TOTAL E&P PNG LIMITED

PAPUA LNG

Upstream Environmental Impact Statement

Volume 3: Technical Studies

Part 3

Noise Modeling for Impact Assessment

TOTAL

TOTAL E&P PNG LIMITED

PAPUA LNG PROJECT

Noise Modeling for Impact Assessment

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EXECUTIVE SUMMARY

SLR Consulting Australia Pty Ltd was commissioned by ERIAS Group Pty Ltd on behalf of Total E&P PNG Limited (TEP PNG) to undertake noise modeling to inform the impact assessment for the Papua LNG Project (the Project). The Project involves the development of the Elk and Antelope hydrocarbon reservoirs, and supporting infrastructure in a series of phases to produce gas and condensate for transmission to liquefied natural gas (LNG) processing facilities at Caution Bay.

The main source of operational noise emissions with potential to impact sensitive receptors will be the central processing facility (CPF) located within Petroleum Retention License 15 (PRL-15) approximately 60 km inland. Other permanent facilities such as the production wells are either very remote (i.e., more than 6 km from any receptors), or will result in negligible noise impacts (i.e., no additional gas compression will be required at any point along the export pipeline). Consequently, noise from these Project components has not been modeled as part of this assessment. Noise associated with the construction and operation of these less critical/lower impact Project components will be considered as part of the Environmental Impact Statement (EIS) Volume 1 (main report).

As the pipeline right of way (ROW) will come into close proximity of two existing villages at the southern Gulf Province coastline, noise associated with the pipeline construction works has also been modeled with the results provided in this report.

Pre-construction background noise levels along the Project alignment were previously identified and reported (Part 20 of Volume 2). The background noise levels in the region of the gas plant/CPF ranged between 35 dBA[1] and 44 dBA, L_{90}[2] during the day period (from 7:00 am to 10:00 pm). During the night period from 10:00 pm to 7:00 am the following morning, the measured background noise levels were typically 3 dB to 9 dB higher due to the influence of insects (with prominent tones typically around 4 kHz[3]).

Very stable meteorological conditions with the ability to enhance noise propagation (i.e., temperature inversions and/or slight northerly winds) were found to be a feature of the area and considered as part of the 'worst-case'/enhanced propagation conditions.

The Papua New Guinea Conservation and Protection Authority (CEPA) *Technical Guideline (Additional Information) for Noise Discharges* (IB-ENV/03/2004) provides a framework for which noise from a facility can be predicted; however, it is noted that the guideline provides no specific criteria against which noise can be assessed. In lieu of any PNG mandatory noise criteria, noise targets have been sourced from the TOTAL General Specification document GS EP ENV 001 *Environmental requirements for project design and E&P activities* (TOTAL, 2011), Section 5.9 *'Noise level'*, which provides suitable noise targets for the operations phase based on the World Health Organization (WHO) *Guidelines for Community Noise* (WHO, 2008) and the International Finance Corporation (IFC) (World Bank) *Noise Management Guidelines* (IFC, 2007a).

[1] dBA: A-weighted decibels or dBA, are an expression of the relative loudness of sounds in air as perceived by the human ear. In the 'A-weighting' system, the decibel values of sounds at low frequencies are reduced to account for the fact that the human ear is less sensitive at low frequencies (below 1,000 Hz, or 1 kHz) than at mid and higher frequencies. A summary of the fundamentals of noise is provided in **Section 2** of this report.

[2] L_{90}: The noise level exceeded for 90% of the sample period. The L_{90} is typically used to describe the 'average minimum' noise level over the measurement period (in the absence of the source under consideration). It is often used to describe the 'background' noise level.

[3] Hz: Frequency refers to the number of vibrations per second of the air in which the sound is propagating as measured in Hertz (Hz). Most environmental sounds are made up of a complex mixture of sound at many different frequencies. For example, noise from insects and rotary plant, such as fans and compressors can be particularly tonal, meaning that the resultant noise is dominant at certain frequencies which can be perceived as more annoying than the noise level alone would indicate.

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Table ES-1 shows the noise criteria used to assess construction and operational noise from the Project.

Table ES1 Project Noise Criteria

Activity/ Operation	Noise Criteria (external)		Comment
	Day/Evening (7.00 am. to 10.00 pm)	Night (10.00 pm to 7.00 am)	
Construction Noise	55 dBA L_{eq}[1] (long-term target, i.e., for works that could impact a receptor for longer than 1 month) 75 dBA L_{eq}[3] (short-term target for all daytime works)	45 dBA L_{eq}	As an overall long-term target, noise management levels equivalent to the general operational noise limits have been nominated. A higher limit of 75 dBA, L_{eq} has also been nominated for short-term daytime construction works. Where noise exceeds this upper threshold the receiver is considered 'highly noise affected', and all feasible and reasonable noise management and mitigation measures should be considered to help reduce the impacts.
General Operational Noise	55 dBA L_{eq}[1]	44 dBA, L_{eq}	The criteria is the lower of: Average night background level (L_{90}) + 3 dBA[2] OR 45 dBA L_{eq}[1] Background noise monitoring results at the closest villages/settlements to the CPF during the critical night period were typically between 41 dBA and 47 dBA, L_{90}. Based on the quietest noise levels of 41 dBA, the lower night-time noise criteria is therefore 44 dBA, $L_{eq(1h)}$.
Off-site Target[4]	55 dBA L_{eq}[1]	45 dBA, Leq[1]	Pre-existing background noise limit at facility boundary not relevant.

Note 1: WHO, 2008 guideline noise level recommended during day period to 'protect the majority of people from being seriously annoyed'.

Note 2: IFC, 2007 requirement to not *'result in a maximum increase in background levels of 3 dB at the nearest receptor location off-site'*.

Note 3: DECC, 2009 represents the *'point above which there may be a strong community reaction to noise'*.

Note 4: Total, 2011a requires the evaluation of *'noise emissions at the facilities boundary limit'*. As information on the proposed fence line for the CPF is not currently available, these emissions have been extracted from the model output files based on the area proposed to be cleared as part of the CPF construction. This approach will result in worst case estimates of maximum off-site emissions, given that the fence line will likely be further away from the sources than assumed in the modeling.

Noise models for both the CPF site and Orokolo Bay coastal region were developed to predict Project noise emissions to the surrounding areas. Available elevation data was used to formulate a digital ground model to account for any shielding affects provided by landform. Preliminary sound power level (SWL[4]) data was sourced for input to the various models based on the proposed works method, and provided process equipment list. The resultant data was verified based on extensive measurements conducted by SLR, along with available reference data/assumptions as adopted on similar projects[5].

[4] Sound Power Level (SWL): The rate at which a noise source emits acoustic energy.

[5] Port Campbell Gas Facility (2014), BassGas Lang Lang (2015), PNG LNG Project (2015).

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The noise model also accounts for other major noise attenuation mechanisms such as distance / geometrical spreading, atmospheric / air absorption, barrier effects, ground cover attenuation and meteorological enhancement. No allowance for vegetation attenuation has been made consistent with current research that recommends that vegetation should not be relied on for any form of real life attenuation loss.

Neutral (i.e., calm) and enhanced (i.e., worst-case) noise propagation meteorological conditions were simulated for both normal and upset operating conditions (assumed to allow for emergency flaring).

The predicted noise from the construction of the CPF was found to be well below the nominated long-term construction noise target at the closest existing villages.

Noise modeling for construction of the onshore export pipeline at Orokolo Bay shore crossing shows that the short- and long-term construction noise targets will be met at all existing sensitive receptor locations during all conditions with the exception of three properties located at the western edge of Mareke Village approximately 250 m from the pipeline. The noise modeling results show that under enhanced propagation conditions (i.e., slight westerly winds, or temperature inversion) the long-term noise target of 55 dBA, L_{eq} will be exceeded at these properties by up to 2 dBA

An exceedance of 2 dBA is generally barely perceptible to the human ear. As the predicted minor excess of the lower noise management target will only occur during worst case propagation conditions, it is highly unlikely that the occupants of these three dwellings will be adversely affected during the scheduled construction works. However, it is recommended that advance notification is provided to occupants of both Mareke and Iuku Villages to inform them of the anticipated nature, timing, and duration of the works, particularly when the louder activities are scheduled (such as the initial ROW clearance works which will require the use chainsaws, wood chippers, and heavy mobile plant such as dozers, graders, and excavators).

The noise modeling results indicate that under normal operating conditions, noise emissions from the CPF will be well below the existing background noise environment. For upset conditions (i.e., with emergency flaring) there was a significant increase in the resulting noise emissions; however, the predicted noise levels were still well below the operational noise criteria.

If the vegetation clearance area were adopted as the CPF perimeter fence, the resultant maximum off-site noise emissions would significantly exceed the nominated 45 dBA, L_{eq} boundary noise criteria by up to 37 dBA along the southeast boundary located approximately 80 m from the medium pressure compressors. On the western and southwestern boundary, this excess is reduced to approximately 16 dBA to 25 dBA.

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1 Introduction

Joint venture partners are currently planning the development of the Elk-Antelope gas field, which is located within Petroleum Retention License 15 (PRL-15) in Gulf Province, Papua New Guinea. Total E&P PNG Limited (hereafter referred to as TEP PNG), a wholly owned subsidiary of TOTAL, has the largest interest in the Elk-Antelope gas field and is the operator of the Papua LNG Project (the Project) on behalf of the other joint venture partners.

The Elk-Antelope gas field is a significant gas discovery in Papua New Guinea (PNG) consisting of a gas reservoir with an estimated 7.2 trillion cubic feet (Tcf) of gas reserves and up to 100 million stock take barrels (MMstb) of condensate located approximately 120 km inland from the township of Kerema, and 360 km northwest of Port Moresby (refer **Figure 1**).

The Project will comprise upstream production well development and associated infrastructure at the gas field within PRL-15, construction of an upstream central processing facility (CPF) and delivery of gas and condensate via onshore and offshore export pipelines to new Liquefied Natural Gas (LNG) facilities to be co-located within existing PNG LNG facilities at Caution Bay, Central Province, 20 km northwest of Port Moresby. The new LNG facilities at Caution Bay are subject to a separate environment impact statement (EIS) and approvals process. The design life for the Project will be 25 years.

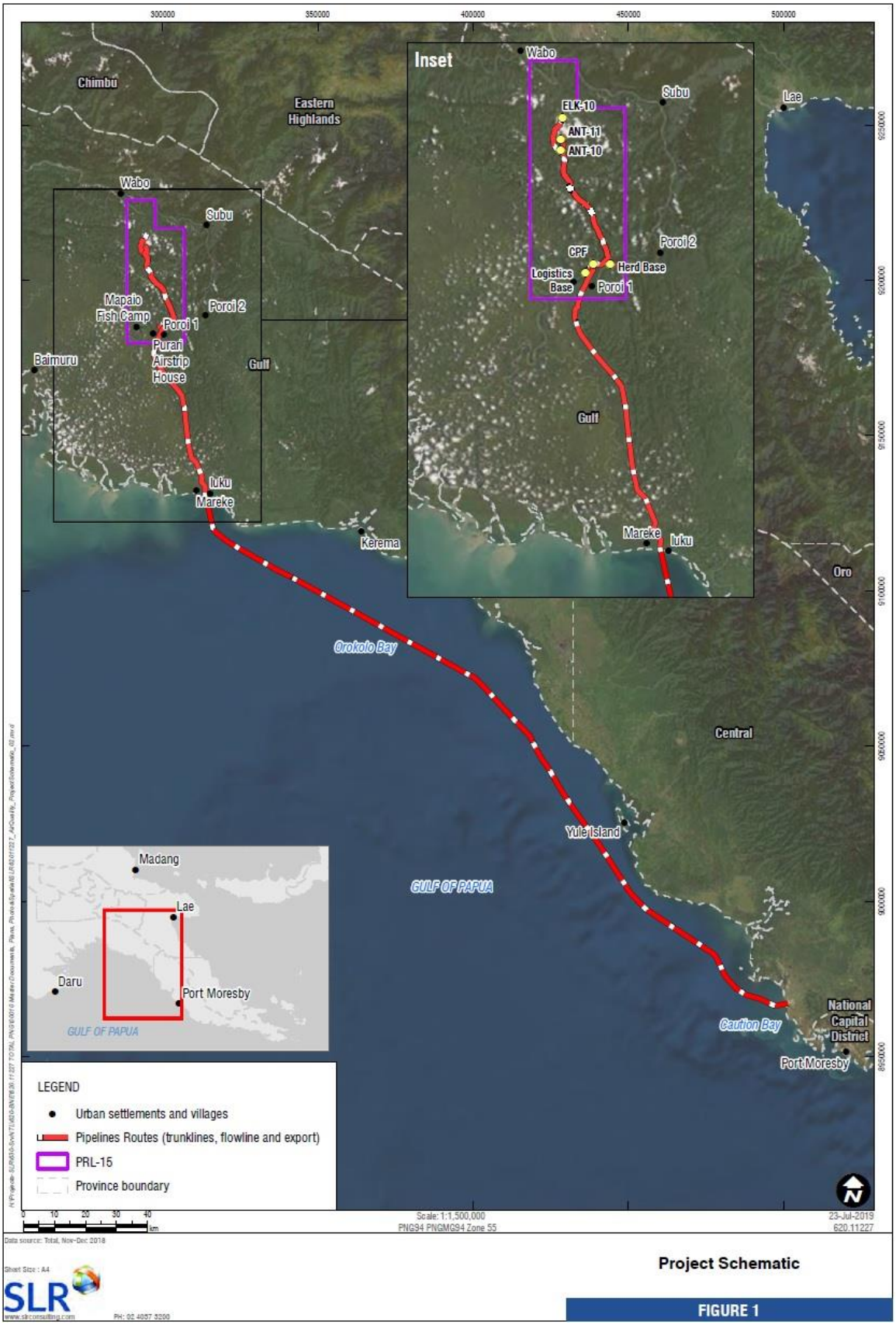
The Project area comprises the physical footprint of the various Project components and associated infrastructure as detailed below.

- Producing and processing the gas:
  - Wellpads and the associated gathering system (including flowlines and trunklines).
  - CPF.
- Transporting the gas:
  - Onshore export pipeline to landfall on the Gulf coast including valve stations.
  - Offshore section of the export pipeline to LNG Plant site, Caution Bay.
- Infrastructure:
  - Camps.
  - Pipeyards.
  - New roads and upgrades.
  - Quarries.
  - Waste facilities including landfills.
  - Logistics base and river offloading facilities.
  - Purari airstrip extension.

River transport will be via the Purari and Ivo-Urika rivers.

SLR Consulting Pty Ltd (SLR) has been commissioned by ERIAS Group on behalf of TEP PNG to undertake a noise modeling study to inform the Papua LNG Environmental Impact Statement (EIS). This report presents the method, inputs and results of the noise modeling study undertaken to assess the potential off-site noise impacts associated with proposed operations at the CPF, as well as pipeline construction works near the Gulf of Papua coastline. The outputs from this modeling study inform the noise impact assessment for the Project presented in the EIS (Volume 1). The modeling is supported by the noise baseline report prepared by SLR for the upstream Project area (Part 20 of Volume 2), which included unattended noise monitoring at representative locations within the Project area of influence.

Figure 1 Project Schematic



2 Fundamentals of Noise

Hearing is a fundamental human sense and is used constantly for communication and awareness of the surrounding environment.

Although the terms 'noise' and 'sound' can be used interchangeably, 'noise' is used to refer to 'unwanted' or 'unfavorable' noise which can impact on the quality of life. The level of impact is to some extent an individual or subjective response, as what may constitute sound to one person may be perceived as noise to another.

From the acoustics point of view, sound and noise constitute the same phenomenon of minute atmospheric pressure fluctuations about the mean atmospheric pressure due to air molecules vibrating back and forth. These variations (or sound waves) travel through the air as a longitudinal wave from the source to the receptor, usually the human ear.

The recognition of noise as a serious health hazard is a development of modern times. With modern industry the multitude of sources has accelerated noise-induced hearing loss.

The measurement and assessment of sound has been developed steadily over the last century, taking into account human response measures such as hearing damage and other potential health effects such as stress. Complex sound measurement and analytical devices have also been developed.

2.1 Measuring Sound and Decibels

The range of pressure changes that can be detected by the human ear is very wide. The minimum acoustic pressure audible to a young human ear in good health is approximately 20 x 10^{-6} Pa or 0.00002 Pa. For the normal human ear, pain is experienced at sound pressures of the order of 60 Pa. To sensibly quantify the large range of pressures that the human ear can be exposed to, the overall level of a sound is usually expressed in terms of the decibel (dB). In acoustics, the decibel represents a logarithmic scale used to denote intensity, or the pressure level of a sound relative to the threshold of human hearing.

2.2 Frequency or Pitch

The frequency of a sound is what gives it a distinctive pitch or tone. For example, the rumble of distant thunder is mostly comprised of low frequency noise, whereas a whistle is mostly high frequency. The ear is more sensitive to high frequency noise events than low frequency ones.

Most environmental sounds contain a broad range of frequencies. However, it is the middle to high frequency sounds that have a greater potential to cause annoyance for the typical person. For example, the muffler of a truck is designed to attenuate annoying mid to high frequency noise from the truck's engine.

Frequency analysis is the process used to examine the tones (or frequency components) which make up the overall noise or vibration signal. This analysis was traditionally carried out using analogue electronic filters, but is now normally carried out using Fast Fourier Transform (FFT) analyzers.

The units for frequency are Hertz (Hz), which represent the number of cycles per second. The audible frequency range is normally considered to be 20 Hz to 20,000 Hz (or 20 kHz) for a person with unimpaired hearing. A person's hearing most sensitive at mid-frequencies (typically 500 Hz to 4,000 Hz) and less sensitive at lower and higher frequencies, although the relative sensitivity changes at differing loudness levels.

For reference, **Table 1** provides a subjective description along with examples for the three main characteristic frequency ranges.

Table 1 Summary of the Three Main Characteristic Frequency Ranges

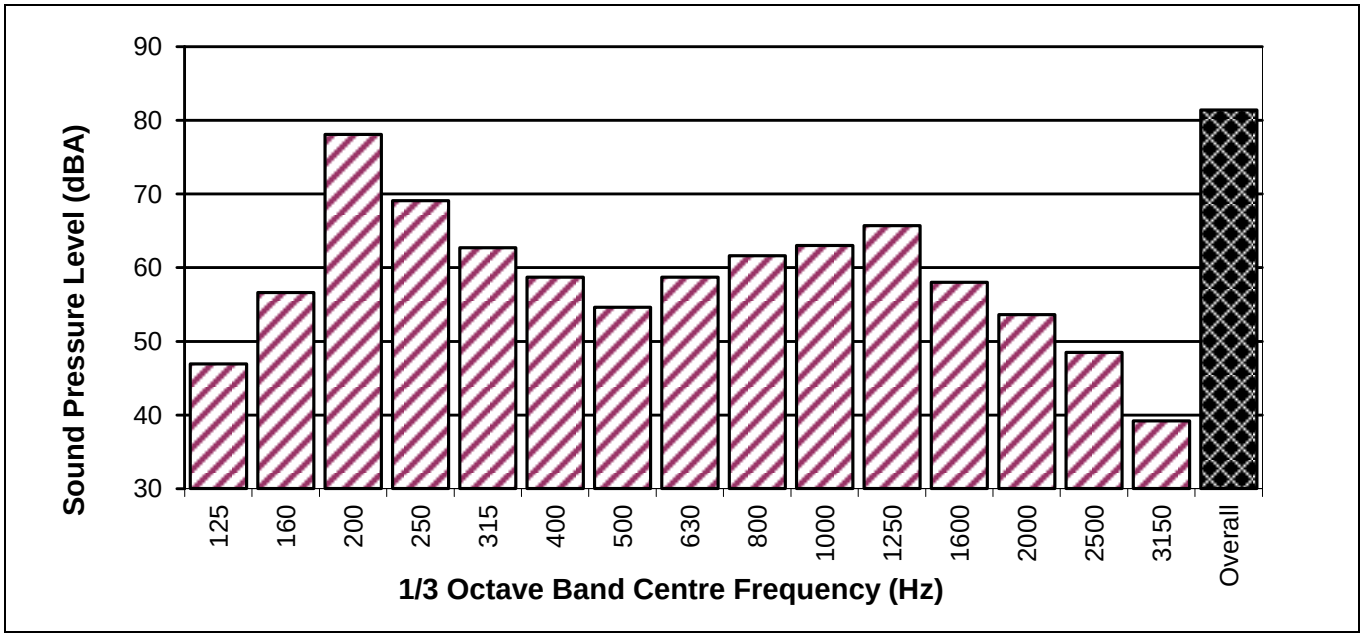
Characteristic Frequency Range	Low (10 Hz – 200 Hz)	Mid (100 Hz – 2,000 Hz)	High (1,000 Hz – 10,000 Hz)
Subjective description	Bass Rumble Boom Hum Thunder Throb	Drone Hum Buzz	High pitched hiss Whine Treble Whistle Squeal/screech
Examples	Electrical substation Bass music beats (from and car or nightclub)	Fans General industrial hum Busy major road	Reversing alarm Trains -wheel squeal Warning alarms

Frequency analysis can be in:

- Octave bands (where the center frequency and width of each band is double the previous band).
- 1/3 octave bands (3 bands in each octave band).
- Narrow band (where the spectrum is divided into 400 or more bands of equal width).

Figure 2 shows a 1/3 octave band frequency analysis where the noise is dominated by the 200 Hz band. Note that the indicated level of each individual band is less than the overall level, which is the logarithmic sum of the bands.

Figure 2 Example of a 1/3 Octave Band Frequency Analysis



2.3 A-Weighting and 'dBA'

To compensate for the fact that the human ear is not equally sensitive to sound at all frequencies various types of filters or frequency weightings have been developed. The A-weighting filter is most commonly used to approximate the human ear's frequency response.

People's hearing is most sensitive to sounds at mid-frequencies (500 Hz to 4,000 Hz), and less sensitive at lower and higher frequencies.

When the overall level of a sound has had the A-weighting filter applied to it, it is represented using the A-weighted decibel, or dBA. The level of a sound in dBA is considered a good measure of the loudness of most sounds. Different sources having the same dBA level generally sound equally as loud, although the perceived loudness can also be affected by the character of the sound (e.g., the loudness of human speech and a distant motorbike may be perceived differently, although they can both have the same measured dBA level).

A change of up to 3 dBA in the level of a sound is difficult for most people to detect, however a 3 dBA to 5 dBA increment change corresponds to a small but noticeable change in loudness. A 10 dBA change will correspond to an approximate doubling or halving in loudness.

The frequency weighting curves were originally defined for use at different average sound levels. In particular, the A-weighting filter was originally intended for the measurement of low level sounds; whereas, it is now commonly used for the measurement of environmental and industrial noise, as well as when assessing potential hearing damage and other noise health effects at all sound levels. The use of the A-weighting filter is now mandated for all of these measurements. However, it can be unsuited for these purposes, being applicable to low levels so that it tends to devalue the effects of low frequency noise in particular.

Table 2 presents examples of typical noise levels.

Table 2 Typical Noise Levels

Sound Pressure Level (dBA)	Typical Source	Subjective Evaluation
140 130	Threshold of pain Jet take-off	Intolerable
120 110	Heavy rock concert Grinding on steel	Extremely noisy
100 90	Loud car horn at 3 m Construction site with pneumatic hammering	Very noisy
80 70	Kerbside of busy street Loud radio or television	Loud
60 50	Department store noise General office	Moderate to quiet
40 30	Inside private office Inside bedroom	Quiet to very quiet
20	Unoccupied recording studio	Threshold of hearing

At higher sound pressure levels, the ear's response is flatter, with the C-weighted filter typically used for Peak measurements and sources with high levels of low frequency noise. Other weightings (e.g., dBB and dBD) are less commonly used. Sound levels measured without any weighting are referred to as “linear”, with the units expressed as dBLin or dB.

2.4 Sound Power Level

The level of noise produced by mechanical plant is often described using either ‘Sound Pressure Level’ or ‘Sound Power Level’. The Sound Pressure Level or SPL is ultimately what our ears hear. In the context of identifying the level of noise from a source, the SPL needs to be specified at a distance (i.e., for mechanical plant this is typically defined at 10 m from the acoustic centre of the source under consideration).

The Sound Power of a source is the rate at which it emits acoustic energy. As with Sound Pressure Levels, Sound Power Levels are expressed in decibel units (dB or dBA), but may be identified by the symbols SWL, L_W, or by the reference unit $1x10^{-12}$ W.

A common analogy used to help describe the relationship between Sound Power and Sound Pressure is an electric radiator in a cold room, versus a sound emitting object in a quiet room.

At every position in the room with the radiator there is a specific temperature, measured in °C. As heat is produced, the temperature is higher closer to the radiator. Likewise, at every position in the room with the sound source, there is a particular sound pressure level (SPL), measured in dBA. As with temperature, the SPL is higher closer to the noise emitting object. Both the SPL and temperature level are *dependent* on the location and distance from the source object.

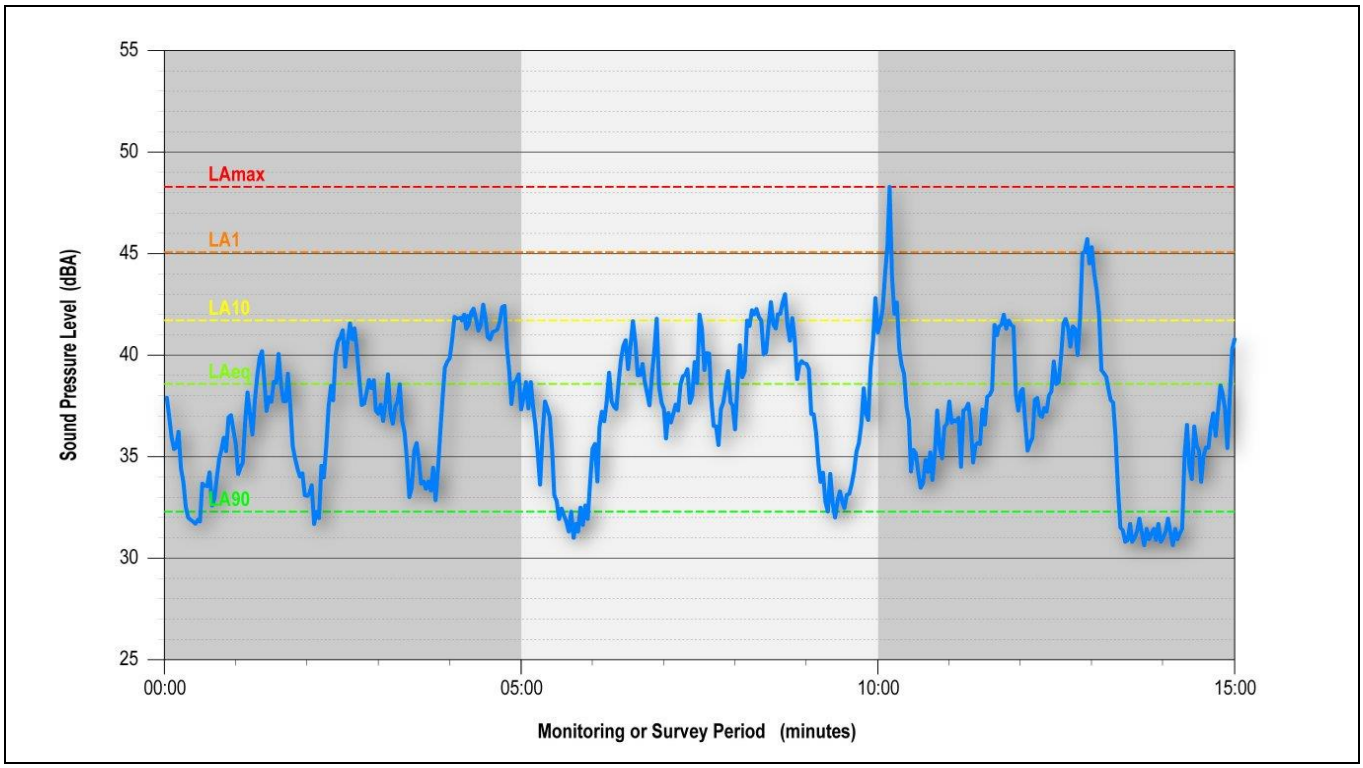
The radiator generates a particular amount of heat per hour. The power required to generate this heat is the same, no matter what the temperature in the room. The radiator power is measured in energy over time, or Watts. Sound power operates on the same principal – the Sound Power of an object is solely a property of the object, which is *independent* of the sound pressure level in the room. Sound power is the rate at which sound energy is emitted per unit time. As with our radiator example, Sound Power is also measured in Watts.

2.5 Statistical Noise Level Descriptors

Sounds that vary in level over time, such as road traffic noise and most community noise, are commonly described in terms of the statistical exceedance levels L_{AN}, where L_{AN} is the A-weighted sound pressure level exceeded for N% of a given measurement period. For example, the L_{A1} is the noise level exceeded for 1% of the time, L_{A10} the noise exceeded for 10% of the time, and so on.

Figure 3 presents a hypothetical 15 minute measurement interval illustrating various common statistical indices of interest.

Figure 3 Example of Various Common Statistical Indices for Noise



Of particular relevance are:

L_{Amax}	The maximum A-weighted noise level associated with a noise measurement interval.
L_{A1}	The noise level exceeded for 1% of a given measurement period. This parameter is often used to represent the typical maximum noise level in a given interval.
L_{A10}	The A-weighted sound pressure level exceeded 10% of a given measurement interval and is utilized normally to characterize average maximum noise levels.
L_{Aeq}	The A-weighted equivalent continuous sound level. It is defined as the steady sound level that contains the same amount of acoustical energy as a given time-varying sound over the same measurement interval. Can be loosely thought of as the 'average'.
L_{A90}	The A-weighted sound pressure level exceeded 90% of a given measurement interval and is representative of the average minimum sound level. Often used to describe the "background" noise level.

2.6 Character

The A-weighted noise level alone is a simplistic parameter and may not be sufficient for providing a thorough assessment of noise. The subjective character of a sound is also a significant parameter which needs to be considered.

Some basic characteristics of sound which can make a sound more, or less, intrusive include:

- The frequency content of the sound, i.e., whether it is low frequency sound (such as exhaust noise) or high frequency sound (such as birds).
- The 'tonality' of a sound (does the sound contain distinct frequency components / one or more prominent tones), e.g. a horn, whistle, emergency alarm / reverse beepers.
- The 'impulsiveness' of a sound (as characterized by one or more sharp peaks in the time domain), e.g. hammering steel, percussive piling rig, a dog barking or a drop forge.

The above parameters can usually be subjectively assessed, but a more thorough assessment can be made with advanced sound measuring devices (e.g., using narrow band or one-third octave analysis).

3 Study Objectives

The objective of this noise modeling study was to provide predictions of potential worst-case noise emissions associated with major components of the Project including:

- Construction and operation of the CPF, and;
- Construction of the pipeline right of way (ROW) near the Orokolo Bay coastline in the Gulf of Papua.

A quantitative three-dimensional (3D) noise modeling approach has been adopted for these Project components due to the potential long-term impacts associated with the operation of the Project, along with the close proximity of villages to the works along the coastline.

Noise impacts associated with other activities and infrastructure proposed as part of the Project (e.g., road construction, Purari Airstrip extension and operation, compressor/valve stations) have been assessed more qualitatively and are not addressed in this modeling report. Noise impacts associated with these less critical/lower impact Project components will be considered in the EIS (Volume 1).

4 Criteria

4.1 Environmental Noise Criteria

4.1.1 Environmental Values

This noise modeling report has been prepared to inform assessment of the Project's potential impacts on biophysical environmental values. A biophysical environmental value is generally defined as a quality or physical characteristic of the environment that is important to ecological health or public amenity. Based on this definition, the environmental values related to noise are:

- Human health and wellbeing, including a suitable acoustic environment for individuals to sleep, study or learn, or be involved in recreation, including relaxation and conversation.
- Health of other forms of life, including the biodiversity of ecosystems.
- Amenity of the community and the enjoyment of the ambient environment.

4.1.2 Overview of Relevant Guidelines

4.1.2.1 Papua New Guinean Legislation

Environment Act No. 64 of 2000

The *Environment Act 2000* (referred to as 'the Act') is the primary legislation in Papua New Guinea that regulates the environmental impact of development activities and how the adverse effects of such activities should be avoided, remedied or mitigated. The Act caters for the sustainable management of the land, air and water resources of the country.

The emission of unreasonable noise is deemed an enforceable offence in accordance with the Act; however, it is noted that the Act does not include or nominate any specific criteria or method outlining how environmental noise should be assessed.

Guideline Documents for Environmental Discharges

The *Information Guideline for Submission of an Application for an Environment Permit to Discharge Waste* (GL-ENV/03/2004) (DEC, 2004a) was developed to guide proponents for Level 2 and Level 3 activities when applying for an environment permit to discharge wastes[6].

The guideline highlights the importance of identifying all potential waste streams over the entire lifecycle of the Project (i.e., from construction, through operation and closure).

Section 8 of the guideline requires a comprehensive analysis of potential impacts of the proposed activity including the effects of its waste discharges (including noise emissions) on the existing environment. Information provided should include the following:

- Details of predicted impacts on the physical, biological and social environment.
- Details of ambient and emission standards used to assess the effects of the Project.

[6] Noting that CEPA currently only issues one environment permit that addresses both waste discharge and water extraction.

- An assessment of resilience of the environment to cope with the expected changes.
- Describe aspects such as worst-case scenarios, potential risks, emergency situations, confidence of prediction of impact.

Where noise emissions *may* be generated by a project, the *Technical Guideline (Additional Information) for Noise Discharges* (IB-ENV/03/2004) (DEC, 2004b) requires the information reproduced in **Table 3** to be provided as part of the environment permit application.

Table 3 IB-ENV/03/2004 Additional Information Requirements for Noise Discharges

Additional Information Required	Description of the Requirements
Outline of the Proposal	Describe the nature and extent of activities to be carried out on the premises
Site Plan and Location	In addition to the A4 site plan (as requested in DEC, 2004a), drawings should indicate the location of all external plant and equipment
Map of Surrounding Area	This map should indicate the positions of nearby residences and residentially zoned areas. An elevation contour map of 1 km radius is also required for rural developments where the land is not predominantly flat
Floor Plan of Internal Plant	To include all major items of noise-producing plant and details of any existing or proposed mitigation measures such as enclosures, silencers or barriers. The plans should also include wall, roof/ceiling, window, door and vent construction details and dimensions
Sound Power Data	Sound power (or alternatively sound pressure level at a specified distance) for all significant plant and equipment
Hours of Operation of the Plant	Background noise measurements should be taken over the proposed operating period with the results presented as hourly A-weighted L_{90} noise levels

The above requirements provide a basis from which environmental noise from a facility can be predicted at the surrounding noise sensitive receptors and assessed. However, it is noted that IB-ENV/03/2004 does not nominate any specific noise limits (as with the Act).

4.1.2.2 International Standards and Guidelines

The primary objective of any environmental noise assessment or policy is to protect people from the adverse effects of noise. Excessive noise can cause nuisance, including sleep deprivation, stress and increased blood pressure, as well as other physical, physiological and psychological effects.

In addition, any noise policy also has to allow for businesses and industries to be able to operate without having to comply with unnecessarily stringent requirements.

Many countries have developed their own noise policies to protect residents and to provide some protection for industries (by, for example, nominating land use zonings or buffer zones, which allow higher noise levels in particular areas). The policies are typically based on previous studies and experience within those countries (and are often based on statistical analysis of community reaction to various levels of noise), or by reference to studies undertaken elsewhere around the world.

Whilst PNG has two guidelines (see **Section 4.1.2.1**) that require noise from a project to be considered, there is no statutory noise policy that sets noise criteria. In the absence of such a policy, it is common practice to adopt suitable International guidelines published by organizations such as the World Health Organization or International Finance Corporation.

There are two international documents that provide indicative noise criteria relevant to this noise study, being:

- World Health Organization (WHO) *Guidelines for Community Noise* ('the WHO Guidelines') (WHO, 2008).
- International Finance Corporation (IFC) and World Bank Group *Environmental, Health and Safety General Guidelines* (EHS Guidelines), Section 1.7 Noise (IFC, 2007a).

The criteria presented in these documents are based on numerous historical studies and, ultimately, are similar to many criteria developed in Australia and other developed countries.

WHO Guidelines for Community Noise 2008

The WHO Guidelines (WHO, 2008) provide the following guidance concerning the onset of health effects from noise.

Day Period

The WHO Guidelines recommend for a steady, continuous noise source the sound pressure level on balconies, terraces and outdoor living areas should not exceed the following levels during the day period:

- 55 dBA L_{eq} to 'protect the majority of people from being seriously annoyed', or;
- 50 dBA L_{eq} to 'protect the majority of people from being moderately annoyed'

In addition, the guidelines nominate an internal noise level inside dwellings below 35 dBA, L_{eq} for the purpose of allowing for good speech communications.

Night Period

The WHO Guidelines prescribe two noise levels at residential locations (i.e., inside bedrooms) to ensure that sleep is not adversely affected, these being:

- Up to 45 dBA, L_{eq} for continuous noise;
- Up to 60 dBA, L_{max} for single events (maximums).

The WHO Guidelines also note that special attention should be given to the following considerations when investigating sleep disturbance:

a. Noise sources in an environment with a low background noise level. For example, night traffic in suburban residential areas.

b. Environments where a combination of noise and vibrations are produced. For example, railways or heavy road vehicles.

c. Sources with low-frequency components. Disturbances may occur even though the sound pressure level during exposure is below 30 dBA.

IFC/World Bank Group Noise Management Guidelines

Section 1.7 of the IFC/World Bank Group General EHS Guidelines ('the EHS Guidelines for noise') (IFC, 2007a) prescribes that: *'Noise impacts should not exceed the levels presented in Table 1.7.1, or result in a maximum increase in background noise levels of 3 dB at the nearest receptor location off-site… Highly intrusive noises, such as noise from aircraft flyovers and passing trains, should not be included when establishing background noise level.'*

The relevant day and night noise levels are presented in **Table 4**.

Table 4 IFC Table 1.7.1 - Noise Level Guidelines*

Receptor	One Hour L_{Aeq} (dBA)	
	Daytime 07:00 – 22:00	Night-time 22:00 – 07:00
Residential, institutional, educational	55	45
Industrial, commercial	70	70

*Guideline values are for noise levels measured out of doors. Source: Guidelines for Community Noise (WHO, 2008).

It is noted that for a generally quiet area, the 'background + 3 dB' limit would be the controlling criteria. The intent of this criterion is somewhat open to interpretation and the IFC document refers to the use of a trained specialist for determining appropriate measurement parameters.

It is considered that a reasonable interpretation of the IFC Guidelines' requirement of *'should not result in a maximum increase in background levels of 3 dB'* is that future plant noise L_{Aeq} noise emissions (received noise) should not be more than 3 dB greater than the existing background noise level, determined as an arithmetic average of the L_{90} statistics for the night period.

4.1.2.3 TOTAL Company Standards and Commitments

Environmental Noise Requirements

The TOTAL General Specification document GS EP ENV 001 *Environmental requirements for project design and E&P activities,* Section 5.9 *'Noise level'* (TOTAL, 2011a) requires the following to be taken into account:

'1. Equipment noise emissions:

All the noise abatement measures shall be taken to ensure an adequate acoustical insulation of the engines, compressors, turbines (enclose engines) and gas flow lines and valves (lagging, in-line silencers, etc.).

2. Noise emissions on the worksite, offices and living quarters (refer to GS EP SAF 221).

3. Noise emissions at the facility's boundary limit and in residential areas close to the installations:

A noise modeling study should be carried out during the design phase to evaluate the global noise level and select appropriate technologies, equipment and arrangements to reduce the impact of the installation on the environment and the local communities. The noise maps should consider normal, downgraded and emergency situations.'

GS EP ENV 001 sets out operational noise level guidelines for off-site receptors based on IFC (2007) (see **Section 4.1.2.2**). Whilst it provides overall noise limits for operational works, the WHO (2008) and IFC (2007) guidelines provides further application guidance as well as additional criteria for noise sources and activities that are not covered.

4.2 OH&S Noise Criteria

4.2.1 OH&S Noise Exposure Requirements

The IFC EHS Guidelines provide Occupational Health and Safety (OH&S) noise limits for different working environments (IFC, 2007b). There are two main criteria as discussed below:

- *'No employee should be exposed to a noise level greater than 85 dBA for a duration of more than 8 hours per day without hearing protection'.* This is commonly defined in the noise exposure standard using the 8 hour equivalent continuous sound pressure level of 85 dBA measured in A-weighted decibels (abbreviated to 85 dBA, $L_{eq(8h)}$ or L_{EX} = 85 dBA), and;
- *'No unprotected ear should be exposed to a peak sound pressure level (instantaneous) of 140 dB(C)'* abbreviated to 140 dBC[7], L_{Peak}[8].

When either of the above criteria is exceeded hearing protection should be actively enforced.

Table 5 shows daily noise exposures that are equivalent to 85 dBA, L_{eq} continuous exposure over an 8 hour standard work day, provided the remainder of the shift is spent exposed to noise levels below 75 dBA L_{eq}.

Thus, continuous noise levels well above 85 dBA are acceptable as long as the duration of the noise at the employee's ears is sufficiently short. For example, in order for an employee working in an area with continuous noise at 100 dBA, L_{eq} to meet the 85 dBA, $L_{eq(8h)}$ noise exposure criterion, they would need to limit their exposure to 15 minutes, with the remainder of the shift spent below 75 dBA, L_{eq}. Conversely, for employees working shifts longer than 8 hours, the acceptable average level of noise exposure is lower than 85 dBA, L_{eq}.

Table 5 Equivalent Exposure Noise Levels & Duration Times to achieve 85 dBA, $L_{eq(8h)}$

Duration of Exposure (in hours)	L_{eq} Noise Level, in dBA
12	83
10	84
8	**85**
4	88
2	91
1	94
0.5	97
0.25	100

[7] dBC: The overall level of sound measured using the "C-weighting" filter. In comparison with the A-weighting filter, the C-weighting filter provides minimal filtering of low and high frequencies (i.e. more similar to an unweighted linear spectrum)

[8] LPeak: The peak sound pressure level over the measurement interval.

4.2.2 TOTAL Company Standards and Commitments

Appendix 6 of TOTAL General Specification GS EP SAF 221 – *Safety Rules for Buildings* (TOTAL, 2011b) provides the noise exposure limit values specific to personnel protection at the work place. The document defines three exposure limit values:

- Exposure limit value: LEX [9]– 87 dBA
- Upper exposure limit value: LEX – 85 dBA
- Lower exposure limit value: LEX – 80 dBA

Based on these values, four risk level cases are defined:

1. Low level of risk for which no preventative measures are required: LEX < 80 dBA
2. Acceptable risk level for which preventative measures are advisable: 80 dBA ≤ LEX < 85 dBA
3. Acceptable risk level for which preventative measures are **mandatory**: 85 dBA ≤ LEX < 87 dBA
4. Unacceptable risk level: LEX ≥87 dBA with ear protection.

The upper exposure limit value is consistent with that provided in IFC, 2007b.

It is noted that at this stage of the project there is usually insufficient technical information to provide a detailed analysis or assessment against OH&S requirements. Furthermore, it is not feasible or practical to incorporate higher order controls (such as silencers, enclosures etc.) to the louder items of plant to achieve these targets. As such, it is likely that mandatory hearing protection will be required for employees working in and around the plant, with double hearing protection (i.e., ear plugs and muffs) possibly necessary for people working near the louder plant items. These requirements are normally determined following a detailed OH&S noise survey of the operational plant which takes into consideration the length of shift/duration of exposure.

4.3 Construction Noise

Construction noise is generally dealt with separately from operational noise. Regulatory authorities in Australia[10] provide guidelines that provide provisions for:

- Adopting 'good industry practice' to avoid unnecessary impacts by ensuring all reasonable and practicable measures are taken to minimize noise resulting from the activity.
- Limiting the hours of construction to standard daytime hours.
- Practical noise limits for construction activities occurring during the day period. For construction projects that are short in duration (e.g., less than a month) it is generally acceptable to have elevated noise limits. To this extent it is accepted that when noise levels exceed 75 dBA there may be a strong community reaction to noise (DECC, 2009). Where noise is above this level it would be prudent to provide respite periods by restricting the hours that very loud activities can occur (e.g., rock breaking or percussive pile driving), taking into account:
    - Times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoons for works near residences).

[9] LEX: The time weighted average of the noise exposure level for a nominal eight hour working day. See definition provided in **Section 4.2**.

[10] There are different regulatory authorities throughout Australia which provide a range of guidelines and policies specific to construction.

  - If the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
- For extended construction periods (e.g., greater than one month) the appropriate noise limit would be 55 dBA, $L_{eq(1h)}$ which is consistent with the WHO (2008)/IFC (2007) standard operational noise limit for daytime construction works.
- For construction outside standard 'daytime' hours, such as night works, noise should comply with the WHO (2008)/IFC (2007) standard operational noise limits (i.e. 45 dBA, $L_{eq(1h)}$ or background + 3 dBA).

4.4 Other Considerations

There are additional social and economic considerations which are relevant to setting noise criteria and assessment methods.

The nuisance caused by noise is also dependent on a community's relationship with the noise source. For example, an industry that provides some form of social or economic benefit to a community may not be considered a nuisance by locals even when – compared to most standards – it can be shown that the noise level is considered high.

While it is very difficult to provide a measure or 'adjustment' to a noise limit based on the above, some consideration needs to be given to this.

4.5 Project Noise Criteria

With reference to the guidelines and consideration presented in **Sections 4.1.1** to **4.4**, a summary of possible criteria for various activities associated with the Project is presented in **Table 6**.

Table 6 Project Noise Criteria

Activity/ Operation	Noise Criteria (external)		Comment
	Day/Evening (7.00 am. to 10.00 pm)	Night (10.00 pm to 7.00 am)	
Construction Noise	55 dBA L_{eq}[1] (long-term target, i.e., for works that impact a receptor for longer than 1 month) 75 dBA L_{eq}[3] (short-term target for all daytime works)	45 dBA L_{eq}	As an overall long-term target, noise management levels equivalent to the general operational noise limits have been nominated. A higher limit of 75 dBA, L_{eq} has also been nominated for short-term daytime construction works. Where noise exceeds this upper threshold, the receiver is considered 'highly noise affected' and all feasible and reasonable mitigation measures should be considered to help reduce the impact.
General Operational Noise	55 dBA L_{eq}[1]	44 dBA, L_{eq}	The criteria is the lower of: Average night background level (L_{90}) + 3 dBA[2] OR 45 dBA L_{eq}[1] Background noise monitoring results at the closest villages/settlements to the CPF during the critical night period were typically between 41 dBA and 47 dBA, L_{90}. Based on the quietest noise levels of 41 dBA, the lower night-time noise criteria is therefore 44 dBA, $L_{eq(1h)}$.
Off-site Target[4]	55 dBA L_{eq}[1]	45 dBA, Leq[1]	Pre-existing background noise limit at facility boundary not relevant.

Note 1: WHO, 2008 guideline noise level recommended during day period to 'protect the majority of people from being seriously annoyed'.

Note 2: IFC, 2007 requirement to not *'result in a maximum increase in background levels of 3 dB at the nearest receptor location off-site'*.

Note 3: DECC, 2009 represents the *'point above which there may be a strong community reaction to noise'*.

Note 4: Total, 2011a requires the evaluation of *'noise emissions at the facilities boundary limit'*. As information on the proposed fence line for the CPF is not currently available, these emissions have been extracted from the model output files based on the area proposed to be cleared as part of the CPF construction. This approach will result in worst case estimates of maximum off-site emissions, given that the fence line will likely be further away from the sources than assumed in the modeling.

For the evaluation of any special audible characteristics present in the noise emissions (e.g., tonality, low frequency) commonly implemented best practice assessment methods have been used such as presented in ISO 1996:2 *'Acoustics – Description, measurement and assessment of environmental noise- Part 2: Determination of environmental noise levels'* (ISO 1996:2, 2007).

5 Modeling Method

This section presents the noise prediction method and procedures, the investigated modeling scenarios, and main modeling inputs.

5.1 SoundPLAN

To calculate the noise emission levels at the nearest noise sensitive receptor locations, a computer noise model was developed using the latest available version of the SoundPLAN (V 8.1) noise modeling package. The package enables the compilation of a sophisticated computer model comprising:

- a 3D digital ground model of the site and surrounding area,
- the location of all critical noise sources on the site,
- the location and height of any significant intervening structures that provide noise shielding, and;
- the location of sensitive receptors.

The noise model predicts received noise levels taking into account such factors as:

- the acoustic sound power level (SWL) of all significant noise sources,
- the directivity[11] of a noise source,
- geometrical spreading/distance attenuation,
- ground absorption,
- air absorption,
- shielding attenuation due to barrier effects, and
- meteorological/atmospheric conditions.

SoundPLAN is able to use a large number of prediction standards and algorithms. For this Project the CONCAWE algorithm as described below was used.

5.2 The CONCAWE Noise Prediction Model

CONCAWE (CONservation of Clean Air and Water in Europe) Report No. 4/81 *'The propagation of noise from petroleum and petrochemical complexes to neighbouring communities'* (CONCAWE, 1981) provides a detailed description of a noise prediction model designed for large industrial facilities, specifically petrochemical complexes. The method incorporates the influence of wind effects and temperature inversions on noise propagation over large distances.

The statistical accuracy of environmental noise predictions using the CONCAWE algorithm was investigated by Marsh who concluded that CONCAWE was accurate to ±2 dBA in any one octave band between 63 Hz and 4 kHz and ± 1 dBA overall (Marsh, 1982).

[11] Directivity is a measure of the directional characteristic of a sound source. For example, noise coming from a vertical stack or exhaust is louder directly above the stack, than at the same distance 90° to the side.

Noise levels for the Project have been calculated using CONCAWE for both neutral and enhanced (i.e., worst case) propagation conditions where appropriate. The parameters used to assess the effect of adverse meteorological conditions such as temperature inversions and slight winds from the source to receptor are discussed in **Section 5.2.1**.

5.2.1 Meteorological Environment

One of the objectives of the noise assessment is to consider the effects of relevant meteorological conditions (wind, temperature, humidity and atmospheric stability) on noise propagation within the Project area. Meteorological conditions such as wind speed and direction, as well as atmospheric stability (which provides an indication of the possibility of temperature inversion) can enhance noise levels to particular receptors.

The associated increase in noise from such meteorological conditions is more significant at larger distances from the noise source.

As part of the air quality modeling report prepared by SLR for this Project (Part 2 of Volume 3), meteorological modeling was undertaken to characterize weather conditions in the study area[12]. The findings relevant to the noise modeling are summarized below.

Wind effects

Wind that is light, stable and blowing towards a receptor from a source of noise has the potential to increase noise levels at that receptor. For this reason, the effect of such wind conditions should be considered when it features in the Project region. As the strength of the wind increases, noise produced by wind will obscure noise from most industrial and transport sources. Winds are therefore generally only considered to be noise enhancing up to 3 m/s.

Wind roses showing the wind data predicted by CALMET (a meteorological modeling system) as per the air quality modeling of the CPF site for 2014 and 2015 are reproduced in **Figure 4**. The wind roses show the frequency of winds blowing from particular directions over a specified period. The length of each 'spoke' around the circle is related to the frequency that the wind blows from a particular direction per unit time. Each spoke is also broken down into color-coded bands to show the frequency of specific wind speed ranges.

Figure 4 indicates that during the modeled years, 2014 and 2015, the CPF site experienced mainly light to moderate winds (less than 5.5 m/s), with winds predominantly from the north-northeast and northeast. Calm wind conditions (wind speeds less than 0.5 m/s) were predicted to occur 4-5% of the time.

The plot of CALMET-predicted wind speed frequencies presented in **Figure 5** further illustrates that the site predominantly experiences low to moderate wind speeds, with a very low frequency of wind speeds above 5 m/s predicted during either 2014 or 2015.

The analysis shows that wind conditions in the vicinity of the CPF are able to enhance noise propagation to the closest villages/settlements along the Purari River to the south. Consequently, enhancement due to wind conditions has been included as part of this assessment as a worst-case situation. For the worst-case situation it has been assumed that a steady 3 m/s wind blows in the direction of the receptor from each source.

[12] The study area for the air quality baseline assessment was defined as any area where air quality may be directly impacted as a result of Project activities, including construction and operation of facilities and infrastructure for the Project. For the purposes of the modeling report, the study area is restricted to areas where air quality may be directly impacted as a result of proposed operations at the CPF.

Figure 4 Wind Roses for the CPF Site (CALMET)

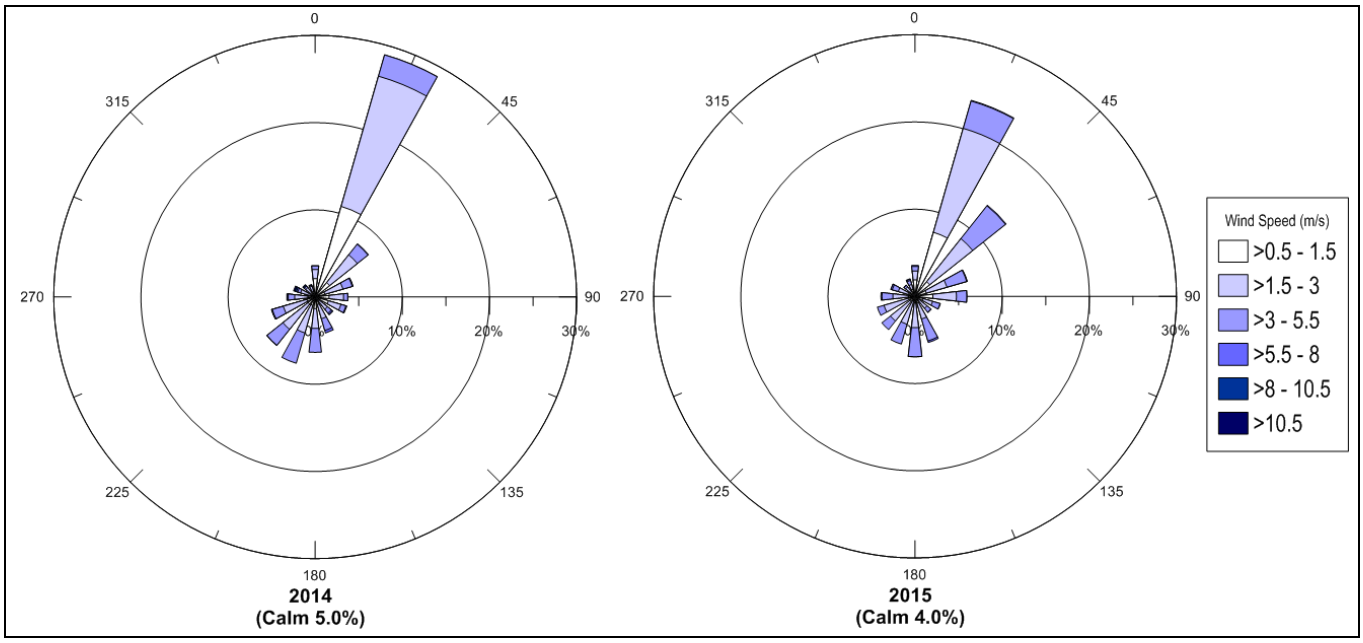
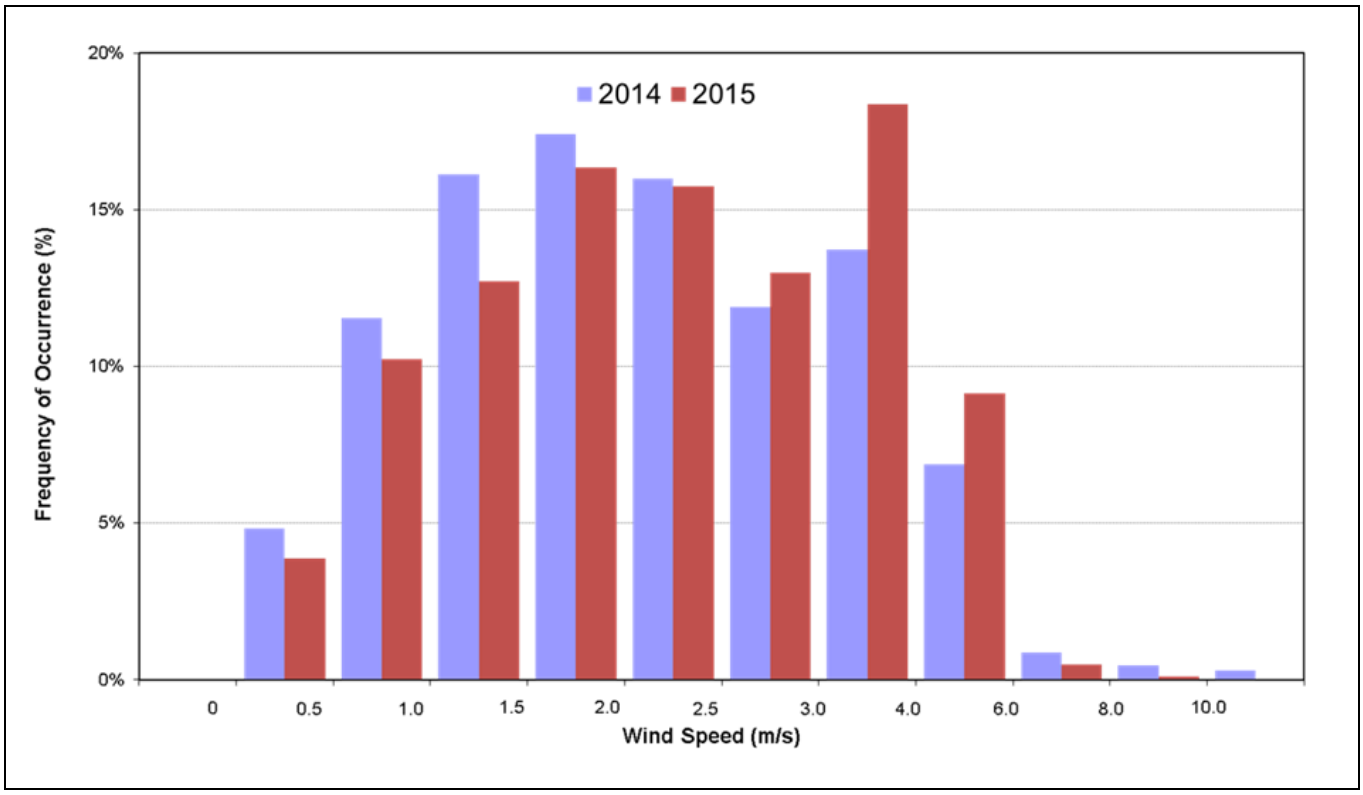


Figure 5 Predicted Wind Speed Frequency Distributions for the CPF Site (CALMET)



Temperature Inversion

Under stable atmospheric conditions (i.e., when there is minimal atmospheric turbulence or mixing) a temperature inversion can occur whereby a layer of cool air at the earth's surface is overlain by a layer of warmer air at higher altitude. When they occur, temperature inversions have the ability to increase noise levels by bending upward travelling sound waves back towards the ground.

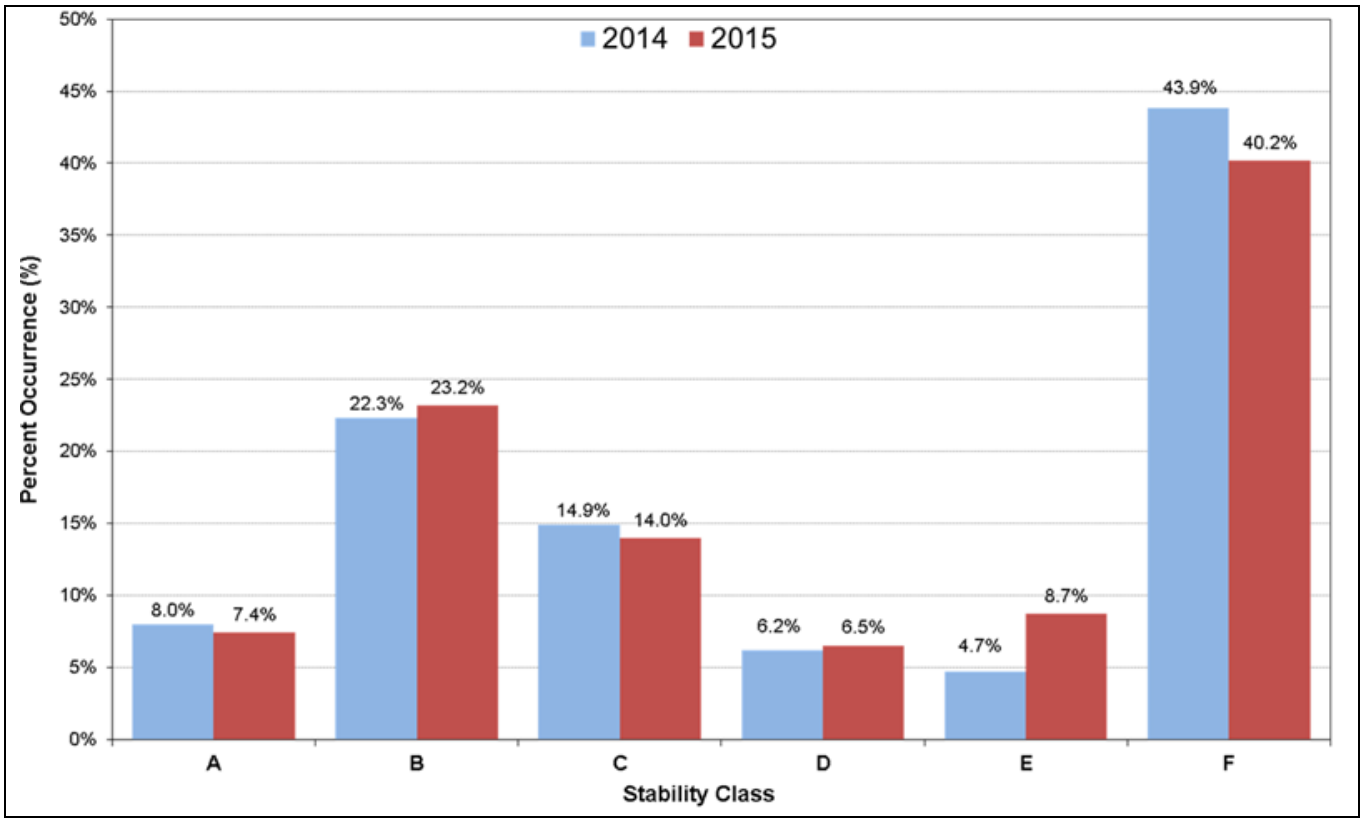
Atmospheric stability refers to the tendency of the atmosphere to resist or enhance vertical motion. The Pasquill assignment scheme identifies six stability classes, A to F, to categorize the degree of atmospheric stability as follows (Pasquill, 1961):

- A = Extremely unstable conditions.
- B = Moderately unstable conditions.
- C = Slightly unstable conditions.
- D = Neutral conditions.
- E = Slightly stable conditions.
- F = Moderately stable conditions.

The percentage occurrence for each stability class was predicted as per the air quality baseline study (Part 19 of Volume 2) (using CALMET) for the proposed CPF site, with the results reproduced in **Figure 6** on the following page. The results indicate a relatively high frequency of stability class F conditions which support temperature inversions. These conditions are prevalent during the evening and night period when people are typically more sensitive to noise.

It is noted that a detailed atmospheric stability analysis was not undertaken for the area along the coast where the export pipeline will be installed. In the absence of this information, the assessment has conservatively assumed both neutral/calm and enhanced/worst case propagation conditions for both the CPF and landfall catchment areas.

Figure 6 Predicted Stability Class Frequency Distributions for the CPF Site (CALMET)



5.2.2 Noise Modeling Meteorological Assumptions

Based on the analysis of available meteorological data described above, both neutral and enhanced (worst-case) meteorological conditions have been modeled.

In the context of CONCAWE neutral conditions assume zero meteorological influence. The enhanced conditions include temperature inversions and wind from source to receptor. It should be noted that this is a hypothetical worst-case condition allowing for both temperature inversion and moderate wind speeds from source to receptor. Temperature inversions do not normally occur when there are moderate winds. Both neutral and enhanced noise modeling parameters adopted for the CPF area are shown in **Table 7.**

Table 7 Neutral (Calm) and Enhanced CONCAWE Noise Modeling Meteorological Parameters

Propagation Condition	Air Temperature	Relative Humidity	Barometric Pressure	Wind Velocity	Atmospheric Stability Class
Neutral/Calm	25°C	90%	1013 mBar	0 m/s	D
Enhanced/Worst Case	25°C	90%	1013 mBar	2 m/s (source to receptor)	F

Similar assumptions were conservatively adopted for modeling of the pipeline construction along the southern coastline.

5.2.3 Other Factors Affecting Noise Propagation

Topographical shielding, ground hardness and dense vegetation are other factors (in addition to the above explained meteorological factors) that can affect noise propagation.

Topographical shielding

Local topography can significantly affect the propagation of noise depending on the level of shielding provided. The actual degree of noise attenuation due to topographical shielding is a function of the frequency spectrum of the noise and the specific physical geometry of the source and receptor intervening terrain.

Noise attenuation due to topographical shielding typically ranges from 5 dBA if line-of-sight between the noise source and receptor location is just obscured, up to approximately 15 dBA where the topography provides substantial blocking of the sound propagation path.

The effect of topographical shielding is taken into account in the 3D modeling based on the digital ground/ elevation model (DEM) prepared for the site.

High-resolution 1-m elevation data for the 5.5 km x 5.5 km area encompassing the CPF site was used. This was supplemented by 3-second arc (90 m) resolution data sourced from the Shuttle Radar Topography Mission (SRTM3) dataset to extend the DEM in the region surrounding the CPF by an additional 200 km² (i.e., 17.5 km x 13.5 km). Where available, higher resolution (5 m) LIDAR data for the region surrounding the CPF was integrated to the DEM to replace the SRTM data.

Currently there is a ridgeline that ranges from 51 m to 75 m above mean sea level (AMSL) that will need to be levelled to 30 m to 35 m to account for the service/utilities area, and process area. Consequently, the construction of the CPF will involve the removal of a significant volume of earth. From the Earthworks Management Plan (EGIS, 2018) it is understood that these works will likely require 6x30T, and 2x80T excavators, along with a wide variety of other plant and equipment (i.e., rock breakers, loaders, dozers, graders).

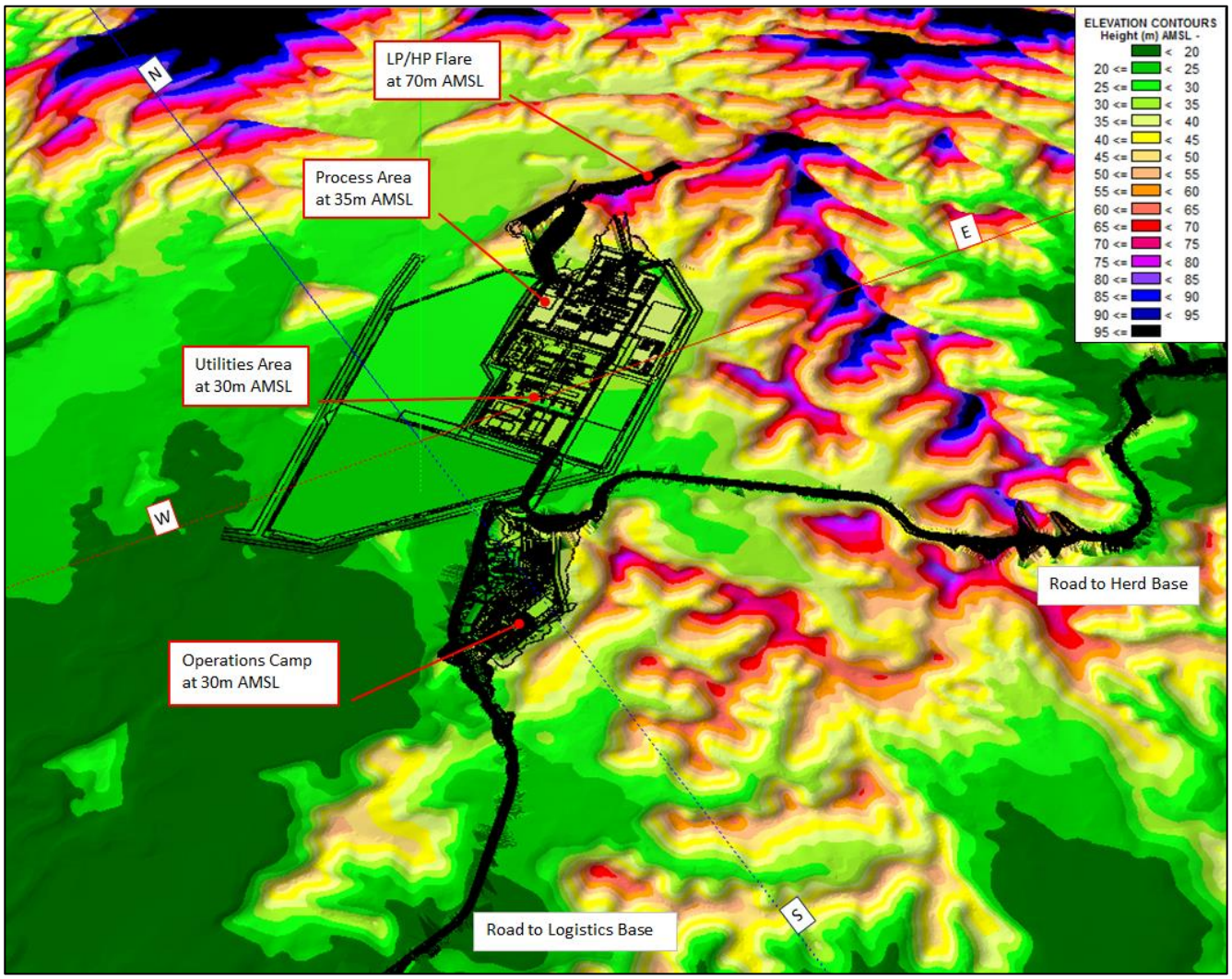
To account for the future topography across the CPF site after construction (and to ensure accurate base height elevations for noise sources within the model) 3D elevation data for the CPF site was imported from the CAD data supplied from TOTAL. The pad height for the main process area (which includes the majority of the operational noise sources considered in the model) is located at 35 m AMSL; whereas the utilities area (which includes the base power generation plant, boilers, and hot water circulation pumps) is at 30 m AMSL. The low pressure/high pressure (LP/HP) flare platform will be installed on a specifically designed 40 m x 40 m pad above the ridge to the northeast of the plant at 70 m AMSL.

An operations camp is planned 500 m southwest of the CPF, on the main access road that connects the Logistics Base located on the northern bank of the Purari River approximately 1.2 km further south. The location and footprint of the operations camp have been initially defined to optimize earthworks quantities and respect seismic constraints; however, it is understood that this footprint may need to be revisited depending on the number of personnel.

A 3D elevation plot showing the CPF site, operations camp, connecting roads, and surrounding terrain is provided in **Figure 7**. Shielding provided by the refined terrain model is considered in the prediction algorithm along with losses due to ground and air absorption.

Where the export pipeline route reaches the coast at Orokolo Bay, land is typically flat with minimal/no shielding provided by existing terrain. For this region, 5 m LIDAR data was incorporated to the predictive noise model.

Figure 7 3D Terrain Model of CPF and Surrounding Elevation Contours



Ground Attenuation

Ground hardness can affect the way in which direct-received noise and ground-reflected noise interacts. Noise will propagate more readily across a hard reflective surface than a soft absorptive surface. Ground attenuation is a function of the acoustic hardness along the propagation path and the height of propagation above ground.

All areas included in the model were modeled with the following ground absorption values (where 1.0 = fully absorptive and 0.0 = fully reflective):

- Absorption coefficient of 1.0 for natural ground vegetation areas (i.e., surrounding rainforest) and village areas.
- Absorption coefficient of 0 for concrete and hardstand areas around CPF, operations camp, roads, and waterbodies, such as the Purari River and ocean.

Vegetation Noise Attenuation

It is a common misconception that vegetation can provide significant noise attenuation; however, in most real life situations, the amount of attenuation provided is minimal. In some cases, where trees or shrubs block line-of-sight there is a psychological benefit, i.e., if a person cannot see the sound source (which may be disturbing them) they may not be as anxious.

The propagation loss due to vegetation is dependent on a large range of factors including, canopy height, tree size and distribution, trunk diameter, undergrowth makeup, and foliage and leaf density (amongst others). In addition to this, the amount of attenuation has been observed to vary with season (i.e., in some climates the level of volume attenuation has been observed to reduce significantly during dry seasons).

Research on the propagation of noise through trees and vegetation has produced greatly conflicting results. *'Ground, Terrain and Structure Effects on Sound Propagation'* (Hannah, 2006) provides a detailed review of factors affecting outdoor sound propagation, including vegetation attenuation as based on existing theory and earlier studies (Eyring, 1946; Wiener & Keast, 1959; Embelton, 1963; Aylor, 1972; USAF, 1995).

Although this topic is normally misunderstood or neglected, research results indicate that trees and scrubs can provide only minor attenuation through scattering by the dense trunks and branches. However, hedges and trees provide little to nil attenuation unless extremely dense with branches reaching to the ground, even then the application of sound attenuation is very limited.

It is possible that the thick forested areas surrounding the CPF could potentially provide additional attenuation in the order of a few decibels at distances of approximately 50 m to 500 m. However, at larger distances (such as those associated with the closest villages approximately 3 km+), any additional attenuation from vegetation is negligible due to the large contribution already provided by atmospheric and ground effects.

Furthermore, under enhanced propagation conditions, the diffraction of noise from the atmosphere (due to temperature and wind speed gradients) back to the ground negates most shielding effects provided by vegetation or other physical obstacles between the noise source and the receiver.

Considering all of the above, no allowance for vegetation attenuation has been included in the noise modeling. This approach is consistent with current research (Hannah, 2006) which recommends that vegetation is not used or relied on for any form of real life attenuation loss.

5.3 Sensitive Receptor Locations

The proposed CPF is situated approximately 1.5 km north of the Purari River, and approximately 3 km west of the existing Herd Base. The area is remote with the closest village, Poroi 1, located approximately 4 km to the south of the CPF. There is also a family house (hereafter 'Purari Airstrip House) situated approximately 5 km southwest of the CPF on the southern bank of the Purari River, approximately 200 m northwest of the Purari Airstrip.

There are two other villages (Poroi 2 and Poroi 3) located approximately 13 km from the CPF, with the next village along the Purari River more than 20 km to the south. Any potential noise impacts to these areas associated with the CPF would be negligible due to the significant distances involved.

Four discrete receptors were included in the noise model to represent the identified sensitive receptors in the surrounding area of the CPF as listed in **Table 8** and shown in **Figure 8**.

Table 8 Sensitive Receptors Included in the Construction and Operational Noise Model for the CPF

Receptor	Location PNG94 MG94 Zone 55	Distance/Direction from CPF
Poroi 1	300,457 E, 9,182,433 N	4.3 km south
Mapaio Fish Camp	292,023 E, 9,185,351 N	8.8 km west-southwest
Purari Airstrip House	296,941 E, 9,183,119 N	4.8 km southwest
Herd Base	303,840 E, 9,186,527 N	3.2 km east

Modeling results are also presented in **Section 7.2** for the 'maximum off-site' noise prediction. As information on the proposed fence line for the CPF is not currently available, the facility boundary has been based on the area to be cleared as part of the CPF construction (**Figure 8**). This approach will result in worst case estimates of maximum off-site noise levels, given that the fence line will likely be further away from the sources than assumed in the modeling.

Figure 8 Aerial Photograph Showing Sensitive Receptor Locations near CPF

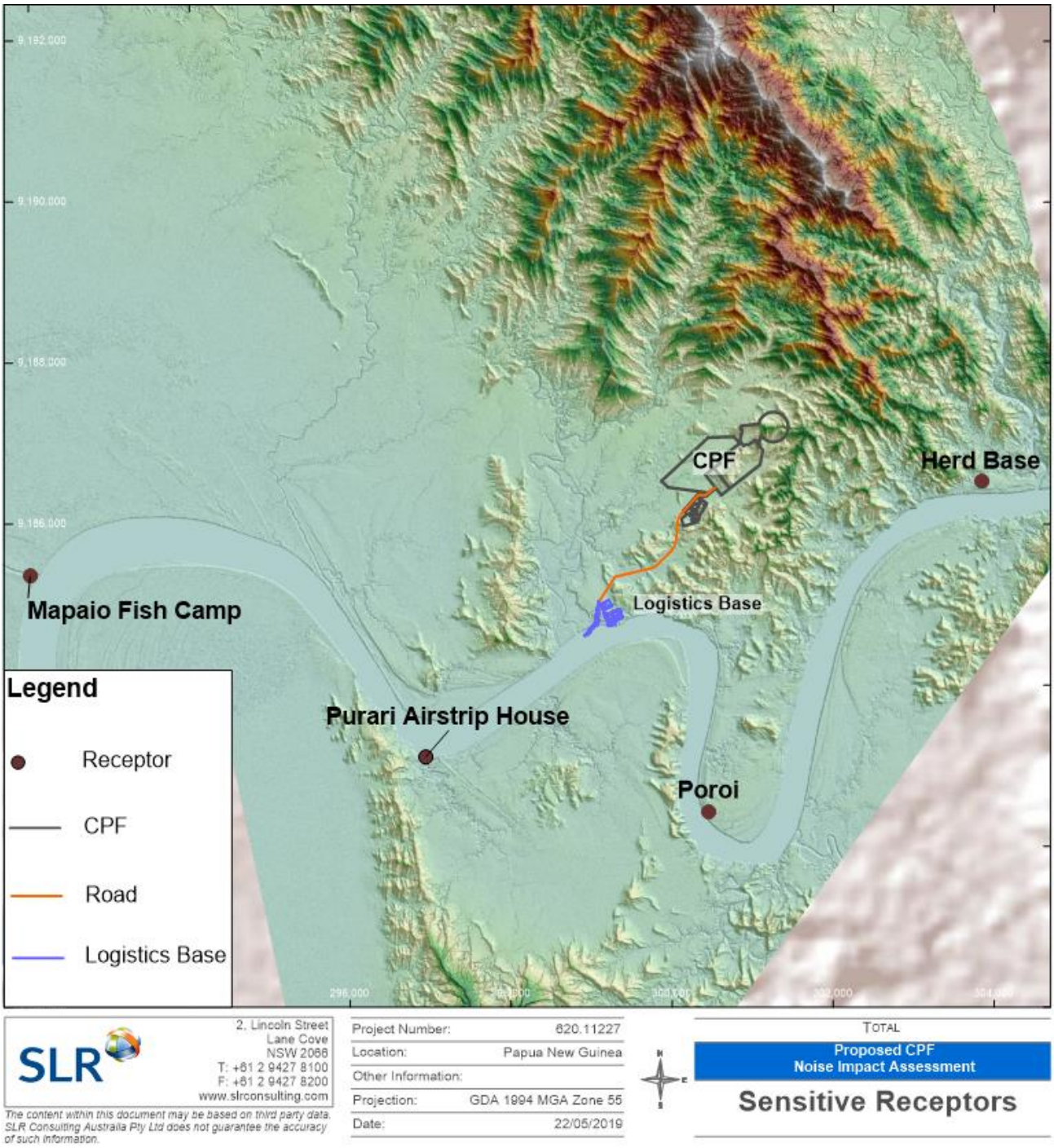


Table 9 provides the closest receptors included in the noise modeling of the pipeline construction works at the Orokolo Bay coast. For the two villages closest to the pipeline ROW, the closest dwellings are in some cases less than half the distance from the approximate centre of the village as provided in the source receptor data. Given the significant effect of distance on transmitted noise levels, it was decided to consider the closest and approximate centre for both villages separately to quantify the range of noise levels in this critical area. As the other villages are located much further away they were excluded from the assessment.

Table 9 Sensitive Receptors Included in the Construction Noise Model along the Orokolo Bay Coast/ Export Pipeline ROW

Receptor	Location PNG94 MG94 Zone 55	Distance/Direction from Pipeline ROW
Mareke West (closest property)	313,892 E, 9,131,718 N	0.3 km east
Mareke (approximate centre of village)	314,309 E, 9,131,632 N	0.7 km east
Iuku East (closest property)	312,938 E, 9,131,835 N	0.5 km west
Iuku (approximate centre of village)	303,840 E, 9,186,527 N	0.7 km west

Figure 9 Aerial Photograph Showing Closest Orokolo Bay Coastal Villages to Export Pipeline Route

6 Noise Modeling Scenarios and Model Inputs

6.1 Scenarios Modeled

The upstream Project components considered as part of the noise modeling process are listed in **Table 10**.

Table 10 Papua LNG Upstream Components for Consideration in Noise Impact Assessment

Project Component	Phase of Project	Activities/Noise Emission Sources	Assessed Scenario/s	Assessment Method
CPF	Construction	Vegetation clearance, earthworks and site preparation, pad preparation, civil works/ building erection	1. Site preparation/bulk earthworks 2. Civil/construction works	Quantitative 3D noise model
	Operation	Gas turbines, compressors, pipework, pumps, flare	See Note A	Quantitative 3D noise model
Export pipeline route at Orokolo Bay coast	Construction	Earthworks (as per ROW)	Trenching	Quantitative 3D noise model

Note A: For the operational CPF two worst-case scenarios have been considered:
1. All plant operating 10 years after plant opening/first gas (i.e., when the additional 5 x medium pressure (MP) gas turbine compressors come online).
2. As above with emergency flaring.

To determine appropriate assumptions/inputs (i.e., suitable construction and operational scenarios) the following documents were reviewed:

- Project Ref.: EP/DSO/ONS/EDI-PNG/ENOC01902-EGI-030-RT-001 *"Earthworks Management Plan"* (EGIS, 2018).
- Project Ref.: EP/DSO/ONS/EDI-PNG/PJM-800437 Preliminary-Constructability-Report_Draft.pdf *"Preliminary Upstream Constructability Study"* (Total, 2018a).
- Project Ref.: EP/DSO/ED/EDI-PNG/CIV-800235 *"Pipelines Routing and Constructability Assessment Study PHASE 1"* (Speiecapag 2016).
- Project Ref.: EP/DSO/ED/EDI-PNG/CIV-800302 *"Papua LNG Pre-Project Civil Engineering Study"*, (KRAMER Ausenco, 2016).
- Project Ref.: EP/DSO/ED/EDI-PNG/PRO-800205 *"Process Equipment List"* (Total, 2018b).
- Project Ref.: EP/DSO/ONS/EDI-PNG/PRO-800311 *"Papua New Guinea/PRL15 Elk-Antelope Development Studies - Pre-Project Upstream Process Report"* (Total, 2018c).
- Drawing showing mechanical plant layout within Process and Utilities Area of CPF (see **Figure 10**).
- SLR Memorandum 01215B_M049_20181214_v1.pdf *"PAPUA LNG/EIS AIR QUALITY MODELING/TENTATIVE SELECTION OF SCENARIOS"* (SLR, 2018).
- SLR Memorandum 01215B_M057_20190219_v1 TOTAL2.pdf *"PAPUA LNG/EIS ASSUUMPTIONS FOR NOISE IMPACT STUDY",* latest version/edits dated 08/03/2019 (SLR, 2019).

6.2 Equipment Sound Power Levels

The fundamental starting point of any sound pressure level (SPL) prediction is the sound power level (SWL – see **Section 2.4**) of significant noise sources. The assumed SWL for the construction and operational phases of the Project are discussed below.

6.2.1 Construction of CPF

The construction of the CPF will initially involve site preparation and significant bulk earthworks to get the CPF (including construction area, roads and piperacks to vents and flares) to the required grade. These works are estimated to take approximately two years and 9 months involving significant noise producing activities such as:

- Vegetation clearance and timber removal, using chainsaws and bulldozers.
- Topsoil removal using bulldozers and scrapers.
- Bulk earthworks and platform construction using front-end loaders, excavators, backhoes, graders, rollers, dump trucks and water carts. Development of quarries (possibly offsite),

The CPF would then be constructed using a modular execution strategy (with some items remaining as stick built). The main civil works are envisaged to involve:

- Installation and operation of concrete and asphalt batching plants.
- Installation of foundation structures and paved areas within the CPF site using pile drivers, heavy rollers, dump trucks, concrete trucks, generators, and steel reinforcement fabrication hand tools such as grinders, welders.
- Installation of on-site roads using equipment such as rollers, dump trucks and asphalt-laying equipment.

During the course of construction, many of these activities would occur simultaneously and at varying levels of intensity. Therefore, it is difficult to accurately predict construction noise emissions throughout the entire construction period. To facilitate the noise modeling, two typical worst-case scenarios have been developed based around the initial site preparation / bulk earthworks, and ensuing civil / construction works.

The predicted noise level in the model is based on the assumption that all equipment for a given scenario is operating simultaneously and at full load. The reality of construction activities using a fleet of mobile equipment is that the intermittent nature of operations and reduced duty cycles of equipment leads to typical overall site noise emissions being approximately 3 to 8 dBA below that predicted. A conservative 'de-rating' factor of 3 dBA has been applied to the various construction noise modeling results.

As per the earthworks management plan (EGIS, 2018), the site preparation and bulk earthworks scenario assumes that topsoil removal and earthworks occur simultaneously (i.e., based around 6x30-T excavators and 2x80-T excavators with screening plant). This scenario conservatively assumed the initial site elevation for which the surrounding landform will provide less shielding (relative to the final pad heights).

The civil works scenario has been modeled based on the final pad heights of the CPF.

The overall type and number of plant and equipment for the two scenarios considered is provided in **Table 11.**

Table 11 CPF Main Construction Scenarios and Plant SWL

Scenario	Plant	Number of Items	SWL, dBA (per unit)
Site Preparation and Bulk Earthworks	Chainsaw (petrol)	3	121
	Woodchipper	1	120
	80-T excavator (breaking out & loading)	2	115
	30-T excavator (general excavation/trenching)	6	108
	Screen	2	115
	Loader (loading lorry)	2	117
	Backhoe (clearing site)	1	96
	Grader	2	115
	Roller	3	105
	Dump trucks (B50 or A30)	8	107
	Water carts	1	104
	Bulldozer (crawler mounted dozer 35 t)	4	111
	General 4WD vehicles	5	96
	Total for Scenario	**40**	**129**
Civil and Construction Works	Vibratory roller	2	105
	Dump trucks (B50 or A30)	2	107
	Concrete batch plant	1	111
	Concrete mixer truck	3	108
	Concrete pump and vibrator	2	107
	Pile driver (percussive)	2	122
	Crane	2	98
	Hand tools (inc. circular saw & welder)	7	101
	Hand held pneumatic breakers	3	110
	Air compressor	2	103
	Grinder	8	109
	General 4WD vehicles	5	96
	Total for Scenario	**39**	**127**

6.2.2 Export Pipeline Construction at Orokolo Bay Coastline

It is understood that the pipeline construction activities will likely include:

- ROW clearing – removal of vegetation using chainsaws, wood chippers, and dozers.
- Civil/ROW preparation – site levelling using graders, excavators and bulldozers.
- Pipe stringing and bending – from the pipe yards, pipes will be loaded onto pipe trucks to be delivered on the ROW. Three bending machines will be required for the different diameters.

- Mainline welding – welding of continuous strings, consisting of two automatic welding crews.
- Trenching – likely to consist of standard excavators, with swamp backhoes for swamp sections.
- Lowering in – Caterpillar 594 and 583 sidebooms or equivalent shall be mobilized to lower the 40" export gas line. For the smaller diameter pipes the same (but fewer) machinery will be used.
- Backfilling – As dug materials to be used for superior backfill on all sections. Standard excavators or swamp backhoes to be used (as per the trenching works).

Construction will be undertaken in teams on a rolling basis along the selected export pipeline route. It is anticipated that the vegetation clearing will have a duration of 11 months followed by 9 months of ROW preparation and pipeline installation. It is therefore estimated that each ROW will be open for approximately 9 to 11 months, i.e., the time between topsoil clearing and re-spreading. The onshore export pipeline installation will involve one pipeline spread.

Of the stages outlined above, the loudest activities are likely to be those associated with the earthworks required for the site preparation, trenching, clearing and backfilling. To assess the effects of these activities a noise model has been used to predict the noise levels in the area surrounding the construction site when work is taking place.

Based on the relative pipe length it was estimated that in total up to 197 heavy vehicles (including some 98 graders, and 22 excavators) would be required to construct the pipeline ROW (SLR, 2019). This maximum number was divided by a factor of three to come up with the plant provided in **Table 12** which was distributed over a 40 m wide work front approximately 2 km along the ROW at the Orokolo Bay coastline (i.e., approximately 60 heavy vehicles, or roughly one heavy vehicle every 30 m).

Table 12 Export Pipeline ROW Construction Scenario at Orokolo Bay Coastline and Plant SWL

Scenario	Plant	Number of Items	SWL, dBA (per unit)
Export Pipeline ROW General Earthworks	Dozer	3	111
	30-T excavator	7	108
	Dump truck	5	107
	Graders	33	107
	Tractors	3	105
	Truck for pipe transport	5	104
	Cranes	1	98
	Side booms	5	110
	General 4x4 Vehicles	15	98
	Total for Scenario	**77**	**125**

6.2.3 Operational CPF

The operational gas plant was modeled with a worst-case scenario set 10 years after first gas (i.e., when the additional five medium pressure (MP) compressors come online to achieve deeper depletion of the Antelope reservoir). These compressors have been based on the Solar Titan 250 gas turbine compressor.

The modeling of emergency/upset plant conditions includes emergency flaring at the 104 m high tower located approximately 400 m northeast of the main plant.

The most significant noise producing equipment at the CPF will be:

- Titan 250 gas turbines (3x off 22.27 MW).
- Acid gas (AG) compressor (1x off 14.1 MW).
- C3 propane gas compressors (2x off 2.4 MW).
- MP compressors (assume Titan 250 gas turbine compressor set – 5x off 22.27 MW).
- Elevated low pressure/high pressure flare (1x off – for startup/maintenance/emergency and upset conditions at 60 MMSCFD except purge and pilot gases).

Other noise sources include fin fans, mono-ethylene glycol (MEG) injection pump/regeneration plant, pilot flare (for normal conditions), propane loop condenser and chiller, liquid and water transfer pumps, pipeline and booster compressor inter-stage and aftercoolers and inlet coolers.

For the gas turbines, SWL data was sourced from available manufacturer data with adjustments based on the ratio of the power output. The calculations assume each gas turbine will be installed in an enclosed package with low performance silencing on both the inlet and exhaust.

Acoustic insulation (Class C) has been assumed for the compressor suction and discharge piping consisting of a porous layer 50 mm thick with 0.8 mm thick aluminized steel jacketing (7 kg/m^2) and a second porous layer 50 mm thick with 1.3 mm aluminized steel jacketing (11.3 kg/m^2).

No inline silencers have been allowed for on the compressor suction or discharge lines. It is noted that even without in-line silencers, there would be some noise attenuation on the suction side provided by the first upstream vessel, and noise attenuation on the discharge side by the first downstream vessel.

Compressors have no acoustic enclosures with the overall SWL determined based on the duty/power rating from *Engineering Noise Control* (Bies & Hansen, 2017). Similar assumptions have been made to determine the noise output for the pumps, condensers, boilers and chillers.

Where SWL data was not available, information was sourced from reference literature, manufacturer data, or available measurements of similar plant and equipment.

Table 13 provides details regarding the number, location, capacity/duty, and assumed sound power level (SWL) for each item of plant considered in the operational noise model.

Figure 10 shows the general layout of the facility along with the location of major plant items.

Table 13 Operational Plant Considered in Noise Model

Description	Equipment Tag	Designation Capacity per Equipment %	No. of Items	Duty/Driver Installed Power	Sound Power Level (SWL) dBA
Titan 250 power gas turbines (PGT)	30-DT-6001A/B/C/D	33%	3 + 1 standby	21,745 kW	107[A]/ 121[B]/115[C]
C3 propane gas compressor	30-KA-7601 A/B	100%	2	2,411 kW	111
Acid gas compressor (electrically driven NO Titan 250 PGT)	30-KA-3101	100%	1	14,107 kW/ 4x stages	118
Compressor suction and discharge piping	Various	100%	1	N/A	122[D]
Acid gas compressor air coolers	30-EA-3101 to 30-EA-3104	100%	4	N/A	106
Fin fans	Various	100%	Multiple	Various	109
Thermal oxidizer	30-HF-3601	100%	1	45,000	106
Flare	30-HF-3600	100%	1	N/A	102/140[E]
Lean amine HP pumps	30-PA-3202 A/B/C	50%	2 + 1 standby	2,963 kW	105
Condensate export pump	30-PA-2501 A/B/C	50%	2 + 1 standby	140 kW/ 112 sm^3/h	102
Hot water circulation pump	30-PA-7200 A/B/C	50%	2 + 1 standby	396 kW	102
Heating medium boiler	30-HB-7201 A/B/C	50%	2 + 1 standby	40,000 kW	107
Propane loop condenser	30-EA-7602	100%	1	292 kW	100
Propane chiller	30-ES-3203	100%	1	7,200 kW	112
MP compressors Y10+ Assume Titan 250 Gas turbine compressor set (gas turbine driver)	30-ES-3203	20%	5 + 1 standby	Assume 21,745 kW as per air quality modeling	107[A]/ 121[B]/115[C]
MP compressors Y10+ Assume Titan 250 gas turbine compressor set (driven compressor)	30-ES-3203	20%	5 + 1 standby	Assume 21,745 kW as per air quality modeling	120
MEG regeneration package	30-UG-7501	100%	1	2 m^3/h	103

Note A: Casing of enclosed gas turbine package.

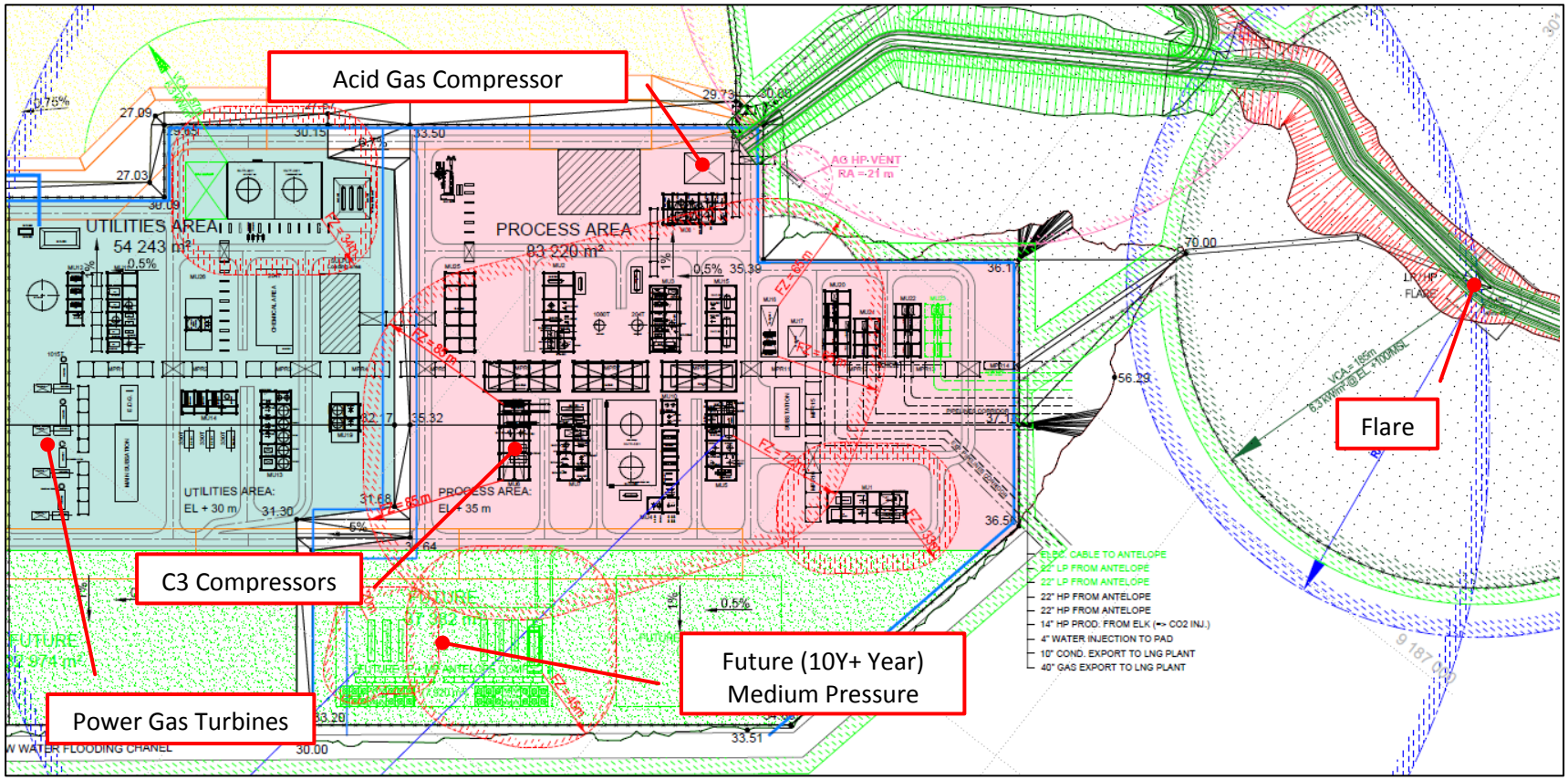
Note B: Inlet (assume inlet silencer equivalent to 16.A.2 Saturn, Centaur, Taurus 60).

Note C: Exhaust (assume exhaust silencer equivalent to 16.A.2 Saturn).

Note D: Acoustic insulation (Class C) for the compressor suction and discharge piping with no inline silencers.

Note E: Pilot flare (normal operations) modeled as 102 dBA. For upset conditions/emergency flaring 140 dBA as per VDI 373, and SLR reference measurements.

Figure 10 Proposed Papua LNG Central Processing Facility Layout



7 Modeling Results

Noise modeling has been used to predict the noise level at sensitive receptors. Noise levels have then been compared against the nominated assessment criteria provided in **Section 4.5**. It is understood that the majority of the construction works will be restricted to occur during the 'day' period for safety reasons. As the CPF will operate on a 24/7 basis, the results have been assessed against the more onerous 'night' time noise criteria for operational noise.

7.1 Construction Noise

7.1.1 Construction of CPF

Table 14 shows the predicted $L_{eq(1h)}$ noise levels from the construction of the CPF for 'neutral' and 'enhanced' meteorologically-enhanced propagation conditions as described in **Section 5.2.2**.

Noise contour plots under both neutral and enhanced propagation conditions are provided in **Appendix A.**

Table 14 Predicted Noise from Construction of CPF, dBA, $L_{eq(1h)}$

Receptor	Site Preparation / Bulk Earthworks		Civil Works		Nominated Construction Noise Goals (Long-term / Short-term)
	Neutral Propagation	Enhanced Propagation	Neutral Propagation	Enhanced Propagation	
Poroi 1	20	28	15	23	**55 / 75**
Mapaio Fish Camp	15	21	8	16	**55 / 75**
Purari Airstrip House	23	30	18	27	**55 / 75**

The modeling results indicate a significant margin of compliance with the conservatively nominated long-term daytime noise target of 55 dBA, $L_{eq(1h)}$, as well as with the short-term Highly Noise Affected (HNA) target of 75 dBA, $L_{eq(1h)}$, under both neutral and enhanced propagation conditions.

7.1.2 Construction of Pipeline at Orokolo Bay Coastline

Table 15 shows the predicted $L_{eq(1h)}$ noise levels from the construction of the export pipeline at the Orokolo Bay coastline region for both 'neutral' and 'enhanced' propagation conditions. The results are shown graphically as a noise contour plot in **Appendix B.**

Table 15 Predicted Noise from Construction of Export Pipeline at Orokolo Bay Coastline, dBA, $L_{eq(1h)}$

Receptor	Site Preparation / Bulk Earthworks		Nominated Construction Noise Goals (Long-term / Short-term)
	Neutral Propagation	Enhanced Propagation	
Iuku	44	48	**55 / 75**
Iuku East	47	50	**55 / 75**
Mareke	43	48	**55 / 75**
Mareke West	53	57	**55 / 75**

Note: When the predicted noise level exceeds the long-term operational noise target of 55 dBA, $L_{eq(1h)}$, the cell is marked with an ORANGE shading.

The predicted construction noise levels at sensitive receptors surrounding the pipeline alignment were predominantly below the long-term operational noise target of 55 dBA, $L_{eq(1h)}$ under both neutral and enhanced meteorological conditions.

At Mareke West located approximately 250 m east of the export pipeline ROW, there are three isolated properties where noise levels are predicted to just exceed the long-term noise target by up to 2 dBA (i.e., 57 dBA, $L_{eq(1h)}$) under enhanced (i.e., worst case) propagation conditions. Under normal propagation conditions the predicted noise levels comply at all receptor locations (see **Table 15** and **Appendix B**).

The predicted noise levels are also well below that likely to result in a significant reaction to construction noise, such as the 75 dBA, $L_{eq(1h)}$ Highly Noise Affected (HNA) target nominated in **Section 4.2.2** for which specific noise management/mitigation measures should be considered.

The maximum noise level at Mareke West (from short-term tree felling/chainsaw works with a SWL of 121 dBA at the closest point approximately 250 m from the property) was predicted to be 62 dBA. This would comply with the short-term 75 dBA noise target.

7.2 Operational Noise from CPF

The predicted noise levels from the operational CPF are presented in **Table 16** for both 'neutral' and 'enhanced'/meteorologically-enhanced propagation conditions.

Noise contour plots are also presented in:

- **Appendix C** shows the region extending to the closest villages to the CPF.
- **Appendix D** illustrates the area surrounding the CPF facility boundary to a higher level of detail.

Table 16 Predicted Noise from Operational CPF, dBA, $L_{eq(1h)}$

Receptor	Normal Operations		Upset Conditions / Emergency Flare		Project Noise Criteria (Day / Night)
	Neutral Propagation	Enhanced Propagation	Neutral Propagation	Enhanced Propagation	
Poroi 1	27	32	38	40	**55 / 45**
Mapaio Fish Camp	22	26	29	33	**55 / 44**
Purari Airstrip House House	29	34	38	41	**55 / 45**

The steep terrain to the southeast of the CPF provides significant acoustic shielding, which can be seen in the non-uniform nature of the noise contours (see **Appendix C** and **D**) and the sometimes significant range of predicted noise levels for each receptor region, as shown in **Table 16.**

The predicted noise from the operational CPF complies with applicable noise criteria (both night-time and day-time criteria, of 45 and 55 dBA respectively) at all surrounding off-site receptors under both normal operating conditions and upset conditions (i.e., with emergency flaring).

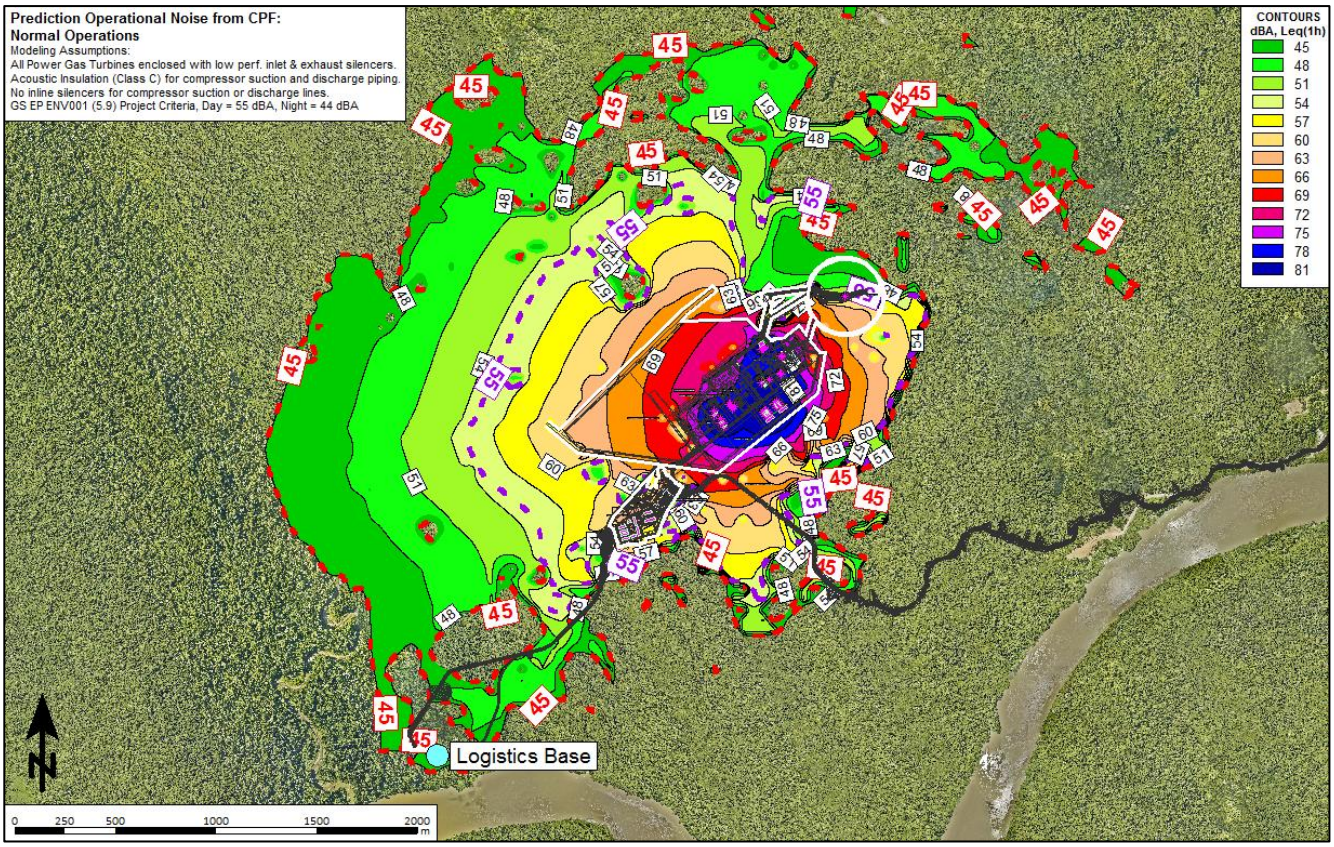
The loudest noise levels were predicted at Poroi 1 Village and Purari Airstrip house, with results during normal operations typically between 27 dBA and 34 dBA, L_{eq} which is well below the pre-existing night time background noise levels (42 dBA, L_{90} and 47 dBA, L_{90}) measured during the baseline noise survey.

Under emergency flaring, the predicted noise level at Poroi 1 Village and Purari Airstrip house increased to a maximum of 40 dBA and 41 dBA, L_{eq} respectively during enhanced propagation conditions. For these emergency conditions the predicted noise levels still comply with the night-time and day-time criteria of 45 dBA and 55 dBA respectively, with plant noise levels quieter than the existing L_{90} background noise levels.

Figure 11 shows the predicted noise emissions from the operational CPF under enhanced propagation conditions relative to the CPF facility boundary area (shown as a white line around the plant area which is based on the vegetation clearance zone).

The predicted maximum off-site noise levels at the southeast boundary near the MP compressors are as high as 81 dBA, L_{eq}, with results on the western and southwestern boundary ranging from approximately 60 dBA to 69 dBA, L_{eq}. Consequently, if the vegetation clearance area were adopted as the CPF perimeter fence, the resultant boundary noise emissions would exceed the nominated night time noise target by approximately 15 dBA to 37 dBA.

Figure 11 Predicted Operational noise from the CPF (under Enhanced Propagation Conditions)



With regard to the OH&S noise exposure requirements discussed in **Section 4.2**, from **Appendix D** it can be seen that there are regions exceeding 85 dBA, L_{eq} predominantly located around the power gas turbines, acid gas compressor, propane compressor, and medium pressure compressors.

During emergency/start-up flaring, noise levels are predicted to exceed 85 dBA, L_{eq} for a radius of approximately 150 m around the flare. However, it is noted that this area will likely be nominated as a restricted clearance zone due to the high temperatures associated with the flare.

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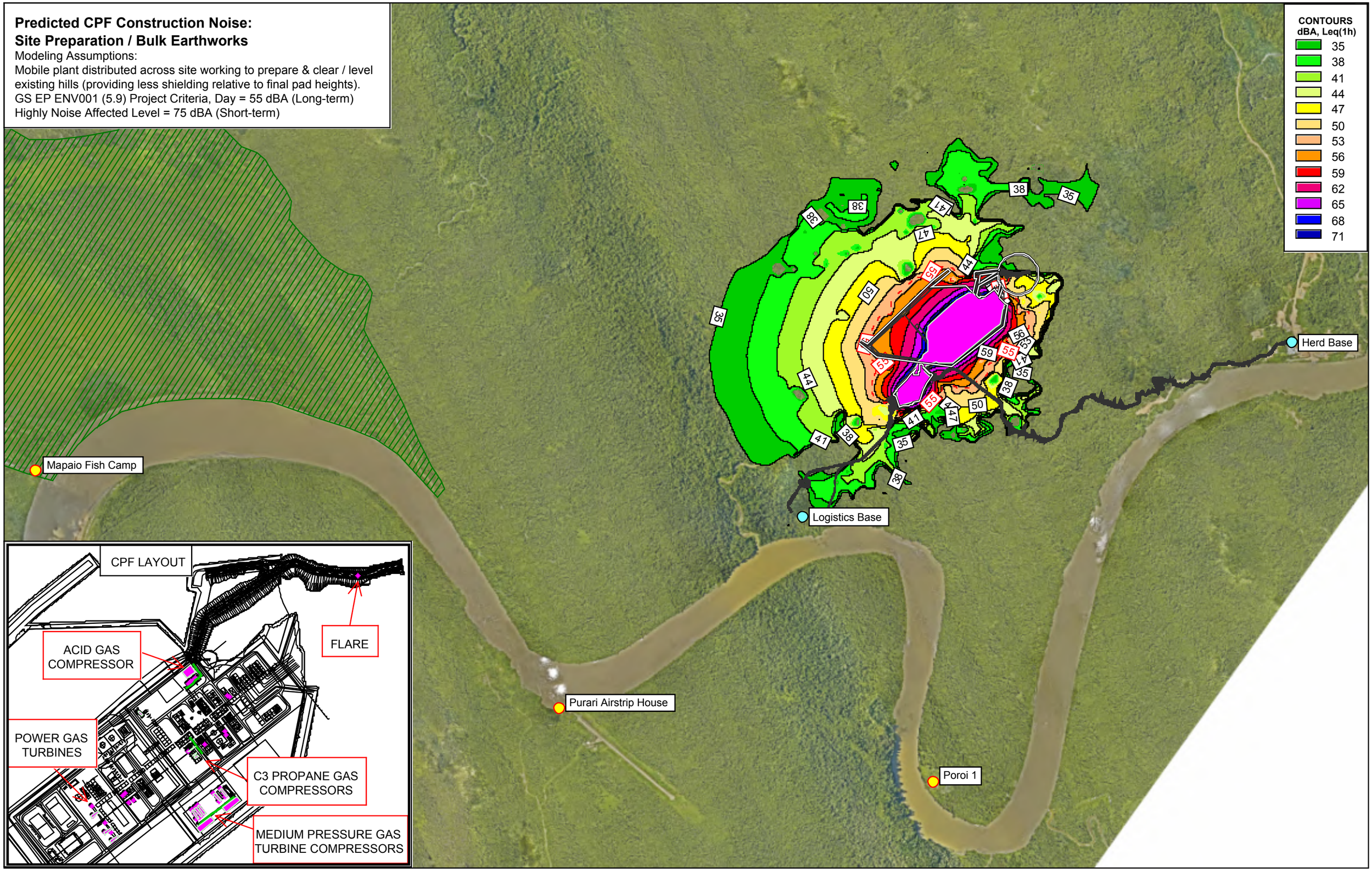
APPENDIX A

Noise Contour Plots – Construction of CPF

Predicted CPF Construction Noise:
Site Preparation / Bulk Earthworks

Modeling Assumptions:
Mobile plant distributed across site working to prepare & clear / level existing hills (providing less shielding relative to final pad heights).
GS EP ENV001 (5.9) Project Criteria, Day = 55 dBA (Long-term)
Highly Noise Affected Level = 75 dBA (Short-term)



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SCALE
0 250 500 1000 1500 2000 m

ORIENTATION
N

LEGEND
- Point source
- Line source
- Area source
- CPF Site
- CPF Facility Boundary
- Oxbow Wetlands
- Village Receiver
- Site / Ref. Bdry. Receiver
- 55 dBA Noise Contour

PROJECT	Papua LNG Project
CLIENT	TOTAL
DESCRIPTION	Predicted CPF Construction Noise - Site Prep / Bulk Earthworks Neutral (calm) Propagation Conditions

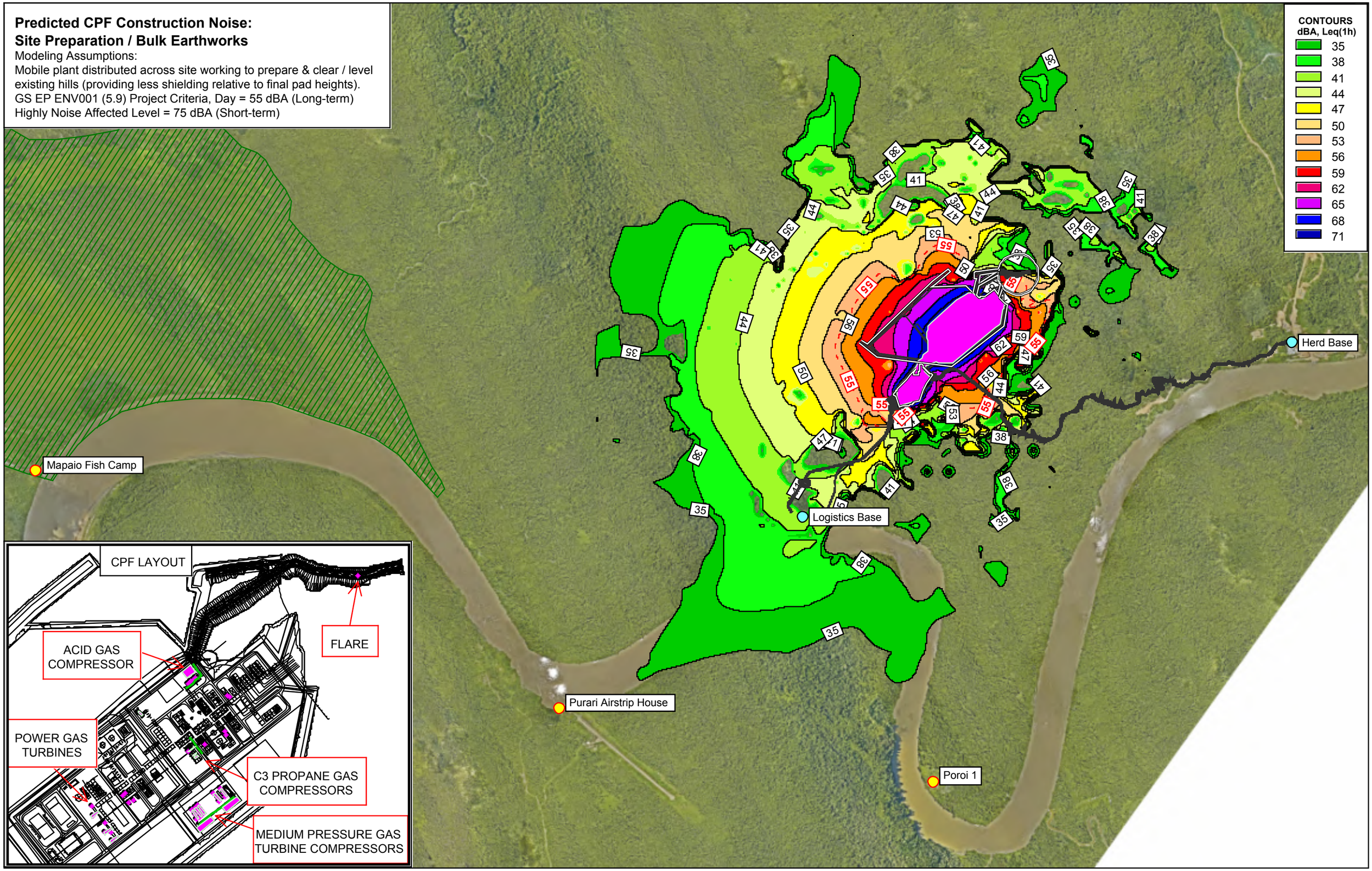
Date: 23-Jul-19
Project No.: 640.11227.00100
Report No.: 640.11227.00100-R1
Prediction Method: CONCAWE Cat 4
Prepared By: IF
Prediction Height:2.0 m

APPENDIX
A

MAP NO.
001

Predicted CPF Construction Noise:
Site Preparation / Bulk Earthworks

Modeling Assumptions:
Mobile plant distributed across site working to prepare & clear / level existing hills (providing less shielding relative to final pad heights).
GS EP ENV001 (5.9) Project Criteria, Day = 55 dBA (Long-term)
Highly Noise Affected Level = 75 dBA (Short-term)



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SCALE
0 250 500 1000 1500 2000 m

ORIENTATION
N

LEGEND
- Point source
- Line source
- Area source
- CPF Site
- CPF Facility Boundary
- Oxbow Wetlands
- Village Receiver
- Site / Ref. Bdry. Receiver
- 55 dBA Noise Contour

PROJECT	Papua LNG Project
CLIENT	TOTAL
DESCRIPTION	Predicted CPF Construction Noise - Site Prep / Bulk Earthworks Adverse (worst case) Propagation Conditions

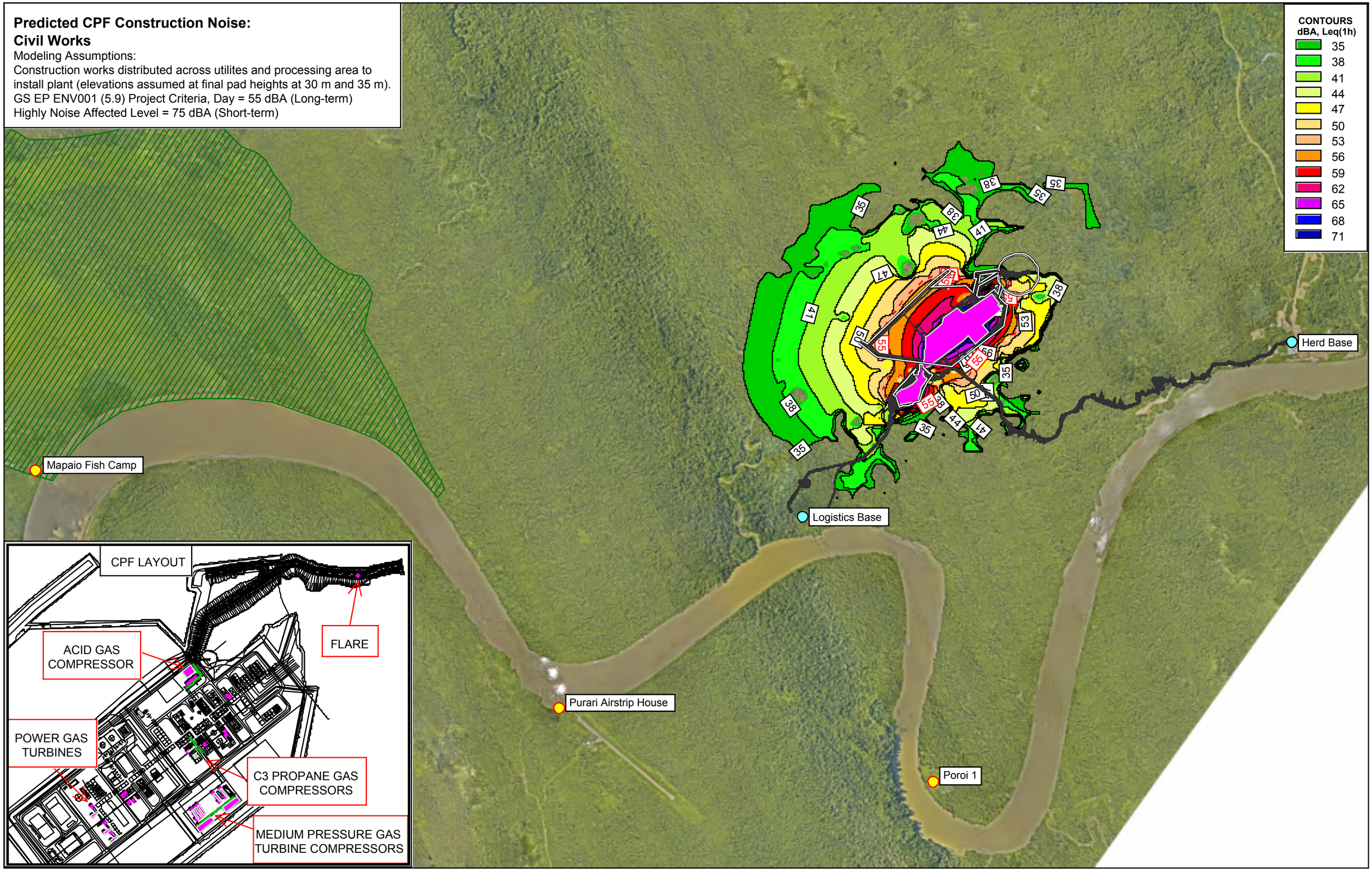
Date: 23-Jul-19	
Project No.: 640.11227.00100	
Report No.: 640.11227.00100-R1	
Prediction Method: CONCAWE Cat 6	
Prepared By: IF	
Prediction Height:2.0 m	

APPENDIX
A

MAP NO.
002

Predicted CPF Construction Noise:
Civil Works

Modeling Assumptions:
Construction works distributed across utilites and processing area to install plant (elevations assumed at final pad heights at 30 m and 35 m).
GS EP ENV001 (5.9) Project Criteria, Day = 55 dBA (Long-term)
Highly Noise Affected Level = 75 dBA (Short-term)



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SCALE
0 250 500 1000 1500 2000 m

ORIENTATION
N

LEGEND
- Point source
- Line source
- Area source
- CPF Site
- CPF Facility Boundary
- Oxbow Wetlands
- Village Receiver
- Site / Ref. Bdry. Receiver
- 55 dBA Noise Contour

PROJECT	Papua LNG Project
CLIENT	TOTAL
DESCRIPTION	Predicted CPF Construction Noise - Civil Works Neutral (calm) Propagation Conditions

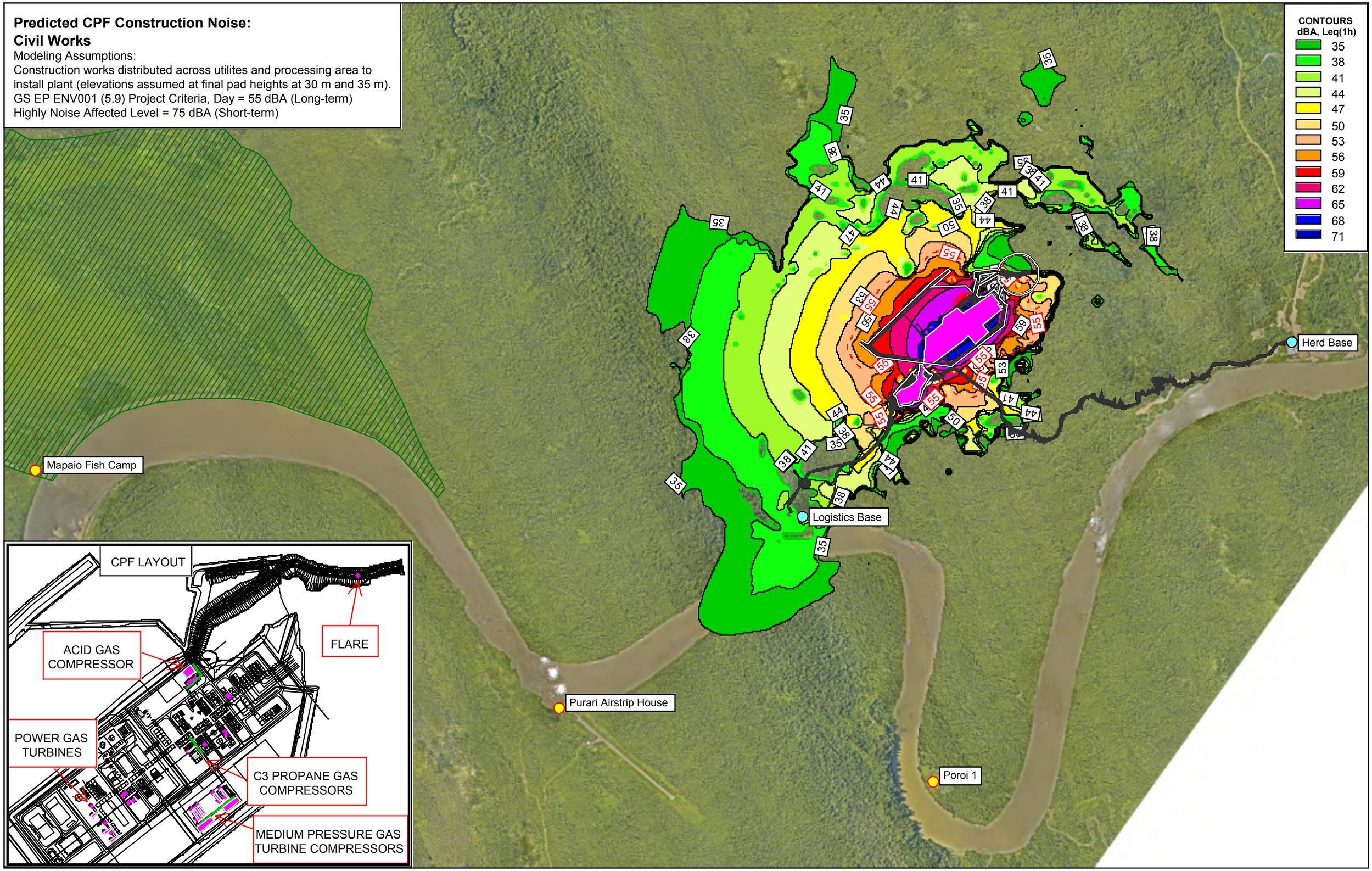
Date: 23-Jul-19
Project No.: 640.11227.00100
Report No.: 640.11227.00100-R1
Prediction Method: CONCAWE Cat 4
Prepared By: IF
Prediction Height:2.0 m

APPENDIX
A

MAP NO.
003

Predicted CPF Construction Noise: Civil Works

Modeling Assumptions:
Construction works distributed across utilites and processing area to install plant (elevations assumed at final pad heights at 30 m and 35 m).
GS EP ENV001 (5.9) Project Criteria, Day = 55 dBA (Long-term)
Highly Noise Affected Level = 75 dBA (Short-term)



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SCALE
0 250 500 1000 1500 2000 m

ORIENTATION
N

LEGEND
- Point source
- Line source
- Area source
- CPF Site
- CPF Facility Boundary
- Oxbow Wetlands
- Village Receiver
- Site / Ref. Bdry. Receiver
- 55 dBA Noise Contour

PROJECT	Papua LNG Project
CLIENT	TOTAL
DESCRIPTION	Predicted CPF Construction Noise - Civil Works Adverse (worst case) Propagation Conditions

Date: 23-Jul-19
Project No.: 640.11227.00100
Report No.: 640.11227.00100-R1
Prediction Method: CONCAWE Cat 6
Prepared By: IF
Prediction Height:2.0 m

APPENDIX
A

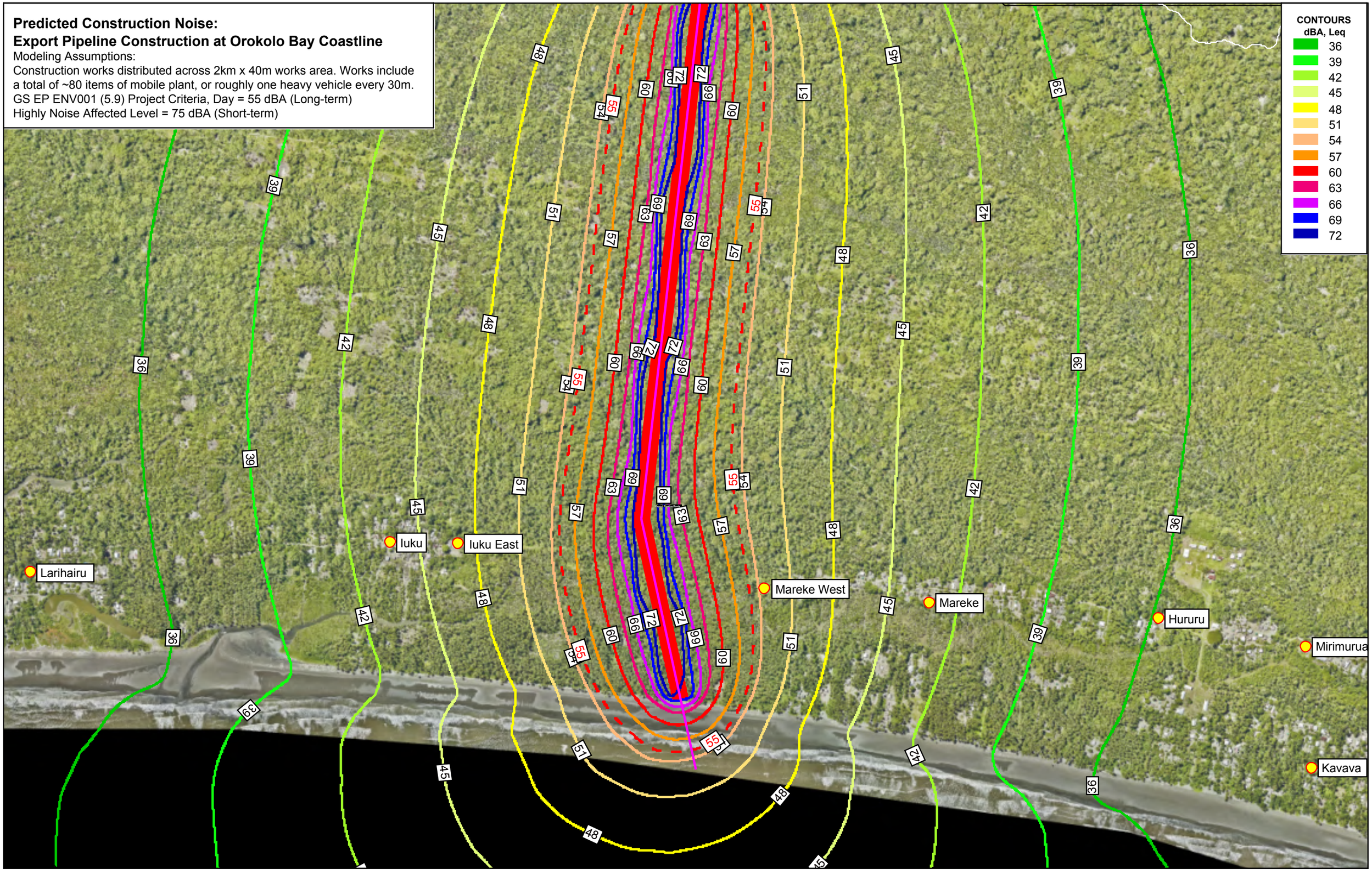
MAP NO.
004

APPENDIX B

Noise Contour Plots – Construction of Pipeline at Orokolo Bay Coastline

Predicted Construction Noise:
Export Pipeline Construction at Orokolo Bay Coastline

Modeling Assumptions:
Construction works distributed across 2km x 40m works area. Works include a total of ~80 items of mobile plant, or roughly one heavy vehicle every 30m.
GS EP ENV001 (5.9) Project Criteria, Day = 55 dBA (Long-term)
Highly Noise Affected Level = 75 dBA (Short-term)



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SCALE
0 45 90 180 270 360 450 540 m

ORIENTATION
N

LEGEND
- Wall
- Emission line
- Pipeline ROW
- Pipeline Construction
- Point receiver
- 55 dBA Noise Contour

PROJECT	Papua LNG Project
CLIENT	TOTAL
DESCRIPTION	Pipeline Construction at Coastline Neutral (calm) Propagation Conditions

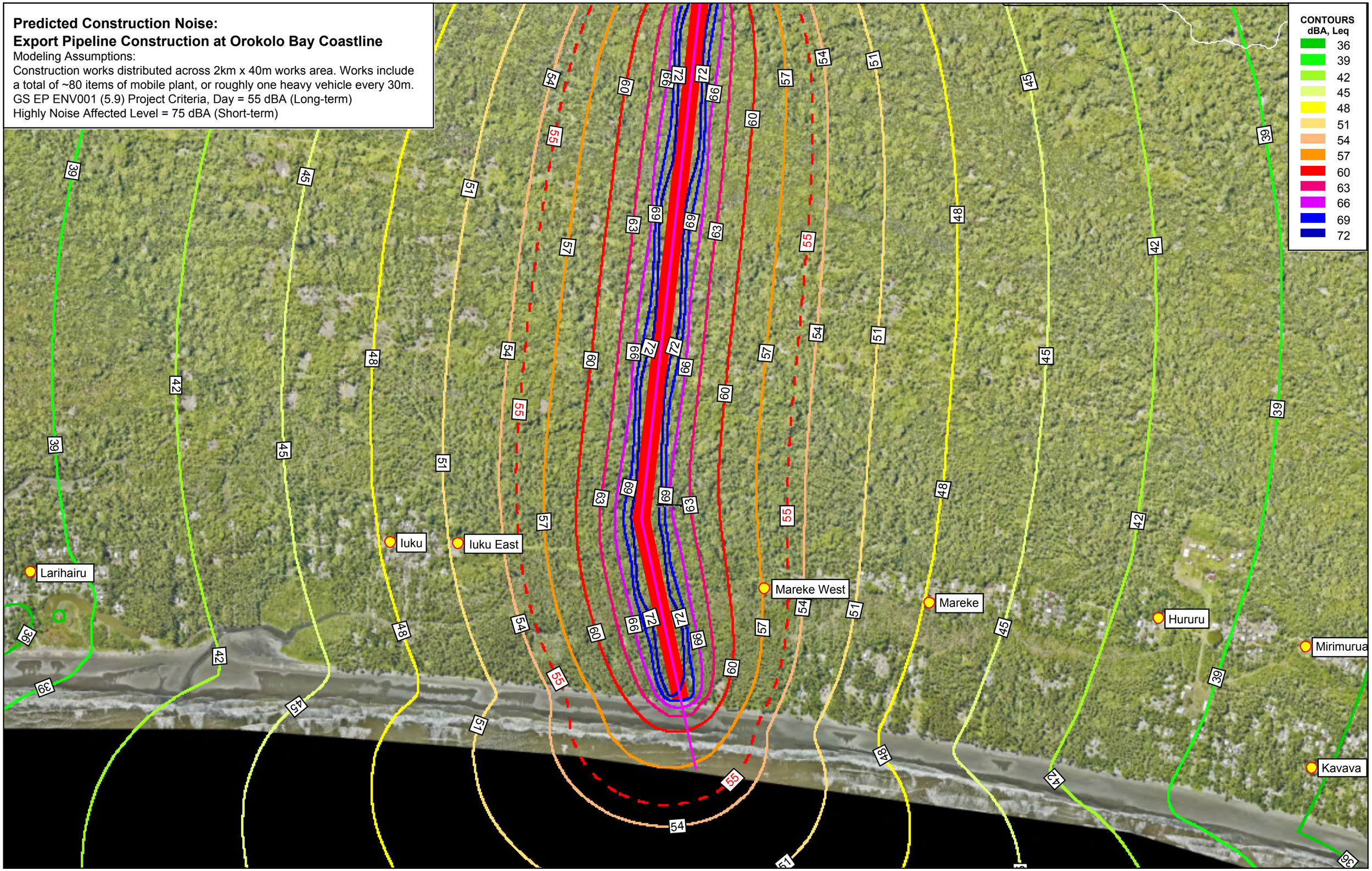
Date: 23-Jul-19
Project No.: 640.11227.00100
Report No.: 640.11227.00100-R1
Prediction Method: CONCAWE Cat4
Prepared By: IF
Prediction Height:2 m

APPENDIX
B

MAP NO.
001

Predicted Construction Noise:
Export Pipeline Construction at Orokolo Bay Coastline

Modeling Assumptions:
Construction works distributed across 2km x 40m works area. Works include a total of ~80 items of mobile plant, or roughly one heavy vehicle every 30m.
GS EP ENV001 (5.9) Project Criteria, Day = 55 dBA (Long-term)
Highly Noise Affected Level = 75 dBA (Short-term)



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SCALE
0 45 90 180 270 360 450 540 m

ORIENTATION
N

LEGEND
- Wall
- Emission line
- Pipeline ROW
- Pipeline Construction
- Point receiver
- 55 dBA Noise Contour

PROJECT	Papua LNG Project
CLIENT	TOTAL
DESCRIPTION	Pipeline Construction at Coastline Adverse (worst case) Propagation Conditions

Date: 23-Jul-19
Project No.: 640.11227.00100
Report No.: 640.11227.00100-R1
Prediction Method: CONCAWE Cat6
Prepared By: IF
Prediction Height:2 m

APPENDIX
B

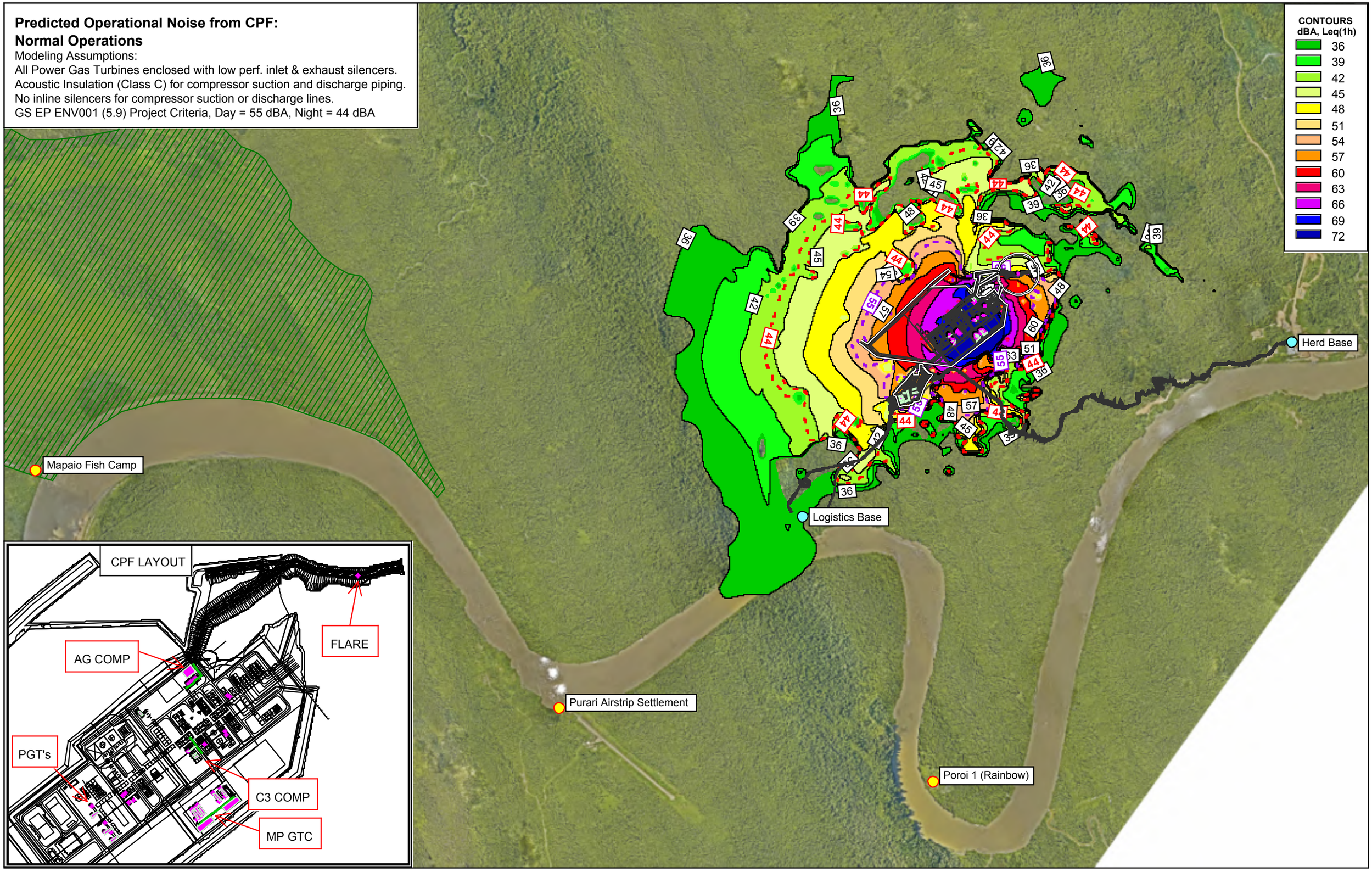
MAP NO.
002

APPENDIX C

Noise Contour Plots - Operational CPF (Normal and Upset Conditions)

Predicted Operational Noise from CPF: Normal Operations

Modeling Assumptions:
All Power Gas Turbines enclosed with low perf. inlet & exhaust silencers.
Acoustic Insulation (Class C) for compressor suction and discharge piping.
No inline silencers for compressor suction or discharge lines.
GS EP ENV001 (5.9) Project Criteria, Day = 55 dBA, Night = 44 dBA



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SCALE
0 250 500 1000 1500 2000 m

ORIENTATION
N

LEGEND
- Point Source
- Line source
- Area source
- CPF Site
- CPF Perimeter Boundary
- Oxbow Wetlands
- Village Receiver
- Site / Ref. Bdry. Receiver
- 44 dBA Night Limit
- 55 dBA Day Limit

PROJECT	Papua LNG Project
CLIENT	TOTAL
DESCRIPTION	Predicted Operational Noise from CPF Neutral (calm) Propagation Conditions

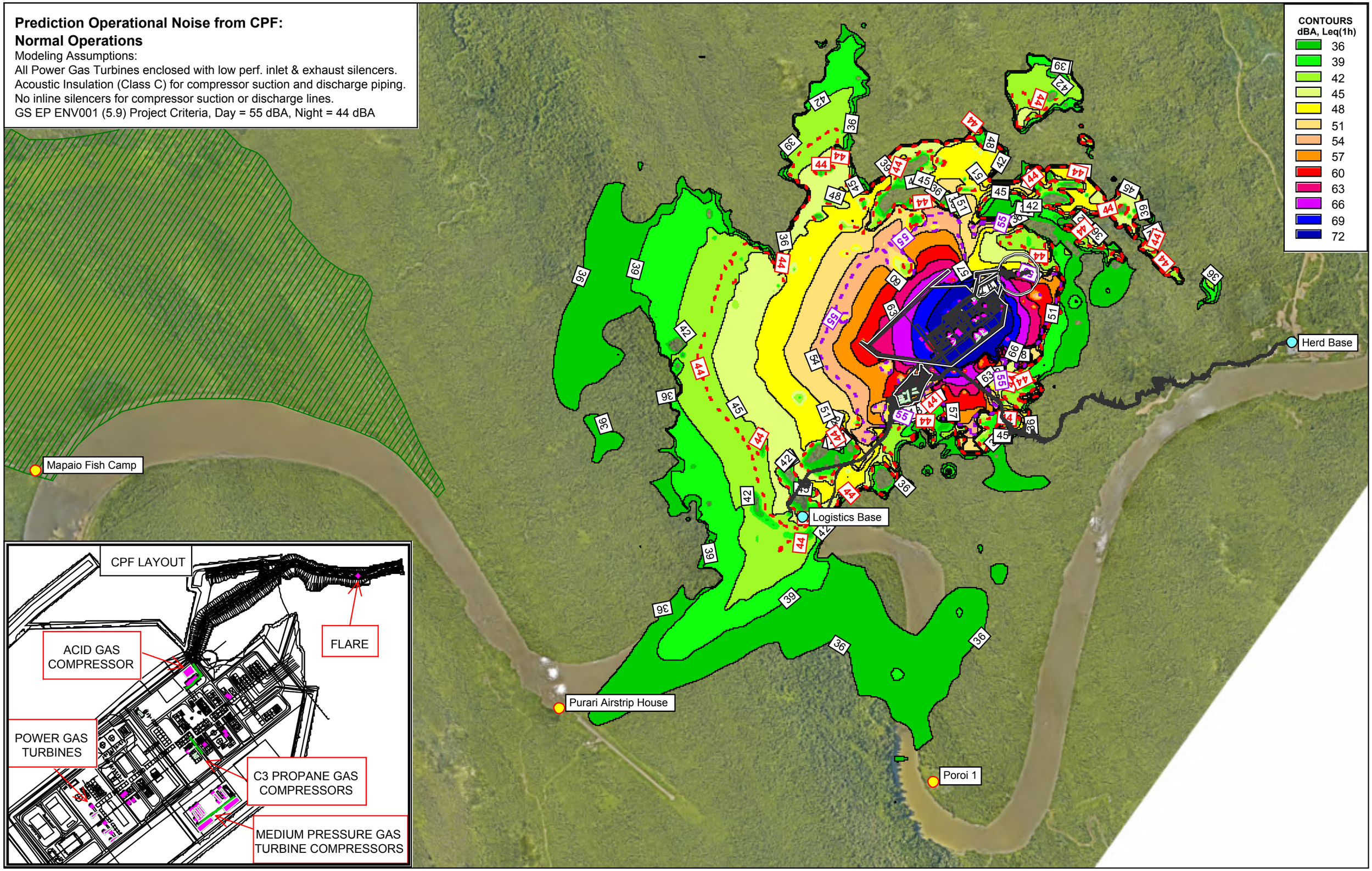
Date: 18-Jun-19
Project No.: 640.11227.00100
Report No.: 640.11227.00100-R1
Prediction Method: CONCAWE Cat 4
Prepared By: IF
Prediction Height:2.0 m

APPENDIX
C

MAP NO.
001

Prediction Operational Noise from CPF:
Normal Operations

Modeling Assumptions:
All Power Gas Turbines enclosed with low perf. inlet & exhaust silencers.
Acoustic Insulation (Class C) for compressor suction and discharge piping.
No inline silencers for compressor suction or discharge lines.
GS EP ENV001 (5.9) Project Criteria, Day = 55 dBA, Night = 44 dBA



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SCALE
0 250 500 1000 1500 2000 m

ORIENTATION
N

LEGEND
- Point Source
- Line source
- Area source
- CPF Site
- CPF Facility Boundary
- Oxbow Wetlands
- Village Receiver
- Site / Ref. Bdry. Receiver
- 44 dBA Night Limit
- 55 dBA Day Limit

PROJECT	Papua LNG Project
CLIENT	TOTAL
DESCRIPTION	Predicted Operational Noise from CPF Adverse (worst case) Propagation Conditions

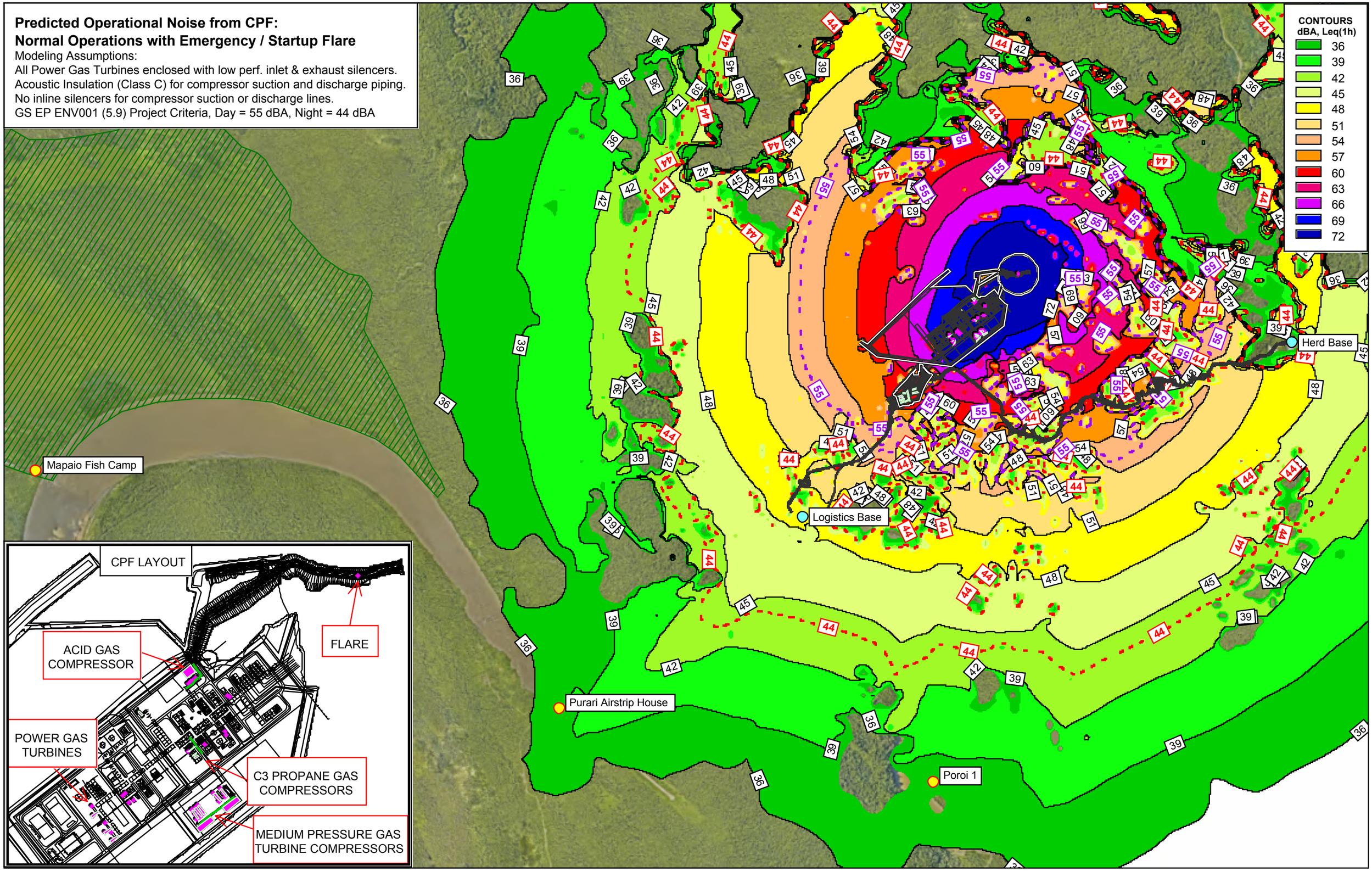
Date: 23-Jul-19
Project No.: 640.11227.00100
Report No.: 640.11227.00100-R1
Prediction Method: CONCAWE Cat 6
Prepared By: IF
Prediction Height:2.0 m

APPENDIX
C

MAP NO.
002

Predicted Operational Noise from CPF:
Normal Operations with Emergency / Startup Flare

Modeling Assumptions:
All Power Gas Turbines enclosed with low perf. inlet & exhaust silencers.
Acoustic Insulation (Class C) for compressor suction and discharge piping.
No inline silencers for compressor suction or discharge lines.
GS EP ENV001 (5.9) Project Criteria, Day = 55 dBA, Night = 44 dBA



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SCALE
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ORIENTATION
N

LEGEND
- Point Source
- Line source
- Area source
- CPF Site
- CPF Facility Boundary
- Oxbow Wetlands
- Village Receiver
- Site / Ref. Bdry. Receiver
- 44 dBA Night Limit
- 55 dBA Day Limit

PROJECT	Papua LNG Project
CLIENT	TOTAL
DESCRIPTION	Predicted Operational Noise from CPF w/ Emergency Flare Neutral (calm) Propagation Conditions

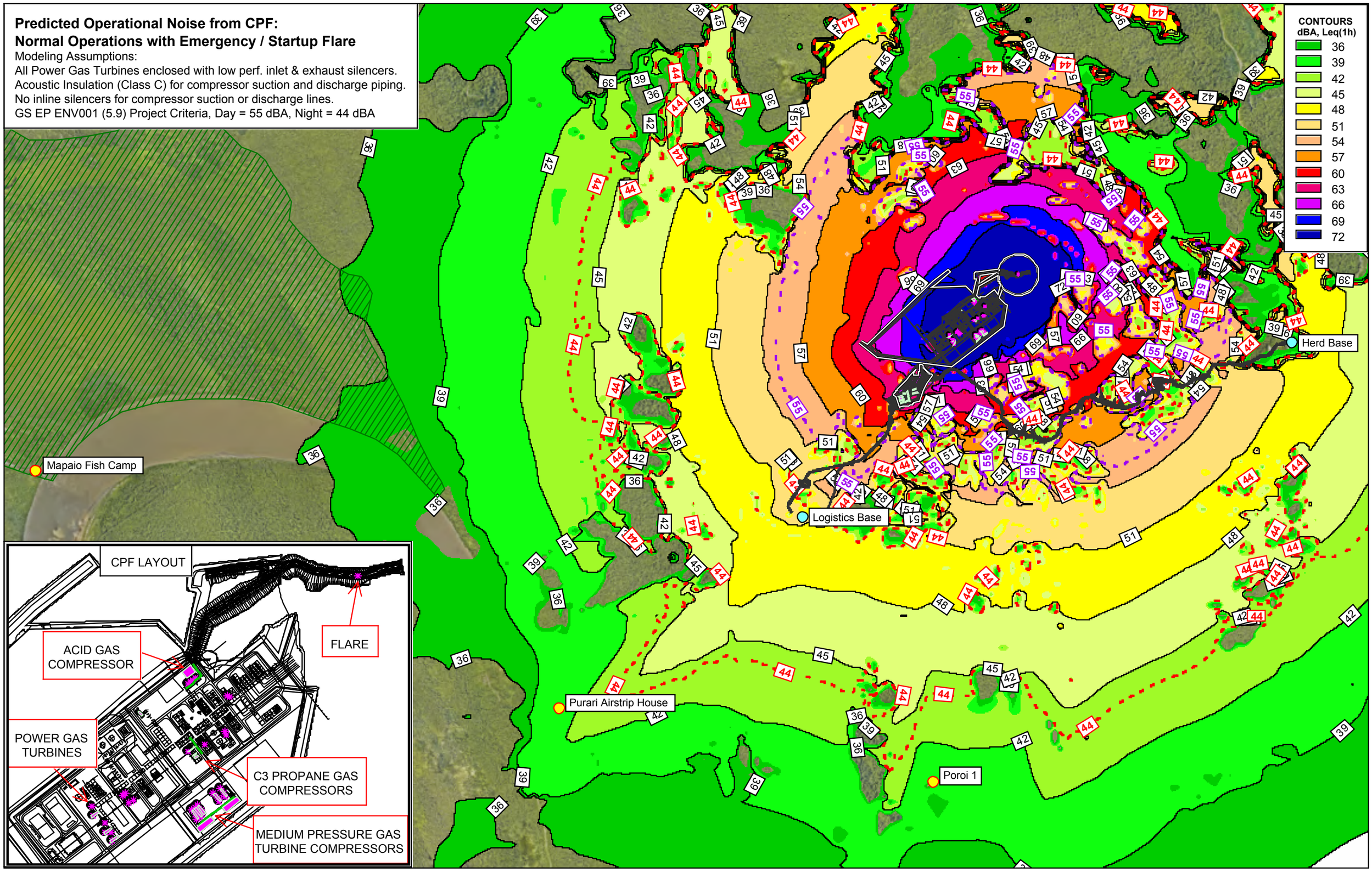
Date: 21-Aug-19
Project No.: 640.11227.00100
Report No.: 640.11227.00100-R1
Prediction Method: CONCAWE Cat 4
Prepared By: IF
Prediction Height:2.0 m

APPENDIX
C

MAP NO.
003

Predicted Operational Noise from CPF:
Normal Operations with Emergency / Startup Flare

Modeling Assumptions:
All Power Gas Turbines enclosed with low perf. inlet & exhaust silencers.
Acoustic Insulation (Class C) for compressor suction and discharge piping.
No inline silencers for compressor suction or discharge lines.
GS EP ENV001 (5.9) Project Criteria, Day = 55 dBA, Night = 44 dBA



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SCALE
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ORIENTATION
N

LEGEND
- Point Source
- Line source
- Area source
- CPF Site
- CPF Facility Boundary
- Oxbow Wetlands
- Village Receiver
- Site / Ref. Bdry. Receiver
- 44 dBA Night Limit
- 55 dBA Day Limit

PROJECT	Papua LNG Project
CLIENT	TOTAL
DESCRIPTION	Predicted Operational Noise from CPF w/ Emergency Flare Adverse (worst case) Propagation Conditions

Date: 23-Jul-19
Project No.: 640.11227.00100
Report No.: 640.11227.00100-R1
Prediction Method: CONCAWE Cat 6
Prepared By: IF
Prediction Height:2.0 m

APPENDIX
C

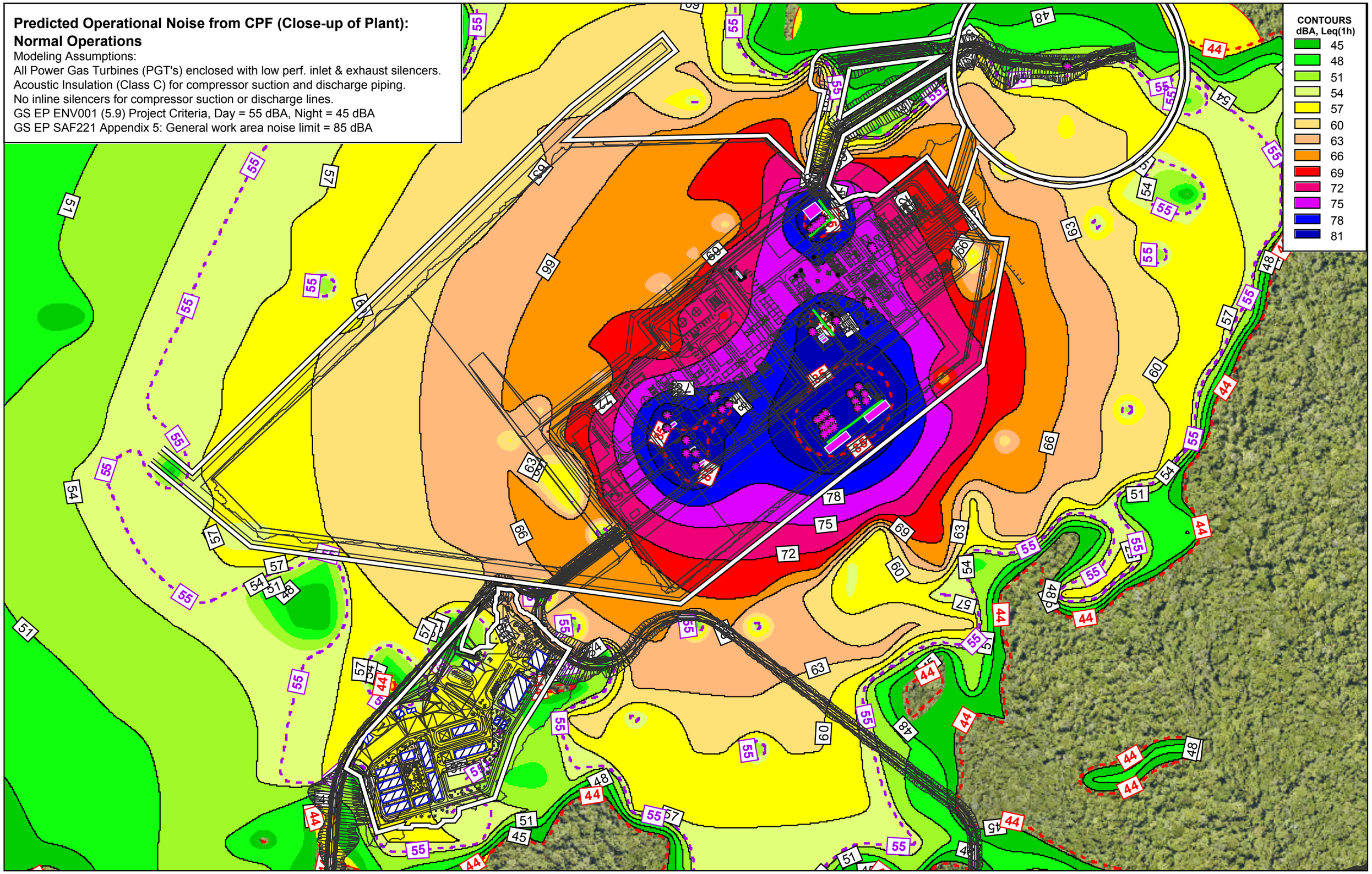
MAP NO.
004

APPENDIX D

Noise Contour Plots - Operational CPF (Close-up View)

Predicted Operational Noise from CPF (Close-up of Plant):
Normal Operations

Modeling Assumptions:
All Power Gas Turbines (PGT's) enclosed with low perf. inlet & exhaust silencers.
Acoustic Insulation (Class C) for compressor suction and discharge piping.
No inline silencers for compressor suction or discharge lines.
GS EP ENV001 (5.9) Project Criteria, Day = 55 dBA, Night = 45 dBA
GS EP SAF221 Appendix 5: General work area noise limit = 85 dBA



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SCALE
0 25 50 100 150 200 250 300 350 m

ORIENTATION
N

LEGEND
- Point source
- Line source
- Area source
- Main building
- CPF Facility Boundary
- CPF Site
- OH&S 85 dBA Noise Contour
- Site / Ref. Bdry. Receiver
- 55 dBA Day Limit (Enviro)
- 44 dBA Night Limit (Enviro)

PROJECT	Papua LNG Project
CLIENT	TOTAL
DESCRIPTION	Predicted Operational Noise from CPF Neutral (calm) Propagation Conditions

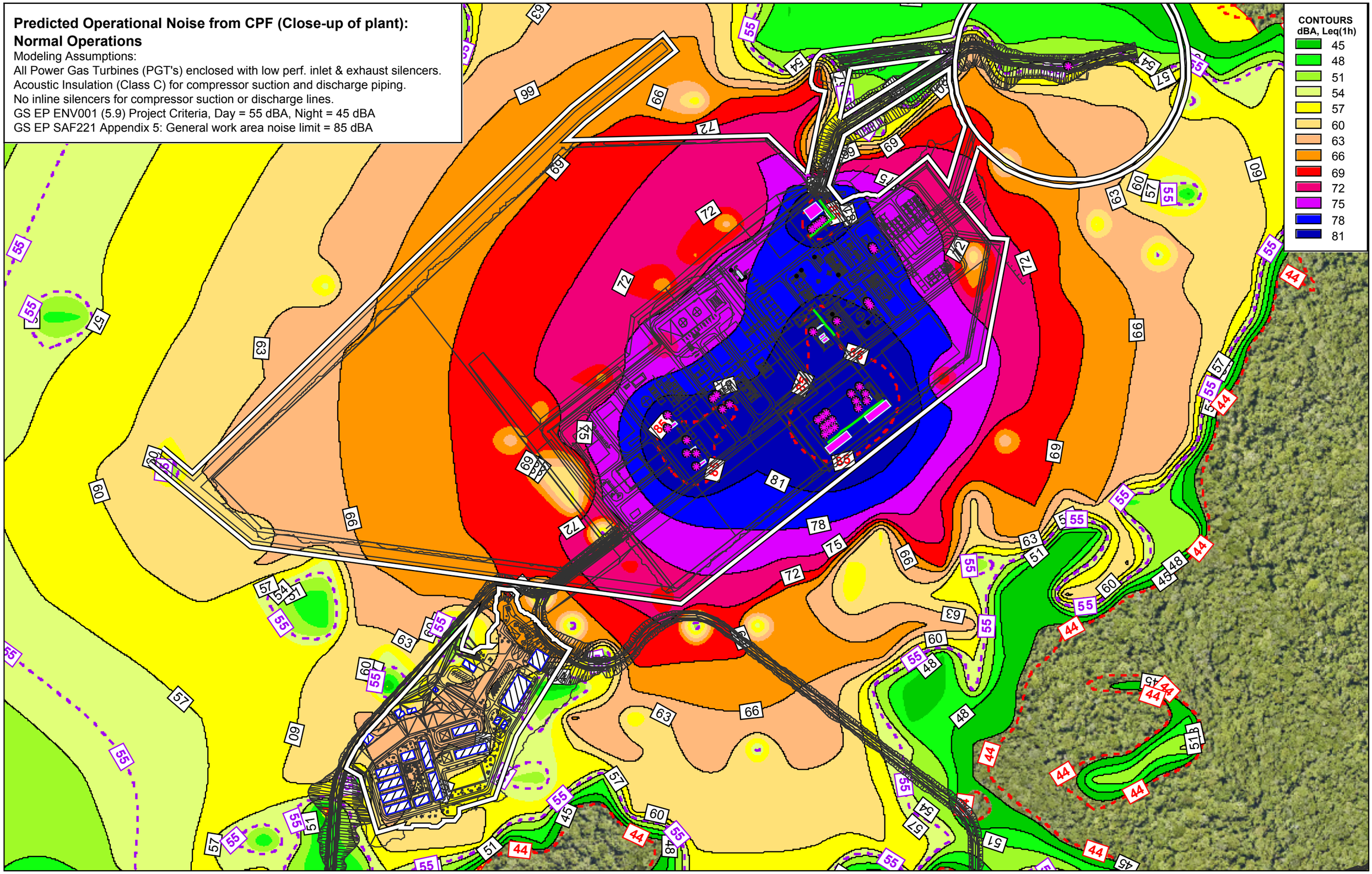
Date: 23-Jul-19
Project No.: 640.11227.00100
Report No.: 640.11227.00100-R1
Prediction Method: CONCAWE Cat 4
Prepared By: IF
Prediction Height:2.0 m

APPENDIX
D

MAP NO.
001

Predicted Operational Noise from CPF (Close-up of plant): Normal Operations

Modeling Assumptions:
All Power Gas Turbines (PGT's) enclosed with low perf. inlet & exhaust silencers.
Acoustic Insulation (Class C) for compressor suction and discharge piping.
No inline silencers for compressor suction or discharge lines.
GS EP ENV001 (5.9) Project Criteria, Day = 55 dBA, Night = 45 dBA
GS EP SAF221 Appendix 5: General work area noise limit = 85 dBA



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SCALE
0 25 50 100 150 200 250 300 350 m

ORIENTATION
N

LEGEND
- Point source
- Line source
- Area source
- Main building
- CPF Facility Boundary
- CPF Site
- OH&S 85 dBA Noise Contour
- Site / Ref. Bdry. Receiver
- 55 dBA Day Limit (Enviro)
- 44 dBA Night Limit (Enviro)

PROJECT	Papua LNG Project
CLIENT	TOTAL
DESCRIPTION	Predicted Operational Noise from CPF Adverse (worst case) Propagation Conditions

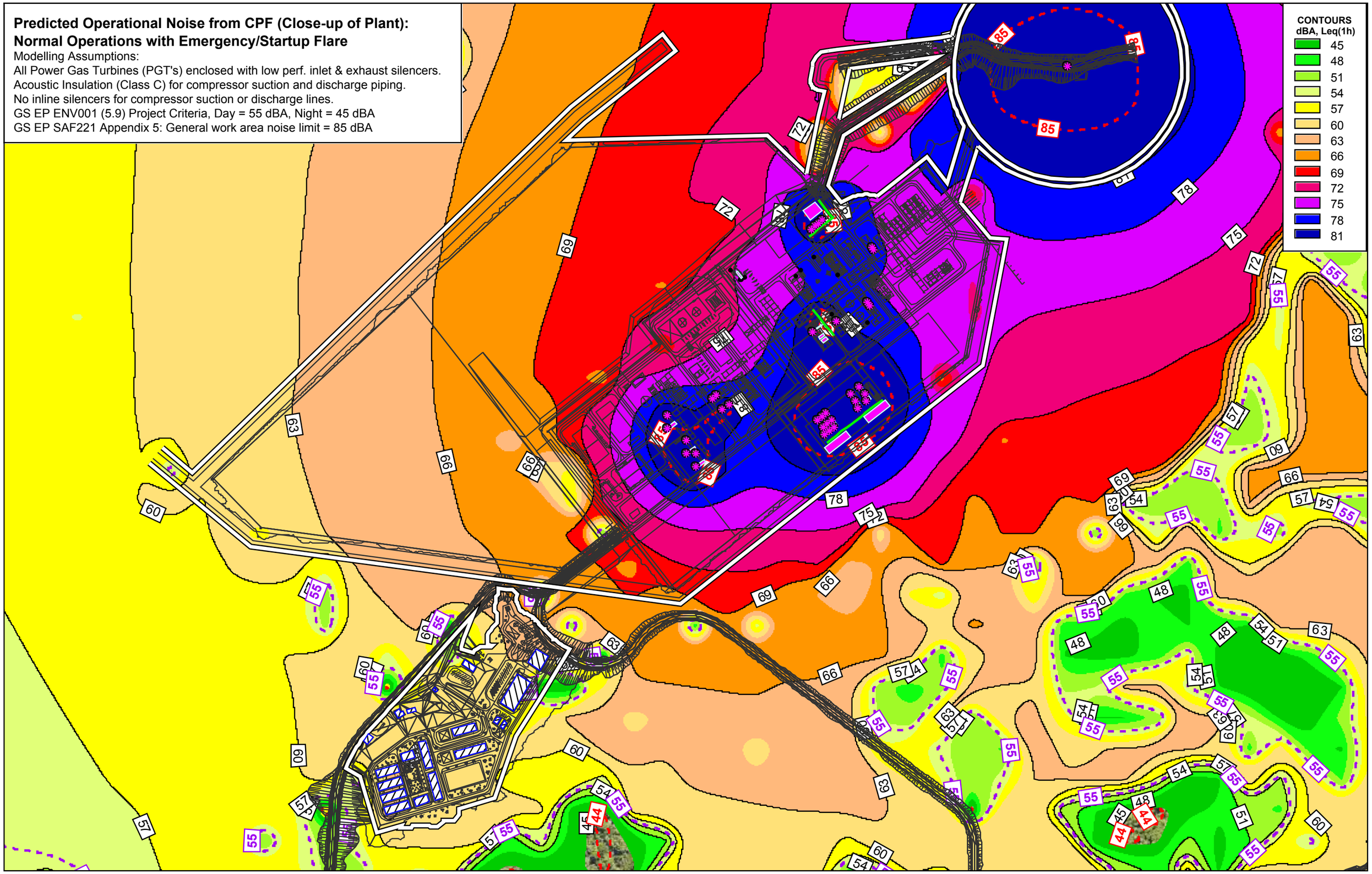
Date: 23-Jul-19
Project No.: 640.11227.00100
Report No.: 640.11227.00100-R1
Prediction Method: CONCAWE Cat 6
Prepared By: IF
Prediction Height:2.0 m

APPENDIX
D

MAP NO.
002

Predicted Operational Noise from CPF (Close-up of Plant):
Normal Operations with Emergency/Startup Flare

Modelling Assumptions:
All Power Gas Turbines (PGT's) enclosed with low perf. inlet & exhaust silencers.
Acoustic Insulation (Class C) for compressor suction and discharge piping.
No inline silencers for compressor suction or discharge lines.
GS EP ENV001 (5.9) Project Criteria, Day = 55 dBA, Night = 45 dBA
GS EP SAF221 Appendix 5: General work area noise limit = 85 dBA



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SCALE
0 25 50 100 150 200 250 300 350 m

ORIENTATION
N

LEGEND
- Point source
- Line source
- Area source
- Main building
- CPF Facility Boundary
- CPF Site
- OH&S 85 dBA Noise Contour
- Site / Ref. Bdry. Receiver
- 55 dBA Day Limit (Enviro)
- 44 dBA Night Limit (Enviro)

PROJECT	Papua LNG Project
CLIENT	TOTAL
DESCRIPTION	Predicted Operational Noise from CPF w/ Emergency Flare Neutral (calm) Propagation Conditions

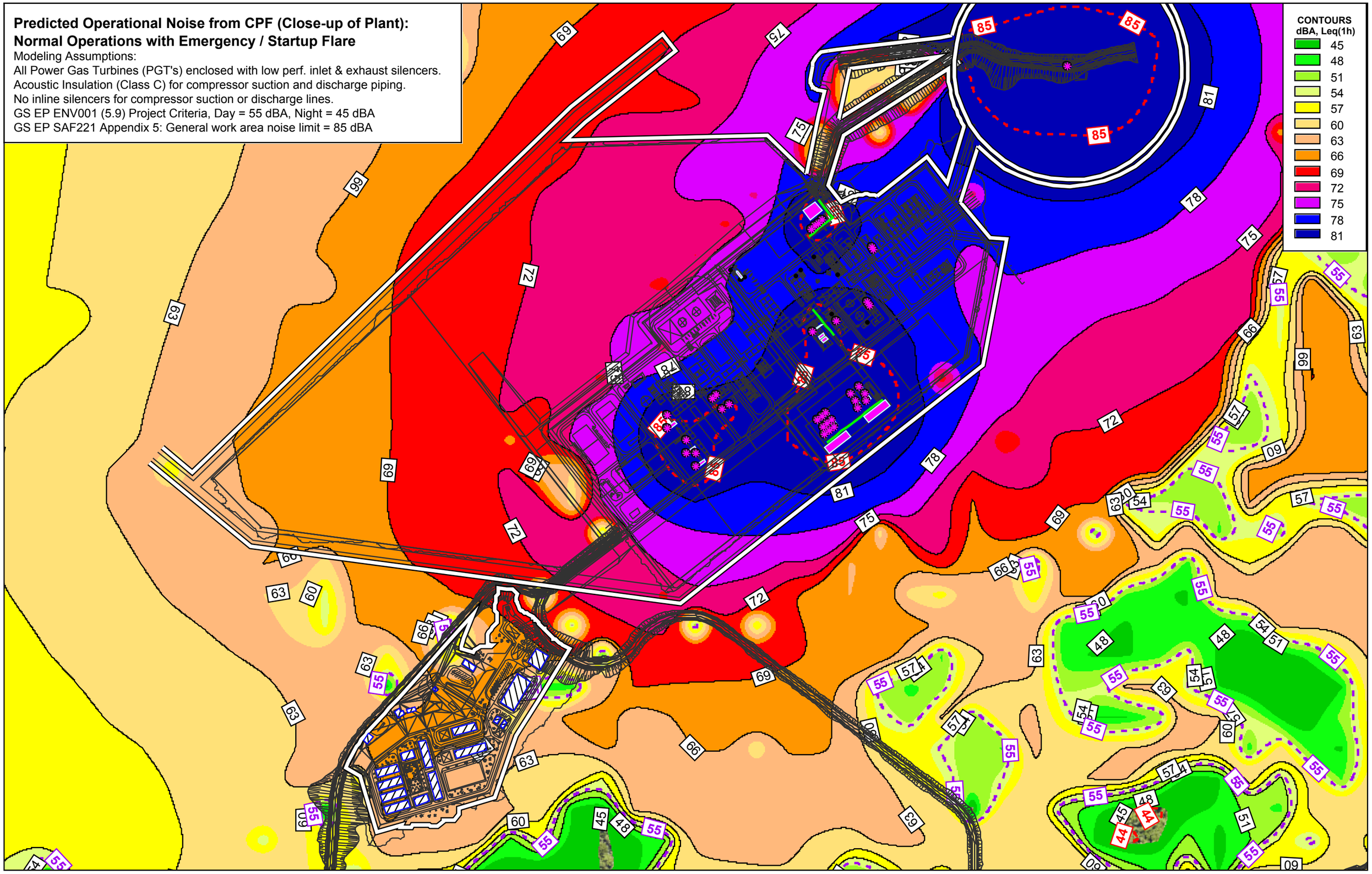
Date: 23-Jul-19
Project No.: 640.11227.00100
Report No.: 640.11227.00100-R1
Prediction Method: CONCAWE Cat 4
Prepared By: IF
Prediction Height:2.0 m

APPENDIX
D

MAP NO.
003

Predicted Operational Noise from CPF (Close-up of Plant):
Normal Operations with Emergency / Startup Flare

Modeling Assumptions:
All Power Gas Turbines (PGT's) enclosed with low perf. inlet & exhaust silencers.
Acoustic Insulation (Class C) for compressor suction and discharge piping.
No inline silencers for compressor suction or discharge lines.
GS EP ENV001 (5.9) Project Criteria, Day = 55 dBA, Night = 45 dBA
GS EP SAF221 Appendix 5: General work area noise limit = 85 dBA



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SCALE
0 25 50 100 150 200 250 300 350 m

ORIENTATION
N

LEGEND
- Point source
- Line source
- Area source
- Main building
- CPF Facility Boundary
- CPF Site
- OH&S 85 dBA Noise Contour
- Site / Ref. Bdry. Receiver
- 55 dBA Day Limit (Enviro)
- 44 dBA Night Limit (Enviro)

PROJECT	Papua LNG Project
CLIENT	TOTAL
DESCRIPTION	Predicted Operational Noise from CPF w/ Emergency Flare Adverse (worst case) Propagation Conditions

Date: 23-Jul-19
Project No.: 640.11227.00100
Report No.: 640.11227.00100-R1
Prediction Method: CONCAWE Cat 6
Prepared By: IF
Prediction Height:2.0 m

APPENDIX
D

MAP NO.
004

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