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11. ENVIRONMENTAL IMPACT ASSESSMENT: ONSHORE

This chapter presents the assessment of the biophysical impacts to the onshore environment associated with Project activities. The impacts and mitigations associated with the marine facilities are discussed in Chapter 12 Environmental Impact Assessment: Marine.

The Papua LNG Project – Downstream is an expansion to the LNG Plant and associated facilities, constructed and operated on the basis of the PNG LNG Project EIS, environment permit and environmental and social management plan. As such, the site is already disturbed, and Project onshore impacts are expected to be incremental to existing changes to the environment that occurred during construction and operation of the LNG Plant. Most of the areas to be disturbed as part of the Project are already cleared, apart from the new laydown area. The onshore impact assessment for the Project has therefore been undertaken in this context. Further, except for hydrology (flooding), air and noise impact assessment reports presented in Appendix I Flood Assessment, Appendix J Air Quality Assessment and Appendix G Noise Impact Assessment, impact assessments in the following sections have been developed based on assessments completed for the PNG LNG Project, the description of new facilities in Chapter 2 Project Description and data collected for the LNG Plant as part of its operational monitoring requirements.

Potential impacts as a result of the Project are listed in the Project Environmental Inception Report (EIR) (Tetra Tech Coffey 2022). The key potential impacts to the onshore environment from the Project are related primarily to air and noise, with secondary impacts to groundwater, surface water, terrestrial biodiversity and freshwater ecology. Therefore, the assessments made within this chapter focus on the primary environmental values with the highest potential for greater incremental impact, and those that could have the greatest effect on communities. Additional assessments have been made for values expected to have lower or no additional incremental impact to the existing facilities.

Impacts to soils and landform, as well as to visual aspects, are expected to be negligible, and have been assumed will be successfully managed through implementation of the construction environmental and social management plan (Construction ESMP) to be prepared for the Project, based primarily on mitigation and management measures developed for the PNG LNG Project. Therefore, formal impact assessments for these aspects have been excluded from the sections below.

The rationale for this approach was based on:

- The new facilities associated with the Project being constructed primarily on previously disturbed land, none of which contain soils requiring specialised management, such as potentially acid sulphate soils and black cracking clays as shown on Figure 7.2 in Chapter 7 Receiving Environment: Onshore. Should these soil types be encountered they will be managed in accordance with measures established in the Project Construction ESMP.
- Incremental impacts to landform and visual aspects because of the Project are not expected to be noticeable in the context of the LNG Plant.

11.1 APPROACH TO IMPACT ASSESSMENT

An overview of the approach and method used to assess environmental and social impacts in this EIS is described in detail in Chapter 5 Overview of Impact Assessment Method. The onshore impact assessment process includes the following steps:

- **Baseline characterisation:** Describing the existing onshore environmental values and sensitivities, and aspects of those values and sensitivities that could be impacted by the Project. Baseline information is presented in detail in Chapter 7 Receiving Environment: Onshore, and various technical appendices.

- **Defining magnitude and sensitivity:** Describing the magnitude of an impact considering the severity, geographical extent and duration of an impact that could potentially occur, and the sensitivity of an environmental value in terms of its susceptibility to change, including its capacity to adapt to, or accommodate, the changes that may be caused by the Project.
- **Identifying potential impacts**: Identifying and describing project related activities that will impact on onshore environments, i.e., mechanisms that cause a change in a value status that can be attributed to the Project. The identification of impacts was based primarily on assessing project activities described in Chapter 2 Project Description.
- **Mitigation measures:** Identifying and assessing the significance and magnitude of the potential impacts of project activities and developing management measures that reduce the significance level.
- **Residual impact assessment**: Assessing the impacts of the Project following the assumed successful implementation of mitigation measures.

Three different methods were adopted to assess the level of impact of the Project on the identified environmental values. The methods that have been adopted are dependent on the aspect that is assessed. As described in Chapter 5, the methods are:

- **Significance assessment:** The significance assessment uses the sensitivity of the value (receptor) and magnitude of impact on that value to determine the significance of an impact. This method has been used to assess impacts on bio-physical environmental values that are not subject to a compliance assessment.
- **Compliance assessment:** The compliance assessment method was adopted where international, national or best practice standards or guidelines define the upper limits of certain parameters (such as pollutants) in the environment. This method requires quantitative assessment (including in some cases, modelling) to determine the predicted levels of these parameters that will result from the Project. The compliance assessment was adopted for air quality and noise.

For most impacts, significance depends on the sensitivity (or vulnerability) of the value to change, as well as the severity (or magnitude) of the impact. The significance assessment method is a function of the sensitivity of a value and the magnitude of impact on that value, which are combined to determine the level of significance. The method also assumes that an identified impact will occur, avoiding any subjectivity about which impacts will or will not materialise. Definitions of the sensitivity of the environmental value (i.e., the receptor in the onshore environment) and the types and magnitude of impacts relevant to the Project are described in the sections below.

11.1.1 Sensitivity of environmental value

The sensitivity of an environmental value is its susceptibility to change, including its capacity to adapt to, or accommodate, the changes that the Project may cause. It also considers the intrinsic importance of that environmental value. In the onshore environment, the sensitivity of an environmental value has been determined by evaluating the following attributes:

- Formal conservation status, i.e., a regionally, nationally, or internationally recognised site or environmental value.
- The level to which the environmental value supports the ecological function of other environmental values, subsistence and/or commercial resource use.
- The existing condition of the environmental value, i.e., intactness.
- The distribution, extent, or rareness of the environmental value and its replacement potential, considering both the local and regional context.
- The vulnerability of the environmental value to material damage or loss and capacity to adapt to change.

The definitions used for assigning sensitivities to environmental values are described in Chapter 5 Overview of Impact Assessment Method, Table 5.1.

11.1.2 Magnitude of impact

The magnitude of impact on an environmental value requires the level of severity of potential impacts to be determined. In general, the magnitude of potential impacts on a value considers: the extent of the impact and how quickly the effect materialises or is felt, whether it is sustained, and the duration of the effect, as follows:

- Geographic extent: The geographic extent where project activities may directly or indirectly impact the values.
- Intensity: The scale, degree and/or severity of change or disturbance experienced by the value, including the rate of change. This change can be positive or negative.
- Temporal extent: The timing of when the impact materialises and its duration (project phases and post-project phase), whether the impact will be immediate or delayed, occur during the day or at night and in which season, is a once-off, periodic, cyclical or is continuous.

Magnitude criteria for the onshore impact assessment are described in Chapter 5 Overview of Impact Assessment Method, Table 5.4.

11.1.3 Assessment of significance

A matrix of significance was developed that combined the definitions of magnitude of impacts with the various scales of sensitivity. The matrix assigns a significance of impact for each possible combination of magnitude of impact and sensitivity of environmental value (resource or receptor). Only the magnitude of an impact can be reduced by mitigation: the sensitivity, as assessed, is fixed and is not changed by project activities. The resultant significance, therefore, reflects the reduction in magnitude that the proposed mitigation can achieve. The matrix is provided in Chapter 5 Overview of Impact Assessment Method and reproduced in Table 11.1.

Table 11.1 Significance-based assessment matrix

Magnitude of the impact	Sensitivity of the value				
	Extremely sensitive	Very sensitive	Sensitive	Not very sensitive	Not sensitive
Very high	Major	Major	Major	High	Moderate
High	Major	Major	High	Moderate	Low
Moderate	High	High	Moderate	Low	Low
Low	Moderate	Moderate	Low	Low	Very low
Very low	Moderate	Low	Very low	Very low	Very low

11.2 OVERVIEW OF PROJECT ACTIVITIES, IMPACTS AND ENVIRONMENTAL VALUES

A summary of the onshore Project facilities and activities that have the potential to impact the onshore environment includes:

- New trains to increase the capacity of the LNG Plant by adding 4 mtpa stream day capacity (SDC) of new liquefaction capacity. LNG will be stored in existing tanks.
- Utilising 2 mtpa of liquefaction capacity in the PNG LNG trains bringing the total LNG SDC production at the plant to approximately 12.8 mtpa SDC.

- The LNG Plant will continue to produce sweet naphtha (a by-product of PNG LNG production) and begin to produce sour naphtha (a by-product of the Papua LNG production) that will be blended and stored with field condensate prior to export. Sweet naphtha will be stored in existing tanks and sour naphtha will be stored in new condensate tanks.
- New condensate tanks required for storage of field condensate to be received directly from the central gas processing facility sourced from the proposed Papua LNG Project Elk and Antelope gas fields (i.e., associated with the Papua LNG Project – Upstream).
- Gas will be delivered to the LNG Plant through the existing PNG LNG pipeline and the new Papua LNG feed gas pipeline.
- New Combined Cycle Power Plant (CCPP) to provide electric power for the LNG Plant. The CCPP will consist of four gas turbine generators, four Heat Recovery Steam Generators (HRSGs) and two steam turbine generators.
- A new sewage treatment plant (STP) will also be developed, located within the LNG Plant process area. Sanitary wastewater will be collected at sanitary collection pits prior to being pumped to the new STP.
- New cold (dry) and hot (wet) flare systems, with the same configuration as the existing systems, will be provided to support the new trains, located to the east of the existing flare stack.
- The Project will use existing and new surface water drainage systems.
- A new fuel gas system common to the new trains will be constructed.
- The Project will use a combination of existing and new roads and walkways within the LNG Plant site.
- Options being reviewed for waste facilities for the Project include:
    - Temporary onsite storage and segregation of waste, with transport to and disposal at a third-party waste management facility.
    - Onsite incinerator for disposal of liquid wastes only and engineered solid waste landfill within the existing LNG Plant fence for disposal of non-restricted waste. An approved waste management facility will be used for restricted waste.

The above Project activities and facilities have the potential to result in the following effects:

- Direct physical impacts to and degradation of onshore habitats
- Increased volumes of suspended sediment and sedimentation reaching watercourses downstream of the Project
- Reduction in water quality in receiving surface and groundwater systems
- Reduction in air quality and increased noise
- Introduction of weeds, pathogens, and invasive species.

These activities can impact the onshore environmental values of the following aspects:

- Groundwater
- Surface water
- Air quality
- Noise
- Terrestrial biodiversity
- Aquatic ecology.

These aspects are discussed in detail in the impact assessment sections below.

11.3 GROUNDWATER

11.3.1 Approach to impact assessment

This section summarises the potential impacts to groundwater, measures to manage potential impacts to groundwater, and discusses residual environmental impacts of project construction and operations relating to groundwater resources at the LNG Plant site and surrounding area. Groundwater impacts for the Project are anticipated to be incremental in the context of the LNG Plant.

Groundwater from the Project area flows to sensitive environments of the coastal fringe and the groundwater aquifer may be used as a water supply for nearby villages. Hence, the sensitivity of groundwater resources has been determined to be very sensitive for the whole site.

Table 11.2 and Table 11.3 present definitions for the sensitivity of groundwater resources and magnitude of impacts to groundwater. The residual groundwater impact assessment uses the matrix of significance provided in Table 11.1.

Table 11.2 Sensitivity of resource/receptor: groundwater

Category	Description
Extremely sensitive	Highland karst terrain where soils are shallow and fractured bedrock exposes aquifers. Reliance on groundwater for consumptive and productive uses and/or maintenance of ecosystems is extremely high.
Very sensitive	Creeks and rivers where soils are highly-erodible and aquifers rise into the surface waters. Reliance on groundwater for consumptive and productive uses and/or maintenance of ecosystems is very high.
Sensitive	Large tracts of lowland forest and swamplands where aquifers are less exposed to the surface. Reliance on groundwater for consumptive and productive uses and/or maintenance of ecosystems is low or on a local scale only.
Not very sensitive	Environment with relatively stable soils where aquifers are less exposed to the surface. Reliance on groundwater for consumptive and productive uses and/or maintenance of ecosystems is very low.
Not sensitive	Environment with stable soils and aquifers are not exposed to the surface. No reliance on groundwater for consumptive and productive uses and/or maintenance of ecosystems.

Table 11.3 Magnitude of impact: groundwater

Category	Description
Very High	Impact likely to be severe on the quality of groundwater at a regional scale (greater than 10 km) over a long period of time. Impact has potential to cause substantial exceedance of water quality guidelines. Impact to significantly affect water supply to existing users.
High	Impact likely to be severe on the quality of groundwater at a local scale (between 2 km and 10 km) over a long period. Impact has potential to cause exceedance of water quality guidelines. Impact to significantly affect water supply to existing users.
Medium	Impact likely to be moderate on the quality of groundwater at a local scale (within 2 km and 10 km) and only short term. Impact has potential to cause minor exceedance of water quality guidelines. Impact does not affect water supply to existing users.

Category	Description
Low	Impact likely to be low on the quality of groundwater, at a site scale (within 2 km) and only short term. Impact does not cause exceedance of water quality guidelines. Impact does not affect water supply to existing users.
Very low	Impact unlikely to be detectable.

11.3.2 Potential impacts

The main groundwater issues during the construction and operations of the additional new facilities at the LNG Plant site relate to groundwater quality and are expected to be incremental to existing potential groundwater impacts. These include:

- Potential contamination from hydrocarbons, fuels, lubrication oils and chemicals due to the transport, storage, and handling of these materials during construction.
- Potential contamination from the STP and sanitary collection pits during operations.
- Potential contamination from leaks should some form of damage occur to pipework or processing units. Volatile organic compounds (VOCs) in liquid form, such as benzene, xylene and toluene, and heavy metals such as mercury are other potential contaminants of concern.

Water supply for the existing LNG Plant and the Project will continue to be sourced from seawater desalinisation by reverse osmosis, and therefore no groundwater supply issues will be associated with construction and operations at the LNG Plant site.

11.3.3 Mitigation and management measures

Measures that were developed to protect groundwater (and surface water, see Section 11.4.3, Mitigation and management) for the PNG LNG Project remain relevant to the Project and will be applied to its construction and operation.

- Maintain vehicles and machinery to minimise the potential for leaks.
- Store fuel, lubricating oils and chemicals required during construction in appropriately designed and sized designated containment areas.
- Develop a spill response plan for the Project and include staff training at induction to inform workers of their responsibilities under the plan.
- Manage wastewaters from the plant and associated facilities appropriately in accordance with the wastewater management plan.
- Provide suitable containment for all parts of the new facilities where hazardous or dangerous goods (e.g., fuel, lubricating oils and chemicals) are stored or used.
- Design, construct and operate new project facilities in line with good industry practice.

A groundwater monitoring network exists within the LNG Plant site and on the hydraulically downgradient side of potentially contaminating activities (e.g., the landfill site). The network was designed to alert the operator to the need for remedial action to contain a leak or spill.

11.3.4 Residual impact assessment

Facilities and activities associated with the Project are similar to those existing as part of the PNG LNG Project. As such, impacts to groundwater are anticipated to be the same or incremental to existing impacts to groundwater.

The residual groundwater impact assessment considers two important naturally occurring constraints to groundwater contamination in the physical environment. These include:

- A layer of low permeability clayey sediments overlaying the alluvial aquifers containing the groundwater, providing a degree of natural attenuation for contaminants. These sediments are between 5 and 10 m thick (see Section 7.1.4.1, Aquifers) and, if contaminants were released, would restrict the percolation of the contaminants to the water table, and bind most potential contaminants during infiltration.
- Upward hydraulic gradients reportedly exist within the coastal plain shallow groundwater system, which will restrict infiltration and mixing of contaminant laden water to the upper section of the water table that occurs within the shallow clayey profile.

The residual impacts to groundwater during construction and operations are described below.

11.3.4.1 Construction

Residual impacts of minor spills following implementation of mitigation measures (e.g., fuel-handling procedures, secondary containment bunds and emergency spill response and clean-up) in the Project area are predicted to be **Low (Very Sensitive, Very Low** magnitude**)** in the short and long term, as the volumes of liquids likely to be involved will be small and will be cleaned up immediately.

Procedures for managing major accidental spills will be based on the existing PNG LNG spill response plan, and these will be incorporated into the Project's Spill Prevention and Response Plan, with updates as required, as part of the Construction ESMP for the Project. Design mitigation measures for potential major project hazards and risks are given in Chapter 17 Environmental Hazard and Risk Management.

11.3.4.2 Operations

New project facilities will be designed, constructed, and operated to good industry practice, hence impacts to groundwater as a result of the Project are expected to be minor.

Assuming the implementation of management measures, residual impacts as a result of minor spills from new plant facilities are expected to be **Low (Very Sensitive** and **Very Low** magnitude**)** in both the short and long term given that spill volumes are expected to be small. Releases will occur to paved and drained catchments that will capture contaminants of concern within a closed process circuit. Spill response plans will also be implemented.

The new STP and associated effluents and residues will be handled in accordance with appropriate standards and specific waste management plans, and will be properly contained. Therefore, residual impacts of spills from this facility are expected to be **Low (Very Sensitive, Very Low** magnitude**)** and localised in the short and long term.

Groundwater quality trends described in Chapter 7 Receiving Environment: Onshore will be reviewed through ongoing monitoring of the existing groundwater network.

11.4 SURFACE WATER

This section summarises Project-related impacts to the surface freshwater (riverine) environment, including general approach to the assessment, identification of potential impacts, mitigation and management measures, and assesses the residual environmental impacts.

Impacts to the marine environment are discussed in Chapter 12 Environmental Impact Assessment: Marine.

11.4.1 Approach to impact assessment

Based on the new facilities and activities associated with the Project that are similar to existing PNG LNG Project facilities and activities, impacts to surface freshwaters as a result of the Project are anticipated to be incremental and of a similar nature to existing impacts in the context of the LNG Plant. A significance assessment method was used for surface water to consider hydrology (including flooding), sediment transport and water quality, and was largely based on relevant sections of the PNG LNG Project EIS and associated supporting studies.

General definitions for sensitivity and for magnitude for physical and biological environmental values presented in Table 5.1 and Table 5.4 (see Chapter 5 Overview of Impact Assessment Method) were used to assess significance of impacts on surface water values. The residual surface water impact assessment uses the matrix of significance provided in Table 11.1.

The sensitivity of the surface water environment in the Project area and surrounds was assessed as **Not Very Sensitive** given that the site is severely disturbed, and these types of surface water environments are abundant and widely distributed in the region.

Details regarding flood modelling and water quality assessment approaches are described below.

11.4.1.1 Flood assessment

Appendix I Flood Assessment was used to inform the surface water impact assessment. This study involved hydraulic modelling of flood conditions at the LNG Plant and at nearby sensitive receptors using existing data, and assessed the movement of surface waters into and through the LNG Plant (and surrounding area) to quantify hazards from flooding of the site, including consideration of high tides and storm surges. A flood modelling scenario was assessed for the Project based on 1% and 10% Annual Exceedance Probability (AEP) storms under varying durations (15 minute to 24 hour). Further details, assumptions and limitations of the flood assessment are described in Appendix I Flood Assessment.

11.4.1.2 Water quality

Ambient water quality criteria to protect aquatic ecosystems that are applicable to the PNG LNG Project are contained within the Environment Permit EP-L3(210) and are shown in Table 11.4. These criteria apply at the end of the defined mixing zone. Faecal contamination risk trigger thresholds are presented in the permit separately and are not presented herein.

Due to the similarity in facilities and activities that will take place for the Project to those that are existing, and the anticipated low level of incremental impacts to water quality, a high-level qualitative impact assessment considering the Environment Permit EP- L3(210) criteria was undertaken.

Table 11.4 Environment Permit EP-L3(210) freshwater quality criteria

Parameters	Units	Freshwater criteria
pH	pH units	6.5 to 9
Temperature	°C	No alteration greater than 2
Turbidity	NTU	No alternation greater than 25 NTU or no change >10% from background levels at any particular time (whichever is greater)
Total suspended solids	mg/L	50 mg/L or no change >10% from background levels at any particular time
Insoluble residues	-	No insoluble residues or sludge formation to occur

Parameters	Units	Freshwater criteria
Dissolved oxygen	mg/L	Not less than 6.0 mg/L or no change >10% from background levels at any particular time (whichever is greater)
Chemical oxygen demand (COD)	mg/L	125
Biological oxygen demand (BOD)	mg/L	25
Sulphate as SO_4^{-2}	mg/L	400
Sulphide as HS^-	mg/L	0.002
Ammonia: nitrogen as NH_3-N	mg/L	pH and temperature dependent* At 30°C and pH 8, criterion is 0.3
Nitrates (NO_3^- +NO_2^-)	mg/L	45
Barium	mg/L	1.0
Boron	mg/L	1.0
Cadmium	mg/L	0.01
Chromium (VI)	mg/L	0.05
Cobalt	mg/L	Limit of detection
Copper	mg/L	1.0
Iron	mg/L	1.0
Lead	mg/L	0.005
Manganese	mg/L	0.5
Mercury	mg/L	0.0002
Nickel	mg/L	1.0
Selenium	mg/L	0.01
Silver	mg/L	0.05
Tin	mg/L	0.5
Zinc	mg/L	5.0
Oil and grease	mg/L	No visible film (for construction discharges) 10 mg/L (for operational discharges)
Phenols†	mg/L	0.085
2-chlorophenol†	mg/L	0.340
4-chlorophenol†	mg/L	0.160
2,4-dichlorophenol†	mg/L	0.120
2,4,5-trichlorophenol†	mg/L	0.003
2,3,4,5-tetrachlorophenol	mg/L	0.010
Pentachlorophenol	mg/L	0.0036

Notes: Dissolved metals passing a 0.45-micron filter; NTU = nephelometric turbidity units.

*Maximum permitted ammonia nitrogen criteria are dependent on pH and water temperature and are derived from Table 2 in Schedule 1 of the *Environment Act 2000*

† Source: ANZECC/ARMCANZ Australia and New Zealand Guidelines for Fresh and Marine Water Quality, October 2000. Trigger values adopted for 99% level of protection for species for a slightly to moderately disturbed aquatic ecosystem with a high conservation value.

11.4.2 Potential impacts

The permanent on-land disturbance area for the Project is expected to be approximately 65 ha, most of which has been previously disturbed. Of the approximately 340 ha (total) areas that will be disturbed for temporary facilities during construction, approximately 60 ha will be used for the temporary construction laydown area, which is located within the lease boundary east of the LNG Plant but outside of the security fence. The permanent Project footprint areas are primarily within the North Vaihua River catchment, with some construction areas falling into the Vaihua River and Karuka Creek catchment. Catchments in the Project area and surrounds are shown on Figure 7.7 in Chapter 7 Receiving Environment: Onshore.

Potential impacts during construction and operation of the Project include:

- Removal of vegetation resulting in exposed surfaces, leading to increased sedimentation in runoff to surface water.
- Construction-disturbed soils exposed to rainfall runoff or to surface water or groundwater in excavations leading to release of dissolved and particulate-associated metals and nutrients.
- Modification of surface water flows and changes to existing hydrological regimes, including flooding.
- Accidental spills of harmful substances which may lead to surface water quality impacts.
- Additional or altered discharges from the LNG Plant during operations, such as hydrotest water (potential impacts from hydrotesting are discussed further in Chapter 12 Environmental Impact Assessment: Marine), brine from the desalination plant and wastewater from the concrete batching plant potentially affecting water quality.

11.4.3 Mitigation and management measures

Impacts to surface water are currently managed through the PNG LNG Project's existing ESMP. Mitigation and management measures within the existing ESMP will be used to inform the Construction ESMP and Operations ESMP for the Project. Adherence to management plans will form part of the contractual obligations and will be monitored under the proposed environmental management, monitoring and reporting program outlined in Chapter 18 Environmental and Social Management, Monitoring and Reporting.

During construction and operations, the following measures will be implemented to manage potential impacts to surface water drainages, primarily within the North Vaihua River catchment:

- Limit clearing of riparian vegetation to the areas necessary to undertake construction activities safely. Prevent construction personnel from entering areas outside of project-related activities to minimise damage to vegetation.
- Limiting ground disturbance and vegetation clearing to areas required for the new plant facilities.
- At new or improved road crossings, maintain connectivity in watercourses for wet season flow to enable fish migration.
- Reinstate disturbed areas to former landforms as far as practicable and revegetate exposed areas as soon as practicable once construction activities are completed in particular locations. Erosion-prone areas will receive particular attention.
- Design and construct watercourse crossings, diversions, and culverts to accommodate expected stream flows during the Project construction phase and maintain these during operations.
- Implement good industry practice erosion control measures downstream of construction areas.

Based on the successful stabilisation of landforms and revegetation that has occurred at the LNG Plant site since its construction period, no additional measures to those already in place to manage erosion and sedimentation are expected to be required.

11.4.4 Residual impact assessment

The Project site is highly modified due to the existing LNG Plant. Facilities and activities associated with the Project are similar to those existing as part of the PNG LNG Project. As such, impacts to surface water are anticipated to be similar and incremental to existing surface water impacts.

11.4.4.1 Construction

Most of the construction activities for the Project will occur in the small coastal North Vaihua River catchment, which is predominantly flat, with some facilities requiring expansion or upgrade in the Vaihua River catchment.

With the implementation of management measures, construction impacts are expected to comprise short term and highly localised elevated total suspended solids (TSS) delivery to watercourses downstream of work areas during and following rainfall and when watercourses are flowing. These impacts are expected to be offset by the naturally elevated TSS concentrations in coastal and subcoastal waters resulting from flushing of mangrove swamp sediments from tidal movements as well as during rainfall events. Downstream of construction areas, increased sedimentation in local drainages may also occur, and these accumulated sediments are expected to be subsequently carried downstream for short distances only (except for the finer material) and dispersed along with natural sediments during higher rainfall events. Due to the flat nature of the catchment and relatively slow flow velocities, TSS and sedimentation impacts are expected to be minor.

While construction is scheduled to take place over a four-year period, it is envisaged that disturbed work areas will be stabilised and revegetated, particularly at river crossings or riparian zones, sequentially following completion of construction in the work area to reduce the area exposed at any one time. Once areas disturbed for construction have been revegetated, release of fugitive sediments will be limited and result in negligible impacts in downstream watercourses.

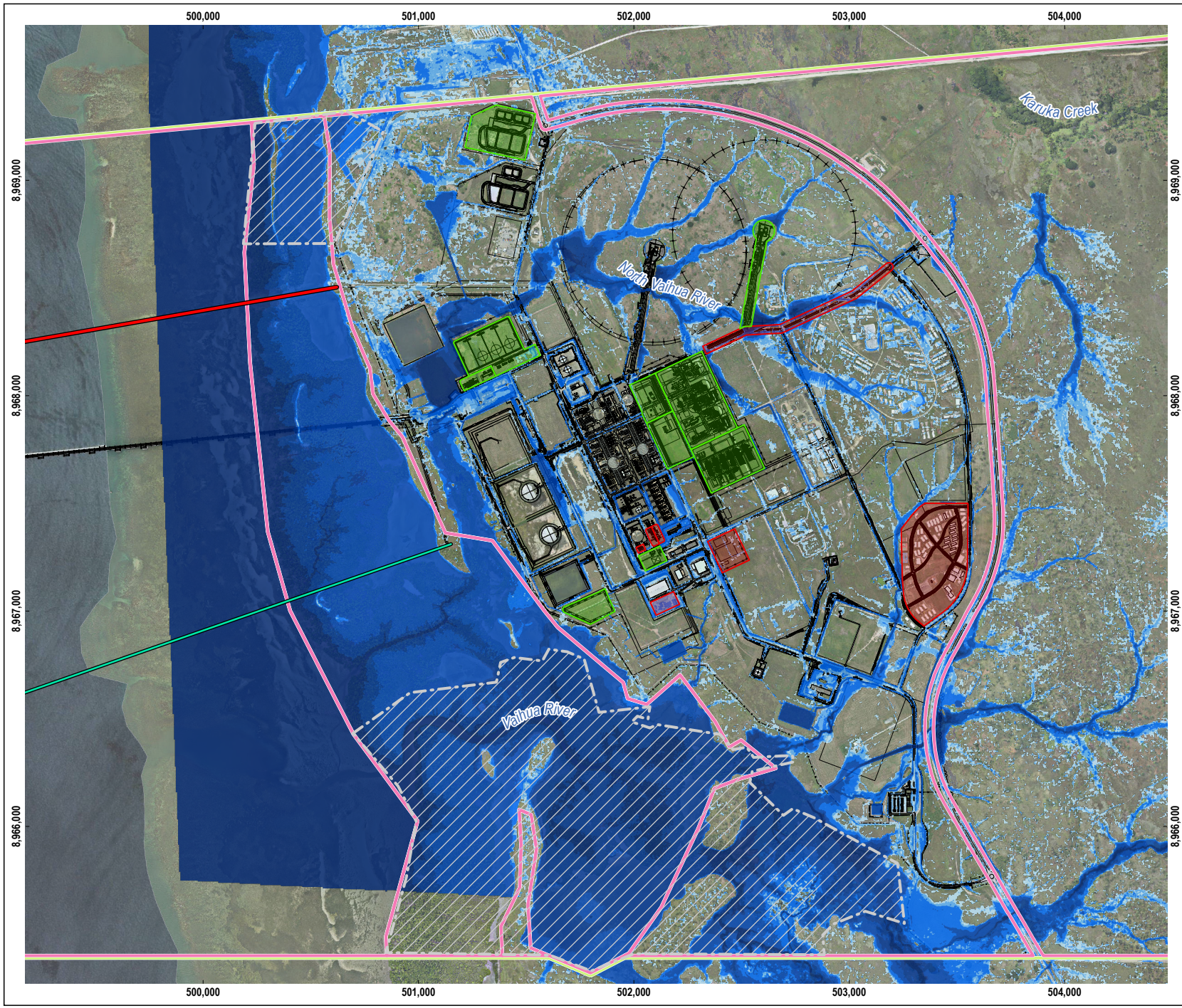
Localised changes to the existing hydrological regime are expected to be negligible based on the implementation of management measures described in Section 11.4.3 and the Construction ESMP to be developed for the Project. Following implementation of mitigation measures (e.g., handling procedures, secondary containment bunds and emergency spill response and clean-up), residual surface water quality impacts in the Project area from minor spills during construction are predicted to be low in the short and long term, as the volumes likely to be involved will be small and will be cleaned up immediately.

The significance of construction impacts on surface water were assessed as **Low (Not Very Sensitive** and **Low Magnitude)** based on the localised nature of the impacts, which can be effectively addressed with standard management controls.

11.4.4.2 Operations

During operations, the significance of residual impacts to surface water are expected to be very low, assuming control measures implemented during construction (i.e., stream connectivity and erosion and sediment control measures) are inspected and maintained following high rainfall events to maintain functionality, and that rehabilitation of disturbed areas has taken place.

Surface water flood modelling results suggest that runoff for the Project behaves in a similar manner to the existing LNG Plant flooding for both the 1% and 10% AEP events, whereby flood depths (Figure 11.1) and velocities for existing (see Figure 7.8 in Chapter 7 Receiving Environment: Onshore) and proposed scenarios are similar. The key differences are an increase in water levels on both sides of the access road running east-west past the two flare sites, increased water levels downstream of the proposed tanks, and some local ponding upstream of proposed infrastructure. The findings of the flood assessment will inform the detailed design for the Project.



LEGEND

- PNG LNG pipeline
- Proposed Papua LNG pipelines route
- Existing and proposed plant layout
- Proposed new facility
- Proposed expanded/upgraded facility
- PPFL2 boundary
- APPFL boundary
- Cultural heritage restricted area

Flood depth (m)

- > 1.5
- 1.0 - 1.5
- 0.5 - 1.0
- 0.2 - 0.5
- 0.1 - 0.2
- < 0.1

SOURCE
Flood model from Water Tech.
Infrastructure, cultural heritage and lease boundary from EMPNGA.
Imagery from EMPNGA and Google Earth.

N

0 500 m

SCALE **1:25,000**
PAGE SIZE: **A4**
PROJECTION: **WGS 1984 UTM Zone 55S**

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PAPUA LNG PROJECT – DOWNSTREAM

FIGURE 11.1

Predicted 1% AEP Project flood depth

TETRA TECH COFFEY

DATE: **04.07.23** PROJECT: **754-MELEN300733** FILE: **300733_02_F11.01_GIS**

Based on management and mitigation measures to be implemented for the Project, such as design and construction of water storage facilities in line with good industry practice, including retention ponds and mixing pits; and hazardous materials storage and handling, and spill response procedures; impacts to surface water during operation of the Project are expected to be **Low (Not Very Sensitive** and **Low Magnitude)**, given that impacts will be highly localised and short-term, and can be effectively addressed with standard management controls.

11.5 AIR QUALITY

This section presents the approach to impact assessment, identifies the potential impacts, proposed mitigation and management measures, and residual environmental impacts of the Project related to construction and operations phase air quality impacts. This section summarises Appendix J Air Quality Assessment, which presents analysis of the LNG Plant's existing air quality impacts, presented in Chapter 7 Receiving Environment: Onshore, and the impacts of Project. The air quality residual impact assessment was undertaken using the compliance assessment method.

11.5.1 Approach to impact assessment

The ambient air quality criteria adopted for the air quality assessment are provided in Table 11.5. Criteria in the current Environment Permit have been given priority; the current World Health Organisation (WHO) ambient air quality guidelines are also presented where they been updated since the permit was issued. Criteria in the PNG LNG ESMP are also provided. Where criteria are absent in the Environment Permit, air quality criteria were adopted based on the following in order of priority:

- Current WHO ambient air quality guidelines (WHO 2021)
- United States Environmental Protection Agency (US EPA) standards (US EPA 2016)
- European Commission Air Quality Standards (EC 2008).

Criteria in the Environment Permit '*are applicable near permanent operations facilities*'. This has been assumed to refer to all areas beyond the existing PNG LNG lease boundaries for the purposes of the air quality assessment.

11.5.1.1 Construction

The potential for impacts during construction was assessed qualitatively based on the nature and scale of activities to be undertaken, the proximity of sensitive receptors to the main construction areas, and the dust mitigation measures that will be implemented during construction. This is because dust emissions modelling during construction is typically not appropriate, as emission rates can be variable depending on the construction activity and prevailing meteorological conditions (e.g., rainfall and wind speed), which cannot be reliably predicted.

11.5.1.2 Operations

Atmospheric dispersion modelling, using computer programs including Weather Research and Forecast (WRF) and CALMET, followed by dispersion modelling using CALPUFF, was used to predict potential off-site impacts of operational air emissions from the Project. This involved calculation of the pollutant concentration downwind of a source using:

- Local topography
- Meteorology of the area
- Ambient or background concentrations of the pollutant

- Contaminant emission rate
- Characteristics of the emission source (release height above ground, temperature and upward velocity, and plume width).

Table 11.5 Ambient air quality criteria used in the assessment

Pollutants	Averaging time	Criterion (µg/m³)	Source
NO_2	1-hour	200	Environment Permit (EP-L3(210), WHO 2021
	24-hours	25	WHO 2021
	Annual	40	Environment Permit (EP-L3(210)
		10	WHO 2021
SO_2	10-Minutes	500	Environment Permit (EP-L3(210), WHO 2021
	1-hour	200	US EPA, 2010
	24-hours	20	Environment Permit (EP-L3(210))
		40	WHO 2021
CO	1-hour	35,000	WHO 2021
		30,000	ESMP (PNG LNG, 2019)
	8-hours	10,000	WHO 2021, ESMP (PNG LNG, 2019)
Benzene	Annual	5.0	EC, 2022, current
		3.4	EC, 2022, proposed
Total suspended particulate (TSP)	24-hours	150 to 230	ESMP (PNG LNG, 2019)
	Annual	60 to 90	ESMP (PNG LNG, 2019)
PM_{10}	24-hours	45	WHO, 2021
	Annual	15	WHO, 2021
$PM_{2.5}$	24-hours	15	WHO, 2021
	Annual	5	WHO, 2021

LNG Plant and Project facilities stack and emission data used in the modelling were based on currently available design data, equipment and feed gas specifications, and published emission factors. Off-site emissions for normal and upset operating conditions (flaring events) scenarios for the existing and proposed integrated LNG Plant were modelled. All modelling scenarios included:

- LNG Plant emissions.
- Shipping emissions, including those from tankers and tugboats operating at the jetty for existing LNG Plant, and emissions from tankers and tugboats operating at both the jetty and the CALM buoy for the proposed Project.
- Third party power stations including emissions from the Niu Power and Dirio gas-fired power plants.

The modelled operational scenarios included:

- **Existing normal operations**: Emissions from the existing LNG Plant operating normally.
- **Existing upset operations:** Train 1 off-line, flares operating at maximum capacity.
- **Proposed normal operations**: The integrated LNG Plant (existing and proposed Project facilities) operating normally under power share mode, with the PNG LNG Plant gas turbine generators all off-line, and power being provided by the CCPP.

- **Proposed upset operations**: Project facilities off-line with the CCPP shut down, three emergency diesel generators on-line and the Project wet flares operating at maximum capacity. The integrated LNG Plant is assumed to be operating normally, with power being provided by the LNG Plant gas turbine generators.

Further details regarding modelling methods and assumptions are presented in Appendix J Air Quality Assessment.

11.5.2 Potential impacts

Potential impacts from construction and operation of the Project are described below.

11.5.2.1 Construction

Construction activities, including vegetation clearing, excavation of foundations and construction of the new trains at the LNG Plant will generate fugitive dust emissions. Wind erosion of disturbed areas and stockpiles, and wheel-generated dust are also expected. These emissions have the potential to increase total suspended particulate (TSP) concentrations and dust deposition rates in the vicinity of construction activities.

Vegetation at the LNG Plant has largely been cleared although an approximately 60 ha temporary laydown area located east of the LNG Plant outside of the security fence (inside the lease boundary) will require clearing, where remaining vegetation is present. Temporary facilities, such as laydown areas, offices, workshops, and concrete batching plants will be constructed within the LNG Plant lease boundary perimeter fence. A construction camp will be established east of the existing operations camp within the LNG Plant site. The closest dwellings, including their associated gardens and plantations, to the Project area could be affected if construction dust emissions are not adequately managed.

Products of combustion will be generated from the diesel-powered construction machinery including trucks, excavators and cranes, and from the transport of workers and equipment. These emissions include nitrogen oxides (NOx), carbon monoxide (CO), carbon dioxide (CO_2), sulphur dioxide (SO_2), volatile organic compounds (VOCs) and fine particulate matter.

11.5.2.2 Operations

The primary air emissions during operations will be from burning of fuel gas in gas turbines for power generation and to drive compressors, as well as from flaring. Small quantities of fugitive emissions of VOCs from the integrated LNG Plant will also be generated.

Key pollutants generated during operations included in the air quality assessment are NOx, CO, SO_2, particulate matter (i.e., PM_{10}) and benzene.

11.5.3 Mitigation and management measures

Mitigation measures implemented to manage air emissions during the PNG LNG Project construction phase will inform preparation of a Construction ESMP for the Project. Operational air quality impacts will be managed in accordance with an Operations ESMP for the integrated LNG Plant that will be developed through a review and update of the PNG LNG Project ESMP.

11.5.3.1 Construction

Construction phase air emissions will be managed through implementation of the following measures:

- Limit erosion and dust effects of exposed soil and spoil material.
- Stabilise exposed areas susceptible to wind erosion using industry good practice measures such as water (non-saline), agglomerating agents, temporary grass/hydro-mulch or mulch where appropriate.

- Control speed limits via posted speed limit signs on project unsealed roads and keep vehicles to marked trafficable areas that will be maintained in a damp and compacted condition, where practicable.
- Use cleared vegetation where practicable for dust control and reinstatement.
- Select construction equipment based on industry good practice.
- Locate fixed and mobile equipment (e.g., generators) with consideration of local people (generally at a minimum distance of 500 meters from residences or other sensitive receptors, except where otherwise agreed by EMPNGA).
- Service diesel-powered equipment regularly.
- Maintain construction vehicles and equipment in order to limit emissions and remove from service any equipment from which emissions are visibly excessive.
- Design high temperature incinerators commensurate with proposed waste inventories.
- Prepare Operating Procedures for temporary incinerators to be utilised during construction. Operating Procedures will detail operational and monitoring/record keeping criteria.
- Operate incinerators in accordance with good industry practise guidance.

11.5.3.2 Operations

Emissions to air from the operation of the Project will be mitigated through engineered solutions that will be incorporated into the design. Such measures include:

- Design will have zero routine flaring as per the *Company Project Environmental Standard for Greenhouse Gas*.
- A 'smokeless' flare design will apply to normal operation.
- Low NO_X turbines will be used in the LNG Plant.
- Turbine generators will use dry, low-emissions technology to maintain NO_X and CO concentrations at less than 25 ppm.
- LNG storage tanks will be of full-containment design, or full-integrity design, in accordance with Good International Industry Practice.
- Flare facilities will be designed to minimise fugitive emissions.
- Flare facilities will include an emergency detection and shutdown system.

Examples of other management measures include:

- BTEX emissions from acid gas removal will be treated by thermal destruction or good industry practice.
- Valves, pipes and tanks will be regularly inspected and maintained to reduce fugitive VOCs emissions.

The type of wastes incinerated will be controlled through the Project ESMP.

11.5.4 Residual impact assessment

The predicted residual air quality impacts, based on modelling results, are presented below.

11.5.4.1 Construction

Construction of the Project is expected to take approximately four years.

Short-term and localised increases in dust concentrations associated with construction areas, particularly during vegetation clearance and earthworks, are anticipated during the construction phase, with no long-term air quality impacts expected. Revegetation of cleared areas as soon as practicable following disturbance and

implementation of erosion control measures where required (e.g., designated stockpile areas) will promote stabilisation of exposed soils and reduction of fugitive dust emissions.

Traffic dust emissions between the Motukea Port and site, and between Port Moresby and site, are expected during construction. These emissions will be minimised through development of a logistics strategy and adequately designing access routes, which are upgraded where required, and maintained to minimise dust emissions. Water trucks, water sprays or dust suppressants will be used as necessary to manage dust.

With implementation of good practice air quality management and measures included in the Project's Construction ESMP, dust impacts to air quality because of construction are expected to be **localised and short-term**.

Combustion products from the diesel-powered equipment, including NOx, CO, CO_2, SO_2 and VOCs and fine particulate matter, will occur over a relatively large area and are expected to disperse to background levels before reaching off-site sensitive receptors. **No air quality impacts are expected due to these emissions.**

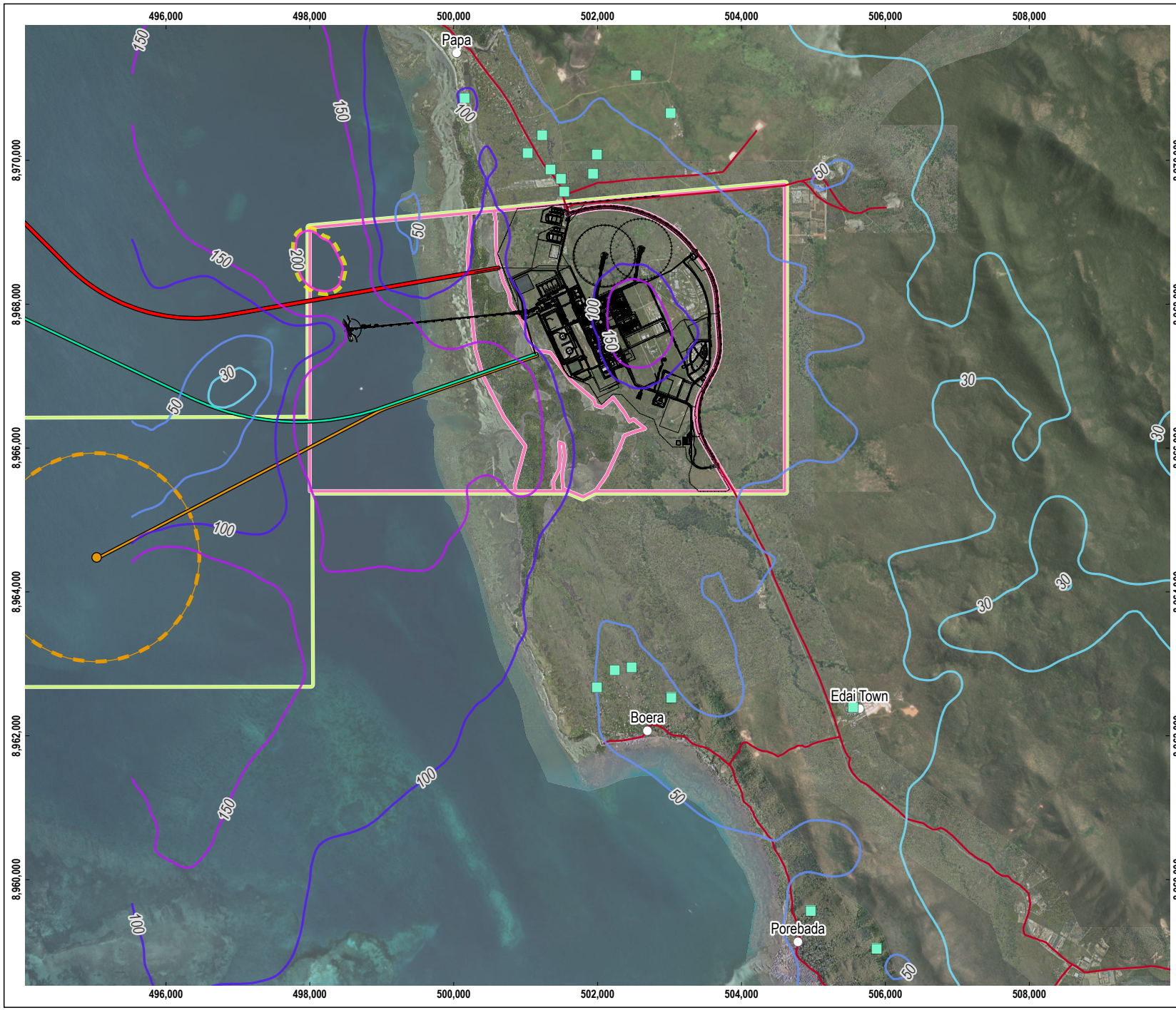
11.5.4.2 Operations

Operational air quality impacts based on conservative worst-case conditions (i.e., maximum concentrations) are summarised below with respect to predictions at sensitive receptors[1]:

- For CO emissions, concentrations predicted for both normal and upset operating scenarios are well below the relevant ambient air quality criteria.
- For NO_2 emissions, predicted concentrations are expected to increase from the operation of the Project; however, the maximum 1-hour, 24-hour and annual average NO_2 concentrations at the sensitive receptors are predicted to remain below the relevant criteria. Predicted maximum 1-hour NO_2 concentrations for normal Project operations are shown in Figure 11.2.
- For PM_{10} emissions, off-site 24-hour average and annual average PM_{10} concentrations are predicted to increase slightly as a result of the Project; however, the predicted concentrations are below the adopted ambient air quality criteria.
- For SO_2, increases in 10-minute and 1-hour average concentrations are predicted at the sensitive receptor locations as a result of the Project due to combustion of mercaptans (organic sulphur compounds) and hydrogen sulphide (H_2S) containing fuel gas in the CCPP. These concentrations, however, are below the relevant criteria for both existing and proposed operations, including normal and worst-case upset operating conditions. Predicted maximum 24-hour SO_2 concentrations for normal Project operations are shown in Figure 11.3.
- For benzene, the predicted concentrations at sensitive receptor locations comply with both the existing EU criterion (of 5 µg/m^3) and the future reduced criterion of 3.4 µg/m^3 (proposed for attainment in the EU by 2030).
- While not specifically modelled, estimated maximum downwind $PM_{2.5}$ concentrations are likely to be slightly lower, but comparable to, the predicted PM_{10} concentrations presented above. These concentrations are below the WHO (2021) $PM_{2.5}$ guidelines adopted for the Project.

Off-site exceedances of some parameters are predicted. However, due to the location of the exceedances, there is unlikely to be exposure to sensitive receptors. No air quality impacts at these off-site locations are therefore predicted.

[1] Off-site air emissions impacts are detailed in Appendix J Air Quality Assessment.



LEGEND

- Village
- Air quality sensitive receptor
- Road
- PNG LNG pipeline
- Proposed Papua LNG pipelines route
- Existing and proposed plant layout
- PPFL2 boundary
- APPFL boundary

Proposed CALM buoy components

- CALM buoy
- Naphtha and condensate pipelines
- CALM buoy navigational area

Predicted maximum 1-hour NO_2 concentration

- 30
- 50
- 100
- 150
- 200
- Environment Permit EP-L3(210) criterion (Criterion 200 µg/m³)

SOURCE
Air contours from SLR.
Monitoring locations, infrastructure, roads, watercourses and lease boundary from EMPNGA.
Imagery from ArcGIS Online and Planet Labs.

0 1 2 km

SCALE **1:75,000**
PAGE SIZE: **A4**
PROJECTION: **WGS 1984 UTM Zone 55S**

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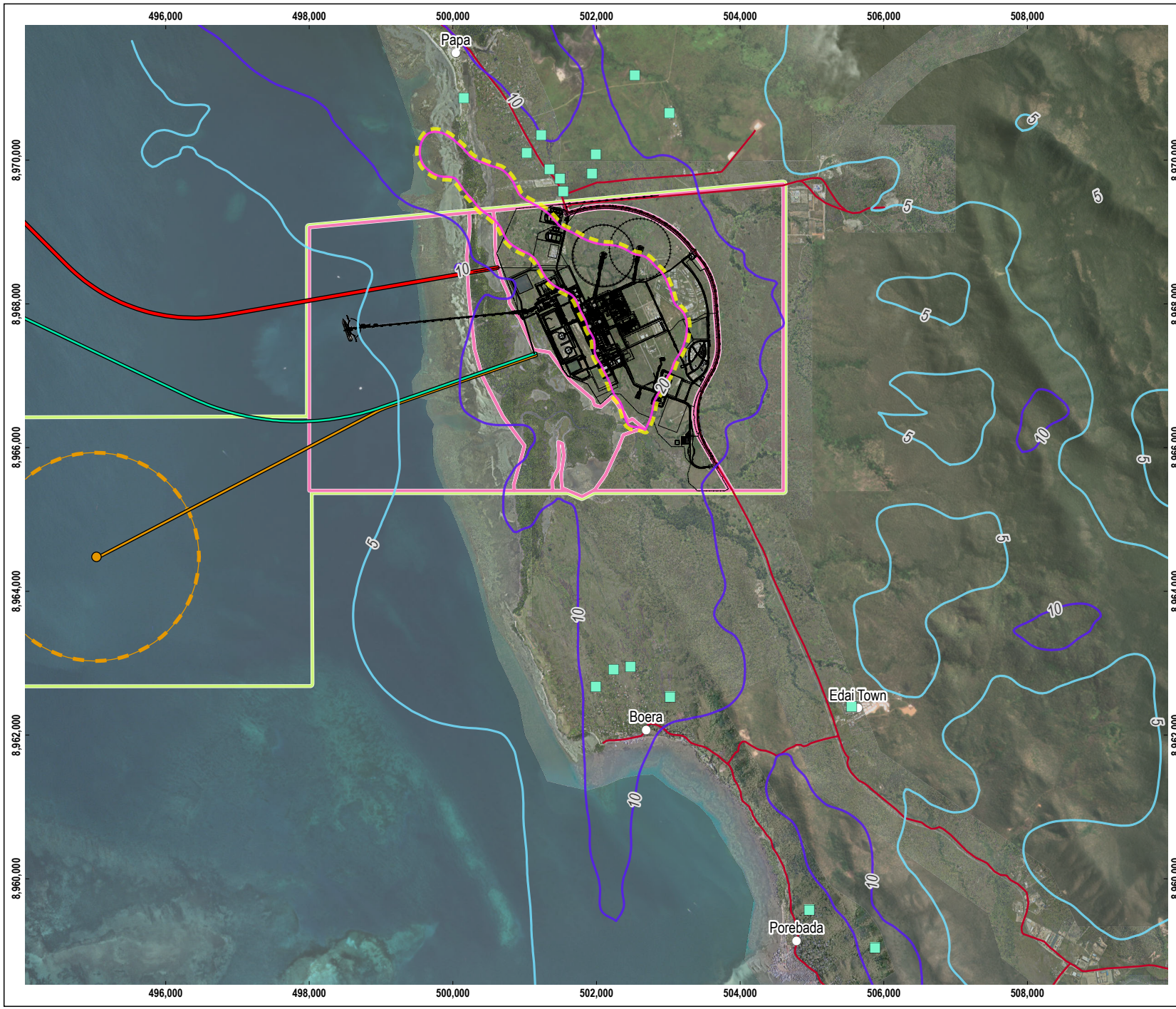
PAPUA LNG PROJECT – DOWNSTREAM

FIGURE 11.2

Predicted maximum 1-hour NO_2 concentrations for normal Project operations

TETRA TECH COFFEY

DATE: **04.07.23** PROJECT: **754-MELEN300733** FILE: **300733_02_F11.02_GIS**



LEGEND

- Village
- Air quality sensitive receptor
- Road
- PNG LNG pipeline
- Proposed Papua LNG pipelines route
- Existing and proposed plant layout
- PPFL2 boundary
- APPFL boundary

Proposed CALM buoy components

- CALM buoy
- Naphtha and condensate pipelines
- CALM buoy navigational area

Predicted maximum 24-hour SO_2 concentration

- 5
- 10
- 20
- Environment Permit EP-L3(210) criterion (Criterion 20 µg/m³)

SOURCE
Air contours from SLR.
Monitoring locations, infrastructure, roads, watercourses and lease boundary from EMPNGA.
Imagery from ArcGIS Online and Planet Labs.

0 1 2 km

SCALE **1:75,000**
PAGE SIZE: **A4**
PROJECTION: **WGS 1984 UTM Zone 55S**

EXXONMOBIL PNG ANTELOPE LIMITED

PAPUA LNG PROJECT – DOWNSTREAM

FIGURE 11.3

Predicted maximum 24-hour SO_2 concentrations for normal Project operations

TETRA TECH COFFEY

DATE: 04.07.23 PROJECT: 754-MELEN300733 FILE: 300733_02_F11.03_GIS

11.6 NOISE

This section presents the approach to the noise impact assessment, the potential impacts, proposed mitigation and management measures and residual environmental noise impacts of construction and operation of the Project.

This section summarises the findings of Appendix G Noise Impact Assessment, undertaken by SLR Consulting, which presents the LNG Plant's existing noise impacts, summarised in Chapter 7 Receiving Environment: Onshore, and the incremental impacts of Project as well as noise impacts from the integrated LNG Plant.

11.6.1 Approach to impact assessment

The noise assessment was based on the Environment Permit EP-L3(210) noise criteria (excluding background noise) that are applicable at the LNG Plant perimeter fence line including:

- Day (7am to 10pm): 55 dBA, external one-hour LAeq
- Night (10pm to 7am): 45 dBA, external one-hour LAeq.

A computer noise model using SoundPLAN (Version 8.1) was developed to predict noise levels at the nearest sensitive receptors using data inputs such as topography (including LNG Plant infrastructure), and location and acoustic sound power levels of noise sources at the Project site. Noise models were developed for construction and operations as described below. Prevailing weather and adverse noise propagation conditions were considered in the modelling results.

The noise residual impact assessment was undertaken using the compliance assessment method.

11.6.1.1 Construction

Construction activities were deemed a long-term noise emission given that construction will take place over four years. As a result, noise criteria applicable to operation of the Project in Environment Permit EP-L3(210) were applicable to the assessment of construction activities. Construction noise emissions were assessed at 16 sensitive receptor locations to consider construction activities associated with the Project (Scenarios C1 to C4), and noise emissions for the LNG Plant combined with construction activities associated with the Project (C5 to C7).

Construction noise scenarios include:

- **Construction – C1[2], C2, C3 and C4:** represent noise emissions for each of the following noise sources in isolation, respectively:
  - **C1**: Mobile equipment including liquefaction for new trains operational
  - **C2**: Mobile equipment for CCPP in operation
  - **C3:** Mobile equipment for utility and offsite in operation
  - **C4:** Mobile equipment for utility and offsite in operation, and static equipment, such as electric generator and waste incinerator, operational.
- **Construction – mobile equipment, new trains (C5)**: This scenario assumes:
  - Existing trains 1 and 2 are in normal operation
  - The 58 MW power plant operated by NiuPower is in normal operation
  - Mobile equipment including liquefaction for new trains operational.
- **Construction – mobile equipment, CCPP (C6)**: This scenario assumes:

[2] Refers to scenario nomenclature in Appendix G Noise Impact Assessment.

  - Existing trains 1 and 2 are in normal operation
  - The 58 MW power plant operated by NiuPower is in normal operation
  - Mobile equipment for CCPP in operation and static equipment.
- **Construction – mobile equipment, utility and offsite (C7)**: This scenario assumes:
  - Existing trains 1 and 2 are in normal operation
  - The 58 MW power plant operated by NiuPower is in normal operation
  - Mobile equipment for utility and offsite in operation.
  - Static equipment, such as electric generator and waste incinerator, operational.

Construction activities will occur 10-hours per day, 6 days a week; nightshift may be required for key activities to maintain the project schedule. The worst-case scenario was modelled assuming a 24-hours-per-day-construction program, for which the noise criterion 45 dBA would apply (i.e., the Night criteria being more stringent than the Day criteria). It is likely, however, that limited construction activity will typically occur at night, with exceptions being activities such as large foundation casting and temporary power generation.

11.6.1.2 Operations

Selected operational noise scenarios were modelled to capture existing noise sources and noise as a result of the Project:

- **Normal operation – existing (O3):** Normal operation of the LNG Plant, no gas flaring required. This scenario assumes:
  - Existing trains 1 and 2 are in normal operation
  - The 58 MW power plant operated by NiuPower is in normal operation.
- **Normal operation – proposed Project (O4):** New trains only in normal operation.
- **Normal operation – existing and proposed Project (O6):** Normal operation of the integrated LNG Plant. This scenario assumes:
  - Existing trains 1 and 2 are in normal operation
  - New trains in normal operation
  - The 58 MW power plant operated by NiuPower is in normal operation.
- **Upset operation – proposed Project only (O5):** New trains in upset operation, dry flare and gensets in operation only.
- **Upset operation – existing and proposed Project (O7):** existing LNG Plant operating normally, new trains under upset operations. This scenario assumes:
  - Trains 1 and 2 remain under normal operation (without Train 1 and 2 flare)
  - Upset conditions for new trains, dry flare and gensets in operation
  - The 58 MW power plant operated by NiuPower is in normal operation.

Further details regarding modelling methods and assumptions are presented in Appendix G Noise Impact Assessment.

11.6.2 Potential impacts

Potential construction and operations noise impacts are described below.

11.6.2.1 Construction

Construction of the new trains will involve site preparation and bulk earthworks to achieve the required grade for the facilities. These works will involve various noise generating activities including:

- Vegetation (in the laydown area) and topsoil removal using bulldozers and scrapers.
- Bulk earthworks and platform construction using front end loaders, excavators, backhoes, graders, rollers, dump trucks and water trucks.

The trains are envisaged to be constructed using a modular and prefabricated execution strategy with some items remaining as stick built (i.e., using a traditional construction method built entirely at the site, piece by piece, with little prefabrication). The primary civil works are expected to involve:

- Installation and operation of concrete and asphalt batching plants.
- Installation of structures at the LNG Plant using heavy rollers, dump trucks, concrete trucks, generators, cranes, and steel reinforcement fabrication hand tools such as grinders and welders.

11.6.2.2 Operations

Most of the noise generating equipment is primarily located within the new trains and associated piping, including sources such as that associated with the new flares, ancillary plant required to prepare the gas for export, upgrades to the boil-off gas system, refrigeration, and power generation.

11.6.3 Mitigation and management measures

11.6.3.1 Construction

During construction, project noise guidelines will be achieved using a combination of sound planning and scheduling of construction activities and engineered controls such as silencers, barriers, enclosures and laggings on equipment. The Project will also implement the following noise mitigation measures which will be detailed in the Construction ESMP:

- Maintain construction vehicles and equipment to limit noise emissions.
- Limit heavy construction works at night where practicable.
- Locate generators and other ‘fixed’ noise sources as far as practicable from adjacent sensitive receptors.
- Manage potential noise complaints via the existing grievance management system.
- Include noise in site induction training with details for worker’s responsibilities in relation to noise emissions.
- Enforce speed limits in and around the site to minimise traffic noise.

11.6.3.2 Operations

Mitigation of operational noise will be similar to the construction mitigation measures. Operational upsets may result in sudden, intrusive noise to the area surrounding the LNG Plant site. These events will be reduced as much as reasonably practicable while maintaining the safety of the employees, community and environment with engineered controls such as pressure sensitive devices and emergency venting and flaring. The following additional mitigation measures will be implemented for operations:

- Implement noise mitigation for gas flares.
- Design noise generating equipment associated with the new plant (e.g., refrigeration, main generation, and boilers) with noise controls, or with the flexibility for noise controls to be incorporated in the future, if required, such as equipment enclosures, noise screens, acoustic silencers and pile lagging.

11.6.4 Residual impact assessment

The predicted residual noise impacts based on modelling results are presented below.

11.6.4.1 Construction

Construction noise predictions can be summarised as follows.

Without existing LNG Plant (i.e., scenarios C1 to C4):

- The 55 dBA LAeq (7am to 10pm) noise criterion is met during prevailing weather and adverse noise propagation conditions at all sensitive receptor locations.
- The construction noise levels during Scenario C1 (under prevailing weather and adverse noise propagation conditions) are predicted to exceed the 45 dBA LAeq (10pm to 7am) noise criterion by up to 3 dBA at three sensitive receptor locations north of the LNG Plant (Residence 1 (NSR 12), Residence 2 (NSR 13) and Residence 4 (NSR 15) as shown on Figure 11.4.

With existing LNG Plant (i.e., scenarios C5 to C7):

- The 55 dBA LAeq (7am to 10pm) noise criterion is met during prevailing weather and adverse noise propagation conditions at all sensitive receptor locations.
- Construction noise levels are predicted to exceed the 45 dBA LAeq (10pm to 7am) noise criterion at five sensitive receptors (Papa 4 (NSR9), Residence 1 to Residence 4 (NSR12 to NSR15) during all scenarios (by up to 4 dBA for Scenario C5 and by 1 dBA at NSR12 during Scenarios C6 and C7) under prevailing weather conditions. These exceedances are caused by mobile equipment including liquefaction new trains.
- The predicted noise levels meet the 45 dBA LAeq (10pm to 7am) noise criteria at all other sensitive receptors.

Exceedances of Environment Permit noise criteria at the perimeter fence line were predicted for scenarios C1, C5, C6 and C7. However, no noise-related impacts are expected due to these exceedances based on the absence of sensitive receptors located at the fence line. Further, the modelling conservatively assumes full construction activities are occurring at night as a worst case; in reality, limited construction activity will typically occur at night, with exceptions being activities such as large foundation casting and temporary power generation.

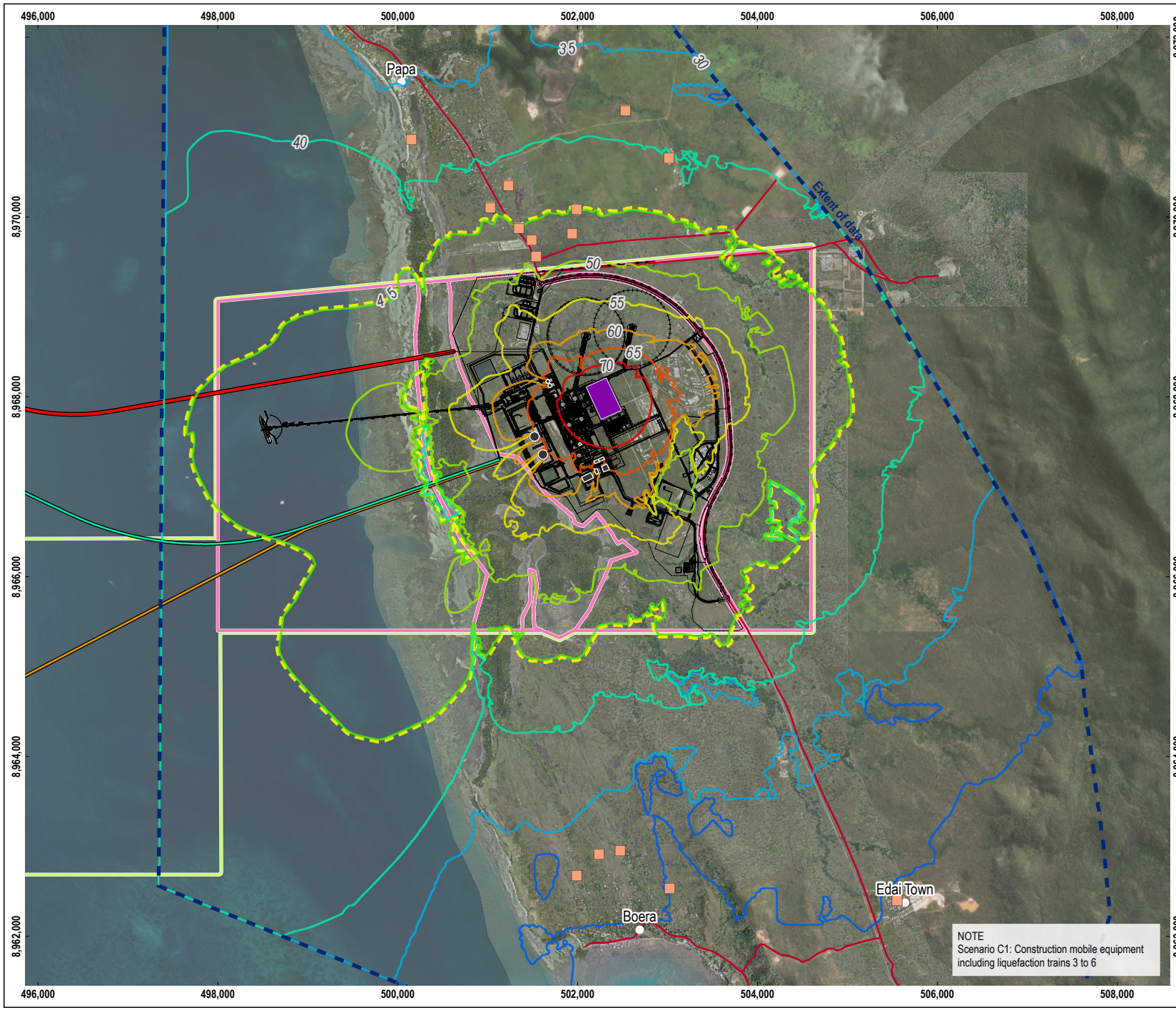
For context, a change of up to 3 dBA in the level of a sound is difficult for most people to detect, whilst a 3 dBA to 5 dBA change corresponds to a small but noticeable change in loudness, while a 10 dB(A) change corresponds to an approximate doubling or halving in loudness.

Based on the conservatism of the modelling results and construction noise exceedances being minor, with implementation of good industry practise noise management measures, noise levels that are compliant with the noise permit criteria are expected to be achieved, which would permit construction activities to take place 24 hours a day without adverse noise impacts to sensitive receptors.

11.6.4.2 Operations

Operations noise predictions can be summarised as follows.

- Normal and upset operation of the new trains in isolation (Scenario O4 and Scenario O5) is predicted to meet noise criteria (i.e., 55 dBA LAeq (7am to 10pm) and 45 dBA LAeq (10pm to 7am) at all sensitive receptors under prevailing weather and adverse noise propagation conditions.
- During normal operation, combined noise from the new trains, existing train 1 and 2, the 58 MW NiuPower power plant (Scenario O6) is predicted to meet noise criteria and adopted background noise levels at all sensitive receptors modelled. An exception to this is noise at Residence 1 (NSR12), where levels are predicted to marginally (by 1 dBA) exceed the 45 dBA LAeq (10pm to 7am) noise criterion. The source of the exceedance is refrigeration noise for which, if noise control was applied, there would be no noise exceedance at NSR12. Noise contours for Scenario O6 are shown in Figure 11.5.



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DOC REFERENCE: \\ETSS772GISFS1\DATA\GIS\300733_EMPNG_PAPUALNGDOWNSTREAM\1_PAPUALNGDOWNSTREAM\GIS\APRX\300733_02_FIGS_E.APRX LAYOUT:300733_02_GIS065_2

LEGEND

- Village
- Noise sensitive receptor
- Road
- PNG LNG pipeline
- Proposed Papua LNG pipelines route
- Existing and proposed plant layout

Proposed CALM buoy components

- Naphtha and condensate pipelines
- PPFL2 boundary
- APPFL boundary
- Area source
- Building
- Extent of data

Scenario C1 noise contour (dBA)

- 30
- 35
- 40
- 45
- 50
- 55
- 60
- 65
- 70
- 45 dBA criteria line

SOURCE
Noise contours from SLR.
Monitoring locations, infrastructure, roads, watercourses and lease boundary from EMPNGA.
Imagery from ArcGIS Online and Planet Labs.

0 0.5 1 km

SCALE **1:60,000**
PAGE SIZE: **A4**
PROJECTION: **WGS 1984 UTM Zone 55S**

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PAPUA LNG PROJECT – DOWNSTREAM

FIGURE 11.4

Construction noise contours, prevailing weather conditions

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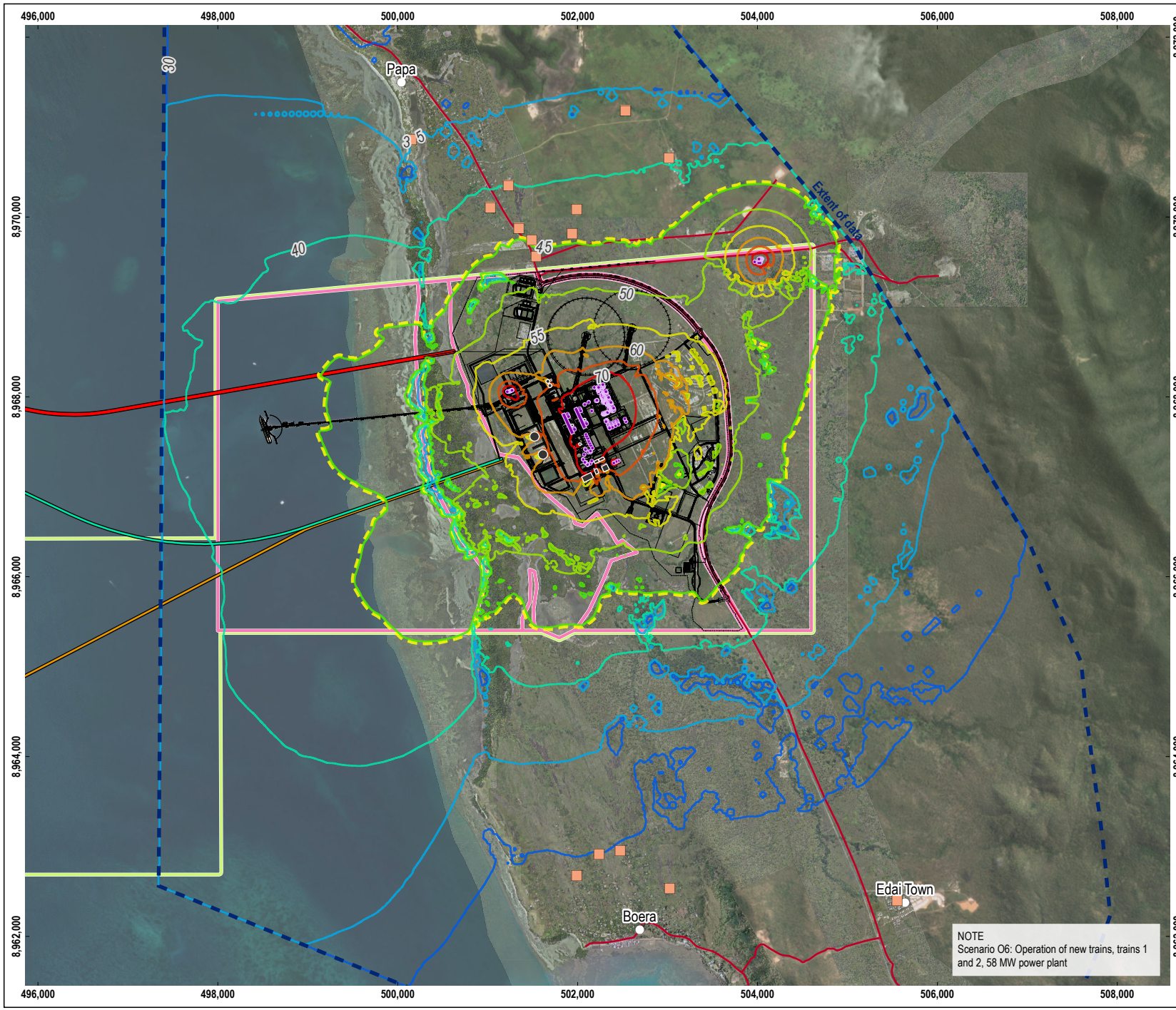
DATE: **04.07.23** PROJECT: **754-MELEN300733** FILE: **300733_02_F11.04_GIS**



LEGEND

- Village
- Noise sensitive receptor
- Road
- PNG LNG pipeline
- Proposed Papua LNG pipelines route
- Existing and proposed plant layout

Proposed CALM buoy components

- Naphtha and condensate pipelines
- PPFL2 boundary
- APPFL boundary
- Area source
- Building
- Extent of data

Scenario O6 noise contour (dBA)

- 30
- 35
- 40
- 45
- 50
- 55
- 60
- 65
- 70
- 45 dBA criteria line

SOURCE
Noise contours from SLR.
Monitoring locations, infrastructure, roads, watercourses and lease boundary from EMPNGA.
Imagery from ArcGIS Online and Planet Labs.

0 0.5 1 km

SCALE **1:60,000**
PAGE SIZE: **A4**
PROJECTION: **WGS 1984 UTM Zone 55S**

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PAPUA LNG PROJECT – DOWNSTREAM

FIGURE 11.5

Operations noise contours, prevailing weather conditions

TETRA TECH COFFEY

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- During normal operations, the predicted noise increases at sensitive receptors due to the new trains compared to the existing normal operation range between 2 to 5 dBA. For context, increases in noise levels of up to 5 dBA LAeq correspond to a small but noticeable change in loudness.
- During normal and upset operations, exceedances of day and night noise criteria are predicted; however, no noise-related impacts are expected due to these exceedances based on the absence of sensitive receptors located at the fence line.
- If the noise criteria were applied at the noise sensitive receptor, not at or near the noise source, as described in WHO and IFC / World Bank Guidelines for noise, then noise criteria associated with the Project would generally be met assuming implementation of noise control measures.

11.7 TERRESTRIAL BIODIVERSITY

This section presents approach to the terrestrial biodiversity impact assessment, comprising the identification of potential impacts, proposed mitigation and management measures, followed by residual terrestrial biodiversity impacts of project construction and operations.

11.7.1 Approach to impact assessment

A detailed baseline characterisation and impact assessment was completed for the PNG LNG Project (Coffey Natural Systems, 2009), and supplementary surveys have been completed since, as detailed in Section 7.2, Terrestrial biological environment.

Commensurate with the degraded nature of the site and expected incremental impacts on terrestrial biodiversity to those existing, the approach to the terrestrial biodiversity impact assessment has been undertaken with a reduced level of detail compared to the method in the PNG LNG Project EIS, similar to surface water and aquatic ecology.

Slightly modified definitions for sensitivity of terrestrial biodiversity values developed for the PNG LNG Project EIS are presented in Table 11.6, and general definitions for magnitude for physical and biological environmental values presented in Table 5.4 (see Chapter 5 Overview of Impact Assessment Method) were used to assess significance of impacts on terrestrial biodiversity values. The residual terrestrial biodiversity impact assessment uses the matrix of significance provided in Table 11.1.

Sensitivities based on definitions in Table 11.6 assigned to terrestrial biodiversity features in the PNG LNG Project EIS, which also apply to the Project, are summarised below:

- Savanna: Very sensitive
- Grassland: Not very sensitive
- Open Woodland: Sensitive
- Gallery Forest: Sensitive
- Vaihua River Ecosystem Complex: Very sensitive.

Table 11.6 Criteria for the value (sensitivity) of terrestrial biodiversity in the Project area and surrounds

Category*	Sites and/or habitats	Species
Extremely sensitive (Very high)	An internationally designated site. A designated national protected area, e.g., wildlife management area. A large area of little disturbed, intact habitat(s) that provides ecosystem services important in maintaining national or global biodiversity. An area with some very high category species or a high concentration of high category species. Site supports 20% or more of a national population of any species.	A population of internationally important species in IUCN category Critically Endangered.
Very sensitive (High)	A sustainable area of priority habitat identified by the World Wildlife Fund. A large area of little disturbed, intact habitat(s) that provides ecosystem services important in maintaining regional biodiversity. A high diversity area with a moderate concentration of high category species and/or a high concentration of medium category species. Site supports up to 20% of national population of any species. Habitat of peculiar sensitivity that is hard to restore or regenerate.	A population of internationally important species in IUCN categories Endangered or Vulnerable.
Sensitive (Medium)	A local reserve. A substantial area of intact habitat(s) with few invasive species and/or that provides ecosystem services important in maintaining local biodiversity. An area with moderate diversity, some high category species and/or a moderate concentration of medium category species. Site supports up to 5% of national population of any species	A population of a species in IUCN category Near Threatened and/or classified as P under PNG legislation.
Not very sensitive (Low)	Sites that enrich the local area. A low to moderate diversity area with no very high or high category species and a low concentration of medium and low category species.	A population of a species in IUCN category Data Deficient and/or classified as R under PNG legislation.
Not sensitive (Minimal)	No significant ecological value.	A population of a species in IUCN category Least Concern or is unclassified and is not listed under PNG legislation.

Source: Modified from Coffey Natural Systems (2009).
*Bracketed text represents terminology used in the PNG LNG Project EIS.

11.7.2 Potential impacts

Permanent on-land disturbance area for the Project is expected to be approximately 65 ha, almost all of which has been previously disturbed. Of the approximately 340 ha (total) areas that will be disturbed for temporary facilities during construction, approximately 60 ha will be used for the temporary construction laydown area, which is located within the lease boundary east of the LNG Plant but outside of the security fence.

As shown in Table 11.7, potential impacts to terrestrial biodiversity that were defined for construction and operation of the PNG LNG Project are also relevant to the Project, albeit to a reduced extent. These are separated according to direct and indirect impacts.

Table 11.7 Direct and indirect potential biodiversity impacts

Impact Type	Construction			Operations
	Habitat and vegetation	Fauna	Habitat and vegetation	Fauna
Direct Impacts				
Habitat loss	X	X		
Edge effects	X	X	I	
Barrier effects	X	X	A	A
Fauna falling into trenches, drains, pits		X		C
Erosion, movement of soil and spoil	X		A	
Changes to hydrology	X		I	I
Materials handling, disposal, and pollution	X	X	C	C
Dust	X	X	C	C
Noise, lights and other disturbance to fauna		X		C
Traffic		X		C
Indirect Impacts				
Fire	X	X	C	C
Dieback	X		I	
Invasive species – weeds and plant pathogens	X		I	
Invasive species – fauna	X	X	I	I
Hunting		X		C
Collection of flora	X		C	

X = impact mainly during this activity; A = impact ameliorating with time; C = impact continuing but at a reduced level; I = impact possibly increasing with time. Source: Coffey Natural Systems (2009).

11.7.3 Mitigation and management measures

Measures to mitigate and manage impacts on terrestrial biodiversity during construction and operations are summarised below:

- Limit clearing of riparian vegetation to the areas necessary to undertake construction activities safely. Prevent construction personnel from entering areas outside of project-related activities to minimise damage to vegetation.
- Where practicable, revegetate promptly areas no longer required for construction or support services.
- Update the existing reclamation plan for the Project that includes the regeneration of natural vegetation communities, wetland substrates and savanna as close to natural levels as possible through seed collection and/or use of topsoil as a seed resource.

- Where tree removal is necessary, limit damage to surrounding habitats by felling trees away from existing stands where practicable taking into account the value and safety of the areas where the trees are being felled into.
- Limit the scraping of standing tree trunks by machinery as far as practicable.
- Where practicable strip and salvage topsoil. Where salvaged, protect topsoil from loss or degradation. Use topsoil in reclamation management plan.
- Use cleared vegetation where practicable for dust control and revegetation.
- Establish and enforce sediment and erosion control measures, as part of the updated Erosion Control Plan, that limits the mobilisation and dispersion of sediment into freshwater and estuarine environments particularly in relation to site preparation earthworks watercourse diversions, site drainage design and road crossings.
- Provide good industry practice containment and handling wherever hazardous or dangerous goods are stored or used.
- Develop the spill response plan for the Project and train staff in their responsibilities under the plan.
- Prohibit disturbance/harassment of wildlife, hunting of fauna, gathering of plants or bush foods, collection of firewood or possession of wildlife products by project workers or contractors while working, travelling in project vehicles, and residing in project accommodation. Implement appropriate inductions and education to encourage staff to comply with regulations.
- During operations prohibit staff from disturbing migratory species and associated habitats, especially along perimeter fence adjacent to saltflat habitat.
- Establish and enforce speed limits for project traffic on all roads. Liaise with government agencies and local villages with regard to general road safety and traffic regulation.
- Limit machinery and vehicle movements to defined works areas and designated project roads.
- Update and enforce project-wide quarantine management procedures, including inspection of equipment, machinery, and consumables such as pipe and imported rock.
- Update and enforce pest and weed management procedures for the Project including procedures to prohibit project workers or contractors from establishing any gardens, introducing, keeping or transporting any plants, seeds or animals (including fish) within the perimeter fence. This plan would include provisions such as worker education to assist in recognition and eradication of pest species and measures specific to the Project.
- At new or improved road crossings, maintain connectivity in watercourses for wet season flow to enable fish migration.

11.7.4 Residual impact assessment

Construction and operation of the additional facilities at the LNG Plant site are expected to present a **low overall** impact on local biodiversity values if the appropriate mitigation and management procedures are adopted. Procedures including the following are standard industry practice for the site: quarantine, weed and plant pathogen hygiene, maintenance of critical hydrological processes, limiting vegetation clearance, erosion and sediment control, and prohibition of burning and poaching. The Project's ESMP (see Chapter 18 Environmental and Social Management, Monitoring and Reporting) will give specific effect to these measures for the Project.

Residual impacts to vegetation and habits, and fauna are described below.

11.7.4.1 Vegetation and habitats

As shown in Figure 1.4 in Chapter 1 Introduction and Figure 7.10 in Chapter 7 Receiving Environment: Onshore, construction and operations will occur mainly within previously disturbed areas that are classified as grassland/open woodland and rocky grassland. These habitat types are classified as **Not Very Sensitive** and **Sensitive**, respectively. With the implementation of management and mitigation measures listed in 11.7.3 Mitigation and management measures, impacts on vegetation as a result of the Project are assessed as **Low**, based on a **Low** magnitude of impact, given that construction activities are expected to be short term and localised.

No impacts to savanna or gallery forest habitats are expected based on these habitats being absent from the Project footprint areas.

While indirect spread of weeds and pathogens was identified as a major potential impact for the Vaihua River Ecosystem Complex (and other vegetation types), implementation of management and mitigation measures is expected to reduce impacts to **Moderate (High** sensitivity and **Low** magnitude of impact)**,** which is conservative.

During operations, impacts on vegetation will be negligible as constructed areas will be rehabilitated in accordance with the Reclamation Plan, which will be updated for the Project.

11.7.4.2 Fauna

The listed species fauna, which could or do occur on the site, are **unlikely to be adversely affected** by the construction and operation of the LNG Plant additional facilities. The Project's footprint will be sited predominantly on land previously cleared for the LNG Plant. The loss of undisturbed habitats represents a small proportion of their local occurrence and a very small proportion of their regional occurrence.

Wallaby populations will continue to be monitored, and numbers and distribution controlled should evidence of overpopulation be identified.

The significance of impacts to fauna as a result of the Project are assessed as **Very Low** (**Not Sensitive** and **Very Low** magnitude).

11.8 AQUATIC ECOLOGY

This section draws on the baseline characterisation information in Chapter 7 Receiving Environment: Onshore, the PNG LNG Project EIS aquatic fauna impact assessment and the surface water impact assessment in Section 11.4 Surface water. The aquatic ecology impact assessment describes the impact assessment approach, potential impacts associated with the construction and operation of the additional facilities at the LNG Plant, the measures that will be implemented to mitigate these impacts, and the residual impacts, assuming successful implementation of these measures.

11.8.1 Approach to impact assessment

An approach similar to that undertaken for the surface water impact assessment in Section 11.4, Surface water, was used for the assessment of aquatic ecology impacts. This is based on the anticipated impacts to aquatic ecology being of a similar nature, and incremental to, existing impacts from the LNG Plant given that the new facilities and activities associated with the Project are similar.

General definitions for sensitivity and for magnitude for physical and biological environmental values presented in Table 5.1 and Table 5.4 (see Chapter 5 Overview of Impact Assessment Method) were used to assess significance of impacts on aquatic ecology values. The residual aquatic ecological impact assessment uses the matrix of significance provided in Table 11.1.

The sensitivity of the aquatic ecological environment in the Project area and surrounds was assessed as **Not Very Sensitive** given that the site is severely disturbed, and these types of aquatic ecological environments are abundant and widely distributed in the region.

11.8.2 Potential impacts

11.8.2.1 Construction

Construction of the additional facilities at the LNG Plant site can affect aquatic habitats, such as remnant pools (during the dry season) and flowing watercourses (during the wet season). In particular, adverse impacts on hydrology, water quality and habitat connectivity (as discussed Section 11.4, Surface water) may impact aquatic habitats.

These changes have implications for the ability of aquatic fauna to survive conditions of changed physical habitat and water quality and the ability to move throughout the catchment area or beyond.

In addition, there is the potential for the introduction of aquatic noxious weeds, pests and pathogens due to construction related activities and the impacts of competition on the resident freshwater aquatic species from introduced species.

11.8.2.2 Operations

Potential impacts to aquatic ecology decrease rapidly once operations begin as disturbed areas stabilise and the construction-related impacts to hydrology, sedimentation and water quality diminish.

11.8.3 Mitigation and management measures

Mitigation measures designed to avoid or ameliorate the impacts of construction on hydrology, sediment transport and water quality presented in Section 11.4.3 Mitigation and management measures, are also designed to mitigate construction and operations impacts on aquatic ecology (in terms of maintenance of habitat quality and connectivity).

Additional mitigation measures to protect aquatic flora and fauna from accidental introductions of exotic pests will include establishing and enforcing pest and weed management procedures that were developed for the LNG Plant and will be updated to incorporate the Project, including the Weed and Pathogen Management Plan and the Invasive Species Management Plan. Examples of these management measures include:

- Implement a risk-based approach to weed management to reduce the spread of weeds.
- Prohibit project personnel and contractors from establishing gardens and from introducing, keeping or transporting plants, seeds or animals (including fish) within the site security fence.
- Implement worker education to assist in the recognition and eradication of pest species and other measures specific to the LNG Plant site.
- Prohibit the disturbance or harassment of wildlife, hunting of fauna, gathering of plants or bush foods, and collection of firewood or possession of wildlife products by project workers or contractors. Enforced this prohibition while undertaking all activities associated with the Project, such as travelling in project vehicles and residing in project field accommodation.

11.8.4 Residual impact assessment

Construction and operations will occur mainly within the North Vaihua River catchment, and to a lesser degree in the Vaihua River catchment. As discussed in Section 7.3 Freshwater aquatic biological environment, during the dry season, freshwater habitats consist of isolated pools in otherwise dry riverbeds, and the estuaries exist

as coastal tidal inlets with little freshwater inputs provided by rivers. Consequently, the fauna in river habitats is less diverse than in the estuarine habitats.

The flow between the freshwater catchments and estuaries is restored during the wet season. The aquatic species found at or near the LNG Plant site are widespread throughout southern Papua New Guinea, and no rare or threatened species were observed.

11.8.4.1 Construction

Bulk earthworks will be minimal, and control of fugitive sediment will be managed by an erosion and sediment control management plan designed to limit the mobilisation and dispersion of sediment into freshwater and estuarine environments; and to avoid the creation of barriers to fish movement. As described in the surface water impact assessment, Section 11.4.4 Residual impact assessment, due to the flat nature of the catchment and relatively slow flow velocities, TSS and sedimentation impacts are expected to be minor, thereby resulting in low impacts to freshwater aquatic ecosystems.

Furthermore:

- Given that for much of the year (during the dry season) the freshwater creeks are dry, and the aquatic environment is predominantly flat, sediment-laden runoff is less likely to reach watercourses and result in impacts to aquatic ecosystems.
- Aquatic plants, mangrove, fish, prawns and other macroinvertebrates tolerate naturally turbid waters, which they encounter regularly within the estuaries and mangroves downstream of watercourses due to tidal flushing and wave action.
- No species of restricted distribution or endangered status was observed or reported to be present.

On this basis and with mitigation measures in place, the significance of the overall impact is **Low** (based on the assessment matrix in Table 11.1) given that the magnitude of impact is assessed as **Low** (Table 5.4) and the sensitivity is **Not Very Sensitive** (Table 5.1).

11.8.4.2 Operations

Impacts to aquatic ecology during operations are expected to decrease rapidly following cessation of construction activities as disturbed areas stabilise and the construction-related impacts to hydrology, sedimentation and water quality diminish. As a result, the significance of residual impacts to aquatic ecology during operations are expected to be **Very Low** (based on **Not Very Sensitive** and **Very Low** magnitude of impact), assuming control measures implemented during construction are inspected and maintained (i.e., stream connectivity and erosion and sediment control measures) following high rainfall events to ensure functionality, and that rehabilitation of disturbed areas has taken place.

11.9 IMPACT ASSESSMENT SUMMARY

Table 11.8 and Table 11.9 summarise the residual impacts on onshore environmental values.

Table 11.8 Residual impacts on onshore environmental values – significance assessment method

Impact description	Residual impact after implementation of management measures		Significance rating
	Magnitude	Sensitivity	
Groundwater – construction and operations • **Minor spills**	Very low	Very sensitive	Low
Surface water – construction and operations • **TSS and sedimentation in watercourses downstream of work areas** • **Changes to the existing hydrological regime** • **Minor spills**	Low	Not very sensitive	Low
Terrestrial biodiversity – construction and operations **Impacts on vegetation (vegetation removal, dust, changes to drainage, invasive species) – grassland /open woodland.**	Low	Not very sensitive	Low
Impacts on vegetation (vegetation removal, dust, changes to drainage, invasive species) – rocky grassland.	Low	Sensitive	Low
Impacts to Vaihua River Ecosystem Complex from construction and operations.	Low	Very sensitive	Moderate
Impacts on fauna as a result of construction and operations.	Low	Not sensitive	Very low
Aquatic ecology – construction and operations • **TSS and sedimentation in watercourses downstream of work areas.** • **Changes to the existing hydrological regime.** • **Introduction of invasive species.**	Low	Not very sensitive	Low

Table 11.9 Residual impacts on onshore environmental values – compliance assessment method

Impact description	Residual impact*
Air quality – construction • **Dust generation from bulk earthworks and traffic.** • **Combustion products from the diesel-powered equipment (NOx, CO, CO_2, SO_2 and VOCs and fine particulate matter).**	No air quality impacts to sensitive receptors
Air quality – operations • **Dust generation from traffic.** • **Emissions of NOx, CO, CO_2, SO_2 and benzene.**	No air quality impacts to sensitive receptors
Noise – construction **Machinery noise from vegetation removal and bulk earthworks.**	No noise impacts to sensitive receptors
Noise – operations **Noise from new trains, new flares, ancillary plant, boil-off gas system, refrigeration, and power generation.**	No noise impacts to sensitive receptors

* Magnitude and sensitivity not applicable based on the use of the compliance assessment method.