Regulation of sediment loads in clearwater streams; role played in groundwater recharge	Rivers, streams, groundwater
Surface water and groundwater regulation	Vegetation communities regulate surface runoff after high rainfall events	Woodland, woody grassland and open grassland, forest, rivers, streams, groundwater
Erosion regulation	Vegetation communities regulate erosion and sediment delivery to rivers/streams	Woodland, woody grassland and open grassland, forest
Water purification	Vegetation communities and soil filter surface runoff and are a major contributing factor to the area's waste assimilative capacity	Woodland, woody grassland and open grassland, forest
Carbon cycling	Vegetation communities and soil sequester carbon from the atmosphere; cattle emit methane	Woodland, woody grassland and open grassland, forest

Table 6.28 – Summary of Major Ecosystem Services in the Project Area (cont'd)

Ecosystem Service	Examples	Broad Habitats/Ecosystems Potentially Impacted
Cultural		
Traditional practices	Hunting, fishing, use of non-timber forest products	Woodland, woody grassland and open grassland, forest, rivers, streams, off-river waterbodies
Sites of significance	Spirit sites, former settlements, burial/ cemetery sites, skull house sites, historic sites, archaeological sites, oral tradition sites	Woodland, woody grassland and open grassland, forest, rivers, streams, off-river waterbodies
Totemic clan affiliations	Symbolic affiliations of clans with natural features, flora or fauna	Woodland, woody grassland and open grassland, forest, rivers, streams, off-river waterbodies
Recreational	Hunting (with dogs)	Woodland, woody grassland and open grassland, forest
Recreational	Aquatic recreation	Rivers, streams (especially clearwater streams)

6.4.2.2 Provisioning Services

Terrestrial

As indicated in earlier sections of this chapter, large parts of the Project area and surrounds consist of modified habitats including anthropogenic grassland and secondary woody regrowth forest. The remaining forest patches are small, fragmented and degraded remnants. Their restricted size and degraded nature limits their landscape function and they are considered to lack capacity to provide >50% of the needs of local communities for building materials, food, medicine or water. Most land within the Project area has low agricultural potential due to poor soils, a long dry season and frequent inundation in floodplain areas.

Gardens are made in grassland areas as well as secondary woody regrowth areas where these are suitable for bananas and other tree crops, and house gardens are rare (except in Kokok village) due to the potential for problems with domesticated pigs. Sago is the most important staple food not grown in garden plots, with its leaves also being used for roofing and walling material and basket making. Foraging for several edible fruits and vegetables sourced from wild/self-sown plants occurs on a semi-regular basis (and generally by women) in forested or secondary regrowth areas.

Hunting is a common pursuit in the Project area, with 89% of people surveyed for the Project confirming that they continue to hunt. The most common prey is bandicoots (34%), wild pigs (31%), birds (14%) and cuscus (6%). Young boys hunt a variety of birds (particularly doves and pigeons) opportunistically with slingshots. The preferred hunting season is the dry season when prey ventures close to the villages looking for water and food. The bulk of harvested animals are consumed within the family. Half the respondents reported that prey is only used for eating, and half stated they both eat prey and use parts for self-decoration. Eggs of New Guinea Scrubfowl (Kerong) are also periodically harvested from their nest mounds in areas where this species still occurs.

More than 28 different types of plant or flower are utilised by Project area landowners as 'bush medicine', with such materials being collected on average two days per month, and whenever people fall ill. The three most common plants or flowers used as medicine are ginger, noni (*Morinda citrifolia*) and moringa (*Moringa oleifera*). These plants are easily obtained.

In terms of the broader use of local plants, a total of 150 species that are useful to local communities and other stakeholders were identified within the Project area, making up 41% of the total flora recorded in the terrestrial ecology survey. In addition to medicinal plants, these include:

- 34 species of food plants.
- 109 species that are used for a variety of material uses, including for timber.
- 6 species utilised for cultural purposes.
- 20 species that provide important habitat to culturally significant fauna.
- 13 species that are used commercially.

The most important species included material resources such as Nginzib (A*lbizia retusa*), Ngempang (*Nauclea orientalis*), Ompar (*Hydriastele costata*) and Watag (*Ichnocarpus sp.*). Nginzib is highly valued for house foundations, is reported to be the best firewood available, and has also been targeted for fence strainer posts. The yellowish timber of Ngempang is high regarded for furniture making and structural building purposes. The split outer trunk of the tall palm Ompar, which has a restricted distribution in limited areas of lowland forest, is valued for flooring. The vine Watag is the most commonly used and valued rope used for house construction and all tying and binding purposes. Other highly valued timber species such as Taun (*Pometia pinnata*), Kwila (*Intsia bijuga*) and Mon (*Dractomelum dao*) are very rare in the Project area, although they are well known resources in the broader region. The knowledge base within the local communities extends outside the Project area into surrounding landscapes where timber species are likely to still occur more commonly. Other building materials included kunai grass, sago leaves, poles, ropes, bamboo and main building rafters from larger trees.

Useful plants within the Project area include 122 indigenous species and 28 introduced species (19% of the total). Exotic shrub and tree species introduced during cattle grazing enterprises, including *Leucaena*, *Glyricidia* and *Senna*, are widespread throughout the landscape and are facilitating habitat transformation. These introduced resources are more readily available than indigenous species, yet are considered by local informants as being of lower quality. The high numbers of useful plants within village and garden areas include many introduced species that contribute to ecosystem services.

Many flora species have multiple uses and occur across a number of habitats. The dominant life forms of useful plants are trees and shrubs (85 species), with 9 herbs, 20 vines, 8 palms, 10 graminoids (2 bamboo, 8 grass) and 2 ferns. The highest numbers of plants were recorded from village gardens and disturbed areas, followed by secondary forests and degraded primary forests.

A large majority (92%) of people surveyed as part of the SIA confirmed that they collect food, medicines, building materials or other products from the forest. On average, six days per month were expended collecting these items, all of which were rated as abundant by respondents. While acknowledging the importance of these items, respondents did not indicate any perceived shortages; the materials were all in good abundance and in proximity to present residences.

Aquatic

Fishing was observed during the aquatic ecology survey at Maralumi River and Klin Wara, where the watercourses are relatively clear and slow flowing with a diversity of habitats, including deep pools. Nets and hook-and-line fishing practices were observed or equipment identified (Plate 6.42). Villagers at Maralumi River also reported the use of fish poisoning by Derris root (known locally as 'poison rope'). In clearwater streams in Papua New Guinea, freshwater prawns are usually collected by hand by diving, and there was one anecdotal report that this activity takes place in Klin Wara. At Maralumi River, which presented the greatest opportunity for observing fishing practices, even small rainbow fishes (sampled to a maximum length of about 70 mm) were observed being caught and retained for food. Larger fish species (usually exotic species such as carp and golden mahseer) were also reported in these streams, as were prawns. Fishing was also observed in the Markham River.

Plate 6.42 – Hook-and-line Fishing Equipment at Maralumi River (Trib C-2)

Source: Appendix 7.

Watercourses that had flowing water were observed to be used by local people at all locations sampled during the aquatic ecology survey. Uses included water collection, bathing, play and recreation, clothes washing, aggregate extraction and fishing. Water collected from rivers and streams in the Project area may be used in cooking.

The levels of acceptance of exotic fish species in northern Papua New Guinea among local communities remain largely unquantified, as do opinions of palatability and concerns regarding maintenance of native fish populations. Discussions held with fishers at Klin Wara indicated that palatability of golden mahseer (*Tor putitora*) and 'other new species' was considered good, but comment was also made that the flesh is 'loose and unformed' and that the head lacks the 'grease' that local species have, which is considered good eating.

All aquatic species and aquatic habitats are considered to provide provisioning services to at least some portion of the local communities in and around the Project area. However, aquatic provisioning services are likely to be secondary to those provided by subsistence gardening and market produce.

Large aggregate stockpiles were observed in Rumu River (and road works were underway at the time of the field survey). The large alluvial deposits in the Project area and surrounds provide a source of aggregate for road maintenance.

6.4.2.3 Regulating Services

The geomorphology of catchments and watercourses in this area of the Markham Valley dictates hydrological regimes of generally high energy flows and sediment transport. Areas that receive inflows from streams draining the foothills of the Finisterre and Saruwaged ranges to the north of the Project area dissipate energy and trap sediments. This process, which may involve groundwater contributions to flow, is likely to maintain clearwater conditions in Maralumi River and Klin Wara, and hence potentially represents a regulating service. This regulating system may also serve to reduce the impacts of floods and landslides originating in headwaters in the Finisterre and Saruwaged Ranges on downstream settlements, agricultural crops and infrastructure.

Vegetation in and around the Project area regulates and filters surface runoff after high rainfall events, thereby having a role in local erosion and sediment delivery to watercourses, as well as affecting local surface hydrology (notwithstanding the significant sediment sources from higher in the catchment). Vegetation and soils are a major contributing factor to the Project area's waste assimilative capacity, particularly in terms of facilitating breakdown of organic material and (at least for some soils) retarding the transport of toxicants by groundwater. Vegetation also sequesters carbon, although this is offset by cattle grazing in and near the Project area which contributes to methane emissions.

6.4.2.4 Cultural Services

A total of 43 cultural heritage and archaeological sites have been identified within the Project area, many of which are multi-component sites (e.g., spirit/burial/former settlement site). The Wampar have also established totemic associations with trees, birds and other animals, as well as particular terrains (e.g., flood zones), and a link between clan totem/symbol and material culture was identified for Chuaif clan, where the leaf of the cotton/kapok tree was used as a motif by clan potters to decorate their clay pots.

The cultural identity of a subsistence lifestyle in Papua New Guinea is intrinsically linked to natural resources, and this is generally applicable to the Project area. Activities such as gardening, hunting, foraging, fishing and using non-timber forest products therefore represent a significant cultural service to local communities.

6.4.2.5 Supporting Services

The majority of supporting services are reflected above in the assessment of the provisioning, regulating and cultural services that they support. In addition, watercourses in the Project area and surrounds may be used as water supply for existing agricultural practices. Soils also contribute to the fertility of the Markham Valley and its agricultural productivity.

7. Description of the Project Activity

This section should include a detail[ed] description of the proposed activity. This must include description of the main activity and all its sub-activities. Detail[ed] information must be provided on the potential waste stream for each sub-activity and the operating conditions of the waste treatment and disposal systems.

(Excerpt from 'Information Requirements for Permit Applications and Registration of Intention to Carry Out Preparatory Work', DEC Operational Procedure, Schedule 3, General Guidelines on the Additional Information Required to Support a Permit Application for a Level 2B Activity)

7.1 Introduction

The Project has two related major components: 1) establishing up to 16,000 ha of eucalypt plantations, and 2) a new 30 MW power plant consisting of two separate 15 MW units that will be constructed several years apart and which will use the biomass (wood) from the plantations as fuel. Additional components include the plant nursery and ancillary infrastructure. These components, together with wastes, emissions and projected workforce, are addressed in this chapter. Details within this chapter have primarily been derived from information provided by MVB, including a summary information memo (AEL, 2016b) and draft reports (Constructability Study Report and Concept Design Report) prepared by Pöyry (2016a, 2016b, respectively) on behalf of the Project.

A summary of Project inputs and outputs is shown in Figure 7.1. The footprint associated with these components and their constituent parts, e.g., plantations, power plant, log yard, nursery, and roads, is summarised in Table 7.1.

Table 7.1 – Project Component Footprint Areas

Component	Area (ha)*
Plantations net stocked area	16,000
Power plant and log yard	30.83
Nursery	9.58
Roads	450 to 600

Source: Dickinson, pers. com., 2017.
*Note that the Project will encompass additional areas for firebreaks, buffer zones and other minor infrastructure.

7.2 Plant Nurseries

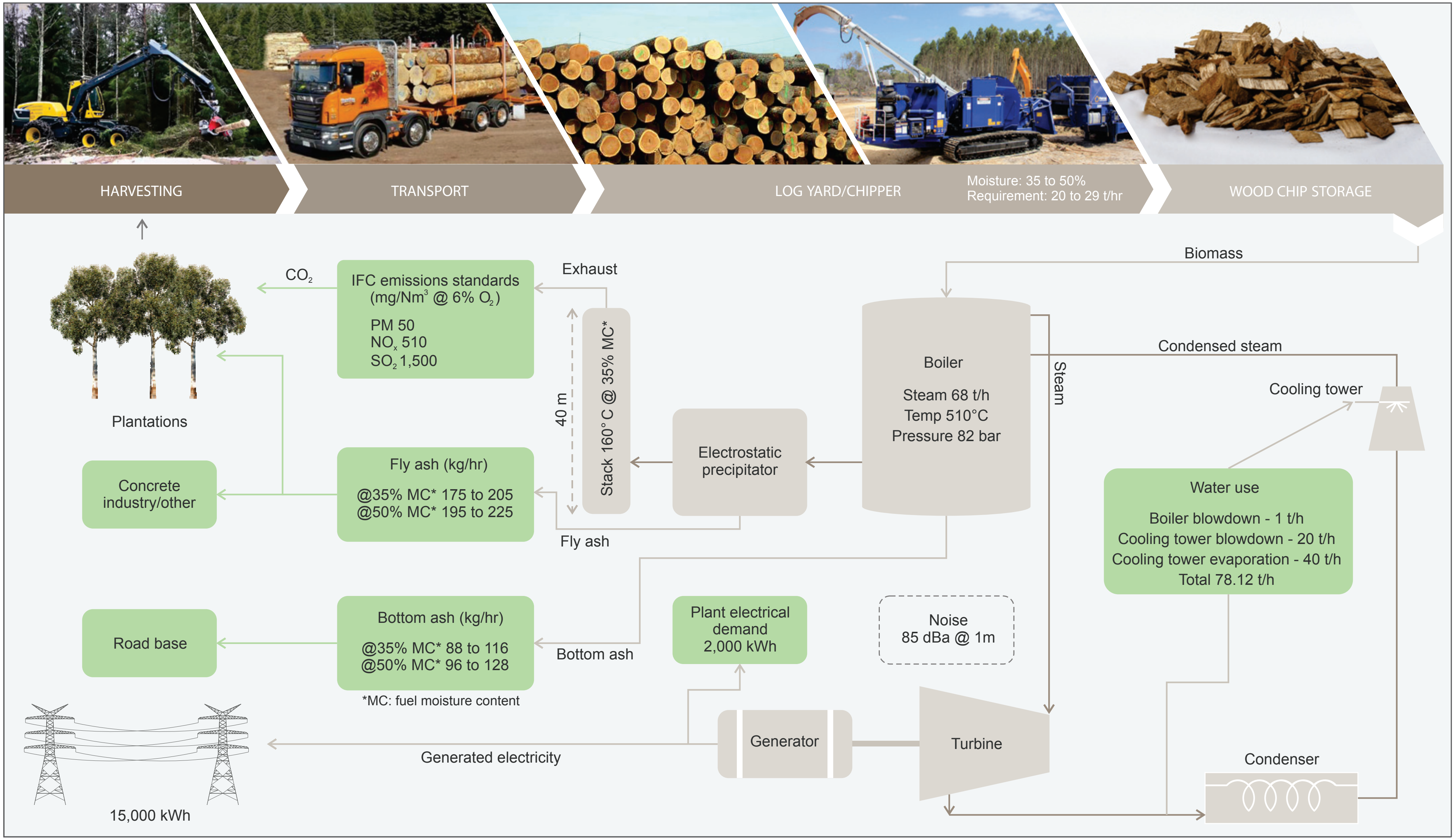
7.2.1 Purpose

The Project will develop plant nursery facilities capable of producing 8,000,000 plants per annum in order to establish plantations (Section 7.3) to produce sufficient biomass to sustainably meet fuel demand for the power plant (Section 7.4).

PROJECT INPUTS AND OUTPUTS

PNG Biomass Markham Valley I Environmental Assessment Report

FIGURE 7.1



Source: adapted from AEL, 2016c.

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7.2.2 Community and Other Nurseries

In order to propagate seedlings and cuttings to support plantation trials/pilot plots within the Project area to date, MVB has established a plant nursery at the Forest Research Institute (FRI) in Lae (Plate 7.1), supplemented by two smaller community-based plant nurseries at Ganef near the Highlands Highway and at Bampu on Wawin Road (Figure 7.2 and Plate 7.2). Throughout the Project life, it is envisaged that community nurseries will provide between 5% and 10% of total required seedling numbers (up to 800,000 plants per annum). These will be community owned and managed, supported by technical and managerial training and mentoring from the Project.

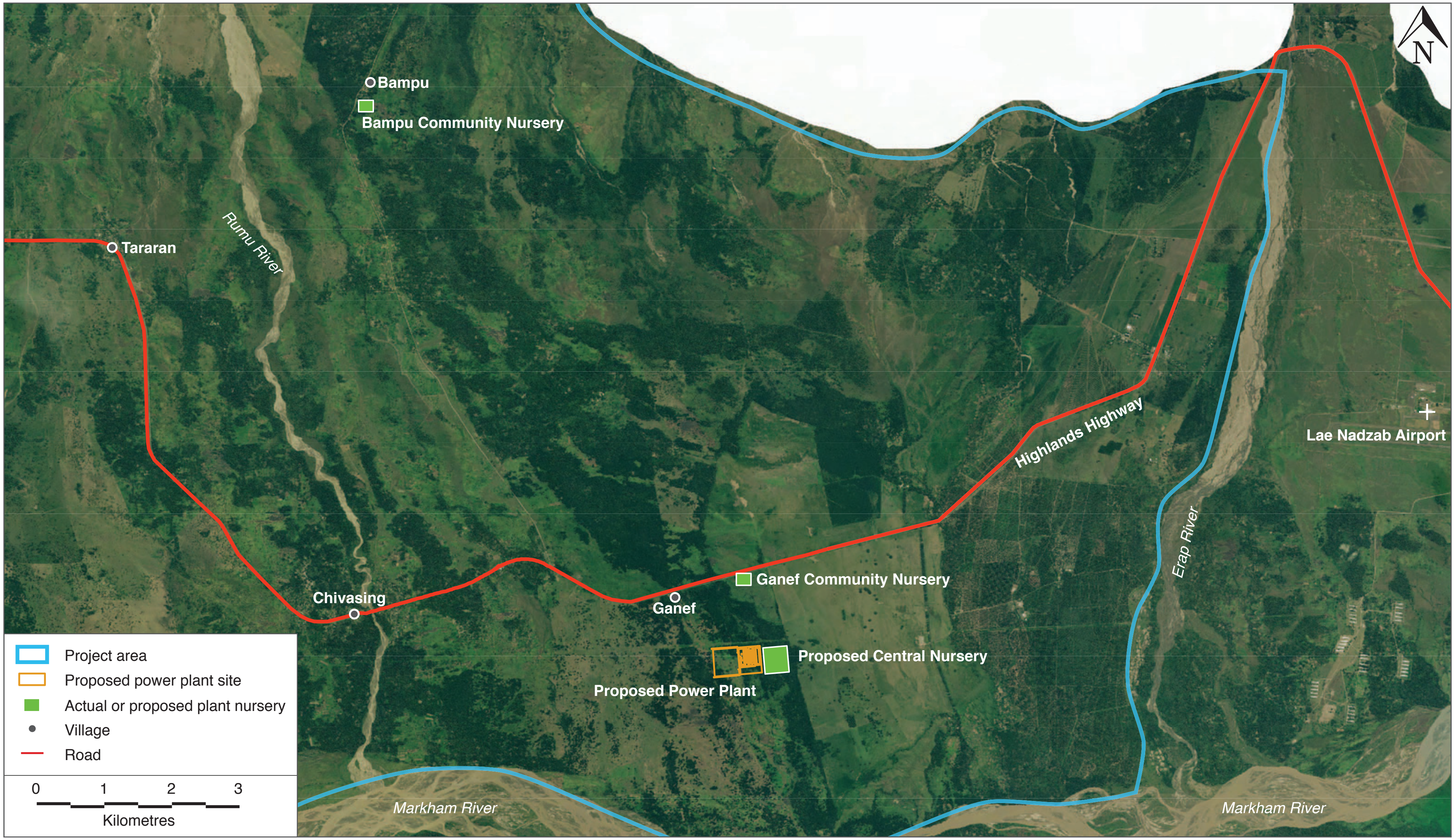
Plate 7.1 – Eucalypt Seedlings at the PNG Biomass Nursery, FRI Lae

Plate 7.2 – Young Seedlings and Cuttings at a Project Community Nursery

PLANT NURSERIES

PNG Biomass Markham Valley I Environmental Assessment Report

FIGURE 7.2



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7.2.3 Central Nursery

A central, fit-for-purpose seedling and propagation nursery will be constructed next to the power plant site in order to utilise common water and power services, security and storage facilities. Markham Valley Biomass proposes to commence construction of the first (temporary) phase of the nursery prior to environmental permit approval and FID (targeted for Q3 of 2017), to facilitate the early plantation establishment period during 2017. Civil works for the permanent nursery will start after FID, at the same time as those for the power plant in Q1 2018. Nursery operations will then be expanded during 2018, with eventual production capacity of 8,000,000 plants per annum being reached by Q1 2019.

The nursery will produce both seedlings (i.e., young plants raised from seed) and clonal planting stock (i.e., grown from cuttings of selected high quality 'mother plants', see Plate 7.2). In the first two to three years of nursery operations, most plants produced will be *Eucalyptus pellita*, grown from seedlings to enable rapid ramp up of production. Nursery production will progressively move towards propagation from cuttings, which provides productivity and quality benefits over seedlings. The Project will aim to produce 100% of plants from cuttings after three to four years of nursery operations. Production will progressively move towards hybrids of *E. pellita* x *E. tereticornis*, since hybrid species tend to exhibit improved growth and vigour. Hybrids of *E. pellita* x *E. camaldulensis* will also be grown for planting in wetter areas and/or where heavier clay soils occur.

As shown in Figure 7.3, the nursery will include four different micro-environments that plants will progress through during their development:

- Mother plant areas: where mother plants will be kept and clonal cuttings initiated.
- Germination/rooting houses: environment-controlled greenhouses with optimised humidity and temperature for the germination of seed and the rooting of clonal cuttings.
- Acclimatisation/'growing on' areas: where young seedlings and clonal plants are provided with sufficient water and nutrition to encourage rapid healthy plant development.
- Hardening areas: where plants are gradually exposed to full sun and watering is reduced to 'harden' plants ready for the planting in the field, thereby reducing mortality in plantations.

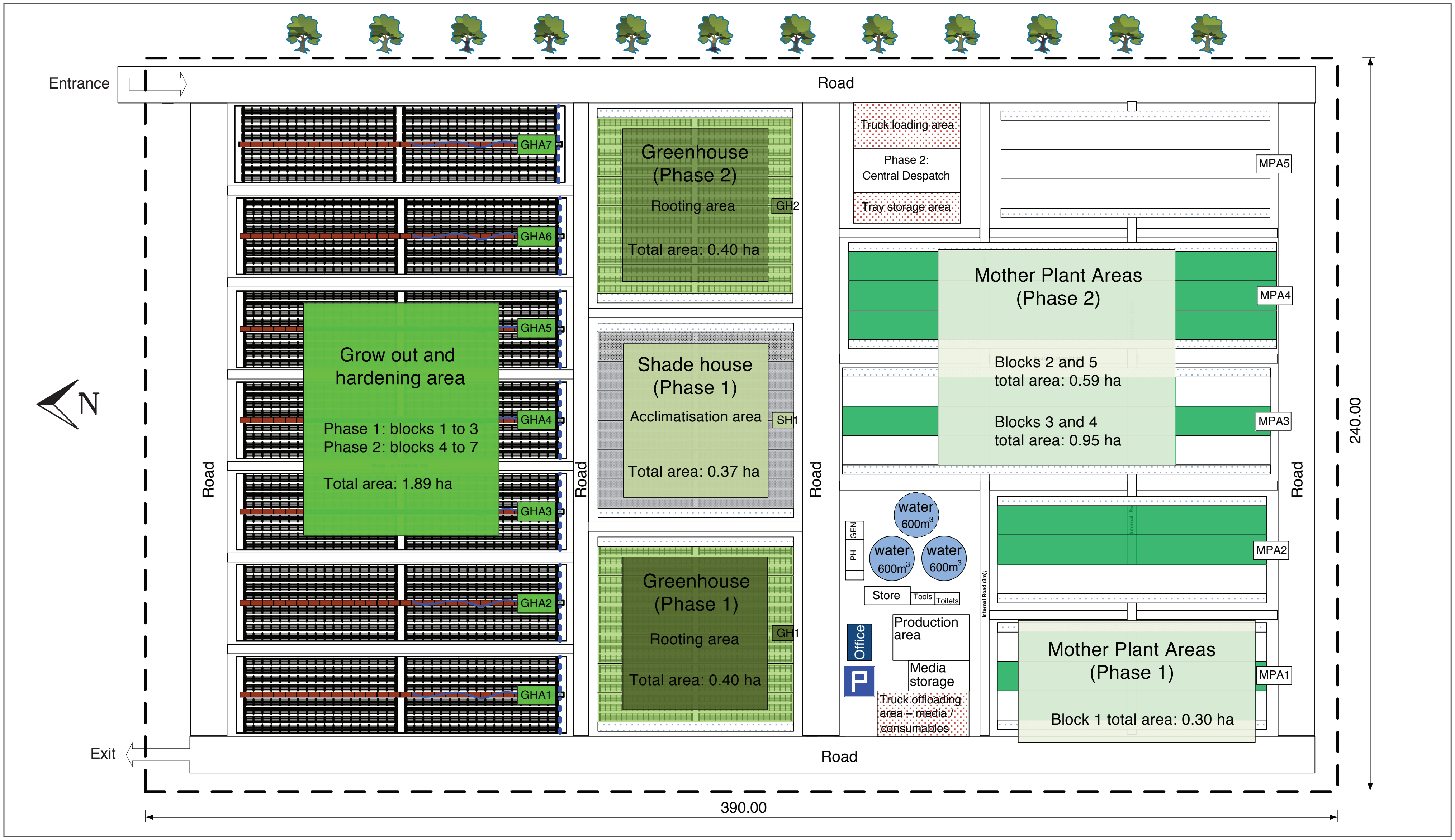
Water for the nursery will be sourced from deep groundwater bores within the power plant and/or nursery site, potentially supplemented by rainwater collected on site (and with a backup water supply being the Markham River if necessary). The first phase of the nursery is estimated to require 15 t (equivalent to 15 m^3) of water per hour, which will ramp up to 30 t/hour at full nursery capacity.

Nursery activities will be managed in accordance with the FAO (1996) Guidelines for the Safe Movement of Germplasm (*Eucalyptus*) and national biosecurity laws including the *Quarantine Act 1953* and Quarantine Regulation 1956, and the *Plant Disease and Control Act 1953* and Plant Disease and Control Regulation 1956.

CENTRAL NURSERY SITE LAYOUT

PNG Biomass Markham Valley I Environmental Assessment Report

FIGURE 7.3



Source: BCC, 2015.

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7.3 Plantations

7.3.1 Overview

Establishment of up to 16,000 ha of eucalypt plantations within the Project area will occur over a seven-year period between 2017 and 2023, with the plantation area to be maintained indefinitely. During this initial phase, plantation establishment will be around 2,000 ha/year on average, with a maximum of 4,500 ha/year in 2019. This scale of plantation estate is proposed regardless of whether one or two 15 MW power plant units are eventually constructed; however, different plantation management regimes will apply should only one unit be constructed (noting that the basis of this assessment is two units) (Section 7.3.6). A summary of plantation operations is shown in Figure 7.4.

7.3.2 Clearing of Existing Vegetation

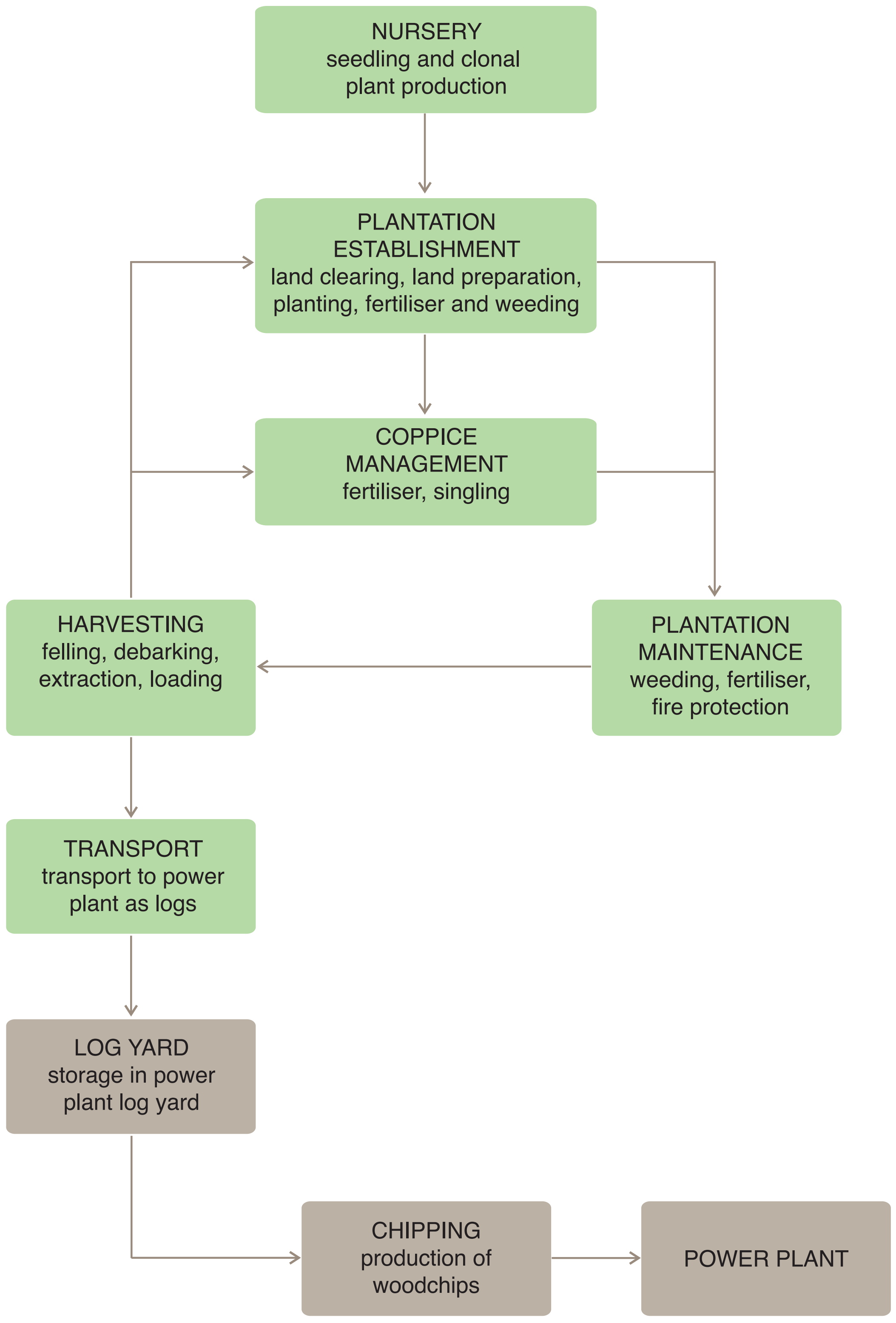
Prior to site clearing and plantation establishment, road access to the proposed plantation areas will be established or upgraded as per Section 7.5.2.

In areas to be planted, existing vegetation will be removed in compliance with FSC guidelines, to enable clear and unrestricted access to the site by manual or mechanical operations. Cleared raintrees (the introduced species *Albizia saman*, as shown in Plate 7.3) will be stockpiled for use as biomass fuel for the power plant. Tree stumps will be retained to minimise soil disturbance, with planting to occur between these.

Cleared non-woody vegetation (e.g., grasses and small shrubs) will be mechanically and/or chemically controlled and retained on site in accordance with FSC guidelines.

Plate 7.3 – Raintrees Within the Project Area

FIGURE 7.4



Source: AEL, 2016b.

7.3.3 Plantation Area

For the purposes of this report, the potential plantation area is defined as those parts of the broader Project area that are under active MOUs with the landowners of Area A, less buffer zones for streams and other environmental and/or social values, as described in Section 7.3.4. At this stage of Project planning, the specific parts of this area to be planted in any one year are not yet defined, as this will depend on landowner negotiations and other aspects of strategic planning.

Where practicable (and subject to landowner negotiations), plantations will be established (and eventually harvested) in a dispersed pattern across the landscape in order to reduce localised impacts on environmental and/or socio-cultural values. Plantations will be established progressively across the Project area in 'compartments' of approximately 20 ha each (e.g., 400 x 500 m), ranging from 5 to 50 ha based on local constraints such as watercourses, existing gardens/crops, or areas of unsuitable soils. Figure 7.5 shows a preliminary design of plantation compartments in the vicinity of the power plant. Within a given compartment, planting (and later maintenance and harvesting) will occur concurrently. Plantation management for the notional 25-year Project life is shown in Table 7.2, although Project planning in relation to plantation management currently extends well beyond this.

Table 7.2 – Plantation Management 2017 to 2041 (ha)

Year	Plantations Established			Total Stocked Area (ha)*	Plantation Thinning			Clearfelled Area	
	Plant/ Replant	Coppice	Total		T1	T2	T3	Plantation	Raintrees
2017	1,600	-	1,600	2,377#	-	-	-	-	-
2018	3,400	-	3,400	5,777	-	-	-	-	-
2019	4,500	-	4,500	10,277	5	-	-	-	381†
2020	1,160	-	1,160	11,437	-	-	-	-	699
2021	1,160	-	1,160	12,596	-	-	-	37	389
2022	1,197	-	1,197	13,755	-	-	-	71	530
2023	1,230	-	1,230	14,915	800	5	-	1,578	-
2024	84	1,493	1,578	14,915	1,130	-	-	1,383	-
2025	-	1,383	1,383	14,915	1,130	-	-	1,105	-
2026	-	1,105	1,105	14,915	1,130	-	-	1,975	-
2027	-	1,975	1,975	14,915	1,130	800	5	1,579	-
2028	-	1,579	1,579	14,915	-	1,130	-	862	-
2029	-	862	862	14,915	-	1,130	-	683	-
2030	-	683	683	14,915	-	1,130	-	1,037	-
2031	605	432	1,037	14,915	-	1,130	800	708	-
2032	628	80	708	14,915	-	-	1,130	1,079	-
2033	1,079	-	1,079	14,915	-	-	1,130	1,101	-
2034	1,101	-	1,101	14,915	-	-	1,130	1,227	-
2035	1,227	-	1,227	14,915	5	-	1,130	1,385	-
2036	1,385	-	1,385	14,915	-	-	-	2,466	-
2037	2,466	-	2,466	14,915	-	-	-	1,927	-
2038	1,927	-	1,927	14,915	-	-	-	2,037	-

Table 7.2 – Plantation Management 2017 to 2041 (ha) (cont'd)

Year	Plantations Established			Total Stocked Area (ha)*	Plantation Thinning			Clearfelled Area	
	Plant/ Replant	Coppice	Total		T1	T2	T3	Plantation	Raintrees
2039	1,452	585	2,037	14,915	400	5	-	1,480	-
2040	1,258	222	1,480	14,915	640	-	-	1,616	-
2041	727	889	1,616	14,915	640	-	-	1,811	-

* Previous year's total stocked area less plantations clearfelled, plus current year's plantations established.
[#] Approximately 777 ha of plantations have been established within the Project area prior to 2017.
[†] The power plant is scheduled to commence operations in Q4 2019; raintrees harvested between 2019 and 2022 will be the initial source of biomass fuel.

7.3.4 Zoning, Intercropping and Buffers

7.3.4.1 Community Zone

Existing villages/hamlets, gardens and other buildings and infrastructure will not be removed by the Project given the need to maintain gardens and food crops located closest to settlements to meet the requirements of communities.

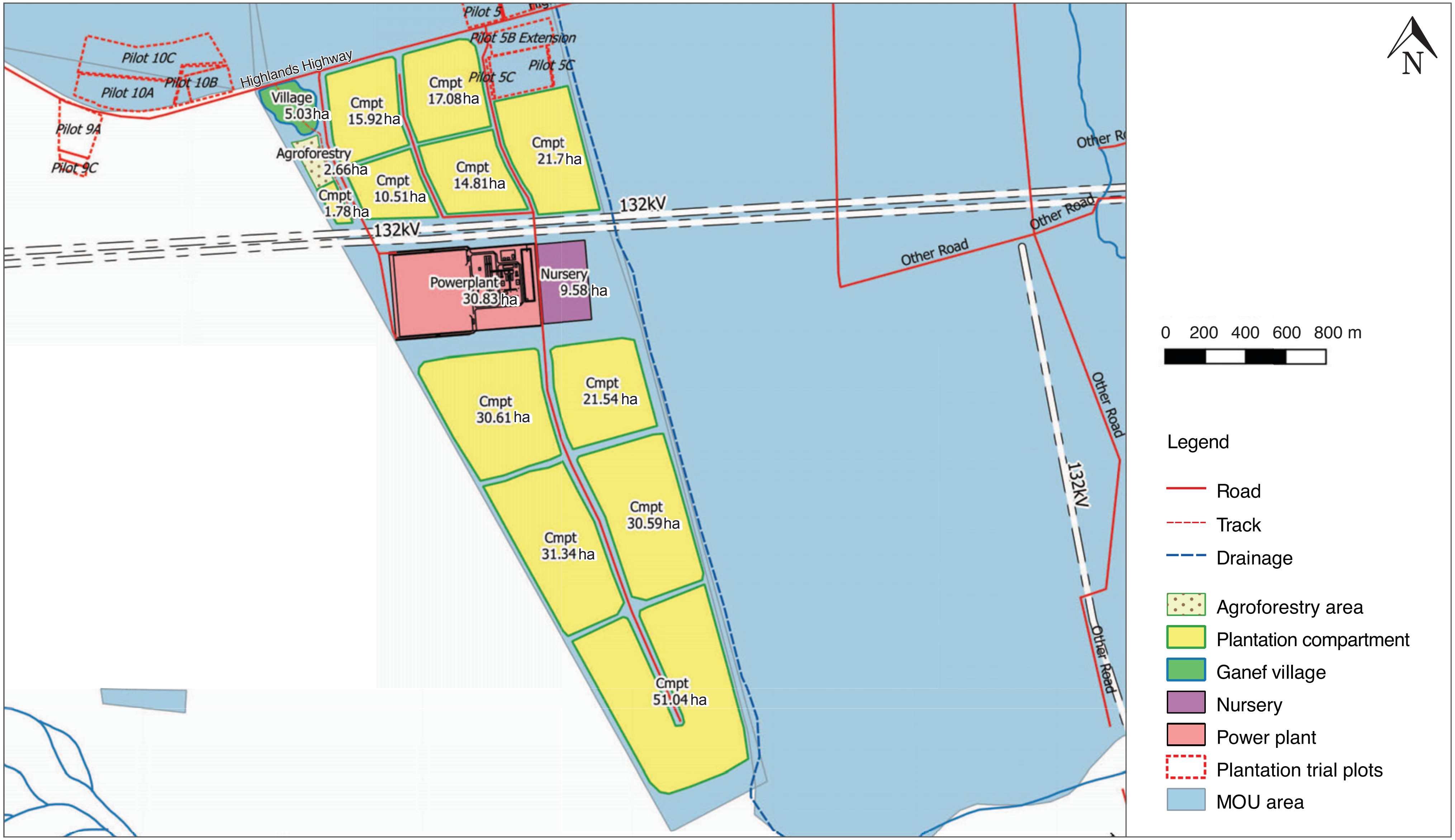
The largest villages (Chivasing and Tararan) will be surrounded by a buffer zone of at least 50 m within which plantation establishment will not occur. Near smaller hamlets (such as Ganef) and other infrastructure, the need for, and size of, buffer zones will be negotiated with the local landowners/residents. In some instances, initial stakeholder engagement has shown that landowners prefer plantations to be established very close to the edge of their settlement. This will be assessed on a case-by-case basis.

7.3.4.2 Agroforestry Zone

In areas immediately outside villages, gardens and food crops (and associated buffers), agroforestry zones may be established by local landowners in areas made available by the Project. Agroforestry includes land use management systems where, for example, agricultural crops are grown among or next to trees. These areas will be multiple use, shared zones of intercropped eucalypt plantations and other crops, such as cassava, peanuts, cacao, melons and/or essential oil crops (e.g., selected eucalypts and other commercial species). These secondary crops may be established in inter-row areas (i.e., the planned 3-m gaps between rows of trees, as shown in Plate 7.4), but may also be developed in other areas (e.g., firebreaks, or in strips around plantation compartment perimeters).

PRELIMINARY DESIGN OF PLANTATION COMPARTMENTS AND ROADS NEAR THE POWER PLANT

FIGURE 7.5



Source: Dickinson, pers. com., 2017.

Plate 7.4 – Intercropping in a Trial Plot

While inter-row cropping will only be practicable until canopy closure (9 to 18 months), a number of factors mean that secondary cropping opportunities will be ongoing throughout the life of the Project. These include:

- Short rotations of the biomass regime (seven to nine years for each compartment).
- Relatively small compartments of plantations (approximately 20 ha each) and availability of land for cropping around the perimeters of compartments.
- Dispersal of plantation compartments in space and time, i.e.:
  - On average, 2,000 ha will be established in each year of the first seven to eight years. By the time that the total 16,000 ha is established, harvesting can begin on the first compartments, which will have reached their seven to nine year rotation lifespan.
  - Establishment of compartments in a dispersed pattern across the landscape, rather than very large consolidated areas being developed in any one year. As such, there are likely to be multiple plantation age classes in the vicinity of each village, with ongoing opportunities for inter-row cropping in the younger compartments.

7.3.4.3 Plantation Zone

The core plantation areas (beyond those zones used for agroforestry) will be intensively managed for biomass to fuel the power plant, as well as a percentage for other uses such as sawlogs/ veneer. However, there may also be opportunities for local people to generate products such as honey. If plantations are certified with FSC, all products harvested from them (including non-wood products) will also be certified, potentially attracting a higher value than non-certified products. Beyond the main agroforestry areas, cropping may still be possible in areas such as firebreaks where appropriate, for crops including peanuts and maize.

7.3.4.4 Environmental Buffers and Informal Reserves

The Project will apply the following riparian (streamside) buffer zones[1]:

- Buffer zone of 100 m from the banks of the Markham River.
- Buffer zones of 60 m from the banks of the Leron and Erap rivers, and also from the edges of lakes, lagoons or swamps (the latter being defined as having surface water present for at least 6 months of the year).
- Buffer zones of 30 m from the banks on either side of permanent watercourses (streams and rivers other than those listed above) with average width greater than 5 m.
- Buffer zones of 20 m from the banks on either side of all watercourses with an average width greater than 1 m but less than 5 m.
- Buffer zones of at least 5 m from the banks on all sides of all perennial or intermittent watercourses with an average width of less than 1 m.

The following activities will be excluded within the riparian buffer zones:

- Machinery access.
- Felling trees or clearing vegetation except where required for designated stream crossings (note that within buffer zones for watercourses <1 m width only, vegetation clearing will be minimised to the extent practicable, due to operational constraints).
- Establishing plantations.
- Storing logs, soil, machinery, fuels or oils, herbicides or fertilisers, or placement of other Project-related infrastructure.
- Construction of roads, except where required for designated stream crossings or bridges.
- Crossing of harvesting machinery, except at appropriately constructed permanent crossing points (bridges) or at designated temporary crossings for dry watercourses. Harvesting machinery can cross watercourses where log crossings or culverts are provided.

7.3.5 Plantation Establishment

Forestry site preparation is intended to assist in the initial establishment and subsequent growth of the tree crop, to provide access for future management and harvestings, and to minimise detrimental environmental effects on and off site, including soil degradation, erosion and sediment

[1] These buffer distances were finalised after completion of Appendices 1 and 7, however the authors of those reports have confirmed that these changes do not alter their assessments or recommendations.

runoff. Site preparation and planting will occur all year round; there will be no temporal sequencing related to seasons.

Plantation establishment will in general follow the timeline summarised in Table 7.3 and discussed below. All aspects are designed to maximise the probability of plantation trees' survival and growth during the first (and most important) 12 months, which will contribute to optimising the biomass fuel crop in the longer term.

Table 7.3 – Plantation Establishment Timeline (Generic Sequence)

Month	Operation
-4	Clear vegetation (grasses and shrubs <20 cm dbh)
-3	Strip plough – first knife Strip plough – harrow
-2	Pre-plant spray 1 (glyphosate 2 L/ha)
-1	Pre-plant spray 2 (glyphosate 2 L/ha)
0	Planting (1,333 trees) Fertilising (200 g of NPK 12.12.17 blend per tree) Hydrogel 300 mL/tree (concentration 600 g/200 L)
1	Manual weed – stripline weed free Tractor – Inter-row slash Survival assessment and blanking
2	Manual weed – stripline weed free Tractor – Inter-row slash
3	Manual weed – stripline weed free Tractor – Inter-row slash Spraying with shields (glyphosate 2 L/ha)
4	Spraying only (glyphosate 2 L/ha)
6	Spraying only (glyphosate 2 L/ha) Fertilising (200 g of NPK 12.12.17 blend per tree)
8	Spraying only (glyphosate 2 L/ha; metsulfuron methyl 62.5 mL/ha)
10	Spraying only (glyphosate 2 L/ha; metsulfuron methyl 62.5 mL/ha)
12	Spraying only (glyphosate 2 L/ha; metsulfuron methyl 62.5 mL/ha) Fertilising (200 g of NPK 12.12.17 blend per tree)

Prior to planting, existing vegetation will be cleared as described in Section 7.3.2. For each plantation compartment, a buffer of 6 to 8 m width must be maintained around the boundary for access and fire control. Internal tracks (approximately 5 m width) and/or internal firebreaks may also be established, although the latter will be uncommon, only being required where very large consolidated areas of plantations are proposed. These will be marked out on site. Fire hazards will be further managed by:

- Fire prevention, including information sharing and working with local communities.
- Early detection, including employment of fire wardens and installation of monitoring cameras.

- Rapid response, including teams of personnel trained in forest fire fighting, maintenance of small fire units (e.g., mounted on the back of a utility vehicle) and larger fire tankers, and maintenance of a network of water points for filling fire units/tankers.

The area will be picketed to keep rows straight and oriented to be as long as possible for the shape of the block, unless restricted by terrain features such as streams. Ploughing will then be undertaken, with the first cut plough to a minimum of 30 cm depth. The need for a second cut ploughing will depend on the soil type, to ensure that soil is friable to facilitate tree root growth. Mound ploughing is likely to be undertaken in most areas to improve plant growth and survival, by keeping seedling roots out of waterlogged zones (where applicable) during early establishment, increasing nutrient availability (by concentrating the topsoil) and aerating the soil (Mullen and White, 2002).

A non-residual, ‘knockdown’ herbicide (glyphosate) along with a surfactant will be sprayed two months before planting to control regrowth of weeds, grasses and shrubs that would compete with the plantation seedlings. Herbicide spraying will be repeated at two to four weeks before planting. Spraying prior to planting is likely to be conducted via a boom spray rig on the back of a tractor.

Based on the findings of plantation trials and experience to date, planting will be at a density of 1,333 stems per hectare (SPH), with 3 m between rows and 2.5 m between trees. Planting will be done by hand, generally with the aid of a ‘Pottiputki’ planting tool (Plate 7.5). During planting, a hydrogel (e.g., Stockosorb brand) will be added to each planting hole, where it will absorb water during damp periods for subsequent release during dry periods, to help ensure survival of trees (Evonik, 2016). A granular nitrogen-phosphorus-potassium (NPK) fertiliser will be applied manually near each seedling (buried in holes 30 cm from the plant) to encourage its growth.

A survival assessment will be undertaken at around one month after planting, with infill planting if necessary. Weed regrowth will be controlled by manual weeding between trees and slashing between rows for the first three months. Spraying of weeds with glyphosate herbicide will also occur in the third and fourth months, and every second month thereafter for the remainder of the first 12 months. After six months, if necessary, spraying may include an additional herbicide designed to control broad-leafed weeds (metsulfuron methyl). All herbicide spraying undertaken post-planting will be done manually, i.e., by personnel using backpack spray units. Weed control regimes may be modified in locations where intercropping is undertaken by local people. Fertiliser (NPK) will be applied again at 6 and 12 months.

Use of pesticides (for control of insect pests) is not proposed unless a significant pest problem arises in a given area.

Plate 7.5 – Using a 'Pottiputki' Planting Tool

Source: Pottiputki, 2017.

7.3.6 Maintenance and Management

7.3.6.1 Biomass Regime

Within the first three to four years of Project development (i.e., 2016/2017 to 2019/2020), all plantations will be managed under a biomass regime. The rotation length (growing phase) of plantations under this regime will generally be seven to nine years. After the first rotation, biomass tree crops will be harvested; the second rotation will be new growth from the existing stumps using their established root system. This approach is called coppicing, and is possible for the Project due to the re-sprouting characteristics of the selected eucalypt species.

Coppicing is more efficient than replanting as it avoids the intensively-managed initial establishment period for seedlings. However, plantation productivity can reduce over time if this approach is repeated. As such, after the second rotation is harvested, MVB will assess on a compartment-by-compartment basis whether another round of coppicing is appropriate.

Alternatively, the third rotation may be established by planting new seedlings in the gaps between the previous stumps. There will be no fallow period, as this encourages regrowth of weeds.

No thinning will be undertaken for plantations under the biomass regime, as the aim is simply to maximise the volume of timber produced as biomass fuel. All of the wood harvested from compartments managed under the biomass regime will be used as biomass fuel for the power plant (after fine branches/crowns/bark are removed).

7.3.6.2 Veneer/Sawlog Regime

Commencing in year 4 (2019), part of the plantation estate will be managed under a veneer/ sawlog regime, which will have a rotation length of 15 to 18 years. Compartments under this regime will be grown from clonal plants (not from coppice or seedlings) to increase the likelihood of straight, consistent stems, which are desirable for veneer and sawlog products. These plantations will be thinned[2] in years 4, 8 and 12 (see Table 7.2), to improve growth of the retained trees. Large diameter logs are preferred for solid timber products such as veneer and sawlogs. Pruning of plantation trees is not proposed.

This plantation regime is designed to maximise the production of sawlogs/veneer logs with biomass generated as a residue. Biomass logs will be produced from thinning operations, as well as the tops of trees and trees with poor quality (lower grade logs) at clearfell. A proportion of sawlogs/veneer logs is likely to be produced in the third thinning operation (year 12), with a higher proportion of these products in the final (clearfell) harvest.

The planting strategy is designed such that the supply of biomass logs (from the biomass regime plus veneer/sawlog regime residues) will meet the demand of the power plant. If, for unforeseen reasons, the supply of biomass logs is insufficient, it is likely that a proportion of plantations would be transferred from the sawlog/veneer regime to a biomass regime.

The proportion of the plantation estate under each regime will depend upon if, or when, PPL instructs the Project to implement the second 15 MW power plant unit:

- If 2 x 15 MW units are established as proposed, by 2023 63% of plantations will be managed under a biomass regime, with 37% under a sawlog/veneer regime (with some of the latter also being used for biomass as described above).
- If only one 15 MW unit were established (which is not the proposal being evaluated herein):
  - From 2017 until 2035, 27% of plantations (on average) would be managed under a biomass regime, with 73% under a sawlog/veneer regime (with some of the latter also being used for biomass as described above).
  - From 2036, only 8% of plantations would be managed under a biomass regime, with the remaining 92% under a sawlog/veneer regime but also providing a proportion of biomass (as described above), adequate to continue fuelling the power station indefinitely.

[2] Thinning is selectively harvesting some of the trees to improve diameter growth in those remaining, due to reduced competition for moisture, nutrients and light.

7.3.7 Harvesting

The power plant is scheduled to commence operations in Q4 2019. As indicated in Figure 7.6, raintrees harvested between 2019 and 2022 will be the initial source of biomass fuel, although *Acacia* from existing plantations west of Madang may also be used during this period. By 2023, the fuel source will have transitioned to using biomass grown in its eucalypt plantations within the Project area. Harvesting of eucalypt plantations will take place at the end of each compartment's designated rotation length in accordance with the applicable management regime, as discussed in Section 7.3.6 and shown in Table 7.2.

Timber harvesting operations will be planned and carried out to minimise long-term adverse impact on the environment and to protect ongoing productivity of the site. Where practicable, harvesting will be dispersed so that adjacent compartments are not harvested within the same year. Harvesting will be undertaken all year round, however, areas selected for harvest in wet versus dry seasons will depend on factors including site drainage, soil erodibility, and local environmental sensitivities. Plantation thinning operations, where applicable, will be undertaken to minimise damage to retained trees as well as to minimise compaction to soils.

Logs are likely to be harvested using machinery such as feller bunchers, and pulled to pre-designated log landings[3]. Temporary (but pre-planned) snig tracks[4] may also be required. After being collected at landings, logs harvested from biomass plantations will be loaded onto trucks and transported to the power plant (Section 7.4.3.1).

Biomass log demand (for the power plant) is expected to reach 175,300 BDMt/yr (bone dry metric tonnes per year) by 2023 and then be maintained at this level. If plantation harvesting results in biomass logs surplus to power plant requirements, these will be transported to Lae and sold to export. Any compartments managed under a sawlog/veneer regime will also be sold to export, most likely to East Asia.

7.4 Power Plant

7.4.1 Overview

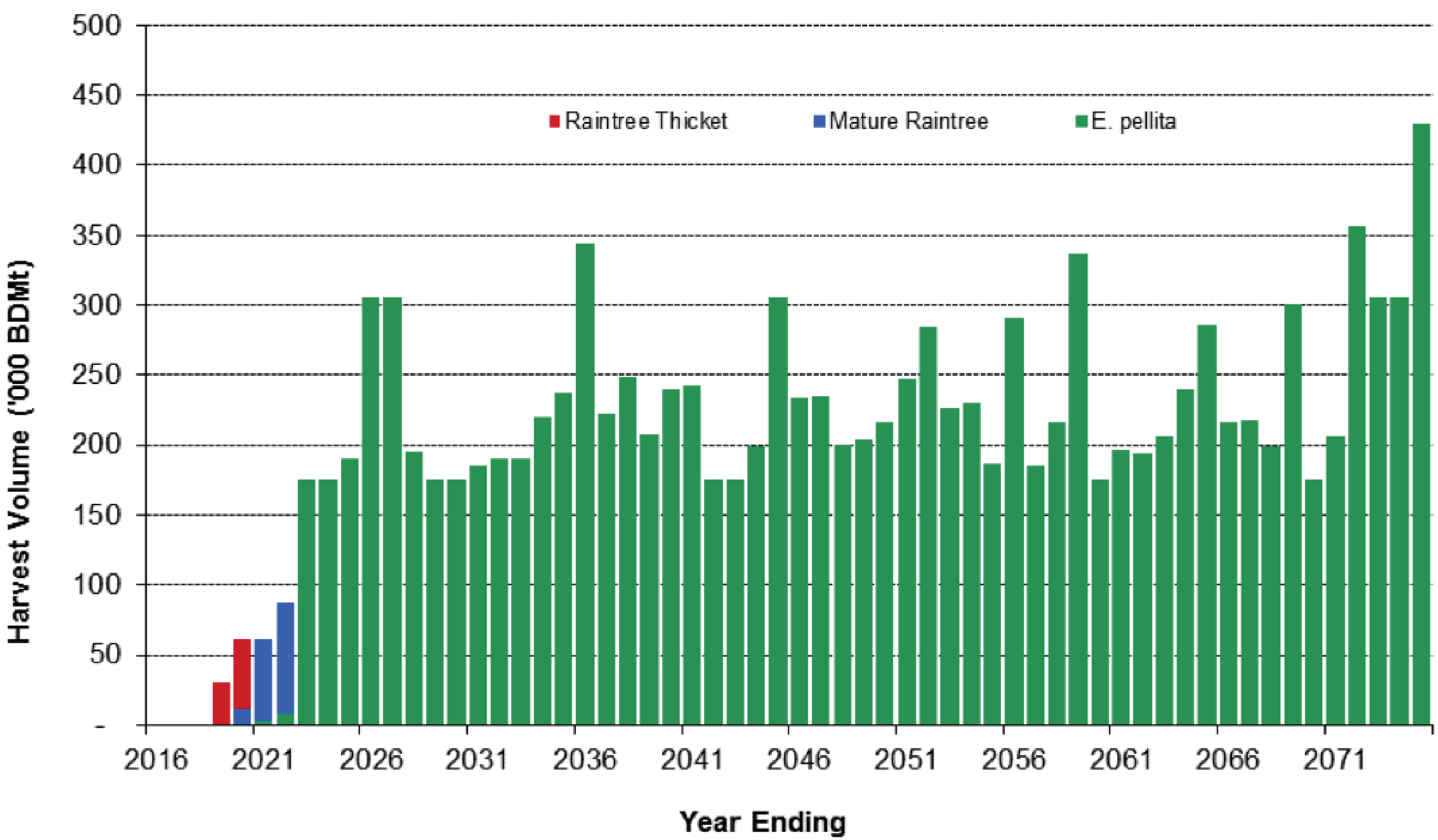
The technology to be employed is a conventional thermal boiler steam plant, as shown schematically in Plate 7.6, incorporating a biomass-fired boiler of proven design and individual components based on over 100 years of experience and deployment in a broad (and global) range of industrial and utility applications. Each of the two 15 MW net power plant modules (Plate 7.7) will consist of one biomass boiler and one steam turbine generator, with the biomass boiler being fired with wood chips supplied initially from raintrees to be cleared from the power plant site and then transitioning to the dedicated plantations (see Section 7.3.7). Fuel security is assured through the Project owning and operating the plantations in conjunction with local

[3] A landing, also known as a skid, is an area to which logs are pulled (usually by machinery) before crosscutting/scaling and sorting if required, then loading onto trucks.
[4] Snig tracks (also known as skid tracks) are temporary tracks along which logs are pulled from the point at which they are felled to a nearby landing. Snigging (or skidding) is the pulling (or carrying) of logs from the felling point (stump) to the landing by wheeled or tracked machinery.

HARVEST VOLUME BY SOURCE OVER TIME

PNG Biomass Markham Valley I Environmental Assessment Report

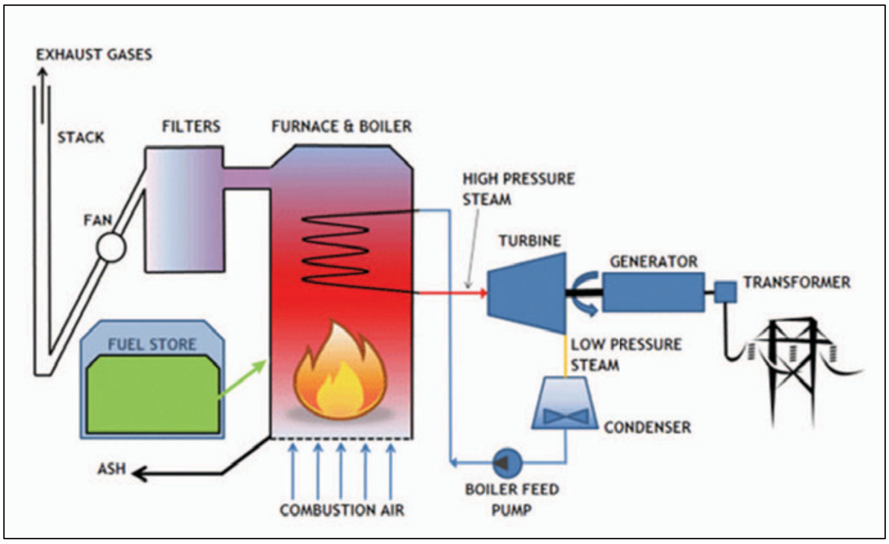
FIGURE 7.6



Source: Dickinson, 2016.

landowners. The net output of each unit will be 15 MWe[5], allowing for parasitic loads for plant operation and woodchipping. Cooling will involve a wet evaporative mechanical system, using water abstracted from groundwater bores with backup supply from the Markham River if necessary. The resulting condensate will be recirculated.

Plate 7.6 – Biomass Power Plant Schematic



Source: AEL, 2016d.

Plate 7.7 – Typical Biomass Power Plant

Source: AEL, 2016d.

[5] MW: megawatt/s: a unit of power; MWth: megawatts thermal: electricity produced by a thermal power plant, prior to accounting for efficiency (heat) losses; MWe: megawatts electric: the electricity output of a power plant in megawatts, after efficiency losses during electricity generation.

The power plant site will cover a total of about 40 ha, including laydown areas for wood stockpiles (log yard). A preliminary layout of the power plant and log yard is shown in Figure 7.7.

The two power plant units have been sized to match the next largest individual units currently on the grid, i.e., the 5 x 15 MW turbines which comprise the Ramu 1 hydroelectric installation, thereby effectively providing some redundancy for the largest units on the grid and matching the existing largest generator size. Each 15 MW unit will be capable of operating independently and providing power to the grid in the event that the other unit is offline for maintenance or other reasons.

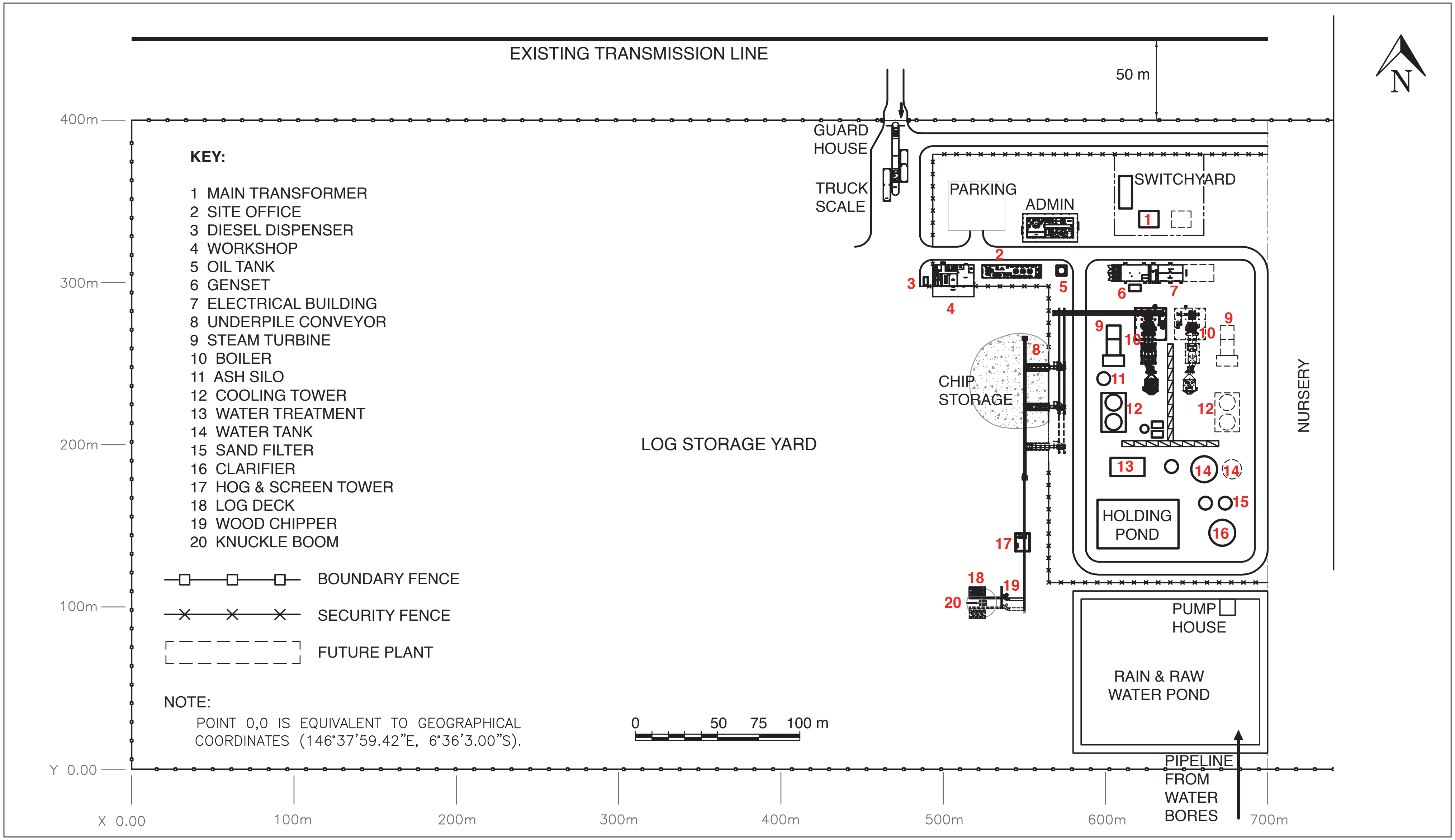
7.4.2 Construction

Construction of the power plant will involve a number of sequential steps culminating in commissioning and power delivery to the Ramu grid. These steps include:

- Site preparation. This includes providing site access and involves clearing, cut and/or fill, and site compacting, as well as establishing site drainage, roads/parking/fencing, and temporary laydown areas, warehouses and construction site offices/cabins (including stores, toilets and workers' eating facility). Construction objectives are to:
  - Complete as much as possible of the earthworks and construction of the stormwater drainage system and roads located within the power island before the rainy season.
  - Construct the sub-base of the roads and the stormwater drainage system as fast as possible to facilitate stormwater drainage during the rainy season.
- Civil works. These will focus on ground excavation, piling and backfilling, and will provide the foundations for plant components such as the boilers, steam turbines and cooling towers, as well as other equipment including fuel handling facilities, log and woodchip handling facilities, and general services. Points to note are:
  - At least two concrete batching plants will be established on site, one with higher capacity (typically 30 m^3 concrete per hour) and one for medium to smaller concrete pours (12 to 15 m^3 concrete per hour).
  - Civil works contractors will be discouraged from side-dumping of earth at the side of open excavations.
  - An estimated 6,000 m^3 of surplus excavated material and a large amount of topsoil (around 50,000 m^3) will be placed in a temporary storage area until the site landscaping commences. An area of about 2,000 m^2 has been reserved to store excess excavation material that will be used again after concreting of foundations for backfilling.
- Building construction. Buildings that will be constructed during this stage include an administration building, weigh bridge building and truck scale, workshop and warehouse, control room and other facilities.
- Mechanical equipment, structures and pipework installation. This includes installation of pipe racks, piping, tanks, boiler, cooling water tower, water treatment plant and similar.

PRELIMINARY POWER PLANT AND LOG YARD LAYOUT

FIGURE 7.7



Source: Pöyry. 2016b.

- Electrical and instrument installation. This includes installation of cables, cable trays, ducts, lighting, transformers, switchgear, lightning and earthing protection systems, plant lighting and fire detection and alarm systems, and similar.

These activities will be supported by site security guards (7 days per week, 24 hours per day) and site survey services. All subcontractors will provide mobile diesel generators for their own power demand for the duration of their works. A typical breakdown of machinery that will be used by the civil subcontractor during construction is as follows:

- One bulldozer.
- Two payloaders.
- Two hydraulic excavators.
- One compactor.
- One water truck.
- One roller compactor.
- Four dump trucks.
- Two piling rigs for driven piles (or bore piling machines in case of bore piles).
- One pile hammer for driven piles.
- Two concrete pumps.
- Four concrete truck mixers.
- Four concrete vibrators.

The mechanical erection contractor will typically use one large crawler crane (approximate capacity of 230 t) for boiler erection and one medium-sized hydraulic crane for the remaining mechanical lifting works. Some small mobile cranes (25 to 35 t) might be used as required. The construction workforce will be accommodated primarily in existing facilities in Lae and surrounds, including local communities.

Power plant design and construction time for the first unit is expected to take 26 months primarily due to the time that suppliers need to design, fabricate and deliver the boiler and the steam turbine, which is about 14 to 18 months. Erection will overlap fabrication works and will take about 10 to 12 months. Commissioning and fine-tuning of the plant will take at least 4 to 6 months.

Where appropriate, pre-fabrication and modularisation (Plates 7.8 and 7.9) will be used to facilitate plant construction, taking into account factors such as the site's proximity to Lae and the seasonal rainfall pattern. Appropriate consideration will also be given to the best balance for modularisation or pre-assembly that could be undertaken directly on-site versus off-site or in surrounding areas. Extensive use will also be made of skid-mounted equipment to optimise installation time and limit works at site. The final decision on extent of modularisation will be taken in the detail design phase. Information concerning port facilities and transport of equipment and material to the site is provided in Section 7.5.

Construction activities will occur primarily from Monday to Friday (10-hour days) and Saturday (5-hour days).

Plate 7.8 – Pipe Bridge Modules (Piping Pre-tested, Insulation Installed, Cable Trays Loaded)

Source: Pöyry, 2016b.

Plate 7.9 – Tank Pre-assembly

Source: Pöyry, 2016b.

7.4.3 Operations

7.4.3.1 Fuel Log Storage and Chipping

Eucalyptus pellita and *E. pellita* hybrids will be the main fuel source, although existing raintrees will be used for firing the boiler in the initial years of operation. The fuel specification is provided in Tables 7.4 and 7.5.

The fuel (logs) will be brought to site by truck for weighing and stacking in the fuel storage yard (log yard), which will have a capacity of around 90 days storage. The trucks will have a capacity of 20 to 30 t (wet) and will use both the public road network and, where possible, company roads, with truck movements being limited to approximately a 40 km radius of the power plant site, thereby avoiding centres of high population density. The forecast numbers of daily truck deliveries will be about 20 to 25 deliveries for each 15 MW unit.

Table 7.4 – *E. pellita* and Hybrids Log Specifications

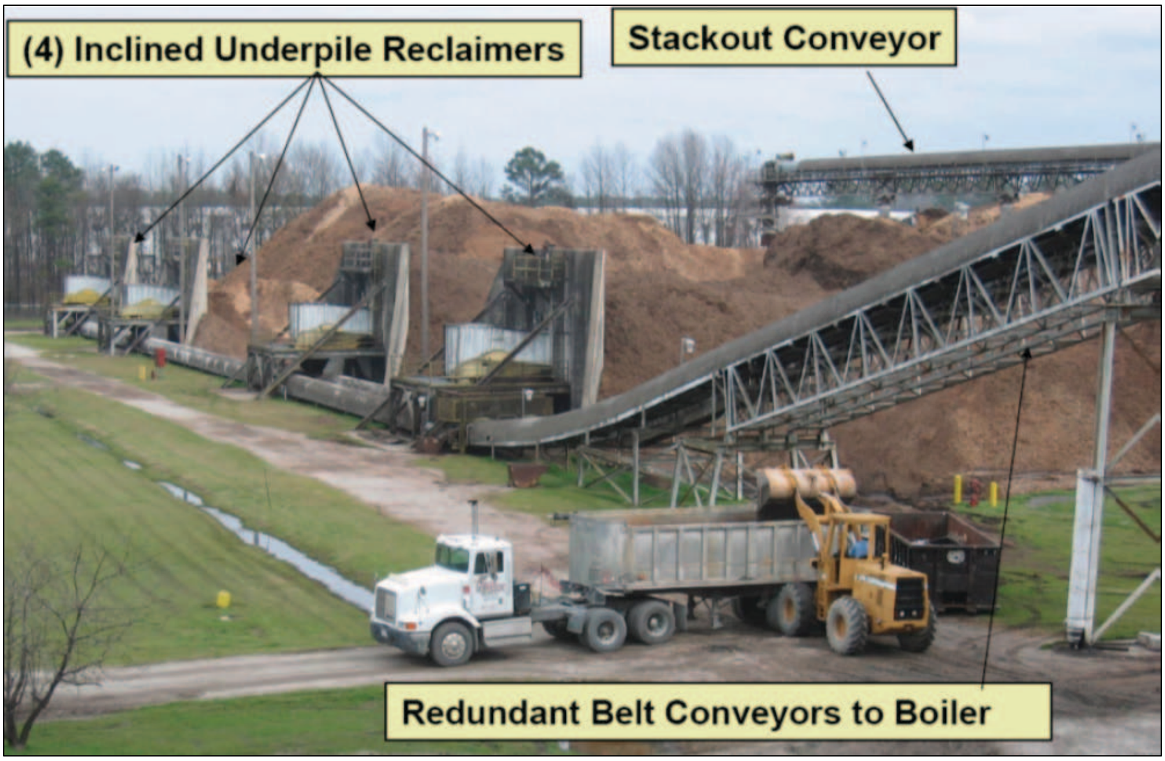
Character	Broad Range		Typical Range	
Log length (mm)	1,600	6,000	2,200	4,000
Diameter (mm)	20	300	30	250
Basic density (kg/m^3)	350	640	420	600
Moisture content (% dry weight basis)	40	95	45	70
Moisture content (% wet basis)	29	49	31	41
Bark content (% volume)	5	25	8	20

Table 7.5 – Raintree (*Albizia saman)* Log Specifications

Character	Broad Range		Typical Range	
Log length (mm)	1,600	6,000	2,200	4,000
Diameter (mm)	20	400	30	300
Basic density (kg/m^3)	250	800	320	500
Moisture content (% dry weight basis)	15	95	35	70
Moisture content (% wet basis)	13	49	26	41
Bark content (% volume)	0	30	8	20

The logs will be allowed to dry naturally (while minimising soil contamination), reducing from the anticipated ‘green’ moisture content of about 50% to about 35% before being used in the power plant. After drying, the logs will be transferred to the chipper area using mobile equipment; the chipper will generate chips of approximately 50 mm with occasional chips from the ends reaching 100 mm to 150 mm. The chips will then be screened to the size required for the boiler before transport to the chip storage yard via belt conveyors. The woodchips will be stored in the open (outdoor) storage yard, which will be sized for a storage capacity of 10 days at full capacity. Chips will be reclaimed by two automatic underpile reclaim systems with one spare (3 x 50%) (Plate 7.10) and transported to the boiler surge bins after passing through a magnetic separator, metal detector and belt scale (flow measurement).

Plate 7.10 – Underpile Reclaim Conveyers for a Wood-fired 30 MW Power Plant



Source: Pöyry, 2016a.

7.4.3.2 Boiler and Auxiliary Systems

Final selection of the type of stoker boiler, e.g., travelling or vibrating stoker/air cooled or water-cooled stoker, will be undertaken during the bidding phase of the FEED study. Regardless of this selection, boiler operation will involve extraction of woodchips from the fuel bins and transport to the furnace, where the fuel will be spread evenly over the stoker to allow uniform combustion. Residual water in the fuel will evaporate during the spreading process, with pyrolysis (loss of volatile matter) occurring within the temperature range of 200 to 400°C. Combustion in the boiler of the volatile matter and the remaining fuel, mainly fixed carbon, will then occur.

During the combustion process, most of the ash (around 60 to 70%) will be carried through the boiler by the flue gas, with around 30 to 40% remaining on the stoker where it will be discharged to the bottom ash handling system. Part of the fly ash will be trapped in the dust collector at the outlet of the air heater and the remaining fly ash will be collected in the electrostatic precipitator (ESP).

The bottom ash will be managed using a wet system, with the ash being used for road construction and hardstanding in the log storage area. The fly ash collected from the flue gas cleaning equipment (cyclones and bag filters/precipitators) will be transferred to the fly ash silo and will be removed in wet or dry condition from the power plant for further use (Section 7.6.2).

The hot flue gas from the furnace will enter the superheaters at the outlet of the furnace and then the steam generating banks. The flue gas will then exit the boiler before passing through the fan and ESP to the stack.

Supporting systems will include a feedwater system (including a deaerator to remove oxygen and other gases from the condensate and make-up water to prevent corrosion) to provide water for steam generation via the generating banks, soot blowers to remove accumulated ash, light fuel oil burner for boiler start-up and/or support firing, chemical dosing, water/steam sampling and burner management system. A Continuous Emission Monitoring System (CEMS) will not be installed in the stack, but provisions (ports) for test equipment or later installation of a CEMS will be provided.

7.4.3.3 Steam Turbine Generator and Cooling Water Systems

The steam turbine generator will generate electricity from the steam produced by the boiler (see above), which flows from the boiler through interconnection piping in the steam turbine generator. The steam turbine and generator will be installed inside a weather and noise enclosure that can be opened for maintenance purposes; no separate steam turbine building will be constructed. The condenser and condensate extraction pumps will be installed outside the enclosure.

The cooling water system will provide the total water requirements for the condenser and the auxiliary plant, and will comprise a pumping facility, cooling tower, water storage basin and associated piping, valves and instrumentation. The cooling tower will discharge the heat collected in the steam turbine condenser and auxiliary systems to the atmosphere. Chemical dosing will be included in the cooling tower design, e.g., acid will be added to the cooling water to control pH, and corrosion/scaling inhibitor and biocide will be dosed either based on a timer or in batches.

Blowdown from the circulating water (i.e., removal of some of the water) will be provided to allow maintaining of the system conductivity by the addition of the higher quality make-up water. The conductivity of the circulating water system will be set to minimise the make-up quantity required, while also minimising solids deposition or scaling and remaining within effluent discharge quality requirements. An automatic control valve will control the blowdown via online conductivity measurement.

7.4.3.4 Raw Water Supply and Water Treatment System

The water treatment system consists of a pre-treatment system to produce filtered or service water quality, as well as a cycle water treatment system to produce demineralised water for the boiler. The raw water is likely to be sourced from water bores located near or on the power plant site. If necessary, the option of a backup water supply via a buried pipeline from pumps in the Markham River would be investigated. A rainwater collection system will collect as much rainwater as possible as a source for the pre-treatment system, thereby also minimising groundwater requirements.

Key aspects of the water supply system are as follows:

- Water for the nursery will be sourced from the bores.
- Rainwater will be used as much as possible for the pre-treatment system, and will be dosed with flocculants and coagulants such as alum, aluminium sulfate, sodium silicate and polyaluminium chloride (PAC) before being fed into the clarifier. From the clarifier the water will flow to the surge tank where it will be mixed with water from the bores, which will not require clarification. The water will be pumped from the surge tank through the multi-media filters to the service water tanks.

- The service water tanks will provide water for the fire water system, cooling tower make-up system, demineralised water plant, backwash pumps for the multi-media filters and the service water distribution system.
- The demineralised water plant is currently expected to involve ion exchange technology, although this may be revised once the raw water quality is confirmed, e.g., to a reverse osmosis system with a mixed bed filter or some other system. The plant will have a neutralisation basin for neutralisation of the regeneration streams.

A preliminary water balance for a single 15 MW unit is shown schematically in Figure 7.8; this can (conservatively) be doubled for two 15 MW units.

7.4.3.5 Electrical System

The power plant site is approximately 2.5 km from the Erap Switching Station. An existing 132 kV above-ground transmission line passes 50 m north of the site and the power plant will be connected to the grid through a Loop In Loop Out (LILO) interconnection arrangement which will assist grid stability. Power will be generated by the steam turbine generator at 11 kV and then delivered via a step-up transformer and a 132 kV circuit breaker to the grid connection.

A 750 kW emergency diesel generator (EDG) will be installed to assure safe shutdown of the power plant in case of plant blackout. The EDG will be sized for safe shutdown, not for black start[6], and will be connected to the essential service board (400 V) to which all consumers requiring power during a blackout situation will also be connected. The EDG will have its own (diesel) fuel supply system that will provide a minimum of two hours of operation.

If the Ramu grid voltage and/or frequency is outside specified limits, or the grid is not available, the power plant will disconnect itself from the grid by opening the circuit-breaker and go into island mode such that the power plant will provide its own auxiliary systems with power and will stay online, generating power at a reduced load. The excess steam will be directed to the steam turbine condenser through a bypass system. When the grid is available and stable, the power plant will be synchronised back to the grid over the circuit breaker.

7.4.3.6 Control System

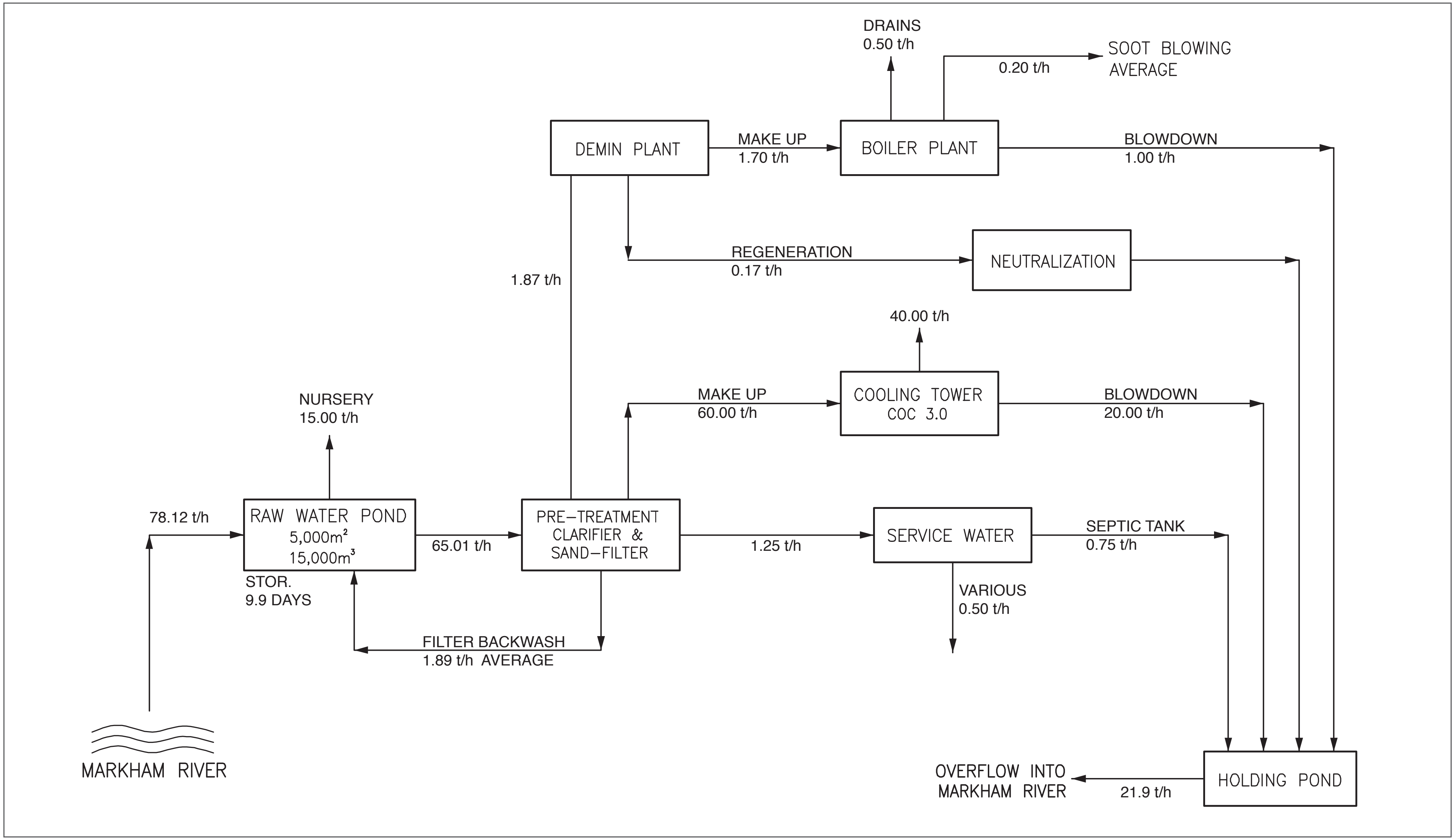
The main control system (referred to as a Distributed Control System (DCS)), which includes control of the boiler and the burner management system (if applicable) as well as the boiler-related subsystems such as soot blowers, fuel handling and bottom/fly ash handling, will be installed in the central control room. This will be the main location of operation and the complete plant will be monitored and controlled from this location. Several other control systems will also be installed within the power plant, all of which will be connected to the DCS.

Start and stop operations will be automated; however, preparations for a (cold) start such as filling the boiler will be controlled by the operators rather than being automated. The start-up sequencing programming will be in step logic, allowing the operator to see in the DCS how the start-up sequence is progressing. At certain points in the start-up a halt step will be performed,

[6] Process of restoring an electric power station to operation without the assistance of an external power source.

PRELIMINARY WATER BALANCE

FIGURE 7.8



Source: Pöyry. 2016b.

where the operator will need to confirm to progress, thereby providing an additional level of safety to the process.

In addition to the control systems for the power plant itself, a supervisory control and data acquisition (SCADA) system will be installed for communication and data exchange of plant switchyard with the PPL grid controller.

7.4.3.7 Buildings

In addition to the central control room referred to above, other buildings associated with the power plant will include:

- Site office and administration.
- Workshop and warehouse.
- Laboratory.
- Mess facilities.
- Medical centre.
- Overnight facilities.

The site will be fully enclosed with a high security fence and access will occur via a single manned security gate. A security and access system will be installed requiring electronic access to site and secure buildings such as switch rooms, administration block and the control room. The security system will allow monitoring of site access. Car parking will also be provided.

7.4.3.8 Operating Hours

The log yard will be open to accept deliveries seven days a week between the hours of 7.00 a.m. and 7.00 p.m. The chipping and log handling facility will be capable of operating 24 hours, with the capacity of the chippers and log handling equipment being sized for 12 hour per day operation supplying fuel for the boiler.

The working hours of the wood processing and chipping plant will normally be 12 hours per day, 6 days per week. The facility will also maintain a capacity for chipping and fuel operations during night-time hours for make up to the chip storage facility when this is depleted, although night hours and Sundays will generally be used to maintain the system and to change out the chipper knives.

Security guards will be in attendance at the front gate during normal business hours only, with security cameras being used to monitor the site outside normal business hours.

The power station's operational staff will consist of a skilled plant operator and a plant attendant. The plant operator will be located at the central control desk and the plant attendant will undertake tasks such as routine checks, isolations and similar outside the plant control room. Each day will comprise three eight-hour shifts.

7.5 Ancillary Infrastructure

7.5.1 Port

Equipment and material for the Project will be imported through the Port of Lae, which, while it has only limited capacity for heavy bulk shipments, is able to unload containers up to a maximum weight of 94 t with ship-to-shore cranes. The port offloads an average of 300 containers per day with an average of 200 ships per month. Given that the Project will generate up to an additional total of 1,000 containers during construction, this is not likely to create a major stress or congestion on the existing port facilities.

It is likely that a bonded area will be established at the power plant site, whereby imported equipment and materials will go directly from the port for inspection and clearance. Fumigation will be given careful consideration, and all wood support/packing will be pressure-treated wood that will be burned at site in a separate burning deposal area. This material will not be given or sold to local landowners, thereby preventing its use for cooking fires and potential consequent health risks.

7.5.2 Roads and Vehicle Movements

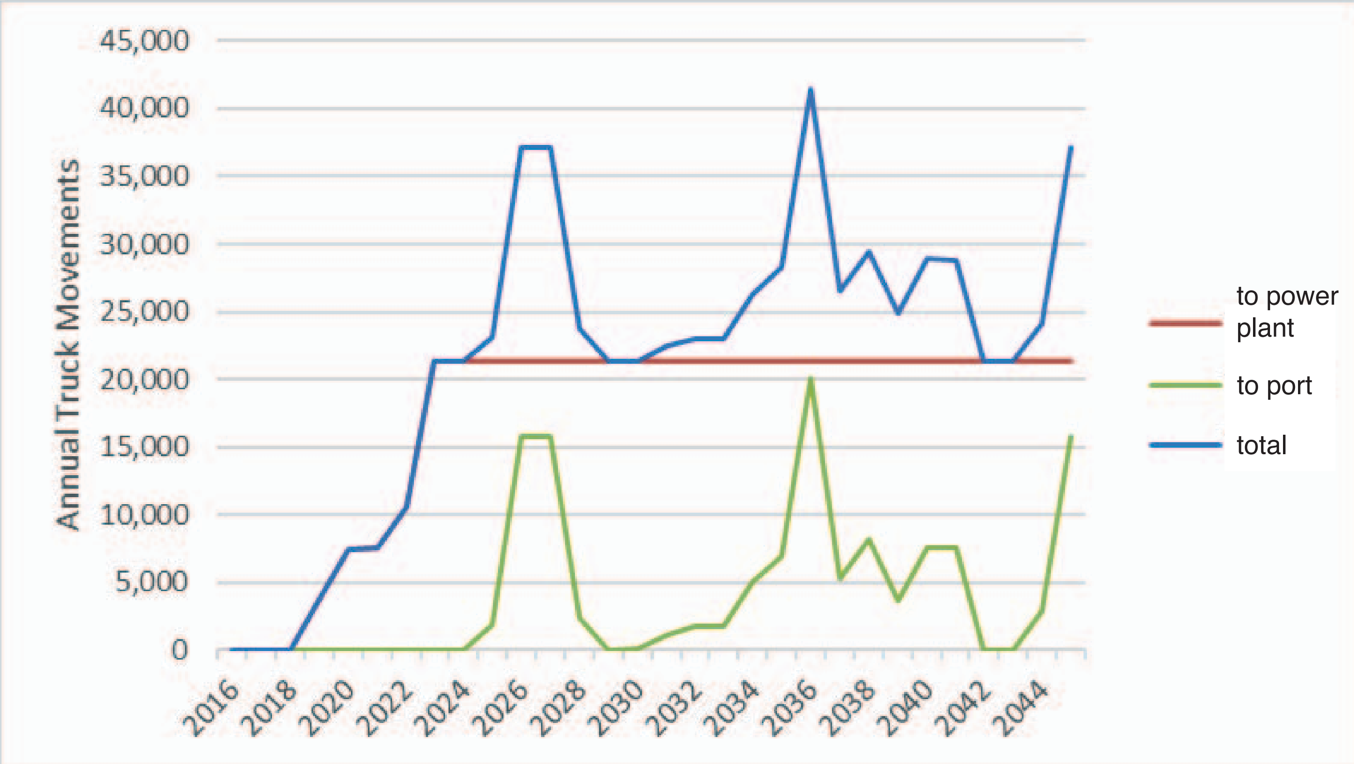
Existing roads, primarily the Highlands Highway, will be used to transport equipment and material from the Port of Lae to the 41 mile marker (power plant site) via tractors and modular trailers. This includes abnormally heavy, wide or tall items, with items wider than 2.5 m requiring a police escort. At the time of writing, improvements were ongoing for a very rough section of road between the port and the power plant site, which also has temporary bridges in some locations due to flooding in late 2016. If the improvements are not completed before Project commencement, the need to appropriately pack and protect the most sensitive materials will be taken into account.

Power plant construction is expected to involve a total of about 400 truck movements for containers and about 30 truck movements for bulk materials. Road transport of chemicals to the power plant, primarily acid and caustic for neutralisation in the water treatment system and pH control in the cooling tower basin, will occur on a monthly basis. Log transport will involve prime movers with two drive wheels and tri-axle trailers. The maximum trailer length is likely to be between 19 and 22 m, with multiple stanchions being used to eliminate drop out of shorter log lengths. Single trailer tipper trucks with a 20 t payload will be used to remove ash from the power plant. The average predicted truck movements (each way) for logs trucks from 2020 to 2054 is 25,400 (Figure 7.9), based on an average payload of 30 t. Figure 7.9 also shows the estimated each way truck movements for ash transport, based on the assumption that 1 dry tonne (BDMt) of wood consumed will generate 22.5 kg of ash that requires transport.

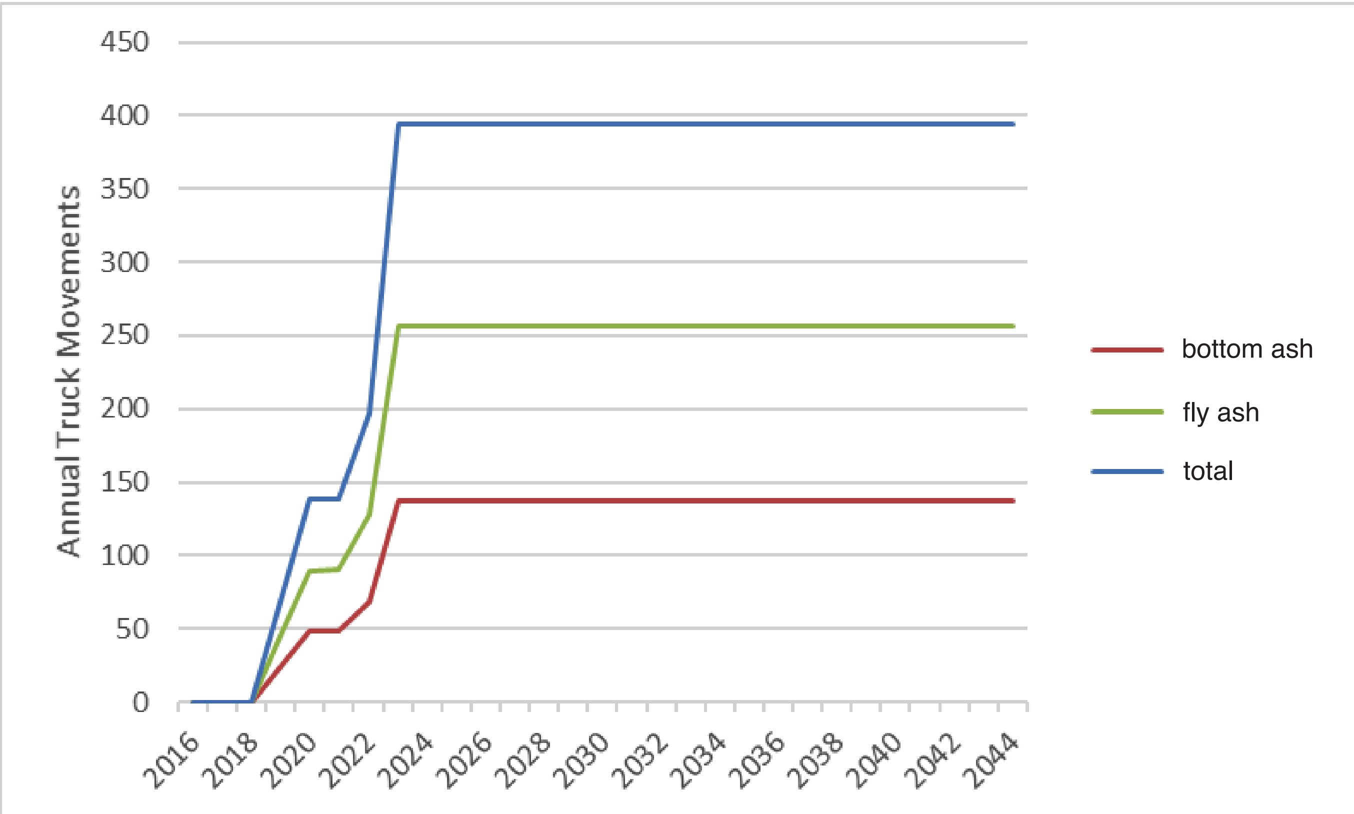
Within the fuel storage and processing plant, all roadways will be suitable for frequent heavy vehicle traffic for biomass deliveries, as well as for site mobile plant and on-site transfer vehicles. Roads around the log storage facility will allow ready access to all areas of the stockpile, such that log stock age can be managed effectively, and a first-in/first-out principle of log storage can be achieved for effective log drying. Site traffic flow on site roads will be indicated showing the main routes for biomass delivery, handling and ash dispatch, with log truck movements occurring daily. A system will be employed to avoid vehicles encountering each other on site roads from

FIGURE 7.9

LOGS



ASH



Source: PNG Biomass, 2016a.

opposite directions, and traffic management will also consider pedestrian routes and barriers to avoid vehicle or plant accidents with pedestrians working around the site.

Plantation roads will be comprised of main roads, secondary roads and access (tertiary) tracks. Carriageway widths will be 8 m, 6 m and 4 m, respectively, with a total tree clearance width of at least 25 m for main roads (and 10 m and 6 m for secondary and tertiary roads, respectively) with 2 m shoulders to the side drains. Road construction will involve a bulldozer for initial formation, with carriageway construction using a grader, roller, water truck and, where required, gravel trucks. Gravel will be sourced from borrow pits or rivers; a large number of existing borrow pits occur along the Highlands Highway and extensive gravel deposits can be found along all the rivers encountered (i.e., Markham, Erap, Leron, Umi and Rumu rivers). Road pavement thickness will be about 30 cm gravel and the roads will be cambered to facilitate stormwater runoff. Culverts will be installed as required, although drainage requirements will be minimal due to the generally flat nature of the plantation area.

Road design will reflect the need to:

- Take into account site topography and catchment characteristics, minimise alterations to natural features, and avoid where possible steep and unstable areas, streamside buffer zones and other exclusion zones.
- Minimise the potential for soil erosion and debris entering watercourses and adversely impacting water quality, and avoid disposal of excess soil into watercourses or other areas excluded from forestry operations.
- Minimise the number of watercourse crossings and cross streams and streamside buffer zones at right angles where possible.
- Plan for dry season construction (where feasible).
- Allow for consolidation of roads before carting.
- Allow for existing road use and social aspects.
- Minimise disturbance outside areas of forestry operations.

Traffic management for the plantations will be comprised of signage and operating rules, with log transport being scheduled and VHF radio call up procedures applied.

7.5.3 Domestic Wastewater

Wastewater from the construction workforce during working hours will be treated via an on-site septic system or package plant that will be sized to accommodate a total of about 500 people.

During operations, an on-site septic system or package plant based on up to 50 equivalent persons will be provided to process wastewater from the power plant ablutions. No other wastewater from the plant will be routed to the sewerage system. Sludge from the system will be incorporated into plantation area soils.

7.5.4 Other Infrastructure

Other infrastructure associated with the Project will include:

- Communications – the site will be serviced by standard telecommunications equipment to allow telephone communications with outside third parties, with a dedicated voice communications link to the PPL control centre and provision for two separate fibre optic voice and data connections to off-site offices.
- Chemicals and diesel fuel storage – Approximately 200 L of diesel fuel will be used daily by the mobile fuel handling equipment, with the diesel fuel being transported to site by truck and pumped to a 30 m^3 diesel storage tank. Chemicals will be transported to site in drums (also by truck) and stored in separate locations or directly transferred to tanks for use.

General construction material will primarily be sourced out of Lae.

7.6 Wastes and Emissions

7.6.1 Plantation Waste

Given the short rotations planned for biomass plantations, harvesting residue (logging slash including branches, leaves and bark stripped from logs) will be retained within the plantation compartments in order to maximise retention of nutrients on site and to suppress weeds. Burning of slash will be avoided or limited for the same reasons, as well as to avoid burning coppice stumps. Stumps of trees not being 'reused' for coppicing in subsequent rotations will be retained in situ, and as such are not considered a waste product, but rather a carbon sink. Regrowth from these stumps will be controlled chemically or mechanically.

7.6.2 Ash

Both fly ash and bottom ash will be generated by the power plant. Predicted ash quantities are shown in Table 7.6.

Table 7.6 – Predicted Ash Generation

Fuel Moisture (%)	Bottom Ash (kg/hr)	Fly Ash (kg/hr)	Total Ash (kg/hr)
35	88 to 116	175 to 205	291
50	96 to 128	195 to 225	320

Representative ash samples will be subjected to the Australian Standard Leaching Procedure to confirm the anticipated low risk posed by use of this material if used for road construction (bottom ash) or as fertiliser within the plantations (fly ash).

7.6.3 Wastewater and Site Runoff

7.6.3.1 Wastewater

As shown in the preliminary water balance (see Figure 7.8), a number of wastewater streams will report to the holding pond located on the power plant site. These include the boiler plant blowdown, cooling tower blowdown, septic tank effluent and water from the neutralisation basin of the demineralisation plant. Treated water from the dirty drain system (see below) will also report to the holding pond. The power plant will be designed and operated such that wastewater discharges from the site, i.e., the overflow from the holding pond, will (as a minimum) comply with IFC (2008) (Table 7.7) (although it should be noted that IFC (2008) refers to facilities that have a total rated heat input capacity above 50 MWth, with guidelines for smaller facilities being the general EHS guidelines (IFC, 2007)). Each of the individual wastewater streams reporting to the holding pond will also comply with these requirements. Regeneration water from the demineralisation water plant will be neutralised before it is pumped to the holding pond. The holding pond discharge will report to an existing man-made drainage line that drains to the Markham River, some 3.5 km from the holding pond.

Table 7.7 – Wastewater Effluent Guidelines for Thermal Power Plants

Parameter	mg/L (Except pH and Temp.)†	Parameter	mg/L†
pH	6 – 9	Chromium – total (Cr)	0.5
TSS	50	Copper (Cu)	0.5
Oil and grease	10	Iron (Fe)	1.0
Total residual chlorine	0.2	Zinc (Zn)	1.0
Temperature increase by thermal discharge from cooling system	♦ Site-specific requirement to be established ♦ Elevated temperature areas due to discharge of once-through cooling water should be minimised, depending on the sensitive aquatic ecosystems around the discharge point	Lead (Pb)	0.5
		Cadmium (Cd)	0.1
		Mercury (Hg)	0.005
		Arsenic (As)	0.5

†IFC, 2008.

7.6.3.2 Site Runoff and Drainage

Power plant site runoff will be managed via clean drains and dirty drains systems. The clean drains system will collect runoff, spills and other discharges from the plant that are within the site discharge limits provided in the environment permit, e.g., water from steam traps, condensate leaks, feedwater leaks and cooling water leakage in the turbine, condensing and feed heating area. This water will be reused or recycled as much as possible. The power plant stormwater drainage system design will be based on a 1 in 5 year frequency rainfall event. Power plant equipment foundations will be above the level of the drainage system, ensuring that the site and equipment will not flood during such events.

The dirty drains system will collect all drainage that might be contaminated with oil, e.g., transformer areas, steam turbine lube oil area, diesel tank area and dispenser, and will be treated in the oily water separator(s) for reuse or discharge to the holding pond.

7.6.4 General Waste

The main solid waste associated with the power plant will be ash, as described above. Additional waste material will be generated and managed as described in Table 7.8 (and detailed in the EMP). Wastes that cannot be reused, recycled, composed or incinerated will be sent to landfill/s, which will be sited, designed and operated in a manner that is consistent with the Environmental Code of Practice for Sanitary Landfill Sites (OEC, 2001) and other relevant guidelines.

Table 7.8 – Summary of Waste Generation and Management

Waste Type	Description	Management
Domestic waste (non-putrescible)	Garbage, paper, cardboard, glass, timber	Landfill, incineration or recycled*
Domestic waste (putrescible)	Food	Composting or landfill
Oil and grease	Used oil and grease from power plant, mobile equipment and similar	Recycled* or incinerated off site
Tyres	–	Traffic management or recycled* off site
Workshop wastes	Batteries, solvents and similar	Recycled* off site or disposed to an approved facility
Chemicals/laboratory wastes/ chemical containers	Various reagents and similar	Recycled* off site or disposed to an approved facility
Plastic	PVC pipes, packaging and similar	Recycled* off site or disposed to an approved facility
Metal	Copper, brass, aluminium cans, steel and similar	Recycled* off site or disposed to an approved facility
Rubber and steel (combined)	Conveyor belting and similar	Rubber stripped and steel recycled* off site or disposed to an approved facility
Other	Various	Landfill or recycled* off site

*If appropriate recycling facilities exist, e.g., within the region.

7.6.5 Hydrocarbon Waste

Fuel (diesel), oil and grease will be required for both the power plant and the plantations, and will be delivered to the power plant where it will be distributed to other locations as required.

Waste oil and degreasers will be collected in separate receptacles and transferred to a designated bunded area within the workshops. Oil filters, grease and absorbent materials will be collected in drums and stored in the bunded facility within the workshops prior to collection. Contaminated soil will be bioremediated. Storage and use of hydrocarbons and associated wastes will be in accordance with the waste management procedures in the EMP.

7.6.6 Air and Noise Emissions

7.6.6.1 Emissions to Air

The power plant will be designed and operated such that emissions to air will (at a minimum) comply with the Equator Principles and the IFC/World Bank EHS guidelines for thermal power plants (IFC, 2008) (Table 7.9). As noted above in relation to wastewater, these values are for facilities that have a total rated heat input capacity above 50 MWth, hence their application to the Project is conservative. The non-degraded airshed values are applicable to the Project.

Table 7.9 – Air Emissions Guidelines for Solid Fuel Plants (>50 to <600 MWth)

Parameter	Degraded Airshed†	Non-degraded Airshed†#
Particulate matter (PM) (mg/Nm^3)	30	50
Sulfur dioxide (SO_2) (mg/Nm^3)	400	900 – 1,500
Nitrogen oxides (NO_x) (mg/Nm^3)	200	510*
Dry gas, excess O_2 content (%)	6%	

†IFC, 2008.
#Applicable to the Project.
*Or up to 1,100 if volatile matter of fuel <10%.

7.6.6.2 Noise Emissions

Excluding start up and shut down periods, blowdown and operation of the bypass vent valve, the power plant will be designed and operated such that near-field noise emissions (within 1 m of equipment) will be limited to 85 dB(A). Far-field noise levels of the overall facility (including start up and shutdown) will be limited to 70 dB(A) at the site boundary (assuming that this is at least 150 m from the highest noise emitter).

7.7 Closure and Rehabilitation

The Project has a notional life of 25 years, i.e., the power plant will have a design life for reliable operation of 25 years, after which it is expected that the two units will be refurbished to provide ongoing power generation. The anticipated total plantation life is in excess of 25 years, and the plantations are expected to continue generating biomass fuel and/or other timber products well beyond the power plant design life. The possibility also exists that, subject to further government approval, additional plantation areas could be established.

Given the above scenario, site closure and rehabilitation is not expected to occur in the foreseeable future and is therefore not further addressed in this document. However, this will be re-visited at regular intervals during the Project life and plans made accordingly in conjunction with stakeholders.

7.8 Workforce

7.8.1 Construction

The combined peak MVB and Pöyry site construction team will be comprised of some 40 to 45 people. Total site manpower estimates for construction of the first 15 MW unit are shown in Figure 7.10, which shows that the workforce will peak in the middle of the construction period at around 230 personnel (base case) or 459 (alternative if less machinery and more manual labour is used). Of these, 187 or 322 personnel (respectively) of the workforce will be PNG citizens. Recruitment will occur from the local Project area, followed in order of preference by recruits from the Project surrounds, elsewhere in Morobe Province and Papua New Guinea, and then internationally as necessary for specialist technical personnel not readily available in Papua New Guinea.

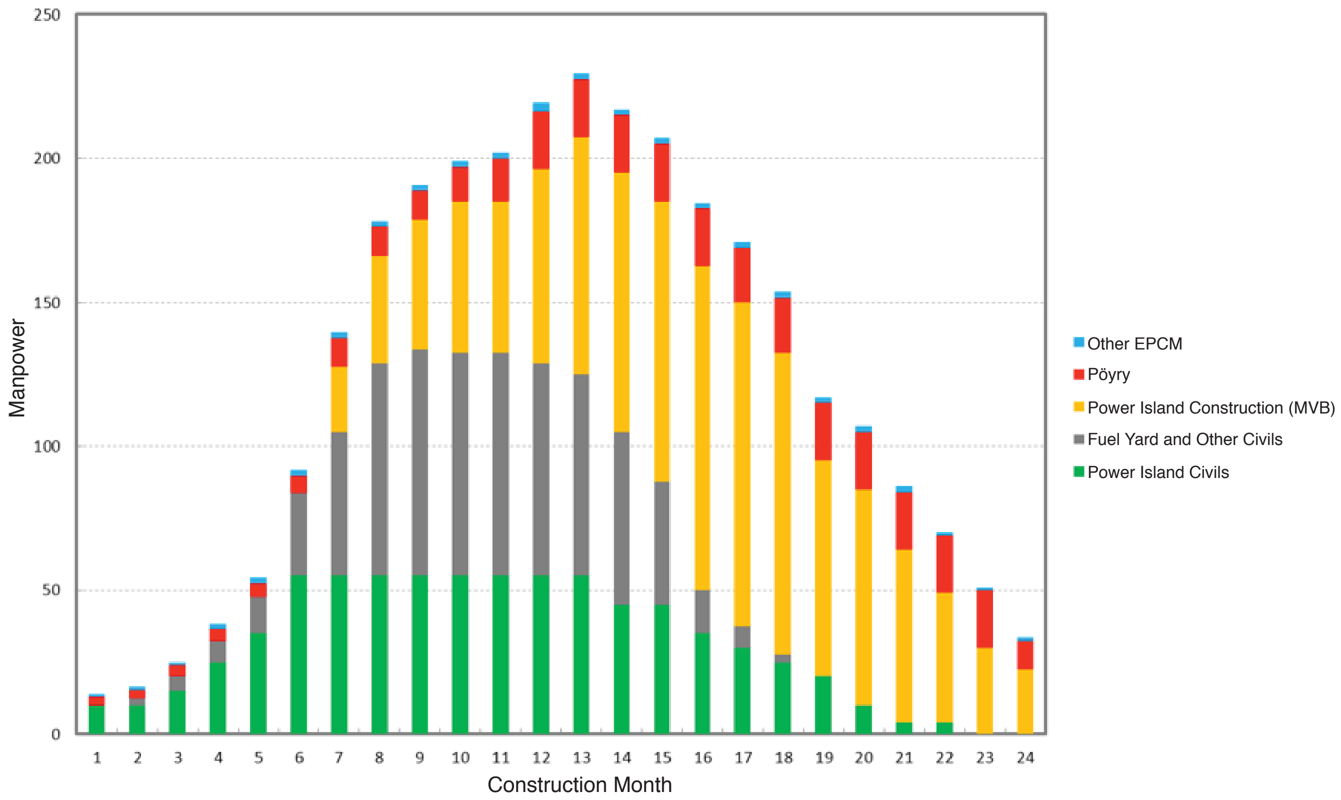
More than 500 people will be employed during the initial establishment of the plantations (2017 to 2019), again following the recruitment policy described above.

ESTIMATED POWER PLANT CONSTRUCTION WORKFORCE

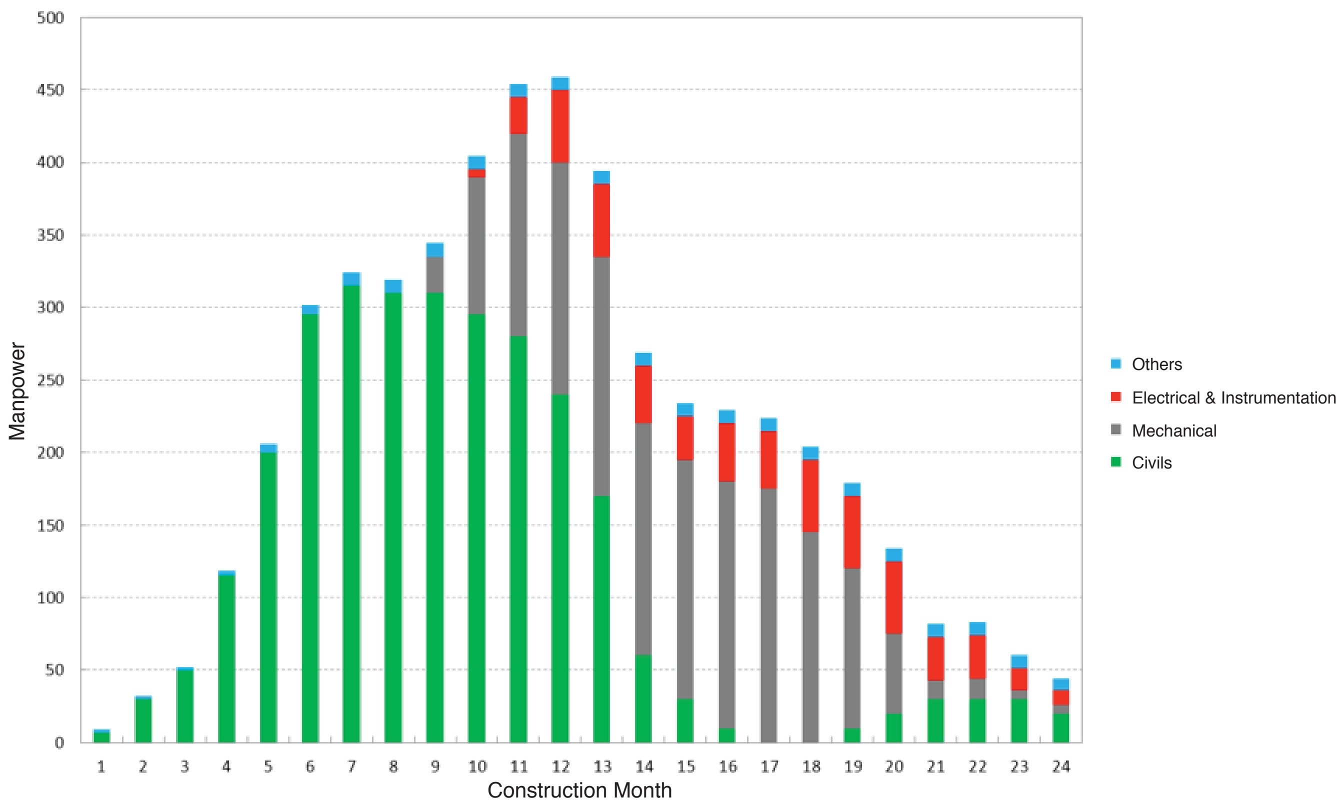
PNG Biomass Markham Valley I Environmental Assessment Report

FIGURE 7.10

A. Base Case



B. Higher Workforce Numbers Case



Source: Pöyry, 2016a.

7.8.2 Operations

The Project will create significant employment during operations, both direct and indirect. An indicative summary of direct employment is provided in Table 7.10. For operation of the plantations, approximately 500 full-time-equivalent personnel will be employed after 2019. For the power plant, an estimated 16 personnel will be employed during the commissioning phase, with 34 personnel during operation of the first 15 MW unit and 49 personnel when both 15 MW units are operating. As for the construction phase, the majority of personnel will be PNG citizens, in line with the recruitment policy specified in Section 7.8.1.

Table 7.10 – Estimate of Project Employment During Operations

Plantations (After 2019)		Power Plant (30 MW Phase)	
Plantation manager	1	Power plant manager	1
Deputy plantation manager	1	Deputy plant manager	1
Health, safety, environment and security (HSES) and certification manager	1	Administration	2
Forestry manager	1	Office/human resources (HR)/accounts	3
Fire coordinator	1	Electrical engineer	2
Land and community affairs (LCA)	3	Mechanical engineer	2
Area supervisors	6	Mechanics	2
Establishment supervisor	6	Fitter and turner	1
Land clearing and preparation teams	22	Welder and metalworker	2
Planting	26	Shift supervisor	3
Silviculture manager	1	Shift operator	3
Nutrition and fertiliser teams	168	Electrician and instrument engineer	3
Weed control and inspection	94	Fuel and ash handling	24
Coppice management	20		
Harvesting manager	1		
Workshops	15		
Harvesting teams	11		
Log transport	15		
Roading construction and maintenance	15		
Technical manager	1		
Nursery (establishment)	45		
Nursery (ongoing)	9		
Research and development/breeding	5		
Legal manager	1		
Human resources (HR)/training/ employee development manager	1		
Finance and office manager	1		
Finance and accounting	10		
Other*	20		
Total	**501**	**Total**	**49**

*Administration/office function, geographic information systems (GIS), forest management information system (FMIS), logistics, LCA support, information technology, HR support, contract management.

8. Potential Impacts of the Activity

This section should include a comprehensive analysis of the potential impacts of the proposed activity, including the effects of its waste discharges on environmental quality and the related socio-economic impacts (if any).

Information provided should include the following –

- *details of predicted impacts on the physical, biological and social environment,*
- *details of ambient and emissions standards used to assess the effects of the project,*
- *an assessment of the resilience of the environment to cope with the expected changes,*
- *describe aspects such as worst case scenarios, potential risks, emergency situations, confidence of prediction of impact.*

(Excerpt from 'Information Requirements for Permit Applications and Registration of Intention to Carry Out Preparatory Work', DEC Operational Procedure, Schedule 3, General Guidelines on the Additional Information Required to Support a Permit Application for a Level 2B Activity)

8.1 Physical Environment Impacts

8.1.1 General Approach to Impact Assessment

8.1.1.1 Introduction

This section describes the approach used to assess potential impacts of proposed Project activities on the physical environment. These activities include transport of materials (and people) to and from the site, use of heavy machinery, road construction and maintenance, construction and operation of the power plant and associated infrastructure, and establishment, maintenance and harvesting of the plantations. Components of these activities that may have an impact on the environment, (i.e., aspects) or which present potential hazards, have been systematically considered in the impact assessment (e.g., land clearing, noise generation, stack emissions and wastewater discharges).

This assessment involves:

- Describing the existing physical environment within and around the Project area, including relevant 'receptors' and beneficial values (see Chapter 6).
- Describing the Project and associated activities, particularly within the context of potential interactions with the existing environment (see Chapter 7).
- Taking into account the existing environment and the nature of the Project activities, identifying:
  - Potential impacts that reflect credible scenarios (i.e., their occurrence is a real possibility) and encompass all phases of the Project, with a conservative approach being adopted when defining these scenarios. Where considered relevant, impacts associated with the construction and operational phases of the power plant, or establishment of the plantations and their ongoing operation, have been considered separately.

  - Avoidance and management measures that address these potential impacts and are both technically and economically feasible within the Project context, and are assumed to be implemented in a timely manner during Project development.
  - Residual impacts, which are those impacts which remain after the successful implementation of management or mitigation measures.

This approach is consistent with that used in other recently completed environmental and social impact assessments for projects in Papua New Guinea and elsewhere (e.g., ERIAS Group, 2016) and with the approach described in IFC (2012).

Various methods of assessment have been used depending on the type of impact. The impacts that have been considered include those resulting from planned activities that affect the:

- Physical environment (Section 8.1 – this section).
- Biological environment (Section 8.2).
- Socio-economic environment (Section 8.3).

Ecosystem services (Section 8.4), cumulative impacts (Section 8.5) and major hazards from accidental/upset/abnormal events (Section 8.6) have also been considered.

Assessment of the above is based primarily on assessing the significance of the impacts, taking into account the impact magnitude and the sensitivity of the value that is affected. In some instances, quantitative criteria have been used where such criteria are available. Further descriptions of these two assessment methods are provided in Sections 8.1.1.2 and 8.1.1.3. Assessment of major hazards associated with accidental, upset or abnormal events involves discussion of the event, its consequences and proposed management and mitigation measures, drawing on information from a hazard identification (HAZID) workshop. This is further described in Section 8.6.

8.1.1.2 Impact Significance Assessment Method

Residual impacts have been assessed by considering both the magnitude of the impact (after the successful application of impact avoidance or management measures) and the sensitivity of the value being impacted. As defined in the *Environment Act 2000*, a beneficial value is:

> a quality or characteristic of the environment or any element or segment of the environment, which (a) is conducive to ecological health, public benefit, welfare, safety, health or aesthetic enjoyment and which requires protection from environmental harm; or (b) is declared in an Environment Policy or permit to be a beneficial value.

The term 'value' has been used in this document to encompass this definition and includes resources, sites, and other receptors as considered relevant.

This approach has allowed determination of each impact’s significance via a matrix, as discussed further below. While the definitions of the various magnitude and sensitivity categories are, to some degree, subjective, the use of a matrix provides an element of transparency that may otherwise be absent from impact assessments.

Magnitude of Impact

The magnitude of an impact reflects the size and nature of change based on its severity, geographical extent and duration. For the purposes of this assessment, these elements have been defined as follows:

- Severity: the scale or degree of change (both positive and negative) from the existing condition as a result of the impact.
- Geographical extent: the spatial extent of the impact where this is defined as site, local, regional or widespread (provincial, national or trans-boundary).
- Duration: the timescale of the effect, such as short, medium or long term (i.e., effectively permanent), and takes into account reversibility.

Based on these elements, the magnitude of impact has been ranked as high, moderate, low and negligible, as described in Table 8.1, with positive impacts (or benefits) also being included but not ranked. The criteria have been modified as required in subsequent sections to reflect the specific focus of each technical discipline. It should also be noted that where the magnitude of impact is ranked as negligible, the overall impact significance is also ranked as negligible regardless of the sensitivity of the value, resource or receptor that is being impacted.

Table 8.1 – Criteria for Magnitude of Impact

Magnitude	Description
High	♦ An impact that is long lasting, widespread, and leads to substantial and possibly irreversible change to the value, resource or receptor
Moderate	♦ An impact that is short term and is contained within the region where the project is being developed, but that extends beyond the area of disturbance to the surrounding area
Low	♦ An impact that is temporary or short term and localised, and where the change is barely detectable with respect to natural variability
Negligible	♦ An impact that is highly transient or very short term, highly localised, and easily remediated, and where the change is unlikely to be detectable with respect to natural variability
Positive	♦ A beneficial impact on an environmental value

Sensitivity of a Value

The Project has assessed relevant values as described in statutory guidelines or policy, or where these are not defined, determined on the basis of experience and accepted practice. The sensitivity of a value is then determined on the basis of a range of factors such as its:

- Formal status, where this may be assigned by statutory and/or regulatory authorities, or appropriately-recognised national and/or international organisations. This can involve legislation, regulations or international conventions or other mechanisms that attribute a particular status to a value.
- Rarity or uniqueness within and beyond the immediate area of interest, i.e., its vulnerability, and the capacity for the value to be replaced.
- Capacity to adapt to change without adverse effects on the values' inherent attributes, i.e., its resilience.

- Importance to local communities and society, and/or its iconic or symbolic importance to cultural value systems.

Sensitivity of values has been ranked as high, moderate or low, as described in Table 8.2. As with the magnitude of impact criteria, the sensitivity criteria have been modified in subsequent sections to reflect the specific focus of each technical discipline, as required.

Table 8.2 – Criteria for Sensitivity of a Value

Sensitivity	Description
High	♦ The value is intact and retains its intrinsic attributes ♦ The value is listed as being of conservation significance on a statutory or recognised international, national or state register ♦ The value is unique to the environment in which it occurs. It is isolated to the affected area or system, and is poorly represented in the region, territory, country or the world ♦ The value has not been exposed to threatening processes, or there has not been a noticeable impact on its integrity ♦ Project activities would have an adverse effect on the value ♦ Potentially affected communities are highly reliant on the value, e.g., it may be the primary or only source of food or income (i.e., the primary provisioning or regulating ecosystem service) for the community ♦ The value is highly important from a cultural heritage perspective
Moderate	♦ The value is recognised as being important at a regional level and may have been nominated for listing on recognised or statutory registers ♦ The value is in a moderate to good condition and retains many of its key characteristics and structural elements ♦ The value is relatively well represented in the areas/systems in which it occurs, but its distribution and abundance are limited by threatening processes ♦ Threatening processes have reduced the environmental value's resilience to change. As such, changes resulting from project activities may lead to degradation ♦ Due to the abundance and distribution of the value, replacement of unavoidable losses is possible ♦ Potentially affected communities are somewhat reliant on the value, resource or receptor. The environmental value is one of a number of food sources or income streams and is not the primary or only provisioning or regulating ecosystem service available to the community ♦ The value is moderately important from a cultural heritage perspective
Low	♦ The value is not listed on any recognised or statutory register, but may be recognised locally by relevant and suitably qualified experts or organisations ♦ The value is in a poor to moderate condition ♦ The value is not rare or unique, and numerous representative examples exist throughout the area/system ♦ The value is widely distributed and abundant throughout the host area or system ♦ Change is not expected to result in further degradation of the value, or there is no detectable response to change ♦ Replacement of unavoidable losses is assured due to the abundance and wide distribution of the value ♦ Potentially affected communities are not reliant on the value, resource or receptor. The value is not an important or regularly used source of food or income (although it may be an occasional ecosystem service) for the community ♦ The value is not important from a cultural heritage perspective

Not all of the attributes listed in Tables 8.1 and 8.2 are necessarily applicable to a specific impact or value, or may be contradictory, with the application of these criteria sometimes leading to inconsistent outcomes. For example, impacts that are widespread (with a high magnitude of impact as described in Table 8.1) may also be barely detectable (with a low magnitude of impact as described in Table 8.1). Where this occurs, professional judgement has been used to determine the criteria of most relevance and the overall impact significance.

Impact Significance

The significance of an impact on a value is determined by combining the likely magnitude of the impact on that value with its sensitivity via a matrix based on the above criteria. This approach is shown in Table 8.3.

Table 8.3 – Significance Assessment Matrix

		Sensitivity of Value		
		High	Moderate	Low
Magnitude of Impact	High	Major	High	Moderate
	Moderate	High	Moderate	Low
	Low	Moderate	Low	Low
	Negligible	Negligible	Negligible	Negligible
	Positive	Positive	Positive	Positive

The magnitude of an impact is assessed after the application of avoidance, mitigation and management measures that are expected to change the impact's severity, geographical extent or duration. As noted above, this is combined with the value's sensitivity, which generally remains unaltered unless proposed actions or activities reduce the susceptibility of that value to adverse effects. The outcome is a determination of the significance of the residual impacts, i.e., the credible impacts associated with Project development.

It should be noted that this represents a 'default' approach. As referred to above, discipline-specific approaches (that remain consistent with this default approach) have been documented in following sections where additional or different criteria were warranted or an alternative matrix was developed.

8.1.1.3 Compliance Assessment Method

Impacts associated with some Project activities – such as wastewater discharges or stack and noise emissions from the power plant – can be readily evaluated by comparison with objective, quantitative criteria, guidelines or standards. This approach has been adopted in a number of areas in this assessment by using, for example, both PNG water quality standards and water quality guidelines provided in ANZECC/ARMCANZ (2000) to evaluate impacts on ambient surface water quality, and WHO air quality guidelines (WHO, 2005). In these examples, predicted Project-derived values have been compared with these criteria, guidelines or standards. Non-compliances were then evaluated in terms of the likely actual impacts on relevant values, using the impact significance method where necessary.

8.1.2 Air Quality, Greenhouse Gases and Stack Plume Rise

8.1.2.1 Discipline-specific Approach

Air Quality

Assessment of air quality data requires consideration of impacts that may be experienced by various 'receptors' within the Project area, with a focus on public health and amenity. Impact assessment therefore involved comparison of potential changes in air quality with criteria, i.e., a compliance assessment was used (see Section 8.1.1.3).

Since Papua New Guinea currently does not have statutory air quality standards, the results of the air quality modelling studies and qualitative assessment techniques (see Appendix 3) were assessed against international air quality guidelines and standards including:

- International Finance Corporation (IFC) Environmental, Health, and Safety (EHS) Guidelines (IFC, 2007 and 2008).
- World Health Organization (WHO) Air Quality Guidelines (WHO, 2000 and 2005).

Table 8.4 shows the air quality criteria selected for this impact assessment. Qualitative assessments of impacts have been guided by the Institute of Air Quality Management (IAQM) guidelines regarding construction distances from sensitive receptors (IAQM, 2014).

Table 8.4 – Project Ambient Air Quality Criteria

Pollutants	Averaging Period	Limit* (µg/m^3)	Source
NO_2	1-hour	200	WHO (2005)
	Annual	40	
SO_2	10-minutes	500	WHO (2005)
	24-hour	20	
CO	1-hour	30,000	WHO (2000)
	24-hour	10,000	
PM_{10}	24-hour	50	WHO (2005)
	Annual	20	
$PM_{2.5}$	24-hour	25	WHO (2005)
	Annual	10	
Benzene*	Annual	0.17	WHO (2005)

*Excess lifetime risk level of 1:1,000,000. Source: Appendix 3.

Construction activities were assessed qualitatively due to their relatively lower potential for adverse impacts on local air quality than some operational activities. This qualitative assessment was based on adequate separation distances between the activity and the nearest sensitive receptor, using the IAQM screening criteria (IAQM, 2014):

- Sensitive receptors are located more than 350 m from the boundary of the site.
- Sensitive receptors are located more than 50 m from the route used by construction vehicles on public roads.

- Sensitive receptors are located more than 500 m from the site entrance.

General buffer recommendations concerning the separation of sensitive land uses from fuel storage of petroleum products and crude oil in tanks exceeding 2,000 t capacity were also used for the assessment, these being (see Appendix 3):

- 300 m from storage with fixed roofs.
- 100 m from storage with floating roofs.

Greenhouse Gases

The approach to the impact assessment for air quality and greenhouse gas (GHG) emissions is based on the compliance assessment method (Section 8.1.1.3) for air quality and impact significance (Section 8.1.1.2) for GHG.

Given that a substantial component of the Project's significance in terms of greenhouse gases rests with use of biomass as boiler fuel, the assessment presented herein focuses on stack emissions and plantation uptake of carbon dioxide (CO_2). Other aspects of GHG emissions associated with the Project will be further addressed during the later stages of FEED.

Project-specific modelling has been undertaken in relation to carbon cycling during Project operations. This includes factors such as tree growth by stem volume, expansion factors (i.e., roots, branches and leaves), carbon fixation volume in plantations, plantation establishment and harvesting, and power plant emissions.

The calculations of net carbon fixation for each harvesting cycle (seven to nine years for logs that will be burnt as fuel) is derived using the method from the Gold Standard afforestation/ reforestation requirements (The Gold Standard Foundation, 2013), which applies the averages of carbon stock in plantations or forests. The long-term fixation of CO_2 in plantations is estimated relative to the volume of stem wood produced, which is converted to dry tonnes of matter. The constants used are shown in Table 8.5.

Table 8.5 – Constants Used to Estimate CO_2 Fixation

Assumption	First Rotation Replant
Biomass expansion factor (BEF)	1.50
Root to shoot ratio	0.45
Carbon fraction	0.47
C to CO_2 factor	3.67
CO_2 (t) to stem volume (m^3)	3.75

The estimated long-term fixation of CO_2 was calculated using the averages of Project emissions and the volume of stem wood over a 30-year period (2019 to 2051). The standing volume of stem wood is estimated using modelling software that has been designed to provide standardised forest estate descriptions, optimisation and valuations.

The derivation of tree volume from stem volume is calculated by the formula:

$$\text{Tree volume} = \text{stem volume} * \text{BEF} * (1 = \text{root to shoot ratio})$$

Derivation of CO_2 fixation is calculated by the formula:

$$CO_2 = \text{tree volume} * \text{carbon fraction} * \text{C to } CO_2 \text{ factor}$$

The estimated plantation stem volume, tree volume and CO_2 fixation (kt/year) for the operation of the 30 MW power plant over 30 years are shown in Figure 8.1.

The fixation of CO_2 in export veneer and saw logs was calculated using the annual change in carbon stored in plantations and the power plant demand for fuel. Power plant emissions were calculated using the average CO_2 emissions of similarly designed biomass power plants of 30 MW.

Stack Plume Rise

Assessment of impacts associated with plume rise from the power plant stacks involved comparing Project modelled plume rise data with criteria established by relevant guidelines/standards, i.e., a compliance assessment was used (Appendix 8). In the absence of relevant regulatory guidelines in Papua New Guinea, the impact assessment was performed following the guidelines described in the Civil Aviation Safety Authority (CASA) Advisory Circular (AC) 139-5(1) for Plume Rise Assessments (CASA, 2012). That document provides guidance concerning matters such as:

- Determining the critical velocity of the vertical exhaust plume in relation to aerodromes and aircraft.
- Design, construction and operation of facilities with vertical exhaust plumes.
- Plume rise assessment process and the need to assess the potential hazard to aircraft posed by any exhaust plume with an exit velocity greater than 4.3 m/s.

Dispersion modelling using CALPUFF was undertaken to predict the critical plume height for the boiler stacks. The post-processor RISEPOST was used to extract statistics on the plume vertical velocity at various user-specified heights.

Two boilers will operate concurrently at the proposed site, each with a separate 40 m tall stack that will be located approximately 25 m apart. As a conservative approach and in lieu of the CALPUFF model being designed for multiple stacks with the potential for flume merging to occur, modelling was undertaken on the basis of a single combined stack (essentially assuming the merging of the plumes would occur within the stack). The model was used to predict the maximum critical plume heights under the full range of meteorological conditions likely to be experienced at the site (using a one year dataset of site-representative hourly meteorological data).

ESTIMATED STANDING VOLUME OF PLANTATIONS AND CO_2 FIXATION

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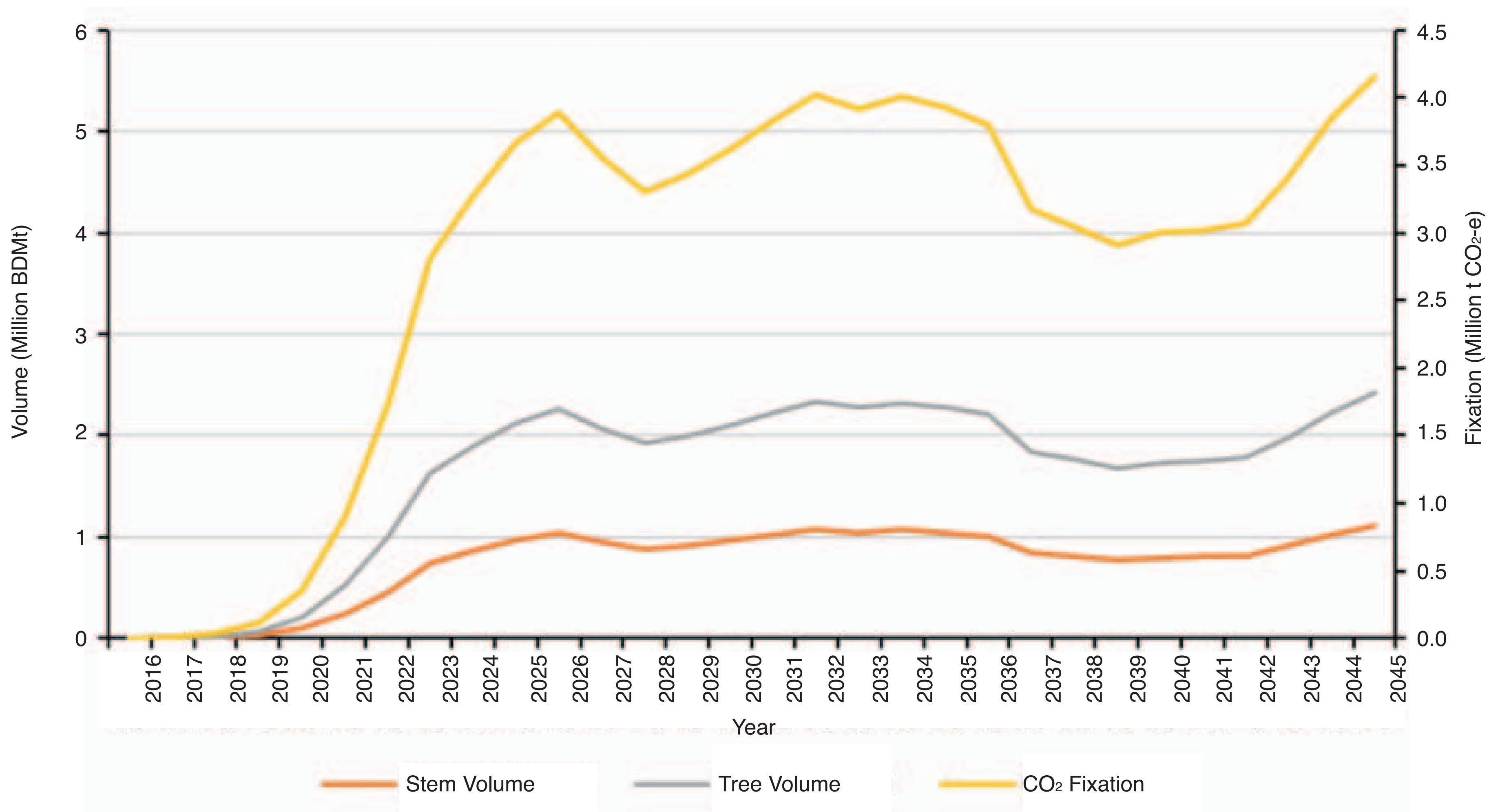
FIGURE 8.1



Source: PNG Biomass, 2016b.

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8.1.2.2 Potential Impacts

Air Quality

Potential sources of emissions to air associated with the construction and plantation establishment phase of the Project include:

- Constructing the power plant, log yard and nursery (through clearing vegetation, truck deliveries and erection of buildings).
- Upgrading and establishing access roads in the plantation areas.
- Establishing plantations (through clearing vegetation and soil cultivation).
- Construction vehicle movement (including transport of workers).
- Vapour losses (volatile organic compounds (VOCs)) from the storage and handling of diesel and fertilisers, and other bulk chemical storage.

Potential sources of emissions to air associated with the operation phase of the Project include:

- Biomass fuel combustion and emissions from power plant stacks.
- Trucks transporting logs to the power plant and ash off site.
- Biomass fuel preparation (i.e., chipping of logs).

Other potential sources of emissions to air associated with the operation phase of the Project include:

- Vehicles travelling along unsealed access roads (including trucks transporting logs to the power plant).
- Equipment associated with plantation maintenance and harvesting of timber.
- Vehicles used to transport workers (passenger buses and light vehicles).
- VOCs from stored biomass fuel, supplementary support fuels (if present) and diesel/petrol required for other fixed and mobile plant.

Potential stressors associated with these emissions sources include:

- Fugitive and point source particulate matter (PM_{10} and $PM_{2.5}$)[1], such as dust.
- Nitrogen dioxide (NO_2).
- Sulfur dioxide (SO_2).
- Carbon monoxide (CO).

[1] PM_{10} – particulate matter ≤10 µm in diameter; $PM_{2.5}$ – particulate matter ≤2.5 µm in diameter.

- Total VOCs (as benzene).

The potential impacts associated with these stressors include:

- Adverse health impacts to people and flora/fauna.
- Adverse impacts on the amenity and aesthetics of the Project area.
- Adverse impacts on vegetation (primarily due to particulates and SO_2).

Greenhouse Gases

Activities relating to biomass production, harvesting and burning during operations will be the largest source of emissions, with CO_2 being by far the most dominant GHG emitted. Relevant activities include:

- Land clearance.
- Plantation establishment, e.g., combustion products from diesel-powered machinery (and, to a lesser extent, the use of fertiliser with the potential to produce nitrous oxide (N_2O)).
- Plantation harvesting and transport, e.g., combustion products from diesel-powered machinery and transport vehicles.
- Boiler and burner emissions throughout operations.
- Use of diesel-powered generators (and consequent generation of combustion products).
- Methane (CH_4) emissions from chipped woodpiles.
- Transport of materials, products, wastes and people, e.g., combustion products from diesel and heavy fuel oils in support and transport vehicles.
- Waste management, e.g., from landfills.

Project-related emissions will contribute to the national GHG emissions total, where such emissions from all countries are a current focus of international attention due to climate change.

Stack Plume Rise

The power plant site is located approximately 10 km from Lae Nadzab Airport. Exhaust plumes from power plant stacks or other industrial facilities can have adverse impacts on aircraft during periods of calm winds, and these can be exacerbated if the temperature is low or the atmosphere is unstable. Potential impacts therefore include threats to aircraft due to:

- The turbulence generated from the upward motion of the plume (and this is the main potential hazard to light, fixed-wing aircraft at low altitude).
- Low oxygen concentrations and elevated temperatures inside the plume (which can be detrimental to slow flying or hovering helicopters).

Potential impacts from plume rise are only relevant to the operations phase of the Project.

8.1.2.3 Avoidance and Management

Air Quality

Mitigation measures that will be implemented during both the construction and operations phases of the Project include (and additional details and measures are provided in the EMP (Appendix 9)) include:

- Use water to suppress dust emissions during periods of extended dry weather and when dust nuisance has the potential to occur as a result of construction activities.
- Locate stockpiles away from areas prone to elevated erosion or sensitive receptor locations.
- Maintain all vehicles and machinery used for the construction in accordance with the manufacturer's specifications to limit exhaust emissions.
- Limit truck queuing, unnecessary idling of trucks and unnecessary trips through logistical planning of materials delivery and work practices.
- Implement speed limits via posted speed limit signs on Project unsealed roads (when required).
- Where loads of materials likely to generate dust (e.g., fly ash or bottom ash) are being transported to or from the power plant, these will be covered if practicable.
- Ensure that vehicles keep to marked trafficable areas which are maintained in a compacted condition (when required) to enhance safety and limit dust emissions.
- Limit cleared areas as far as practicable and retain existing vegetation where possible.
- Strip areas progressively and only where it is necessary for works to occur.
- Employ soil stabilisation methods such as matting, grassing or mulch, where practicable.
- Ensure that clean up and restoration proceeds as soon as is practicable after works are completed to limit the duration of exposure of disturbed areas.

When construction activities occur close to sensitive receptors (i.e., within 1 km), the following additional mitigation measures will be implemented:

- Locate fixed and mobile equipment (i.e., generators) sensitively with respect to local people.
- Postpone, limit or relocate dust-generating activities in windy conditions (where practicable).
- Notify each village of the times and duration of works, and the possibility that they may be affected by emissions from the works as construction approaches.
- Establish clear communication methods to ensure that affected communities have access to effective communication links to the operational managers, and substantiated complaints can be addressed appropriately.

The underlying principles are that:

- The works are conducted in a manner that limits the generation of air emissions.
- The effectiveness of the controls being implemented is monitored.
- Additional measures are implemented where required, as determined by the monitoring program.
- A complaints management system is implemented so that identified incidents or substantiated complaints are dealt with through investigation and implementation of corrective treatments.

Greenhouse Gases

Biomass as an Alternative to HFO Generated Power

From a high level (and national) perspective, the Project itself can be viewed as a mitigation measure in terms of power generation and associated greenhouse gas emissions that are often associated with power sources. Use of biomass is also consistent with the IFC's general environmental health and safety (EHS) guidelines for thermal power plants (IFC, 2008), which advocates carbon neutral fuels (e.g., biomass).

The impacts relating to the absence of the Project on power supply for the Ramu grid have been determined during the Project's feasibility study and are shown in Figure 8.2. The data shows that the 30 MW of baseload and shoulder supply would need to be met in 2024 by heavy fuel oil (HFO) (and it is assumed that over the longer term (i.e., after 10 years) other renewable, hydropower or lower intensity gas generation would be deployed to meet large mining loads) in the absence of the Project. The use of HFO as an alternative fuel source, with its related emissions, would result in a lost opportunity to reduce GHG by biosequestration that is integral to the Project.

Development of the Project is estimated to avoid 145 kt CO_2 per year of emissions from an alternative diesel/HFO power development through carbon displacement.

Carbon Credits

Under the PPA, there is potential to leverage off the Project's 'Independent Sustainability Certification' to generate voluntary carbon credits from Project operations. Over the life of the Project, it is expected that approximately 5,000,000 t of carbon credits may be available based on displacement of diesel, HFO or hydrocarbon liquids generation.

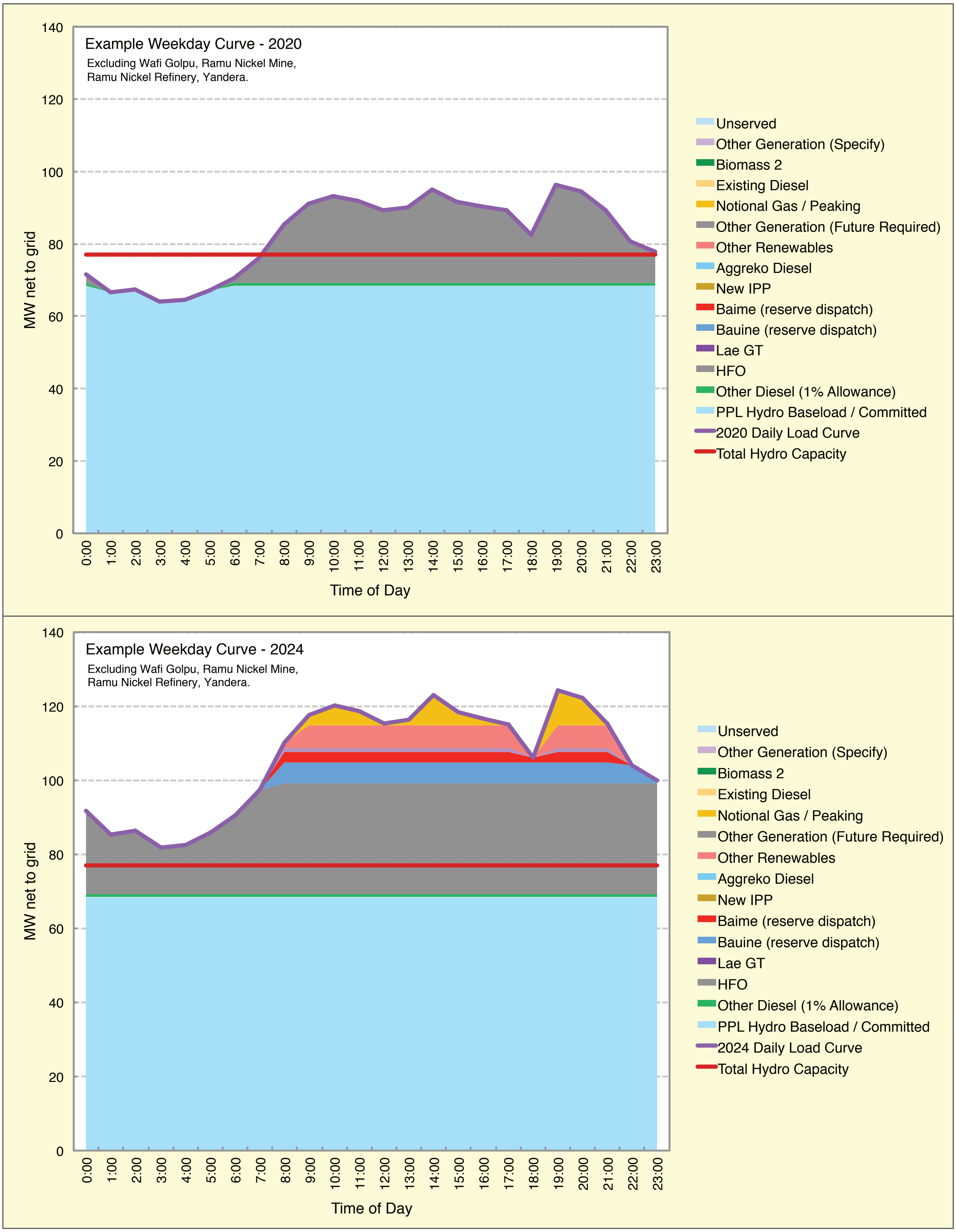
Project Level Mitigation Measures

At a more Project-specific level, mitigation measures that will be implemented to reduce CO_2 emissions in particular (and GHG emissions in general) include:

- Designing an energy efficient plant, using high quality, sustainable boilers and supporting infrastructure.

FIGURE 8.2

PNG BIOMASS Oil Search ERIAS GROUP



Source: AEL, 2016b.

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- Using the design proponent (Pöyry) as the contractor for ongoing maintenance of the power plant. This will ensure that the expertise of a biothermal energy specialist company is carried out across the long-term management and operation of the plant.
- Implementing a management system that accurately quantifies emissions on a regular basis, thereby allowing major sources of emissions and the effectiveness of adopted measures to be continually identified and measured.
- Implementing a program whereby:
  - The power plant, plantation machinery and equipment will be regularly tuned and audited to ensure an efficient system.
  - Diesel consumption is minimised by measures such as vehicle speed reduction, minimal idling times, maintaining roads in good condition and minimising road gradients.
- Adopting a recording system using nationally and internationally recognised and approved calculation methods.

Stack Plume Rise

The potential impact associated with plume rise will be addressed by appropriate notification to aviators via aviation charts.

8.1.2.4 Residual Impacts

Air Quality

Fugitive Particulate Emissions

The construction phase of the Project is expected to result in generation of fugitive particulate emissions and elevated levels of PM_{10} and $PM_{2.5}$ in the Project area. Construction activities with the greatest potential to cause this impact at sensitive receptors (i.e., village locations) are the construction of the power plant, log yard and nursery sites, upgrading and establishing access roads into the plantation areas, and the establishment (particularly cultivation) of plantation areas.

The nearest village of Ganef is 800 m from the power plant site boundary and hence more than the required separation distances of 350 m from the site boundary and 500 m from the site entrance. However, since Ganef is located next to the Highlands Highway, some dwellings may be less than 50 m from the route used by construction vehicles. As most construction traffic is expected to access the power plant site via the Highlands Highway from Lae and will slow down and turn off just prior to reaching Ganef, minimal impacts are expected and monitoring of dust impacts at Ganef is not expected to be warranted. If a substantial number of trucks carrying spoil and/or equipment to and from the site will directly pass Ganef, then an assessment of dust impacts may be required during construction. Additional management measures (such as a truck/wheel wash facility) may be required if dust impacts to Ganef are encountered during construction.

Based on the IAQM screening criteria, construction activities in plantation areas that are located more than 350 m from an existing village do not require a risk assessment of dust impacts. The largest villages in the Project area (Chivasing and Tararan) will be surrounded by a buffer zone of at least 50 m, within which plantation establishment will not occur. Consideration will be given to planning intense construction activities (e.g., access roads) to maximise the separation distance between the villages and these activities. Where possible, access roads into plantation areas will be located more than 350 m from existing residential receptors. Where this is not possible, additional mitigation measures will be considered.

During operations, movement of Project-related vehicles other than log and ash trucks is likely to be relatively infrequent, with potential particulate emissions being minimal compared to those generated by the log and ash trucks (which were considered in the dispersion modelling study). It is considered unlikely that these additional vehicle movements will result in significant elevation of suspended particulate matter concentrations in the area. Relevant mitigation measures such as speed limits, road maintenance and logistics will further reduce the impacts of these emissions.

With respect to impacts on vegetation, dust deposition rates generally decrease rapidly with distance from the source, and any damage to vegetation as a result of dust emissions is expected to be very localised and limited to less than 100 m from the source. Local rainfall within the region that 'washes' the foliage will further reduce the impacts.

Combustion-related Gaseous Pollutants

Increased ambient concentrations of combustion-related gaseous pollutants during both construction and operations will occur. However, given the scale of the proposed activities, the relatively sparsely populated nature of the area and the distance to receptors, such impacts will be minimal and adverse emission effects will generally be limited to dust-related impacts.

Fuel Storage

Fugitive VOC emissions will occur as a result of ‘breathing’ and working losses during storage and through evaporation as a result of minor spills during handling. These will be relatively minor, will disperse rapidly, and are not expected to have any measurable impact on ambient concentrations beyond a few hundred metres from the fuel storage areas. The identified sensitive receptors are located more than the recommended buffer distances of 300 m from the power plant site, hence no adverse air quality impacts are expected.

Stack Emissions

Potential air quality impacts associated with emissions from the power plant stacks, and trucks transporting logs to the power plant and ash off-site, have been quantitatively assessed using dispersion modelling. The results indicate that the maximum ground level concentrations of PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, and total VOC at all existing sensitive receptors will be well below the relevant air quality criteria. Relevant contour plots are shown in Appendix 3, with an example given in Figure 8.3.

The model predicted that the cumulative maximum 24-hour average and annual average PM_{10} ground level concentrations north of the site would exceed the air quality criteria in a localised area immediately next to the power plant site boundary. Predicted worst case ground level PM_{10} concentrations at this location are up to 53 µg/m^3 as a 24-hour average, compared to the air quality assessment criterion of 50 µg/m^3. However, this area is not currently populated and hence these predicted values are of limited significance.

MODELLED INCREMENTAL IMPACT FOR PM_{10} (ANNUAL AVERAGE, µg/m^3)

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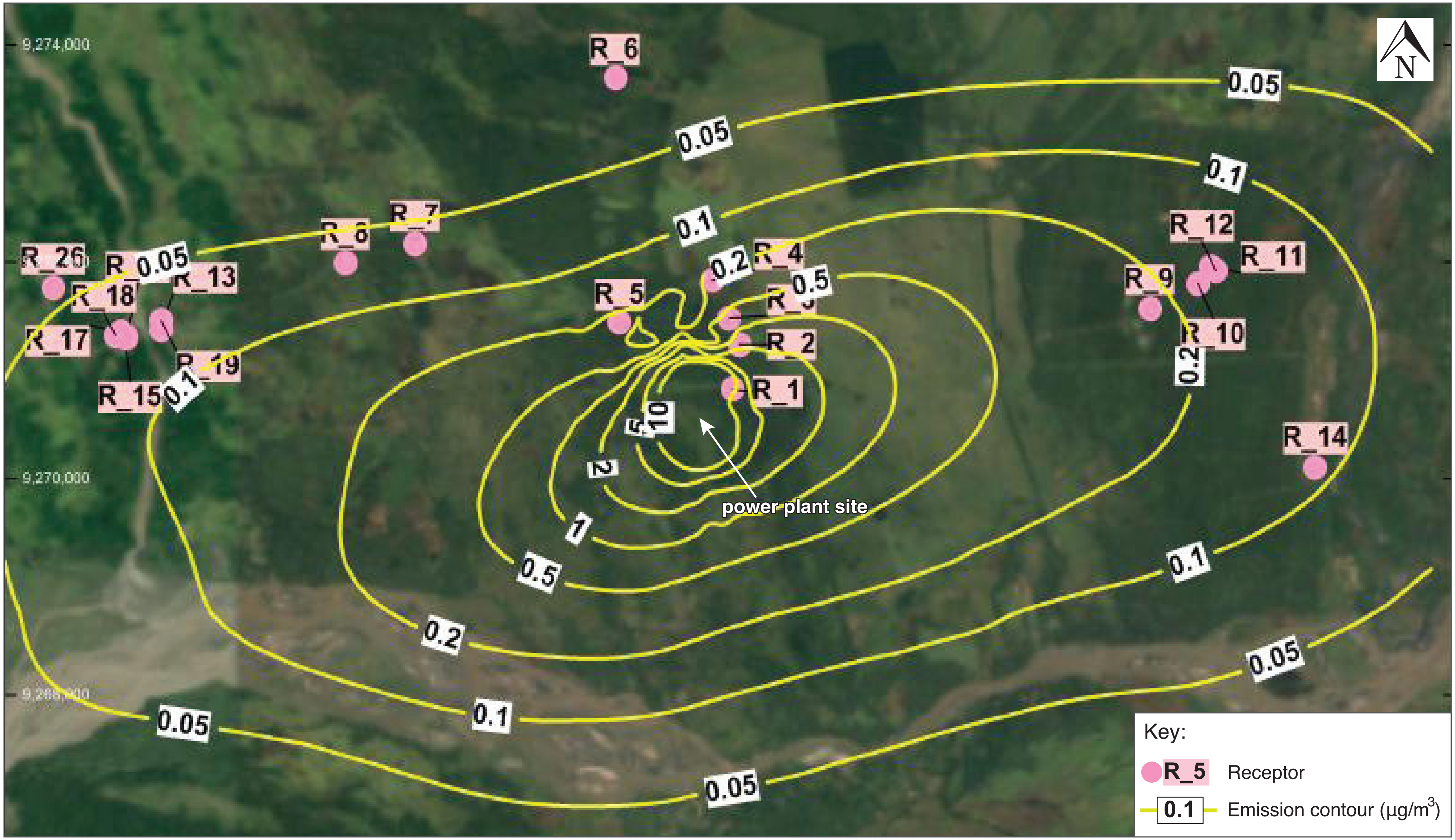
FIGURE 8.3

PNG BIOMASS Oil Search ERIAS GROUP



Source: Appendix 3.

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Damage to plants can occur from exposure to SO_2 and can include two-sided lesions or yellowing or chlorosis of the leaves. The modelling predicted that annual average SO_2 concentrations beyond the power plant site boundary would be well below the WHO (2000) annual average guideline for vegetation impacts of 20 µg/m^3, with a maximum annual average concentration of 0.7 µg/m^3 predicted on the northern boundary[2]. Adverse impacts on vegetation due to SO_2 exposure are therefore expected to be negligible.

Greenhouse Gases

Project Carbon Cycle

The plantation trees, coppice and seedlings will absorb CO_2 from the atmosphere, with the carbon subsequently being stored in the plant fibre, including root systems (i.e., a form of biosequestration). When the trees are used as fuel in the power plant, carbon is released back into the atmosphere as CO_2. This will be compensated by the ongoing absorption of CO_2 by the remainder of (and new) plantation trees, which will then be used as fuel, and so on.

The modelling results presented in Figure 8.4 show that the Project will be virtually carbon neutral (or carbon negative) due to the constant cycling of CO_2 and the use only of biomass as fuel. Based on the Gold Standard method, the total fixation of CO_2 by existing plantations is estimated to be 773 kt CO_2/year ('A' in Figure 8.4); of this, approximately 40 to 50% (419 kt CO_2/year ('B')) will be released back to the atmosphere by breakdown of harvesting slash and roots. Another 2.3 kt CO_2 (2.1 + 0.2 kt CO_2/year ('G' + 'H')) will be released through plantation establishment and harvesting via diesel combustion from machinery and transport vehicles. The harvested plantation logs to be used to fuel the power plant and for export timber will net fix an estimated 354 kt CO_2 ('C'), of which 280 kt CO_2 ('D') will be released back into the atmosphere via stack emissions.

Net Project Operations Emissions

The biomass tonnage that will fuel the power plant will remain constant (as long as the plant is running to capacity, with excess wood being exported as solid timber products). Two scenarios have been considered relating to carbon fixation in timber that is destined for veneer and sawlogs for export:

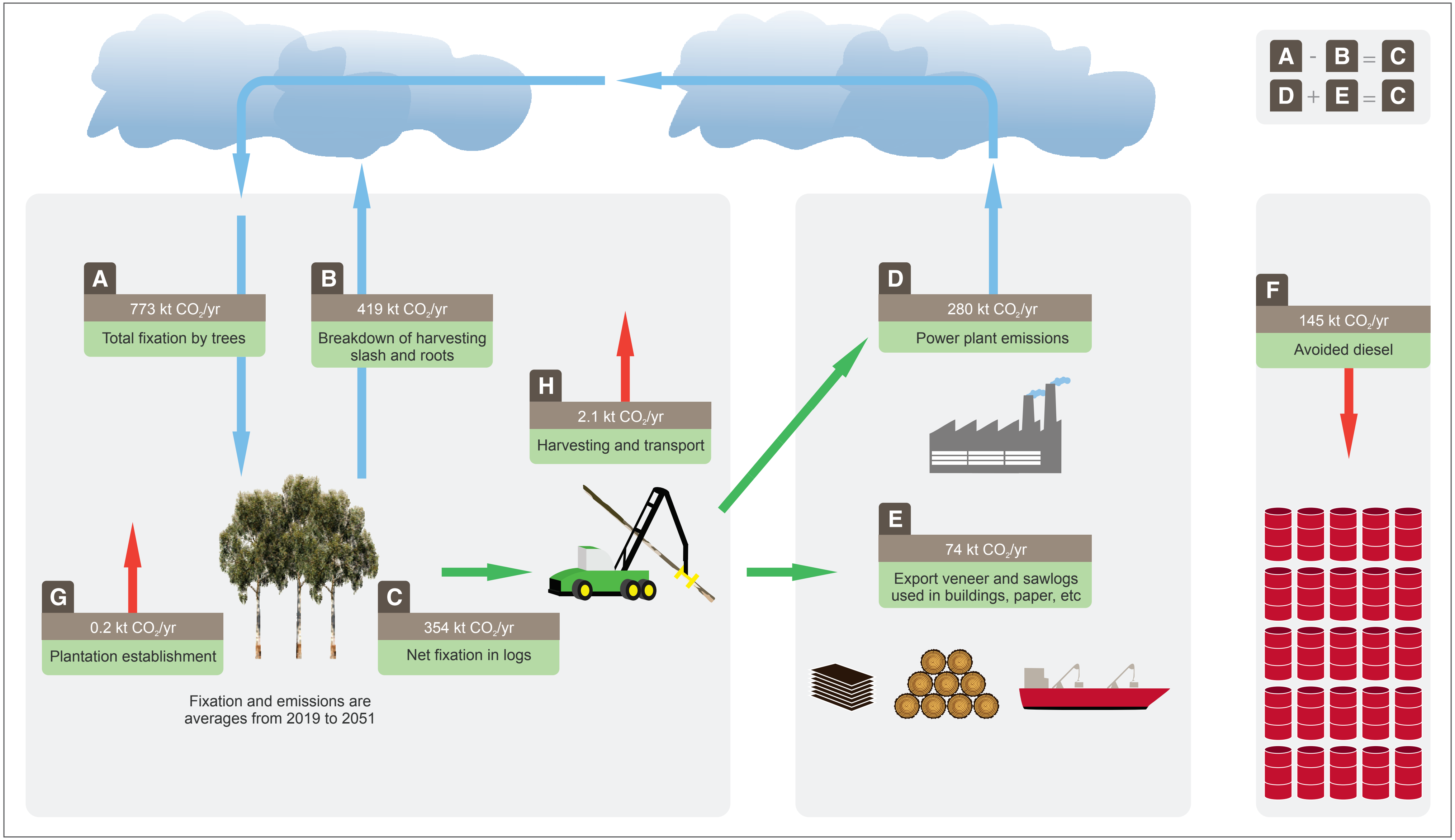
- Scenario A – Net emissions if (E) is permanently captured/stored: if it is assumed that carbon incorporated in export veneer and sawlogs is permanently fixed, then this is 'lost' from the carbon cycle resulting in Project net emissions of -71.7 kt CO_2/year (i.e., G+H-E, Figure 8.4).
- Scenario B – Net emissions if (E) is temporarily stored: if it is assumed that carbon incorporated in export veneer and sawlogs is only temporarily fixed, then this remains part of the carbon cycle resulting in Project net emissions of 2.3 kt CO2/year (i.e., G+H, Figure 8.4).

[2] The annual guidelines for potential impacts of SO_2 on vegetation (WHO, 2000) are different from those indicated in Table 8.4, which relate to human health only (WHO, 2005).

PROJECT CARBON CYCLE

PNG Biomass Markham Valley I Environmental Assessment Report

FIGURE 8.4



Source: adapted from Dickinson, pers. com., 2016.

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Impact Significance

Using the 1994 value for national CO_2 emissions including land use change and forestry (LUCF) (see Section 6.1.7), Scenario B results in the Project-related CO_2 emissions being approximately 0.05% of the total PNG emissions. More recent data generated in 2014, including LUCF, indicates that the Project emissions for Scenario B would contribute to 0.003% of total national emissions.

For the purposes of this assessment, the sensitivity of this value has been characterised as '**high**' due to the international concern about GHGs and the implication of increasing levels on the global climate. However, the magnitude of change related to GHG emissions from the Project is considered to be '**negligible'** due to the minimal (<0.1%, worst case) contribution these emissions will have to the overall GHG emissions of Papua New Guinea, hence the impact significance is also '**negligible**'.

Papua New Guinea, in turn, contributes a very small proportion (approximately 0.15%) of GHG emissions (including LUCF) with respect to global emissions (FAO, 2014). Therefore, the overall effect of GHG emissions from the Project are assessed as having a '**negligible**' magnitude of impact on global climate change. If Scenario A is assumed to be applicable (whereby carbon is permanently stored in veneer and sawlogs), then the impact is '**positive'**. This is further enhanced when the fact that the Project as a whole is a mitigation measure for an HFO equivalent Project is taken into account (i.e., 'F', Figure 8.4).

Stack Plume Rise

The exhaust plumes from the power plant stacks will have no significant effect on aircraft operations associated with Lae Nadzab Airport if the critical plume height (i.e., the height at which the vertical velocity drops below 4.3 m/s) is less than 150 m in the outer horizontal surface[3].

The modelling results show that, even under worst-case meteorological conditions and assuming complete merging of the two plumes, the maximum predicted plume height with a vertical velocity of 4.3 m/s or higher is 103 m above ground level, which is well below the required height. The exhaust plumes will therefore have no significant effect on aircraft landing or taking off from Lae Nadzab Airport.

8.1.3 Noise

8.1.3.1 Discipline-specific Approach

Since Papua New Guinea does not have specific domestic noise policies, appropriate noise level criteria for the Project have been developed using relevant national/international criteria, particularly:

- World Health Organization (WHO) Guidelines for Community Noise 1999 (WHO, 1999).
- IFC/World Bank Noise Management Guidelines 2007 (IFC, 2007).

The Project noise criteria are detailed in Table 8.6.

[3]This is a plane located 150 m above the reference elevation datum and extending from the upper edge of the conical surface for a distance of 15,000 m (radius) from the aerodrome reference point (CASA, 1999).

Table 8.6 – Project Noise Criteria/Goals

Activity	Source	Noise Receiver	Time Period	Noise Criteria/Goals	Reference
Normal operations and construction periods longer than three months	Continuous	Site boundary	All hours	$L_{Aeq,\ 1\ hour}$ 70dB	Internal Project commitment
	Continuous	Residential	Night	$L_{Aeq,\ 1\ hour}$ 45dB (internal noise goal: $L_{Aeq,\ 1\ hour}$ 37dB)[#]	WHO, 1999/IFC, 2007
			Day	$L_{Aeq,\ 1\ hour}$ 55dB	IFC, 2007
	Single events	Residential	Day	$L_{Aeq,\ 1\ hour}$ 60dB (internal noise goal: $L_{Amax,\ 1\ hour}$ 52dB)[#]	WHO1999
Construction periods less than three months	Continuous	Residential	Night	$L_{Aeq,\ 1\ hour}$ 45dB (internal noise goal: $L_{Aeq,\ 1\ hour}$ 37dB)[#]	WHO, 1999/IFC, 2007
		Residential	Day	$L_{Aeq,\ 1\ hour}$ 75dB	WHO,1999
	Single events	Residential	Night	$L_{Aeq,\ 1\ hour}$ 60dB (internal noise goal: $L_{Amax,\ 1\ hour}$ 52dB)[#]	WHO,1999
Vehicle movements on existing roads	Intermittent	Residential	Day	No numerical limit	-
			Night	$L_{Aeq,\ 1\ hour}$ 60dB (internal noise goal: $L_{Amax,\ 1\ hour}$ 52dB)[#]	WHO, 1999

[#]A noise level 8 dB lower than that indicated in the WHO/IFC Guidelines is recommended as an internal goal to reflect the low level of sound attenuation provided by most village accommodation in Papua New Guinea.
Source: Appendix 4.

In regards to general continuous operational noise, a criterion of L_{Aeq} 45 dB at night for residential receivers, in accordance with the IFC Noise Management Guidelines, has been adopted for the assessment. A best practice design goal of L_{Aeq} 37 dB is an internal goal for night-time continuous noise to reflect the lower level of sound attenuation provided by most village accommodation in Papua New Guinea.

The noise assessment and prediction applied two broad approaches (see Appendix 4 for further details and assumptions):

- Where site locations and defined layouts for the Project were available (e.g., power plant site), noise predictions were made in relation to discrete receptors and the surrounding area using the CONCAWE environmental noise attenuation model that was implemented within the SoundPLAN (SoundPLAN GmbH) (Version 7.4) numerical platform.

- A generalised buffer distance approach has been adopted for construction works which are geographically linear with anticipated short-term associated impacts or where detailed information regarding construction equipment or method is not yet available. This involved noise level prediction using either a simplified SoundPLAN noise model or calculation spreadsheets, depending upon available information.

Indicative offset distance calculations have been conducted to assist with planning of the construction stage of the power plant. The sound power levels (SWL) have been sourced from SLR Consulting's noise source database (see Appendix 4).

8.1.3.2 Potential Impacts

Noise emissions related to power plant construction and operation activities have the potential to cause adverse impacts on the sensitive receptors in the vicinity of the power plant and surrounding environment. Potential noise sources are likely to occur both in the construction and operation phases of the power plant. During construction, these include:

- The construction of civil works, support facilities and fuel storage areas, involving excavators, bulldozers, graders, cranes and other construction vehicles.
- Erection of the main buildings, again involving construction vehicles, portable refrigeration and standby diesel generators.
- On-site power, including small air conditioners and diesel generators.

Noise impacts for the operation phases of the power plant were modelled for mobile and fixed plant and equipment for a number of scenarios with specified noise level definitions. Potential specific sources included:

- Biomass furnace and supporting plant building.
- Wood chipper and conveyors.
- Stream turbine buildings.
- Cooling towers.
- Electrical transformer station.
- Workshop.
- Air compressors.
- Induced draft (ID) stack fan.
- Generator set.
- Trucks, crane, forklifts, front end loaders.
- Electrical corona discharge.

The key issues relate mainly to public health and amenity, and include possible impacts on:

- People's health (including sleep disturbance, stress and other physical, physiological and psychological effects).
- Speech communication.

- Health of other forms of life (including the protection of ecosystems and biodiversity).
- Local amenity and aesthetic enjoyment.

Noise can also impact fauna such as mammals, invertebrates, birds, amphibians and reptiles by causing physical damage, increasing energy expenditure from avoidance, interfering with normal activities and impairing communication.

8.1.3.3 Avoidance and Management

Excluding start up and shut down periods, blowdown and operation of the bypass vent valve, the power plant will be designed and operated such that near field noise emissions (within 1 m of equipment) will be limited to 85 dB(A). Far field noise levels of the overall facility (including start up and shutdown) will be limited to 70 dB(A) at the site boundary (assuming that this is at least 150 m from the highest noise emitter).

While the noise model represents anticipated typical scenarios for the Project, actual operational scenarios may be different at times to those assumed in the model. The following good practice impact management strategies will therefore be considered to reduce the likelihood of any noise impacts:

- Where practicable, the offset distance between noisy plant items (including fixed construction plant) and nearby noise sensitive receptors will be maximised.
- With respect to the activities located in the vicinity of sensitive receptors, advanced notice of high noise activities will be provided and respite periods implemented.
- As far as possible, maintenance work on all construction plant will be carried out away from noise sensitive receptors and confined to standard daytime construction hours.
- Plant will be selected with consideration of lowest noise emission level ('buy quiet').
- All plant and machinery used for the Project will be regularly maintained to minimise noise emissions.
- Site access roads will be well maintained so as to mitigate the potential for vibration from trucks, which induces noise.
- The number of individual vehicle pass-bys through villages will be minimised by grouping vehicles into a convoy, to the extent possible during construction.
- Use of the access roads during the night period will be minimised.

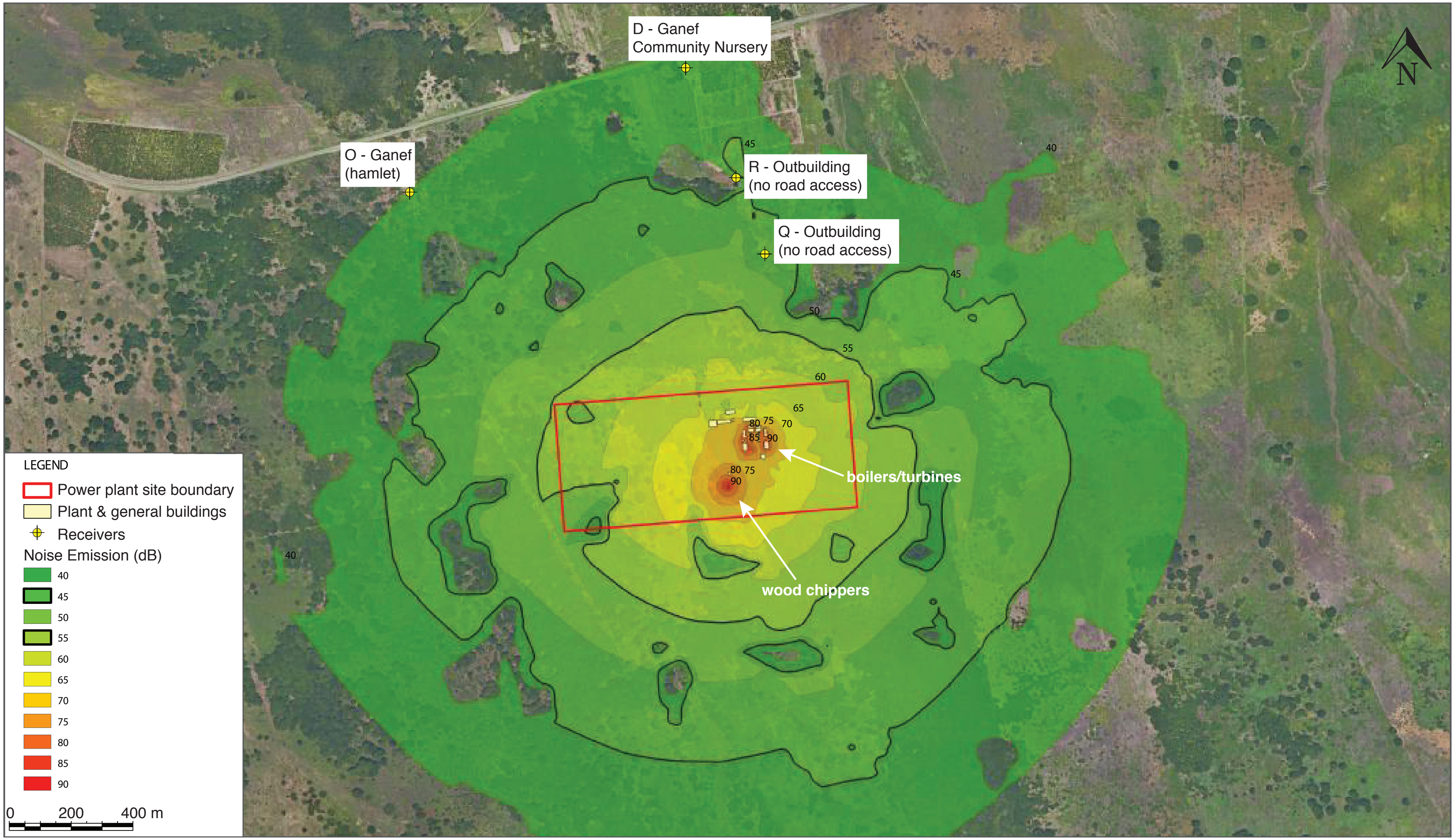
Noise levels in the nearest residential receptors (i.e., settlement outbuildings labelled ‘Q’ and ‘R’ in Figure 8.5) are likely to be controlled by noise from the cooling tower fan, turbine buildings and wood chippers. To meet the Project night-time noise criterion of $L_{Aeq,\ 1hour}$ 45 dB, a noise reduction of at least 5 dB at these locations is achievable by implementing the following:

- Cooling towers: fit a straight lined ducting cowl or suitable attenuator to the vertical discharge fans and implement variable fan speed controls; consider lower speed, larger diameter fans.

FORECAST OPERATIONAL NOISE EMISSIONS – ENHANCED CONDITIONS

PNG Biomass Markham Valley I Environmental Assessment Report

FIGURE 8.5



Source: Appendix 4.

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- Turbine building: the model considers the turbine prior to being acoustically treated, hence a suitable acoustic enclosure and ducting can effectively reduce noise emissions.
- Wood chippers: orientate the feed chute openings away from the direction of nearest residential areas and/or fit acoustically lined shrouds which absorb and screen noise; select suitable wood chippers with lowest noise emissions.

These improvements, if implemented, are expected to result in noise levels at these locations that are consistent with existing ambient noise levels and comply with Project criteria.

8.1.3.4 Residual Impacts

Construction noise levels are predicted to comply with recommended criteria (assuming that construction is limited to the day period). For the night period, the normal operational noise goals of L_{Aeq} 37 dB would be applicable. The modelling indicates that, at the nearest residences 400 to 700 m north of the power plant (outbuildings 'Q' and 'R'), noise levels are expected to be compliant during the day for either long or short-term construction but above the recommended levels at night.

Table 8.7 shows the main items of plant associated with construction and indicative calculated noise levels at an offset distance for each item of plant (i.e., single source of noise). The closest offset distance shown is 50 m, which would be representative of worst-case construction activities conducted near the boundary of the power plant site.

Table 8.7 – Construction Noise Levels at Offset Distances from Source

Source	Noise Levels at Offset Distance, L_{Aeq} dB					Project Goals
	50 m	*100 m*	*200 m*	*400 m*	*800 m*	
Concrete batching plant	68	62	56	49	42	**75 dB** for 3 month construction period or less (day) **55 dB** if construction activities last more than a 3 month period (day) **37 dB** during the night
Generators (55kW)	50	44	38	31	<30	
Water trucks, tractors, graders, crane	68	62	56	49	42	
Compressors, bobcat, rollers, excavator	63	57	51	44	37	

Source: Appendix 4.

The vast majority of construction activities are anticipated to occur during the day period only (where there are no strict noise goals) but are predicted to be less than 75 dB at a distance of 50 m from the source. Noise levels are also predicted to be below the L_{Aeq}55 dB limit (for construction lasting longer than three months) at distances of more than 300 m from the site boundary (although it should also be noted that a number of activities will occur simultaneously on the site and the noise will be cumulative from the various sources).

At night, the concrete batching plant, trucks, tractors, graders and cranes are expected to be above recommended night-time levels (but below the criterion of L_{Aeq}45 dB) up to 800 m from the source, which could include outbuildings 'Q' and 'R'. Night operations involving truck pass-bys near villages may not be appropriate, and alternative routes or timings may need to be considered to reduce the potential for noise impacts.

Operational noise levels in relation to the power plant are provided in Table 8.8 and shown for enhanced conditions in Figure 8.5 based on worst case peak operational conditions (30 MW operation) with enhanced meteorological conditions. Noise emissions are considered to be generally acceptable on the basis that:

- For the day period, Project noise criteria will be met at all known residences under all scenarios and under all meteorological conditions.
- At the nearest residential receptors (i.e., outbuildings ‘Q’ and ‘R’), noise levels are below or equal to the night-time criterion of L_{Aeq}45 dB for neutral and enhanced conditions (with the exception of a value of L_{Aeq} 49 dB predicted for outbuilding ‘Q’ under worst case meteorological conditions).
- Under neutral conditions, the noise levels meet the recommended (internal) target.
- Under both neutral and worst case conditions, these levels are similar to, and less than, ambient noise levels expected in the area (L_{Aeq} values ranging from approximately 40 to 50 dB during evening and night periods (see Section 6.1.8)).

Noise levels above recommended (internal) target levels are forecast for the two settlement outbuildings referred to as locations ‘Q’ and ‘R’ (i.e., settler residences south of Ganef Community Nursery), although the predicted levels will typically be similar to background noise levels.

Table 8.8 – Predicted Operational Noise Levels, L_{Aeq} dB

Location	Approx. Distance from Site Boundary	Noise Goal/ Criterion		Weather Conditions		Expected Result
		Day	Night *	Neutral	Enhanced (Worst Case)	
Site boundary	0 m	70	70	Up to 62	Up to 64	Not a noise sensitive receptor
Q – settlement outbuilding	0.40 km N	55	37/45	45	49	Compliant during day At night, marginally compliant with IFC criteria under neutral conditions but up to +4 dB exceedance under worst case weather conditions At night, typically 1 to 12 dB above internal WHO goals assuming poor acoustic insulation. Outdoors at night, likely to be occasionally audible above background noise levels Result primarily controlled by cooling tower emissions, then turbine
R – settlement outbuilding	0.67 km N			38	42	

Table 8.8 – Predicted Operational Noise Levels, L_{Aeq} dB (cont'd)

Location	Approx. Distance from Site Boundary	Noise Goal/ Criterion		Weather Conditions		Expected Result
		Day	Night *	Neutral	Enhanced (Worst Case)	
D – Ganef Community Nursery	1.0 km N			37	41	Meets recommended (internal) target under neutral conditions. Exceeds night-time internal WHO goals under enhanced weather conditions, if wood chippers are used outside 7am to 10pm
O – Ganef hamlet	0.8km NW			36	42	
E, F, G, H – Markham Farm #	3.8 – 4.4 km ENE			<30	<30	Compliant, less than ambient noise level. Meets recommended targets
A – 41 Mile Marker #	4.9 km					
L, N, K, M #	5.3 km WNW					

* The Project night-time noise goal is 37 L_{Aeq} dB, while the night-time criterion is 45dB.
# Locations not shown on Figure 8.5 are situated further afield, as shown in Appendix 4.

Current estimates require a suitable setback distance of around 650 m from the power plant site boundary to reliably meet LAeq 45 dB or less for residential areas at night, prior to any further noise controls. Meeting the internal Project goal is likely to be challenging at distances substantially less than this, such as the settlement outbuilding at location 'Q' which is approximately 400 m from the northern boundary. However, long-distance noise emissions from the site are predicted to be most influenced by noise from the cooling towers, turbine buildings, wood chippers and stack exhausts. The additional mitigation and management measures described above will ensure that noise levels are consistent with typical ambient noise levels of similar locations and comply with Project criteria.

In relation to traffic and plantation activities:

- Separation distances in the order of 400 m or less are appropriate for the day period, assuming constant operation of equipment.
- An excavator with timber processing head is considered to be the highest risk in regards to meeting night-time noise requirements, with the likely separation distance being at least 1 km. In practice at these distances, received noise levels will vary substantially according to prevailing weather conditions and may not be perceptible from ambient levels.
- if trucks are to be used during the night period, the route should be more than 200 m from nearby residences where practicable.

Corona discharge noise from transmission lines has also been assessed and is estimated to be compliant with Project noise limits (and/or less than or equal to ambient noise levels) on the basis of a spatial buffer distance of at least 120 m (increasing to 300 m in relation to Project targets). However, this type of noise is highly variable and subject to local conditions and prevailing weather, hence field assessment will be undertaken to confirm actual noise emission levels before implementing specific buffer controls.

Given that noise emissions from Project activities will generally be continuous rather than sporadic and will be relatively low above ambient conditions noise, impacts to fauna are predicted to be minimal and localised. Fauna are thought to tolerate continuous noise more readily than sporadic noise, hence some impacts from the start up of machinery, sounding of alarms and truck movements are anticipated within close proximity to these noise-emitting sources. These impacts are predicted to be behavioural only (rather than physical) and could include avoidance behaviour with consequent temporary or permanent displacement of fauna. However, there is limited understanding of the effects of noise on fauna given the varied response from one species to another, and effects can also depend on a range of factors such as noise level, frequency distribution, duration, source and the time the noise occurs.

8.1.4 Water and Land Discharges

8.1.4.1 Discipline-specific Approach

As noted in Section 6.1.5.3, assessment of water quality and bed sediment quality data reflects the relevant beneficial values of the water. The protection of aquatic ecosystems generally requires the highest quality of water of all beneficial values, including drinking water. Impact assessment therefore involved comparison of predicted changes of selected water quality variables with relevant guidelines/standards that have been developed both in Papua New Guinea and internationally, i.e., a compliance assessment approach was used (see Section 8.1.1.3). As noted in Section 2.4, these guidelines/standards include:

Drinking Water

- Papua New Guinea Public Health (Drinking Water) Regulation 1984. Schedule 2 (Drinking Water).
- World Health Organization guidelines for drinking water quality, 4th edition (WHO, 2011).

Freshwater Aquatic Ecosystem Protection

- Independent State of Papua New Guinea. Environment (Water Quality Criteria) Regulation 2002, Schedule 1.
- Australia and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ ARMCANZ, 2000).

The requirements specified in the PNG Environment (Water Quality Criteria) Regulation 2002, Schedule 1, provide PNG statutory obligations. These are prescribed water quality guidelines that apply at the downstream limit of a site-specific mixing zone[4]. ANZECC/ARMCANZ (2000) guideline values, which similarly apply to ambient waters rather than wastewater discharges, provide a more conservative assessment framework than that presented in the PNG statutory requirements but have no legislative authority within Papua New Guinea. It should also be noted that the approach advocated by ANZECC/ARMCANZ (2000) involves using the guidelines as

[4]A mixing zone is the body of water into which waste is discharged and where the prescribed water quality guidelines are not required to be met. In freshwater systems, the downstream end of the mixing zone is normally the first location downstream of the proposed discharge point where local people use the watercourse or water body, and is called the compliance point.

trigger values, which are estimates aimed at protecting ambient waters from chronic toxicity. The trigger values are derived statistically and are aimed at four different protection levels, i.e., 99%, 95%, 90% and 80%, where protection level signifies the percentage of species expected to be protected. Exceedance of these values triggers further investigation aimed at assessing whether this exceedance will result in serious or material environmental harm, and at refining a guideline value by accounting for environmental factors that can modify the effect of the chemical.

Assessment of water quality against guidelines includes assessment of both unfiltered (total) and filtered (dissolved) metal concentrations, although greater emphasis is placed on filtered concentrations for aquatic ecosystem protection given the increased bioavailability of dissolved metals. Drinking water guidelines are generally based on total metal concentrations but are usually applicable 'at tap', i.e., after treatment to remove suspended sediment.

In relation to bed sediment quality, and in the absence of PNG statutory requirements, sediment quality in streams has been assessed against the updated ANZECC/ARMCANZ sediment quality guidelines (Simpson et al., 2013). Analytical data are compared with two sets of values:

- Sediment quality guideline values (SQGV) – biological effects are likely to be negligible if the contaminant concentration is less than the SQGV.
- Upper guideline (SQG-High) values – biological effects are expected where the contaminant concentration exceeds the SQG-High values.

Contaminant concentrations between the SQGV and SQG-High values represent a range where effects are possible.

Other assessment procedures such as toxicity testing, examining pore water and elutriates, and assessing benthic community structure (described in Simpson et al. (2013)), were not used.

No criteria or guidelines are available for sediment loads, hence these have been evaluated by comparison with current (pre-Project) data and assessment of Project-related changes using the impact significance approach described in Section 8.1.1.2.

8.1.4.2 Potential Impacts

Water and land discharges associated with power plant construction and operation, and plantation development, include:

- Discharge from the wastewater holding pond at the power plant site (where inputs to the holding pond include boiler plant blowdown, cooling tower blowdown, septic tank/sewage treatment plant discharges and neutralisation plant discharge).
- Runoff from power plant areas (including the log yard and nursery).
- Catchment runoff, including runoff from plantations, roads and other cleared areas (including potentially contaminated areas).
- Spills and accidental releases.
- Seepage and runoff from landfill/s.

- Quarry/borrow pit discharges.

Potential stressors associated with these discharges that require consideration include:

- Suspended solids and sedimentation (due to turbid stormwater and erosion and/or runoff from disturbed areas (particularly stream crossings and the power plant site during construction) and changes in catchment sediment yield resulting from altered land use).
- Organic matter/organic carbon (and colour from dissolved organic materials) (from the nursery and log yard, the plantations and, potentially, landfill seepage).
- Oil and grease (from stormwater runoff).
- Elevated temperature (from boiler and cooling tower blowdown).
- Metals and hydrocarbons, including polycyclic aromatic hydrocarbons (PAHs) (primarily in stormwater runoff and, potentially, the holding pond discharge and landfill seepage).
- Herbicides (primarily glyphosate) and fertilisers (from plantation runoff); pesticides will be used only in response to tree damage or imminent damage for pests and disease rather than based on a schedule.
- pH (if acid sulfate soils were to be disturbed or acidic effluents not treated prior to discharge).
- Conductivity (if relatively high conductivity water were to be discharged).

The potential impacts associated with these stressors include:

- Adverse effects on aquatic biota due to toxicants (e.g., metals, trace organics, herbicides). Toxicants can directly affect aquatic biota over short (acute) or long (chronic) periods, with potential consequences with respect to conservation values and resource use for local people.
- Adverse effects on aquatic biota due to dissolved oxygen (DO) depletion in the water column, increased sedimentation rates, and other stressors such as temperature, colour, total suspended soils (TSS), organic matter/organic carbon, pH, conductivity, oil and grease). High organic matter loads (organic C) can lead to DO depletion with resulting loss of aquatic biota (mainly fish and macroinvertebrates). Elevated TSS levels can modify fish behaviour, smother benthic organisms and alter habitats. These impacts can have potential consequences with respect to conservation values and resource use for local people.
- Nuisance growth of aquatic plants, e.g., algal blooms, due to nutrients and fertilisers. High nutrient concentrations can result in excessive plant growth, although elevated TSS and colour can reduce a system's primary production.
- Adverse impacts on human health due to toxicants (e.g., metals, trace organics, herbicides and pesticides). Some metals and organic chemicals in effluents may occur at levels that could be potentially harmful to people who drink the water.

- Adverse impacts on recreational uses of local drainages. Nuisance organisms (e.g., algae) and physical and chemical characteristics of the discharges and/or stormwater runoff can affect recreational use.

Additional adverse impacts on water quality could potentially result from poorly managed hazardous or non-hazardous materials or wastes. This matter is addressed in Section 8.1.6.

Potential adverse impacts on aquatic ecology are discussed in Section 8.2.3.

8.1.4.3 Avoidance and Management

In addition to following the principles of guidelines relating to matters such as logging (PNGFA/ DEC, 1996), landfill sites (OEC, 2001) and workshops (DEC, 1997), specific measures that will be implemented in relation to the various stressors described below.

Suspended Solids and Sedimentation

- Determine the extent of vegetation clearing that is required and whether existing cleared areas can be used.
- Only clearing the area to the extent required for its designated use, ensuring that the boundaries of areas to be cleared are physically demarcated.
- Maintaining riparian buffer zones along watercourses and aligning roads to minimise the number of stream crossings.
- Constructing and maintaining stormwater runoff and erosion/sediment controls, including clean water diversion drains upstream of disturbed areas such as the power plant site (where feasible).
- Rehabilitating cleared areas progressively where possible.
- Treating power plant wastewater streams to ensure that discharge guideline values specified in IFC (2008) are met at the discharge point from the holding pond (and hence discharge from the power plant site boundary).

Organic Matter/Organic Carbon (and Colour)

- As described above for suspended solids and sedimentation.
- Stripping logs of bark during harvesting (and therefore leaving bark in plantation compartments).

Temperature

- Directing cooling water to the holding dam prior to release (followed by discharge to a drain, which will provide additional cooling prior to the wastewater reporting to the Markham River).

pH and Conductivity

- Undertaking a risk assessment in relation to acid sulfate soils and implementing management measures as appropriate.

- Treating power plant wastewater streams to ensure that discharge guideline values specified in IFC (2008) are met at the discharge point from the holding pond (and hence discharge from the power plant site boundary).

Metals, Oil and Grease, and Other Hydrocarbons

- Minimising waste through efficient use of resources.
- Ensuring sufficient secondary containment is provided to contain potential spills.
- Properly maintaining vehicles and machinery to prevent oil leaks.
- Refuelling vehicles in a manner that limits the probability of spills.
- Treating power plant wastewater streams to ensure that discharge guideline values specified in IFC (2008) are met at the discharge point from the holding pond (and hence discharge from the power plant site boundary).

Herbicides, Pesticides and Fertilisers

- Using only FSC-approved chemicals, e.g., glyphosate.
- Implementing controlled application of fertilisers to minimise the potential for elevated nutrient concentrations in stormwater runoff.
- Restricting pesticide use to an 'as needs' basis.
- Implementing an adaptive management approach that seeks to maximise efficiencies between weed control and volume application of glyphosate.

These and other measures are described in the EMP (Appendix 9), which contains a number of procedures that will minimise impacts on surface water quality (e.g., Procedure 2: Vegetation clearing, earthworks, topsoil management and rehabilitation; Procedure 3: General waste management; Procedure 4: Hydrocarbons, chemical and hazardous waste management; Procedure 8: Water management; Procedure 9: Watercourse crossing management). As also discussed in the EMP, monitoring will be undertaken to determine what, if any, impacts to surface water occur.

Where practicable, holding pond water will be used to irrigate plantations located close to the power plant (excluding crops for human consumption). Excess holding pond water will be discharged to the existing man-made drain near the power plant site that reports to the Markham River, in accordance with expected environment permit conditions. If monitoring indicates that CEPA's water quality objectives are not met, additional actions such as further treatment will be considered (in consultation with CEPA).

8.1.4.4 Residual Impacts

Power Plant

A sediment transport model was developed to assess impacts on downstream water quality due to sediment reporting to local drainages during both construction and operations phases (see Appendix 1). The modelling considered sources of suspended solids from the general upstream catchments of the major tributaries within and near the Project area, i.e., the Leron, Erap, Rumu and Maralumi rivers, as well as the power plant site and the Markham River itself. A number of scenarios were considered, where these included construction/vegetation clearing, plantation establishment, harvesting and well-established plantations.

The results show that, in terms of increases to riverine sediment loads, only negligible changes in sediment supply are predicted, i.e., negligible increases during construction/vegetation clearing and initial plantation establishment, and negligible decreases during harvesting and full establishment. The Project is therefore predicted not to affect overall sediment yields from the four sub-catchments and, hence, there will be no impacts to Markham River sediment yields. However, management measures will need to be implemented to minimise sediment delivery to clearwater streams and wetlands during vegetation clearing. In addition, minor impacts on channel condition and behaviour are expected.

Using the matrix and various definitions described in Section 8.1.1.2, the residual impacts, i.e., those that are expected to occur after the successful implementation of management measures, can be summarised as follows:

- Changes in sediment yields in receiving watercourses and the occurrence of sediment-laden runoff – the magnitude of the various impacts is assessed as being '**negligible**', with the sensitivity ranging from '**low**' to '**moderate**'; the impact significance is therefore '**negligible**'.
- Changes in channel form, including localised sediment aggradation, the risk of avulsion and bank instabilities – the magnitude of the various impacts is assessed as ranging from '**negligible**' to '**moderate**', with the sensitivity ranging from '**low**' to '**high**'; the impact significance is therefore '**negligible**' to '**low**'.

During operations, the main point source discharge from the power plant will be from the holding pond. As noted above, the quality of this discharge will be consistent with the requirements of IFC (2008), as shown in Table 8.9. This discharge will occur at a relatively low rate (0.012 m^3/s for two 15 MW units) and will report to the Markham River where it will subsequently be considerably diluted. Table 8.9 shows the predicted water quality values after dilution and allows comparison with both PNG water quality standards and Australian water quality guidelines (ANZECC/ARMCANZ, 2000). These results are based on a simplistic load model, which is appropriate given the small scale of the power plant and the small volumes of holding pond discharge water that require assessment. The model is based on dilution of the holding pond discharge after mixing with the Markham River and, based on a highly conservative approach, uses the lowest Markham River flow value (i.e., the 10^{th} percentile) presented in Section 6.1.5.1 of 3.38 m^3/s. This provides a dilution factor of about 280, which increases substantially at higher (and more common) flows. It should also be noted that a conservative approach has been adopted whereby all metals present in the holding pond discharge have been assumed to be filterable metals, whereas in practice the metals will be partitioned between the dissolved phase and suspended particulate matter. For the purposes of this assessment, both the PNG and Australian criteria and guidelines are assumed to apply to the filterable (i.e., dissolved) phase.

Table 8.9 – Comparison of Predicted Ambient Water Quality from the Holding Pond Discharge with Ambient Water Quality Guidelines

Parameter*	Holding Pond Discharge (IFC, 2008)	Ambient Water Quality (Markham River)#	Predicted Increment in Markham River after Mixing of Holding Pond Discharge (assuming 280-fold dilution)	PNG Environment (Water Quality Criteria) Regulation 2002	ANZECC/ARMCANZ (2000) (trigger values for slightly-moderately disturbed systems; 95% species protection level)
pH (units)	6 to 9	7.96 – 9.10	No change	No change to natural pH	**
TSS	50	544 – 3,990	0.2	No change more than 25 NTU	None
Oil and grease	10	<5	0.04	None	None
Total residual chlorine	0.2	no data	0.001	0.005 (at pH 6)	None
Temp. (°C)	Ambient (site-specific requirement to be established)	28.0 – 28.5	No change	No change more than 2°C	None
Cr (total)	0.5	<0.001†	0.002	0.05 (as Cr VI)	0.0025##
Cu	0.5	<0.001 – 0.002†	0.002	1.0	0.0035##
Fe	1.0	<0.05†	0.004	1.0	N/A
Zn	1.0	<0.005†	0.004	5.0	0.020##
Pb	0.5	<0.001†	0.002	0.005	0.0136##
Cd	0.1	<0.0001†	0.0004	0.01	0.00054##
Hg	0.005	<0.0001†	0.00002	0.0002	0.00006
As	0.5	<0.001 – 0.002†	0.002	0.05	0.024

* mg/L unless otherwise indicated. # From Appendix 5. † Filtered concentration.
** Values provided for lowland rivers in tropical Australia are not applicable to PNG rivers/streams.
Hardness of 90 mg/L as $CaCO_3$.

The data is Table 8.10 shows that, even when adopting a conservative approach, PNG water quality standards in the Markham River will be easily met. Most of the ANZECC/ARMCANZ (2000) guideline values will also be met, a notional exception being Cr although the exceedance is small and, in practice, unlikely to be detectable. Given that flows in the Markham River will generally be more than 3.38 m^3/s, and that notionally dissolved metals will partition between the dissolved and particulate phases (see discussion below), the actual situation is likely to be somewhat better than the modelled outcomes.

Table 8.10 similarly allows comparison of predicted ambient water quality from the holding pond discharge in terms of drinking water quality guidelines. Both PNG and WHO (2011) drinking water guidelines will be easily met, in most cases by an order of magnitude.

Table 8.10 – Comparison of Predicted Ambient Water Quality from the Holding Pond Discharge with Drinking Water Quality Guidelines

Parameter*	Holding Pond Discharge (IFC, 2008)	Ambient Water Quality (Markham River)#	Predicted Increment in Markham River after Mixing of Holding Pond Discharge (assuming 280-fold dilution)	PNG Public Health (Drinking Water) Regulation 1984 (Schedule 2) (maximum permissible level/ upper limit of concentration)	WHO (2011) (maximum permissible levels)
pH (units)	6 to 9	7.96 – 9.10	No change	6.5 – 9.2	No health-based value
TSS	50	544 – 3,990	0.2	25 units (JTU)	No value
Oil and grease	10	<5	0.04 mg/L	0.01 (mineral oil)	No value
Total residual chlorine	0.2	no data	0.001	No value	5
Temperature (°C)	Site-specific requirement to be established	28.0 – 28.5	No change	No value	No value
Chromium (total)	0.5	<0.001†	0.002	No value	0.05 (P)
Copper	0.5	<0.001 – 0.002†	0.002	1.5	2
Iron	1.0	<0.05†	0.004	1.0	No health-based value
Zinc	1.0	<0.005†	0.004	15	0.02
Lead	0.5	<0.001†	0.002	0.1	0.01 (A,T)
Cadmium	0.1	<0.0001†	0.0004	0.01	0.003
Mercury	0.005	<0.0001†	0.00002	0.001	0.006
Arsenic	0.5	<0.001 – 0.002†	0.002	0.05	0.01 (A,T)

*mg/L unless otherwise indicated. # From Appendix 5. † Filtered concentration.
A – provisional guideline value because calculated guideline value is below the achievable quantification level.
P – provisional guideline value because of uncertainties in the health database.
T – provisional guideline value because calculated guideline value is below the level that can be achieved through practical treatment methods, source control.

Bed sediment quality in the Markham River and other rivers that drain the Project area is highly unlikely to be impacted by Project activities at the power plant site, due primarily to the small scale of the activities (the total disturbed area at the site is only about 40 ha including the power plant, log yard and plant nursery), the small volume of water that will be discharged from the holding pond, and treatment prior to discharge such that IFC effluent guideline are met. Bed sediment quality will therefore remain unaffected by such discharges.

Plantations

As noted above, increases in plantation-derived sediment loads to adjacent watercourses will be negligible to low.

The impact resulting from other stormwater components, such as nutrients and various toxicants, are similarly expected to be negligible to low given the management measures described above and the extent of dilution available in the major streams draining the Project area and the Markham River itself.

Additional Considerations

The potential for adverse impacts on surface water quality will be further mitigated by the following factors:

- In general, nuisance growth of aquatic plants is likely to be affected by nutrient concentrations and loads, and optical properties such as water colour and clarity. Increased nutrient inputs can potentially stimulate growth while decreased clarity, i.e., increased turbidity, can reduce light penetration and potentially reduce plant growth. Given the elevated TSS levels that already exist in the Markham River and the associated high levels of turbidity, changes in nutrient concentrations in the Markham River (and other turbid rivers in or near the Project area) due to the stormwater runoff from the plantations are considered unlikely to stimulate nuisance growth of aquatic plants, although this may not be the case in the clearwater streams. It is also worth noting that all chlorophyll a measurements taken to date in Project area watercourses have been less than the reporting limit, suggesting low levels of primary productivity, although total N and total P have been variable but occasionally elevated, possibly indicating that nutrient concentrations are not a limiting factor.

- The toxic effects of trace metals are related to partitioning between the dissolved phase and the suspended particulate phase, with dissolved metals generally regarded as being the more toxic species. Although the extent of partitioning varies between metals, the high TSS concentrations in the Markham River (and to a lesser extent some of the other rivers in the Project area), together with the relatively alkaline pH of the water, means that a significant degree of partitioning is likely to occur. This will reduce the likelihood and magnitude of toxic effects that might otherwise be attributed to increased metal concentrations resulting from Project activities.

Bed sediment quality in the Markham River and other rivers that drain the Project area is highly unlikely to be impacted by plantation activities, although some sedimentation may occur as noted above.

Given the preceding discussion, it is expected that adverse impacts on surface water quality associated with local drainages will be small, assuming the effective treatment of power plant discharges. Review of monitoring data generated during the early stages of Project development will determine if additional management measures, e.g., enhanced water treatment prior to discharge, are required.

Residual short-term impacts to surface water quality in the Project area may occur immediately downstream of stream crossings associated with road construction and operation (particularly in the initial period following construction).

The management procedures detailed in the EMP (Appendix 9) will ensure that impacts to surface water quality and the associated beneficial values, i.e., aquatic ecosystem protection, recreation and human health, are minimised during Project development. This is also expected to apply to groundwater, which will be the subject of ongoing monitoring to confirm that the Project does not adversely affect groundwater quality.

8.1.5 Water Balance (Hydrology and Hydrogeology)

8.1.5.1 Discipline-specific Approach

No criteria or guidelines are available for changes to surface hydrology, hence these have been evaluated by comparison with current (pre-Project) data and assessment of Project-related changes using the impact significance approach described in Section 8.1.1.2. Changes to the area's hydrogeology have been assessed primarily by comparison with existing conditions, e.g., depth to groundwater.

8.1.5.2 Potential Impacts

Water and land discharges associated with power plant construction and operation, and plantation development, have been listed in Section 8.1.4.2. This assessment has focussed on those discharges which could materially affect local surface hydrology, i.e.:

- Discharge from the wastewater holding pond at the power plant site.
- Runoff from power plant areas (including the log yard and nursery).
- Stormwater runoff from the plantations, including runoff from roads and other cleared areas (including potentially contaminated areas).

Aspects of the Project that therefore require consideration from a hydrological/hydrogeological perspective include:

- Changes in surface hydrology flows due to land use change and Project-related discharges.
- Changes to local hydrogeology due to land use changes associated with broad-scale establishment of tree plantations.
- Changes to local hydrogeology (and/or hydrology) due to use of water to supply for the proposed power plant and associated infrastructure, which will be drawn from groundwater bores (with a backup being the Markham River itself).

Potential impacts associated with the above include:

- Changes in the total water balance in the Markham Valley.
- Changes in depth to groundwater in the Project area, with the consequent potential to affect groundwater-dependent ecosystems and local water supply wells.

- Changes in local surface hydrology flows, taking into account the sensitivity of the more ephemeral waterways and the clearwater streams relative to the more turbid, perennial streams.
- Changes in flooding regime within the floodplain contained in the Project area, which is subject to regular inundation.
- Changes in channel form and behaviour across the Project area, taking into account that most Project area watercourses (including the ephemeral foothill tributaries, and the Leron, Rumu, Erap, and Markham rivers) are naturally highly mobile systems due to the extremely large volumes of sediment conveyed through these systems, and therefore these values have reduced sensitivity (in the context of the impact assessment approach described in Section 8.1.1.2). However, the clearwater streams within the Project area are more sensitive to changes in channel form and processes.

Potential adverse impacts on aquatic ecology are discussed in Section 8.2.3.

8.1.5.3 Avoidance and Management

Considering point sources such as the holding pond discharge, the scale of the power plant is such that the discharge from the holding pond is almost negligible compared with flows in adjacent watercourses, particularly the Markham River. No additional mitigation measures are therefore required in relation to the volumetric aspects of this discharge.

Management measures that address the hydrological/hydrogeological aspects of diffuse discharges such as stormwater runoff are included in the PNG Logging Code of Practice (PNGFA/DEC, 1996). Key management measures from that document and others that also reflect good practice, and the findings of investigations undertaken to support this assessment, include:

- Establishing and maintaining riparian buffer zones.
- Where large, consolidated areas of plantations (more than 100 ha) are to be situated upslope of pre-existing local water supply wells, establishing buffer zones of at least 300 m between the plantation boundary and the wells (and using these wells to monitor groundwater depth and water quality).
- Where practicable, locating bores that will be used to provide water to the power plant downslope of both plantations and the water supplies of villages and hamlets.

Given the uncertainty associated with the flooding estimates and groundwater modelling undertaken to date, additional investigation will be undertaken into:

- Flooding extents and depths, with consequent development of additional management measures as required.
- Groundwater drawdown associated with providing water to the power plant from bores. In the first instance, this may simply involve establishing groundwater monitoring bores during construction and operation of the first 15 MW and using the data to refine predictions for impacts associated with the second 15 MW unit. Other variables to be further considered

include i) the full depth of the reliable aquifer, and ii) the specific yield and hydraulic conductivity of the aquifer.

- Groundwater modelling if changes of more than 3 m are observed in community wells.

8.1.5.4 Residual Impacts

Although hydrological and hydrogeological matters have not been separately addressed in the above discussion due to their obvious linkages, residual impacts are discussed individually for each of these matters in this section.

Hydrogeology

Modelling undertaken to describe the catchment water balance and the potential effects of the plantations took into account a range of factors including rainfall, evapotranspiration, catchment storage and crop factors. However, quantifying water use does not provide a sufficient basis for making land use decisions, hence wood production and value generated from water use, i.e., resource (water) use efficiency, were also considered. This involved additional modelling in terms of the wood yield, which is a function of transpiration and other variables, and 'water productivity' of the plantations.

The underlying requirement of the next step of the modelling was to examine the changes in hydrogeology that are likely to result from growing eucalypt plantations versus the current situation of largely grassland vegetation. Both shallow groundwater with short kangaroo grass (*Themeda* spp.) and tall Kunai grassland (*Imperata cylindrica*) were used for comparison with *Eucalyptus pellita*. Two different models were used:

- The first model used predicts the crop factor or ratio of evapotranspiration to potential evaporation as a function of relative plant-available soil water.

- The second model was 3PG-PJS. This is a process-based model that discounts light use efficiency as a function of a range of site and stand factors, and allocates carbon to three pools including foliage. Photosynthesis and evaporation by the resultant canopy are then modelled independently.

The two models predicted a very similar effect of plantations on water balance. Compared with the short stature grass, a *Eucalyptus* plantation will decrease runoff by up to 200 mm per year, while compared to a taller stature grass the difference will be approximately 50 to 100 mm per year in a 3 m deep soil and up to 200 mm per year in a 5 m deep soil. The effect of plantations will be to increase evapotranspiration, decrease runoff and increase the number of months where no water drains to groundwater by two or three per year. Although the total effect across the Project area will be to prevent between 7,000 and 30,000 ML per year from reaching the Markham River, the effect on flow in the Markham River will be negligible given the latter's current annual discharge.

The more pertinent issue is the effect of this change in water balance on the recharge of the groundwater and therefore on seasonal patterns of groundwater depth. Adopting a number of conservative assumptions such as groundwater recharge only from rainfall with no inputs from upslope, the historic net change in groundwater depth was calculated along with the maximum annual change of groundwater depth under a plantation and the alternatives of short and tall (shallow- and deep-rooted) grassland. This modelling predicted a seasonal fluctuation of groundwater of 3 m under tall grass for the period between 2013 and 2016. This is slightly larger (about 0.5 m) than the fluctuation currently observed in local wells (see Section 6.1.6.1), which is not surprising given the (unlikely) assumption that the only input is from rainfall.

Using the approach described above, and outputs from the 3PG modelling, the change in groundwater depth when either a short or tall grassland is replaced by a plantation of *E. pellita* was calculated. In Figure 8.6, the results of this modelling are plotted as a function of the probability that a given change is exceeded. For example, noting again that the predicted values are probably overestimates, the probability of a change in groundwater depth more than 1 m is 0.4 (40%) when tall grassland is replaced by plantation and 0.7 (70%) when short grassland is replaced by plantation on a 5 m soil. When tall Kunai grassland is compared to a plantation with access to 5 m of soil, which gives the maximum possible effect on water balance, the model predicts changes of groundwater depth between 0 and 4.5 m, and the predicted change is very similar to that predicted from a change from short grassland to a plantation in 3 m of soil (see Figure 8.6).

However, these predicted changes will only occur directly underneath a compartment of trees and will diminish towards the edge. The proposed streamside buffers (100 m for the Markham River, 60 m for the Leron and Erap rivers as well as lakes/lagoons/swamps, 30 m for other permanent watercourses >5 m wide, 20 m for watercourses 1 to 5 m wide, and 5 m for watercourses <1 m wide) will be sufficient to protect these ecosystems from any changes in groundwater depth caused by the plantations.

With respect to changes in groundwater levels in wells, the modelling predicts that in the worst-case scenario of a change from tall Kunai grassland to *E. pellita* with access to 5 m of soil:

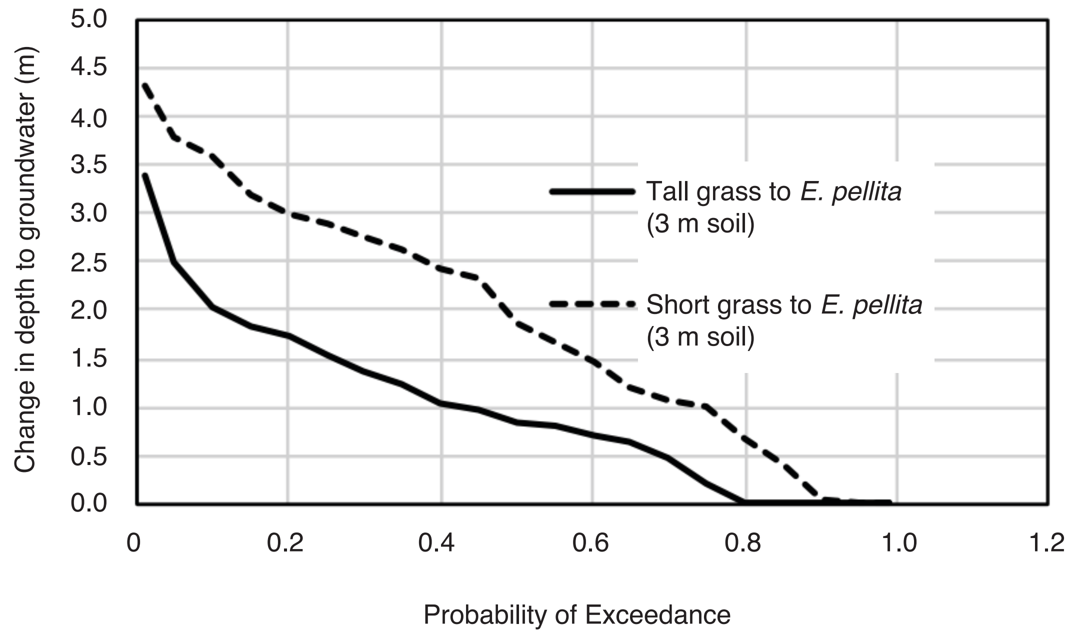
- The change in groundwater depth near the centre of the plantation may exceed 3 m once every five years.
- The change will also be less than 1 m in three of every five years.
- These changes will diminish to zero within 50 m of the edge of the plantation.

In summary, the modelling suggests that the maximum likely increase in seasonal fluctuation in groundwater level is 4.5 m, and that in 60% of years the change would be between 0 and 2 m, where this would be observed as an increase in the seasonal dynamics. As concluded in Appendix 2, there is little cause for concern that the plantation will result in a trend of continuous decline in the groundwater, given rainfall within the historical range.

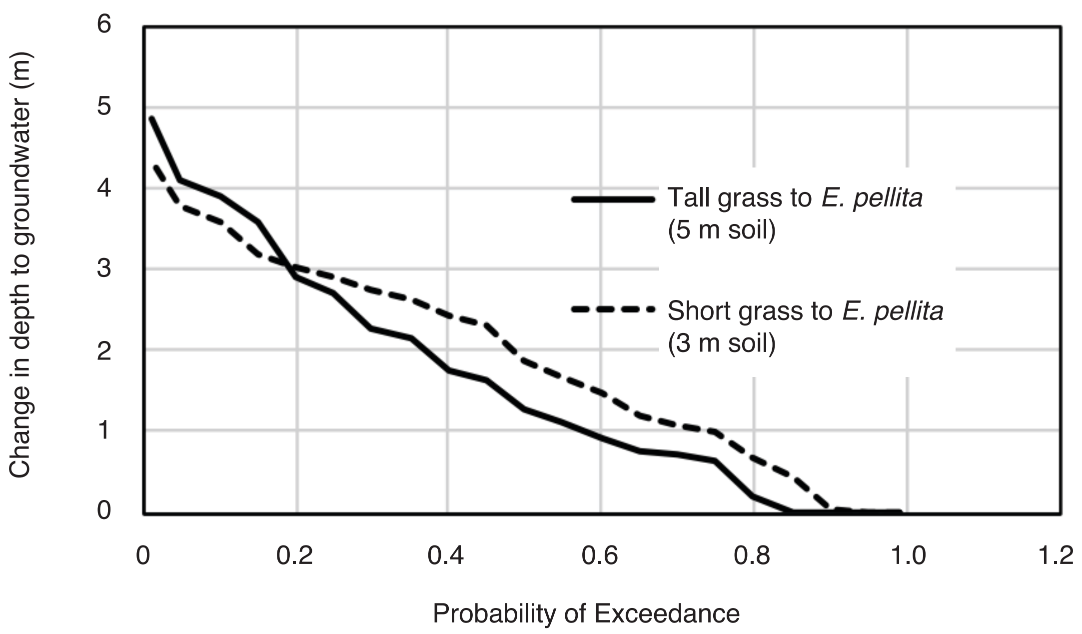
Potential drawdown from bores used to supply water to the power plant was also examined as part of the hydrogeological assessment. This analysis indicates that, if the aquifer were only 50 m thick and saturated hydraulic conductivity is 1.5 m/day, then it would be difficult to extract the required amount of water for two 15 MW units at the required rate without at least five well-spaced bores, located about 1,000 m apart, to limit cumulative impact (or similarly, for the first 15 MW unit, at least three bores located 1,000 m apart). However, the existing data will be subject to additional analysis and conceptual groundwater modelling prior to construction and, if required,

FIGURE 8.6

A. Plantation replacing tall vs. short grassland, both on 3 m soil depth



B. Plantation replacing tall grassland on 5 m soil depth vs. short grassland on 3 m soil depth



Source: Appendix 2.

further investigation will be undertaken, e.g., groundwater level monitoring during construction and operation of the first 15 MW unit and updated modelling predictions.

Hydrology

The hydrological modelling undertaken to establish baseline hydrological statistics for the rivers in or near the Project area – Leron, Rumu, Maralumi and Erap rivers, as well as the Markham River – was also used to assess Project impacts in relation to changes in hydrology. The same scenarios that were considered in relation to sediment transport, i.e., construction/vegetation clearing, plantation establishment, harvesting and well-established plantations, were also used for the hydrological assessment. Results from the modelling can be summarised as follows:

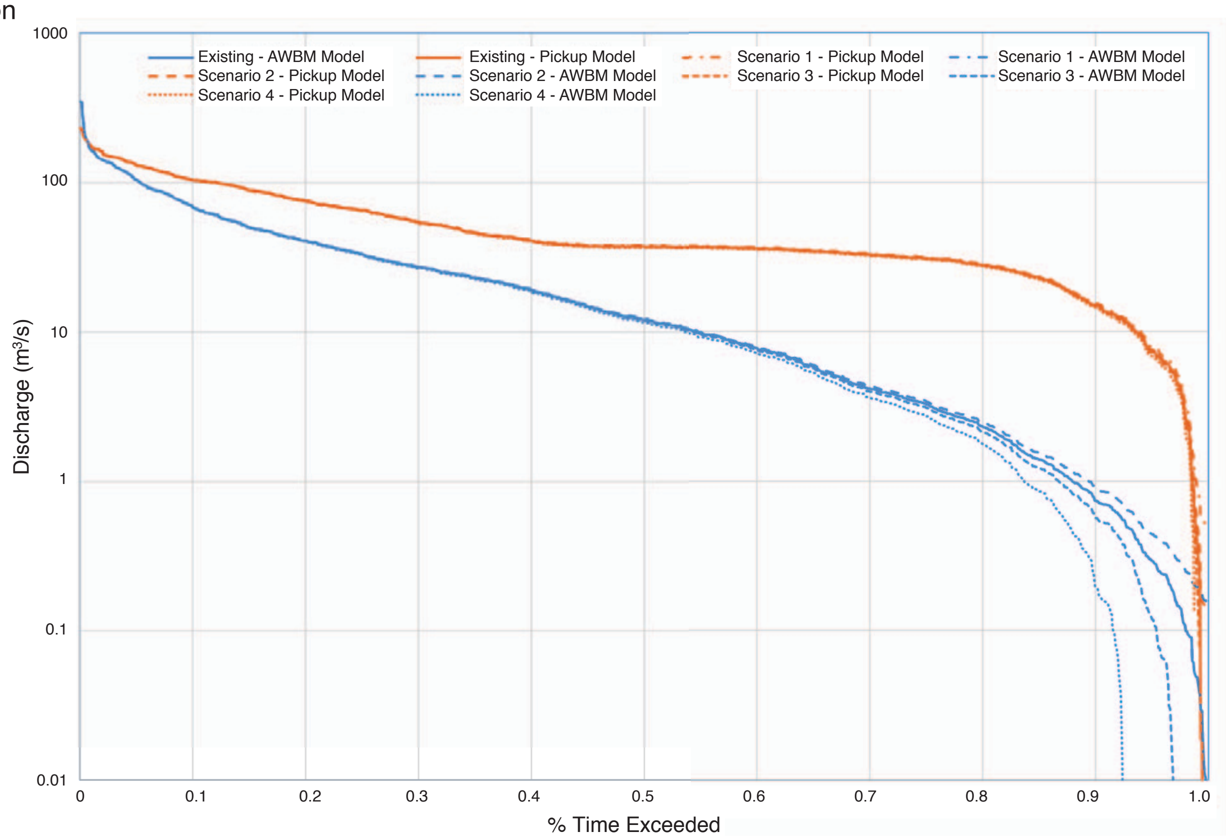
- The Pickup model predicted that there will be negligible differences between the different scenarios.
- The AWBM model predicted that, in all sub-catchments, the Project is unlikely to affect the following (and Figure 8.7 shows flow duration curves for the Leron sub-catchment):
  - Higher magnitude, less frequent (>50th percentile) flows.
  - Short-term or long-term median flows.
  - Flood heights, with negligible impact on flood inundation (although some risk to Project infrastructure already exists).
- The AWBM model predicted that, in all sub-catchments, the Project may result in major decreases in the more frequent (10th percentile) flows for scenarios 3 and 4 (harvesting/ established plantations) (also shown in Figure 8.7).
- The AWBM model predicted that the Project may result in an increase in the number of zero flow days in all four sub-catchments (using a very conservative approach). These impacts are more likely to be seen in the smaller, clearwater streams than the main channels, although the likelihood of this is low if plantations are not developed in the source areas of these streams.

Using the matrix and various definitions described in Section 8.1.1.2, the residual impacts, i.e., those that are expected to occur after the successful implementation of management measures (which will be modified as required based on monitoring program results), can be summarised as follows:

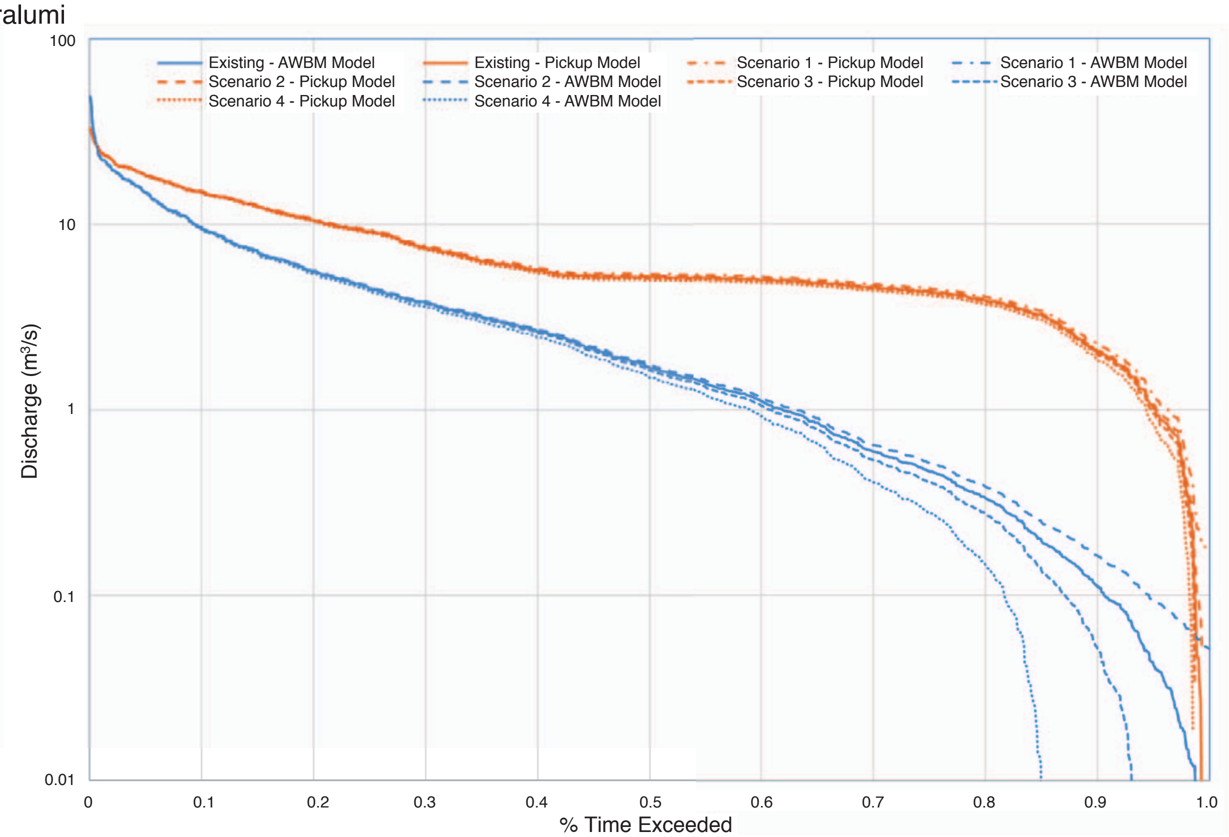
- Changes in surface hydrology (flows) – the magnitude of the various impacts is assessed as being '**negligible**' or '**low**', with the sensitivity ranging from '**low-moderate**' to '**high**'; the impact significance is therefore '**negligible**' or '**low**'.
- Localised sediment aggradation – the magnitude of the impact is assessed as being '**negligible**' and the sensitivity is '**high**', hence the impact significance is '**negligible**'.
- Flood risk to Project infrastructure – the magnitude of the impact is assessed as being '**low**', although the sensitivity is '**high**'; the impact significance is therefore '**moderate**'.

FIGURE 8.7

Leron



Maralumi



Source: Appendix 1.

8.1.6 Land Contamination and Solid Waste Management and Disposal

8.1.6.1 Discipline-specific Approach

The approach adopted for this assessment is consistent with that described in Section 8.1.1.2.

8.1.6.2 Potential Impacts

Project activities that could potentially lead to land contamination includes generating both domestic and industrial wastes, as well as the transport, handling, storage, use and disposal of hazardous materials required during the construction and operations. These can be separated into four sources, examples being:

- Hazardous materials:
  - Glyphosate and metsulfuron methyl herbicides.
  - NPK fertiliser.
  - Pesticides.
  - Fuel (mainly diesel), and oil and grease.
  - Chemicals to add to the cooling water such as acid, alum, aluminium sulfate, sodium silicate and polyaluminium chloride (PAC).
  - Fumigation chemicals.
  - Chemicals used for the septic system/package treatment plant.
- Hazardous waste:
  - Septic effluent and biosolids.
  - Workshop waste such as batteries, cleaning fluids and solvents.
  - Waste oil and degreasers.
  - Gas cylinders.
- Non-hazardous domestic and industrial waste:
  - Ash (fly and bottom).
  - Plastics.
  - Metal.
  - Rubber.
  - Steel.
  - Paper.

  - Putrescible and non-putrescible domestic waste.
- Acid sulfate soils:
  - Disturbance or movement of actual (existing) acid sulfate soils (AASS).
  - Disturbance of potential acid sulfate soils (PASS).

The use of hazardous materials during construction and operation poses potential impacts associated with their direct use and application, as well as from spills and leaks associated with their transport, storage, handling and disposal.

Herbicides, fertilisers and potentially pesticides will be used in the plantation and nurseries where they will be applied directly to land in the plantation and to seedling containers stored above the ground in the nurseries. Both applications have the potential to result in the accumulation of these chemicals in soils and, subsequently, groundwater. The reuse of bottom ash for road construction and fly ash for fertiliser also has the potential to cause the direct contamination of land on and off site.

In addition to the potential impacts from the use of anthropogenic materials and waste generation, the disturbance of unidentified PASS could occur during the construction phase of the Project, where excavation and clearing of some land will be required, particularly for the Project infrastructure. If oxidised, PASS poses a risk of leaching acidic water, which can affect soil quality, groundwater and runoff quality while also reducing the fertility of the soil and its ability to support vegetation. However, PASS are generally only found at low elevations in coastal and tidal areas (OEH, 2015). Acid sulfate soils are more likely to occur around the Lae Tidal Basin, low lying areas and floodplains in the region, hence the lower lying parts of the Project area would be the most likely areas to contain this type of soil.

8.1.6.3 Avoidance and Management

The overall approach to waste minimisation will be to adopt the following good practice principles described in Chapter 9. Specific management measures for eliminating or minimising impacts from hazardous materials, general waste, hydrocarbons, chemicals and hazardous waste are described in the EMP (see Appendix 9).

The possibility of contaminating land is primarily related to: the application of chemicals and ash in the plantation and nurseries; spills and leaks of stored/used materials; the disposal of waste generated on site; and the disturbance of PASS. Key management measures for each of these are presented below.

Direct Application of Chemicals, Ash and Biosolids to Land

The use and application of chemicals to land will be minimised as far as practicable. The use of herbicides and fertiliser will be minimised and the use of pesticide is not proposed unless a significant pest problem is encountered. Additional management measures have been incorporated into the waste management procedure (see EMP (Appendix 9)) and include:

- Only chemicals with proven environmental safety and not subject to bans or phase-outs will be used; chemicals used in plantations will be approved for use under FSC guidelines.

- Spraying of glyphosate (considered to be a non-residual herbicide) will be minimised, with no spraying to occur within the established riparian buffer zones.
- Ash to be reused in road construction (bottom ash) or as fertiliser for the plantations (fly ash) will be subjected to the laboratory leaching tests for confirmation of the anticipated low risk related to its reuse.
- Biosolids will only be used as a fertiliser in areas of the plantation that are not used to grow food crops.

Hydrocarbon or Chemical Leakage, Spillage and Disposal

Proper design, quality control and operating procedures will minimise the risk associated with spills or leaks including the proper storage, use and disposal of these potentially hazardous materials and routinely maintaining and inspecting equipment. Additional management measures have been incorporated into the waste management procedure (see EMP (Appendix 9)), which address fuels and chemicals, and include measures such as:

- All fuels and chemicals will be securely stored in bunded areas within the bund design limits, and fuels and oils will be stored in appropriate and maintained receptacles in an undercover area, away from waterbodies and office/living quarters.
- A Spill Response Plan will be developed and implemented and the required equipment maintained.
- Inductions and training will be provided to staff concerning handling hazardous materials and implementing the Spill Response Plan.
- Refuelling and servicing of vehicles and equipment will be undertaken in a designated bunded area close to the fuel storage area.
- Liquid waste produced in the workshop will be collected and sent to either a sullage pit or treated with an oily water separator before disposal.
- Empty fuel and chemical drums and containers will be properly stockpiled, with lids secured and periodically removed and disposed of or recycled.
- Activities involving fuels and chemicals are to be limited to designated areas with appropriate buffer zones in place.

Management and Disposal of Non-Hazardous Waste

Recognised industry and good practice management procedures will minimise the risk associated with the management and disposal of non-hazardous waste. Detailed management measures are provided in the waste management procedure (see EMP (Appendix 9)).

To avoid the contamination of land from non-hazardous domestic and industrial waste including steel, paper and cardboard, wood, tyres, plastics, cans and putrescible waste, the general approach will be based on the following principles:

- Minimise waste through efficient use of resources.

- Maximise reuse and recycling opportunities.
- Segregate at the source.
- Ensure handling, storage and disposal practices meet environment permit requirements.
- Facilitate disposal in a responsible manner, including minimising volumes disposed to landfill.
- Appropriately treat where required.
- Continually improve in areas such as material handling and waste management training.

Disturbance of Potential Acid Sulfate Soils

Given the topography, geology and distance from the coast, it is unlikely that PASS will be found in the Project area. However, to minimise potential impacts from disturbing PASS during construction, a risk assessment will be undertaken, and if required, an acid sulfate soils management plan will be developed.

8.1.6.4 Residual Impacts

Residual impacts have been assessed for each of the four key identified potential impacts described above.

Although the environment that could be potentially contaminated as a result of Project development is modified and not considered of moderate or high sensitivity from an environmental perspective, communities are somewhat reliant on the associated ecosystem services. As such, the sensitivity of the environment is considered to be **'moderate'** in the following sections.

Direct Application of Chemicals, Ash and Biosolids to the Land

During construction of the power plant, chemicals and ash will not be applied to the land and as such impact significance has not been considered.

Chemicals such as herbicides and fertilisers will be used during plantation establishment and the operations phases. Pesticides will only be used if a significant pest problem is encountered. The ash by-product (if suitable) will be used in road construction and as a plantation fertiliser during operations. The biosolids collected from the septic system will also be disposed to land and used as a fertiliser in non-food growing areas. Impacts from the direct application of chemicals, ash and biosolids to land will be short term and localised. The magnitude of impact from operations is therefore assessed as '**low'**. Given that the sensitivity of the environment where chemicals and ash will be applied is '**moderate'**, the residual impact significance for land contamination resulting from the direct application of chemicals is **'low'**.

Leakage, Spillage and Disposal of Hazardous Waste and Materials

Hydrocarbons and chemicals will be used, stored and disposed of during the construction and operation phases of the Project. With adherence to the management procedures described in the EMP (Appendix 9) (and the Spill Response Plan), the magnitude of impact during both construction and operations is assessed as '**low'**. Given the sensitivity of the environment where a leak, spill or incorrect disposal could occur is '**moderate'**, the residual impact significance for land contamination resulting from a hydrocarbon or chemical leak, spill or incorrect disposal is '**low**'.

Management and Disposal of Non-hazardous Waste

Due to the expected lifetime of the Project and the amount of waste generated during the relatively short construction phase compared to operations, the residual impact significance for these phases has been assessed separately. Experience elsewhere in Papua New Guinea has shown that the management and disposal of non-hazardous waste, e.g., litter, can be a significant issue. Adherence to, and compliance with, the management procedures described in the EMP (Appendix 9) will ensure that impacts are minimised, but this will require ongoing vigilance by MVB (and contractors).

On site burial of some non-hazardous waste may be required during construction and operations and this will be consistent with good practice measures. Burial of rubbish will occur where materials cannot be reused, recycled or sent off site. Only inert waste will be buried, which poses a low risk to the environment. If the burial of waste is found to be having a negative impact on the surrounding environment, this waste can be recovered and sent for off site disposal.

Although a substantial amount of construction materials will be required to build Project infrastructure, effective implementation of the management procedures described in the EMP (Appendix 9) will result in impacts that are highly localised and readily remediated. The magnitude of impact for construction is therefore assessed as '**negligible**'. Given the sensitivity of the environment that could be impacted is '**moderate'**, the residual impact significance for land contamination resulting from non-hazardous waste is '**negligible**'.

During operations, the largest source of non-hazardous waste will be domestic waste produced by the Project workforce. Given the longevity of the Project, a substantial amount of non-hazardous waste will be produced. Adherence to the management measures described in the EMP (Appendix 9) and following good practice waste minimisation procedures will ensure that the impacts are short term and localised. The magnitude of impact for the operations phase is therefore assessed as '**low'**. Given the sensitivity of the environment that could be impacted is '**moderate'**, the residual impact significance for land contamination resulting from non-hazardous waste is '**low**'.

Potential Disturbance of Potential Acid Sulfate Soils

As part of a risk assessment, the likelihood of occurrence of PASS and the associated impacts will be determined and, if required, an acid sulfate soil management plan will be prepared and implemented. This will ensure that potential impacts will be highly localised and easily remediated. The magnitude of impact for construction and operations is therefore assessed as '**negligible**'. Given the sensitivity of the environment that could be impacted is '**moderate'**, the residual impact significance for land contamination resulting from the disturbance of potential acid sulfate soils is '**negligible**'. However, this assessment should be re-visited on completion of the risk assessment.

8.1.7 Landscape and Visual Amenity

8.1.7.1 Discipline-specific Approach

Assessment of potential Project impacts on visual amenity and landscape requires:

- Identification of the visual components of the Project and how these will change over time.
- Identification of locations from which Project components may be seen (viewpoints) and the distance of viewpoints from seen area/s, and consideration of whether receptors are permanent (e.g., villages) or transient (e.g., road or air traffic).
- Estimation of public sensitivity levels from different viewpoints.
- Review of the landscape character and scenic quality of the local area (see Section 6.1.1.2) and determination of landscape priority zones.
- Identification of landscape management objectives on the basis of the above.

The approach used for visual impact assessment has been adapted for the local context from Tasmania's *A Manual for Forest Landscape Management* (FPB, 2006).

Magnitude of potential visual impacts has been defined as shown in Table 8.11.

Table 8.11 – Magnitude of Visual Impacts

Magnitude	Description
High	♦ Visual impact that causes a clearly evident, long-term, fundamental change to the landscape character over an extensive area ♦ Visual impact that leads to substantial and irreversible negative change to visual amenity
Moderate	♦ Visual impact that causes an apparent but not overwhelming change to the landscape character ♦ Visual impact that leads to moderate change to visual amenity
Low	♦ Visual impact that may be apparent but is blends in with the existing view and will not cause a fundamental change to the landscape character ♦ Visual impact that leads to a minor change to visual amenity
Negligible	♦ Visual impact that is highly transient or very short term, highly localised or a very long distance from the viewer, or where the change is imperceptible or barely detectable with respect to the existing landscape
Positive	♦ An improvement to visual amenity or scenic quality

In the context of visual amenity, rather than sensitivity of values, levels of public sensitivity are assessed and applied to travel routes, residential areas and other fixed viewpoints based on the following principles (FPB, 2006):

- Different types of viewers tend to have different levels of concern for the visual environment, with commercial traffic being lowest, commuters being moderate, and tourists being highest.
- Higher numbers of viewers increase the importance of a viewpoint or route.
- Greater duration of viewing time increases the importance of a viewpoint.

Table 8.12 describes the public sensitivity criteria used in this impact assessment.

Table 8.12 – Public Sensitivity Levels for Visual Amenity

Sensitivity	Description
High	♦ Primary roads of national or provincial importance and/or primary recreational waterways (i.e., major rivers/lakes) where these are frequented by recreational traffic or tourists ♦ Walking tracks, roads and use areas of significance in National Parks or similar areas ♦ Primary, high-use recreational areas such as lookouts and visitor centres ♦ Cities, towns and residential areas/regions that have sensitive communities and high levels of concern for scenic quality and landscape change
Moderate	♦ Primary roads where most traffic is commercial, industrial or local/regional commuters ♦ Secondary roads with 100 to 200 vehicles per day, or roads to recreational destinations with more than 25 vehicles per day on holidays or in peak season ♦ Recreational, cultural or scenic sites, walking tracks and viewpoints of regional significance ♦ Secondary waterways, where these are used by recreational traffic or tourists ♦ Secondary, low-use recreational areas, such as camp grounds or picnic areas ♦ Large villages or residential areas with moderate concern for scenery and landscape change
Low	♦ Minor/tertiary roads or tracks with less than 25 recreational vehicles per day on holidays or in peak seasons ♦ Walking tracks of no more than local significance ♦ Recreational areas with only very occasional use and of no more than local significance ♦ Small villages or settlements with low concern for scenery and landscape change

Note: Criteria adapted for the PNG/Markham Valley context from FPB, 2006.

The significance of visual impacts is determined by combining the likely magnitude of the impacts with the assessed public sensitivity level, using a matrix based on the above criteria. The general significance assessment matrix provided in Section 8.1.1.2 has been adapted for visual impact assessment as shown in Table 8.13.

Table 8.13 – Visual Impact Significance Assessment Matrix

		Public Sensitivity Level		
		High	Moderate	Low
Magnitude of Impact	High	High	High	Moderate
	Moderate	High	Moderate	Low
	Low	Moderate	Low	Low
	Negligible	Negligible	Negligible	Negligible
	Positive	Positive	Positive	Positive

8.1.7.2 Potential Impacts

Potential impacts on landscape and visual amenity relate to how changes to views are likely to affect the existing character of the landscape or reduce the amenity or enjoyment that viewers are provided by the visual landscape. Development of the Project (including construction and ongoing presence/operation of the power plant, and establishment and ongoing operation of the plantations) will unavoidably result in alterations to the visual landscape of the Project area.

Potential impacts on visual amenity and/or landscape as a result of the Project include:

- Medium-term changes to visual amenity (over several years) as a result of power plant and nursery construction activities.
- Long-term changes to visual amenity and landscape character as a result of:
  - Changes to the vegetation of the Project area, and ongoing presence of the plantations.
  - Physical presence of power plant structures and other infrastructure.
  - Visual impacts of minor gaseous plumes and night lighting from the power plant.
- Periodic short-term impacts on visual amenity as a result of activities associated with road construction and use, vegetation clearing, plantation establishment and harvesting activities.

These impacts will be observed by transient viewers from aircraft and highway traffic, and/or by more permanent viewers such as village or hamlet residents.

8.1.7.3 Avoidance and Management

Plantations

As noted in Section 7.3.4, the largest villages in the Project area (Chivasing and Tararan) will be surrounded by buffer zones of at least 50 m within which plantation establishment will not occur. Streamside buffer zones (see Section 7.3.4) will assist in maintaining the visual character of riparian zones, which are considered to be of higher scenic quality than the surrounding plains.

Within the foreground view zone (<500 m; discussed further in Section 8.1.7.4) of smaller villages and hamlets in the Project area, plantation design will be subject to consultation with local landowners, rather than applying a 'blanket rule' with regards to buffer zones and consideration of visual amenity. Consultation to date has indicated that some landowners would prefer to have plantations developed immediately next to their residential areas while others may prefer a buffer zone.

In addition to the above, the following plantation planning and management measures will be applied to reduce impacts on visual amenity throughout the Project area, but in particular for areas within 500 m of the Highlands Highway:

- Initial vegetation clearing, plantation establishment and subsequent harvesting of plantation compartments will be dispersed in time and space to form a mosaic of age classes, avoid large/consolidated areas being cleared or harvested in the same year, and reduce cumulative visual impacts.
- Compartments in a given location will be designed with varying sizes and shapes to better blend with the existing landscape character.
- If plantation compartments (or groups of compartments) are large in scale, where practicable they will be designed with more 'natural' (irregular on non-geometric) shapes that are similar to forms in the surrounding landscape or nearby areas of pre-existing vegetation.
- If it is necessary to design plantation compartments with strong rectilinear or geometric shapes, where practicable they will be small to medium in scale.

Power Plant

The power plant will be designed to reduce the visual impact of structures that are visible from surrounding areas. The proponent requires that construction contractors adhere to the following guidelines in developing the power plant site layout and in choosing surface colours and finishes for the facilities:

- Minimise the colour contrast between the structures and the surrounding environment.
- Reduce the impact of skyline views of the stacks by colour and texture treatment.
- Avoid highly reflective building materials that may cause glare when viewed from surrounding areas and aircraft.
- Minimise off-site impact of lights at night, both during construction and operations.
- Conduct planting and landscaping and reinstate areas disturbed during construction to the ‘as found’ condition or equivalent as required for final landscaping (e.g., laydown areas not required for operations will be revegetated).

8.1.7.4 Residual Impacts

Visual Components

For the purposes of this visual assessment, only key visual elements of the Project have been considered. These include the proposed 16,000 ha of plantations (including construction of roads and tracks), as well as aspects of the power plant and log yard that are listed in Table 8.14 and shown in Figure 7.7 (plan view) and Figure 8.8 (side view). In terms of temporal sequence of visual impacts, as described in Chapter 7, clearing of existing grasslands and raintrees followed by initial establishment of the plantations will occur progressively over approximately seven years. Each biomass rotation (to harvest and re-establishment) will then be seven to nine years, continuing indefinitely. Construction of the first 15 MW unit of the power plant will take two years, with the second 15 MW unit complete approximately two years later. The power plant operational life is nominally 25 years but, as noted in Section 7.7, it is likely to extend beyond this.

The most visually significant components of the power plant – in terms of height – will be the boiler stacks at 40 m each, followed by the main power plant building (the biomass boiler) at 31 m, flanked by shorter components. The adjacent plant nursery comprises short structures (less than, say, 5 m) only. The layout of the power plant and adjacent facilities is shown in Figure 7.5.

The boundary of the power plant site is 50 m to the south of existing 132 kV electricity transmission lines. Power generated by the plant will be conveyed directly to these lines via a short section of 132 kV transmission line from the on-site switchyard and transformer. This new connection will be visually unobtrusive, and a new substation is not required.

In addition to built components, minor visible emissions (plumes) from the power plant will be evident during normal operations. These will include a small plume of non-condensable gases visible from the vent of the deaerator. Depending on the ambient air conditions (i.e., relative humidity and temperature) a plume of limited height may be visible from the top of the cooling tower. This will disappear when ambient temperature increase and/or humidity levels decrease.

Table 8.14 – Heights of Power Plant Structures

Component	Approximate Height (m)*
Biomass Boilers (2 units, both including the following components)	
Stack (southernmost part of the boiler)	40.0
'Biomass boiler' structure (main power plant building)	31.0
Economiser (attached to the boiler building)	28.0
Roof over fuel bins (northernmost part of the boiler building)	22.0
Electrostatic precipitator (ESP)	17.0
Dust collector	12.5
Other Power Plant Structures	
Fly ash silo	12.0
Water tanks	12.0
Cooling tower	9.4
Steam turbine building	8.5 (tallest point)
Hog and screen tower	8.0
Workshop and warehouse building	7.0 (tallest point)
Log yard – log stacking height	5.0 or 6.0
Administration building and canteen	5.3 (tallest point)
Oil tank	4.0
Guardhouse	3.8 (tallest point)
Electrical building	3.3
Weigh bridge building	3.0 (tallest point)

*See Figure 7.7 for building footprint dimensions.

On the rare occasion of a power plant emergency stop (once or twice per year, after shut down of plant), a plume of black smoke will be visible from the stack outlet for less than one minute.

The power plant will be operated 24 hours per day and, as such, night lighting will be required. This will contrast visually with the generally dark landscape of the Project area.

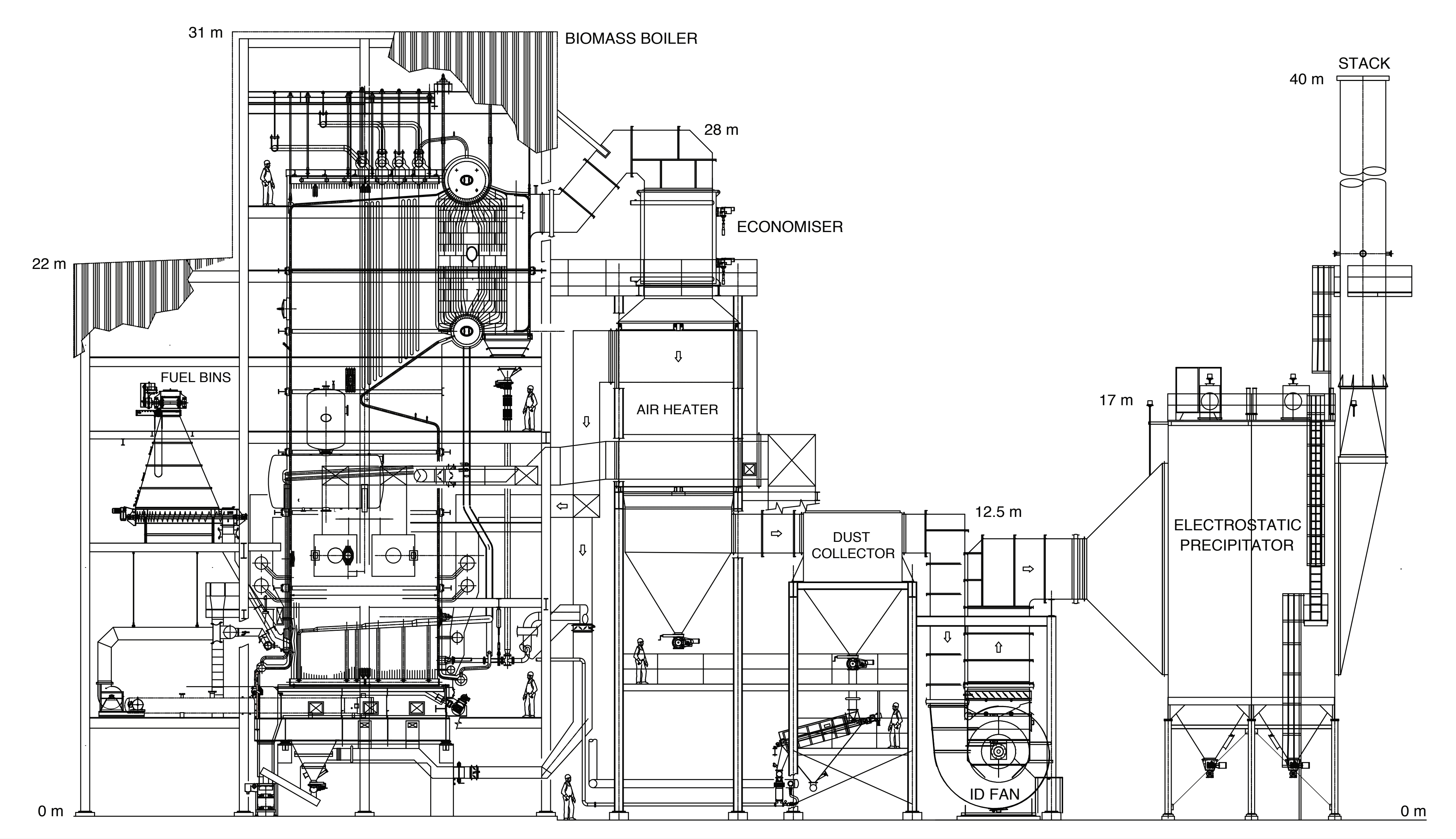
Plantation Viewpoints

As described in Section 6.1.1, the Project area and the Markham Valley within which it is located consist of broad flat plains. As such, analysis of topographical maps and satellite imagery shows that villages, settlements and roads in the valley are unlikely to overlook the proposed plantation area except where it is in the foreground of view (<500 m; as per Table 8.15). A number of villages and hamlets are within or next to current MOU areas (see Figure 6.34), and are therefore likely to view plantations in their foreground view on a daily basis.

BOILER SIDE ELEVATION WITH STACK

PNG Biomass Markham Valley I Environmental Assessment Report

FIGURE 8.8



Source: Pöyry, 2017.

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Table 8.15 – Distance Zones

Distance Zone	Description
Foreground	♦ Zone where receptors are within 500 m of the viewed area (where detail of the landscape is most clearly perceived)
Mid-ground	♦ Zone where receptors are further than 500 m but less than 6 km from the viewed area (where the context of the landscape becomes apparent)
Background	♦ Zone where receptors are further than 6 km but less than 16 km from the viewed area (where fine detail is not apparent but broader landforms are of more note)
Distant or unseen	♦ Zone where receptors are further than 16 km from the viewed area/s, or where landscape impacts will be unseen from any identified receptors

The main road through the plantation area and from which a number of compartments will be seen by transient receptors is the Highlands Highway, a major transport route supporting vehicular traffic between Lae and the Eastern Highlands, as well as feeding into the Ramu Highway that continues northwest to Madang. The verges of the Highlands Highway are also commonly used by pedestrians in the vicinity of (and between) villages, markets and hamlets.

There are no towns, large villages or major tourist ventures that overlook the plantation area from the nearby foothills or mountains to the north or south of the valley. However, parts of the plantation area may be viewed in the mid-ground to background by a few small villages in the northern foothills (e.g., upstream on the Rumu River).

A main 'viewpoint' of the plantation area will be from transient receptors in terms of airplane passengers approaching or departing Lae Nadzab Airport, which is located approximately 8 km to the east of the power plant and easternmost plantation area (see Section 6.3.4.1). Most observers from aircraft will be residents of Lae or surrounds, business people, or contractors for various enterprises such as the Hidden Valley Mine. There is currently limited tourism in Lae or the Markham Valley, although this is gradually increasing with at least one adventure tourism operator flying into Lae Nadzab Airport and transporting trekkers through the Project area to Dumpu.

Power Plant Viewpoints

As for the plantations, passengers in approaching and departing aircraft will also briefly view the power plant, log yard and nursery throughout their construction and operational life.

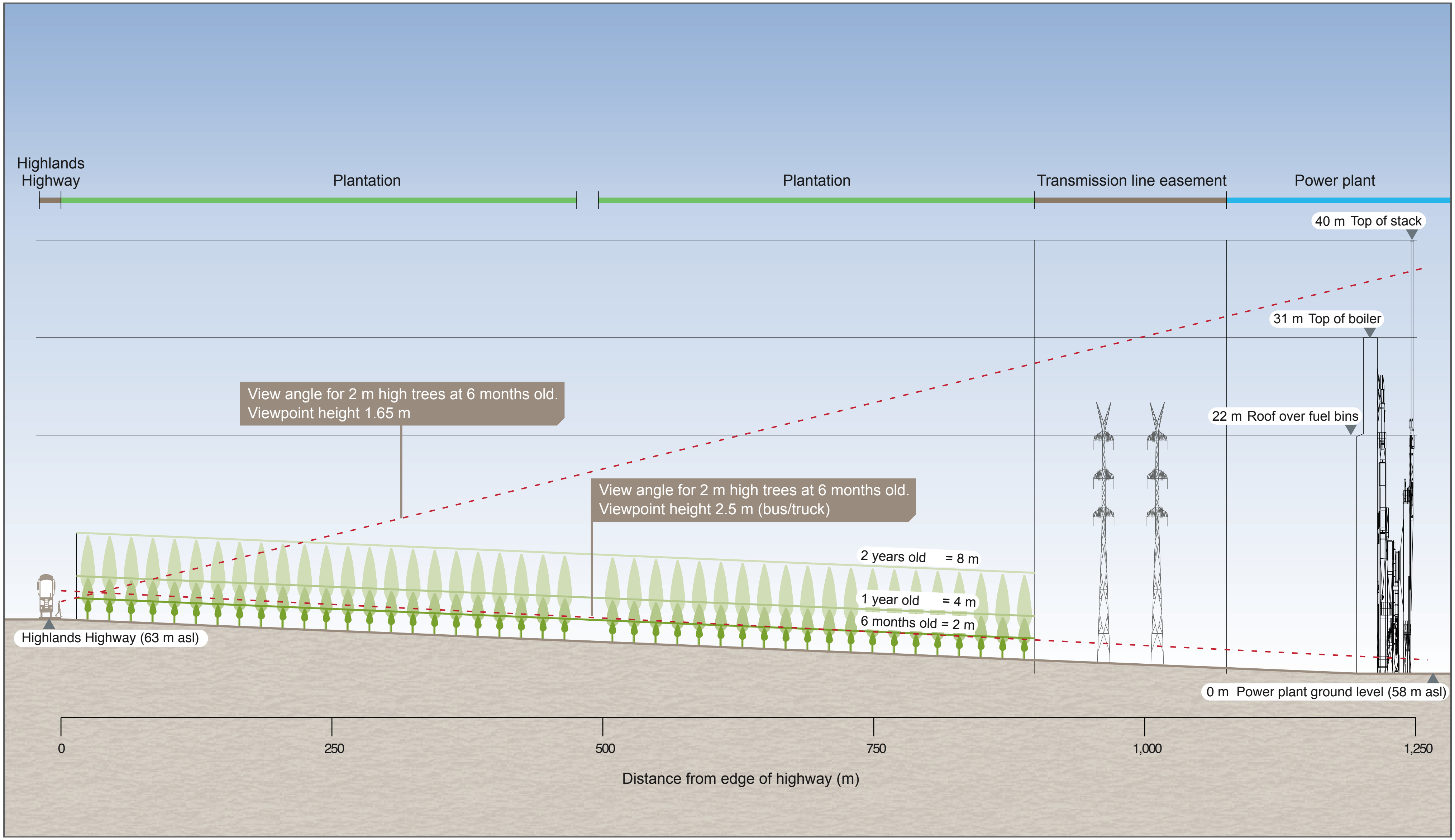
At its nearest, the Highlands Highway is 5 m higher in elevation than the power plant site (63 versus 58 m asl), and is approximately 1.10 km from the site boundary and 1.25 km from the proposed power plant stacks (both classified as mid-ground view using the definitions in Table 8.15) (Figure 8.9). Depending on the timing of power plant construction, as well as clearing of raintree forest and plantation development between the power plant site and the highway, parts of the facility may be seen from the highway for a short period at the start of the Project.

Power plant construction is scheduled to commence in Q4 of 2017, and structural erection is planned for mid-2018 (see Figure 4.1). Plantation establishment will be progressive, but is planned to start on a broad scale by Q4 of 2017. Based on measurements of plantation trial plots developed within the Project area over the past five years, eucalypt trees are expected to grow at an average rate of 4 m per year for at least the first two years after planting.

VISIBILITY OF THE POWER PLANT FROM THE HIGHLANDS HIGHWAY

PNG Biomass Markham Valley I Environmental Assessment Report

FIGURE 8.9



For the purposes of this visual analysis, it is assumed that the plantation compartments between the power plant and the highway (see Figure 7.5) will be planted at the same time as commencement of power plant construction[5]. As such, trees in this area will be six months old (and approximately 2.0 m tall) by the time the first biomass boiler and stack are erected. At this point in time, viewers from taller highway traffic (e.g., buses and trucks where viewer eye level is approximately 2.5 m above the ground) will be able to observe all of the power plant buildings, while a pedestrian on the highway with eye level at 1.65 m above ground will be able to see only the power plant stack (see Figure 8.9). By the time plantations in this area are 12 months old, neither highway pedestrians nor viewers from buses/trucks will observe any power plant structures (see Figure 8.9).

The southernmost part of the small village or hamlet of Ganef is within 700 m of the northwest corner of the proposed log yard. Parts of the log yard will remain visible from Ganef along the access road for the duration of operations. The power plant itself, while situated within 1 km of Ganef, will not be visible from the hamlet once adjacent plantation compartments are more than 12 months old.

It should be noted that plantations managed under a biomass regime will be harvested and re-established every seven to nine years. As such, the power plant, log yard and nursery may be periodically visible from both Ganef and the Highlands Highway throughout the life of the Project, depending on the harvest timing of the four compartments proposed in this vicinity.

Sections of the highway further to the east and west of the log yard, power plant and nursery (2 to 3 km distance) are unlikely see the power plant facilities due to existing raintree vegetation within the line of site. Areas of land >65 m asl and more distant from the power plant (including eastern parts of Chivasing, some 5 km from the site) may view taller parts of the facility in the mid-ground or background of view, depending on the configuration of proposed plantations in between.

Public Sensitivity Levels within the Project Area

Major roads of national or provincial importance are typically classified as having a high level of public sensitivity for visual amenity (see Table 8.12) (FPB, 2006). However, this classification may be moderated if the majority of travellers along the route have a moderate or low level of concern for scenery and landscape change. Based on experience in Papua New Guinea, along with the landscape character of the Project area (see Section 6.1.1.2), local observers as well as commercial and industrial traffic using the Highlands Highway and Lae Nadzab Airport (including resources industry participants) are likely to have a low to moderate level of concern for the proposed changes to the landscape of the Project area. In part, this is due to the existing modified nature of the local landscape and long history of visual amenity changes associated with land uses such as cattle grazing, palm oil, coconut and sugar cane plantations, resulting in an expectation of ongoing change.

For the majority of local landowners, the proposed plantations may also be viewed as a positive development representing opportunities. Conversely, the limited numbers of tourists travelling to

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[5] If the initial clearing and planting of this area occurs at a later date, the power plant will be visible from the highway for a longer period of time than discussed herein.

or through the Markham Valley are more likely to have a moderate or high level of concern for scenic quality, and may view the plantations as less desirable features, either in isolation or cumulatively with other local land use developments.

Landscape Priority Zones and Management Objectives

With consideration of the existing scenic quality of the Project area (see Section 6.1.1.2), Table 8.16 details landscape priority zones assessed on the basis of public sensitivity and distance from the viewer (FPB, 2006).

Table 8.16 – Assessment of Landscape Priority Zones for Areas of Low Scenic Quality

		Public Sensitivity Level		
		High	Moderate	Low
Distance	Foreground	Zone B	Zone B	Zone C
	Mid-ground	Zone B	Zone C	Zone C
	Background	Zone B	Zone C	Zone C
	Distant or Unseen	N/A	N/A	N/A

Based on the above analysis and applying an adaptation of the FPB (2006) approach, plantation areas viewed in the foreground (within 500 m) from the Highlands Highway are considered to be in landscape priority Zone B (moderate priority for landscape/of moderate concern for visual amenity). All other parts of the Project area are considered to be in landscape priority Zone C (low priority for landscape/of low concern for visual amenity).

The different landscape priority zones have corresponding management objectives. Within Zone B (moderate priority areas), the objective to be achieved is an 'apparent alteration' to the landscape, i.e., alterations to the landscape may be apparent to the viewer, but appear subordinate to the surrounding scenery (i.e., less noticeable than other components of the view), or temporarily dominant in the view (i.e., for up to two years). Although activities may introduce some unnatural visual elements (e.g., shapes and colours that are noticeably dissimilar to the surrounding environment), the objective in Zone B is to retain key aspects of the visual character of the landscape. Within Zone C (low priority areas), a management objective of a 'dominant alteration' is allowed, i.e., alterations to the landscape can be dominant in the view and modify the visual character of the landscape, if necessary. However, the goal in these areas is to limit the introduction of unnatural visual elements where possible, via mitigation measures as described above.

The landscape priority zones and management objectives assessed for different Project area viewpoints are summarised in Table 8.17.

Table 8.17 – Landscape Priority Zones and Management Objectives for the Project Area

Viewpoint/s	Public Sensitivity Level	Distance Zone/s	What Viewed	Landscape Priority Zone	Landscape Management Objective
Highlands Highway	Moderate to low	Foreground	Plantations	Zone B	Apparent alteration
		Mid-ground; background	Plantations, power plant	Zone C	Dominant alteration

Table 8.17 – Landscape Priority Zones and Management Objectives for the Project Area (cont'd)

Viewpoint/s	Public Sensitivity Level	Distance Zone/s	What Viewed	Landscape Priority Zone	Landscape Management Objective
Airplanes approaching/ departing Lae Nadzab Airport	Moderate to low	Background	Plantations, power plant	Zone C	Dominant alteration
Other Project area roads	Low	Foreground	Plantations	Zone C	Dominant alteration
		Mid-ground; background	Plantations, power plant		
Project area villages and hamlets	Low	Foreground	Plantations	Zone C	Dominant alteration[#]
		Mid-ground; background	Plantations, power plant		

[#] Subject to negotiation with local landowners/residents; the two largest villages will have minimum 50 m buffer zones.

Assessment of Residual Impacts

The Project area is characterised by generally flat topography, a long history of landscape modification (e.g., vegetation disturbance and land use) and an existing mosaic of grassland areas with patches of raintrees and various land uses. As such, it has a high capacity to absorb visual alterations as a result of new developments. The area is considered to have a '**low**' level of sensitivity to change in visual character due to these factors.

Although the plantation development will result in a noticeable change across broad areas of the landscape, these changes – incorporating the design and management principles outlined in Section 8.1.7.3 – will be in keeping with the modified landscape character of the Project area. Plantations are expected to result in a '**low**' magnitude impact to visual amenity in the Project area.

The power plant and surrounding facilities are unlikely to be visible from identified viewpoints for any more than 12 months at a time throughout construction or operations. Given the screening effects of plantations combined with the design and management principles outlined above, these facilities are not expected to cause a fundamental change to the landscape character of the Project area. The power plant is expected to result in a '**low**' magnitude impact to visual amenity in the Project area.

As discussed in Section 8.1.7.2, viewers from the Highlands Highway as well as viewers from airplanes to/from Lae Nadzab Airport are expected to have, at most, a '**moderate**' level of public sensitivity. Given the management measures described above, the magnitude of visual impacts within 500 m of the highway is expected to be '**low**'. Visual impacts as viewed from aircraft are also expected to be of '**low**' magnitude. The overall visual impact significance is therefore rated as '**low**'.

Viewers from other viewpoints are expected to have a '**low**' level of public sensitivity. Given the management measures described above, the magnitude of visual impacts elsewhere in the Project area is expected to be '**low**' to '**moderate**'. The visual impact significance within the context of these other viewpoints is therefore also rated as '**low**'.

8.1.8 Soils

8.1.8.1 Discipline-specific Approach

The approach adopted for the soils impact assessment is consistent with the impact significance assessment method described in Section 8.1.1.2.

8.1.8.2 Potential Impacts

This section addresses potential Project impacts on the productive capacity of soils, such as erosion, compaction and mixing, and nutrient depletion. Potential impacts associated with soil contamination, as well as acid sulfate soils, are addressed in Section 8.1.6.

Project activities that could potentially impact soils include:

- Vegetation clearing for both power plant construction and plantation establishment.
- Earthworks during construction of the power plant, nursery and roads, particularly vehicle/ plant movement on unconsolidated soils.
- Soil cultivation in plantation compartments.
- Planting/growing eucalypt seedlings and intercropping (food and other) plants.
- Plantation harvesting, including development of log landings and snigging of logs to landings.
- Hauling timber along plantation access tracks (tertiary roads).
- Construction and operation of Project area roads.

The potential impacts of these activities on Project area soils are discussed in more detail below.

Erosion

The following Project activities could cause soil erosion:

- Vegetation clearing (including cyclical plantation harvesting), resulting in exposure of soils to wind and water erosion, and reduced cohesion of soils by plant roots making soils more susceptible to erosion, as well as use of machinery for these activities resulting in direct soil disturbance.
- Earthworks during construction activities and cultivation during plantation establishment, both resulting in direct disturbance and exposure of soils.
- Establishment and operation of new Project area roads, where concentrated runoff could cause water erosion of roadside areas.

Compaction and Mixing

Heavy machinery including excavators, tractors and harvesting equipment, as well as large trucks, will be required for clearing and excavation works during power plant, nursery and road construction, as well as for plantation establishment, harvesting and hauling timber during operations. These activities have the potential to result in soli compaction (aside from deliberate soil compaction works during construction) in laydown areas other than hardstands, as well as on plantation landings and snig tracks.

Earthworks and cultivation also have the potential to lead to soil mixing (i.e., inversion of topsoil and subsoil layers), and removal or relocation of topsoil, which can alter existing soil properties by exposing deeper soil types, thereby potentially affecting soil productive capacity.

Nutrient Balance

The change in Project area vegetation type from predominately grasslands with patches of raintrees to consolidated areas of eucalypt plantations has potential to alter the existing nutrient balance in soils. Given the higher nutrient demand of plantation forests (as opposed to grasslands), this could lead to nutrient depletion over time and hence lower soil fertility.

8.1.8.3 Avoidance and Management

Measures to minimise impacts to soils from Project activities are described in the EMP (Appendix 9), specifically Procedure 2, which addresses vegetation clearing, earthworks, topsoil management and rehabilitation. In addition, Project activities will adhere to the PNG Logging Code of Practice (PNGFA/DEC, 1996). Key management measures to minimise impacts to soils from erosion, compaction and/or mixing and nutrient loss are described below.

Vegetation Clearing and Construction

- Vegetation clearing will only be undertaken to the extent required for the designated land use; boundaries of areas to be cleared will be physically demarcated prior to commencement of clearing.
- At the completion of ground disturbance activities, where feasible, all disturbed areas will be rehabilitated to minimise ongoing soil erosion and promote the natural revegetation of these areas.
- Where practicable, road construction and major earthworks will occur during the dry season.
- Where possible, areas to be cleared will exclude locations of high erosion potential (e.g., steep slopes).
- Project facilities will be located in already disturbed areas as far as practicable.
- All removed topsoil and vegetation will be stockpiled for later use during rehabilitation or recycled.
- Erosion and sediment control measures together with locations and types of control devices (e.g., sediment pond, silt fence, diversion drain) will be installed, where required.
- Groundcover vegetation will be retained if possible.
- The length of time that cleared/disturbed areas are exposed will be minimised to the greatest extent practicable.
- Topsoil will be carefully removed and stockpiled when an area is being cleared for subsequent use in rehabilitation where feasible.

- Revegetation of stockpiles will be promoted to protect soil from erosion, discourage weeds and maintain soil microbe populations.
- Vegetation clearing will adhere to the PNG Logging Code of Practice (PNGFA/DEC, 1996).

Plantation Operations

- Fly ash produced from the combustion of biomass will be returned to the soil to enhance soil properties within the plantations (provided it meets relevant standards).
- Logging slash will be left in situ.
- During (or following) wet weather, when operations may damage the soil, dry weather logging and/or moving to another log landing or a production area reserved for wet weather logging will be considered.
- Second and subsequent rotations of plantations will be established as promptly as practicable after harvesting the previous rotation.
- Plantation operations will adhere to the PNG Logging Code of Practice (PNGFA/DEC, 1996).

8.1.8.4 Residual Impacts

Residual impacts have been assessed for each of the three key potential impacts to soils resulting from Project activities described above (i.e., erosion, compaction/mixing and nutrient loss).

Soils of the Project area are not considered unique or rare, with vast areas in the region having similar conditions. The key value of Project area soils is its role as a resource or ecosystem service to local communities. However, the Project aims to use land areas that are currently under-utilised with respect to existing land uses (in consultation with landowners).

As such, the sensitivity of the environment is considered to be **'low'** in the residual impact significance assessment described in the following sections.

Erosion

With adherence to the management measures described in the EMP, soil erosion as a result of Project construction activities will be localised and will not extend beyond the area of disturbance. The magnitude of impact for is therefore assessed as '**low**'. Given that the sensitivity of the environment that could be impacted is '**low**', the residual impact significance for erosion of soils during construction is '**low**'.

Industry good practice and adherence to the PNG Logging Code of Practice (PNGFA/DEC, 1996) and the management measures described in the EMP (and Project FMP) will minimise soil erosion from plantation operation activities, including harvesting and hauling of timber. Potential impacts to soil from erosion during plantation operations will be contained within the Project area, but considering the size of the area that will be disturbed during operations the magnitude of impact is assessed as '**moderate**'. Given that the sensitivity of the environment that could be impacted is '**low**', the residual impact significance for erosion of soils from plantation operation activities is '**low**'.

Compaction and/or Mixing of Soils

Earthworks and other use of heavy plant and traffic during construction are likely to cause some soil compaction and/or mixing of soils. The management measures described in the EMP will, however, minimise the areas subjected to compaction, which will be localised to the infrastructure footprint and the construction access roads. The magnitude of impact is therefore assessed as '**low**'. Given that the sensitivity of the environment that could be impacted is '**low**', the residual impact significance for compaction and/or mixing of soils during construction is '**low**'.

During plantation establishment, soil cultivation has potential to lead to soil mixing. However, application of good practice in terms of cultivation machinery and methods will minimise this impact – also noting that soil mixing is undesirable from a plantation productivity perspective. The magnitude of impact for soil mixing during plantation establishment is therefore assessed as '**low**'. Given that the sensitivity of the environment that could be impacted is '**low**', the residual impact significance for soil mixing during plantation establishment is '**low**'.

During plantation operations, the use of heavy machinery on landings and snig tracks will be unavoidable. The number of landings and extent of snig tracks will be minimised to the extent practicable, with potential impacts contained to localised areas. The magnitude of impact for soil compaction during plantation operations is therefore assessed as '**low**'. Given that the sensitivity of the environment that could be impacted is '**low**', the residual impact significance for compaction of soils is '**low**'.

Nutrient Balance

Nutrient loss from soils is not considered to be a potential impact during construction or power plant operations, and as such has not been assessed.

The ongoing planting and harvesting of plantations (and, to a lesser extent, food plants established during intercropping) has the potential to lead to nutrient depletion in soils. As noted in Section 6.1.2.2, the soils in the Project area already have low nutrient levels. The addition of NPK fertiliser during plantation establishment, as well as fly ash (where suitable), and retention of harvesting slash will increase nutrient levels and therefore maintain or improve fertility in plantation area soils. The magnitude of impact is therefore assessed as '**positive**', hence the residual impact significance of nutrient balance of soils is '**positive**'.

8.2 Biological Impacts

8.2.1 General Approach to Impact Assessment

The approach adopted for both the terrestrial and aquatic ecology impact assessment is consistent with the impact significance assessment method described in Section 8.1.1.2.

8.2.2 Terrestrial Ecosystems

The information presented in this section is based primarily on an investigation and report undertaken by BAAM and attached as Appendix 6.

8.2.2.1 Discipline-specific Approach

The impact assessment criteria described in Section 8.1.1 have been further defined for the assessment of impacts on terrestrial ecosystems. In particular, the sensitivity of a terrestrial ecology value was determined on the basis of the following factors:

- Conservation status under the IUCN Red List.
- Rarity or uniqueness within, and beyond, the immediate area of interest.
- Capacity to adapt to change without adverse effects on its attributes, i.e., resilience.

8.2.2.2 Potential Impacts

A number of mechanisms could potentially affect terrestrial flora and fauna during the clearing, construction and operation phases of the Project. The factors leading to impacts to terrestrial ecology receptors can be considered in terms of direct and indirect effects, both short-term and long-term.

Direct Impacts

Direct impacts could occur through:

- Land clearing for the development of Project infrastructure, including the power plant, plantation nursery and access tracks, as well as for establishing plantations, which will result in the loss of existing vegetation and natural habitats with the following potential impacts:
  - Direct mortality to individual plants and animals during the clearing process.
  - Reduction in the extent of habitat for native terrestrial flora and fauna species and transformation to a different land cover. Mobile species such as birds and bats will be able to escape to adjoining uncleared habitat, but slower moving species such as reptiles and amphibians will have a greater likelihood of being killed, and bird nests active at the time of clearing will be destroyed.
  - Increased population densities in retained refuge habitat beyond the Project footprint due to this movement of mobile species out of the cleared area, thereby increasing competition for remaining resources.
  - Relatively minor habitat values to terrestrial biodiversity in the plantation areas due to the paucity of groundcover, refuge sites and foraging resources.
  - Removal of most native flora species and natural vegetation from the plantation areas.
- Increased traffic and the transport of machinery and a range of materials into the study area, with the following potential impacts:
  - Transport of weed propagules (seeds and self-reproducing plant parts, many of which are very small) and disease vectors (e.g., by being attached to soil/grease on vehicles, machinery or materials) into the area.
  - Invasive spread of plantation tree species and hybrids (see Section 6.2.1).

- Invasive spread of weeds that may initially establish on disturbed ground and subsequently invade the vegetation bordering the Project infrastructure, thereby compromising the ecological integrity of the terrestrial ecosystems (although the study area already contains a large variety of introduced plant species, including invasive weeds that have since heavily impacted habitats (see Section 6.2.1).
- Increased cane toad populations due to the open ground layer in the plantation areas (although this pest has well-documented negative effects on native fauna, it is already abundant throughout the area and the contribution of the Project to the spread of this species will be minor).

♦ Use of chemicals and hazardous materials in Project activities, and waste generation, which may impact on flora, fauna and vegetation by:

- Uncontrolled releases of chemicals to the environment, particularly waterways, through spills, seepage or stormwater flows, or inappropriate use[6].
- Inappropriate management of hazardous waste (e.g., batteries, spent reagents and waste oil) non-hazardous waste (e.g., timber, scrap metal, paper, plastic) and putrescibles.

♦ Fauna mortality from vehicle strike, power cables, fences and trenches via the following mechanisms:

- Increased road traffic in the local region which will, in turn, increase the risk of direct mortality of slow-moving fauna through vehicle strike.
- Fauna (especially frogs and reptiles) becoming trapped in open, steep-sided trenches.
- Entanglement (particularly of pteropodid bats) in fences with top strands of wire.
- Potential electrocution of flying-foxes by powerline cables.

♦ Air emissions, with the following potential impacts:

- Reduced photosynthetic efficiency of vegetation due to dust on foliage, and reduced fruit yields through reduced pollination success of dust-affected flowers.
- Inhibition of photosynthesis by sulfur dioxide and nitrogen oxides.

♦ Light and noise at the power plant, which may affect the behaviour of both diurnal and nocturnal species.

[6] This includes glyphosate, the primary herbicide to be used by the Project, and the associated surfactants that are mixed with the herbicide before spraying, where the latter (e.g., polyethoxylated tallowamine surfactant (POEA)) appears to be the main cause of toxicity rather than the herbicide itself; recently developed formulations that do not contain POEA are less toxic.

Indirect Impacts

Indirect impacts arise from Project activities, but with a degree of separation in time or space, i.e., they are at least one step removed from Project activities in terms of cause-and-effect links. For example, if the Project leads to an increase in population density through in-migration, an indirect impact could be an increase in hunting pressure. The potential indirect impact mechanisms of Project activities include:

- Habitat fragmentation and edge effects, where land clearing and habitat transformation for the Project could have additional indirect impacts on habitat quality for terrestrial flora and fauna through:
  - Habitat fragmentation, where land clearing fragments previously intact natural habitat and potentially isolates some areas of natural habitat from other areas.
  - The creation of hard edges via fragmentation and the consequent 'edge effects'. The magnitude of edge effects is strongly correlated with the degree of contrast in physical and structural condition between retained vegetation and the surrounding matrix, and hence edge effects are more severe in fragmented rainforest than more open habitats. The plantations that form the great majority of the Project footprint will provide a vegetated edge to retained habitats, and this ‘softer’ edge is expected to reduce the indirect impact.
- Erosion leading to habitat degradation, where the exposure, disturbance and stockpiling of soil during land clearing and other construction activities may cause increased soil erosion, leading to reduced freshwater quality and sedimentation of creek channels.

8.2.2.3 Avoidance and Management

Measures to minimise impacts to terrestrial ecology from Project activities are described in the EMP (Appendix 9), the PNG Logging Code of Practice (PNGFA/DEC, 1996) and the National Forest Management Standards for Papua New Guinea (FSC, 2010). Key management measures that reflect these documents and good practice are described below.

Avoidance Measures

Project planning has been informed by the identification and mapping of relevant terrestrial ecology receptors to the extent that the direct impacts of vegetation clearing (for plantations, power plant and plantation nursery) on terrestrial ecology receptors of higher sensitivity will be avoided as far as possible.

Species of Conservation Significance

A small population of the conservation priority plant species *Cycas schumanniana* occurs on the boundary of the MOU area. To avoid direct impacts on this species, the plants will be protected by a buffer of at least 20 m, with no Project activities occurring within that buffer. If avoiding direct impacts is not possible, the plants will be translocated to suitable habitat outside of the currently proposed plantation area or used in rehabilitation landscaping where they will be protected from fire and herbicide treatments. Translocated plants will be replanted as a single cluster of plants. Cycads, including *Cycas* species, are known to have been successfully translocated.

Habitat Fragmentation and Landscape Connectivity

Implementation of the following riparian buffer zones throughout the Project area, which will maintain habitat connectivity along riparian corridors at a landscape scale, will mitigate the relatively minor impact of the Project on habitat fragmentation and landscape connectivity:

- Buffer zone of 100 m from the banks of the Markham River.
- Buffer zones of 60 m from the banks of the Erap and Leron rivers, and also from the edges of lakes, lagoons and swamps.
- Buffer zones of 30 m from the banks on either side of other permanent watercourses with average width greater than 5 m.
- Buffer zones of 20 m from the banks on either side of all watercourses with an average width greater than 1 m but less than 5 m.
- Buffer zones at least 5 m from the banks on either side of watercourses with an average width less than 1 m.

The following activities will not occur within the riparian buffer zones:

- Machinery access.
- Felling trees or clearing vegetation, except where required for designated stream crossings (note that within buffer zones for watercourses <1 m width only, vegetation clearing will be minimised to the extent practicable, due to operational constraints).
- Felling plantation trees or raintrees from adjacent land into the buffers.
- Establishing plantations.
- Storing logs, soil, machinery, fuels or oils, herbicides or fertilisers, or placement of other Project-related infrastructure.
- Crossing of harvesting machinery, except at appropriately constructed permanent crossing points (bridges) or at designated temporary crossings for dry watercourses. Harvesting machinery can cross watercourses where log crossings or culverts are provided.
- Construction of roads, except where required for designated stream crossings or bridges.

Invasive Weeds, Pest Fauna and Disease

To mitigate the potential for the Project to introduce or facilitate the spread of invasive weeds, pest fauna and disease, the management measures that will be implemented include:

- With regards to test plantings of *Acacia* spp. within the Project area:
  - Areas adjacent to and downslope of *Acacia* test plantings will be monitored for spread of these species. Any identified recruitment of *Acacia* plants from seed or suckering outside of the test planting areas will be controlled using an appropriate herbicide.

  - When plots of *Acacia* spp. are harvested or cleared, where practicable these plots will not be burnt (to minimise germination of seeds). Plots will be monitored for recruitment of new *Acacia* plants, which will be controlled with an appropriate herbicide as required.

- The implementation of riparian buffer zones, with no plantations to be established within the buffers, will mitigate the potential for the plantation tree species *Eucalyptus camaldulensis* to establish and spread along riparian zones. Any plants that establish in riparian zones downstream of the plantation areas will be controlled using an appropriate herbicide before they reach sexual maturity.

- Papua New Guinea quarantine requirements for soil or other plant material will be implemented.

- Washdown protocols will be implemented, including inspections to ensure that machinery and equipment brought into the area is free of soil, seeds and other plant parts.

- The presence of invasive weeds and pest animals in areas disturbed by the Project will be regularly monitored.

- Invasive weeds will be controlled using species-appropriate methods, with prioritisation based on risk assessment.

- Pest rodents including black rat (*Rattus rattus*) and house mouse (*Mus musculus*) will be controlled wherever they are detected by monitoring in Project infrastructure areas.

Chemicals, Hazardous Materials and Waste

The implementation of riparian buffer zones will mitigate the potential impacts of glyphosate herbicide application. The negative impacts of glyphosate can be further minimised if formulations of glyphosate that do not include POEA surfactant are used. To minimise potential impacts from chemical spills and waste on terrestrial ecology, management measures that will be implemented include:

- All fuels and chemicals will be stored in appropriate bunded storage sites at below the maximum allowable storage quantities.

- Spill response procedures and equipment will be provided.

- All hazardous and non-hazardous waste will be stored in appropriate receptacles and dispose of at appropriate waste receiving facilities.

- All waste liable to decay will be stored in a manner that excludes pest animals such as rodents, disposed by incineration, transported to an urban waste disposal facility or buried on-site.

Lighting

To minimise impacts to terrestrial ecology from artificial lighting, the following mitigation and management measure will be implemented:

- External lights will be shielded and directed onto work areas wherever practicable to minimise light spill to both the sky and adjoining natural habitats.

Fauna Mortality from Project Activities

To minimise fauna mortality from general Project activities, the following mitigation and management measures will be implemented:

- A traffic management plan including appropriate speed limits on Project roads and vehicle crossings to minimise the risk of vehicle strike on fauna will be implemented.
- The period of time that trenches are left open will be minimised.
- Trench plugs with slopes less than 45° will be installed in open trenches (to provide exit ramps for fauna) or trenches will be patrolled on a daily basis to check for, and rescue, trapped fauna.
- Small-gauge mesh fencing will be used and topping the fence with barbed wire or razor wire will be avoided where practicable.
- Where possible, powerline designs will include a horizontal separation of at least 1.5 m and a vertical separation of at least 1.2 m between adjacent powerline cables.

The EMP (Appendix 9), as well as other sections of this chapter, contains a number of measures that address erosion and sediment control, and air and noise emissions. These measures are not repeated in this section.

8.2.2.4 Residual Impacts

The direct impact of the Project on terrestrial ecology receptors was calculated as the area of the respective receptor that intersected the Project footprint, which comprises all areas subject to a MOU with the landowners. Indirect impacts are considered to be of negligible importance due to the already modified or degraded condition of vegetation within the broader Project area. The residual impact of the Project on various ecological values was calculated as the total area of the value that intersected with the total area under MOU. However, this area will be reduced once buffers to waterways and wetlands are accounted for and villages and other sensitive areas are avoided.

Terrestrial Vegetation Communities

The residual impact areas of the Project footprint on terrestrial vegetation communities are summarised in Table 8.18 and compared with the total area of the corresponding vegetation community within the study area. The study area is the area of assessment of terrestrial ecology values, whereas the Project area is a subset of the study area that comprises the areas under MOUs within which the plantations, power plant, plantation nursery and associated infrastructure will be developed.

Table 8.18 – Residual Impact Areas (Areas Under MOU) with Respect to Terrestrial Vegetation Communities

Vegetation Community Code	Vegetation Community Description	FIM equivalent[2]	Total Area (ha)[3]	Area Under MOUs (ha)	% Under MOU
Minimal to Moderate Present-Day Disturbance Vegetation Communities					
1a	Large to medium crowned forest (disturbed)	PL: Large to medium crowned forest	13.6	0.0	0.0
2a	Small crowned forest/regrowth forest	PS: Small crowned forest	102.5	0.0	0.0
3a	*Nauclea orientalis/Albizia procera* savannah	SA: Savannah	53.8	8.4	15.7
4a	Kunai grassland on riverine alluvium	G: Grassland	907.3	146.3	16.1
4b	Kunai grassland on footslopes and hillslopes	G: Grassland	390.3	0.0	0.0
Moderate to High Levels of Disturbance Vegetation Communities					
3b	*Nauclea orientalis/Albizia procera* savannah - moderately degraded	SA: Savannah	937.7	657.7	70.1
4c	Kunai grassland on riverine alluvium -moderately /patchily degraded with weeds	G: Grassland	19,322.6	9,278.6	48.0
12a	Active river channels	O: Other non-vegetation and areas dominated by land use[4]	1,072.3	347.2	32.4
Highly Degraded Vegetation Communities					
2b	Mixed native/exotic secondary forest	O: Non-vegetation and areas dominated by land use[4]	1,148.5	678.5	59.2
3c	Native savannah woodland with severely degraded ground cover	SA: Savannah	59.5	17.7	29.7
4d	Kunai grassland on riverine alluvium - heavily modified and degraded with weeds and pasture plants	G: Grassland	10,424.6	1,407.5	13.5
4e	Mixed native/exotic grassland, shrubland and woodland on river alluvium	G: Grassland	553.7	89.9	16.2
4f	*Saccharum robustum, Leucaena leucocephala* grassland/shrubland on recent river deposits	G: Grassland	469.2	118.3	25.2
5a	*Albizia saman* dominated savannah	G: Grassland	210.9	96.4	45.7

Table 8.18 – Residual Impact Areas (Areas Under MOU) with Respect to Terrestrial Vegetation Communities (cont'd)

Vegetation Community Code	Vegetation Community Description	FIM equivalent[2]	Total Area (ha)[3]	Area Under MOUs (ha)	% Under MOU
Highly Degraded Vegetation Communities (cont'd)					
10a	Sago swamp - regrowth/degraded forest	O: Non-vegetation and areas dominated by land use[4]	92.9	46.4	49.9
Habitat Modification Vegetation Communities					
5b	*Albizia saman* dominated open forest	O: Non-vegetation and areas dominated by land use[4]	7,430.2	2,681.8	36.1
6a	*Leucaena leucocephala, Albizia sp., Albizia saman* dominant shrubland	O: Non-vegetation and areas dominated by land use[4]	206.1	29.6	14.4
7a	Village area	O: Non-vegetation and areas dominated by land use[4]	397.3	60.2	15.2
8a	Plantation areas/*leucaena*/palm oil	O: Non-vegetation and areas dominated by land use[4]	936.7	0.3	0.0
8b	Plantation areas: *Pinus* and *Araucaria*	O: Non-vegetation and areas dominated by land use[4]	25.8	0.0	0.0
9a	Former gardens/coconut plantations	O: Non-vegetation and areas dominated by land use[4]	2,155.4	430.7	20.0
11a	Garden areas with evidence of recent modification	O: Non-vegetation and areas dominated by land use[4]	294.1	0.0	0.0
Total			**47,205.0**	**16,097.0**	

[1] Description derived from Paijmans (1976), applied to natural vegetation communities only.
[2] Classification derived from Hammermaster and Saunders (1995).
[3] Total area of the vegetation community within the study area.
[4] Referring to areas utilised by humans for agriculture, settlement or other industrial or extractive activity.

The residual impact areas of the Project footprint by vegetation condition are summarised in Table 8.19 and compared with the total area of the corresponding condition category within the study area.

Table 8.19 – Residual Impact Areas (Areas Under MOU) with Respect to Vegetation Condition Category

Vegetation Category Code	Condition Category Description	Total Area (ha)[1]	Area Under MOUs (ha)	% Under MOUs
2b	Moderately disturbed (stable or regenerating)	156.2	8.4	5.4
2a	Moderately disturbed (stable to declining)	1,085.9	347.2	32.0
3	Modified (cultural)	1,297.5	146.3	11.3
4	Degraded	21,970.9	10,780.9	49.1
5	Highly degraded	22,694.4	4,814.1	21.2
Total		**47,205.0**	**16,097.0**	

[1] Total area of the condition category within the study area.

Of the 16,097 ha under MOUs, 2.2% is moderately disturbed (condition category 2a and 2b), 0.9% is modified (cultural) (condition category 3), 67.0% is degraded (condition category 4) and 30.0% is highly degraded (condition category 5). Therefore, the great majority of the residual impact of the Project (approximately 97% of the areas under MOUs) involves degraded or highly degraded vegetation communities.

IFC Habitat Types

The residual impact areas of the Project footprint on IFC habitat types are summarised and compared with the total area of the corresponding habitat type within the study area in Table 8.20.

Table 8.20 – Residual Impact Areas of the Project on IFC Habitat Types

Habitat Category	Total Area (ha)[1]	Area Under MOU (ha)	% Under MOU
Modified habitat	45,962.9	15,741.4	34.2
Natural habitat	1,242.1	355.6	28.6
Total	**47,205.0**	**16,097.0**	

[1] Total area of the habitat category within the study area.

The Project area contains 355.6 ha of natural habitat under the IFC habitat classification, comprising 347.2 ha of active river channels (VC12a) that will be protected by implementation of the riparian buffers and 8.4 ha of savannah (VC3a). In compliance with IFC Performance Standard 6, the Project will not significantly convert the savannah unless all of the following can be demonstrated:

- No other viable alternatives within the region exist for development of the Project on modified habitat.
- Consultation has established the views of stakeholders, including affected communities, with respect to the extent of conversion and degradation.

- Any conversion or degradation is mitigated according to the mitigation hierarchy designed to achieve no net loss of the natural habitats affected, for example through habitat restoration or implementation of biodiversity offsets.

FSC Forest Types

The residual impact areas of the Project footprint on FSC forest types are summarised and compared with the total area of the corresponding forest type within the study area in Table 8.21.

Table 8.21 – Residual Impact Areas of the Project on FSC Forest Types

Habitat Category	Total Area (ha) [1]	Area Under MOU (ha)	% Under MOU (ha)
Natural forest	116.0	0.0	0.0
Not classified under FSC	47,089.0	16,097.0	34.2
Total	**47,205.0**	**16,097.0**	

[1] Total area of the habitat category within the study area.

Compliance with Principle 6 of the FSC National Forest Management Standard for Papua New Guinea in both the current and revised draft versions requires that no areas of natural forest be converted to plantations or non-forest land use. The Project will have no impact on natural forest under the FSC forest classification, since all areas of natural forest within the study area occur outside the areas under MOUs.

Compliance with the revised draft version, which is not currently in force, also requires that wetlands, peatlands, savannahs or natural grasslands are not converted to plantations or any other land use except where:

- The conversion is producing clear, substantial, additional, secure, long-term conservation benefits in the management unit.
- The total area of plantation on sites converted is less than 5% of the total area of the management unit.

The implementation of buffers to wetlands will ensure no wetlands in the Project area will be converted to plantations or any other land use. No peatlands or natural grasslands were identified within the Project area (see discussion of 'natural grasslands' in Section 4.8). The 8.4 ha of natural savannah (VC3a) are addressed above. While conversion of this vegetation community would constitute less than 0.1% of the management unit, such a conversion is not expected to produce a conservation benefit.

Conservation Priority Flora and Fauna Species

Two conservation priority species are known to occur in the study area, both of which are plant species, namely *Intsia bijuga* (Kwila) and *Cycas schumanniana*. Kwila was not detected within the area under MOU, hence the Project will have no residual impact on this species. While all occurrences of habitat most suitable for *C. schumanniana* occur outside the area under MOU that will be potentially directly impacted by the Project, a single occurrence of the species was detected on the boundary of the area under MOU. At this location, the species occurs as a single, mature seed-producing plant, 1.5 m tall, surrounded by up to 20 immature plants over a radius of 10 to 20 m from the mature plant, growing in recently burnt grassland on an outwash plain (VC4c) that was variably degraded through invasion of woody weeds, mostly *Leucaena*.

Successful implementation of the recommended avoidance or mitigation measures (e.g., conservation buffer to avoid impacts or translocation to mitigate impacts) is likely to result in no net loss of individuals of the species due to the Project.

Significance of Residual Impacts

The significance of the residual impacts of the Project, assuming the successful implementation of recommended avoidance and mitigation measures, was assessed against the following terrestrial ecology beneficial values that are known to occur in the study area (and listed in order of relative importance or sensitivity):

- *Intsia bijuga* (Kwila, listed as vulnerable by the IUCN Red List) and its habitat.
- *Cycas schumanniana* (listed as near threatened by the IUCN Red List) and its habitat.
- Natural forest habitats, which are not considered threatened but support greater biodiversity and provide relatively more resources for potentially affected communities.
- Modified habitats, other natural habitats and general flora and fauna biodiversity, which are not considered threatened but provide some resources for potentially affected communities.

The terrestrial ecology beneficial values identified as being the most sensitive to Project activities within the study area are the plants *Cycas schumanniana* and Kwila, which have a **'high'** sensitivity. Due to the absence or restricted occurrence of these species in the Project area, where most of the habitat is degraded or highly degraded, and the management measures described above, the Project will have a '**negligible'** impact magnitude on these species. The significance of residual impacts is therefore also '**negligible'**.

The natural habitats in the study area are degraded and fragmented, and do not provide adequate habitat for conservation priority flora and fauna species, hence their sensitivity is ranked as **'moderate'**. Although local communities are reliant on natural forests for food and timber, this is not the primary or only provisioning or regulating ecosystem service available to these communities. No natural forest habitats occur within the areas under MOUs. The Project's impact magnitude will therefore be '**negligible**' and, hence, the impact significance with respect to this value will also be '**negligible**'.

The sensitivity of modified habitats, other natural habitats and general biodiversity in the Project area has been identified as being of **'low'**. The magnitude of impact on flora and fauna resulting from the conversion of these habitats to plantations will be '**moderate'** due to the already degraded condition of these habitats and the management measures described above, hence the significance of impact on this value is categorised as **'low'**.

8.2.3 Aquatic Ecosystems

The information presented in this section is based primarily on an investigation and report undertaken by Fathom Pacific and attached as Appendix 7.

8.2.3.1 Discipline-specific Approach

The impact assessment criteria described in Section 8.1.1 have been further defined for the assessment of impacts on aquatic ecosystems. In particular, the sensitivities and resilience of the aquatic habitat types in and near the Project area differ, and the impact assessment is therefore separately addressed:

- The Markham River.
- High energy, high sediment load streams, recognising that this includes some ephemeral reaches.
- Clearwater tributaries.

8.2.3.2 Potential Impacts

The potential impacts of the Project on aquatic organisms, processes and habitats, and aquatic ecosystem services are listed below. A number of these were screened out of the assessment process because they are of negligible scale or severity, and these are described in detail in Appendix 7. The remaining potential impacts are further addressed in the residual impacts section.

Project activities that could affect aquatic ecosystems include:

- Plantation site preparation, including vegetation clearing, earthworks and road construction activity.
- Plantation establishment and harvesting, with specific activities including ploughing, chemical use and planting.
- Power plant construction and operation.
- Nursery and ancillary infrastructure construction and operation.

Potential impacts associated with these activities include:

- Altered regimes of allochthonous[7] production supply to watercourses due to:
  - Vegetation clearing removing supply.
  - Plantation species with different leaf litter and woody debris regimes and altered foodweb breakdown, detrital properties and nutritional content.
- Reduced availability of in-stream root and woody debris habitat and canopy shading due to vegetation clearing removing supply.
- Altered environmental flows due to groundwater and surface water use by the plantations and power plant.
- Altered regulating capacity of clearwater tributary sources to buffer high-energy flows and sediment loads due to vegetation clearing.
- Changes in water quality due to:

[7] Organic material that is developed or derived outside a particular waterbody.

  - Altered nutrient regimes associated with fertiliser use.
  - Release of contaminants associated with herbicide treatments, wastewater or other discharges/spillages from infrastructure, machinery and materials/chemicals storages.
  - Increased sediment loads in runoff or other sources.
  - Fire and firefighting (e.g., reduced dissolved oxygen content, sediment releases from burnt areas, release of firefighting chemicals).
- Changes to stream banks including:
  - Damage and instability due to physical impacts to bank habitat from watercourse crossing construction or upgrade.
  - Ongoing stream bank erosion and sediment release from unstable banks and crossings.
- Barriers to upstream/downstream fish movements associated with channel scour or creation of barriers to movement.
- Cumulative impacts to:
  - Native fish populations by Project-derived impact to stressed populations of native species.
  - Fisheries productivity through impacts to aquatic species and habitats.

8.2.3.3 Avoidance and Management

Measures to minimise impacts to aquatic ecology from Project activities are described in the EMP (Appendix 9), the PNG Logging Code of Practice (PNGFA/DEC, 1996) and the National Forest Management Standards for Papua New Guinea (FSC, 2010). Key management measures that reflect these documents and good practice in terms of the current knowledge of the aquatic ecosystems of the Project area and experience from other projects are described below.

Riparian Buffer Zones

Buffer zones are a proven measure to mitigate impacts of vegetation clearing and altered land-use on aquatic systems. Intact riparian zones will:

- Maintain bank stability, thereby maintaining in-stream habitat integrity and limiting erosional sediment supply.
- Maintain stream canopy cover, thereby maintaining water temperature conditions for aquatic organisms.
- Maintain in-stream root and branch habitat and supply of woody debris to provide physical habitat.
- Maintain supply of terrestrial derived vegetative organic matter (e.g., leaves, terrestrial insects, woody debris) that is the main source of production in these aquatic foodwebs.

- Trap sediment-laden runoff from disturbed areas and prevent it from entering watercourses.
- Provide a spatial buffer between watercourses and contaminants that may be originate from operational areas, e.g., wind-blown herbicide sprays or spillages from chemical, fuel, oil storages and/or machinery.

The riparian buffer zones and activities that will be excluded within these zones are described elsewhere in this report, e.g., Section 8.2.2.3.

Fish Passage Through Watercourse Crossings

In addition to the optimisation of crossing location and bank stabilisation, the design and construction of crossings will adopt the principles of maintaining fish passage and will cater for the range of expected flows. This will include:

- Avoiding the creation of barriers to fish movement that can include hydraulic barriers (e.g., high flow velocity, reduced depth, steps between culvert and river bed) or physical barriers (e.g. trapping of sediment/logs).
- Considering the flow characteristics of the watercourse being traversed and the characteristics of the resident fauna.
- Constructing watercourse crossings during dry periods, with regular inspections and maintenance.

Sediment Delivery

Management measures to address erosion and sediment delivery to watercourses have been discussed previously, e.g., in relation to water and land discharges (Section 8.14) and hence are not repeated in this section.

Herbicides and Fertiliser Application

Riparian buffer zones will be the primary measure mitigating the potential impacts of herbicide on aquatic ecosystems. Related management measures include:

- Avoid spraying during high winds.
- Mix, store, secure and dispose glyphosate so that leaks and spillages are avoided.
- Limit spraying next to riparian buffers in drier months, where feasible.
- Limit harvesting to the drier months in areas next to riparian buffers, where feasible.
- Implement an adaptive management plan that seeks to maximise efficiencies between weed control and volume application of glyphosate.
- Monitor riparian buffer zones, particularly along the borders of plantations.

Chemicals and Materials Handling and Spillages

Applying the buffer zones referred to above, adhering to the PNG Logging Code of Practice (PNGFA/DEC, 1996), and implementing good practice management of chemicals, machinery and sediment according to the Project's standard operating procedures will be fundamental to minimising the impacts associated with the use, transport and storage of chemicals and other materials. Key measures will include:

- Designating chemicals, fuels and oils and machinery storage and washdown/maintenance areas that are protected from the elements as appropriate and consistent with good practice.
- Where such areas are exposed to rain, erosion, or runoff, protecting the area with hard-stand, bunds, drainage and diversion systems and sediment control devices such as silt socks or silt curtains as appropriate and consistent with good practice.
- Using leak-proof storage containers, with regular inspection.
- Regular maintenance of machinery and designated areas for storage and use of fuels, oils and lubricants.
- Developing a spills emergency response plan including appropriate spills containment and training that is consistent with good practice.
- Continually improving areas such as material handling training and waste management.

Unplanned Fire and Firefighting

The riparian buffer zones described above will be the key measures mitigating the risks associated with fires and firefighting. Additional key measures include:

- Construct access roads suitably to act as firebreaks.
- Train the workforce in fire safety.
- Manage undergrowth and other plantation regimes to reduce risk and severity of accidental fires.
- Control vegetation on roadside verges.
- Design plantation boundaries with respect to watercourses (and buffer zones) and existing roads that provide natural firebreaks.

Power Plant Water Abstraction

Water will be pumped at a rate of 156,000 litres per hour from groundwater bores to supply the power plant. By way of context, this volume represents approximately 0.001% of the surface water discharge of the Markham River mainstream recorded during a flood event at Markham Bridge. Management and mitigation measures are as described in Section 8.1.5.

Eucalyptus Plantations in the Lowland Flats/Receiving Areas

The spatio-temporal pattern of planting and harvesting is yet to be determined. However, all areas currently falling under the MOUs with landowners are options for plantation. Within the areas described as 'lowland flats/receiving areas' in this report, specific watercourse channels, and therefore riparian buffer zones, have not been delineated. Taking into account relevant hydrological and hydrogeological information (as described in Appendices 3 and 4), the results of the aquatic ecology survey, and the unknowns regarding hydrogeology of the flats/receiving areas and their role in sustaining associated ecosystems, the following measures will be implemented:

- Plantation development will be avoided on the flats/receiving areas until further information can be obtained concerning matters such as:
  - The possible dependence of aquatic ecosystems associated with Klin Wara and Maralumi River on groundwater.
  - The role of the flats/receiving areas in relation to groundwater and surface water regimes.
  - Inundation characteristics and ecological functioning of the flats/receiving areas during wet periods.
  - The classification of soils in the flats/receiving areas to ascertain if peatlands are present.
  - Surface water seepage characteristics of the flats/receiving areas that may provide guidance as to effective sub-area management.
- Plantation development will be avoided in the forest patch located in the headwaters of Klin Wara until further information can be obtained. This patch of forest has been assessed as degraded and dominated by exotic species (Appendix 6). However, the potential role of this vegetation in mediating groundwater or surface water flows and sediment delivery from foothill streams to Klin Wara requires further assessment if this area is to be considered for plantation development.

8.2.3.4 Residual Impacts

Existing Stressors

The Project is to be developed in a non-pristine area. As noted in Section 6.2.2.3, the most significant existing anthropogenic stressors on aquatic systems in the Project area are:

- Introduced exotic fish species.
- Riparian vegetation removal.
- Agricultural land use practices (current and historical).
- Aggregate extraction practices in river channels.

The non-anthropogenic stressors potentially limiting aquatic biodiversity and productivity in watercourses of the Project area can be broadly characterised by the following inter-related factors:

- Catchment-scale geomorphology and sediment transport processes.
- Watercourse energy regimes and their relationship with in-stream habitat diversity and stability.

- Watercourse or reach ephemerality.

De-coupling existing impacts from those potentially associated with the development of the Project will form part of the objectives of future monitoring. However, quantifying the severity of the existing and potentially increasing effects of introduced exotic species presents particular challenges due to the lack of temporal data and the large scale of the problem across northern Papua New Guinea. Therefore, while the maintenance of native fish populations, for example, is a desirable environmental performance objective for the Project, and while water quality criteria may be met to achieve this, the ongoing impacts of exotic fish species that are beyond the control of the Project are likely to threaten native populations.

Similarly, assessing existing water quality and potential chronic toxicological impacts associated with decades of agricultural practice (particularly glyphosate and its residues) in the area will be a challenge for future monitoring that will require selection of appropriate indicators.

Notwithstanding the above, the following impact assessment assumes successful implementation of the management and mitigation measures described above and their continued performance evaluation by routine monitoring. Since no differences between construction phase and operations phase impacts or among the plantation cycles are expected, and assessment reflects all Project phases.

Markham River

The Markham River aquatic biological habitats are characterised by low diversity in structural types, high levels of suspended sediment concentrations, bed sediment loads, high-energy flows and areas of disturbed riparian vegetation. Due to the conditions of these aquatic habitats, the Markham River's sensitivity is ranked as **'low'**. Bed sediments are subject to mobilisation and reworking, with benthic surfaces and occupying micro-habitats subject to smothering and scouring. Benthic macroinvertebrate communities of the Markham River are characterised by low diversity and a dominance of forms that are tolerant of high sediment conditions. Fish and prawn assemblages are dominated by migratory and exotic species that can tolerate the high sediment and high flow conditions. Detrital food webs based on terrestrial vegetation input are important to prawns and fishes but is likely to be limited in reaches with disturbed riparian habitats that are dominated by grasslands. Given the low diversity of benthic macroinvertebrates, fishes and prawns in the Markham River, the sensitivity is ranked as **'moderate'.**

The Markham River is used for subsistence fishing, recreation and canoe transport. Access to, and travel on, the river by local people will not be affected by the Project. Project development is not expected to significantly alter the lifestyle of local people at the scale of the Markham River catchment and within the context of surface watercourses. The provisioning and cultural services of the Markham River are ranked as being of **'moderate'** sensitivity. However, any incremental increases in Project-derived fugitive sediment reaching the Markham River will have no effect due to the current baseline conditions. There will be no additional disturbance to riparian vegetation and only a small volume of Project-related treated wastewater (from the power plant holding pond) entering the river. The Project is expected not to adversely affect flow conditions resulting from water abstraction and therefore there will be no subsequent impact to fish and prawn migration.

Given the above considerations, the Project's impact magnitude will be **'negligible'** with respect to biological communities and flows, and hence **'negligible'** with respect to provisioning services and cultural services. Therefore, the impact significance of the Project on the Markham River is expected to be **'negligible'**.

High Energy, High Sediment Load Streams

Aquatic habitats in these watercourses are generally low diversity, dominated by gravel habitats with disturbed riparian zones. Some areas are ephemeral and most appear to be exposed to high energy, high sediment-load flows. Bed habitats are therefore expected to be exposed to high sediment mobilisation, scouring and sedimentation. Given the disturbed baseline conditions, the sensitivity of these aquatic habitats is identified as **'low'**. Gravel extraction activity represents a significant existing impact to aquatic habitats in some watercourses of this type in the Project area. Benthic macroinvertebrate communities of these watercourses are characterised by the presence of taxa that are relatively tolerant of high sediment conditions. Terrestrial vegetation is expected to represent the main production source for macroinvertebrates and detrital processes are expected to be important in foodwebs.

Fish communities of these watercourses are characterised by lower diversity and biomass and are dominated by exotic fish species. High sediment loads, episodic high energy and ephemerality in some reaches, low habitat diversity and water quality, riparian impacts of settlements, roads and in-stream aggregate extraction works are factors limiting fish diversity and biomass in these streams. Prawn communities are similarly restricted. Fish and prawn species are expected to migrate between the Markham River and these watercourses and expand their range into upstream reaches. Maintenance of fish and movement is therefore considered important to the maintenance of ecological functioning and ecosystem services in these watercourses. As benthic macroinvertebrates of these streams are tolerant of high sediment and the fish communities are of low diversity, the sensitivities are identified as **'moderate'**.

No direct observations were made of fishing in this type of watercourse during Project surveys. However, it is expected that fishing does occur and that fishes, eels or prawns caught are eaten. Bathing, recreation and clothes washing were observed in these watercourses. The cultural and provisioning services are ranked as being of **'low'** sensitivity.

No Project-related impacts are expected in relation to flow, and incremental impacts to sediment loads, water quality related to herbicides and other chemicals, no wastewater releases and negligible impacts to aquatic biological resources. Therefore, the impact magnitude is **'negligible'** and the impact significance is expected to be **'negligible'** with regard to high energy, high sediment load streams.

Clearwater Tributaries

Perennial clearwater tributaries are geographically restricted in the Project area, and are represented by two streams: Klin Wara in the west and Maralumi River in the east. These streams have the highest diversity of aquatic habitats and are more stable and have less disturbed riparian zones than the high energy watercourses. Aquatic habitats in clearwater streams and related ecosystems are more sensitive to perturbations in flow sediment loads. The maintenance of environmental flows and connectivity between a complex of habitats is important to maintenance of ecological function. At their downstream extents, these tributaries are expected to represent important clearwater refugia for mobile species in the Markham River.

Clearwater tributaries recorded the highest diversity of benthic macroinvertebrates and included feeding guilds that were more adapted to low sediment conditions. Benthic microalgae and biofilms available to scraper-collector feeding types and fine suspended organic matter available to filter feeders are expected to be more important in these streams compared to the high energy, high sediment load watercourses.

Clearwater tributaries also recorded the highest diversity of fishes and prawns and relatively high biomass. Importantly, native fish species were recorded in these habitats that were not recorded elsewhere. Exotic fish species have become established in these streams. Clearwater conditions favour visual predators and reproductive styles that involve delicate egg/nest structures that are prone to suspended or bed load sediment damage. The highest biomass of prawns in sampling was recorded from Klin Wara.

Subsistence fishing, recreation, bathing and washing were observed in clearwater tributaries. The introduced golden mahseer and common carp, as well as native rainbowfishes, were among the most common species observed in local catches. All fishes and prawns that are caught in these streams are likely to be eaten. Anecdotal observations in the field suggest that these clearwater streams are particularly appreciated by local people for bathing, washing and recreation.

The aquatic habitats of clearwater tributaries and benthic macroinvertebrates, fish, provisioning and regulating services are identified as being of **'moderate'** sensitivity. This is due to the higher diversity of species found here in comparison with other sites in the Project area and the importance of clearwater tributaries to the local people. Cultural services are ranked as being of **'low'** sensitivity.

The magnitude of Project-related impacts is expected to be **'low'** for all values. This reflects the reflects the mitigation measures described above, particularly the avoidance of plantation development on the flats/receiving areas until further information can be obtained. The impact significance is therefore '**low**' with regard to clearwater tributaries.

8.3 Socio-economic Impacts

The guidelines on information required to support a permit application for a project that is classified as a Level 2B activity specify that assessment of socio-economic impacts that may result from the bio-physical and biological impacts of the activity is required (DEC, 2013). The context is that these are social effects that can be addressed by the environmental permitting process. Examples in the guidelines include degradation of air and water quality, increased noise levels, land contamination, loss of food resources and/or habitat loss.

Detailed assessments have been presented in other sections of this chapter in relation to the above but also including matters such as potential impacts on terrestrial and aquatic ecology, soils, surface hydrology and hydrogeology (see Sections 8.1 and 8.2). Ecosystem services have also been addressed, particularly in relation to provisioning services such as food from hunting, crop cultivation, fishing and foraging, as well as biomass fuel, animal products, natural medicines, building materials and water supply (see Section 8.4).

The residual impacts in relation to all of these matters (i.e., the impacts that are predicted to occur after the successful implementation of management and mitigation measures) are negligible, low or, at worst, moderate. No impacts have a significance rating of high or major. Socio-economic impacts associated with these environmental impacts are also predicted to be low.

In addition to these findings, the information presented in SIMP (2017) allows key points about other socio-economic impacts (both positive and negative) to be summarised.

Beneficial socio-economic impacts expected from the Project relate to:

- Increased income levels through Project employment.
- Distribution of plantation-land cropshare and annual land rentals.
- Opportunities for the establishment of local business enterprises to share in construction-related contracts and other small-scale business opportunities.
- Opportunities for additional income through intercropping.
- Improved road access and infrastructure.
- Increased education and training opportunities, including financial literacy.

For the people of the Project area, the majority of both negative and positive impacts will be derived from one key resource, land. Given the significance of this land to local communities, a number of potential impacts will require specific management focus. These include:

- Some loss of land that is currently used for subsistence (e.g., gardens, foraging and hunting, building materials and natural medicines) and/or cash income.
- Possible inequitable distribution of plantation-land cropshare and land rentals, and access to intercropping opportunities and benefits.
- Poorly established business entities managing the land leasing, which may lead to land conflict within clans and across generations.

With regard to health, there are existing concerns across the Wampar Local-level Government (LLG) area with respect to respiratory-related communicable diseases (e.g., tuberculosis), along with vector-related diseases (e.g., malaria) and STIs including HIV. Following Project implementation there is potential for increased transmission of these diseases and infections, as well as additional pressure on the local health care system due to higher numbers of people moving into the area and changes in environmental and social conditions. However, with low levels of Project-induced in-migration predicted and no construction camps proposed, impacts from the Project on these health concerns and services are substantially lowered.

Potential exposure to hazardous materials as a result of the Project is likely to be minimal. Impacts on access to safe drinking water and resulting water-related diseases are also expected to be low due to predicted low levels of Project-induced in-migration. While higher incomes from the Project may lead to poor food choices (impacting nutrition) and increased lifestyle-related diseases (e.g., cancer, diabetes, obesity), these are not predicted to be of major concern.

Road traffic is expected to increase only minimally as a result of the Project. The residual impacts of congestion to the Highlands Highway, Lae Port and Lae Nadzab Airport are expected to be low. Despite this, management of potential traffic-related accidents and injuries will be an ongoing focus of MBV.

There will be no impact from construction of the proposed power plant on any of the cultural heritage and archaeological sites identified during the surveys and database reviews. The implementation of management measures will reduce the residual impact on all identified sites and those that may be identified in the future.

All residual impacts relating to gender (e.g., inequitable share in income, loss of land use rights and important land resources, increased burdens on younger females) are predicted to be low, and the majority of those relating to human rights are also expected to be low or non-existent. The two exceptions to this concern potential increases in both gender-based violence and family and sexual violence as a result of socio-cultural changes such as Project-related incomes, and arguments over land and the division of labour. In addition, a limited ability for women and other socially vulnerable groups to express opinions and/or obtain information is predicted (but with some uncertainty as to its likelihood). While women may speak in public meetings, they are likely to be excluded from important discussions relating to compensation, payments, employment and business funding opportunities. There may also be a lack of recognition among, and management of disadvantages by, government personnel.

The negative residual impacts in relation to these matters are predicted to be generally low or minimal. The Project will also bring positive socio-economic impacts in the form of income, infrastructure and education/training.

8.4 Ecosystem Services

This section is based on information contained in the various appendices to this report and SIMP (2017) (and the references cited therein), as well as the discussion in the preceding sections of this chapter.

Section 6.4.2 summarises the main ecosystem services in the Project area, where the focus is on provisioning services such as food from hunting, crop cultivation, fishing and foraging, as well as biomass fuel, animal products, natural medicines, building materials and water supply. However, regulating and cultural services are also of importance, particularly in relation to matters such as surface water and groundwater quality, sites of significance, and traditional practices.

Impact assessment has involved evaluation of the importance or value of the service to beneficiaries in conjunction with the replaceability or resilience of that service, where the latter ranges from high (i.e., many spatial alternatives exist) through to low (i.e., few or no spatial alternatives exist). Within this context, services such as crops/garden cultivation are regarded as being essential to local communities but have moderate replaceability, and hence are of critical value, while biomass fuel (wood) is equally essential but has high replaceability and hence is of high (rather than critical) value. Both of these can therefore be considered to be priority services that require further assessment. Other services are of lesser value (but have still been considered where appropriate), although a number have also been 'screened out' given that initial scoping found them unlikely to be affected.

Project-related direct 'drivers of change' in relation to ecosystem services are primarily:

- Changes in land use due to Project construction and operation.
- Land disturbance resulting in habitat loss and reduced access to animal, plant and other resources for beneficiaries.

The impact on ecosystem services has been determined by assessing the magnitude of the change and the sensitivity of the beneficiaries, i.e., the impact significance method described in Section 8.1.1.2. Management and mitigation measures are as described in preceding sections and the EMP (Appendix 9), and are too numerous to repeat in this section. However, it is worth noting that key measures include:

- Developing a land use policy and program that defines maximum land areas and land types that can be leased as a ratio of total land holdings of each leaseholder.
- Establishing a resettlement implementation team (RIT) that will undertake leaseholder-acreage and usage assessments to minimise land shortages.
- Providing information to Project personnel and stakeholders that are involved in plantations about ‘land types’ that can and cannot be used.
- Ensuring that there is adequate, alternative garden land available to landowners who forgo existing or potential garden/commercial-crop land for plantations.

Assuming the successful implementation of these and other relevant management and mitigation measures, the residual impact is predicted to be '**low**' across Type I ecosystem services (i.e., ecosystem services over which MVB has direct management control or significant influence, and where impacts on such services may adversely affect communities).

In relation to Type II ecosystem services (i.e., ecosystem services over which MVB has direct management control or significant influence, and where the Project itself directly depends on such services for its operations), measures will be implemented by the Project to avoid placing additional pressure on subsistence resources in the area. The Project's reliance on the availability of land for plantations (and the associated supply of biomass for the power plant), as well as water, will also ensure that these resources are appropriately managed.

8.5 Cumulative Impact Assessment

8.5.1 Introduction

The need to assess cumulative impacts is not explicit in either the *Environment Act 2000* or the operational procedure under which this document has been prepared. However, good practice requires consideration of cumulative impacts, where these can be defined as follows (IFC, 2013):

> Cumulative impacts are those that result from the successive, incremental, and/or combined effects of an action, project, or activity when added to other existing, planned, and/or reasonably anticipated future ones.

Furthermore, IFC (2013) considers that:

A cumulative impact assessment includes two components:

- The anticipated future condition, which is the total effect of the other existing, and predictable future developments and external natural environmental and social drivers, and
- The contribution of the development under evaluation to the cumulative impacts.

This definition of cumulative impacts therefore considers the additive impact of (1) the Project and (2) activities by other parties. Taking account of existing or other projects and developments planned for the foreseeable future is intended to overcome the deficiencies associated with the limited scope of an individual project-based environmental assessment. Current and known planned projects and developments in the local area and/or the surrounding region include:

- Expansion of existing palm oil industries in the Markham Valley.
- Expansion of existing agricultural activities in the Markham Valley.
- Other forestry operations (e.g., those of PNG Forest Products) in the Bulolo area.
- Continuation/expansion of the Hidden Valley Mine (located in the upper Watut River catchment).
- Continuation/expansion of Edie Creek Mine (located in the upper Watut River catchment).
- Development of the Wafi-Golpu Project (located in the lower Watut River catchment).
- Expansion of the Port of Lae facilities.
- General growth in the city of Lae, including the new Angau Memorial Hospital.

The current impacts of other projects and development are, by necessity and as they relate to the Project, reflected in the current existing environment characterisation that is presented in Chapter 6 of this report. Cumulative impacts of this Project and existing projects and developments (as they are at the time of writing and with specific reference to the Project) have been included where relevant in the assessment presented in other sections of Chapter 8. Cumulative impacts in terms of anticipated changes to existing projects and developments, and anticipated future projects, are discussed in this section. This assessment considers the outcomes presented in earlier sections of Chapter 8.

8.5.2 Biophysical and Biological

From a biophysical and biological perspective, the Project is expected to have relatively localised (and generally low) impacts concerning matters such as air quality, noise, land contamination, soil, water quality, hydrology, hydrogeology and aquatic ecology. The Project's contribution to cumulative impacts in the region will therefore similarly be low (or negligible).

Terrestrial ecology requires additional consideration due to the Project footprint being up to 16,000 ha of plantation plus other areas for the power plant and Project infrastructure. Referring to the developments listed above, a number of these (e.g., expansion of the port facilities, and the new Angau Memorial Hospital) will be located in highly disturbed areas in the city of Lae and have therefore been assessed as having negligible cumulative impacts on terrestrial ecology receptors, while others have little relevance to the Project's lowland setting (e.g., Hidden Valley Mine, Edie

Creek Mine). The expanding palm oil industry and other agricultural initiatives in the Markham Valley may have similar potential impacts to the Project since they are likely to be undertaken in similar habitats. However, their residual impacts may be greater if mitigation and management measures are not investigated and implemented as part of a formal environmental assessment. Parts of the Wafi-Golpu Project are expected to be undertaken in intact lowland rainforest, and can be expected to have greater impacts on terrestrial biodiversity than the Project. It can therefore be expected that, as with the other biophysical and biological matters, the Project's contribution to cumulative terrestrial ecology impacts in the region will be low (or negligible).

8.5.3 Socio-economic

Cumulative impacts from a socio-economic perspective are possibly more challenging in that a number of matters are best addressed (and managed) by the various levels of government rather than Project proponents. Nevertheless, it is possible to consider areas most likely to be of concern, which include:

- Loss of land and/or access to land, due to new or expanded large-scale oil palm or agricultural developments, which leads to impacts on subsistence agriculture, income and economic displacement (even if voluntary in nature).
- Higher levels of dispute over land, and related cropshare and land rentals, especially when non-Wampar are involved.
- Increased pressure on land and natural resources, education and training facilities, and health services due to in-migration.
- Increased risk of transmission of respiratory-related communicable diseases and STIs/HIV due to in-migration.
- Increased risk of traffic-related accidents on the Highlands Highway due to higher levels of vehicular movements.
- Increased household incomes from additional or expanded employment and business opportunities, as well as potential cropshare and land rentals.
- Reduced nutrition as a result of higher incomes being spent on market goods and related poor food choices.
- Decreased access to water (through decreased quality and/or quantity) due to in-migration and use in future project/development operations, leading to increased health issues.

In particular, the local socio-economic context of the area is likely to be subjected to considerable change should the Wafi-Golpu Project be developed by Wafi-Golpu Joint Venture (WGJV). That project is located approximately 65 km southwest of Lae, in the lower Watut River catchment south of the PNG Biomass Markham Valley Project area, and has an estimated capital cost to build Stage 1 of US$2.3 billion (MMJV, 2017a). Available information indicates that landowners and other host communities in the Wafi-Golpu Project impact area will be prioritised with respect to potential business development and employment opportunities, while WGJV also expects the project to make a substantial positive economic contribution to the country at both a national and provincial level (MMJV, 2017b). A Special Mining Lease (SML) application was registered with the Mineral Resources Authority in August 2016 and an environmental impact statement (EIS) is currently being prepared. Additional information about cumulative impacts in the broader area is likely to be available once that EIS is released.

8.6 Major Hazards and Emergency Response

8.6.1 Introduction

Accidental and natural events that could potentially lead to environmentally hazardous discharges due to factors such as a loss of containment are fundamentally different from the normal operational wastewater discharges, air emissions and similar that will be associated with the Project. The probability of accidental events is low, given that the design operating and control measures adopted by MVB will have the specific aim of their prevention. Similarly, natural occurrences of sufficient magnitude to cause significant damage have a low probability of occurrence. Nevertheless, events of this nature that lead to spills, fires, explosions and/or hazardous emissions can occur, with potential consequences including:

- Serious injury or loss of life, both to Project personnel and to others who may be involved in the event.
- Serious environmental harm, e.g., contamination of surface water and/or groundwater, loss of terrestrial and/or aquatic biota.
- Degraded amenity.
- Loss of, or damage to, resources used by local communities (and other ecosystem services).
- Asset loss or damage, and/or reputational damage.
- Psychological and financial stress on the dependants of workers or others killed or seriously injured.
- Psychological and financial stress for workers and their dependants should the Project close.

These unplanned (but possible) events require preventative action and, should they actually occur, reactive responses. In such cases, the resources of MVB will be mobilised in accordance with predetermined emergency plans to respond to the event.

The following sections, which are based on a hazard identification (HAZID) workshop that examined a range of hazards within the context of Project design, construction and operation, provide an initial assessment of specific events and their associated safeguards and control procedures. The workshop adopted the approach whereby:

- Project activities were reviewed within the context of hazard categories such as natural and environmental hazards or man-made hazards.
- Potential specific (and credible) hazards and their effects (consequences) were identified, e.g., heavy rainfall could lead to flooding.

- Control measures, recommendations and responsibilities for the various actions were identified.

Papua New Guinea legislation does not contain any specific requirement for environmental hazard identification or risk assessment for a project of this nature. However, Section 7(1) of the *Environment Act 2000* imposes a general environmental duty on persons not to carry out an activity that causes or is likely to cause an environmental harm unless that person takes all reasonable and practicable measures to prevent or minimise that harm.

Markham Valley Biomass has adopted both the requirements of Section 7(1) of the Environment Act and risk management principles when considering major hazards associated with accidental and natural events. These risk management principles are described in:

- AS/NZS ISO 31000:2009 Risk management – principles and guidelines (Standards Australia, 2009).
- SA/SNZ HB 436:2013 Risk management guidelines companion to AS/NZS 31000:2009 (Standards Australia, 2013).
- HB 203:2012 Managing environmental-related risk (Standards Australia, 2012).

General safeguards that will be adopted include induction training and periodic refresher training for all employees on all aspects of safety, including site-specific rules and emergency situations.

The emergency response procedure will be regularly reviewed and updated as required, as additional information becomes available during Project development.

8.6.2 Major Hazards and Their Avoidance and Management

8.6.2.1 Seismic Risk and Landslides

As discussed in Chapter 6, Papua New Guinea is prone to seismic disturbance. Shallow (0 to 40 km depth) earthquakes of magnitude up to 7.0 Mw[8] have been recorded around the Project area associated with the subducted Woodlark Plate slab, with by far the majority being to the north of the power plant site and north of the Ramu-Markham fault zone (see Figure 6.4). Seismic events can cause (Fugro, 2016):

- Surface rupture, which is the displacement of the ground surface along a fault plane that extends deep within the earth. This rupture typically occurs along pre-existing faults and is generally confined to within a narrow zone several to tens of meters wide.
- Landslides, which are triggered by the strain that is induced in soil and rock by the ground-shaking vibrations.
- Liquefaction, which is the phenomenon whereby unconsolidated (loose) soils under saturated conditions are drastically reduced in strength and stiffness during an earthquake, with subsequent damage to buildings and other infrastructure. Lateral spreading on gently sloping

[8] Moment magnitude.

ground is generally the most pervasive and damaging type of liquefaction-related ground failure, and involves lateral extension and fracturing of intact surficial material caused by liquefaction of a subjacent layer. Lateral spreads develop on gentle slopes, typically towards a free face (e.g., stream banks, canals, and arroyos/wadis), and may produce horizontal displacements of as much as several meters.

During non-earthquake (static) conditions, slope failures occur most frequently during the rainy season when high groundwater conditions persist. Landslides occur most frequently during or following large storms and in years with significant rainfall.

Analysis of the area's geology, geomorphology, slope and depositional features, in conjunction with seismic source characterisation, analysis of earthquake recurrence and activity parameters, and a probabilistic seismic hazard analysis, lead to the following conclusions in relation to the area between the Erap and Rumu rivers (which includes the power plant site):

- The potential for surface fault rupture is low.
- The risk of potential landslides is low.
- The potential for liquefaction, resulting from a large magnitude earthquake, is high.

The greatest potential environmental implications following a major seismic event or landslide would arise from either the rupture of pipelines, failure of containers/equipment, and/or failure of water storages. Safeguards against these types of failures include bunding, monitoring of pipeline flow and development of contingency plans to handle spills or leakages (as discussed below).

Given the above conclusions, detailed design will incorporate the findings of further geotechnical site investigations that will be used to determine liquefaction factors of safety and induced settlements, foundation and ground improvement recommendations.

8.6.2.2 Flooding

Flooding may occur during extreme rainfall events or, for sites close to rivers and streams, high flow events, with consequent adverse impacts including water inundation of facilities and infrastructure, access restrictions, environmental impacts, and erosion/scour.

Analysis of the area's geomorphology and hydrology leads to the conclusion that, in relation to the power plant site, flooding as a result of a large rain or storm event remains possible.

Given this finding, detailed design will incorporate measures such as raising the level of the plant, adequate sizing of ponds, and re-directing surface drainage around the plant site.

8.6.2.3 Hydrocarbon or Chemical Leakage or Spillage

Use of hydrocarbons (e.g., diesel fuel) and chemicals (e.g., herbicides) at the power plant site and in the plantations is described in Chapter 7. Spillage of hydrocarbons and chemicals, either from routine usage or accidental spillage or leakage from storage vessels, will have the potential to cause environmental damage.

Proper design, quality control and operating procedures will minimise the risk associated with spills or leaks. Additional management measures have been incorporated into the relevant procedures in the EMP (Appendix 9). These address all fuels and chemicals, and include measures such as:

- Appropriate bunding and secondary containment measures around hazardous material storage tanks and containers in accordance with PNG and Australian standards.
- Appropriate bulk storage vessel, pipework and equipment design in accordance with PNG and Australian standards.
- Ensuring that spills are contained within hazardous materials areas.
- Regular integrity testing and maintenance of hazardous materials transfer hosing and couplings.
- Emergency shutdown systems.

Operators will be trained to cope in an emergency and other parties (e.g., local villagers, authorities) affected will be informed as required. Contractors working for MVB will be contractually required to have measures in place that comply with MVB's operating standards and that are consistent with the EMP.

Minor spillage of fuel and lubricant, such as during vehicle maintenance and refuelling, will be safeguarded against through bunding, drains and a high level of operator training and diligence.

Any fuel or chemical spills will be reported through the incident reporting management system.

8.6.2.4 Fire and Explosion

Plantation development and biomass power plant operations, including the storage and handling of flammable substances (e.g., timber and hydrocarbons) and the occurrence of multiple sources of ignition (e.g., sparks in the wood chipper and spontaneous combustion in the chipped wood fuel pile) can lead to fire and explosion hazards. Bushfire within the plantations is also a hazard that requires consideration.

Potential environmental impacts include breakout of fire (from the power plant) into surrounding vegetation, power plant damage (from a plantation fire), release of significant quantities of fire-related air emissions, and contaminated runoff (e.g., from firewater).

Management measures include both passive fire systems (which minimise ignition or spread of fire in the event of an incident) and active fire systems (which focus on extinguishing the fire):

- Specific plant and facility design criteria for fire prevention, detection, control and personnel safety requirements, and clarification of hazardous areas and associated requirements.
- Appropriate handling and storage of flammables (e.g., bunding, separation distances between potential ignition sources and flammable materials).
- Proper maintenance of bearings (lubrication).
- Proper housekeeping to ensure that the power plant is clean.

- Installation of temperature sensors in fuel metering bin to indicate back flow into the fuel bunkers.
- Frequent turn over of chipped wood fuel piles.
- Plant fire protection system, fire water volumes and fire equipment commensurate with the level of risk identified for the Project and regularly maintained and tested to ensure good working order.
- Implementation of an Emergency Response Plan (see EMP, Procedure 11).

8.6.2.5 Vehicle Accident

Road transport of personnel, equipment and materials gives rise to the potential for collisions or crashes to occur due to factors such as driver error, equipment malfunction or extreme weather. Management measures to address such events include:

- Regular servicing and inspection of vehicles to ensure that they remain in good working order.
- Ensuring that only appropriately licensed personnel operate light or heavy vehicles.
- Installing speed limits and signage to advise road users of safe operating speeds and conditions.
- Developing a traffic management plan in accordance with appropriate authorities that will include:
  - Providing measures such as escort vehicles and appropriate signage for heavy haulage of construction equipment and pre-fabricated components to the power plant site.
  - Constructing temporary diversion roads for local traffic (if required).
  - Deploying graders to maintain the condition of the unsealed roads that may be affected by the movement of construction and mining equipment.
  - Restricting access to local, Project-specific roads.
  - Informing road users of changed road conditions prior to and during construction and, in particular, prior to material changes on the Highlands Highway.

Contractors will be required to comply with MVB's procedures and the relevant codes and standards for transport, storage and handling of hazardous materials (including emergency response). Similarly, contractors will be required to adhere to local road rules.

Fuel trucks will carry equipment necessary to respond to an accident that may result in a spill. Incident notification procedures will be implemented should a spill occur during transport. Should fuel or hazardous materials come into contact with surface drainage, water quality will be monitored to ensure that the area is appropriately remediated, if necessary.

8.6.2.6 Disease Outbreaks

Outbreaks or significantly increased incidences of diseases, including communicable diseases such as HIV/AIDS and vector-born diseases such as malaria, can be associated with development of this type of project. Contributing factors include in-migration, poor hygiene practices and interaction of the Project workforce with the local communities. Management measures include:

- Pre-employment and ongoing regular medicals for workers.
- Developing and implementing a workplace program that focuses on identification and management of communicable diseases.
- Developing and implementing a health and hygiene education program for the Project workforce and local communities.
- Ensuring that appropriate facilities are available during Project construction and operation, including effective sewage treatment and the clean drinking and washing water sources.

8.6.2.7 Civil Unrest

Although not an accidental or natural event, civil unrest needs to be considered within the context of unplanned events that could result in significant adverse impacts, particularly from a social perspective. Such unrest could relate to the Project due to factors such as perceived unequal distribution of Project-associated incomes or disputes between MVB and local landowners, or it could be due to events occurring elsewhere in the province or country, with the Project providing a focus for agitators. Other factors could include changes in social structure or gender issues which may or may not be Project-related. Although a number of these causal factors are beyond MVB's control, management measures that will be implemented include:

- Developing a Project security plan, which includes human rights training for security personnel.
- Ensuring that the Project's grievance mechanism is fully implemented and is effective at appropriately addressing complaints.
- Engaging with local communities and fully consulting with them about Project developments.
- Maximising local employment and business development opportunities.

The Project will also draw on the Project team's experience gained in the area since 2010 and the establishment of successful relationships with local communities.

8.6.3 Emergency Response

Emergency response procedures to address the scenarios described above, as well as other emergency scenarios that may affect the Project, are addressed in Chapter 9 and described in more detail in the EMP (Appendix 9). Such procedures are therefore not further discussed in this section.

9. Environmental Management, Monitoring and Reporting (Including Waste Management)

This section should include commitment by applicant to incorporate waste minimisation measures into the design and operation of the activity.

Information provided in this section should include the following –

- *details of the Waste Management and Minimisation Strategy developed for the proposal (e.g. wastewater reuse and recycling, etc.).*

(Excerpt from 'Information Requirements for Permit Applications and Registration of Intention to Carry Out Preparatory Work', DEC Operational Procedure, Schedule 3, General Guidelines on the Additional Information Required to Support a Permit Application for a Level 2B Activity)

9.1 Introduction

This chapter outlines the environmental management, monitoring and reporting framework for the Project, with additional detail and specific procedures being provided in the EMP (Appendix 9). The EMP describes the requirements for the Project (with a focus on construction) and will both provide a basis for contractors' EMPs and serve as a framework for future management plans.

The specific objectives of the EMP are to describe:

- The general approach that MVB will adopt with regards to environmental management, such as the environmental aspects of the Project's integrated management system (IMS), organisational structure and responsibilities, and checking and corrective actions.
- How the Project's environmental impacts will be managed and mitigated, based on the 'in principle' assessment described in this EA report.
- Commitments made by the Project for reference in future internal and external audits.
- An environmental monitoring and reporting program that addresses the need to:
  - Undertake routine operational monitoring to ensure compliance with environment permit conditions.
  - Validate impact predictions described in this EA report.
  - Identify unforeseen effects and determine the need for additional management, mitigation or remedial measures.

9.2 Organisation Structure and Responsibilities

Markham Valley Biomass has overall responsibility for the environmental and social performance associated with Project development. The company's Stakeholder Engagement Manager (SEM) will be responsible for ensuring that activities associated with the Project are undertaken in full compliance with statutory requirements and are consistent with relevant corporate policies. The SEM will ensure that the Project's environment permit conditions are accessible to senior management and other personnel on request at all times. All personnel will be responsible for ensuring that their work complies with these conditions.

All Project employees and contractors will be required to ensure that they comply with the requirements of the EMP and related documents, as well as all applicable legislation and statutory obligations. Specific responsibilities and accountabilities for the environmental performance management of the Project will be assigned to the relevant personnel and contractors, and documented in the EMP. Individual responsibilities and accountability will be defined through position descriptions and conditions of contracts of employment. Environmental and social responsibilities will also be written into service agreements for contractors, with major contractors being contractually obligated to prepare an EMP for the work areas and activities for which they are responsible. These plans will be reviewed and approved by MVB prior to commencement of on site works.

9.3 Management System

9.3.1 Environmental Management System

Markham Valley Biomass is developing a corporate IMS for the Project that is consistent with the principles of relevant international standards such as ISO 9000 (quality and loss control), ISO 14000 (environment) and OHSAS 18000 (occupational health and safety), and will incorporate all aspects of MVB's documentation including policies, planning procedures and management prescriptions. The environmental aspects will be consistent with ISO 14001:2015, as reflected in the Australian and New Zealand equivalent, i.e., AS/NZS ISO 14001:2016. The management system is being developed in a staged manner that is commensurate with Project activities.

AS/NZS ISO 14001:2016 specifies that an environmental management system (EMS) should consist of the following, which are tailored specifically to the activities of the business: leadership, planning, support and operation, performance evaluation, and improvement.

These elements as they relate to the Project are described in the EMP.

9.3.2 Environmental Management Plan

Preparation and implementation of an EMP is a key component of an EMS framework. The Project's EMP will address the management, monitoring and reporting requirements for the Project, taking into account the commitments made in this EA report, the environment permit conditions (when they become available), design refinements as Project development progresses, and changes in regulatory requirements (should they occur).

The EMP (Appendix 9) consists of the following sections:

- Introduction.
- Project description.
- Legislative, policy and guidelines.

- Environment and social setting.
- Environmental management framework.
- Issue-specific management procedures that address a range of matters including (but not limited to):
  - Cultural heritage and archaeology.
  - Vegetation clearing, earthworks, topsoil management and rehabilitation.
  - General waste management.
  - Hydrocarbons, chemical and hazardous waste management.
  - Noise management.
  - Air emissions and air quality management.
  - Invasive alien species management.
  - Water management.
  - Watercourse crossing management.
  - Environmental incident and non-compliance reporting.
  - Emergency response plans and drills.
  - Environmental auditing.
- Stakeholder engagement.
- References.

As well as the EMP, MVB will submit a Forest Management Plan (FMP) for the plantation operations to the Papua New Guinea Forest Authority (PNGFA), for their approval. This plan will be consistent with the requirements of the FSC standards for Papua New Guinea and will address a range of matters, from description of the markets for forest products and compliance requirements through to plantation design and areas to be planted, species and genetics, plantation and stand management regimes, planned harvesting and other forestry operations methods. It will be, in effect, a five-year tactical forestry plan. Implementation of the FMP will be supported by a Project-specific Forest Management Information System (FMIS; GIS-linked software) that will facilitate collation and management of information and allow planning regarding plantation operations.

9.3.3 Waste Management and Minimisation

Markham Valley Biomass will comply with applicable PNG legislative requirements related to waste management. In the absence of such requirements or relevant national policies or guidelines, appropriate industry practices will be adopted.

The Project's waste management approach is to use accredited and experienced local waste management contractors and facilities to the maximum extent possible. Markham Valley Biomass will implement a recycling and waste minimisation program that reflects standard waste minimisation principles as follows (see Section 8.1.6.3):

- Minimise waste through efficient use of resources.
- Maximise reuse and recycling opportunities.
- Segregate waste at the source.
- Ensure handling, storage and disposal practices meet statutory (environment permit) requirements.
- Facilitate disposal in a responsible manner, including minimising volumes disposed to landfill.
- Appropriately treat wastes where required.
- Continually improve in areas such as material handling and waste management training.

Markham Valley Biomass will ensure a high level of staff, employee and contractor awareness of these principles.

A key component that is addressed within the EMP is waste management and minimisation, with specific measures that address waste management being contained within various of the management procedures listed above.

9.3.4 Social Management Plans

The Project will also develop a number of social management plans during the FEED and detailed design phases. These will be aimed at maximising benefits to stakeholders and minimising adverse impacts, and will address a range of matters including Project-induced in-migration and a resettlement policy framework/communal resource plan.

9.3.5 Monitoring

Each management procedure within the EMP contains relevant monitoring requirements, which will be used to determine the effectiveness of mitigation measures, confirm impact predictions and demonstrate compliance with environment permit conditions. In addition to implementing these requirements, the Project will implement a monitoring program to assess compliance with the EMP, as detailed in the environmental auditing procedure. Ad hoc audits will also be undertaken as required, e.g., following events such as an environmental incident, a major storm, an environment-related community complaint, or the occurrence of Project-related impacts on sites that are environmentally or culturally sensitive.

9.3.6 Records and Reporting

9.3.6.1 Routine Reporting

The outcomes of the auditing and monitoring programs will be routinely recorded and reported to MVB senior management and appropriate corrective action will be undertaken as required, based on compliance and performance against monitoring criteria. Reporting of auditing and monitoring results to regulatory authorities will be undertaken in accordance with regulatory requirements. Results will also be provided to other stakeholders on a regular basis, where applicable.

9.3.6.2 Incidents

Environmental incidents (including near-misses and potential hazards) that occur as a result of an emergency, accident or equipment malfunction will be reported using an environmental incident report form. Incidents that cause or threaten material harm to the environment will be reported to the relevant regulatory authority as specified by statutory regulations. Environmental incidents include, but are not limited to, the following:

- Unauthorised vegetation clearing.
- Hydrocarbon or chemical spills.
- Unauthorised discharges to groundwater or surface water.
- Inappropriate waste disposal.
- Disturbance of sites of archaeological or cultural heritage significance.
- Breach of legal environmental requirements.

Incidents will be registered as detailed above and investigated, and a report prepared which will describe the corrective and management methods used to address the incidents. Management procedures will be reviewed and revised as necessary as part of the incident investigation process. Incident and non-compliance reporting is detailed in a specific EMP procedure.

9.3.7 Management Review

Management reviews will be undertaken to ensure that management systems remain suitable, adequate and effective, and that they are appropriately communicated to all relevant parties. In particular, the reviews will focus on ensuring that all aspects of the management systems remain relevant to the specific task being undertaken on site and the associated environmental and social risks. Procedures that are found to be deficient will be revised and updated as required, and the need for additional management measures will be determined as part of the management reviews.

10. Confidential Information

Details of classified information relating to a manufacturing or industrial process or trade secret used in carrying on or operating any particular undertaking or equipment or information of a business or financial nature in relation to the proposed activity should be clearly defined. This information would be classified as “confidential information” and excluded from the document before it is made available for public review. *(Excerpt from ‘Information Requirements for Permit Applications and Registration of Intention to Carry Out Preparatory Work’, DEC Operational Procedure, Schedule 3, General Guidelines on the Additional Information Required to Support a Permit Application for a Level 2B Activity)*

This document contains no confidential information.

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12. Glossary

12.1 Symbols, Acronyms and Abbreviations

The following acronyms and abbreviations are defined in the context of their use in this report.

/	per
%	percentage
°C	degree/s Celsius
<	less than
>	greater than
$m	million dollars
a.m.	ante meridiem, meaning between midnight and noon
A&R	afforestation and reforestation
AADT	annual average daily traffic
AC	advisory circular
ADR	alternative dispute resolution
AEL	Aligned Energy Limited
Ag	silver
AGO	Australian Greenhouse Office
AHD	Australian Height Datum
Al	aluminium
Aligned	Aligned Energy Ltd and/or Aligned Energy (PNG) Limited
AMPA	aminomethylphosphonic acid
ANZ	Australia and New Zealand Banking Group

ANZECC	Australian and New Zealand Environment and Conservation Council
ARI	average recurrence interval
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
As	arsenic
AS	Australian Standard
asl	above sea level
ASS	acid sulfate soils
ASX	Australian Securities Exchange
AWQGTVs	Australian Water Quality Guideline Trigger Values
B	boron
Ba	barium
bbl	standard barrel containing 42 gallons of crude oil or equivalent
BDMt	bone dry metric tonne/s
BDMt/yr	bone dry metric tonnes per year
BDt	bone dry tonne/s
BEF	biomass expansion factor
BTEXN	benzene/toluene/ethylbenzene/xylenes/naphthalene
Ca	calcium
CA	community affairs
CASA	Civil Aviation Safety Authority
CCDA	Climate Change and Development Authority
Cd	cadmium
CEMS	continuous emission monitoring system

CEPA	Conservation and Environment Protection Authority (PNG)
CFC	chlorofluorocarbon
CFP	chance finds protocol
CH_4	methane
CHMP	cultural heritage management plan
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
Cl	chlorine
CLO	community liaison officer
cm	centimetre
CO	carbon monoxide
CO_2	carbon dioxide
CO_2-e	carbon dioxide equivalent
CO_3	carbon trioxide
Cr	chromium
Cu	copper
dB	decibel; used to express sound intensity
dB(A)	decibel/s, A-weighted; measure of the relative loudness of sounds in air as perceived by humans
DBH	diameter at breast height; in terms of tree measurement
DCS	distributed control system
DEC	Department of Environment and Conservation (now CEPA) (PNG)
DNPM	Department of National Planning and Monitoring (PNG)
DO	dissolved oxygen

DSCR	debt service coverage ratio
EA	environmental assessment
EC	electrical conductivity
ECI	early contractor involvement
EDG	emergency diesel generator
EFIC	Export and Finance Insurance Corporation, the Australian export credit agency
EHS	environmental, health and safety
EIA	environmental impact assessment
EIR	environmental inception report
EIS	environmental impact statement
EMP	environmental management plan
EOI	expression of interest
EP	environment permit
EPC	engineering, procurement and construction
EPCM	engineering, procurement and construction management
ESIA	environmental and social impact assessment
ESMP	environmental and social management plan
ESP	electrostatic precipitator
ESPS	environmental and social performance standards
FAO	Food and Agriculture Organization of the United Nations
FCA	Forest Clearing Authority
Fe	iron
FEED	front-end engineering and design

FID	final investment decision (or financial close)
FIDIC	International Federation of Consulting Engineers
FIM	Forest Inventory Mapping System
FMP	forest management plan
FOB	free on board
FPIC	free, prior and informed consent
FRI	Forest Research Institute
FSC	Forest Stewardship Council
FSV	family and sexual violence
g	gram
g/L	grams per litre
GBV	gender-based violence
Gg	gigagram (1,000 tonnes)
GHG	greenhouse gas
GIFT	genetically improved farmed Tilapia
GII	Gender Inequality Index
GIS	geographic information system
GJ	gigajoule/s
GW	gigawatt/s
GWh	gigawatt hour/s
ha	hectare/s
HAZID	hazard identification
HCO_3	bicarbonate

HDPE	high density polyethylene
HFC	hydrofluorocarbon
HFO	heavy fuel oil
Hg	mercury
HIA	health impact assessment
HIV	human immunodeficiency virus
HSFO	high sulfur fuel oil
IAQM	Institute of Air Quality Management
ICCC	Independent Consumer and Competition Commission (PNG)
ICP	informed consultation and participation
ID	induced draft
IFC	International Finance Corporation
ILG	Incorporated Land Group
IPBC	Independent Public Business Corporation
IPIECA	International Petroleum Industry Environmental Conservation Association
IPP	Independent Power Producer
IRR	internal rate of return, normally expressed in after-tax nominal terms
ITCZ	intertropical convergence zone
IUCN	International Union for the Conservation of Nature
JTU	Jackson turbidity unit
JICA	Japan International Cooperation Agency
K	potassium
KCH	Kumul Consolidated Holdings

kg	kilogram
kg/hr	kilograms per hour
kL	kilolitre
km	kilometre/s
km^2	square kilometre/s
kt	kilotonne
kV	Kilovolt
kVA	kilovolt-ampere
kW	kilowatt
L	litre/s
L/ha	litres per hectare
L/s	litres per second
$L_{A1(1\ hour)}$	a sound level that is exceeded for 1% of a 1 hour period
L_{A90}	the noise level exceeded for 90% of the measurement period
L_{Aeq}	the steady sound level that contains the same amount of acoustical energy as a given time-varying sound
$L_{Aeq(x\ minutes)}$	level of equivalent continuous noise (above background noise)
LCA	life-cycle assessment
LILO	loop In loop out
LLCR	loan life coverage ratio
LLG	local-level government
LUCF	land use change and forestry
LULUCF	land use, land-use change and forestry

m	metre/s
m^2	square metre/s
m^3	cubic metre/s
MAI	mean annual increment
MC	Monte Carlo (model framework)
Mg	magnesium
mg	milligram/s (one thousandth of a gram)
mg/kg	milligrams per kilogram; unit commonly used to express the concentration of metal (such as copper) in a rock or sediment; is equal to parts per million
mg/L	milligrams per litre; unit commonly used to express the concentration of a metal, ion, suspended solids or similar in a liquid
mg/m^3	milligram per cubic metre
mg/Nm^3	milligrams per normal cubic metre
MJ	megajoule/s
ML	megalitre, one million litres
mL/ha	millilitres per hectare
MLA	multi-lateral agency, such as Asian Development Bank, World Bank, International Finance Corporation or similar
mm	millimetre/s
Mm^3	million cubic metres
MMJV	Morobe Mining Joint Ventures
Mn	manganese
MOTD	money-of-the-day (then-current cash flow)
MOU	Memorandum of Understanding

MSF	Médecins Sans Frontières/Doctors Without Borders
Mt	million tonnes
MVB	Markham Valley Biomass Limited
M_W	measure of earthquake magnitude
MW	megawatt/s
MWe	megawatts electric; the electricity output of a power plant in megawatts, after efficiency (heat) losses during electricity generation
MWh	megawatt hour
MWth	megawatts thermal: electricity produced by a thermal power plant, prior to accounting for efficiency losses
N_2O	nitrous oxide
Na	sodium
NATA	National Association of Testing Authorities (Australia)
NCD	National Capital District
NGO	non-government organisation
NH_4	ammonium
Nm^3	normal cubic metre, at 1 atmospheric pressure and 0°C
NMAG	National Museum and Art Gallery
NMVOC	non-methane volatile organic compounds
NO_2	nitrogen dioxide
NO_3	nitrate
NOx	oxides of nitrogen
NPK	nitrogen phosphorus potassium
NPV	net present value

NSPT	National Strategic Plan Taskforce
NTU	nephelometric turbidity unit
NZS	Standards New Zealand
O&M	operations and management
O_2	oxygen
OEM	original equipment manufacturer
OSL	Oil Search Limited
p.m.	post meridiem, meaning after midday
PAC	polyaluminium chloride
PAH	polycyclic aromatic hydrocarbon/polynuclear aromatic hydrocarbons
PASS	potential acid sulfate soils
Pb	lead
PET	Plecoptera (stoneflies), Ephemeroptera (mayflies) and Trichoptera (caddisflies)
PFC	Perfluorocarbon
PFS	pre-feasibility study
PGK	Kina (the currency of Papua New Guinea)
pH	value that represents the acidity or alkalinity of an aqueous solution, defined as the negative logarithm of the hydrogen ion concentration of the solution
PIER	Pacific Island Ecosystems At Risk Database
PJ	petajoules (10^{15} joules)
PLCR	project life coverage ratio
PM	particulate matter
PM_{10}	particulate matter ≤10 µm in diameter

$PM_{2.5}$	particulate matter ≤2.5 µm in diameter
PMV	public motor vehicle
PNG	Papua New Guinea
PNGDSP	Papua New Guinea Development Strategic Plan
PNGFA	PNG Forest Authority
PO_4	phosphate
POEA	polyethoxylated tallowamine
POMSoX	Port Moresby Stock Exchange (PNG)
PPA	power purchase agreement
PPL	PNG Power Limited
ppm	parts per million
RDT	rapid diagnostic test
RIT	resettlement implementation team
s	second/s
SCADA	supervisory control and data acquisition
SF_6	sulfur hexafluoride
SIA	social impact assessment/socio-economic impact assessment
SO_2	sulfur dioxide
SO_4	sulfate
SPV	special purpose vehicle, a corporate entity established for a specific purpose
SQG-High	upper sediment quality guideline values
SQGV	sediment quality guideline values
STI	sexually transmissible infection

SWL	sound power level
t	tonne/s
t/hour	tonnes per hour
TB	Tuberculosis
TDS	total dissolved solids
TIC	total inorganic carbon
TOC	total organic carbon
TPH/TRH	total petroleum hydrocarbons/total residual hydrocarbons
TSS	total suspended solids
UNEP	United Nations Environmental Program
UNFCCC	United Nations Framework Convention on Climate Change
V	Volts
VBD	vector-borne disease
VC	vegetation community
VHF	very high frequency, refers to radio waves from 30 megahertz to 300 megahertz
VLO	Village Liaison Officer
VOC	volatile organic compound
w/m^2	watts per square metre; measure of solar radiation
WHC	Wampar (NADZAB) Health Centre
WHO	World Health Organization
WMO	World Meteorological Organization
WRA	weed risk assessment
WWF	World Wildlife Fund

yr	year/s
Zn	zinc
µg	microgram/s
µm	micrometre/s; micron
µS	micro Siemen/s; a measure of conductivity

12.2 Terms and Definitions

The following words are defined in the context of their use in this report.

ablutions (power plant)	wastewater produced from washing and the use of toilets and bathrooms
acclimatisation/ 'growing on' areas	where young seedlings and clonal plants are provided with sufficient water and nutrition to encourage rapid healthy plant development
acid	substance with a pH less than 7.0; the lower the pH the higher the corrosivity of the substance
acid sulfate soils	naturally occurring soils formed under waterlogged conditions containing iron sulfides that can produce sulfuric acid when exposed to oxygen
acidic	having a pH less than 7.0
adsorption	the adhesion of a molecule or particle to a surface
agroforestry	land use management systems where, for example, agricultural crops are grown among or next to trees
algal bloom	excessive growth of algae, often caused by high nutrient concentrations
alkaline	having a pH greater than 7.0
allochthonous	organic material that is developed or derived outside a particular waterbody
alluvial	pertaining to material, such as sand or silt, deposited by running water (e.g., a creek or river)

alluvium	a general term for stream-deposited sediment (e.g., sand, silt, gravel) within stream beds or on flood plains or alluvial fans
ambient waters	all surrounding waters, generally of largely natural occurrence
amenity	the desirability of an area
amphiphytes	plants that grow on the edges of water or wetlands, and are sometimes submerged
Anabat	a system designed to help users identify and survey bats by detecting and analysing their echolocation calls
anastomosing	watercourses comprising two or more interconnected channels, separated by semi-permanent banks formed of cohesive material
anion	negatively charged ion
annuals	plants that complete their life cycle within one season
aquifer	an underground layer of permeable rock, sand or gravel that absorbs water and allows it free passage through pore spaces
aquitard	a layer in the geological profile that separates two aquifers and restricts the flows between them
artefact	anything made by human workmanship, particularly by previous cultures (such as chipped and modified stones used as tools)
artesian aquifer	confined aquifer with a potentiometric level that is above the ground surface; when a well penetrates an artesian aquifer, water will rise to the ground surface without the need for pumping
autochthonous	organic material that is developed or produced within a particular waterbody
background	visual assessment zone, defined in this report as the zone where receptors are further than 6 km but less than 16 km from the viewed area (where fine detail is not apparent but broader landforms are of more note)
basic	see alkaline

bioavailability	the fraction of the total of a chemical in the surrounding environment that can be taken up by organisms; the environment may include water, sediment, soil, suspended particles, and food items
biocide	a poisonous substance to living organisms
biodiversity/ biological diversity	the diversity of different species of plants, animals and microorganisms, Including the genes they contain, in the ecosystem of which they are part
biomass	fuel that is developed from organics materials (e.g., trees)
bioremediated	process of using organisms to neutralise or remove contamination from waste
biosequestration	the capture and storage of carbon dioxide by biological processes, in living organisms such as plants and algae
biosolids	organic solids produced from treating sewage that can be used as an agricultural fertiliser or soil conditioner
black start	process of restoring an electric power station or a part of an electric grid to operation without the assistance of an external power source
blowdown	water that is drained from equipment to remove mineral accumulation and minimise scale, corrosion and similar
boiler	a closed vessel containing water which is heated to produce steam
bottom ash	non-combustible, non-airborne material that remains after combustion of a solid fuel (such as biomass) in a furnace, and which falls to the bottom of the boiler
braided	waterway characterised by a network of interconnected converging and diverging channels; the intervening bars are exposed at low water and are highly mobile/transient
Braun-Blanquet	a method for scoring the relative abundance of plant species in surveys, generally on a scale from 1 to 5
buffering	the chemical process by which some substances or mixtures can resist or retard changes to their pH
bund	an earth, rock, or concrete embankment constructed to prevent the inflow or outflow of liquids or the transmission of noise

catchment	the total area draining into a river, reservoir, or other body of water
cation	positively charged ion
chipper (wood)	machinery used to produce woodchips from large woody material
chlorosis	loss of the usual green colouration of plant leaves
clonal planting stock	plants grown from cuttings of selected high quality mother plants
coagulant	a substance that causes particles in a liquid to form a solid or semi-solid state
COD (commercial operation date)	date of first power to be supplied by the Project, estimated to be met by third quarter 2019
compaction (soil)	process where soil is compressed and the air spaces in the soil are reduced, e.g., as a result of machinery traffic
compliance assessment	a type of impact assessment involving the comparison of predicted changes against specified criteria
concrete batching plants	equipment that is used to produce concrete from mixing various ingredients
concrete vibrators	a construction tool used to ensure concrete is poured evenly and without air bubbles
condensate	liquid resulting from condensation of a gas, such as water produced by the condensation of steam
coppice	regrowth of new stems from a cut tree stump
coppicing	see 'coppice'
CR (IUCN category)	a taxon is Critically Endangered when it is facing an extremely high risk of extinction in the wild (probability of extinction in the wild is at least 50% within 10 years or three generations)
critical plume height	the height at which the vertical velocity of a plume (stack emission) drops below a specified value
crop factor	the ratio of evapotranspiration to reference evaporation
culvert	a tunnel that carries a waterbody under a road, path or railway

dissolved metal	see filterable metal
drawdown	a reduction in water level and/or pressure level in an aquifer as a result of groundwater extraction
earthworks	engineering works requiring the disturbance of soil or rocks
ecoregion	distinct ecosystems that share broadly similar environmental conditions and natural communities, defined at a 1:1,000,000 scale
effluent	a complex waste material (e.g., liquid industrial discharge or sewage) that may be discharged into the environment
electrofishing	fishing using electric shocks to stun the fish
electrostatic precipitator	device that removes fine particles such as dust and smoke from a flowing gas
elutriate	supernatant water from tests designed to measure the short-term release of chemicals from disturbed bed sediments in aquatic systems
EN (IUCN category)	a taxon is Endangered when it is facing a very high risk of extinction in the wild (probability of extinction in the wild is at least 20% within 20 years or five generations)
EPC contract	the turnkey engineering, procurement and construction contract to be entered into between MVP and the EPC Contractor
erosion	process whereby water or wind moves soil, rock or dissolved material from one place to another.
evapotranspiration	the sum of all sources of evaporation from the land surface
EW (IUCN category)	a taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalised population (or populations) well outside the past range.
EX (IUCN category)	a taxon is Extinct when there is no reasonable doubt that the last individual has died
fan deposit	a fan or cone-shaped mass of material (usually sand/gravel) deposited by a stream where it emerges from the constriction of a narrow valley at a mountain front and debouches onto a plain or into a wide trunk valley

feedwater (boiler)	water sent to the boiler contacting condensate and fresh water which has usually been purified by some process
felling	cutting down, usually in reference to trees
filterable metal	the portion of a metal in a water sample that is able to pass through a filter normally having a pore size of 0.45 μm
firebreak	a cleared section of land used to prevent the spread of fire
flocculants	a substance which promotes particles clumping together, used in treating water
flue	a duct for smoke and waste gases produced by a fire, a gas heater, a power station or other combustion source
fly ash	non-combustible fine particles generated by combustion of a solid fuel, which is carried out of the boiler by flue gases
foreground	visual assessment zone, defined in this report as the zone where receptors are within 500 m of the viewed area (where detail of the landscape is most clearly perceived)
FPIC	a process to establish participation and consultation of 'indigenous' people prior to the beginning of a development; entitles these people to ‘determine’ the outcome of decision-making that affects them
free on board	the price of a commodity after loading onto a ship
fugitive dust emission	dust suspended in the air by wind action and human activities
geomorphic	relating to the form of the earth and other natural features of the earth's surface
germination/rooting houses	environment-controlled greenhouses with optimised humidity and temperature for the germination of seed and the rooting of clonal cuttings
gill net	a type of net used for fishing, which traps fish by their gills
groundwater	water stored underground in rock crevices and in the pores of geologic materials that make up the earth's crust; water that supplies springs and wells
hamlet	a small settlement

hardening areas	where plants are gradually exposed to full sun and watering is reduced to 'harden' plants ready for the planting in the field, thereby reducing mortality in plantations
hardness	the concentration of all metallic cations, except those of the alkali metals, present in water; in general, hardness is a measure of the concentrations of Ca and Mg ions in water and is frequently expressed as mg/L $CaCO_3$ equivalent
harvesting residue	organic debris including branches, leaves and bark stripped from logs
heat rate	the amount of fuel required to produce a given quantity of electrical energy, typically quoted in kJ/kWh, and which can be converted to tonnes of fuel per MWh
hydraulic excavator	a large construction vehicle consisting of a chassis, boom and bucket that moves on tracks and wheels
hydrogel	a soil additive that absorbs and stores water and nutrients during damp periods and releases them during dry periods
hydrogeology	the study of groundwater, including its occurrence, recharge and discharge processes and the properties of aquifers
hydrology	the study of water, particularly its movement in streams and rivers
Independent Public Business Corporation	former sole shareholder of PPL, which has recently been renamed Kumul Consolidated Holdings (KCH)
inert waste	waste which will not decompose and is neither chemically or biologically reactive
inter-row cropping	see 'intercropping'
intercropping	growing crop plants among other plants of a different species, usually in separate rows for each species
intermittent (watercourse)	refers to a watercourse that ceases to flow at some times during the year
knockdown herbicide	non-selective herbicides that can kill a wide range of plants
Kumul Consolidated Holdings	a 100% PNG state-owned corporation owning a range of state-owned businesses, including PNG Power Limited (PPL)

landing	an area to which logs are pulled and then loaded onto trucks, i.e., the working areas for cross-cutting, sorting and loading of logs (not including areas used solely for stockpiling)
LC (IUCN category)	a taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened; widespread and abundant taxa are included in this category
log crossing	the use of stacked or piled logs to create a crossing over a waterway or ditch
logging slash	material left on the ground after harvesting operations including tree heads, shrubs and other non-merchantable woody material
macrocrustacean	crustacean that is visible to the human eye
macroinvertebrate	invertebrate animals that are visible to the human eye, live in or on the sediments, and include crustaceans, molluscs and polychaetes
mean annual increment	volume of wood growing on 1 ha of forest during one year (m^3/ha/year) on average since the forest has been established; for a tree plantation, the MAI (which is a standard unit to describe plantation productivity) is the present total growing stock volume of 1 ha divided by the total age
metamorphic	pertaining to rocks which have developed as a result of transformation of pre-existing rock types by heat and/or pressure
mid-ground	visual assessment zone, defined in this report as the zone where receptors are further than 500 m but less than 6 km from the viewed area (where the context of the landscape becomes apparent)
mixing zone	an explicitly defined area around an effluent discharge where effluent concentrations may exceed guideline values and therefore result in certain environmental values not being protected; the size of the mixing zone is site specific
modularisation	where systems can be broken down into smaller components assembled off-site and then combined and finalised on-site
mother plant areas	where mother plants will be kept and clonal cuttings initiated
non-woody vegetation	plants that do not form a woody stem above ground, e.g., grasses and small shrubs

NT (IUCN category)	a taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future
nuisance growth	excessive growth of aquatic plants, often caused by high nutrient concentrations
O (FIM code)	non-vegetation and areas dominated by land use
outer horizontal surface	a plane located 150 m above the reference elevation datum and extending from the upper edge of the conical surface for a distance of 15,000 m (radius) from the aerodrome reference point
outer horizontal surface/obstacle limitation surface	a series of planes associated with each runway at an aerodrome that defines the desirable limits to which objects may project into the airspace around the aerodrome so that aircraft operations may be conducted safely
parasitic loads	refers to the amount of power consumed by something when it is off
partitioning	process whereby chemicals in aquatic systems are either dissolved or associated with particulate matter
payloader	a heavy wheeled vehicle and type of tractor with a large moveable blade or scoop
perennial (watercourse)	refers to a watercourse that flows continually
piedmont	used to describe the gentle slope leading down from the steep mountain slopes to the plains, including the bedrock (pediment) and the accumulated colluvial and alluvial material (bahada)
PL (FIM code)	large to medium crowned forest on plains and fans vegetation community
plantation	the biomass plantation established as part of the Project, which will be the main source of fuel input for the power plant
planform	view from above
ploughing	turning or breaking up of the soil (e.g., when preparing the soil for sowing seed)

potential acid sulfate soils	undisturbed soils that contain iron sulfides that, when disturbed and exposed to oxygen, can produce sulfuric acid
pottiputki	a tool used to plant tree seedlings
power plant	the Project IPP power plant, which will produce and supply power as agreed under the PPA
pre-fabrication	practice where components of a structure are assembled off site and transported to the final location for completion
Project	the PNG Biomass Markham Valley project, comprising the power plant and plantations, owned by Markham Valley Biomass Limited
Project Partners	Aligned Energy and Oil Search
propagation (plants)	creating new plants from seeds, cuttings, bulbs or other parts of a plant
PS (FIM code)	small crowned forest/regrowth forest vegetation community
putrescible	solid waste that is liable to decay
pyrolysis	loss of volatile matter brought about by high temperatures
receptors	locations used in modelling to provide a focus for predicting gaseous and particulate concentrations
reference evaporation	a measure of the potential or maximum energy limited rate of evaporation (roughly analogous to the rate of evaporation from a free water surface under a given set of conditions)
reverse osmosis	a process for water purification whereby dissolved inorganic solids such as salts can be removed
RISEPOST	a post-processor designed to characterise the vertical velocity of the plume during rise
sawlogs	tree trunks suitable for cutting into sawn timber or veneer sheets
scaling	hard deposits that can build up on metal equipment
scenic quality	a classification of visual amenity based on the scenic variety, distinctiveness or prominence, and naturalness of a landscape, in relation to the landscape character of the region.

sedimentation	the process of settling or being deposited as sediment
seedlings	young plants raised from seed
seismicity	the occurrence or frequency of earthquakes in a region
septic	anaerobic conditions under which waste is treated
snig track	a track along which logs are pulled from the felling point to a nearby landing
soil erodibility	see 'erosion'
soot blowers	device for removing soot deposited on the furnace tubes of a boiler during combustion
stoker boiler	a type of boiler
stressor	physical, chemical or biological factor that can cause an adverse effect in an aquatic ecosystem
sullage pit	a pit for storing or holding wastewater
surfactants	compounds that reduce the surface tension between two liquids and a solid; when used with a herbicide they help it spread over the surface of the plant
temporal sequencing	the succession of something after another
total metal	the concentration of a metal in an unfiltered sample that is digested in strong acid
total suspended solids (TSS)	a common measure used to determine suspended solids concentrations in a waterbody and expressed in terms of mass per unit of volume (e.g., milligrams per litre)
trace metals	generally used to describe the following metals: arsenic, iron, manganese, silver, mercury, chromium, lead, zinc, copper, nickel, selenium and cadmium
transpiration	evaporation, through the leaf surface, of water that has been taken up from the soil by roots and transported to the leaves via stem and branches
turbulence	a disturbance in the air

unconsolidated soils	loose materials ranging from clay to sand to gravel that have not been metamorphosed or cemented together
veneer (logs)	logs that can be used to produce timber panels from slicing or peeling a log
VU (IUCN category)	a taxon is Vulnerable when it is facing a high risk of extinction in the wild (probability of extinction in the wild is at least 10% within 100 years).
water table	the level of groundwater; the upper surface of the zone of saturation of underground water

13. Study Team

The EA/EMP Project team comprises representatives from MVB and ERIAS Group (as the lead environmental assessment (EA) consultant), as well as specialists who executed technical investigations to support the EA. A number of additional specialists who were contracted directly to the Project also provided information or other means of support, as did other MVB personnel.

Key personnel who contributed to the preparation of this EA report and EMP are listed below in Tables 13.1, 13.2, 13.3 and 13.4.

Table 13.1 – Markham Valley Biomass

Name	Title/Role
Michael Henson	Project Director
Jessie Mitir	Stakeholder Engagement Manager, EA/EMP review
Andrew Grogan	Technical Director
Francis Kabano	Community Affairs Manager
Garry Townley	Operations Manager
David Burbidge	Business Development
Jordan Cox	Field Services
Kim Judge	Business Services
Gorethy Dispen	Operations Supervisor
Trevor Galgal	Plantations Supervisor
Tim Siegenbeek van Heukelom	EA/EMP review
Peter Stevens	EA/EMP review

Table 13.2 – ERIAS Group

Name	Title/Role
Michael Jones	Project director, technical writer and review
Michelle Clark	Project manager, technical writer and review
Luci David	EA/EMP review
Inneke Nathan	Technical writer
Kate Sinai	Technical writer
Scott Breschkin	Technical writer
Geordie Brock	Technical writer
Derek Mascarenhas	Graphics

Table 13.3 – Supporting EA Specialists

Name	Specialty	Company
Penn Lloyd David Stanton David Fell David Gooding Frans Arentz Paulette Jones	Terrestrial ecosystems	Biodiversity Assessment and Management Pty Ltd (BAAM)
Adrian Flynn Justin Catajar Simon Drummond	Aquatic ecosystems	Fathom Pacific Pty Ltd Hydrobiology Pty Ltd
Gustaf Reuterward Fardausar Rahaman Alison Radford Kirsten Lawrence	Air quality and plume rise	SLR Consulting Australia Pty Ltd
Gustaf Reuterward Luke Zoontjens Miguel de la Mata	Noise	SLR Consulting Australia Pty Ltd
Andy Markham Ben Pearson	Hydrology and sediment transport	Hydrobiology Pty Ltd
Don White Richard Silberstein	Hydrogeology and plantation water use	Whitegum Forest and Natural Resources Pty Ltd HydroEnviro Scientific Solutions Pty Ltd

Table 13.4 – Other Consultants to Aligned Energy/Markham Valley Biomass

Name	Specialty/Role	Company
Laurence Goldman	Social impact assessment lead	Social Impact Monitoring & Programs (SIMP)
Mike Lowe	Land and agriculture	Social Impact Monitoring & Programs (SIMP)
Gary Krieger	Community health	Social Impact Monitoring & Programs (SIMP)
Joe Crouch	Archaeology/cultural heritage	Social Impact Monitoring & Programs (SIMP)
Helen Johnson	Gender and human rights	Social Impact Monitoring & Programs (SIMP)
John Brooksbank	Social services, infrastructure, governance and benefits	Social Impact Monitoring & Programs (SIMP)
Andy Bachofen	ECI	Pöyry
Albert Prins	ECI	Pöyry
Andrew Dickinson	Forestry	Biovalue
Blake McBurney	Boiler design	--
Vincent Weng	Scheduling	Constructive Planning
John Reddel	Owner's engineer	Jacobs
Ian Boardman	Owner's engineer	Jacobs

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