ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

INTEGRATED WASTE MANAGEMENT FACILITY

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TWM | Total Waste Management

ERIAS

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TWM PNG Ltd t/a Total Waste Management

Integrated Waste Management Facility

Environmental Impact Statement

Volume 1 – Main Report

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Executive Summary

1 Proposed Development

TWM PNG Limited t/a Total Waste Management (TWM), as proponent of the Integrated Waste Management Facility (IWMF) Project ('the Project'), is proposing to further develop and extend the existing infrastructure and operations of the IWMF, located adjacent to the AES Industrial Park at Site Portion 2703, Napa Napa Road, Porebada, Central Province, Papua New Guinea, approximately 21 km from Port Moresby by road (Figure ES1; Plates ES1and ES2).

Plate ES1 – View of the Napa Napa Peninsula



Photo: Google Earth.

Plate ES2 – The AES Industrial Park



Photo: TWM.

PROJECT LOCATION

Integrated Waste Management Facility | Environmental Impact Statement

FIGURE ES1



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ERIAS

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DATA SOURCE:
Project data from TWM, 2020.
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TWM proposes to extend the waste types to be processed and treated at the facility, including hazardous solid and liquid wastes. TWM anticipates up to 150,000 tonnes of waste will be received at the facility each year. The extended IWMF is anticipated to have an operational life of up to 50 years. The details of rehabilitation and decommissioning activities are yet to be determined but will comply with regulatory requirements that are in force at the time of decommissioning, and good industry practice.

1.1 Project Justification

The IWMF will be the first facility of its kind in Papua New Guinea, increasing the country's capacity to treat, recover and recycle waste material and dispose of hazardous contaminants in an environmentally sustainable manner, reducing the current need to export waste to other countries (e.g., Australia). By providing in-country waste management solutions, the Project also aims to reduce the current uncontrolled waste stockpiling practices in Papua New Guinea and aims to address the existing environmental, health and safety risks associated with unlicensed waste storage and disposal.

1.2 Project Objectives

The overarching Project objective is to construct and operate engineered infrastructure capable of sustainably storing, treating and disposing of industrial and commercial wastes, including hazardous wastes. Specifically, the Project aims to:

- Improve the safe and environmentally sustainable handling of waste materials including hazardous waste and reduce the current stockpiling of such materials in uncontrolled circumstances throughout Papua New Guinea.
- Address the current environmental and public health risks associated with unlicensed waste storage and disposal.
- Improve cost structures for the safe management of end of life hazardous materials for industry and government agencies.
- Build in-country capacity and provide local access to sustainable hazardous waste treatment and disposal services to reduce the current reliance on hazardous waste export.
- Expand Papua New Guinean exports of hazardous waste knowledge and capacity to provide hazardous waste services to other Pacific countries.
- Increase government tariff revenues through waste imports and provide reliable feedstock for IWMF development.
- Support the PNG Government in meeting its current and future obligations under a number of multilateral environmental agreements (e.g., Montreal Protocol, Stockholm Convention).

1.3 Environmental Permit Requirements

Several activities and components of the IWMF are already approved under TWMs existing Level 2 Environment Permit EP-L2 (485), either in regard to construction or operation and receival and treatment of wastes.

For the proposed Project (extended IWMF), a Level 3 environmental permit is required in order to undertake construction and operation of the following specific activities:

- Construction and operation of engineered infrastructure capable of receiving and managing hazardous waste.
- Extension of types of waste materials to be received/handled/stored at the IWMF, including hazardous solid and liquid wastes.
- Resource recovery activities including e-waste dismantling and plastics reprocessing.

The EIS assesses the potential environmental and socio-economic (including cultural heritage) impacts of the Project on the study area. The EIS has been prepared in line with the requirements of:

- Relevant Papua New Guinea laws, regulations and permits.
- TWM corporate requirements.

1.4 Study Area

The environmental and socio-economic study area is shown in Figure ES1.

The following aspects were considered in defining the study area, all of which set the context for the area in which environmental and socio-economic baseline studies (desktop reviews, stakeholder engagement and field studies) were undertaken:

- The expansion footprint (5.5 ha to the southeast and 2.4 ha to the southwest of the existing site boundaries) with an additional 500 m buffer from the boundary.
- Ongoing site operational activities and intermittent activities such as construction works.
- Surface water catchments and the potential for runoff to extend beyond the facility boundaries and 500 m buffer.
- The location of sensitive receptors, including neighbouring industries (and Roku village).
- Community land use and traditional resource use activities surrounding the IWMF.
- Transportation routes (i.e., roads, shipping routes).
- The location of local infrastructure (e.g., schools, health centres and markets).
- Organisations or communities that could be indirectly affected by the proposal (e.g., landowners, communities who use/access surrounding natural resources, supply chains, Project workforce and government departments).

Within the environmental study area sampling locations were determined based on representativeness of receptors and potential impact pathways for soil, groundwater, surface water and stream sediment, air and noise and aquatic and terrestrial biodiversity.

Given the localised expansion of the IWMF and distance from most local communities, the socio-economic study area (i.e., the area where primary data would be collected from the community) focussed on Roku village.

1.5 Data Collection

The environmental and socio-economic conditions in the study area are characterised using a combination of a bibliographic (desktop) review of publicly available information, data gathered during previous surveys at the IWMF and surrounding area, and data gathered during field surveys and interviews undertaken by ERIAS between the 15 and 22 July 2020, which included community interviews, discussion with specialists (e.g., CEPA), site field assessments and sediment sampling.

Interviews were conducted with the local community (with Roku village leaders and the Roku Women's Fellowship), with businesses in the neighbouring industrial precinct and with government agency representatives. Information on community use of natural resources was supplemented through the environmental field surveys.

2. Project Setting

2.1 Physical Environment

The Project is located within the Southern Plains and Lowlands region of Papua New Guinea, comprising of hilly lowlands and foothills, and depositional plains. The IWMF site is located on the top of a low, flat hill or ridge, running northwest to southeast at an elevation of between 112 m above sea level (asl) at the highest point to 49 m (asl) at the lowest. Plates ES3 and ES4 demonstrate the landscape in the study area. Plates ES1 and ES5 show the development on the Napa Napa Peninsula and the extensive existing ground disturbance in the study area.

Air quality in the study area is affected by dust and emissions from vehicles operating at the various industrial facilities in the area, including the IWMF site; equally existing industry in the area contributes to current background noise levels.

There are no creeks within the IWMF site and water primarily drains from the site towards the AES industrial park and Fairfax Harbour. Generally, water flow and quality in the region are affected by seasonal rainfall, in particular during the monsoon season (December to May). Land clearance and industrial development in the region have limited natural flood protection, allowing heavy monsoon rains to wash through the study area potentially mobilising pollutants from human and industrial activities into downstream waterways.

The Project is located in the vicinity of the AES Industrial Park and already experiences a degree of air pollution and noise disturbance from industrial activity and vehicles on the Napa Napa Road.

Plate ES3 – Landscape Type: Wooded Drainage Lines



Plate ES4 – Landscape Type: Eucalypt Savanna



Plate ES5 – Pre-Existing Disturbance within the Study Area



2.2 Biological Environment

In keeping with the characteristics of the southern coastal lowlands of Central Province of Papua New Guinea, the entire study area is identified as savanna vegetation, comprising scattered eucalypt trees and grassland; however, the IWMF site and adjacent land, including the nearby AES Industrial Park, is heavily disturbed with little to no original vegetation remaining (see Plate ES5). Biodiversity in the study area is therefore less diverse than other parts of Papua New Guinea with only a number of fauna (including birds, amphibians and reptiles) observed during field surveys (Plate ES6) or previous surveys in the broader region. Small mammals, such as the agile wallaby, were not identified during surveys however are known to exist in the area (as identified by the local community). Marine biodiversity was not studied as part of the EIS as the Project is not predicted to impact on the marine environment.

Plate ES6 – Green Tree Frog (*Ranoidea caerulea)*



2.3 Socio-economics and Cultural Heritage

Roku village has a population of between 2,000 and 2,500 people and is the closest village to the IWMF (located approximately 500 m away, to the southeast of the facility), located on the shores of Idler's Bay (Plates ES7 and ES8). The traditional language of Roku village is Koita (also known as Koitabu); however, the Koita have interacted extensively with neighbouring Motu villages, such that intermarriage has slowly changed Koita society. The Kuriu clan are the traditional landowners in Roku village.

The broader study area does not contain any active commercial forestry, agriculture or livestock production, and is primarily used for industrial purposes. Over half of the local community (Roku) earn income from waged (formal) employment, mostly at businesses at the AES Industrial Park, including TWM. Subsistence practices are still part of daily life for the local community; however, few households maintain gardens, despite communal land being available adjacent to Roku village. Those that do garden, grow cassava, banana, mango and yam during the rainy season (see Plate ES9).

Firewood is still regularly collected from the savanna surrounding Roku village and is used for cooking and/or is sold locally at table markets and trade stores (see Plate ES10). Fishing is an important activity for the local community (see Plate ES11), both in terms of nutritional benefits and because of the income generated through sale of fish locally or at the Koki market in Port Moresby (approximately 20 minutes by dinghy).

There is an elementary school and a primary school in the village, however there are no health facilities (the closest is the Porebada Health Sub-Centre, approximately 8.5 km away).

Plate ES7 – Typical Housing in Roku Village and Dinghies Used for Fishing



Plate ES8 – Eastern side of Roku village



Plate ES9 – Garden in Roku Village



Plate ES10 – Firewood Being Dried to Sell



Plate ES11 – Fish Caught in Waters off Roku Village



In March 2018, a survey of the IWMF site was conducted by the National Museum and Art Gallery of Papua New Guinea to identify any archaeological and cultural heritage sites. No sites of cultural significance were found within the study area.

3 Stakeholder Engagement

TWM is committed to establishing and maintaining positive stakeholder relations through effective communication and consultation with identified stakeholders throughout the life of the IWMF. Due to the nature of the existing operations at the IWMF, TWM already has an in-depth understanding of its stakeholders, including key representatives of the local community and had established a program of regular stakeholder engagement.

TWM has undertaken a number of engagement activities specific to the proposed expansion of the IWMF with affected stakeholder groups, in line with the requirements set out in the *Environment Act 2000,* to further understand potential impacts on stakeholders, including on the local community at Roku village and neighbouring businesses. Further formal stakeholder engagement on the EIS will be undertaken in conjunction with Papua New Guinea's Conservation and Environment Protection Authority in order to satisfy requirements of the Act.

4 Assessment of Project's Impacts and Benefits

Project activities (described in Section 1) have the potential to generate the following impacts and benefits described in Table ES1. However, the EIS does not include a 'blanket' assessment of all impacts; some potential impacts have been discounted during preliminary screening as part of the impact assessment process due to not meeting significance or magnitude criteria, as described in Table ES1 below. Table ES1 summarises the residual impact significance assessment for each environmental and socio-economic discipline and, where applicable, highlights any impacts that were considered negligible or unlikely following preliminary screening of impacts. Additional detail is provided in Chapters 10 and 11 of the EIS.

Table ES1 – Potential Project Impacts

EIS Section No.	Potential Impacts	Residual Impact Assessment	Impacts Discounted during Preliminary Screening and Not Assessed Further in EIS
ENVIRONMENT			
10.1	***Landform and Soils***		
	Destabilisation of landform resulting in increased soil erosion	Negligible	None
	Deterioration in soil quality	Negligible to Minor	None
10.2	***Hydrological Processes***		
	Altered surface water processes (industrial landfill)	Negligible	• Preliminary screening determined that there will be no impact to the hydrological regimes of downslope surface waters from surface water abstraction as this will not be required to meet the domestic and industrial water demands of the Project. Further assessment in EIS not required
	Change to groundwater levels	Not assessed	• Preliminary screening determined that no groundwater drawdown will occur as no groundwater will be abstracted to meet Project water demands. Further assessment in EIS not required • Preliminary screening determined that groundwater mounding from seepage is unlikely to occur as all stormwater and sediment dams and the leachate storage pond will be lined with multiple HDPE geo-membrane barriers combined with clay liners. Further assessment in EIS not required
10.3	***Surface Water Quality***		
	Increased sediment and turbidity from rainfall erosion	Negligible to Minor	None
	Deterioration in surface water quality	Negligible to Minor	• Preliminary screening determined that discharge of treated wastewater from the IWMF site is not proposed and discharge of stormwater does not need to be assessed as

EIS Section No.	Potential Impacts	Residual Impact Assessment	Impacts Discounted during Preliminary Screening and Not Assessed Further in EIS
			TWM has an existing environment permit for the offsite discharge of storm water. Further assessment in EIS not required
10.4	***Groundwater Quality***		
	Deterioration in groundwater quality due to contamination	Negligible	• Preliminary screening determined that no water will be discharged from the IWMF, apart from stormwater, (from weighbridge and guardhouse) which is approved under an existing environment permit. Further assessment in EIS not required
10.5	***Air Quality and Greenhouse Gas***		
	Decline, loss of or change to existing air quality and amenity from dust and particulate matter and from incinerator emissions	• Residual impact assessment determines air quality emissions (dust and particulate matter and from incinerator emissions) comply with acceptable criteria and there will be no discernible change resulting from Project activities	None
	Increased levels of greenhouse gases resulting from fuel and electricity consumption and from waste management plant operations	Minor	None
10.6	***Noise***		
	Reduction in local amenity due to increased noise emissions from construction and operation of industrial landfill	Minor	None
10.7	***Visual Amenity***		
	Change in visual amenity due to landform modification, dust and windblown litter	Negligible	• Preliminary screening determined that the following potential impacts did not require further assessment in the EIS: – Changes to the visual character of the area from additional infrastructure as these changes will be in keeping with the

EIS Section No.	Potential Impacts	Residual Impact Assessment	Impacts Discounted during Preliminary Screening and Not Assessed Further in EIS
			infrastructure and facilities already present – Visual amenity as a result of land use changes associated with the removal of vegetation or artificial lighting
10.8	***Terrestrial Biodiversity***		
	Habitat loss and fragmentation	• Negligible for species of non-conservation significance • Minor for species of conservation significance	• Preliminary screening determined that habitat loss and fragmentation resulting from reduced movement of species (barrier effects) is unlikely to occur given minimal clearing of vegetation for Project activities at the existing IWMF site and the poor habitat quality within the site. Further assessment in EIS not required
	Habitat degradation	Negligible to Minor	None
	Introduction or increase of invasive weeds and pest fauna	Negligible	None
	Increase in death and disturbance of animals from hunting and vehicle collisions	Negligible	None
10.9	***Aquatic Biodiversity***		
	Habitat degradation or modification	Negligible to Minor	• Preliminary screening determined that impacts to surface water processes and aquatic biodiversity from surface water abstraction will not occur as surface water will not be abstracted for Project water demands. Further assessment in EIS not required
	Sub-lethal or lethal toxicity effects on aquatic biota as a result of surface water contamination	Negligible to Minor	None
	Introduction of aquatic weeds	Negligible	• Preliminary screening determined that there is no credible pathway for the introduction of introduced/pest fish species to aquatic habitats as a result of Project activities. Further assessment in EIS not required
SOCIO-ECONOMICS AND CULTURAL HERITAGE			
11.1	***Economy and Employment***		
	Increased direct and indirect economic opportunities, workforce training, skills and experience	Positive	None

EIS Section No.	Potential Impacts	Residual Impact Assessment	Impacts Discounted during Preliminary Screening and Not Assessed Further in EIS
11.2	***Community Health and Safety***		
	Increase in accidents and injuries as a result of increased traffic volumes on Napa Napa Road	Minor	None
	Reduced amenity and wellbeing as result of air and noise emissions	Minor	None
	Health risks associated with the transportation and handling of hazardous wastes	Minor	None
11.3	***Land and Natural Resource Use***		
	Loss of access to natural resources	Negligible	• Preliminary screening determined that: – The potential for increased noise emissions to contribute to a reduction in hunting success (given the impact on noise on local fauna) is negligible. Further assessment in EIS not required – Contamination of the marine environment and subsequent impacts on marine fisheries and Roku village (apart from impacts resulting from a Major Hazard, see Chapter 12 of EIS) is unlikely as there are no planned Project activities that would result in impacts extending to the marine environment. Further assessment in EIS not required – Project impacts on regulating and maintaining ecosystem services such as maintaining surface water quality, erosion control and regulation of natural hazards are unlikely given the highly localised nature of the activities. Further assessment in EIS not required
11.4	***Traffic and Transport***		
	Disrupted access to social services (i.e., health, education, economic services) as a result of increased traffic congestion	Minor	None
11.5	***Law and Order***		
	Increased conflict and antisocial behaviour resulting	Negligible	None

EIS Section No.	Potential Impacts	Residual Impact Assessment	Impacts Discounted during Preliminary Screening and Not Assessed Further in EIS
	from increased income, distribution of benefits and Project-induced in-migration		
11.6	***Cultural Heritage and Archaeology***		
	Loss or damage to unknown cultural heritage	Negligible	• Preliminary screening determined that impacts to known cultural heritage are unlikely as there are no known materials or sites within or in the vicinity of the IWMF site. Further assessment in EIS not required

An assessment of major hazards and potential unplanned (accidental or abnormal) incidents or events) identified a number of impacts/risks potentially resulting from external (e.g., major seismic activity, uncontrolled fire from natural or non-Project human source, flooding) and Project-related hazards (e.g., unplanned major spills or loss of containment of chemicals, fuel or hazardous materials; landslide resulting from failure of landfill construction). Potential Project risks from major hazards will be managed through the implementation of mitigation measures which will aim to manage the potential for unplanned events and incidents through prevention, response, reporting and corrective action.

Mitigation measures have been applied to potential impacts by implementing the mitigation hierarchy, e.g., avoid impacts where possible, minimise impacts when avoidance is impossible and, when they remain, consider rehabilitation or restoration, and ultimately compensate/offset.

While most residual impacts were assessed as negligible to minor (considering the existing design and mitigation and management measures already in place at the IWMF), Table ES2 provides further details on some key impacts that may still be perceived as significant by the local community and other Project stakeholders, despite existing and proposed mitigation measures and management controls.

Table ES2 – Summary of Key Interest Areas for Stakeholders

Potential Key Impact	Assessment of Potential Impact on Key Stakeholders
Employment and economic opportunities	• The Project will result in increased job opportunities for local communities in the area and TWM is committed to hiring locally where the relevant skillsets exist, or training can be provided • Logistics companies supporting TWM (in transporting waste to the IWMF) may experience increased business activity • Local community members who have small businesses (e.g., trade stores, table markets) in the vicinity of the IWMF (e.g., in Roku) may also experience an increase in income if local community members and other members of the increased workforce who have jobs at the IWMF spend their money locally
Noise impacts disturbing the local community	• Existing noise levels are influenced by the existing IWMF activities and the surrounding industrial activities and the associated traffic using Napa Napa Road • Studies have shown that construction and operation of the expanded IWMF (including noise from traffic using the Napa Napa Road to access the

Potential Key Impact	Assessment of Potential Impact on Key Stakeholders
	IWMF) are only likely to cause a small increase in noise levels, mostly affecting industrial neighbours around the IWMF; the predicted noise levels are at or below acceptable noise limits • Noise levels are unlikely to increase in Roku village during Project construction and operations
Incineration of hazardous waste and medical waste affecting air quality and thus the health of the local community	• Most of the existing air emissions in the area around the IWMF is caused by traffic on the Napa Napa Road and the adjacent industrial areas • Air quality studies show that there is likely to be a small increase in air emissions, as a result of increased traffic using the Napa Napa Road to access the IWMF, mostly affecting industrial neighbours around the IWMF • Air quality levels are unlikely to change at all in Roku village during Project construction activities and operations (e.g., operation of the incineration plant) based on appropriate mitigation of dust emissions, in particular • The incinerator at the IWMF is located in the southwest corner of the IWMF site, as far away as possible from Roku village. It was built in 2019 and has pollution control system technology capable of meeting US EPA and European Union emission standards for the thermal destruction of hazardous (and other) wastes • The incineration of hazardous waste is not likely to increase the existing levels of emissions such as carbon monoxide, sulphur dioxide and oxides of nitrogen in comparison to incineration of general wastes, and therefore is unlikely to affect the health of the local community
Contamination of water and soils from fuel/oil/chemical spills	• Project activities and the normal day-to-day operations of the IWMF are unlikely to have any effect on land-based resources (e.g., firewood), groundwater, surface water or marine resources (e.g., fish stocks) because the IWMF has been designed to international standards and has adopted sustainable waste management practices • Natural drainage of water from the IWMF site is primarily to the north and northeast, towards the AES Industrial Park and Fairfax Harbour and away from Roku village and Idler's Bay

5 Environmental and Social Management System

TWM operates within an integrated quality, health, safety and environment (QHSE) management system and has triple ISO certification (Environment Management ISO 14001 – 2015, Quality Management ISO 9001 – 2015 and Occupational Health and Safety OHSAS 18001 – 2017). The TWM QHSE Management System will underpin the implementation of the Project Construction Environmental and Social Management Plan (CESMP) and, in time, the Project operations EMP.

The Project CESMP comprises a series of detailed management plans, each of which detail the aspect-specific objectives, targets, compliance requirements, management/mitigation measures, performance measures, roles and responsibilities and monitoring and reporting regime. Contractors undertaking work on behalf of TWM will be contractually obligated to comply with the CESMP and other applicable (detailed) management plans.

1. Introduction

1.1 Project Overview

TWM PNG Limited t/a Total Waste Management (TWM) as proponent of the Integrated Waste Management Facility (IWMF) Project ('the Project') aims to develop and extend the operations of the existing IWMF located at Site Portion 2703, Napa Napa Road, Porebada, Central Province, Papua New Guinea (Figure 1.1). The Project will involve the safe handling, recycling, storage, treatment and disposal of a broad range of solid, liquid and intractable wastes, including quarantine wastes, that may be defined as hazardous contaminants under provisions contained within Section 133 of the *Environment (Amendment) Act 2014*.

The IWMF will be the first facility of its kind in Papua New Guinea and will expand Papua New Guinea's in-country capacity to recover, recycle remanufacture and treat waste materials and dispose of hazardous contaminants. The IWMF is designed to manage up to 150,000 tonnes of commercial and industrial waste materials annually. Expanding the capabilities of the IWMF will provide local access to sustainable hazardous waste treatment and disposal services, reducing the reliance on hazardous waste export. By providing in-country waste management solutions, the Project also aims to reduce the current uncontrolled waste stockpiling practices in Papua New Guinea and aims to address the existing environmental, health and safety risks associated with unlicensed waste storage and disposal.

TWM currently hold an approved environment permit (EP) for Level 2 (L2) activities, EP-L2 (485), which includes the construction and operation of a wastewater treatment plant, quarrying activities, construction and operation of a landfill for disposal of municipal wastes, operation of an incinerator and reprocessing, treatment or disposal of industrial or biomedical waste and recycling waste material.

While the construction and operation of much of the IWMF plant and infrastructure is already approved under an existing Level 2 Permit, TWM wish to receive, process and dispose of additional wastes which are not approved. As such the Project has been classified as a Level 3 Activity under s. 50 of the *Environment Act 2000* and therefore requires an environmental impact statement (EIS) to be prepared. This EIS has been prepared as the statutory basis for the environmental and social assessment of the Project. ERIAS Group Pty Ltd (ERIAS) was commissioned by TWM to assist with the preparation of this EIS.

1.1.1 Project Proponent

The Project proponent and proposed operator is TWM, a Papua New Guinea owned and operated company. TWM is a privately owned PNG company with two national directors. TWM is an established waste and environmental services provider and have been operating in Papua New Guinea since 2011 and currently employ nearly 150 staff. TWM currently service the oil and gas, resource, commercial and government sectors and also install and commission waste management infrastructure, industrial services and provide waste and environmental management advisory services.

PROJECT LOCATION

Integrated Waste Management Facility | Environmental Impact Statement

FIGURE 1.1



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ERIAS, 13-25 Church Street
Hawthorn VIC 3122, Australia

DATA SOURCE:
Project data from TWM, 2020.
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1.1.2 Project Schedule

Design, construction and commissioning of IWMF infrastructure will be undertaken in four key phases, as detailed in Chapter 4. Phase 1 commenced in Q4 of 2018 with the industrial landfill design, and the installation of a waste oil processing unit (WOPU) and storage of hazardous waste for export. A high temperature (HT) incinerator and associated infrastructure was installed and commissioned in 2019 and works associated with industrial service wash bays (e.g., cleaning of ISOtainers), and fixation bays for stabilising materials prior to disposal have also been completed, as has the design for stormwater management, electrical supply and security fencing. Additional plant and infrastructure for waste processing will be commissioned for operation gradually and incrementally, with completion of the IWMF development expected by Q4 of 2021.

An operational life of up to 50 years is anticipated for the Project. Further information regarding project schedule and key milestones is provided in Chapter 4.

1.2 EIS Objectives and Scope

The key objective of the EIS is to gain government approval for the Project to proceed in an environmentally and socially acceptable manner. It aims to:

- Provide the necessary integration of the Project's social, economic and environmental factors into a sustainable development proposal.
- Identify and assess potential Project impacts, to propose appropriate mitigation and management measures for identified adverse impacts and to enhance beneficial effects.
- Allow government regulatory agencies and the Minister to make an informed decision on the relative benefits and residual impacts of the Project.
- Provide a tool for the Conservation and Environment Protection Authority (CEPA) to determine appropriate environment permit conditions under which the Project will operate.
- Provide Project information to the public and stakeholders.

An environmental inception report (EIR) for the Project was submitted to CEPA in August 2019. The EIR (approved on 18 October 2019) sets out the proposed EIS approach, studies and investigations. Based on the EIR, subsequent investigations and stakeholder engagements, the following categorises the key requirements of the EIS:

- Provision of a detailed description of all elements of Project activities occurring in Papua New Guinea, such as landfill design and construction, handling of hazardous wastes and unplanned events. The analysis also addresses workforce and accommodation, material transportation, utility requirements, such as energy and water supply and anticipated discharges, emissions and wastes.
- Identification of aspects of the Project that could have interactions with the environment and social impacts on the coastal community and other stakeholders.

- Collection, interpretation and analysis of environmental baseline data within the study area from secondary sources and through primary baseline studies and consultation.
- Identification and assessment of potential impacts from Project activities using various predictive tools and models.
- Adoption of appropriate standards and acceptable levels of impacts (both beneficial and adverse) on social and environmental values.
- Provision of public information on the need for the Project and its likely environmental effects and social outcomes.
- Proposed avoidance, mitigation and/or management measures for reducing/eliminating potential adverse environmental and social impacts and recommended mitigation measures in line with international good practice. Demonstration of how environmental and social impacts can be managed through the protection and/or enhancement of the environmental and social values.
- Preparation of a Construction Environmental and Social Management Plan (CESMP) to fulfil the management, monitoring and reporting requirements for the construction Project phase as required by CEPA.

1.3 Project Area and Environmental and Social Setting

Papua New Guinea is extremely diverse, both environmentally and culturally. It sits atop a collision point of several tectonic plates, known as the Pacific Ring of Fire, which has produced a rugged and heterogeneous volcanic landscape. Much of the country is covered in dense tropical forest which supports a high level of endemic flora and fauna. The Port Moresby area however is less humid than other areas of Papua New Guinea and characterised by a coastal savanna environment more similar to Northern Australia.

The existing IWMF site is located on a State Lease in Central Province and is within an industrial precinct in the Roku area, opposite the Avenell Engineering Systems (AES) Industrial Park, adjacent Fairfax Harbour. Approximately 8 hectares (ha) of additional land will be acquired for the expansion of the IWMF which will also be State Lease land. Roku village is located approximately 500 m southeast of the southern boundary of the site.

The region supports a tropical savanna climate and receives low, seasonal rainfall, influenced by the northwest monsoon and the southeast trade winds. Vegetation clearing has occurred to allow the growth of industrial operations, particularly towards the northeast, while savanna forest surrounds the site from the southeast to the west. Ephemeral watercourses in the form of drainage channels are present throughout the area, and flow intermittently into the adjacent marine environments, and groundwater availability is low. Fairfax Harbour is located to the east while Idlers Bay is located to the south.

Koita, or Koitabu, is the main language group in the study area, in addition to Motu. Over time, and as a result of intermarriage between the Koita and the Motu, traditional Koita practices have almost disappeared from daily life. Residents of Roku village continue to engage in subsistence practices, although to a lesser extent than many villages in rural Papua New Guinea. Over half of

Roku residents derive their income and livelihoods from formal employment, including at TWM and other businesses in the AES Industrial Park. Fishing is a daily activity; however, few residents maintain gardens (where cassava, banana and yam are grown) and hunting for wallabies is practiced only sometimes.

1.4 Potential Issues and Benefits

Aspects associated with commercial and industrial waste management facilities that can potentially impact the biophysical and socio-economic environment are well understood. The most significant of these relevant to the Project are:

- Atmospheric emissions and greenhouse gases (GHG).
- Odour.
- Noise generation.
- Traffic.
- Solid and liquid waste management.
- Spills and leaks.

While there will be some unavoidable impacts to the biophysical and socio-economic environment, the Project is expected to generate additional benefits for Papua New Guinea, which include:

- Enhancing economic opportunities, and skills development, for the local community and Papua New Guinea nationals.
- Supporting the development of a national workforce by enhancing employment opportunities, at the local and national level.
- Building of in-country capacity and knowledge in sustainable treatments for solid, liquid and hazardous waste management and services.

1.5 Development Purpose

The IWMF will be TWMs primary waste management facility and the first facility of its kind in Papua New Guinea. The Project development objective is to expand TWMs capacity in Papua New Guinea to receive, treat, recover, recycle and dispose of commercial and industrial wastes and hazardous contaminants to meet the current and future commercial and industrial waste management demands.

Expanding the IWMF capabilities to receive and manage additional waste types and complexities presents a potential new source of wealth generation for Papua New Guinea and an opportunity to address the uncontrolled stockpiling of such wastes, and the environmental and health risk associated with unlicensed waste storage and disposal. Papua New Guinea relies heavily on the international export for treatment and disposal of hazardous wastes, and the recycling of recovered waste materials. This reliance limits the growth potential in the nation's waste management sector where there is significant opportunity. The Project will also provide benefits to

the national, provincial and local economies through new business opportunities and will provide employment and training opportunities to Papua New Guineans.

2. Project History and Justification

2.1 Project History

TWM was established in 2010 and commenced the provision of waste and environmental services in 2011 from a warehouse located on Scratcheley Road in Badili, Port Moresby. In 2014, TWM received a letter of endorsement from the CEPA to operate a waste treatment facility for the collection, separation and storage of recyclable materials at the Badili warehouse. The majority of wastes were consolidated and exported for recycling.

In 2015 TWM invested in Papua New Guinea's first mobile WOPU and received approval from CEPA to operate the WOPU at the AES Industrial Park on Napa Napa Road under a Level 2 environmental permit (EP-L2 (485)). The WOPU was operated from the AES site (Portion 2493C) within the Industrial Park from 2016 to 2018 under a commercial lease agreement with AES. In 2018, driven by the need to expand operations, TWM purchased the State lease for land adjacent to the AES Industrial Park (State Lease Volume 67 Folio 21, Portion 2703), from Firewall Logistics (a catering and hospitality company), with 96 years remaining on the lease period. Previously the land had been used for a timber mill and timber treatment operation. The previous owner had a concept master plan for a residential housing development and had undertaken some site preparation by clearing much of the site and preparing a series of levelled benches.

The leased site is approximately 12.5 ha and forms part of a growing industrial precinct (yet to be zoned under the PNG *Physical Planning Act 1989*), with adjacent activities comprising construction, road building, domestic shipping port operations and other industrial services.

TWM transitioned its operations from Badili to the current site at the AES Industrial Park in 2018. Development of the IWMF commenced with the transfer of the WOPU from the previous location and storage of waste oils and hazardous wastes (for export) in an already constructed warehouse. The installation of a HT incinerator and incinerator building and fencing, hazardous waste storage building and bunded concrete pad for the WOPU followed in 2019 and early 2020. TWM are planning to further expand the site via two portions of land immediately adjacent to the IWMF site, which will be acquired through a State lease (see Section 4.1.3).

2.2 Project Objectives

The overarching Project objective is to construct and operate engineered infrastructure capable of sustainably storing, treating and disposing of industrial and commercial wastes, including hazardous wastes. Specifically, the Project aims to:

- Improve the safe and environmentally sustainable handling of waste materials including hazardous waste and reduce the current stockpiling of such materials in uncontrolled circumstances throughout Papua New Guinea.
- Address the current environmental and public health risks associated with unlicensed waste storage and disposal.

- Improve cost structures for the safe management of end of life hazardous materials for industry and government agencies.
- Build in-country capacity and provide local access to sustainable hazardous waste treatment and disposal services to reduce the current reliance on hazardous waste export.
- Expand Papua New Guinean exports of hazardous waste knowledge and capacity to provide hazardous waste services to other Pacific countries.
- Increase government tariff revenues through waste imports and provide reliable feedstock for IWMF development.
- Support the PNG Government in meeting its current and future obligations under a number of multilateral environmental agreements (e.g., Montreal Protocol, Stockholm Convention).

Supplementary objectives are to:

- Ensure compliance with all relevant national and local regulations and good industry practice.
- Ensure the Project delivers maximum benefits to Papua New Guinea with minimal impacts on affected communities and the environment.
- Maintain constructive relationships with key stakeholders.

2.3 Project Viability

The Asian Development Bank (ADB, 2014) estimates that Port Moresby alone generates around 135 tonnes of municipal solid waste per day, equivalent to over 50,000 tonnes per year. The waste is collected by 36 private contractors under contract to the National Capital District Commission. Solid waste from medical institutions, commercial facilities and sanitation and wastewater are collected by a single company (PRIF, 2018). However, the majority of the 63 settlements in Port Moresby are not serviced for solid waste collection (PRIF, 2018).

The only official municipal facility for the disposal of Port Moresby's waste is the Baruni disposal site; however, the Pacific Region Infrastructure Facility (PRIF) reports that PNG has over 21 unregulated disposal sites (PRIF, 2018). Further, ADB (2014) reports that medical wastes, while the responsibility of the Department of Health, are sometimes not incinerated (due to public incinerators having ceased to function and a lack of funds for replacements) and are buried in pits.

In 2014, formal recycling services in Papua New Guinea comprised two commercial recycling operators in Port Moresby, that collect, process, store, and ship nonferrous metals to foreign ports. Recyclable nonferrous metals and used batteries are exported to Australia, the Republic of Korea, and Singapore. Informal, household, and community recycling is also practiced, including the use of food waste as animal feed; and reuse of materials such as plastics. Waste pickers work in dangerous and unhealthy conditions, at the Baruni disposal site and other dumping grounds, sorting through piles of garbage to segregate and recover recyclables (ADB, 2014).

The IWMF is designed to consolidate and manage wastes in-country, in accordance with the waste management hierarchy and internationally recognised standards (see Chapter 3). Little or no infrastructure of the type proposed by TWM currently exists within the Pacific region outside of Australia and New Zealand, which is where Pacific Island countries usually send their hazardous wastes and recycling. Expanding the operations of the IWMF develops in-country capacity to recover, recycle and treat waste materials and dispose of hazardous contaminants in an environmentally sustainable manner, reducing the current dependence on export arrangements for off-shore treatment and disposal, and providing centralised services to government, commercial and industry sectors, located throughout Papua New Guinea. This will establish Papua New Guinea as a regional hub location for the sustainable treatment, recycling and disposal of recovered materials and hazardous wastes.

Further, the future development and expansion of resource projects in Papua New Guinea will increase the demand for sustainable industrial and commercial waste treatment and disposal services, and the expanded IWMF will help meet this demand in-country.

2.3.1 Location Viability

The location of the IWMF at Napa Napa provides low transport costs from Port Moresby and positions the facility adjacent to a number of medium to large scale private sector commercial activities which are gradually and collectively forming an industrial precinct, and which TWM services. The addition of hazardous waste management facilities at the existing IWMF enables TWM to leverage existing infrastructure at the facility, suitable access (by Napa Napa Road and via the nearby port) and has been informed by the baseline studies conducted on geology, hydrology, biodiversity, land use and socio-economic factors. Refer to Chapter 4 and 5 for the criteria used to inform site selection.

2.3.2 Financial Viability

The cost of the expansion of the existing IWMF is primarily captured under the existing Level 2 environment permit which approves the construction and operation of a hazardous waste storage facility, incineration plant, wastewater treatment plant, recycling and composting facilities and quarrying activities. The estimated total development budget is PGK 30 million which based on business and return on investment modelling, makes the full development financially viable.

The Project proposes to expand the scope of the feedstock to be received, recovered, recycled, treated and disposed of at the IWMF to include hazardous wastes, e-waste and plastics. TWM have identified both operational gains and economic efficiencies to be achieved through maximising the volume of feedstock through the IWMF, which will be sourced from within Papua New Guinea and (pending government approval) from neighbouring countries, predominantly in the western and northern Pacific Region.

2.3.3 Community Support

TWM has been engaging with customary landowners, via the Ohobiduduare Holdings Ltd Incorporated Landowner Group (ILG) and Roku village residents since 2018. TWM provide support for community events and programs and the community has generally been very supportive of TWMs operations.

Landowners have maintained long held relationships with some of the industrial companies on Napa Napa Road, having leased land parcels to a number of operators over the years, enabling the growth of the industrial precinct. TWM has been working with the landowner company to acquire additional land to support the IWMF expansion. The land has been transferred from customary land to State lease and ownership will be transferred to TWM.

During the collection of data to support the environmental and socio-economic baseline study, Roku village leaders and the Women's Fellowship were asked whether they supported the proposed IWMF expansion, and whether they had any concerns about the development. The community saw the benefits of the Project as increased employment and the potential for improved waste management in the village itself. Concerns were raised around odour and the potential for hazardous contaminants to enter the groundwater and further community engagement will seek to provide information, including the management measures proposed, to avoid or mitigate these potential issues and alleviate any residual concerns (see Chapter 6).

2.3.4 Consistency with Papua New Guinean Policy and Strategy

The Project is consistent with the Papua New Guinea Constitution and various PNG government policies and strategies as described in Table 2.1.

Table 2.1 – Project Alignment with PNG Policies and Strategies

National Policy or Strategy	Goals and Targets	Project Alignment
PNG Constitution	The fourth goal of the PNG Constitution states that natural resources and the environment are to be conserved and used for the collective benefit of us all and be replenished for the benefit of future generations The three directive principles beneath this goal are: • Wise use to be made of our natural resources and the environment in and on the land or seabed, in the sea, under the land, and in the air, in the interests of our development and in trust for future generations • The conservation and replenishment, for the benefit of ourselves and posterity, of the environment and its sacred, scenic, and historical qualities • All necessary steps to be taken to give adequate protection to our valued birds, animals, fish, insects, plants and trees	The Project meets the intent of the fourth goal of the PNG Constitution firstly through avoiding, minimising or mitigating potential adverse environmental impacts. Secondly, the Project aligns with the fourth goal through the improvement of sustainable waste management practices in Papua New Guinea which will help reduce the risk of waste contaminating surface water, groundwater, soils or the marine environment
Vision 2050 (NSPT, 2009)	Papua New Guinea's strategic direction is to develop and grow the manufacturing, services, agriculture, forestry, fisheries and eco-tourism sectors from 2010 to 2050	The Project meets the intent of Vision 2050, as TWM is a PNG-registered and owned business, with Papua New Guineans comprising approximately 85% of its workforce; many of whom are

National Policy or Strategy	Goals and Targets	Project Alignment
	An objective of the strategy is to 'create more business opportunities for citizens', by increasing productivity of import competing businesses	recruited from communities around Napa Napa One of the Project's objectives is to reduce the current reliance on hazardous waste export, and to import wastes from neighbouring countries to increase feedstock and improve the in-country management of those wastes
National Strategy for Responsible Sustainable Development (StaRS) (DNPM, 2014)	The strategy promotes economic growth driven by sustainable clean energy and resource use where carbon emissions and pollution are reduced, and energy efficiency is enhanced	The Project is very well aligned with the core goals of STaRS as it supports a reduction in pollution by providing waste facilities and services designed to shift waste from unregulated, poorly managed dumps into a facility that is designed and operated to international standards
Papua New Guinea Development Strategic Plan 2010-2030 (DNPM, 2010)	The strategic plan sets out the framework to achieve the government's targets and strategies, particularly those outlined in Vision 2050. Two goals within the plan relevant to the Project include: • Develop partnerships between the Government and the private sector to provide services and public infrastructure • Develop and promote small and medium enterprises (SME) in Papua New Guinea	The Project has the following objectives that support the intent of the strategic plan: • Improve cost structures for the safe management of end of life hazardous materials for industry and government agencies • Increase government tariff revenues and provide reliable feedstock for IWMF development • Support the Government in meeting its current and future obligations under a number of multilateral environmental agreements TWM is a PNG-registered and owned SME
Medium Term Development Plan (MTDP) III 2018-2022 (DNPM, 2018)	The overarching goal of the 2018–2022 development plan is to increase investment in the economic sector to stimulate broad based economic growth. The plan identifies eight Key Result Areas (KRAs) that are translated to specific sector strategies and deliverables for the national economy and community The following KRAs are particularly relevant to the Project: • KRA 5 (Improved Service Delivery) focuses on strategic investments in district hospitals, court houses, police stations, markets, district communities and other social and economic facilities • KRA 7 (Responsible Sustainable Development) includes a target to improve waste management in all provinces	The Project aligns with the MTDP III through delivering strategic private sector investment in waste facilities, which will support government delivered services, and improves the management of waste across multiple provinces

National Policy or Strategy	Goals and Targets	Project Alignment
United Nations (UN) Sustainable Development Goals	The 17 Sustainable Development Goals provide a roadmap for countries to improve health and education, reduce inequality and promote economic growth. Two of the goals in particular are revenant to the Project: Goal 6: Clean Water and Sanitation • By 2030, improve water quality by reducing pollution, eliminating dumping and minimising release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally Goal 9: Industry, Innovation and Infrastructure • By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities	The Project showcases the adoption of green technologies to improve resource-use efficiency and will provide in-country alternatives to unregulated dumping or stockpiling of waste, minimising the potential for hazardous materials to be released into the environment
Draft National Waste Management Policy	The draft National Waste Management Policy sets out a series of objectives to improve waste management in Papua New Guinea. These objectives are focused around: • Strengthening governance • Sharing the responsibility of waste management throughout the manufacture/import-supply-consumption chain • Developing integrated waste management systems throughout Papua New Guinea • Removing barriers to recycling • Safely handling hazardous wastes • Establishing a reliable waste management information system • Empowering people and corporations to make informed decisions about use and consumption of materials	The Project supports several of these objectives; in particular through shared responsibility, the development of integrated waste management and information systems, and the safe handling of hazardous wastes

2.4 Project Impacts and Benefits

Chapters 10 and 11 outline the potential environmental and socio-economic impacts and benefits associated with the Project. The potential environmental impacts are associated with a small area

of land clearing, the potential for pests and weed incursions, noise and air emissions, localised changes to landform stability and soil capacity, and the potential for wastes transported to, stored and treated at the IWMF to be released into the surrounding local environment (i.e., soils, surface water or groundwater). All potential impacts can be adequately managed through the adoption of embedded design controls and mitigation measures. Environmental residual impacts are all assessed as either ***Minor*** or ***Negligible*** given the mitigation measures proposed, and operational noise and air emissions as modelled will meet compliance standards. Localised impacts are further offset by the benefits associated with addressing the poor storage of hazardous wastes, stockpiling of legacy wastes and unlicensed disposal practices that currently exist in Papua New Guinea, which pose risks to human health and the environment.

Most socio-economic impacts are likely to be ***Positive***, providing local communities with increased employment, training and business opportunities (i.e., as contractors or suppliers), both during construction and longer term during the operations phase. The design of the IWMF to international standards, and the sustainable waste management practices adopted reduce the risk of waste contaminating surface water, groundwater, soils or the marine environment, which underpins community livelihoods in the area. As a socially responsible company, TWM will also continue to work alongside Roku village to identify and invest in opportunities that build capacity and support improved health, education and economic outcomes for these communities.

Potential adverse impacts include reduced local amenity (through increased noise, odour, dust or litter leaving the IWMF boundaries), and an increase in traffic during construction and operations which may cause localised and temporary congestion of traffic using Napa Napa Road and increase the potential for traffic-related accidents. Residual impacts are all assessed as either ***Minor*** or ***Negligible*** given the mitigation measures proposed.

2.5 References

ADB. 2014. Solid Waste Management in the Pacific. Papua New Guinea Country Snapshot. Asian Development Bank. Philippines.

DNPM. 2010. Papua New Guinea Development Strategic Plan 2010-2030. Department of National Planning and Monitoring, Port Moresby, Papua New Guinea.

DNPM. 2014. National Strategy for Responsible Sustainable Development for Papua New Guinea – A Paradigm Shift: Addendum to the Development Strategic Plan 2010 – 2013. Report prepared by the Department of National Planning and Monitoring, Waigani, Papua New Guinea.

DNPM. 2018. Papua New Guinea Medium Term Development Plan III 2018-2022. Department of National Planning and Monitoring, Port Moresby, Papua New Guinea.

NSPT. 2009. Papua New Guinea Vision 2050. National Strategic Plan Taskforce, Port Moresby, Papua New Guinea.

PRIF. 2018. Papua New Guinea Country Profile. Pacific Region Infrastructure Facility. C/O Asian Development Bank, Sydney, Australia.

3. Regulatory Framework, Policies, Standards and Guidelines

3.1 Introduction

This Chapter describes the main laws, regulations and policies applicable to the IWMF Project and good practice standards and guidelines that have informed the preparation of this document, namely:

- Papua New Guinea legislation and CEPA's guidelines and codes of practice.
- Papua New Guinea ratified conventions relevant to waste management activities.
- TWM environmental and social policies and procedures.

The chapter addresses the legislative and administrative framework for the proposed construction and operations activities for the IWMF Project.

3.2 Papua New Guinean Authorities and Legislation

There is no specific legislation relating to waste management facilities in Papua New Guinea, instead the sector is primarily governed by broader environmental management legislation, the *Environment Act 2000* being the principal legislation as described below. Other applicable legislation is summarised in Section 3.2.3.

3.2.1 *Environment Act 2000*

The *Environment Act 2000* (Environment Act) (and *Environment (Amendment) Act 2002* and *Environment (Amendment) Act 2014*) is Papua New Guinea's principal legislation governing protection of the environment. The Environment Act, and the supporting *Environment (Prescribed Activities) Regulations 2002*, provides the legal framework for regulating the potential environment and socio-economic impacts of a project. The regulation classifies activities as either Level 1, 2 or 3 activities, depending on the extent to which they will impact the environment. CEPA is the lead PNG government agency responsible for administering the provisions of the Environment Act. CEPA has replaced the previous PNG Department of Environment and Conservation (DEC) with the passing of the *Conservation and Environment Protection Authority Act 2014*.

3.2.1.1 Environmental Impact Statement

To determine the application of the Environment Act to the proposed IWMF Project, TWM submitted a notice of intention (NOI) to carry out preparatory works and an environment permit application to CEPA outlining the proposal to further develop the infrastructure and operations of the IWMF to expand the feedstock that is currently approved under TWMs environment permit (EP-L2 (485)), as amended, to include materials that are defined as hazardous waste under provisions contained within Section 133 of the *Environment (Amendment) Act 2014*. Advice was provided by CEPA in May 2019 that the activity falls under Schedule 2, Level 3 Activities, of the *Environment (Prescribed Activities) Regulation 2002*, Sub-category 21.2: Waste Disposal, Construction of commercial sites for the storage, treatment, reprocessing, incineration or disposal of hazardous contaminants. The activity therefore requires the preparation of an EIS.

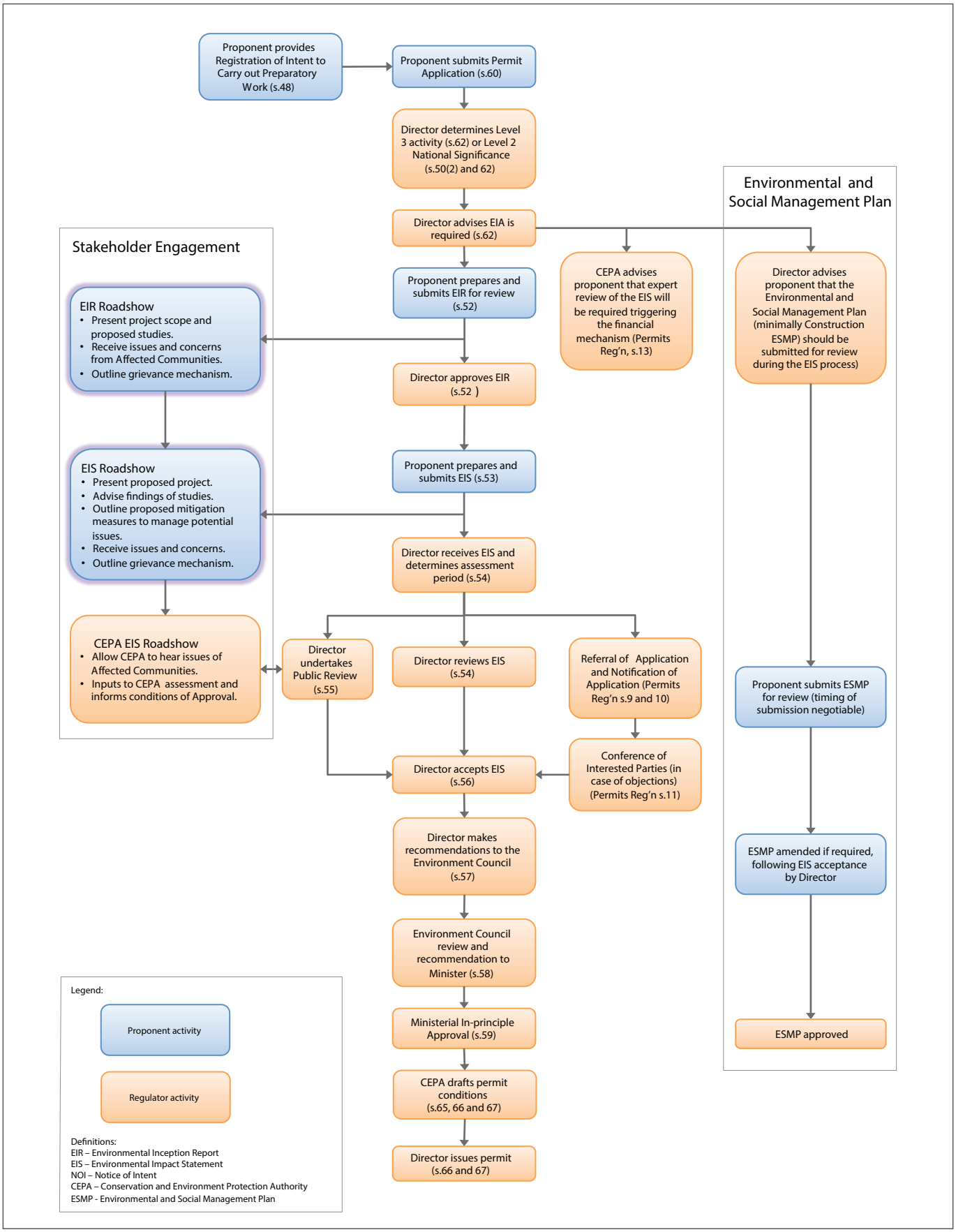
The key steps in the EIS process in support of an environment permit application are outlined below and in Figure 3.1.

- The proponent prepares and submits to CEPA an EIR (Section 52). The EIR provides terms of reference for the EIS and includes a preliminary description of the project and details the scope of the environmental and social investigations and studies that will be undertaken to prepare the EIS. An EIR was submitted to CEPA in August 2019 and was approved in October 2019.
- The proponent undertakes the environmental and social (including health, culture, and ecosystem services (i.e., land and natural resource use)) studies program and prepares the EIS as required under Section 53 (this document).
- Formal assessment of the final as submitted EIS by CEPA. This process involves the following steps:
  - CEPA receives and within 30 days formally accepts the EIS for assessment and determines the likely assessment period (Section 54 (2)).
  - CEPA reviews the EIS (Section 54) and undertakes public review (Section 55) and road shows to landowners/affected communities, and a formal (and separate) site visit by CEPA.
  - Upon acceptance of the EIS (Section 56), the Director has 14 days to recommend the EIS to the Environment Council (Section 57).
  - The Environment Council reviews the Director's recommendation and the EIS and within 90 days makes a recommendation to the Minister (Section 58).
  - Subject to receiving the recommendation from the Environment Council, the Minister has 28 days to grant approval in-principle (Section 59).

PAPUA NEW GUINEA ENVIRONMENTAL APPROVALS PROCESS

Integrated Waste Management Facility | Environmental Impact Statement

FIGURE 3.1



3.2.1.2 Stakeholder Engagement

Section 55 of the Environment Act sets out the requirements for stakeholder engagement for the EIS, including requirements for the proponent (TWM) to make the Draft EIS available for public review, to publicly present the findings of the Draft EIS to affected stakeholders and to clearly incorporate issues raised during the impact assessment and public review of the Draft EIS into the Final EIS.

3.2.2 CEPA Guidelines and Relevant Codes of Practice

CEPA has published several guidelines to assist prospective projects regarding environmental and socio-economic assessments. These include specific baseline characterisation requirements as stipulated in the Guideline for Conduct of Environmental Impact Assessment & Preparation of Environmental Impact Statement (GL-Env/02/2004) (DEC, 2004a). Attachment 1 identifies where each requirement of the guideline has been addressed in this EIS.

The following guidelines and codes of practice are also applicable to the Project:

- Technical Guideline (Additional Information) for Air Discharges (DEC, 2004b).
- Technical Guideline (Additional Information) for Noise Discharges (DEC, 2004c).
- Technical Guideline (Additional Information) for Water & Land Discharges (DEC, 2004d).
- Environmental Code of Practice for Vehicle/Machinery Workshops and Petroleum (hydrocarbons), Storage/Resale/Usage Site 1997 (DEC, 1997).
- Environmental Code of Practice for Sanitary Landfill Sites (DEC, 2001).
- Draft Environmental Guideline for Sewage Treatment and Disposal (DEC, 2009).

3.2.3 Other Papua New Guinea Legislation

In addition to the *Environment Act 2000*, the following Papua New Guinea legislation may also apply to the Project:

- *Environment (Prescribed Activities) Regulation 2002*.
- *Environment (Water Quality Criteria) Regulation 2002*.
- *Fauna (Protection and Control) Act 1966 and Fauna (Protection and Control) (Amendment) Act 2014*.
- *Public Health Act 1973* and the *Public Health (Sanitation and General) Regulation 1973*.
- *National Water Supply and Sanitation Act 2016*.
- *Environmental Contaminants Act 1978.*
- *Environmental Contamination (Pesticides) Regulations 1988*.
- *Water Resources Act 1982*.

- *Industrial Safety, Health and Welfare Act 1961*.
- *Inflammable Liquid Act 1953*.
- *Building Act 1971*.
- *National Cultural Property (Preservation) Act 1965*.
- *National Museum and Art Gallery Act 1992*.
- *Organic Law on Provincial Governments and Local Level Government 1995*.
- *Customs Act 1951*.
- *Plant Disease and Control Act 1953.*
- *Road Traffic Act 2014.*
- *War Surplus Materials Act 1952.*
- *Cemeteries Act 1955.*
- *Discriminatory Practices Act 1963.*
- *Employment Act 1978 and the Employment Regulation 1980.*
- *Employment of Non-citizens Act 2007,* the *Employment of Non-citizens (Amendment) Act 2013* and the *Employment of Non-citizens Regulation 2008.*

3.3 Ratified Conventions and Other Agreements

Table 3.1 lists the international conventions that have been ratified by the PNG Government and may be relevant to the Project. In general, these conventions are effective in local law only after implementing legislation has been enacted in a signatory country. Elements of these conventions may relate to managing the Project's environmental and social impacts in those instances where the PNG Government has passed local laws to fulfil its statutory obligations.

Table 3.1 – Conventions and Other Agreements Ratified by Papua New Guinea

Instrument	Description/Objective	Relevance
Conservation and Biodiversity		
International Plant Protection Convention (1952) with associated Plant Protection Agreement for the Asia and Pacific Region (1956) as amended	The convention promotes international cooperation to control the introduction and spread of pests and diseases of plants and plant products	Construction and operational hygiene and minimising disturbance
Convention on Biological Diversity (1992)	The convention covers conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising from using genetic resources, including sharing by appropriate access to genetic resources; and by appropriate transfer of relevant	Minimising Project impacts on biodiversity

Instrument	Description/Objective	Relevance
	technologies, taking into account all rights over those resources and to technologies; and by appropriate funding	
Convention for the Protection of the Natural Resources and Environment of the South Pacific Region related Protocols	The convention obliges parties to endeavour to take all appropriate measures to prevent, reduce and control pollution from any source and to ensure sound environmental management and development of natural resources, using the best practicable means at their disposal	Minimising pollution resulting from Project activities
Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) (1979)	The convention aims to conserve terrestrial, marine and avian migratory species throughout their range. It is an intergovernmental convention concerned with conserving wildlife and habitats on a global scale	Minimising Project impacts on migratory species
Convention Concerning the Protection of World Cultural Heritage and Natural Heritage (1972)	The convention is aimed at the protection of indigenous cultural and environmental heritage	Managing Project impacts on cultural heritage sites, traditions and natural features
Pollution Prevention		
The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	The convention's objective is to protect human health and the environment against the adverse effects of hazardous wastes, through encouraging reduced generation of hazardous wastes, environmentally sound waste management, and restriction and regulation of transboundary hazardous wastes movements	Minimising and managing hazardous wastes resulting from Project activities
The Waigani Convention to Ban the Importation into Forum Island Countries of Hazardous and Radioactive Wastes and to Control the Transboundary Movement of Hazardous Wastes within the South Pacific Region	The convention aims to 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	Minimising and managing the generation and transport of hazardous waste
The Stockholm Convention on Persistent Organic Pollutants (POPs) (2001)	The convention aims to protect human health and the environment from a range of POPs, via requiring signatories to ban the production, use, import and export of these. The convention also requires waste management to reduce or eliminate releases of POPs into the environment	Avoiding the use of POPs and minimise release to the environment
Vienna Convention for the Protection of the Ozone Layer (the Vienna Convention) and the Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol)	The Vienna Convention provides the framework for international cooperation in addressing ozone depletion while the Montreal Protocol is designed to stop the production and import of ozone depleting substances and reduce their concentrations in the atmosphere	Compliance with Papua New Guinea's requirements under the conventions

Instrument	Description/Objective	Relevance
Emissions and Climate Change		
United Nations Framework Convention on Climate Change (1992)	The convention aims to 'stabilise GHGs concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'. It focuses on reducing negative changes to the earth's climate, with a particular focus on GHGs. It places the onus on industrialised countries to reduce emissions	Minimising Project contributions to GHG emissions
Labour		
International Labour Organization conventions (1976 – 2000)	These conventions collectively provide protection to workers against anti-union discrimination and encourage collective bargaining. They aim to suppress the use of forced labour in all its forms, set a minimum age for employment and support action against child labour, encourage equal remuneration for men and women, and consider the rights of migrant workers	Respecting worker's rights in employment of local and international workers
UN Convention on the Rights of the Child, Article 32.1	This human rights convention sets out the civil, political, economic, social, health and cultural rights of children. The convention defines a child as any human being under the age of eighteen, unless the age of majority is attained earlier under a state's own domestic legislation	
UN Convention on the Protection of the Rights of all Migrant Workers and Members of their Families	The convention takes into account the principles embodied in the basic instruments of the UN concerning human rights and those of the International Labour Organization. The convention defines a migrant worker as 'a person who is to be engaged, is engaged or has been engaged in a remunerated activity in a State of which he or she is not a national'	
Human and Civil Rights		
International Covenant on Civil and Political Rights (1966)	The covenant recognises that the inherent dignity and the equal and inalienable rights of all members of the human family are the foundation of freedom, justice and peace in the world	Providing opportunities for men and women from all races, backgrounds and abilities
International Covenant on Economic, Social and Cultural Rights (1966)	The covenant commits its parties to work toward the granting of economic, social, and cultural rights to the Non-Self-Governing and Trust Territories, and individuals, including labour rights and the right to health, the right to education, and the right to an adequate standard of living	Providing opportunities for men and women from all races, backgrounds and abilities are provided by the Project
Convention on the Elimination of All Forms of Discrimination Against Woman (1979)	The convention takes an important place in bringing women into the focus of human rights concerns. The spirit of the convention is rooted in the goals of the UN	
International Convention on the Elimination of All Forms	The convention proclaims that everyone is entitled to all the rights and freedoms set out	

Instrument	Description/Objective	Relevance
of Racial Discrimination (1965)	therein, without distinction of any kind, in particular as to race, colour or national origin	
Convention on the Rights of Persons with Disabilities (2006)	The convention is intended to protect the rights and dignity of persons with disabilities. Parties to the convention are required to promote, protect, and ensure the full enjoyment of human rights by persons with disabilities and ensure that they enjoy full equality under the law	

3.4 TWM Corporate Standards and Policies

The IWMF operations will comply with TWMs quality, health, safety and environment (QHSE) policies including:

- TWM Quality Policy, February 2020.
- TWM Environmental Policy, June 2019.
- TWM Workplace Health and Safety Policy, February 2020.
- Environment Complaints Procedure (TWM-OI-56), May 2020.
- Grievance Handling Policy, October 2016.
- Grievance and Complaint Handling (TWM-OI-61), May 2020.

3.5 Industry Standards, Guidelines and Codes of Practice

The following industry standards, guidelines and codes of practice are also relevant to the Project:

- AS3780-2008 Storage and handling of corrosive substances (Standards Australia, 2009).
- Code of Federal Regulations, Title 40, protection of environment. Volume: 26 Part 264 standards for owners and operators of hazardous waste treatment, storage and disposal facilities (US EPA, 2014).
- AS1940 – The storage and handling of flammable and combustible liquids (bunding) (Standards Australia, 2017).
- ANZECC/ARMANZ guidelines for fresh and marine water quality (ANZECC/ARMANZ, 2000).
- Australian and New Zealand guidelines for fresh and marine water quality (ANZG, 2018).
- Revised ANZECC/ARMCANZ sediment quality guidelines (Simpson et al., 2013).
- General environmental, health and safety guidelines for noise (IFC, 2007a).
- National Environment Protection (Ambient Air Quality) Measure (DoE, 2016).

- World Health Organization (WHO) guidelines for drinking water quality (WHO, 2011).
- WHO air quality guidelines (WHO, 2006).
- WHO guidelines for community noise (WHO, 1999).
- Techniques for Effective Public Participation, International Association for Public Participation (IAP2, 2011).
- Stakeholder Engagement: A Good Practice Handbook for Companies Doing Business in Emerging Markets, International Finance Corporation (IFC) (IFC, 2007b).
- Environment Management ISO 14001 – 2015.
- Quality Management ISO 9001 – 2015.
- Occupational Health and Safety OHSAS 18001 – 2017.
- National Greenhouse and Energy Reporting (NGER) (Measurement) Determination 2008 as amended 1 July 2020.
- National NGER technical guidelines (DoEE, 2017).

3.6 References

ANZECC/ARMCANZ. 2000. Australia and New Zealand guidelines for fresh and marine water quality. April. Australian and New Zealand Environment and Conservation Council/Agricultural and Resource Management Council of Australian and New Zealand. Canberra, ACT.

ANZG. 2018. Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra, ACT.

DEC. 1997. Environmental Code of Practice for Vehicle/Machinery Workshops and Petroleum Storage/Resale/Usage Sites. Department of Environment and Conservation. Waigani, Papua New Guinea.

DEC. 2001. Environmental Code of Practice for Sanitary Landfill Sites. PNG Department of Environment and Conservation, Port Moresby.

DEC. 2004a. Guideline for Conduct of Environmental Impact Assessment and Preparation of Environmental Impact Statement (GL-ENV/02/2004). PNG Department of Environment and Conservation, Port Moresby.

DEC. 2004b. Technical Guideline (Additional Information): Air Discharges (IB-ENV/02/2004). PNG Department of Environment and Conservation, Port Moresby.

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4. Project Description

4.1 Project Overview

TWM is proposing to further develop and extend the existing infrastructure and operations of the IWMF to expand the waste types and complexities able to be processed and treated at the facility. These include solid, liquid and intractable wastes and wastes defined as hazardous contaminants under Section 133 of the *Environment (Amendment) Act 2014* and as specified under United States Environment Protection Agency (US EPA) Standards (see Section 4.4). The Project involves the construction, extension and operation of waste management infrastructure capable of receiving, treating, storing and disposing such additional wastes at the IWMF.

Based on current estimates, the Project will handle up to 150,000 tonnes of commercial and industrial waste per year over a facility life of up to 50 years, at an approximate capital cost of PGK30 million. Development will proceed using industry standard methods that are environmentally and socially responsible and acceptable, technologically achievable, economically viable and are consistent with Papua New Guinea legislation and obligations.

Several activities included in the proposed development of the IWMF are already permitted under EP-L2 (485) as Level 2 activities. However, in order to facilitate the extension of the IWMF to receive and manage additional waste types and complexities including hazardous waste types, TWM requires approval under a Level 3 environmental permit.

For completeness and to inform the impact assessment, this chapter describes components of the IWMF development that are already approved for construction and operation as well as additional aspects not currently approved. Clarification is provided throughout with regard to activities relevant to this EIS.

4.1.1 Project Activities

Project activities, which have been grouped into construction and operations phases, are summarised below and described in further detail in later sections of this chapter. The key Project components and activities described in this chapter are:

- Expansion of feedstock materials (i.e., waste materials for treatment) utilised and processed in the handling, storage, treatment and disposal of waste at the IWMF.
- Construction of engineered infrastructure capable of receiving and managing hazardous waste, including waste types and complexities additional to those approved under EP-L2 (485).

The main Project components that will form the IWMF will include the following:

- Weighbridge and receival hall (Section 4.5.1).
- Waste sorting and segregation facility (Section 4.5.2).

- Recycling, composting, beneficial reuse and resource recovery operations (Section 4.5.3).
- Incineration plant (Section 4.5.4).
- WOPU (Section 4.5.5).
- Industrial cleaning services (Section 4.5.6).
- Fixation bays (Section 4.5.7).
- Domestic wastewater treatment plant (WWTP) and industrial wastewater treatment plant (IWWTP) (Section 4.5.8).
- Quarrying (Section 4.5.9).
- Industrial landfill activities (Section 4.5.10).
- Hazardous waste storage (Section 4.5.11).
- Stormwater management system (Section 4.5.12).

The layout of the IWMF site and the location of these components are shown in Figure 4.1, and the various Project components and activities are described in Section 4.5.

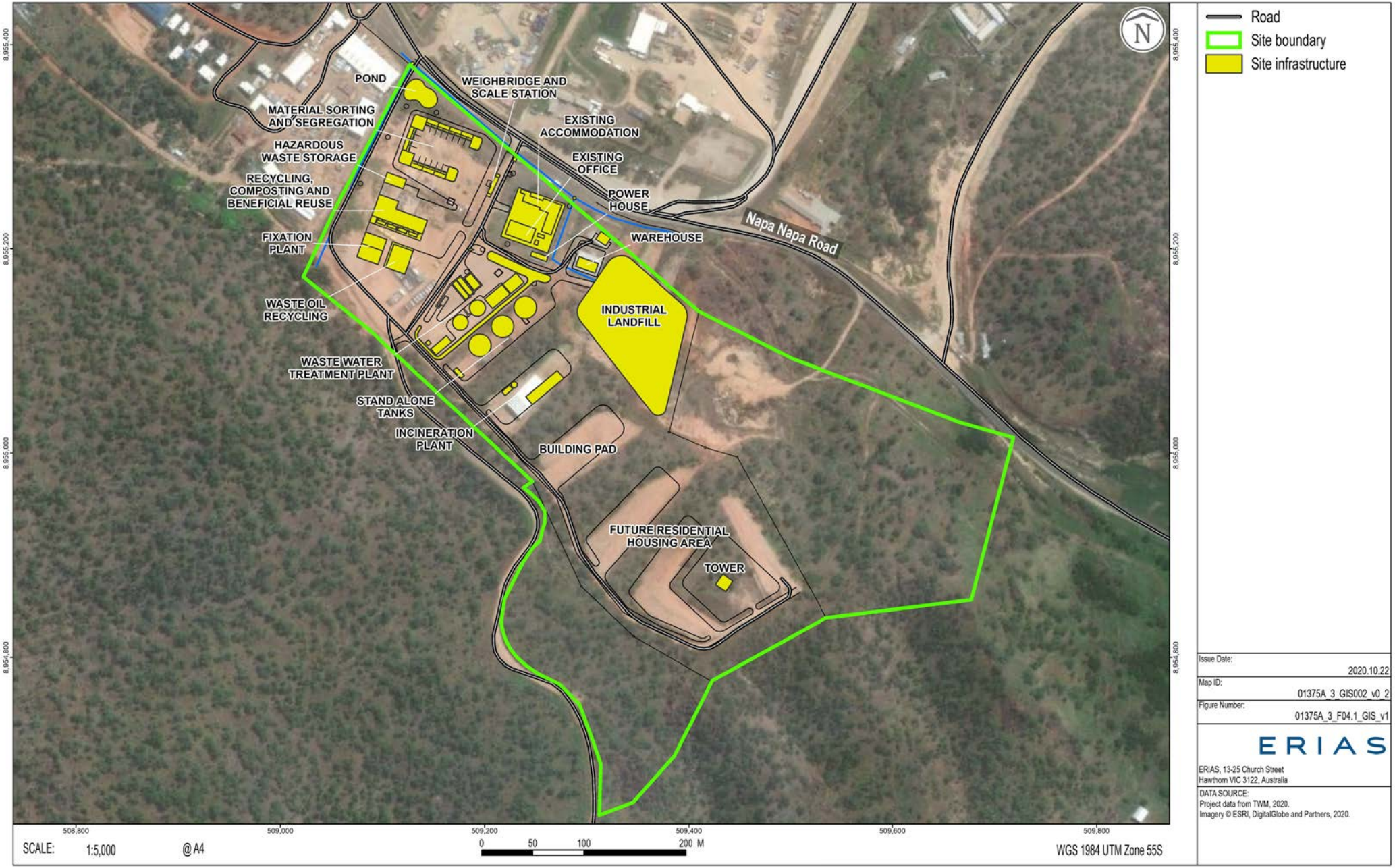
To date, the incinerator and the WOPU have been commissioned and are operational, and the hazardous waste storage facility has also been constructed and is currently used for storing wastes for export. Design has been completed for the industrial landfill, and construction has commenced for the industrial services wash bays and fixation bays.

This chapter presents the current concept for the Project, and while this information is correct at the time of preparation of this document, aspects may change as further detailed engineering studies are completed. The main Project components as outlined in the following sections are likely to remain fundamentally similar; however, any material changes may require reassessment in the context of this EIS.

IWMF SITE LAYOUT

Integrated Waste Management Facility | Environmental Impact Statement

FIGURE 4.1



Issue Date: 2020.10.22

Map ID: 01375A_3_GIS002_v0_2

Figure Number: 01375A_3_F04.1_GIS_v1

ERIAS, 13-25 Church Street
Hawthorn VIC 3122, Australia

DATA SOURCE:
Project data from TWM, 2020.
Imagery © ESRI, DigitalGlobe and Partners, 2020.

4.1.2 Scope of Project Requiring Level 3 Approval

Several activities and components of the IWMF listed in Section 4.1.1 are already approved under TWMs existing Level 2 environment permit EP-L2 (485), either in regard to construction or operation and receival and treatment of wastes. Table 4.1 identifies the IWMF components that are currently permitted under EP-L2 (485), and therefore outside of the scope of this EIS, and the components that require approval under a Level 3 permit and are therefore within the scope of this EIS. As indicated in Table 4.1, much of the infrastructure already approved for construction and operation under the existing permit is yet to be constructed.

As shown in Table 4.1, the only construction activity considered in this EIS relates to the construction of the industrial landfill. All other construction activities related to the development of the components listed in Table 4.1 are already approved under the existing Level 2 permit and are therefore out of scope for this EIS.

While EP-L2 (485) permits the incineration, reprocessing, treatment or disposal of biomedical waste, including 2019 novel coronavirus disease (COVID-19) waste, TWM may receive radiotherapy wastes which could be classed as a hazardous waste, rather than biomedical waste. In this case, this activity would require approval under a Level 3 permit; however, TWM have been advised that CEPA and the health authorities are in discussions regarding the classification of this waste type. The receiving and handling of radiotherapy waste has been broadly considered in the EIS.

Table 4.1 – IWMF Plant and Activities Requiring Level 3 Assessment

IWMF Component	Level 2 Permit Status	Construction/Operations Status	Additional Activities Requiring Level 3 Permit	Relevance to the EIS
Weighbridge and receival hall	Approved	Not constructed	Extension of wastes received to additional hazardous and non-hazardous wastes	All waste received will pass through the weighbridge and e-wastes and plastics for reprocessing will be received at the receival hall
Waste sorting and segregation facility	Approved	Not constructed	Extension of wastes handled to include e-wastes and plastics for reprocessing	Sorting and segregating e-waste and plastics for reprocessing
Recycling	Approved	Not constructed	E-waste dismantling and plastics reprocessing	Handling of e-waste and plastics reprocessing during operations
Composting	Approved	Not constructed	None	Not assessed
Incineration plant	Approved	Operational	Extension of wastes incinerated to include additional hazardous wastes	Incineration of additional waste streams during operations
Waste oil processing unit	Approved	Operational	None	Not assessed
Fixation bays	Approved	Commenced construction	Treatment of additional hazardous wastes	Fixation of additional waste streams during operations
Industrial cleaning services	Approved	Commenced construction	None	Not assessed
Domestic wastewater treatment plant/industrial wastewater treatment plant	Approved	Not constructed	Extension of industrial waste types to be treated	Treatment of additional hazardous and industrial liquid wastes in the industrial wastewater treatment plant
Quarrying	Approved	Not yet operational	None	Not assessed
Industrial landfill	Not approved (construction and operation of landfill for municipal waste approved which would	Not constructed	Construction and operation of industrial waste landfill	Construction and operation of industrial waste landfill

IWMF Component	Level 2 Permit Status	Construction/Operations Status	Additional Activities Requiring Level 3 Permit	Relevance to the EIS
	also include pre-construction activities required for industrial andfill construction)			
Hazardous waste storage	Approved	Operational for storage of hazardous wastes for export under Australian import permits	Extension of hazardous contaminants to be stored ahead of treatment and/or export	Handling and storage of additional wastes during operations
Stormwater management system	Approved	Commenced construction	None	Not assessed but included in EIS for mitigation of potential impacts associated with Level 3 activities

4.1.3 Land Acquisition

Two portions of land immediately adjacent IWMF site will be acquired from local landholders to facilitate the extension of IWMF operations. The land has been transferred from customary land to State lease and ownership will be transferred to TWM. The first land parcel is located within and adjacent to the former quarry, located adjacent to the northeast site boundary (see Figure 4.1). The area is approximately 5.56 ha and part of this land will be used for the construction and operation of the industrial landfill and ancillary infrastructure. The second area is approximately 2.45 ha and is located along the access road to Roku village in the south of the IWMF site (see Figure 4.1). This area may be used for future development but this is outside of the scope of this EIS and such development would be subject to a separate approvals process.

4.1.4 Landfill Construction

As described in Section 4.1.2, the only construction activity requiring assessment in the EIS is the construction of the industrial waste landfill. Previous quarrying works have excavated an area suitable for the construction of the initial cell of the landfill. Pre-construction activities and site preparation will include general earthworks and civil works to be undertaken prior to construction of the landfill cells (Section 4.5.10.2). The landfill will be constructed with a leachate collection system, engineered lining, landfill stability, surface water management, access, and landfill gas management (Section 4.5.10). Preparatory works for the landfill construction will involve earthworks and the clearing of approximately 1.58 ha of sparse vegetation. All staging of works, including the storing of construction equipment and materials, and the mobilisation of the construction workforce, will occur from within the IWMF site boundaries with no external staging areas required.

4.1.5 Operations

4.1.5.1 Waste Receival, Sorting Segregation and Recovery

Waste will be delivered to the IWMF via road transportation by TWM vehicles, with all incoming waste loads passing over a weighbridge for visual inspection and verification. Waste loads will be directed either to the waste receival hall located immediately adjacent to the weighbridge, or to processing/treatment points as determined by the waste type and characteristics. Once received, waste will be unloaded for segregation, before being transferred to the relevant treatment, processing or disposal location. Waste segregation will allow for the appropriate storage treatment or disposal of waste received by the IWMF. The IWMF operations will be conducted using proven and innovative technologies for processing, treatment and disposal of wastes, in accordance with waste best practice industry standards and internationally recognised standards employing the waste management hierarchy of (from most to least preferable) avoidance and reduce, reuse, recycle, recover, treatment and disposal of waste. Project procurement for IWMF operations will incorporate the requirement that procured plant and equipment will have low energy and water usage where practicable.

4.1.5.2 Waste Processing and Treatment

Wastes will be directed to a range of further processing or treatment options appropriate to the received waste type and final disposal options. Where appropriate, waste materials and wastewaters will be reprocessed for beneficial reuse purposes, thereby reducing volumes of

waste disposed to landfill. Waste processing will include waste shredding, composting, crushing, packaging, baling and temporary storage of recyclable and dangerous good wastes. Treatment will involve the operation of a HT incinerator, fixation and stabilisation, wastewater treatment at the domestic WWTP and IWWTP, and operation of the WOPU.

4.1.5.3 Waste Disposal and Export

Following processing and treatment, the residual solid and liquid wastes materials generated will be either disposed of on-site or exported off-site. Liquid wastes will be treated via the WWTP or the IWWTP (see Section 4.5.8), either for beneficial reuse on-site, fixated for incineration or landfill disposal. Treated wastewaters will not be discharged to the environment; however, clean water collected from some parts of the site may be discharged to stormwater (see Section 4.5.12). Various treated residual wastes including those produced from the incinerator and fixation bays will be disposed of to the on-site industrial landfill (Section 4.5.10). Some waste types, including recyclables and dangerous goods, will either be exported for further treatment or sold to relevant markets (Section 4.5.11). Compost will be reused on site or sold to the domestic market.

4.1.6 Decommissioning and Rehabilitation

Decommissioning requirements will be developed as the IWMF operations progress over the life of the Project and will be finalised prior to closure. Decommissioning activities are likely to include the decommissioning and disposal options for all equipment and materials, including waste management plant, products used, and wastes generated on site, and the reinstatement of land. Decommissioning details will be based on standards and technology that exist at that time and will include details on decommissioning activities and arrangements for post-decommissioning monitoring.

Project decommissioning activities will comply with regulatory requirements that are in force at the time of decommissioning, and good industry practice. Individual equipment items may be decommissioned when they have no further foreseeable use, and when their operation is no longer economically viable. Reuse and recycling alternatives will be considered where feasible. The overall aim will be to leave Project land, and any equipment and infrastructure that remains, in a condition that allows it to be transferred with minimal residual liabilities or risk to public safety and the environment. The current expected life of the Project is up to 50 years, and it is therefore reasonable to expect that the decommissioning procedures and regulatory requirements of the day will reflect advances in technology, new information, different monetary and other values for land and materials. Commitments to specific procedures cannot, at this point in time, anticipate future circumstances. Notwithstanding, the Project will follow the regulatory requirements and good industry practice at the time of decommissioning.

4.2 Project Schedule

Design, construction, and installation of IWMF infrastructure is being undertaken separately for the various components, and as such waste management operations will commence incrementally as new infrastructure is commissioned (and approved). The anticipated operational life of the Project is up to 50 years. An indicative timeline for the Project is shown in Table 4.2 and includes the following key milestones:

- Design of the industrial landfill, which commenced in Q4 2018 and was completed in Q4 of 2019.
- Construction of the industrial landfill is scheduled to commence in Q1 2021 with initial survey works and pending Level 3 approval construction will be completed in Q4 2021.
- Installation of remaining infrastructure, scheduled for completion by the end of Q4 2021.

Table 4.2 – Proposed Development Timetable

Activities	2020		2021			
	Quarter					
	3	*4*	*1*	*2*	*3*	*4*
Finalise IWMF design						
L3 permit process and land procurement						
Construct overheads for industrial services and fixation bays						
Install weighbridge						
Preparation of invitation to tender for landfill						
Perimeter and air lock security fencing installed						
Mechanical workshop and accommodation						
Stormwater/rainwater collection systems						
Commence survey, pre-construction activities and construction of industrial landfill						
Receival hall installation						
IWWTP and WWTP installation						
Compost plant installation						
Laboratory installation						

Both the incinerator and the WOPU have been installed and are operational, and the hazardous waste storage facility is constructed and currently used for storing hazardous wastes to be exported for treatment and disposal.

4.3 Project Location

The IWMF is located on Site Portion 2703 on Napa Napa Road, Porebada, in Central Province, within an industrial precinct adjacent to the AES Industrial Park, approximately 8 km northwest of Port Moresby and 500 m northwest of Roku village (see Figure 1.1).

4.3.1 Site Selection Criteria

The IWMF location is primarily based on its proximity and adjacency to a number of medium to large private commercial activities, which are gradually and collectively forming an industrial precinct in the Roku locality. From an operational perspective, the IWMF site is located adjacent to the Napa Napa Road and is therefore readily accessible by road transport, and in close proximity to shipping facilities in the Port Moresby area.

Understanding this location to be well suited to waste management activities, TWM procured State lease of the area and established the 12.5 ha site as an IWMF in mid-2018, with the transfer of its operations previously located at Badili in the National Capital District (NCD) and at AES in Roku.

The IWMF location was also chosen given it is visually obscured from the local community, in particular the nearby Roku village and because much of the required clearing had already been undertaken, which includes a number of cleared level benches. The site was previously used by a manpower company, which had cleared the benches within the site with the intention of building site accommodation. The cleared bench now used for the hazardous waste storage area was previously used as a timber yard.

The IWMF is situated on the hill above and to the north of Roku Village and Idlers Bay, and occupies a ridge running northwest to southeast. The site's highest elevation is 112 m above sea level (asl) at a hilltop to the south, and its lowest point is 49 m asl to the north. Perimeter lines and internal bands of native vegetation remain on site, providing visual amenity to surrounding areas. The area between the site and the Roku village is vegetated with native trees and grassland mixed with weeds, which combined with the rise in landscape provides a visual barrier between Roku village and the IWMF.

4.4 Proposed Waste Streams and Treatments

The IWMF is expected to receive up to 150,000 tonnes of commercial and industrial waste materials per year. The proposed extension of waste types and complexities to be received and treated at the IWMF will include commercial and industrial, municipal and hazardous solid and liquid wastes and both regulated and non-regulated waste. TWM have previously held Australian Import Permits for several hazardous waste streams for export to Australia, including activated carbon, waste oxidisers and waste biocides, although these permits have now expired. TWM will hold permits for waste acids, waste alkalis, waste non-halogenated solvents, oily water and waste oil.

Additional waste types to be received, treated and disposed or exported at the IWMF, and that require assessment under the EIS for approval of the Level 3 permit, will include the following:

- Hazardous wastes and contaminants specified under the US EPA Title 40 Code of Federal Regulations Part 261 – Identification and Listing of Hazardous Waste, and the provisions within Section 133 of Papua New Guinea's *Environment (Amendment) Act 2014*. These hazardous wastes and contaminants include:
  - Acids, alkalis and biocides.
  - Oily water and waste oil.
  - Non-halogenated solvents.
  - Oxidisers.
  - Used lead acid batteries, end of life tyres and spent activated carbon.
  - Asbestos.
- Plastics for re-processing, and electrical equipment (e-waste).

More detailed descriptions of the IWMF plant and waste management activities are provided in Section 4.5. Estimated annual materials flows including regulated wastes are provided in Table 4.3. These wastes may be received and stored on site or exported directly from international ports located in proximity to Client sites.

Table 4.3 – Estimated Annual Material Flows of Regulated Wastes

Waste Material	Estimated Annual Weight or Volume	Treatment
General Wastes		
Recyclables including end of life tyres	35,000 tonnes	Baled for export Crushed for on-site use
Non-hazardous commercial and industrial wastes	25,000 tonnes	Recovery/recycling/incineration/landfill disposal
Putrescible organic wastes	25,000 tonnes	Composting
Restricted Wastes		
Clinical and medical wastes (including quarantine wastes)*	3,000# tonnes	Incineration
Contaminated soils	2,500# tonnes	Incineration/landfill disposal
Industrial waste waters	15 megalitres	Wastewater treatment
Soils and sludges	10,000 tonnes	Composting
Hazardous Waste Exports		
Acids	50,000 litres	Physico-chemical treatment/landfill disposal
Alkalis	50,000 litres	Physico-chemical treatment/landfill disposal
Biocides	50,000 litres	Physico-chemical treatment/stabilised for landfilling. Higher toxicity materials batch blended as a fuel source
Non-halogenated solvents	100,000 litres	Physico-chemical treatment/stabilised for landfilling and batch blended as a fuel source
Oxidisers	10,000 litres	Physico-chemical treatment/landfill disposal
Waste Oils	1 million litres	Physico-chemical treatment/used as fuel to generate energy

Source: TWM, 2020.
* As described in Section 4.1.2, clinical and medical wastes may include radiotherapy wastes in the future.
# The volume of material estimated for incineration are approximate only and will be limited to the actual capacity of the incinerator (500 kg/hour).

4.5 Development Activities

The IWMF development components are described in the following sections. As described in Section 4.1.2, the construction and operation of most of these components are already approved under the existing Level 2 permit. For completeness and to inform the impact assessment, the following sections describe these components; however, detailed information is only provided for components of the IWMF development relevant to Level 3 activities and therefore the EIS. The impact assessment in Chapter 10 and 11 only considers the potential impacts associated with the

proposed Level 3 activities which are not approved under the existing Level 2 permit, as indicated in Table 4.1.

4.5.1 Weighbridge and Receival Hall

A weighbridge and waste receival hall will be installed at the IWMF entry and exit point, approximately 50 m from the northeast site boundary along Napa Napa Road (see Figure 4.1). These facilities will be developed for the purposes of inspecting, verifying and tracking incoming waste loads, and for the direction of waste to appropriate facility components for processing, treatment and disposal.

Following a visual inspection to verify compliance with site and environmental permit acceptance criteria, incoming waste loads will be directed to the waste receival hall, immediately adjacent, or to appropriate waste management points (determined by the load material type and characteristics) for further processing, treatment or disposal.

The weighbridge and the receival hall are currently permitted under EP-L2 (485). All waste received at the IWMF will pass through the weighbridge, including waste types requiring a Level 3 permit. Hazardous wastes (including newly proposed wastes) will then be directed to the relevant part of the IWMF for storage and or treatment, while the more benign waste types (including e-waste and plastics) will be directed to the receival hall.

4.5.2 Sorting and Segregation Facility

The waste sorting and segregation facility will be constructed in the northern corner of the IWMF facility, adjacent to Napa Napa Road (see Figure 4.1). The facility will consist of three contained, vented sheds, with bunding to prevent potential leaks or spills of waste materials to the environment (Plate 4.1). The facility will be operated for the purpose of segregating recoverable materials from incoming waste streams, utilising both mechanical and manual methodologies, and for segregating recyclable materials.

Plate 4.1 – Sorting and Segregation Facility Concept Design



Source: TWM, 2018.

Commercial and industrial, construction and demolition wastes will be unloaded in the sorting and segregation facility for further inspection. Loads will be mechanically separated and materials suitable for recycling and/or beneficial reuse will be recovered and stored temporarily in segregated bunkers. Recovered materials will be managed according to approved handling procedures and directed to specific site areas for storage, treatment or disposal.

The construction and operation of the waste segregation and sorting facility is approved under EP-L2 (485); however, the Project includes the extension of the type and complexity of waste sorting, storage and recycling, and will include dismantling of e-waste and plastics reprocessing which requires a Level 3 permit.

4.5.3 Recycling, Composting, Beneficial Reuse and Resource Recovery

The IWMF has been designed to optimise the recovery of resources and the minimisation of waste volumes disposed to landfill, including through the use of recycling, composting and beneficial reuse options. The following recycling activities will be conducted to maximise the supply of recyclables to the international market, or the reprocessing and value adding of materials for use on site or distribution to domestic markets:

- Baling and containerising of recyclables.
- Crushing of glass.
- Shredding and composting of green waste.

These activities will be undertaken at the recycling, compositing and beneficial re-use centre located near the northwest corner of the IWMF (see Figure 4.1) and are approved under EP-L2 (485).

Resource recovery activities will include plastics reprocessing and dismantling of e-waste (Level 3 activities) as well as recovery of timbers, building materials and metal (e.g., steel and tin) for recycling and reprocessing which are approved under EP-L2 (485). Green waste will also be recovered for composting. Waste oil will be recovered at the WOPU (Section 4.5.5)

As composting activities are already approved under the EP-L2 (485) and no additional hazardous waste materials will be received by the composting plant, this activity is not assessed in this EIS.

4.5.4 Incineration Plant

4.5.4.1 Incinerator Feedstock

A HT incinerator was constructed in 2019 and is operational as approved under EP-L2 (485). An example of the incinerator model is shown in Plate 4.2, and the building in which the incinerator is housed is shown in Plate 4.3. The Level 3 environment permit application seeks to extend the type and complexity of hazardous contaminants able to be thermally destructed using the HT incinerator. The incineration of hazardous wastes will be undertaken to meet the emissions limit values provided in the US EPA Title 40 – Code of Federal Regulations Part 60 Subpart CCCC Standards of Performance for Commercial and Industrial Solid Waste Incineration Units. The incinerator will receive combustible waste streams including oily rags, health care wastes

including COVID-19 waste and quarantine waste, hazardous wastes, contaminated soils, and liquid wastes including paints and non-halogenated solvents, of which only fixated hazardous wastes and non-halogenated solvents are not approved feedstock and therefore require assessment in this EIS. Grease trap waste may also be treated through the incineration process by loading through the liquid feed.

Plate 4.2 – Example of High Temperature Incinerator Model



Photo: Inciner8 Ltd.

Plate 4.3 – Current Incinerator Building



Photo: TWM.

4.5.4.2 Incinerator Process and Design

The incinerator is located at the southwest boundary of the IWMF, on the constructed benchtop second from the exiting IWMF offices (see Figure 4.1). The incinerator is positioned on the upper slope of the site, and the incinerator stack is 2.8 m above the body of the incinerator's secondary chamber, which helps control ground level concentrations of residual pollutants in the ambient air. The incinerator has a chamber capacity of 6.75 m^3 and a burn rate of approximately 500 kg/hr. Diesel fuel is fed to the burners via a reticulation line from its own diesel storage tank, and fuel consumption is approximately 40 to 50 L/hr. The incinerator is a dual combustion chamber, with a main and secondary combustion chamber, and has an operating temperature in excess of 850ºC, which optimises combustion and pollutant destruction. The secondary chamber prevents dioxins from cracking into smaller more reactive molecules, which can be apparent in the presence of heavy metals.

The incinerator has pollution control system technology capable of meeting US EPA and European Union emission standards for the thermal destruction of received waste streams. The pollution control system is a flue gas treatment with a self-ignition process to force the micro particulates to pass through a flame curtain which burns harmful emissions. A particulate filter and an air-cooled heat exchanger with a cooling air fan are used to cool the flue gas. Gas remnants are then retained in the secondary chamber, through thermal decomposition and cyclonic air distribution to ensure a clean odourless emission in the form of vapour. The system has constant ventilation with adjustable airflow to provide optimal combustions conditions and efficient gradual cooling of the system.

4.5.4.3 Processing of Residual Waste

Combustion efficiency is more than 99%, and approximately 3 to 5% ash residue is generated through the incineration process. Bottom ash and fly ash are produced from the incineration process and require toxicity leachate analysis for classification as regulated or non-regulated materials under US EPA Title 40 – Protection of Environment, Chapter 1, Subchapter 1, Part 268, Subpart D Treatment Standards. Ash that is categorised as non-regulated will be directed to the landfill for disposal. Ash that is categorised as regulated will be stabilised in cement during the fixation process (Section 4.5.7) prior to being directed to the landfill for disposal. Healthcare waste including waste utilised in COVID-19 management will undergo a separate burn cycle, and ash from this process will also be stabilised independently within the IWMF fixation bays and disposed of to landfill. Currently, ash produced from the incineration of COVID-19 waste undergoes analysis to determine if it is a restricted or non-restricted waste. Ash classified as non-restricted is disposed of as is, at the Baruni disposal site, located in Port Moresby. Ash classified as restricted is stored on site in sealed containers for fixation and encapsulation in concrete prior to disposal at the Baruni disposal site. Waste materials received from Clients are currently burnt separately from COVID-19 waste and transferred back to private Client landfills. Once the IWMF is operational, all fixated ash will be disposed of at the industrial landfill on site.

4.5.5 Waste Oil Processing Unit

4.5.5.1 WOPU Design

Waste oils will be directed from incoming waste loads to external holding tanks adjacent to the WOPU, located in the western corner of the IWMF as shown in Figure 4.1. The WOPU has been

operating since 2018. The WOPU is used for processing and treating feedstock, including hydrocarbon based oils (i.e., waste oils), fuels, sludge's and contaminated waters, to a quality sufficient for re-use. TWM does not require further Level 3 approvals for the operation of the WOPU, and as such further description of the WOPU is not provided and the operation of the WOPU is not assessed in the EIS.

4.5.6 Industrial Cleaning Services

Industrial services will include cleaning of ISOtainers and large tanks and vessels, to allow for beneficial reuse. These containers will undergo internal and external industrial cleaning using cleaning chemicals and high-pressure equipment within the industrial services wash bays. These activities are already approved under EP-L2 (485) and are in operation and are not assessed in the EIS.

4.5.7 Fixation Bays

Fixation bays have been constructed and will operate in the western corner of the IWMF, as shown in Figure 4.1, for the stabilisation, neutralisation and fixation of selected hazardous materials prior to landfilling. Stabilisation of these materials will occur through mixing and fixation within cementing material. Waste streams that will undergo fixation prior to disposal in the landfill will include hazardous wastes such as acids, alkalis, and biocides, and the ash of regulated wastes that have undergone incineration, including oil filters and rags, paints (oil and water based), health care wastes, and contaminated soils.

Six fixation bays have been constructed (Plate 4.4) to enable mixing to be carried out using an excavator (or similar). Fixation and stabilisation media will be added in a pre-determined proportion to the material being fixated. Stabilisation material is usually cement based and will occasionally utilise proprietary products such as cement/clay/polymer mixes dependent of the materials to be stabilised or inert solid chemical material. Following successful stabilisation and fixation of waste in fixation bays, residual materials will be transported and disposed to the industrial landfill.

The construction and operation of the fixation bays for treating some hazardous wastes is currently approved under EP-L2 (485); however, the fixation bays will be operated for the purposes of neutralising and fixating the proposed additional hazardous waste streams described in Section 4.4, and as such this activity requires assessment in this EIS.

Plate 4.4 – Concrete Bunded Pad for WOPU, Fixation Bays and Industrial Services



Photo: TWM.

4.5.8 Wastewater Treatment Plants

4.5.8.1 Wastewater Streams and Classifications

The wastewater treatment plant at the IWMF will comprise two individual plants: a domestic WWTP and the IWWTP. The WWTP/IWWTP is located in the centre of the IWMF, southwest of the existing site offices (see Figure 4.1). A concept design of the WWTP is shown in Plate 4.5.

Plate 4.5 – WWTP Concept Design



Source: TWM, 2018.
Key: G1 (collection station); G2 (primary clarifier); G3 (aeration basin and blower station); G4 (secondary clarifier); G5 (digesters); G6 (sludge treatment and storage station); G7 (disinfection station); G8 (final effluent station).

The domestic WWTP will receive wastewaters including sewage and greywater from the existing facility's accommodation and office, and commercial feedstock waste. The IWWTP will receive leachates collected from both the industrial landfill and composting operations, contaminated stormwaters from the operational areas of the site via the stormwater management system (Section 4.5.12), industrial commercial feedstock, industrial process water and water used during industrial cleaning services or cleaning of IWMF plant such as the incinerator. The construction and operation of a WWTP is approved under EP-L2 (485); however, given the extension of hazardous and industrial liquid waste types to be received and processed at the IWMF, the operation of the IWWTP requires assessment in this EIS. Further detail of the IWWTP is provided in the following section.

4.5.8.2 Industrial WWTP

The IWWTP will utilise dissolved air flotation (DAF) processing to clarify wastewaters (or other waters) by removing suspended matter such as oil, grease, suspended solids and fine particulates.

Raw water intended for treatment at the IWWTP will be transferred from a collection sump into the raw water storage tank and then transferred to the flocculation system where pH correction, coagulation and flocculation chemicals are dosed and mixed into the water. The chemically dosed water will then enter the dissolved air flotation (DAF) system where water saturated with air is introduced into the bottom of the vessel and the dissolved air floats to the surface as small air bubbles carrying with it suspended matter such as oil, grease and particulates. The frothy sludge is then scraped into a sludge hopper and then transferred to a sludge storage tank where it is periodically removed. The treated water from the DAF unit overflows into the treated water distribution/collection storage.

It is anticipated the IWWTP will treat approximately 17.52 megalitres (ML) per year of water, 14.3 ML of which is commercial feedstock and 3.22 ML of which is sourced from industrial process within the IWMF. Similar to the WWTP, treated water from the IWWTP will mostly be diverted for beneficial reuse on-site, and to a lesser extent sent for fixation for incineration or disposal at the landfill.

4.5.9 Quarrying Activities

The existing permit approves quarrying of up to 100,000 tonnes per year. Quarry material may be used as products for construction materials, including for coastal and river flood defence or retaining walls, where quarry block sizes are suitable, or in other construction projects including the IWMF internal road network. As quarrying activities are already approved under EP-L2 (485) they are not assessed within the EIS.

4.5.10 Industrial Landfill Activities

4.5.10.1 Landfill Overview

The proposed hazardous waste landfill will be located at the existing, disused quarry (see Figure 4.1). The landfill will be utilised for the disposal of hazardous contaminants that have undergone fixation and stabilisation, quarantine and medical wastes not suitable for incineration, incinerator ash, asbestos, construction and demolition materials and other wastes unsuitable for recycling and reuse and that require deep burial. Hazardous and regulated wastes that undergo incineration and/or stabilisation and fixation will be disposed of to landfill following treatment, while certain solid non-regulated wastes will be disposed of directly. Waste types to be accepted by the landfill include:

- Putrescible waste, bricks and concrete, disposed direct to the landfill, where the materials are unsuitable for recovery.
- Oil filters and rags, paints, health care wastes including COVID-19 waste and quarantine waste, contaminated soils, non-halogenated solvents, either as fly ash directly following incineration, or as fly ash fixated in cement, depending on the classification of toxicity leachate analysis results (Section 4.5.4.3).
- Acids, alkalis, and biocides, following fixation.

The construction and operation of the landfill for disposal of municipal wastes is currently approved under EP-L2 (485). However, the industrial landfill has been designed and will be constructed and operated for the acceptance of hazardous waste to prescribed industrial standards including:

- TWMs existing environment permit EP-L2 (485).
- Papua New Guinea Environmental Code of Practice for Sanitary Landfill Sites (DEC, 2001).
- *Environment (Registration of Contaminants and Hazardous Contaminants) Regulation 2011*.

- Code of Federal Regulations, Title 40 Protection of Environment. Volume: 26 Part 258 – Criteria for Municipal Solid Waste Landfills.
- Solid Waste Disposal Facility Criteria, US EPA (1998).
- Code of Federal Regulations, Title 40 Protection of Environment. Volume: 26 Part 261 – Identification and Listing of Hazardous Waste.
- Code of Federal Regulations, Title 40 Protection of Environment. Volume: 26 Part 264 – Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities and Part 265 – Interim Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities 2014.
- Code of Federal Regulations, Title 40 Protection of Environment. Volume: 26 Part 268 – Land Disposal Restrictions.
- Code of Federal Regulations, Title 40 Protection of Environment. Volume: 26 Part 267 – Standards for Owners and Operators of Hazardous Waste Facilities Operating Under a Standardised Permit.

A concept design for the IWMF industrial landfill was prepared in 2019 by SLR Consulting Australia Pty Ltd (SLR) and is provided in Appendix 1. The industrial landfill includes the following key design features:

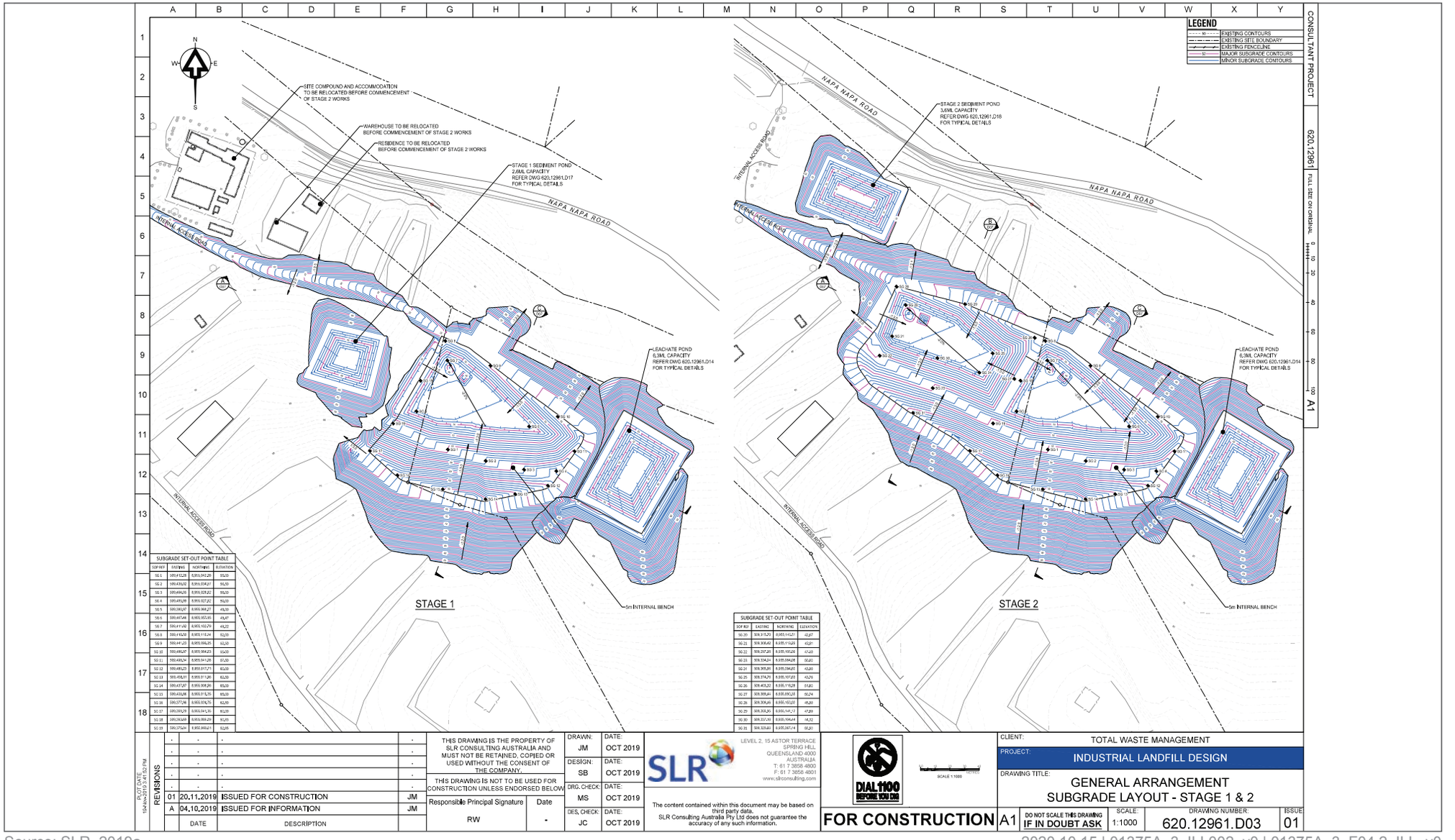
- Landfill subgrade design.
- Detailed engineered lining system.
- Inter-stage bund.
- Access ramp.
- Landfill leachate management system.
- Landfill settlement.
- Landfill gas management system.
- Surface water management.
- Conveyance channel design.

Figure 4.2 provides a diagram of the proposed landfill subgrade layout.

PROPOSED LANDFILL GENERAL ARRANGEMENT OF SUBGRADE LAYOUT

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FIGURE 4.2



Source: SLR, 2019a

4.5.10.2 Pre-construction Works

Preparatory earthworks and civil works will be required prior to construction of the industrial landfill. While previous quarrying works have excavated an area suitable for the construction of the initial landfill cell, pre-construction earthworks and civil works will allow for the construction of the landfill cell and will involve general site preparation works including excavating, earthmoving, importing and stockpiling of material and access road construction. These preparatory works are expected to take between 2 and 3 months and may be undertaken prior to TWM receiving a Level 3 permit as the existing permit allows for the construction of a municipal waste landfill; therefore, such works would be commensurate with these approvals.

4.5.10.3 Landfill Design Capacity and Construction

It is anticipated the landfill will receive up to approximately 40 tonnes of commercial and industrial non-restricted waste materials per day. Landfill construction and fill staging will occur in two stages. Stage 1 will be the Eastern Footprint Area, located in the disused quarry, and Stage 2 the Western Footprint Area (see Figure 4.2). Void spaces and earthworks cut and volumes for both stages and the combined landfill are provided in Table 4.4. Earthworks for landfill construction will be undertaken using several heavy vehicles, including, a D9 dozer with rippers, a 20 to 24 tonne excavator, and an 18.5 tonne front end loader.

Table 4.4 – Landfill Void Capacity and Earthwork Volumes

Stage	Void Space (m^3)	Earthworks Cut (m^3)	Earthworks Fill (m^3)
Stage 1	45,200	52,775	49,075
Stage 2	71,700	27,025	15,175
Total	116,900	79,800	64,250

Source: SLR, 2019a.

The landfill will be constructed with multiple high-density polyethylene (HDPE) geo-membrane barriers combined with clay liners and a leachate collection system. The landfill has been designed for two separate cells to be constructed in sequence and as required. The use of sediment ponds and siltation fencing during construction will avoid sediment entering sensitive receptor areas and any opportunities for soil erosion. The cells will be filled and covered prior to the next cell being utilised. All cells will be separated by internal bunds to manage stormwater and leachate and each cell will be installed with a leachate sump.

The final landfill landform design will include the construction of external landfill batters to ensure slope stability and the management and diversion of surface water, as shown in Figure 4.2, and intermediate slopes and benches from the landfill void to the landfill perimeter. A geotechnical stability assessment for the landfill was also undertaken as part of the landfill design (SLR, 2019b). Batters will be designed with a maximum slope gradient of 1:3 m (i.e., a slope ratio of 1 m vertical to 3 m horizontal) in order to reduce the risk of slope failure. The final landform will be designed to include textured HDPE to ensure adequate interface shear strength (SLR, 2019a). Hydromulching and progressive revegetation will be applied to final constructed batters to reduce the potential for erosion and increase the stability of batter slopes. The final restored landfill profile on the northern, western and eastern landfill boundaries will be constructed to form a benched profile, with intermediate slope faces of varying height separated by flat benches 5 m

wide. Maximum overall slope height will be 24 m on the northern slope and 28 m on the northwest slopes, and 10 m for the intermediate slopes between the 5 m wide benches.

4.5.10.4 Disposal Operations

The landfill will employ progressive slope operations and wastes will be carefully positioned over the entire floor of the new cell until a sufficiently compacted based is established to protect the geo-membrane liner. Wastes will then be deposited to the base of the working face and compacted from the floor up in layers. A layer of cover material will be applied daily to suppress odour, prevent wind-blown litter, minimise opportunity for mosquito infestation and discourage bird and animal grazing. The operating cover material will be an earthen mix with low clay content combined with inert materials that have been processed on site to make use of varying contributions of crushed glass, brick and concrete. Once the cell has reached capacity a layer of predominantly clay/earthen mix will be placed as an interim cover to secure the surface. Temporary stormwater channels will be constructed to divert water away from the surface and into the stormwater drainage system. The process for daily landfill activities including receipt of wastes and daily closure is provided in Figure 4.3.

4.5.10.5 Cell Closure and Final Closure

The final covering of a completed landfill cell will occur as soon as practicable in order to reduce ingress of rainwater and to collect and vent the landfill gases, which are expected to be minimal given the inert nature of the bulk of the materials to be landfilled. The final cover will consist of three layers:

- First: gas distribution layer comprising porous materials and a network of HDPE pipes connecting the landfill gas trenches to vent the landfill gases.
- Second: a layer of compacted soil and a geo-synthetic clay liner.
- Third: the surface or cap layer will be topsoil, which is then planted with shallow rooted vegetation (e.g., natural grasses) that are drought and heat tolerant with low nutrient needs.

4.5.10.6 Landfill Leachate Management

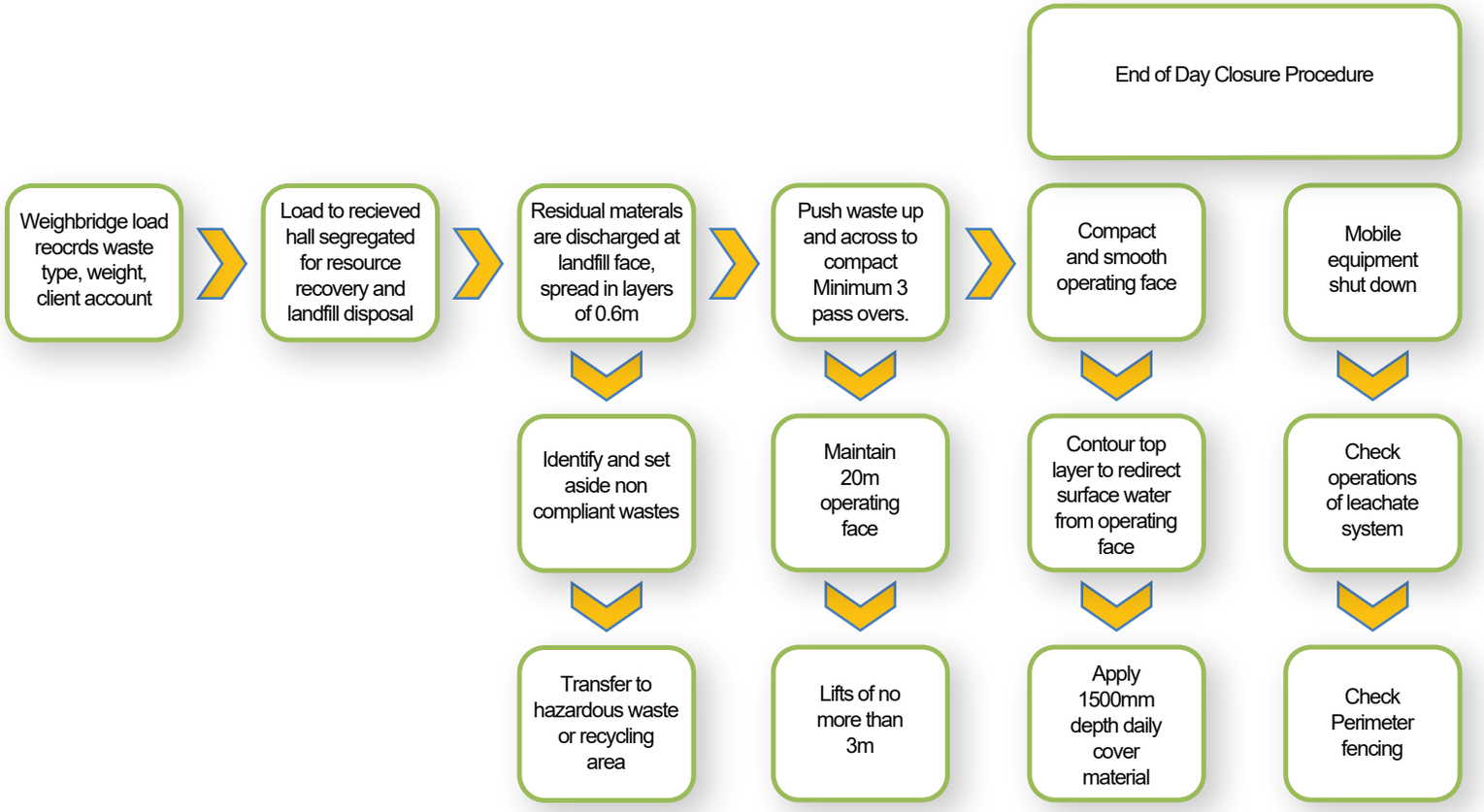
The landfill will predominantly receive inert materials and is expected to generate relatively low levels of leachate. The design capacity for the leachate system is based on the relationship between leachate level and landfill volume and the calculated annual rainfall infiltration volume, taking into account daily cover materials and the stormwater diversion drains at the active landfill cells. Nonetheless, the leachate collection system is to be designed with a minimum 2% slope to drain liquids to the collection sumps. Leachates generated in the active and closed landfill cells will be pumped from the leachate sump via leachate riser pipes (HDPE) to a central collection well before it is pumped and conveyed to a leachate holding pond or to the on-site wastewater treatment system (i.e., the IWWTP).

The leachate holding pond will store leachate generated within the landfill during Stages 1 and 2 and is located to the east of the Stage 1 landfill footprint as shown in Figure 4.2.

LANDFILL PROPOSED DAILY PROCESS FLOW

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FIGURE 4.3



Source: TWM, 2020

The leachate holding pond has been designed to the same prescribed standards as the industrial landfill, with pond sized based on water balance modelling, leachate generation modelling and assumptions detailed in SLR (2019a). Water balance modelling assessed the following three scenarios:

- Base Case – cumulative monthly rainfall over a 1-year period, as per a 90th percentile wet year based on Townsville data from 1981, and taken to be 1,733 mm.
- Sensitivity Case 1 – a 50% increase to the percentile rainfall.
- Sensitivity Case 2 – a 100% increase to the percentile rainfall.

Modelling of worst-case leachate generation was also undertaken for the purposes of designing the leachate holding pond size to be sufficient for the temporary storage of landfill leachates over a 1-year period, the anticipated timeframe for the construction of the IWWTP. Worst-case leachate generation modeling was conducted on the basis of the 90th percentile rainfall occurring (as described above) and on the assumptions that:

- One third of the landfill Stage 1 area would be filled with waste.
- The landfill will comprise a 300 mm thick intermediate cover.
- The landfill will have an active working area of 625 m^2.

As such, the leachate pond will have a volume of 6.3 ML, a width of 43 m, a length of 58 m and a depth of 5.3 m. The surface area of the top of the pond will be 2,475 m^2 (SLR, 2019a). The pond will be constructed with 0.5 m freeboard, with the required freeboard volume based on the 5% annual exceedance probability (AEP) for 24-hour rainfall period (SLR, 2019a).

The leachate holding pond lining system will be constructed, from top to bottom, with a floor ballast system, a 2 mm HDPE geomembrane liner, a 600 mm compacted clay liner, a composite drainage net, a geosynthetic clay liner, and a 200 mm thick prepared subgrade. The pond will be uncovered. In the short term, pending construction of the IWWTP, leachates from the industrial landfill will be collected in the leachate holding pond where they will be managed through evaporation, as the pond will be uncovered. In the long term, leachates will be transferred to the IWWTP for treatment and, if possible, beneficial reuse. The landfill will also have a number of groundwater monitoring wells and surface water monitoring points installed to monitor the potential impacts of landfill leachates on existing water quality.

4.5.10.7 Landfill Gas Management

As the landfill will receive inert materials and materials of low calorific value, it is expected minimal gases will be generated. However, the closure of the cells will include a gas capture system comprising horizontal collection piping and vertical gas extraction wells installed into the deposited wastes to collect landfill gases. Landfill gases will be vented to the environment and gas extraction wells monitored in accordance with the environmental management plan (EMP). Should the gas generation levels alter over time, consideration will be made for the installation of a gas flare system to burn off the gas prior to release to the environment. Gas monitoring probes will also be installed outside the perimeter of the landfill to detect landfill gas migration.

4.5.11 Hazardous Waste Storage

A hazardous waste storage facility has been constructed and will be operated on-site for the safe consolidation and storage of hazardous contaminants for on-site treatment or for export to approved disposal facilities. The hazardous waste storage facility is located in the northern corner of the IWMF, opposite the recycling and composting area. This activity is approved under the current EP-L2 (485), but a Level 3 permit is required to accommodate the extended hazardous contaminants that can be stored ahead of treatment and/or export at this facility. Activities undertaken at the hazardous waste storage facility will include receival of wastes identified as hazardous, confirmation of waste type and safe handling and dangerous goods storage requirements, decanting of materials as necessary, packaging of wastes and storage in the dangerous goods area of the hazardous waste storage facility, prior to export of all regulated wastes as identified in Section 4.4.

The hazardous waste storage facility has been constructed (Plate 4.6) with impervious concrete bunds, under-foundation barriers, and blind sumps able to hold at least 110% of the chemical storage capacity. Surface water will be diverted from operational areas to storage tanks, as will guttering on building roofs (see Section 4.5.12). Packaging and storage of wastes is in accordance with AS 1940-2004 Storage and Handling of Flammable and Combustible Liquids and AS3780- 2008 Storage and Handling of Corrosive Substances (Standards Australia, 2008).

Plate 4.6 – Hazardous Waste Storage Facility



Photo: TWM.

Industrial steel racking and secondary bunded floor areas separate chemicals in accordance with dangerous goods classifications for storage. Stalls are used to segregate non-compatible materials, and firewalls may also be used to ensure materials cannot interact. Packages for storage of chemicals are in some cases be self-bunded. Decanting areas, vents and gauges will

be located within a bunded area. Dust control devices, such as fire retardant shade cloth, are to be located at all openings to prevent visible emissions from the building during operating or maintenance activities, or when staff or vehicles enter the storage building. A decontamination area located within the building has also been constructed and will be operated with site-specific procedures to ensure waste is not tracked outside of the building. Wastes and associated cleaning liquids generated through the decontamination process will be collected for treatment via the IWWTP.

4.5.12 Stormwater Management System

In accordance with the conditions of EP-L2 (485) a site stormwater management system will be constructed in order to divert contaminated surface water and stormwater from operational areas to the IWWTP for treatment. The design of the stormwater management system is provided in Figure 4.4, and will include a system of stormwater storage tanks, roof guttering, diversion channels, collection sumps and a sediment pond.

Processing areas will be constructed on fully bunded concrete pads to prevent surface water escaping outside the operating area. Pads will also be equipped with diversion drains and blind collection sumps for the collection of surface waters that have come into contact with the operating areas, and surface water drainage channels and sediment control systems will also be installed at roadways, storage and working areas. Stormwaters that have come into contact with operational areas will be drained to the collection sumps, and transferred to the WWTP plant for processing. Stormwater from uncontaminated or non-operational areas of the site, such as the existing three-bedroom house and administration buildings will be collected in drainage channels and discharged directly to the stormwater drainage system along Napa Napa Rd, as shown in Figure 4.1.

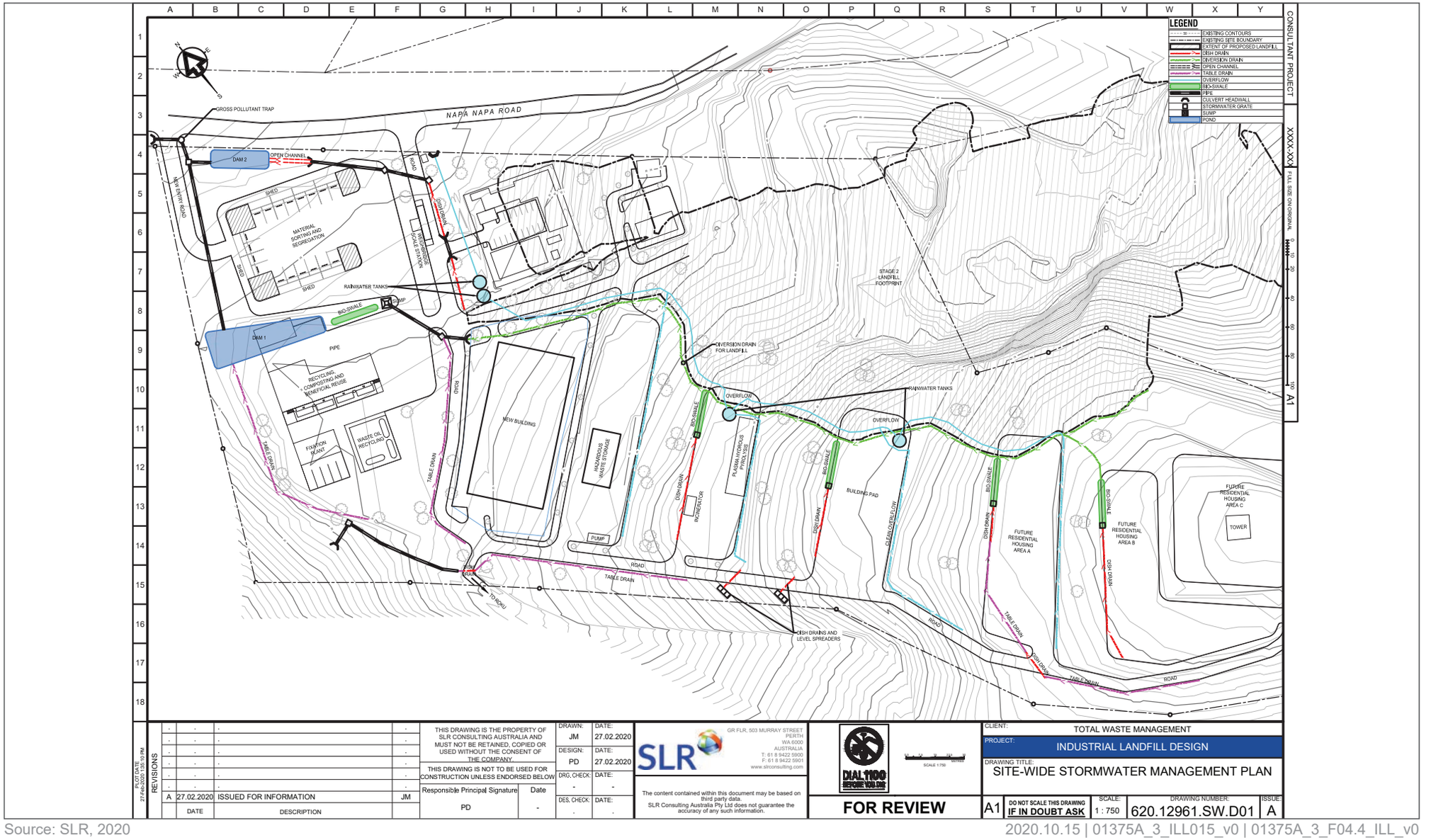
Surface water will be categorised as ‘clean water’ or ‘dirty water’. Clean water is defined as having not come into contact with operational areas and is generally free of sediment and does not require treatment or sediment and erosion control. Dirty water has originated or passed through operational areas, although not in direct contact with waste materials, and generally contains sediment loads but is free of contaminants. Dirty water requires sediment and erosion control and treatment before discharge. The stormwater system will be constructed with both a clean and dirty system, in which clean water is diverted away from the dirty system storage and drainage channels. Based on the estimated rainfall capture and stormwater storage capacity, it is estimated the total annual stormwater supply at the IWMF is 1.5 ML per year of water from the clean system, and 1.4 ML per year from the dirty system.

The industrial landfill design includes a stormwater management system, shown in Figure 4.5, which will include a series of toe drains, clean water diversions and the use of sediment fencing and a level spreader to manage stormwater runoff. A sediment pond will also be constructed at the western edge of the landfill for the capture of surface water from the landfill construction area before treatment. The sediment pond will require periodical dewatering following rainfall and desilting of remaining sedimentation. The sediment pond will increase in surface area and total volume from Stage 1 to 2 of the landfill construction. For Stage 1, the catchment area will be 2.4 ha which will require a total sediment pond volume of 2.24 ML. In Stage 2, the catchment area will be 3.30 ha which will require a total sediment volume of 3.08 ML (SLR, 2019a).

IWMF SITE STORMWATER MANAGEMENT SYSTEM

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FIGURE 4.4



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FOR REVIEW

CLIENT: TOTAL WASTE MANAGEMENT

PROJECT: INDUSTRIAL LANDFILL DESIGN

DRAWING TITLE: SITE-WIDE STORMWATER MANAGEMENT PLAN

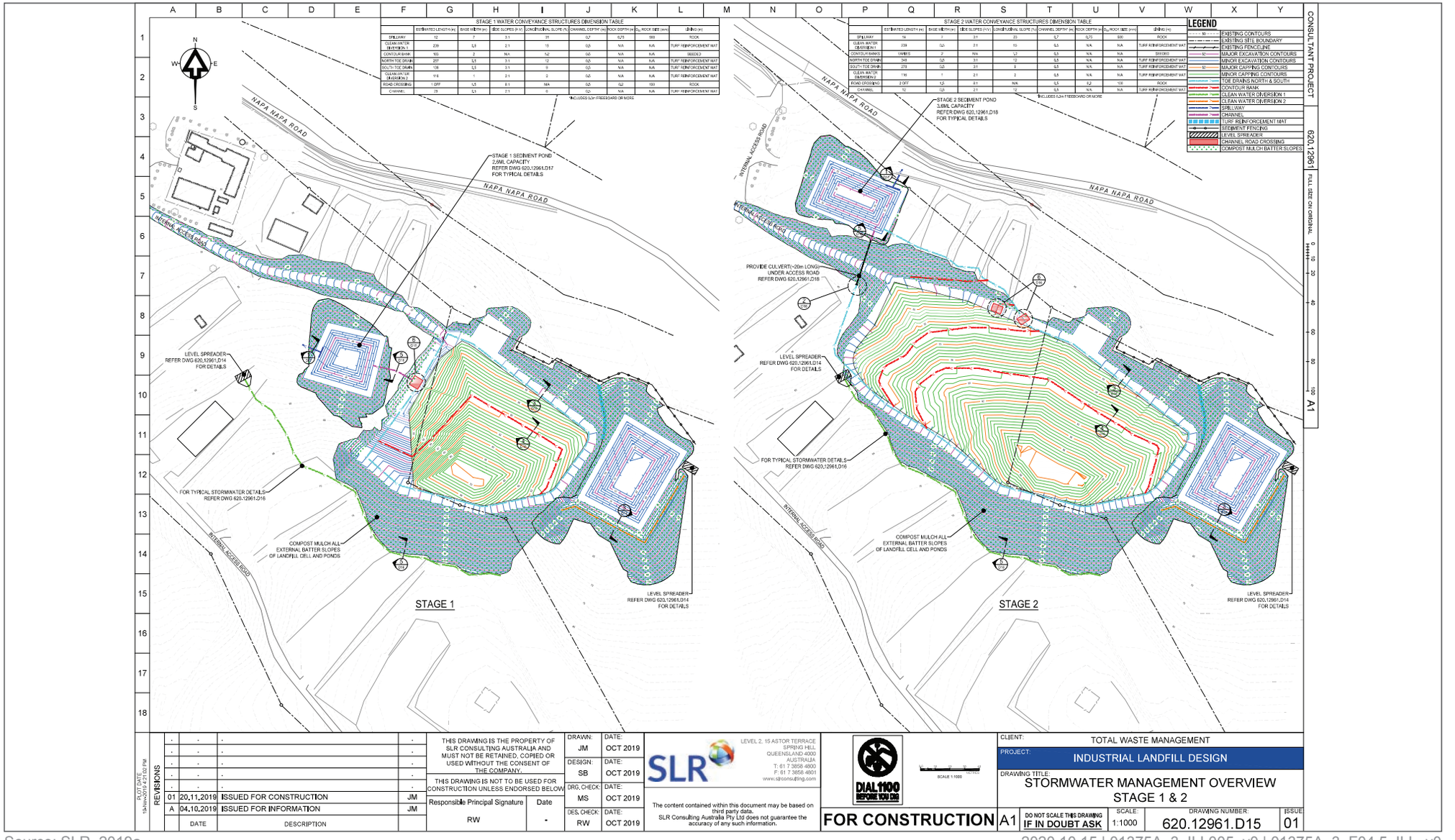
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Source: SLR, 2020

INDUSTRIAL LANDFILL STORMWATER MANAGEMENT DESIGN

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FIGURE 4.5



Source: SLR, 2019a

Clean stormwater will be discharged offsite to the Napa Napa Road drainage system which runs adjacent to the IWMF and is an open stormwater drain constructed as two sections, from the top of the hill to the southeast along Napa Napa Road (i.e., passed the landfill), to the gatehouse runs one section of the drain which then dog legs and goes to AES under the road. From the other side of the gatehouse is the second section which drains along Napa Napa Road northwest towards Rhodes, but it is unknown where this terminates.

4.6 Workforce and Accommodation

4.6.1 Accommodation

During construction, the contractor workforce will commute to site daily and will not require accommodation. The construction supervisor and project managers will be housed at the adjacent Tuhava Town accommodation. The limited existing accommodation facilities located at the IWMF, which includes a three bedroom house and an accommodation building, will be utilised by the Project during operations where required. The accommodation facility is supported by an administration office and carpark and obtains power from the existing PNG Power supply (Section 4.9). Existing septic tanks at the site offices and accommodation will be utilised throughout construction and operations (Section 4.10.1.1).

4.6.2 Construction Workforce

The landfill construction workforce will comprise up to a total of approximately 40 national contract personnel, in addition to construction supervisors and team leaders, likely to be expatriates. As described in the previous section, construction contractors will commute to the site daily while expatriate project managers and construction supervisors will be accommodated at Tuhava Town. Construction hours will be from 7 a.m. to 5 p.m. Monday to Friday.

4.6.3 Operations Workforce

Workforce requirements for the anticipated 50-year operations phase will vary according to the stage of completion of the IWMF, with workforce numbers expected to increase as the facility incrementally expands its operations. Current operations comprise 40 site personnel including site operators, cleaners, drivers, office administration and professional staff.

The anticipated workforce for the fully operational IWMF is estimated to be 91 staff, including operators for all IWMF plant, administration, maintenance, labourers, transportation, cleaning, security, professional staff, and supervisory and manager roles. The operations workforce will include approximately 83 local employees and 8 expatriate staff, and 56 male and 35 female employees.

Hours of operation will be from 7 a.m. to 5 p.m. Monday to Friday, and 7 a.m. to 12 p.m. on Saturday, with extended hours as required. The development will also create indirect and induced employment. Examples of indirect employment include logistics which support the Project and the transportation of waste. Examples of induced employment include employment resulting from Project employees spending earned income in the community.

4.6.4 Local Content

'Local content' refers to the added value brought to a host nation (or region or locality), through workforce development and training of local workforce and investments in supplier development, including developing and procuring supplies locally. TWM will seek to maximise the use of Papua New Guinean human resources, materials, equipment and services in its operations, to support the nation's aspirations to develop local capabilities in the waste management industry. TWMs current workforce comprises more than 100 multi-skilled national and expatriate staff, with a national content of approximately 85%, and currently has two Papua New Guinean national directors, and the IWMF operations staff comprise more than 90% national employees. The Project will also help develop technical and vocational education and training to facilitate local workforce skills development.

4.7 Logistics and Transport

4.7.1 Transport of Materials, Equipment, Fuel and Chemicals

During construction of the landfill, imported materials and equipment will include HDPE geomembrane liners, clay liner material, concrete and construction equipment for the leachate collection and leak detection systems. These materials will be transported to the Project site over an approximate 12-month period during landfill construction from Q1 2021 to Q4 of 2021. Earthen material and spoil will also be transported using the IWMF's internal road network from the landfill site to either construction areas within the IWMF or exported offsite as construction materials. The internal unpaved roads will be sealed with a bentonite mix.

Fuel and chemicals will also be transported to site during landfill construction and operation of the IWMF. Diesel will be transported to the IWMF for use by mobile plant, diesel generators, and the incinerator and stored on-site (see Section 4.9). Fuel deliveries will occur weekly, averaging 1,500 L per week.

Waste materials, as described in Section 4.4, will be transported to the IWMF during operations for processing and treatment. Additional items transported to the IWMF during operations will include chemicals required in waste treatment processes, and various equipment and parts required for maintenance purposes. Various chemicals will be used in both operation processes and domestic activities and are likely to include the following:

- Chlorine.
- Polyaluminium chloride.
- Sodium hypochlorite.
- Sucrose.
- Citric acid.
- Oxalic acid.
- Ferric chloride or aluminium sulphate (coagulants).

- Polymer chemicals.

Chemicals are expected to be transported to site in drums or IBCs, and stored at the mechanical workshop in accordance with dangerous goods requirements.

4.7.2 Transport Methods and Routes

4.7.2.1 Landfill Construction

Transportation to and from the IWMF site for landfill construction will occur via Napa Napa Road, with access to the IWMF site through the existing entry and exit gate. Construction activities will also utilise the site's internal road network, which will be treated with a bentonite mix to limit dust and erosoion.

It is anticipated there will be a peak of 36 vehicle movements per day to and from the IWMF site during landfill construction, increasing from the existing volume of 20 per day, with vehicle types depending on the type of material or load being transported. Haulage of earthen material from pre-construction activities and landfill construction will occur via a 2007 Western Star 4800 FX Stratosphere haulage truck, and 2012 CAT 740B 6 x 4 articulated dump truck. The construction workforce will be transported via utility vehicles, sport utility vehicles (SUVs) and buses.

4.7.2.2 Operations

Transportation during the operations of the IWMF will include incoming waste loads for processing and treatment, outgoing waste loads for export, transportation of workforce personnel, and transportation of maintenance equipment. Vehicle movements to and from the IWMF during operations are anticipated to roughly double compared to existing movements and are expected to include approximately 40 vehicle movements per day. The increase in traffic and transport movements will occur gradually as IWMF plant and technology become incrementally operational, with the anticipated doubling of traffic expected to occur in the next three to five years. Waste load volumes will vary for each waste load and waste type and will be dependent on the vehicle type and size. Increased traffic will be most associated with the transport of incoming waste loads destined for the IWWTP and the industrial landfill, with peak traffic times between 7 and 9 a.m. for incoming loads and 3 and 5 p.m. for outgoing loads. Transportation during operations will use the same route as during construction and will also utilise the internal road network. The future transportation of waste to site may also occur through domestic shipping transport, using the existing port at the AES facility on Fairfax Harbour. As the domestic market expands throughout Papua New Guinea, more waste may be delivered by sea.

Internal transport of materials will be undertaken using forklifts (1.5 tonne and 5 tonne models) and a 12-tonne front end loader. Site personal will be transported to, from and within the IWMF site using SUVs and buses. Trucks of varying sizes will be used for the transportation of waste, internally and externally and will include three 6 x 4 articulated trucks, a 3 tonne truck and two 4 x 2 articulated light trucks.

4.8 Water Supply and Usage

4.8.1 Domestic Water Use

Potable water will be transported to site for use by the IWMF workforce during both construction and operations. Non-potable domestic water will be supplied predominantly via the existing water connection from the adjacent AES industrial park, in which desalinated water is extracted from the marine environment and reticulated to the existing accommodation, offices and three bedroom house at the IWMF. Rainwater collection systems across the IWMF site will also be used to supply water for the Project, where practicable, reducing the volume of supplied water required from AES. No surface water or groundwater extraction will occur as a part of the Project. Non-potable water demand for domestic activities from the AES supply is expected to be 1.36 ML per year, based on approximate current usage and volumes of water purchased from AES.

4.8.2 Industrial Water Use

Industrial water use will be required during construction (i.e., dust suppression) and operation of the IWMF, including for use in industrial cleaning services and washing the incinerator. Industrial process water will be supplied from the existing AES connection, rainwater collection tanks installed throughout the IWMF and beneficial reuse water following treatment from the WWTP and IWWTP. Water demand for the IWMF industrial operations from the AES supply is expected to be 3.39 ML per year. Water supplied from beneficial reuse of water treated onsite via the WWTP or IWWTP is anticipated to be 27.3 ML per year, and estimated rainwater capture on site is 6.6 ML per year. Total water usage will be monitored and documented, as specified in the CESMP. An energy and water conservation plan will be developed and implemented during operations to ensure the efficiency of water use and will be prepared with set annual targets for monitoring effectiveness.

4.9 Energy Supply

The main power supply for the operations of the IWMF will be provided by three-phase power, supplied through PNG Power. Two 250 kVA diesel generators will be maintained at the IWMF and kept on standby as a backup power source in the event of a power failure. Additional mobile diesel generators may be required during construction of the landfill and ongoing operations and the incinerator will also require an individual diesel generator. Diesel fuel will be required to supply heavy and light vehicles, and equipment, during landfill construction and ongoing operations. Refuelling of mobile plant will occur at the IWMF within impermeable hardstand areas.

Bulk fuel storage on-site will be required, with approximately 3,000 L of diesel fuel storage for the backup generators, an in-built 1,000 L diesel storage tank for feeding through fuel to the incinerator burners via a reticulation line for incineration and a 10,000 L fuel bulk storage tank for supplying the incinerator, located adjacent to the incinerator building. Additional bulk fuel storage on site will be at the mechanical workshop, located behind the existing three bedroom house, in accordance with dangerous goods classifications. As above, an energy and water conservation plan will be prepared during operations to ensure the efficient use of energy by the Project.

4.10 Anticipated Discharges, Emissions and Wastes

Anticipated discharges, emissions and wastes are described in this section, including wastes that will likely be generated by the Project during both construction and operations of the IWMF and either discharged on-site or exported off site to domestic and international markets.

4.10.1 Liquid Wastes

Liquid waste streams and the processes for managing each stream are described below and include sewage and greywater from domestic activities (Section 4.10.1.1), leachates (Section 4.10.1.2), industrial wastewater (Section 4.10.1.3) and stormwater (Section 4.10.1.4). These waste streams exclude commercial feedstock imported to the IWMF for treatment. The vast majority of liquid waste will be directed to the domestic WWTP or IWWTP for treatment, with the exception of clean stormwater. Following treatment, wastewater will be either reused for beneficial purposes on site, fixated or composted. Water collected from the washdown of the weighbridge and guardhouse may be discharged offsite to the stormwater system (described in Section 4.5.12) located along Napa Napa Road. The discharge of stormwater off-site is currently approved under the existing environment permit EP-L2 (485) and requires adherence to the freshwater receiving water quality criteria for the protection of aquatic life as per the Environment (Water Quality Criteria) Regulation 2002. The expected annual volumes of wastewater (excluding commercial feedstock) to be disposed of or reused are provided in Table 4.5.

Table 4.5 – Anticipated Annual Volume of Liquid Waste Disposal and Reuse

Wastewater Type	Volume Per Year (ML)
Beneficial Reuse	27.3
Fixation for incinerator or landfill disposal	4.8
Composted	0.00052
Discharged offsite to stormwater	0.01

4.10.1.1 Sewage and Greywater

Sewage and greywater generated from domestic activities such as dish washing, laundry and showers will be generated at the existing accommodation and administration facilities at the IWMF site during both construction and operations. Sewage volumes generated will vary depending on the number of people present at the IWMF site. Currently, septic tanks at the existing site offices and accommodation on-site are pumped out and transferred to the Eda Ranu water treatment plant in Port Moresby for disposal. It is expected that this process will remain in place until the completion of the domestic WWTP. Once the WWTP is operational, liquid sewage components from on-site septic tanks will be directed to the WWTP for treatment, and sewage sludge will be blended with organic waste and composted. It is anticipated that 1.32 ML of wastewater from the accommodation and administration facilities will be discharged to the domestic WWTP, with disposal or reuse options as follows:

- 1.12 ML per year of treated domestic wastewater for beneficial reuse.
- 0.19 ML per year of treated domestic wastewater for fixation.

4.10.1.2 Leachates

Leachate collection systems will be designed for the industrial landfill (see Section 4.5.10) and the composting operations (Section 4.5.3.3), with all leachates eventually transferred to the IWWTP for treatment. Leachate from the composting plant will be collected via a system of interceptor drains and directed to a storage tank at the IWWTP. Until the final installation of the IWWTP, leachates collected from the industrial landfill will be stored at the leachate holding pond and will undergo evaporation. Leachate levels in the pond will be monitored on a daily basis. On completion of the IWWTP, leachate collection systems will collect all leachates for transfer and treatment through the IWWTP for beneficial reuses such as cleaning industrial plant. Leachates will not be released to the environment.

4.10.1.3 Industrial Wastewater

Industrial wastewater will include waters used in the cleaning of IWMF plant and will be utilised in various operational activities at the mechanical workshop, industrial service wash bays, hazardous waste storage building, incinerator building, the WOPU and the receival hall. Approximately 3.2 ML of industrial wastewater will be directed to the IWWTP per year, with the following volumes reused or disposed of:

- 2.74 ML per year of treated industrial wastewater for beneficial reuse.
- 0.48 ML per year of treated industrial wastewater for fixation and incineration or disposal at the landfill.

4.10.1.4 Stormwater

As described in Section 4.5.12, surface water from operational areas of the IWMF (i.e., dirty water) will be diverted to storage tanks via the site's stormwater management system shown in Figure 4.4 and Figure 4.5. Stormwater from operational areas will be transferred to the IWWTP, treated for beneficial reuse, fixated for disposal or incineration or discharged to environment if deemed to meet discharge criteria. Stormwater from uncontaminated or non-operational areas of the site will be discharged directly to the environment without collection via the clean stormwater system. An estimated 0.01 ML per year of water collected from the weighbridge and receival hall area will be discharged to the environment per year without treatment.

4.10.2 Hazardous Wastes

Hazardous wastes not undergoing final disposal at the IWMF will be stored at the hazardous waste storage facility prior to export to either domestic or international markets. These wastes will be packaged and stored in accordance with dangerous goods requirements. Hazardous wastes that may be exported off-site include:

- Used lead acid batteries.
- Spent activated carbon.
- End of life tyres.

4.10.3 Non-hazardous Solid Wastes

Non-hazardous solid wastes, including regulated and non-regulated wastes, will also be exported to either domestic or international markets, following processing and in some cases treatment. These wastes may include:

- Recyclable materials including plastics, aluminium and steel cans.
- Electrical waste.
- Recycled oils.
- Composted organic waste, if not re-used on site.

4.11 References

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5. Analysis of Alternatives

5.1 Introduction

Chapter 4 presents the current optimised configuration proposed for the Project, which has been selected to provide safe, cost effective and sustainable waste treatment and recycling services for Papua New Guinea and its Pacific neighbours. This chapter provides an overview of the alternatives and the process used to define the Project that is the basis of this EIS. Similarly to Chapter 4 and for completeness, this chapter discusses components of the IWMF development that are already approved for construction and operation as well as additional aspects not currently approved.

The Project is subject to a range of constraints and opportunities, which include:

- Technological – the selection of processing and treatment equipment in accordance with the best available technology.
- Environmental – the existing environmental values (e.g., high conservation areas, water bodies, suitable terrain and geotechnical constraints).
- Social – the values, expectations and concerns of affected communities and businesses with an interest in the Project.
- Economic – the Project must be commercially viable and represent value-for-money for investors. Market drivers must also be taken into account.
- Governance/compliance – the Project must satisfy industry regulations and government legislation.

These constraints and opportunities have been considered throughout the stages of Project development; concept design, pre-feasibility and feasibility, and will continue to influence the decisions made throughout Project implementation.

5.2 Alternatives Considered

TWM has considered viable Project design and location options through the application of the constraints and opportunities identified in Section 5.1. Specifically, the options considered include:

- Site and infrastructure location alternatives.
- Landfill design and construction.
- Waste treatment and disposal pathways.

The following sections outline the alternatives considered and selected as a result of this process, and the justification for the current Project configuration.

5.2.1 Site and Infrastructure Location Alternatives

As described in Chapter 2, TWMs waste management facilities were initially located at Badili, Port Moresby. While these facilities were suitable for the collection, separation and storage of wastes, it was not suitable for complex waste treatment processes. In 2015, TWM began operating their

WOPU at the AES site within the AES Industrial Park and began considering site alternatives for a larger site located close to Port Moresby and commercial customers with good transport route access and adequate buffer distances from receptors (e.g., residential areas). The following options were considered by TWM before selecting the current site:

- A 3,000 m^2 site at Gerehu with warehouse and sealed working areas. This site was considered too small to enable the construction and effective operation of the plant required for the full range of waste treatment and management proposed.
- A site on Napa Napa Road (between the current location and the Puma Refinery) on the waterfront was considered; and while the site's size and location were suitable, the capacity to lease or acquire land was limited.

The current site on Napa Napa Road was selected as it met both size and location requirements, and contained existing office, accommodation and workshop buildings and cleared benches, providing flat land suitable for the waste infrastructure planned (see Section 4.3.1). Further, the site was able to be secured under a 99-year State lease, providing long term security on which to commit the investment.

TWM considered various options for the location of infrastructure, plant and equipment on the site, including the location of the landfill, hazardous waste storage, waste oil recycling, the wastewater treatment plant and warehousing. Siting of IWMF infrastructure considered the location of existing facilities and locations or pre-cleared and prepared areas, process flow and operational requirements, the need for separation of non-compatible activities (e.g., future housing and waste processing areas), and environmental factors such as soil conditions, geotechnical considerations such as slope stability, rainfall conditions, drainage and wind conditions in relation to plant location and design.

5.2.2 Landfill Design and Construction

Section 4.5.10.1 and Appendix 1 outline the key design features of the proposed landfill. The landfill has been designed and will be constructed considering PNG codes of practice and good international industry practice (GIIP), the planned acceptance of hazardous waste, the desired capacity and geotechnical and hydrological considerations of the site. The landfill will be constructed with multiple barriers including HDPE geo-membrane liners combined with geo synthetic clay liners, low permeability clay liners with double leachate collection and leak detection system.

The landfill has been designed in accordance with US EPA and Australian standards. Although the materials that will be disposed to landfill will be largely inert, TWM made the decision to utilise a multiple barrier, double leachate collection and leak detection system, to fully optimise environmental protection measures.

Surface water management utilises diversion drainage to avoid rainwater coming into contact with the landfill and operational procedures also minimise ingress of rainwater to the landfill operating area.

Leachate will predominantly be produced via rainfall ingress, as the materials to be disposed of will largely be non-putrescible. The production of leachate will therefore be minimised through the

application of surface water management controls such as using diversion drains to minimise water coming into contact with the landfill, the use of temporary cover to the operating face to prevent rainwater from entering the landfill, and the immediate revegetation via hydromulching of closed sections of the landfill.

Landfill gas is not expected to be a key environmental contributor as the materials being disposed of to the landfill will be largely inert and won't produce methane. Nonetheless a gas capture system has been incorporated into the landfill design.

Construction techniques were selected based on standard methods and the availability of resources (technology, machinery and equipment) in Papua New Guinea. All construction contractors are required to maintain current environmental, safety and quality management systems and site-specific management plans. The landfill construction and operation is governed by conditions within the TWM environmental operating permit issued by CEPA and the relevant environmental policies, codes of practice and legislation of Papua New Guinea.

The final form of the landfill has been designed to align with the current natural landform.

5.2.3 Waste Treatment and Disposal

Chapter 4 outlines the proposed waste treatment streams, treatment and disposal pathways. TWMs development program includes the reprocessing/remanufacture of recovered waste materials. This includes plastics, and investigations are underway to determine the viable technologies capable of receiving and processing mixed polymers as opposed to single polymers. In the early stages of operations single polymers may be prepared for market by shredding or bailing, however export of recovered product in its current form is not considered to be a long-term approach to managing plastics in-country.

Waste treatment technologies have been selected based on their ability to:

- Be operated safely and efficiently.
- Be serviced and maintained effectively in-country.
- Scale up to handle increased volume in accordance with future needs.
- Utilise a reduced spatial footprint and not require land clearing.
- Integrate with, supply and/or receive feedstock from other IWMF plant.
- Provide employment opportunities to local communities.
- Meet environmental protection criteria, including:
  - Capacity and performance of emission controls including dust, odour and noise.
  - Water and power efficiency.
  - Ability to operate using the processed fuel oil produced by the WOPU on site.
  - Ability to use beneficial reuse water.

The waste management hierarchy is at the core of the design of the site as are principles of environmental protection and social benefit, natural resource conservation, renewable energy, beneficial reuse and circular economy approaches to the recovery of valued resources from the waste stream.

5.3 No Project Option

Not proceeding with the Project would mean that the potential adverse environmental and social impacts described in Chapters 10 and 11 would not pose a risk or occur. However, it will also result in the more substantial Project benefits not being realised, which include:

- The consolidation and sustainable management of general and hazardous wastes and the improvement in social health and environmental outcomes as a result of less waste being disposed in illegal or unregulated landfills, or facilities that do not meet regulatory standards.
- Reducing the current dependence on export arrangements for offshore waste treatment and disposal.
- Government support for Papua New Guinean SMEs and progress towards implementing the national strategies outlined in Table 2.1 (Chapter 2).
- Direct benefits to legally recognised landowners through lease revenue and sale of land.
- Projected employment and training opportunities during Project construction and operation, particularly for Roku residents.
- The social investment and capacity-building programs described in Chapter 11.

6. Stakeholder Engagement

6.1 Engagement Approach and Methods

TWM is committed to establishing and maintaining positive stakeholder relations through effective communication and consultation with identified stakeholders; individuals or organisations that are directly or indirectly impacted by the Project, and/or who can influence its success. TWM recognises there is no single approach for engaging with all stakeholders and employs the engagement approach that reflects the specific needs and issues associated with each individual stakeholder or stakeholder group, and the potential level of impact on each.

A Project stakeholder engagement plan (SEP) (ERIAS, 2020) has been developed for the Project, with the following key objectives:

- To meet public consultation and disclosure requirements under Section 55 of the *Environment Act 2000* and relevant TWM company policies.
- To clearly identify and 'map' (categorise) relevant stakeholders, specifically local communities, individuals, businesses that may be affected by the Project.
- To clearly identify potential Project impacts and stakeholders' issues to ensure that engagement activities are tailored to the EIS process.
- To align with, as well as supplement and support, issues and activities that have been previously identified by TWM.
- To provide a solid foundation upon which Project impacts may be identified, assessed and mitigated where necessary, which is informed by key stakeholders and affected communities so as to gain their feedback during the ongoing development of the Project.
- To ensure grievances are addressed through an appropriate grievance mechanism.
- To document all processes, methods, activities, participants, issues raised and outcomes in an appropriate format for both TWM internal and EIS reporting purposes.
- To provide TWM with an engagement and communications action plan for key phases of the Project's development to ensure that all necessary stakeholders are engaged with in a timely manner so as to reduce Project risk and enhance TWMs stakeholder relations.

6.1.1 Principles of Engagement

Stakeholder engagement has and continues to be undertaken by TWM based on the following principles which have been adapted from the International Association for Public Participation's Spectrum (IAP2, 2011):

- Undertake identification, analysis and planning for stakeholder engagement to ensure tailored and inclusive approach.
- Inform stakeholders via timely and tailored disclosure of relevant Project information.

- Support prior and informed engagement to enable stakeholders to provide input on potential risks, issues and concerns.
- Involve and empower stakeholders in the Project design and decision-making process, fostering a collaborative and transparent dialogue between stakeholders and TWM.
- Plan for ongoing engagement with affected stakeholders throughout all stages of Project development.

6.1.2 Stakeholder Identification

TWM has an in-depth understanding of its stakeholders due to the existing operational facility; however, in line with the requirements set out in the *Environment Act 2000* and the principles outlined in Section 6.1.1, TWM sought to identify all stakeholders that are likely to be directly or indirectly affected by the proposed Project, have an interest in the Project, or might have a positive or negative influence on the Project.

TWM understands that stakeholder identification and analysis are ongoing activities that should be undertaken throughout the Project lifecycle to ensure that any potentially impacted stakeholders are identified and engaged within a timely and transparent manner. As part of the ongoing process of stakeholder identification, TWM has and will continue to employ the following steps throughout the Project lifecycle:

1 Update and maintain the stakeholder database which has been developed through an iterative process of engagement spanning the previous three years.

2 Verify stakeholder details with TWM internal Community Affairs (CA) staff.

3 Verify stakeholder details with key stakeholder representatives.

Key stakeholder groups identified and engaged during the development of this EIS include those listed in Table 6.1.

Table 6.1 – Stakeholder Groups

Stakeholder Type	Description
Roku village leaders and residents	• Landowner clans and community leaders • Representatives of residents in Roku village that may benefit or be adversely affected by direct and/or indirect Project impacts • Representatives of small-scale businesses in Roku village that may benefit or be adversely affected by direct and/or indirect Project impacts
Community-owned companies	• Board of Ohobiduduare Holdings Limited • Leaders of Kuriu Landowner Group
Papua New Guinea national government agencies and authorities	• CEPA • Department of Transport (DOT) • Department of Provincial and Local Level Government (DPLLG) • Department of Lands and Physical Planning (DLPP) • National Museum and Art Gallery (MMAG)

Stakeholder Type	Description
Provincial and local-level government (LLG) areas	• Central Provincial Administration – Hiri District
Industry and Business	• Rhodes PNG and AGL Builders (Rhodes/AGL) • AES • Agility • Puma Energy Oil Refinery (Puma) • Oilmin Holdings Ltd (Oilmin) • Pagini Group (Pagini) • Islands Petroleum • Longfa Cement
Community-based organisations (CBOs)	• Roku Church • Roku Women's Fellowship • Motu Koita Association • Future Endowment Fund

6.2 Engagement Activities

Engagement activities related to the Project began in 2017, with a meeting with CEPA to provide a summary of the proposal and understand likely permitting requirements. Reoccurring meetings have since been held with CEPA at least quarterly, to determine the appropriate approval process and provide updates on Project progress and issues.

Regular informal meetings and phone conversations with village leaders have commenced to provide updates on progress of the Project. Village leaders in turn pass on Project-related information to their communities in addition to the direct engagement at the community level by TWM CA staff.

Stakeholder engagement activities undertaken for the Project relevant to its development and additional to the EIS baseline studies are summarised in Table 6.2.

Table 6.2 – Project Stakeholder Engagement

Date	Stakeholder	Purpose of Engagement	Key Issues Discussed	Outcomes
2018	National Museum and CEPA	To discuss protection of natural and cultural heritage	Cultural heritage survey undertaken	Supported application for the environment permit
2018	Village Chairman	To address safety concerns with Chairman	Discussion on villagers continuing to enter and walk through the IWMF site to access Napa Napa Road	Support gained from the Chairman to address these matters with the Community
Multiple 2018 to 2020	Village Chairman	Roku Community request for	Provision of funds and uniforms	Supply of funds and uniforms

Date	Stakeholder	Purpose of Engagement	Key Issues Discussed	Outcomes
		assistance with local sporting clubs		
2018 to 2020	Village Chairman	General discussions/meeting at IWMF	Requests for shirts and hats for Board Members	Shirts and hats provided
2018 to 2020	AES and Rhodes/AGL	TWM provide neighbours with an understanding of business operations	Discussion on proposed TWM development	Understanding of development. Supply of construction services to TWM and the development of the site - continuing
2019	Industrial neighbours inc. AES, Rhodes/AGL, Pagini, Agility, Island Petroleum	Join collaboration to repair Napa Napa Road after damage by heavy rains	Works plan, cost distribution	Repairs made to Napa Napa Road
2019	Roku Community, surrounding Industrial neighbours inc. Oilmin, AES, Rhodes/AGL, Pagini	World Environment Day celebrations	Collaborative approach to raising awareness of environment protection within Roku village	Clean-up day, luncheon and environmental awareness raising at Roku Village
2019	Roku Community/ Ohobiduduare Holdings	Discuss village issues and how TWM may assist	Village sanitation issues	TWM donation of two portable toilets to the village
2019	Roku Community/ Ohobiduduare Holdings	Focused request from Chairman	Request for funds to cover medical costs for community member	Funds provided
Multiple 2019 to 2020	Ohobidiudare Holdings	Procurement of land	Objective of procurement; use of land; area required; pricing; pathway to procurement e.g., transition to State lease	Agreement reached on land use
2019 to 2020	Roku Community/ Ohobiduduare Holdings	General discussions/meeting at IWMF	Request for waste collection service to village	TWM considering a range of community support options
2020	Village Chairman	To address safety concerns with Chairman	Discussion on villagers continuing to light fires on the boundary and within the IWMF site	Support gained from the Chairman to address these matters with the community
2020 Multiple	Rhodes/AGL and Tuhava	Community support	Support for local sporting clubs	Provision of sporting equipment
2020	Dr. C. Yala	To discuss an organisation	Establishment of the PNG Future	K. Chan is a Director of FEF

Date	Stakeholder	Purpose of Engagement	Key Issues Discussed	Outcomes
		focused on assisting communities with essential services and infrastructure	Endowment Fund (FEF)	

Key engagement activities undertaken during July 2020 to support EIS baseline studies are presented in Table 6.3 and Figure 6.1, Plate 6.1 and Plate 6.2.

Engagement methods used to support informed consultation and participation in EIS baseline studies included:

- Pre-survey information and awareness sessions – translated pre-survey awareness flyers (Figure 6.1) were provided to community (Roku Village leaders, Roku Councillor and Roku Women's Fellowship) and business stakeholders.
- Informal interviews – targeted conversations with specific groups, including village leaders and women.
- Key informant interviews – meetings to gather data for planning and decision-making.
- Formal and informal meetings – organised with government at national, provincial and local levels.

Further detail on study methods and objectives are provided in Section 9.1.

Table 6.3 – EIS Engagement Activities

Date of Engagement	Stakeholder Groups	Purpose of Engagement
9-10 July 2020	Roku Village leaders, local industry and business (Oilmin and AGL/Rhodes, Puma Oil, Pagini, AES and Agility)	Distribute flyer and hold short meetings with villages leaders prior to baseline surveys to inform stakeholders of the upcoming surveys and to seek consent to undertake the surveys
7-17 July 2020	DOT, DPLLG, DLPP, NMAG	Discuss Inform and seek feedback on economic and social services, infrastructure, any development plans/priorities, local governance, administration and cultural heritage matters relevant to the study area with the purpose of informing EIS baseline data. A Project update was provided, and feedback was sought
14 July 2020	CEPA	Inform and seek feedback on any known environmental values and sensitivities of the study area and provide a Project update for approvals purposes
15 July 2020	Industry and business (Puma Oil Refinery)	Inform and seek feedback on existing and planned use of shared infrastructure, traffic and transport/movement of

Date of Engagement	Stakeholder Groups	Purpose of Engagement
		goods with the purpose of informing EIS baseline data. A Project update was provided, and feedback was sought
16 July 2020	Industry and business (AES and Agility)	Inform and seek feedback on existing and planned use of shared infrastructure, traffic and transport/movement of goods with the purpose of informing EIS baseline data. A Project update was provided, and feedback was sought
17 July 2020	Industry and business (Oilmin and AGL/Rhodes)	Inform and seek feedback on existing and planned use of shared infrastructure, traffic and transport/movement of goods with the purpose of informing EIS baseline data. A Project update was provided, and feedback was sought
18 July 2020	Community/Village leaders	Inform and seek feedback on existing economic and employment, governance and administration, access to infrastructure and social services, natural resource and land use, any law and order issues, cultural heritage and practices as well as other general demographic topics with the purpose of informing EIS baseline data. A Project update was provided, and feedback was sought
21 July 2020	Roku Village leaders and residents	Interview key informants during the terrestrial biodiversity field survey to seek information on use of natural resources
22 July 2020	Industry and business (Pagini)	Inform and seek feedback on existing and planned use of shared infrastructure, traffic and transport/movement of goods with the purpose of informing EIS baseline data. A Project update was provided, and feedback was sought
22 July 2020	Roku Women's Fellowship	Inform and seek feedback on existing economic and employment, governance and administration, access to infrastructure and social services, natural resource and land use, any law and order issues, cultural heritage and practices as well as other general demographic topics with the purpose of informing EIS baseline data. A Project update was provided, and feedback was sought

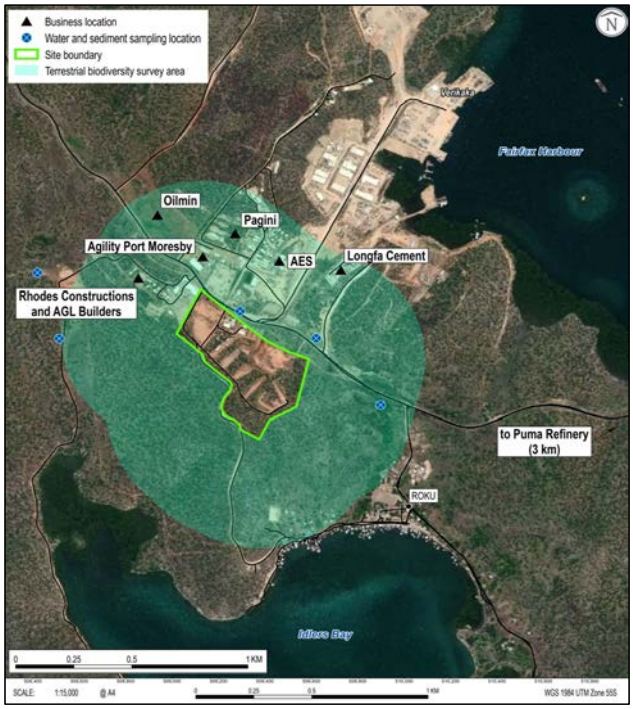
Figure 6.1 – Pre-Survey Awareness Flyer

What is proposed?

TWM has been operating since 2011 (and at Roku since 2018) and is a PNG owned and operated company, with ISO accreditation for its quality, safety and environmental systems.

TWM is proposing to expand its existing Integrated Waste Management Facility (IWMF) located at Site Portion 2703, Napa Napa Road, Roku. The expansion will allow TWM to safely handle recycling, non-hazardous and hazardous wastes and to operate an engineered landfill. The current IWMF site is 12.5 ha and the expansion in site operations will require an additional 8 ha (see map).

TWM is preparing an Environmental Impact Statement (EIS) for the PNG Government (CEPA) to assess the potential impacts, determine how to mitigate these and to seek feedback from the community and businesses on the proposal.



What does the EIS involve?

Collecting information on plants and animals, vegetation and habitats, surface water and sediment quality, and use of natural resources (i.e., hunting, fishing, collecting firewood or plants for food).

Collecting information on how people live and what is important to them, including cultural practices.

How will the information be collected?

A study team will visit the village for 1 to 2 days to ask questions, listen to people and record answers.

The team will conduct meetings, and may visit community places (e.g., school, health services and church) and local businesses, taking photos and making notes of what they see.

They will also sample surface water and sediment and identify the types of plant and animal (land and aquatic) species present in the survey area (see map).

The team seeks your help and cooperation to participate in meetings and surveys.

Participation is voluntary (there is no payment).

Survey findings are included in the EIS report which will describe how TWM will avoid or minimise potential impacts on the environment and on the community and local businesses.

The EIS report will be presented to the community and you will have further opportunity to provide feedback.

Please direct any questions about the proposal or the studies to the contact details below.

Contact:
Debra Mackeen

Ph: 320 3242
Email: info@twm.com.pg

Plate 6.1 – Roku Village Leader's Survey



Plate 6.2 – Roku Community Engagement (Women's Fellowship)



6.3 Engagement Outcomes

Early and ongoing engagement with government agencies indicates positive support for the Project, as it is viewed as a significant opportunity to address waste management standards in

the country. There is potential for this facility to help drive national waste management policy and also to be replicated in other provinces.

Landowner representatives (including village leaders) and the Women's Fellowship are also generally supportive of the Project and the potential revenue and employment opportunities that are expected to arise from it. The businesses in the AES Industrial Park and Puma Oil Refinery suggested only positive impacts would be felt on their operations and there was general consensus that TWMs expected standards would raise the value of the area to those considering future development.

Concerns raised about the Project predominantly related to uncertainties surrounding hazardous waste (e.g., the potential for air or water pollution), and increased road traffic along Napa Napa Road. There is opportunity here for TWM to increase awareness of the high standards the company meets in this regard through increased and ongoing Project development engagement. Equally, the community is encouraged by the prospect of improved waste management in the area and there is opportunity for TWM to become involved in this issue at a community level.

Feedback provided by stakeholders in relation to development of the Project, are summarised in Table 6.4.

Table 6.4 – EIS Engagement Outcomes

Theme	Stakeholder Group (Raised By)	Description of Issue/Benefit Identified	Where Addressed in the EIS
Increased employment opportunities	Industry and business	Increased employment will result in increased business for surrounding organisations	Section 11.1
	Community	Increased employment opportunities are seen as a positive and supported by the community	Section 11.1
Economic and community development	Government	Support the Project as it provides good practice recycling and hazardous material management and would support additional waste management facilities in Papua New Guinea	Chapter 2
		Considering developing a National waste management policy for all Provincial Governments to assist in future economic development	NA
		Would like to understand any corporate social responsibility initiatives TWM may be considering in relation to local communities	Chapter 11
	Industry and business	Increased standards (to international standards) by TWM is welcomed and will lift the value of the area, particularly to any other businesses considering further development of the area	Chapter 2
		Continue to work with local communities on ongoing community development opportunities (road maintenance and	Chapter 11

Theme	Stakeholder Group (Raised By)	Description of Issue/Benefit Identified	Where Addressed in the EIS
		community waste management for example)	
Increased traffic on Napa Napa Road	Government	Would like to understand expected traffic (types and frequency of vehicle) to assist in understanding cumulative impacts of road use	Section 11.4 Section 11.7
	Business	Concerns surrounding road condition may deteriorate with increased traffic flow	Section 11.4 Section 11.7
Environmental and health related to chemical and hazardous waste management and treatment	Government	Supports the Project as it aims to reduce high volume waste material in project sites that has the potential to negatively affect others (an important issue in Papua New Guinea)	Chapter 2
		Would like to understand further details on the transportation of hazardous wastes. Chemical and hazardous waste handling and transportation laws may apply	Chapter 4 Chapter 11 Section 11.2
	Roku village leaders and residents	Concerns/misconceptions surrounding pollution/contaminants, particularly to groundwater and increased odour (considering north-easterly winds)	Sections 10.1, 10.3, 10.4 and 10.5 Section 11.2
		Concerns raised relating to level 3 permit involving higher volumes of waste management	Chapter 4 Chapter 11 Section 11.2
Law and order	Industry and business Community-owned companies	Community concerns/misconceptions surrounding potential contamination has previously led to interruption to traffic flow via a roadblock / protest	Sections 10.1, 10.3, and 10.4 Section 11.2
Construction activities	Industry and Business Community-owned companies	Some concern surrounding the control of sedimentation during the construction of TWM facilities, particularly during rainy periods (based on past experience from industrial area development)	Sections 10.1 and 10.3 Section 11.2
Cumulative impacts	Government	Concerns/misconceptions surrounding cumulative environmental and socio-economic impacts on local community livelihoods, lifestyles, amenity and marine/natural resources and land use and damage. Hunting areas for wallabies/maganies, infestation of pests, flies and creates increased dust particles in local villages	Section 11.3 Section 11.2
Ongoing engagement	Government	High awareness of the Project through the EIR process and expectation of forthcoming EIS to meet approvals requirements	Chapter 6

Theme	Stakeholder Group (Raised By)	Description of Issue/Benefit Identified	Where Addressed in the EIS
		Ensure further engagement with Provincial government prior to submission of the EIS to CEPA	Chapter 6
		Ongoing engagement with landowners is required to avoid any potential land disputes	Chapter 6
	Industry and business	Well informed by TWM and encourage ongoing arrangements for engagement	Chapter 6
	Roku village leaders and residents	Concerns/misconceptions relating to potential impacts on the collection of firewood. Community would like more information on the proposal and how TWM will address potential impacts, including pictures	Section 11.2

NA not applicable; general policy comment.

6.4 Planned Engagement

In addition to engagement surrounding issues raised by stakeholders during EIS baseline studies (see Table 6.3), formal EIS engagement, comprising two EIS roadshows, will be undertaken in accordance with the requirements of the *Environment Act 2000*. The first roadshow is for the Draft EIS (Draft EIS Roadshow), led by TWM and the second is for the Final EIS, led by CEPA (CEPA EIS Roadshow). The roadshows will both be preceded by a pre-awareness engagement campaign to advertise the forthcoming roadshow to maximise attendance and participation by affected stakeholders.

6.4.1 Draft EIS Roadshow

The Draft EIS Roadshow will involve presentation of the proposed Project (via Project posters or similar visual means and a public meeting) to affected stakeholders, including public disclosure of key findings and results from the environmental and socio-economic baseline studies, validation of issues and impacts as well as discussion of key project design and mitigation aspects. Stakeholders will be provided opportunity to raise concerns or issues related to Project information presented at the roadshow and TWM is provided opportunity to outline its formal grievance mechanism to roadshow attendees.

Any concerns or issues raised during the Draft EIS roadshow will be noted and, if possible, addressed at the Roadshow and also considered and incorporated into the Final EIS.

6.4.2 CEPA EIS Roadshow

Similar to the roadshow for the Draft EIS, the CEPA-led roadshow will present the Final EIS and will aim to:

- Allow CEPA to receive feedback from affected communities.

- Input to CEPA's assessment and inform the conditions of environmental permit approval if granted.

6.4.3 Ongoing Stakeholder Engagement

Stakeholder engagement is ongoing for TWMs current and planned operations at the IWMF and will continue throughout the development of the Project and into the operations phase. In addition to the activities specified previously in relation to the EIS preparation, TWM will:

- Maintain the stakeholder database.
- Maintain and publicise amongst key stakeholders the grievance mechanism (Section 6.5).
- Continue to engage with the local community, providing updates on site operations and continuing to engage in local initiatives.
- Provide informal updates to relevant government agencies and local businesses and industry, as appropriate.

The CESMP provides further detail on the stakeholder engagement proposed for the construction phase of the Project.

6.5 Grievance and Data Management

TWMs grievance management procedure or grievance mechanism is designed to complement and inform ongoing stakeholder engagement, building on the principles of transparent engagement and timely response to stakeholder concerns.

Similarly, transparent documentation (data management) of engagement activities is a key aspect of good practice engagement and will enable TWM to track stakeholder concerns, perceptions and expectations regarding the development and operation of the Project. It will also support the identification of new stakeholders and inform the selection of engagement level and tools.

Both grievance and data management will be implemented in accordance with the Project SEP (ERIAS, 2020).

6.6 References

ERIAS. 2020. Total Waste Management Integrated Waste Management Facility Stakeholder Engagement Plan. ERIAS Group Pty Ltd, Melbourne, VIC.

IAP2. 2011. Techniques for Effective Public Participation. International Association for Public Participation (IAP2).

7. Impact Assessment Method

7.1 Introduction

This chapter describes the impact assessment process and methods used to assess the potential environmental and social impacts of the Level 3 activities associated with the Project. As described in Section 4.1.2 and shown in Table 4.1 several components of the IWMF development are already approved for construction and operation under TWMs existing Level 2 environment permit EP-L2 (485). The impact assessment provided in Chapter 9 and 10 of this EIS only considers potential impacts associated with activities requiring a Level 3 environment permit, as indicated in Table 4.1.

The assessment of the Project's potential impacts is intended to satisfy PNG regulatory requirements for the preparation of an EIS under the *Environment Act 2000*, which is necessary to obtain a Level 3 environment permit for the Project.

The CEPA, formerly DEC, Guideline for Conduct of Environmental Impact Assessment and Preparation for Environmental Impact Statement (DEC, 2004) states that:

> The developer must prepare and submit an EIS that provides full documentation of all environmental and social issues and committing to the employment of relevant mitigation measures in relation to the development activity.
>
> The required format for the EIS provided within the DEC (2004) guidelines is intended to provide DEC and other stakeholders with unambiguous documentation of potential environmental impacts on which DEC can base its assessment and any subsequent approval that may be granted.

7.2 General Approach to Impact Assessment

7.2.1 Overview

This section provides an overview of the EIS method, which will be described in the proceeding sections:

- Identify environmental and social values or sensitive receptors relevant to the Project by describing the existing physical, biological and socio-economic environment within and around the Project area, including relevant 'receptors' and beneficial values (Section 7.2.2).
- Identify Project activities/aspects and potential impacts of those activities on environmental and social values by describing the Project and associated activities, particularly within the context of potential interactions with the existing environment (Chapter 10 and 11).
- Determine appropriate avoidance, mitigation and management measures that will address the potential impacts and are both technically and economically feasible and are assumed to be implemented in a timely manner during Project development (Section 7.3.1.3).

- Undertake residual impact assessment, taking into account the implementation of mitigation and management measures (for construction and operations) (Section 7.3.1.4).
- Undertake cumulative impact assessment to assess the total potential impact in conjunction with other current or future projects on common receptors (Section 7.3.3).
- Undertake risk assessment of major hazards associated with accidental, upset or abnormal events e.g., earthquake or major spill. Assessment involves identifying potential events, its consequences, and proposed management and mitigation measures, using information from a hazard identification workshop (Section 7.4).

This approach is consistent with that used in other recently completed environmental and social impact assessments for Projects in Papua New Guinea.

7.2.2 Environmental and Social Values

In order to apply these methods, an understanding of the affected environmental and social values is required. The relevant environmental and social values requiring assessment in the EIS have been determined from the preparation and approval of the EIR, the results of the field studies, including stakeholder engagement, and from consideration of the potential impacts and risks of the Project.

The Project has assessed the relevant environmental and social values set out in statutory guidelines or policy, or where these are not defined, assessed values based on experience and accepted practice. These values are broad components of the environment such as aquatic ecosystems, water or air quality, or socio-economic values such as cultural heritage, land use and natural resources.

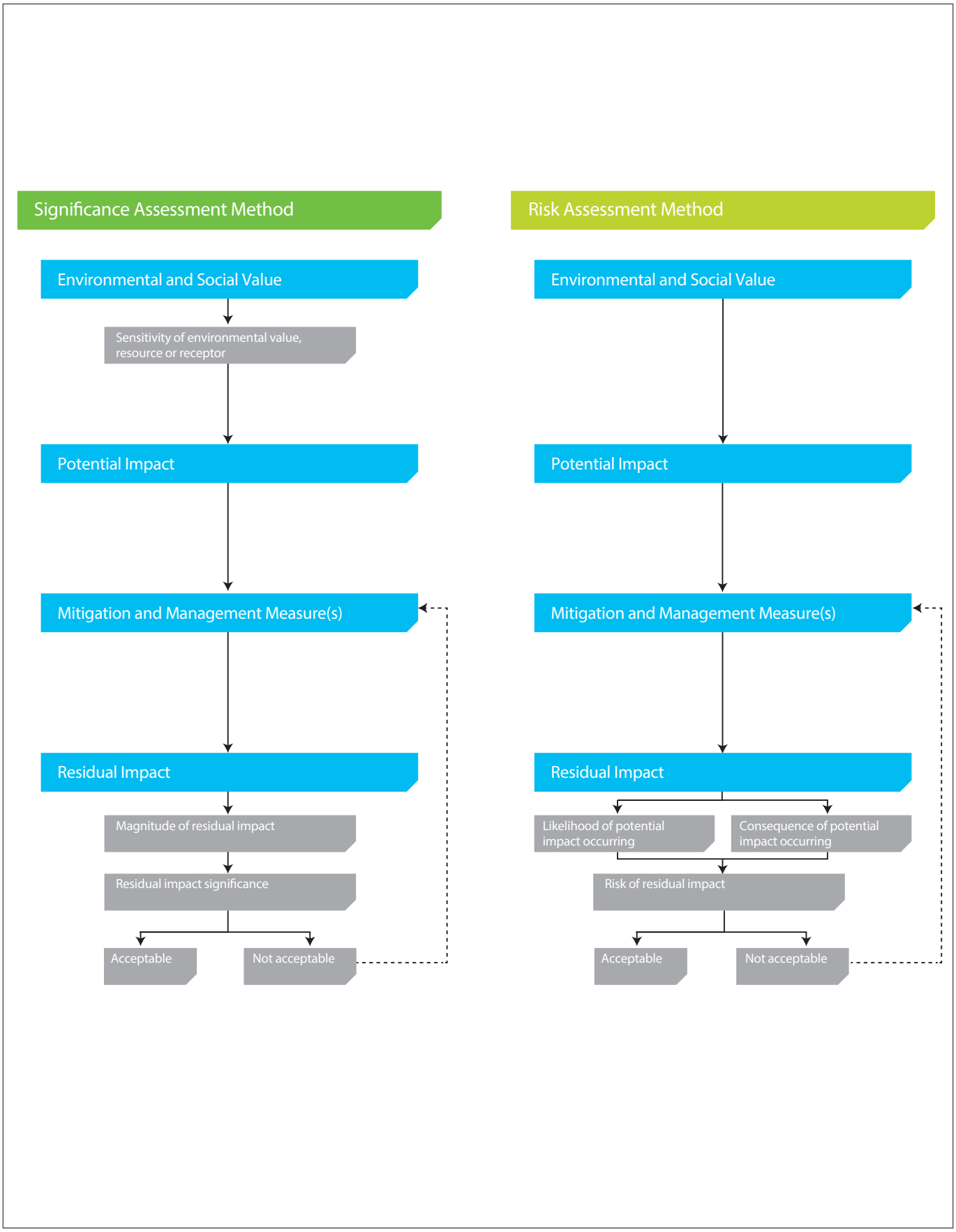
7.3 Environmental and Social Impacts from Planned Activities

7.3.1 Significance Impact Assessment Method

The significance assessment approach was used to assess potential environmental and social impacts. The method is based on understanding the vulnerability of an environmental or social value, resource or sensitive receptor to determine the potential severity of impacts. The method assesses credible impacts that are expected to occur during the Project's life cycle, i.e., associated with planned activities. The approach for this method is shown in Figure 7.1.

The significance assessment method considered the ***sensitivity*** of the value or receptor being impacted, and the ***magnitude*** of the impact following mitigation to determine the residual impact significance. The residual impact significance is then assessed as a product of the value or receptor's sensitivity and the magnitude of the impact as determined by the significance matrix. Sensitivity, magnitude and residual impact significance are described in more detail in the following sections.

FIGURE 7.1


Significance Assessment Method
Environmental and Social Value
Sensitivity of environmental value, resource or receptor
Potential Impact
Mitigation and Management Measure(s)
Residual Impact
Magnitude of residual impact
Residual impact significance
Acceptable
Not acceptable
Risk Assessment Method
Environmental and Social Value
Potential Impact
Mitigation and Management Measure(s)
Residual Impact
Likelihood of potential impact occurring
Consequence of potential impact occurring
Risk of residual impact
Acceptable
Not acceptable

7.3.1.1 Sensitivity of Environmental and Social Values and Receptors

Environmental Values and Receptors

The sensitivity of an environmental value is determined on the basis of its intrinsic value as well as its susceptibility or vulnerability to threatening processes. In order to reflect the specific focus of each technical study, key attributes that define sensitivity were reviewed, including:

- Intactness: a measure of the existing condition of the environmental value, including its representativeness and how intact it is.
- Formal status: this may be assigned by statutory or regulatory authorities or by appropriately recognised national or international organisations. This may involve legislation, regulations or international conventions or other mechanisms that attribute a particular status to a value or receptor.
- Rarity or uniqueness: as assessment of an environmental value's incidence, abundance and distribution within and beyond its bioregion.
- Replacement potential: an assessment of the potential for any losses of the environmental value to be replaced by an equivalent or representative example.
- Resilience to change: an assessment of the capacity of an environmental value to adapt to change without adversely affecting its intactness, conservation status, rarity or uniqueness.
- Importance: it's worth to local communities and society, its iconic or symbolic importance to cultural value systems.

Social Values and Receptors

Sensitivity is defined as the susceptibility of the receptor to change, including its capacity to adapt to or accommodate the kinds of changes that the Project may bring about. Social receptor sensitivity considers access to resources (physical, capital, financial and social), existing skills and experience of the labour pool (the group of people to which Project-related jobs will potentially be available) and the opinions, concerns or perceptions of stakeholders related to Project activities. Local factors can be very important as individuals, households and communities vary in their sensitivity and reactions to actual or anticipated changes.

There is possibility for sensitivity to change over time, particularly in the case of human capital and where capacity building occurs (e.g., increased skills and health outcomes). Sensitivity considers:

- Physical capital (infrastructure, equipment and facilities).
- Social capital (social networks and organisations, culture, religion and decision-making structures).
- Human capital (skills, education, health and leadership capacity).
- Natural capital (land, forests, water and biodiversity).

- Economic capital (diversity, legitimacy and productivity of livelihoods, cash and income).
- Formal status (where this may be assigned by statutory or regulatory authorities or by appropriately recognised national or international organisations).
- Pre-existing vulnerability.
- Stakeholder concerns and perceptions.

Environmental and Social Sensitivity Criteria

Applying the attributes described in the previous sections enables the sensitivity of an environmental or social value to be ranked as high, medium, low, or negligible as described by the model criteria in Table 7.1.

Table 7.1 – Environmental and Social Sensitivity Criteria

Sensitivity	Description
High	• The environmental value is listed as being of conservation significance on a statutory or recognised international, national or state register • The environmental 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 environmental value has not been exposed to threatening processes, or there has not been a noticeable impact on the integrity of the environmental value • Resource that provides the sole source of food, income, health, infrastructure for local people, or on which they are frequently dependent • Resource cannot be relocated or replaced without major loss of cultural values • There is a lack of skilled and experienced labour 'pool' • Users of the resource or service have limited to no capacity to access nearby alternatives • Receptor is unaffected by this impact prior to Project interaction or has been affected and has demonstrated no capacity to adapt to change • The majority of stakeholders have expressed concern about the impact
Medium	• The environmental value is recognised as being important at a regional level, and may have been nominated for listing on recognised or statutory registers • The environmental value is in a moderate to good condition despite it being exposed to previous impacts or threatening processes. It retains many of its key characteristics and structural elements • The environmental value is relatively well represented in the areas/systems in which it occurs, but its distribution and abundance are limited by threatening processes • Resource or service upon which local people are occasionally dependent for provision of food, income, health, infrastructure, etc • Resource can be relocated or replaced, or data/artefacts recovered in consultation with stakeholders • Limited skills in labour 'pool' with only limited experience • Users of the resource or service have limited capacity to access nearby alternatives • Some sign of exposure to this impact is already evident in the receptor prior to Project interaction • Some stakeholders have expressed concern about the impact
Low	• The environmental value is not listed on any recognised or statutory register. It might be recognised locally by relevant and suitably qualified experts or organisations

Sensitivity	Description
	• The environmental value is in a poor to moderate condition as a result of previous impact or threatening processes, which have degraded its intrinsic value • The environmental value is not rare or unique, and numerous representative examples exist throughout the area/system • Resource or service upon which local people are rarely dependent on for provision of food, income, health, infrastructure • Users of the resource or service have capacity to access nearby alternatives • Some skills in labour 'pool' with only limited experience • Users of the resource or service have capacity to access nearby alternatives • Receptor already demonstrating resilience to this impact prior to Project interaction • A minority of stakeholders have expressed concern about the impact
Negligible	• The environmental value is highly degraded compared to equivalent benchmarks • The environmental value supports physical properties or processes that are very resilient to change • Resource or service upon which local people are never dependent on for provision of food, income, health, infrastructure • Users of the resource or service have access to many nearby alternatives • Highly skilled and experienced labour 'pool' • Receptor already demonstrating full resilience to this impact prior to Project interaction • No/minimal stakeholders have expressed concern about the impact

7.3.1.2 Magnitude of Potential Impacts

The magnitude of a potential impact reflects the predicted size and nature of change based on several elements. For the purposes of this assessment these elements are defined as follows:

- Duration: the timescale of the effect, whether short, medium (i.e., reversible) or long term (i.e., effectively permanent).
- Geographical extent: the spatial extent of the impact where this is defined as site, local, regional or widespread (provincial, national or trans-boundary).
- Severity: the scale or degree of change (both positive and negative) from the existing condition, as a result of the environmental impact.

Applying the above elements enables the magnitude of an impact to be ranked as high, medium, low, negligible or positive as described in Table 7.2.

Table 7.2 – Magnitude Criteria

Magnitude	Description
High	• An impact that is long lasting (i.e., more than 15 years), widespread, and leads to substantial and possibly irreversible change to the environmental and/or social value which is either supported in a highly modified condition or not supported at all • To address the impact, avoidance of the value through appropriate design responses and/or implementation of site-specific environmental and/or social management controls are required • Impact results in fatalities, disabilities or debilitating effects on individuals
Medium	• An impact that is medium term (i.e., lasting 5 to 15 years), is contained within the region where the Project is being developed and/or where the intensity and

Magnitude	Description
	frequency of the impact is outside the range of natural variability or environmental/social value is supported in a moderately modified condition • It is possible to reduce or largely reverse the impacts/changes via specific environmental and/or social management controls
Low	• An impact that is short term (i.e., lasting less than 5 years) and localised in extent and/or the intensity and frequency of the impact is detectable with respect to natural variability or the environmental/social value is only slightly impacted • The change can be effectively mitigated and reversed through routine environmental and/or social management controls • Impact results in reversible minor injuries (i.e., that require medical treatment)
Negligible	• An impact that is unlikely to be detectable or completely reversed with respect to natural and social variability • No lost time injuries and low first aid treatments required
Positive	• A beneficial impact on an environmental and/or social value

7.3.1.3 Mitigations and Management Measures

The Project will implement mitigation and management measures to avoid and minimise adverse environmental and social impacts, and to enhance positive impacts where possible. Potential environmental and social impacts are assessed on the assumption that mitigations and management measures have been successfully implemented. Mitigation measures presented in this report were developed using the principles of the mitigation hierarchy (i.e., avoid, minimise, rehabilitate and offset) and in accordance with relevant PNG legislative requirements and TWM policies and procedures.

The mitigation hierarchy establishes the preferential order for applying management measures to most effectively reduce the magnitude of an impact or the sensitivity of the receptor (applicable to social impacts only), as far as practicable. Project mitigations have been developed from the early stages of Project design (embedded design), input from specialist studies and best practice. A number of embedded design controls exist which are inherent in the construction and operation of Project infrastructure (e.g., the use of an impermeable liner in the industrial landfill). These embedded design controls are described in Chapter 4 and mitigate potential environmental and social impacts. In some cases, these embedded design controls are sufficient to effectively reduce the magnitude of impact and so further mitigation measures are not required.

The mitigation and management measures presented in this report will be captured in the Project's CESMP and operations EMP) and are provided in a Commitments Register in Appendix 2. Each embedded design control and environmental and social mitigation and management measure has been assigned a unique identifier using the prefix 'ED' for embedded design controls, 'EM' for environmental mitigations and 'SM' for socio-economic mitigations. These unique identifiers are used in the impact assessment summary tables presented in Chapter 10 and Chapter 11 with the corresponding detail provided in Appendix 2 and the relevant mitigation and management sections of those chapters.

7.3.1.4 Residual Impact Significance

The significance of an impact on a value or receptor was determined using the significance matrix presented in Table 7.3, which combines the likely magnitude of an impact with the sensitivity of

the value or receptor. The magnitude of an impact was assessed considering the application of mitigation measures that were expected to reduce the impact's severity, geographic extent or duration. The result is a significance rating for the residual impact.

Table 7.3 – Significance Assessment Matrix

		Sensitivity of Value			
		High	Medium	Low	Negligible
Magnitude of Impact	High	Severe	Major	Moderate	Minor
	Medium	Major	Moderate	Minor	Minor
	Low	Moderate	Minor	Minor	Negligible
	Negligible	Minor	Negligible	Negligible	Negligible
	Positive	Positive	Positive	Positive	Positive

The classifications (severe, major, moderate, minor, negligible and positive) for significance of an impact are defined as follows:

- **Severe:** when an impact will potentially cause widespread or irreversible harm to an environmental or social value that is irreplaceable (e.g. because of its rarity or uniqueness, or inability to adapt or recover). Avoidance of the value/impact through appropriate design responses is the only effective mitigation.
- **Major:** when proposed activities are likely to worsen threatening processes affecting the core characteristics or structural elements of an environmental or social value. Although replacement of unavoidable losses is possible, avoidance through appropriate design responses is preferred in order to preserve the environmental or social value conservation status or habitat intactness.
- **Moderate:** where an environmental or social value is somewhat resilient to change, but would be further degraded due to the scale of the impact or its susceptibility to further change. The abundance and/or distribution of the environmental or social value ensures that it is adequately represented in the region, and that replacement, if required, is achievable.
- **Minor:** where an environmental or social value is of local importance, but temporary changes will not adversely affect its viability, provided that routine environmental and social management controls are implemented.
- **Negligible:** where impact to an environmental or social value will not result in any noticeable change in its intrinsic value, and as such, the proposed activities will have negligible effect on its viability.
- **Positive:** where a Project activity will have a beneficial impact on an environmental or social value that enhances its resilience to change.

7.3.2 Compliance Assessment Method

Impacts associated with some Project activities such as air quality and noise, can be readily evaluated by comparison with objective, quantitative criteria, guidelines or standards where

modelling has been undertaken to predict impacts of discharges on ambient quality. Predicted Project derived values can be compared with these criteria, guidelines or standards. In the event of predicted non-compliances, impacts may be further evaluated in terms of the likely actual impacts on relevant environmental values, using the impact significance method where necessary.

7.3.3 Cumulative Impacts

The definition of cumulative impacts adopted in this assessment is consistent with the IFC Good Practice Handbook for Cumulative Impact Assessment and Management (IFC, 2013), which states that:

> 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 the primary activity (i.e., the current Project) and third party activities. By taking account of existing or other projects planned in the foreseeable future, it is intended to overcome the deficiencies associated with the limited scope of an individual project-based environmental and social impact assessment.

Cumulative impacts of the proposed Project and existing projects, and anticipated future projects, are described in Chapter 10 and 11. This assessment considers the outcomes of the environmental and socio-economic impacts of the Project and possible additional impacts from third party activities. The cumulative impact assessment considers only residual impacts assessed as moderate, major or severe. Residual impacts assessed as less than moderate, are considered too minor to present a credible pathway for cumulative impacts.

The cumulative impact assessment process involves examining:

1. Project impacts that could be contributing factors, i.e. residual impacts assessed as moderate and above (see Section 7.3.1.4).
2. Determining spatial boundaries by identifying geographical connections between projects and temporal boundaries, or the timeframe over which analysis takes place (i.e., expected life of the Project).
3. Identifying credible projects, which are defined as those that are existing, planned or reasonably anticipated based on publicly available information:
   - Currently operating or are expanding.
   - Under construction or being commissioned.

- Undertaking detailed feasibility studies or a small-scale pilot project in preparation for the full-scale project.
- Approved by government and awaiting final investment decision or are in the final design stages.
- Midway through their environmental approvals process and are likely to proceed if a permit is granted.

4 Assessment of cumulative impacts.

5 Design and implementation of mitigation measures.

7.4 Major Hazards

Unplanned discharges of environmentally hazardous substances or other impacts may occur due to major hazards and extreme natural events. These events are normally associated with loss of containment leading to spills, fires, explosions, collisions and/or hazardous emissions. While rare, such events may result in significant loss of life, serious environmental harm and asset and reputation damage. These are essentially unplanned events, to be anticipated as possibilities, for which preventative action and reactive responses are required and which are usually embedded in project design.

Preliminary analysis of major hazards and associated impacts has been undertaken for the Project in workshops held by TWM and with contractors and included a safety in design workshop for the landfill design as well as further safety in design risk assessments for other Project components and risk assessment related to specific plant on site, an ongoing process. These mechanisms. This information was used to inform the major hazards risk assessment. The approach to the risk assessment is described in the following section, with outcomes described in Chapter 12.

7.4.1 Risk Assessment Approach

TWM and ERIAS have determined potential hazards of the Project based on knowledge of the existing environment, current Project planning and experience with other similar projects in Papua New Guinea and elsewhere. The risk assessment was undertaken as a three-step process:

1. Review of all Project activities that could result in unplanned hazards with the potential to impact the environment and local community.
2. Assessment of the potential hazards or threats that those activities might pose to the physical, biological or social environment.
3. Assessment of the potential risks of those hazards or events.

Potential impacts from Project activities were assessed in terms of both their likelihood and the potential consequence if that impact were to occur, using ERIAS's risk assessment matrix. The

rating of the risk is made by reference to an assessment of the severity of the potential consequences and the likelihood[1] at which those consequences are estimated to occur.

The risk assessment assumes the effective implementation of the proposed mitigation measures that TWM will implement for the Project. It then examines the residual likelihood of a credible impact occurring as a result of an incident or hazard, and the severity of the potential consequences should the impact occur.

The principles of risk management described in the following documents were adopted in the risk assessment method:

- AS/NZS ISO 31000:2018 Risk management – Guidelines (Standards Australia, 2018).
- 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).

Tables 7.4 and 7.5 describe qualitative criteria developed to rank the likelihood and consequence of potential impacts, respectively. The consequences of potential Project impacts due to major hazards were defined in terms of four aspects – environment, health and safety, business reputation and financial loss.

The level of risk of each impact was assessed by combining likelihood and consequence in a matrix as per Table 7.6.

Table 7.4 – Qualitative Criteria for Risk Consequence

Consequence	Health and Safety	Environment/Social	Business Reputation	Financial Loss
Negligible	Minimal impact	Minimal impact	Minimal impact	Minor financial loss
Minor	First-aid treatment	Minor local impact and/or regulatory notification required	Some impact	Financial loss <1 million Kina
Moderate	Medical treatment	Significant local environmental/social impact and/or regulatory intervention	Small to moderate impact	Financial loss 1 to 4 million Kina
Major	Extensive injury or hospitalisation	Significant ecological or cultural impact and/or regulatory intervention	Significant impact and/or national media exposure	Financial loss 4 to 40 million Kina
Catastrophic	Fatality	Critical ecological or cultural impact and/or regulatory intervention	Critical impact and/or international media exposure	Financial loss >40 million Kina

[1] It is an important distinction that likelihood refers to the likelihood of the consequence occurring, rather than the likelihood of the event that leads to the consequence.

Table 7.5 – Qualitative Criteria for Risk Likelihood

Consequence	Description
Rare	• The impact may only occur in exceptional circumstances. Extremely rare occurrence (once per 1,000 years). Unlikely that it has occurred elsewhere and, if it has occurred, it is regarded as unique.
Unlikely	• The impact could occur but is not expected. May be technically possible but would be considered extremely unusual (once per 100 years).
Possible	• The impact could occur, however has seldom occurred in similar operations. There is likely to be an impact on average every 5 to 20 years
Likely	• There is likely to be an impact on average every 1 to 5 years. Likely to have been a similar incident occurring in similar environments. The impact will probably occur in most circumstances
Almost certain	• The impact will occur, is of a continuous nature, or the likelihood is unknown. There is likely to be an impact at least once per year or more (up to 10 times per year). It often occurs in similar environments. The impact is expected to occur in most circumstances

Table 7.6 – Risk Assessment Matrix

		Likelihood				
Consequence		Almost Certain	Likely	Possible	Unlikely	Rare
	Catastrophic	Extreme	Extreme	High	High	Medium
	Major	Extreme	High	High	Medium	Medium
	Moderate	High	High	Medium	Medium	Low
	Minor	High	Medium	Medium	Low	Low
	Negligible	Low	Low	Low	Low	Low

Low risks are considered minor and acceptable and will be managed by TWMs standard operating procedures and managing for continual improvement. Medium risks are considered tolerable but require close management attention during the Project to mitigate the level of risk to as low as reasonably practicable. Where the risk is higher than medium additional management and mitigation measures are required to be considered and implemented to reduce the risk to as low as reasonably practicable.

7.5 References

DEC. 2004. Guideline for Conduct of Environment Impact Assessment and Preparation of Environment Impact Statement. Information Guideline DEC Publication GL-Env/02/2004. Government of Papua New Guinea Department of Environment and Conservation. Port Moresby, Papua New Guinea.

IFC. 2013. Good Practice Handbook for Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets. International Finance Corporation. Washington DC, USA.

Standards Australia. 2012. Managing environmental-related risk. Australian Standard HB 203:2012. Standards Australia, Sydney, Australia.

Standards Australia. 2013. Risk management guidelines companion to AS/NZS 31000:2009. Australian Standard SA/SNZ HB 436:2013. Standards Australia, Sydney, Australia.

Standards Australia. 2018. Risk management – Guidelines. Australian Standard AS/NZS ISO 31000:2018. Standards Australia, Sydney, Australia.

8. Environmental Setting

8.1 Environmental Setting

8.1.1 Study Area

The environmental study area was defined considering the Project's activities and facilities (both current and planned) and the predictable direct, indirect and cumulative impacts of these activities on the physical and biological environment. The environmental study area sets the context for the area in which desktop review, modelling and field surveys were undertaken.

Specifically, the environmental study area considers:

- The proposed expansion footprint (5.5 ha to the southeast and 2.4 ha to the southwest of the existing site boundaries) with an additional 500 m buffer from the boundary.
- Ongoing site operational activities and intermittent activities such as construction works.
- Surface water catchments and the potential for runoff to extend beyond the facility boundaries and 500 m buffer.
- The location of sensitive receptors, including neighbouring industries and Roku village, located approximately 500 m to the southeast of the existing facility.
- A desktop review of local vegetation and habitat types, landforms and soils.
- Other sensitive receptors identified through screening and risk assessment (e.g., coastal mangroves).

The environmental study area is presented in Figure 8.1, including soil and groundwater sampling locations, water and sediment sampling locations, aquatic habitat investigation locations and the extent of the terrestrial biodiversity survey.

8.1.2 Environmental Studies

The environmental studies were designed to supplement existing studies that were previously commissioned by TWM and reflect the requirements of PNG's EIS guidelines (DEC, 2004) and the approach outlined within the EIR.

The environmental conditions in the study area are characterised using a combination of a bibliographic (desktop) review of publicly available information, data gathered during previous surveys at the IWMF and surrounding area, and data gathered during field surveys and interviews undertaken by ERIAS between 15 and 22 July 2020, which included community interviews, discussion with specialists (e.g., CEPA), site walk-throughs and sediment sampling.

The study methods used for each environmental discipline are summarised in Table 8.1. The following sections further describe the approach and methods used for each of these disciplines.

ENVIRONMENTAL IMPACT ASSESSMENT STUDY AREA

Integrated Waste Management Facility | Environmental Impact Statement

FIGURE 8.1

TWM Total Waste Management

ERIAS



SCALE: 1:10,000 @ A4

0 50 100 200 Meters

WGS 1984 UTM Zone 55S

- Town or village
- Air monitoring location
- Geotechnical bore
- Groundwater monitoring bore
- Soil sampling site
- Surface water, sediment and acquatic habitat sampling site
- Noise monitoring location
- Road
- Terrestial biodiversity walk throughs
- Site boundary

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Issue Date: 22.10.2020

Map ID: 01375A_3_GIS007_v0_7

Figure Number: 01375A_3_F08.1_GIS_v1

DATA SOURCE:
Project data from TWM, 2020.
Base data from ASK & GEODATA 250K, 2006.
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Table 8.1 – Discipline and Study Methods

Discipline	Methods	Relevant Section
Geology, terrain and soils	Desktop review, data from previous studies (Appendices 3 and 4), field observations 20 and 21 July 2020	8.2
Hydrology and meteorology	Desktop review, data from previous studies (Appendices 3 and 4)	8.3
Surface water and sediment quality	Desktop review, data from previous studies (Appendix 3), field survey 20 July 2020	8.4
Groundwater	Desktop review, data from previous studies (Appendices 3 and 4)	8.5
Visual amenity	Field observations 15 to 22 July 2020	8.6
Ambient air quality and GHG assessment	Desktop review, field study (Appendix 4), ambient air quality modelling (Appendix 5)	8.6
Ambient noise	Field study (Appendix 4), ambient noise modelling (Appendix 6)	8.6
Terrestrial and aquatic biodiversity	Desktop review, consultation with specialists, community interviews and field survey 20 and 21 July 2020	8.7 and 8.8

8.1.2.1 Geology, Terrain and Soils

The characterisation of the geology, terrain and soils of the study area is based on a review of existing information, in particular the geotechnical investigation undertaken for the IWMF site in 2018 which investigated geotechnical and soil properties at six test pit locations within the site (Appendix 3). Physical and chemical testing was undertaken with samples analysed for the following parameters:

- Total metals (As, Cd, Cr, Cu, Pb, Hg, Ni, Zn).
- Total recoverable hydrocarbons (TRHs).
- Cation exchange capacity and exchangeable cations.
- Particle size analysis.
- Emerson aggregate analysis.

This data is supplemented with information from regional studies, including geological mapping data. Field observations and photographs taken during ERIAS field survey were also used to validate desktop research.

8.1.2.2 Hydrology and Meteorology

The local hydrology and regional meteorology is characterised using a desktop review, including a review of regional and local topography and catchment boundaries and available geographic information systems (GIS) data, supported by information presented in Appendices 3 and 4, and by observations made during the ERIAS field survey.

8.1.2.3 Surface Water and Sediment Quality

Surface water and sediment quality is characterised through observations and sediment samples collected during the ERIAS field survey.

As the field sampling was undertaken during the dry season (due to Project timelines), there were no standing waters available for sampling within the study area. Sediment samples were collected from within drainage channels (refer to TWM1, TWM2, TWM3 and TWM4 in Figure 8.1) and logged and photographed, before being sent to SGS laboratory in Port Moresby, who holds NATA accreditation for the analysis undertaken. Sediment samples were analysed for the following parameters:

- Total metals (As, Cd, Cr, Cu, Ni, Pb, Zn, Hg).
- TRHs.
- Benzene, toluene, ethylbenzene and xylene (BTEX).
- Polycyclic aromatic hydrocarbons (PAHs).
- Polychlorinated biphenyls (PCBs).
- Total organic carbon (TOC).

A quality assurance and quality control program (QA/QC) was included in the sampling and analytical program. This involved the collection of one intra-laboratory duplicate sample and maintaining appropriate records concerning samples (including chain-of-custody procedures) and sample handling, storage and transport protocols to maintain sample integrity.

8.1.2.4 Groundwater

Groundwater is characterised using the information collected during groundwater investigations, undertaken in September 2018 at the IWMF with the primary objective of assessing general groundwater conditions and to identify any potential water bearing layers (aquifers) within the site (Appendix 4) and to assess groundwater quality (Appendix 3).

Investigations consisted of hydrogeological field traverses over the site, geophysical investigations, primarily using ground resistivity probing and drilling of two bores (BH1 and BH2, see Figure 8.1) for testing and sampling. Two groundwater samples were collected and analysed for the following parameters:

- Total metals (As, Cd, Cr, Cu, Pb, Ni, Zn, and Hg).
- TRH.
- pH.
- Electrical conductivity (EC).
- Total dissolved solids (TDS).
- Major anions and cations (Ca, Mg, K, Na, Cl and sulfate).

- Alkalinity.
- Ionic balance.

Additional samples were collected by TWM in April 2020 from three bores (BH1, MB05 and MB06, see Figure 8.1) for analysis of pH, temperature, dissolved oxygen, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), ammonia nitrogen, oil and grease, and faecal coliforms.

Information about local use of groundwater was also collected from community interviews conducted during the ERIAS field survey.

8.1.2.5 Visual Amenity

The landscape character and visual amenity of the study area are characterised by describing representative landscapes and selected viewpoints that help illustrate the existing views from key receptors, such as people driving along Napa Napa Road, nearby settlements and businesses in the industrial facility. A desktop review was undertaken to support the characterisation of the landscape, supported by aerial photographs and photographs taken during the ERIAS field survey.

8.1.2.6 Air Quality and Greenhouse Gases

In-field air quality monitoring was undertaken by ASK Consulting Engineers Pty Ltd (ASK) and ACEM Geotechniques (ACEM) at the IWMF from 1 to 10 November 2018. The monitoring methodology comprised:

- Total suspended particulates (TSP) – a TSI DustTrak II Aerosol Monitor 8530 was used to measure aerosol concentrations in the range from 0.001 to 400 µg/m^3. The monitor was setup to log particulate concentrations with a 1-minute sampling time-step. The inlet was configured for sampling of TSP.
- Sulfur dioxide (SO_2) – a MultiRAE Lite PGM6208 monitor was used to measure SO_2 gas continuously. The SO_2 gas was measured using an electrochemical sensor that measures a concentration range of 0 to 20 parts per million (ppm) with a resolution of 0.1 ppm. The monitor was setup to log SO_2 concentrations with a 1-minute sampling time-step.
- Nitrous oxides (NOx) – a GrayWolf Probe TG501 was used to measure NOx gases. Up to five gas sensors and a temperature sensor can be installed in one probe. All gas sensors are electrochemical. The monitor was setup to log concentrations with a 1-minute sampling time-step.

Monitoring results were compared to WHO (2005) air quality guidelines for PM_{10}, $PM_{2.5}$, SO_2 and NOx, and TSP criteria for Queensland and New South Wales, Australia for TSP (QLD EPA, 2008; NSW EPA, 2016).

Appendix 3 provides full details of the sampling methods, locations and results.

Since conducting the field monitoring in 2018, the incineration plant has been commissioned. Therefore, baseline air quality has been re-established to support this EIS. ASK undertook desktop-based modelling, based on the data previously collected in the field, to characterise ambient air quality for the current and planned infrastructure relevant to this EIS (Appendix 5). The modelling considers:

- Project and PNG government requirements, including relevant air quality criteria.
- Current and future operational equipment and activities.
- Incinerator stack testing data.
- Estimates (based on modelling) of the local climate including seasonal wind roses and inversion heights.
- Estimated regional background concentrations of relevant pollutants using available monitoring data.
- Nearby sensitive receptors.
- The location of emission sources.
- An emission inventory based on existing operations, routine stack testing, and published emission factors in literature. Air pollutants included are particulates less than 2.5 microns (PM2.5), particulates less than 10 microns (PM10), TSP, sulphur dioxide and nitrogen oxides.

The modelling considers a worst-case emission scenario and provides predicted dust deposition and airborne concentrations across the study area, particularly considering sensitive receptors (e.g., the neighbouring industrial area and Roku village).

A GHG assessment was also conducted involving a GHG inventory including maximum annual GHG emissions from the proposed operations including off-site transport of supplies and products, using current Australian account factors and NGER guidelines.

8.1.2.7 Noise

Environmental studies undertaken by TWM as part of their L2 environment permit conditions included a baseline noise assessment to measure ambient noise levels and determine the background levels at the site boundaries. Acoustic measurements consisted of attended noise measurements and noise logging at five locations around the perimeter of the site. Noise monitoring was undertaken in accordance with Australian Standard AS1055 Acoustics – Description and measurement of environmental noise (Appendix 6). The measurements were undertaken between 9:00 a.m. and 2:00 p.m. on 6 November 2018 over 15-minute periods using a field and laboratory calibrated Norsonic NOR140 sound level meter. Continuous unattended noise loggin was also undertaken at one location between 5 and 10 November 2018 using a calibrated ARL NGARA environmental noise logger.

As additional noise sources have since been commissioned, noise levels have been re-established to support this EIS. ASK undertook desktop-based noise emissions modelling, which considers:

- Project and PNG government requirements, including relevant noise criteria.
- Current and proposed noise emissions sources/activities.
- Operational equipment and activity data.
- Nearby sensitive receptors.
- Estimates of expected regional background noise levels using the baseline monitoring data and published monitoring data for similar locations in Papua New Guinea.

The likely noise levels from key Project sources during operations were estimated using internationally recognised and accepted software package SoundPLAN (version 8.2) and CONCAWE noise propagation algorithms. These predicted noise levels were assessed against relevant noise criteria to identify any potential exceedance of Project noise targets at sensitive receptors (Appendix 6).

The noise levels were predicted for calm (no wind) and credible worst-case meteorological conditions and at nominated sensitive locations, with noise contours produced across the local area.

8.1.2.8 Terrestrial and Aquatic Biodiversity

The ERIAS field survey included a terrestrial and aquatic biodiversity survey conducted between 20 and 21 July 2020. An experienced ecologist recorded flora and fauna species using visual searches and audial detection and characterised habitat and vegetation types. Figure 8.1 indicates the area that was the focus of the terrestrial biodiversity survey, and the transects walked as well as the aquatic biodiversity survey sites (refer to TWM1, TWM2, TWM3 and TWM4).

The ERIAS field survey is supported by discussions with specialists from CEPA, interviews with Roku community leaders and a literature review, including of the PNG Forest Inventory Mapping System (FIMS) (Hammermaster and Saunders, 1995) and previous studies undertaken for ExxonMobil's Papua New Guinea Liquified Natural Gas (PNG LNG) Project which provide useful regional information (CNS, 2009a).

Table 8.2 shows the sampling methods that were used to characterise terrestrial vegetation types, flora and fauna, aquatic habitats and terrestrial and marine resource use.

Table 8.2 – Terrestrial and Aquatic Biodiversity Field Survey Methods

Survey Method	Terrestrial Vegetation Types	Terrestrial Flora	Terrestrial Fauna	Aquatic Habitats	Terrestrial Resource Use	Marine Resource Use
Visual searches (including scats, tracks, nests etc.)	x	x	x	x	-	-
Habitat characterisation	x	-	-	x	-	-
Audial detection	-	-	x	-	-	-
Informal interviews	-	x	x	x	x	x

Note: the 'x' denotes when sampling methods were used and the '-' denotes when they were not used.

The terrestrial field survey recorded the presence of all observed species (including conservation-significant species) and identified remnant vegetation, threatening processes and invasive species. The field component was supported by a literature review and discussions with specialists to determine potential conservational values of the study area and to support the development of a species list for the study area. Vegetation descriptions are based on the FIMS dataset, with additional context and modifications based on local field observations. Flora, including native and invasive alien species, were identified during the field survey or were photographed in the field to facilitate subsequent identification through the use of published keys and comparison with herbarium specimens. No physical specimens were collected.

Aquatic habitats were described and photographed during the surface water and sediment field survey. Descriptive habitat notes were collected, documenting riparian and aquatic vegetation types and species, stream width and streambed composition. Photographs were taken of representative features of each site and the location of the site was recorded using a hand-held GPS.

Aquatic habitat observations are supported by a desktop review to provide a description of the general aquatic ecology assemblages expected to occur in the study area, including potential sensitive species and species of conservation importance that may be found in such environments.

The field ecologist also conducted interviews with Roku village representatives to understand land and natural resource use (discussed further in Section 9.1).

8.1.3 Study Limitations

The following limitations are noted in relation to the characterisation of the existing environment:

- Due to the ERIAS field survey being conducted during the dry season, no water was available for sampling in the ephemeral creeks and drainage lines within the study area.
- The field survey utilised a rapid assessment approach and provides a snapshot of existing biodiversity values and sediment quality and does not account for seasonal or inter-annual variability.

- There is limited existing data available for the study area aside from the studies commissioned by TWM to date.
- Some groundwater parameters were analysed outside of recommended laboratory holding times (pH, Ca, Mg, Na, K, alkalinity, TRHs) and so these results should be interpreted with caution.
- Baseline air quality data was only available for particulate matter and from incinerator stack testing. Ambient concentrations of dust, dioxins and furans, and benzo(a)pyrene were adopted from available data from comparable environments.
- Baseline noise levels were measured within the IWMF site boundaries and were not measured at sensitive receptors. The baseline noise measurements from the site and comparable literature values were used to characterise existing noise levels at offsite receptors.

8.2 Geology, Terrain and Soils

8.2.1 Regional Context

The Project is located within the Southern Plains and Lowlands region of Papua New Guinea, a narrow, lowlands belt trending northwest to southeast along the coast before a steep incline into the Central Ranges (Löffler, 1977) which run parallel to the lowlands from Milne Bay in the southeast to Indonesia's Irian Jaya in the west. The lowlands extend more than 600 km from its western extent in the Purari Delta to Mullins Harbour in the east, with a width of approximately 15 to 20 km (Löffler, 1977). The region is highly heterogeneous in its geomorphology, and is comprised of hilly lowlands and foothills, and depositional plains (Löffler, 1977).

The Southern Plains and Lowlands are located within Papua New Guinea's Eastern Fold Belt (Figure 8.2), which has been formed through the collision of the Australian and Pacific tectonic plates. The Project is located on the northern portion of the northeasterly moving Australian tectonic plate, which is colliding with the southwesterly moving Pacific Plate. The Pacific Plate lies to the north and east of the Australian Plate and is being subducted beneath the Australian Plate. Movement between these two plates are accommodated by four microplates: North Bismarck Plate, South Bismark Plate, Woodlark Plate and the New Guinea Highlands block. Crustal deformation and seismicity are concentrated along these boundaries (Wallace et al., 2004; Williamson & Hancock, 2005).

The IWMF site is located within Seismic Zone 4 based on the zoning provided by the Papua New Guinea building standards (PNGNSC, 1982). This zone is considered the least seismically active zone in Papua New Guinea (PNGNSC, 1982). Figure 8.3 shows the Port Moresby region and the Eastern Fold Belt have not historically been subject to high levels of seismic activity, with the highest seismic activity and geohazard risks occurring in eastern Papua New Guinea and the country's highlands.

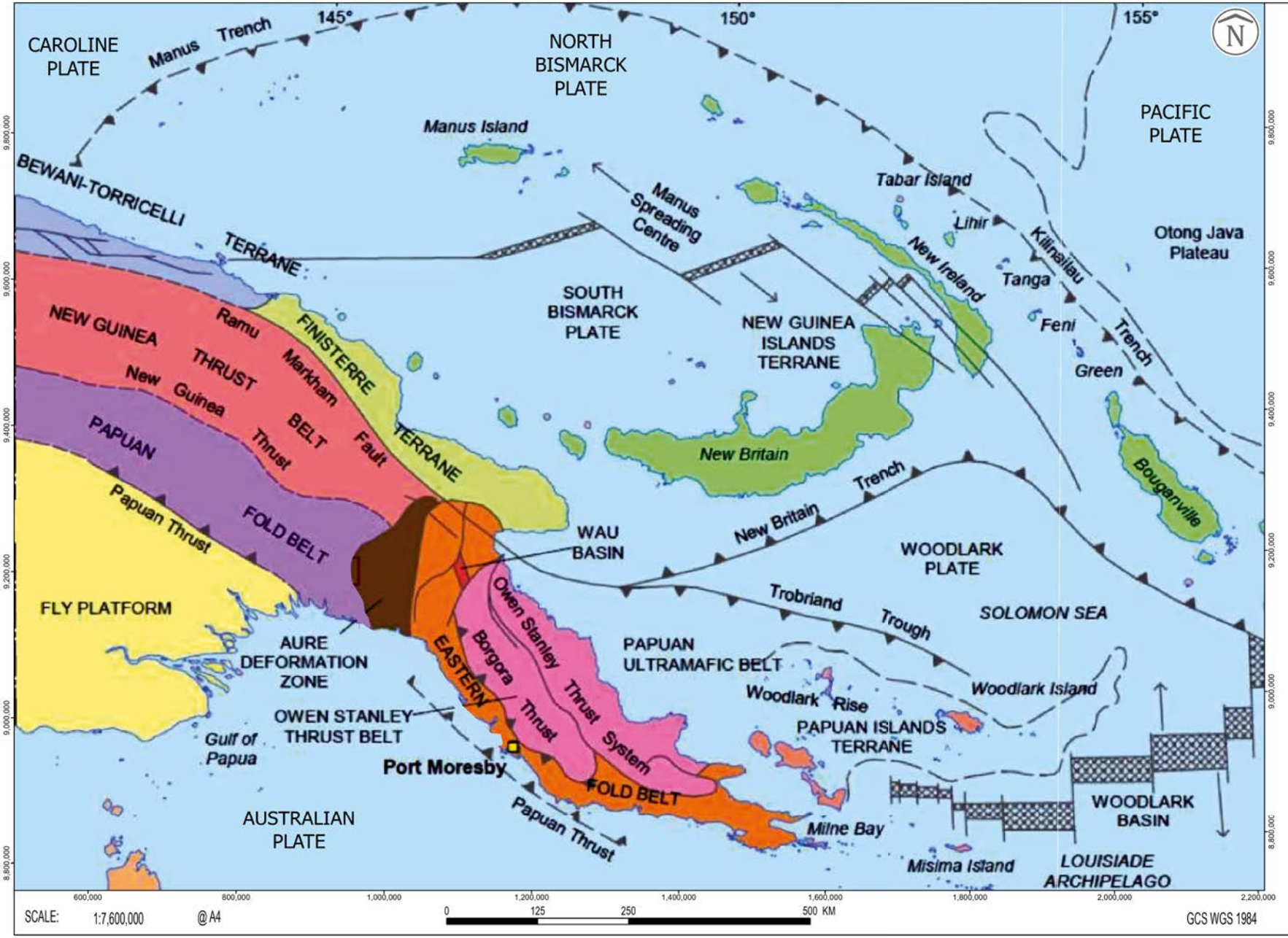
TECTONIC DOMAIN MAP OF PAPUA NEW GUINEA

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FIGURE 8.2

TWM Total Waste Management

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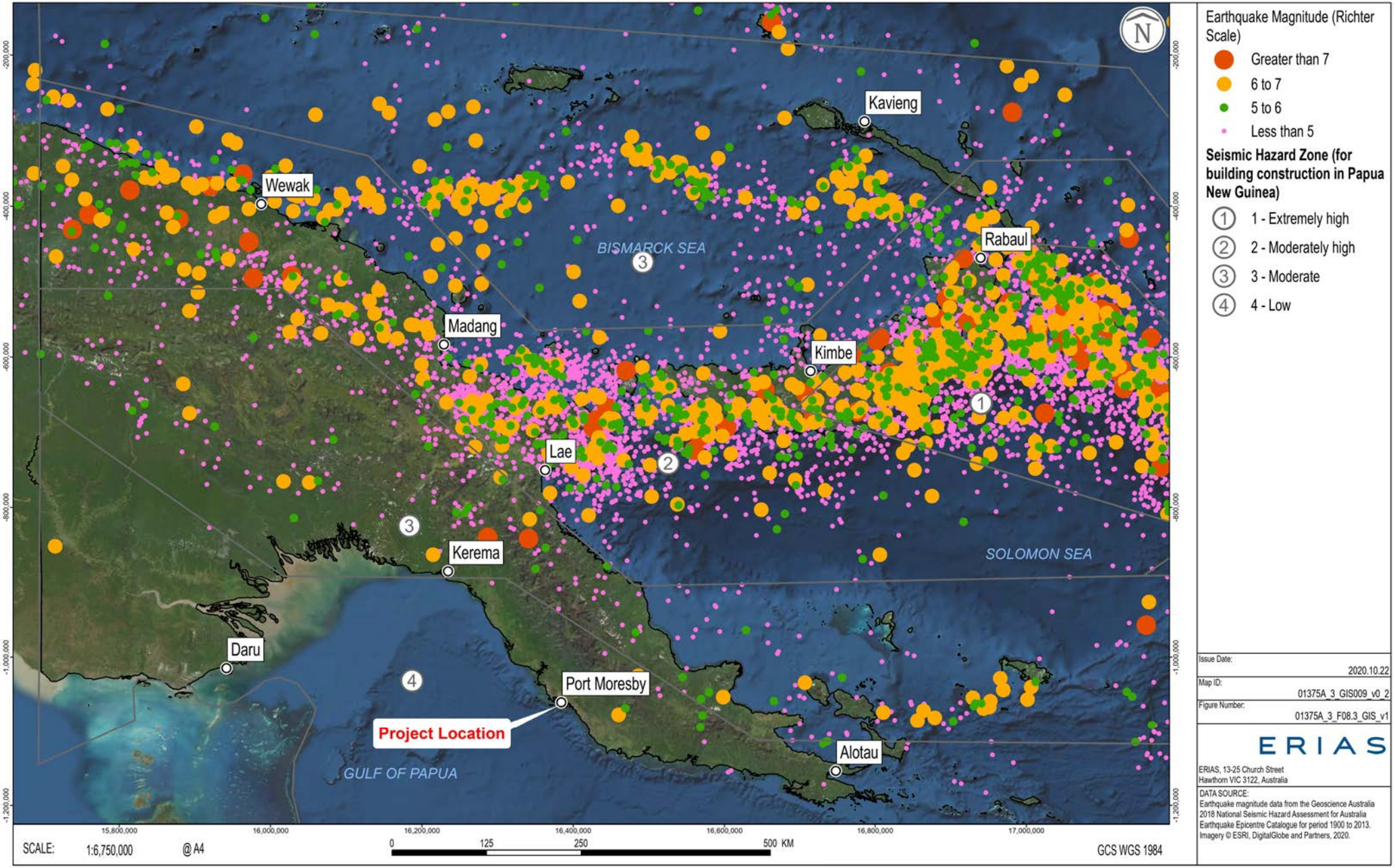
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DATA SOURCE:
Project data from TWM, 2020.
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HISTORICAL SEISMIC ACTIVITY IN THE PAPUA NEW GUINEA REGION (1900 TO 2013)

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FIGURE 8.3



8.2.2 Geology

The geology of the IWMF site, is characterised by consolidated geological formation of mixed sedimentary and limestone rock (geology Tep3, as described below). The broader region beyond the IWMF site, as shown in Figure 8.4, is the same geological formation, but is also interspersed with pockets of overlying, unconsolidated alluvial deposits (Appendix 3, Appendix 4, Bryan & Shearman, 2008). Other nearby geological formations outside the IWMF site include raised coral reefs located offshore of Roku. The geology of the IWMF site is shown in Figure 8.4, and descriptions of the geological formations occurring within and outside the IWMF site are as follows:

- Tep3 – this formation comprises consolidated calcareous, mixed sedimentary rock, and is described as interbedded layers of limestone and (frequently calcareous) sedimentary rock (Bryan & Shearman, 2008). This formation characterises the entire IWMF site and immediate surrounds and is the dominant geology in the Roku and Fairfax Harbour area. This geology is described in the Papua New Guinea Resource Information System (PNGRIS) (Bryan & Shearman, 2008) as partly calcareous, siliceous argillite and shale, calcilutite, chert, minor calcarenite and dolomite. The formation corresponds with the geological formation known as the Port Moresby Beds, which are described as of early to middle Eocene age, comprised mostly of argilites, siliceous argilites, calcilutite, shale, and minor chert and calcarenite (Appendix 4, Pieters, 1978). Outcrops of the Port Moresby Beds deposits were observed on the IWMF site during geotechnical baseline survey in 2018 (Appendix 4) as shown in Plates 8.1 and 8.2.

Plate 8.1 – Rock Profile from Cutting within IWMF Site

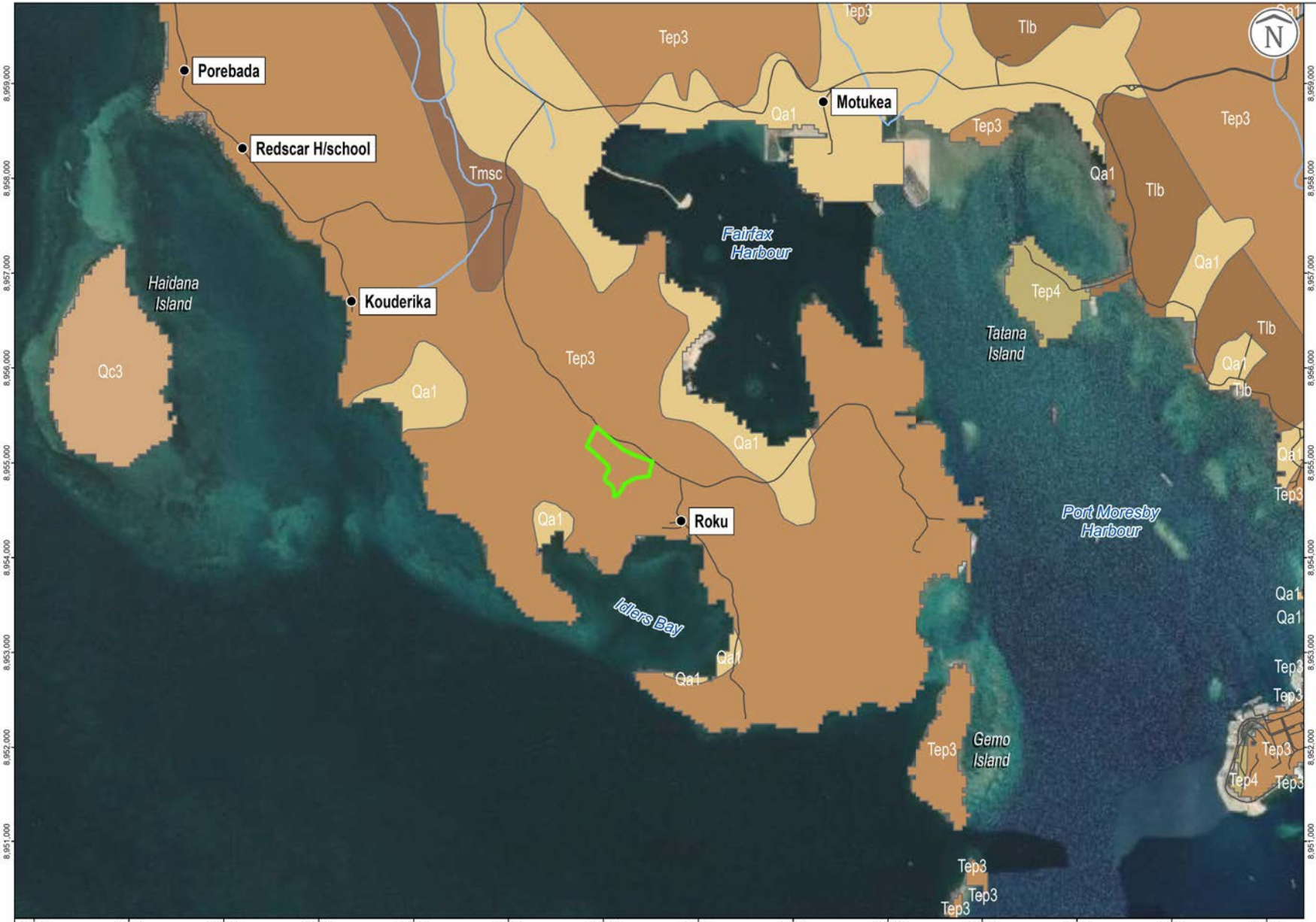


Source: Appendix 3.

GEOLOGY OF THE IWMF SITE

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FIGURE 8.4



- Town or village
- Road
- Watercourse
- Site boundary

Geology Type and Lithology Description

- Qa1 (Gravel, sand, silt, mud, clay: alluvium and beach deposits)
- Qc3 (Raised coral reef)
- Tep3 (Partly calcareous, siliceous argillite and shale, calcilutite) chert, minor calcarenite and dolomite)
- Tep4 (Calcarenite, minor calcirudite; glauconitic)
- Tlb (Calcarenite, calcirudite, minor recrystallized argillaceous limestone)
- Tmsc (Polymictic orthoconglomerate, sandstone, siltstone, mudstone; moderately consolidated)

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DATA SOURCE:
Project data from TWM, 2020.
Geology data from PNGRIS, 1986, CSIRO.

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Plate 8.2 – TWM Quarry and Rock Profile



Source: Appendix 3.

- Qa1 – a Quaternary alluvial formation, described in PNGRIS (Bryan & Shearman, 2008) as gravel, sand, silt, mud, clay: alluvium and beach deposits. This formation is unconsolidated and overlies the Port Moresby Beds mixed limestone and sedimentary rock formation (Appendix 4). It occurs as pockets of alluvial deposits, including on the coastal edges of Fairfax Harbour northeast of the IWMF site, on Idlers Bay to the southeast of the IWMF site, and to the east of the IWMF site. The geology of the IWMF site does not include this formation.
- Tmsc – a formation described in PNGRIS as consolidated non-calcareous, and mixed or undifferentiated sedimentary rock located in a thin strip trending northwest-southeast, parallel to the coastline, and occurring to the north of the IWMF site. This geological formation is described as polymictic orthoconglomerate, sandstone, siltstone, mudstone; moderately consolidated (Bryan & Shearman, 2008). This geology does not occur within any part of the IWMF site.
- Qc3 – Raised coral reefs, which occurs as small island offshore of Roku, one to the west of the IWMF site and another to the southwest (Figure 8.4). This formation is similar to the Tmsc formation above (consolidated non-calcareous, and mixed or undifferentiated sedimentary rock type) with a mixture of coarse to fine sedimentary grained sediment rocks, or in which the predominant grain size may be unknown (Bryan & Shearman, 2008).

8.2.3 Geomorphology and Terrain

8.2.3.1 Overview

As described in Section 8.2.1, the Southern Plains and Lowlands of Papua New Guinea are predominantly characterised by low hills that decline steeply down from the mountainous Central Ranges, intermixed with alluvial deposits. Landforms including coastal plains, mangrove swamps and beaches also occur within the area surrounding the Project. The IWMF site is located on the top of a low, flat hill or ridge, running northwest to southeast at an elevation of between 112 m (asl) at the highest point to 49 m (asl) at the lowest (Appendix 3). The terrain declines moderately towards the AES Yard and Fairfax Harbour to the northeast of the IWMF site, and more steeply down to the Coral Sea to the west, and Idlers Bay and Roku village to the southeast. The lithology of the Roku area is predominantly characterised as a fine grained sedimentary lithology (Figure 8.5) (Bryan & Shearman).

8.2.3.2 Mountains or Hills with Weak or No Structural Control

Mountains or hills with weak or no structural control are the predominant landform within the vicinity of the Project and is the landform on which the IWMF is situated (Figure 8.5). The mountains and hills with weak or no structural control are characterised by narrow, sharp crested ridges, separated by V-shaped valleys with steep river gradients, and by the presence of steep escarpments. This landform has a high to very high relief, defined as more than 100 m (Bryan & Shearman, 2008) and a fine grained sedimentary lithology (Figure 8.5). The landform is an erosional landform of fluvial erosion and mass movement, meaning the landform has been developed by the erosion and denudation (i.e., wearing away of) of the terrain surface over time through fluvial and mass movement processes (Bryan & Shearman, 2008).

8.2.3.3 Other Landforms

No other landforms exist within the IWMF site; however, several are present in areas surrounding Roku, Fairfax Harbour and Port Moresby (Figure 8.5). These other landforms are described in the following sections.

Undifferentiated Coastal Plain

Undifferentiated coastal plain with an alluvial deposits lithology occurs approximately 3 km north of the IWMF site, on the northern coastline of Fairfax Harbour and near Motukea Island. This landform is described in PNGRIS as a complex of tidal flats, small alluvial plains, sandy beaches, low emerged coral platforms, and coral reefs (Bryan & Shearman, 2008). Undifferentiated coastal plains are described as a recent, littoral, depositional landform, meaning the landform is an estuarine environment currently under active influence from fluvial depositional processes, on a large scale (Bryan & Shearman, 2008).

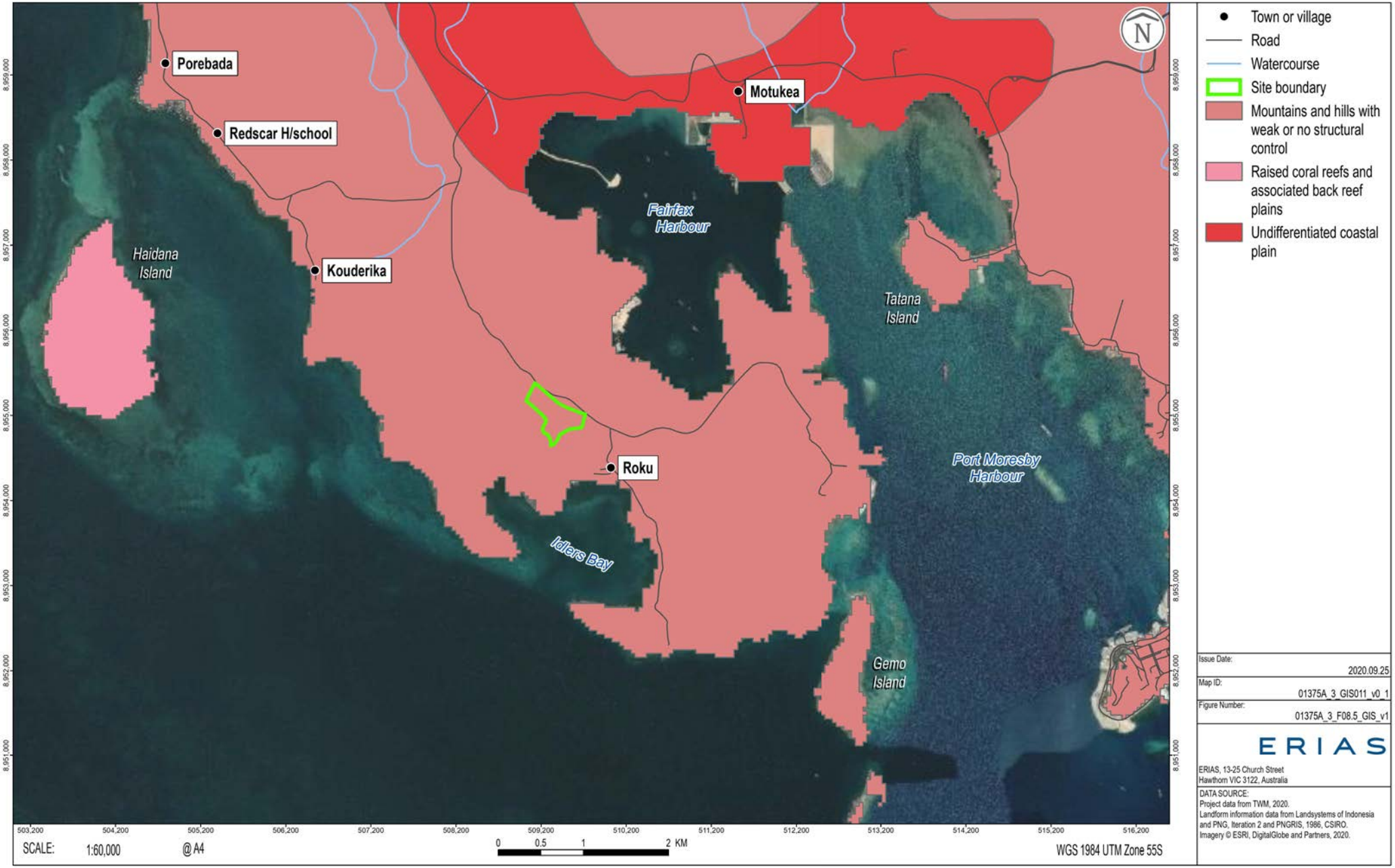
Raised Coral Reef and Associated Back Reef Plan

Raised coral reef and associated back reef plain landforms occur as small islands located offshore of Roku, with Haidana Island located approximately 4.5 km to the west, and Daugo Island 7.5 km to the southwest. Raised coral reef and associated back reef plain are described as a relict, littoral, depositional landform, meaning the landform was previously subject to fluvial deposition processes but this is no longer the case (Bryan & Shearman, 2008). This landform has a limestone lithology.

LANDFORM AND LITHOLOGY OF THE IWMF SITE

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FIGURE 8.5



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DATA SOURCE:
Project data from TWM, 2020.
Landform information data from Landsystems of Indonesia and PNG, Iteration 2 and PNGRIS, 1986, CSIRO.
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Hilly Terrain with Weak or No Structural Control

Hilly terrain with weak or no structural control occurs approximately 8 km north, and 10 km east, of the Project. The landform is described in PNGRIS as being comprised of dissected hills of low relief (defined as less than 100 m), with weak or no structural control. This landform has steep slopes, and sharp crests separated by narrow incised, V-shaped valleys (Bryan & Shearman, 2008). The landform is a recent, erosional landform of fluvial erosion and mass movement, as described above under 'Undifferentiated Coastal Plain' in Section 8.2.3.3.

Mangrove Swamps

A mangrove swamp landform occurs approximately 12 km northwest of the Project, near the PNG LNG facility at Caution Bay. Mangrove swamps are described in PNGRIS as swampy interchannel tidal flats with raised margins and depressed centres. These are generally separated by funnel shaped tidal channels (Bryan & Shearman, 2008). The landform is a recent, littoral, depositional landform with an estuarine deposits lithology.

8.2.4 Soils

The IWMF site is comprised of soils identified as Ustorthents (Bryan & Shearman, 2008), a soil type classified within the Entisols soils order, and the Orthents suborder. Entisols are recently formed soils that usually occur on recent alluvium deposits (Bryan & Shearman, 2008). Orthents typically overly rock at a depth of 25 cm or less, have loamy or finer textures, and are absent of characteristics associated with soil wetness. Ustorthents are as generally slowly permeable soils with moderate organic matter content (Bryan & Shearman, 2008). Ustorthents are classified in PNGRIS as of moderate soil erodability risk. Other soil types including Tropofibrists (order Histosols) Fluvaquents (order Entisols), and Ustropepts (order Inceptisols) are more common north of Fairfax Harbour and do not occur within the IWMF site (Figure 8.6).

8.2.4.1 Soil Quality and Condition

A soil and geotechnical investigation was undertaken at the IWMF site (Appendix 4) which included soil sampling from six TP locations (see Figure 8.1), with TP depths varying from 200 and to 600 mm. Two samples were collected from the soil profile, one from a surface strata from depths of 0 to 300 mm, and one from a lower strata, usually from between 300 to 600 m, with strata sample depths depending on actual soil strata at each test pit location (Appendix 3). Samples were collected for physical and chemical testing. Topsoil at the IWMF site was shallow and had a maximum thickness of 150 mm at the sampling sites and was absent at three of the soil sampling sites (Appendix 3), indicating a lack of continuity in the presence of topsoil across the surface of the IWMF site.

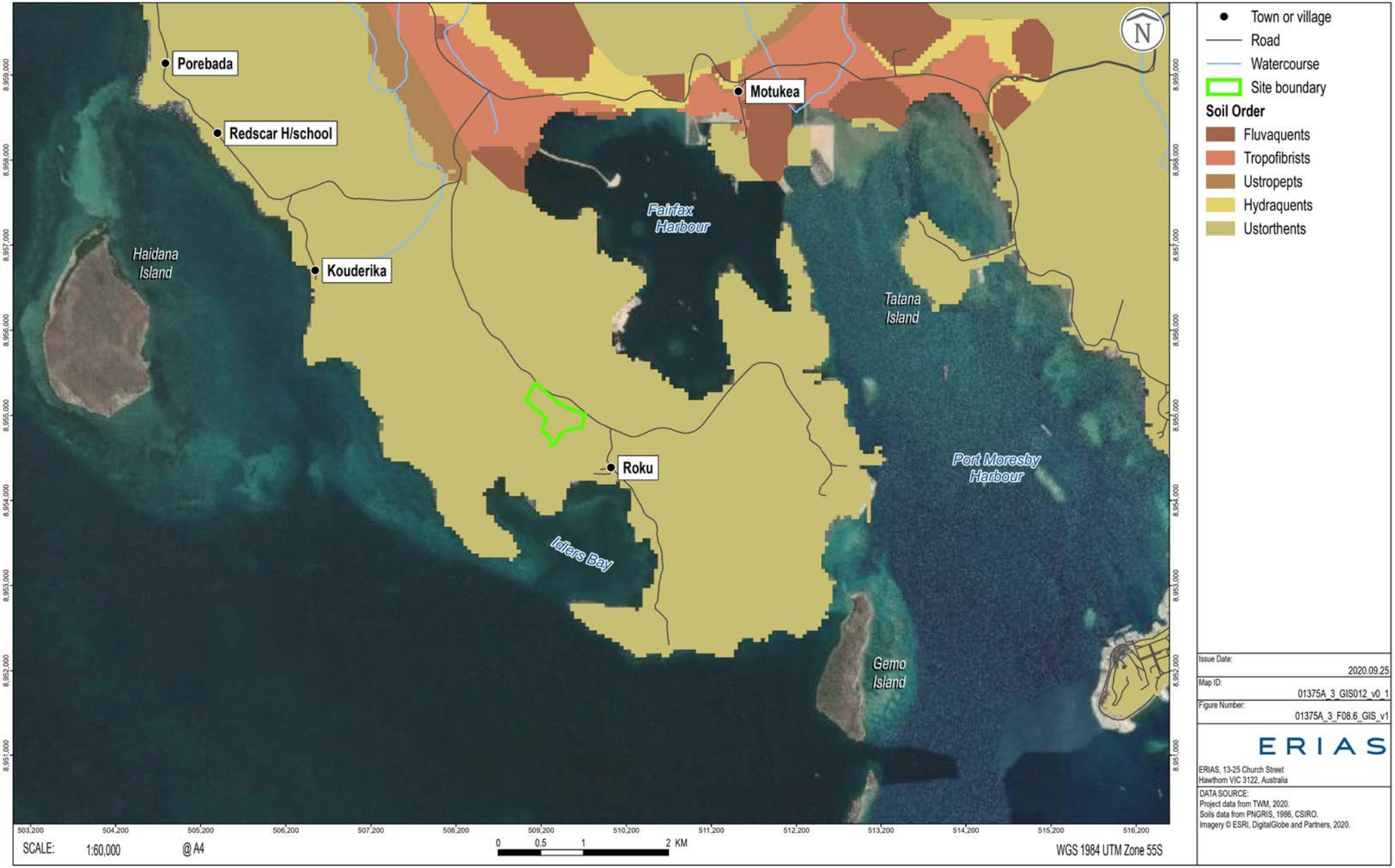
Heavy Metals, Metalloids and Hydrocarbons

Concentrations of cadmium and mercury were below the laboratory limit of reporting (LOR) in all samples while arsenic was detected above the LOR at TP5 only. Concentrations of arsenic (As), chromium (Cr), copper (Cu) and lead (Pb) were elevated in surface strata at Test Pit (TP) 5 (TP5, see Figure 8.1), in comparison to surface strata samples from the five other test pits, as shown in Table 8.3. Arsenic was also elevated in the lower strata sample (S2) from TP5 (24 mg/kg) compared to the other test pits. Test Pit 5 was located in an area of the IWMF that had previously

SOIL ORDERS OF THE IWMF SITE

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FIGURE 8.6



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DATA SOURCE:
Project data from TWM, 2020.
Soils data from PNGRIS, 1986, CSIRO.
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Table 8.3 – Soil Quality Results

Analyte	Unit	Test Pit	TP1		TP2		TP3		TP4		TP5		TP6	
		Sample	*S1*	*S2*	*S1*	*S2*	*S1*	*S2*	*S1*	*S2*	*S1*	*S2*	*S1*	*S2*
		Sample Depth (m)	*0.0 to 0.3*	*0.3 to 0.6*	*0.0 to 0.15*	*0.15 to 0.35*	*0.0 to 0.15*	*0.15 to 0.3*	*0.0 to 0.3*	*0.3 to 0.6*	*0.0 to 0.2*	*0.2 to 0.5*	*0.0 to 0.12*	*0.12 to 0.2*
pH (1:5 soil/water leach)	pH Unit		5.5	5.8	6.4	6.8	6.5	6.4	5.2	5.4	6.3	6.3	6.3	5.6
EC at 25ºC soil/water Leach	µS/cm		3	5	21	14	34	16	6	6	10	11	32	7
Organic Matter	%		0.5	0.9	2	1.2	4.9	1.6	<0.5	0.6	<0.5	0.8	2.3	0.6
Total Metals and Metalloids														
Arsenic	mg/kg		<5	<5	<5	<5	<5	<5	<5	<5	49	24	<5	<5
Cadmium	mg/kg		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chromium	mg/kg		11	9	27	24	21	29	8	30	55	26	4	6
Copper	mg/kg		30	20	38	37	25	27	42	29	72	40	11	26
Lead	mg/kg		8	7	18	13	15	18	10	10	68	6	<5	5
Mercury	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nickel	mg/kg		7	8	11	9	23	20	7	8	24	7	4	5
Zinc	mg/kg		18	5	15	9	7	7	8	6	11	7	6	7
Total Recoverable Hydrocarbons														
C6 to C10 fraction	mg/kg		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
> C10 to C16 fraction	mg/kg		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
> C16 – to C34 fraction	mg/kg		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
> C34 to C40 fraction	mg/kg		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100

Analyte	Unit	Test Pit	TP1		TP2		TP3		TP4		TP5		TP6	
		Sample	*S1*	*S2*	*S1*	*S2*	*S1*	*S2*	*S1*	*S2*	*S1*	*S2*	*S1*	*S2*
		Sample Depth (m)	*0.0 to 0.3*	*0.3 to 0.6*	*0.0 to 0.15*	*0.15 to 0.35*	*0.0 to 0.15*	*0.15 to 0.3*	*0.0 to 0.3*	*0.3 to 0.6*	*0.0 to 0.2*	*0.2 to 0.5*	*0.0 to 0.12*	*0.12 to 0.2*
Cation Exchange Capacity and Exchangeable Cations														
Cation exchange capacity	meq/ 100 g		8.8	7.6	11.1	11.4	13.8	8	11.3	6.9	11.1	9.7	10.1	7.6
Exchangeable aluminium	meq/ 100 g		0.2	<0.1	NA	NA	NA	NA	1.7	0.6	NA	NA	NA	0.8
Exchangeable calcium	meq/ 100 g		2.7	3.4	7.9	8.6	9.9	5.5	2.6	2.3	4.9	4	6.3	2.8
Exchangeable magnesium	meq/ 100 g		5	3.5	2.4	2	3	2	5.8	3.3	5.5	5	3.1	2.8
Exchangeable potassium	meq/ 100 g		0.3	0.4	0.2	0.2	0.8	0.4	0.3	0.2	0.4	0.3	0.5	0.4
Exchangeable sodium	meq/ 100 g		0.4	0.3	0.5	0.6	0.1	<0.1	0.5	0.3	0.4	0.4	0.2	0.6
Soil Particle Sizing														
Clay (<2 µm)	%		11	15	16	18	22	19	15	22	17	18	13	19
Silt (2 to 60 µm)	%		19	29	24	16	41	35	16	24	14	17	42	30
Sand (0.06 to 2 mm)	%		30	24	36	29	28	27	35	25	28	26	23	28
Gravel (> 2 mm)	%		40	32	24	37	9	19	34	29	41	39	22	23
Cobbles (<2 µm)	%		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Source: Appendix 3.
NA not analysed.

been used as a timber mill and for the treatment of timber, which may have been the source of this contamination.

Analytical results for total metals and metalloids were compared to the Residential A health-based investigation levels for soil contaminants from Schedule B1, Table 1A(1), of the Australian National Environment Protection (Assessment of Site Contamination) Measure (NEPC, 2013), which considers residential, recreational and commercial/industrial land uses. While the commercial/industrial criteria are more relevant to the IWMF site, the Residential A criteria are the most stringent and provide the most conservative guidelines for comparison. All results for total metals were below the Residential A health-based investigation levels (and therefore all other land use criteria), indicating that soil poses minimal risk to human health.

Total metals and metalloid results were also compared to the US EPA Interim Ecological Soil Screening Levels (ESSL) for metal contaminants (mg/kg dry weight in soil) for plant, soil invertebrates, avian and mammalian criteria. Arsenic results at TP 5 (both S1 and S2) exceeded all ecological criteria, while concentrations of Ni and Zn did not exceed any criteria in any samples. Lead exceeded the mammalian criteria (56 mg/kg) at TP5 (S1) with a concentration of 68 mg/kg, lead also exceeded the avian criteria (11 mg/kg) for both samples from TP2 and TP3 with concentrations ranging from 13 to 18 mg/kg. Copper exceeded mammalian criteria at TP5 (S1) with a concentration of 72 mg/kg, and exceeded the lower avian value at TP1 (S1), TP2 (S1 and S2), TP4 (S1 and S2), and TP5 (S1 and S2). Chromium exceeded the mammalian criteria (Cr III) at TP5 (S1), and the lower avian criteria at TP2 (S1), TP3 (S2), and TP4 (S2). Cadmium results were all below the LOR, and there are no criteria for Hg under the US EPA ESSL

Concentrations of all TRH fractions (C6 to C40) were below the LOR in all samples.

Following the results of the analytical testing contaminated soils associated with previous timber operations in proximity to TP5 were excavated and removed from the site in 2019. A total volume of approximately 50 m^3 was removed from this area.

Soil Properties

Soil analysis results indicate the site has slightly acidic soil, with pH ranging from 5.2 to 6.8 across all samples. Organic matter was generally low in all samples and ranged from less than 0.5% at TP4 S1, to 4.9% at TP3 S1.

Soil classification based on particle size varied across the IWMF site and at different sample depths. As shown in Table 8.3, soil was classified as a mix of predominantly silt (2 to 60 µm), sand (0.06 to 2 mm) and gravel (less than 2 mm), and to a lesser extent clay (more than 2 µm). Less than 1% of particles were classified as cobble from all sampling locations. The range of particle size distribution, excluding cobble, across all sampling locations were as follows:

- Clay – 11 to 22% for surface strata samples and 15 to 22% for lower strata samples.
- Silt – 14 to 42% for surface strata samples and 16 to 35% for lower strata samples.
- Sand – 23 to 36% for surface strata samples and 24 to 29% for lower strata samples.
- Gravel – 9 to 40% for surface strata samples and 19 to 39% for lower strata samples.

Most soil samples had an exchangeable sodium percentage (ESP) of between 0 and 5%, indicating soils are predominantly non-sodic, with results presented in Table 8.3. The lower strata sample (S2) at TP6 was the only sample assessed as sodic, with an ESP of 8% (Appendix 3). Sodic soils can have structural problems and water and air movement can be restricted.

Soil colour varied from strong brown, brown, very dark brown, reddish yellow, yellowish red and red, and texture was a mix of gravelly sand and sandy loam (Table 8.4).

Table 8.4 – Results from Soil Emerson Aggregate Test

Site	Sample	Depth (m)	Colour (Munsell)	Texture	Emerson Class Number
TP1	S1	0.0 to 0.3	Strong Brown (7.5YR 4/6)	Gravelly sand	8
	S2	0.3 to 0.6	Brown (7.5YR 4/4)	Gravelly sand	8
TP2	S1	0.0 to 0.15	Strong Brown (7.5YR 4/6)	Gravelly sand	8
	S2	0.15 to 0.35	Strong Brown (7.5YR 4/6)	Gravelly sand	8
TP3	S1	0.0 to 0.15	Very Dark Brown (7.5YR 2.5/2)	Sandy loam	3
	S2	0.15 to 0.3	Dark Brown (7.5YR 3/4)	Sandy loam	4
TP4	S1	0.0 to 0.3	Reddish Yellow (7.5YR 5/6)	Gravelly sand	8
	S2	0.3 to 0.6	Brown (7.5YR 5/4)	Gravelly sand	8
TP5	S1	0.0 to 0.2	Red (2.5YR 4/8)	Gravelly sand	8
	S2	0.2 to 0.5	Yellowish Red (5YR 5/8)	Sandy loam	3
TP6	S1	0.0 to 0.12	Very Dark Brown (7.5YR 2.5/2)	Gravelly sand	8
	S2	0.12 to 0.2	Strong Brown (7.5YR 5/6)	Gravelly sand	8

Source: Appendix 3.

Emerson aggregate testing (EAT) was undertaken on soil samples to assess the potential risk of fine sediment export and the susceptibility of soils at the IWMF site to erosion (see Table 8.4). Using EAT, the majority of soil samples were classified as Emerson class 8, given they did not slake or swell. Sample TP3 S2 was classified as Emerson class 4, as slaking was observed but there was no dispersion and carbonate or gypsum was present. TP3 S1 and TP5 S2 were assessed as Emerson class 3, in which both slaking and dispersion (after remoulding) were observed. Both surface and lower strata soil samples from sites TP1, TP2 and TP4, and the surface strata samples from TP5 and TP6 were assessed as having low erosion susceptibility and a low risk of fine sediment export (Appendix 3). Both surface and lower strata samples at TP3 and the lower strata samples (S2) from TP5 and TP6 were assessed as having elevated erosion susceptibility and an elevated fine sediment export risk (Appendix 3).

The EAT results indicate that all soil surface strata, in which topsoils are most likely to be disturbed, had a low erosion susceptibility and low risk of fine sediment export, with the exception of surface soils at TP3. The surface strata sample at TP3, located along the northeast boundary of the IWMF near the disused quarry, had an elevated risk for both erosion and fine sediment export.

The permeability of soil (and rock formations) at the IWMF site is discussed in Section 8.5.3.

8.2.5 Geotechnical Conditions

Geotechnical logs undertaken for the six test pits sampling sites determined the ground profile of the IWMF varied from shallow topsoil overlying completely weathered rock (CWR) bedrock, to bare CWR bedrock in other parts of the site (Appendix 3). The site ground profiling baseline indicated that CWR bedrock occurs at shallow depths, mostly from 0 to 0.15 m below surface level (bsl), and at a depth of 1 m bsl at TP5, shown in Figure 8.1, as a clay-bound gravel (Appendix 3). Bedrock Qa values, which indicate the allowable bearing capacity of the rock, at TP1, TP2, TP3, TP4 and TP6, ranged from less than 0.1 to 1 MPa. Generally, the CWR bedrock quickly becomes stronger with depth, exceeding 2 MPa at depths between 0.4 and 1 m (Appendix 3). The CWR rock continues to a depth of at least 8 m, which was the maximum extent of borehole drilling, and comprises bands of completely fractured and fragment rock interspersed with bands of harder rock (Appendix 3). The CWR bedrock is a siltstone of the Port Moresby Beds formation (Appendix 3).

8.3 Hydrology and Meteorology

8.3.1 Regional Context

The study area is located within the Vanapa-Brown-Biaru catchment, which forms part of the Papua New Guinea Coast Basin (Rivers Network, 2020). The Vanapa-Brown-Biaru catchment originates in the alpine and montane highlands of the Central Ranges and flows to the Gulf of Papua and the Coral Sea (Rivers Network, 2020). It extends over approximately 200 km^2 northwest to southeast, and from sea level to Mt Wilhelm at 4,509 m asl,

The Vanapa, Brown and Laloki river, of which the Brown river is a tributary, are significant rivers in the region that drain the Central Ranges and feed the southern lowlands of Central Province and the Port Moresby region (Rivers Network, 2020). The Laloki and Vanapa rivers flow through montane and lowland forests, swampy lowlands and savanna and drain out into a mangrove system along the coast of the Southern Plains and Lowlands. The Vanapa-Brown river system drains into the Galley Reach, a large estuary characterised by mangrove forest and subcoastal wetlands (CNS, 2009b) located approximately 40 km northwest of the study area. The Laloki River discharges directly into the Coral Sea and Gulf of Papua immediately south of the Galley Reach inlet mouth. The hydrology of the region is seasonal, influenced by rainfall patterns of the region, and flows are intermittent and highest during the wet monsoon (see Section 8.3.2). The Sirinumu Dam is a major inland lake within the region, formed by the damming of the upper Laloki River and located approximately 40 km to the east of the study area. Topographic catchment boundaries within the region are shown in Figure 8.7, along with major rivers of the region.

The Vanapa-Brown-Biaru catchment encompasses the Vanapa-Brown river system, which is identified as a critical watershed in the Papua New Guinea Conservation Needs Assessment (CAN) Synopsis Report (Swartzendruber, 1993). The rivers system is considered critical to the health of marine and coastal areas with high biodiversity (Swartzendruber, 1993), and is consequently assessed as an area of conservation significance. The Brown River is approximately 35 km to the north-northwest, and the Vanapa River approximately 45 km northwest. While the Project lies within the Vanapa-Brown-Biaru catchment, drainage from the

TOPOGRAPHIC CATCHMENT BOUNDARIES OF THE REGION

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FIGURE 8.7



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Map ID: 01375A_3_GIS014_v0_3

Figure Number: 01375A_3_F08.7_GIS_v1

ERIAS, 13-25 Church Street
Hawthorn VIC 3122, Australia

DATA SOURCE:
Project data from TWM, 2020.
Catchment boundaries from World Wildlife Fund US (WWF) as HydroBASINS and HydroSHEDS 2006-2014. Boundaries are approximate only at maximum 15 arc-seconds resolution (approximately 500 m at the equator).

Imagery © ESRI, DigitalGlobe and Partners, 2020.

IWMF site is unlike to feed directly in to the Vanapa-Brown watershed given the coastal location of the Project, and the IWMF's situation on an elevated ridgeline running between two coastal areas, Fairfax Harbour and Idlers Bay. The hydrological regime of the region has undergone modification as a consequence of land clearing and infrastructure, urban and industrial development, particularly in the Port Moresby area, in addition to the construction of dams such as the Sirinumu Dam.

8.3.2 Climate

The study area is characterised by the tropical savanna climate of the Port Moresby area (Appendix 3), with low, seasonal rainfall (Löffler, 1977). The region is amongst the driest in Papua New Guinea and is subject to the seasonal influences of the northwest monsoon, which occurs from approximately December to May, and the southeast trade winds, occurring from approximately May to November. Transitional periods between the two seasons also occur, during which the change in pressure systems forms an equatorial trough and produces light, variable surface winds (McAlpine et al., 1983).

Temperatures in the Port Moresby region are relatively consistent throughout the year (Appendix 3), with an average annual temperatures of 26.8°C (1982 to 2012) (Climate-Data.org, 2020). December has the highest monthly average temperature at 28°C, and July the lowest at 25.3°C, as shown in Table 8.5 (Climate-Data.org, 2020). Average daily maximums range from 28 to 32°C, and average daily minimum temperatures are approximately 23°C (Appendix 3).

Table 8.5 – Monthly Air Temperature in Port Moresby from 1982 to 2012

Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average °C	27.7	27.5	27.4	27	26.8	25.9	25.3	25.6	26.2	26.9	27.5	28
Minimum °C	23.4	23.3	23.3	23	23	22.3	21.7	22	22.4	22.8	23	23.5
Maximum °C	32.1	31.8	31.5	31.1	30.6	29.6	29	29.2	30	31	32	32.5

Source: Climate-Data.org, 2020.

Rainfall patterns in the Project area vary seasonally, with lower rainfall occurring during the southeast trade wind season (i.e., the dry season). Mean annual rainfall in Port Moresby is 1,017mm (Climate-Data.org, 2020) but can fall below 1,000 mm in drier years (CNS, 2009b). Roku and Port Moresby are within the region of Papua New Guinea with the lowest annual rainfall (Appendix 4), and Port Moresby is considered the driest place in the country (Appendix 3). July is the driest month in Port Moresby with an average rainfall of 23 mm, and March the wettest with an average of 195 mm, as shown in Table 8.6.

Table 8.6 – Average Monthly Rainfall in Port Moresby from 1982 to 2012

Rainfall	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	168	177	195	93	56	46	23	31	31	26	47	124

Source: Climate-Data.org, 2020.

Wind patterns in Papua New Guinea are consistent, and seasonally influenced. Winds during the southeast trade wind season are typically drier and cooler (Appendix 4). Wind speeds within the

Project area are very light and predominantly north-northwesterlies and south-southeasterlies (Appendix 3). Maximum wind velocities range from approximately 6 knots (approximately 11 km/h) in March and April to 10 knots (approximately 18 km/h) in July and September (Appendix 3). Tropical cyclones do occur within Papua New Guinea; however, cyclones with surface wind speeds of more than 62 km/h are rare (McAlpine et. al., 1983, CNS, 2009b).

The El Niño Southern Oscillation also contributes to Papua New Guinea's climate and environmental conditions. Meteorological records of El Niño events indicate that severe droughts occurred in Papua New Guinea in 1896, 1902, 1914, 1982, 1997, 2015 and 2017 (Gillieson, 2015; IOD PARC, 2017). La Niña events are characterised by wetter conditions over most of Papua New Guinea and increase the likelihood of flooding, landslides and other natural disasters in the region.

8.3.3 Hydrology

The hydrological characterisation focuses on features from within the study area and the IWMF site boundary, and key catchments and nearby water bodies. Characterisation is derived from information reported in the baseline investigation conducted in 2019, local drainage lines and flow directions derived from a digital elevation model (DEM), and field-based stream habitat assessments from the ERIAS field survey in July 2020.

8.3.3.1 Study Area Hydrology

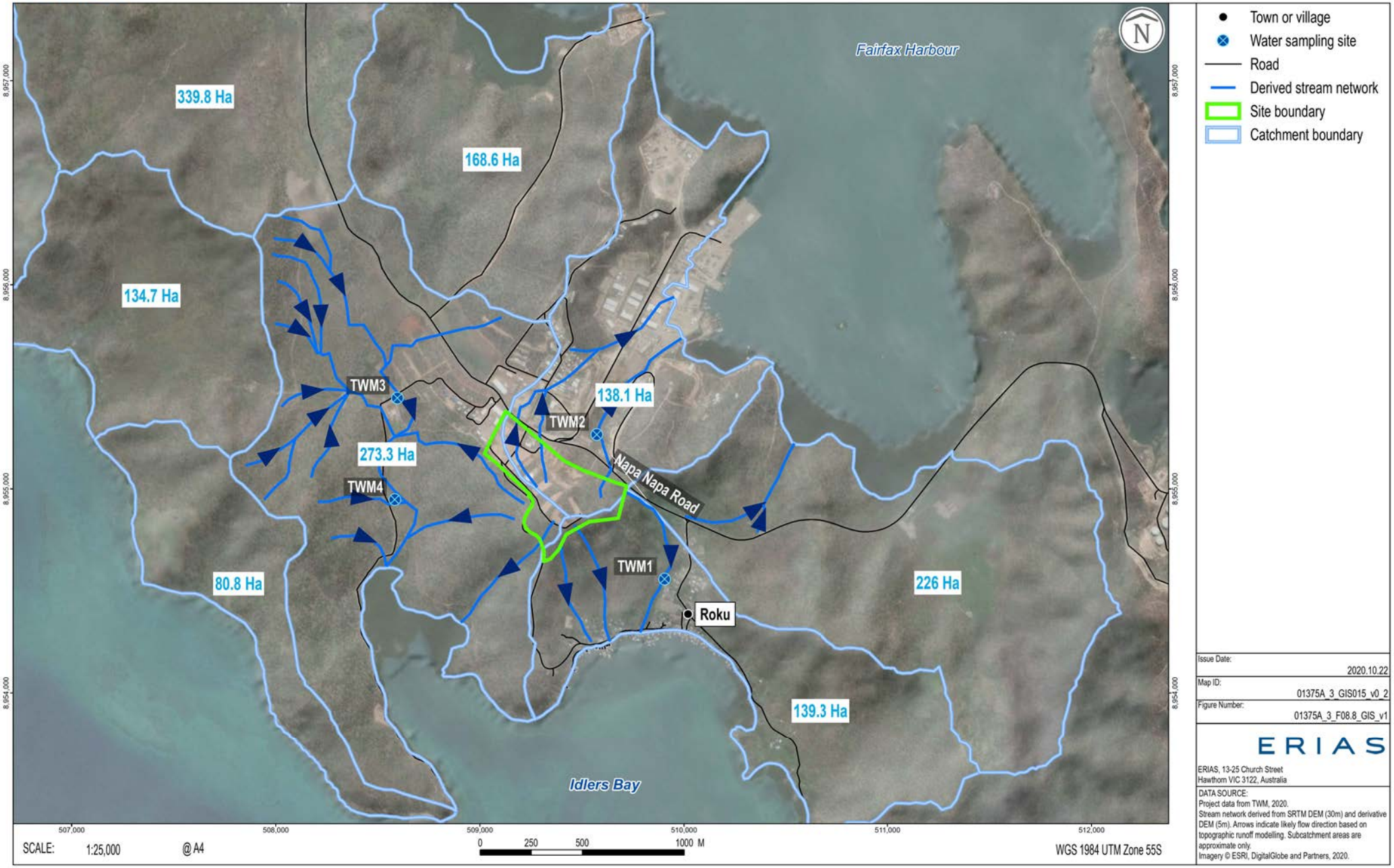
The study area occurs on undulating terrain, characterised by low hills, ridges and valleys, and is located on a small peninsular, between the Coral Sea/Gulf of Papua to the southwest, and Fairfax Harbour to the northeast. The drainage network of the study area and the IWMF site is not distinct and is subject to the seasonal nature of rainfall in the area (Appendix 4). Drainages are therefore intermittent, and watercourses are ephemeral drainage channels with no known stream names. The derived drainage network of the study area has been generated based on an interpolated DEM of the area to 5 m resolution and is shown in Figure 8.8. The generated drainage network also provides delineated catchment areas, which indicates local catchments within the study area are very small and characterised by ridgelines sloping down to small valleys and ephemeral watercourses that discharge into the marine environment. There are no major watercourses or permanent waterbodies within the IWMF site, or within the study area. Field surveys investigated four drainage channels within the study area, all of which were dry at the time of the field survey and would only flow following periods of sufficient rainfall. Some of the drainage channels are important sources of washing and cleaning water for residents of Roku village, when flowing (see Section 9.7).

The IWMF site is located on the top of a ridge running northwest to southeast, with a maximum elevation of 112 m asl at the southern end of the facility and a minimum elevation of 49 m asl at the northern end (Appendix 4). The generated drainage lines shown in Figure 8.8 indicates the flow direction of water in the study area. Drainage from the IWMF will occur to the southwest of the ridgeline, with water draining towards a north-to-south running valley west of the IWMF, where there is a drainage channel that drains into Idlers Bay (Figure 8.8). The channel is located around 500 m west of the IWMF at an elevation of approximately 20 m asl at its northern extent and is approximately 20 m below the IWMF site.

DRAINAGE LINES AND SURVEY SITES IN THE STUDY AREA

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FIGURE 8.8



Water flow will also move downhill to the north and northeast from the majority of the IWMF area, through the AES industrial park and towards Fairfax Harbour. The terrain slopes gently through the AES area from an elevation at the IWMF of approximately 50 m asl to sea level over a 1 km distance. Surface water can also runoff from the southeast boundary of the IWMF downhill towards Roku village and Idlers Bay to the south. Another drainage line east of the IWMF discharges towards the mangroves on the margin of Fairfax Harbour, approximately 800 m to the northeast (see Figure 8.8). The southeast boundary of the IWMF falls from approximately 112 m asl to an elevation of 7 m asl at the nearest house in Roku village over a distance of approximately 500 m (Appendix 3).

Approximate watershed boundaries and watershed sizes within the study area are also presented in Figure 8.8. Eight small catchments are identified, ranging in size from approximately 80.8 hectares (ha) to 339.8 ha.

8.3.3.2 Hydrological Characteristic of Drainage Channels in the Study Area

The following hydrological descriptions are based on observations made during the ERIAS field survey conducted in July 2020 at four unnamed drainage channels within the study area (see Figure 8.1). Survey locations are also shown in Figure 8.8. The following sections describe the general hydrological characteristics of these drainage channels (e.g., stream width, gradient and elevation). Further detail about aquatic habitats within these drainage channels is provided in Section 8.8.

Drainage Channel 1

Drainage Channel 1 (TWM1) flows from the ridgeline along Napa Napa Road east of the IWMF, and flows south-southeast to Roku village and Idlers Bay (see Figure 8.8), descending from approximately 82 m asl to sea level over a distance of 700 m. During the ERIAS field survey, there was no water flow and the drainage channel was dry. The drainage channel is ephemeral and would only flow after periods of sufficient rainfall or flood events. The drainage channel had a stream width, bank to bank, of approximately 6 m with a moderate gradient. Substrate comprised predominantly of fine to medium sand with low water content with some soil mixture, as shown in Plate 8.3, and exposed boulders.

Plate 8.3 – Facing Downslope at Drainage Channel 1 (TWM1)



Drainage Channel 2

Similar to Drainage Channel 1 (TWM1), Drainage Channel 2 (TWM2) originates at the ridgeline on the eastern boundary of the IWMF. The channel flows north-northeast, adjacent to the AES industrial park and into Fairfax Harbour (see Figure 8.8) over a distance of approximately 800 m. During the ERIAS field survey in July 2020 there was no water flow and the drainage channel was dry. This drainage channel is also ephemeral, with periods of water flow limited to the wet season. The drainage channel has a width of approximately 3 m with a moderate gradient. Channel substrate was dominated by cobbles, gravel and coarse sediment, which is mostly discharged from the upstream construction activities, as well as several boulders, as shown in Plate 8.4.

Plate 8.4 – Facing Downslope at Drainage Channel 2 (TWM2)



Drainage Channel 3

Drainage Channel 3 (TWM3) originates from a ridgeline to northwest of the IWMF and was investigated approximately 400 m from the IWMF (see Figure 8.8). The drainage channel feeds several other drainage lines further south. Similar to the ephemeral TWM1 and TWM2 drainage channels, the drainage line was dry during the field survey and is likely to have water flow after high rainfall events only. Channel width is approximately 4 m with a low gradient, and substrate predominantly coarse gravel and cobbles (Plate 8.5).

Plate 8.5 – Facing Downslope at Drainage Channel 3 (TWM3)



Drainage Channel 4 (TWM4)

Drainage Channel 4 (TWM4) is fed from several small drainage channels from the IWMF site, and ridgelines to the west and northwest, including the upper arm of Drainage Channel 3 (TWM3) (see Figure 8.8). The drainage channel flows over 1 km through the base of a valley east of the IWMF, including drainage lines that occur on the upper slopes of the catchment at higher elevations, and discharges into Idlers Bay. Similar to other drainage channels, it is ephemeral, and would only flow after periods of sufficient rainfall or flood events. The stream was significantly wider than other surveyed drainage channels, with a width of approximately 13 m. The channel width is likely reflective of the larger catchment size in which the drainage channel occurs, at 273.3 ha, which is the largest catchment for those with generated drainage lines and within the study area. Substrate comprised dry sand, gravel, and fine sediment believed to be from construction, with quartz stones surrounding the channel (Plate 8.6).

Plate 8.6 – Facing Upslope at Drainage Channel 4 (TWM4)



8.4 Surface Water and Sediment Quality

8.4.1 Regional Context

As described in Section 8.3.1, the water flow and quality of the area is greatly influenced by seasonal rainfall, in particular, the monsoon season each year (approximately December to May). The monsoon season brings scattered flash flooding across the area, which can lead to contamination of water and sediment quality from litter, industrial waste, chemical runoff and eutrophication (Nicholls, 2004).

Land clearing and industrial development in the region have limited the natural flood deterrents of the area, allowing monsoon flood waters to cascade through previously protected land areas, and mobilise contaminants associated with wastewater, grey water and pollutants from human and industrial activities which can influence the freshwater and sediment quality of the downstream environment.

8.4.2 Surface Water and Sediment Quality of the Study Area

There are no standing water bodies or creeks within the IWMF site boundaries. As described in Section 8.3.3, local catchments are characterised by ridgelines sloping down to small valleys and ephemeral watercourses that drain into the ocean. Drainage from the IWMF site is primarily to the north and northeast, towards the AES industrial park and Fairfax Harbour. Based on observations made during the ERIAS field survey, water quality of the drainage channel would likely experience large natural fluctuations in water quality parameters such as turbidity, total suspended sediments and dissolved oxygen due to the effects of rainfall runoff mobilising soils from the catchment.

Four sediment samples were collected from four distinct drainage channels downslope of the IWMF during the ERIAS field survey in July 2020 (see Figure 8.1). These locations included sites both up and downstream of the IWMF.

As described in Section 8.1.2, as the field sampling was undertaken during the dry season there were no standing waters available for sampling within the study area. The sediment samples collected provide some indication as to the existing quality of these drainage channels and ERIAS provided training to TWM personnel to allow them to collect surface water samples for analysis during the next monsoon season to characterise existing water quality within these drainage channels.

8.4.2.1 Assessment Framework

Adopted Standards and Guidelines

The standards and guidelines adopted for the sediment analyses follow the tiered approach of:

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

Sediment Quality

No Papua New Guinea guidelines for sediment quality exist. Therefore, assessment has been undertaken based on the revision of the ANZECC/ARMCANZ Sediment Quality Guidelines (Simpson et al., 2013; Simpson & Batley, 2016).

The guidelines described in Simpson et al. (2013) and Simpson & Batley (2016) provide two values; a sediment quality guideline value (SQGV) and sediment guideline value-high (SQG-high). These values delineate three biological effects ranges:

- Concentrations below the SQGV represent a range where adverse biological effects are negligible.
- Concentrations between the SQGV and SQG-high represent a range where adverse biological effects are possible.
- Concentrations above the SGQ-high represent a range where adverse biological effects are expected to occur.

Contaminants that exceed the SQGV are considered contaminants of potential concern.

8.4.2.2 Physical and Physicochemical Properties

Filed Observations

Descriptions of each of the samples taken in the field are described in Table 8.7. Photographs were also taken in the field of each sediment sample location and are presented in Plates 8.7 to 8.10.

Table 8.7 – Sediment Sample Locations and Description

Sampling Location	Coordinates		Sample Date	Sediment Description
	Longitude	Latitude		
TWM1	09° 27.454	147° 05.414	20/07/20	Black/brown dry sandy sediment intertwined with soil, fine particles with exposed, scattered boulders. Twigs and leaves present in sediment. Note: Sample taken close to human activity (Roku school)
TWM2	09° 27.070	147° 05.232	20/07/20	Coarse dry gravel with finer sediment particles present, red brown in colour, exposed, scattered boulders
TWM3	09° 26.973	147° 04.698	20/07/20	Dry cobbles red brown in colour, native weeds growing within the channel
TWM4	09° 27.243	147° 04.691	20/07/20	Fine dry sediment, discarded construction sediment, white brown in colour. Cobbles present. Exposed scattered quartz stones

Plate 8.7 – Site TWM1



Plate 8.8 – Site TWM2

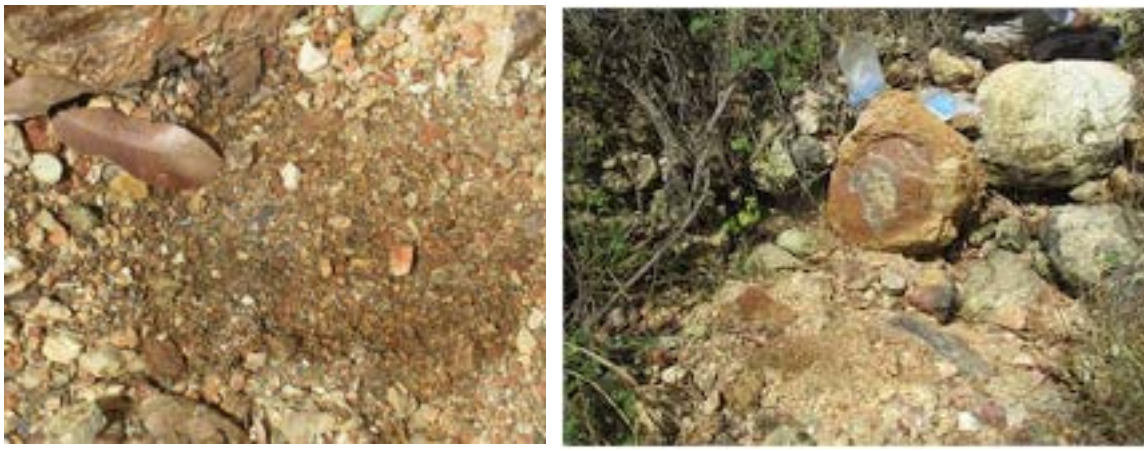


Plate 8.9 – Site TWM3



Plate 8.10 – Site TWM4



Moisture Content

Moisture content varied from 9 to 17 % between sites, with moisture content slightly higher for sediments at TWM1 compared to the remaining sites.

Total Organic Carbon

Total organic carbon (TOC) analyses were undertaken to allow normalisation of organic contaminant concentrations against organic carbon content (sediment quality guidelines for most organic contaminants are based on a TOC concentration of 1%, with toxicity decreasing with increasing organic carbon content). TOC was very low at sites TWM2, TWM3 and TWM4, ranging 0.1 to 0.7 % while slightly higher at site TWM1 at 2.2%.

8.4.2.3 Chemical Analyses

This section presents the results of the sediment quality sampling program, the complete laboratory report is provided in Appendix 7. The total values are compared to the sediment quality guideline values (SQGVs) described in Simpson et al. (2013) and Simpson & Batley (2016). Where appropriate results for organic contaminants such as hydrocarbons and PCBs were normalised to 1% TOC.

Hydrocarbons

Total Petroleum Hydrocarbons/Total Recoverable Hydrocarbons

TPHs and TRHs were below the laboratory LOR at all sites (Appendix 7) and total TPHs were below the SQGVs at all sites.

BTEXN

All results for BTEXN for all sample locations were below the LOR (Appendix 7). There are no applicable criteria for BTEXN in sediments.

Polycyclic Aromatic Hydrocarbons

Results across all sites for PAHs were below the LOR (0.1 mg/kg for all PAHs) (Appendix 7). The sum of individual PAHs did not exceed applicable guideline values (Simpson et al., 2013) at any of the sites.

The zero recordings above LORs of all TPH, BTEXN and PAH analytes in all samples indicate that there are very little hydrocarbons present within the sediment from the sample locations and indicate that there is no evidence of existing hydrocarbon contamination in sediments.

Polychlorinated Biphenyls

Results for PCBs were below the LOR at all sites and total PCBs were below the SQGVs at all sites (Appendix 7).

Total Metals

Metal results with comparison to the relevant guideline values are provided in Table 8.8. All metal results (As, Cd, Cr, Cu, Hg, Ni, Pb, Zn) were below the applicable guideline values with the exception of one result at TWM3 for nickel (39 mg/kg) which exceeded the SQGV of 21 mg/kg but was below the SQG-high value of 52 mg/kg. Nickel concentrations at TWM3 are within the range where adverse biological effects are possible (but not necessarily expected). Nickel was also elevated at TWM1 and TWM4 but below the SQGV. Arsenic, chromium, copper and lead were also elevated at TWM4 compared to the remaining sites. During the field survey discarded construction and quarry material was noted at site TWM4. The analytical results suggest that previous activities including the disposal of industrial waste may have resulted in some contamination of sediment in this drainage channel. Concentrations of metals at sites TWM1, TWM2 and TWM3 were generally similar with the exception of zinc which was slightly elevated at TWM2 compared to these other sites, but still notably lower than the SQGV.

Table 8.8 – Metal Results and SQGVs.

Site	Metal (mg/kg dry weight)							
	As	Cd	Cr	Cu	Ni	Pb	Zn	Hg
SQGVs	20	1.5	80	65	21	50	200	0.15
SQG-High	70	10	370	270	52	220	410	1.0
Result								
TWM1	1.3	<0.1	13	34	17	6.7	46	0.01
TWM2	1.8	<0.1	14	33	11	4.9	110	<0.01
TWM3	8.6	<0.1	68	45	39	22	61	<0.01
TWM4	1.3	<0.1	12	46	18	7.5	22	<0.01

Grey shading indicates an exceedance of the SQGV.

Quality assurance and Quality Control

Field Duplicate

One intra-laboratory field duplicate and corresponding primary sample was collected at site TWM4. Results are provided in Appendix 7 (TWM4a representing the primary sample and TWM4b representing the duplicate sample). Intra-laboratory duplicates provide an indication of the precision and reproducibility of the field sampling techniques and analytical results. Duplicate results were assessed by calculating their relative percent difference (RPD), with a target RPD of less than 50%. All of the results met the data quality objective of a RPD less than 50%. Overall the field duplicate results indicate good precision and reproducibility for the sampling and analyses.

Laboratory Quality Assurance and Quality Control Program

The laboratory QA/QC program included analysis of laboratory duplicates, method blanks, laboratory controls, matrix spikes and surrogate spikes (Appendix 7). The results of the laboratory QA/QC program were all within the laboratory acceptance criteria indicating that the analytical methods employed provided acceptable results and give confidence in the quality of the data obtained from the survey.

8.5 Groundwater

8.5.1 Regional Context

Information on potential hydrogeology at a regional scale is limited, and principally contextualised by known geological properties (Section 8.2.2) and the area's predisposition to seasonal rainfall patterns (Section 8.3.2). The Port Moresby region receives low, seasonal rainfall and is considered the driest region in Papua New Guinea (Appendix 3). Ephemeral watercourses are common throughout the region (Section 8.3.3). The dominant geology of the Port Moresby and Fairfax areas is consolidated and comprised of interbedded layers of limestone and sedimentary rock. The formation is identified as the Port Moresby Beds, which is considered to have low groundwater potential (Appendix 4). Based on this information, it can be inferred that groundwater availability in the region is influenced by seasonal rainfall and is generally limited.

8.5.2 Groundwater Conceptualisation

The existing hydrogeological characterisation of the study area is based primarily on a groundwater investigation undertaken at the IWMF site by the Mineral Resources Authority (MRA) in 2018 (Appendix 4), and rock permeability and groundwater bore testing undertaken during the IWMF geotechnical and soil survey conducted by ACEM in 2018 (Appendix 3). Groundwater surveys identified two potential aquifers within the IWMF site; a shallow perched aquifer, and a second, deeper aquifer (Appendix 4). Both were identified as freshwater aquifers, with a brackish water layer underlying the deeper aquifer.

The shallow perched aquifer was identified as unconsolidated, and comprised predominantly of gravel, sand and clay. Aquifer recharge is most likely through direct infiltration of rainfall (Appendix 4). The shallow aquifer is underlain by clay which likely acts as a temporary water trap during periods of high rainfall, providing conditions for the perched aquifer conditions (Appendix 4). The deeper aquifer was encountered at depths ranging from 7 to 9 m bsl in more low-lying

areas, and at depths of 16 to 28 m bsl at higher elevations (Appendix 4). The deeper aquifer is likely to be consolidated, given the geology of the area, and predominantly comprised of coarse sand and gravel, overlain by clay (Appendix 4). Groundwater availability at the IWMF site is likely to be seasonally influenced, with some degree of aquifer recharge expected to occur from surface water drainage during the higher rainfall periods in the northwest monsoon season, which occurs from December to May.

The deeper aquifer ranged from 12 to 33 m in thickness and was expected to provide a good groundwater yield (Appendix 4). Higher elevated areas located on sloped surfaces will have a similarly sloping water table at the subsurface, and as such, groundwater will eventually flow downslope from these locations to more low lying areas (Appendix 4).

Two groundwater bores drilled approximately 2.5 km northwest of the AES Yard, by Central Drillers, in 2012 and 2013 indicated daily yields of 57,600 L and 86,400 L respectively, as shown in Table 8.9. Groundwater was found at between 1.4 and 1.85 m bsl. The AES Yard is located downslope from the IWMF site and so these bores were drilled at a much lower elevation where groundwater availability is expected to be higher than at the IWMF site.

Table 8.9 – Pumping Test Data From AES Bores in 2012 and 2013

Well ID	Pumping Rate (L/min)	Duration (hrs)	Drawdown (m)	Full Recovery Time (mins)	Daily Yield (L)	Bore Depth (m bsl)	Standing Water Level (m bsl)
AES Bore 1	40	3	5.85	8	57,600	15	1.85
AES Bore 2	60	4	6.55	14	86,400	19.5	1.40

Source: Appendix 4.
*Daily yield results determined using constant discharge pumping tests.

However, as described is Section 8.2.2, the dominant geological formation of the study area is Port Moresby Beds, which are considered to have low groundwater potential. Groundwater is also not currently used as the main source of industrial water by AES, which predominantly relies on desalinated ocean water. No evidence of streams or groundwater seepages were observed during the 2018 groundwater survey (Appendix 4). Groundwater testing was conducted at two bores within the IWMF site in 2018 (see Figure 8.1), using standpipe piezometers. Over two visits to the groundwater bores, groundwater was observed at one of the two bores on the first visit but both bores were dry on the second visit indicating that there is no reliable permanent standing groundwater at the IWMF site (Appendix 3). Additional groundwater testing was conducted fortnightly over the period April to August 2020, which further confirmed the lack of available groundwater at the IWMF site, particularly during the drier months.

Three additional groundwater monitoring bores, identified as MB05, MB06, MB07 were installed within the IWMF site (see Figure 8.1). Bore rest water level measurements were taken in July 2019, however all three bores were found to be dry. The presence of water was reported by TWM personnel at MB05 in October 2019, although accurate measurements of water depth were

unable to be recorded. Bores were also found to be dry in July 2020, when bores were inspected as part of routine monitoring.

8.5.3 Permeability

The soil and rock of the IWMF site has low permeability, with the permeability of topsoil and CWR rock across all six soil sample locations and the two borehole locations shown in Figure 8.1 classified as predominantly 'practically impermeable' or 'impermeable'. Only one sample was not classified as 'practically impermeable' or 'impermeable', TP3 S2, which was described as having 'poor drainage' (Appendix 3). The geotechnical investigation determined that shallow percolation at the IWMF site is possible, and will be dependent on the permeability of the soil, and the thickness of topsoil. Topsoil was close to absent at some soil sampling locations and had a maximum thickness of 150 mm within the sampling sites (Appendix 3). Given the shallow thickness or lack of topsoil across the IWMF site (see Section 8.2.5) and the low permeability of topsoils that are present, shallow percolation through topsoils would likely be minimal (Appendix 3). The intact CWR bedrock, which occur at shallow depths generally between 0 and 15 cm bsl (but up to 1 m bsl in some locations), is considered virtually impermeable (Appendix 3), given geotechnical investigations classified the rock within the IWMF site as predominantly 'practically impermeable' or 'impermeable'. As such, water moving through the bedrock would most likely concentrate in fractures within the rock as described Section 8.2.5.

8.5.4 Groundwater Quality

Groundwater samples were collected from two bores (see Figure 8.1) for analysis of physicochemical and chemical parameters, which included pH, EC, TDS, major anion and cations (Ca, Mg, K, Na, Cl, and sulfate), alkalinity, ionic balance, total metals (As, Cd, Cr, Cu, Pb, Ni, Zn, and Hg) and TRHs. Results are presented in Table 8.10 with comparison made to the following water quality criteria:

- *Papua New Guinea Public Health (Drinking Water) Regulation 1984, Schedule 2 (Drinking Water).*
- *Papua New Guinea Environment (Water Quality Criteria) Regulation 2002, Schedule 1.*
- World Health Organisation 2011, Guidelines for Drinking-water Quality, fourth edition (WHO, 2011).

All results were below the relevant water quality criteria with the exception of pH at both boreholes which was below the lower limit of pH 6.5 of the Papua New Guinea drinking water criteria. Some parameters, including the pH results, were however analysed outside of holding times, and so the results should be interpreted with caution, but are likely indicative of groundwater quality. Groundwater was assessed as having moderately high salinity and being slightly acidic, which is likely reflective of the slightly acidic soil conditions described in Section 8.2.4.1 and the local geology. Sulfate and chloride were the dominant major ions in both boreholes. Some fractions of hydrocarbons were above laboratory limits of reporting in both bores. While there are no applicable guidelines for comparison, the results indicate either anthropogenic or natural sources of hydrocarbons in groundwater; however, given the low organic content of soils it's unlikely to be due to natural sources. Either cross-contamination during the

borehole installation and sampling or current and historical activities within the Roku industrial area are more likely to be the source of hydrocarbons detected in the samples.

Additional water quality monitoring was conducted in April 2020 for BH1, MB05 and MB06, with analytical results presented in Table 8.11 with comparison made to PNG and WHO water quality criteria. Water quality was analysed for pH, temperature, dissolved oxygen (DO), biochemical oxygen demand, COD, TSS, ammonia nitrogen, oil and grease, and faecal coliforms. Results for pH at all three bores were found to be within the PNG drinking water criteria guideline range and circum-neutral. Dissolve oxygen was below the PNG Environment (Water Quality Criteria) Regulation 2002 guideline value of 6 mg/L at all sample locations (Table 8.11). Total suspended solids concentrations ranged from 3,200 to 3,300 mg/L.

Oil and grease was not detected above the LOR, whie faecal coliforms were detected at all three bores, from 10 to 30 most probably number(MPN)/100 mL, exceeding the WHO (2011) guidelines for water intended for drinking/treater water distribution systems, and the PNG Public Health (Drinking Water) Regulation 1984 (Schedule 2) for non-disinfected water supplies for individuals or small communities (Table 8.11).

Table 8.10 – Groundwater Quality Results of Project Area

Analyte	Unit of Measurement	PNG Environment (Water Quality Criteria) Regulation 2002	PNG Public Health (Drinking Water) Regulation 1984 (Schedule 2)	WHO (2011) (Health-based Guideline Values)	Groundwater Bore	
					BH1	BH2
pH	pH Unit	No alteration to natural condition	6.5 to 9.2	NA	5.2*	6.4*
EC (at 25°C)	µS/cm	NA	NA	NA	589	616
TDS (Calc)	mg/L	NA	NA	NA	383	400
Major Anions and Cations						
Sulfate as SO_4	mg/L	400	400	250#	145	117
Chloride (Cl)	mg/L	NA	NA	250#	68	84
Calcium (Ca)	mg/L	NA	NA	NA	41*	44*
Magnesium (Mg)	mg/L	NA	NA	NA	11*	14*
Sodium (Na)	mg/L	NA	NA	200#	40*	44*
Potassium (K)	mg/L	NA	NA	NA	3*	4*
Alkalinity						
Hydroxide alkalinity as $CaCO_3$	mg/L	NA	NA	NA	<1*	<1*
Carbonate alkalinity as $CaCO_3$	mg/L	NA	NA	NA	<1*	<1*
Bicarbonate alkalinity as $CaCO_3$	mg/L	NA	NA	NA	6*	45*
Total Alkalinity as $CaCO_3$	mg/L	NA	NA	NA	6*	45*
Ionic Balance						
Total Anions	meq/L	NA	NA	NA	5.06	5.7
Total Cations	meq/L	NA	NA	NA	4.77	5.36
Ionic Balance	%	NA	NA	NA	2.94	3.08

Analyte	Unit of Measurement	PNG Environment (Water Quality Criteria) Regulation 2002	PNG Public Health (Drinking Water) Regulation 1984 (Schedule 2)	WHO (2011) (Health-based Guideline Values)	Groundwater Bore	
					BH1	BH2
Dissolved Metals						
Arsenic (As)	mg/L	0.05	0.05	0.01	0.002	0.002
Cadmium (Cd)	mg/L	0.01	0.01	0.003	0.0002	0.0002
Chromium (Cr)	mg/L	0.05†	NA	0.5†	0.001	<0.001
Copper (Cu)	mg/L	1	1.5	2	0.034	0.031
Lead (Pb)	mg/L	0.005	0.1	0.01	0.002	0.003
Nickel (Ni)	mg/L	1		0.7	0.016	0.013
Zinc (Zn)	mg/L	5	15	4**	1.42	2.61
Mercury (Hg)	mg/L	0.0002	0.001	0.006	<0.0001	<0.0001
Total Recoverable Hydrocarbons						
C6 – C10 Fraction	µg/L	NA	NA	NA	350*	220*
>C10 – C16 Fraction	µg/L	NA	NA	NA	<100*	<100*
>C16 – C34 Fraction	µg/L	NA	NA	NA	120*	380*
>C34 – C40 Fraction	µg/L	NA	NA	NA	<100*	170*

Source: Appendix 3.
Note: Grey shading indicates an exceedances of the Papua New Guinea drinking water guidelines.
* Results were extracted and/or analysed outside of recommended holding times, so should be interpreted with caution.
# Not a health-based guideline value; however, concentrations of chloride or sulfate in excess of 250 mg/L and sodium in excess of 200 mg/L can give rise to detectable taste in water.
† Chromium (Cr) as hexavalent form.
** Not a health based value; however, at levels above 4 mg/L zinc can give rise to a detectable taste in water.

Table 8.11 – Groundwater Quality Results from April 2020

Analyte	Unit of Measurement	PNG Water Quality Criteria (Freshwater)	PNG Public Health (Drinking Water) Regulation 1984 (Schedule 2)	WHO (2011) (Health-based Guideline Values)	Groundwater Bore		
					BH1	MB05	MB06
pH (at 25°C)	pH Unit	No alteration to natural condition	6.5 to 9.2	NA	6.9	7.1	7.2
Temperature	°C	No alteration greater than 2°C	NA	NA	25	25	25
DO	mg/L	Not less than 6.0	NA	NA	2	4	5
BOD	mg/L	NA	NA	NA	12	6	<5
COD	mg/L	NA	NA	NA	<20	<20	<20
TSS	mg/L	NA	NA	NA	3,200	3,200	3,300
Ammonia nitrogen (NH3-N)	mg/L	3.6*	NA	NA	0.28	1.1	0.34
Oil and grease	mg/L	None	NA	NA	<0.1	<0.1	<0.1
Faecal coliforms	MPN/100 mL	200#	3†	Not detectable in any 100 mL samples**	10	30	10

* Ammonia nitrogen presented for freshwater with a pH of 7.0 and a temperature of 25°C.
# Median value based on not fewer than five samples taken over a period of not more than 30 days.
† Criterion is for non-disinfected water supplies for individuals or small communities.
** Water directly intended for drinking/treated water in distribution systems.

8.5.5 Groundwater Use

Groundwater is used in Roku village for washing clothes, bathing and sewage. Roku village has three groundwater bores; however, bore water is not used for drinking by the community, due to the saline nature and its supply being generally unreliable. A groundwater bore (Plate 8.11) was observed during the field survey near site TWM1 (see Figure 8.1) but was dry at the time.

Plate 8.11 – Example of Community Groundwater Bore



Groundwater extraction does not occur at the IWMF site. Groundwater has been previously extracted from two bores (see Table 8.9) 2.5 km northwest of the AES industrial park, however currently water is now predominantly extracted by AES from the marine environment for desalinations prior to use (Appendix 3). One of the two bores indicates very high levels of faecal coliforms and E. Coli, and as such is not relied on by the AES Industrial Park for water supply (Appendix 3).

8.6 Amenity

8.6.1 Air Quality and Greenhouse Gases

8.6.1.1 Existing Air Quality

As identified in Chapter 1, the IWMF is located within a developing industrial precinct with adjacent activities comprising construction, road building, port operations and other industrial services including the AES Industrial Park. As described in Section 8.1.2.6, air quality monitoring was undertaken at one location (see Figure 8.1) at the IWMF from 5 to 10 November 2018 to assess background levels of particulate matter as TSP. While development of the IWMF has continued since the monitoring was undertaken, the results from this previous study are considered to provide a representative understanding of existing ambient air quality.

Table 8.12 provides a summary of the 24-hour average particulate monitoring results. Data collected on the 5th and 10th of November has been excluded from Table 8.12, as the length of monitoring on these dates was insufficient for calculating the 24-hour average concentrations (Appendix 5).

Table 8.12 – 24-Hour Average Particulate Concentrations

Monitoring Date	Measured TSP Concentration (µg/m³)	Calculated PM_{10} Concentration (µg/m³)	Calculated $PM_{2.5}$ Concentration (µg/m³)
6/11/2018	56	22	6
7/11/2018	100	39	10
8/11/2018	74	29	7
9/11/2018	71	28	7
Average	**75**	**29**	**8**
Maximum	**100**	**39**	**10**

Source: Appendix 5.

Table 8.13 provides a summary of background air pollutant concentrations (during the monitoring period) with comparison made to relevant ambient air quality criterion provided in EP-L2 (485), although TSP is not included in the existing permit, a criterion was adopted for comparison based on Queensland and New South Wales (Australia) regulations. Concentrations for PM_{10} and $PM_{2.5}$, over 1-year and 24-hour averaging periods were significantly below the relevant permit criteria, while TSP concentrations over a 1-year averaging period were also below the adopted criterion of 90 µg/m³. While monitoring results were below permit and adopted criteria levels, overall the background air quality is considered to have relatively high particulate matter concentrations, with the vehicle movement along Napa Napa Road, north of the site, observed to be a major source of particulate matter emissions.

Table 8.13 – Summary of Air Pollutant Concentrations

Pollutant	Averaging Period	Concentrations (µg/m³)	TWM EP-L2 (485) Criteria (µg/m³)
TSP	1-year	75	90*
PM_{10}	24-hours	39	150
	1-year	29	70
$PM_{2.5}$	24-hours	10	75
	1-year	8	35

Source: Appendix 5.
* Based on Queensland and New South Wales regulations.
Note 1. The average measured concentrations for the monitoring period were used for the one-year average period.
Note 2. The maximum concentrations were reported for averaging periods of less than a year.

Baseline data on other air quality parameters were not collected. Background level data for dust deposition, dioxins and furans and PAHs in the form of benzo(a)pyrene have been adopted from available data considering comparable environments (Appendix 5). Background concentrations of other pollutants are expected to be negligible.

Existing background levels of dust deposition are likely to vary depending on local sources and have been assumed to be 50 mg/m^2 per day for the IWMF site, which is considered typical of rural agricultural and industrial areas (Appendix 5).

The adopted background level for concentrations of dioxins and furans for the Project is 0.01 pg/m^3 (see Appendix 5) which provides a conservative over-estimate of expected concentrations and has been established on the basis of typical Australian background concentrations of dioxins and furans that have been published by the Queensland Department of the Environment and Heritage (Gras et al., 2004).

Background concentrations of benzo(a)pyrene for the IWMF site have been adopted from selected studies in areas considered typical of an urban background. An assumed background level of 0.1 ng/m^3 of benzo(a)pyrene in PM_{10} has been used for the Project, which was taken from 56 samples collected at Rocklea, Queensland, in 2003 and 2004 (Kumar, 2008).

8.6.1.2 Sensitive Receptors

The IWMF is situated in an industrial location, with Roku village the only nearby local community, located approximately 500 m southeast of the IWMF site boundaries. Tuhava Town is considered to be the closest residential receptor, located approximately 160 m to the west of the IWMF. Accommodation at the AES industrial precinct is located approximately 230 m to the north and the closest sensitive receptor at Roku village is approximately 360 m to the southeast. These locations are summarised below in Table 8.14 and are shown in Figure 8.9.

Table 8.14 – Identified Sensitive Human Receptors

Receptor ID	Receptor Location	Approximate Distance and Direction from the IWMF Site Boundary
A	Tuhava Town	160 m west
B	AES Industrial Park	230 m north
C	Roku Village	360 m southeast
D	Roku Village	500 m southeast
E	Roku Village	580 m southeast
F	Roku Village	480 m southeast
G	Roku Village	430 m southeast

Source: Appendix 5.

In addition to these human receptors, Project infrastructure will be surrounded by terrestrial biodiversity, as described in Section 8.7, which may also be sensitive to changes in air quality and could be considered sensitive ecological receptors.

SENSITIVE HUMAN RECEPTOS FOR AIR AND NOISE QUALITY

Integrated Waste Management Facility | Environmental Impact Statement

FIGURE 8.9



8.6.2 Noise

The IWMF is located with an industrial precinct adjacent Napa Napa Road where existing noise levels are dominated by car and truck movements as well as industrial noise sources. Background noise measurements were recorded at five locations across the IWMF on 6 November 2018 over a 15-minute interval using a hand-held sound level meter (see Section 8.1.2.7 and Figure 8.1). Continuous unattended noise logging was undertaken at one location (Location A, see Figure 8.1) between 5 and 10 November 2018.

Since the baseline assessment was conducted, additional noise sources, e.g., the incinerator, have been commissioned which will have altered the background noise levels. Additional field data was not collected; however, noise modelling considering current and future operations was conducted to understand the potential changes in noise conditions associated with the Project. These results are presented in Section 10.6 (and Appendix 6). The results of the baseline noise assessment are described in the following section.

8.6.2.1 Background Noise Measurements

Background noise statistics from the five assessment locations are provided in Table 8.15 and shown in Figure 8.1. Noise levels were highest at assessment Location D due to the communications tower. Location A had the next highest noise levels due to the proximity to traffic using Napa Napa Road and industrial activities both within the IWMF and the AES facility. Moving away from the road, anthropogenic noise associated with the industrial precinct and the harbour reduce and insects, birds and wind rustling the grass and trees become the dominant noise sources.

Table 8.15 – Summary Noise Statistics from Attended Noise Measurements

Location	Identified Noise Sources	Noise Levels (dBA) (Maximum-Top 10%-(Average)-Bottom 10 %-Minimum)		
		L_{10}	L_{eq}	L_{90}
A	Crane, AES activities, harbour operations, trucks, birds	56 (a.m.)/52 (p.m.)	52 (a.m.)/49 (p.m.)	44 (a.m.)/43 (p.m.)
B	Trucks, cars, AES activities and harbour (faint), wind, birds	44	44	37
C	Machinery, impact noises, insects, wind, birds	44	44	37
D	Communications tower	58	58	58
E	Forklift operations, impact noises, grinder, wind, reverse beepers	48	45	40

Calculated noise statistics from the continuous noise logging at Location A are provided in Table 8.16 and the background noise levels calculated using the lowest 10th percentile method are provided in Table 8.17. Background night time noise levels were 5 dBA lower than daytime levels.

Table 8.16 – Statistical Noise Levels at Location A

Parameter	Noise Levels (dBA) (Maximum-Top 10%-(Average)-Bottom 10 %-Minimum)		
	Day (7 a.m. to 6 p.m.)	*Evening (6 p.m. to 10 p.m.)*	*Night (10 p.m. to 7 a.m.)*
L_{max}	87-74-(69)-60-55	84-73-(60)-51-47	74-69-(54)-46-41
L_1	71-67-(60)-53-50	69-65-(53)-45-43	68-62-(49)-42-40
L_{10}	62-54-(50)-48-44	58-51-(47)-43-41	59-48-(43)-39-37
L_{eq}	61-54-(50)-46-41	55-51-(46)-42-40	55-49-(42)-38-36

Source: Appendix 3.

Table 8.17 – Background Noise Levels at Location A

Period	Background Noise Level L_{90} dBA
Day (7 a.m. to 6 p.m.)	39
Evening (6 p.m. to 10 p.m.)	38
Night (10 p.m. to 7 a.m.)	34

8.6.2.1 Noise Receptors

Residential and commercial/industrial receptors are located to the northwest, north and southeast of the IWMF site boundaries (see Figure 8.9). The closest commercial/industrial receptors are located immediately adjacent the northwest boundary at Rhodes/AGL and approximately 30 m northeast across Napa Napa Road at AES and Agility. The closest residential receptors from the IWMF site boundaries are located at Tuhava Town (130 m northwest), accommodation at AES (350 m northeast) and at Roku Village (385 m southeast).

8.6.3 Visual Amenity

This section provides a description of the landscapes and visual amenity within and surrounding the study area which have been shaped by variations in geology, soils, landform, vegetation and the settlement and use by people. The visual baseline is described in terms of views from the air (to provide a visual overview of the landscape character), by describing representative landscapes and selected viewpoints that help illustrate the existing views from key receptors, such as people driving along Napa Napa Road, nearby settlements and businesses in the adjacent industrial precinct.

The study area is located within the Southern Plains and Lowlands region of PNG, a narrow, lowlands belt trending northwest to southeast along the coast before a steep incline into the Central Ranges. Locally, the study area is characterised by the Fairfax landform system. It consists of low plateaus and hills with undulating plains with brown clay soils and is dominated by open eucalypt savanna with narrow strips of riparian forest along the seasonal waterways (hilly terrain with weak or no structural control leading onto mountains and hills with weak or no structural control) (Bryan & Shearman, 2008).

Regionally, the topography comprises areas of elevated topography that is generally separated by broad valleys, with water courses, many of which are ephemeral, flowing after the wet season but not throughout the dryer times of the year (EDAW, 2008). Topography within the study area is gently undulating surrounding the industrial area, which sits on an elevated area that gradually drops away to the coast at Idlers' Bay and Fairfax Harbour. The topographic assessment of the Project area is further described in Section 8.2.

The vegetation of the study area comprises eucalypt savanna and grassland, comprising scattered trees, predominantly eucalypts, on higher hills and along seasonal drainage lines and dense bands of mangroves occur in patches along the coastline. The terrestrial biodiversity, including vegetation characterisation is further described in Section 8.7.

Settlements within the study area are of a rural character, comprising a mixture of traditional, semi-modern and modern buildings – a significant proportion of which are stilted over the coastal beaches – intersected by dirt roads and walkways. Aside from the villages the landscape in the study area is dotted with occasional individual houses or other small buildings.

The study area is within a growing industrial precinct with adjacent activities comprising construction, road building, domestic shipping port operations and other industrial services. The AES Industrial Park, where the Project is located, extends from Napa Napa Road down to the water at Fairfax Harbour. There are a number of other industrial areas located along Napa Napa Road, including the Puma Refinery at the western extent of the peninsular facing into Port Moresby Harbour, and further to the north there are several port facilities (Plate 8.12).

Plate 8.12 – View of the Napa Napa Peninsula



Photo: Google Earth, 2020.

The main road (Napa Napa) in sealed, and there are a number of smaller 'feeder roads', all unsealed with no curbing, and are primarily used by local rural or industrial facility traffic. The IWMF is opposite the AES industrial park, which operates a domestic shipping port resulting in a large number of heavy vehicle transfers using Napa Napa Road day and night. Further south of the TWM site along Napa Napa Road is the PUMA oil refinery. This operation contributes to the large number of heavy vehicles using Napa Napa Road. Traffic and transport are further described in Section 9.8.

The existing IWMF is situated to the south of Napa Napa Road in an area that is undulating, extending to a hill located in the south-eastern corner of the site. The site has been cleared and levelled in a series of benches following a natural incline to the crest of the hill. Bands of endemic dry forest, understory vegetation and grasses remain intact. The existing facilities include an incineration and waste oil processing plant, a mechanical workshop and a hazardous waste storage building. A disused quarry exists on the south-eastern boundary of the property and an administration compound including staff accommodation and car parking are located immediately to the south of the site access fronting the Napa Napa Road.

The landscape character types present in the study area are described in Table 8.18 and illustrated in Plates 8.12 to 8.17.

Table 8.18 – Landscape Types and Characteristics

Landscape Type	Key Characteristics
Industrial Precinct	• Operational areas are cleared of vegetation and comprise buildings, roads, power infrastructure, waste operations infrastructure and signage • Heavily modified environment • Interspersed with bands of endemic vegetation and introduced species. • Site is fenced and not accessible by the public/local communities. • See Plate 8.13 and 8.14
Eucalypt Savanna/ grassland	• Terrain is gently undulating, intersected by ephemeral drainage lines. • Tall grasses dominate the understorey, interspersed with scattered (open) eucalyptus canopy • Evidence of weeds, fire and clearing, providing a somewhat modified/degraded environment. • See Plate 8.15
Wooded Drainage Lines	• Relatively shallow and narrow creek rocky drainage, some areas with exposed rock outcrops, interspersed with young eucalypts • Trees along drainage lines contribute to a strong sense of visual continuity • Character of the drainage lines is strongly influenced by the seasons and climatic conditions (i.e., there is no standing or running water in the dry season; vegetation is significantly greener in the wet season). • See Plate 8.16
Settlements (Roku village)	• Roku village extends around Idlers Bay and up along Napa Napa Road, with several scattered isolated dwellings • Traditional coastal village with a mixture of traditional and modern housing; traditional housing is built out over the shoreline • Roads are unsealed, powerlines are visible, giving the village a semi-rural, and (transitional) modernising character • See Plate 8.17

Plate 8.13 – The AES Industrial Park



Photo: TWM.

Plate 8.14 – View of the IWMF from Napa Napa Road



Plate 8.15 – Landscape Type: Eucalypt Savanna/Grassland



Plate 8.16 – Landscape Type: Wooded Drainage Lines



Plate 8.17 – Landscape Type: Coastal Village



8.7 Terrestrial Ecology

8.7.1 Biogeographic Setting

The PNG CNA (Beehler, 1993) delineated biogeographic zones for major faunal groups based on known species distributions and patterns of endemism. Each biogeographic zone is expected to support a distinctive faunal community at the landscape level. Adopting the terminology applied to warm-blooded vertebrates (mammals and birds) (Beehler, 1993), the study area is located within the Owen Stanleys biogeographic zone, which extends from the southern to northern coastlines of Papua New Guinea, encompassing the Owen Stanley Ranges. The Project is located on the south coast of this biogeographic region, which is characterised as a savanna region (Section 8.7.2.1). In Papua New Guinea, savanna occurs along the southern lowlands, south of the Central Range, typically within areas with low rainfall and distinct dry seasons (Hammermaster & Saunders, 1995), such as Port Moresby. The savanna region around Port Moresby has been demonstrated to be an important area for restricted range lizard species and is an important region of endemism for such species (Alcorn, 1993).

8.7.2 Vegetation

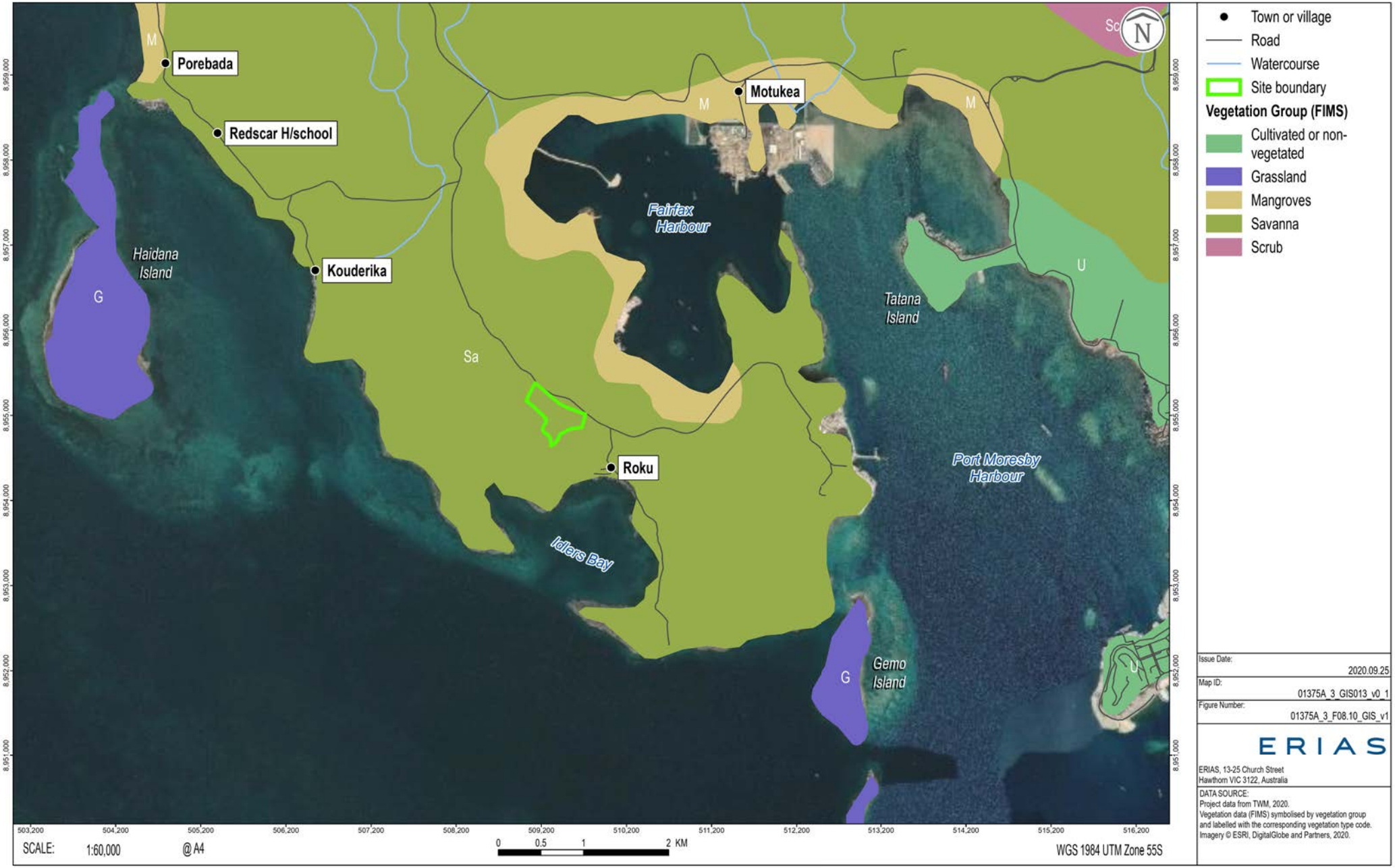
8.7.2.1 Vegetation in the Region

Several Forestry Inventory Mapping System (FIMS) vegetation types are mapped beyond the IWMF site boundary and the study area, as shown in Figure 8.10. FIMS delineates existing broad vegetation classes across Papua New Guinea on the basis of country wide aerial photography with an average map scale of 1:110,000 (Woxvold, 2008). The FIMS vegetation type savanna (Sa) is the dominant FIMS vegetation type in the Roku area and characterises the study area.

FOREST VEGETATION TYPES (FIMS)

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FIGURE 8.10



The structural and floristic attributes of the FIMS savanna vegetation type in the study area is described in Section 8.7.2.2. Other FIMS vegetation types that occur in the broader region of the Project include Grassland (G), Mangroves (M), and Scrub (Sc) as shown in Figure 8.10. These vegetation types are described below however do not occur within the study area. FIMS mapping also characterises the Port Moresby area west of the study area and Fairfax Harbour as Cultivated or non-vegetation (U), which describes the urban nature of Port Moresby, and is therefore not described further. Descriptions of each FIMS vegetation types in the Project region are provided below after Hammermaster and Saunders (1995), along with the location, landform and lithology.

Savanna

Savanna (Sa) is described by Hammermaster and Saunders (1995) as a vegetation type comprising a scattered to moderately dense layer of trees, generally less than 6 m tall, with a clearly visible ground layer of herbs and/or grasses. Savanna characterises the study area, and the Roku area, as well as the majority of the area west and northwest of Fairfax Harbour. In Papua New Guinea, savanna occurs on a wide range of landforms, however within the study area, the savanna is coastal and occurs on a mountains or hills landform with weak or no structural control, which form low, undulating hills with a fine-grained sedimentary lithology. The tree layer typically includes a range of Eucalyptus species, including *Eucalyptus confertiflora*, *E. papuana*, *E. alba* and *E. tereticornis* (Hammermaster & Saunders, 1995). Eucalyptus trees overly the mixed grass layer which is typically dominated by *Themeda australis*, and depending on location within savanna forest, *Sehima nervosum* and *Heteropogon contortus* (Hammermaster & Saunders, 1995). Associated grasses within the mixed grass layer may include *Sorghum nitidum*, *Arundinella setosa*, *Capillipedium parviflorum*, *Cymbopogon proceras*, *Pseudopogonatherum irritans*, *Eulalia leptostachys* and *Ischaemum spp* (Hammermaster & Saunders, 1995). Taller associated grass species associated typically occur in savanna locations with more moist soils (Hammermaster & Saunders, 1995).

Grassland

Grassland (G) under FIMS typically comprises grasses, sedges, herbs and very low woody shrubs, and is generally less than 3 m tall (Hammermaster & Saunders, 1995). Scattered tress may also be present (Hammermaster & Saunders, 1995). This vegetation type characterises small, coastal pockets of the surrounding region, including two islands located offshore of the Roku area and an area approximately 10 km northwest of the study area. Grasses are widespread throughout Papua New Guinea, occurring in a range of climates, landforms elevations and soil types (Hammermaster & Saunders, 1995). Species present are varied, according to the above determining factors. Grassland vegetation may also contain scattered, low trees, which in low rainfall areas such as the Project area frequently include *Eucalyptus*, *Melaleuca* and *Tristania* species. Grasslands near the study area occur on mountains or hills with weak or no structural control and find grained sedimentary lithology (the same as savanna) and raised coral reefs and associated black reef plains on the small islands offshore the IWMF site, which have a limestone lithology.

Mangroves

All vegetation within the mangroves (M) vegetation type is of the saline or brackish communities' tidal zone. The vegetation type ranges from forest over 30 m tall, to low halophytic herbs or nearly

bare tidal flats (Hammermaster & Saunders, 1995). Mangroves occur as thin strips along the coastal margin of Fairfax Harbour, including immediately adjacent to the study area, and in a small pocket approximately 8 km to the northwest, as shown in Figure 8.10. Mangroves often occur on sheltered shorelines or estuaries and slope gradually from the marine environment to the inland extent of tidal creeks. Mangroves near the study area occur on a variety of landforms and lithologies, including but not limited to mangrove swamp landforms with an estuarine deposits lithology, and undifferentiated coastal plain with alluvial deposits. Mangroves occur along the northern, western and southern edges of Fairfax Harbour, including a mangrove area immediately adjacent to the AES Industrial Park, approximately 1 km northeast of the IWMF site (see Figure 8.1). Mangroves also occur within Idlers Bay, including southeast of Roku village, and a larger mangrove stand on the north coastline of Idlers Bay, approximately 1 km southwest of the IWMF site (see Figure 8.1).

Scrub

Scrub (Sc) is described by Hammermaster & Saunders (1995) as comprising dense shrubs with or without scattered low trees, and generally less than 6 m tall. This FIMS vegetation type characterises higher elevations inland of the study area, approximately 6 to 8 km north of the study area. In some coastal areas with low rainfall, such as the Project area, typical flora species found in the scrub vegetation community include *Hibiscus tiliaceus* and *Desmodium umbellatum*, commonly entangled with vine species (Hammermaster & Saunders, 1995).

Similarly to the savanna community, scrub also occurs on mountains or hills with weak or no structural control with a fine grained sedimentary lithology, albeit on steeper terrain.

8.7.2.2 Vegetation within the Study Area

FIMS mapping characterises the entire study area for the proposed development as savanna (Sa). Flora field surveys conducted in 2020 confirmed the study area as a savanna vegetation type, with no recognised forest formation, comprising eucalypt savanna and grassland (see Plates 8.18 and 8.19). Previous investigations at the IWMF support this description, describing the vegetation cover of the area as savanna grassland with numerous scattered eucalyptus trees (Appendix 4). Savanna vegetation type is widespread in the local region, and throughout the southern coastal lowlands of Central Province of Papua New Guinea.

Plate 8.18 – Eucalyptus and Grassland Vegetation in the Study Area



Plate 8.19 – Scattered Trees and Underlying Grasses



The IWMF site is an existing and operational facility that is partially cleared with strips of remnant patches of savanna vegetation. As such, while the entirety of the study area and the proposed IWMF site are mapped under FIMS as savanna, existing disturbance and clearing of previous land use activities, undertaken prior to the establishment of the IWMF, have resulted in the direct loss of vegetation within the Project footprint, as shown in Figure 8.11. Approximately 63% of the total study area, encompassing the IWMF site, is covered by savanna vegetation (130.97 ha), and 48% (9.94 ha) of the IWMF site boundary. However, the IWMF site itself is now heavily disturbed and the original vegetation greatly altered or absent (Plate 8.20). Natural vegetation remaining within the IWMF site is located predominantly on slopes between cleared bench tops constructed southeast of the IWMF offices (Figure 8.11), as well as thin strips scattered throughout the site between differing operational areas, and the northeast corner adjacent to the disused quarry.

Plate 8.20 – Pre-Existing Disturbance within the Study Area



Remnant vegetation in the proposed IWMF site and the study area has also been subject to indirect impacts through the disturbance or clearing of adjacent vegetation. Vegetation within the study area is also frequently burnt, either for gardening or leisure, mostly during the dry season and subject to firewood collection. Most of the IWMF site is surrounded by roads along which the vegetation is heavily disturbed from the existing operational areas of the IWMF, the AES Industrial Park, Rhoades Construction site, the Napa Napa Road and the road accessing Roku village (see Figure 8.11). Vegetation to the west and southeast of the IWMF site is largely intact, although intermixed with weeds. In addition to the impacts of previous clearing, introduction and spread of weeds, vegetation condition in the study area has also been affected by dieback occurring as a result of burning.

REMNANT VEGETATION WITHIN THE STUDY AREA

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FIGURE 8.11



Issue Date: 2020.10.09

Map ID: 01375A_3_GIS016_v0_3

Figure Number: 01375A_3_F08.11_GIS_v1

ERIAS, 13-25 Church Street
Hawthorn VIC 3122, Australia

DATA SOURCE:
Project data from TWM, 2020.
Vegetation imagery from Google Earth, 2020.
Imagery © ESRI, DigitalGlobe and Partners, 2020.

8.7.3 Native Flora and Fauna

8.7.3.1 Species Recorded

A total of 22 terrestrial flora and vertebrate fauna species, excluding weed species, were recorded in the terrestrial biodiversity study area (see Figure 8.1) during the 2020 flora and fauna field surveys (Appendix 8). All flora and fauna species recorded in 2020 are listed in the following sections. These species lists have been used to supplement and confirm fauna recorded or potentially occurring in savanna habitats along the peninsula from Fairfax Harbour and the Roku area to Caution Bay by Woxvold (2008) for the PNG LNG Project, and for species identified in a 2013 environmental assessment of the AES Ravavu Industrial Park (ERIAS, 2013).

Flora

Savanna flora species identified in the 2013 AES Ravavu environmental assessment, included *E. alba*, *E. confertiflora*, *E. teteticornis*, and *E. papuana* with kangaroo grass (*Themeda australis*) and Kunai grass (*Imperata cylindrical*) dominating the grass layer. Based on the description of the FIMS savanna vegetation type, this species composition is typical of savanna habitats in Papua New Guinea. Field surveys at the IWMF site in 2020 confirmed the presence of a total of 15 plant species, excluding those identified as weeds in Appendix 3, seven of which were only identifiable to genus (Table 8.19). Field surveys confirmed that eucalyptus species were the dominant tree type in the study area, including *E. alba*, *E. confertiflora*, and *E. teteticornis* which were dispersed throughout the area (Plate 8.21), with a Garuga sp. also common across the study area (Plate 8.22). The most common and widespread species forming the underlying grassland layer include kangaroo grass (*Themeda triandra*) (Plate 8.23), and black spear grass (*Heteropogon contortus*) (Plate 8.24).

Table 8.19 – Flora Species Recorded within the Study Area in 2020

Scientific Name	English Name
Trema orientalis	Charcoal-tree
Cryptocarya sp.	NA
Azadirachta indica	Neem
Eucalyptus alba	White gum
Eucalyptus confertiflor	Broad leaf carbeen
Eucalyptus teteticornis	Forest red gum
Mangifera indica	Mango tree
Canarium sp.	NA
Terminalia catappa	Indian almond tree
Acacia sp.	NA
Pandanus sp.	Pandanus
Leucaena sp.	NA
Garuga sp.	NA
Themeda triandra	Kangaroo grass
Heteropogon contortus	Black spear grass

NA not applicable as not identified to species level.

Plate 8.21 – Eucalyptus Species Dominating the Study Area



Plate 8.22 – *Garuga* Species within the Study Area



Plate 8.23 – Kangaroo Grass (*Themeda triandra*)



Plate 8.24 – Black Spear Grass (*Heteropogon contortus*)



Although outside the study area, the mangrove community adjacent to the AES Ravavu Industrial Park consists of a mixture of mangrove trees and low tidal shrubs and plants. Species include red mangrove (*Rhizophora stylosa*), orange mangrove (*Bulguira gymmnorhiza*), small leafed orange

mangrove (*Bulguira parviflora*), milky mangrove (*Excoecaria agallocha*), and puzzlenut (*Xylocarpus sp.*) (ERIAS, 2013).

Fauna

Fauna species recorded in savanna habitat at Caution Bay, approximately 14 km northwest of the Project, for the PNG LNG Project in 2008 (Woxvold, 2008), either directly or indicated as present during village interviews, are provided in Table 8.20. These species included two mammals (agile wallaby and Cape York rat), six reptiles, one amphibian (cane toad), and 23 bird species, including the white-bellied cuckoo-shrike. None of the species recorded in savanna habitat at Caution Bay are International Union for Conservation of Nature (IUCN) listed or are of conservation status in Papua New Guinea under the *Fauna Act* (Woxvold, 2008). Species that were not recorded during the 2008 PNG LNG surveys, but that may have potentially occurred in savanna near Caution Bay are also provided, in Table 8.21.

Table 8.20 – Fauna Species Recorded in Savanna at Caution Bay in 2008

Scientific Name	English Name	Status*
Mammals		
Macropus agilia	Agile wallaby	LC
Rattus leucopus	Cape York rat	Introduced
Reptiles		
Lophognathus temporalis	Ta-ta lizard	LC
Carlia bicarinata	None	LC
Sphenomorphus fragilis	None	LC
Hemidactylus frenatus	Asian house gecko	LC
Nactus sp cf pelagicus	Pelagic gecko	LC
Demansia vestigiata	Lesser black whipsnake	LC
Amphibians		
Bufo marinus	Cane toad	Introduced
Birds		
Dacelo leachii	Blue-winged kookaburra	LC
Todirhamphus macleayii	Forest kingfisher	LC
Todirhamphus sanctus	Sacred kingfisher	LC
Merops ornatus	Rainbow bee-eater	LC
Cacomantis variolosus	Brush cuckoo	LC
Centropus phasianinus	Pheasant coucal	LC
Trichoglossus haematodus	Rainbow lorikeet	LC
Geopelia striata	Zebra dove	LC
Haliastur sphenurus	Whistling kite	LC
Accipiter fasciatus	Brown goshawk	LC
Chlamydera cerviniventris	Fawn-breasted bowerbird	LC
Lichenostomus flavescens	Yellow-tinted honeyeater	LC
Philemon novaeguineae	New Guinea friarbird	LC
Conopophila albogularis	Rufous-banded honeyeater	LC

Scientific Name	English Name	Status*
Colluricincla harmonica	Grey shrike-thrush	LC
Corvus orru	Torresian crow	LC
Cracticus mentalis	Black-backed butcherbird	LC
Artamus leucorynchus	White-breasted woodswallow	LC
Coracina novaehollandiae	Black-faced cuckooshrike	LC
Coracina papuensis	White-bellied cuckooshrike	LC
Lalage tricolor	White-winged triller	LC
Rhipidura leucophrys	Willie-wagtail	LC
Hirundo tahitica	Pacific swallow	LC

Source: Woxvold, 2018.
* Status: LC = Least Concern (IUCN).

Table 8.21 – Fauna Species Potentially Occurring in Savanna at Caution Bay

Scientific Name	English Name	Status*
Non-Volant Mammals		
Planigale novaeguineae	New Guinean planigale	LC, R
Melomys leucogaster	White-bellied melomys	LC
Rattus exulans	Pacific rat	LC
Rattus mordax	Eastern rat	LC
Rattus sordidus	Canefield rat	LC
Uromys caudimaculatus	Mottled-tailed giant-rat	LC
Bats		
Pteropus alecto	Black flying-fox	LC
Pteropus hypomelanus	Variable flying-fox	NT
Pteropus macrotis	Big-eared flying-fox	LC
Pteropus scapulatus	Little red flying-fox	LC
Saccolaimus flaviventris	Yellow-bellied sheathtailbat	LC
Saccolaimus mixtus	Troughton's sheathtailbat	DD
Saccolaimus saccolaimus	Naked-rumped sheathtail-bat	LC
Chalinolobus nigrogriseus	Hoary bat	LC
Nyctophilus bifax	North Queensland nyctophilus	LC
Nyctophilus microtis	Small-eared nyctophilus	LC
Nyctophilus timoriensis	Greater long-eared bat	DD
Pharotis imogene	New Guinea big-eared bat	CR
Philetor brachypterus	Rohu's bat	LC
Pipistrellus papuanus	Papuan pipistrelle	LC
Pipistrellus wattsi	Watt's pipistrelle	LC
Otomops papuensis	Big-eared mastiff-bat	DD
Reptiles		
Oxyuranus scutellatus canni	Taipan	LC

Scientific Name	English Name	Status*
Pseudechis papuanus	Papuan black snake	DD
Apodora papuana	Papuan python	LC
Morelia amethistina	Amethystine python	LC, R
Birds		
Eurystomus orientalis	Dollarbird	LC
Cuculus saturatus/optatus	Oriental/ Himalayan cuckoo	LC
Chrysococcyx lucidus	Shining bronze-cuckoo	LC
Eudynamys scolopacea	Asian koel	LC
Scythrops novaehollandiae	Channel-billed cuckoo	LC
Chalcopsitta sintillata	Yellow-streaked lory	LC
Pseudeos fuscata	Dusky lory	LC
Charmosyna placentis	Red-flanked lorikeet	LC
Cyclopsitta gulielmitertii	Orange-breasted fig-parrot	LC
Collocalia esculenta	Glossy swiftlet	LC
Hirundapus caudacutus	White-throated needletail	LC
Hemiprocne mystacea	Moustached treeswift	LC
Tyto alba	Barn owl	LC
Ninox connivens	Barking owl	LC
Ninox theomacha	Jungle Hawk-owl	LC
Aegotheles cristatus	Australian owlet-nightjar	LC
Podargus papuensis	Papuan frogmouth	LC
Eurostopodus mystacalis	White-throated eared-nightjar	LC
Caprimulgus macrurus	Large-tailed nightjar	LC
Ptilinopus aurantiifrons	Orange-fronted fruit-dove	LC
Ptilinopus iozonus	Orange-bellied fruit-dove	LC
Ducula spilorrhoa	Torresian imperial-pigeon	LC
Aviceda subcristata	Pacific baza	LC
Elanus axillaris	Black-shouldered kite	LC
Milvus migrans	Black kite	LC
Circus approximans	Swamp harrier	LC, R
Accipiter novaehollandiae	Grey goshawk	LC
Accipiter poliocephalus	Grey-headed goshawk	LC
Accipiter cirrocephalus	Collared sparrowhawk	LC
Hieraaetus morphnoides	Little eagle	LC
Falco cenchroides	Australian kestrel	LC, R
Falco severus	Oriental hobby	LC, R
Falco longipennis	Australian hobby	LC, R
Falco peregrinus	Peregrine falcon	LC, R
Myzomela obscura	Dusky myzomela	LC
Lichmera alboauricularis	Silver-eared honeyeater	LC

Scientific Name	English Name	Status*
Meliphaga albonotata	Scrub honeyeater	LC
Meliphaga gracilis	Graceful honeyeater	LC
Xanthotis polygramma	Spotted honeyeater	LC
Melithreptus albogularis	White-throated honeyeater	LC
Ramsayornis modestus	Brown-backed honeyeater	LC
Gerygone olivacea	White-throated gerygone	LC
Microeca fascinans	Jacky-winter	LC
Microeca flavigaster	Lemon-bellied flyrobin	LC
Pachycephala leucogastra	White-bellied whistler	LC
Manucodia atra	Glossy-mantled manucode	LC
Paradisaea raggiana	Raggiana Bird-of-paradise	LC, P
Sphecotheres viridis	Green figbird	LC
Lalage leucomela	Varied triller	LC
Rhipidura rufiventris	Northern fantail	LC
Rhipidura rufifrons	Rufous fantail	LC
Myiagra rubecula	Leaden flycatcher	LC
Myiagra cyanoleuca	Satin flycatcher	LC
Aplonis cantoroides	Singing starling	LC

Source: Woxvold, 2018.
* Status: CR = Critically Endangered (IUCN); NT = Near Threatened (IUCN); DD = Data Deficient (IUCN); LC – Least Concern (IUCN); P = species Protected under Papua New Guinea law; R – trade restricted species under Papua New Guinea Law.

Additionally, native and introduced fauna species identified as commonly occurring around the AES Ravavu area in 2013 included reptiles (e.g., blind snake, python, brown tree snake), amphibians (e.g., introduced cane toad and the common green frog), birds (e.g., kingfishers, kookaburras, eagles, rainbow bee eater) and insects (e.g., grasshoppers, butterflies). Common mammals described as occurring in the habitat type present at the AES included grass wallabies, rodents, bats, bandicoots, striped possums and sugar gliders (ERIAS, 2013). Savanna forests surrounding Port Moresby has also been considered as essential habitat to several lizard species, including *Carlia bicarinata*, *C. luctosa*, *Lepidodactylus browni*, and *L. orientalis* (Alcorn, 1993).

Field surveys conducted in July 2020 confirmed the presence of seven native vertebrate fauna species in the study area (Table 8.22). These included three bird species, two amphibian species and two reptile species, with no mammals observed. Species included the Papuan frogmouth (*Podargus papuensis*) (Plate 8.25), white-bellied cuckoo-shrike (*Coracina papuensis*) (Plate 8.26), black cuckoo-shrike (*Coracina schisticeps*) (Plate 8.27), green tree frog (*Ranoidea caerulea*) (Plate 8.28), snake-eyed skink lizard (*Cryptoblepharus yulensis*), (Plate 8.29), a gecko species that could be identified to genus level only (*Nactus sp.*) (Plate 8.30), and a cane toad (*Bufo marinus*) (Plate 8.35 in Section 8.7.4.2). However, while not recorded during the 2020 field surveys, it remains likely that some or all of the reported species in Table 8.20, and potentially species reported in Table 8.21, may occur.

Table 8.22 – Fauna Species Recorded in the Study Area 2020

Scientific name	English name	Status*
Podargus papuensis	Papuan frogmouth	LC
Coracina papuensis	White-bellied cuckoo-Shrike	LC
Coracina schisticeps	Black cuckoo-Shrike	LC
Ranoidea caerulea	Green tree frog	LC
Nactus sp.	Gecko	NA
Cryptoblepharus yulensis	Snake-eyed skink lizard	LC
Bufo marinus	Cane toad	Introduced

NA not applicable as not identified to species level.
*Status: LC = Least Concern (IUCN).

None of the identified fauna species recorded in the study area are listed under the IUCN or are listed as of conservation status under the Papua New Guinea *Fauna Act*. Evidence of other fauna in the study area included the presence of birds nests, skeletons, a tree roots burrow believed to have been caused by a marsupial (Plate 8.31), termite nests, and scats, although these are believed to belong to a feral cat.

Plate 8.25 – Papuan Frogmouths (*Podargus papuensis*)



Plate 8.26 – White-Bellied Cuckoo-Shrike (*Coracina papuensis*)



Plate 8.27 – Black Cuckoo-Shrike (*Coracina schisticeps*)



Plate 8.28 – Green Tree Frog (*Ranoidea caerulea*)



Plate 8.29 – Snake-Eyed Skink Lizard (*Cryptoblepharus yulensis*)



Plate 8.30 – Gecko (*Nactus sp.*)



Plate 8.31 – Tree Roots Burrow



8.7.3.2 Conservation Listed Species

Species of conservation significance considered in this report include IUCN listed species (including Critically Endangered, Endangered, Vulnerable, Near Threatened and Data Deficient),

nationally Protected species (P) and trade restricted (R) species. They are collectively termed conservation listed species. Of highest conservation concern are IUCN Threatened (i.e., Critically Endangered, Endangered and Vulnerable) species that may occur locally, and these are presented in Table 8.23. A total of 14 conservation listed species may potentially occur in the study area, based on previous assessments of fauna occurring, or potentially occurring, within savanna vegetation for the PNG LNG Project at nearby Caution Bay. The 2020 field survey did not encounter any flora or fauna species of listed conservation status.

Table 8.23 – Conservation Listed Species Potentially Occurring within the Study Area

Scientific Name	English Name	Status*
Non-Volant Mammals		
Planigale novaeguineae	New Guinean planigale	LC, R
Bats		
Pteropus hypomelanus	Variable flying-fox	NT
Saccolaimus mixtus	Troughton's sheathtail bat	DD
Nyctophilus timoriensis	Greater long-eared bat	DD
Pharotis imogene	New Guinea big-eared bat	CR
Otomops papuensis	Big-eared mastiff-bat	DD
Reptiles		
Pseudechis papuanus	Papuan black snake	DD
Morelia amethistina	Amethystine python	LC, R
Birds		
Circus approximans	Swamp harrier	R
Falco cenchroides	Australian kestrel	LC, R
Falco severus	Oriental hobby	LC, R
Falco longipennis	Australian hobby	LC, R
Falco peregrinus	Peregrine falcon	LC, R
Paradisaea raggiana	Raggiana Bird-of-paradise	LC, P

Source: Woxvold, 2018.
*Status: CR = Critically Endangered (IUCN); NT = Near Threatened (IUCN); DD = Data Deficient (IUCN); LC – Least Concern (IUCN); P = species Protected under Papua New Guinea law; R – trade restricted species under Papua New Guinea Law.

8.7.4 Invasive Alien Species

Invasive alien species include any taxa that are introduced beyond their original geographic range. They include species not native to New Guinea, and species originally present only in other parts of New Guinea.

8.7.4.1 Weeds

Twelve weed species were identified within the study area. Weed species are common throughout the study area and are intermixed with native species. All recorded weed species are listed in Table 8.24, and a selection shown in Plates 8.32 to 8.34.

Table 8.24 – Weed Species Recorded in the Study Area

Scientific Name	English Name
Passiflora foetida	Stinking passionflower
Cycas circinalis	Queen sago
Stachytarpheta jamaicensis	Light blue stinkweed
Celosia argentea	Silver cock's comb
Crotalaria zanzibarica	Zanzibar rattlepod
Euphorbia geniculata	Fireplant
Boerhavia erecta	Erect spiderling
Tridax procumbens	Coat buttons
Clitoria ternatea	Butterfly pea
Calopogonium mucunoides	Caloponium
Ipomoea triloba	Little bell
Euphorbia hirta	Asthma plant

Plate 8.32 – *Passiflora foetida* (Stinking Passionflower)



Plate 8.33 – *Cycas circinalis* (Queen Sago)



Plate 8.34 – *Ipomoea triloba* (Little Bell)



8.7.4.2 Invasive Fauna

One invasive fauna species was directly recorded during the 2020 survey, a cane toad shown in Plate 8.35. However, it is likely that feral cats, and introduced mice and rats also occur within the

area, on the basis of previous information from the environmental assessment of AES Ravavu Industrial Park, scats detected during the flora and fauna survey, and introduced species recorded within savanna at Caution Bay.

Plate 8.35 – Cane Toad (*Bufo marinus*)



8.7.5 Protected Areas, Priority Ecosystems and Focal Sites

There are no protected areas, conservation areas, wildlife management areas or recognised areas of international, national, provincial or regional conservation value within the study area. Similarly, areas or features that would be regarded as priority ecosystems or focal sites such as caves, lakes and swamps that might provide a natural habitat for fauna, were not identified within the study area. There is, however, the thin strip of mangroves along the shoreline adjacent to the AES Industrial Park, although this occurs outside the study area.

8.7.6 Condition and Conservation Value of the Study Area

The IWMF site and study area has undergone significant disturbance from approved land clearing and construction activities. The study area has also been subject to continuous disturbances from fires, hunting and firewood collection, with the fauna of the study area common in most parts of Port Moresby with similar vegetation and climatic conditions. As such, the remnant vegetation and habitat within the Project footprint of disturbance of the study area is not considered to be of significant conservation value.

8.8 Aquatic Biodiversity

8.8.1 Regional Context

Polhemus et al. (2004) categorised the Island of Papua New Guinea into 40 areas of freshwater endemism from 6 broad regions based on the distribution of freshwater fish, crayfish and aquatic insects. The Project is located in Region 6 (Papuan Peninsula) Area 30 (The South Papuan Peninsula Foreland). This area is known to support endemic Zygoptera (damselflies) and Naucoridae (creeping water bugs). It corresponds to the southern sector of the formerly separate East Papua Composite Terrane, which was sutured to the main body of New Guinea in the Oligocene.

Further to the work undertaken by Polhemus et al. (2004) the global freshwater systems were divided into distinct ecoregions by Abell et al. (2008) considering the distributions and compositions of freshwater fish species. The Project area falls into ecoregion 816 (Papuan Peninsula), this ecoregion encompasses the Papuan Peninsula and offshore islands (including the Trobriand Islands, D'Entrecasteaux Islands, and Louisiade Archipelago) off the southeast coast of New Guinea, the peninsula also separates the Solomon and Coral seas.

Ecoregion 816 includes tropical and subtropical coastal rivers with the main drainages from the region flowing into the Solomon Sea, Coral Sea and the Pacific Ocean. The key rivers associated with the ecoregion include the Musa, Mambare, Waria, Tauri, Alabule and Vanapa. Freshwater biotas in the ecoregion have a high degree of endemism clustered around tectonic provinces.

Ecoregion 816 contains nearly 20 endemic fish species from the families Eleotridae (sleepers), Zenarchopteridae (needlefishes), Pseudomugilidae (blue eyes), Atherinidae (silversides), Ambassidae (Asiatic glassfishes), Melanotaeniidae (rainbowfishes) (Hales, 2019).

8.8.2 Aquatic Habitats

Aquatic habitat was characterised at four sampling locations within four distinct drainage channels downslope of the IWMF during the ERIAS field survey in July 2020 (see Figure 8.1). While there was no water present at any of these sites during the survey, aquatic habitats were characterised considering the observed physical and biological characteristics of the sampling sites. Aquatic biodiversity survey sites encompassed two habitat types:

- Low gradient drainage channels.
- Moderate gradient drainage channels.

These habitats have been assumed due to the slopes and gradients visible within the dried-out drainage channels. When water is present the flow rate, depth and turbidity of the water will change according to the habitat type. Table 8.25 outlines the identified aquatic habitat characteristics at each site. Generally, the aquatic habitat types did not vary greatly between sites, reflecting the similar topographic positions. Photos of the aquatic habitat and further description of the hydrological characteristics of the sampling sites is provided in Section 8.3.3. More detail on riparian vegetation (including species recorded) is provided in Section 8.7.

Table 8.25 – Aquatic Habitat Characteristics Per Site

Site	Gradient	Channel Width Bank-to-Bank (m)	Substrate and Channel Type	Vegetation
TWM1	Moderate	6	• Black brown sediment with fallen foliage • Predominantly fine to medium sand substrate with scattered boulders • Ephemeral drainage channel	• No aquatic flora species • High vegetation cover • Terrestrial vegetation growing within the drainage channel • Savanna riparian vegetation with grasses and shrubs alongside the channel and small standing trees
TWM2	Moderate	3	• Red/brown sediment mostly disturbed by construction • Predominantly cobbles, gravel and coarse sediment substrate (including construction waste) with scattered boulders • Ephemeral drainage channel	• Steep eroding bank with scattered flora • ~95% overgrown dried channel • Grassy banks (weeds) and surrounding eucalypt tree species
TWM3	Low	4	• Predominantly coarse gravel and cobble substrate • Slightly elevated eroded slope • Ephemeral drainage channel	• Swamp morning glory (*Ipomea aquatica*), introduced food plant • High vegetation cover • Vegetated bank with savanna forest eucalypts and weeds, with some terrestrial weeds and vines within the drainage channel
TWM4	Low	13	• Sand, gravel and fine sediment (potential construction origin) substrate with quartz stones surrounding the channel • Quartz are sporadically exposed • Drainage channel	• Channel is overgrown with weeds, but no vines are present • Evidence of recent bush burning • ~95% overgrown dried channel • High vegetation cover • Riparian vegetation dominated by eucalypt trees with weeds along channel margins and both weeds and grasses within the in-stream channel

8.8.3 Aquatic Flora and Fauna

Due to the lack of water, aquatic flora and fauna were not observed at any of the sampling sites during the ERIAS field survey. Swamp morning glory (*Ipomea aquatica*) was observed at site TWM3, an introduced semi-aquatic food plant. Some reptiles were observed at the aquatic survey sites and are described in Section 8.7. Given the lack of permanent water, the drainage channels investigated do not provide permanent habitat for aquatic flora and fauna species; however, during ephemeral flows following sufficient rainfall, these drainage channels would provide

temporary habitat for aquatic fauna such as macroinvertebrates, fishes and crustaceans. Based on the observed habitat characteristics of the drainage channels they area unlikely to support a high diversity or abundance of freshwater biota. Table 8.26 and Table 8.27 provide a list of freshwater fishes and endemic macroinvertebrates with potential to occur in the drainage channels of the study area (during periods of flow) based on a review of Allen (1991), Polhemus et al. (2004) and Abell et al. (2008) and considering the availability of suitable habitat and the known distribution of these species. The potential occurrence of majority (if not all) of these species would be limited to the main drainage channel located to the west of the IWMF (i.e., sites TWM3 and TWM4), which have some potential connectivity to upstream catchments where these species may occur. The headwaters of the smaller drainage channels (i.e., TWM1 and TWM2) originate close to the IWMF, and have no connectivity to upstream catchments and permanent freshwater bodies and so are highly unlikely to provide habitat for the species listed in Table 8.26, but could potentially provide habitat for the species listed in Table 8.27.

Table 8.26 – Freshwater Fishes with Potential to Occur in the Drainage Channels of the Survey Area

Species	Likelihood of Occurrence	IUCN Conservation Status*	Distribution and Habitat (Allen, 1991)
Papuan rainbow fish (*Melanotaenia papuae*)	Possible	LC	The full extent of geographic range remains undetermined. Endemic to the South Papuan Peninsula Foreland. Most collections have been within numerous streams within 35 km of Port Moresby. The habitat consists mainly of small rainforest creeks
Goldie river rainbow fish (*Melanotaenia goldiei*)	Possible	LC	Broadly distributed throughout the south of the Central Dividing Range, and inhabits swamps, backwaters, tributary streams and larger rivers
Parkinson's rainbow fish (*Melanotaenia parkinsoni*)	Unlikely	LC	Widespread along the southern coast of eastern Papua New Guinea, endemic to the South Papuan Peninsula Foreland. Primary habitat is rainforest streams in lowland areas. Known from only a few scattered sites
Four-spined glass perchlet (*Tentracentrum apogonoides*)	Possible	LC	Tropical freshwater species endemic to the South Papuan Peninsula Foreland, distributed around Port Moresby within the Brown, Goldie, Laloki and Kemp Welsh rivers. Also common in the Sirinumu Reservoir (Laloki River)
Barramundi (*Lates calcarifer*)	Possible	LC	Widely spread throughout the southerly flowing rivers draining into the Gulf of Papua
Threespot grunter (*Hephaestus trimaculatus*)	Possible	NE	It is endemic to the South Papuan Peninsula Foreland, where it is found only in the vicinity of Port Moresby from the Laloki River and its tributaries including the Brown and Goldie Rivers. It is found in rock pools in lowland streams
Broad snout catfish (*Arius graeffei*)	Likely	LC	Widespread throughout Southern New Guinea

Species	Likelihood of Occurrence	IUCN Conservation Status*	Distribution and Habitat (Allen, 1991)
Short finned tandan (*Neosilurus brevidorsalis*)	Likely	LC	Widespread in Southern Papua New Guinea
Narrow-fronted tandan (*Neosilurus ater*)	Unlikely	NE	Widespread in central-southern PNG, the only sighting on the eastern side of the gulf of Papua was around 75km northwest of Port Moresby
Goldie river mullet (*Cestraeus goldiei*)	Likely	LC	Widespread throughout PNG sighted often around Port Moresby. Can occur in freshwater and brackish water and fast-flowing streams
Moresby morgurnda (*Morgurnda pulchra*)	Possible	NE	Laloki River system near Port Moresby, widespread in eastern Papua New Guinea. It occurs in lowland swamps and streams
Roman nose goby (*Awaous sp*)	Possible	LC	Found in southern New Guinea inland streams near Port Moresby. Occurs in rivers, streams and rainforest tributaries
Barcheek goby (*Stenogobius sp*)	Possible	LC	An undescribed species found on coastal plains of southern PNG. Habitat consists of turbid or clean rivers usually in backwaters or rocky pools

*LC = Least Concern, NE = Not Evaluated, VU = Vulnerable, CR = Critically Endangered.

Table 8.27 – Endemic Freshwater Macroinvertebrates with Potential to Occur in the Drainage Channels of the Survey Area

Species	Likelihood of Occurrence	IUCN Conservation Status*	Description
Water bug (*Aptinocoris fenneri*)	Likely to Occur	NE	Endemic species to freshwater inactive waters on the Papuan Peninsula
Water bug (*Aptinocoris sogeri*)	Likely	NE	Endemic species found around freshwater rivers, ponds and drainages
Water bug (*Cavocoris ismayi*)	Possible	NE	Endemic species to freshwater inactive waters on the Papuan Peninsula
Water strider (*Ciliometra femorata*)	Possible	NE	Endemic species to freshwater still and stagnant waters on the Papuan Peninsula
Water strider (*Ptilmoera breddini*)	Possible	NE	Endemic species to freshwater inactive waters on the Papuan Peninsula

Source: Polhemus (2004).
* NE = Not Evaluated.

8.8.4 Sensitive Species, Ecosystems and Habitat Features

8.8.4.1 Sensitive Species

Sensitive aquatic species are considered to be those listed as threatened under the IUCN Red List and species considered to be endemic or to have restricted ranges. Endemic species are those that have equal to or greater than 95% of its global range inside the country or region being considered. For the purpose of this assessment, the region is considered to be the South Papuan Peninsula Foreland, Area 30 as defined by Polhemus (2004), where the Project is located. Restricted-range aquatic species are considered to be those with a global range less than or equal to a 500 km linear geographic span.

The geography of the South Papuan Peninsula Foreland facilitates many river systems and water bodies (as outlined in Section 8.8.1). In turn, these habitats support a high number of endemic and or restricted-range species. Endemic species occur in a specific area (such as a catchment, region or country) and nowhere else. As a result, endemic species typically have reduced ranges, which can make them more vulnerable to extinction than a species with a larger distribution. The IUCN lists geographic range as a key criterion in measuring the threat of extinction.

While Ecoregion 816 contains nearly 20 endemics and the South Papuan Peninsula Foreland is defined by the occurrence of a number of endemic true bugs (Hemiptera) and fish from the families asiatic glassfishes (Ambassidae), rainbowfishes (Melanotaeniidae) and grunters (Terapontidae), only four fish species (Papuan rainbow fish, Parkinson's rainbow fish, four-spined glass perchlet and threespot grunter) and the five insect species listed in Table 8.27 are considered to have the potential to occur in the drainage channels surveyed.

No species identified with potential to occur in the drainage channels surveyed are listed as threatened on the IUCN Red List, with all species either classified as Least Concern or Not Evaluated. It should however be noted that three species of fish (narrow-fronted tandan, threespot grunter and Moresby morgurnda) and all five insect species listed in Table 8.27 have not been evaluated by the IUCN and so the conservation status of these species is unknown.

8.8.4.2 Sensitive Ecosystems and Habitat Features

The aquatic habitats surveyed were well represented in the study area and are not considered to be sensitive ecosystems or contain sensitive habitat features. While the drainage channels have the potential to support some endemic or restricted range species, due to the ephemeral nature of the drainage channels they do not provide permanent habitat for such species.

8.8.5 Introduced and Invasive Species

Papua New Guinea exhibits relatively moderate incidents of invasive freshwater fish species; however, in more recent years the problem is becoming more extensive (Polhemus et al., 2004). If they become established, introduced fish are a problem due to their negative impact on native species, either by competing for space and limited food resources, or by feeding on native species, including their eggs and fry.

Mosquitofish (*Gambusia affinis*) were introduced in Papua New Guinea to help control mosquitoes as they feed on their aquatic larvae and pupae, although it has had little effect (Allen, 1991). This fish is found in the Sepik and Ramu river systems, Lake Kutubu and around major

population centres such as Port Moresby, Lae and Madang and therefore has the potential to occur in the drainage channels surveyed.

Guppies (*Poecilia reticulate*) were introduced to the Port Moresby district around 1967, potentnially for mosquito control. It is now very common in part of the Goldie River and its smaller tributaries and in streams around Port Moresby it can be the only fish present (Allen, 1991). This fish is likely to occur in the drainage channels surveyed.

Snakeskin gouramis (*Trichogaster pectoralis*) were introduced into the Western Highlands, Central and Gulf districts in 1957 (Allen, 1991). It is established on the southern lowland floodplain systems and certain areas around Port Moresby (Werry, 1998). This fish has the potential to occur in the drainage channels surveyed.

The specific impacts of such invasive species on aquatic organism's endemic to the area have for the most part not been determined. Similarly, little work has been undertaken regarding the identity or spread of other invasive freshwater animal species, particularly invertebrates that could have a negative effect on species endemic to the Project area (Polhemus et al., 2004).

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9. Socio-economic Setting

9.1 Socio-economic Setting

9.1.1 Study Area

The socio-economic study area was defined considering the Project's activities and facilities (both current and planned) and the predictable direct, indirect and cumulative impacts of these activities on the social and cultural environment. The socio-economic study area sets the context for the area in which desktop review, stakeholder engagement and field studies were undertaken.

Specifically, the socio-economic study area considers:

- The proposed expansion footprint (5.5 ha to the southeast and 2.4 ha to the southwest of the existing site boundaries) with an additional 500 m buffer from the boundary.
- Ongoing site operational activities and intermittent activities such as construction works.
- Surface water catchments and the potential for runoff to extend beyond the facility boundaries and 500 m buffer.
- The location of sensitive receptors, including neighbouring industries and Roku Village, located approximately 500 m to the southeast of the existing facility.
- Community land use and traditional resource use activities surrounding the IWMF.
- Transportation routes (i.e., roads, shipping routes, airports used by the workforce).
- The location of local infrastructure (e.g., schools, health centres and markets).
- Organisations or communities that could be indirectly affected by the proposal (e.g., landowners, communities who use/access surrounding natural resources, supply chains, Project workforce and government departments).

Given the localised expansion of the IWMF and distance to local communities, the socio-economic field study area (i.e., the area where primary data would be collected from the community) was constrained to Roku. Initial screening in the EIR and in developing the socio-economic study execution plan indicated there would be no predictable direct impacts to these communities as a result of the Project.

9.1.2 Socio-economic Studies

The key objective of the socio-economic baseline characterisation (baseline study or study) is to identify and summarise the social values in the study area in order that those values are recognised and appropriately considered in the development of the Project. Specifically, these values include:

- Social and cultural anthropology.

- Social services and infrastructure (i.e., health, education, governance, transport, communication) that exist and communities' use of and access to them.
- Land and natural resources used by communities.
- Public amenity (i.e., ambient noise, air quality, visual amenity etc).

The socio-economic studies were designed to address the requirements of PNG's EIS guidelines (DEC, 2004) and the approach outlined within the EIR. No previous socio-economic studies have been conducted by TWM in the study area.

The socio-economic conditions in the study area are characterised using a combination of a detailed bibliographic review of available information and data gathered during interviews and field surveys undertaken between the 15 and 22 July 2020. The development of interview questions considered the need for both qualitative and quantitative data collection, and gaps identified during the bibliographic review.

Interviews were conducted with the local community (with Roku Village leaders and the Women's Fellowship), with business in the neighbouring industrial facility and with government agency representatives. Information on community use of natural resources was supplemented through the environmental field surveys (see Section 8.1).

The bibliographic review considers information relevant to Papua New Guinea and Central Province in particular, and includes census data, resources describing cultural heritage, language and ethnicity, national health and education data, known development plans and the results of previous studies and surveys, including Appendix 9 and Goldman (2009).

The study methods used for each socio-economic discipline area are summarised in Table 9.1. The sections below further describe the approach and methods used for each of these disciplines.

Table 9.1 – Discipline and Study Methods

Discipline	Methods	Relevant Section
History, language and ethnic groups	Desktop review, Roku community and business interviews	9.2
Demographics	Desktop review, Roku community and government interviews	9.3
Infrastructure and services	Desktop review, Roku community and government interviews	9.4
Governance and leadership	Desktop review, Roku community and business interviews	9.5
Employment and employment	Desktop review, Roku community and business interviews	9.6
Land and natural resource use	Desktop review, Roku community interviews, terrestrial biodiversity field surveys	9.7
Transport	Business interviews, data collected by security at the entrance to TWMs facility, data provided by TWM	9.8

Discipline	Methods	Relevant Section
Law and Order	Desktop review, Roku community and business interviews	9.9
Cultural heritage and archaeology	Desktop review, previous archaeology survey (Appendix 9), Roku community interviews	9.10

Prior to the commencement of the field surveys and interviews, a pre-awareness engagement flyer (see Figure 6.1) was distributed to business stakeholders and Roku village community leaders. The flyer described the proposal, what the EIS process involves, how information would be collected via the upcoming engagement activities and provided contact details for any queries or concerns. The flyer was provided in English and Tok Pisin. See Chapter 6 for further information on pre-awareness engagement.

9.1.2.1 Roku Village Community Interviews

ERIAS and TWM personnel met with the Ohobiduduare Holdings Limited Board on 18 July 2020, which incorporates representatives from the Roku village clan leaders and the village Councillor. The objective of the meeting was two-fold; to help build a profile of village life in order to understand how the Project could impact on the local community, and as a stakeholder engagement activity, to raise awareness of the Project and identify any issues or concerns. The meeting took the form of a semi-structured/informal interview and collected information on:

- Existing economic activities and employment.
- Local governance and administration.
- How and where local community members use or access infrastructure and social services.
- How and where local community members use or access natural resources (e.g., fishing, hunting and gathering of wild plants).
- Existing issues with law and order, security, health and safety.
- Languages spoken, practiced religions and important religious/cultural features in the local area.
- Community concerns with the proposed expansion of TWM operations.

The meeting was attended by two ERIAS interviewers and two TWM representatives. ERIAS personnel took notes which were collated to provide a summary of the discussion. Meeting attendee names were recorded, and photos were taken as a further record.

To ensure that women's views were captured, and that Roku women had the opportunity to hear about the Project, ERIAS and TWM personnel held a community meeting with the Roku Women's Fellowship on 22 July 2020 in Roku Village, which approximately 40 women attended. The same questions were asked as in the Village leaders' interview, with particular focus given to health and

education, law and order and services (such as drinking water and sanitation). Women were also given the opportunity to comment on the IWMF expansion proposal.

ERIAS personnel visited Roku village twice during the field survey; once to engage with the Roku Women's Fellowship, and once as part of the terrestrial biodiversity field survey. During these visits, ERIAS personnel took photos of key infrastructure, housing and transport and natural resources being used or harvested to support the description of community life discussed in the interviews.

9.1.2.2 Business Interviews

Similar to community interviews, business interviews had the dual objective of gathering information to support an assessment of potential Project impacts on these businesses, and to provide a Project update and seek feedback.

Meetings were extended to eight businesses within the AES Industrial Park. These are Puma Energy (Puma) Oil Refinery, Rhodes PNG and AGL Builders (Rhodes/AGL), Pagini Group (Pagini), Agility, Oilmin Holdings Ltd (Oilmin), AES, Longfa Cement and Islands Petroleum. Six meetings were held with representatives from all businesses excepting Longfa Cement and Islands Petroleum, and took between 20 minutes and 1.5 hours, depending on the interest and availability of the stakeholder.

The meetings took the form of a semi-structured/informal interview and collected information on:

- Existing and planned use of shared infrastructure (e.g., roads and potable water).
- Existing and planned traffic and transport/movement of goods.
- Feedback on how the Project could impact their operations.

Results of the meetings with businesses are recorded in Chapter 6.

Most meetings were attended by two ERIAS interviewers and a TWM representative. ERIAS personnel took notes which were collated to provide a summary of the discussion. Meeting attendees were recorded and where permitted, photos were taken as a further record.

9.1.2.3 Government Interviews

Meetings with representatives from government agencies were conducted with the dual purpose of gaining an understanding of the local services, infrastructure, administration and plans for future development relevant to the study area and providing an opportunity for government agencies to comment on the proposal. Meetings were held with representatives from CEPA, DOT, DPLLG, DLPP, NMAG and Central Province Administration between 7-17 July 2020, and were supported by the pre-awareness flyer and a Project outline, which were used by the ERIAS representative to describe the Project activities and reason for engagement.

The meetings took the form of a semi-structured/informal interview and collected information on:

- Economic and social services and infrastructure in the surrounding area.
- Development plans/priorities for the surrounding area or Province.

- Local governance and administration.
- Feedback on the proposed expansion of TWM operations.
- Archaeology and cultural heritage.

Results of the meetings with government agencies are recorded in Chapter 6.

Meetings were attended by an ERIAS representative who took notes which provide a summary of the discussions.

9.2 Socio-cultural Context

9.2.1 History, Language and Ethnic Groups

In Papua New Guinea, the language that people speak defines where people came from, their ancestors and ancestral migration history (from the land on which they originated to the land they occupy in the present). As a result, it defines their cultural values, where they live, with whom they communicate, trade and marry, and in many cases, the behavioural and social norms they are expected to observe.

There are over 850 known languages in Papua New Guinea, although 12 are classified as extinct (Lewis, Simons & Fennig, 2016). PNG is the most linguistically diverse area in the world and 89% of the languages are spoken by 10,000 people or less. English, Tok Pisin (Pidgin), and Hiri Motu (the lingua franca of the Papuan region) are the official languages.

Within the study area, the people generally originate from the Koirian language family; the primary language is Koita (or Koitabu), one of six Koirian languages. The Koirian language family consists of two sub-families – Koiaric (Koita, Koiari and Mountain Koiari) and Baraic (Barai, Managalasi, Aomie). The similarities between the Koita and the two other Koiaric languages (Koiari and Mountain Koiari languages) could indicate that the Koiaric sub-family separated from the Baraic sub-family a long time ago, possibly several thousand years (Dutton, 1969).

The Koita were known to generally inhabit the Papuan coastal area around Port Moresby, living in their own separate maritime villages or as a minority in Motu villages. The following observations were made by Dutton (1969) with regard to the Koita's interactions with the neighbouring Motu:

> For the most part Koita villagers cannot be distinguished from Motu, except linguistically. In former times the Koita maintained their identity in dress (particularly with the chignon hairstyle), language, and occupation. By tradition they are the hunters and gardeners who owned the land, but now those who live near the sea fish and sail. The Koita have also intermarried extensively with the Motu, and most are fluent in that language. Where they inhabit the same villages as the Motu, the Koita have practically forgotten their own language. Yet the Koita as a whole are still very keen to preserve their identity, especially as expressed through language. (Dutton, 1969: 26)

Roku village is considered a mostly Koita village (Dutton, 1969), however time and intermarriage with the Motu people has slowly changed Koita society. In a study undertaken for the ExxonMobil PNG LNG Project in 2008, the following was observed:

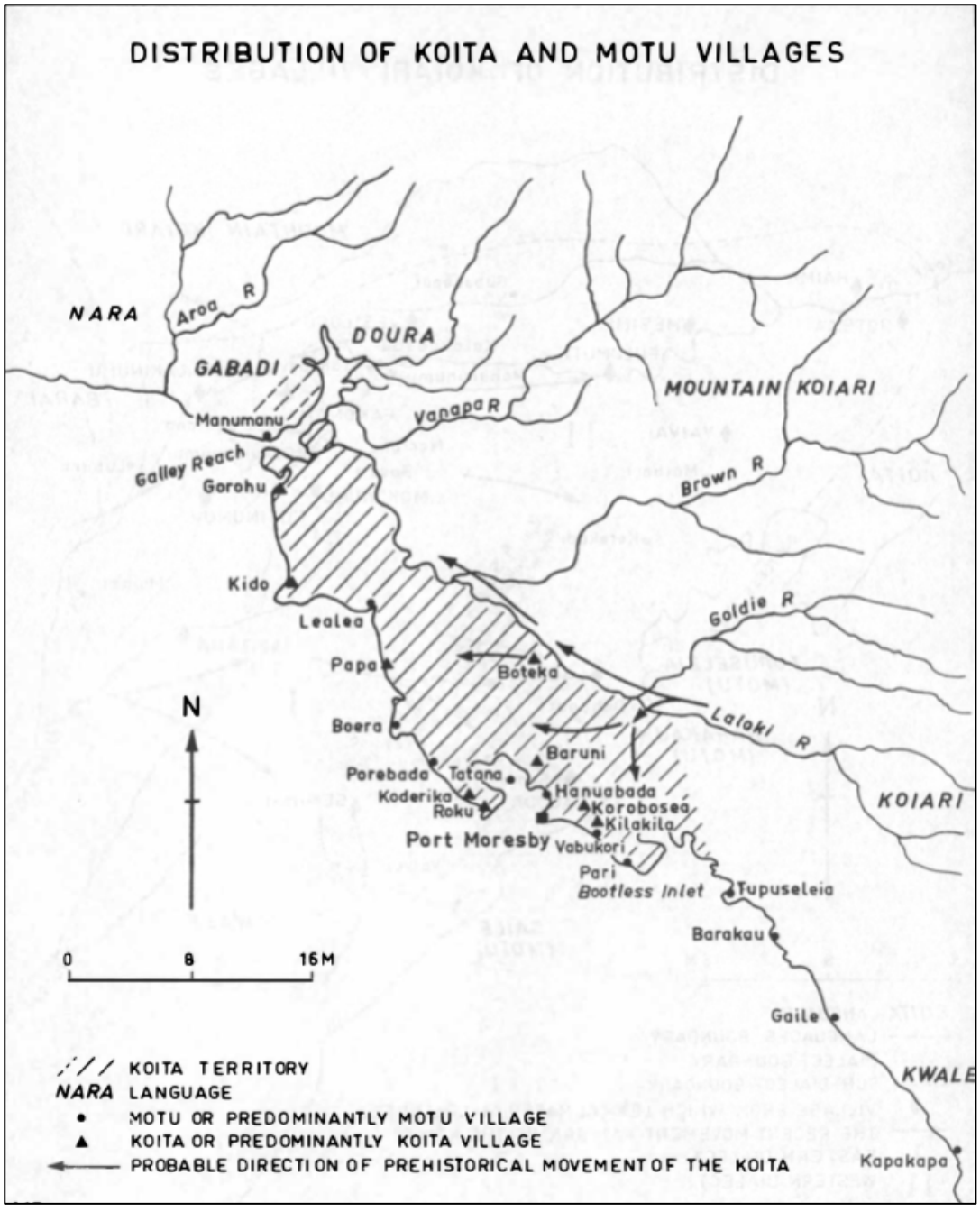
> The Motu-Koita can be said to constitute a 'portmanteau' social group, two distinct languages and cultures, two distinct subsistence ways of life and orientations towards land and territory, that have

converged on the same village space and have formed over the last 200 to 300 years a single social construct.' (Weiner, 2008)

The main language ('tok ples') in Roku village is Koita (Koitabu/Koitabuan). Other languages that are commonly spoken in Roku village include Motu, Pidgin and English.

Figure 9.1 shows the likely direction of movement of the prehistoric Koita people and the distribution of Koita villages along the coastline to the north west and east of Port Moresby.

Figure 9.1 – Origins and Settlements of the Koita People



Source: Dutton, 1969

9.2.2 Land Ownership

Clans and language groups occupy (or have rights to occupy) specific territories. Rights are held by the clan or by sub-clans (that are related extended families), which are protected through agreements with neighbouring clans. The rights of landowning groups are based on mutually agreed-upon histories that describe how clans came into being and occupied the land. The majority (97%) of land in Papua New Guinea is under customary ownership. Generalisations about customary land-owning practices are difficult given widely varying traditions and practices amongst Papua New Guinean clans; the exact nature of customary titles vary from one clan or culture to another.

Customary land cannot be purchased or sold, however, it can be alienated by the State and leased to other users. In these cases, customary landholders legally lose interest in the land. Less than 3% of land in Papua New Guinea has been alienated from customary ownership and is in private hands (held under a 99-year State lease) or held by the State.

There are three main clans in Roku village – Kuriu, Gaibadu and Tanomotu. Other clans represented in the village include the Kaino, Rebisi and Mavara. Landowners from the Kuriu clan, represented by the Kuriu Clan Land Group Inc. of Roku Village, were declared the traditional landowners of Napa Napa land in 2016 (Pokiton, 2016). Refer to Section 9.5.3 for further information related to landowner groups and companies in the study area.

Village leaders reported that land rights in and around Roku village are not restricted to particular families, and that clan land is largely communal, allowing any clan member from Roku to fish, hunt, collect plants, building materials or firewood from any location on clan land, while some villagers maintain their own gardens. See Section 9.7 for further discussion relating to land and natural resource use.

9.2.3 Migrants and Settlers

Papua New Guineans are becoming more mobile, seeking livelihood and wage employment opportunities, even in remote areas of the country (Koczberski et al., 2009). Migration within Papua New Guinea is occurring more frequently and in large numbers, and is itself driving urbanisation, as most wage employment is found in large urban centres. However, not all migration is from rural to urban areas (Koczberski et al., 2009); some is between rural areas, as people seek agricultural land or follow the employment opportunities presented through resource and infrastructure projects.

In the study area, village leaders report little, if any, migration to Roku village. For the most part, migrants have come to the village through marriage rather than in search of employment or economic opportunities.

9.3 Demographics

9.3.1 Population

The population of Papua New Guinea was estimated to be 8.7 million in 2019 (World Bank, 2020); the most recent national census (2011) recorded a total population of 7.3 million.

Central Province is the third largest province of the southern region after NCD and Milne Bay Province. In 2011 the population of Central Province was recorded as 269,135, with 57.1% of the population aged between 15 and 64 years, 40% aged between 0 and 14 years and 2.9% aged 65 years and above (NSO, 2015).

In 2011, the population of Kairuku-Hiri District was recorded as 121,586 (52.8% males and 47.2% females), representing the largest proportion (45.1%) of the total population of Central Province. The sex ratio (number of males per 100 females) at the provincial and district level was 112 (2011), compared to 108 nationally (NSO, 2013).

Village leaders estimate the current population of Roku village to be between 2,000 and 2,500 people with approximately 500 houses. The 2011 census recorded a population of 1,367, which indicates an approximate growth of approximately 47% over 10 years. The sex ratio in the village was 120 males per 100 females in 2011 (NSO, 2014).

Population counts (2011 census) by relevant district, LLG and administrative ward are summarised in Table 9.2

Table 9.2 – Key Demographic Data by Province, District, LLG and Ward (2011)

	Province	District	LLG	Ward
	Central	*Kairuku-Hiri*	*Hiri Rural*	*Roku Village*
Area (km^2)	29,998 km^2	10,215 km^2	1,637 km^2	NA
Total Population	269,756	121,586	47,094	1,367*
Total Males	142,231 (53%)	64,150 (53%)	24,960 (53%)	747 (55%)
Total Females	127,525 (47%)	57,436 (47%)	22,134 (47%)	620 (45%)
Sex ratio (males per 100 females)	112	112	113	120
Population density (per km^2)	9	12	29	NA
Number of households	41,309	18,147	5,520	116*
Average household size	6.5	6.7	8.5	11.8

Source: NSO, (2013).
NA: Formal data not available on Ward delineation and population density in 2011 census. However, satellite imagery calculates that Roku village occupies an area of approximately 0.17 km^2.
*Estimates from TWM suggest the current population of Roku village is approximately 2,000 people, with 500 houses. Based on this data, the current average household size is 4 people.

9.3.2 Religion

Religion plays an important role in Papua New Guinea alongside indigenous/traditional cultural practices. The dominant religion is Christianity (95.6% of the population), followed by indigenous beliefs (3.3%) (Scroope, 2016). In Central Province, 40% of the population report that the United Church of Papua New Guinea as the main religion. In Roku village, the main religion is reported to be United Church of Papua New Guinea.

9.3.3 Education Attainment and Literacy

Participation and access rates vary widely across Papua New Guinea; however, in general, secondary school attendance is lower across the country than elementary and primary school attendance. The 2011 census recorded national school attendance at only 35% (of the population aged between 5-29 years). Central Province recorded similar attendance, with 35.5% of males and 33.3% of females (aged between 5-29 years) attending school; however, only 4.8% had completed Grade 12 and 6.5% reported having a formal qualification.

Retention of secondary school cohorts (Grade 9 to Grade 12) was 39% (2013) nationally. Central Province's secondary school retention rate was just below the national average (35%), with NCD the highest performing province (71%). A comparison of data between 2000 and 2013 showed an 84% increase in secondary school enrolments in Central Province and a 26% reduction in vocational education enrolments (DoE, 2015).

In 2011, national literacy levels were reported as approximately 67.6% (population aged 10 years and over) (NSO, 2015). Literacy is more widespread in Central Province, with 80.1% of the population aged 10 years and above (82.5% males and 77.4% females) reporting the ability to read and write.

According to interviews conducted with village leaders and residents, approximately 80% of children in Roku village between 6 and 13 years of age attend school. There are 12 students attending Redscar High School (near Porebada) and 5 students attending Badihagwa Secondary Technical School (in Port Moresby). One individual reportedly attends the University of Papua New Guinea and lives in Port Moresby in order to attend classes.

Refer to Section 9.4.5 for a description of education infrastructure in the study area.

9.3.4 Health Status

In 2017, Papua New Guinea was ranked 153 on the Human Development Index, making it a country with a 'low human development' index and one of the least developed countries in the Western Pacific (UNDP, 2018). Limited health infrastructure (as described in Section 9.4) remains an issue and is considered a major contributing factor to low human development in the country, as evidenced by the high burden of disease such as tuberculosis (TB), malaria and enteric (diarrhoeal) diseases. More recently, Papua New Guinea has made some progress towards increasing life expectancy and reducing child and maternal mortality rates, in line with the United Nation's Sustainable Development Goal.

Risk factors that account for the most disease burden in Papua New Guinea are malnutrition and dietary risks, high fasting plasma glucose, tobacco smoking, and household air pollution from solid fuels (e.g., many households across Papua New Guinea still rely on firewood for cooking). The leading causes of mortality (death) in 2017 were ischemic heart disease, stroke, chronic obstructive pulmonary disease and lower respiratory infection; road injuries have fallen by 20.4% since 2007 and the prevalence of human immunodeficiency virus (HIV) has dropped by 43.5% (IHME, 2020).

Health sector performance indicators for Kairuku-Hiri District are summarised in Table 9.3 based on the National Department of Health 2018 Sector Performance Annual Review report (NDoH,

2018). National equivalent statistics are provided for comparison. At the time of writing, no official data was available for Hiri Rural LLG nor for Roku village, however the health status of the village is likely to be similar to that of the wider District. Women in Roku village report that TB (see Section 9.3.4.1) and malaria (the exact incidence is unknown) are present in the village. In 2019, a further four adults (three men and one woman) died of unknown causes.

Table 9.3 – Summary of Health Sector Performance Indicators, 2018

Performance Indicator	Papua New Guinea	Kairuku-Hiri District
Outpatient visits (per person/per year)	1.3	1.0
Percentage of women giving birth in a health facility	40%	26%
Antenatal care (% of pregnant women attending antenatal care check-up)	54%	49%
Family planning (couple years protection provided per 1,000 women aged 15-44 years)	81	29
Malnutrition in children under 5	22.6%	25.9%
Measles vaccine (under 5s)	37%	32%
Outreach clinics (No. of clinics per 1,000 children)	29	22
Pneumonia deaths (% of under 5s)	2%	0.7%

Source: NDoH, 2018

9.3.4.1 Key Communicable Diseases

Tuberculosis

Papua New Guinea is considered one of the high burden countries for TB and multi-drug resistant-TB (MDR-TB). The estimated total TB incidence in Papua New Guinea is 432 per 100,000 population, the burden of MDR-TB is 23 (per 100,000 population) (WHO, 2020). The incidence of TB and MDR-TB in Kairuku-Hiri District is not clear, however reports from the Catholic Health Services working in Central Province reported an increase in MDR-TB in the District as a result of limited access to medical treatment (EM TV, 2015).

The official infection rate for TB/MDR-TB in the study area is not known; however, women in Roku village report that TB is present in the village, with three young women dying from it in the first half of 2020 and ten people dying from it in 2019 (one child, four women, five men).

COVID-19

At the time of writing, Papua New Guinea has recorded 401 cases of COVID-19 (4 deaths and 232 recovered), with most cases occurring from mid-July 2020 (Worldometers, 2020). Despite the spike in cases, Papua New Guinea has a relatively low number of recorded cases; this could be due to delayed access to testing in more rural areas and/or to the limited testing occurring in more rural parts of the country and the limited access to health infrastructure outside of major urban centres. Certainly, the Papua New Guinea health system has neither the capacity nor the resources to deal with a large-scale outbreak of the virus (NDoH, 2020) and significant reliance is being placed on aid donor country support.

The infection rate for COVID-19 in the study area is not known, however, recent spikes in Port Moresby during August 2020 have been recorded.

HIV and Other STIs

Sexually transmitted infections (STIs), which includes HIV, syphilis, gonorrhoea and chlamydia, carry a high burden, particularly amongst female sex workers in Papua New Guinea.

Of the total population, approximately 45,000 are living with HIV (2018) and approximately 65% are on antiretroviral therapy (ART); of those living with HIV, 25,000 are women aged 15 years and over (WHO, 2019). The HIV epidemic in Papua New Guinea appears to be concentrated in highlands provinces and the NCD (Grundy et al., 2019).

The infection rate for common STIs and for HIV is not known for the study area.

9.3.4.2 Key Non-Communicable Diseases

The incidence of non-communicable diseases (NCDs) is rising in Papua New Guinea. Cases of tobacco-related and alcohol-related illness appear to be increasing, along with diabetes and hypertension. Mouth cancer is the most common cancer in PNG and has a largely preventable cause (betel nut chewing and tobacco smoking) (WHO, 2011).

Diet and Nutrition

NCDs are driven primarily by a changing lifestyle, from subsistence foods to a more western-style diet. Changes in income, particularly conversion from subsistence to wage based, can drive increased western-style trade-store product, alcohol, and cigarette consumption.

Under-nutrition is a significant issue in Papua New Guinea, with under-five stunting at 49.5%, which is significantly greater than the developing country average of 25% (GNR, 2020). The prevalence of stunting is higher in rural areas (50%) compared to in urban areas (35%) (ADB, 2015).

In the study area, residents of Roku village are reliant upon store-bought food (from trade stores and table markets) as well as fish; limited subsistence gardening takes place in the village (refer to Section 9.7 for further discussion on fishing and subsistence land use).

9.4 Infrastructure and Services

9.4.1 Energy Sources

PNG Power Ltd provides electricity to most residents of Roku village (approximately 95%) (Plate 9.1). However, residents reported that the mains power current is low, which results in villagers only being able to operate a limited number of appliances or lighting at the same time. Approximately 4% of Roku residents reportedly have generators and 1% use solar power.

Firewood is the main source of fuel for cooking in the village, followed by electricity (which is used to run appliances such as rice cookers) and gas.

Plate 9.1 – Water Tank and Power Lines at Residence in Roku Village



9.4.2 Water and Sanitation

Roku villagers report that since the early 1980s water supply to the village has been affected by low water pressure, such that there is no longer piped water to the village. The development at Motukea is cited as the reason for the drop in pressure and supply to Roku village. Previously, Eda Ranu (National Capital District Water and Sewerage Pty Ltd) supplied piped water to Roku, however, when Eda Ranu commenced supplying water to the Motukea development (circa 1990), this resulted in a drop in water pressure in the village. Roku residents now truck water in from Port Moresby to the village approximately once a week. A 5,000-litre truck costs PGK 300. The water is then sold to individual households and is stored in water tanks (see Plate 9.1) with a gravity feed. Potable water is also brought in by dinghy from Koki market. Anecdotal evidence also suggests that Eda Ranu open the water pipeline to Roku approximately two times per week; water from the pipeline is used to fill up a tank in the village which is then regulated by a female village leader (i.e., people pay her to access water from the tank).

There are three boreholes in the village, although water is reported to be generally unreliable and highly saline, so it is only used for washing clothes, bathing and sewerage.

Most people in Roku village toilet in latrines located over the sea; a few households have a hand-dug pit toilet and only a handful have a toilet within their residence.

9.4.3 Domestic Waste Management

There is no public infrastructure for waste disposal in Roku village. Villagers reportedly dispose of rubbish on the ground or in open pits (where it is typically burnt) or into the sea.

9.4.4 Health Facilities

There used to be a community aid post in Roku village, however it is reportedly no longer functioning and needs to be rebuilt. The nearest functioning health facility is the Porebada Health Sub-Centre (approximately 8.5 km away), however villagers report that they prefer to attend the Papa Health Sub-Centre north of the PNG LNG Plant (approximately 22 km along the road to Lea Lea) (Figure 9.2) as this is reportedly supported by ExxonMobil and is well staffed and well stocked. Both centres operate 8am to 5pm and provide antenatal and family planning services as well as birthing facilities. Emergency cases can be treated for K20. The Papa Health Sub-Centre is staffed by one nurse, one medical doctor and two to three volunteers. Roku village does not have a trained birth attendant, however women report helping each other during childbirth.

The nearest hospitals are Gerehu General Hospital (approximately 18 km away) and the Port Moresby General Hospital (approximately 35 km away).

9.4.5 Education Facilities

In Papua New Guinea, education is delivered via a decentralised service delivery model involving multiple government levels (i.e., national, provincial, district, local) and non-government organisations (NGOs), in particular, faith-based organisations. While, the education system in Papua New Guinea has undergone significant reform since a review of the sector was initiated in 1991, there are still improvements required to address access to adequate infrastructure and teaching materials (particularly in remote parts of the country), retention of staff and students (affordability and other socio-cultural issues affect retention), quality, equity and management (DoE, 2009; DoE, 2016).

As is typical of rural or semi-rural Papua New Guinea, elementary and primary schools are more widely available, however secondary schools are less common. In Roku, education infrastructure includes Roku Elementary School and Roku Primary School (Plate 9.2). There are eight classrooms on the campus, however there is reportedly a shortage of desks for students. The school has four water tanks that are used by the eight classrooms (one tank was provided by the Ward Councillor). There are a further five tanks that service the teachers' houses. The water tanks are refilled by water carts. A sports field is also located adjacent to the school.

The nearest secondary schools are Redscar High School (near Porebada, approximately 7.5 km away by road) and Badihagwa Secondary Technical School (in Port Moresby, approximately 24 km away by road) (Figure 9.2).

INFRASTRUCTURE WITHIN AND ADJACENT TO THE STUDY AREA

Integrated Waste Management Facility | Environmental Impact Statement

FIGURE 9.2



Issue Date: 2020.09.25

Map ID: 01375A_3_GIS018_v0_1

Figure Number: 01375A_3_F09.2_GIS_v1

ERIAS

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DATA SOURCES:
Project data from TWM, 2020.
Base data from OSM & ERIAS, 2020.
Imagery © Google Earth, 2020.

Plate 9.2 – Roku Elementary and Primary School (with Sports Field in Foreground)



9.4.6 Church, Banking and Other Community Infrastructure

In Roku village, there is one church (United Church of Papua New Guinea) with approximately 460 members (Plate 9.3). There is also a public cemetery in the village.

Plate 9.3 – Church (United Church of Papua New Guinea), Roku village



There are no automated teller machines (ATMs) or banking services in Roku. The nearest bank is located in the Motukea port area (Bank of South Pacific Motukea Branch) approximately 10 km

from Roku via the Napa Napa Road. There are ATMs at the Bank of South Pacific Motukea branch and at Laba Holdings at the Lea Lea Plant (approximately 18 km away), although the ATMs reportedly are not always functioning.

Village leaders report that residents also borrow money from family (at 0% interest) and from money lenders, with interest charged over time. 'Dinau moni' (or money loans) is a profit-making exercise for the money lenders, and although it is illegal (Goddard, 2005), it is a common practice across Papua New Guinea. Roku village residents reported that it is 'a big problem' in the village, likely when the debt cannot be repaid.

There is a community hall which doubles as the village court (Plate 9.4). There is also a women's hall located in the village, which is used as a day care centre, operated by the Women's Fellowship and for weekly Fellowship meetings (Plate 9.5). While the women's hall is being repaired, the church is used for these activities.

Plate 9.4 – Community Hall and Village Court, Roku village



Plate 9.5 – Women's Hall, Roku village



9.4.7 Trade Stores and Markets

There is no formal market in the village, however trade stores (Plate 9.6) and informal table markets (Plate 9.7) are open every day (except Sundays they typically open later). These markets reportedly mainly sell noodles, tinned fish and biscuits. Villagers visit the Koki market (approximately 20 minutes by dinghy, PGK 3 one way) to buy vegetables and to sell fish (see Figure 9.2).

See Section 9.6 for a summary of income generating activities associated with Roku village residents.

Plate 9.6 – Trade Store, Roku village



Plate 9.7 – Informal Table Market, Roku village



9.5 Governance and Leadership

9.5.1 Traditional and Religious Leadership

Traditional leadership still plays a key role in Papua New Guinean society, particularly in rural villages. It is mainly practiced in an informal setting, at the village or community level, and mostly where the tribe or village structure is not formalised through government administration. Leadership status is gained through displaying leadership qualities and through inheritance, either from family, clan or tribe, however practices differ between major cultural regions (Prideaux, 2006).

The role of traditional leaders has changed as government officials, church leaders and in areas where resource and other projects have developed, company employees or company-elected representatives, have played more prominent roles in various aspects of village life. This is the case in Roku village.

Village leaders and residents interviewed suggested a formal clan 'chief' does not exist and that village leaders have the authority to speak on behalf of their community, although consultation among the group may be expected before decisions are made or shared with outsiders. Roku village leaders currently consist of landowners, the ward Councillors and the local Pastor. The leaders comprise multiple-clan membership and all reside within the village of Roku.

During the field survey, village leaders reported being involved in settling disputes with various leaders often coming together to discuss and resolve issues. Leaders noted that the police help to solve some emerging issues and that village courts and churches are also important in assisting in resolving disputes (see Section 9.9).

The village leader's Councillor representative/s (of which there are two) currently include a ward member and a ward committee chairperson with responsibilities including organising meetings relating to governance of Roku village, implementing relevant government policy and representing Roku village at a provincial government level.

In general, landowner issues are dealt with by the landowner group leaders. See Sections 9.2 and 9.5 for further information of landowner groups and current issues.

Church leaders were identified as having an important role in providing community leadership (via church principles and guidance for the community) and supporting law and order along with other village leaders and the village court system. Church leaders (the local Pastor) organises and leads church activities. During court cases, there is a church representative to assist as a spiritual leader.

Women were also suggested as strong and active leaders in the community, particularly with organising women's activities within the village and outside with surrounding villages. Women from the village have formed the Roku Women's Fellowship, a church-based women's group that is very active in the community and has a strong membership base. Some women have also been appointed to more formal leadership roles through active membership of the church and as contributors toward landowning decision-making processes. Within Roku village, women currently hold leadership roles including the Church Treasurer, Chairlady and Secretary along with Court Magistrate and Clerk.

9.5.2 Government Administration

Papua New Guinea as part of the British Commonwealth is a constitutional monarchy. The Head of State is Her Majesty Queen Elizabeth II, represented by the Governor General who is elected directly by Members of the National Parliament and performs mainly ceremonial duties. The National Parliament is elected for five-year terms by universal suffrage. The Prime Minister is appointed and dismissed by the Governor-General on the proposal of Parliament, and the Cabinet is appointed by the Governor-General on the recommendation of the Prime Minister. The Supreme Court, National Court, and local and village courts form an independent justice system (DFAT, Undated). Papua New Guinea has developed a complex and decentralised system of government, with three tiers (national, provincial, and local), and four levels of administration (national, provincial, district, and LLG). District Development Authorities, chaired by the local Member of Parliament and including the council presidents, have recently emerged as another prominent and often well-resourced tier of government.

The Project is located in the Southern Region, Central Province, Kairuku-Hiri District and Hiri Rural LLG area of Papua New Guinea.

Village interviews indicate that there is no official ward plan although a Poreporena-Napa Napa Development Plan was reportedly in draft form at the time of writing this report and is yet to be made public. In the interim, the Councillor, landowners and a community development committee, chaired by a prominent female leader, generally collaborate on the development of Roku village.

9.5.3 Landowner Companies

Landowners in the study area are represented by the Kuriu Landowner Group Inc. for all land management matters. Incorporated Land Groups (ILGs) are groups formed and registered for the Voluntary Customary Land Registration System. They are legally registered corporations for the management of land resources. Their registration process is governed by the Minister of Lands and the Registrar of Titles. Their functions include the receipt of benefits such as royalty and equity dividends. As part of the formation of an ILG it is required for landowners to appoint an ILG Chairman.

Ohobiduduare Holdings Ltd is the development company representing the local landowners on all commercial land leases and development activities. Ohobiduduare Holding Ltd and APAC Investments Pty Ltd form OPD Ltd, a joint venture company responsible for commercially developing a part of the local landowner land. The additional land to be acquired for the IWMF expansion has been transferred from customary land to State lease and ownership will be transferred to TWM from OPD.

Rokotaba Limited is reportedly a landowner organisation used by Puma Energy for workforce recruitment.

9.5.4 CBOs, NGOs and Other External Support

Other than the Roku Women's Fellowship, there are no known CBOs or NGOs that have previously, or are planning to, provide community support to Roku village. Much of the external support comes from the businesses in the AES Industrial Park.

In general, local businesses have supported the Roku community by sponsoring sporting clubs, assisting to cover medical treatments and assisting in the maintenance of infrastructure (such as local roads). More recently a number of industrial companies have contributed to the upgrade of badly deteriorated sections of the Napa Napa Road. TWM has provided sponsorship to support the local netball and football teams and coordinated the 2019 World Environment Day event held at Roku Village for a beach clean-up activity, environmental awareness raising and luncheon celebration. Other examples of business support include the Roku elementary school, classrooms for the local primary school, houses, and the Pastor's house (Plate 9.8).

Plate 9.8 – Pastor's House



During survey, it was reported that financial support continues to be provided to Roku village by local businesses through various land payments, sales and rental although specifics were not discussed further. Financial assistance for the Roku Women's Fellowship has also been provided. Local businesses are also assisting in setting up a Roku community trust account. Trust money will be split into the following; 20% social (community social events), 40% education (school fees of students who go to colleges or universities or school renovations or other as agreed), and 40% construction (community shared facilities).

It was also reported that local business provide in-kind support to various initiatives and donations including fundraising events (colour run in Kokopo for example), donations to the local library and St John's, fuel for police and health personnel during emergency and COVID-19 Pandemic and snake anti-venom to local health centre. Donations have also included the timber sawmill, water tanks, outboard motors and dinghies to the Roku community.

Details for future/planned community development projects were also provided by businesses interviewed including increased employment opportunities to assist in decreasing local social issues.

9.6 Economy and Employment

9.6.1 Commercial and Large to Small-Scale Economic Activities

The formal economy in Papua New Guinea is dominated by resource exploration and production, commercial agriculture, tuna processing, logging and a small manufacturing sector. The informal economy, which supports approximately 85% of the population, is primarily dependent on subsistence agriculture (ADB, 2015). Papua New Guinea has experienced strong growth in the gross domestic product over the past decade, with much of the growth in 2014 and 2015 attributed to the PNG LNG Project, with its main facilities located at Hides, Hela Province, and at Caution Bay, 15 kms west of Roku village.

The main industries in Southern Region (including Central Province) include oil production and petroleum exploration, prawn fishing and logging. The majority of Papua New Guinea's commercial prawns are fished in the Gulf of Papua; however, all are processed in Port Moresby.

The PNG LNG Project is located approximately 10-15 minutes' drive from TWMs IWMF. This was a major consideration in TWM selecting and acquiring the site (see Chapter 5) given the fact that TWM has been operating a waste management services contract with ExxonMobil PNG for both the PNG LNG Project downstream and upstream sites since June 2014.

There are a number of small to medium businesses which share the general industrial precinct with the IWMF. Table 9.4 identifies the businesses interviewed that are located adjacent to the IWMF and along Napa Napa Road within a 500 m zone of the IWMF boundary.

Table 9.4 – Key Businesses Surrounding the IWMF

Business Name	Key Business Activity	Hours of Operation	Business Interaction/ Shared Resources with TWM
Rhodes PNG and AGL Builders (Rhodes/AGL)	Building fabrication and construction company providing housing/property development; manufacturing prefabricating building materials	Factory opens 5 days a week The hotel facility operates 24/7 on shifts	TWM utilise the civil and construction services of AGL in the development of the IWMF. This is reciprocated with TWM providing waste & environmental services to AGL. Both utilise Napa Napa Road
AES	Provides end to end construction and project service solutions across civil and construction works. AES also operate an international port terminal	Port opens from 7 a.m. to 10 p.m. 7 days a week and operates on shifts	TWM utilise the civil and construction services of AES in the development of the IWMF. This is reciprocated with TWM providing waste & environmental services to AES. Both utilise Napa Napa Road
Agility	An international shipping, logistics and warehousing company	8 a.m. to 4:30 p.m. from Monday to Friday 8 a.m. to 12.30 p.m. Saturdays (or on call if urgent)	Agility facilitated an import of some construction materials for TWM. Both utilise Napa Napa Road

Business Name	Key Business Activity	Hours of Operation	Business Interaction/ Shared Resources with TWM
Puma Energy (Puma) Oil Refinery	Refines hydrocarbon into diesel, jet A1 petrol, and other products	8 a.m. to 5 p.m. from Monday to Friday Contract security staff are on shift (24/7)	Hazardous waste (surrounding accommodation site) was contracted to TWM in 2017. Grease traps on site are managed by TWM. Both utilise Napa Napa Road
OilMin Holdings Ltd (Oilmin)	Provides logistics services, camp services in the mining, oil and gas sector. They have a laydown yard located close to Roku village, 2 km from the main Napa Napa Road	8 a.m. to 5 p.m. 7 days a week (laydown site)	Both utilise Napa Napa Road
Pagini Group (Pagini)	Road transport and logistics company. Provide both mining and general machinery	5 a.m. to 8 p.m. 7 days a week	Pagini supply TWM transport services. Both utilise Napa Napa Road

There has for many years and continues to be a significant cross supply of goods and services among the companies in the industrial precinct. TWM provides waste collection, treatment and disposal services and receives fuels, materials, civil construction services from local companies. Further, the landowners have maintained long held relationships with some of the industrial companies on Napa Napa Road, having leased land parcels to a number of operators over the years enabling the growth of the industrial precinct.

9.6.2 Local Employment and Income Generation

Papua New Guinea had a working-age population of approximately 4.6 million in 2018, two-thirds of which form part of the labour force. The large majority of the labour force is employed, with over 80% working in the informal or subsistence economy (Jones & McGavin, 2015). The formal labour market provides livelihoods to approximately 10-15% of the working age population (Pryke and Kirk, 2016). Latest census data suggests the Central Province labour force participation rate is 59.7% and an unemployment rate of 4.1% for males and 7.3% females. Wage job employment in the Central Province in 2011 was recorded as 19.1% for males and 7.3% for females (NSO, 2015).

While formal employment levels for the study area not available, village and business interviews suggest local formal employment levels are higher than average due to the nearby industrial precinct. Leaders reported as many as 50% of local, young men and women are employed by local industrial businesses. Approximately four to five truckloads of people can be seen arriving from local villages each morning for work within the Napa Napa area.

Further anecdotal evidence suggests however, that formal employment is not common in the study area and that Roku village maintains high levels of unemployment and has limited opportunities for tertiary education or for women to enter the workforce or undertake entrepreneurial business activities.

Businesses interviewed reported more than 820 employees and contractors on average at any time of the year are employed at the industrial precinct. Of these approximately 70% are male and 30% are female with approximately 150 of these employees and contractors living onsite in dedicated houses and yard or camp-style accommodation. The overall employee and contractor staff number is reportedly comprised of approximately 140 from the local villages of Roku, Porebada, Tatana, Baruni and Koderika.

TWMs current workforce comprises more than 100 multi-skilled national and expatriate staff, with a national content of approximately 85%. The Project will develop technical and vocational education and training initiatives to facilitate local workforce participation in the Project. Further TWM employment details are included in Chapter 4.

Village leaders reported that Roku village members do no leave the local area in search for work. In addition to formal employment, interview results suggest fishing, selling betel nut/cigarettes, the sale of store goods and firewood at trade stores and table markets (Plate 9.9 and Plate 9.10, respectively) provide alternative income generation for members of the Roku village community. Fishing in particular is an important livelihood activity, practiced by every household in Roku, and forms the next most important source of income for villagers after wage employment. See Section 9.7 for further information on Roku village fishing activities.

Plate 9.9 – Roku Village Community Trade Store



Plate 9.10 – Roku Village Community Table Market



9.6.3 Access to Markets

There are no formal markets in the study area, however local residents sell store goods at table markets and trade stores set up at various locations along established transport routes and within the village itself. Access to table markets is via foot and/or vehicle along existing roads.

The closest formal market to the study area is in Koki and is usually accessed by dinghies.

9.7 Land and Natural Resource Use

9.7.1 Land Use

The study area does not contain any active commercial forestry, agriculture or livestock production, and is primarily used for industrial purposes, although there is no formal zoning of the land use. Surrounding the industrial land (including the AES Industrial Park) is disturbed savanna habitat, and mangrove pockets along parts of the coastline, and small rural coastal settlements. Much of the land remains undeveloped secondary and tertiary regrowth savanna.

The AES Industrial Park comprises approximately 134 ha of land off Napa Napa Road between Fairfax Harbour and Idlers Bay. The AES Industrial Park consists of a port, and cleared land supporting warehousing and storage facilities, offices and accommodation (i.e. for security personnel), laydown areas, parking, waste treatment facilities, landfills and quarries.

The AES Industrial Park is one of several industrial areas surrounding Fairfax Harbour. The Puma Refinery is located approximately 7 km to the west, at the end of Napa Napa Road, and Motukea Port is located on the opposite side of the harbour (see Plate 8.12 in Section 8.6.3). The PNG

LNG facility is located approximately 15 km from the AES Industrial Park on the coast of Caution Bay.

The proposed Tuhava Town development stretches from the southern boundary of the IWMF to the coastline and is proposed to comprise a 500-lot development, business accommodation, an education precinct, marina and hotels (Tuhava, nd.). The development is currently in a masterplan stage, however if implemented, it will significantly alter the existing rural coastal settlement land use to the south of the AES Industrial Park.

9.7.2 Natural Resource Use and Ecosystem Services

This section describes how Roku residents use natural resources and the services provided by ecosystems in which they live. The IFC (2019) defines ecosystem services as the benefits that people, including businesses, derive from ecosystems. Ecosystem services were reviewed considering the services relevant to the study area and potentially affected beneficiaries (those who benefit from ecosystem services) and the Project activities that could potentially affect these services. Provisioning services are the goods or products obtained from ecosystems, such as food, timber, fibres, fresh water and medicinal plants, and are the focus of Section 9.7.2.1. Regulating, maintaining and supporting services include the contributions to human wellbeing arising from an ecosystem's control of natural processes, such as climate regulation, disease control, erosion prevention, water flow regulation, surface water purification, carbon storage and sequestration, and protection from natural hazards, and are described in Section 9.7.2.2.

9.7.2.1 Provisioning Services

Residents of Roku village report that they continue to engage in subsistence practices, although to a lesser extent than many villages in rural Papua New Guinea, as more than 50% derive their income and livelihoods from formal (wage) employment (see Section 9.6.2). Roku residents report that more food is purchased from local trade stores and table markets or markets in Koki and Port Moresby than grown or collected locally.

Cassava, banana, sweet potato and yam are the staple crops grown in the area; however, land productivity is relatively poor due to a combination of poor soils, low rainfall, seasonal inundation and land degradation (Goldman, 2009). Oram (1970) reports that as a result of urban growth of Port Moresby, land held by villages extended only a short way beyond the village itself, which contributed to a reduction in communal garden-making. This observation was accurate for coastal villages inspected by Weiner as part of social and landowner mapping for the PNG LNG Project (Goldman, 2009), and also applies to Roku village. While Roku village residents have access to communal land adjacent to the village for gardening, few maintain gardens, which comprise small plots where they predominantly grow cassava (tapioca), banana, mango (fruit) and yam during the rainy season (November to April). Plate 9.11 shows a typical garden in Roku.

Plate 9.11 – Garden in Roku Village



Roku residents reported keeping few livestock, except pigs, which are kept on a small scale for use as bride price or for sale.

Land is owned by the three main clans (see Section 9.5), however the rights to use the land are extended to all clan members within the Roku community to fish, hunt or to collect building materials and firewood. This observation is supported by Esso Highlands Limited (EHL, 2012) that reports that major resource areas within clan lands are communally utilised by all villagers.

Oram (1977) reported that hunting and collecting were important components of the traditional subsistence economy for villages in the central coast area of Central Province. Today, these activities have become less important due to the prevalence of wage employment, as Roku village residents report that hunting for wallabies and 'bush burning' for bandicoots is practiced only sometimes. Eggs and other traditional bushfoods (i.e., grubs, birds, snakes, etc.) are also no longer collected.

However, firewood (eucalypt sp.) is still regularly collected from the savanna surrounding the village and is reported to be available in relative abundance (Plate 9.12). It is the main fuel used for cooking and the sale of firewood provides a source of income for some Roku village residents (Plate 9.13).

Plate 9.12 – Firewood Collected from Savanna Surrounding Roku Village



Plate 9.13 – Wood Being Dried to Sell



Three species of eucalypts, and mangroves are also used as hardwood posts for house and fence construction in the village (Plate 9.14). House posts are prepared by submersion in the sea to cure the timber and aid drying, before use as building material. Roku village residents reported using modern nails and other materials to build houses.

Plate 9.14 – Eucalypt House Posts



Roku village residents reported that traditional canoes have largely been replaced by banana boats or dinghies. Tree species suitable for making canoes are not found locally, and if a traditional canoe is sought, the wood is brought in from a local sawmill.

Medicinal plants are still collected from the savanna surrounding the village, and include:

- Parasite plant (*Cuscuta gronovii*) which is used to help heal broken bones.
- Neme tree (*Azadirachta indica*) (Plate 9.15) which is used to treat malaria, joint pain and the flu.
- noni plant (*Morinda citrifolia*), of which the fruit is used for skin therapy, diarrhea, high blood pressure and other medicinal purposes.
- A species of Moringa (known as the 'drumstick' tree), which is used to treat a range of diseases.

Roku village residents did not report using any local plants or animals for cultural purposes (e.g., making traditional clothing or body decoration), as apart from an annual cultural festival held in Port Moresby and occasional bride price ceremonies (the last in Roku having been held in 2017), traditional cultural practices are no longer in common use (see Section 9.10.2).

Plate 9.15 – Neem Tree (*Azadirachta indica*)



The Motu are traditionally coastal peoples and fishing has always been an important subsistence, and more recently economic, activity (Goldman, 2009). EHL (2012) report that the Koitabu people, while traditionally land-based people, moved to the coast more recently and some have become good fishers.

There are a range of fishing habitats surrounding Roku village, including mangroves, onshore fringing reefs, inner and outer barrier reefs and open ocean. These diverse habitats provide for a variety of marine species, and fishing is a daily activity undertaken by the men in the village. The tools used for fishing are typically fishing lines, nets, spears and spear guns (Goldman, 2009).

Fishing is an important livelihood activity, practiced by every household in Roku village, and forms the next most important source of income for villagers after wage employment. Fishers primarily fish on inner reefs, however Goldman (2009) reports that outer reef and pelagic species are also targeted when the conditions are right (i.e., when the laurabada or 'east wind' is blowing). Some of the catch species observed during the field survey include: the scarlet-breasted Maori wrasse (*Cheilinus fasciatus*), Black and white snapper (*Macolor niger*), Anchor tuskfish (*Choerodon anchorago*), Twospot maori wrasse (*Cheilinus bimacuatus*), Moses perch (*Lutjanus russelli*) and the Yellowtail barracuda (*Sphyraena flavicauda*). Plate 9.16 shows some of the species of fish caught locally from Roku village.

Plate 9.16 – Fish Caught Locally from Roku Village



Fish caught by Roku village residents is either consumed locally, or is sold at the Koki market, which is approximately 20 minutes by dinghy from Roku village. A good fisherman can catch up to K250 of fish in one day (in terms of what he will get at Port Moresby's Koki market) (Goldman, 2009).

During the village interviews undertaken in 2020, Roku village residents did not report using the mangrove areas surrounding Idlers Bay other than for supply of hardwood, however EHL (2012) describes the importance of these areas for women who collect mud crabs which are sold at markets in Port Moresby, and Goldman (2009) reports that men also use the mangrove areas to collect snails, which are used as fish bait.

The Torres Strait Tropical Rock Lobster Fishery is the only commercial fishery relevant to the study area, with fishing activity occurring nearshore from Port Moresby to Yule Island. Roku village residents did not report catching rock lobster, although Goldman (2009) reports that villagers from Boera and Papa, further along the coast from Roku village, did catch rock lobster, albeit likely to be less for subsistence and more as informal artisanal fishery for income generation.

9.7.2.2 Regulating, Maintaining and Supporting Services

Regulating, maintaining and supporting ecosystem services refer to the regulation of natural processes that intact ecosystems provide and from which humans benefit. For example, vegetation cover stabilises soil and therefore helps regulate erosion and sediment delivery to streams, particularly on steep slopes where erosion potential is high, by providing a protective vegetative cover and reducing runoff (i.e., increasing infiltration). Vegetation also influences the volume of water available and the timing of water delivery, and intact and healthy ecosystems assist in regulating natural hazard frequency and intensity, including floods, cyclones, tsunamis and landslides (with the exception of seismic-induced landslides).

9.8 Transport

9.8.1 Roads and Walking Tracks

The Napa Napa Road is a bitumen sealed road that transects the study area, connecting TWM, local commercial industry and residents of Roku village with businesses and infrastructure in Fairfax Harbour and, ultimately, in Port Moresby. The road also connects the study area with other coastal locations to the north west, including those located along the Lea Lea Road – including Lea Lea, Papa and the PNG LNG Plant site. Boera, Porebada and Kouderika are connected to the Napa Napa Road via a sealed road. Redscar High School, located between Porebada and Kouderika, is also accessed along this road. The Napa Napa Road around the AES Industrial Park is reportedly in poor condition and the substructure has given way in some places, and there are lots of potholes and cracks and the bitumen is breaking at the edges. The road should be maintained by the Ministry of Transport, however AES, with support from other local industry, have previously undertaken some maintenance works. The road between Roku village and the Puma Refinery is in good condition and maintained by Puma Energy.

Roku village is most commonly accessed via a smaller unsealed road that comes directly off the Napa Napa Road (approximately 900 m from the entrance to the existing TWM site). The village can also be accessed via a number of alternative unsealed roads and tracks, however, as shown in Figure 9.2, these are reportedly in bad condition and/or closed.

A number of walking tracks exist in and around the village. These are used to access gardens and outlying residences, water sources for washing, the nearby mangroves (which are used for house posts and possibly the collection of snails and crustaceans), and the nearby savanna (used for firewood collection and medicinal plants).

Based on interviews with TWMs industrial neighbours, daily commercial traffic volumes for other commercial sites around the IWMF (including deliveries, trucks and security, staff and client vehicles) are estimated to be as little as 1 to 2 per day up to as many as 100 per day. This equates to approximately 250 vehicles per day using the Napa Napa Road between the Napa Napa Road and Lea Lea Road intersection and the TWM Project site, with some traffic continuing on to Roku village and the Puma refinery (see Figure 9.2).

There is no data pertaining to traffic volumes associated with private or public transport to/from Roku village, however it is reported that at least four or five trucks pass through the village each morning to collect residents for work within the industrial area around Roku.

Businesses interviewed indicated that there were no plans to alter their current road use in the foreseeable future.

9.8.2 Airstrips

The nearest airstrip to the study area is located in Port Moresby at the Jackson's International Airport (approximately 25 km via the Napa Napa Road and the Waigani Road). There are no alternate airstrips in the vicinity of the study area.

9.8.3 Marine Traffic

The existing AES port facilities at Fairfax Harbour are the closest facilities to the TWM site as well as to other commercial industrial sites in the area, providing an alternative access route to the area rather than the longer land-based route via Port Moresby and therefore may potentially receive barged containerised waste from a variety of locations around Papua New Guinea. An estimated 30 to 50 vessels, primarily cargo barges and tankers, currently access the AES port facilities each month.

In terms of the wider Port Moresby Port, Table 9.5 summarises the types of vessels that enter the port.

Table 9.5 – Vessels Entering the Port Moresby Port

Vessel type	% of Overall Vessels
Special craft	36.3
Tug	39.93
Pleasure craft	10.23
Cargo	9.24
Tanker	3.3
Other	0.66
Fishing	0.33

Source: MarineTraffic, 2020.

9.9 Law and Order

9.9.1 Law and Order Issues, System and Resolution

Established in 1975, village courts have the primary role of ensuring peace and harmony in the communities in which they operate. The village court system is the main mechanism for dealing with local crimes and disputes in the study area. Village courts deal with disputes relating to theft of garden produce, general bad behaviour (e.g., arguments, noise and gossip) and domestic disputes for example. Village courts are obliged to attempt to resolve disputes with mediation. Traditional or church leaders often play a supportive role in conflict resolution to the village court officials. If disputes cannot be resolved in the village court, they are referred to the provincial court.

Roku village leaders reported the presence of a Ward Councillor and Village Court Magistrate in Roku as the key representatives who would assist in solving community disputes. The village community hall is used as the courthouse, where cases are heard weekly on a Tuesday (see

Plate 9.4). Village leaders and Women's Followship members interviewed reported that most community problems are solved by the village at ward level with very few requiring escalation to the provincial level. In total, there are four village magistrate (chairman included) and one clerk (female) representatives of the village court.

9.9.2 Current Land Disputes

Land disputes in Papua New Guinea are administered under the *Land Disputes Settlement Act 1975* (the Act) and are traditionally formally settled through a three-stage process. The first stage is compulsory mediation by a local land mediator, whose role is to try and mediate and resolve land disputes between conflicting parties.

If land disputes cannot be resolved by the land mediator, then the parties may take their dispute to a local land court for arbitration, which will include a magistrate and two to four land mediators. The court has wide powers under the Act to reach a settlement between the parties, but if no agreement can be reached it can impose settlement (Oliver & Fingleton, 2008).

In general, disputes cannot be taken further than the Local Land Court, but the Act does allow a limited right of appeal against a Local Land Court's decision, to the Provincial Land Court. Grounds for appeal are confined to errors of jurisdiction, decisions made contrary to natural justice or cases of manifest injustice (Oliver & Fingleton, 2008).

Roku village leaders advised that they are involved in settling disputes with leaders often coming together to discuss and solve issues (Section 9.5) and Ohobiduduare Holdings Ltd is the development company representing the local landowners on all commercial land leases and development activities.

In September 2014, a complaint was lodged with the Compliance Advisor Ombudsman (CAO) on behalf of the Kuriu clan of Roku. The complainants raised concerns regarding the alleged illegal occupation of their customary land by AES and the IFC's due diligence process was argued to have failed to appropriately identify the Kuriu clan as legitimate landowners. After investigation consistent with its operational guidelines, the CAO closed the case in April 2015 with no further actions required (CAO, 2015).

9.9.3 Security Services

At independence (1973), police coverage in Papua New Guinea extended to only 10% of the country's land area and 40% of the population (Dinnen, 2017). Since then, the reach of the Royal Papua New Guinea Constabulary (RPNGC) has diminished; although the overall population has more than trebled, the RPNGC has only grown by around 3% (Dinnen, 2017). Insufficient numbers of police have resulted in a reliance on auxiliary and reserve police drawn from the wider community. Working alongside regular officers, these voluntary police may be sponsored by private businesses that provide allowances, uniforms, and other kinds of support (Dinnen, 2017).

Whilst Roku village itself does not have a permanent police presence there are five peace officers present to assist the community with any conflict. The nearest police station to Roku is 15 kms by road at Idubada on the outskirts of Port Moresby.

Private security organisations are governed by the *Security Protection Industry Act 2004*, which specifies that the Security Industries Authority is responsible for licensing firms and granting

permits to guards. Legally, firearms permits should only be granted to private security staff in exceptional circumstances; however, some guards have reportedly used excessive force with fatal consequences. Holding guards accountable for these human rights breaches is difficult as the Security Industries Authority is overstretched with little power to regulate the conduct of its members; companies often fail to provide training manuals or standing orders and the probability of securing convictions in the criminal justice system is low (Heyns, 2014).

It is estimated that every business within the Roku industrial precinct currently employs private security personnel. Personnel are responsible for providing services to the individual businesses within business site boundaries and when escorting expatriate personnel to and from site.

9.9.4 Sense of Safety

Village leaders and residents interviewed reported very little serious conflict within the community with domestic violence being low (as women tend to step in to stop any such violence) and only some (minimal) fighting during sporting competition which is resolved over the course of a few days following the sporting event. Where there has been conflict, this was reported as being associated with drugs and alcohol.

Only one serious crime was reported by leaders where in 2013, a former politician and businessman of Simbu (Highlands) was murdered near Roku village.

9.10 Cultural Heritage and Archaeology

The environment and cultural heritage are intrinsically linked in Papua New Guinea where cultural heritage signifies the relationships between people and landscapes. This is due mainly to the high percentage of customary land ownership and subsistence lifestyles throughout the country.

9.10.1 Tangible Heritage

Tangible cultural heritage values have a physical presence that can be seen or touched and include archaeological sites where physical remains of past cultural activity are present (e.g., pieces of pottery or shell on the ground surface), landscape features such as hills, caves and river mouths, individual trees or strands of vegetation or other landscape or biogeographic manifestations of spiritual, sacred or ritual significance. In addition, tangible cultural heritage values include movable material cultural items (e.g., ancestral heirlooms, traditionally made items used in day-to-day subsistence or leisure activities).

An archaeological and cultural site survey conducted by the Papua New Guinea National Museum and Art Gallery (NMAG) on 9 March 2018 for the initial development of the site IWMF identified no sites of cultural significance within the study area.

The nearest significant archaeological site to the study area is the Ranvetutu site west of Roku village (site AFD, approximately 3km south of Porebada); the site dates from 1,600 before present (Guise et al., 2018).

Further consultation with the Roku village leaders and with the Director of NMAG confirmed no additional cultural heritage material have subsequently been identified within the site since completing the surveys.

9.10.2 Intangible Heritage

Examples of intangible cultural heritage include:

- Language
- Spirit sites (residence of/associated with a spirit)
- Story sites (places that have significant stories, whether spiritual, mythological or historical)
- Origin story site (place associated with the origin of a particular group or thing)
- Oral histories of old settlement sites (location of former villages which may contain burials)
- Spirit of the dead sites
- Ritual or ceremonial sites
- Women's/men's sites (where rituals or ceremonies of various forms occur/occurred)
- Oral traditions and ancestral knowledge (in particular with regard to traditional medicinal and subsistence practices)
- Traditional song, dance and dress
- Sorcery and witchcraft (*sanguma*)

According to interviews with village leaders, traditional spiritual practices are not practised anymore, and residents do not practise *sanguma* (sorcery). However, it was reported that bride price is still practised, although it is less common (the last bride price ceremony in Roku was in 2017).

While traditional spiritual practices are less common, village leaders report that village residents attend the annual Hiri – Motu Koitabu singing and culture festival in Port Moresby. The festival is described as a celebration of the past (Hiri) bartering system, where people from all over Papua New Guinea came to trade.

Village residents also reportedly attend the church 'bou bou', an annual church event that is common in the United Church of Papua New Guinea in Central Province. Church groups and individuals make contributions (approximately PGK 300) to their parish toward this event.

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10. Potential Environmental Impacts of Proposal

10.1 Landform and Soils

10.1.1 Discipline Specific Approach

The significance assessment method described in Chapter 7 has been used to qualitatively assess potential impacts to landform and soils. This considers the sensitivity of the resource/receptor and the magnitude of the impact on that resource/receptor.

The impact assessment addresses potential impacts to landforms and soils within the IWMF site as described in Section 8.2. Landform and soils outside the IWMF site have not been considered in the impact assessment given Project activities with potential to impact landform and soils will only occur within the IWMF site boundary. As discussed in Section 8.2.4 soils within the IWMF site boundary are Ustorthents, occurring on low, hilly terrain. Landforms and soils have been previously disturbed from construction of the existing building pads and benches by the previous owner, its former land use as a timber mill site, and TWMs current operations. Elevated levels of arsenic, chromium, copper and lead were found to occur in surface soil strata at one sampling location at the previous timber mill site (TP5 as shown in Figure 8.1) however contaminated soils have subsequently been removed. Surface soil samples were assessed as predominantly having a low erosion susceptibility, with one exception (TP3) at the disused quarry (see Figure 8.1) which was assessed as having an elevated risk. Lower strata samples for three of six sample sites (TP3, TP5 and TP6) were also assessed as an elevated risk (Section 8.2.4). Topsoil was shallow, and discontinuous across the site.

This section specifically assesses potential impacts to the following sensitivities for landform and soils:

- Landform stability and susceptibility to erosion.
- Soil quality and capacity, including soil structure and development status, soil profiles, fertility and soil quality.

While surface soil strata closest to the proposed landfill footprint were assessed as having an elevated susceptibility to erosion, the proposed landfill footprint has significant levels of pre-existing disturbance from former quarrying activities and previous vegetation clearing. Across the IWMF site landforms have been subject to vegetation clearing for construction of building pads and benches by the previous owner. TWM have utilised these cleared benches as operational areas and for the installation of IWMF plant, with approximately 51.7% of the site already cleared of vegetation. Landforms within the IWMF site are therefore in a poor to moderate condition and have already been exposed to the potential impact of increased erosion. As such landform stability and susceptibility to erosion has been assessed to have a ***Low*** sensitivity.

In respect to soil quality and capacity, contaminated soils have been removed from the IWMF site; however, unsealed roads and exposed operational areas have been subject to soil

compaction, and disturbance, including at the former quarry site proposed for part of the landfill footprint. As such, the sensitivity of soil quality and capacity has also been assessed as a ***Low***.

The implications of changes to landform stability and soil quality and capacity to downstream surface waters, groundwater and aquatic biodiversity are considered in Sections 10.3, 10.4 and 10.9 respectively. Implications for air quality as a result of changes to landform and soils are considered in Section 10.5, while impacts to visual amenity from changes to landform are considered in Section 10.7 and impacts to terrestrial biodiversity are considered in Section 10.8.

10.1.2 Potential Impacts

10.1.2.1 Destabilisation of Landform Resulting in Increased Soil Erosion

Project vegetation clearing, excavation and earthwork activities have the potential to destabilise landforms within the IWMF site and increase the incidence of soil erosion or uncontrolled mass movements. Increased soil erosion may result in the loss of topsoil and contribute to the degradation of soil structure by burying structured and fertile topsoil and plant propagules, degrading soil aggregates and exposing more dispersive subsoils. Landform impacts will take place primarily where new ground disturbances occur, and not in already disturbed areas. Areas that were previously covered by vegetation are also susceptible to decreased stability and increased erosion, as exposed topsoil will no longer be bound by roots and protected by vegetative matter. Project components that will impact on landform stability and erosion susceptibility will be limited to the industrial landfill construction, including the clearing of vegetation, ground disturbance and earthworks excavation and placement of fill. All other Level 3 activities assessed in the EIS are to occur within existing footprints and will not contribute to potential landform destabilisation.

Increased soil erosion and uncontrolled mass movements may also result in increased sediment runoff to streams. Increased sediment runoff may cause potential declines in water quality and could subsequently affect aquatic biota due to increased suspended sediment and turbidity. These potential impacts are considered in Sections 10.3 and 10.9 respectively. Control measures embedded in the final landform design will include:

- Ensuring the gradient of landfill batters are designed with a maximum slope ratio of 1 m vertical to 3 m horizontal. [ED1]
- Including textured HDPE geomembranes in landform final design to provide adequate interface shear strength. [ED2]
- Locating Project infrastructure in an area of existing disturbance areas where practicable. [ED3]

10.1.2.2 Disturbance of Soils Resulting in Reduction of Soil Quality and Capacity

Earthworks for the construction of the industrial landfill may result in the disturbance of soil profiles and soil inversion during soil excavation and movement, degrading soil structure and fertility for future regeneration. Degrading soil structure may also reduce the quantity of good-quality topsoil available for reuse in site rehabilitation works. Soil compaction may occur as a result of general vehicle and machinery movements and machinery operation. Soil compaction increases the soil density of affected areas by packing the soil particles closer together and can

impact vegetation that was not planned to be disturbed by the Project (Section 10.8). Such impacts may occur within the proposed industrial landfill footprint during landfill construction and during daily landfill activities. Embedded design controls for the mitigation of soil disturbance will include:

- Locating Project infrastructure in an area of existing disturbance areas where practicable. [ED3]

10.1.2.3 Soil Contamination Resulting in Reduction of Soil Quality and Capacity

Soil Contamination from Accidental Release of Hazardous Industrial and Liquid Wastes, Hydrocarbons and Chemicals

The Project will involve the transport, handling, processing, treatment, storage, and disposal of hazardous and non-hazardous materials which have the potential to contaminate soils across the Project area if not appropriately managed. Potential sources of contamination include accidental spills or leaks to ground of hazardous industrial and liquid wastes, hydrocarbons and stored chemicals. Soil contamination as a result of such accidental spills can degrade soil structure and permeability, reduce soil fertility and may be toxic to soil-associated biota and plants (see Section 10.8). Effects can last from weeks to years depending on the type and quantity of substance released. Embedded design controls for the containment of hazardous and industrial liquid wastes, and hydrocarbons and chemicals, have been included in the Project design, and will include:

- A hazardous waste storage facility with impervious concrete bunds capable of holding at least 110% of the chemical storage capacity. [ED4]
- A purpose-built decontamination area within the bunding of the hazardous waste storage area to ensure waste is not tracked outside of the store and collection of wastes and associated cleaning liquids generated through the decontamination process for treatment at the IWWTP. [ED5]
- Constructing bunds and impermeable drainage with blind collection sumps or enclosed and weatherproof facilities with impermeable floor lining draining to a blind collection sump for all waste handling and treatment areas. [ED6]

Soil Contamination from Accidental Release of Landfill Leachate

Soil contamination may also occur a result of the accidental release of landfill leachate through seepage to surrounding soils from the industrial landfill leachate collection system, leachate storage pond and the transport of landfill leachates to the IWWTP for treatment. Similarly to hazardous wastes, hydrocarbons and chemicals, the accidental release of leachates to the environment may result in the degradation of soil quality and soil-associated biota and plants (Section 10.8). The release of leachates may occur as a result of leaks or seepage from the industrial landfill, or its leachate management systems. Flooding of the open landfill leachate pond may result in overtopping, releasing leachates to surrounding land and soils, which is assessed as a major hazard in Chapter 12. The leachate holding pond sizing has been designed on the basis of water balance and leachate generation modelling (see Section 4.5.10.6), in order to prevent overtopping occurring under normal operating conditions.

Waste materials disposed of to the landfill will be mostly inert, comprising treated hazardous wastes following neutralisation, fixation or stabilisation. Potential adverse properties of the landfill leachate include elevated concentrations of heavy metals and metalloids, ammonia, organic and inorganic contaminants and low pH. Embedded design control measures have been designed to mitigate impacts of leachate releases, leaks or seepage on the surrounding environment, including:

- Designing and constructing the industrial landfill with multiple HDPE geo-membrane barriers combined with clay liners and a leachate collection system which will drain leachate to collection sumps (with a 2% drainage slope). [ED7]
- Constructing a network of perforated leachate collection pipes within the collection layer, to promote the flow of leachate to the primary and secondary (leak detection) sumps. [ED8]
- Designing submersible pumps, vertical extraction pipework (primary) and inclined leachate extraction pipe (secondary) to facilitate the removal of leachate from the collection sumps by progressive pumping to the leachate storage pond or IWWTP. [ED9]
- Designing a leachate leak detection system, i.e., the secondary leachate collection and removal system which will allow the collection and flow of leachate out of the leak detection system. [ED10]
- Diverting clean stormwater away from the landfill to minimise the ingress of rainfall runoff into the landfill thereby reducing the volumes of leachate generated. [ED11]
- Designing the leachate storage pond considering worst-case leachate generation conditions to minimise the chance of overflow, including:
  - Using leachate water balance modelling based on maximum cumulative volume over a one-year period, using a 90th percentile wet year.
  - Assuming that one third of the Stage 1 landfill area is filled with waste, and comprises a 300 mm thick intermediate cover, and has an active working area of 625 m^2. [ED12]
- Designing the leachate holding pond freeboard volume based on the 5% AEP for 24-hour rainfall period. [ED13]
- Designing and constructing the leachate storage pond to the equivalent performance standard as the landfill which will include a 2 mm thick HDPE liner, compacted clay liner, composite drainage net, geosynthetic clay liner and prepared subgrade. [ED14]

10.1.2.4 Summary of Potential Impacts

Potential impacts to landform and soils due to the Project that have been considered in the impact assessment are summarised in Table 10.1.

Table 10.1 – Potential Impacts to Landform and Soils

Project Phase	Activity/Aspect	Project Component	Potential Impact
Construction and operations	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure • Industrial landfill activities	Industrial landfill construction; operation of industrial landfill	Destabilised landforms resulting in increased soil erosion
Construction and operations	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure • Industrial landfill activities • Transport of Project equipment, materials and personnel • Transport of earthen material • General vehicle movements • Transport of hazardous and non-hazardous wastes	Industrial landfill construction; traffic and transport	Degraded soil capacity due to impacts on soil structure and developmental status, fertility or disturbance of soil profiles
Construction and operations	• Storage, handling and use of chemicals and fuels • Transport of Project equipment, materials and personnel • Transport of earthen material • General vehicle movements • Use of machinery, equipment and vehicles • Discharge of stormwater to environment	Construction of industrial landfill and associated infrastructure; operation of industrial landfill; traffic and transport; operation of incinerator; fixation bays	Contamination of soils due to accidental release of hydrocarbons and chemicals
Operations	• Disposal of hazardous and industrial wastes	Operation of industrial landfill; hazardous waste storage; operation of incinerator; fixation bays; IWWTP; waste sorting and	Contamination of soils due to accidental release of hazardous wastes

Project Phase	Activity/Aspect	Project Component	Potential Impact
	• Storage of hazardous and non-hazardous wastes • Handling and processing of hazardous wastes • Transport of hazardous and non-hazardous wastes • Fixation of hazardous waste materials	segregation; weighbridge and receival hall	
Operations	• Collection of leachate in leachate collection system • Storage of leachate in leachate storage pond	Operation of industrial landfill	Contamination of soils from accidental release of landfill leachate

10.1.3 Mitigation and Management

10.1.3.1 Destabilisation of Landform Resulting in Increased Soil Erosion

Measures to mitigate impacts to landform stability and susceptible to erosion will include:

- Limiting vehicle and plant movements to defined access roads and existing operational areas. [EM1]
- Utilising land-clearing techniques that preserve the rootstock of removed vegetation in the ground (where practicable). [EM2]
- Limiting ground disturbance and vegetation clearing to the extent prescribed in landfill development plans by demarcating areas that require clearing on project mapping/design drawings and by flagging or signage in the field. [EM3]
- Delineating areas of vegetation to be protected. [EM4]
- Undertaking major earthworks and ground disturbance activities during the drier months, wherever practicable when exposed surfaces will be less prone to rainfall erosion and avoiding such works during high rainfall periods. [EM5]
- Installing diversion drains, swales, slope breakers, and berms to reduce erosion and subsidence where necessary from landfill construction and operations activities. [EM6]
- Developing and implementing an Erosion and Soil Management Plan, during landfill construction and IWMF operations. [EM7]
- Identifying the methods and locations of erosion and sediment control measures on site layout plans. [EM8]

- Rehabilitating batters progressively during earthworks to limit erosion and sedimentation. [EM9]
- Regenerating previously damaged and newly disturbed areas with native flora species. [EM10]
- Reducing time between clearing and revegetation of sites as far as practical to limit exposure of the site soils and subsoils to potential erosion. [EM11]
- Hydromulching batters as soon as practicable following formation to promote vegetation growth and reduce erosion potential. [EM12]
- Inspecting and monitoring site restoration and rehabilitation works and the progress of soil stabilisation and rehabilitation measures. [EM13]
- Monitoring and maintaining the effectiveness of the erosion and sediment control systems. [EM14]

10.1.3.2 Disturbance of Soils Resulting in Reduction of Soil Quality and Capacity

Measures to mitigate impacts to soil quality and capacity from disturbances including soil profile disturbance, inversion and compaction will include:

- Limiting vehicle and plant movements to defined access roads and existing operational areas. [EM1]
- Limiting ground disturbance and vegetation clearing to the extent prescribed in landfill development plans by demarcating areas that require clearing on project mapping/design drawings and by flagging or signage in the field. [EM3]
- Delineating areas of vegetation be protected. [EM4]
- Rehabilitating batters progressively during earthworks to limit erosion and sedimentation. [EM9]
- Regenerating previously damaged and newly disturbed areas with native flora species. [EM10]
- Hydromulching batters as soon as practicable following formation to promote vegetation growth and reduce loss of soil quality and capacity. [EM12]
- Inspecting and monitoring site restoration and rehabilitation works and the progress of soil stabilisation and rehabilitation measures. [EM13]
- Conserving topsoil (where practicable) in designated topsoil stockpile areas for later reuse in rehabilitation of disturbed areas. [EM15]

10.1.3.3 Soil Contamination Resulting in Reduction of Soil Quality and Capacity

Hydrocarbons and Chemicals

Measures to mitigate impacts to soil quality and capacity from hydrocarbon and chemical releases will include:

- Storing fuels, lubricants and process reagents in covered areas or in bunded and lined areas. Bunding will be implemented in accordance with relevant standards and guidelines including *AS 1940 Storage and handling of flammable and combustible liquids* and the Australian Dangerous Goods Code. [EM16]
- Refuelling on impermeable hardstand areas with spill prevention and spill containment kits available in close proximity. [EM17]
- Ensuring workshop activities and fuel storage facilities comply with the minimum requirements in the PNG Code of Practice for Vehicle/Machinery Workshops and Petroleum (Hydrocarbons) Storage/Resale/Usage Site (DEC, 1997). [EM18]
- Providing spill kits and safety data sheets (SDS) appropriate to the spill risk at the Project site and within vehicles as necessary. All fuel tankers and those tankers transporting hazardous materials shall carry appropriate spill kits. [EM19]
- Providing training to relevant staff in emergency spill response procedures and responsibilities. [EM20]
- Inspecting, maintaining and repairing fittings, pipes and hoses regularly. [EM21]
- Displaying emergency contact details and spill management procedures in prominent positions in all operating areas. [EM22]
- Training personnel in the handling, transportation and storage of hazardous materials and providing training to an appropriate number of staff in the handling of emergency response and release scenarios. [EM23]
- Clearly labelling vessels with name or description of hazardous material with accompanying SDS to be stored in close proximity and readily available in case of a spill or leak. [EM24]
- Testing permanent storage vessels and enclosures intended for hazardous materials storage for leaks prior to installation and operation. [EM25]
- Routinely inspecting vessels, tanks and secondary containment for leaks. If a leak is identified activate appropriate actions as per the Emergency Spill Operation Instruction. [EM26]
- Developing and implementing a service and maintenance schedule according to manufacturer's specifications. [EM27]
- Using pesticides and herbicides that are low in human toxicity, effective on target species and that have minimal effects on non-target species and the environment. [EM28]

Hazardous and Industrial Liquid Wastes

Measures to mitigate impacts to soil quality from hazardous and industrial liquid wastes include will include:

- Operating the hazardous waste storage facility in accordance with AS 1940-2004 Storage and Handling of Flammable and Combustible Liquids, the Papua New Guinea and Australian Standards for the Storage of Hazardous Substances (*PNG Inflammable Liquids Act 1953*) and PNG/AS3780-2008-storage and handling corrosive substances. [EM29]
- Collecting spills from the WOPU, fixation bays and industrial services area and returning this water to the IWWTP for treatment. [EM30]
- Collecting waters from operational areas in blind sumps for transfer and processing at the IWWTP. [EM31]
- Conducting weekly inspections of the hazardous waste storage facility and initiating immediate remedial action where required. [EM32]

Industrial Landfill Leachate

Measures to mitigate impacts to soil quality from landfill leachate will include:

- Pumping leachate from the collection sumps via HDPE risers to a central collection well, before being pumped and conveyed to the leachate storage pond or IWWTP. [EM33]
- Monitoring and maintaining the Industrial landfill leachate collection system. [EM34]
- Monitoring leachate levels in the leachate pond to maintain a minimum design freeboard (0.5 m). If this freeboard level is reached, the leachate pond will be immediately pumped out and either sent to the IWWTP or taken offsite for disposal at an approved and licensed facility. [EM35]
- Monitoring of landfill leachate leak detection system. [EM36]

10.1.4 Residual Impact Assessment

The following section provides the assessment of residual impacts to soil quality and capacity, and landform stability assuming successful implementation of the proposed mitigation measures.

10.1.4.1 Destabilisation of Landform Resulting in Increased Soil Erosion

Vegetation clearing, ground disturbance and earthworks for construction of the industrial landfill may destabilise landforms and result in increased soil erosion or uncontrolled movement of soils. Impacts on landform are dependent upon site-specific landform conditions and climate factors, including the susceptibility to erosion of soils and rainfall patterns of the site described in Section 8.3. New ground disturbance will occur in areas of fine grained sedimentary lithology occurring on mountains or hills with weak or no structural control landform (see Figure 8.5), and an Ustorthents soil type. Ustorthents are soils with a moderate erosion susceptibility, while surface soil strata closest to the proposed footprint (TP3 in Figure 8.1) were assessed as having an elevated susceptibility to erosion. Rainfall is seasonally low, although high rainfall events do

occur. However, the majority of surface strata soils within the IWMF site assessed as low susceptibility to erosion, while the existing landform within the IWMF site are in poor to moderate condition. Landform stability and susceptibility to erosion has been assessed to have a ***Low*** sensitivity (Section 10.1.1).

Vegetation clearing, ground disturbance and earthworks will be contained to the proposed Stage 1 and Stage 2 industrial landfill footprints as shown in Figure 10.1. A total of 1.58 ha of existing sparse vegetation will be cleared within the proposed construction footprint (see Section 10.8), although the total proposed landfill footprint will cover an area of approximately 4.67 ha. Ground disturbance will occur after vegetation clearing, and earthen material including topsoils and subsoils will be excavated for the construction the landfill cells and used in the construction of landfill batters, the construction of internal roads, or exported off-site. Excavation will involve the construction of additional landfill cells, with the already excavated quarry suitable for construction of the initial cell. Landfill construction will require a total void volume of 116,900 m^3, 79,900 m^3 of earthworks cut, and 79,900 m^3 of earthworks fill.

Construction of the landfill and associated infrastructure may generate an unstable landform with the potential to induce increased erosions of topsoil and uncontrolled mass movement or release of soils down gradient. The physical alteration of the landform will be long term in nature, given the Project life of up to 50 years, however the impact will be localised within the proposed landfill footprint.

Final landform design will help mitigate the potential for increased erosion and reduce landform instability through the implementation of embedded design controls described in Section 10.1.2.1.

Measures to ensure slope stability is sufficient will include the construction of the external landfill batters with a minimum vertical to horizontal slope gradient ratio of 1:3, and the inclusion of HDPE geomembranes in the landform design. Landform will further stabilise following the end of disturbance activities, as revegetation of batters and disturbed areas is undertaken progressively, and vegetation re-establishes itself.

Erosion controls including the installation of diversion drains, swales, slope breakers, and berms (Section 10.1.3.1) will mitigate the potential for soil erosion and rehabilitation of landfill batters will reduce potential landform instability. The potential for landform instability and increased erosion will be highest during construction activities, where all ground disturbance and earthwork activities will occur. Increased erosion may continue to occur during operations from the ongoing potential for rainfall erosion from exposed soils. However the potential impact will be lower given the revegetation activities are likely to increase in effectiveness as vegetation becomes re-established and soils are no longer being actively disturbed. The magnitude of impact on landform stability within the IWMF site during the construction phase is assessed as ***Low***, providing an overall significance rating of ***Minor***. The magnitude of the impact during operations is assessed as ***Negligible***, resulting in a residual impact significance of ***Negligible***.

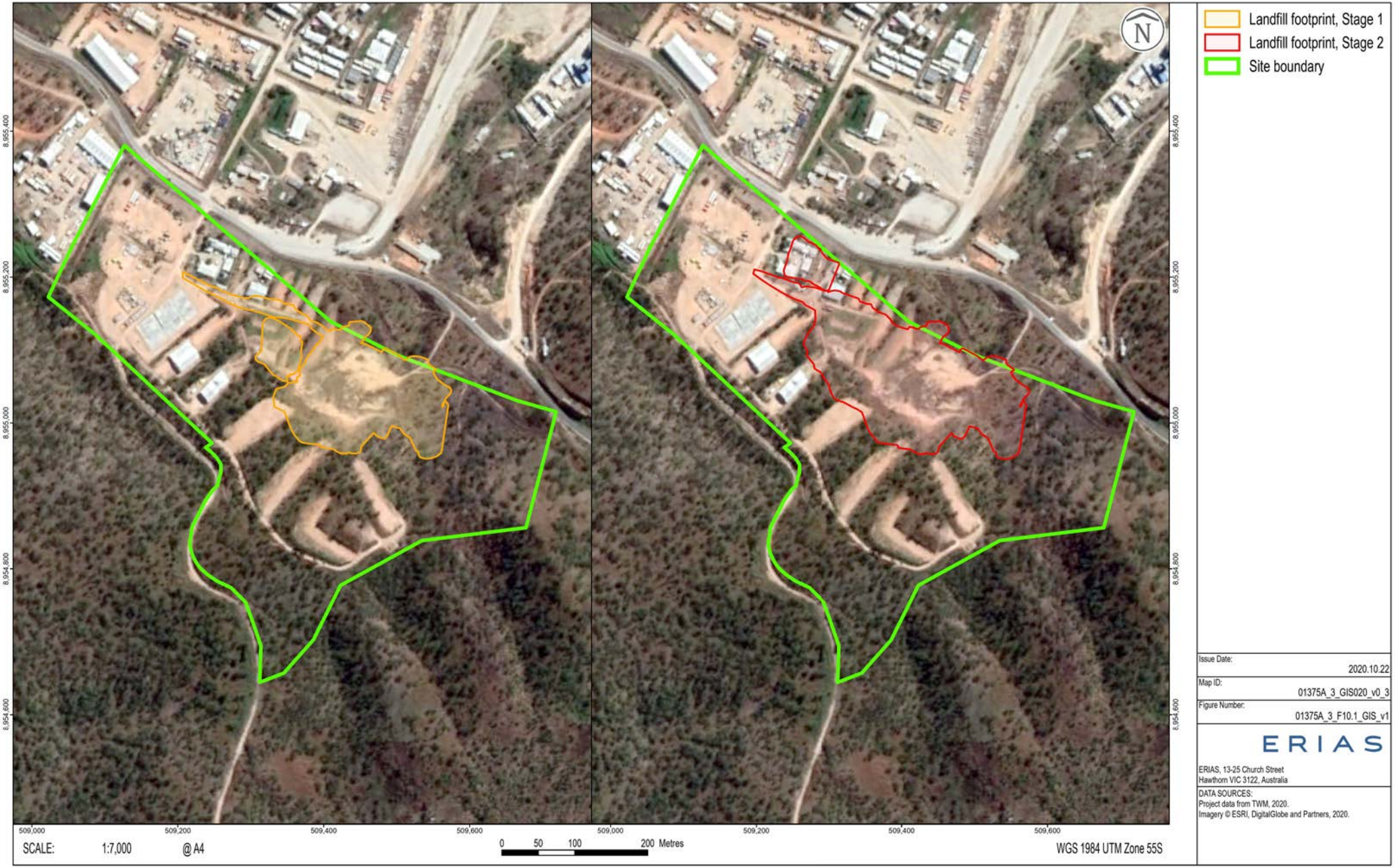
PROPOSED INDUSTRIAL LANDFILL FOOTPRINT

Integrated Waste Management Facility | Environmental Impact Statement

FIGURE 10.1

TWM Total Waste Management

ERIAS



Issue Date: 2020.10.22

Map ID: 01375A_3_GIS020_v0_3

Figure Number: 01375A_3_F10.1_GIS_v1

ERIAS

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DATA SOURCES:
Project data from TWM, 2020.
Imagery © ESRI, DigitalGlobe and Partners, 2020.

10.1.4.2 Disturbance of Soils Resulting in Reduction of Soil Quality and Capacity

The potential for reduced soil quality and capacity as a result of soil profile disturbance, inversion and compaction may occur as a result of the landfill construction and ongoing operations, including movement of traffic and transport within the IWMF site. Landfill excavation and placement of fill may result in the disturbance of soil profiles and soil inversion, while soil compaction may occur during transportation of earthen materials, earthmoving machinery and plant, and vehicle movement outside of defined access roads and operational areas.

Potential impacts from soil profile disturbance are likely to be short term, occurring over the 12-month landfill construction period, although soil compaction outside existing disturbed areas may occur over the life of the Project operations. However, mitigation measures listed in Section 10.1.3.2 will limit traffic and vehicle movement to existing areas while rehabilitation mitigation measures will reduce impacts to soil quality. Impacts are expected to be localised to the proposed footprint of the industrial landfill and would not be expected outside of access roads and can be mitigated through routine rehabilitation and topsoil management controls. Impacts will be greater during construction phase given the requirement for excavation and ground disturbance, while impacts during operations will be limited to soil compaction from traffic and vehicle movement. With the implementation of effective management measures, potential impacts from soil disturbances are considered to have a ***Low*** impact magnitude on existing soil quality and capacity, during construction, and a ***Negligible*** impact magnitude during operations. As described in Section 10.1.1, the sensitivity ranking of soil quality and capacity within the IWMF is ***Low***. The significance of residual impacts to soil quality and capacity from soil disturbance including disturbance of soil profiles, inversion and soil compaction is therefore ***Minor*** for the construction phase of the Project, and ***Negligible*** for the operations phase.

10.1.4.3 Soil Contamination Resulting in Reduction of Soil Quality and Capacity

Soil Contamination from Accidental Release of Hydrocarbons and Chemicals

Hydrocarbons and chemicals will be used and stored on site during landfill construction and ongoing operations of the IWMF, including the treatment of hazardous waste materials, and for the operation of IWMF plant and supporting services such as use of diesel generators and diesel fuelled equipment. If not managed appropriately, accidental releases of hydrocarbons and chemicals have potential to contaminate soils and reduce soil quality and capacity. Potential hydrocarbons on site will include diesel fuels, oils, lubricants, hydraulic fluids, stored at the mechanics workshop. Bulk fuel storage will include, 10,000 L of diesel fuel stored adjacent to the incinerator which also has a 1,000 L in-built diesel fuel tank, and 3,000 L for the back-up generators, stored at the mechanical workshop and adjacent the incinerator. Chemicals will be stored at the hazardous waste storage facility, in accordance with mitigation measures described in Section 10.1.3.3. Chemicals will include chlorine, polyaluminium chloride, sodium hypochlorite, sucrose, citric acid, oxalic acid, ferric chloride, aluminium sulphate, and polymer chemicals.

Minor spills or leaks, even with effective management, are a somewhat common occurrence at construction sites and operational industrial sites. During operation, the handling and storage of fuel and chemicals will occur predominantly within concrete hardstand areas, designed with bunding and blind sumps as described in Section 10.1.3.3. As such, spills of chemicals and hydrocarbons to soils during operations are unlikely to occur. Where these spills do occur,

volumes released to the environment are likely to be minor. Spills resulting in contamination of soils are considered to be more likely during the construction phase of the Project, where activities involving machinery and construction plant are more likely to be undertaken in exposed and areas of bare earth. Spills, although still likely to be minor, therefore have greater potential for being released directly into soils. Regardless, impacts during both phases will be localised to IWMF site as minor spills or leaks are not difficult to contain where the measures detailed in the Spill Prevention and Response Plan and Emergency Spill Operating Instructions are followed, and are therefore also likely to be short term. The magnitude of a minor spill or leak of hydrocarbons or chemicals during construction has been assessed as ***Low***, and as ***Negligible*** during operations. The significance of residual impacts to soil quality and capacity from contamination from hydrocarbons and chemicals during construction is therefore ***Minor***, and ***Negligible*** during operations.

Soil Contamination from Accidental Release of Hazardous Industrial and Liquid Wastes

The IWMF site will receive, handle, treat, dispose of, and store several hazardous industrial and liquid waste streams, at several locations across the IWMF site. These locations include the receival hall and weighbridge, the sorting and segregation facility, the HT incinerator, fixation bays, the hazardous waste storage facility, the industrial landfill and the IWWTP. Embedded design controls (described in Section 10.1.2.3) include the construction of designated storage areas, and bunded concrete pads of sufficient capacity with blind sumps. However, accidental spills or leaks of such hazardous wastes to ground, either directly or indirectly to soil, may occur during the operations phase of the Project, and may result in the contamination of soils and degradation of soil quality and capacity. Relevant hazardous waste streams with the potential to impact soil quality and capacity include:

- Acids, alkalis and biocides.
- Oily water and waste oil.
- Non-halogenated solvents.
- Oxidisers.
- Used lead acid batteries, end of life tyres and spent activated carbon.
- Asbestos.
- Industrial wastewater following contact with potentially hazardous contaminants.
- Radiotherapy wastes.

As described in Section 10.1, the sensitivity of soil quality and capacity is ***Low***. Potential for hazardous waste materials releases to land and soils is largely mitigated through embedded design features and via specific environmental management controls, outlined in Section 10.1.3. Releases of hazardous wastes have the potential to occur during the operations phase of the Project only, and in the event would likely be highly localised to the spill location and short term given the environmental controls in place for spill response, and impacts can therefore be effectively mitigated through routine environmental controls. As such, the potential impact

magnitude of soil contamination from accidental releases of hazardous industrial wastes and liquid wastes during operations, resulting in degraded soil quality and capacity, is assessed as ***Low***, and the residual impact significance is therefore ***Minor***.

Soil Contamination Resulting from Accidental Release of Landfill Leachate

Soil contamination resulting from the accidental release of landfill leachate, either through leaks or seepage into surrounding soils, has potential to contaminate soil and reduce soil capacity during the operations phase of the Project. The flooding and overtopping of the leachate holding pond also has the potential to result in contamination of soils; however, is considered to be an unplanned event associate with the occurrence of a major natural hazard (i.e., flooding resulting in overtopping) and therefore is considered in Chapter 12. However, the leachate holding pond will be constructed with a minimum freeboard of 0.5 m and has been designed with capacity sufficient for the modelled water balance including extreme rainfall events and leachate generation from the landfill. Furthermore, the anticipated volume of leachate is low given embedded design features will include runoff diversion and reducing infiltration of rainfall into the landfill cells.

With the successful implementation and regular monitoring of the basal lining system, the leachate management and collection system, and the leachate detection system, potential leaks or seepages are expected to not occur. The magnitude of the impact from accidental releases of landfill leachates to soil quality and capacity is therefore assessed as ***Negligible.*** Considering a ***Low*** sensitivity for soil quality and capacity, the overall impact significance rating for soil contamination from landfill leachates is assessed as ***Negligible***.

10.1.4.4 Summary of Residual Impact Assessment

A summary of the landform and soils impact assessment, including proposed mitigation and management measures to minimise impacts, is provided in Table 10.2. All residual impacts to landform and soils were as assessed to be ***Negligible*** to ***Minor***.

Table 10.2 – Landform and Soils Residual Impact Assessment

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
Landform stability and susceptibility to erosion	Destabilised landforms resulting in increased soil erosion	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure	• EM1 • EM2 • EM3 • EM4 • EM5 • EM6 • EM7 • EM8 • EM9 • EM10 • EM11 • EM12 • EM13 • EM14	Construction	Low/Low	Minor
		• Industrial landfill activities		Operations	Low/Negligible	Negligible
Soil quality and capacity	Degraded soil capacity due to impacts on soil structure and developmental status, fertility or disturbance of soil profiles	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure • Transport of Project equipment, materials and personnel • Transport of earthen material • General vehicle movements	• EM1 • EM3 • EM4 • EM9 • EM10 • EM12 • EM13 • EM15	Construction	Low/Low	Minor
		• Industrial landfill activities • Transport of Project equipment, materials and personnel		Operations	Low/Negligible	Negligible

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
		• Transport of hazardous and non-hazardous waste • General vehicle movements				
Soil quality and capacity	Contamination of soils from the accidental release of hydrocarbons and chemicals	• Storage, handling and use of chemicals and fuels • Transport of Project equipment, materials and personnel • Transport of earthen material • General vehicle movements • Use of machinery, equipment and vehicles	• EM16 • EM17 • EM18 • EM19 • EM20 • EM21 • EM22 • EM23 • EM24 • EM25 • EM26 • EM27 • EM28	Construction	Low/Low	Minor
		• Storage, handling and use of chemicals and fuels • Transport of Project equipment, materials and personnel • General vehicle movements • Use of machinery, equipment and vehicles		Operations	Low/Negligible	Negligible
Soil quality and capacity	Contamination of soils from accidental release of hazardous and industrial liquid wastes	• Disposal of hazardous and industrial wastes • Storage of hazardous and non-hazardous wastes • Handling and processing of hazardous wastes • Transport of hazardous and non-hazardous wastes • Fixation of hazardous waste materials	• EM29 • EM30 • EM31 • EM32	Operations	Low/Low	Minor
Soil quality and capacity	Contamination of soils from accidental	• Collection of leachate in leachate collection system	• EM33 • EM34	Operations	Low/Negligible	Negligible

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
	release of landfill leachate	• Storage of leachate in leachate storage pond	• EM35 • EM36			

10.2 Hydrological Processes

10.2.1 Discipline-specific Approach

The significance assessment method described in Chapter 7 was adopted to qualitatively assess impacts to hydrological processes. This considers the sensitivity of the resource/receptor and the magnitude of impact on that resource/receptor.

The surface water hydrology of the IWMF and downstream waterways is described in Section 8.3. There are no watercourses or permanent waterbodies within the IWMF site and there are no major watercourses or permanent waterbodies within 500 m of the site. Ephemeral drainage channels are located to the east, southeast and west and flow for short periods of time following sufficient rainfall runoff.

The sensitivity of the surface water drainage channels located downslope from the IWMF with regard to hydrological processes is categorised as ***Medium***, considering such ephemeral drainage channels are limited due to the local topography and climate.

Groundwater availability at the IWMF, described in Section 8.5, is limited and likely to be seasonally influenced with some degree of aquifer recharge expected to occur from infiltration of rainfall during the northwest monsoon season. Groundwater is used by the Roku village community for washing clothes, bathing and sewage, with three groundwater bores located in the village. Supply is however considered to be generally unreliable. The sensitivity of groundwater in the Project area with regard to hydrological processes is also categorised as ***Medium*** given its limited availability in the area and the fact that the Roku village community uses it occasionally for domestic uses (excluding drinking water).

10.2.2 Potential Impacts

10.2.2.1 Altered Surface Water Hydrological Regime

Industrial Landfill

Hydrological processes may potentially be impacted by the construction, and physical presence, of the industrial landfill due to alteration of the natural surface drainage regime. This could alter downslope flow direction, volume and velocity.

In addition to the physical footprint of the industrial landfill and the resulting change to topography and drainage patterns, the industrial landfill will be designed to minimise the ingress of rainfall runoff and surface runoff will be diverted to a sediment dam. Clean stormwater will also be diverted away from the landfill. This has the potential to alter downslope flow direction, volume and velocity.

Project Water Demands

Project water demands are described in Section 4.8. Potable water will be brought to site and will potentially be supplemented by rainwater deemed suitable for drinking. Non-potable domestic water will be supplied via an existing connection from the adjacent AES industrial park which provides desalinated seawater, with an estimated 1.36 ML of water to be required per year.

Desalinated water from the existing AES connection will also be used to supply an estimated 3.39 ML/year for industrial water uses, with a further 27.3 ML/year beneficial reuse water estimated to be provided from the WWTP and IWWTP and an estimated 6.6 ML/year of captured rainwater to make up the remaining requirements.

As there will be no surface water abstraction required to meet the domestic and industrial water demands of the Project, there will be no impact to the hydrological regimes of downslope surface waters. Therefore, potential impacts to hydrological regimes from Project water demands have not been considered in the impact assessment.

Water Capture and Storage

The site stormwater management system is described in Section 4.5.12. The system has been designed to capture, divert and treat potentially contaminated surface and stormwater from operational areas of the IWMF as well as to capture and store water collected from infrastructure roofing. Stormwater collected from operational area will undergo treatment at the IWWTP and will then be reused to meet industrial process water demands. While the collection and reuse of stormwater captured on the site could alter hydrological regimes of the drainage channels in the downslope catchment by reducing volumes of runoff leaving the site, this activity is already approved under the existing environment permit and is not considered in the impact assessment.

Discharge of Stormwater

Some stormwater collected from the weighbridge and guardhouse may be discharged offsite to the stormwater drainage channel along Napa Napa Road. Such a discharge is permitted under the existing environment permit and is considered out of scope for this EIS and has therefore not been considered in the impact assessment.

10.2.2.2 Groundwater Levels

Groundwater Drawdown

Construction of the industrial landfill will not require dewatering and no groundwater will be abstracted to meet Project water demands. As such, there will be no drawdown of groundwater and this has not been considered in the impact assessment.

Groundwater Mounding from Seepage

All stormwater and sediment dams and the leachate storage pond will be lined with multiple HDPE geo-membrane barriers combined with clay liners. This will prevent seepage which could potentially result in groundwater mounding. As such, potential impacts from seepage have not been considered in the impact assessment.

10.2.2.3 Summary of Potential Impacts

Potential impacts to hydrological processes due to the Project that have been considered in the impact assessment are summarised in Table 10.3.

Table 10.3 – Summary of Potential Impacts on Hydrological Processes

Project Phase	Activity/Aspect	Project Component	Potential Impact
Construction and operations	• Physical presence of Project infrastructure • Storage of stormwater in sediment storage ponds	Industrial landfill construction and operation	Altered surface water hydrological regime

10.2.3 Mitigation and Management

10.2.3.1 Altered Surface Water Hydrological Regimes from Industrial Landfill

Measures to minimise impacts to surface water hydrological regimes will include:

- Reducing disturbance of natural drainage channels during earthworks where practicable and ensuring stockpiles not placed within natural drainage channels. [EM37]
- Conducting routine inspections of stormwater management systems (after high rainfall events in particular) to ensure that drains, sumps and other structures are maintained in good working condition to allow free and unobstructed flow of drainage. [EM38]
- Designing the stormwater management system to minimise as far as practicable any changes to natural direction and flow rate in downstream catchment. [EM39]
- Designing and constructing surface water controls in accordance with the appropriate guidelines as applied to site features and conditions. [EM40]

10.2.4 Residual Impact Assessment

The following section provides the assessment of residual impacts to hydrological processes assuming successful implementation of the proposed mitigation measures.

10.2.4.1 Altered Surface Water Hydrological Regimes from Industrial Landfill

The design of the industrial landfill includes using clean water diversion drains to direct rainfall runoff away from the landfill, with this water to be discharge on site via a level spreader, and construction of toe drains at the base of batters to convey potentially sediment-laden water to a sediment dam. The sediment dam has been designed to contain water from an extreme rainfall event (a 5 day 90th percentile rainfall event), with the dam requiring a storage capacity of 2.24 ML in Stage 1 of landfill operations and 3.08 ML for Stage 2.

The landfill stormwater management design will reduce the volume of leachate produced from the landfill and limit the release of sediment-laden runoff to the downstream catchment. These measures will however create minor changes to the existing drainage conditions by reducing the volume and potentially the direction of rainfall runoff reporting to the local catchment. This could alter the hydrological regime of downslope drainage channels located to the east of the landfill. Given these drainage channels are ephemeral and only flow following periods of sufficient rainfall and that the landfill footprint represents less than 4% of the local catchment, such changes are not expected to be detectable with respect to natural variability. As such, the magnitude of the

impact for altered surface water hydrological regimes from the industrial landfill during construction and operations is assessed as ***Negligible***.

Given the sensitivity of surface water hydrology is ***Medium***; the overall impact significance rating for altered surface water hydrological regimes from the industrial landfill is assessed as ***Negligible*** for construction and operations.

10.2.4.2 Summary of Residual Impact Assessment

A summary of the hydrology impact assessment, including proposed mitigation and management measures to minimise impacts, is provided in Table 10.4. All residual impacts to hydrology were assessed as ***Negligible.***

Table 10.4 – Hydrological Processes Impact Assessment

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
Surface water	Altered surface water hydrological regime	• Physical presence of Project infrastructure (industrial landfill) • Storage of stormwater in sediment storage ponds	• EM37 • EM38 • EM39 • EM40	Construction and operations	Medium/Negligible	Negligible

10.3 Surface Water Quality

10.3.1 Discipline-specific Approach

The significance assessment method described in Chapter 7 was adopted to qualitatively assess impacts to surface water quality. This considers the sensitivity of the resource/receptor and the magnitude of impact on that resource/receptor.

There are no watercourses or permanent waterbodies within the IWMF site. The impact assessment considers potential impacts to surface water bodies in the downslope catchment which includes ephemeral drainage channels located to the east, southeast and west of the IWMF, but no major or permanent waterbodies.

While there is some uncertainty around existing surface water quality within the drainage channels, as there was no water available for sampling during the ERIAS field survey in July 2020, the water quality of these drainage channels is expected to experience a high degree of natural variability due to their ephemeral nature. Surface waters in the downslope catchment that may be potentially impacted by the Project are considered to have a ***Medium*** sensitivity. This sensitivity is based on the likely influence from the surrounding industrial activities on ephemeral surface water quality and the indication of some degree of anthropogenic disturbance (evident by the construction waste dumped in some of the drainage channels and the elevated levels of nickel in sediments at Site TWM3, see Figure 8.1).

10.3.2 Potential Impacts

As described in Section 8.3 and shown in Figure 8.8, while there are no surface water bodies located within the IWMF, rainfall runoff from the site reports to downslope drainage channels, located primarily to the east, with a small portion of the IWMF draining towards the west and south towards Roku village. As such, activities within the IWMF site boundaries have the potential to impact surface water quality of the downslope catchment. Impacts to surface water quality specific to Level 3 activities may potentially occur due to:

- Surface runoff mobilising sediment from exposed surfaces associated with construction and operation of the industrial landfill.
- The accidental release of leachate from the industrial landfill leachate storage pond.
- The accidental release of hazardous and industrial liquid wastes from operational and storage areas.
- Accidental release of hydrocarbons and chemicals.

These potential impacts are discussed in the following sections.

Apart from stormwater, discharge of water from the IWMF site is not proposed. Stormwater collected from the weighbridge and guardhouse may be discharged offsite; however, this activity is approved under the existing environment permit and is therefore out of scope for this EIS and not considered in the impact assessment.

10.3.2.1 Increased Suspended Sediment and Turbidity from Rainfall Erosion

The exposure and disturbance of soil during earthworks and ground disturbance works associated with the construction and operation of the industrial landfill could cause soil to be eroded by rainfall and mobilised to nearby surface water bodies. This could lead to a decline in surface water quality from increased suspended sediment loads and turbidity in receiving surface waters.

A number of embedded design controls address impacts on surface water from increased suspended sediment and turbidity associated with landfill construction and operations. Such design controls will include:

- Using clean water diversions drains to direct clean rainfall runoff away from the landfill to minimise the volumes of potentially sediment-laden water generated and installing a level spreader at the on-site termination of the clean water diversion drain to limit erosion and mobilisation of soils. [ED15]
- Construction of a sediment dam for both Stage 1 and Stage 2 industrial landfill operations prior to the commencement of landfill cell construction works (e.g., stripping and bulk earthworks). The sediment dam has been designed to contain water from an extreme rainfall event (a 5 day 90th percentile rainfall event), with a storage capacity of 2.24 ML in Stage 1 operations and 3.08 ML for Stage 2. [ED16]
- Installation of toe drains at the base of batters to convey sediment-laden runoff to the sediment dam. [ED17]

10.3.2.2 Surface Water Contamination from Accidental Release of Landfill Leachate

Leachate will be generated from the industrial landfill operations and collected in the leachate collection system and stored in the leachate storage pond or sent directly to the IWWTP for treatment. Leachate could have elevated concentrations of ammonia, heavy metals and metalloids, organic and inorganic contaminants and low pH. Leachate can also have elevated BOD and COD. If not contained, leachate could impact surface water quality.

A number of embedded design controls address impacts on surface water quality from landfill leachate. These design controls are provided in Section 10.1.2.3 as they also relate to mitigating impacts to soil quality and capacity.

10.3.2.3 Surface Water Contamination from Accidental Release of Hazardous and Industrial Liquid Wastes

TWM are already approved for receiving and storing hazardous liquid wastes prior to export to Australian; however, the Project will involve treating and disposing of hazardous liquid wastes at the site, which is not currently approved under the existing environment permit. This could result in accidental releases from leaks and spills which could lead to a reduction in surface water quality if mobilised.

A number of embedded design controls address impacts on surface water from hazardous and industrial liquid wastes. Such design controls will include:

- A hazardous waste storage facility with impervious concrete bunds capable of holding at least 110% of the chemical storage capacity. [ED4]
- A purpose-built decontamination area within the bunding of the hazardous waste storage area to ensure waste is not tracked outside of the store and collection of wastes and associated cleaning liquids generated through the decontamination process for treatment at the IWWTP. [ED5]
- Constructing bunds and impermeable drainage with blind collection sumps or enclosed and weatherproof facilities with impermeable floor lining draining to a blind collection sump for all waste handling and treatment areas. [ED6]
- A stormwater management system designed to capture, divert and treat stormwater that has come into contact with operational areas and reticulate it to collection sumps and the IWWTP for processing and beneficial reuse. [ED18]

A major loss of industrial or hazardous liquid waste due to a failure of the IWWTP and associated storage vessels from major natural hazards and unplanned events is considered in Chapter 12.

10.3.2.4 Surface Water Contamination from Accidental Release of Hydrocarbons or Chemicals

The Project will require bulk diesel fuel and dispensing areas and the use and storage of various chemicals. While fuel use and chemical storage and use is already approved under the existing environment permit, industrial landfill operations and the general expansion of the IWMF site capacity associated with Level 3 activities will result in additional handling, storage and use of these liquids. For the purposes of the impact assessment, this has been considered in general, rather than trying to specifically assess the potential impacts associated with the release of hydrocarbons and chemicals pertaining to Level 3 activities only.

Bulk fuel storage on site will include approximately 3,000 L of diesel fuel storage for the backup generator and a 10,000 L fuel storage tank for supplying the incinerator. These will be located at the mechanical workshop and adjacent the incinerator. In addition, a 1,000 L diesel storage tank is located within the existing incinerator plant. Fuel deliveries are anticipated to average 1,500 L per week. Transferring, storing and dispensing fuels could result in spills or leaks of hydrocarbons which could be mobilised to the downslope catchment and degrade surface water quality.

Outside of bulk fuel storage, workshop and refuelling areas, leaks and spills of hydrocarbons from vehicles, plant and machinery could occur while in use from leaks in hoses, fittings and fuel storage tanks. Such leaks or spills could occur more broadly within the Project area and along transport roads and could also lead to a reduction in surface water quality if mobilised.

Chemicals required for fixation of hazardous wastes such as cement and other products and cement/clay/polymer mixes will be stored in a silo adjacent to the fixation bays. Other chemicals required for waste processing and treatment and for use in various equipment will be transported to site in drums or IBCs and stored at the mechanical workshop in accordance with dangerous goods requirements. Chemicals required for industrial processes may be accidently spilt or could leak during handling (e.g., dosing) or storage and could be mobilised during rainfall events and could report to downslope surface waters. Chemicals can degrade receiving water quality.

The embedded design controls listed in 10.3.2.3 for mitigating impacts to surface water from accidental release of hazardous and industrial liquid waste are also applicable to mitigating impacts to surface water from accidental release of hydrocarbons and chemicals.

10.3.2.5 Summary of Potential Impacts

Potential impacts to surface water quality due to the Project that have been considered in the impact assessment are summarised in Table 10.5.

Table 10.5 – Summary of Potential Impacts on Surface Water Quality

Project Phase	Activity/Aspect	Project Component	Potential Impact
Construction and operations	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure • Industrial landfill activities	Industrial landfill construction; operation of industrial	Increased turbidity and sedimentation in downstream surface waters due to erosion of soils/exposed surfaces associated with the industrial landfill
Operations	• Collection of leachate in leachate collection system • Storage of leachate in leachate storage pond	Operation of industrial landfill	Contamination of downstream surface waters from accidental release of landfill leachate
Operations	• Storage of hazardous and non-hazardous wastes • Handling and processing of hazardous wastes • Fixation of hazardous waste materials	Hazardous waste storage; operation of incinerator; fixation bays; IWWTP; waste sorting and segregation; weighbridge and receival hall	Contamination of downstream surface waters from accidental release of hazardous and industrial liquid wastes
Construction and operations	• Storage, handling and use of chemicals and fuels • Operation of fixed and mobile plant and equipment • Operation of diesel generators	Industrial landfill construction; traffic and transport; IWWTP	Contamination of downstream surface waters from the accidental release of hydrocarbons and chemicals

10.3.3 Mitigation and Management

10.3.3.1 Increased Suspended Sediment and Turbidity from Rainfall Erosion

In addition to the embedded design controls described in Section 10.3.2.1, measures to minimise impacts to surface water quality from increased suspended sediment and turbidity will include:

- Installing sediment fencing downstream of the sediment dam footprint prior to commencing construction of the sediment dam. [EM41]
- Controlling sediment runoff from stockpiles by installing sediment control structures to prevent sediment release to watercourse. [EM42]
- Avoiding stockpiling spoil and/or topsoil close to existing drainage lines, maintaining a minimum distance of approximately 50 m, where practicable. [EM43]
- Undertaking major earthworks and ground disturbance activities during the drier months, wherever practicable when exposed surfaces will be less prone to rainfall erosion and avoiding such works during high rainfall periods. [EM5]
- Rehabilitating batters progressively during earthworks to limit erosion and sedimentation. [EM9]
- Hydromulching batters as soon as practicable following formation to promote vegetation growth and reduce erosion potential. [EM12]
- Installing sediment control devices downstream of the landfill northeast batter (where drainage to a sediment dam is not practicable due to the proximity to the site boundary and topography). [EM44]
- Installing diversion drains, swales, slope breakers and berms to reduce erosion and subsidence where necessary from landfill construction and operations activities. [EM6]
- Installing sediment controls including sedimentation ponds and siltation fences prior to the commencement of landfill construction activities. [EM45]
- Designing and constructing surface water controls in accordance with the appropriate guidelines as applied to site features and conditions. [EM40]

10.3.3.2 Surface Water Contamination from Accidental Release of Landfill Leachate

Measures provided in Section 10.1.3.3 to mitigate impacts to soil quality from accidental release of landfill leachate will also mitigate impacts to surface water. No additional measures are proposed.

10.3.3.3 Surface Water Contamination from Accidental Release of Hazardous and Industrial Liquid Wastes

Measures provided in Section 10.1.3.3 to mitigate impacts to soil quality from accidental release of hazardous and industrial liquid wastes will also mitigate impacts to surface water. No additional measures are proposed.

10.3.3.4 Surface Water Contamination from Accidental Release of Hydrocarbons or Chemicals

Measures provided in Section 10.1.3.3 to mitigate impacts to soil quality from accidental hydrocarbon and chemical releases will also mitigate impacts to surface water. No additional measures are proposed.

10.3.4 Residual Impact Assessment

The following section provides the assessment of residual impacts to surface water quality assuming successful implementation of the proposed mitigation measures.

10.3.4.1 Increased Suspended Sediment and Turbidity from Rainfall Erosion

Clearing around 1.58 hectares of sparse vegetation and removal of some topsoil will be required for the construction of the industrial landfill. During construction, erosion and sediment control structures (including the landfill sediment dam and sediment fencing) and undertaking construction activities during the drier months, or periods of reduced rainfall wherever practicable, will minimise sediment loads reporting to surface water bodies from rainfall runoff. During periods of heavy rainfall, and prior to the construction of the sediment dam, sediment control measures may not completely contain mobilised sediment and so increased sediment may report to surface water bodies under such conditions. This would likely coincide with periods of naturally increased suspended sediment and turbidity as a result of increased rainfall runoff in the broader catchment. Impacts may be detectable with respect to natural variability but are expected to be short term (i.e., limited to construction and particularly following high rainfall events) and would be limited to the drainage channels located to the east of the industrial landfill (i.e., localised). As such, the magnitude of the impact for construction of the industrial landfill is assessed as ***Low***.

Once constructed, the industrial landfill sediment dam will provide for settling of suspended solids in sediment-laden water from the landfill and this water will either undergo evaporation or be reused to meet industrial process water demands within the IWMF or for site irrigation Potentially sediment-laden water will be collected within a toe drain and will be directed to the sediment dam. Clean water diversion drains will direct natural drainage around the southern boundary of the industrial landfill, and this will discharge to the site via a level spreader, which will limit potential erosion and mobilisation of soils downslope. With these measures in place, impacts to surface water quality from increased suspended sediment and turbidity during operations are expected to be within the range of natural variability (i.e., will be undetectable); therefore, the magnitude of the impact for operations is assessed as ***Negligible***.

Given the sensitivity of surface water is ***Medium***; the overall impact significance rating for increased suspended sediment and turbidity from rainfall erosion is assessed as ***Minor*** during construction and ***Negligible*** for operations.

10.3.4.2 Surface Water Contamination from Accidental Release of Landfill Leachate

The industrial landfill will receive predominantly inert materials (e.g., neutralised/stabilised/fixated hazardous wastes and incinerator ash) and is expected to generate relatively low levels of leachate. The embedded design controls listed in Section 10.1.2.3 will further reduce the volume of leachate produced, by diverting runoff and minimising rainfall infiltration of the landfill cells. Notwithstanding, leachate could have elevated concentrations of ammonia, heavy metals and metalloids, organic and inorganic contaminants elevated BOD and COD and low pH, which could affect receiving surface water quality.

The leachate collection system and leachate storage pond will be designed to prevent the loss of leachate and the leachate pond will be of sufficient capacity considering potential extreme rainfall events and will be routinely monitored to ensure sufficient freeboard is maintained. The leachate

leak detection system will also be regularly monitored to assess performance of the leachate collection system and the landfill liner. With these controls in place no leachate should be released to the environment. As such, the magnitude of the impact to surface water from the accidental release of landfill leachate is assessed as ***Negligible.***

Given the sensitivity of surface water is ***Medium***; the overall impact significance rating for surface water contamination from accidental release of landfill leachate is ***Negligible*** for operations.

10.3.4.3 Surface Water Contamination from Accidental Release of Hazardous and Industrial Liquid Wastes

Hazardous industrial and liquid waste will be stored and treated within bunded areas, designed to sufficient capacity considering the liquids to be stored and handled, and captured rainfall runoff will drain to collection sumps. This water and water that has come into contact with operational areas will be diverted to collection sumps and ultimately the IWWTP for processing and beneficial reuse. The design of the hazardous waste storage facility is such that it will also prevent the release of hazardous liquid wastes. Bunds and sumps will be regularly inspected and pumped if required to maintain sufficient storage capacity. Considering these design controls and mitigation measures hazardous and industrial liquid wastes will not be released to the environment. As such, the magnitude of the impact to surface water from the accidental release of landfill leachate is assessed as ***Negligible.***

Given the sensitivity of surface water is ***Medium***; the overall impact significance rating for surface water contamination from accidental release of hazardous and industrial liquid wastes is ***Negligible*** for operations.

10.3.4.4 Surface Water Contamination from Accidental Release of Hydrocarbons or Chemicals

The assessment addresses leaks and spills that are typically incidental (but controllable) as part of construction of the industrial landfill and operations specifically related to managing and handling wastes requiring Level 3 approval. Large-scale spills associated with major natural hazards and unplanned events are considered in Chapter 12.

For both phases of the Project, the primary source of potential contamination from hydrocarbons and chemicals is associated with the use, refuelling and maintenance of vehicles, plant and machinery. Bulk fuel storage on-site will include 3,000 L of diesel fuel storage for the backup generators, a 1,000 L diesel storage tank fed through to the incinerator burners and a 10,000 L fuel storage tank for supplying the incinerator. Bulk fuel storage on site will be at the mechanical workshop, located behind the existing three bedroom house and adjacent the incinerator. Bulk fuel storage may be used for refuelling mobile plant within hardstand areas.

Additional potential sources of contamination from spills and leaks during operations, may occur due to the use and storage of chemicals including:

- Chlorine.
- Polyaluminium chloride.
- Sodium hypochlorite.

- Sucrose.
- Citric acid.
- Oxalic acid.
- Ferric chloride or aluminium sulphate (coagulants).
- Polymer chemicals.

Chemicals are expected to be transported to site in drums or IBCs, and stored at the mechanical workshop (a bunded area) in accordance with dangerous goods requirements. If spilt and mobilised/dissolved by rainfall they could report to surface water bodies where they are potentially toxic to aquatic biota. Chemical storages will be bunded and located away from surface water bodies and drainage lines. Chemicals and reagents will also be securely stored undercover.

Hydrocarbons (i.e., fuels and oils) are dispersive in water as they are less dense and therefore lighter, meaning that they will be transported downstream on the water surface rather than mixing through the water column. Chemicals may not disperse as far downstream due to their less hydrophobic properties (depending on the exact chemical involved) allowing for dilution through the water column. Most of the chemicals listed above are soluble and some are potentially toxic to aquatic biota (e.g., sodium hypochlorite. oxalic acid and ferric chloride).

The mitigations measures listed in Section 10.1.3.3 require that fuels, oils and chemicals are stored and handled appropriately, that machinery is well maintained and regularly inspected, and that accidental leaks or spills are contained and remediated quickly.

Regular inspections and maintenance of equipment will aim to ensure leaks in hoses, fittings and fuel storage tanks are prevented or detected early. TWMs Spill Prevention and Response Plan and Emergency Spill Operating Instructions will identify procedures for preventing and managing spills and relevant personnel will be appropriately trained in spill response measures. The required spill containment equipment will be maintained and readily available close to fuel and chemical storage and handling areas or within vehicles and machinery as necessary. With the implementation of the mitigation measures provided in Section10.1.3.3, leaks or spills of fuels, oils and chemicals will either be prevented or detected early and contained locally and in a timely manner.

During construction of the landfill, spills or leaks of hydrocarbons or chemicals which are not detected and contained would likely only report to surface water drainage channels during rainfall events. Under such circumstances, dispersion or dilution in receiving surface water bodies would mean that impacts would be localised (i.e., limited to the drainage channels to the east of the landfill) and with surface water moderately affected in the short term. Therefore the magnitude of the impact is assessed as ***Low*** for construction.

During operations, accidental spills or leaks of hydrocarbons or chemicals that are not immediately contained will likely be captured by the site stormwater management system, which will collect water from potentially impacted operational areas. This water will be diverted to the IWWTP for processing and reuse within the site. Therefore the magnitude of the impact is assessed as ***Negligible*** for operations.

Given the sensitivity of surface water is ***Medium***; the overall impact significance rating for surface water contamination from accidental hydrocarbon or chemical release is ***Minor*** during construction and ***Negligible*** for operations.

10.3.4.5 Summary of Residual Impact Assessment

A summary of the surface water quality impact assessment, including proposed mitigation and management measures to minimise impacts, is provided in Table 10.6. All residual impacts to surface water quality were assessed to be ***Negligible*** to ***Minor.***

Table 10.6 – Surface Water Quality Impact Assessment

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
Surface water	Increased suspended sediment and turbidity	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure	• EM41 • EM42 • EM43 • EM5 • EM9 • EM12 • EM44 • EM6 • EM45 • EM40	Construction	Medium/Low	Minor
		• Industrial landfill activities		Operations	Medium/Negligible	Negligible
Surface water	Contamination of downstream surface waters from accidental release of landfill leachate	• Collection of leachate in leachate collection system • Storage of leachate in leachate storage pond	• EM33 • EM34 • EM35 • EM36	Operations	Medium/Negligible	Negligible
Surface water	Contamination of downstream surface waters from accidental release of hazardous and industrial liquid wastes	• Storage of hazardous and non-hazardous wastes • Handling and processing of hazardous wastes • Fixation of hazardous waste materials	• EM29 • EM30 • EM31 • EM32	Operations	Medium/Negligible	Negligible
Surface water	Contamination of downstream surface waters from the	• Storage, handling and use of chemicals and fuels • Operation of fixed and mobile plant and equipment	• EM16 • EM17 • EM18	Construction	Medium/Low	Minor
				Operations	Medium/Negligible	Negligible

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
	accidental release of hydrocarbons and chemicals	• Operation of diesel generators	• EM19 • EM20 • EM21 • EM22 • EM23 • EM24 • EM25 • EM26 • EM27 • EM28			

10.4 Groundwater Quality

10.4.1 Discipline-specific Approach

The significance assessment method described in Chapter 7 was adopted to qualitatively assess impacts to groundwater quality. This considers the sensitivity of the resource/receptor and the magnitude of impact on that resource/receptor.

As discussed in Section 8.5, groundwater water availability at the IWMF is limited and likely to be seasonally influenced with some degree of aquifer recharge expected to occur from infiltration of rainfall during the northwest monsoon season. Groundwater is used by the Roku village community for washing clothes, bathing and sewage, with three groundwater bores located in the village (see Plate 8.11). Supply is however considered to be generally unreliable. There is no evidence of existing contamination of groundwater at the IWMF from two samples collected, although hydrocarbons were above detection limits and groundwater at AES has previously had very high levels of faecal coliforms and *E. Coli* and faecal coliforms have also been detected in monitoring bores at the IWMF.

Groundwater that may be potentially impacted by the Project is considered to have a ***Medium*** sensitivity, given its limited availability in the area and the fact that the Roku village community uses it occasionally for domestic uses (excluding drinking water).

10.4.2 Potential Impacts

This section addresses impacts on groundwater quality. Potential impacts on groundwater availability are considered in Section 10.2.

Shallow groundwater is considered most vulnerable to impacts from the Project. As discussed in Section 8.5, groundwater availability at the IWMF is limited, likely due to the low permeability of soils across the site which limit the percolation of rainfall through soils and recharge of groundwater. The lack of groundwater and low permeability of soils therefore limits the pathway for potential impacts to groundwater quality from Project activities.

Apart from stormwater, discharge of water from the IWMF site is not proposed. Stormwater collected from the weighbridge and guardhouse may be discharged offsite; however, this activity is approved under the existing environment permit and is therefore out of scope for this EIS and not considered in the impact assessment.

The primary pathway for impacts to groundwater quality is from accidental spills or leaks from unsealed areas, which could percolate through soils and report to groundwater. Potential sources of contaminants include leachate from the industrial landfill, hazardous and industrial liquid wastes and hydrocarbons and chemicals. These potential impacts are discussed in the following sections.

10.4.2.1 Groundwater Contamination from Accidental Release of Landfill Leachate

Leachate will be generated from the industrial landfill operations and stored in the leachate storage pond or sent directly to the IWWTP for treatment. If not contained, leachate could impact groundwater quality where a pathway for infiltration through soils exists. Leachate could have

elevated concentrations of ammonia, heavy metals and metalloids, organic and inorganic contaminants, elevated BOD and COD and low which can degrade groundwater quality.

The embedded design controls listed in Section 10.1.2.3 which address potential impacts to surface water quality from landfill leachate will also address potential impacts to groundwater quality.

10.4.2.2 Groundwater Contamination from Accidental Release of Hazardous Industrial and Liquid Wastes

TWM are already approved for receiving and storing hazardous liquid wastes prior to export to Australian; however, the Project will involve treating and disposing of hazardous liquid wastes at the site, which is not currently approved under the existing environment permit. This could result in accidental releases from leaks and spills which could lead to a reduction in groundwater quality where a pathway for infiltration through soils exists. The embedded design controls listed in Section 10.3.2.3 which address potential impacts to surface water quality from the accidental release of hazardous and industrial liquid wastes will also address potential impacts to groundwater quality.

10.4.2.3 Groundwater Contamination from Accidental Release of Hydrocarbons or Chemicals

As described in Section 10.3.2.4, the Project will require bulk diesel fuel and dispensing areas and the use and storage of various chemicals and will include approximately 3,000 L of diesel fuel storage for the backup generator and a 10,000 L fuel storage tank for supplying the incinerator. These will be located at the mechanical workshop and adjacent the incinerator. In addition, a 1,000 L diesel storage tank is located within the existing incinerator plant. Fuel deliveries are anticipated to average 1,500 L per week. Transferring, storing and dispensing fuels could result in spills or leaks of hydrocarbons which could percolate through soils and degrade groundwater quality.

Outside of bulk fuel storage, workshop and refuelling areas (for mobile plant), leaks and spills of hydrocarbons from vehicles, plant and machinery could occur while in use from leaks in hoses, fittings and fuel storage tanks. Such leaks or spills could occur more broadly within the Project area and along transport roads and could also infiltrate soils, particularly where there is no hardstand, and report to groundwater.

Chemicals required for fixation of hazardous wastes such as cement and other produces such as cement/clay/polymer mixes will be stored in a silo adjacent to the fixation bays. Other chemicals required for waste processing and treatment and for use in equipment will be transported to site in drums or IBCs and stored at the bunded mechanical workshop in accordance with dangerous goods requirements. Chemicals required for industrial processes may be accidently spilt or could leak during handling (e.g., dosing) or storage and could percolate through soils and degrade groundwater quality.

The embedded design controls listed in Section 10.3.2.3 for mitigating impacts to surface water (and groundwater) from accidental release of hazardous and industrial liquid waste are also applicable to mitigating impacts to groundwater from accidental release of hydrocarbons and chemicals.

10.4.2.4 Summary of Potential Impacts

Potential impacts to groundwater quality due to the Project that have been considered in the impact assessment are summarised in Table 10.7.

Table 10.7 – Summary of Potential Impacts on Groundwater Quality

Project Phase	Activity/Aspect	Project Component	Potential Impact
Operations	• Collection of leachate in leachate collection system • Storage of leachate in leachate storage pond	Operation of industrial landfill	Contamination of groundwater from accidental release of landfill leachate
Operations	• Storage of hazardous and non-hazardous wastes • Handling and processing of hazardous wastes • Fixation of hazardous waste materials	Hazardous waste storage; operation of incinerator; fixation bays; IWWTP; waste sorting and segregation; weighbridge and receival hall;	Contamination of groundwater from accidental release of hazardous and industrial liquid wastes
Construction and operations	• Storage, handling and use of chemicals and fuels • Operation of fixed and mobile plant and equipment • Operation of diesel generators	Industrial landfill construction; traffic and transport; operation of industrial landfill	Contamination of groundwater from accidental release of hydrocarbons and chemicals

10.4.3 Mitigation and Management

10.4.3.1 Groundwater Contamination from Accidental Release of Landfill Leachate

The embedded design controls and management measures listed in Section 10.1.2.3 and 10.1.3.3 to address impacts to soil quality (and surface water quality) from accidental release of landfill leachate will also mitigate impacts to groundwater quality. The following measure will further mitigate impacts to groundwater:

- Conducting routine groundwater monitoring of at least four landfill monitoring bores to be located around the landfill to detect potential contamination and initiate remedial action. [EM46]

10.4.3.2 Groundwater Contamination from Accidental Release of Hazardous Industrial and Liquid Wastes

The embedded design controls and management measures listed in Section 10.1.2.3, 10.1.3.3 and 10.3.2.3 to address impacts to soil quality and surface water quality from accidental release of hazardous industrial and liquid wastes will also mitigate impacts to groundwater. In addition, the following measure will further mitigate impacts to groundwater:

- Conducting routine groundwater monitoring of the IWMF monitoring bores (see BH1, MB05, MB06, MB07, Figure 8.1) to detect potential contamination and initiate remedial action. [EM47]

10.4.3.3 Groundwater Contamination from Accidental Release of Hydrocarbons or Chemicals

The embedded design controls and management measures listed in Section 10.1.2.3, 10.1.3.3 and 10.3.2.3 to mitigate impacts to soil quality and surface water quality from hydrocarbon and chemical releases will also mitigate impacts to groundwater as well the routine monitoring of the sites groundwater monitoring bores as described in the previous section.

10.4.4 Residual Impact Assessment

The following section provides the assessment of residual impacts to groundwater quality assuming successful implementation of the proposed mitigation measures.

10.4.4.1 Groundwater Contamination from Accidental Release of Landfill Leachate

The industrial landfill will receive predominantly inert materials (e.g., neutralised/stabilised/fixated hazardous wastes and incinerator ash) and is expected to generate relatively low levels of leachate. The embedded design controls listed in Section 10.1.2.3 will further reduce the volume of leachate produced, by diverting runoff and minimising rainfall infiltration of the landfill cells Notwithstanding, leachate could have elevated concentrations of ammonia, heavy metals and metalloids, organic and inorganic contaminants, elevated BOD and COD and low pH which can degrade groundwater quality.

The design of the landfill and leachate storage pond with multiple HDPE geo-membrane barriers combined with clay liners and the industrial landfill leachate collection system and leachate leak detection system will prevent the loss of leachate to the underlying geology thereby preventing potential impacts to groundwater quality. The leachate leak detection system will be regularly monitored to assess performance of the leachate collection system. With these controls in place no leachate will be released to the environment. As such, the magnitude of the impact to groundwater quality from the accidental release of landfill leachate is assessed as ***Negligible.***

Given the sensitivity of groundwater quality is ***Medium***; the overall impact significance rating for groundwater contamination from accidental release of landfill leachate is ***Negligible*** for operations.

10.4.4.2 Groundwater Contamination from Accidental Release of Hazardous Industrial and Liquid Wastes

Hazardous industrial and liquid waste will be stored and handled within bunded areas, designed to sufficient capacity considering the liquids to be stored and handled and captured rainfall runoff will drain to collection sumps. This water and water that has come into contact with operational areas will be diverted to collection sumps and ultimately the IWWTP for processing and beneficial reuse. The design of the hazardous waste storage facility is such that it will also prevent the release of hazardous liquid wastes. Bunds and sumps are regularly inspected and pumped if required to maintain sufficient storage capacity. Considering these design controls and mitigation measures, hazardous and industrial liquid wastes will not be released to the environment. As

such, the magnitude of the impact to groundwater from the accidental release hazardous industrial and liquid wastes is assessed as ***Negligible.***

Given the sensitivity of surface water is ***Medium***; the overall impact significance rating for groundwater contamination from accidental release of hazardous and industrial liquid wastes is ***Negligible*** for operations.

10.4.4.3 Groundwater Contamination from Accidental Release of Hydrocarbons or Chemicals

The assessment addresses leaks and spills that are typically incidental (but controllable) as part of construction of the industrial landfill and operations specifically related to managing and handling wastes requiring Level 3 approval. Large-scale spills associated with major natural hazards and unplanned events are considered in Chapter 12.

Migration of contaminants to groundwater is dependent upon their physical and/or chemical characteristics and the local hydrogeological regime. It will also depend on the volume of any spill or leak and the response and remediation measures initiated.

From a groundwater perspective, contaminants released at the surface will migrate down through the ground under the influence of gravity where soil permeability allows. Some hydrocarbons would be adsorbed onto soil and retained, whereas others could reach the water table and continue to migrate along the direction of groundwater flow.

Standard good industry practices will be adopted to prevent and protect against ground pollution due to accidental hydrocarbon and chemical spills or leaks during industrial landfill construction and IWMF operations, and to promptly remediate where it occurs.

With the implementation of these measures, the pathway for contaminants to enter groundwater is expected to be limited particularly considering the low permeability of soils at the IWMF and the lack of available groundwater at the IWMF. Impacts from a minor spill or leak that goes undetected would be highly localised should they occur. Impacts to groundwater quality are therefore unlikely to be detectable and the magnitude of impact is assessed as ***Negligible***. Given the sensitivity of groundwater is ***Medium***; the overall impact significance rating for groundwater contamination from accidental release of hydrocarbons and chemicals during all phases of the Project is ***Negligible***.

10.4.4.4 Summary of Residual Impact Assessment

Table 10.8 provides a summary of the residual impact assessment for groundwater quality. All residual impacts to groundwater quality were assessed as ***Negligible.***

Table 10.8 – Groundwater Quality Impact Assessment

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
Groundwater	Contamination of groundwater from accidental release of landfill leachate	• Collection of leachate in leachate collection system • Storage of leachate in leachate storage pond	• EM33 • EM34 • EM35 • EM36 • EM46	Operations	Medium/Negligible	Negligible
Groundwater	Contamination of groundwater from accidental release of hazardous and industrial liquid wastes	• Storage of hazardous and non-hazardous wastes • Handling and processing of hazardous wastes • Fixation of hazardous waste materials	• EM29 • EM30 • EM31 • EM32 • EM47	Operations	Medium/Negligible	Negligible
Groundwater	Contamination of groundwater from accidental release of hydrocarbons and chemicals	• Storage, handling and use of chemicals and fuels • Operation of fixed and mobile plant and equipment • Operation of diesel generators	• EM16 • EM17 • EM18 • EM19 • EM20 • EM21 • EM22 • EM23 • EM24 • EM25 • EM26 • EM27 • EM28	Construction and operations	Medium/Negligible	Negligible

10.5 Air Quality and Greenhouse Gas

10.5.1 Discipline-specific Approach

10.5.1.1 Air Quality

Assessment of air quality data requires consideration of impacts that may be experienced by various environmental receptors as a result of Project activities, with a focus on public health and amenity. The impact assessment addresses potential impacts to ambient air quality and residential and industrial sensitive receptors including Roku village, Tuhava Town and the AES Industrial Park. As described in Section 8.6.1, the IWMF site is located within a developing industrial precinct with relatively high levels of existing particulate matter and dust attributed to existing traffic along Napa Napa Road and construction and industrial activities in the area. An air quality assessment (Appendix 5) modelled and assessed impacts to ambient air quality as a result of Project operations only and involved comparison of predicted pollutant concentrations at sensitive receptors with relevant criteria. As such, the compliance assessment method described in Section 7.3.2 was used to assess air quality impacts from operations. The air quality impact assessment considers the following key pollutants:

- Particulate matter as TSP, PM_{10}, and $PM_{2.5}$.
- Dust deposition.
- Hydrochloric acid (HCl).
- Cadmium (Cd), lead (Pb), mercury (Hg), arsenic (As), and nickel (Ni).
- Dioxins and furans.
- PAH, as benzo(a)pyrene.
- Hexochlorobenzene (HCB).

Since Papua New Guinea currently does not have statutory air quality standards; therefore, the results of the air quality modelling provided in Appendix 5 were assessed against the existing TWM environment permit EP-L2 (485) ambient air quality standards (see Table 10.9). The permitted air quality criteria are based on the following international standards:

- National Environment Protection (Ambient Air Quality) Measure (2016) (NEPC, 2016).
- WHO (2006) Air Quality Guidelines: Global Update 2005: Particulate matter, ozone, nitrogen dioxide (NO_2) and SO_2.

Table 10.9 – EP-L2 (485) Ambient Air Quality Standards

Pollutant	Averaging Period	Maximum Concentration	Maximum Allowable Exceedances
CO	8 hours	9.0 ppm	1 day per year
NO_2	1 hour	0.12 ppm	1 day per year
	1 year	0.03 ppm	None

Pollutant	Averaging Period	Maximum Concentration	Maximum Allowable Exceedances
Ozone	1 hour	0.10 ppm	1 day per year
	4 hours	0.08 ppm	1 day per year
SO_2	1 hour	0.20 ppm	1 day per year
	1 day	0.08 ppm	1 day per year
	1 year	0.02 ppm	None
Lead	1 year	0.50 µg/m^3	None
PM_{10}	24 hours	150 µg/m^3	None
	1 year	70 µg/m^3	None
$PM_{2.5}$	24 hours	75 µg/m^3	None
	1 year	35 µg/m^3	None

For parameters where WHO (2006) and PNG ambient air concentration criteria were absent, relevant criteria from other sources were adopted for the purposes of the assessment and are provided in Table 10.10. These criteria are adopted from the following guidelines:

- Queensland Environmental Protection (Air) Policy (EPP (Air)) 2019.
- Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (NSW EPA, 2016).
- Queensland Department of Environment and Science (DES, 2019) 'Guideline: Application requirements for activities with impacts to air'.
- Texas Commission on Environmental Quality (2016), Effects Screening Levels used by the TCEQ Toxicology Division.

Table 10.10 – Adopted Air Quality Assessment Criteria

Parameter	Averaging Period	Maximum Concentration (µg/m$^{3)}$	Maximum Allowable Exceedances	Source
Cadmium and compounds (measured as the total metal content in PM10	1 year	0.005	None	Qld EPP (Air) 2019
Cadmium and compounds	1 hour	0.018	99.9th percentile	NSW EPA (2016)
Inorganic mercury vapour	1 year	1.1	None	Qld EPP (Air) 2019
Inorganic mercury	1 hour	1.8	99.9th percentile	NSW EPA (2016)
Organic mercury	1 hour	0.18	99.9th percentile	NSW EPA (2016)
Dioxins and furans	1 hour	2.0^{E-6} TEQ	99.9th percentile	NSW EPA (2016)
Hydrogen chloride	1 hour	140	99.9th percentile	NSW EPA (2016)
Arsenic and compounds	1 hour	0.09	99.9th percentile	NSW EPA (2016)

Parameter	Averaging Period	Maximum Concentration (µg/m3)	Maximum Allowable Exceedances	Source
	1 year	0.006	None	Qld EPP (Air) 2019
Nickel and compounds	1 hour	0.18	99.9th percentile	NSW EPA (2016)
	1 year	0.022	None	Qld EPP (Air) 2019
PAH as benzo(a)pyrene	1 hour	0.4	99.9th percentile	NSW EPA (2016)
	1 year	0.0003	None	Qld EPP (Air) 2019
HCB	1 hour	0.25	None	NA
	1 year	0.025	None	Texas Commission on Environmental Quality (2016)
Deposited dust	1 month	120 mg/m²/day	None	DES (2019)
		2 g/m²/month (incremental)	None	NSW EPA (2016)
		4 g/m²/month (cumulative)	None	NSW EPA (2016)

The air quality impact assessment only assesses potential impacts to ambient air quality with impacts to human health and terrestrial biodiversity discussed in Sections 11.2 and 10.8 respectively. Air quality modelling specific to the construction of the industrial landfill was not undertaken; however, the modelled operational scenario included quarrying activities that are similar in nature to earthworks and excavation which will be required for the industrial landfill construction and are likely the key sources for impacts to air quality. As such, the compliance method has also been used for the construction phase using the modelled pollutant concentrations.

Air Pollutant Dispersion Modelling Method

Modelling and prediction of air pollutant concentrations and dispersion were undertaken using the following approach as detailed in Appendix 5:

- Conducting meteorological modelling in the region and vicinity of the Project, using TAPM and Calmet models and incorporating available representative metrological data, to establish wind conditions for input into pollutant dispersion models.
- Establishment of emissions inventories for assessed air pollutants for two project scenarios:
  - **Scenario 1:** A ‘base case’ scenario which represents the currently approved, but not yet operational Level 2 activities; and
  - **Scenario 2:** A ‘proposed scenario’ which includes the extended activities requiring Level 3 assessment in this EIS and represents the change in ambient air quality from the approved Level 2 activities, to the fully operational Level 3 IWMF.

- Conducting air pollutant dispersion modelling using Calpuff (Version 7.2.1) based on the proposed activities emission inventories to predict emissions impacting sensitive receptors and to develop dispersion contours.

10.5.1.2 Greenhouse Gases

The GHG assessment (Appendix 5) considered the Project's potential contribution to climate change by developing an annual GHG emissions inventory for the Project's Level 3 operational activities and adopting an impact significance assessment approach. In this approach, the residual significance of the impacts from Project's estimated annual emissions have been assessed in relation to PNG's national GHG emission inventory from 2000 to 2015, as prepared by the PNG Climate Change Development Authority (CCDA, 2018). As Papua New Guinea does not have GHG assessment or reporting guidelines, the Australian legislative framework has therefore been used instead. Specifically, the GHG assessment has adopted the Australian NGER framework (see Appendix 5) has instead been used for the calculation of Project emissions.

Emissions inventories were compiled for Scope 1 and Scope 2 emissions as defined under the NGER Scheme, which are defined as direct results of one of the following:

- Scope 1 emissions: an activity, or series of activities (including ancillary activities) that constitutes the facility.
- Scope 2 emissions: one or more activities that generate electricity, heating, cooling or steam that is consumed by the facility but that do not form part of the facility.

Scope 3 emissions, defined as indirect emissions other than Scope 2 emissions from sources not owned or controlled by the facility, are not reported under the NGER scheme and have not been included in the GHG assessment.

The following data and assumptions were used in the calculation of the Project's GHG emissions:

- Fugitive gas emissions released from the use of liquid fuels for mobile and fixed plant equipment, and from composting and wastewater, have been determined using Method 1 from the NGER Technical Guidelines (DEE, 2017).
- Emissions from incineration have been calculated using incinerator stack testing results from 2019 (Assured Environmental, 2019).
- There are no areas of vegetation to be cleared that have a crown cover greater than 20%.
- There are no methane or carbon dioxide emissions from the working and breathing losses of tanks containing waste oil (API, 2009).
- Emissions from the landfill are assumed to be minimal considering organic putrescible wastes will be composted and have therefore not been included in the assessment. Non-organic putrescible waste will be incinerated, and the ash fixated for disposal at the landfill and will not result in emissions.

- Emissions from industrial wastewater are also assumed to be minimal, considering the process only involves physical separation of impurities.
- The electricity consumption of the facility has been calculated (see Appendix 5).

Further technical information on the methods used in the calculation of Scope 1 (direct) and Scope 2 (indirect) emissions are provided in Appendix 5. For the purposes of the GHG assessment, the sensitivity of existing GHG levels and the global climate has been characterised as ***High*** given the international concern regarding GHGs and global climate change and PNG's national and international commitments.

10.5.2 Potential Impacts

10.5.2.1 Air Quality

Particulate Matter and Dust Deposition

The temporary increase in local concentrations of airborne particulate matter (TSP, PM_{10}, and $PM_{2.5}$) and dust are expected to occur during both the construction and operations phases as a result of Project activities and may reduce the amenity and quality of ambient air quality. This may result in adverse impacts to the health of local residents and business communities (Section 11.2) and native fauna (Section 10.8) and may impact on the visual amenity of the area (Section 10.7). During landfill construction, particulate matter will likely be emitted during earthworks and excavation works required to prepare the landfill cells and from the transportation of earthen materials, Project personnel and general vehicle movements.

During operations, particulate matter emissions are likely to occur from the handling of dust-covered waste materials, traffic movements including general vehicle movements, the transportation of personnel and equipment and incoming and outgoing waste loads. The dispersion of particular matter from local sources will be influenced by local wind conditions and the topography of the region.

Deposition of Project-generated dust may occur during construction and operations phases of the Project but is more likely to occur during construction where earthen materials will be excavated and transported for construction of the landfill, in addition to transportation of Project personnel and general vehicle movements. During operations, dust emissions will also occur from the transportation of waste, TWM employees and various equipment and materials and the general movement of vehicles and machinery on unsealed surfaces. The dispersion of dust across the landscape will be influenced by local wind and rainfall patterns and topography. Impacts to natural visual amenity as a result of increased dust emissions are described in Section 10.7. Embedded design controls for the mitigation of particulate matter and dust will include:

- Locating Project infrastructure in previously disturbed areas where practicable. [ED3]
- Designing pit and dump haul roads and ramps to limit the travel time and duty cycle for trucks especially when fully loaded. [ED19]

Incinerator-related Emissions

Increased ambient concentrations of pollutants as a result of waste incineration will only occur during the operations phase of the Project, while operational. Potential pollutants that may be present in emissions from the incinerator stack include hydrochloric acid, metals and metalloids (Cd, Pb, Hg, As and Ni), dioxins and furans, PAH, as benzo(a)pyrene, and HCB. The emission of such pollutants will occur through the operations phase of the Project, largely between 7 a.m. and 5 p.m., Monday to Friday and between 7 a.m. and 12 p.m. Saturdays. The incinerator stack (located at the incinerator building) will be the source of potential pollutants. Embedded design controls for the mitigation of particulate matter and dust will include:

- Operating the flue gas treatment as the incinerator pollution control system, for the management of hazardous emissions from the burning of wastes. [ED20]

10.5.2.2 Greenhouse Gases

The emissions of GHGs is a primary driver of climate change, and the Project will contribute to the annual GHG emissions inventory of Papua New Guinea (estimated in kilotonnes (kt) carbon dioxide equivalent units (kt CO_2-e)) and global emissions. The Project has the potential to contribute to an increase in atmospheric GHG levels and therefore contribute to the impacts of global climate changes.

Estimated annual Scope 1 and Scope 2 GHG emissions were calculated for Level 3 operations activities. Potential sources for emissions during construction may include the purchase of electricity (Scope 2), the clearing of vegetation (Scope 1), and the use of diesel fuel in operation of mobile and fixed plant and equipment, use of diesel generators, and vehicles (Scope 1). However, as no areas of vegetation to be cleared have crown cover greater than 20%, GHG emissions as a result of vegetation clearing (i.e., vegetation decay and release of carbon) are included in the GHG emissions inventory as zero, and not assessed.

During operations, GHG emissions will also be released via the use of diesel fuel in the operation of mobile and fixed plant and equipment, use of diesel generators, and vehicles (Scope 1), and grid electricity use (Scope 2). However, potential emissions may also occur through the operations of waste management plant include the incinerator, the IWWTP and the composting operations (Scope 1).

The emissions inventory has not been calculated separately for construction and operations. However, emissions during construction will not include those released to the operation of waste management plant and would therefore be considerably lower. Embedded design controls for the mitigation of GHG emissions will include:

- Including a gas capture system during closure of landfill cells comprising horizontal collection piping and vertical gas extraction wells installed into the deposited wastes to collect landfill gases. [ED21]

- Designing a landfill gas management system for venting of landfill gases to the environment, and installation and gas extraction wells and gas monitoring probes installed. [ED22]

- Considering use of solar energy and other clean energy sources in Project design. [ED23]

10.5.2.3 Summary of Potential Impacts

Potential impacts to ambient air quality and sensitive receptors, as described in Section 8.6.1, as a result of the Project that have been considered in the impact assessment are summarised in Table 10.11.

Table 10.11 – Potential Impacts to Air Quality

Project Phase	Activity/Aspect	Project Component	Potential Impact
Construction and operations	• General vehicle movements • Transport of earthen material • Transport of Project equipment, materials and personnel • Transport of hazardous and non-hazardous wastes • Industrial landfill activities • Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure • Handling of hazardous and non-hazardous wastes	Traffic and transport; accommodation and administration facilities; industrial landfill construction; operation of industrial landfill; operation of incinerator; waste sorting and segregation; weighbridge and receival hall; recycling	Deterioration in receiving air quality and amenity from dust and particulate matter
Operations	• Incineration of hazardous waste	Operation of incinerator	Deterioration in receiving air quality and amenity from incinerator emissions
Construction and operations	• Operation of diesel generators • Operation of fixed and mobile plant and equipment • General vehicle movements • Transport of earthen material • Transport of Project equipment, materials and personnel	Traffic and transport; accommodation and administration facilities; industrial landfill construction; operation of industrial landfill; operation of incinerator	Increased levels of GHGs as a result of fuel and electricity consumption

Project Phase	Activity/Aspect	Project Component	Potential Impact
	• Transport of hazardous and non-hazardous wastes		
Operations	• Incineration of hazardous waste • Treatment of hazardous and industrial liquid wastes	Operation of incinerator; IWWTP	Increased levels of GHGs as a result of waste management plant operations

10.5.3 Mitigation and Management

10.5.3.1 Air Quality

Measures to minimise impacts to ambient air quality due to Project activities will include:

- Using a bentonite mix on unpaved roads and watering of the unpaved haul route within the landfill and quarry area. [EM48]
- Using a bentonite mix on unpaved roads and watering paved/unpaved roads within the IWMF site. [EM49]
- Using wet handling of ash from the incinerator, or alternatively handling the ash in a fully enclosed system or using vacuum trucks. [EM50]
- Ensuring the secondary combustion chamber of the incinerator maintains a temperature above 850°C to reduce dioxin and furan emissions. [EM51]
- Maintaining vehicle speed limits on-site at 20 km/h, or below. [EM52]
- Develop and implement an Air Quality Management Plan. [EM53]
- Scheduling activities involving potential dust generation to avoid wind conditions above 60 km/h. [EM54]
- Limiting vehicle and plant movements to defined access roads and existing operational areas. [EM1]
- Using tarps or covers for trucks and trailers transporting materials to and from the site. [EM55]
- Using a bentonite seal on unsealed roads and spraying water on unsealed roads between the site entrance and site office in dry conditions to reduce dust from vehicle movements. [EM56]
- Operating and maintaining plant and equipment appropriately and in accordance with manufacturers specifications. [EM57]
- Watering of materials prior to loading for haulage, where appropriate. [EM58]

- Avoiding the spraying of herbicides and pesticides during windy conditions. [EM59]
- Minimising the size of stockpiled materials and using water suppression systems, where necessary. [EM60]
- Limiting ground disturbance and vegetation clearing to the extent prescribed in landfill development plans by demarcating areas that require clearing on Project mapping/design drawings and by flagging or signage in the field. [EM3]

10.5.3.2 Greenhouse Gas Emissions

Measures to minimise impacts from GHG emissions as a result of the Project will include:

- Considering energy efficiency as a criterion when selecting diesel and electric powered motors and other equipment for purchase. [EM61]
- Using biodiesel for mobile plant, where practicable. [EM62]
- Installing light sensitive switches and motion sensors to switch on lighting throughout the Project site, where practicable and safe. [EM63]
- Using large haul trucks where practical, to decrease diesel consumption by reducing the number of trips. [EM64]
- Reusing cleared vegetation as timber produce or hydromulch for rehabilitation, to reduce emissions due to decay of vegetation, where practicable. [EM65]
- Establishing vegetation buffers in the direction of the nearest sensitive receptors and Napa Napa Road, using mulch form cleared vegetation. [EM66]
- Rehabilitating disturbed land as soon as practicable to allow subsequent growth of vegetation to provide an offset sink for CO_2. [EM67]
- Using production monitoring systems and payload management to maximise the loads of each bucket dug by excavators and each load carried by trucks. [EM68]
- Using production monitoring systems to minimise fuel-burn rates and reduce the time when trucks are idling. [EM69]
- Maintaining equipment to retain energy efficiency. [EM70]
- Compacting haul roads to minimise vehicle rolling resistance, for reductions of diesel consumption. [EM71]
- Recycling water in processing operations to reduce off-site pumping requirements. [EM72]
- Undertaking regular checking of compressed air tubing to identify and repair leaks. [EM73]

- Providing training for operators of mobile plant in how to minimise fuel consumption, including no unnecessary idling. [EM74]
- Using local personnel to reduce transport emissions, where practicable. [EM75]
- Obtaining construction materials and ongoing consumables from local suppliers to reduce fuel consumption, as far as practicable. [EM76]
- Undertaking an internal energy audit and energy mass balance following completion of annual reporting to ensure that the activities are using best practice for minimisation of energy consumption. [EM77]
- Developing a system for tracking, monitoring and optimising energy use across the site. [EM78]
- Monitoring of landfill gas extraction wells monthly for pressure, temperature, methane, carbon dioxide and oxygen levels using hand held single reading monitors. [EM79]

10.5.4 Residual Impact Assessment

10.5.4.1 Air Quality

Predicted concentrations and levels of Project-related air pollutants are presented in Table 10.12 for the worst affected receptor for each indicator, with comparison made to the relevant air quality criteria. Predicted concentrations at all other sensitive receptors were equal to or below those shown in Table 10.12.

Table 10.12 – Summary of Results for Predicted Concentrations

Indicator	Worst Affected Receptor	Prediction from Projected ($\mu g/m^3$)		Cumulative Prediction with Background		Criterion ($\mu g/m^3$)
		Scenario				
		Base Case	*Proposed*	*Base Case*	*Proposed*	
Annual average TSP	B	4	4	79	79	90
Maximum 24-hour average PM_{10}	B	6	6	45	45	150
Annual average PM10	B	2	2	31	31	70
Maximum 24-hour average $PM_{2.5}$	B	4	4	14	14	75
Annual average $PM_{2.5}$	B	1	1	9	9	35
Annual average lead	A	2.5^{E-6}	1.2^{E-4}	2.5^{E-6}	1.2^{E-4}	0.5
Maximum 1-hour average cadmium	A	1.8^{E-5}	2.1^{E-4}	1.8^{E-5}	2.1^{E-4}	0.018

Indicator	Worst Affected Receptor	Prediction from Projected (µg/m³)		Cumulative Prediction with Background		Criterion (µg/m³)
		Scenario				
		Base Case	*Proposed*	*Base Case*	*Proposed*	
Annual average cadmium	A	7.67^{E-7}	9.2^{E-6}	7.67^{E-7}	9.2^{E-6}	0.005
Maximum 1-hour average mercury	A	3.6^{E-5}	1.2^{E-4}	3.6^{E-5}	1.2^{E-4}	0.18
Annual average mercury	A	1.5^{E-6}	5.2^{E-6}	1.5^{E-6}	5.2^{E-6}	1.1
Maximum 1-hour average dioxins and furans	A	8.2^{E-7}	8.3^{E-7}	8.4^{E-7}	8.4^{E-7}	2.0E-6
Maximum 1-hour average hydrogen chloride	A	2.8^{E-2}	2.8^{E-2}	2.8^{E-2}	2.8^{E-2}	140
Maximum 1-hour average arsenic	A	4.3^{E-4}	4.3^{E-4}	4.3^{E-4}	4.3^{E-4}	0.09
Annual average arsenic	A	1.8^{E-5}	1.8^{E-5}	1.8^{E-5}	1.8^{E-5}	0.006
Maximum 1-hour average nickel	A	4.3^{E-3}	4.3^{E-3}	4.3^{E-3}	4.3^{E-3}	0.18
Annual average nickel	A	1.8^{E-4}	1.8^{E-4}	1.8^{E-4}	1.8^{E-4}	0.022
Maximum 1-hour average PAH	A	1.0^{E-7}	4.3^{E-5}	1.0^{E-4}	1.0^{E-4}	0.4
Annual average PAH	A	4.4^{E-9}	1.8^{E-6}	1.0^{E-4}	1.0^{E-4}	3.0E-4
Maximum 1-hour average HCB	A	2.1^{E-4}	2.2^{E-4}	2.2^{E-4}	2.2^{E-4}	0.25
Annual average HCB	A	9.2^{E-6}	9.2^{E-6}	9.2^{E-6}	9.2^{E-6}	0.025
Maximum 30-day dust deposition	B	46 mg/m² per day	46 mg/m² per day	96 mg/m² per day	96 mg/m² per day	120 mg/m² per day
Annual average dust deposition	B	0.9 g/m² per month	0.9 g/m² per month	2.4 g/m² per month	2.4 g/m² per month	4 g/m² per month

Source: Appendix 5.

Particulate Matter and Dust Deposition

Particulate Matter

Predicted concentrations and levels of all particulate matter parameters (TSP, PM_{10}, $PM_{2.5}$) at each sensitive receptor are presented in Table 10.12. All assessed pollutants are predicted to be below the relevant criteria, including background levels, for both the 'base case scenario' of existing approved activities and the 'proposed scenario' for Level 3 extended activities at all

receptor locations. As such, all particulate matter emissions pollutants are anticipated to comply with relevant guideline criteria. Concentrations are predicted to vary minimally between 'base case' and 'proposed' scenarios, with the difference considered unlikely to be discernible (Appendix 5). Furthermore, the relatively high background levels assumed for the impact assessment, as described in Section 8.6.1, are higher contributors to the cumulative predicted concentrations (i.e., both Project and background levels) for both modelled scenarios than the increased particulate emissions from the Project (Appendix 5). The only particulate matter parameter in which modelled predictions approach the relevant criterion was the cumulative annual average TSP, for which a concentration of 79 µg/m^3 was predicted at receptor B (AES), 75 µg/m^3 of which was from existing background levels. However, the predicted concentration was still compliant with the adopted criterion of 90 µg/m^3 for both scenarios (Table 10.12). Figure 10.2 shows the modelled contours of predicted TSP concentrations in relation to sensitive receptors.

Dust Deposition

The results of the air pollutant dispersion monitoring, as shown in Table 10.12 indicate that dust deposition levels for both the 'base case scenario' and the 'proposed scenario' will comply with adopted criteria at all sensitive receptors. For dust deposition levels, there is little to no between the 'base case' predictions and the 'proposed scenario' for Level 3 activities and the differences in dust levels would be undetectable. Impacts are likely to be minimal given that construction activities will occur over a 1-year period only and will not continue into the long term, and as the IWMF site already has relatively high background levels of particulate matter and dust (see Section 8.6.1). Additionally, local rainfall within the region that 'washes' the foliage will further reduce the impacts. Dust deposition rates generally decrease rapidly with distance from the source, and any damage to vegetation or human receptors as a result of dust emissions is expected to be very localised.

Furthermore, dust deposition levels were compliant with adopted Project criteria for cumulative concentrations, for both the maximum 30-day dust deposition and annual average dust deposition, that included existing levels of background dust levels. The nearest predicted concentration to a relevant criterion is the cumulative maximum monthly (30-day) deposition level including background, which is predicted to be 96mg/m^2 per day at Tuhava Town, in comparison to the relevant guidelines value of 120 mg/m^2 per day. Contours of predicted maximum 30-day cumulative dust deposition are shown in Figure 10.3. For both the maximum 30-day and annual average dust deposition predictions, the majority of cumulative concentrations will be as a result of existing background dust deposition (see Table 10.12). Regardless, dust deposition predictions for both scenarios are expected to be compliant with the relevant criteria at all sensitive human receptors during operations. While the emission of particulate matter and dust deposition were not modelled explicitly for the construction phase of the Project, the modelled scenarios did include quarrying activities including crushing, handling of material and screening that could be considered similar to landfill construction works such as earthworks and ground disturbance. As such, the modelled predictions provided in Table 10.12 and Appendix 5 for operations have been used in place of modelling specifically for landfill construction. As such, compliance with relevant criteria for dust deposition and particulate matter emissions during landfill construction is also expected.

PREDICTED ANNUAL AVERAGE TSP CONCENTRATIONS INCLUDING BACKGROUND (µg/m³)

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FIGURE 10.2



Source: Appendix 5

PREDICTED MAXIMUM 30-DAY CUMULATIVE DUST DEPOSITION LEVELS INCLUDING BACKGROUND (mg/m²/day)

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FIGURE 10.3



Source: Appendix 5

Incinerator-related Emissions

The predicted concentrations and levels of all incinerator-related emissions are expected to comply with the relevant air quality criteria, as shown in Table 10.12 at the sensitive human receptors for both 'base case' and 'proposed' scenarios. While the modelled cumulative predictions include adopted background levels and comply with the relevant air quality criteria, the vast proportion of predicted cumulative concentrations are as a result of the burning of waste and not existing background levels which are expected to be minimal. Modelling predicted that the pollutants of most concern due to the incinerator emissions would be dioxins and furans (maximum 1-hour average), with Tuhava Town predicted to be the worst affected receptor.

The predicted concentrations at the sensitive receptors were within the criterion with the highest predicted concentration at Tuhava Town, 8.4^{E-7} µg/m^3, substantially lower than the relevant criteria of 2.0^{E-6}. Tuhava Town is predicted to be the worst affected receptor for all other pollutants but predicted results for all pollutants are compliant with relevant criteria and there are no discernible differences predicted to air quality between Level 2 and Level 3 activities. Figure 10.4 shows the predicted dispersion of predicted dioxins and furans concentrations, in relation to the sensitive human receptors identified in Section 8.6.1. Predictions for dioxins and furans are based on the highest concentrations recorded on site during stack testing (under the 'base case' scenario) which are likely to be an overestimate of actual concentrations due to the adjustments made to operation of the incinerator since.

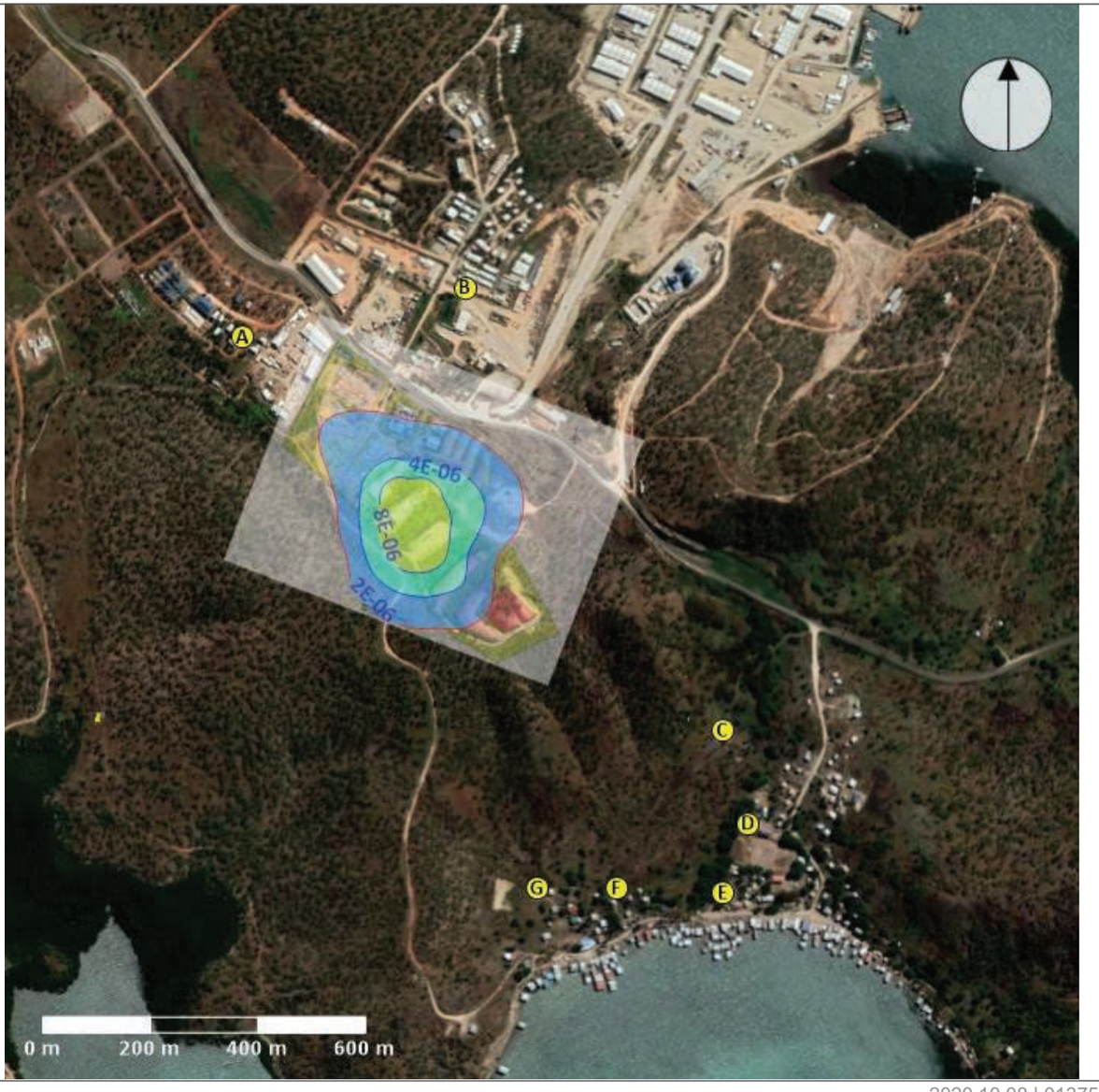
10.5.4.2 Greenhouse Gases

A summary of the estimated annual GHG emissions for Level 3 operations (i.e., the 'proposed scenario) is presented in Table 10.13, with an estimated annual GHG emissions of 4.7 kt CO2-e. The major contributing source of GHG emissions is the operation of waste management plant such as the IWWTP, composting and the incinerator. Although not calculated for Level 2 activities (i.e., the 'base case scenario'), the difference in GHG emissions for the 'base case' and the 'proposed' scenarios is likely to be minimal (Appendix 5). It is considered likely that both Scope 1 and 2 GHG emissions would be slightly higher for the 'proposed scenario', as it would be expected that waste volumes treated at the IWMF would be slightly higher (Appendix 5). Furthermore, while also not modelled, GHG emissions from construction would likely be lower than the operations activities given the operation of the waste management plant is the largest contributor to annual estimated GHG emissions (see Table 10.13).

PREDICTED 99.9th PERCENTILE 1-HOUR DIOXINS AND FURANS CONCENTRATIONS INCLUDING BACKGROUND (µg/m³)

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FIGURE 10.4



Source: Appendix 5

Table 10.13 – Summary of Estimated Annual GHG Emissions for Operations

Activity	Emissions Scope	Total Emissions (kt CO_2-e)
Equipment and power generation fuel combustions	Scope 1	0.21
Vegetation cleared	Scope 1	0
Composting	Scope 1	1.7
Wastewater treatment	Scope 1	22
Waste incineration	Scope 1	0.63
Grid electricity consumption	Scope 2	0.67
Total	**-**	**4.7**

Source: Appendix 5.

As described in Section 10.5.1, the sensitivity of the environmental value/receptor of GHG levels and global climate has been characterised as ***High*** due to the international concern about GHGs, the implication of increasing levels on the global climate and the climate change commitments of Papua New Guinea. In 2015, Papua New Guinea's reported GHG emissions inventory was 15,193 kt CO_2-e. As such, estimated annual GHG emissions from both energy consumption (diesel fuel and electricity) during construction and operations, and from the operation of waste management plant, will contribute approximately 0.0003% to the combined national annual GHG emissions. The impact magnitudes for increased GHG emissions from energy consumption during both construction and operations is therefore considered ***Negligible***, as is the impact magnitude for GHG emissions from waste management plant operations. The residual impact significance for impacts occurring from energy consumption during construction and operations are therefore ***Minor***, as is the residual impact significance of GHG emissions from waste management plant operations.

10.5.4.3 Summary of Air Quality and Greenhouse Gas Impact Assessment.

The compliance method adopted for assessing air quality impacts indicates that all potential pollutants considered in the assessment are compliant with relevant criteria for both phases of the Project and there are no discernible differences predicted to air quality between Level 2 and Level 3 activities

Table 10.14 provides a summary of the residual impact assessment for GHG emissions which was assessed as ***Minor*** for both phases of the Project.

Table 10.14 – Air Quality and Greenhouse Gas Impact Assessment

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
GHG levels and global climate	Increased levels of GHGs as a result of fuel and electricity consumption	• Operation of diesel generators • Operation of fixed and mobile plant and equipment • General vehicle movements • Transport of earthen material • Transport of Project equipment, materials and personnel • Transport of hazardous and non-hazardous wastes	• EM48 • EM49 • EM50 • EM51 • EM52 • EM53 • EM54 • EM1 • EM55 • EM56 • EM57 • EM58 • EM59 • EM60 • EM3	Construction and operations	High/Negligible	Minor
	Increased levels of GHGs as a result of waste management plant operations	• Incineration of hazardous waste • Treatment of hazardous and industrial liquid wastes	• EM61 • EM62 • EM63 • EM64 • EM65 • EM66 • EM67 • EM68 • EM69 • EM70 • EM71	Operations	High/Negligible	Minor

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
			• EM72 • EM73 • EM74 • EM75 • EM76 • EM77 • EM78 • EM79			

10.6 Noise

10.6.1 Discipline-specific Approach

The significance assessment method described in Chapter 7 was adopted to qualitatively assess noise-related impacts associated with construction of the industrial landfill. This considers the sensitivity of the resource/receptor and the magnitude of impact on that resource/receptor. The IWMF is located within an industrial precinct where existing daytime noise levels are dominated by traffic using Napa Napa Road and industrial activities. Night time noise is expected to be dominated by insects, birds, wind and rain. There are both residential and commercial/industrial receptors located within close proximity to the IWMF and the site is adjacent to savanna habitat which may provide habitat to a range of fauna which could be sensitive to changes to the local noise amenity. The existing noise environment that may be impacted by construction noise is considered to have a ***Medium*** sensitivity, considering construction activities will be limited to daytime hours when existing industrial activities and traffic are the dominant sound sources in the surrounding area.

The assessment of noise-related impacts associated with operations was undertaken using the compliance assessment method (described in Section 7.3.2) by comparing the noise modelling results (Appendix 6) to the existing noise criteria specified in EP-L2 (485). The permitted noise criteria are based on the IFC noise level guidelines (IFC, 2007) and are provided in Table 10.15. Given that normal operations at the IWMF will be limited to daytime hours, these are the most applicable criteria for the compliance assessment.

Table 10.15 – EP-L2 (485) Noise Criteria

Receptor Type	Noise Criteria L_{Aeq} (1-hour Equivalent Continuous Sound Pressure Level)	
	Day (7 a.m. to 10 p.m.)	*Night (10 p.m. to 7 a.m.)*
Residential	55 dBA	45 dBA
Industrial and Commercial	70 dBA	70 dBA

10.6.2 Potential Impacts

Noise emissions related to industrial landfill construction and the broader operational activities of the IWMF have the potential to cause adverse impacts on the sensitive receptors in the vicinity of the site and surrounding environment. Potential noise sources will occur in both construction and operations phases of the Project and will include vehicles, mobile plant, equipment and machinery as well as waste receiving, sorting, treating and disposing activities. Received noise levels above those specified in Table 10.15 have the potential to affect local 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.

This section considers potential impacts to noise quality, i.e., local amenity. The potential impacts of increased noise on people's health and speech communication are considered in Section 11.2 while potential impacts of noise on terrestrial fauna are considered in Section 10.8.

Potential noise impacts due to the Project considered in the noise impact assessment are summarised in Table 10.16.

Table 10.16 – Summary of Potential Impacts on Noise

Project Phase	Activity/Aspect	Project Component	Potential Impact
Construction	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure • Operation of fixed and mobile plant and equipment • Transport of Project equipment, materials and personnel • Operation of diesel generators	Industrial landfill construction; traffic and transport	Reduction in local amenity due to increased noise emissions from industrial landfill construction
Operations	• Operation of fixed and mobile plant and equipment • General vehicle movements • Transport of earthen material • Transport of Project equipment, materials and personnel • Transport of hazardous and non-hazardous wastes • Operation of diesel generators • Industrial landfill activities • Incineration of hazardous waste • Handling of e-waste and plastics reprocessing	Operation of industrial landfill; traffic and transport; operation of incinerator; waste sorting and segregation; weighbridge and receival hall; IWWTP; fixation bays; hazardous waste storage	Reduction in local amenity due to increased noise emissions from operations

10.6.3 Mitigation and Management Measures

10.6.3.1 Reduction in Local Amenity due to Increased Noise Emissions from Industrial Landfill Construction and IWMF Operations

Measures to mitigate impacts from noise emissions associated with construction of the industrial landfill and IWMF operations will include:

- Maximising the offset distance between noisy plant items (including fixed construction plant) and nearby noise sensitive receptors, where practicable. [EM80]
- Selecting construction plant and equipment based on industry good practice and reducing the amount of equipment and machinery operating simultaneously, where practicable. [EM81]
- Maintaining construction vehicles and equipment in order to limit noise emissions. [EM82]
- Maintaining noise suppression devices on construction vehicles and equipment. [EM83]
- Developing and implementing a service and maintenance schedule according to manufacturer's specifications. [EM27]
- Using engineering controls to diffuse or minimise the noise at the source such as fitting exhaust mufflers or fixing damping materials to reduce vibration. [EM84]
- Limiting construction and operations to daylight hours where possible and providing advanced notice to neighbouring operations and/or residents if work is proposed outside normal operating hours. [EM85]

10.6.4 Residual Impact Assessment

10.6.4.1 Reduction in Local Amenity due to Increased Noise Emissions from Industrial Landfill Construction

Construction of the industrial landfill will require up to an additional 36 vehicles per day to access the IWMF as well as earthworks and ground disturbance works to be undertaken by excavators, dozers, front end loaders and trucks, and the use of other fixed and mobile plant and equipment. It is anticipated the landfill construction will take up to 12 months for completion (including pre-construction activities). An increase in noise emissions will occur during this time. The existing environment permit (which permits the construction of a municipal waste landfill) does not specify construction noise criteria. Modelling of noise emissions associated with construction of the industrial landfill was not specifically undertaken as the landfill contractor is yet to be appointed, so the details regarding the specific plant and machinery to be used are unknown. Notwithstanding, a number of scenarios were modelled which are considered to be indicative of construction noise and have been used to guide the impact assessment. The detailed noise modelling report is provided in Appendix 6.

Noise modelling was carried out using SoundPLAN and the CONCAWE algorithm. The model incorporates terrain data and the surrounding natural topography. Noise levels were predicted for calm conditions (no wind) and worst-case credible wind directions at the three closest residential

and commercial/industrial receptors considering a number of different operational scenarios. The wind speed adopted for the worst-case scenario was 4 m/s based on meteorological modelling undertaken (Appendix 5). These wind speeds are most likely to occur in the afternoons, particularly between 2 and 5 p.m. One of the closest residential receptors is a stilted house (located at Tuhava Town) which is equivalent to a two-story building, so the model considered receptor heights of both 4.6 m and 1.8 m above ground levels to predict noise levels for both stilted and ground level receptors.

The SoundPLAN model assumes the wind direction is from the source to each receptor and thus modelling for multiple wind directions is not required. The model considered the sound power levels of a variety of mobile and fixed equipment and operational activities. The model considers noise produced from the IWMF operations but not existing background noise levels at the identified receivers.

Pre-construction activities will be undertaken at the proposed industrial landfill site in preparation for construction of the landfill cell. Pre-construction activities will occur over an approximate 2 to 3 month period and will be followed by landfill construction which is expected to take 6 to 7 months. Quarrying activities may also be undertaken during this period. Two scenarios were modelled relevant to quarrying, pre-construction and construction activities, which included:

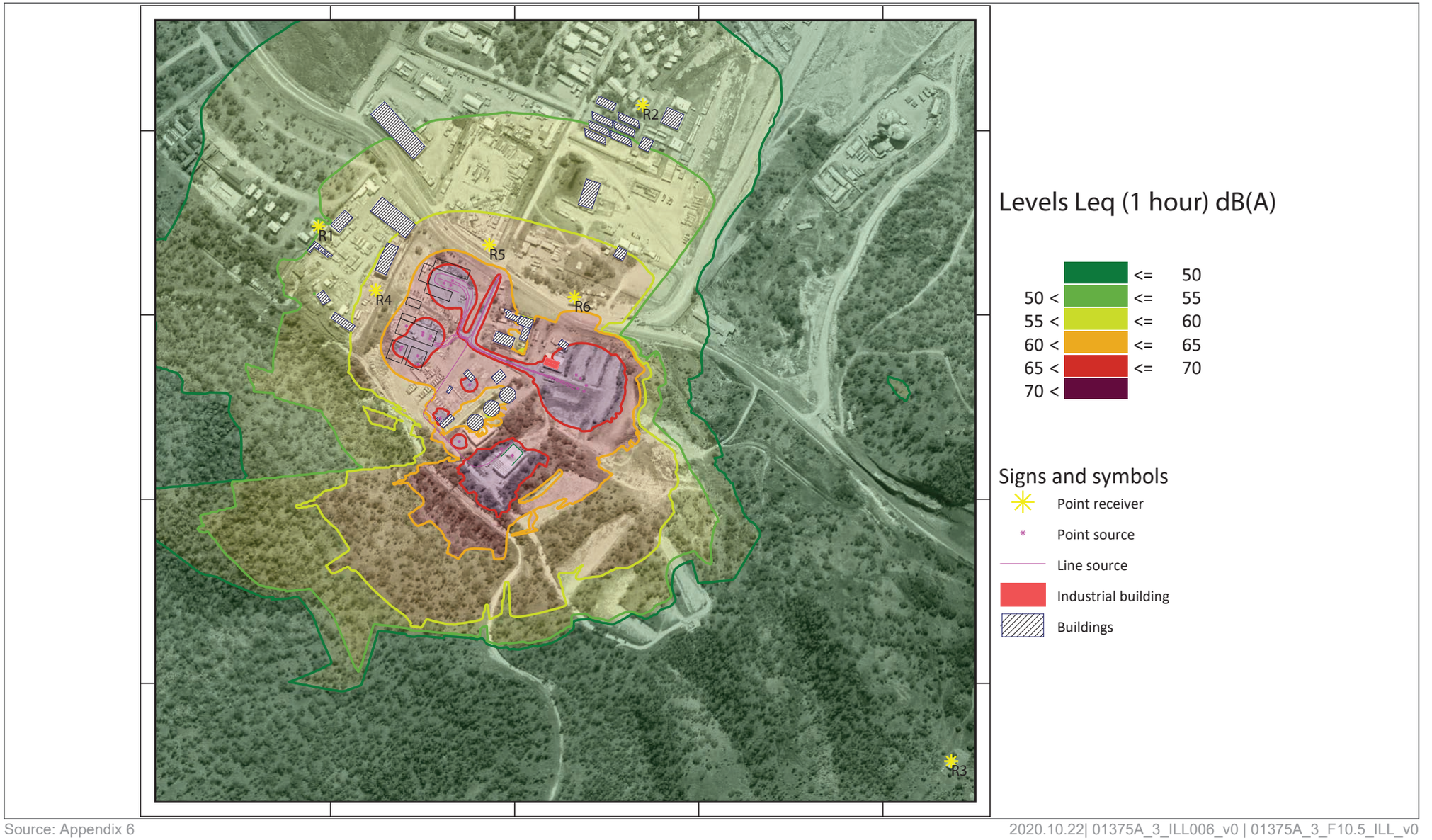
- **Scenario 1**: quarrying/pre-construction activities involving the use of a dozer and excavator and front end loader occurring concurrently with the other IWMF operations (except the industrial landfill).
- **Scenario 2**: quarrying activities involving the use of a screener and crusher and front end loader occurring concurrently with the other IWMF operations (except the industrial landfill).

Scenario 1 resulted in the highest noise levels with results provided in Table 10.17. In addition to the quarrying and pre-construction activities modelled, this scenario includes the use of forklifts, front end loaders, dump trucks, articulated trucks, haulage trucks, pumps, generators and the operation of the incinerator within the other operational areas of the IWMF (see Appendix 6). This scenario is considered indicative of the noise levels expected during construction of the industrial landfill due to the use of similar plant and machinery in the same area. The predicted noise levels from this scenario under calm and worst-case conditions are provided in Table 10.17 and noise contour plots and the modelled receptor locations are shown in Figure 10.5 and Figure 10.6 for worst-case conditions considering a receiver height of 4.6 m (double story/stilted dwelling) and 1.8 m (single story dwelling) respectively. Noise contour plots for Scenario 1 calm conditions are included in Appendix 6 along with results for Scenario 2.

SCENARIO 1 NOISE CONTOUR PLOTS FOR WORST-CASE CONDITIONS AT 4.6 m

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FIGURE 10.5

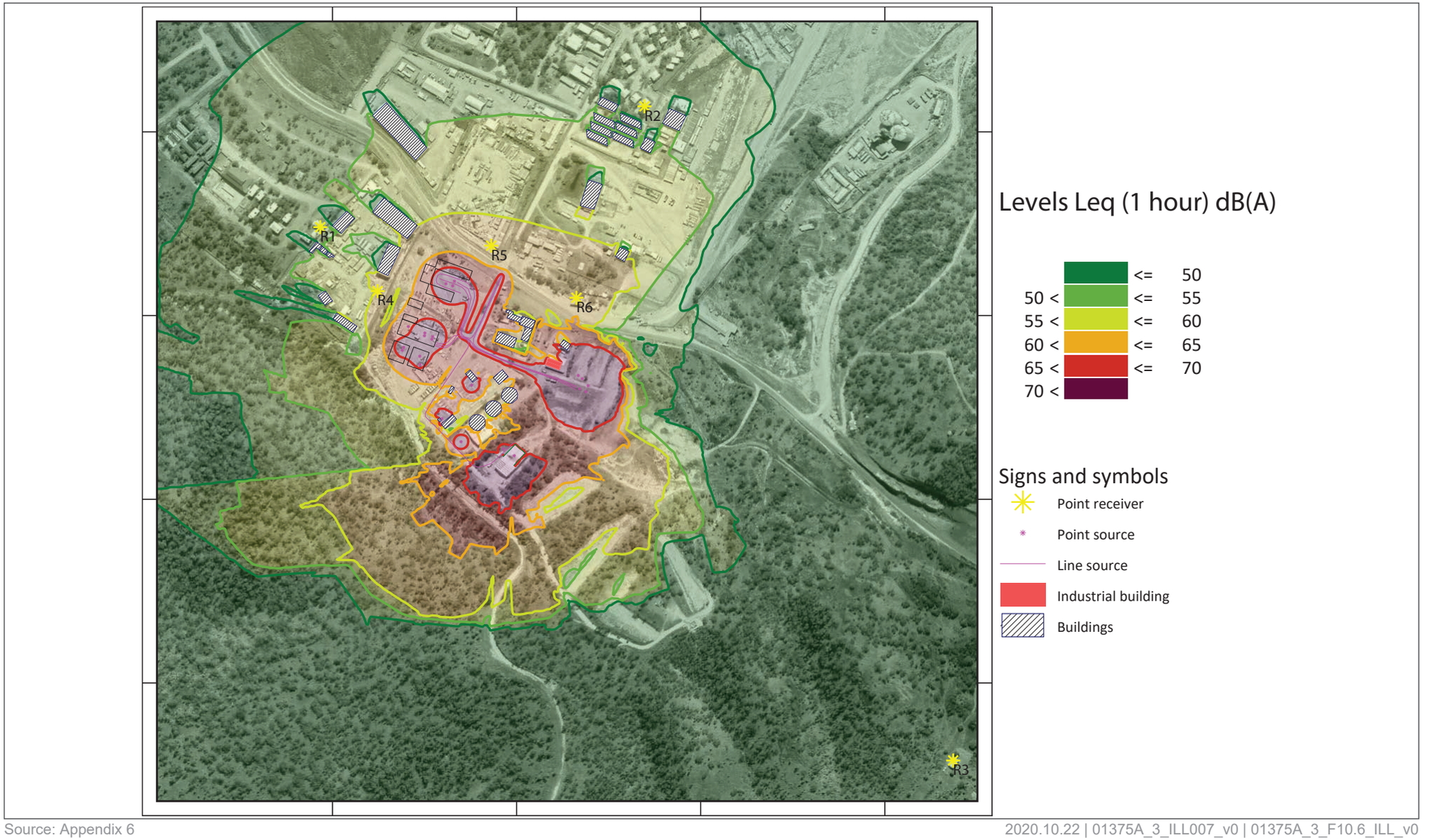


Source: Appendix 6

SCENARIO 1 NOISE CONTOUR PLOTS FOR WORST-CASE CONDITIONS AT 1.8 m

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FIGURE 10.6



Source: Appendix 6

Table 10.17 – Predicted Noise Levels for Scenario 1

Receptor Location	Receptor Height (m)	Receptor Type	Predicted Noise Level $L_{eq, 1hour}$ dBA	
			Calm Conditions (Day)	*Worst-case Conditions (Day)*
R1 (Tuhava Town)	4.6	Residential	52	55
R2 (AES accommodation)	1.8	Residential	49	54
R3 (Roku village)	1.8	Residential	26	31
R4 (Rhodes PNG & AGL Builders)	1.8	Commercial	59	61
R5 (Agility)	1.8	Commercial	61	63
R6 (AES)	1.8	Commercial	62	64

Source: Appendix 6.

Given industrial landfill construction could take up to 12 months, the operational noise criteria presented in Table 10.15 are considered appropriate for comparison to the noise levels provided in Table 10.17. Considering the results for Scenario 1, indicative of landfill construction, noise levels from IWMF operations (not considering background noise levels) may be close to the operational noise criteria at the Tuhava Town and AES accommodation but would be substantially lower at the nearest house in Roku village. Considering the nearest commercial and industrial receptors, under worst-case conditions noise levels will likely be well below the operational noise criteria.

Based on the indicative noise levels provided in Table 10.17, short term impacts (up to 12 months) to the local amenity are expected to occur during the industrial landfill construction, but these impacts will be localised, being primarily limited to within a few hundred metres of the IWMF and to accommodation within the existing industrial precinct. While an increase in noise will likely be discernible at Roku village, noise levels are predicted to be substantially lower than applicable noise criteria. Worst-case conditions, when impacts are most likely to occur, would not occur for extended periods of time (if at all) thereby also reducing the potential duration of impacts and increased noise levels will be limited to daylight hours and the type of noise will be commensurate with the existing noise sources in the industrial precinct. As such, the magnitude of the impact of is assessed as ***Low.*** Considering the sensitivity of local noise amenity is ***Medium***; the overall impact significance rating for reduction in local amenity due to increased noise emissions from construction of the industrial landfill is ***Minor***.

10.6.4.2 Reduction in Local Amenity due to Increased Noise Emissions from Operations

As described in Section 10.6.4.1, noise modelling was undertaken considering three operational scenarios. In addition to Scenario 1 and 2 described in the previous section, the third scenario modelled involved the operations of the industrial landfill occurring concurrently with all other IWMF operations. This scenario represents the combined noise levels associated with the IWMF once all Project components have been commissioned and are operational and represents the cumulative scenario of the already approved Level 2 activities as well as the proposed Level 3 activities. With the exception of the industrial landfill, the operation/use of the Project components

described in Chapter 4 are approved under the existing environment permit; however, much of this infrastructure is yet to be commissioned.

Table 10.17, provided in the previous section, presents the worst-case predicted noise levels considering the operations of the already approved, but yet to be fully commissioned Level 2 activities and Project infrastructure. This scenario includes activities, plant, vehicles and machinery associated with material sorting and segregation, recycling, incineration, waste oil recycling, fixation, wastewater treatment, operations at the warehouse and quarrying. While the Level 3 permit proposes to extend the types of waste received, treated, stored and disposed of at the IWMF, the operation of these components is already approved. Table 10.17 and Figures 10.5 and 10.6 show that under worst-case conditions noise levels associated with the approved Level 2 activities will be at or below the applicable criteria for residential and commercial/industrial receptors. It should be noted that there are a number of conservative assumptions used in the model and worst-case conditions are unlikely to occur for extended periods, if at all.

Table 10.18 presents the predicted noise levels for Scenario 3 which considers landfill operations and represents the change in predicted noise levels from the approved Level 2 activities, to the fully operational IWMF under a Level 3 permit. This scenario does not include the relatively short-term quarrying and construction activities which will not occur simultaneously with landfill operations. Figures 10.7 and 10.8 show the predicted noise contours for worst-case conditions considering a receiver height of 4.6 m (double story/stilted dwelling) and 1.8 m (single story dwelling) respectively. Noise contour plots for calm conditions are included in Appendix 6.

Table 10.18 – Predicted Noise Levels for Scenario 3

Receptor Location	Receptor Height (m)	Receptor Type	Applicable Day Time Noise Criteria ($L_{eq, 1hour}$ dBA)	Predicted Noise Level ($L_{eq, 1hour}$ dBA)	
				Calm Conditions (Day)	*Worst-case Conditions (Day)*
R1 (Tuhava Town)	4.6	Residential	55	51	54
R2 (AES accommodation)	1.8	Residential	55	48	52
R3 (Roku village)	1.8	Residential	55	26	31
R4 (Rhodes PNG & AGL Builders)	1.8	Commercial	70	59	60
R5 (Agility)	1.8	Commercial	70	61	62
R6 (AES)	1.8	Commercial	70	60	62

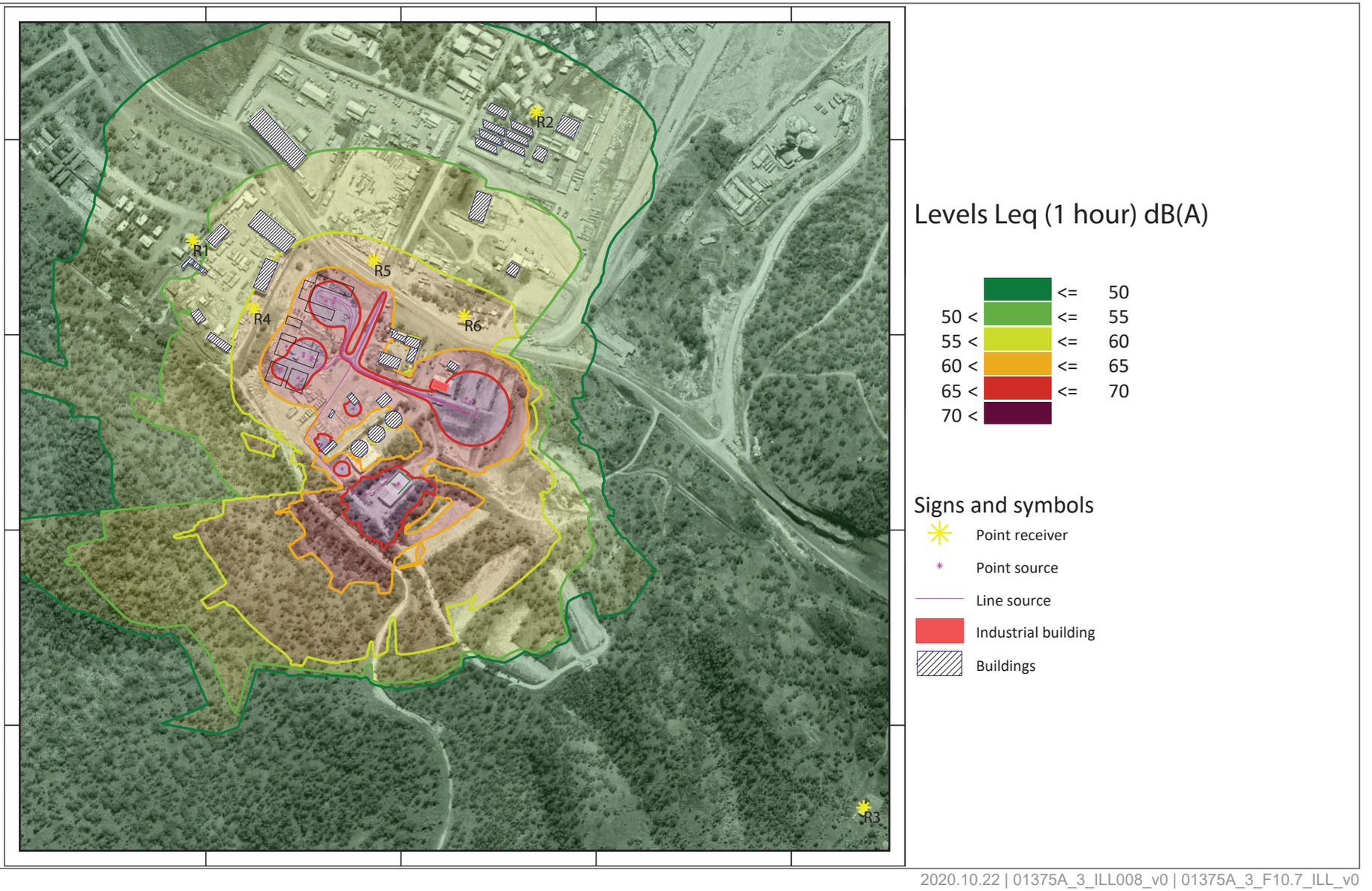
Source: Appendix 6.

As shown in Table 10.18, the predicted noise levels which are related to IWMF operations, but do not consider background noise levels, are at or below the applicable noise criteria and therefore demonstrate compliance for both calm and worst-case conditions. Under worst-case conditions the predicted noise levels at the nearest stilted dwelling at Tuhava Town would be just below the applicable criteria. It should be noted that this accommodation is located within an industrial precinct where existing noise is already influenced by surrounding industrial activities and traffic

SCENARIO 3 NOISE CONTOUR PLOTS FOR WORST-CASE CONDITIONS AT 4.6 m

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FIGURE 10.7

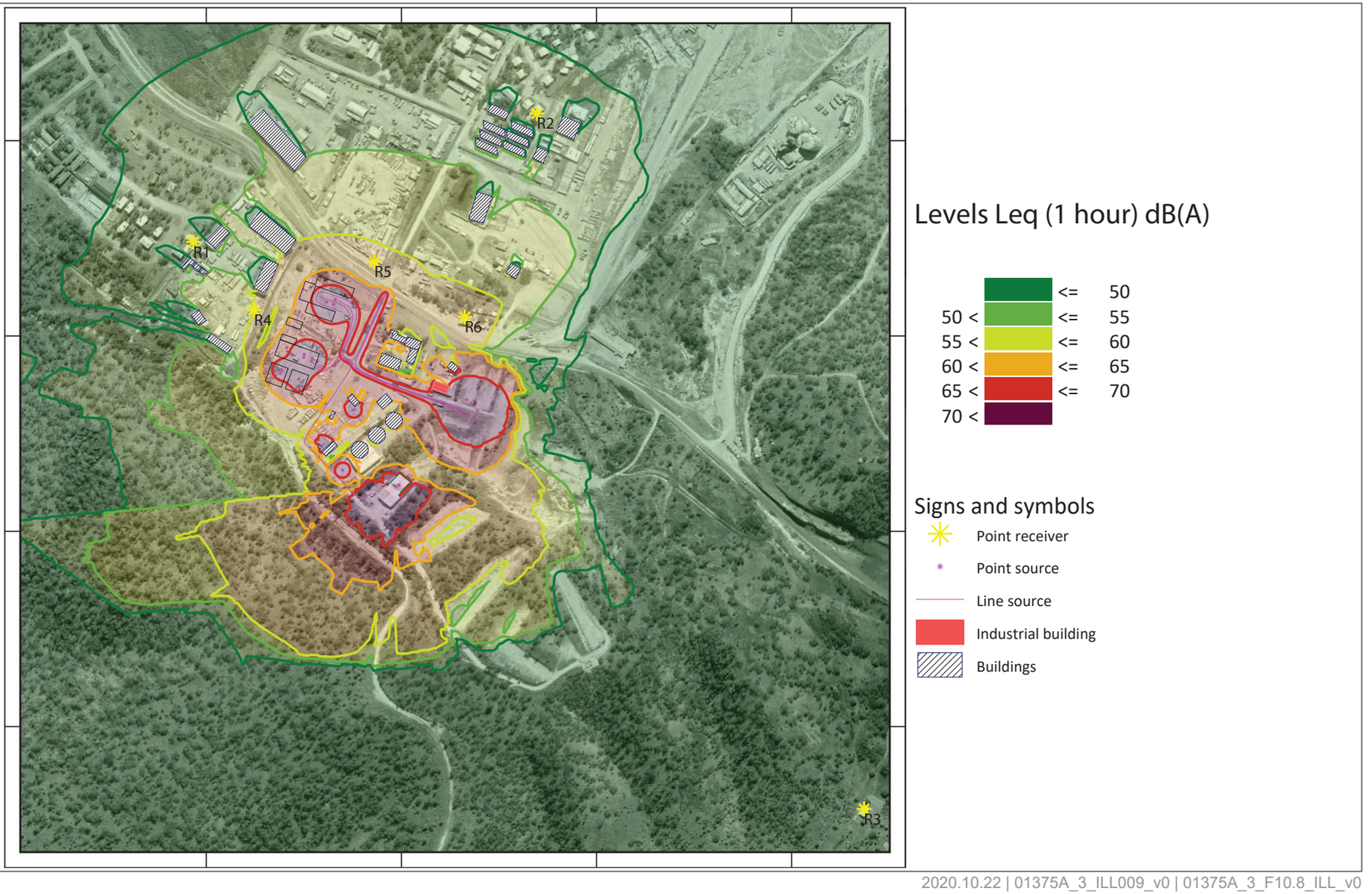


Source: Appendix 6

SCENARIO 3 NOISE CONTOUR PLOTS FOR WORST-CASE CONDITIONS AT 1.8 m

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FIGURE 10.8



Source: Appendix 6

along Napa Napa Road and worst-case conditions are unlikely to occur for extended periods. The noise model also does not consider the effect of noise attenuating mitigation measures or the actual noise levels received inside the residents (which will be influence by the building materials used).

Noise levels will also decrease between Scenario 1, which includes the approved Level 2 activities and Scenario 3, the fully operational IWMF, when pre-construction and construction activities have ceased. While an increase in noise will likely be discernible at Roku village, noise levels are predicted to be below applicable noise criteria and changes to the local noise amenity will be limited to daytime hours. Further, the noise sources during operations will be commensurate with existing (and future) noise sources in the industrial precinct.

10.6.4.3 Summary of Residual Impact Assessment

Table 10.19 provides a summary of the residual impact assessment for noise associated with construction of the industrial landfill which was assessed as ***Minor.***

The compliance method adopted for operational noise levels indicates that once all Project components have been commissioned and the industrial landfill is operational, noise levels will comply with the criteria provided in EP-L2 (485) under worst-case noise propagating conditions. Under worst-case conditions, which are unlikely to occur for extended periods (if at all), operational noise levels will be close to the criteria at the closest accommodation at Tuhava Town and AES.

Table 10.19 – Construction Noise Impact Assessment

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
Residential, commercial and industrial receptors	Reduction in local amenity due to increased noise emissions from industrial landfill construction	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure • Operation of fixed and mobile plant and equipment • Transport of Project equipment, materials and personnel • Operation of diesel generators	• EM80 • EM81 • EM82 • EM83 • EM84 • EM27 • EM85	Construction	Medium/Low	Minor

10.7 Visual Amenity

10.7.1 Discipline-specific Approach

The significance assessment method described in Chapter 7 was adopted to qualitatively assess impacts to visual amenity. Changes in visual amenity are considered in the context of three components:

1. The existing landscape character and the relative capacity of the landscape to accommodate changes resulting from the Project (sensitivity of the resource).
2. How changes to the landscape are viewed by receptors (or viewers) based on their likely expectations and experience (sensitivity of the receptor).
3. The magnitude of the changes (or the extent of changes or modifications to the existing landscape, degree of visibility).

Landscape character refers to the distinct, recognisable and consistent pattern of elements in the landscape that makes one landscape different from another. Landscape character for the study area is described in Section 8.6.3. Table 8.18 (see Section 8.6.3) describes the characteristics of four main landscape types in the study area; industrial, eucalypt savanna/grassland; wooded drainage lines, and settlements. Section 8.6.3 also describes that the IWMF is part of a growing industrial precinct with adjacent activities comprising construction, road building, domestic shipping port operations and other industrial services.

The IWMF is not visible from Roku village due to screening by native vegetation and the rise in landscape which provides a visual barrier between the village and the IWMF. Therefore, any changes to visual amenity would only be relevant to businesses in the AES Industrial Park or by the local community when they are travelling along Napa Napa Road.

The sensitivity of both the resource and receptors (i.e., neighbouring businesses and local community using Napa Napa Road) is assessed as ***Low***, as the local community and businesses have in general expressed support for the Project and have not raised concerns relating to visual impact. Further, the addition of a landfill in a waste management facility in this context and the industrial area more broadly is in keeping with the current and intended industrial land use of the area is likely to align with community and business expectations.

10.7.2 Potential Impacts

The introduction of new features and the loss or modification of existing features has the potential to affect landscape character and its contribution to a ‘sense of place’. The Project comprises a small (8 ha) expansion to the existing footprint currently used for industrial activities (waste processing, storage and treatment) and a change in the material currently being processed to include hazardous wastes. The Project setting is in a growing industrial area, so there will be no change in land use. Much of the area that will be used for the additional footprint (i.e., landfill) is already cleared of vegetation. Approximately 1.58 ha of vegetation clearing will be required, and part of the expanded footprint is a disused quarry.

The additional infrastructure proposed for the IWMF is in keeping with the infrastructure and facilities already present (i.e., it will look visually similar to the existing buildings and

infrastructure) and therefore no discernible change in visual character. There are no proposed changes to the broader savanna and wooded drainage lines or that will impact the character of the Roku village.

In the context of the Project, potential changes to visual amenity could be caused by landform modification through the construction of the industrial landfill, dust emissions, caused by earthmoving activities, traffic and transport and movement of waste around the site, and windblown litter. These potential impacts associated with Project activities and are discussed in more detail in the following sections.

10.7.2.1 Change in Visual Amenity due to Landform Modification

Landform modification will result from the addition of the landfill, which will be partly constructed in a disused quarry, in the southern-most slope of a natural hill near Napa Napa Road. The area is already largely cleared of vegetation. The change in landform will be visible to those travelling south along Napa Napa Road, and potentially from some of the AES Industrial Park businesses' operational areas.

10.7.2.2 Change in Visual Amenity due to Dust

Earthworks, transport and storage of excavated material, vegetation clearing, the operation of vehicles, machinery, equipment and facilities, handling of dust-covered waste materials and the operation of the HT incinerator may temporarily increase the local concentrations of airborne particulate matter and pollutants during Project construction and operations (see Section 10.5.2). Dust, particularly PM_{10} and TSP, can affect human health (see Section 11.2.1) and local amenity.

Particulate matter that remains in the air (fugitive dust) is generated during Project construction activities, including earthmoving, excavation of landfill cells and transportation of earthen materials. Fugitive emissions can limit visibility and reduce visual amenity. Similarly, dust that is deposited on surfaces (i.e., buildings, machinery, vegetation) can also adversely affect visual amenity. The dispersion and deposition of particulate matter will be influenced by local wind conditions and topography but are generally more noticeable closer to the source.

10.7.2.3 Change in Visual Amenity due to Litter

Windblown litter can result during the transfer of solid waste from trucks to the landfill, during waste sorting and segregation, stockpiling and during operation of the landfill if the landfill is not covered or compacted regularly. If the landfill is left uncovered and uncompacted, this can attract birds and mammals which can contribute to windblown litter through carrying away material from the landfill site. Further, there is potential for illegal dumping outside the IWMF, which if left unattended, can contribute to unmanaged and windblown litter.

If litter is allowed to leave the site or accumulate around boundary fences, it will reduce visual amenity of the area surrounding the IWMF and could have indirect social and environmental impacts (e.g., increase in pests and disease).

10.7.2.4 Summary of Potential Impacts

Potential impacts to visual amenity due to the Project that have been considered in the impact assessment are summarised in Table 10.20.

Table 10.20 – Summary of Potential Impacts to Visual Amenity

Project Phase	Activity/Aspect	Project Component	Potential Impact
Construction and operations	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure	Industrial landfill construction	Change in visual amenity due to landform modification
Construction and operations	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure • Traffic and transport	Industrial landfill construction; traffic and transport; operation of fixed and mobile plant and equipment	Change in visual amenity due to dust
Operations	• Industrial landfill activities • Handling and processing of wastes	Operation of industrial landfill; waste sorting and segregation; weighbridge and receival hall; traffic and transport	Change in visual amenity due to litter

10.7.3 Mitigation and Management

10.7.3.1 Change in Visual Amenity due to Landform Modification

The management measures listed in Section 10.1.3.1 to address potential impacts to landform stability and erosion associated the construction of the industrial landfill will also mitigate impacts to a change in visual amenity due to landform modification. No additional measures are proposed.

10.7.3.2 Change in Visual Amenity due to Dust

The management measures listed in Section 10.5.3.1 to address potential impacts to air quality associated with Project construction and operations will also mitigate impacts to a change in visual amenity due to dust. The following measures will further mitigate impacts to visual amenity from dust:

- Reviewing and implementing the existing TWM project grievance procedure to receive, record, respond to and to address any grievances made regarding Project activities. Monitor the progress of grievances and provide updates to aggrieved parties and other relevant stakeholders. [SM1]
- Undertaking ongoing engagement with local community and businesses, providing clear, factual and accurate information relating to potential impacts, in an open and transparent manner. [SM2]

10.7.3.3 Change in Visual Amenity due to Litter

Measures to mitigate impacts to visual amenity from litter will include:

- Managing all waste in a manner that avoids impacts to the environment, including appropriate segregation for storage, treatment and disposal. [EM86]
- Informing all personnel of their responsibility to reduce waste where possible by the use of colour coded and labelled bins. [EM87]
- Considering waste in procurement decisions. [EM88]
- Applying cover daily at the landfill to suppress odour and prevent wind-blown litter while minimising the opportunity for mosquito infestation and discouraging bird and animal foraging. [EM89]
- Installing litter fences where required to catch and collect windblown litter to stop it from leaving the site. [EM90]
- Using tarps or covers for trucks and trailers transporting materials to and from the site. [EM55]
- Conducting weekly inspections around the IWMF and surrounding area and conducting regular clean-ups of litter as required. [EM91]

10.7.4 Residual Impact Assessment

10.7.3.1 Change in Visual Amenity due to Landform Modification

Plate 10.1 shows the current landform from Google Earth (2020), and Plate 10.2 is a concept design showing location of the new landfill as viewed from Napa Napa Road.

Plate 10.1 – View of the Quarry Looking South



Photo: Google Earth.

Plate 10.2– View of the Proposed Landfill and IWMF Looking South from Napa Napa Road



Source: TWM
Key: (A) weighbridge and scale station; (B) material sorting and segregation; (C) Recycling and composting; (D) incineration plant; (E) waste oil recycling; (F) fixation plant; (G) waste water treatment plant; (H) proposed landfill; (I) hazardous waste storage.

The new landfill will be constructed in the side of a low hill, which will limit visibility from Napa Napa Road when approaching the site from the south. The impact magnitude of a change in visual amenity resulting from the construction and operation of the new industrial landfill is assessed as ***Negligible***, as the change is in keeping with the existing facilities and industrial landscape and represents negligible change to visual amenity. The addition of an industrial landfill in a waste management facility in this context, and the industrial area more broadly, is in keeping with the current and intended industrial land use of the area and is likely to align with stakeholder and community expectations. Given the sensitivity of receptors (i.e., viewers using Napa Napa Road, or from the industrial precinct across the road), is assessed as ***Low***, the residual impact significance is therefore ***Negligible***.

10.7.3.2 Change in Visual Amenity due to Dust

The impact magnitude of a change in visual amenity due to dust (particulate emissions and deposition) is assessed as ***Negligible***, due to the relatively high levels of existing particulate matter and dust (given the presence of existing road use and construction activities in the area) and that modelled concentrations are predicted to vary minimally between 'base case' and 'proposed' scenarios, with the difference considered to not be discernible (see Section 10.5.4.1).

The sensitivity of receptors is assessed as ***Low***, which provides a residual impact significance assessment of ***Negligible***.

10.7.3.3 Change in Visual Amenity due to Litter

The impact magnitude of a change in visual amenity due to an increase in windblown litter resulting from the transport of waste and operation of the industrial landfill is assessed as ***Low***, as the impact is likely to only be short term and localised and can be effectively mitigated by the management measures identified to minimise litter leaving the site. Due to the surrounding industrial land use, if windblown litter was to leave the site, it is unlikely to significantly change the

character of the area and thus visual amenity. Given the sensitivity of receptors is ***Low***, the residual impact significance is assessed as ***Minor***.

10.7.3.4 Summary of Residual Impact Assessment

Table 10.21 provides a summary of the residual impact assessment for visual amenity. All residual impacts to visual amenity were assessed as ***Negligible*** to ***Minor***.

Table 10.21 – Visual Amenity Impact Assessment

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
• Local community • Business	Change in visual amenity due to landform modification	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure	• EM1 • EM2 • EM3 • EM4 • EM5 • EM6 • EM7 • EM8 • EM9 • EM10 • EM11 • EM12 • EM13 • EM14	Construction and operations	Negligible/ Negligible	Negligible
	Change in visual amenity due to dust	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure • Traffic and transport	• SM1 • SM2 • EM48 • EM49 • EM50 • EM51 • EM52 • EM53 • EM54 • EM1 • EM55 • EM56	Construction and operations	Low/Negligible	Negligible

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
			• EM57 • EM58 • EM59 • E160 • EM3			
	Change in visual amenity due to litter	• Industrial landfill activities • Handling and processing of wastes	• EM86 • EM87 • EM88 • EM89 • EM90 • EM55 • EM91	Construction and operations	Low/Low	Minor

10.8 Terrestrial Biodiversity

10.8.1 Discipline Specific Approach

The impact assessment approach for terrestrial biodiversity is consistent with the significance assessment method for the Project described in Chapter 7, qualitatively assessing credible potential impacts from the proposed Project Activities described in Chapter 4. This approach considers the sensitivity of the terrestrial biodiversity value or receptor, and the magnitude of the impact on that value or receptor. Definitions for the sensitivity of values or receptors and the magnitude of impacts are provided in Table 7.1 and Table 7.2, respectively, and the significance assessment matrix shown in Table 7.3. The impact assessment addresses potential impacts to terrestrial biodiversity within the study area as described in Section 8.7 and shown in Figure 8.1. The implications of changes to terrestrial biodiversity values on community land and natural resource use are discussed in Section 11.3.

This section specifically assesses potential impacts to the following sensitivities for terrestrial biodiversity:

- Native vegetation and habitat.
- Conservation significant species.
- Native flora and fauna species.

As discussed in Section 8.7.2, previous activities within the IWMF site have resulted in vegetation clearing, and as such the site is significantly disturbed. Vegetation is characterised as savanna, comprising Eucalyptus trees and native grasses, intermixed with weed species. Remnant vegetation within the IWMF site occurs mostly in thin strips or pockets between areas of pre-existing disturbance, with more intact areas of vegetation occurring to the west and southeast of the IWMF site. While no species of conservation significance were recorded during the 2020 field surveys within the study area, conservation significant species may occur in savanna communities around Port Moresby and are described in Section 8.7.3.

Considering the criteria for assessments of the sensitivity of an environmental value or receptor provided in Table 7.1, and given the disturbed nature of vegetation within the IWMF site from previous clearing and fragmentation of vegetation, the presence of existing weeds, the absence of statutory or any recognised formal listing for such vegetation, and the numerous representations of savanna habitats near the Project and around Port Moresby, the sensitivity of native vegetation and habitat that may be impacted by the Project is assessed as ***Low***. Native flora and fauna that may be potentially impacted by the Project are also considered to have a ***Low*** sensitivity, given they do not have a statutory or formally recognised listing and are not considered to be rare or unique within Papua New Guinea, and given the level of previous disturbance and operational activities within the IWMF site species.

Although not detected during 2020 field surveys, conservation significant species defined as those protected under Papua New Guinea law or IUCN-listed are assessed as of ***High*** sensitivity, given their formal statutory and/or internationally recognised status as threatened or vulnerable, and the poor representation of some of these species in Papua New Guinea and worldwide. No conservation significant species were recorded in savanna at Caution Bay in 2008 (Woxvold,

2008) however listed or protected species have been identified as potentially occurring (Section 8.7.3).

10.8.2 Potential Impacts

This section describes the potential impacts on terrestrial biodiversity values or receptors that may occur as a result of Project activities described in Chapter 4.

Impacts to terrestrial biodiversity sensitivities may potentially occur due to:

- Habitat loss and fragmentation.
- Habitat degradation.
- Introduction or increase of invasive alien species.
- Other causes of mortality and disturbance to fauna.

These potential impacts are discussed in the following sections.

10.8.2.1 Habitat Loss and Fragmentation

Clearing of Savanna Vegetation

The Project will involve the clearing of 1.58 ha of remnant vegetation within the IWMF for the construction of the industrial landfill, with all other Project activities requiring Level 3 assessment occurring within existing footprints. The proposed industrial landfill footprint in relation to remnant vegetation within the IWMF site is shown in Figure 10.9. The immediate impact of vegetation clearing is the loss of habitat and associated terrestrial biodiversity, resulting in a decrease in species abundance, diversity and distribution. Clearing of vegetation may reduce the quantity of savanna habitat within the study area, and potentially fragment remaining habitat, preventing fauna dispersal between areas of suitable habitat. Vegetation clearing will also result in the direct removal of individual flora species, potentially contributing to a decline in species abundance, diversity, density or distribution.

Fauna unable, or with limited capacity, to vacate habitat during the clearing of vegetation are unlikely to survive the process. Such fauna include the majority of non-volant mammals, reptiles and amphibians. Larger and more agile species such as wallabies, bats and birds may be able to move into surrounding areas. However many of such species are territorial, and displaced individuals are likely to encounter existing populations of the same species, with poor survivorship of displaced individuals expected (Burns, 2005). For wider ranging, non-territorial species, vegetation clearing results in the loss of foraging, sheltering and breeding habitat used at various times of the year. Savanna vegetation is the only habitat type to occur within the study area. Fauna species, including those identified as conservation significant species, have been recorded within the study area, or may potentially occur within savanna habitats near Port Moresby (Section 8.7.3). Loss of savanna habitat as a direct result of vegetation clearing will be limited to the construction phase of the Project. An embedded design control for mitigating the impact of the Project on habitat loss includes the location of Project infrastructure in previously disturbed areas where practicable (ED3).

PROPOSED LANDFILL FOOTPRINT AND REMNANT SAVANNA VEGETATION

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FIGURE 10.9



Barrier Effects

Barrier effects occur where a strip of open habitat provides a barrier to the movement of fauna, fragmenting populations or restricting access to resources such as a water source within a home range. Some species completely avoid crossing gaps, while others may have their movement rates significantly reduced (Goosem, 1997). Roads and other linear forest clearings may restrict the movement of a range of species, including terrestrial and arboreal mammals, understory forest birds, reptiles, and amphibians (Laurance et al., 2004; Andrews et al., 2015; van der Ree et al., 2015). Larger gaps and roads with heavier traffic loads act as more effective barriers, with barrier effects strongest when gaps are widest, and traffic is heaviest. Given the minimal clearing of vegetation proposed within the existing IWMF site, and its likelihood of poor habitat quality, barrier effects will not fragment populations as a result of the Project's activities. The impact of barrier effects is therefore not considered a credible potential impact and is not assessed further in the EIS.

10.8.2.2 Habitat Degradation

Edge Effects

Edge effects occur where the clearance of vegetation results in changes to the condition of adjacent remnant habitat. Abiotic edge effects can result from increased exposure of the forest edge to sun and wind, leading to changes in forest microclimate that include lighter, hotter and drier conditions (Murcia, 1995) Biological edge effects can include direct and indirect effects. Direct biological effects include changes in the presence and abundance of various species in direct response to the change in physical conditions (Murcia, 1995). Indirect biological effects can occur through changes in species interactions, such as predation, competition, herbivory and seed dispersal (Murcia, 1995). Edge environments are more susceptible to desiccation and burning, wind throw of trees, and the establishment of invasive species (Section 10.8.2.3). Clearing of vegetation may exacerbate existing edge effects through increased erosion and movement of soil, as discussed in Section 10.1.2.1. Edge effects will only occur during the construction phase of the Project and can be mitigated through the location of Project infrastructure in previously disturbed areas, where practicable (ED3).

Erosion and Disturbance of Soil

Vegetation clearing, ground disturbance and earthworks for the industrial landfill construction, may destabilise landforms and result in increased soil erosion or uncontrolled movement of soils (Section 10.1.2.1). Soil previously covered and bound by vegetation will become exposed, resulting in an increase in erosion of topsoil, and potentially a loss of available seed bank within the topsoil, decreasing the effectiveness of rehabilitation. Soil disturbance including inversion, excavation, placement of fill and soil compaction from Project traffic and machinery movements may degrade the soil quality and capability for native flora and vegetation to persist or to regenerate (Section 10.1.2.3). Increased erosion can result in increased sedimentation of waterways, and the direct mortality of vegetation or flora that inhabit such waterways, and degrading habitat for native flora and fauna. Erosion and soil disturbance will be most significant during construction, as impacts will occur from the excavation of the landfill cells and the earthworks associated. Impacts during operations will be less significant and will occur in relation to soil compaction from vehicle and plant movements. Embedded design controls for the mitigation of increased soil erosion and disturbance will include:

- Ensuring the gradient of landfill batters are designed with a maximum slope ratio of 1 m vertical to 3 m horizontal. [ED1]
- Inclusion of textured HDPE geomembranes in landform final design to provide adequate interface shear strength. [ED2]
- Location of Project infrastructure in previously disturbed areas where practicable. [ED3]
- Using clean water diversions drains to direct clean rainfall runoff away from the landfill to minimise the volumes of potentially sediment-laden water generated and installing a level spreader at the on-site termination of the clean water diversion drain to limit erosion and mobilisation of soils. [ED15]
- Construction of a sediment dam for both Stage 1 and Stage 2 industrial landfill operations prior to the commencement of landfill cell construction works (e.g., stripping and bulk earthworks). The sediment dam has been designed to contain water from an extreme rainfall event (a 5 day 90th percentile rainfall event), with a storage capacity of 2.24 ML in Stage 1 operations and 3.08 ML for Stage 2. [ED16]
- Installation of toe drains at the base of batters to convey sediment-laden runoff to the sediment dam. [ED17]

Contamination

The Project will require the transport, handling, treatment, storage and disposal of hazardous industrial and liquid wastes, use and storage of chemicals and hydrocarbons, and collection, storage and transfer of landfill leachates. Such materials have the potential to degrade habitats in the event an accidental release, and to harm or kill individuals that come into contact with them. Contamination of soil (Section 10.1), surface waters (Section 10.3), groundwater (Section 10.4) or air (Section 10.5) utilised by terrestrial flora and fauna could occur. Weed management will also require pesticide and herbicide spray and has potential to result in the contamination of native non-target species. The magnitude of impacts will be dependent on the scale and frequency of contaminant release, and the tolerance of individual species to contamination. Embedded design controls for the containment of potential contaminants for flora and fauna, including hazardous and industrial liquid wastes, hydrocarbons and chemicals, and landfill leachates, have been included in the Project design, and will include:

- A hazardous waste storage facility with impervious concrete bunds capable of holding at least 110% of the chemical storage capacity. [ED4]
- A purpose-built decontamination area within the bunding of the hazardous waste storage area to ensure waste is not tracked outside of the store and collection of wastes and associated cleaning liquids generated through the decontamination process for treatment at the IWWTP. [ED5]
- Constructing bunds and impermeable drainage with blind collection sumps or enclosed and weatherproof facilities with impermeable floor lining draining to a blind collection sump for all waste handling and treatment areas. [ED6]

- Designing and constructing the industrial landfill with multiple HDPE geo-membrane barriers combined with clay liners and a leachate collection system which will drain leachate to collection sumps (with a 2% drainage slope). [ED7]
- Constructing a network of perforated leachate collection pipes within the collection layer, to promote the flow of leachate to the primary and secondary (leak detection) sumps. [ED8]
- Designing submersible pumps, vertical extraction pipework (primary) and inclined leachate extraction pipe (secondary) to facilitate the removal of leachate from the collection sumps by progressive pumping to the leachate storage pond or IWWTP. [ED9]
- Designing a leachate leak detection system, i.e., the secondary leachate collection and removal system which will allow the collection and flow of leachate out of the leak detection system. [ED10]
- Diverting clean stormwater away from the landfill to minimise the ingress of rainfall runoff into the landfill thereby reducing the volumes of leachate generated. [ED11]
- Designing the leachate storage pond considering worst-case leachate generation conditions to minimise the chance of overflow. [ED12]
- Designing and constructing the leachate storage pond to the equivalent performance standard as the landfill which will include a 2 mm thick HDPE liner, compacted clay liner, composite drainage net, geosynthetic clay liner and prepared subgrade. [ED13]

Unplanned Fire

Fire is an existing and frequent disturbance in the study area and savanna environments in Papua New Guinea. Under exceptional circumstances, the Project may directly cause fires through sparks from machinery, equipment or vehicles, Project personnel, or inappropriate land management practices, during construction and operations. Once established, fire has the capacity to impact extensive areas of natural habitat well beyond its point of ignition, reducing total vegetation cover. Animals that fail to escape its path will be killed, and limited resources such as fruiting trees and trees with nesting hollows may be damaged or destroyed. Species that are particularly vulnerable to fire include slow-moving animals, and fire-sensitive flora. The potential for fire in the study area will be most intense during the dry southeast trade wind season from May to November.

Reduced Air Quality

Project activities have the potential to result in increased emissions of dust, particulate matter and incinerator-related emissions, and as such may have adverse health impacts to vegetation and fauna within the study area. Potential impacts are likely to occur from dust emissions occurring during landfill construction and ongoing operations of the IWMF. During the landfill construction, increased dust emissions will potentially occur from the clearing of vegetation, earthworks, excavation and ground disturbance, and the construction of the industrial landfill and its associated infrastructure. During operations daily industrial landfill activities are also likely to result in increased dust emissions. Traffic and transport, including of Project materials, equipment and personnel, earthen material, hazardous and non-hazardous wastes, and general vehicle

movements will also likely result in reduced air quality from dust. Increased emissions of dust and particulate matter have the potential to reduce the health of nearby vegetation via deposition of dust on plant foliage, which can affect the ability to photosynthesise, resulting in decreased plant productivity and health. Increased dust emissions can also cause fauna to temporarily avoid such areas, therefore reducing habitat suitability. Emissions from the incineration of hazardous waste may result in further health impacts, particularly where fauna inhales or ingests particles. Such emissions include dioxins and furans, lead, mercury, arsenic, cadmium, nickel, PAHs as benzo(a)pyrene, HCB and hydrochloric acid. These pollutants can potentially harm or kill flora and fauna that come into contact with these emissions. Impacts to ambient air quality as a result of Project activities are described in Section 10.5. Embedded design features for mitigating impacts from reduce air quality will include:

- Locating Project infrastructure in previously disturbed areas where practicable. [ED3]
- Designing pit and dump haul roads and ramps to limit the travel time and duty cycle for trucks especially when fully loaded. [ED19]
- Operating a flue gas treatment as the incinerator pollution control system, for burning of hazardous emissions. [ED20]

Increased Noise Disturbance

The Project will generate noise during both construction of the landfill, and operation of the IWMF including both incremental operation of individual waste management plant, and the entirety of the IWMF once fully commissioned. Increased levels of noise may disturb fauna, and reduce the suitability of the area for fauna habitation and leading to fauna avoidance of the area. Potential sources of increased noise and vibration during construction will include the operation of fixed and mobile plant, traffic and transport for the transportation of construction materials and equipment and personnel, earthen material from the landfill void, the use of diesel generators, and equipment for the construction of the landfill. During operations, increased noise disturbance may also occur as a result increased traffic and transport levels, in addition to the operation of IWMF plant treating wastes, specifically the operation of the IWWTP, daily industrial landfill activities, operation of diesel generators, the incinerator, fixation bays, and handling of wastes at the weighbridge and receival hall, waste storage area and the sorting and segregation facility. Impacts to existing noise levels from the Project are described in detail in Section 10.6.

10.8.2.3 Introduction or Increase in Invasive Alien Species

The Project has the potential to impact native flora and fauna through the unintentional introduction of new weed and introduced fauna species from outside the study area, and the additional spread and increased distribution of existing introduced species to undisturbed areas. The Project may introduce new, or contribute to the spread of existing, invasive alien species through the increased transport of Project equipment, materials and personnel and general traffic movements during construction and operations, the transport of earthen material, and the transport of hazardous and non-hazardous wastes to and from the IWMF during operations.. Invasive alien species may predate on, compete with, or displace native flora and fauna, and may introduce new pathogens which can cause population declines in local native species. Areas of environmental disturbance provide the most likely establishment sites for most weeds and pests, and once established, invasive species are challenging to eradicate. Potential impacts from

invasive or alien species may intensify as populations become more firmly established and if they are not eradicated, are likely to persist beyond closure.

Invasive Weeds

Seeds or vegetation material may be attached to the wheels of vehicles, tracks on earthmoving equipment, equipment for vegetation clearing, and the movement of equipment and material throughout the Project life, and potentially within incoming waste loads. As such, the potential spread of these introduced weeds will most likely be associated with the construction of the industrial landfill, and the movement of vehicles, machinery and equipment through pre-existing disturbed areas where weeds are already present during operations. Introduced weeds have the potential to result in the loss and disturbance of native vegetation, the degradation of habitat for native and threatened fauna, and therefore reduction in abundance, density and distribution of native flora and fauna. Introduced weeds can result in changes to existing habitat structure, and the availability of food and shelter for native fauna. Weed species are present within the study area and are intermixed with native savanna vegetation, as described in Section 8.7.4. The location of Project infrastructure in previously disturbed areas, where practicable (ED3), is an embedded design control that will help mitigate the potential for introduction or increase of weeds during constriction.

Pest Fauna

Project activities may exacerbate existing conditions for introduced fauna, or present new opportunities for the introduction of additional pests. Existing pest fauna populations, such as cane toads which have been recorded in the study area, may be further dispersed as a result of Project traffic and transport, and as such existing impacts may become exacerbated if not appropriately managed. Cane toads could be easily transported outside the study area by outgoing truck movements and would readily colonise local disturbed areas elsewhere. Cane toads, if ingested, may poison native carnivores. The clearing of vegetation during construction may also increase the pathways of introduced predators, such as feral cats, through the Project area, providing access to more areas than prior to the Project. An increase in abundance of feral cats in the Project area is likely to increase predation pressure on native bird, reptile and mammal species, leading to a reduction in their population size.

10.8.2.4 Other Causes of Mortality or Disturbance to Fauna

Hunting

Hunting has been a substantial factor in the decline and rarity of large animal species in Papua New Guinea. Increased hunting as a result of the Project may reduce the abundance, diversity and distribution of native fauna occurring, or potentially occurring, in the study area. Increased hunting may occur as a result of an increased Project workforce, and a potential growth in the local population as a result of Project employment. However, while hunting remains an important component of subsistence economies of landowners throughout Papua New Guinea, hunting within the study area and by the nearby Roku village community has become less prevalent. Burning of vegetation to aid in the hunting of bandicoots is undertaken by villagers from Roku, although only occasionally and the collection of bushfood such as birds and snakes is no longer undertaken (Section 9.7). Project induced in-migration leading to increased local population and

subsequent increased hunting pressure is not likely to be a significant impact (see Section 11.5.1.3).

Vehicle Collisions

Increased traffic and transport volumes as a result of increased volumes of waste transported to and from the IWMF site, internal movements of vehicles for transport of waste, Project personnel and equipment, and the transport of earthen material during landfill construction, may result in an increase in vehicle collisions with native fauna, and therefore increased fauna injury or death. Vehicle strikes are considered to be more likely along routes where vehicles will be travelling at greater speeds, such as Napa Napa Road, and less likely in operational areas where vehicle speeds are most likely to be restricted. The potential for vehicle collisions is also especially high at night when visibility is reduced, and when slow-moving and/or nocturnal fauna, such as wallabies and bandicoots, are particularly vulnerable.

10.8.2.5 Summary of Potential Impacts

Potential impacts to flora and fauna due to the Project that have been considered in the impact assessment are summarised in Table 10.22.

Table 10.22 – Potential Impacts to Terrestrial Biodiversity

Project Phase	Activity/Aspect	Project Component	Potential Impact
Habitat Loss and Fragmentation			
Construction	• Clearing of vegetation	Industrial landfill construction	Direct loss or disturbance of native vegetation and/or fauna habitat
			Reduction in native flora and fauna species abundance, density and diversity
			Reduction in habitat for conservation significant species
Habitat Degradation			
Construction	• Clearing of vegetation	Industrial landfill construction	Edge effects resulting in habitat degradation
Construction and operations	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure • Industrial landfill activities	Industrial landfill construction; operation of industrial landfill	Increased erosion and soil disturbance resulting in habitat degradation

Project Phase	Activity/Aspect	Project Component	Potential Impact
Construction and operations	• Storage, handling and use of chemicals and fuels • Transport of Project equipment, materials and personnel • Transport of earthen material • General vehicle movements • Use of machinery, equipment and vehicles • Discharge of stormwater to environment • Disposal of hazardous and industrial wastes • Storage of hazardous and non-hazardous wastes • Handling and processing of hazardous and non-hazardous wastes • Transport of hazardous and non-hazardous wastes • Fixation of hazardous waste materials • Collection of leachate in leachate collection system • Storage of leachate in leachate storage pond • Operation of diesel generators	Industrial landfill construction; operation of industrial landfill; traffic and transport; operation of incinerator; hazardous waste storage; traffic and transport; Project workforce	Contamination of environment resulting in habitat degradation
Construction and operations	• Storage of hazardous and non-hazardous wastes • Project employment • Transport of hazardous and non-hazardous wastes • Transport of Project equipment, materials and personnel • Transport of earthen material • General vehicle movements	Industrial landfill construction; operation of industrial landfill; traffic and transport; operation of incinerator; hazardous waste storage; Project workforce	Unplanned fires resulting in loss or disturbance of native vegetation and/or fauna habitat

Project Phase	Activity/Aspect	Project Component	Potential Impact
	• Use of machinery, equipment and vehicles • Incineration of hazardous waste • Construction of industrial landfill and associated infrastructure		
Construction and operations	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure • Transport of hazardous and non-hazardous wastes • Transport of Project equipment, materials and personnel • Transport of earthen material • General vehicle movements • Handling of hazardous and non-hazardous wastes • Industrial landfill activities • Incineration of hazardous waste	Traffic and transport; accommodation and administration facilities; industrial landfill construction; operation of industrial landfill; operation of incinerator; waste sorting and segregation; weighbridge and receival hall; recycling	Excessive dust deposition resulting in damage to vegetation and habitat degradation
Construction and operations	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure • Transport of hazardous and non-hazardous wastes • Transport of Project equipment, materials and personnel • Transport of earthen material • General vehicle movements	Traffic and transport; accommodation and administration facilities; industrial landfill construction; operation of industrial landfill; operation of incinerator; waste sorting and segregation; weighbridge and receival hall; recycling	Altered fauna behaviour and use of local habitat as a result of reduced air quality

Project Phase	Activity/Aspect	Project Component	Potential Impact
	• Construction of industrial landfill and associated infrastructure • Handling of hazardous and non-hazardous wastes • Industrial landfill activities • Incineration of hazardous waste		
Construction and operations	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure • Operation of fixed and mobile plant and equipment • General vehicle movements • Transport of earthen material • Transport of Project equipment, materials and personnel • Transport of hazardous and non-hazardous wastes • Operation of diesel generators • Industrial landfill activities • Incineration of hazardous waste • Handling of e-waste and plastics reprocessing	Industrial landfill construction; operation of industrial landfill; traffic and transport; operation of incinerator; waste sorting and segregation; weighbridge and receival hall; IWWTP; fixation bays; hazardous waste storage	Altered fauna behaviour and use of local habitat as a result of increased noise disturbance
Introduction or Increase in Invasive Alien Species			
Construction and operations	• Transport of Project equipment, materials and personnel • Transport of earthen material • Transport of hazardous and non-hazardous waste • General vehicle movements	Traffic and transport; industrial landfill construction	Introduction or increase of invasive weeds
Construction and operations			Introduction or increase of pest fauna

Project Phase	Activity/Aspect	Project Component	Potential Impact
	• Clearing of vegetation		
Other Causes of Mortality or Disturbance to Fauna			
Construction and operations	• Project employment	Project workforce	Increased hunting resulting in loss of fauna
Construction and operations	• Transport of Project equipment, materials and personnel • Transport of earthen material • Transport of hazardous and non-hazardous waste • General vehicle movements	Traffic and transport	Injury or death of fauna as a result of vehicle collision

10.8.3 Mitigation and Management

10.8.3.1 Habitat Loss and Fragmentation

Clearing of Savanna Vegetation

Measures to minimise habitat loss and fragmentation impacts due to clearing of vegetation will include:

- Developing and implementing a Biodiversity Management Plan, during landfill construction and IWMF operations. [EM92]
- Limiting vehicle and plant movements to defined access roads and existing operational areas. [EM1]
- Limiting ground disturbance and vegetation clearing to the extent prescribed in landfill development plans by demarcating areas that require clearing on project mapping/design drawings and by flagging or signage in the field. [EM3]
- Delineating areas of vegetation be protected. [EM4]
- Utilising land-clearing techniques that preserve the rootstock of removed vegetation (where practicable). [EM2]
- Regenerating previously damaged and newly disturbed areas with native flora species. [EM10]

- Felling large trees in a manner that minimises harm to wildlife and damage to surrounding vegetation, e.g. felling away from existing stands taking into account safety factors. [EM93]
- Stockpiling cleared vegetation in a manner that facilitates re-spreading or salvaging for later use during rehabilitation. [EM94]
- Employing low-impact vegetation clearing methods that minimise disturbance to adjoining intact vegetation and allow for movement of mobile fauna into adjoining intact areas before the area is cleared. [EM95]
- Conducting regular site inspections to ensure that works do not exceed the approved disturbance boundaries. [EM96]

10.8.3.2 Habitat Degradation

Edge Effects

Measures to minimise impacts due to edge effects from vegetation clearing will include:

- Regenerating previously damaged and newly disturbed areas with native flora species. [EM10]
- Utilising land-clearing techniques that preserve the rootstock of removed vegetation (where practicable). [EM2]
- Limiting ground disturbance and vegetation clearing to the extent prescribed in landfill development plans by demarcating areas that require clearing on project mapping/design drawings and by flagging or signage in the field. [EM3]
- Delineating areas of vegetation to be protected. [EM4]

Erosion and Disturbance of Soil

The management measures listed in Section 10.1.3.1 and 10.1.3.2 to mitigate soil erosion and disturbance will also mitigate impacts to terrestrial biodiversity. In addition, the following measure will further mitigate impacts to habitat degradation:

- Reducing damage to stockpiled topsoil and hydromulch with sterile medium, where practicable, to protect seed resource. [EM97]

Contamination

The embedded design controls and management measures listed in Section 10.1.2.3, 10.1.3.3 and 10.3.2.3 to mitigate impacts to soil quality and surface water quality will also mitigate impacts to habitat degradation due to contamination. No additional measures specific to mitigating impacts to terrestrial biodiversity are proposed.

Unplanned Fires

Measures to minimise impacts due to unplanned fires as a result of the Project will include:

- Avoiding the use of fire for weed management at all times. [EM98]

- Updating and implementing Fire and Emergency Response Plan Operating Instructions. [EM99]
- Ensuring that the 'Person in Charge' and site and process personnel are fully trained in the implementation and practice of the Fire and Emergency Response Plan Operating Instructions. [EM100]
- Ensuring that all TWM staff and contractors undergo training for the Fire and Emergency Response Plan Operating Instructions. [EM101]
- Ensuring the effectiveness of training is regularly assessed through emergency spill response practice and drills. [EM102]
- Ensuring the Fire and Emergency Response Plan Operating Instructions are regularly reviewed and updated following lessons learned and with development of new or upgraded waste handling processes and technologies, and updates are incorporated into training. [EM103]
- Ensuring that fire-fighting equipment is maintained and available on site. [EM104]

Reduced Air Quality

Measures to minimise impacts due to Project air emissions are listed in Section 10.5.3.1 and will also mitigate impacts to terrestrial biodiversity from reduced air quality. No additional measures are proposed.

Increased Noise Disturbance

Measures to minimise impacts due to Project noise emissions are listed in Section 10.6.3.1 and will also mitigate impacts to terrestrial biodiversity from noise emissions. No additional measures are proposed.

10.8.3.3 Introduction or Increase in Weeds and Pest Fauna

Measures to minimise impacts due to an increase or invasion in weeds and introduced fauna will include:

- Spraying for weeds and pests to be undertaken on a routine basis, as required based on risk, to control the spread of invasive species. [EM105]
- Using pesticides and herbicides that are low in human toxicity, effective on target species and that have minimal effects on non-target species and the environment. [EM28]
- Developing and implementing a Biodiversity Management Plan, during landfill construction and IWMF operations. [EM92]
- Delineating areas of vegetation to be protected. [EM4]
- Limiting vehicle and plant movements to defined access roads and existing operational areas. [EM1]
- Avoiding the use of fire for weed management at all times. [EM98]

- Limiting ground disturbance and vegetation clearing to the extent prescribed in landfill development plans by demarcating areas that require clearing on project mapping/design drawings and by flagging or signage in the field. [EM3]
- Regenerating previously damaged and newly disturbed areas with native flora species. [EM10]

10.8.3.4 Other Causes of Mortality and Disturbance to Fauna

Hunting

Measures to minimise impacts due to hunting activities by Project staff or contractors will include:

- Prohibit disturbance and or harassment of terrestrial wildlife, hunting of fauna, or collection of bushfoods by Project staff or contractors whilst employed on Project work activities. [EM106]
- Implement appropriate inductions and education to ensure personnel comply with hunting and bush food collecting requirements. [EM107]

Vehicle Collisions

Measures to minimise impacts due to an increase in traffic and Project vehicles will include:

- Limiting vehicle and plant movements to defined access roads and existing operational areas. [EM1]
- Ensuring site traffic flows are designed to minimise risk of collision. [EM108]
- Maintaining vehicle speed limits on-site at 20 km/h, or below. [EM52]

10.8.4 Residual Impact Assessment

The following section provides the assessment of residual impacts to terrestrial biodiversity assuming successful implementation of the proposed mitigation measures.

10.8.4.1 Habitat Loss and Fragmentation

Clearing of Savanna Vegetation

Sparse savanna is the only vegetation type to occur within the IWMF site, and therefore the only habitat type to be potentially impacted by the clearing of vegetation for landfill construction. A total of 1.58 ha of savanna vegetation and potential habitat will be cleared for the construction of the industrial landfill, as shown in Figure 10.9. The 1.58 ha of habitat to be cleared equals approximately 15.91% of remnant savanna habitat within the IWMF, and 1.12% within the study area (Table 10.23). Furthermore, the vegetation is immediately adjacent to already disturbed areas, and as such is considered degraded, having been subject to ongoing impacts including barrier and edge effects, noise, dust and soil erosion. The 1.58 ha of remnant savanna vegetation to be cleared is therefore considered to be significantly disturbed, and to provide poor quality habitat for fauna.

Table 10.23 – Area of Habitat to be Cleared

FIMS Classification and Habitat Type	Extent of Remnant Habitat – in IWMF Site		Extent of Habitat Type – in Study Area*	
	ha	%	ha	%
Savanna	9.91	48.28	140.96	67.6
Area to be Cleared	1.58	15.91	1.58	1.12

* Study area includes the IWMF Site boundary.

Considering the minimal total clearing of savanna habitat to occur within the IWMF and the study areas, and the low quality habitat potential of that area, the impact magnitude from the clearing of savanna vegetation during the construction Project phase is considered to be ***Negligible.*** The residual impact significance from clearing savanna vegetation on native vegetation and habitat, and native flora and fauna, both assessed as Low sensitivity, are therefore assessed as ***Negligible***. The residual impact significance to species of conservation significance, assessed as ***High*** sensitivity, is considered to be ***Minor***.

10.8.4.2 Habitat Degradation

Edge Effects

Edge effects will be limited to vegetation adjacent to the 1.58 ha of remnant vegetation to be cleared within the proposed landfill footprint (see Figure 10.9) and will only occur during the construction phase of the Project. Impacted vegetation occurs as a thin strips or small pockets, predominantly surrounded by disturbed areas, within the existing IWMF site. Edge effects will be limited to vegetation with existing disturbed edges, although clearing activities will expose more interior areas of disturbed vegetation to higher levels of edge interactions. These areas comprise sparse vegetation already subject to edge effects, and other disturbances, from previously cleared areas including the former quarry, bench tops, access tracks and the Napa Napa Road to the north. Given the minimal clearing required, the impact of edge effects on native vegetation and habitat is unlikely to be detectable with respect to natural variability. As such the impact magnitude for edge effects is assessed as ***Negligible***, the sensitivity of native vegetation and habitat has been assessed as ***Low***, and the residual impact significance is therefore ***Negligible***.

Erosion and Disturbance of Soil

Impacts will be of a greater magnitude during construction as a result of the excavation and earthworks required for landfill construction, while potential impacts during operations will occur in relation to soil compaction only. As such, the magnitude of impacts to native vegetation and habitat a result of increased erosion and soil disturbance, given the proposed industrial landfill footprint and the minimal area of vegetation to be cleared and the mitigation measures to be developed and implemented in the Erosion and Soil Management Plan, is considered to be ***Low*** during the construction phase, as impacts will be localised and will require the implementation of routine environmental mitigation controls. During operations, the impact magnitude will be ***Negligible*** as impacts from soil disturbance to terrestrial flora and fauna will not be noticeably detectable in relation to the existing natural variability. The sensitivity of native vegetation and

habitat is ***Low***, and the residual impact significance is therefore ***Minor*** during construction, and ***Negligible*** during operations.

Contamination

Potential sources of contamination resulting in degradation of habitat for flora and fauna include traffic and transport during construction and operation, operation of the hazardous waste storage area, the mechanics workshop, bulk fuel storage, and all waste processing areas and plant within the IWMF. Potential contaminants include hazardous industrial and liquids wastes being treated and disposed of on-site, hydrocarbons and chemicals, and landfill leachates, and are described in Chapter 4. Potential for hazardous waste materials releases to land and soils is largely mitigated through embedded design features including bunded concrete pads with bunding and storage designed in accordance with appropriate standards, and via specific environmental management controls, outlined in Section 10.8.2.2.

Releases of hazardous wastes are likely to be localised to the spill location and short term given the environmental controls in place for spill responses, and impacts can therefore be effectively mitigated through routine environmental controls. However, minor spills or leaks, even with effective management, are a somewhat common occurrence on operational industrial sites. Potential for spills impacting terrestrial biodiversity are considered to be more likely during construction, as operations activities will occur predominantly within concrete hardstand areas. Construction activities with potential for spills of contaminants are more likely to be undertaken in unsealed areas and are therefore more likely to reach the environment and result in a higher degree of impact to flora and fauna. However, spill volumes are likely to be minor during both phases, and with the effective implementation of a Spill Response Prevention and Response Plan and the Emergency Spill Operating Instructions are likely to be short term. As such, the potential impact magnitude of contamination resulting in habitat degradation for terrestrial flora and fauna is assessed as ***Low*** for construction, and ***Negligible*** for operations, and the residual impact significances are ***Minor*** and ***Negligible*** respectively.

Unplanned Fire

While unplanned fires may result in the loss of native vegetation cover and available savanna habitat as a result of Project activities, fire is an existing and frequent disturbance in the savanna environment of the study area. As such, the savanna environment is likely somewhat adapted to and potentially maintained by the occurrence of fire, in particular Eucalyptus tree species which are often fire-dependent, and unplanned fires as a result of the Project are unlikely to be detectable in respect to natural variation. With the successful implementation of mitigation measures including avoiding bushfire use in weed management practices (see Section 10.8.3.3) and the use of firefighting equipment on-site, the impact magnitude of unplanned fires on native vegetation and fauna habitat is considered to be ***Negligible*** during both construction and operations phases of the Project. Therefore, with native vegetation and fauna habitat assessed as ***Low*** sensitivity, the residual impact significance is assessed as ***Negligible*** for both Project phases.

Reduced Air Quality

Emissions to air will include dust and particulate matter during construction and operations and emission of pollutants from the incinerator during operations (see Section 10.5). Dust emissions

during landfill construction and ongoing operations are likely to be short-term and reduced by rainfall and wind dispersion with potential impacts to vegetation expected to be localised. It is anticipated that maximum 30-day cumulative dust deposition (96 mg/m^2 per day) and annual average dust deposition (2.4 g/m^2 per month) will comply with adopted Project criteria (see Section 10.5.1). The most affected area will be to the west of the IWMF, and dust and particulate matter will be managed via using a bentonite seal on unsealed roads, watering of unsealed surfaces and restrictions on vehicles speeds. All particle sizes for particulate matter (TSP, PM_{10} and $PM_{2.5}$) will also comply with relevant air quality guidelines (see Section 10.5.1). Given the compliance of all pollutants with relevant criteria and with the successful implementation of mitigation measures, the impact magnitude of dust deposition on vegetation is assessed as ***Negligible*** during construction and ***Negligible*** during operations. The residual impact significance is therefore ***Negligible*** for both phases of the Project.

Incinerator emissions will be managed by the pollution control system and the noncontinuous operational hours of the incinerator. As such, impacts are likely to be short term and temporary and are predicted to be below all relevant air quality criteria. Fauna are likely to be more susceptible to air pollutants than human receptors and may occur in closer proximity to the emissions sources than human receptors identified in Section 8.6.1. All incinerator-related emissions are predicted to comply with relevant criteria, with the most affected direction predicted to be to the north of the IWMF, towards the AES industrial park.

With the successful implementation of mitigation measures, the impact magnitude of reduced air quality to fauna from incinerator emissions and particulate matter, which can reduce the amenity of fauna habitat, is assessed as ***Negligible*** during both construction and operations. The residual impact significances for both phases of the Project is therefore ***Negligible***.

Increased Noise Disturbance

Impacts of increased noise levels to fauna, and therefore the potential for the Project to degrade potential habitat, varies by species, and are dependent on noise duration, volume and frequency. As described in Section 10.6.4, noise modelling results that are considered indicative of the landfill construction activities indicates under worst-case conditions noise levels will likely be well below the representative operational noise criteria at the nearest human receptors. Noise modelling conducted for the operations of the Project, as described in Section 10.6.4, predicted noise levels would be at or below the applicable noise criteria and compliant for both calm and worst-case conditions at all residential and commercial receptors, with a maximum predicted noise level of 64 dBA at AES around 30 m from the IWMF site boundary. However, fauna responses to noise have been reported to begin at approximately 40 dB(A) (Shannon, et al., 2016) and noise levels closer to the IWMF, where fauna may inhabit, will likely be higher. However, such impacts are likely to be localised, intermittent and not occurring for extended periods. Furthermore, given the current operations at the IWMF and the industrial setting of the IWMF, it is likely that fauna are already somewhat habituated to industrial noise or already avoid the area to some degree. As such, with the implementation of mitigation measures for the reduction of noise emissions, the impact magnitude of increased noise levels on native fauna habitat, which has a sensitivity of ***Low***, is considered ***Low*** during construction and ***Low*** during operations. The residual impact significance is therefore ***Minor*** for both phases of the Project.

10.8.4.3 Introduction or Increase in Invasive Alien Species

The magnitude of potential impacts from the Project from the introduction or increase in invasive alien species in the study area will be limited by the fact that Project activities will take place in a significantly disturbed and operating site with an existing presence of weeds and pest fauna. Impacts could occur during both construction and operations phases but are unlikely to be detectable outside of natural variability for either phase given the current level of impacts from invasive species, and in consideration of the implementation of effective mitigation measures. The impact magnitude for the introduction or increase of pest fauna is therefore assessed as ***Negligible*** for both construction and operations, and the residual impact significance to both native fauna and native vegetation and/or habitat, assessed as ***Low*** sensitivity, have therefore been assessed as ***Negligible***. The magnitude of potential impacts from the introduction or increase in invasive weeds during construction and operations are also considered ***Negligible***, considering the presence of existing weeds within the study area, and the successful implementation of weed management practices including spraying of weeds. As such, residual impact significances to native vegetation and habitat across both Project phases have been considered to be ***Negligible***.

10.8.4.4 Other Causes of Mortality or Disturbance to Fauna

Hunting

The capacity for Project activities to result in increased hunting from the Project workforce is limited given hunting and the collection of bushfood is no longer a common occurrence within the study area, and that Project-induced in-migration is considered to be minimal, and will therefore not result in increased hunting pressures. Impacts may occur during construction or operations, however is not anticipated to differ in regards to impact magnitude across either Project phase. Impact magnitudes to native fauna for both Project phases will therefore be ***Negligible*** after avoidance and mitigation, resulting in ***Negligible*** residual impact significances to ***Low*** sensitivity native fauna.

Vehicle Strikes

Traffic will increase by 36 vehicle movements to and from the IWMF during construction, with approximately 40 vehicle entries during operations. However, impacts will be contained to the existing transport route along Napa Napa Road and the IWMF site entry and exit point, and to all operational areas and internal access roads utilised for the transport of construction materials, hazardous wastes, equipment, and associated Project personnel. The potential impact to vulnerable nocturnal fauna will also be reduced given that industrial landfill construction and the majority of IWMF operations will be undertaken during daylight hours from 7 a.m. to 5 p.m. Further mitigation measures such as adherence to speed limits will further reduce the potential impacts to fauna. While impacts are anticipated to be slightly higher during operations than construction given the far longer timeframe, impacts are not expected to be significant for either Project phase. As such the impact magnitudes for both phases are considered ***Negligible*** and as such the residual impacts are also ***Negligible***.

10.8.4.5 Summary of Residual Impact Assessment

Table 10.24 provides a summary of the residual impact assessment for terrestrial biodiversity. All residual impacts to terrestrial biodiversity were assessed to be ***Negligible*** to ***Minor.***

Table 10.24 – Terrestrial Biodiversity Impact Assessment

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
Habitat Loss and Fragmentation						
Native vegetation and habitat	Direct loss or disturbance of native vegetation and/or fauna habitat	• Clearing of vegetation	• EM92 • EM1 • EM3 • EM4 • EM2 • EM10 • EM93 • EM94 • EM95 • EM96	Construction	Low/Negligible	Negligible
Native flora and fauna	Reduction in native flora and fauna species abundance, density and diversity				Low/Negligible	Negligible
Conservation significant species	Reduction in habitat for conservation significant species				High/Negligible	Minor
Habitat Degradation						
Native vegetation and/or habitat	Edge effects resulting in habitat degradation	• Clearing of vegetation	• EM10 • EM2 • EM3 • EM4	Construction	Low/Negligible	Negligible
Native vegetation and/or habitat	Increased erosion and soil disturbance resulting in	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure	• EM1 • EM2 • EM3 • EM4	Construction	Low/Low	Minor

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
	habitat degradation	• Industrial landfill activities	• EM5 • EM6 • EM7 • EM8 • EM9 • EM10 • EM11 • EM12 • EM13 • EM14 • EM15 • EM97	Operations	Low/Negligible	Negligible
Native vegetation and/or habitat	Contamination of environment resulting in habitat degradation	• Storage, handling and use of chemicals and fuels • Transport of earthen material • Transport of Project equipment, materials and personnel • General vehicle movements • Operation of diesel generators	• EM16 • EM17 • EM18 • EM19 • EM20 • EM21 • EM22 • EM23 • EM24 • EM25 • EM26 • EM27 • EM28 • EM29 • EM30	Construction	Low/Low	Minor
		• Storage, handling and use of chemicals and fuels • Operation of diesel generators • Disposal of hazardous and industrial wastes • Storage of hazardous and non-hazardous wastes • Handling and processing of hazardous and non-hazardous wastes		Operations	Low/Negligible	Negligible

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
		• Transport of hazardous and non-hazardous wastes • Transport of Project equipment, materials and personnel • General vehicle movements • Use of machinery, equipment and vehicles • Fixation of hazardous waste materials • Collection of leachate in leachate collection system • Storage of leachate in leachate storage pond	• EM31 • EM32 • EM33 • EM34 • EM35 • EM36			
Native vegetation and/or habitat	Unplanned fires resulting in loss or disturbance of native vegetation and/or fauna habit	• Industrial landfill construction • Transport of Project equipment, materials and personnel • Transport of earthen material • General vehicle movements • Project employment • Storage, handling and use of chemicals and fuels	• EM98 • EM99 • EM100 • EM101 • EM102 • EM103 • EM104	Construction	Low/Negligible	Negligible
		• Industrial landfill activities • Incineration of hazardous waste • Storage, handling and use of chemicals and fuels • Storage of hazardous and non-hazardous wastes • Project employment • Transport of hazardous and non-hazardous wastes		Operations	Low/Negligible	Negligible

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
		• Transport of Project equipment, materials and personnel • Transport of earthen material • General vehicle movements				
Native vegetation and/or habitat	Excessive dust deposition resulting in damage to vegetation and habitat degradation	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Transport of Project equipment, materials and personnel • Transport of earthen material • General vehicle movements • Construction of industrial landfill and associated infrastructure	• EM48 • EM49 • EM50 • EM51 • EM52 • EM53 • EM54 • EM1 • EM55 • EM56 • EM57 • EM58 • EM59 • EM60 • EM3	Construction	Low/Negligible	Negligible
		• Transport of Project equipment, materials and personnel • Transport of earthen material • General vehicle movements • Handling of hazardous and non-hazardous wastes • Industrial landfill activities		Operations	Low/Negligible	Negligible
Native vegetation and/or habitat	Altered fauna behaviour and use of local habitat as a result of reduced air quality	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Transport of Project equipment, materials and personnel • Transport of earthen material • General vehicle movements		Construction	Low/Negligible	Negligible

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
		• Construction of industrial landfill and associated infrastructure				
		• Transport of hazardous and non-hazardous wastes • Transport of Project equipment, materials and personnel • General vehicle movements • Handling of hazardous and non-hazardous wastes • Industrial landfill activities • Incineration of hazardous waste		Operations	Low/Negligible	Negligible
Native vegetation and/or habitat	Altered fauna behaviour and use of local habitat as a result of increased noise disturbance	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure • Operation of fixed and mobile plant and equipment • General vehicle movements • Transport of Project equipment, materials and personnel • Transport of earthen material • Operation of diesel generators	• EM80 • EM81 • EM82 • EM83 • EM27 • EM84 • EM85	Construction	Low/Low	Minor
		• Operation of fixed and mobile plant and equipment • General vehicle movements • Transport of earthen material		Operations	Low/Low	Minor

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
		• Transport of Project equipment, materials and personnel • Transport of hazardous and non-hazardous wastes • Operation of diesel generators • Industrial landfill activities • Incineration of hazardous waste • Handling of e-waste and plastics reprocessing				
Introduction or Increase in Invasive Alien Species						
Native vegetation and/or habitat	Introduction or increase of invasive weeds	• Transport of Project equipment, materials and personnel • Transport of earthen material • General vehicle movements • Clearing of vegetation	• EM105 • EM28 • EM92 • EM4 • EM1 • EM98 • EM3 • EM10	Construction	Low/Negligible	Negligible
		• Transport of hazardous and non-hazardous wastes • Transport of Project equipment, materials and personnel • General vehicle movements		Operations	Low/Negligible	Negligible
Native vegetation and/or habitat	Introduction or increase of pest fauna	• Transport of Project equipment, materials and personnel • Transport of earthen material • General vehicle movements • Clearing of vegetation		Construction	Low/Negligible	Negligible
		• Transport of hazardous and non-hazardous wastes		Operations	Low/Negligible	Negligible

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
		• Transport of Project equipment, materials and personnel • General vehicle movements				
Native fauna		• Transport of Project equipment, materials and personnel • Transport of earthen material • General vehicle movements • Clearing of vegetation		Construction	Low/Negligible	Negligible
		• Transport of hazardous and non-hazardous wastes • Transport of Project equipment, materials and personnel • General vehicle movements		Operations	Low/Negligible	Negligible
Other Causes of Mortality or Disturbance to Fauna						
Native fauna	Increased hunting resulting in loss of fauna	• Project employment	• EM106 • EM107	Construction	Low/Negligible	Negligible
				Operations	Low/Negligible	Negligible
Native fauna	Injury or death of fauna as a result of vehicle collision	• Transport of Project equipment, materials and personnel • Transport of earthen material • General vehicle movements	• EM1 • EM108 • EM52	Construction	Low/Negligible	Negligible
		• Transport of hazardous and non-hazardous wastes • Transport of Project equipment, materials and personnel • General vehicle movements		Operations	Low/Negligible	Negligible

10.9 Aquatic Biodiversity

10.9.1 Discipline-specific Approach

The significance assessment method described in Chapter 7 was used to qualitatively assess impacts relevant to aquatic biodiversity. This considers the sensitivity of the resource/receptor and magnitude of impact on that resource/receptor.

There are no watercourses or permanent waterbodies within the IWMF site. The impact assessment considers potential impacts to aquatic biodiversity in the downslope catchment which includes ephemeral drainage channels located to the east, southeast and west of the IWMF, but no major or permanent aquatic habitats.

As described in Section 8.8.4.2 the aquatic habitats of the drainage channels in the downstream catchment are well represented in the broader area and are not considered to be sensitive ecosystems or contain sensitive habitat features. While the drainage channels have the potential to support some endemic or restricted range species, due to the ephemeral nature of the drainage channels they do not provide permanent habitat for such species. These ephemeral drainage channels are expected to support a low diversity and abundance of aquatic biota, particularly the drainage channels located to the east and southeast of the IWMF, which are minor drainage channels with no connectivity to a larger upstream catchment, with their headwaters originating close to the IWMF. Considering this, aquatic habitats and species in the drainage channels are assessed as having a ***Low*** sensitivity.

The impact assessment for aquatic biodiversity draws on the impact assessments for hydrological processes (Section 10.2) and surface water quality (Section10.3). Much of the information used to assess pathways for impacts to aquatic biodiversity is provided in those sections and is referenced in this section.

10.9.2 Potential Impacts

10.9.2.1 Habitat Degradation or Modification

Increased Suspended Sediment and Turbidity from Soil Erosion

As discussed in Section 10.1, clearing of approximately 1.58 ha of sparse vegetation and ground disturbance works within the 4.67 ha landfill footprint for the construction of the industrial landfill will result in the exposure and disturbance of soils. Soils could then be eroded by rainfall and mobilised to nearby surface waters. The mobilisation of sediment could lead to increased suspended sediment in surface water, i.e., increased turbidity and reduced light, and sedimentation. These processes can affect the survival, behaviour and health of aquatic biota.

Increased turbidity could reduce water clarity, thereby affecting the ability of fauna to detect predators or prey. Increased turbidity can also reduce the availability of light in the water column, which can lead to reduced phytoplankton and benthic microalgae productivity. This could impact the availability of food sources for fish, crustaceans and macroinvertebrates and change habitat and water quality (e.g., reduced dissolved oxygen). Suspended sediment can also cause physiological stress by clogging respiratory or feeding structures. The mobilisation of sediment from increased sedimentation (i.e., deposition of sediment) could alter benthic habitat, whereby

fine sediment can smother coarse substrate such as gravel and cobbles as well as sedentary benthic species such as benthic invertebrates and benthic microalgae. This smothering could lead to a decline in abundance and diversity and the health of fish, macroinvertebrate and algal assemblages.

The ephemeral drainage channels downslope of the industrial landfill experience large natural fluctuations in suspended sediment concentrations and turbidity, with high levels likely occurring following rainfall events, particularly during the wet season. Aquatic biota which may occur temporarily in these drainage channels when there is water present are therefore expected to be tolerant of short-term increases in turbidity and suspended sediment concentrations. Long-term changes in turbidity could however cause the loss of some species in the impacted area, with low light or sediment-tolerant species potentially replacing existing assemblages.

There are a number of embedded design controls which address potential impacts on aquatic habitats and species from increased suspended sediment and turbidity. These are provided in Section 10.3.2.1, as they relate to managing impacts to surface water quality.

Altered Hydrological Regime

The potential impacts to altered hydrological regimes are considered in Section 10.2. Changes to hydrological regimes can alter habitat availability and connectivity, affect aquatic faunal movement patterns and change reproductive processes and aquatic productivity.

As discussed in Section 10.2, changes to hydrological regimes from Project infrastructure, which could alter existing flow direction, volumes and velocities, could occur due to the construction and physical presence of the industrial landfill, which will permanently alter existing drainage patterns.

There will be no abstraction of surface water to supply Project water demands and hence there will be no impacts to hydrological regimes and aquatic biodiversity from water abstraction.

10.9.2.2 Sub-lethal or Lethal Toxicity Effects on Aquatic Biota

Surface Water Contamination from Accidental Release of Landfill Leachate

The collection and storage of landfill leachate in the uncovered leachate holding pond in the short term and the transfer of leachate to the IWWTP in the long term has the potential to contaminate surface waters due to leaks in pipework, floods and management system failures. If released to the environment leachate could have toxic effects on aquatic biota where these contaminants are mobilised to surface waters.

The industrial landfill will receive predominantly inert materials (e.g., neutralised/stabilised/fixated hazardous wastes and incinerator ash) and is expected to generate relatively low levels of leachate. Notwithstanding, leachate could have elevated concentrations of ammonia, heavy metals and metalloids, organic and inorganic contaminants, elevated BOD and COD and low pH which can affect surface water quality and the health and survival of aquatic biota. A number of embedded design control measures will mitigate impacts on surface water from potential contamination from landfill leachate (see Section 10.1.2.3) thereby also mitigating potential impacts to aquatic biota.

Surface Water Contamination from Accidental Release of Hazardous Industrial and Liquid Wastes, Hydrocarbons and Chemicals

Accidental release of fuel and other chemicals to the environment has the potential to have toxic effects on aquatic biota where these contaminants are mobilised to surface waters. Key potential contaminants are PAHs, metals, metalloids and a range of other synthetic compounds, which may have lethal or sub-lethal toxic effects or may bioaccumulate in biota.

The potential risk to aquatic biota depends on several factors, most notably the spatial extent of contamination, the duration of exposure, the contaminant type and the hydrological (flushing) characteristics of the affected waterway. Many contaminants are persistent in the environment, particularly when present in sediments, and can have long-term impacts if remediation is not undertaken. Aquatic environments with poor flushing (i.e., small drainage channels with low flow) and waterholes are most at risk of chemicals persisting in the environment.

Oils and petroleum hydrocarbons are less dense than water and are biodegradable. The most toxic fractions of oils to aquatic biota are lighter fractions that contain higher proportions of aromatic hydrocarbons; however, exposure of aquatic organisms to such fractions is usually limited due to their high volatility. Apart from direct toxic effects to aquatic biota, oils and hydrocarbons can also cause tainting of fish flesh, loss of invertebrates and food sources, and increase in algal growth (ANZECC/ARMCANZ, 2000).

10.9.2.3 Introduced of Aquatic Weeds

Project construction materials and vehicles, machinery and equipment will be brought from outside the local catchment and may also come from overseas. These could contain seeds or other fragments of aquatic weeds which may be lodged or attached to vehicles, equipment and machinery. If released to the aquatic environment, such seeds or fragments could establish viable populations. Aquatic weeds can smother waterways, reducing light availability and oxygen availability, displace native biota, affect the availability of food for aquatic fauna, alter hydrological regimes and change the structure of aquatic assemblages. Given the construction of the landfill will require earthworks and ground disturbance works within close proximity to surface water drainage channels there is a potential pathway for the introduction of aquatic weeds to the downstream catchment.

While there are a number of introduced fish species known to occur in the region, there is no credible pathway for the introduction of these species from Project activities. Impacts from the introduction invasive or pest aquatic fauna is therefore not considered in the impact assessment.

10.9.2.4 Summary of Potential Impacts

Potential impacts to aquatic biodiversity due to the Project that have been considered in the impact assessment are summarised in 10.25.

Table 10.25 – Summary of Potential Impacts on Aquatic Biodiversity

Project Phase	Activity/Aspect	Project Component	Potential Impact
Construction and operations	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure	Industrial landfill construction; operation of industrial landfill	Habitat degradation or modification from increased turbidity/ sedimentation in downstream surface waters due to erosion of soils/exposed surfaces
Construction and operations	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure	Industrial landfill construction; operation of industrial landfill	Habitat degradation or modification from altered hydrological regime
Operations	• Collection of leachate in leachate collection system • Storage of leachate in leachate storage pond	Operation of industrial landfill	Sub-lethal or lethal toxicity effects to aquatic biota due to accidental release of landfill leachate
Operations	• Storage of hazardous and non-hazardous wastes • Handling and processing of hazardous and non-hazardous wastes • Fixation of hazardous waste materials • Incineration of hazardous waste	Hazardous waste storage; operation of incinerator; fixation bays; IWWTP; waste sorting and segregation; weighbridge and receival hall	Sub-lethal or lethal toxicity effects to aquatic biota due to accidental release of hazardous and industrial liquid wastes
Construction and operations	• Storage, handling and use of chemicals and fuels • Operation of fixed and mobile plant and equipment • Operation of diesel generators	Industrial landfill construction; traffic and transport; operation of industrial landfill	Sub-lethal or lethal toxicity effects to aquatic biota due to accidental release of hydrocarbons and chemicals
Construction and operations	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure	Industrial landfill construction; operation of industrial landfill	Introduction of aquatic weeds

Project Phase	Activity/Aspect	Project Component	Potential Impact
	• Transport of Project equipment, materials and personnel • General vehicle movements • Operation of fixed and mobile plant and equipment		

10.9.3 Mitigation and Management

10.9.3.1 Habitat Degradation or Modification

Increased Suspended Sediment and Turbidity from Soil Erosion

Measures to minimise impacts to surface water quality and subsequently aquatic biota from increased suspended sediment and turbidity are described in Section 10.3.2.1 and 10.3.3.1. No additional measures specific to mitigating impacts to aquatic ecosystems are proposed.

Altered Hydrological Regime

The measures to mitigate impacts on surface water hydrological regimes from Project infrastructure are described in Section 10.2.3.1. No additional measures specific to mitigating impacts to aquatic ecosystems are proposed.

10.9.3.2 Sub-lethal or Lethal Toxicity Effects on Aquatic Biota

Surface Water Contamination from Accidental Release of Landfill Leachate

The embedded design controls and management measures listed in Section 10.1.2.3 and 10.1.3.3 to address impacts to soil quality (and surface water quality) from accidental release of landfill leachate will also mitigate impacts to aquatic biota. No additional measures specific to mitigating impacts to aquatic ecosystems are proposed.

Surface Water Contamination from Accidental Release of Hazardous Industrial and Liquid Wastes

The embedded design controls and management measures listed in Section 10.1.2.3, 10.1.3.3 and 10.3.2.3 to address impacts to soil quality and surface water quality from an accidental release of hazardous industrial and liquid waste will also mitigate impacts to aquatic biota. No additional measures specific to mitigating impacts to aquatic ecosystems are proposed.

Surface Water Contamination from Accidental Release of Hydrocarbons or Chemicals

The embedded design controls and management measures listed in Section 10.1.2.3, 10.1.3.3 and 10.3.2.3 to mitigate impacts to soil quality and surface water quality from hydrocarbon and chemical releases will also mitigate impacts to aquatic biota. No additional measures specific to mitigating impacts to aquatic ecosystems are proposed.

10.9.3.3 Introduction of Aquatic Weeds

Measures to mitigate impacts due to the introduction of aquatic weeds will include:

- Inspecting and washing down all vehicles, machinery and equipment coming from within the local area (i.e., NCD) prior to arrival on site, or if washing down on site, ensuring material washed from machinery and equipment is collected and either treated prior to discharge or disposed of appropriately. [EM109]
- Ensuring all vehicles, machinery and equipment brought from outside of Papua New Guinea or brought into the Project area from elsewhere in Papua New Guinea are verified to be weed-free before arrival on site. [EM110]
- Prohibiting washing of equipment, vehicles or machinery near or within drainage channels. [EM111]
- Limiting work vehicles and machinery to designated access and work site areas. [EM112]
- Implementing accepted weed control measures where weeds are established and obtaining expert advice from CEPA or a qualified aquatic ecologist. [EM113]
- Providing training to relevant personnel in weed prevention and management protocols. [EM114]

10.9.4 Residual Impact Assessment

The following section provides the assessment of residual impacts to aquatic biodiversity assuming successful implementation of the proposed mitigation measures.

10.9.4.1 Habitat Degradation or Modification

Increased Suspended Sediment and Turbidity from Soil Erosion

As discussed in Section 10.1, clearing of approximately 1.58 ha of sparse vegetation and ground disturbance works within the 4.67 ha landfill footprint for the construction of the industrial landfill will result in the exposure and disturbance of soils. During construction, rainfall runoff from exposed surfaces could mobilise sediment to surface water bodies which could increase turbidity and suspended sediment and affect aquatic fauna behaviour and health and ecosystem productivity and structure.

As discussed in Section 10.3.4.1, considering the mitigation measures, which will minimise sediment loads reporting to the downslope catchment, increased turbidity and suspended sediment concentrations during construction would most likely occur during periods of high rainfall and would be short term (i.e., construction period in the wet season) and localised. Given the large fluctuations naturally occurring in the local drainage channels, aquatic biota in this environment are expected to be tolerant of short term increased turbidity and suspended sediment concentrations. Given the short construction period and the localised extent of potential changes to water quality, the magnitude of the impact from increased suspended sediment and turbidity during construction to aquatic species and habitats is assessed as ***Low***. Since the sensitivity of aquatic habitat and species in the drainage channels is ***Low***, the overall impact significance rating for construction of the landfill is assessed as ***Minor***.

As discussed in Section 10.3.4.1, with the embedded design controls and the implementation of mitigation measures which includes the installation of a sediment dam to collect potentially sediment laden runoff from the industrial landfill, impacts to water quality from increased turbidity and suspended sediment from rainfall erosion of the operational industrial landfill are predicted to be within the range of natural variability during operations. Consequently, no detectable impacts to aquatic habitat and species are predicted. The magnitude of the impact is assessed as ***Negligible***. Since the sensitivity of aquatic habitat and species in the drainage channels is ***Low***, the overall impact significance rating for operation of the industrial landfill is assessed as ***Negligible***.

Altered Hydrological Regime

Impacts to hydrological regimes due to the construction of and physical presence of the industrial landfill are assessed in Section 10.2.4.1. Short-term (i.e., only after significant rain events), localised (i.e., limited to the nearby drainage channels) changes to existing hydrological regimes may occur during construction and operation of the industrial landfill. The impact significance for changes to hydrological regimes from the industrial landfill was assessed as negligible for construction and operations. Considering this, the magnitude of the impact to aquatic ecosystems from altered hydrological regimes from the industrial landfill is also assessed as ***Negligible*** for construction and operations. Since the sensitivity of aquatic habitat and species in the drainage channels is ***Low***, the overall impact significance rating for altered hydrological regimes associated with construction and physical presence of the industrial landfill is assessed as ***Negligible***.

10.9.4.2 Sub-lethal or Lethal Toxicity Effects on Aquatic Biota

Surface Water Contamination from Accidental Release of Landfill Leachate

Impacts to surface water quality from accidental release of landfill leachate are considered in Section 10.3.4.2. The embedded design controls and mitigation and management measures applicable to mitigating impacts to surface water quality will prevent the loss of leachate from the industrial landfill, leachate collection system and leachate storage pond. As such, the magnitude of the impact to aquatic fauna from the accidental release of landfill leachate is assessed as ***Negligible***.

Given the sensitivity of aquatic species in the downstream drainage channels is ***Low***; the overall impact significance rating for lethal or sub-lethal toxicity effects on aquatic fauna from accidental release of landfill leachate is ***Negligible*** for operations.

Surface Water Contamination from Accidental Release of Hazardous and Industrial Liquid Wastes

Impacts to surface water quality from accidental release of hazardous industrial and liquid waste are considered in Section 10.3.4.3. Hazardous industrial and liquid waste will be stored and handled within bunded areas, designed to sufficient capacity considering the liquids to be stored and handled, and captured rainfall runoff will drain to collection sumps. This water and water that has come into contact with operational areas will be diverted to collection sumps and ultimately the IWWTP for processing and beneficial reuse. The design of the hazardous waste storage facility is such that it will also prevent the release of hazardous liquid wastes. Bunds and sumps will be regularly inspected and pumped if required to maintain sufficient storage capacity.

Considering these design controls and mitigation measures hazardous and industrial liquid wastes will not be released to the environment. As such, the magnitude of the impact to aquatic fauna from the accidental release of hazardous and industrial liquid wastes is assessed as ***Negligible.***

Given the sensitivity of aquatic species in the downstream drainage channels is ***Low***; the overall impact significance rating for lethal or sub-lethal toxicity effects on aquatic fauna from the accidental release of hazardous and industrial liquid wastes is ***Negligible*** for operations.

Surface Water Contamination from Accidental Release of Hydrocarbons or Chemicals

Impacts to surface water quality from accidental hydrocarbon or chemical releases are considered in Section 10.3.4.4. During operations and construction, short term, localised impacts (i.e., limited to the nearby drainage channels), outside of the range of natural variability may occur where surface water quality may be moderately affected. Impacts to aquatic fauna could therefore occur within the nearby drainage channels but such impacts would also be short term and localised. Flows in the drainage channels are ephemeral and therefore limited to periods of sufficient rainfall. Flows will increase substantially following heavy rainfall events and this is likely to flush, dilute and or disperse contaminants in the system. The magnitude of the impact to aquatic fauna is assessed as ***Low*** for construction. During operations accidental spills or leaks of hydrocarbons or chemicals that are not immediately contained will likely be captured by the site stormwater management system, which will collect water from potentially impacted operational areas. As such, the magnitude of the impact is assessed as ***Negligible*** for operations.

Given the sensitivity of aquatic fauna in the nearby drainage channels (where impacts could occur) is ***Low***, the overall impact significance rating is assessed as ***Minor*** for construction and ***Negligible*** operations.

10.9.4.3 Introduction of Aquatic Weeds

Construction and operation of the industrial landfill and the general use of vehicles, machinery and equipment could result in the introduction of aquatic weed seeds or fragments to site which could be spread to the downstream catchment where they may establish viable populations. The wash-down and inspection of vehicles, machinery and equipment and general weed management measures will reduce the likelihood of an introduction. Prevention is key to managing aquatic weeds since, once established, they can spread quickly and be difficult to eradicate. Considering that vehicles, equipment and machinery will be weed-free prior to undertaking works on the site, an incursion is highly unlikely to occur. Further, due to the ephemeral nature of the drainage channels in the downstream catchment it is highly unlikely that an introduced aquatic weed would be able to establish a viable population given the absence of permanent water. Therefore the magnitude of the impact for construction and operations is assessed as ***Negligible***.

Given the sensitivity of aquatic habitats and species in the downstream drainage channels is ***Low***; the overall impact significance rating for the introduction of aquatic weeds is ***Negligible*** for construction and operations.

10.9.4.4 Summary of Residual Impact Assessment

Table 10.26 provides a summary of the residual impact assessment for aquatic biodiversity. All residual impacts to aquatic biodiversity were assessed to be ***Negligible*** to ***Minor.***

Table 10.26 – Aquatic Biodiversity Impact Assessment

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
Aquatic habitat	Habitat degradation or modification from increased turbidity/ sedimentation in downstream surface waters due to erosion of soils/exposed surfaces	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure	• EM41 • EM42 • EM43 • EM5 • EM9 • EM12 • EM44 • EM6 • EM45 • EM40	Construction	Low/Low	Minor
		• Industrial landfill activities		Operations	Low/Negligible	Negligible
Aquatic habitat	Habitat degradation or modification from altered hydrological regime	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure	• EM37 • EM38 • EM39 • EM40	Construction and operations	Low/Negligible	Negligible
Aquatic fauna	Sub-lethal or lethal toxicity effects to aquatic biota due to accidental release of landfill leachate	• Collection of leachate in leachate collection system • Storage of leachate in leachate storage pond	• EM33 • EM34 • EM35 • EM36	Operations	Low/Negligible	Negligible
Aquatic fauna	Sub-lethal or lethal toxicity effects to aquatic biota due to accidental	• Storage of hazardous and non-hazardous waste • Handling and processing of hazardous wastes • Fixation of hazardous waste materials	• EM29 • EM30 • EM31 • EM32	Operations	Low/Negligible	Negligible

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
	release of hazardous and industrial liquid wastes					
Aquatic fauna	Sub-lethal or lethal toxicity effects to aquatic biota due to accidental release of hydrocarbons and chemicals	• Storage, handling and use of chemicals and fuels • Operation of fixed and mobile plant and equipment • Operation of diesel generators	• EM16 • EM17 • EM18 • EM19 • EM20 • EM21 • EM22 • EM23 • EM24 • EM25 • EM26 • EM27 • EM28	Construction	Low/Low	Minor
				Operations	Low/Negligible	Negligible
Aquatic habitat and species	Introduction of aquatic weeds	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure • Transport of Project equipment, materials and personnel • General vehicle movements • Operation of fixed and mobile plant and equipment	• EM109 • EM110 • EM111 • EM112 • EM113 • EM114	Construction and operations	Low/Negligible	Negligible

10.10 Cumulative Impact Assessment

All residual environmental impacts described in this chapter were assessed as negligible to minor. The environmental impacts associated with the Project are predicted to be localised and or short term or not detectable with respect to natural variability and existing conditions. Therefore, in accordance with the cumulative impact assessment method described in Section 7.3.3, there are no impacts considered to present a credible pathway for consideration in the cumulative impact assessment, which would be limited to residual impacts assessed as moderate, major or severe. The Project is unlikely to result in discernible cumulative impacts considering the likely continued development of the industrial precinct, including the proposed Tuhava Town development or other future developments in the area.

10.11 References

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11. Potential Socio-economic Impact on Proposal

The socio-economic impact assessment method follows the significance assessment method set out in Chapter 7. It involves assessment of impacts through a process of firstly identifying potential impacts and then assessing residual impacts by examining both the sensitivity of the receptors being impacted and the magnitude of the potential impact. Discipline-specific criteria for receptor sensitivity and impact magnitude used for this assessment are described in Section 7.3.1.

Social receptors are the individuals, organisations, groups or resources that can be affected by Project activities. For this assessment, receptors are broadly defined according to the groups presented in Table 11.1.

Table 11.1 – Description of Social Receptors Relevant to the Impact Assessment

Social Receptor	Description
Village leaders	Individuals representing the interests of the local community and Landowners in Roku village in discussions with TWM
Landowners	Individuals/groups from landowning clans in the study area. Organised into formal landowner company (Kuriu Landowner Group Inc. and Ohobiduduare Holdings Limited) to represent the interests of landowning clans and persons
Local community	Individuals/families residing in Roku village that may be impacted directly or indirectly by Project activities
Business	Industry and business located near the TWM site that may be impacted directly or indirectly by Project activities. Businesses include: • Pagini Transport • Oilmin • AES • Agility • Islands Petroleum • Longfa Cement • Rhodes/AGL • Puma Refinery Also includes industry and business workforce who may use, work at or are accommodated at any of the sites as well as existing workforce using the Tuhava Town facilities (eg., Tuhava Town Restaurant) and any potential future workforce accommodated at Tuhava Town

Impacts are focused on six thematic areas described below:

- Economy and employment.
- Community health and safety.
- Land and natural resource use.

- Traffic and transport.
- Law and order (including any potential impacts related to governance and leadership).
- Cultural heritage and archaeology.

11.1 Economy and Employment

11.1.1 Potential Impacts

Formal employment in the study area is high when compared to other rural areas in Papua New Guinea, due to employment with businesses in the existing industrial precinct. Fishing is also an important livelihood activity (see Section 9.7.2.1). In addition to formal employment and fishing, the local community benefits from the sale of store goods and firewood (see Section 9.6.2).

Despite this, it is likely that there are some sectors of the community in the study area that experience high levels of unemployment, have limited opportunities for tertiary education and for women to enter the workforce or undertake entrepreneurial business activities (see Section 9.6.2).

The Project recently acquired additional customary land to support the proposed extension of IWMF operations. The process of transfer of customary land to State ownership is complete, and TWM will become the owners of the additional land. The process of the sale of land represents the full scope of financial payments to landowners.

As described in Section 4.6, the construction workforce is estimated at approximately 40 national contractor sraff (with some additional expatriate specialist staff), and the operations workforce is anticipated to increase as the facility becomes incrementally operational. The workforce for the fully operational IWMF is estimated at 91 staff; comprising 83 local employees and 8 expatriate staff, with a 56 male and 35 female split working in roles including operators for all IWMF plant, administration, maintenance, labouring, transportation, cleaning, security, professional staff, and supervisory and managerial positions. Additional formal employment will result in increased income for local community members, which may also have positive impacts on access to physical capital (i.e., infrastructure, equipment and facilities) and improvements to housing.

11.1.1.1 Increased Direct and Indirect Economic Opportunities, Workforce Training, Skills and Experience

The Project will result in increased job opportunities for local communities in the area. Some households from the local communities may experience increased household income as a direct impact from Project employment with TWM as the facility becomes incrementally operational.

Given the expected widespread literacy and education levels in the study area (see Section 9.3.3), skillsets amongst the working-age population are expected to be proportionately widespread. It is likely there are a number of individuals from the local communities who already hold the required qualifications for direct employment as the facility becomes incrementally operational and TWM has committed to hiring locally (see Section 4.6.4).

Project staff and contractors are also expected to benefit indirectly from TWMs ongoing commitment to technical and vocational education and training of its staff/contractors. This will contribute toward increased local workforce skills development.

Further direct economic opportunities will likely be felt by logistical organisations which will be used to support the Project and the transportation of waste. Local community members who own local businesses (e.g., trade stores, table markets, fuel sellers) in the study area may experience an indirect increase in household income due to increased expenditure from the operational workforce commuting to and from the site, daily, via roads serviced by these local businesses.

Landowners will benefit directly from the Project through the sale of land to TWM.

11.1.1.2 Summary of Potential Impacts

Potential impacts to economy and employment as a result of Project activities are summarised in Table 11.2.

Table 11.2 – Summary of Potential Impacts to Economy and Employment

Project Phase	Activity/Aspect	Project Component	Potential Impact
Construction and operations	• Project employment • Land sale	Project workforce	Increased direct and indirect economic opportunities, workforce training, skills and experience

11.1.2 Mitigation and Management

Measures to support benefits to economy and employment will include:

- Maximising the employment and training of PNG and local citizens in all job categories where appropriate and in accordance with PNG law. [SM3]
- Maintaining good relations and continue to engage with host communities most impacted by the Project on issues/concerns raised by these communities (to be regularly updated consistent with the Stakeholder Engagement Plan). [SM4]
- Continuing to work with local communities on ongoing community development and capacity building opportunities. Examples may include:
  - Napa Napa Road maintenance.
  - Community-level waste collection and management.
  - Support for the Roku Women's Fellowship activities, particularly those aimed at increasing women's tertiary education and entrepreneurial business opportunity rates. [SM5]

11.1.3 Residual Impact Assessment

11.1.3.1 Increased Direct and Indirect Economic Opportunities, Workforce Training, Skills and Experience

The impact magnitude of increased direct and indirect economic opportunities, workforce training, skills and experience associated with construction and operations activities is assessed as ***Positive***, as these opportunities continue to improve on current baseline conditions. TWM will seek to maximise positive outcomes arising from increased direct and indirect economic opportunities by continuing to build the capacity of the local workforce via vocational education and training of its staff. The sensitivity of local communities to increased opportunities, training, skills and experience is considered to be ***Low*** given there exists a skilled and experienced labour pool within the study area. This results in a residual impact significance of ***Positive***.

11.1.3.2 Summary of Residual Impact Assessment

A summary of residual impacts to the economy and employment as a result of the Project is presented in Table 11.3. Residual impacts to the economy and employment as a result of Project activities are assessed as ***Positive***.

Table 11.3 – Economy and Employment Impact Assessment

Value/Receptor	Potential Impact	Activity/ Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
• Landowners • Local community	Increased direct and indirect economic opportunities, workforce training, skills and experience	• Project employment • Land sale	• SM3 • SM4 • SM5	Construction and operations	Low/Positive	Positive

11.2 Community Health and Safety

11.2.1 Potential Impacts

This section describes the potential impacts of the Project on community health and safety. Project workforce occupational health and safety is not assessed unless the Project workforce are found to contribute or cause community health and safety impacts.

Napa Napa Road is sealed and reportedly in better condition between Roku village and the Puma refinery than between Roku and the junction with Lea Lea Road (towards the PNG LNG site). However, congestion on Napa Napa Road is reportedly high as a result of the other commercial/industrial activities that occur in the immediate area and will increase again as a result of the Project. This could also lead to an increase in accidents and injuries along with increased noise emissions during construction and operation phases of the Project.

The local community have expressed concerns regarding prevailing winds and the potential impact of increased odour emissions on existing amenity values. While air emissions modelling results indicates that emissions criteria will be met during construction and operations (see Section 10.5.4), these concerns still have the potential to negatively impact on the amenity and wellbeing of the local community. Similarly, any increase in noise from construction or operations could also impact the on peoples' wellbeing, despite modelling indicating that predicted noise emissions from Project activities will be at or below nominated noise limits (see Section 10.6.4)

The local community also raised concerns regarding health risks associated with contamination of natural resources used for subsistence due to contamination of soils, surface water and groundwater from leaks and spills of hazardous waste; these concerns are considered in Section 11.3.

11.2.1.1 Increased Accidents and Injuries as a Result of Increased Traffic Volumes During Construction and Operation

The local community use Napa Napa Road to access health, education and economic infrastructure between Porebada and Port Moresby. Access is typically by private motor vehicle as private vehicle ownership is low in Roku; however, a few residents who work locally (e.g., at the AES Industrial Park) reportedly access Napa Napa Road on foot. Businesses at the AES Industrial Park also use small buses to collect staff from the local community.

An increase in vehicles accessing Napa Napa Road and the TWM site during construction and operation will present an increased risk of traffic accidents between Project-related vehicles and other road users (vehicles and pedestrians).

In terms of the volume of vehicles in the vicinity of the study area, currently 20 vehicles access the TWM site per day over a 6-day week via Napa Napa Road. In addition, up to 250 vehicles per day are estimated (based on business interviews) to use Napa Napa Road to access other industrial sites in the area.

The Project anticipates an additional 36 vehicles per day will access the TWM site at the peak of construction of the industrial landfill and up to 40 vehicles per day during full operations of the expanded IWMF, with vehicle types dependant on the type of material or load being transported.

11.2.1.2 Reduced Amenity and Wellbeing as a Result of Air and Noise Emissions

Section 10.5 describes the modelled air emissions (pollutants) associated with the currently approved, but not yet operational Level 2 activities and the proposed scenario which represents the full operational IWMF including the additional Level 3 activities addressed in this EIS. Section 10.6 describes the potential noise sources, sensitive receptors and predicted construction and operations noise emissions associated with the Project. Both air (construction and operations) and noise (operations) emissions are predicted to meet applicable criteria. The potential for construction-related noise emissions to impact on local amenity was assessed as ***Minor*** (see Section 10.6.4.1) for all receptors, including the Tuhavu Town, AES Industrial Park and Roku village.

The local community (Roku village) and businesses within the AES Industrial Park are not expected to experience a discernible change in air quality as a result of Project activities (see Section 10.5.4.1. However, community perceptions of health risks may increase as an indirect result of Project activities at the IWMF, particularly those associated with the industrial landfill and the incineration of hazardous wastes, which in turn may cause stress and related physical, physiological and psychological effects.

The construction of the industrial landfill will increase noise emissions for the 12-month period of construction and may cause localised impacts to amenity within a few hundred meters of the IWMF. For the operations phase, even under worst-case conditions, noise levels will be at or below the applicable criteria for residential and commercial/industrial receptors, although at the nearest stilted dwelling at Tuhava Town, noise levels would be just below the applicable criteria (see Section 10.6.4.2). Perception of sound in day-to-day life is important for human wellbeing and amenity. Excessive noise has the potential to impact health and wellbeing causing nuisance, interfering with normal speech communication, causing changes in behaviour/upset daily work patterns, sleep disturbance/deprivation, and anxiety over sudden or unknown loud noises. These impacts can lead to stress and increased blood pressure, as well as other physical, physiological and psychological effects. There is the potential for nearby residents in Tuhava Town and employees accommodated at AES to experience reduced amenity and wellbeing from noise, although emissions will meet health-based criteria. The Roku community may experience additional noise during construction and operations, depending upon the prevailing wind direction and the existing ambient noise, but noise levels at Roku village are predicted to meet applicable criteria

11.2.1.3 Health Risks Associated with the Transportation and Handling of Hazardous Wastes

The IWMF already receives a range of medical wastes and may consider accepting radiotherapy wastes (i.e., medical wastes associated with the treatment of cancer) in the future. With cases of COVID-19 increasing in Papua New Guinea, perceptions of heightened health risks to the local community and businesses around the IWMF may indirectly increase as a result of TWMs decision to handle additional waste types. This is in addition to concerns previously raised by the local community relating to transportation and treatment of other medical waste such as those relating to HIV and TB.

If TWM decide to accept and process radiotherapy wastes in the future, there is potential for increased health risk to the local community and neighbouring businesses, if this waste type was improperly transported or handled, or if there was a significant incident in transit; the latter of which is considered in Chapter 12 (Major Hazards).

11.2.1.4 Summary of Potential Impacts

Potential impacts to community health and safety as a result of Project activities are summarised in Table 11.4.

Table 11.4 – Summary of Potential Impacts to Community Health and Safety

Project Phase	Activity/Aspect	Project Component	Potential Impact
Construction and operations	• Transport of Project equipment, materials and personnel • General vehicle movements	Traffic and transport	Increased accidents and injuries as a result of increased traffic volumes during construction and operation
Construction and operations	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure • Operation of fixed and mobile plant and equipment • General vehicle movements • Transport of earthen material • Transport of Project equipment, materials and personnel • Transport of hazardous and non- hazardous wastes • Operation of diesel generators • Industrial landfill activities • Incineration of hazardous waste	Industrial landfill construction; traffic and transport; operation of incinerator; operation of industrial landfill; waste sorting and segregation; weighbridge and receival hall; IWWTP; fixation bays; hazardous waste storage	Reduced amenity and wellbeing as a result of air and noise emissions
Operation	• Transport of hazardous and non-hazardous wastes • Handling and processing of hazardous waste	Traffic and transport; operation of incinerator; operation of industrial landfill	Health risks resulting from the transportation and handling of hazardous wastes

11.2.2 Mitigation and Management

11.2.2.1 Increased Accidents and Injuries as a Result of Increased Traffic Volumes During Construction and Operation

Measures to mitigate a potential increase in traffic-related accidents and injuries will include:

- Implementing traffic controls including detailed signage, driver training, speed limits and vehicle speed controls and ensuring compliance from staff and contractors. [SM6]
- Limiting the transportation of hazardous waste at peak traffic hours (e.g., school start/finish times and shift changes), where possible. [SM7]
- Maintaining pedestrian access points to/along the Napa Napa Road. [SM8]
- Engaging with Central Government and local businesses to maintain upkeep of Napa Napa Road. [SM9]
- Undertaking ongoing engagement with local community and businesses relating to Project traffic and any potential impacts. [SM10]
- Reviewing and implementing the existing TWM Project grievance procedure to receive, record, respond to and to address any grievances made regarding Project activities. Monitor the progress of grievances and provide updates to aggrieved parties and other relevant stakeholders. [SM2]
- Maintaining vehicle speed limits on-site at 20 km/h, or below. [EM52]

11.2.2.2 Reduced Amenity and Wellbeing as a Result of Increased Air and Noise Emissions

Measures to mitigate air and noise emissions and described in Section 10.5.3.1 and Section 10.6.3. In addition, the following measure will be implemented to mitigate community and business concerns about amenity and wellbeing:

- Undertaking ongoing engagement with local community and businesses, providing clear, factual and accurate information relating to Project impacts, in an open and transparent manner. [SM2]
- Reviewing and implementing the existing TWM Project grievance procedure to receive, record, respond to and to address any grievances made regarding Project activities. Monitor the progress of grievances and provide updates to aggrieved parties and other relevant stakeholders. [SM1]
- Investigating community grievances and undertaking noise monitoring where required. [SM11]
- Providing advance notice to neighbouring operations and/or residents where temporary high-intensity noise events are planned and advising of the intended type and duration of works to be undertaken. [SM12]

11.2.2.3 Health Risks Associated with the Transportation and Handling of Hazardous Wastes

Measures to mitigate risks associated with the transportation and handling of hazardous materials are detailed in Section 10.1.3.3. Measures to mitigate community concerns associated with the transportation and handling of hazardous waste include:

- Undertaking ongoing engagement with local community and businesses, providing clear, factual and accurate information relating to Project impacts, in an open and transparent manner. [SM2]
- Reviewing and implementing the existing TWM Project grievance procedure to receive, record, respond to and to address any grievances made regarding Project activities. Monitor the progress of grievances and provide updates to aggrieved parties and other relevant stakeholders. [SM1]

11.2.3 Residual Impact Assessment

11.2.3.1 Increased Accidents and Injuries as a Result of Increased Traffic Volumes During Construction and Operation

The sensitivity of social receptors to increased traffic volumes is assessed as ***Medium*** given there are limited alternative transport routes for the local community and for businesses around the IWMF and, as such, receptors are already exposed to an increased risk of accident and injury on the Napa Napa Road. The additional traffic projections associated with the Project represents an estimated near doubling in traffic accessing the IWMF during Project construction, and a doubling of operational traffic, which will be experienced incrementally over a period of 3 to 5 years as additional plant and waste technology are brought online. This increase represents approximately 8% of the current total estimated traffic accessing the AES Industrial Park and Puma Oil Refinery via Napa Napa Road. The impact magnitude is assessed as ***Low*** given the anticipated minor increase in total traffic volumes resulting from Project construction and operational activities. The residual impact is therefore assessed as ***Minor***.

11.2.3.2 Reduced Amenity and Wellbeing as a Result of Increased Air and Noise Emissions

As discussed in Section 11.2.1.2, air and noise emissions will not exceed applicable criteria, which considers community health. However there may still be residual health concerns surrounding amenity and wellbeing from community members and neighbouring businesses. The sensitivity of the local community and local businesses to heightened health concerns associated with Project air or noise emissions, is assessed as ***Low***, as although some receptors within the industrial precinct are in close proximity to the IWMF, they are located within an existing and operational industrial area (and therefore will be used to the current levels of air and noise emissions). The impact magnitude is assessed as ***Low*** due to the modelled emissions meeting applicable criteria, construction being limited to daytime hours and the change from approved Level 2 emissions to projected Level 3 emissions is minimal. The residual impact is therefore assessed as ***Minor***.

11.2.3.3 Health Risks Associated with the Transportation and Handling of Hazardous Wastes

The sensitivity of the local community to perceived or real health risks associated with the transportation and handling of hazardous waste is assessed as ***Low*** given that the IWMF already accepts various types of medical, hazardous and quarantine waste. The impact magnitude is assessed as ***Low*** given the existing health and safety measures in place at the IWMF with managing hazardous waste, including medical wastes and the measures to keep community and businesses informed of Project impacts and risks. The residual impact is assessed as ***Minor***.

11.2.3.7 Summary of Residual Impact Assessment

Table 11.5 provides a summary of the residual impact assessment for community health and safety. Residual impacts to community health and safety are all assessed as ***Minor***.

Table 11.5 – Community Health and Safety Impact Assessment

Value/ Receptor	Potential Impact	Activity/ Aspect	Mitigation Measures	Project Phase	Sensitivity/ Magnitude	Residual Impact Significance
• Local community • Business	Increased accidents and injuries as a result of increased traffic volumes during construction and operation	• Transport of Project equipment, materials and personnel • General vehicle movements	• SM6 • SM7 • SM8 • SM9 • SM10 • SM2 • EM52	Construction and operations	Medium/Low	Minor
• Local community • Business	Reduced amenity and wellbeing as a result of increased air and noise emissions	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure • Operation of fixed and mobile plant and equipment • General vehicle movements • Transport of earthen material • Transport of Project equipment, materials and personnel • Transport of hazardous and non-hazardous wastes • Operation of diesel generators • Industrial landfill activities • Incineration of hazardous waste	• SM2 • SM1 • SM11 • SM12 • EM48 • EM49 • EM50 • EM51 • EM52 • EM53 • EM54 • EM1 • EM55 • EM56 • EM57 • EM58 • EM59 • EM60 • EM3 • EM80	Construction and operations	Low/Low	Minor

Value/ Receptor	Potential Impact	Activity/ Aspect	Mitigation Measures	Project Phase	Sensitivity/ Magnitude	Residual Impact Significance
			• EM81 • EM82 • EM83 • EM27 • EM84 • EM85			
• Local community • Business	Health risks resulting from the transportation and handling of hazardous wastes	• Transport of hazardous and non-hazardous wastes • Handling and processing of hazardous waste	• SM2 • SM1 • See also measures in Section 10.1.3.3	Operations	Low/Low	Minor

11.3 Land and Natural Resource Use

11.3.1 Potential Impacts

As discussed in Sections 9.6.2 and 9.7, Roku village residents continue to engage in subsistence practices, although to a lesser extent than many villages in rural Papua New Guinea, as more than 50% derive their income and livelihoods from formal employment. This section addresses potential impacts on land and natural resource use by the Roku community, and draws on assessments made in Chapter 10.

Roku village residents reported that hunting for wallaby is only sometimes practiced, and the potential for noise to drive away game was considered. Section 10.8.4.2 assesses the impact of noise on local fauna as ***Negligible***, therefore the potential for noise to contribute to a reduction in hunting success is not assessed.

Freshwater for drinking and washing is in general not sourced from natural supplies, as the streams in the study area are ephemeral, and the groundwater is saline, making it unsuitable for drinking. Therefore, there will be no indirect impacts on freshwater for domestic use resulting from potential Project impacts on surface or groundwater (see Sections 10.3 and 10.4).

Firewood and timber posts are sourced from the savanna forest surrounding the village and comprise an important source of income for some Roku residents. Women interviewed during the baseline survey indicated they were concerned that the Project could reduce the amount of firewood available. Wild plants are also used for medicinal purposes.

Fishing, practiced daily by men in the village, contributes the main protein source for the villagers and is also an important income source. Contamination of the marine environment in Idlers Bay or Fairfax Harbour has the potential to adversely affect natural resource use (specifically fishing activities) by Roku villagers, with implications for subsistence and livelihoods. If Project activities were to cause contamination of the marine environment as a result of contaminated surface water runoff from a leak or spill of hazardous waste, this could subsequently affect fish stocks and catch rates, with potential impacts on income and nutrition. However, there are no planned activities that would result in impacts extending to the marine environment (see Section 10.3). Chapter 12 assesses the risk of major loss of containment of chemicals. Therefore contamination of the marine environment and subsequent impacts on marine fisheries and the Roku community is not considered a credible impact and is not assessed.

Project impacts on regulating and maintaining ecosystem services such as maintaining surface water quality, erosion control and regulation of natural hazards is considered unlikely given the highly localised nature of the activities. Therefore, impacts to supporting and maintaining services are not assessed further. Sediment control measures, which respond to localised soil and sediment control, are presented in Sections 10.1.3.

11.3.1.1 Loss of Access to Timber Used for Firewood and House Posts

Vegetation clearing for the expanded Project infrastructure will not occur beyond the boundary of the land currently being leased by TWM from landowners and is minimal, at 1.58 ha (see Section 4.1.4). The total land area that has recently been acquired to support the IWMF

expansion is approximately 8 ha. The larger parcel (approximately 5.56 ha) to the north east of the current boundary is already largely cleared or degraded and is unlikely to be currently used for the collection of firewood or timber posts. The smaller parcel (approximately 2.45 ha) is more heavily vegetated and may be utilised by Roku residents for timber or firewood collection.

11.3.1.2 Loss of Wild Plants Used for Medicinal Purposes

Roku village residents reported that only a few wild plants are collected from the area surrounding the village. There is the potential for expanded Project operations to contribute to the loss of some individuals of these wild plant species (e.g., neme tree, parasite plant, noni plant) and to the spread of invasive species via 'edge effects' (see Section 10.8.2.2), which could in turn affect the availability of some wild plants, mainly used for medicinal purposes.

11.3.1.4 Summary of Potential Impacts

Potential impacts to land and natural resource use as a result of Project activities are summarised in Table 11.6.

Table 11.6 – Summary of Potential Impacts on Land and Natural Resource Use

Project Phase	Activity/Aspect	Project Component	Potential Impact
Construction	• Land sale • Land clearing	Industrial landfill construction	Loss of access to timber used for firewood and house posts
Construction and operations	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure • General vehicle movements • Transport of earthen material • Transport of Project equipment, materials and personnel	Operation of industrial landfill	Loss of wild plants used for medicinal purposes

11.3.2 Mitigation and Management

11.3.2.1 Loss of Access to Timber Used for Firewood and House Posts

Measures to minimise impacts on community collection and use of timber and firewood include:

- Making wood cleared from within the IWMF boundary available to Roku village residents for use as building material or firewood. [SM13]

11.3.2.2 Loss of Wild Plants Used for Medicinal Purposes

The management measures listed in Section 10.8.3.1 and 10.8.3.2 to address impacts to habitat loss and fragmentation and degradation from edge effects will also mitigate potential impacts to wild plant foods. No additional measures are proposed.

11.3.3 Residual Impact Assessment

11.3.3.1 Loss of Access to Timber Used for Firewood and House Posts

Both land parcels that are in the process of being transferred from customary land to TWM represent a negligible percentage (less than 1%) of the forested area within a 2 km radius of Roku village. Further, TWM will make any cleared vegetation available to the Roku community, and landowners will receive revenue for the sale of the State lease land, which will effectively compensate for any longer-term loss of timber or access to timber growing on the two land parcels. Therefore, the impact magnitude of a loss of access to timber is assessed as ***Negligible***. Roku villagers are only minimally dependent on natural resources in the study area, have alternatives available (i.e., electricity and modern housing materials), and income to support their purchase. However, Roku women expressed concern about the potential loss of firewood and would be affected more than men by loss of access, as the collection of firewood is largely 'women's work', and women use the wood for cooking. Therefore, the sensitivity of the local community to the loss of access to timber is assessed as ***Medium***. Therefore, the residual impact significance assessment of the loss of access to timber is ***Negligible***.

11.3.3.2 Loss of Wild Plants Used for Medicinal Purposes

The impact magnitude of the loss of wild medicinal plants due to clearing and movement of machinery is assessed as ***Negligible*** given the small area required (8 ha) for the expansion of the IWMF, the already degraded state of some areas of the surrounding savanna and the measures proposed to manage weed incursions off site. The sensitivity of the local community to the loss of wild medicinal plants is assessed as ***Low***, due to minimal dependence on wild plants, some of which are introduced species themselves, and the availability of conventional medicine at nearby health clinics and hospitals. Therefore the residual impact significance for a loss of wild plants used for medicinal purposes is ***Negligible***.

11.3.3.3 Summary of Residual Impact Assessment

A summary of residual impacts to land and natural resource use as a result of the Project is presented in Table 11.7. Both residual impacts are assessed as ***Negligible***.

Table 11.7 – Land and Natural Resource Use Impact Assessment

Value/ Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
• Local community	Loss of access to timber used for firewood and house posts	• Land sale • Land clearing	• SM13	Construction	Medium/Negligible	Negligible
	Loss of wild plants used for medicinal purposes	• Clearing of vegetation • Earthworks, excavation and ground disturbance • Construction of industrial landfill and associated infrastructure • General vehicle movements • Transport of earthen material • Transport of Project equipment, materials and personnel	No additional measures	Construction and operations	Low/Negligible	Negligible

11.4 Traffic and Transport

11.4.1 Potential Impacts

This section considers impacts associated with increased traffic volumes resulting from Project activities during construction and operation, with the exception of potential traffic impacts on community health and safety which are addressed in Section 11.2 and potential traffic impacts on amenity (air quality and noise) which are addressed in Section 10.5 and Section 10.6. Potential major hazards resulting from the transportation of hazardous waste are addressed in Section 12.

The proximity of Roku village to the Napa Napa Road enables residents to access infrastructure, services and employment in the local area as well as in Port Moresby. While no formal public transport system exists in the study area, a number of public motor vehicles (PMVs) operate a service on the Napa Napa Road. Any increase in Project-related traffic (estimated to double during construction and slowing increase to double current operational traffic over approximately 3 to 5 years) is likely to result in a minor increase in traffic congestion during hours of construction and operations; particularly during peak hours (7 a.m. to 9 a.m. and 3 p.m. to 5 p.m. weekdays). This may potentially impact local community access to social services, such as schools, health care or markets.

The Project is unlikely to have a significant impact on the already poor condition of Napa Napa Road to the extent that it would affect other road users (e.g., PMVs, pedestrians and traffic associated with other commercial activities in the area), given the small number of additional vehicle movements estimated during construction (approximately 37 per day) and operations (approximately 40 per day, an increase of approximately 20 per day).

11.4.1.1 Traffic Congestion Disrupts Access to Social Services

There are no alternative routes available for Roku village residents to access social infrastructure and services, with the exception of those services located in the Port Moresby area that can be accessed by dinghy (e.g., Koki market) and congestion along this road is currently high.

Traffic is most noticeable during peak periods of the day (i.e., early morning and mid-to-late afternoon when people are moving to/from work, school and/or markets). There is potential that Project-related traffic could impact on the local community, (particularly during construction through adding to congestion, causing delays in accessing PMVs and getting to/from work and school), businesses and other road users particularly during these peak times.

11.4.1.2 Summary of Potential Impacts

Potential impacts to traffic and transport as a result of Project activities are summarised in Table 11.8.

Table 11.8 – Summary of Potential Impacts to Traffic and Transport

Project Phase	Activity/Aspect	Project Component	Potential Impact
Construction	• Transport of earthen material • Transport of Project equipment, materials and personnel • General vehicle movements	Traffic and transport	Traffic congestion disrupts access to social services
Operations	• Transport of Project equipment, materials and personnel • General vehicle movements		

11.4.2 Mitigation and Management

Measures to mitigate traffic congestion associated with Project construction and operations include:

- Implementing traffic controls including detailed signage, driver training, speed limits and vehicle speed controls and ensuring compliance from staff and contractors. [SM6]
- Reducing traffic congestion at peak periods where possible. [SM14]
- Engaging with local residents and industrial neighbours on likely peak periods for traffic congestion during construction, and where possible, identifying opportunities to minimise construction traffic during these periods. [SM15]
- Reviewing and implementing the existing TWM Project grievance procedure to receive, record, respond to and to address any grievances made regarding Project activities. Monitor the progress of grievances and provide updates to aggrieved parties and other relevant stakeholders. [SM1]

11.4.3 Residual Impact Assessment

The following section provides the assessment of residual impacts on access to infrastructure and social services as a result of increased traffic, assuming successful implementation of the proposed mitigation measures.

11.4.3.1 Traffic Congestion Disrupts Access to Social Services

Given the reliance on the Napa Napa Road as a primary means to access infrastructure and social services and employment in the local and wider area (as far as Porebada and Port Moresby), the sensitivity of the local community to a disruption in access (albeit temporary) is rated as ***Medium.*** Given the anticipated minor increase in traffic volumes (approximately 8% based on current estimates of daily vehicle numbers) as a result of Project construction and operational activities, the impact magnitude of both Project construction traffic and an increase in operational traffic on local community access to social services is therefore rated as ***Low.*** This results in a residual impact significance rating of ***Minor***.

11.4.3.2 Summary of Residual Impact Assessment

A summary of residual impacts to traffic and transport as a result of the Project is presented in Table 11.9. The single residual impact was assessed as ***Minor.***

Table 11.9 – Traffic and Transport Impact Assessment

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
• Local community • Business	Traffic congestion disrupts access to social services	• Transport of Project equipment, materials and personnel • General vehicle movements • Transport of earthen material	• SM6 • SM14 • SM15 • SM1	Construction and operations	Medium/Low	Minor

11.5 Law and Order

11.5.1 Potential Impacts

As described in Section 11.1, the Project will result in increased job opportunities to the local community. With any increase in job opportunities and therefore in disposable income, there is potential for an increase in antisocial behaviour and conflict within local communities, associated and exacerbated by alcohol and drug use, gambling and fighting.

Land ownership claims are unlikely to be a driver for conflict as is the case in many other parts of Papua New Guinea, as the transfer of customary land to the State has already occurred. TWM will continue to deal with Ohobiduduare Holding Ltd in the sale of the lease titles to TWM. However, the distribution of benefits from the sale of the land has potential to cause conflict amongst the local community, if the distribution is seen as unfair or inequitable.

During survey, the Central Province Administration raised general concerns surrounding historical illegal land grabbing and settlement around the industrial precinct. The opportunity for Project employment could potentially result in Project-induced in-migration associated with construction and operation activities, which has the potential to cause tensions between locals and migrants.

As described in Section 9.5, Roku village has a well-established governance and leadership structure that does not rely on a formal clan ‘chief’ as other rural villages in Papua New Guinea do. Village leaders are respected, comprise multiple-clan membership and women and the church play important roles in decision-making and dispute settlement processes. TWM has been successfully working within the local Roku village governance and leadership structure since 2018, along with other commercial organisations within the industrial precinct.

11.5.1.1 Increased Conflict and Antisocial Behaviour Resulting from Increased Income

Antisocial behaviours in local communities, including excessive alcohol consumption, smoking marijuana, gambling and prostitution can occur as a result of an increase in income and wealth levels, and a limited local capacity to expend that income. These antisocial behaviours can cause conflict and adversely impact community cohesion.

Communities within the study area have reported very little serious conflict or anti-social behaviours and suggest a strong sense of safety exists (see Section 9.9.4) despite the industry presence and resulting employment rates (and therefore increased disposable income). It is also estimated that every business within the Roku industrial precinct currently employs private security personnel and there are five peace officers present to assist the community with any conflict (see Section 9.9.3).

Most of the operational workforce will continue to be employed from local communities. Some households from local communities may experience increased household income as a direct impact from Project employment with TWM and/or with their contractors.

11.5.1.2 Increased Conflict Resulting from Distribution of Benefits

Whilst the transfer of customary land to the State has already occurred, there is potential for increased local community conflict as a result of real or perceived inequitable distribution of benefits from the transfer, sale or lease of land to TWM if not managed carefully. As described in Section 9.5, a well-established governance and leadership structure exists which is expected to minimise any such potential impact. Further, and as stated previously, communities within the study area have reported very little serious conflict and suggest a strong sense of safety exists despite existing industry and any subsequent land transfer.

11.5.1.3 Increased Conflict and Antisocial Behaviour Resulting from Project-induced In-migration

As described in Section 9.2, Village leaders reported very little, if any, migration to Roku village during survey. For the most part, migrants have come to the village through marriage rather than in search of employment or economic opportunities. In-migration is not expected to change to any great degree as a result of employment opportunities.

11.5.1.4 Summary of Potential Impacts

Potential impacts to law and order as a result of Project activities are summarised in Table 11.10.

Table 11.10 – Summary of Potential Impacts to Law and Order

Project Phase	Activity/Aspect	Project Component	Potential Impact
Construction and operations	• Project employment	Project workforce	Increased conflict and antisocial behaviour resulting from increased income
Construction and operations	• Land sale	Industrial landfill construction; operation of industrial landfill	Increased conflict resulting from distribution of benefits
Construction and operations	• Project employment	Project workforce	Increased conflict and antisocial behaviour resulting from Project-induced in-migration

11.5.2 Mitigation and Management

The management measures listed in Section 11.1.2 to support the local economy and employment will also mitigate potential impacts to law and order. No additional measures are proposed.

11.5.3 Residual Impact Assessment

11.5.3.1 Increased Conflict and Antisocial Behaviour Resulting from Increased Income

The impact magnitude of the potential for increased conflict and antisocial behaviour as a result of Project workforce interaction with local communities, is assessed as ***Negligible*** due to very little expected change to current baseline conditions. The sensitivity of local communities to this potential impact is considered to be ***Negligible*** given the local community is already demonstrating full resilience to this impact prior to Project interaction. The residual impact significance is therefore ***Negligible***.

11.5.3.2 Increased Conflict Resulting from Distribution of Benefits

The impact magnitude of increased conflict resulting from the distribution of benefits, is assessed as ***Negligible*** due to very little expected change to current baseline conditions. The sensitivity of local communities to this potential impact is considered to be ***Negligible*** given the local community is already demonstrating full resilience to this impact prior to Project interaction. The residual impact significance is therefore ***Negligible***.

11.5.3.3 Increased Conflict Resulting from Project-induced In-migration

The impact magnitude of increased conflict and antisocial behaviour as a result of Project-induced in-migration associated with construction and operations activities is assessed as ***Negligible*** due to very little expected change to current baseline conditions. The sensitivity of local communities to this potential impact is considered to be ***Negligible*** given the local community is already demonstrating full resilience to this impact prior to Project interaction. The residual impact significance is therefore ***Negligible***.

11.5.3.3 Summary of Residual Impact Assessment

A summary of residual impacts to law and order as a result of the Project is presented in Table 11.11. All residual impacts to law and order are ***Negligible***.

Table 11.11 – Law and Order Impact Assessment

Value/Receptor	Potential Impact	Activity/ Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
• Local community • Landowners	Increased conflict and antisocial behaviour resulting increased income	• Project employment • Land sale	• SM3 • SM4 • SM5	Construction and operations	Negligible/ Negligible	Negligible
	Increased conflict resulting from distribution of benefits				Negligible/ Negligible	Negligible
	Increased conflict and antisocial behaviour resulting from Project-induced in-migration				Negligible/ Negligible	Negligible

11.6 Cultural Heritage and Archaeology

11.6.1 Potential Impacts

As discussed in Section 9.10, there are no known sites of archaeological significance within the study area. Village leaders have also confirmed there are no tangible cultural heritage materials or sites within or in the vicinity of the IWMF site boundary. Impacts on known cultural heritage are therefore not assessed further in this section.

However, with any ground clearance activities, there is always potential for impacts to unknown cultural heritage and/or archaeological finds. Further, development in general, and resulting population influx to an area, also has potential to contribute to further loss of intangible cultural heritage (e.g., oral traditions, traditional practices, knowledge).

11.6.1.1 Loss or Damage to Unknown Cultural Heritage (Objects/Artefacts)

Despite extensive ground disturbance within the site boundary, there is still potential for chance finds and/or damage to archaeological objects within the TWM site boundary, particularly where further excavation activities will take place for construction of the industrial landfill.

11.6.1.2 Loss of Intangible Cultural Heritage (Oral Traditions, Traditional Practices and Knowledge)

Intangible cultural heritage, such as language, oral traditions, traditional practices and knowledge, are highly valued across most of Papua New Guinea, especially in more remote areas of the country that have not experienced in-migration. However, as described in Section 9.2, this is less likely to be the case for the local community in the study area, which, located close to Port Moresby, has a history of intermarriage between language groups (e.g., between Motu and Koita), where traditional practices (and potentially the knowledge associated with them) have been gradually declining and where more recently employment has increased contact with other languages, cultures and values.

11.6.1.3 Summary of Potential Impacts

Potential impacts to cultural heritage and archaeology as a result of Project activities are summarised in Table 11.12.

Table 11.12 – Summary of Potential Impacts to Cultural Heritage and Archaeology

Project Phase	Activity/Aspect	Project Component	Potential Impact
Construction	Construction of industrial landfill and associated infrastructure	Construction of industrial landfill	Loss or damage to unknown cultural heritage (objects/artefacts)
Construction and operations	Project employment	Project workforce	Loss of intangible cultural heritage (oral traditions, traditional practices and knowledge)

11.6.2 Mitigation and Management

Measures to mitigate impacts on cultural heritage and archaeology include:

11.6.2.1 Loss or Damage to Unknown Cultural Heritage (Objects/Artefacts)

- Implementing operating procedures and staff training to identify artefacts and manage the reporting of cultural heritage. [SM16]
- Stopping all works immediately and implementing the Chance Finds Procedure if suspected indigenous or non-indigenous culturally significant material or artefacts are found within 50 m. [SM17]
- Establishing and maintaining an exclusion zone around identified potential heritage items observed on site. [SM18]
- Notifying the Senior Leadership Team immediately if potentially culturally significant items are found on site. [SM19]
- Seeking written confirmation from the National Museum if required prior to work recommencing in the area. [SM20]

11.6.2.2 Loss of Intangible Cultural Heritage (Oral Traditions, Traditional Practices and Knowledge)

- Implementing cultural awareness training for personnel and contractors before commencing Project activities. [SM21]
- Discouraging in-migration of persons in search of employment opportunities. [SM22]

11.6.3 Residual Impact Assessment

The following section provides the assessment of residual impacts to cultural heritage and archaeology assuming successful implementation of the proposed mitigation measures.

11.6.3.1 Loss or Damage to Unknown Cultural Heritage (Objects/Artefacts)

The sensitivity of the local community to loss or damage of unknown cultural heritage is considered to be ***Low*** given that neither the community nor NMAG have identified any sites of cultural or archaeological significance in the Project area. The impact magnitude of loss or damage to unknown cultural heritage, including archaeological materials, during construction of the industrial waste landfill is considered to be ***Negligible*** given the mitigation measures; in particular a Chance Finds procedure, already in place at the IWMF. The residual impact is therefore assessed as ***Negligible***.

11.6.3.2 Loss of Intangible Cultural Heritage (Oral Traditions, Traditional Practices, Knowledge)

The sensitivity of the local community to potential impacts to intangible cultural heritage (oral traditions, traditional practices, knowledge) is considered to be ***Negligible*** given the existing rate of intermarriage and the limited importance placed on traditional spiritual practices. The impact magnitude of loss of intangible cultural heritage is considered to be ***Low*** given the size and

duration of the Project and the limited existing and anticipated economic in-migration to Roku village (Section 11.1). The residual impact is therefore assessed as ***Negligible***.

11.6.3.3 Summary of Residual Impact Assessment

Table 11.13 provides a summary of the residual impact assessment for cultural heritage and archaeology. Residual impacts are assessed as ***Negligible***.

Table 11.13 – Cultural Heritage and Archaeology Impact Assessment

Value/Receptor	Potential Impact	Activity/Aspect	Mitigation Measures	Project Phase	Sensitivity/Magnitude	Residual Impact Significance
Local community	Loss or damage to unknown cultural heritage (objects/artefacts)	• Construction of industrial landfill and associated infrastructure	• SM16 • SM17 • SM18 • SM19 • SM20	Construction	Low/Negligible	Negligible
Local community	Loss of intangible cultural heritage (oral traditions, traditional practices, knowledge)	• Project employment	• SM21 • SM22	Construction and operations	Negligible/Low	Negligible

11.7 Cumulative Impacts

All residual socio-economic and cultural impacts described in this chapter were assessed as positive, negligible or minor. The potentially adverse socio-economic and cultural impacts associated with the Project are predicted to be localised and or short term or are unlikely to be detectable with respect to existing conditions. In many cases, receptors (i.e., local communities and businesses) are already experiencing similar impacts from the existing IWMF and surrounding industrial operations and demonstrate some or full resilience to these impacts. Therefore, in accordance with the cumulative impact assessment method described in Section 7.3.3, there are no impacts considered to present a credible pathway for consideration in the cumulative impact assessment, which would be limited to residual impacts assessed as moderate, major or severe. The Project is unlikely to result in discernible cumulative impacts considering the likely continued development of the industrial precinct, including the proposed Tuhava Town development, or other future developments in the area.

12. Major Hazards

12.1 Introduction

Major hazards or risks associated with accidental or abnormal events, also referred to as unplanned impacts have been identified with respect to the Project construction and operations activities and are discussed in this chapter. Such events, although rare, can be either natural and/or due to human activity, and may cause injury, loss of life, significant environmental harm, asset loss and reputational damage.

These are essentially unplanned impacts, to be anticipated as possibilities, for which preventative action and reactive responses are embedded in the Project design and operating processes.

12.2 TWM Risk Management

The potential environmental and social risks from TWMs activities, including those in relation to unplanned events and major hazards, are managed through the implementation of TWMs integrated QHSE management system. Potential Project risks from major hazards will be managed through the implementation of mitigation measures provided in the CESMP and the operations EMP, both of which are underpinned by the QHSE. These mitigation measures will aim to manage the potential for unplanned events and incidents through prevention, response, reporting and corrective action.

Chapter 13 provides further detail on TWMs QHSE management system and the framework for environmental and social management, monitoring and reporting.

12.3 Impact Assessment Method

The purpose of the major hazard assessment was:

- To identify and evaluate 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.
- To identify and develop appropriate control and contingency measures to prevent pollution and minimise and manage the risks, threats, hazards and impacts to an acceptable level.

The identification and assessment of major hazards and potential unplanned incidents or events relating to the Project was undertaken considering risks to environment, health and safety, asset/financial loss and reputational damage. Identified major hazards were assessed qualitatively using the risk assessment approach described in Chapter 7. This approach assesses the potential risk of an impact using qualitative criteria to consider the severity of the potential impact's consequences (see Table 7.4) and the likelihood of the consequences occurring (see Table 7.5). The product of the consequence and the likelihood calculates the level of risk assigned to each potential impact (see Table 7.6). The risk assessment assumed the effective implementation of the proposed mitigation measures that TWM will implement for the Project and examined the residual likelihood of a credible impact occurring as a result of the event. As such,

the consequence of the impact remains unchanged. A Safety in Design Risk Assessment was also undertaken for hazards relating to the construction and operations of the landfill (SLR, 2019) and has been used to inform the qualitative risk assessment for major hazards relating to the industrial landfill.

12.4 Identification of Major Hazards

The principal major hazards identified for the construction and operations phases of the Project include:

External hazards:

- Naturally generated major seismic activity (e.g., earthquakes, mass movement) resulting in injury/loss of life to Project personnel, damage to Project property/infrastructure and/or loss of containment of chemicals, fuel, hazardous wastes and landfill leachate through failure or damage to equipment and infrastructure.
- Uncontrolled fire from a natural or third party source (e.g., lightning strike or non-Project human source) causing injury/loss of life to Project personnel, damage to Project property/infrastructure and/or loss of containment of chemicals, fuel, or hazardous wastes through failure or damage to equipment and infrastructure.
- Flooding resulting in injury/loss of life to Project personnel, damage to Project property/infrastructure and/or loss of containment of chemicals, fuel, or hazardous wastes and landfill leachate through failure or damage to equipment and infrastructure.

Project hazards:

- Slope failure and mass movement as a result of landfill construction (e.g., landslide) resulting in injury/loss of life and livelihoods, damage to property, and causing significant environmental harm.
- Uncontrolled fire as a result of Project activities (e.g., ignited by machinery, electrical equipment or vehicles, or hot works) causing injury/loss of life and livelihoods, damage to property, and causing significant environmental harm.
- Unplanned major spills or loss of containment of chemicals, fuel, or hazardous wastes from bulk storage, bunding or during transportation, causing damage to property and significant environmental harm.
- Uncontrolled loss of containment of landfill leachates, from the failure of the industrial landfill leachate lining system as a result of damage, causing damage to property and significant environmental harm.
- Uncontrolled loss of containment of landfill leachates from the overtopping or structural failure of the industrial landfill leachate holding pond, causing damage to property and significant environmental harm.

- Explosions as a result of reactive agents including chemicals, fuel, and dangerous goods, resulting in injury/loss of life and livelihoods, damage to property, and causing significant environmental harm.
- Uncontrolled release of landfill gas resulting in fire, explosion, and/or asphyxiation, resulting in injury/loss of life and livelihoods, damage to property, and causing significant environmental harm.

12.5 Mitigation and Risk Assessment

Table 12.1 presents the qualitative risk assessment for major hazards associated with the construction and operations phases of the Project and describes the potential consequences and mitigation measures that will be implemented to manage the risk to an acceptable level. Consequence considers the severity of harm and loss and was rated according to the most harmful scenario for each potential impact, while the likelihood rating considered the likelihood of the consequence occurring, and not the likelihood of the event that leads to the consequence. This risk assessment was completed assuming the successful implementation of mitigation measures. Potential impacts arising from most major hazards will be successfully managed through the design of the Project and operational procedures.

12.5.1 Summary of Residual Risk Assessment

Assuming the successful implementation of mitigation measures and embedded design controls, all residual risks associated with potential major hazards have been assessed as ***Medium*** as shown in Table 12.1. Despite the low likelihood of occurrence, the residual risk ratings remain elevated due to the potentially high consequences of major hazards, with all risks with potential for fatalities automatically assessed as at least a ***Medium*** residual risk, regardless of the likelihood (see Table 7.6, Chapter 7). The likelihood of all major hazards occurring have been assessed as either rare or unlikely and the residual risks are considered to be as low as reasonably practicable.

Table 12.1 – Major Hazards Residual Risk Assessment

Hazard	Potential Impact	Mitigation Measures/ Embedded Design Controls	Consequence/Likelihood	Residual Risk
Construction of the Industrial Landfill				
Earthquake/mass movement (landslide) – natural event	• Injury/loss of life to Project personnel • Damage to Project property • Loss of containment of fuel or chemicals	• Updating and implementing the IWMF spill prevention and emergency response plans [EM115] • Developing and implementing appropriate warning, evacuation and response procedures [EM116]	Catastrophic/Rare	Medium
Slope failure from landfill construction (landslide) – Project related	• Injury/loss of life to Project personnel • Damage to Project property • Loss of containment of fuel or chemicals • Significant environmental harm • Reputational damage	• Ensuring the gradient of landfill batters are designed with a maximum slope ratio of 1 m vertical to 3 m horizontal [ED1] • Including horizontal benches, where necessary, to allow space for machinery access [EM117] • Using inspection test plans to verify construction quality control [EM118] • Undertaking weekly surveys, including slope movements and drone inspections [EM119] • Requiring the landfill construction contractor to develop and implement a safe work method statement [EM120] • Completing a geotechnical stability assessment for the landfill for input into landfill design [EM121] • Constructing a benched landform profile, with intermediate slope faces separated by flat benches of 5 m width [ED24] • Monitoring slope instability [EM122] • Constructing stabilisation works, as required [EM123]	Catastrophic/Rare	Medium

Hazard	Potential Impact	Mitigation Measures/ Embedded Design Controls	Consequence/Likelihood	Residual Risk
Flood events – natural event	• Damage to Project property • Loss of containment of fuel or chemicals • Significant environmental harm	• Updating and implementing the IWMF spill prevention and emergency response plans [EM115] • Developing and implementing appropriate warning, evacuation and response procedures [EM116]	Major/Rare	Medium
Uncontrolled fire – natural event	• Injury/loss of life to Project personnel • Damage to Project property	• Updating and implementing Fire and Emergency Response Plan Operating Instructions [EM99] • Ensuring that all TWM staff and contractors undergo training for the Fire and Emergency Response Plan Operating Instructions [EM101] • Ensuring that fire-fighting equipment is maintained and available on site [EM104] • Avoiding the use of fire for weed management at all times [EM98]	Catastrophic/Rare	Medium
Uncontrolled fire – Project related	• Injury/loss of life to Project personnel • Damage to Project property • Significant environmental harm • Reputational damage		Catastrophic/Rare	Medium
Major loss of containment of chemicals or fuels – Project related	• Loss of containment of fuel or chemicals • Significant environmental harm • Reputational damage	• Ensuring operating procedures have spill prevention mechanisms [EM124] • Constructing bunds and impermeable drainage with blind collection sumps or enclosed and weatherproof facilities with impermeable floor lining draining to a blind collection sump for all waste handling and treatment areas [ED6] • Providing spill kits and SDS appropriate to the spill risk at the Project site and within vehicles as necessary. All fuel tankers and those tankers transporting hazardous materials shall carry appropriate spill kits [EM19]	Major/Unlikely	Medium

Hazard	Potential Impact	Mitigation Measures/ Embedded Design Controls	Consequence/Likelihood	Residual Risk
		• Providing training to relevant staff in emergency spill response responsibilities [EM125] • Displaying emergency contact details and spill management procedures in prominent positions in all operating areas [EM22] • Providing emergency services the IWMF Emergency Response Plan [EM20]		
Explosion from reactive chemical, fuel or dangerous goods – Project related	• Injury/loss of life to Project personnel • Damage to Project property • Significant environmental harm • Reputational damage	• Operating the hazardous waste storage facility in accordance with AS 1940-2004 Storage and Handling of Flammable and Combustible Liquids, the Papua New Guinea and Australian Standards for the Storage of Hazardous Substances (PNG Inflammable Liquids Act 1953) and PNG/AS3780-2008-storage and handling corrosive substances [EM29] • Conducting weekly inspections of the hazardous waste storage facility and initiating immediate remedial action where required [EM32] • Storing fuels, lubricants and process reagents in covered areas or in bunded and lined areas. Bunding will be implemented in accordance with relevant standards and guidelines including AS 1940 Storage and handling of flammable and combustible liquids and the Australian Dangerous Goods Code [EM16] • Training personnel in the handling, transportation and storage of hazardous materials and providing training to an appropriate number of staff in the handling	Catastrophic/Rare	Medium

Hazard	Potential Impact	Mitigation Measures/ Embedded Design Controls	Consequence/Likelihood	Residual Risk
		of emergency response and release scenarios [EM23] • Clearly labelling vessels with name or description of hazardous material with accompanying SDS to be stored in close proximity and readily available in case of a spill or leak [EM24] • Testing permanent storage vessels and enclosures intended for hazardous materials storage for leaks prior to installation and operation [EM25] • Routinely inspecting vessels, tanks and secondary containment for leaks. If a leak is identified activate appropriate actions as per the Emergency Spill Operation Instruction [EM26] • Developing and implementing a service and maintenance schedule according to manufacturer's specifications [EM27]		
Operations				
Earthquake/mass movement (landslide) – natural event	• Injury/loss of life to Project personnel • Damage to Project property • Loss of containment of fuel or chemicals	• Updating and implementing the IWMF spill prevention and emergency response plans [EM115] • Developing and implementing appropriate warning, evacuation and response procedures [EM116]	Catastrophic/Rare	Medium
Uncontrolled fire – natural event	• Injury/loss of life to Project personnel • Damage to Project property	• Updating and implementing Fire and Emergency Response Plan Operating Instructions [EM99] • Ensuring that all TWM staff and contractors undergo training for the Fire and	Catastrophic/Rare	Medium
Uncontrolled fire – Project related	• Injury/loss of life to Project personnel		Catastrophic/Rare	Medium

Hazard	Potential Impact	Mitigation Measures/ Embedded Design Controls	Consequence/Likelihood	Residual Risk
	• Damage to Project property • Significant environmental harm • Reputational damage	Emergency Response Plan Operating Instructions [EM101] • Ensuring that fire-fighting equipment is maintained and available on site [EM104] • Avoiding the use of fire for weed management at any time [EM98]		
Major loss of containment of chemicals or fuels – Project related	• Loss of containment of fuel or chemicals • Significant environmental harm • Reputational damage	• Ensuring operating procedures have spill prevention mechanisms [EM124] • Constructing bunds and impermeable drainage with blind collection sumps or enclosed and weatherproof facilities with impermeable floor lining draining to a blind collection sump for all waste handling and treatment areas [ED6] • Providing spill kits and SDS appropriate to the spill risk at the Project site and within vehicles as necessary. All fuel tankers and those tankers transporting hazardous materials shall carry appropriate spill kits [EM19] • Providing training to relevant staff in emergency spill response procedures and responsibilities [EM20] • Displaying emergency contact details and spill management procedures in prominent positions in all operating areas [EM22] • Providing emergency services the IWMF Emergency Response Plan [EM20]	Major/Unlikely	Medium
Explosion from reactive chemical, fuel or dangerous	• Injury/loss of life to Project personnel • Damage to Project property	• Operating the hazardous waste storage facility in accordance with AS 1940-2004 Storage and Handling of Flammable and Combustible Liquids, the Papua New	Catastrophic/Rare	Medium

Hazard	Potential Impact	Mitigation Measures/ Embedded Design Controls	Consequence/Likelihood	Residual Risk
goods – Project related	• Significant environmental harm • Reputational damage	Guinea and Australian Standards for the Storage of Hazardous Substances (*PNG Inflammable Liquids Act 1953*) and PNG/AS3780-2008-storage and handling corrosive substance*s* [EM29] • Conducting weekly inspections of the hazardous waste storage facility and initiating immediate remedial action where required [EM32] • Storing fuels, lubricants and process reagents in covered areas or in bunded and lined areas. Bunding will be implemented in accordance with relevant standards and guidelines including AS 1940 Storage and handling of flammable and combustible liquids and the Australian Dangerous Goods Code [EM16] • Training personnel in the handling, transportation and storage of hazardous materials and providing training to an appropriate number of staff in the handling of emergency response and release scenarios [EM23] • Clearly labelling vessels with name or description of hazardous material with accompanying SDS to be stored in close proximity and readily available in case of a spill or leak [EM24] • Testing permanent storage vessels and enclosures intended for hazardous materials storage for leaks prior to installation and operation [EM25]		

Hazard	Potential Impact	Mitigation Measures/ Embedded Design Controls	Consequence/Likelihood	Residual Risk
		• Routinely inspecting vessels, tanks and secondary containment for leaks. If a leak is identified activate appropriate actions as per the Emergency Spill Operation Instruction [EM26] • Developing and implementing a service and maintenance schedule according to manufacturer's specifications [EM27]		
Loss of containment from industrial landfill or leachate holding pond from damage to lining system – Project related	• Damage to Project property • Significant environmental harm • Reputational damage	• Ensuring sufficient material between the operating equipment and the lining system [EM126] • Defining adequate materials within technical specifications [EM127] • Adhering to technical specification by operator [EM128] • Designing and constructing the industrial landfill with multiple HDPE geo-membrane barriers combined with clay liners and a leachate collection system which will drain leachate to collection sumps (with a 2% drainage slope) [ED7] • Constructing a network of perforated leachate collection pipes within the collection layer, to promote the flow of leachate to the primary and secondary (leak detection) sumps [ED8] • Designing submersible pumps, vertical extraction pipework (primary) and inclined leachate extraction pipe (secondary) to facilitate the removal of leachate from the collection sumps by progressive pumping to the leachate storage pond or IWWTP [ED9]	Major/Unlikely	Medium

Hazard	Potential Impact	Mitigation Measures/ Embedded Design Controls	Consequence/Likelihood	Residual Risk
		• Pumping leachate from the collection sumps via HDPE risers to a central collection well, before being pumped and conveyed to the leachate storage pond or IWWTP [EM33] • Designing a leachate leak detection system, i.e., the secondary leachate collection and removal system which will allow the collection and flow of leachate out of the leak detection system [ED10] • Designing and constructing the leachate storage pond to the equivalent performance standard as the landfill which will include a 2 mm thick HDPE liner, compacted clay liner, composite drainage net, geosynthetic clay liner and prepared subgrade [ED14]		
Overtopping of leachate holding pond or structural failure of the pond from flooding event – Project related	• Damage to Project property • Significant environmental harm • Reputational damage	• Diverting clean stormwater away from the landfill to minimise the ingress of rainfall runoff into the landfill thereby reducing the volumes of leachate generated [ED11] • Designing the leachate storage pond considering worst-case leachate generation conditions to minimise the chance of overflow, including: – Using leachate water balance modelling based on maximum cumulative volume over a one year period, using a 90th percentile wet year – Assuming that one third of the Stage 1 landfill area is filled with waste, and comprises a 300 mm thick intermediate cover, and has an active working area of 625 m^2 [ED12]	Major/Unlikely	Medium

Hazard	Potential Impact	Mitigation Measures/ Embedded Design Controls	Consequence/Likelihood	Residual Risk
		• Designing the leachate holding pond to include 0.5 m freeboard [ED25] • Designing the leachate holding pond freeboard volume based on the 5% AEP for 24-hour rainfall period [ED13] • Designing and constructing surface water controls in accordance with the appropriate guidelines as applied to site features and conditions [EM40] • Developing and implementing a service and maintenance schedule according to manufacturer's specifications [EM27] • Monitoring leachate levels in the leachate pond to maintain a minimum design freeboard (0.5 m). If this freeboard level is reached, the leachate pond will be immediately pumped out and either sent to the IWWTP or taken offsite for disposal at an approved and licensed facility [EM35]		
Fire, explosion and/or asphyxiation from landfill gas – Project related	• Injury/loss of life to Project personnel • Damage to Project property • Significant environmental harm • Reputational damage	• Installing a subsurface landfill gas drainage system to prevent build-up of pressure below the liner system [ED26] • Considering landfill gas generation and prevention of 'whales' forming on the final landfill capping system during design [ED27] • Venting of landfill gas to the environment to prevent gas build-up [EM129] • Monitoring of landfill gas extraction wells monthly for pressure, temperature, methane, carbon dioxide and oxygen levels	Catastrophic/Rare	Medium

Hazard	Potential Impact	Mitigation Measures/ Embedded Design Controls	Consequence/Likelihood	Residual Risk
		using hand held single reading monitors [EM79] • Considering installation of a gas flare system If gas generation levels alter over time [EM130] • Installing gas monitoring wells outside the perimeter of the landfill to detect landfill gas migration [EM131] • Monitoring of gas, using a hand-held monitor, in building or enclosures that are adjacent to the landfill [EM132]		

12.6 References

SLR. 2019. TWM industrial landfill facility design report. Report prepared by SLR Consulting Australia Pty Ltd for TWM PNG Ltd, Porebada, Central Province.

13. Environmental Management, Monitoring and Reporting

13.1 Integrated Management System Overview

This chapter outlines the framework for environmental and social management, monitoring and reporting under which the potential Project impacts and benefits, identified in Chapters 10 and 11, will be avoided, mitigated or realised.

TWM operates within an integrated QHSE management system which will underpin the implementation of the Project CESMP. Specifically, business performance and compliance is managed through the following accredited pillars of the QHSE management system:

- Environment Management ISO 14001 – 2015.
- Quality Management ISO 9001 – 2015.
- Occupational Health and Safety OHSAS 18001 – 2017.

The QHSE management system contains systems and processes for managing environmental and social impacts and improving performance, which involves planning, implementing, monitoring, reviewing and maintaining policy, procedures and associated sub-systems (e.g., management plans or programs). TWMs triple ISO certification is due for renewal in 2021 and will be assessed and re-certified against the 2015 and 2017 versions of the standards, as applicable.

TWM has developed an EMP for the current operations at the IWMF. The TWM-OI-58 EMP (TWM, 2020) is updated as plant and infrastructure are brought online and within the QHSE management system review schedule (see Section 13.8). It will be also updated to incorporate relevant commitments from this EIS, environment permit requirements, findings of any additional assessments and monitoring results, and lessons learnt from implementation of the CESMP. Socio-economic commitments relevant to operations will be captured in an updated stakeholder engagement plan.

The Project CESMP has been prepared in accordance with TWMs integrated QHSE management system and has the following objectives:

- Demonstrate compliance with laws and other Project obligations.
- Assign responsibilities for environmental and social management so that all requirements are understood and completed, and actions and outcomes are appropriately documented and communicated.
- Provide consolidated guidance to line management on the implementation of Project-specific environmental and social management commitments.

- Identify and communicate the legal obligations and expected standards in relation to contractors' environmental and social performance.
- Provide detailed information that support the implementation of the mitigation and management measures associated with Project activities.
- Manage the potential for unplanned events and incidents including prevention, response, reporting and corrective action.

The CESMP comprises a series of management plans that address the mitigation and management measures identified in Chapters 10 and 11 to address construction-related impacts. Each plan details aspect-specific compliance requirements, objectives, performance criteria (targets), performance measures, management measures and monitoring regime. The embedded design controls identified in Chapter 10 are not incorporated in the CESMP. They will be implemented through the QHSE management system processes and procedures (e.g., via the compliance register or construction contracts).

The CESMP incorporates the following management plans, and whilst identified as plans, they are incorporated within a single CESMP document rather than as separate documents:

- Air Emissions Management Plan.
- Noise and Vibration Management Plan.
- Water Management Plan.
- Erosion and Soil Management Plan.
- Spill Prevention and Response Management Plan.
- Biodiversity Management Plan.
- Waste Management Plan.
- Socio-economic Management Plan.
- Traffic Management Plan.
- Stakeholder Engagement Plan.
- Major Hazards Management Plan.

The implementation of these plans are underpinned by the policies, processes and procedures within the QHSE management system, which are summarised in this chapter.

13.2 Company Policies

TWM maintains an Environmental Policy (Attachment 2), which sets out the company's commitment to environmental management, including to maintain and implement a certified (to AS/NZS ISO 14001:2015) environmental management system (EMS).

TWM also maintain a Quality Policy (Attachment 3) and a Workplace Health and Safety (WHS) Policy (Attachment 4). These documents together establish the core principles and commitments that inform the QHSE management system.

13.3 Roles and Responsibilities

As the operator, TWM has overall responsibility for the construction and operation of the IWMF in accordance with the requirements of the Project CESMP, TWM-OI-58 EMP (TWM, 2020), current and future environment permits and relevant legislation. TWM is responsible for communicating responsibilities to contractors, who in turn will be required to implement and comply with relevant TWM core values, policies and procedures, the CESMP and all relevant legislative requirements.

All levels within the management structure have duties and responsibilities associated with implementing the Project CESMP. The TWM Board of Directors set the organisational direction and provide leadership for effective environmental and social management, and the Senior Leadership Team allocate appropriate resources for the implementation of the management measures and demonstrate a commitment to the organisation's environmental and social objectives and continuous improvement practices.

Specific responsibilities and accountabilities for the environmental and social management of the Project are assigned to relevant TWM personnel and contractors. Table 13.1 sets out the primary roles and responsibilities relevant to the management of environmental and social aspects and impacts. Further details on responsibilities are provided in the CESMP.

Table 13.1 – Environmental and Social Roles and Responsibilities

Role	Responsibilities
Board of Directors, Chief Executive Officer, and Managing Director	• Maintain strong leadership and visual commitment to QHSE management • Ensure the quality, OHS and environmental policies are reviewed and updated regularly • Ensure QHSE management is appropriately resourced within the organisation
Senior Leadership Team	• Allocate responsibility for QHSE management in their respective division • Ensure the implementation of the QHSE management system in their respective division • Ensure all controls and mitigation measures have been put in place prior to the start of works • Undertake regular inspections and monitoring procedures are conducted in respective site/business operations to support compliance • Ensure all required approvals and permits are in place to conduct operations/services • Ensure staff are appropriately trained in environment and social management and monitoring procedures • Provide advice with regard to corrective actions
Environment Manager	• Maintain the efficacy of the environmental management system (EMS) • Provide environment protection leadership and mentoring • Develop, manage and implement the EMS • Review and evaluate the performance of the EMS

Role	Responsibilities
	• Prepare environmental performance reports for submission to internal and external stakeholders • Liaise with environmental regulators as required • Conduct regular Environment Team meetings • Complete risk assessments of Project activities and manage risks on site • Provide/support environmental training and inductions • Provide technical advice across business operations and oversee the implementation of site management plan(s) • Report incidents to the appropriate authorities when required
Workplace Health and Safety Manager	• Maintain the efficacy of the safety management system (SMS) • Provide workplace health and safety leadership and mentoring • Develop, manage and implement the EMS • Review and evaluate the performance of the SMS • Prepare safety performance reports for submission to internal and external stakeholders • Conduct regular Safety Team meetings • Complete risk assessments of Project activities and manage risks on site • Provide/support safety training and inductions • Provide technical advice across business operations and periodically assess safety requirements • Report incidents to the appropriate authorities when required
General Manager Waste and Water	• Responsible for onsite implementation of the CESMP including identifying and managing any activity that has the potential: – for odour emissions – to negatively impact the amenity of adjacent landholders – to negatively impact water quality – to cause erosion and discharge sediment to the environment – to result in a fuel or chemical spill – to negatively impact biodiversity on site or in surrounding areas – to negatively impact sites or artefacts of cultural heritage • Documenting, responding to and acting on any complaints or grievances • Re-evaluate TWM work practices to support continuous improvement • Coordinate internal training, such as toolbox talks, as required
Environment Officer	• Implement the environment monitoring schedule • Maintain hard copy and electronic data and information management records • Monitor and report on day to day environmental performance • Deliver environmental toolbox training • Coordinate incident response and management • Input and analyse environmental data • Prepare data reports for regular Senior Leadership Team meetings • Maintain the Waste Register and Corrective Actions Register • Prepare internal and external reports on environmental performance
IWMF Operators	• Ensure all work is undertaken in a safe manner and compliant with all TWM policies and procedures • Undertake site activities in compliance with the CESMP or operating EMP, as applicable

Role	Responsibilities
	• Report any potential incidents to the Line Manager immediately. Stop work as necessary and undertake corrective action as directed • Ensure the work areas are kept tidy and all materials are stored in appropriate areas • Monitor the operations of the IWMF to ensure QHSE management is maintained • Attend all toolbox talks and identify whether further QHSE management training is required
Contractors	• Ensure all work is undertaken in a safe manner and compliant with all TWM policies and procedures • Maintain their own accredited management systems (as appropriate) • Develop specific management plans as required, including identification of, and adherence to relevant legislative and other compliance requirements • Undertake site activities in compliance with the CESMP or operating EMP, as applicable • Ensure the work areas are kept tidy and all materials are stored in appropriate areas • Attend all toolbox talks and identify whether further QHSE management training is required • Report any potential incidents to the Line Manager immediately (with an incident form completed within 24 hours). Stop work as necessary and undertake corrective action as directed • Undertake regular reporting to TWM representatives, including health, safety and environmental incidents and issues, key risks and any relevant industrial relations matters/issues

13.4 Competency and Training

Employees and contractors are required to demonstrate that they are experienced and appropriately qualified in their respective areas of expertise using F60 Verification of Competency. All construction contractors will be required to maintain current environmental, health and safety management systems. Records of qualifications are held in the personnel files at TWMs Head Office (Roku).

All new Project personnel, contractors and unaccompanied visitors are required to complete a site induction using the F32 Employee Induction Checklist. Induction and general awareness training provides a summary of the key points of environmental and social value, mitigation controls and specific instructions to ensure compliance with the QHSE management system, key commitments in this EIS and the CESMP on site. Inductions are regularly reviewed to ensure they contain relevant information and current procedures.

Training is designed to ensure understanding of the QHSE procedures and protocols and individual responsibilities within the QHSE management system and comprises on-the-job training, mentoring, practical drills, computer-based training and workshops. Job specific training provides employees with information relative to individual direct duties and for specific functions that personnel may have responsibility for under the CESMP (e.g., monitoring and reporting functions). Management training provides supervisors and management personnel with the specific functions of the CESMP and governance responsibilities of the QHSE management system. Training is planned and recorded in the F15 Training Plan and F52 Training Record Register.

Topics included in the training include but are not limited to:

- Overview of the operations of the IWMF.
- Company policies and related commitments.
- Identification of roles and responsibilities.
- Overview of site locations and areas of environmental sensitivity.
- Site environmental and occupational health and safety controls.
- Inspection and auditing requirements.
- Reporting process for environmental or OHS incidents.
- Process for non-conformance and corrective action.
- Environmental incident and emergency response procedures.

13.5 Emergency Preparedness and Response

An emergency is any event that causes or has the potential to cause material harm to people or the environment. TWM implements emergency preparedness and response primarily through the following documents:

- OI-18 Emergency Spill Operation Instructions.
- OI-05 Fire and Emergency Response Plan.

Emergency response team members are trained in hazardous material response. Spill kits are readily available at locations of hazardous material storage and use. Safety Data Sheets (SDS) are available at all areas where dangerous goods and other chemicals are stored, so that emergency preparedness and response procedures can be rapidly informed.

13.6 Monitoring and Corrective Action

13.6.1 Monitoring

Monitoring is a key commitment of the QHSE management system and is necessary to evaluate the effectiveness of the design, construction and operational measures implemented to mitigate predicted environmental and social impacts and to inform continual improvement. Monitoring considers PNG Government requirements, the legal and regulatory framework, GIIP and TWMs environment permit conditions.

The purpose of the monitoring program is to track and address:

- Changes to environment, process and/or equipment.
- The effectiveness of control measures, compliance with work procedures and site safety rules.

- Compliance with statutory requirements and GIIP.
- Community sentiment and support for TWM and the Project.

TWM already operate a robust monitoring program which would be extended to support monitoring of the measures identified in the CESMP. The current monitoring program includes:

- The completion of an F18 QSE Observation Report Form or an F20 Incident Investigation Report by employees and contractors when they notice a non-conformance or an incident (e.g., a spill or a breach of a procedure).
- Daily inspections of all work areas using the F06 Daily Site Inspection Checklist.
- Weekly inspections of the facility, including the storage container integrity and hazardous storage areas using the F79 Weekly Environment Inspection Form.
- Scheduled audits using the F02(c) Audit Checklist (environment).
- Monthly environmental and social performance assessments conducted by all managers.
- Regular monitoring of complaints or community grievances, including the timeliness of close-out.

Regular inspections form a significant part of TWMs current monitoring approach and will also underpin the CESMP monitoring program. The QHSE management system procedures, forms, checklists and datasheets relating to inspections include:

- F06 Daily Site Inspection Checklist.
- F79 Weekly Environment Inspection Form.
- F18 QSE Observation Report Form.
- F121 Hazardous Storage Facility Weekly Inspection Checklist.
- F114 Storage Vessel Inspection Checklist.
- F119 Noise Monitoring Datasheet.
- F120 Odour Monitoring Datasheet.
- F118 Groundwater Monitoring Datasheet.
- F117 Surface Water Sampling Datasheet.
- OI-57 Groundwater Monitoring Procedure.

The results of the regular inspections are reported back to senior management as part of the monthly reporting process (see Section 13.7.1).

The CESMP includes further detail on the performance criteria, monitoring approaches and monitoring frequency for the management measures identified in Chapters 10 and 11. As a

summary, environmental monitoring considers air quality, energy consumption and GHG emissions, noise, odour, erosion and sediment control, stormwater/surface water quality and spill management. Monitoring of the effectiveness of the Project's social management initiatives targets local employment and training, community health and safety, community development and cultural heritage.

Table 13.2 highlights the management objectives and performance criteria around which the CESMP is based.

Table 13.2 – Environmental and Social Management Objectives

Aspect	Objective	Performance Criteria	Management Plan
Environmental			
Emissions to air	• Avoid release of pollutants to atmosphere and prevent degradation of ambient air quality and nuisance to adjoining properties • Meet applicable air quality emission criteria	• No exceedance of emissions criteria • No exceedance of air quality criteria • No complaints received from nearby residents or businesses	Air Emissions Management Plan
Odour	• Conduct all activities in order to avoid or minimise the generation of odours	• 100% compliance with air quality control design criteria • No complaints received from nearby residents or businesses	Air Emissions Management Plan
Noise	• Adhere to noise criteria guidelines • Avoid excessive and prolonged noise or vibration levels that may impact the community and native fauna	• 100% compliance with noise criteria guidelines • No complaints received from employees, nearby residents or businesses	Noise and Vibration Management Plan
Discharge to water	• Adhere to water quality discharge criteria • Avoid the release of pollutants to surface and groundwater systems	• No exceedance of discharge criteria • 100% compliance with monitoring procedures • No complaints received from nearby residents or businesses	Water Management Plan
Erosion and sediment control	• Minimise soil erosion and the discharge of sediment to lands and surface waters • Promote regeneration of native flora in previously disturbed areas to control existing erosion • Avoid the release of pollutants to soils • Maintain soil integrity and stability	• No uncontrolled release of sediment to surface waters • No occurrences of significant erosion • No complaints received from nearby residents or businesses	Erosion and Soil Management Plan; Water Management Plan

Aspect	Objective	Performance Criteria	Management Plan
Spill prevention and response	• Prevent spills of chemicals, fuels, leachates and wastes • Respond immediately to contain and effectively manage any spills	• No release of chemicals, fuels, leachates or waste to the environment • No complaints received from nearby residents or businesses	Spill Prevention and Response Management Plan
Biodiversity	• Avoid impacts to native flora and fauna • Prevent the establishment of invasive species, pests, vermin and/or pathogens • Control and eradicate invasive species, pests, vermin and/or pathogens already established	• No change to the conditions of sensitive habitat or population of a PNG or IUCN listed endangered or protected species • 100% of pesticide and herbicides used are classed as 'low toxicity' and 'target-specific' • 100% compliance with weed and vermin control procedures and inspection schedule • No complaints received from nearby residents or landowners	Biodiversity Management Plan
Waste and energy	• Apply the waste management hierarchy • Conserve energy • Prevent the discharge of litter from the premises • Maintain client third party approved facility status	• Increase diversion and recovery of waste materials • Reduce annual consumption of energy, fuel and water • 100% compliance with waste management procedures. • No complaints received from nearby residents or businesses	Waste Management Plan; Air Emissions Management Plan
Socio-economic			
Employment and training	• Maximise the employment of local community members in Project construction and operations roles	• Maintain 85% local content in the workforce (where possible) • At least 40% of the workforce are women (where possible) • No complaints or incident reports received from nearby residents or landowners	Socio-economic Management Plan
Community health and safety	• Avoid accidents and injuries resulting from Project activities, and exposure to hazardous materials	• No accidents and injuries resulting from Project activities, • No exposure to hazardous materials • No complaints or incident reports received from	Socio-economic Management Plan; Traffic Management Plan

Aspect	Objective	Performance Criteria	Management Plan
		employees or nearby residents	
Community development	• Support the Roku community to identify and implement development initiatives	• Meetings held at least bi-monthly with Roku residents (leaders and women) • All projects successfully delivered and acquitted	Socio-economic Management Plan
Traffic	• Avoid any loss of access to public services (e.g., health, education, economic) resulting from Project traffic	• No loss of community access to public services • No complaints or incident reports received from residents	Traffic Management Plan
Cultural heritage	• Avoid disturbance and protect cultural heritage sites and/or artefacts identified through site operations • Manage cultural heritage sites in consultation with landowners and regulator	• No unauthorised disturbance to cultural heritage material • No complaints received from nearby landowners	Socio-economic Management Plan
Stakeholder engagement	• Meet public consultation and disclosure requirements under Section 55 of the *Environment Act 2000* and relevant TWM company policies • Ensure grievances are addressed through an appropriate mechanism	• 100% of grievances lodged are addressed in accordance with the grievance procedure • Regular consultation with Roku village residents (leaders and women)	Stakeholder Engagement Plan

TWM will periodically undertake internal audits to ascertain conformance with the objectives and performance measures. External audits will be arranged with qualified third parties to provide a further level of assurance over the company's performance.

Additionally, the QHSE management system and operational works practices will be reviewed annually in line with requirements for ISO AS/NZS accreditation standards.

13.6.2 Corrective Action

The monitoring and inspection process incorporates both formal and informal corrective actions. Any environmental incident investigations or non-conformance identify the factor(s) that led to the hazard, injury/illness, incident or other system failure and recommend appropriate corrective actions to be taken including the re-evaluation of work practices. Revised work practices are communicated through the relevant manager to employees and contractors, and where relevant (e.g., if in response to a grievance), to community members or other stakeholders.

Corrective actions will be documented and tracked in a register in accordance with OI-044 Document Control Procedure (see Section 13.7.2).

13.7 Reporting and Record Keeping

13.7.1 Reporting

Internal reporting is inherently linked to the monitoring activities outlined in Section 13.6.1. For example, an F18 QSE Observation Report Form or an F20 Incident Investigation Report is provided to the Environment Manager and the General Manager Waste and Water in response to any observational non-conformances or incidents or as outcomes of daily or weekly inspections or audits, within 24 hours of the non-conformance or incident.

All Managers of the Senior Leadership Team conduct monthly environmental performance assessments on a rotating basis for the purposes of reporting to the Senior Leadership Team meeting. This includes reporting on:

- Monitoring program outcomes, including progress against objectives and key performance measures.
- Audits or inspections conducted.
- Incidents or non-conformance that may have occurred during the reporting period.
- Assessments of overall compliance with the environment permit.
- Inductions and training conducted during the reporting period.

The Environment Manager and/or General Manager Waste and Water are responsible for reporting any incident which causes or threatens to cause material environmental harm or breaches requirements to Directors as soon as possible.

All reports are supported by qualitative and quantitative information and will include sampling and analysis data relating to the outputs of the environmental or social monitoring program where applicable. Data obtained through environmental inspections, audits and monitoring of performance measures will be managed through the electronic integrated information management system.

TWM will provide environmental performance reports to CEPA in accordance with the conditions of the environment permit. TWM Directors will report emergency non-compliance events to the regulator where it is of a severity to do so. Under normal operating circumstances, reports will be provided on non-conformance and incidents occurring during the reporting period, including remedial and corrective actions as may be required by the conditions of the environment permit.

13.7.2 Record Keeping

Records form a critical component of evidence of QHSE management on site. At a minimum, the following records are maintained in accordance with OI-044 Document Control Procedure:

- Records of personnel qualification and training records.
- Monitoring and inspection reports.
- Records of environmental audits.

- Details of any environmental incidents and corrective actions undertaken.
- Records of any complaints or grievances received.
- Details of any permits applied for and obtained through CEPA.
- Correspondence with regulators and other stakeholders.
- Tracking of waste received, processed and dispatched.

13.8 Continuous Improvement

The QHSE management system is a 'living document' that is continually updated and reviewed to address changes in legislation or permitting, or any deficiencies or areas for improvement.

Key documents, such as the operating EMP are reviewed and updated annually, which provides an opportunity to deliver staff training in line with additional or changed responsibilities.

Inputs to continuous improvement include:

- Assessments of the need for an update of the QHSE management system in response to changes in Project design or processes, environmental permit conditions or regulatory requirements.
- A review of the incident and complaints register with changes to other system elements as needed.
- The extent to which current targets and objectives have been met.
- Follow-up actions from previous management reviews.

13.9 References

TWM. 2020. Procedure: Integrated Waste Management Facility Environmental Management Plan. TWM-OI-58 Environmental Management Plan. May 2020. TWM PNG Ltd, Porebada, Central Province.

14. Study Team

ERIAS provides specialist services in life-of-project environmental and social baseline, impact assessment and management, and has significant experience and expertise in resource development and infrastructure projects in Papua New Guinea. ERIAS was commissioned by TWM as the lead environmental and social consultant responsible for the preparation of this EIS.

The EIS team comprises lead practitioners and consultants from ERIAS, leading specialists who executed technical investigations/modelling studies, and in-country specialists who conducted the field studies and stakeholder engagement activities. Key personnel and organisations who contributed to the field studies and preparation of the EIS are acknowledged in Table 14.1.

Table 14.1 – ERIAS Team

Name	Role	Organisation
Andrew Pym	Project Director	ERIAS
Scott Breschkin	Project Manager, EIS author	ERIAS
Andrea Lucas	Socio-economic Technical Lead, EIS author	ERIAS
Joanna Cundy	EIS author	ERIAS
Melanie Brown	Field studies coordination, EIS author	ERIAS
Geordie Brock	EIS author	ERIAS
Jennah Williams	EIS author	ERIAS
Grant Dickins	GIS services	ERIAS
Ethan Shaw	GIS services support	ERIAS
Claire Gangai	Field Social Scientist	ERIAS
Ninkama Yoba	Field Ecologist, Field Social Scientist	ERIAS
Crony Henry	Field Ecology Assistant	ERIAS
John Mosoro	Stakeholder Engagement Specialist	ERIAS
Michelle Yu	Air Quality, GHG and Noise Studies Project Manager	ASK Consulting Engineers
Andrew Martin	Lead Air Quality and GHG Specialist	ASK Consulting Engineers
Stephen Pugh	Lead Noise Specialist	ASK Consulting Engineers
-	Sediment sample analysis	SGS Environmental Services

The environmental field surveys were gratefully supported by Roku villagers; Jack Kone and Valentine Pundi.

ERIAS and TWM acknowledges the time generously donated by personnel from the following companies: Puma Oil Refinery, Rhodes/AGL, Pagini, Agility, Oilmin and AES; and the following PNG Government agencies: CEPA, DOT, DPLLG, DLPP, NMAG and Central Province Administration.

Previous studies commissioned by TWM in 2018 to support the Level 2 environment permit, and that comprise appendices of this EIS, were undertaken by:

- ACEM Geotechniques (environmental and geotechnical studies).
- National Museum and Art Gallery (NMAG) (archaeological survey).
- Mineral Resources Authority (MRA) (groundwater study).

The management team and advisors from TWM that led and directly oversaw the program of work, including the participation in the baseline field studies and providing detailed reviews of the EIS report are listed in Table 14.2.

Table 14.2 – TWM Team

Name	Role
Kori Chan	EIS Project Director
Debra Mackeen	EIS Project Manager
Nicole Frani	Environment Officer, field studies support
Eva Riggen	Environment Officer, field studies support

15. Confidential Information

The EIS report has been made available to the Conservation and Environment Protection Authority of Papua New Guinea solely for the purpose of considering and assessing the application made by TWM PNG Limited t/a Total Waste Management for environmental approval of the IWMF Project under the *Environment Act 2000*.

Being the first facility of its kind in Papua New Guinea, there are aspects related to the design and operations of the IWMF which are considered to be confidential and commercially sensitive. Sufficient detail on the IWMF components and the integrated processes has been provided in the EIS and the associated appendices and attachments to inform the assessment; however, it is requested that some information be withheld during the public review process. Relevant parts of the EIS considered to contain confidential information are:

- First and second paragraph of Section 4.5.7.
- Plate 4.5.
- Section 4.5.8.2.
- Second and third paragraph of Section 4.5.10.3.
- Figure 4.3.
- Appendix 1.
- Appendix 5, Section 3.6 and 3.8.

16. Glossary and Abbreviations

16.1 Acronyms and Abbreviations

µg	micrograms
µm	micrometre
µS/cm	microSiemens per centimetre
ACEM	ACEM Geotechniques
ADB	Asian Development Bank
AEP	annual exceedance probability
AES	Avenell Engineering Systems
AGL	AGL Builders
ANZECC	Australian and New Zealand Environment and Conservation Council
APAC	APAC Investments Pty Ltd
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AS	Australian Standard
ASK	ASK Consulting Engineers Pty Ltd
asl	above sea level
ATM	automated teller machine
BOD	biological oxygen demand
bsl	below surface level
BTEXN	Benzene, toluene, ethylbenzene, xylene, naphthalene
ºC	degrees Celsius

CA	Community Affairs
CAO	Compliance Advisor Ombudsman
CBOs	community-based organisations
CEPA	Conservation and Environmental Protection Authority
CESMP	Construction Environmental and Social Management Plan
CNA	Conservation Needs Assessment
CO	carbon monoxide
CO_2	carbon dioxide
CO_2-e	carbon dioxide equivalent units
COD	chemical oxygen demand
COVID-19	2019 novel coronavirus disease
CR	Critically Endangered
CWR	completely weathered rock
DAF	dissolved air flotation
dBA	A-weighted decibels
DD	Data Deficient
DEC	Department of Environment and Conservation
DEM	digital elevation model
DLPP	Department of Lands and Physical Planning
DOT	Department of Transport
DPLLG	Department of Provincial and Local Level Government
EAT	Emerson aggregate testing
EC	electrical conductivity

EHL	Esso Highlands Limited
EIR	Environmental Inception Report
EIS	Environmental Impact Statement
EMP	Environmental Management Plan
EMS	Environmental Management System
EN	Endangered
EP	environment permit
EPP	Environmental Protection Policy
ESP	exchangeable sodium percentage
ESSL	Ecological Soil Screening Levels
FIMS	Forest Inventory Mapping System
g	grams
GDP	gross domestic product
GHG	greenhouse gas emissions
GIIP	good international industry practice
GIS	geographic information system
GPS	Global Positioning System
HCB	Hexochlorobenzene
HDPE	high-density polyethylene
HIV	human immunodeficiency virus
hr	hours
HT	high temperature
IBC	intermediate bulk container

ID	identification
IFC	International Financial Corporation
ILG	Incorporated Landowner Group
ISO	International Organisation for Standardisation
IUCN	International Union for Conservation of Nature
IWMF	Integrated Waste Management Facility
IWWTP	industrial wastewater treatment plant
kg	kilogram
km	kilometre
km^2	square kilometre
KRA	Key result area
kt	kilotonnes
kVA	kilo-volt-amperes
Kw	kilowatt
L	litre
LC	Least Concern
LLG	local-level government
LOR	limit of reporting
L2	Level 2 (activity)
m^2	square metre
m^3	cubic metre
m	metre
MBR	membrane bioreactor unit

MDR-TB	multi-drug resistant tuberculosis
mg	milligrams
ML	megalitres
mm	millimetre
MRA	Mineral Resources Authority
MSW	municipal solid waste
MTDP	Medium Term Development Plan
NA	not applicable
NATA	National Association of Testing Authorities
NCD	National Capital District
NCDs	non-communicable diseases
NE	Not Evaluated
NGER	National Greenhouse and Energy Reporting
NO_2	nitrous dioxide
NOx	nitrous oxides
NOI	notice of intention
NT	near threatened
NZS	New Zealand Standard
OHS	Occupational Health and Safety
OHSAS	Occupational Health and Safety Assessment Series
OPD	Ohobiduduare Holding Ltd and APAC Investments Pty Ltd
P	PNG protected species
PAH	polycyclic aromatic hydrocarbons

PCBs	polychlorinated biphenyls
PGK	Papua New Guinea Kina
PM	particulate matter
PMV	public motor vehicle
PNG	Papua New Guinea
PNG LNG	Papua New Guinea Liquified Natural Gas
PNGRIS	Papua New Guinea Resource Information System
POPs	persistent organic pollutants
ppm	parts per million
QA/QC	quality assurance and quality control
QHSE	quality, health, safety and environment
R	PNG trade restricted species
RPD	relative percent difference
RPM	revolutions per minute
RPNGC	Royal Papua New Guinea Constabulary
SDS	Safety Data Sheets
SLR	SLR Consulting Australia Pty Ltd
SME	small and medium enterprises
SO_2	sulphur dioxide
SQG-high	sediment guideline value-high
SQGV	sediment quality guideline value
STIs	sexually transmitted infections
SUV	sport utility vehicle

TAPM	The Air Pollution Model
TB	tuberculosis
TDS	total dissolved solids
TEQ	toxic equivalent
TOC	total organic carbon
TP	test pit
TPH	total petroleum hydrocarbons
TRHs	total recoverable hydrocarbons
TSP	total suspended particulates
TSS	total suspended solids
TWM	TWM PNG Limited t/a Total Waste Management
UN	United Nations
US EPA	United States of America Environmental Protection Agency
VU	Vulnerable
WHO	World Health Organization
WOPU	waste oil processing unit
WWTP	Wastewater treatment plant

16.2 Glossary of Terms

abiotic	of or relating to the non-living components of an ecosystem; physical rather than biological; not involving biological activity.
abundance	(biological and other sciences) the quantity or amount of something present in a particular area, volume, or sample e.g., total numbers of individual animals or of taxonomic groups of animals.
background	the circumstances, situation, or levels of a particular parameter prevailing at the time of assessment; natural or pre-existing level of a variable.
baseline	an initial value of a measure, parameter or variable used as a starting point for comparison.
biodiversity	biological diversity; the variety of species (of plants, animals, etc.), their genes, and the ecosystems they comprise, in relation to a particular habitat. A high level of biodiversity is usually considered to be desirable and/or important.
clay	a fine-grained earth/soil material, defined by AS1726-1993 as being composed of particles finer than 0.002 mm. when used as a soil texture group such soils contain at least 35% clay particles.
community	a group of interacting people living in a common area.
community infrastructure/services	includes but is not limited to water, electric, power, communication lines as well as roads, paths, tracks, springs, culverts, washing areas, bridges and wharfs used by the community.
construction	a project phase that comprises the building of an installation (i.e., waste processing plant, landfill cells and infrastructure, etc.).
contaminant	something which contaminates, i.e., renders impure via pollution. In ecology, a substance which may degrade an environment (e.g., soil or water) due to toxicity to human, animals or plants, or detriment to beneficial uses.
contamination	making or being made contaminated; to pollute a substance with another substance. Considered to have occurred when the concertation of a specific element or compound is established as being greater than the normal expected (or quantified) background concentration.

cumulative impact	an impact 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.
customary landowners	a person who has an interest in customary land. Under customary principles in PNG, land is help at the clan entity level, not an individual level. Therefore, the term customary landowner is typically referencing a communal group.
decommissioning	a project phase that comprises the removal, disposal or reuse of an installation when it is no longer required for its current purpose.
degradation	the process by which the inherent quality or value of something is being destroyed or diminished.
density	(botany, zoology, population geography) the quantity of plants, animals or people within a given area, or the average number of individuals per area sampled or assessed. For example, the number of animals or plants (individuals or taxa) per unit area.
direct impacts	impacts that result from primary planned interactions between a planned Project activity and environmental, social and cultural heritage receptors, e.g., a Project will have discharges resulting in increased river turbidity.
dispersion	the act of dispersing; the state of being dispersed. A mixture of one substance dispersed in another medium, such as water or air.
disturbance	the interruption of a settled condition. Ecology: a temporary change in environmental conditions causing a change or impact to an ecosystem.
diversity	the state of being diverse. Biological diversity (biodiversity) is the variety of species (of plants, animals, etc.), theirs genes, and the ecosystems they comprise, in a particular habitat.
ecosystem	a community of living organisms and their interactions with each other and the physical environment.
ecosystem service	the benefits that people gain from functioning ecosystems.
environmental value	particular values or uses of the environment that are important for healthy ecosystems or for the public benefit, safety or health and that require protection from the effects of pollution.

fault	(geology) a type of fracture (separation in a geologic formation) that divides a volume of rock into two or more pieces, along which there has been displacement.
feedstock	raw material to supply or fuel a machine or industrial process.
fluvial	of or found in a river.
gradient	the degree of inclination of a slope.
greenhouse gas	Any gaseous compound in the atmosphere that is capable of absorbing and emitting infrared radiation, thereby trapping and holding heat in the atmosphere.
grievance	a formal complaint lodged by stakeholders alleging damage, impact or dissatisfaction.
hazard	Something that can cause harm; a situation that poses a level of threat to the environment, life, health of property.
hydrocarbon	any of the class of organic compounds containing only hydrogen and carbon, such as any of those which are the chief compounds in petroleum and natural gas.
impact	a marked effect or influence. Negative or positive effect/s caused directly or indirectly by an event or activity, or by the release of a substance into the environment, causing a change in the biological, physical and/or socio-economic environment.
incineration	the destruction of waste material by burning.
indirect impacts	impacts that are subsequent to the primary planned interactions between the Project and its environmental, social and cultural heritage receptors, e.g., a Project will have discharges resulting in increased river turbidity with subsequent potential impacts on health of fish species and economic livelihood of fishing dependent villagers.
induced impacts	successive impacts that have no direct relationship to a planned Project activity, but may nonetheless result from flow on activities associated with the Project, e.g., in-migration, increased hunting.
influx	an arrival or entry of large numbers of people.

in-migration	process of moving into or coming to live in a new region or community.
intangible cultural heritage	the practices, representations, expressions, knowledge and skills that individuals recognise as part of their cultural heritage.
introduced species	plants, animals, pathogens and other organisms that are living outside their native distribution range and have arrived there predominantly due to anthropogenic activity either deliberately or accidentally.
invasive species	species that may be introduced or native and spread and out-compete other species.
invertebrates	animals without a backbone or bony skeleton.
leachate	water that has percolated through a solid or semi-solid material (e.g., soil or mine waste) and leached out some of the constituent impurities.
magnitude	a qualitative measure that considers the severity, size, scale duration or extent of an impact.
mitigation	action(s) taken to avoid or reduce the impact of an activity on the environmental, cultural and/or socio-economic interests.
nutrient	a constituent required by organisms for maintenance and growth.
operations	a project phase that comprises the operation of a facility or installation, when the core business or purpose of that asset is realised.
parameter	any constituent variable quality; a characteristic, feature or measurable factor forming one of a set that defines a system or sets the conditions of its operation.
pH	a figure expressing the acidity or alkalinity or a solution on a logarithmic scale on which 7 is neutral, lower values are more acidic and higher values more alkaline.
pollutant	a substance that pollutes something, especially water or the atmosphere.
potential impact	the possible outcome resulting from the exposure of a receptor or value to an activity.

residual (impact)	those impacts that remain after the effective implementation of avoidance, mitigation and management measures, which are designed to reduce the magnitude or severity of the impact.
resilience	the capacity to recover from an impact.
riparian	relating to wetlands adjacent to rivers and streams.
ritual or ceremony sites	a place where traditional rituals ceremonies are or were carried out.
sensitivity (of a receptor)	a qualitative measure of the susceptibility of a social receptor to change.
silt	sediment with particles finer than sand and coarser than clay.
soil capacity	capacity of soil to support productive land use, e.g., horticulture.
soil structure	the arrangement of soil into aggregates and the pore spaces between them.
soil development status	state of soil evolution from parent geological material.
species richness	the number of different species represented in a sample, taxonomic group, ecological community, landscape or region.
spirit site	a place or residence of/associated with a spirt.
stakeholders	persons or groups who are directly or indirectly affected by a project, as well as those who have interests in a project and/or the ability to influence its outcomes, either positively or negatively.
substrate	an underlying substance or layer; the surface or material on or from which an organism lives, grows, or obtains its nourishment.
tangible cultural heritage	cultural heritage values that have a physical presence and can be seen and/or touched (e.g. archaeological sites, landscape features and material items such as heirlooms).
taxa	plural of taxon, a taxonomic group of any rank, such as species, family, or class.
terrestrial	on or relating to dry land.

toxicity	the inherent potential or capacity of a material to cause adverse effects in a living organism; the degree to which a substance can damage an organism.
tributary	a river or stream flowing into a larger river or lake.
turbidity	a measure of the relative clarity of a liquid, particularly water, as a result of the amount of suspended particulate matter present, such as sediment particles, algae, plankton, microbes, and other substances. One indicator of water quality.
vulnerability	the diminished capacity of an individual or group to anticipate, cope with, resist and recover from the impact of a natural or man-made change.
watercourse	a stream, creek, river or other flowing channel of water.

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