Frieda River Limited

Sepik Development Project

Environmental Impact Statement

Appendix 10 – Noise Impact Assessment

SDP-6-G-00-01-T-003-021

SDP-6-G-00-01-T-003-021

SEPIK DEVELOPMENT PROJECT

Noise Impact Assessment

Prepared for:

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SLR Ref: 620.12130-R01
Version No: -v4.0
September 2018

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Coffey Services Australia Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

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DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
620.12130-R01-v4.0	6 September 2018	Steven Walker	Mark Caslin	Mark Caslin
620.12130-R01-v3.0	24 July 2018	Steven Walker	Mark Caslin	Mark Caslin
620.12130-R01-v2.0	19 Jun 2018	Steven Walker	Mark Caslin	Mark Caslin
620.12130-R01-v1.0	27 May 2018	Steven Walker	Mark Caslin	Mark Caslin

EXECUTIVE SUMMARY

SLR Consulting Australia Pty Ltd (SLR Consulting) was contracted by Coffey Services Australia Pty Ltd (Coffey) on behalf of Frieda River Limited (FRL) to conduct a noise and vibration assessment for the Sepik Development Project (the Project) which is located in the Sandaun and East Sepik provinces of Papua New Guinea (PNG). The Project involves the development of a large-scale open-pit copper-gold mine and associated infrastructure (including an Integrated Storage Facility (ISF), hydroelectric power facility, concentrate pipeline, main access route, transmission line and Vanimo Ocean Port).

The objectives of the noise and vibration assessment were as follows:

- Characterise baseline noise and vibration conditions at key Project locations and identify nearby sensitive receptors.
- Provide early indication of potential exceedance(s) of any applicable legislation, guidelines or standards to allow design modifications to be implemented if required.
- Assess potential impacts of noise and vibration (including that resulting from blast overpressure) during construction and operation of the Project on sensitive receptors.
- Identify measures to avoid, minimise and mitigate adverse impacts from noise and vibration levels and manage residual impacts.

Noise

There are no applicable statutory regulations or guidelines that include specific criteria for managing noise and vibration in PNG. Appropriate Project noise guidelines have been developed for the Project based on the relevant national and international guidelines: World Health Organization (WHO) (1999) and International Finance Corporation World Bank Group (IFC) (2007).

The adopted Project noise guidelines provide for consideration of the estimated background noise levels and IFC and WHO guidelines, and aims to achieve an acceptable level of acoustic amenity at residences in the nearby villages.

SLR has previously undertaken noise monitoring in PNG. The range of measured ambient background noise levels at these locations indicates that the 'background + 3 dBA' noise guideline may result in higher guideline values than those described in WHO and IFC. However, since the background noise level is only estimated and not measured at this stage, a conservative approach of applying the lower noise guideline values from WHO and IFC has been used.

Adoption of a noise guideline based on the 'existing average background level (L_{A90}) + 3 dBA' may be warranted for the Project given background noise levels in similar environments have been shown to exceed the WHO and IFC guidelines. In order to apply a site specific guideline using this method, the background noise levels would need to be measured by pre-construction noise monitoring.

The adopted Project noise guidelines are summarised below and are to be met at sensitive receptors (external to any dwelling) in the vicinity of the Project.

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Adopted Project Noise Guidelines - Construction and Operation

Phase	Guidelines		
	Day (7.00am – 6.00pm)	**Evening (6.00pm – 10.00pm)**	**Night (10.00pm – 7.00am)**
Construction	55 LAeq dBA	50 LAeq dBA	35 LAeq dBA
Operation (general)	40 LAeq dBA	40 LAeq dBA	35 LAeq dBA
Aircraft	80 LAmax dBA	80 LAmax dBA	80 LAmax dBA
Road traffic	65 LAeq dBA	65 LAeqdBA	50 LAmax dBA
Barge traffic	65 LAeq dBA	65 LAeq dBA	50 LAmax dBA

Notes:

The adopted Project noise guidelines above are expressed in terms of noise contribution from the Project (ie not including noise contribution from existing ambient background noise sources).

Short term construction describes construction activities which occur for days or weeks.

Long term construction describes construction activities which occur for months or longer.

As it is proposed to undertake the majority of operational activities on a 24 hours a day, 7 days per week basis, the most stringent noise guideline level for all time periods is applicable for the assessment of these Project activities (for monitoring and compliance purposes; the applicable day, evening and night guideline values would still apply to the Project). Therefore, the night period guideline of **35 dBA LAeq** has been adopted to determine the impacts of 24 hour activities (general operation). The Project noise guidelines for assessment of construction noise emissions during the daytime and evening periods are based on the recommended outdoor noise levels from the WHO and IFC guidelines. The Project noise guidelines for assessment of construction noise emissions during the night time assessment period are based on preventing sleep disturbance at sensitive receptors. This Project guideline for night time construction activities is the same as that adopted for operational activities during the night time period. For the concentrate pipeline and main access route construction, which will include daytime activities only, the adopted Project noise guideline is **55 dBA LAeq.**

Project related road traffic, aircraft traffic and barge traffic have been assessed against the following Project noise guideline levels:

- Aircraft Traffic – **80 dBA LAmax**
- Road Traffic – **65 dBA LAeq**
- Barge Traffic – **65 dBA LAeq (50 dBA LAmax** for night-time).

The following construction and operational scenarios have been identified for this assessment:

Construction	Operational
Mine area	Mine area
Vanimo Ocean Port	Vanimo Ocean Port
Concentrate pipeline and main access route	Main access route traffic
Green River Airport and Frieda River airstrip	Vanimo Airport, Green River Airport and Frieda River airstrip

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Construction	Operational
Frieda River Port, Upper Sepik River Port and May River Port	N/A
Quarries	N/A
Construction material barging	N/A
Sepik River bridge	N/A

In order to calculate the noise emission levels at the nearest noise sensitive receptor locations, SoundPLAN (Version 7.4) environmental computer models were developed.

Two main Project sites have been identified for assessment using 3D computer modelling consisting of:

- Mine area and FRHEP area – open-pit, primary crushing facility, Run of Mine (ROM) pad, process plant, ISF and hydroelectric power facility; and
- Vanimo Ocean Port.

The remaining Project sites and facilities have been assessed using off-set distance calculations or qualitative assessment.

Noise emission levels have been predicted at the nearest noise sensitive receptor(s) surrounding the proposed Project sites for the relevant meteorological conditions. Noise contour plots have been produced for the construction and operation of the mine area and Vanimo Ocean Port in order to determine noise emissions from the Project.

Based on an analysis of the available noise source data for the different Project components, no correction factors have been included in this assessment for low frequency components.

Assessment of Potential Impacts

Construction of Major Project Sites

Predicted noise levels associated with the construction phase are presented as noise contour plots. Based on these contours, the maximum required offset distances to achieve the night-time guideline value of 35 dBA (under adverse weather conditions, which includes consideration of wind speed, direction and temperature inversions) are as follows:

- Mine area and FRHEP area – 5,000 m (adverse weather); and
- Vanimo Ocean Port – 2,700 m (adverse weather).

There are no sensitive receptors located within the offset distances described above for the mine area and FRHEP construction areas.

Adverse noise impacts are expected at the majority of sensitive receptors within Vanimo during the Vanimo Ocean Port construction. Community consultation and noise management practices should be implemented during the construction of the Vanimo Ocean Port where practicable.

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Construction of Concentrate Pipeline and Main Access Route

Based on the findings of the noise assessment (see **Section 2.5**), one of the potential scenarios for adverse noise levels from the Project are from the construction of the concentrate pipeline and main access route.

Based on aerial imagery, there are potentially sensitive receptors which are within 300 m of the concentrate pipeline construction alignment at ten (10) villages (see **Section 2.5.4)**. There is potential for temporary adverse noise impacts at these potential receptors during the concentrate pipeline construction. It should be noted that the road construction, when passing these receptors, will be short term and likely to last for only a few days as the construction front passes. Making residents aware of likely future occurrence of noisy activities can significantly reduce annoyance.

Barging (Materials Transport) – Construction Phase

Maximum pass by noise emission levels of approximately 48 to 59 dBA are predicted at identified sensitive receptors from barging activities along the Frieda River, Sepik River and May River barging corridors. There will be a maximum of 1 barge trip per day (up and back, 2 pass by events) during daylight hours only to facilitate transport of construction materials. The predicted daytime pass by noise emission level is less than the daytime Project noise guideline value of 65 dBA L_{Aeq}.

Construction of Green River Airport and Frieda River Airstrip

The nearest sensitive receptors to the Frieda River airstrip are located in Paupe, approximately 1.9 km from the construction area with no adverse noise impacts expected for the construction of this Airport.

Based on aerial imagery, the Green River Airport is situated approximately 40 m from potentially sensitive receptors. There is potential that temporary adverse noise impacts may be generated by construction works at these receptors within 300 m of the Green River Airport. Community consultation and noise management should be included during the construction works required for this facility.

Construction of Quarries

There will be quarries associated with the construction of some Project infrastructure (ie roads etc). These quarries are located 400 m or more from the nearest sensitive receptors. As a result of the offset distance, no adverse noise impacts are expected from these quarries.

Frieda River Port, Upper Sepik River Port and May River Port Construction

The nearest villages to the Frieda River Port, Upper Sepik River Port and May River Port construction sites are Nekkei, Dioru and Samou, 12.8 km, 8 km and 11 km respectively from the construction work sites. The predicted worst-case construction noise emissions from the River Ports are less than 30 dBA at each of these receptors. No adverse noise impacts are expected for the construction of the Frieda River Port, Upper Sepik River Port or May River Port.

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Sepik River Bridge Construction

Based on aerial imagery, a potential sensitive receptor is situated approximately 2.5 km from the Sepik River bridge construction activities.

The Sepik River bridge construction is only expected to be carried out during daytime hours. The required offset distance to meet the Project noise guideline for daytime construction activities is 1.0 km. No adverse noise impacts are expected for the construction of the Sepik River bridge.

Operation of Major Project Sites

Predicted noise levels associated with the Project operation are presented as noise contour plots. Based on these contours, the maximum required offset distances to achieve the night-time guideline value of 35 dBA (under adverse weather conditions) are as follows:

- Mine area and FRHEP area (Year 5, open-pit, primary crushing facility, ROM pad and process plant – 4,500 m).
- Mine area and FRHEP area (Year 12, open-pit, primary crushing facility, ROM pad, process plant, ISF and hydroelectric power facility) – 4,600 m.
- Vanimo Ocean Port (typical operations) – 2,500 m (from site boundary).

There are no sensitive receptors located within the offset distances described above for the mine area. Due to the large buffer distance between the mine area and any existing sensitive receptors no adverse noise impacts are expected from the operation of the mine area.

The majority of existing receptors within Vanimo are predicted to exceed the relevant Project noise guideline of 35 dBA L_{Aeq}. The resultant noise environment (inclusive of the operation of the Vanimo Ocean Port) may not differ considerably from the existing noise environment in Vanimo with the current logging operations. However, this would need to be confirmed prior to commencement of operations to ensure that, where applicable, appropriate noise management measures are incorporated.

Operation of Main Access Route

According to WHO (1999) background noise levels above approximately 65 dBA have the potential to interfere with speech communication. Receptors located 10 m or more from the main access route are predicted to experience road traffic noise levels of 65 dBA L_{Aeq} or lower during the operational phase. There are no sensitive receptors predicted to exceed the Project noise guideline for road traffic noise from the main access route. It should be noted that Project related road traffic will only occur during daytime hours with relatively few vehicle movements (expected vehicle movements of less than 90 per day).

Operation of Airports

The longest offset distance required to achieve the operational aircraft fly-over noise guideline is 1.9 km. There are no sensitive receptors within 1.9 km of the Frieda River airstrip. No adverse noise impacts are predicted for the operation of the Frieda River airstrip.

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Using aerial imagery, there are potential sensitive as close as 40 m to the Green River Airport. These sensitive receptors would be likely to exceed the project noise criterion. It should be noted that the Green River Airport is currently operational and that the new flights which will use this airport as part of the Project are not expected to significantly increase existing maximum noise levels above those already experienced by the nearby receptors.

Summary of Potential Noise Impacts

There are no existing sensitive receptors which are predicted to be adversely impacted by noise from any of the mine area, ISF, hydroelectric power facility or Frieda River airstrip during the construction or operation phases.

The concentrate pipeline construction represents a relatively short term impact and would be adequately resolved through consultation with the nearby residents at Vanimo, which are located within 300 m of road construction activities and may experience some short term noise impact.

No receptors have been identified to be located within 10 m of the main access route, with no noise impacts expected from the operation of the main access route.

Noise impacts from the Vanimo Ocean Port construction activities have been predicted for receptors within 2,700 m during the night time period and 550 m during the daytime period (adverse weather). Noise impacts from the operation of the Vanimo Ocean Port have also been predicted for receptors within 2,500 m of the port operations during the night time period and 1,900 m during the daytime period (adverse weather). The resultant noise environment (inclusive of the operation of the Vanimo Ocean Port) may not differ considerably from the existing noise environment in Vanimo with the current logging operations. However, this would need to be confirmed prior to commencement of operations to ensure that, where applicable, appropriate noise management measures are incorporated.

Noise impacts from the Green River Airport are expected at nearby sensitive receptors during both the construction and operational phases. It should be noted that the Green River Airport is currently operational and that the additional flights required as part of the Project, would not be expected to result in a significant increase in maximum noise levels above those already experienced at these sensitive receptors.

Community consultation and best practice noise mitigation and management measures are recommended for both the construction and operation of the Vanimo Ocean Port and the Green River Airport.

Any sensitive receptors identified above should be consulted prior to construction in order to determine appropriate methods for managing construction impacts. General, best practice noise management strategies will also assist in minimising noise emission from all of the Project sites.

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Vibration

A comprehensive study of vibration emissions (and associated overpressure) from blasting activities and construction and operation works associated with the Project has been undertaken.

The vibration study has been divided into two categories as follows:

- Blasting activities (ground vibration and airblast overpressure); and
- General construction and operation vibration sources (excluding blasting) such as rock breaking, heavy vehicles, compaction, etc.

The adopted Project blasting guidelines used for this assessment would prevent health effects/adverse comment by individual building occupants and also structural damage to buildings. The proposed blasting guidelines taken from AS 2128-2 (2006) are:

- Ground vibration – 5 mm/s for 95% of blasts (maximum of 10 mm/s); and
- Airblast – 115 dBL for 95% of blasts (maximum of 120 dBL).

The adopted Project vibration guidelines for non-blasting activities, based on relevant international standards and guidelines derived from BS 6472, DIN 4150-2, DIN 4150-3 and BS7385-2, are:

- Structural damage – 12.5 mm/s; and
- Human comfort – daytime 0.3-0.6 mm/s; night-time 0.2 mm/s.

Airblast overpressure and ground vibration have been predicted and assessed for blasting associated with the following construction and operation activities:

- ISF embankment – construction;
- concentrate pipeline and main access route – construction;
- Quarries associated with process plant, ISF, concentrate pipeline and main access route – construction; and
- Open-pit– operation.

The maximum offset distance required to achieve the ground vibration and airblast overpressure guidelines for blasting are summarised below.

Maximum Offset Distance Required to Achieve Project Blasting Guidelines

Project Activity	Maximum Offset Distance Required to Achieve Project Blasting Guideline[1] (m)	
	Ground Vibration	Airblast Overpressure
Open-pit	1150	1300
ISF embankment / Quarries	315	540
Concentrate Pipeline and main access route construction	210	415

Note 1: Blasting Guideline values formed in consideration of AS 2128-2

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The identified existing sensitive receptors are generally outside these offset distances required for blasting at the open-pit and ISF. Therefore, compliance with the adopted Project ground vibration and airblast overpressure guidelines would be achieved at all existing sensitive receptors.

The nearest sensitive receptors to any of the quarries are 400 m (Paupe) and 460 (Temsapmin) away; all other sensitive receptors are located at significantly longer distances from the quarries. There is potential for airblast overpressure impacts at the nearest sensitive receptors in Paupe and Temsapmin within 540 m of the nearest quarry. If blasting is required adjacent to these receptors then specific blast management measures may be required.

No other adverse blasting related airblast overpressure impacts are anticipated adjacent to any of the quarries. If blasting is required adjacent to these receptors then specific blast management measures may be required.

There are potential sensitive receptors in eleven (11) villages within 415 m of the concentrate pipeline and main access route and sensitive receptors in nine (9) villages located within 210 m of the concentrate pipeline and main access route. Exceedances of the adopted Project ground vibration guidelines may be experienced at the sensitive receptors in these villages within 210 m of the concentrate pipeline and main access route. Exceedances of the airblast overpressure guidelines may be experienced at both the villages identified within 415 m of the concentrate pipeline and main access route (see **Section 3.5.2**. It is not known whether blasting will be required during the concentrate pipeline and main access route construction at these villages. Appropriate management of blasting impacts will be required should blasting be conducted at these locations.

Vibration levels from general construction and operation activities (ie, excluding blasting) have been predicted and assessed against the Project guidelines. Due to the large buffer distances between the Project related infrastructure (during both construction and operational activities) and the nearest potentially sensitive receptors, compliance with the adopted Project vibration guidelines would be readily achieved. The possible exception is where the construction of the concentrate pipeline and main access route passes close to existing receptors. It should be noted that this is a short term construction event and will only have potential vibration impact as the construction work front passes very close to receptors (ie 15 m to 55 m for daytime). Seven (7) villages been identified as being located within 55 m of the concentrate pipeline and main access route alignment (see **Section 3.5.3**). Any sensitive receptors identified within the required offset distances should be made aware of the times and duration that they may be affected. Making residents aware of likely future occurrence of vibration generating activities significantly reduces annoyance.

Based on the predicted vibration emissions in this report, it is considered that vibration emissions from the Project are not expected to adversely impact on the surrounding environment.

Best practice vibration management strategies will also assist in minimising vibration emission from all of the Project sites.

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Abbreviations

<	less than
>	greater than
~	approximately
%	percent
°C	degrees Celsius
AS	Australian Standard
dBA	decibels (A weighted)
dBL	decibels (unweighted or linear)
DWT	deadweight tonnage
EMB	Environmental Management Bureau
FRCGP	Frieda River Copper-Gold Project
FRHEP	Frieda River Hydroelectric Project
FRL	Frieda River Limited
Hz	Hertz (unit of measurement for frequency)
IFC	International Finance Corporation World Bank Group
IFO	Intermediate fuel oil
ISF	Integrated storage facility
Kg	kilograms
Km	kilometres
M	metres
m/s	metres/second
Mm	millimetres
mm/s	millimetres/second
MIC	Maximum Instantaneous Charge
NATA	National Association of Testing Authorities
PNG	Papua New Guinea
PPV	Peak Particle Velocity
ROM	Run of mine
SIP	Sepik Infrastructure Project
SLR	SLR Consulting Australia Pty Ltd
SPGP	Sepik Power Grid Project
SWL	Sound Power Level
TAPM	The Air Pollution Model
WHO	World Health Organization
UTM	Universal Transverse Mercator

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Glossary

C-weighted	Refers to weighting for different frequencies of noise emissions typically expressed as dBC
CONCAWE	CONCAWE Report 4/81 "The propagation of noise from petroleum and petrochemical complexes to neighbouring communities" prediction method
Fast	Time weighting constant of 125 milliseconds
Free-field	Noise measurement or prediction conducted at a minimum of 4 m from a building facade and where no facade reflections is observed/incorporated
FRHEP area	The area inclusive of the hydroelectric power facility and Intergrated Storage Facility (ISF)
Impulse noise	Short, sharp, almost instantaneous noises
LA10 (dBA)	Noise level (in decibels – A weighted) exceeded for 10% of the measurement period
LA90 (dBA)	Noise level (in decibels – A weighted) exceeded for 90% of the measurement period
LAeq (1hour)	Equivalent continuous (or 'average') noise level (in decibels – A weighted) over a one (1) hour measurement period
LAmax	Maximum A-weighted noise level associated with site activity
LAmax,adj T	Noise level is the average of the maximum noise levels during time period T adjusted for tonality and impulsiveness
LAeq (dBA)	Equivalent continuous (or 'average') noise level (in decibels – A weighted)
dBA	Measure of sound, decibel (dB), A-weighted. The "A-weighting" filter has a frequency response corresponding approximately to that of human hearing
dBL	Measure of sound, decibel (dB), L-weighted. The "Linear-weighting" filter has a flat (or unweighted) frequency response
MIC	The Maximum Instantaneous Charge (MIC) is the maximum amount of explosive in kg on any one specific delay detonator in any one blast hole
Mine area	The open-pits, process plant and site accommodation
Noise attenuation	Reducing sound
Quasi steady state	Resembling a stable or regular state
Sensitive receptor	Locations such as residential dwellings, hospitals, churches, schools, recreation areas etc where people (particularly the young and elderly) may often be present, or locations with sensitive vegetation and crops
SoundPLAN	Software package that enables compilation of a sophisticated computer model that can generate noise emission levels taking into account such factors as source noise levels and locations, distance attenuation, ground absorption, air absorption, shielding attenuation and meteorological conditions
Sinusoidal Vibration	A waveform whose variation as a function of time is a sine wave
Sleep Disturbance	Awakening and disturbance to sleep stages
Study Area	Area within approximately 15 km of the mine and FRHEP infrastructure, 2 km of the main access route, pipeline and transmission line corridor, and 2 km of Vanimo Ocean Port..
Tonal noise	Noise that is concentrated in a narrow part of the frequency spectrum
Vanimo Ocean Port	An ocean port constructed in the town of Vanimo, allowing for two new berths accommodation import and export facilities for the Project and other users.
Villages	Collective term for PNG residential buildings and community infrastructure

1 Introduction

SLR Consulting Australia Pty Ltd (SLR Consulting) was contracted by Coffey Services Australia Pty Ltd (Coffey) on behalf of Frieda River Limited (FRL) to conduct a noise and vibration assessment for the Sepik Development Project (the Project) located in Papua New Guinea (PNG).

This report forms part of an Environmental Impact Statement (EIS) for the Project. It describes the methodology used in the assessment, summarises the results of the assessment and describes the management measures proposed to mitigate the potential noise and vibration impacts of the Project.

The Project consists of four interdependent projects:

- **Frieda River Copper-Gold Project (FRCGP).** Includes the open-pit, process plant, site accommodation camp and mine access roads, concentrate pipeline and Vanimo infrastructure area, concentrate handling and export facility.
- **Frieda River Hydroelectric Project (FRHEP).** Includes the Integrated Storage Facility (ISF), hydroelectric power facility, Frieda River Port, FRHEP access road, and quarries to support construction of the FRHEP. Hydroelectric power generation peaking at 400 MW once the reservoir has filled.
- **Sepik Infrastructure Project (SIP).** Including the Vanimo Ocean Port (an upgrade to the existing Port of Vanimo), Green River Airport and a public road from Vanimo to Hotmin.
- **Sepik Power Grid Project (SPGP).** A 370 km 275 kV Northern Transmission Line from the FRHEP to Vanimo with an extension to the Indonesian border via Vanimo.

1.1 Objectives of the Assessment

The objectives of the noise and vibration assessment were as follows:

- Characterise baseline noise and vibration conditions at key Project locations and identify all nearby sensitive receptors.
- Provide early indication of potential exceedances of any applicable legislation, guidelines or standards to allow design modifications to be implemented if required.
- Assess potential impacts of noise and vibration on sensitive receptors (including that resulting from blast overpressure) during construction and operation of the Project.
- Identify measures to avoid, minimise and mitigate adverse impacts from noise and vibration levels and manage residual impacts.

The Noise and Vibration Impact Assessment is structured as follows:

- **Section 1** – Introduction
- **Section 2** – Noise Assessment
- **Section 3** – Vibration
- **Section 4** – Conclusions (for both noise and vibration assessments)
- **Section 5** – References

Further details regarding the structure of each subsection (ie noise, vibration) is provided in the relevant section of the report.

1.2 Project Description

An overview of each of the major components of the Sepik Development Project is provided in the following sections.

1.2.1 Frieda River Copper-Gold Project

The greenfield FRCGP is based on the Horse-Ivaal-Trukai, Ekwai and Koki (HITEK) porphyry copper-gold deposits which contain an estimated total combined Measured, Indicated and Inferred Mineral Resource (JORC classifications) of approximately 2.7 billion tonnes at an average grade of 0.44% copper and 0.23 grams per tonne gold. Copper mineralisation was first identified at Frieda River in 1966/67 and the long history of exploration and study activities undertaken by several companies has generated a considerable body of information.

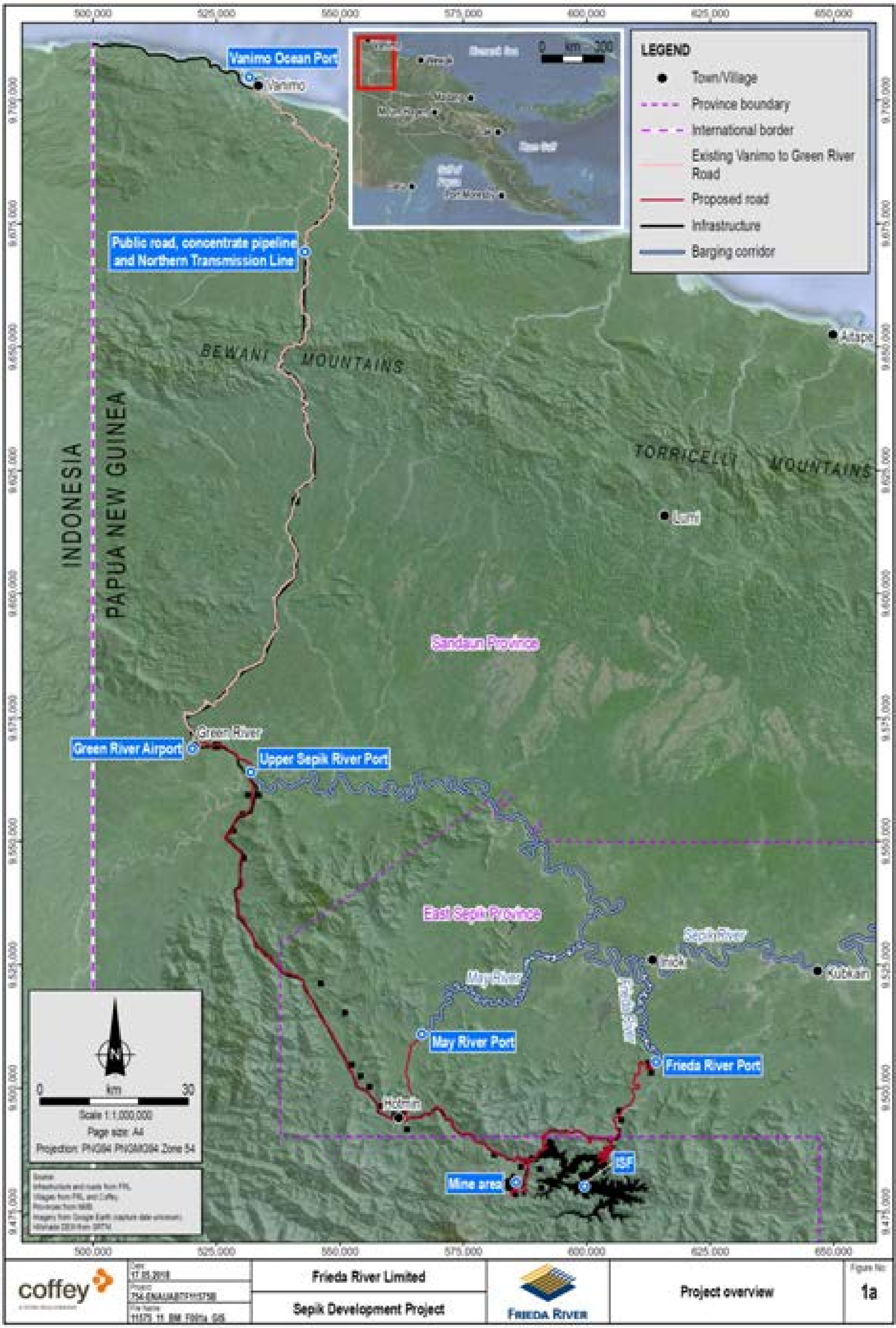
Figure 2 shows the general FRCGP layout around the open-pits including the HITEK deposits and supporting infrastructure. Mined ore will be treated at a process plant located approximately 8 km northeast of the open-pits to produce a copper-gold concentrate.

The FRCGP comprises a large-scale open-pit mine operation feeding ore to a conventional comminution and flotation process plant producing a copper-gold concentrate for export to custom smelters.

Mining inventory comprises approximately 1,500 Mt of mill feed. The average annual copper-gold concentrate production will be 740,000 wet tonnes and the average annual metal in concentrate production will be 175,000 tonnes (t) copper and 235,000 ounces (oz) gold. The FRCGP will have mine life of approximately 33 years preceded by a six-year implementation period.

A concentrate pipeline that follows the road corridor will transport the copper-gold concentrate produced at the process plant to a concentrate dewatering, storage and export facility located at the Vanimo Ocean Port.

The FRCGP's power demand will be approximately 155 MW increasing up to 235 MW by Year 11. Offsite power demands for the Vanimo Ocean Port facilities and two concentrate booster pump stations will require approximately 10 MW and 1.5 MW respectively.


Vanimo Ocean Port
Vanimo
LEGEND
Town/Village
Province boundary
International border
Existing Vanimo to Green River Road
Proposed road
Infrastructure
Barging corridor
Public road, concentrate pipeline and Northern Transmission Line
BEWANI MOUNTAINS
TORRICELLI MOUNTAINS
INDONESIA
PAPUA NEW GUINEA
Aitape
Lumi
Sandaun Province
Green River
Green River Airport
Upper Sepik River Port
East Sepik Province
Sepik River
May River
Iniok
Kubkain
May River Port
Frieda River Port
Hotmin
ISF
Mine area
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Frieda River Limited
Sepik Development Project
Project overview
1a

Figure 2 Mine and ISF area

1.2.2 Frieda River Hydroelectric Project

Mine waste, including tailings and waste rock, will be stored sub aqueously in an integrated storage facility (ISF) located in the Frieda River Valley downstream of the mine site, the ISF will also store water for power generation. The hydroelectric power facility will generate power for the Project commencing in Year 1.

The hydroelectric power facility will provide power for the FRCGP which will be transmitted via a 22-km transmission line.

The hydroelectric power facility will be capable of producing 600 MW (8 x 68 MW and 2 x 19 MW turbines) with a firm generating capacity of 400 MW. At least one turbine at a time will be offline for periods of planned maintenance and on standby for back up.

Power generation will peak at 400 MW (2,800 gigawatt hours per annum (GWh/a)) once reservoir filling is complete in Year 2 to 3 of operations. From approximately Year 4, the excess power will be in the order of 100 MW which will be available for export.

The ISF final embankment will be approximately 187 m (RL 235 m) in height, utilising 26 million cubic metres (Mm^3) of fill material and creating a total storage capacity of 10.8 billion cubic metres (Bm^3). The operating water level will be approximately RL 225 m .

1.2.3 Sepik Infrastructure Project

The mine area will be accessed by the infrastructure corridor, which consists of an existing road from Vanimo to Green River and a new road through to Hotmin and to the site. The road will be a public road from Vanimo to Hotmin and a private mine road from Hotmin to the site.

The existing airstrip at Green River is located 150 km from the mine area. It will be upgraded to an international airport to cater for larger aircraft.

A 325 km-long infrastructure corridor will be developed between the mine site and the Vanimo Ocean Port, located on the north coast of mainland Papua New Guinea. Diesel trucks will transport fuel to the site using the road corridor.

The existing Port of Vanimo will be upgraded (and termed the Vanimo Ocean Port) to include up to two new berths to support the FRCGP and other port users.

1.2.4 The Sepik Power Grid Project

The SPGP consists of a new 325 km 275 kV Northern Transmission Line from the FRHEP to Vanimo, which will provide power for the offsite FRCGP facilities. The Northern Transmission Line will be located within the infrastructure corridor.

The excess power from the FRHEP also provides an opportunity to supply power to communities along the infrastructure corridor and to industries such as agriculture, fisheries, food and timber processing, mining and manufacturing.

1.3 Key Characteristics

Table 1 provides a summary of the key characteristics of the Sepik Development Project. Some of these aspects are in the process of being refined and may change, particularly in relation to the workforce and accommodation facilities.

Table 1 Key characteristics of the Sepik Development Project

Item	Description
Frieda River Copper-Gold Project	
Mining method	Large-scale open-pit.
Mining	Approximately 1,493 Mt of mill feed and 1,558 Mt of waste rock to be mined from the open-pit over the life of the mine. Life of mine strip ratio of 1.1:1 (waste:ore).
Open-pit dimensions (final shell)	The Horse, Ivaal, Trukai (HIT) open-pit will be 2.6 km long and 2.4 km wide, the Ekwai open-pit will be 0.8 km long and 0.6 km wide and the Koki open-pit will be 0.7 km long and 0.9 km wide. The Ekwai open-pit void will be used as an intermediate ore stockpile.
Mine life	Approximately 33 years (with an additional 6-year construction period).
Mining rate	Average ore production of 44 Mt/year of mill feed and 47 Mt/year of waste, and peak total material movements of 135 Mt/year. The total material mined over the life of mine will be 3,051 Mt comprising 1,493 Mt of mill feed (0.46% copper and 0.24 g/t gold) and 1,558 Mt of waste rock.
Processing method	Primary crushing, grinding and flotation circuit. Initially one 28 MW semi-autogenous grinding (SAG) mill and two 22 MW ball mills, expanding to two 28 MW SAG and four 22 MW ball mills in Year 11.
Mill throughput	Nominal volumetric ore processing rates are: • Years 1 to 10: up to 49 Mtpa (6,000 tph); and • Year 11 to LOM: up to 65 Mtpa (8,000 tph).
Concentrate and metal production	Concentrate and metal production will include: • Average copper-gold concentrate production of 740,000 wmt per year with a peak of 1.1 Mwmt per year at 9.5% moisture. • Average copper metal production 175,000 tpa (peak of 270,000 tpa). • Average gold metal production 235,000 oz per year (peak of 350,000 oz per year) production.
Tailings and waste rock storage	• A waste spoil dump will be developed in the headwaters of the Ok Binai. This spoil dump will store NAF waste rock from Year -1 and organic pre-strip material over the 33 year mine life. • All waste rock (other than that reporting to the Ok Binai waste dump) including potentially acid forming (PAF) waste will be barge placed within the ISF. • At the barge loading station, the waste rock will be stockpiled, reclaimed and loaded into 5,000 t barges. The barges will transport and deposit the waste rock for subaqueous storage in the ISF. • Thickened tailings will be pumped via a dedicated pipeline from the process plant for subaqueous storage in the ISF.

Item	Description
Power requirement and distribution	Power demand for the mine: • Approximately 155 MW (1,200 gigawatt hours per year (GWh/year)) energy demand increasing to 235 MW (1,800 GWh/year) in Year 11. Power demand off-site: • Vanimo Ocean Port concentrate and logistics facilities – 10 MW (75 GWh/year). • Two concentrate booster pump stations – 1.5 MW (15 GWh/year) each. Power supply will be via a 22 km, 132 kV transmission line from the hydroelectric powerhouse to the process plant. Power supply to the offsite facilities will be provided by the Northern Transmission Line as part of the SPGP.
Raw water requirement and supply	Raw water will be sourced from the FRHEP at a rate of up to approximately 3,800 cubic metres per hour (m^3/h) for ore processing and general non-potable consumption. Potable water will be sourced from the Nena River upstream of the ISF and pumped to the site accommodation village.
Mine infrastructure area	The mine infrastructure area (MIA) will be located close to the HITEK open-pits. The MIA will consist of the following major facilities: • Workshops. • Warehouse. • Muster, training and dining areas. • Fuel storage.
Overland logistics	Overland logistics includes: • 39 km mine access road from Hotmin to the mine (unsealed 7.5-m-wide dual lane). • 33 km unsealed 7.5-m-wide dual-lane Link Road from the powerhouse to the mine. • A buried 325-km-long pipeline providing transport of concentrate to the Vanimo Ocean Port. • Equipment and goods will be transported via road along the main access route during operations. • Coaches will be used to transport personnel between points of hire along the public road and from the Green River Airport to the mine.
Ocean/riverine Logistics	• During construction, freight will be imported via existing ports at Wewak, Lae and Madang and barged upstream along the Sepik River to the Frieda or May River ports until upgrade of the Vanimo to Green River Road has been completed. Freight will then be trucked from Vanimo to Green River and barged from the Upper Sepik River Port downstream along the Sepik River. Once the main access route from Green River to the mine is complete all freight will be trucked to site. • During operations, freight will be imported via the upgraded Vanimo Ocean Port and trucked to site. • Bulk carriers for concentrate export, multipurpose feeder vessels for containerised cargoes and parcel tankers for diesel will be utilised. • Riverine transport is not expected to be used during operations.

<table>
<tr><th>Item</th><th>Description</th></tr>
<tr><td colspan="2">Frieda River Hydroelectric Project</td></tr>
<tr><td>Power generation</td><td>Hydroelectric power generation will be produced using Francis turbines with an installed hydroelectric power capacity of up to approximately 600 MW and a firm generating capacity of 400 MW. At least one turbine at a time will be offline for periods of planned maintenance and one on standby.
From approximately Year 4, the excess power will be in the order of 150 MW, which will be available for export.
The powerhouse will be approximately 190 m x 34 m in size and will be located at the toe of the dam. A penstock pipeline will connect the tunnel to the powerhouse. The powerhouse complex will include:
• Tunnel exit portal and penstock.
• Main turbine hall housing the generating equipment.
• Erection bay and workshop area for assembling the equipment and undertaking future maintenance to the equipment.
• Local control room and office facilities.
• Electrical equipment rooms.
• An area to locate the step-up transformers and adjacent substation building.
• A tailrace discharging into the Frieda River.</td></tr>
<tr><td>Design</td><td>The FRHEP will include an engineered ISF for the storage of water, construction spoil, mine waste rock and tailings, and sediment control.
The embankment will be located in the Frieda River Valley and designed as an engineered rock-fill embankment with a central asphalt core. Design characteristics include:
• Embankment height of 187 m (RL 237 m) using 26 Mm^3 of fill material.
• Crest elevation of RL 235 m and maximum operating water level of RL 225 m.
• Total storage capacity of 10.8 Bm^3.
• Maximum waste rock and tailings storage capacity of 3.5 Bm^3 (approximately 4.9 Bt).
• Designed to store and release water from a Probable Maximum Flood event (26,000 cubic metres per second (m^3/s)).
• Designed to withstand maximum credible earthquake of 1.09 g.
• Catchment area of 1,036 km^2.
• Operating life of greater than 100 years.</td></tr>
<tr><td>Construction facilities</td><td>The FRHEP will require the development of the following site-based facilities to allow construction of the embankment, spillway and powerhouse:
• Quarry.
• Coffer dams.
• Diversion tunnels.
• Concrete batch plant.
• Maintenance workshop.
• Geotechnical laboratory.
The FRHEP will be constructed in a single stage over a 4 - 5-year construction duration.</td></tr>
<tr><td>Overland logistics</td><td>40 km unsealed 7.5 m wide dual-lane FRHEP access road from the Frieda River Port to the powerhouse.</td></tr>
</table>

Item	Description
Ocean/riverine logistics	The Sepik and Frieda rivers will be required to support transport of construction materials for the FRHEP. The rivers will also provide a contingency in the event of loss of access along the infrastructure corridor.
Sepik Infrastructure Project	
Vanimo to Green River Road and Hotmin Road (public)	The existing road from Vanimo to Green River will be upgraded, and a new road constructed from Green River to Hotmin. The road will be at least 7.5-m-wide with a gravel pavement surface, built to allow for 12-tonne axle loading. The remaining road sections may be sealed during the operations phase. The road will allow for public transport, commercial ventures and access to new markets.
Sepik River bridge	A new public bridge will be built on the Hotmin Road (public) at the Sepik River. A cross-river ferry service will be required during construction of the bridge. The proposed Sepik River bridge consists of: • Steel box girder superstructure. • Dual lane deck with 8.0 m width between kerbs. • Total bridge length of 350 m.
Green River Airport	• The existing airstrip at Green River, located 150 km from the mine area, will be upgraded for commercial use. • The airstrip will be made suitable for up to Lockheed C-130 sized aircraft • The new facilities will include a terminal with the capacity for 80 passengers, baggage handling facilities, immigration and customs, freight handling and storage facilities.
Vanimo Ocean Port	Construction of up to two new berths at the Vanimo Ocean Port to provide import and export facilities for the Project and other users.
Sepik Power Grid Project	
Northern Transmission Line	• A 370 km long 275 kV transmission line from the FRHEP to the Indonesian Border via Vanimo. • The Northern Transmission Line will provide power to the FRCGP facilities based at Green River and Vanimo. • Excess power will be made available for a power distributor to sell to regional users within PNG and for export to Indonesia. • The Northern Transmission Line will be located within the infrastructure corridor and will follow the existing Vanimo-Jayapura Highway from Vanimo to the Indonesian border.
Substation	Up to three substations will be located along the Northern Transmission Line: • At the FRCGP site accommodation village; • Near Green River; and • At Vanimo.

1.4 Sensitive Receptor Locations

For the purposes of this assessment, in order to quantify the noise and vibration impacts from the Project on the surrounding communities, the nearest sensitive receptors were identified. The sensitive receptors typically comprise of villages which include residential dwellings and recreational areas, and can include service buildings (such as schools).

The overall study area incorporates the mine area and FRHEP area, Vanimo Ocean Port as well as the main access route, concentrate pipeline and River Port areas.

Both the mine areaand FRHEP area are situated in a remote region with a small number of villages located within the area as shown in **Figure 1**. Some of the identified villages are located in the vicinity of the southern end of the infrastructure corridor and the mine access road.

The locations of all villages identified in the areas surrounding the open-pits, mine infrastructure area and ISF are shown in **Figure 3**. As shown in **Figure 3**, some villages are proposed to be resettled as part of the Project and a number of options for their relocation are being considered. Wabia and Ok Isai will need to be relocated as they are located within the ISF footprint. Hence the current locations of these villages have not been assessed.

Those existing villages shown in **Figure 3** that are located in the vicinity of major Project infrastructure or that have been identified within 4 km of the main access route or infrastructure corridor are summarised in **Table 2**. This is considered to be the study area for the noise and vibration assessment for the mine area, based on preliminary modelling results that indicated that any noise impacts beyond these distances would be negligible, hence villages located outside these areas were not considered further.

Vanimo Township is located approximately 230 km north of the mine area and FRHEP area. Immediately west and east of Vanimo Port, there are houses scattered amongst the surrounding vegetation, with the closest residences within 50 – 100 m of the existing log storage areas.

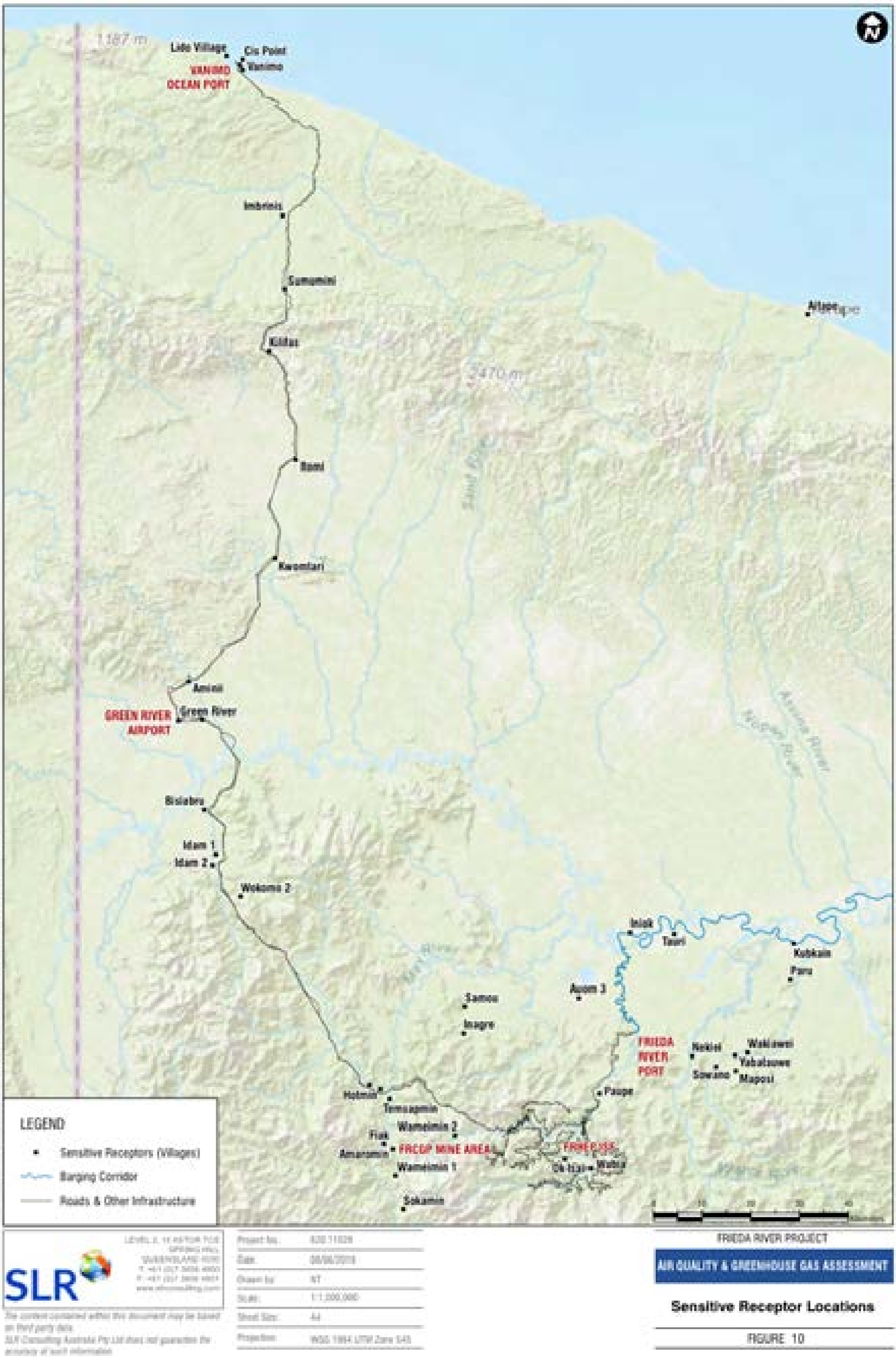

1187 m
Lido Village
Cis Point
Vanimo
VANIMO OCEAN PORT
Imbrinis
Sumumini
Kilifas
2470 m
Aitape
Bami
Kwomtari
Amini
GREEN RIVER AIRPORT
Green River
Bisiabru
Idam 1
Idam 2
Wokomo 2
Iniok
Tauri
Kubkain
Paru
Auom 3
Samou
Inagre
FRIEDA RIVER PORT
Nekiei
Wakiawei
Yabatauwe
Sowano
Maposi
Paupe
Hotmin
Tenmsagmin
Wameimin 2
Fiak
Amaromin
FRCDP MINE AREA
Wameimin 1
Sokamin
Wabia
LEGEND
Sensitive Receptors (Villages)
Barging Corridor
Roads & Other Infrastructure
SLR
FRIEDA RIVER PROJECT
AIR QUALITY & GREENHOUSE GAS ASSESSMENT
Sensitive Receptor Locations
FIGURE 10

Table 2 Sensitive Receptors Located in the Vicinity of Major Project Infrastructure

Sensitive Receptor	Approximate Distance to the open-pits or Associated Mine Infrastructure
Paupe – *current location - proposed to be resettled*	24 km northeast of the open-pits 6.5 km northeast of FRHEP
Wameimin 2 – *current location - proposed to be resettled*	7.5 km northwest of the open-pits
Wabia – *current location – would be resettled*	Within ISF boundary – not assessed
Ok Isai – *current location – would be resettled*	Within ISF boundary – not assessed
Sensitive Receptor	**Approximate Distance to the Pipeline/main access route**
Tamsapmin	900 m southeast (nearest receptors)
Hotmin	340 m north (nearest receptors)
Usaremin 2	550 m northeast (nearest receptors)
Wokomo 2	90 m southwest (nearest receptors)
Idam 1	1.5 km southwest (nearest receptors)
Idam 2	1.2 km west (nearest receptors)
Bisiabru	440 m west (nearest receptors)
Dioru	20 m southwest (nearest receptors)
Green River Station	30 m west (nearest receptors)
Aminii	10 m east (nearest receptors)
Kwomtari	300 m east (nearest receptors)
Itomi	140 m east (nearest receptors)
Kilifas	30 m east (nearest receptors)
Sumumini	20 m east and west (nearest receptors)
Imbrinis	25 m east and west (nearest receptors)
Vanimo	15 m both sides of the alignment (nearest receptors)
Sensitive Receptor	**Approximate Distance to Vanimo Ocean Port**
Various residences	50 m (nearest receptors)
Sensitive Receptor	**Approximate Distance to Airstrips**
Paupe – *current location - potentially to be resettled*	2.5 km north of Frieda River airstrip
Green River Station	40 m north of Green River Airport
Sensitive Receptor	**Approximate Distance to River Ports**
Dioru	8 km northwest of Upper Sepik River Port
Samou	11 km east of May River Port
Nekiei	12.8 km southeast of Frieda River Port

* Noise impacts at villages shaded grey have not been assessed as they would have to be resettled.

1.5 Local Topography and Land Use

The open-pits, mine infrastructure area, hydroelectric power facility and ISF are located in mountainous, heavily vegetated terrain in the hill zone at the south-eastern end of the Project. The Vanimo Ocean Port is located some 230 km to the north in the coastal zone where the topography is flatter.

1.6 Existing Climate and Meteorology

PNG has a monsoon-type climate, with the rainfall and temperature being influenced by three large scale wind convergence and rainfall regimes: the Inter-Tropical Convergence Zone, the South Pacific Convergence Zone and the West Pacific Monsoon.

Due to its proximity to the equator, average daily temperatures in PNG are very stable throughout the year without any marked seasonality. Mean daily temperatures at Port Moresby (southern PNG) are 27˚C and show very little variation throughout the year: similarly, average daily temperatures at Solano, Admiralty Islands (far north) are 27˚C (World Bank, 2013).

Western and northern parts of PNG experience the highest rates of precipitation, since the north- and westward-moving monsoon clouds are heavy with moisture by the time they reach these more distant regions. The dry season typically runs from June to September, while the rainy season typically occurs during December to March. Rainfall patterns in PNG are also strongly influenced by the El Niño Southern Oscillation (ENSO) Cycle with droughts in El Niño years and excess rain/flooding in La Niña Years (World Bank, 2013).

Typhoons can occur during the rainy season from December to mid-March, and can cause heavy damage, flooding and erosion (World Bank, 2013).

A detailed review of the meteorology of the project site was performed as part of the air quality and greenhouse gas assessment (SLR, 2016) which concluded that very low wind speed and calm conditions are a dominant feature of the area. Wind data recorded at Moruapie and Nena automatic weather stations (AWS) also showed significant differences in the predominant wind directions which are a result of the topographical features of this large and complex study area. To address this, 3-dimensional meteorological files covering the mine area and FRHEP area (ie open-pit, process plant and ISF meteorological file) was compiled and the results of this analysis has been used to identify appropriate meteorological inputs for the noise modelling as discussed in **Section 2.3.4**.

1.7 Existing Acoustic Environment

SLR (formerly Heggies Pty Ltd) has previously undertaken noise monitoring in coastal and mountainous areas of PNG at locations which are a few hundred kilometres from the Project site. With the exception of Vanimo, sensitive receptors are typically located in rural, mountainous, coastal and riverine areas. Whilst there is significant distance between the previous noise monitoring locations and the Project site, the terrain and expected rural environment (with the exception of Vanimo) is very similar (with the Mine and FRHEP also located within mountainous, coastal and riverine areas). It is therefore reasonable to expect the ambient noise environment would be similar. The range of measured ambient background noise levels at sensitive receptors (ie villages) for the previous PNG studies (Heggies 2009 & Heggies 2009a) are as follows:

- Day (7am to 6pm) - 30 dBA to 43 dBA.
- Evening (6pm to 10pm) - 40 dBA to 49 dBA.
- Night (10pm to 7am) - 34 dBA to 46 dBA.

The previous PNG noise studies (Heggies 2009 & Heggies 2009a) showed that the ambient background noise was dominated by insects, wind noise in foliage, birds, periods of heavy rain and domestic animals, together with typical village activities. The noise study concluded that high insect noise levels are a common feature of the ambient environment. This is due to the tropical weather resulting in little variation in temperature from season to season and whilst the prevalence and activity of individual insect species may vary slightly throughout the year, there is generally a consistent high level of insect activity all year around.

The noise levels in Vanimo are expected to be higher than those shown above however it is unlikely that the noise levels would be lower than those measured in more rural environments (as documented above). Given that no noise monitoring data is available for Vanimo the available background noise monitoring data referenced above has been used to assess the noise impacts at Vanimo, this is considered to be a conservative assessment methodology.

2 Noise Assessment

This section investigates the noise emissions from the Project and includes the following key components:

- Technical Information – a short description of technical terminology and basic concepts used (**Section 2.1**).
- Adopted Project Noise Guidelines – outlines the applicable noise assessment standards and guidelines for the Project (**Section 2.2**).
- Noise Modelling Methodology and Procedures – describes the noise modelling methodologies, procedures and relevant noise modelling data inputs (**Section 2.3**).
- Noise Modelling Scenarios – describes the noise modelling scenarios (**Section 2.4**).
- Noise Predictions and Impact Assessment – presents the results of the noise modelling and an assessment of the predicted noise levels against the adopted Project noise guidelines (**Section 2.5**).

- Noise Mitigation/ Best Practice Management – describes best practice noise management strategies which may be employed for the Project (**Section 2.6**).

2.1 Technical Information – Noise

2.1.1 Standard Noise Indices

This report makes reference to certain noise level descriptors, in particular the L_{Aeq}, L_{A90}, L_{A10} and L_{Amax} noise levels.

- The L_{Aeq} is essentially the average 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 period.
- The L_{A90} noise level is the A-weighted sound pressure level exceeded for 90% of a given measurement period and is representative of the average minimum background sound level (in the absence of the source under consideration), or simply the "background" level.
- The L_{A10} is the A-weighted sound pressure level exceeded for 10% of a given measurement period.
- The L_{Amax} noise level is the maximum A-weighted noise level associated with site activity.
- The $L_{Amax,\ adj\ T}$ noise level is the average of the maximum noise levels during the time period T, adjusted for tonality and impulsiveness.

2.1.2 Typical Noise Levels

Table 3 presents examples of typical noise levels to provide perspective to the noise values that are referred to throughout this report.

Table 3 Typical Noise Levels

Sound Pressure Level (dBA)	Typical Source/ General Reference Level	Subjective Evaluation
130	Threshold of pain	Intolerable
120 110	Heavy rock concert Steel grinding	Extremely noisy
100 90	Loud car horn at 3 m Construction site with pneumatic hammering	Very noisy
80 70	Kerb-side of busy street Loud radio or television	Loud
60 50	Department store General Office	Moderate to Quiet
40 30	Inside private office Inside bedroom	Quiet to Very quiet
20	Unoccupied recording studio	Almost silent

Source: SLR (originally modified from acoustic documents).

2.1.3 A-Weighting or dBA Noise Levels

The overall level of a sound is usually expressed in terms of A-weighted decibels (dBA). Decibel is a unit of sound and the A-weighting refers to a filter that has a frequency response corresponding approximately to that of human hearing.

People's hearing is most sensitive to sounds at mid frequencies (500 Hertz (Hz) to 4000 Hz), and less sensitive at lower and higher frequencies. Thus, the level of a sound in dBA is a good measure of the loudness of that sound.

Different sources having the same dBA level generally sound about equally as loud, although the perceived loudness can also be affected by the character of the sound (eg the loudness of human speech and a distant motorbike may be perceived differently, although they are of the same dBA level).

2.2 Noise Assessment Standards and Guidelines

The primary objective of any environmental noise assessment/policy is to protect people from the adverse effects of noise. Excessive noise has the ability to 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 around the world have developed their own noise policies to protect the health and amenity of residents. 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.

There are no applicable statutory regulations or guidelines which include specific criteria for managing noise and vibration in PNG. PNG has a noise discharge technical guideline (DEC Publication: IB-ENV/03/2004) which does not include noise level criteria but does contain general permit application guidelines.

The *Environment Act 2000* is the primary legislation in PNG that regulates the environmental impact of development activities and how adverse effects of such activities should be avoided, remedied or mitigated. This document references Environmental Codes of Practice and suggests that compliance with an Environmental Code of Practice is generally specified within project-specific environmental permits.

The PNG *Environmental Code of Practice for the Mining Industry, 2000* is relevant to the Project and states, "*Until national regulations are developed, the Worldbank General Environmental Guidelines for ambient noise should be met*".

The noise and vibration assessment has therefore been undertaken in accordance with these guidelines and other relevant noise and vibration criteria from international standards and guidelines, as discussed in the following subsections.

2.2.1 International Finance Corporation World Bank Group (IFC) Noise Guidelines

The IFC's *General Environmental Health and Safety (EHS) Guidelines* (2007) supersede the World Bank Group *General Environmental Guidelines* (mentioned above). The section specific to Environmental Noise Management provides noise level guidelines prescribing day and night period noise levels. The recommendations are replicated below:

> *"Noise impacts should not exceed the levels presented in Table 1.7.1, or result in a maximum increase in background levels of 3 dB at the nearest receptor location off-site.*
>
> ***Table 1.7.1 Noise Level Guidelines***

Receptor	*One Hour LAeq (dBA)*	
	Day (7:00 am -10:00 pm)	*Night (10:00 pm -7:00 am)*
Residential / Institutional /educational	*55*	*45*
Industrial / Commercial	*70*	*70*

> *Highly intrusive noises, such as noise from aircraft flyovers and passing trains, should not be included when establishing background noise level."*

The noise levels indicated in the above table are external noise levels and are based on the WHO guidelines (WHO 1999), with a 15 dBA difference correction applied to the internal level to obtain the external level (also from WHO 1999).

The WHO guidelines suggest that a correction of 15 dBA can be applied to determine the equivalent internal guidelines for a typical house with the windows slightly open, which is consistent with typical western/European construction. Dwellings in rural PNG would typically be made of very lightweight construction with openings (eg no windows or gaps between joins), and a correction of up to 5 dBA is considered more appropriate for this type of dwelling.

The exact definition and intent of the 'background + 3 dBA' guideline is somewhat open to interpretation and the IFC document refers to the use of a trained specialist for determining appropriate measurement parameters. A reasonable interpretation would be to ensure that the L_{Aeq} noise emissions of the industry do not exceed the existing L_{A90} average background level by more than 3 dBA.

2.2.2 WHO Guidelines for Community Noise

The WHO *Guidelines for Community Noise* are based on the outcomes of the WHO expert taskforce meeting held in London in 1999.

The Guidelines provide detailed background information and cover various noise related issues such as hearing impairment (occupational noise), sleep disturbance, and cardiovascular and physiological effects. Recommendations from the WHO Guidelines for various sources and situations, that are relevant for the Project, are provided below.

As discussed above, when determining external noise guidelines from internal guide values, a 5 dBA correction factor is appropriate for villages in the project area.

Day Period (7:00 a.m.–6:00 p.m.)

The WHO guidelines recommend day period noise levels for outdoor living areas as follows:

- 55 dBA L_{Aeq} to "protect the majority of people from being seriously annoyed"; and
- 50 dBA L_{Aeq} to "protect the majority of people from being moderately annoyed".

In addition, the guidelines nominate an internal noise level inside dwellings of 35 dBA L_{Aeq} for the purposes of allowing good speech intelligibility and moderate annoyance. The internal noise level of 35 dBA L_{Aeq} corresponds to an external 40 dBA L_{Aeq}, based on the 5 dBA correction factor adopted for typical dwellings in the project area.

Evening Period (6:00 p.m.–10:00 p.m.)

The WHO guidelines recommend that the sound pressure levels during the evening and night should be 5-10 dBA lower than for the day.

Night Period - Sleep Disturbance (10:00 p.m.–7:00 a.m.)

The WHO guidelines generally prescribe two indoor noise levels at residential locations to ensure that sleep is not adversely affected, being:

- 30 dBA L_{Aeq} for continuous noise (ie 35 dBA L_{Aeq} external to dwelling)
- 45 dBA L_{Amax} at no more than 10-15 times per night (ie 50 dBA L_{Amax} external to dwelling)

The 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, eg, night-traffic in suburban residential areas.

b. Environments in which a combination of noise and vibrations are produced, eg, railway noise and heavy-duty vehicles.

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

The Project includes various sources of noise and vibration (ie mining operational equipment, barging, construction sources and aircraft etc) which may have the potential to exhibit low frequency noise characteristics.

2.2.3 Road Traffic Noise

The Project related road traffic during operation of the main access route is proposed to occur during daylight hours only. The proposed Project noise guideline for daytime intermittent road traffic is based on a 65 dBA noise level from WHO (1999) which allows for speech intelligibility. Therefore a Project noise guideline of 65 dBA LAeq has been adopted for road traffic pass by events to allow for speech intelligibility.

2.2.4 Aircraft Noise Guideline

Maximum aircraft noise levels in the vicinity of the proposed Green River Airport and Frieda River airstrip have been determined using *Acoustics - Aircraft Noise Intrusion - Building siting and construction* (AS 2021:2000) (as discussed in Sections **2.3.6** and **0**). The standard provides a calculation procedure to determine the maximum bypass noise level having consideration of: the distances from the airstrip; offset from the centreline of the runway; differences in elevation between the runway and the assessment point; and specific aircraft types, to calculate maximum allowable noise levels for building uses.

It is expected that the proposed upgraded Frieda River airstrip, and Green River Airport would operate approximately up to seven (7) code 2 commuter aircraft movements per day, respectively. AS 2021 (2000) recommends that a maximum (external) aircraft flyover noise level of 80 dBA is deemed to be acceptable for residential accommodation.

2.2.5 Barge Traffic Noise

The Project noise guideline for barging related noise emissions is a pass by noise emission of 65 dBA L_{Aeq} noise level (from WHO 1999 which allows speech intelligibility) during the daytime period. For night-time barge pass by events, the proposed Project noise guideline is 50 dBA L_{Amax} noise level outside the dwelling (from WHO 1999 to ensure sleep is not adversely affected). The 50 dBA L_{Amax} noise level should not be exceeded more than 10-15 times per night (as outlined in WHO 1999) in order to ensure that sleep is not adversely affected.

2.2.6 Impulsive Noise Sources

Impulsive noise sources associated with construction and operations activities would typically include noise from blasting activities. Blasting can cause high instantaneous sound levels.

The primary concern regarding blasting is to ensure that it does not cause damage to hearing. Studies presented in the WHO guidelines prescribe the following limits for sources such as blasts:

- 140 dB Peak for adults; and
- 120 dB Peak for children.

The above levels are recommended to ensure that the risk of hearing damage is minimised.

Similarly, Australian guidelines (AS 2187.2, 2006) recommend a peak blasting level of no greater than 115 dB, but with allowance for a small percentage (typically 5%) to be up to 120 dB.

2.2.7 Low Frequency Noise

The frequency range of audible noise is typically from 20 Hz to 20,000 Hz. Low frequency noise is defined as the level of noise within the 20 Hz to 250 Hz frequency range. It is typically characterised as a low hum or drone emitted from industrial fixed plant and mobile plant when observed at a distance. It may exist at any construction or mining site and the level and potential impact will vary.

The New South Wales Environment Protection Authority (NSW EPA) *Noise Policy for Industry* (NPI) (2017) outlines 'correction factors' to be applied to the source noise level at the noise sensitive receptor when assessing the impact of low frequency noise. The correction factor is applied to the source noise level in order to account for any potential additional annoyance caused by a noise source which is defined as having low frequency characteristics.

The INP provides the following guidance with respect to the application of a 'correction factor' to account for low frequency noise.

> *A 'correction factor' of +5 dB is to be applied to the predicted source noise level (prior to comparison with the noise criteria) where the difference between the overall C-weighted and A-weighted noise levels for that noise source is greater than or equal to 15 dB.*

C-weighting is an adjustment made to a source noise level that takes account of low-frequency components of noise within the audibility range of humans.

2.2.8 Other Considerations

There are additional social and economic considerations that should be considered when setting noise guidelines and assessment methods.

The nuisance caused by noise is also dependant on a community's relationship with the noise source. For example, in villages that experience high levels of motorised river traffic by locals (resulting in high pass by noise levels), it is not expected that there would be an adverse reaction to similar noise sources being introduced by a project.

Similarly, an industry that provides some form of social or economic benefit to a community may not be considered a nuisance by locals, even if the noise level emission from the industry is considered to be high when compared to most standards.

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

The existing noise environment and annoyance of people to that environment are other factors requiring consideration.

Given that the existing noise environment in Vanimo would consist of noise emissions from logging activities, ship loading and aircraft noise, there is potential for there to be less perceived impact from the addition of noise emissions from the Project in this area. Additional factors such as the economic and social benefits of the Project may further reduce the perceived impact of the noise emissions from operations in Vanimo.

The same consideration for perceived noise impacts could be made for receptors near to both the Frieda River airstrip and Green River Airport, given that there are already noise emissions generated by aircraft using these airports. Social and economic benefits from the upgrade works may also reduce perceived noise impacts from the Project.

The upgrade works for the existing road from Vanimo to Green river may have reduced perceived noise impacts given the social and economic benefits to the local communities which would use this road. There would be direct benefit to these receptors given the road would be upgraded and available for used by these villages.

For the remaining Project areas such as the Mine and FRHEP area, it would be expected that little to no difference in perceived noise impacts may be expected given that these facilities may not directly have a social or economic benefit to the local communities (eg the upgraded road is directly beneficial to the nearby villages). The existing noise environment in these locations is also likely to be absent of any industrial sources of noise, which would be unlikely to result in lower perceived noise impacts.

2.2.9 Summary of Adopted Project Noise Guidelines

The methodology proposed for determining the relevant general guidelines for the operation of the Project is described below. The proposed methodology gives consideration to the IFC and WHO guidelines and aims to achieve an acceptable level of acoustic amenity at residences in the nearby villages. The methodology to determine relevant noise guidelines for the operation is as follows:

1. Determine the existing average background noise level for the particular time period (ie day and night).
2. Where the existing average background noise level + 3dBA for a particular time period results in an L_{Aeq} noise guideline which is lower than the absolute levels in the WHO/IFC guidelines (ie 45 dBA during the daytime and evening and 35 dBA during the night time period), then the relevant WHO/IFC guideline shall apply.
3. Where the existing average background noise level + 3dBA for a particular time period results in an L_{Aeq} noise guideline which is higher than the absolute levels in the WHO/IFC guidelines (ie 45 dBA during the daytime and evening and 35 dBA during the night time period), the 'background + 3dBA' noise guideline shall apply.

The Project noise guidelines for assessment of construction noise emissions during the daytime and evening periods are based on the recommended outdoor noise levels from the WHO and IFC guidelines. The Project noise guidelines for assessment of construction noise emissions during the night time assessment period are based on preventing sleep disturbance at sensitive receptors. This Project guideline for night time construction activities is the same as that adopted for operational activities during the night time period.

The adopted noise guidelines at the nearest sensitive receptors in the vicinity of the Project, with reference to the various activities associated with the mine operations, are presented in **Table 4**.

Table 4 Project Noise Guidelines

Activity / Operation	Noise Guideline (external to building)			Comment
	Day (7.00am to 6.00pm)	Evening (6.00pm to 10.00pm)	Night (10.00pm to 7.00am)	
General Operation Noise (processing plant, works in open-pits etc)	Higher of the existing average[1] background level (L_{A90}) + 3 dBA or 40 dBA L_{Aeq}	Higher of the existing average[1] background level (L_{A90}) + 3 dBA or 40 dBA L_{Aeq}	Higher of the existing average[1] background level (L_{A90}) + 3 dBA or 35 dBA L_{Aeq}	Based on achieving both outdoor and indoor noise limits according to WHO and IFC, and giving consideration to existing background levels.
Construction Noise (construction of primary crushing facility, ROM, process plant, ISF embankment, hydroelectric power facility, Sepik River bridge, Vanimo Ocean Port , pipeline, main access route and River Ports).	55 dBA L_{Aeq}	50 dBA L_{Aeq}	Higher of the existing average[1] background level (L_{A90}) + 3 dBA or 35 dBA L_{Aeq}	. Based on achieving the outdoor noise limits according to WHO and IFC during day and evening, and same as operation for night-time.
Blasting	Typically 115 dBL Peak but up to 120 dBL Peak for small percentage of blasts	Inaudible – no blasting to be conducted at evening	Inaudible – no blasting to be conducted at night	Based on AS 2187.2 and WHO guidelines
Short Term Single Events (other than blasting)	No L_{Amax} guideline suggested	No L_{Amax} guideline suggested	50 dBA L_{Amax}	Primarily concerned with sleep disturbance for night period (WHO)
Road Traffic	65 dBA L_{Aeq}	65 dBA L_{Aeq}	50 dBA L_{Amax}	Based on WHO guidelines
Aircraft Traffic	80 dBA L_{Amax}	80 dBA L_{Amax}	80 dBA L_{Amax}	Based on AS 2021
Barge Traffic	65 dBA L_{Aeq}	65 dBA L_{Aeq}	50 dBA L_{Amax}	Based on WHO guidelines

Note 1: Average refers to the arithmetic average of the 15 minute L_{A90} data measured over the particular period (ie day, evening and night).

All L_{Aeq} noise levels refer to 1 hour averaging time, in accordance with IFC guidelines.

It is noted that the WHO guidelines do not specify a time averaging period for the purposes of noise assessment and therefore an averaging time of 1 hour has been applied to all L_{Aeq} noise levels (with the exception of road traffic and barge noise) in accordance with the internationally recognised IFC noise guidelines. The one (1) hour averaging period is considered appropriate for assessing noise from quasi steady state noise sources such as general operational and construction noise. Given the low numbers of barge and vehicle movements, both barge and road traffic noise pass by events have been assessed using theLAeq noise emission level associated with a single pass by event.

If low frequency noise (20 Hz to 250 Hz frequency range) is determined to be a characteristic of the noise emissions from the Project (both from individual sources or a combination of sources), then a +5 dB ‘correction factor’ would be applied to the predicted source noise level prior to comparison with the noise guidelines documented in **Table 4** in accordance with the NSW INP.

The above guidelines are external to any dwelling, with the assumption that the lightweight house constructions in the villages in the vicinity of the Project are not expected to provide any substantial noise reduction (only 5 dBA has been allowed for). For this Project, the existing average background noise level has been estimated (see **Section 1.7**). Whilst these background noise levels have been considered when determining the appropriate Project noise guideline, a conservative approach of applying the lower noise guideline values from WHO and IFC has been used.

Adoption of a noise guideline based on the 'existing average background level (L_{A90}) + 3 dBA' may be warranted given background noise levels in similar environments have been shown to exceed the WHO and IFC guidelines. In order to apply a site specific guideline using this method, the background noise levels would need to be measured by pre-construction noise monitoring. This approach should be considered for scenarios where noise levels are predicted to exceed the WHO and IFC guidelines adopted for this assessment.

As it is proposed to undertake the majority of operational activities on a 24 hours a day, 7 days a week basis, the most stringent noise guideline level of **35 dBA L_{Aeq}** is applicable for the assessment of these (ie 24 hours a day) Project activities. Construction activities are to be assessed based on the recommended outdoor noise levels in the WHO and IFC guidelines for the daytime and evening periods (**55 dBA L_{Aeq}** and **50 dBA L_{Aeq}** respectively). During the night time period construction noise emissions are to be assessed against the operational night time Project noise guideline value of **35 dBA L_{Aeq}**. This aims to prevent sleep disturbance at sensitive receptors as a result of construction noise emissions. The construction of the concentrate pipeline and main access route is proposed to be short term and undertaken during the daytime hours only. Thus, the applicable Project noise guideline level is **55 dBA L_{Aeq}**.

It is noted that while these general construction and operational guideline levels (**35 dBA L_{Aeq}** for 24 hour activities and **55 dBA L_{Aeq}** for short-term day-time activities) have been applied for assessment purposes, the applicable day, evening and night guideline values (specified in **Table 4**) will still apply to the Project.

2.3 Noise Modelling Procedures and Methodology

This section describes the noise modelling procedures and methodology for the noise assessment. The noise assessment scenarios are discussed in the subsequent section (Section **2.4**).

Noise predictions were formed using two main methodologies, 3D Noise modelling was completed for the majority of operational and construction scenarios such as the Vanimo Ocean Port construction and operations. Spreadsheet calculations were used for more simplified scenarios such as the main access route construction.

The 3D noise model methodology took into account the source SWLs and locations, distance attenuation, ground absorption, air absorption and shielding attenuation, as well as meteorological conditions, including wind effects.

Noise modelling with 3D computational modelling software required various inputs discussed below.

Spreadsheet calculations were undertaken using noise source inputs and offset distance to achieve the Project guideline levels. These calculations considered the source SWLs and locations, distance attenuation, ground absorption, air absorption and default daytime meteorological conditions. Topographical shielding and reflections were not included in spreadsheet calculations.

2.3.1 Noise Modelling Input Information

The following input data was supplied for the purposes of undertaking the noise modelling/prediction component of the assessment:

- Lists detailing the number and type of dominant noise sources associated with each modelling scenario for both the construction (Refer to **Appendix B**) and operation (Refer to **Appendix C**).
- 3D DXF drawings detailing the open-pit mine layouts for the two (2) operation modelling scenarios to be assessed.
- 3D DXF drawing detailing the extent of the ISF.
- 3D DXF drawing detailing topography covering the entire mine area.
- Noise source sound power levels (Refer to **Appendix B** and **C**).

Representative noise source sound power levels were developed from SLR's internal noise source database and provided to Coffey and FRL for confirmation prior to inclusion in the noise model.

The SoundPLAN noise models were set up based on the Project site plans, information on the plant and equipment to be used and the 3D DXF information supplied.

2.3.2 SoundPLAN

In order to calculate the noise emission levels at the nearest noise sensitive receptor locations, SoundPLAN (Version 7.4) environmental computer models were developed. SoundPLAN is a software package that enables compilation of a sophisticated computer model comprising a digitised ground map (containing ground contours and buildings), the location and acoustic sound power levels (SWL) of potentially critical noise sources on site, and the location of sensitive receptors for assessment purposes.

The computer model can generate noise emission levels taking into account such factors as the source SWL and locations, distance attenuation, ground absorption, air absorption and shielding attenuation, as well as meteorological conditions, including wind effects.

All areas (except for water bodies) of the model have been modelled as absorptive (soft) surfaces with a ground absorption coefficient of 1.0. For areas containing water bodies, a ground absorption coefficient of zero has been modelled to account for a reflective surface (ie water).

Noise emission levels have been predicted at the nearest noise sensitive receptor(s) surrounding the proposed Project sites. All receivers have been positioned 1.5 m above ground and assessed under free-field conditions.

Noise predictions have been carried out under both 'neutral' and 'adverse' weather conditions. Neutral predictions assume no adverse or prevailing contribution from meteorological factors and adverse predictions include contributions from prevailing meteorological factors relevant to the Project area.

Noise contour plots have been produced for the nominated SoundPLAN modelling scenarios in the area surrounding the Project site. The noise contour plots are located in the following appendices:

Appendix D Mine area and FRHEP Area Construction including open-pit, primary crushing facility, ROM pad, process plant, ISF embankment and hydroelectric power facility.

Appendix E Construction of the Vanimo Ocean Port.

Appendix F Year 5 Mine Operations.

Appendix G Year 12 Mine Operations.

Appendix H Vanimo Ocean Port Operations.

The SoundPLAN modelling scenarios are discussed in subsequent sections.

2.3.3 CONCAWE

The CONCAWE prediction methodology was utilised within SoundPLAN. The CONCAWE prediction method is specially designed for large industrial facilities (and large mining projects) and incorporates the influence of wind effects and the stability of the atmosphere.

The statistical accuracy of environmental noise predictions using CONCAWE was investigated by Marsh (Applied Acoustics 15 - 1982). Marsh concluded that CONCAWE was accurate to ±2 dBA in any one octave band between 63 Hz and 4 kHz and ± 1 dBA overall.

2.3.4 Meteorological Modelling Conditions

One of the objectives of the noise assessment is to consider the effects of relevant meteorological conditions (wind, temperature, humidity and temperature inversions) on noise propagation from the Project sites. The relevant meteorological conditions used for the noise modelling have been determined in accordance with common practice techniques used for various mining projects being developed within Australia (ie the guidelines presented in the NSW EPA NPI).

In order to determine the appropriate meteorological parameters for the noise modelling study, meteorological modelling using CALMET has been performed. CALMET is a diagnostic meteorological model that develops wind and temperature fields on a three-dimensional gridded modelling domain. Associated two-dimensional fields such as stability class are also included in the file produced by CALMET. The interpolated wind field and stability class field is then modified within the model to account for the influences of topography, as well as differential heating and surface roughness associated with different land uses across the modelling domain. These modifications are applied to the winds at each grid point to develop a final wind field. The final meteorological field, including wind and stability classes, thus reflects the influences of local topography and land uses.

A detailed analysis was undertaken to characterise prevailing weather conditions at the project sites as part of the air quality assessment for the Project (SLR 2018).

Year 2014 annual meteorological data (the most recent available) was analysed by SLR using the CALMET meteorological model to determine prevailing wind and atmospheric conditions and to determine whether noise modelling should account for enhanced propagation conditions.

Weather data for modelling and analysis of weather parameters was not available at the time of this assessment for the Vanimo Ocean Port area, therefore default worst case weather parameters have been used in accordance with the common practice techniques used for various mining projects developed within Australia.

Wind Effects

A summary of the annual wind behaviour predicted by CALMET for the mine area and FRHEP area are presented in **Appendix I**. The wind roses indicate that winds at the mine area predominantly blow from the northeast during daytime and southwest during night-time.

As such, the wind roses indicate that wind is a prevailing condition for the mine area.

Default daytime meteorological (inclusive of wind) conditions were used for all spreadsheet calculations (refer to **Table 6**).

Temperature Inversion

The other meteorological effect to be considered is that of temperature inversions. A temperature inversion occurs during relatively calm, stable atmospheric conditions where a layer of colder air is trapped nearer to the ground surface by a layer of warmer air, which causes little or no vertical air movement. The layers can cause a great refraction of sound waves which may increase noise levels at the receptor locations.

Temperature inversions occur during stable atmospheric conditions (low winds and clear skies) and typically between dusk and dawn. Atmospheric stability refers to the tendency of the atmosphere to resist or enhance vertical motion. Stability classes A through to F are used to categorise the degree of atmospheric stability which in turn relates to the likelihood of a temperature inversion occurring. **Table 5** provides a description of the Atmospheric Stability Classes.

Table 5 Description of Atmospheric Stability Classes

Surface wind speed (m/s)	Daytime insolation			Night-time conditions	
	Strong	Moderate	Slight	Thin overcast or > 4/8 low cloud	<= 4/8 cloudiness
< 2	A	A - B	B	E	F
2 - 3	A - B	B	C	E	F
3 - 5	B	B - C	C	D	E
5 - 6	C	C - D	D	D	D

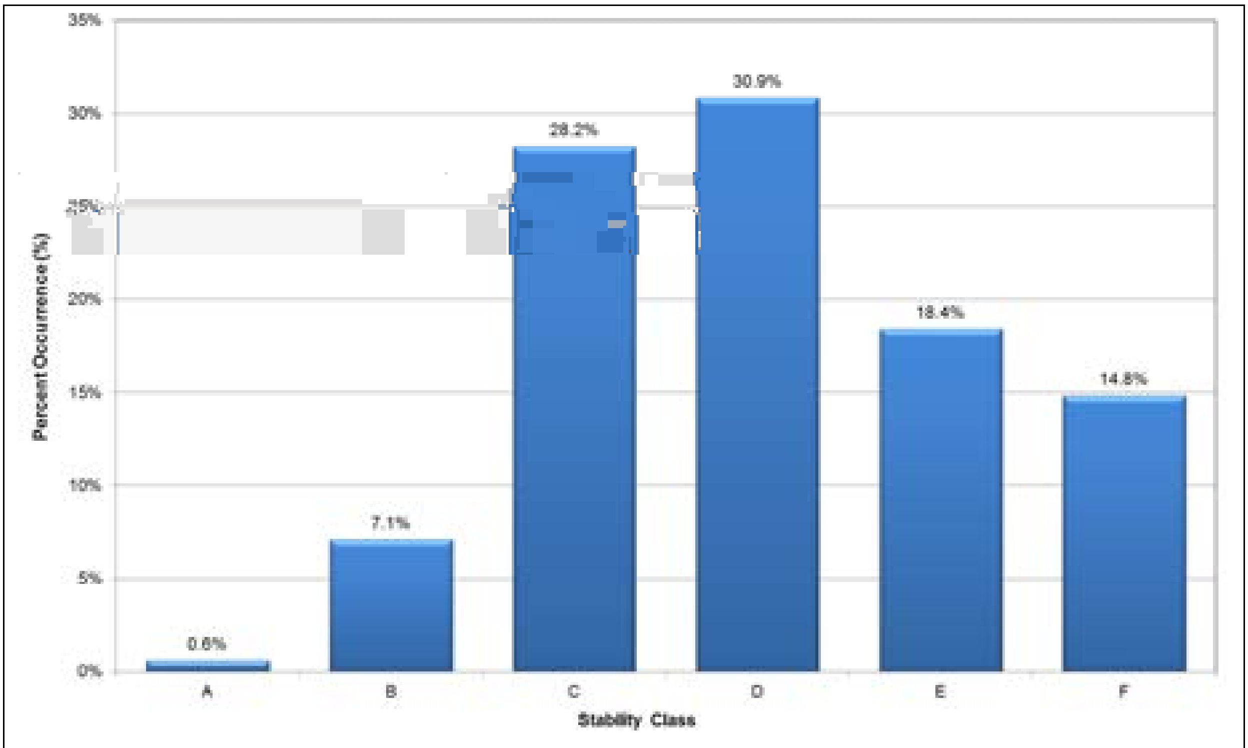
Surface wind speed (m/s)	Daytime insolation			Night-time conditions	
	Strong	Moderate	Slight	Thin overcast or > 4/8 low cloud	<= 4/8 cloudiness
> 6	C	D	D	D	D

Source: Pasquill, 1961

Atmospheric Stability Class F represents the conditions in which temperature inversion are likely to occur. Class D represents neutral conditions, where temperature inversions are unlikely to occur.

The calculated frequency of temperature inversions for the project site is shown in **Figure 4**.

Figure 4 Atmospheric Stability Class Frequencies, as Predicted by CALMET (2014)



Temperature inversion was not found to be a prevailing weather condition for the mine area and FRHEP area and as such has not been included in the modelling of this area.

Default daytime meteorological conditions (considering temperature inversions) were used for all spreadsheet calculations (refer to **Table 6**).

Modelled Meteorological Parameters

Based on an analysis of available meteorological data described above and default weather parameters used in common practice for projects of this nature, the weather conditions used for the different modelling scenarios (applicable for both construction and operations) are presented in **Table 6**. For all modelling scenarios, a neutral weather condition has been modelled. For the mine area and FRHEP area downwind has been modelled as an adverse weather condition and for the Vanimo Ocean Port temperature inversions has been modelled as an adverse weather condition.

Table 6 Modelled Meteorological Parameters

Modelling Scenario	Mine Area		Vanimo[2]	
Weather Conditions	Neutral Weather	Adverse Weather	Neutral Weather	Adverse Weather
Temperature	20°C	20°C	20°C	20°C
Humidity	70%	70%	70%	70%
Pasquill Stability Category[1]	D	D	D	F
Wind Speed	0 m/s	2 m/s	0 m/s	3 m/s
Wind Direction	N/A	Downwind (source to receiver)	N/A	Downwind (source to receiver)
Temperature Inversion	No	No	No	Yes

Note 1. The Pasquill Stability Class D refers to neutral atmospheric turbulence (ie no temperature inversion) and Pasquill Stability Class F has been selected to represent temperature inversions for the purposes of this assessment.

Note 2. Default industry standard meteorological conditions have been used for Vanimo given that no detailed weather data was available for analysis.

Meteorological data for Vanimo was not available for analysis, as a result default weather parameters for both neutral and adverse scenarios (refer to **Table 6**) have been used for 3D noise modelling.

Spreadsheet calculations used default daytime weather parameters for neutral weather representative of the daytime period, when these activities are likely to occur (refer to **Table 6**).

2.3.5 Other Factors Affecting the Noise Propagation

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

Topographical Effects

Local topography can significantly affect the propagation of noise, especially if the project activities are conducted through areas with steep terrain. The extent of change in noise levels due to topographical effects would be dependent on the level of shielding provided (which would be very much site specific). The actual degree of noise attenuation due to topographical shielding is a function of the frequency spectrum of the noise and the length of the diffracted noise path compared to the direct noise path.

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, and up to approximately 15 dBA where the topography provides optimal blocking of the sound transmission path.

The effect of topographical shielding is taken into account in the 3D modelling and noise predictions for the modelling scenarios described in **Section 2.3.2**.

Vegetation Attenuation

Dense forest increases the amount of sound absorption along the noise propagation path. The increased sound absorption of typical forest vegetation is estimated to be between 0.02 to 0.1 dBA per metre of propagation distance for distances between 20 m and 200 m. For less than 20 m of forest vegetation there is no attenuation. For more than 200 m of forest vegetation the maximum attenuation achieved is approximately 15 to 20 dBA. No corrections for vegetation attenuation were considered

2.3.6 Low Frequency Noise

The low frequency component of the noise emissions from the Project site have been considered in accordance with the principles of the NSW EPA NPI as there are no relevant guidelines within the PNG regulatory system. This is typically assessed as follows:

- Initial screening test – assesses the source noise contributions at the noise sensitive receptor locations to ensure that the overall linear (flat) noise level predicted at the noise sensitive receptor does not exceed 50 dBL.
- Secondary screening test – compares the difference between the C-weighted noise levels and the A-weighted noise levels. If there is a difference of greater than 15 dBA between these two values for the 20 Hz to 250 Hz frequency range, then some consideration of low frequency noise would be warranted.

There is potential for operations at the Vanimo Ocean Port to exceed the screening test criterion level of 50 dBL. Given that the exact fleet and equipment to be used has not yet been determined and that the third-octave spectral data for this equipment is not yet known it is recommended that low frequency noise is considered when the exact fleet (and corresponding third-octave noise data) is available.

Following an analysis of the above screening tests, for all noise sensitive receptors under all other modelling scenarios, no exceedances of the 50 dBL noise levels occurred.

Therefore, no correction factors due to low frequency noise components are required at any sensitive receptors at this stage.

2.3.7 Tonal and Impulsive Noise

The noise assessment considers the impact of both tonal and impulsive noise sources (where applicable) by applying the relevant corrections to the appropriate noise source(s) in order to account for these characteristics. As no prominent frequencies were observed during a review of the predicted noise levels and associated noise spectrum, no corrections were required for tonal noise sources in this assessment. No impulsive noise is expected at any of the existing sensitive receptors due to the substantial buffer distance between any of the Project work sites and identified existing sensitive receptors.

Where there are smaller buffer distances between sensitive receptors and Project related noise sources, such as along the main access route and concentrate pipeline construction corridor, no impulsive noise generating plant is expected to be in use.

Noise emissions from the concentrate thickener may warrant consideration of tonal adjustments given that the concentrate thickener will likely be in continuous operation. Given that that concentrate thickener is over 10 dBA below the loudest noise source at the Vanimo Ocean Port and that the buffer distance from the concentrate thickener at the process plant to the nearest sensitive receptor is large, even with a tonal correction of 5 dBA in line with the NSW EPA NPI, noise emissions from the concentrate thickener would not significantly change noise emissions generated by the Project.

Assessment of the tonality of noise emissions from the concentrate thickeners would ultimately need to be conducted upon receiving detailed supplier data or through noise measurements.

2.4 Modelling Scenarios – Construction and Operation

This section describes the noise modelling scenarios.

Two main Project sites have been identified for assessment using 3D computer modelling consisting of:

- Mine area – open-pit, primary crushing facility, ROM pad, process plant, ISF embankment and hydroelectric power facility.
- Vanimo Ocean Port.

The remaining Project sites and facilities have been assessed using off-set distance calculations. Noise predictions from offset distance calculations have assumed flat open ground (ie no topographical shielding) between the noise sources and the receptor under default neutral weather conditions. Any further assessment has been undertaken based on a review of likely noise sources and proximity of nearest sensitive receptors.

Table 7 summarises the noise assessment scenarios, including the noise generating activities associated with each site that have been assessed for this Project and the method of assessment for each Project Site. The noise generating equipment (ie dominant noise sources) associated with these site activities are also provided. For most scenarios, many noise sources have been considered and thus the full equipment list in Appendix B and Appendix C has been referenced.

Table 7 Summary of Noise Assessment Scenarios

Project Site	Noise Generating Activities	Dominant Noise Sources	Prediction/ Assessment Method	Scenario Type/ Year
Construction				
Mine area	Clear and grub, pre-strip mining, blasting, facilities assembly.	Appendix B, Table B1 and B2	3D Computer Modelling	Worst Case
Vanimo Ocean Port	Construction of storage facility and docking area.	Appendix B, Table B6 source list	3D Computer Modelling	Worst Case
Frieda River Port, Upper Sepik River Port and May River Port	Construction of the River Ports	Appendix B Table B3 source list	Offset Distance Calculations	Worst Case
concentrate pipeline, transmission line and main access route	Clear and grade, earthworks, possible blasting	Appendix B, Table B4 source list	Offset Distance Calculations	Worst Case
Barging (Materials Transport)	Operation of aluminum landing crafts	Aluminum landing crafts	Offset Distance Calculations	Worst Case
Frieda River airstrip and Green River Airport	Clear and grade, earthworks, construction sources	Appendix B, Table B5 source list	Offset Distance Calculations	Worst Case
Quarries	Clear and grade, earthworks, possible blasting	Appendix B, Table B4 source list	Offset Distance Calculations	Worst Case
Sepik River bridge	Impact Piling	Appendix B, Table B7 source list	Offset Distance Calculations	Worst Case
Operation				
Mine area	Blasting, hauling and dumping of rock, operation of crushing facilities, ongoing construction and operation of ISF, operation of hydroelectric power facility	Appendix C, Table C1 and C2 source list	3D Computer Modelling	Year 5 Year 12 (peak operation)
Main access route – Road Traffic	Operation of heavy vehicle trucks and buses	Heavy vehicle trucks, buses	Offset Distance Calculations	Typical Operations
Frieda River airstrip and Green River Airport	Take-off and landing of code 2 commuter aircraft	Code 2 commuter aircraft	Offset Distance Calculations	Typical Operations
Vanimo Ocean Port	Storage facility operations and loading/unloading of ship	Appendix C, Table C3	3D Computer Modelling	Worst Case

Notes:

Dominant Noise Sources – Where many noise sources have been included in the assessment scenario, reference has been made to the applicable Equipment List in Appendix B and Appendix C,

3D Computer Modelling – SoundPLAN (Version 7.4) environmental computer model comprising digitised ground map.

Offset Distance Calculations – noise predictions have assumed flat open ground between the noise sources and the receptor.

Worst Case Scenario – construction plant and equipment simultaneously operating according to construction equipment information supplied by FRL.
Typical Operations – scenario representative of typical operations at the facility.

Each of the construction and operational scenarios for the various Project sites are discussed in the following subsections.

2.4.1 3D Noise Modelling Scenarios – Construction

Representative cases for the construction phase of the Project have been determined for the following 3D modelling scenarios:

- Mine area (open-pit, primary crushing facility, ROM pad, process plant, ISF and hydroelectric power facility).
- Vanimo Ocean Port.

The mobile (and fixed) plant and equipment and associated SWL for each modelling scenario are presented in **Appendix B**. The equipment list has been supplied by FRL with SWLs taken from relevant standards and using in house noise measurement data from SLR.

3D noise prediction models have been developed in SoundPLAN for the above modelling scenarios. Predicted construction noise levels will inevitably depend upon the number of plant items and equipment operating at any one time and on their precise location relative to the sensitive receptor(s). Therefore, a sensitive receptor will experience a range of values representing "minimum" and "maximum" construction noise emissions depending upon:

- The location of the particular construction/operation activity (ie if the plant item of interest is as close as possible to or further away from the sensitive receptor of interest).
- The likelihood of the various items of equipment operating simultaneously.

2.4.2 Concentrate Pipeline and Main Access Route – Construction

The mobile plant and equipment and associated SWLs for construction of the concentrate pipeline and main access route between Vanimo and the mine area are presented in **Appendix B**.

The construction of the concentrate pipeline and main access route will be a short-term event at any one location as it progressively moves along the route. Therefore, worst case noise levels have been predicted for the road and pipeline construction which are representative of the maximum noise levels as the clear and grade construction front passes any one location (the clear and grade stage has the loudest construction equipment associated with it).

The clear and grade modelling scenario has assumed the mobile plant and equipment would be distributed over approximately a 500 m moving front. This is considered to be a short-term construction event (taking days or weeks not months). The road construction is proposed to only be carried out during daylight hours and a higher noise level can be accepted during day and evening periods (refer to the noise guidelines **Section 2.2.9**) compared to the night-time period.

The average rate of progress for the construction of the road and pipeline has been estimated as approximately 200 m per week, based on 4 work fronts constructing approximately 30 km of access road over a twelve (12) month period. It is noted that the clear and grade construction stage is likely to have a faster progress rate than some of the work following behind.

2.4.3 Barging (Materials Transport) – Construction Phase

During the construction of the main access route there will be a maximum of 1 barge trip per day (ie one (1) return trip) along the Sepik River during daylight hours only to facilitate transport of materials during construction of the mine area. The vessel will be a 23 m, 12 m wide, 150 DWT capacity aluminium landing craft. A SWL of 102 dBA is assumed for the aluminium landing craft based on measurements on similar size barges (ie 110 tonne).

Noise emissions from the aluminium landing craft have been predicted at the nearest sensitive receptors along the shoreline of the May, Frieda and Sepik River barging corridors.

2.4.4 Sepik River Bridge - Construction

The Sepik River bridge construction activities are expected to take place during the daytime assessment period only. Typical bridge construction equipment has been used as per the equipment list presented in **Appendix B**.

2.4.5 Green River Airport and Frieda River Airstrip - Construction

The nearest sensitive receptors to the Green River Airport are approximately 100 m north (Green River) of the site. The nearest sensitive receptor to the Frieda River airstrip is located approximately 2.5 km (Paupe) from the site, with some receptors 1.9 km from the runway based on aerial imagery.

The worst-case construction noise scenario associated with the upgrade to the airports is expected to be similar to that for the clear and grade of the access road. The mobile plant and equipment and associated SWLs for construction of the Airports and Airstrips are presented in **Appendix B**.

2.4.6 Quarries – Construction

There will be quarries associated with the construction of some Project infrastructure (ie roads etc). These quarries will be located 300 m or more from the nearest sensitive receptors.

2.4.7 3D Noise Modelling Scenarios – Mine Operation

In order to provide representative noise impacts across the life of the mine, the mobile and fixed plant and equipment associated with the Project has been assessed for the following scenarios:

- **Year 5** – Mining in the Ekwai and Koki open-pits is proposed to occur during the first seven (7) operational years only. While Year 4 is proposed to have relatively high activity rates in Ekwai Pit with mining also occurring in the Koki pit, Year 5 has significantly higher activity rates for the Koki Pit but no mining in Ekwai. Given that the Koki pit is located furthest from the HIT pit and the processing area, modelling the highest activity rates at Koki was prioritised over modelling activities in Ekwai, hence Year 5 was selected for assessment. This year also has a higher mining rate for HIT and a higher processing throughput.

- **Year 12** – The Year 12 scenario represents the period of peak activity rates of ore and waste rock extraction. The ore and waste rock would be extracted from the HIT open-pit only for this scenario. The Year 5 operations represent operations five years after the mine opening. The Year 5 operations scenario includes mobile and fixed plant and equipment associated with vegetation clearance for expansion of the open-pit. The Year 12 operations scenario is during peak operation with the maximum number of mobile and fixed plant and equipment.

During both Year 5 operations and Year 12 operations, the hydroelectric power facility will be operating under typical conditions.

3D SoundPLAN noise prediction models have been developed for the above modelling scenarios. Within the noise model, operations consisted of all plant and equipment operating concurrently in order to simulate the overall maximum potential noise emission for each scenario. The mine operation modelling scenarios also include dominant noise sources associated with the primary crushing facility, ROM pad, overland conveyor belt, process plant, ISF embankment, waste rock barges and hydroelectric power facility.

The plant and equipment and associated SWL for each modelling scenario are presented in **Appendix C**.

2.4.8 3D Noise Modelling Scenario – Vanimo Ocean Port Operation

For the operation of Vanimo Ocean Port, a 3D SoundPLAN noise prediction model was developed representative of the worst-case operation conditions at the port. The dominant noise sources assumed to be operating simultaneously at any one time for this scenario are shown in **Appendix C**.

2.4.9 Main Access Route Traffic

The traffic volumes on the main access route are below those required to accurately predict noise levels using the normal road prediction models. The Project related traffic volumes include approximately 200 truck movements (semi-trailers with 12 m trailers) and 10 buses per day during the peak of the construction phase of the Project and approximately 80 truck movements and 8 buses per day during the peak of operation.

Noise impacts from heavy vehicle movements have therefore been assessed by predicting L_{Aeq} pass by noise levels at offset distances from the main access route.

2.4.10 Aircraft Operation

Aircraft noise emission levels from Green River Airport and Frieda River airstrip have been predicted using the procedure detailed in AS 2021 (2000). Assuming noise emission levels for light aviation as specified in AS 2021 (2000), the minimum distance to achieve the guideline of 80 dBA flyover noise level for take-off and landing have been predicted.

2.5 Noise Impact Assessment

This section presents predicted noise levels assessed against the relevant Project noise guidelines (refer to **Section 2.2.9**) for the modelling scenarios as defined above (Section **2.4**).

2.5.1 Mine Area – Construction

Predicted noise levels associated with the construction of the open-pit, primary crushing facility, ROM pad, process plant, ISF embankment and hydroelectric power facility are presented as noise contour plots in **Appendix D** for both neutral and adverse weather conditions (refer **Table 6**). Based on the adverse weather noise contours in **Appendix D**, the required offset distance to achieve compliance with the adopted Project noise guideline of 35 dBA L_{Aeq} have been determined and are presented in **Table 8**. If the noise guideline (35 dBA) for night-time is achieved, the applicable noise guideline for the daytime and evening will also be achieved.

Table 8 Predicted Offset Distances to Achieve the Night-time Noise Guideline – Mine Area Construction – Adverse Weather Conditions

Construction Site	Night-time Noise Guideline [1] (dBA LAeq)	Predicted Offset Distance to Achieve the Noise Guideline (m)
Open-pit	35	500 - 1900 [2]
Primary crushing facility and ROM pad	35	800 - 1800[2]
Process plant	35	2100 - 4800[2]
ISF embankment and hydroelectric power facility	35	2100 - 5000[2]

Note 1: The guideline values based on achieving both outdoor and indoor noise limits according to WHO and IFC, and giving consideration to existing background levels.

Note 2: The noise emission from mine area construction can differ significantly depending on the location of the plant and equipment as well as the topography and soft ground (ie vegetated ground) or hard ground (ie water body). Therefore, a range of offset distances have been presented.

The nearest sensitive receptor to any of the open-pit, primary crushing facility, ROM pad and process plant construction sites is Wameimin 2 which is approximately 7.5 km from the open-pit construction work site.

The nearest sensitive receptor to any of the ISF and hydroelectric power facility construction sites is Paupe which is approximately 6.5 km from the hydroelectric power facility construction work site.

The predicted worst-case construction noise is less than 35 dBA at both these receptors.

No adverse noise impacts are predicted from the construction of the open-pit, primary crushing facility, ROM pad, process plant, ISF embankment and hydroelectric power facility.

2.5.2 Vanimo Ocean Port - Construction

Predicted noise levels associated with the construction of the Vanimo Ocean Port as noise contour plots are presented in **Appendix E** for both neutral and adverse weather conditions (refer **Table 6**). Based on the adverse weather noise contours in **Appendix E**, the required offset distance to achieve compliance with the adopted Project noise guideline of 35 dBA L_{Aeq} has been determined as 2.7 km to the east and northeast of the site and 2.7 km to the south and southeast of the site. The daytime noise guideline of 55 dBA L_{Aeq} has been predicted to require an offset distance of 520 m to the east from the border of the Vanimo Ocean Port construction activities, in the direction of the nearest sensitive receptors. The daytime noise guideline has been predicted to require an offset distance of 550 m from the boundary to the south and southeast of the Vanimo Ocean Port construction site.

The nearest sensitive receptors to the Vanimo Ocean Port construction site are 50 m to the east (Wesdeco), and approximately 100 m to the south and southeast (Vanimo) of the site and are predicted to exceed the daytime noise guideline during the Vanimo Ocean Port construction.

Predictions of construction noise emissions from the Vanimo Ocean Port do not account for screening from existing dwellings in Vanimo. Typically noise emissions would be expected to be significantly lower past the first row of dwellings (assuming a solid building construction) potentially impacting a significantly lower number of receptors.

Existing logging activities in Vanimo may already result in similar noise levels at the sensitive receptors within Vanimo during daytime hours.

The majority of sensitive receptors within Vanimo are predicted to have noise levels in excess of the Project noise guideline of 35 dBA during the Vanimo Ocean Port Construction.

2.5.3 River Ports – Construction

A worst case offset distance calculation has been made for the construction of the Frieda River Port, May River Port and Upper Sepik River Port using adverse weather conditions (refer **Table 6**). Based on the adverse weather noise predictions, it is demonstrated that the relevant Project noise guideline of 35 dBA L_{Aeq} is achieved at distances greater than approximately 3.5 km from the all of the River Port construction sites.

The nearest villages to the Frieda River Port, Upper Sepik River Port and May River Port construction sites are Nekkei, Dioru and Samou, 12.8 km, 8 km and 11 km from the River Port construction sites respectively. The predicted noise levels at these sensitive receptors are below the relevant Project noise guideline of 35 dBA from the construction work site.

No adverse noise impacts are predicted from the construction of the Frieda River Port, Upper Sepik River Port or the May River Port.

2.5.4 Concentrate Pipeline and Main Access Route – Construction

Worst case noise levels as a function of distance from the noise source have been predicted for the construction of the concentrate pipeline and main access route between the mine area and Green River Station with the same methodology adopted for the road upgrade works and concentrate pipeline construction works between Green River and Vanimo. The highest predicted noise levels are for the clear and grade as a progressively moving front (refer to **Section 2.4.2**).

The noise predictions have assumed flat open ground between the noise sources and the receptor. It should be noted that topographical shielding and/or dense vegetation between the road construction and the receptor(s) can significantly reduce noise levels to below the predicted noise levels (refer to **Section 2.3.5**).

The road construction is only expected to be carried out during daytime hours. The predicted offset distance to achieve the noise guideline during daytime is presented in **Table 9**.

Table 9 Predicted Offset Distances to Achieve the Construction Noise Guideline – Concentrate Pipeline and Main Access Route Construction

Time Period	Project Guideline (dBA LAeq) [1]	Predicted Offset Distance to Achieve the Guideline (m)
Day (7am to 6pm)	55	300

Note 1: The guideline values based on achieving both outdoor and indoor noise limits according to WHO and IFC, and giving consideration to existing background levels.

The main access route and concentrate pipeline construction works pass within 300m of ten (10) existing villages including;

- Wokomo 2 (90 m)
- Dioru (20 m)
- Green River Station (30 m)
- Aminii (10 m)
- Kwomtari (300 m)
- Itomi (140 m)
- Kilifas (30 m)
- Sumumini (20 m)
- Imbrinis (25 m)
- Vanimo (15 m)

There may be potential for the concentrate pipeline and main access route construction activities to cause noise impacts where potential receptors in the abovementioned villages are within 300 m of the concentrate pipeline and main access route construction activities.

The concentrate pipeline and road construction, when passing receptors, will be short term and likely to last for only a few days as the construction front passes. Making residents aware of likely future occurrence of noisy activities can significantly reduce annoyance.

Locations with dense vegetation and/or some topographic shielding between construction and receptor(s) may have situations where the noise guideline is achieved at shorter offset distances compared to those presented in **Table 9**.

2.5.5 Sepik River Bridge - Construction

Based on aerial imagery, a potential sensitive receptor is situated approximately 2.5 km from the Sepik River bridge construction activities.

The Sepik River bridge construction is only expected to be carried out during daytime hours. The predicted offset distance to achieve the Project noise guideline during daytime is presented in **Table 10**.

Table 10 Predicted Offset Distance to Achieve the Construction Noise Guideline – Sepik River Bridge Construction

Time Period	Project Guideline (dBA LAeq)[1]	Predicted Offset Distance to Achieve the Guideline (m)
Day (7am to 6pm)	55	1000

Note 1: The guideline values based on achieving both outdoor and indoor noise limits according to WHO and IFC, and giving consideration to existing background levels.

Noise from the Sepik River bridge construction works is expected to be below the daytime project noise criteria at distances over 1.0 km from the site.

No adverse noise impacts from the Sepik River bridge construction are expected during the daytime period.

2.5.6 Barging (Materials Transport) – Construction Phase

While the main access route is being constructed, the Sepik, Frieda and May Rivers will be used to transport materials during construction of the mine area. There will be a maximum of 1 barge trip per day equalling two pasty’s (ie one (1) return trip) along the respective river barging corridors during daylight hours only. A SWL of 102 dBA is assumed for the aluminium landing craft based on measurements on similar size barges (ie 110 tonne).

There are no sensitive receptors along the riverbank of the Frieda River between the confluence with the Sepik River and the Frieda River port. The width of the Sepik River at the identified villages along the riverbanks and the resulting noise emission levels at these villages are presented in **Table 11**. The Sepik River is more than 300 m wide for most of the distance to the coast. Therefore, the distance between the barging corridor and sensitive receptors along the Sepik River is approximately 150 m.

Table 11 Predicted Barge Passy Noise levels at Villages along May and Sepik Rivers

Village	River Width at Villages (m) [1]	L_{Aeq} Passy Noise Level (dBA)
Sepik Riverbank		
Iniok	370	49
Other villages	~300 m	55 to 60 dBA
May Riverbank		
Potential unidentified villages	~300 m	55 to 60 dBA

Note 1: It is assumed that the separation distance to the villages from the barge pass by would be at least half the river width.

Note 2: Exact distances of villages to the likely barging corridor are unknown so noise levels have been predicted based on approximate river width along the May River.

There is no accurate data available for potentially noise sensitive receptors along the May River barging corridor. The width of the May River is approximately 300 m, resulting in L_{Aeq} pass by noise levels between 55 and 60 dBA.

The pass by noise emissions from the barging on the Sepik River during daylight hours achieve the Project noise guideline of 65 dBA L_{Aeq} noise level from WHO, which allows speech intelligibility during the daytime period.

There are no identified sensitive receptors along the Frieda River barging corridor.

The barging pass by noise emissions are not expected to cause adverse noise impact at the sensitive receptors along the River shorelines.

2.5.7 Airports – Construction

The worst-case construction noise scenario associated with the construction of the airports is expected to be similar or less than that from the clear and grade for the access road (ie 300 m). Similar mobile plant and equipment as for the concentrate pipeline and main access route clear and grade has been assumed (see **Appendix B**).

The nearest sensitive receptor to the Frieda River airstrip is Paupe which is located approximately 1.9 km away from Frieda River airstrip. No adverse noise impacts are expected from the construction of the Frieda River airstrip.

The Green River Airport is located approximately 40 m from the nearest potential noise sensitive receptors at Green River Station. There is potential that adverse noise impacts may be generated by construction works at these receptors within 300 m of the Green River Airport.

2.5.8 Quarries – Construction

There will be a number of quarries associated with the construction of some infrastructure (ie roads, ISF etc). These quarries are located more than 300 m from the nearest sensitive receptors. The worst-case construction noise scenario associated with quarry construction activities is expected to be similar or less than that from the clear and grade for the access road (ie 300 m). Therefore, no adverse noise impacts are expected from these quarries.

These quarries are further assessed with respect to ground vibration and air blast overpressure from blasting in **Section 3.5**.

2.5.9 Mine Operation Year 5 (Phase)

Predicted noise levels associated with the Year 5 mine operation, including noise from the open-pit, primary crushing facility, ROM pad, process plant and ISF are presented as noise contour plots in **Appendix F** for both neutral and adverse weather conditions (refer **Table 6**). Based on the adverse weather noise contours in **Appendix F**, the required offset distance to achieve compliance with the adopted Project noise guideline of 35 dBA L_{Aeq} have been determined and are presented in **Table 12**. If the noise guideline (35 dBA) for night-time is achieved, the applicable noise guideline for the daytime and evening will also be achieved.

Table 12 Predicted Offset Distances to Achieve the Night-time Noise Guideline – Mine Operation Year 5 – Adverse Weather Conditions

Project Site	Night-time Noise Guideline[1] (dBA LAeq)	Predicted Offset Distance to Achieve the Noise Guideline (m)
Open-pit	35	1000 – 4,400[2]
Primary crushing facility and ROM pad	35	1,100 – 1,600[2]
Processing plant	35	2,800 – 4,500[2]
ISF and hydroelectric power facility	35	300 –600[2]

Note 1: The guideline values based on achieving both outdoor and indoor noise limits according to WHO and IFC, and giving consideration to existing background levels.

Note 2: The noise emission from mine area can differ significantly depending on the location of the plant and equipment as well as the topography and soft ground (ie vegetated ground) or hard ground (ie water body). Therefore, a range of offset distances have been presented.

The nearest sensitive receptor to any of the open-pit, primary crushing facility, ROM pad and process plant sites is Wameimin 2, which is approximately 7.5 km from the open-pit. The predicted noise level associated with the Year 5 mine operation is less than 35 dBA at this receptor.

The nearest sensitive receptor to the hydroelectric power facility is Paupe which is located approximately 6.5 from the hydroelectric power facility site. The predicted noise level associated with the Year 5 mine operations is less than 35 dBA at this receptor

No adverse noise impacts are predicted from the Year 5 mine operations, which include noise from the open-pit, primary crushing facility, ROM pad, process plant, ISF and hydroelectric power facility.

2.5.10 Mine Operation Year 12 (Peak Operation)

Predicted noise levels associated with the Year 12 mine operation (including noise from the open-pit, primary crushing facility, ROM pad, process plant, ISF and hydroelectric power facility) are presented as noise contour plots in **Appendix G** for both neutral and adverse weather conditions (refer **Table 6**)**.** Based on the adverse weather noise contours in **Appendix G**, the required offset distance to achieve compliance with the adopted Project noise guideline of 35 dBA L_{Aeq} have been determined and are presented in **Table 13**. If the noise guideline (35 dBA) for night-time is achieved, the applicable noise guideline for the daytime and evening will also be achieved.

Table 13 Predicted Offset Distances to Achieve the Night-time Noise Guideline – Mine Operation 12 – Adverse Weather Conditions

Project Site	Night-time Noise Guideline[1] (dBA LAeq)	Predicted Offset Distance to Achieve the Noise Guideline (m)
Open-pit	35	600 – 2,600[2]
Primary crushing facility and ROM pad	35	1,100 – 1,900[2]
Processing Plant	35	3,000 – 4,600[2]
ISF and hydroelectric power facility	35	300 –600[2]

Note 1: The guideline values based on achieving both outdoor and indoor noise limits according to WHO and IFC, and giving consideration to existing background levels.

Note 2: The noise emission from mine area can differ significantly depending on the location of the plant and equipment as well as the topography and soft ground (ie vegetated ground) or hard ground (ie water body). Therefore, a range of offset distances have been presented.

The nearest sensitive receptor to any of the open-pit, primary crushing facility, ROM pad, process plant sites is Wameimin 2 which is approximately 7.5 km from the open-pit. The predicted noise level associated with the Year 12 mine operation is less than 35 dBA at this receptor.

The nearest sensitive receptor to the hydroelectric power facility is Paupe which is located approximately 6.5 from the hydroelectric power facility site. The predicted noise level associated with the Year 12 mine operations is less than 35 dBA at this receptor.

No adverse noise impacts are predicted from the Year 12 mine operations, which include noise from the open-pit, primary crushing facility, ROM pad, process plant, ISF and hydroelectric power facility.

2.5.11 Vanimo Ocean Port Operation

Predicted noise levels associated with the Vanimo Ocean Port operation (ie concentrate storage, conveyor belts, container yard pad and ship loading) are presented as noise contour plots in **Appendix H** for both neutral and adverse weather conditions (refer **Table 6**). Based on these contours, it is shown that at distances of more than approximately 2.3 km to the east and northeast and 2.5 km to the south and southeast from the nearest boundary of the Vanimo Ocean Port operations, the predicted noise levels are below the relevant Project noise guideline of 35 dBA L_{Aeq}.

They daytime Project noise guideline of 40 dBA L_{Aeq} is achieved at distances between m and 1,900 m to the east and northeast of the Vanimo Ocean Port boundary during operations. At distances of 1,800 m or more to the south of the Vanimo Ocean Port boundary the daytime Project noise guideline is achieved.

The nearest sensitive receptors to the Vanimo Ocean Port operational site are 50 m to the east, and approximately 100 m to the south and southeast of the site and are predicted to exceed the daytime noise guideline during operation of the Vanimo Ocean Port.

Predictions of operational noise emissions from the Vanimo Ocean Port do not account for screening from existing dwellings in Vanimo. Typically noise emissions would be expected to be significantly lower past the first row of dwellings (assuming a solid building construction) potentially impacting a significantly lower number of receptors.

Receptors in Vanimo would already be subject to noise emissions from existing port and other infrastructure operations in the area. The resultant noise environment may not differ considerably from the existing noise environment in Vanimo with the current logging operations. However, this would need to be confirmed prior to commencement of operations to ensure that, where applicable, appropriate noise management measures are incorporated.

The majority of existing dwellings within Vanimo are predicted to exceed the relevant Project noise guideline of 35 dBA L_{Aeq}.

2.5.12 Main Access Route Traffic

The traffic volumes on the main access route are below those required to accurately predict noise levels using the normal road prediction models. The Project related traffic volumes include approximately 200 truck movements (semi-trailers with 12 m trailers) and 10 buses per day during the peak of the construction phase of the Project and 80 truck movements and 8 bus movements per day during the peak of the operation phase of the Project.

Noise impacts from heavy vehicle movements have therefore been assessed by predicting pass by noise levels at offset distances from the main access route. It is expected that the main access route will only be used during daylight hours, as a result, only the daytime Project noise guideline has been assessed for the main access route.

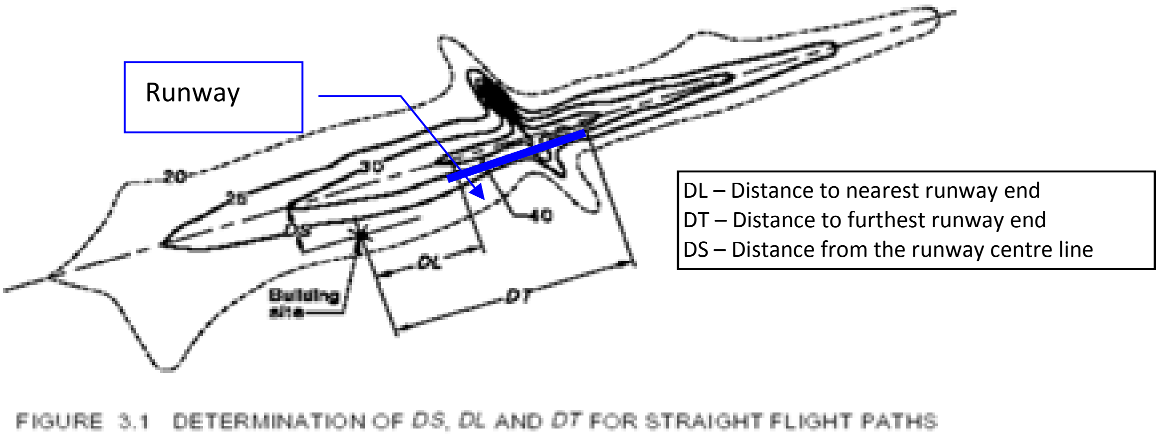
The predicted L_{Aeq} noise emission level at 10 m from the road for a semi-trailer (medium truck) travelling at approximately 50 km/hr on cruise throttle is 65 dBA (FHWA 1998). At 10 m or more from the road the pass by noise levels would be equal to or below the Project noise guideline of 65 dBA L_{Aeq}.

According to the WHO Guideline (WHO 1999), noise levels above approximately 65 dBA may interfere with speech communication. No sensitive receptors are identified to be located within 10 m of the main access route, as such, compliance with the Project noise guideline is predicted for all receptors along the main access route.

2.5.13 Aircraft Noise - Operation

Aircraft flyover noise levels have been predicted assuming only light aviation aircraft will be operating. The assumed noise emission levels from the aircraft are as specified in AS 2021 (2000). The adopted Project noise guideline for maximum (external) aircraft flyover noise level is 80 dBA (refer to **Section 2.2.4**). Noise emission levels from aircraft fly-over have been predicted at two offset distances from the runway, with the receptor located in line with the flight path (worst case) and a receptor located 300 m off the flight path centreline. The predicted offset distances refer to distance to the nearest runway end (DL) and the furthest runway end (DT). The distance from the runway centre line is defined as DS. The DL, DT and DS are shown in **Figure 5**.

Figure 5 Definition of Distances to Nearest (DL) and Furthest (DT) Runway Ends



The offset distances at which the guideline is achieved are shown in **Table 14**.

Table 14 Predicted Offset Distances to Achieve the Aircraft Flyover Guideline

Location	Project Guideline (dBA LAmax)[1]	Predicted Offset Distance to Achieve the Guideline (m)
Worst case – dwelling in line with the runway centre line	80	1,900 to the nearest runway end (DL) 3,300 to the furthest runway end (DT)
Dwelling 300 m from the runway centre line	80	500 to the nearest runway end (DL) 1,500 to the furthest runway end (DT)

Note 1: Project noise guidelines for aircraft operational noise based on AS2021.

As can be seen in **Table 14**, the predicted offset distance to achieve an aircraft flyover noise level of 80 dBA is up to 1.9 km from the nearest end of the runway. If the dwelling is set off to the side of the flight path centreline, the offset distance is significantly less (ie in the order of 500m from the nearest runway).

There are no existing sensitive receptors within 1.9 km of the Frieda River airstrip (measured from the nearest runway end ie DL). Paupe is the nearest village located to Frieda River airstrip approximately 1.9 km from the nearest runway end (DL) of the Frieda airstrip. The nearest sensitive receptors in Paupe are slightly offset from the runway centre line of the Frieda River airstrip resulting in a required offset distance of less than 1.9 km.

Using aerial imagery, there are potential sensitive at Green River Station as close as 40 m to the Green River Airport. These sensitive receptors would be likely to exceed the Project noise guideline. It should be noted that the Green River Airport is currently operational and that the additional flights required as part of the Project, would not be expected to result in a significant increase in maximum noise levels above those already experienced at these sensitive receptors.

2.5.14 Summary of Noise Assessment

Table 15 presents a summary of the predicted noise impacts from the various facilities and noise sources associated with the Project.

Table 15 Summary of Noise Assessment

Project Site	Noise Generating Activities	Dominant Noise Sources	Noise Level Guideline	Nearest Receptor	Summary of Noise Assessment	Mitigation
Construction						
Mine area and FRHEP	Clear and grub, pre-strip mining, blasting, facilities assembly.	Appendix B, Table B1 and B2	35 dBA LAeq	Wameimin 2 (7.5 km)	Predicted noise levels <35 dBA at nearest noise sensitive receptors. **No adverse noise impacts**	Not required
Vanimo Ocean Port	Clear and grade, earthworks, construction of buildings (concentrate storage, container storage area etc), wharf construction	Appendix B, Table B6 source list	35 dBA LAeq	Wesdeco (east) (50 m) Vanimo (South) (100 m) Cis Point (Northeast) (1.2 km)	Predicted noise levels >55 dBA at noise sensitive receptors within 550 from the construction site to the east. Predicted noise levels >55 dBA at noise sensitive receptors within 520 m from the construction site to the south. Predicted noise levels between 35 and 40 dBA at nearest sensitive receptors at Cis Point.	**Section 2.6.1**
Frieda River Port, Upper Sepik River Port and May River Ports	Construction of the River Ports	Appendix B, Table B3	35 dBA LAeq	Nekki (8 km), Dioru (8 km) and Samou (11 km)	Predicted noise levels <35 dBA at nearest noise sensitive receptors. **No adverse noise impacts**	Not required
Concentrate pipeline and main access route	Clear and grade, earthworks, possible blasting	Appendix B, Table B4 source list	55 dBA LAeq	Ten (10) Villages within 300 m of the alignment.	Predicted noise level is <55 dBA at distances of >300 m from the pipeline and road alignment. Potential for some short-term noise impact at receptors located <300 m from	**Section 2.6.1**

Project Site	Noise Generating Activities	Dominant Noise Sources	Noise Level Guideline	Nearest Receptor	Summary of Noise Assessment	Mitigation
					the proposed pipeline alignment in the ten (10) identified villages.	
Barging (Materials Transport)	Operation of aluminium landing crafts	Aluminium Landing Crafts	65 dBA LAeq	Iniok (>60 m)	Predicted noise levels below 65 dBA at nearest identified sensitive receptors. Short duration (<1 minute) and low number of events (2 barge pass by events per day). **No adverse noise impacts**	Not required
Green River Airport and Frieda River airstrip	Clear and grade, earthworks, construction sources	Appendix B, Table B5 source list	35 dBA LAeq	Paupe (1.9 km) Green River Station (40 m)	Predicted noise levels <25 dBA at Paupe. Potential noise impacts at nearby receptors in Green River Station.	**Section 2.6.1**
Quarries	Clear and grade, earthworks, possible blasting	Appendix B, Table B4 source list	35 dBA LAeq	Paupe (400 m) Temsapmin (460 m)	**No adverse noise impacts**	Not required
Sepik River bridge	Bridge Construction	Appendix B, Table B7 source list	35 dBA LAeq	Aerial imagery only (2.5 km)	**No adverse noise impacts**	Not required
Operation						
Mine area (Year 5)	Blasting, hauling and dumping of ROM, operation of crushing facilities, ISF and hydroelectric power facility.	Appendix C, Table C1 source list	35 dBA LAeq	Wameimin 2 (7.5 km)	Predicted noise levels <35 dBA at nearest noise sensitive receptors. **No adverse noise impacts**	Not required
Mine area (Year 5)	Blasting, hauling and dumping of ROM, operation of crushing facilities, operation of ISF, operation of hydroelectric power facility	Appendix C, Table C2 source list	35 dBA LAeq	Wameimin 2 (7.5 km)	Predicted noise levels <35 dBA at nearest noise sensitive receptors. **No adverse noise impacts**	Not required
Main access route –	Operation of heavy vehicle	Heavy vehicle	65 dBA LAeq	Aminiii (10 m)		Not required

Project Site	Noise Generating Activities	Dominant Noise Sources	Noise Level Guideline	Nearest Receptor	Summary of Noise Assessment	Mitigation
Road Traffic	trucks and buses	trucks, buses			**No adverse noise impacts**	
Vanimo Ocean Port	Loading of ship, docked ship, container storage and concentrate conveyor operation.	Appendix C, Table C3	35 dBA LAeq	Wesdeco (east) (50 m) Vanimo (South) (100 m) Cis Point (Northeast) (1.2 km)	Predicted noise levels >35 dBA at distances less than 2.5 km from the Vanimo Ocean Port. Predicted noise levels >40 dBA at noise sensitive receptors within 1,900 m from the site to the east. Predicted noise levels 40dBA at noise sensitive receptors within 1,800 m from the site to the south. Predicted noise levels >45 dBA at noise sensitive receptors at Cis Point.	**Section 2.6.2**
Green River Airport, and Frieda River airstrip	Take-off and landing of code 2 commuter aircraft	Code 2 commuter aircraft	80 dBA LAmax	Paupe (1.9 km) Green River (40 m)	Predicted noise levels <80 dBA at nearest noise sensitive receptors to the Frieda River airstrip. Potential for noise impacts in Green River Station at nearest sensitive receptors.	**Section 2.6.2**

2.6 Noise Management Measures

2.6.1 Construction

Based on the findings of the noise impact assessment (see **Section 2.5**), the only potential adverse noise impacts during construction activities are predicted for the Vanimo Ocean Port, Green River Airport and the concentrate pipeline and main access route construction and operation of the main access route.

2.6.1.1 Concentrate pipeline and main access route

The concentrate pipeline and main access route construction represents a relatively short-term impact and should be mitigated through the following management measures at the ten (10) sensitive receptors identified in **Section 2.5.4**. The major noise sources for these construction works (ie the clear and grade works) are the dump trucks, rock breaker and compactor. The following measures can be considered in order to minimise and manage noise impacts from the construction of the concentrate pipeline and main access route:

- Notify each village, as the concentrate pipeline and main access route construction works approach, of the times and duration that they may be affected by noise emissions from the works.
- Provide clear communication methods so that the affected communities have access to effective communication links to the operational managers, and any substantiated complaints can be addressed appropriately and sensitively.
- Where possible, limit these construction activities to the daytime, or schedule significant noise generating activities during the daytime .Horn signals should be kept at a low volume, where feasible.
- Limit vehicle speed on roads and the use of compression brakes when accessing and within the construction area.
- Conduct noise monitoring, where appropriate, at sensitive receptors that are located near the concentrate pipeline and main access route in response to complaints and/or to verify construction noise levels.
- If required, the concentrate pipeline and main access route corridor may have some flexibility in design to allow minor deviations to minimise or avoid potential noise impacts at sensitive receptor locations.

2.6.1.2 Green River Airport

The Green River Airport construction will be a relatively short term impact and should be mitigated through the following measures at the nearest sensitive receptors. The dominant noise sources for this construction scenario (ie the clear and grade works) are the dump trucks, rock breaker and compactor. The following measures can be considered in order to minimise and manage noise impacts from the construction of the Green River Airport:

- Notify each receptor as the Green River Airport construction works begin, of the times and duration that they may be affected by noise emissions from the works.
- Provide clear communication methods so that the affected communities have access to effective communication links to the operational managers, and any substantiated complaints can be addressed appropriately and sensitively.
- Where possible, limit these construction activities to the daytime, or schedule significant noise generating activities during the daytime.

- Horn signals should be kept at a low volume, where feasible.
- Limit vehicle speed on roads and the use of compression brakes when accessing the Green River Airport construction site.
- Conduct noise monitoring, where appropriate, at sensitive receptors that are located near the Green River Airport in response to complaints and/or to verify construction noise levels.
- Complete noisiest construction activities during the daytime period to avoid adverse noise impacts during the night time period.
- Where possible, store equipment and materials to form noise barriers (such as using raw materials as temporary noise bunds during construction where practicably possible).

2.6.1.3 Vanimo Ocean Port

The Vanimo Ocean Port construction will be a relatively short term impact and should be mitigated through the following measures at the nearest sensitive receptors. The dominant noise sources during the construction works for the Vanimo Ocean Port are the dump trucks, piling rig and the compactor. The following measures can be considered in order to minimise and manage noise impacts from the construction of the Vanimo Ocean Port:

- Notify each receptor as the Vanimo Ocean Port construction works begin, of the times and duration that they may be affected by noise emissions from the works.
- Where possible, limit these construction activities to the daytime, or schedule significant noise generating activities during the daytime.
- Provide clear communication methods so that the affected communities have access to effective communication links to the operational managers, and any substantiated complaints can be addressed appropriately and sensitively.
- Horn signals should be kept at a low volume, where feasible.
- Limit vehicle speed on roads and the use of compression brakes when in Vanimo or accessing the construction site.
- Conduct noise monitoring, where appropriate, at sensitive receptors that are located near the Vanimo Ocean Port in response to complaints and/or to verify construction noise levels.
- Complete noisiest construction activities during the daytime period to avoid adverse noise impacts during the night time period.
- Where possible, store equipment and materials to form noise barriers (such as using raw materials as temporary noise bunds during construction where practicably possible).

For all other Project related construction activities there are no predicted noise impacts and therefore specific noise mitigation measures are not warranted.

2.6.2 Operation

Based on the findings of the noise assessment (see **Section 2.5**), the only potential adverse noise impacts during operational activities are predicted for the Vanimo Ocean Port, Green River Airport and the main access route.

2.6.2.1 Vanimo Ocean Port

Whilst noise impacts at Vanimo are predicted, the existing noise environment may not change significantly as there are already industrial activities (ie logging activities) at the port location which generates noise emissions with similar characteristics. However, this would need to be confirmed prior to commencement of construction and operations to ensure that, where applicable, appropriate noise management measures are incorporated. The dominant noise sources during operation of the Vanimo Ocean Port are the conveyor, tug boats and barges. General mitigation measures from the Vanimo Ocean Port operations can be minimised and managed through the below methods:

- Conduct a noise assessment of the Vanimo Ocean Port facility operations upon finalisation of the port design and operations in order to confirm the extent of any noise impacts from the site. This assessment should be inclusive of background noise measurements to establish existing background noise levels.
- Consider noise impacts during the detailed design of the facility inclusive of the specific design of plant items such as the conveyor, locations of plant items and tugboats.
- Investigate quieter alternatives to the noisiest plant items such as the conveyor, tugboats and barges.
- Maintain fixed and mobile plant regularly.
- Communicate non-routine noise events to relevant sensitive receptors.
- Provide clear communication methods for community complaints.
- Investigate noise emissions from the Project should a complaint be received.
- Communicate any compliant findings to on site personnel.
- Operators of equipment to be made aware of the potential noise emissions and of techniques to reduce noise emissions through a continuous process of operator education.
-

2.6.2.2 Green River Airport

Noise emissions generated by the Project at Green River Airport during operations will be similar to those already generated by the Green River Airport. Whilst noise impacts are predicted at sensitive receptors in Green River Station, the overall acoustic environment is likely to be similar to the existing acoustic environment, given the existing operation of the Green River Airport. The only adverse noise impacts generated by the Green River Airport are from the aircraft arrival and departure. The following measures can be considered in order to minimise and manage noise impacts from the Green River Airport:

- Schedule aircraft movements during the daytime period to minimise sleep disturbance and annoyance.
- Engage with the localised community at Green River Station to notify them of the scheduled flights and potential noise impacts.
- Keep flight schedules consistent where practicable so that the localised community are aware of the timing of potential noise impacts after initial consultation.

Although the abovementioned measures are specific for each activity, a selection of typical noise management measures which could be implemented wherever noise mitigation and management may be required are provided in **Section 2.6**.

There are no other adverse noise impacts predicted for Project related operational activities.

2.6.3 Best Practice Noise Management Strategies

Although the findings of the noise assessment indicate that predicted noise levels are generally within the adopted Project noise guidelines, good practice noise management measures may be considered appropriate in specific circumstances (ie where a noise complaint is received). The typical best practice noise management strategies that could be implemented, if required, are discussed below.

Source Noise Control and Project Design Strategies

- Ensure fixed plant and equipment are regularly maintained.
- Consider noise impacts during design and location of significant infrastructure.
- Provide enclosures and partial enclosures of fixed plant and equipment (eg conveyors etc).
- Use existing topography to shield the nearest noise sensitive receptors from dominant noise sources.
- Construct bunds and noise barriers.
- Install low-noise exhaust systems on mobile plant (eg excavators etc).

Work Practice Control Strategies

- Where possible, limit high noise generating activities to times when residents are not sleeping (ie daytime).
- Operators of construction equipment to be made aware of the potential noise emissions and of techniques to reduce noise emission through a continuous process of operator education.
- Large rocks are to be placed in dump trucks not dropped.
- Horn signals should be kept at a low volume, where feasible and applicable.
- Limit vehicle speed on roads and the use of compression brakes, where applicable.

Community Liaison Strategies

- Conduct community consultation to provide information to the community and maintain positive relations.
- Communicate the findings of a complaints investigation to construction site personnel.
- Residents are to be made aware of the times and duration of construction and operation activities that may potentially cause noise impacts. Making residents aware of likely future occurrence of noise significantly reduces annoyance and allows people to make arrangements accordingly.
- Implement a community awareness program inviting representative groups of the community to a short, concentrated noise and vibration briefing prior to commencement of works near or within their community.

- Provide clear communication methods for community complaints.
- Investigate noise emissions from the Project should a complaint be received.

3 Vibration

This section investigates ground vibration (from both blasting and construction sources) and airblast emissions from the Project and includes the following key components:

- Technical Information – a short description of technical terminology and basic concepts used (**Section 3.1** and **3.2**).
- Vibration and Airblast Guidelines – outlining the applicable vibration and airblast assessment standards and guidelines for the Project (**Section 3.3**).
- Vibration and Airblast Predictions (including methodology) – describes the vibration and airblast prediction methodologies and data inputs in addition to presenting the predicted vibration levels (**Section 3.4**).
- Vibration and Airblast Impact Assessment – provides an assessment of the predicted vibration and airblast levels against the applicable vibration guidelines (**Section 3.5**).
- Vibration and Airblast Management/Control Measures – describes typical vibration and airblast management practices which may be implemented on the Project (**Section 3.6**).

The key vibration intensive activities related to the Project which are to be assessed include:

- Blasting activities (open-pit, ISF, quarries, main access route and concentrate pipeline construction); and
- General construction and operation vibration sources (excluding blasting) such as rock breaking, heavy vehicles, compaction, etc.

3.1 Technical Information - Vibration

Humans are far more sensitive to vibration than is commonly realised. They can detect and possibly even be annoyed by vibration levels that are well below those causing any risk of damage to a building or its contents.

The actual perception of motion or vibration may not, in itself, be disturbing or annoying. An individual's response to that perception, and whether the vibration is "normal" or "abnormal", depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as "normal" in a car, bus or train is considerably higher than what is perceived as "normal" in a shop, office or dwelling.

Human tactile perception of random motion, as distinct from human comfort considerations, was investigated by Diekmann and subsequently updated in DIN 4150-2 (1999). On this basis, the resulting degrees of perception for humans are suggested by the continuous vibration level categories given in **Table 16**.

Table 16 Vibration Levels and Human Perception of Motion

Approximate Vibration Level	Degree of Perception
0.10 mm/s	Not felt
0.15 mm/s	Threshold of perception
0.35 mm/s	Barely noticeable
1 mm/s	Noticeable
2.2 mm/s	Easily noticeable
6 mm/s	Strongly noticeable
14 mm/s	Very strongly noticeable

Note: These approximate vibration levels (in floors of building) are for vibration having frequency content in the range of 8 Hz to 80 Hz.

While humans can detect and possibly even be annoyed by vibration levels that are well below those causing any risk of damage to a building or its contents; it is the fear of structural damage to the complainant's property that is the primary cause of complaints and has the potential to cause individual stress and anxiety (Scannell, 1995).

Scannell (1995) also refers to research that shows the important psychological factors influencing the human reaction to stressful vibration events are predictability and to some extent controllability. The research shows that the individual(s) negative reaction to the vibration events can be reduced if they are predictable (ie the individual/building occupant is kept well informed of scheduled events).

3.2 Technical Information – Airblast Overpressure

Airblast is the pressure wave (sound) produced by the blast and transmitted through the air. The sources of airblast include a usually small air pressure pulse generated by the ground vibration, a direct air pressure pulse generated by the rock movement during blasting and an air pressure pulse caused by direct venting of gases from the region of the blast. It is important to recognise that airblast may be reflected by layers within the atmosphere and that the airblast may be refocused at distances remote from the blast.

Airblast may be heard by people if it contains energy in the audible frequency range, typically between 20 Hz and 20 kHz. A blast perceived as loud may have a low airblast level and a blast that is barely noticeable outdoors may have a high airblast level.

At distances where both effects are above perceptible levels, airblast is usually felt after any ground vibration. Ground-transmitted vibration waves from a blast normally travel faster than the air-transmitted airblast overpressure.

Airblast is generally the cause of more complaints than ground vibration.

Airblast levels that are barely noticeable are much lower than those that will cause damage.

3.3 Vibration Assessment Standards and Guidelines

The primary objective of the vibration assessment is to protect people from the adverse effects of vibration. Excessive vibration has the ability to cause nuisance, including sleep deprivation, stress and increased blood pressure, as well as other physical, physiological and psychological effects.

While considering theses effects vibration guidelines also have to allow for businesses and industries to be able to operate without having to comply with unnecessarily stringent requirements. The vibration guidelines described below have been determined with the above-mentioned considerations in mind.

There are no relevant standards or guidelines available in PNG with regard to vibration or airblast emissions. Therefore, the vibration assessment has been performed based on the most relevant international standards and guidelines.

There will be buildings constructed by the Project that will be of conventional structure, they do not form part of this assessment.

It is expected that the major source of ground vibration associated with the Project would be due to blasting (both ground vibration and airblast overpressure) conducted within the open-pit. In addition to blasting, impacts from other general construction and operation vibration generating sources such as rock breaking, heavy vehicles and compaction activities will also be addressed as part of this assessment.

The following sections describe the relevant Project specific vibration and airblast guideline values for these categories.

3.3.1 Blast Guideline - Ground Vibration

Vibration can affect human comfort and also result in structural damage in buildings if it is of a sufficiently high level. The level of vibration required to cause building damage is significantly higher than that which will cause discomfort to occupants.

Specific vibration building damage criteria are provided in British Standard BS 7385 (1993). *Evaluation and measurement for vibration in buildings Part 2: Guide to damage levels from groundborne vibration* and the United States Bureau of Mines (USBM) (1980). Similarly, Appendix J4 of Australian Standard AS 2187.2 (2006) *Explosives - Storage and Use Part 2: Use of Explosives* contains human comfort limits for ground vibration from blasting.

A summary of the blasting vibration guidelines proposed for the Project (based on abovementioned criteria) for both building damage and human comfort are provided in **Table 17**.

Table 17 Vibration Guidelines - Building Damage and Human Comfort

Guideline Type	Vibration level, Peak Component Particle Velocity, mm/s	Guideline Source Reference
Building Damage	15 mm/s at 4 Hz, increasing to 20 mm/s at 15 Hz and further increasing to 20 mm/s at 40 Hz 20 mm/s above 40 Hz	BS 7385-2 criteria values for "prevention of minor or cosmetic damage"
	5 mm/s at 1 Hz increasing to 12.7 mm/s at 4 Hz, 12.7 mm/s between 4 Hz and 15 Hz, rising to 50 mm/s at 40 Hz and above	USBM RI 8507 "Safe blasting vibration level criteria"
Human Comfort	5 mm/s for 95% of blasts, up to 10 mm/s maximum. Based on operation for more than 12 months.	AS 2187.2 - commonly used criteria by regulatory authorities

Table 17 shows that the 5 mm/s human comfort criterion is the most stringent of all the above vibration guidelines and is therefore considered appropriate for assessment of vibration from blasting activities associated with the Project.

The applicable **ground vibration blasting** guideline adopted for use in this study **is 5 mm/s for 95% of blasts**, maximum of 10 mm/s (percentiles are assumed over a period of 12 months).

3.3.2 Blast Guidelines – Airblast Overpressure

Airblast can cause discomfort to persons and, at high levels, damage to structures and architectural elements.

Appendix J5 of AS 2187.2 (2006) refers to airblast limits (peak sound pressure level, dBL) for both human comfort and building damage:

- Building damage – 133 dBL for airblast with a frequency above 6 Hz; and
- Human comfort – 115 dBL for 95% of blasts, up to 120 dBL maximum. Based on operation for more than 12 months.

The 115 dBL human comfort criterion is the most stringent of all airblast guidelines and is therefore considered appropriate for assessment of airblast from blasting activities associated with the Project.

The applicable **airblast overpressure blasting** guideline adopted for use in this study **is 115 dBL for 95% of blasts**, maximum of 120 dBL (percentiles are assumed over a period of 12 months).

3.3.3 Construction and Operation Vibration Guidelines

When dealing with construction vibration (excluding blasting), the effects can be divided into the following main categories:

- Human comfort;
- Structural damage;
- Safe vibration levels for common services; and
- Effects of vibration on building contents.

The vibration assessment has been based on the relevant international standards British Standard BS 6472 (1992). *Evaluation of human exposure to vibration in buildings (1 Hz to 80 Hz)*, BS 7385-2 (1993), German Standards DIN 4150-2 (1999). *Structural Vibration Part 2: Human Exposure of Vibration in Buildings* and German Standards DIN 4150-3 (1999). *Structural Vibration Part 3: Effects of Vibration on Structures*.

It is noted that the most stringent vibration guideline of the above four (4) main categories is the human comfort criteria. The human comfort criteria are also considered to be relevant regardless of the type of residential dwelling. Therefore, only the human comfort criteria are presented in full below, however both human comfort and structural damage have been considered in the assessment.

3.3.3.1 Human Comfort

Table 16 (**Section 3.1**) suggests that people will just be able to feel continuous floor vibration at levels of about 0.15 mm/s and that the motion becomes “noticeable” at a level of approximately 1 mm/s.

The most substantial guidance in relation to assessing the potential human disturbance from ground-borne vibration inside buildings and structures is contained in BS 6472 (1992).

Satisfactory magnitudes of peak vibration velocity (ie below which the probability of "adverse comment" is low) from BS 6472 (1992) are shown in **Table 18**.

Table 18 Satisfactory Level or Peak Vibration Velocity (8 Hz to 80 Hz)

Type of Space Occupancy	Time of Day	Satisfactory Peak Vibration Levels in mm/s Over the Frequency Range 8 Hz to 80 Hz			
		Continuous Vibration		Impulsive Vibration with up to 3 Occurrences per Day	
		Vertical	Horizontal	Vertical	Horizontal
Residential	Day Night	0.3 to 0.6 0.2	0.8 to 1.6 0.6	8.4 to 12.6 2.8	24 to 36 8

Note: Other types of Occupancy described in the Standard have not been included as they are not relevant to the Project area.

Activities which may be considered as continuous vibration sources associated with the construction and operation phases of the Project may include compaction works (vibrator rollers); rock drilling/breaking; haul truck operation and mineral processing.

Acceptable levels of vibration for continuous vibration sources (ie compaction activities etc) are significantly lower than for short duration (and infrequent) vibration events such as from blasting.

The applicable **non-blasting vibration** guidelines adopted for use in this study, based on the aforementioned international standards and guidelines are shown below in **Table 19** for the various categories of criteria.

Table 19 Construction and Operation Vibration Guidelines – Summary

Guideline Category	Guideline Values (mm/s)		Guideline Source Reference
	Day	Night	
Human Comfort (residential)	0.3 to 0.6	0.2	BS 6472; DIN 4150-2
Structural Damage	12.5	12.5	BS 7385; DIN 45130-3
Common Services[1] – Telecommunications services	50	50	DIN 45130-3
Building Contents	0.5 to 0.9	0.5 to 0.9	BS 6472; DIN 4150-2

1. Other 'Common Services' are relevant to Project infrastructure (rather than to sensitive receptors in the Project area) and are therefore not applicable to this assessment.

3.4 Vibration Estimations

Given a sufficiently high vibration level, the potential adverse effects of vibration in buildings generated by large mine projects are threefold:

- Occupants or users of the building may be inconvenienced or possibly disturbed;
- The building contents may be disturbed or affected; and
- Cosmetic or structural building damage may be induced.

The vibration study methodology used includes assessment of the potential vibration impacts associated with:

- Blasting activities (open-pit, ISF, quarries, main access route and concentrate pipeline construction); and
- General construction and operation vibration sources (excluding blasting) such as rock breaking, heavy vehicles, compaction, impact piling, etc.

The general methodology for predicting vibration (and airblast) emissions from these activities is described in the following sections.

3.4.1 Blast Estimation Methodology

Ground vibration and airblast emission levels have been predicted using the formulae given in the AS 2187-2 (2006) and ICI Explosives Blasting Guide, applicable to blasting in average rock.

In the absence of Project site specific data, the generic blast emission formulae used in this assessment generally give a conservative estimate of the blast emission levels. The relevant formulae are as follows:

PPV =	$1140\ (R/Q^{0.5})^{-1.6}$	(free face) Applicable for open-pit and Quarries.
PPV =	$5000\ (R/Q^{0.5})^{-1.6}$	(heavily confined blast, where no free face exists) Applicable for road construction.
dB =	$164.2 - 24(\log_{10} R - 0.33 \log_{10} Q)$	(free face and confined blasts)
Where:		
PPV =	Ground vibration in Peak Particle Velocity Level (mm/s)	
dB =	Peak airblast level (dBL)	
R =	Distance between charge and receptor (meters)	
Q =	Maximum Instantaneous Charge (MIC) mass per delay (kilograms)	

The level of blast emissions can be estimated using the above-mentioned formulae and incorporating the nominated typical blast designs (discussed below).

Offset distances required to achieve the airblast guideline of 115 dBL and ground vibration guideline of 5 mm/s have been determined based on the prediction formulae and the specified blast design parameters for the corresponding activity (ie open-pit, ISF, quarries and road and pipeline construction).

3.4.1.1 Typical Blast Design Parameters

The typical blast design parameters assumed for this assessment are presented in **Table 20** (open-pit), **Table 21** (ISF/quarries) and **Table 22** (road/pipeline construction).

The relationship between distance, and the ground vibration and peak airblast from blasting have been determined for the representative MIC values. The representative MIC value for the open-pit was supplied by FRL. For the quarries and road construction typical MIC values have been assumed based on SLR's previous experience from similar activities.

Table 20 Indicative Blast Design Details – Open-pit

Parameter	Free Face
Bench height	15.0 m
Blasthole spacing	9 m
Burden	8 m
Maximum Instantaneous Charge (MIC)	1500 kg

Table 21 Indicative Blast Design Details – ISF/Quarries

Parameter	Free Face
Bench height	7.5 m
Blasthole spacing	4.5 m
Burden	3.9 m
Maximum Instantaneous Charge (MIC)	110 kg

Table 22 Indicative Blast Design Details – Road/Pipeline Construction

Parameter	Confined (No Free Face)
Bench height	Various
Blasthole spacing	Various
Burden	Various
Maximum Instantaneous Charge (MIC)	50 kg (assumed maximum)

3.4.2 Construction and Operation Vibration Estimation Methodology

The methodology for estimating potential vibration impacts from general construction and operation vibration sources (excluding blasting) associated with the Project is described below.

A review of all construction and operation plant and equipment was carried out in order to identify potential sources of vibration emissions. The following vibration sources have been identified for assessment:

- Rock breaking.
- Heavy vehicle movement.
- Compaction activities (vibratory rollers).
- Impact piling

Typical vibration source levels for the identified vibration generating items of plant and equipment have been determined from SLR's vibration source reference database of measured vibration levels. The measured vibration levels were obtained using calibrated vibration monitoring equipment with measurements taken at various offset distances from the source in order to determine the level of vibration attenuation with distance.

Ground vibration levels have been predicted at various offset distances from the identified plant and equipment in order to develop safe vibration level offset distances for this equipment (in accordance with the relevant guideline values).

3.5 Vibration Impact Assessment

3.5.1 Blasting Vibration - Ground Vibration

Blast emission levels have been predicted based on the typical blast design parameters in **Section 3.4.1**.

The applicable ground vibration guideline for the Project caters for the inherent variation in emission levels from a given blast design by allowing 5% exceedance of a general guideline (5 mm/s) up to a (never to be exceeded) maximum (10 mm/s). Correspondingly, "5% exceedance" and "maximum" predictions were generated for this assessment.

The resulting ground vibrations as a function of distance from the blasting activities are shown in **Figure 6**, **Figure 7** and **Figure 8** for the following scenarios:

- MIC 1500 kilograms – open-pit as per **Table 20**
- MIC 110 kilograms – ISF / Quarries as per **Table 21**
- MIC 50 kilograms – concentrate pipeline and main access route construction as per **Table 22**

Figure 6 Ground Vibration (mm/s PPV) - 1500 kg MIC - Open-pit

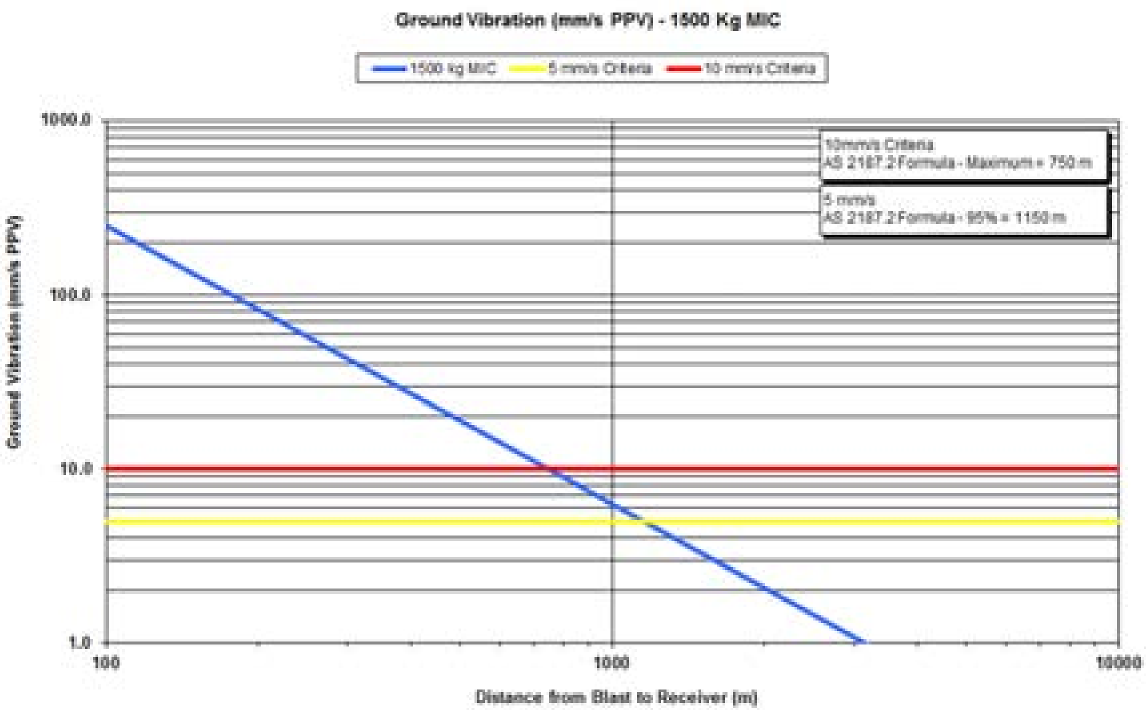


Figure 7 Ground Vibration (mm/s PPV) - 110 kg MIC - ISF/ Quarries

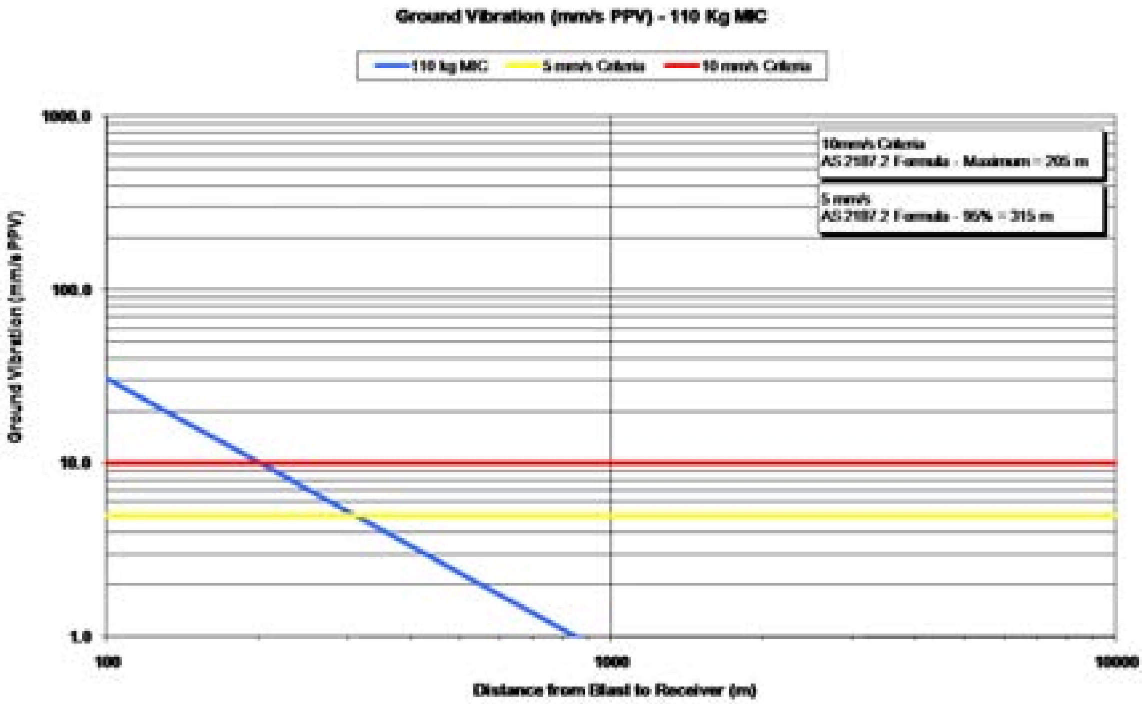
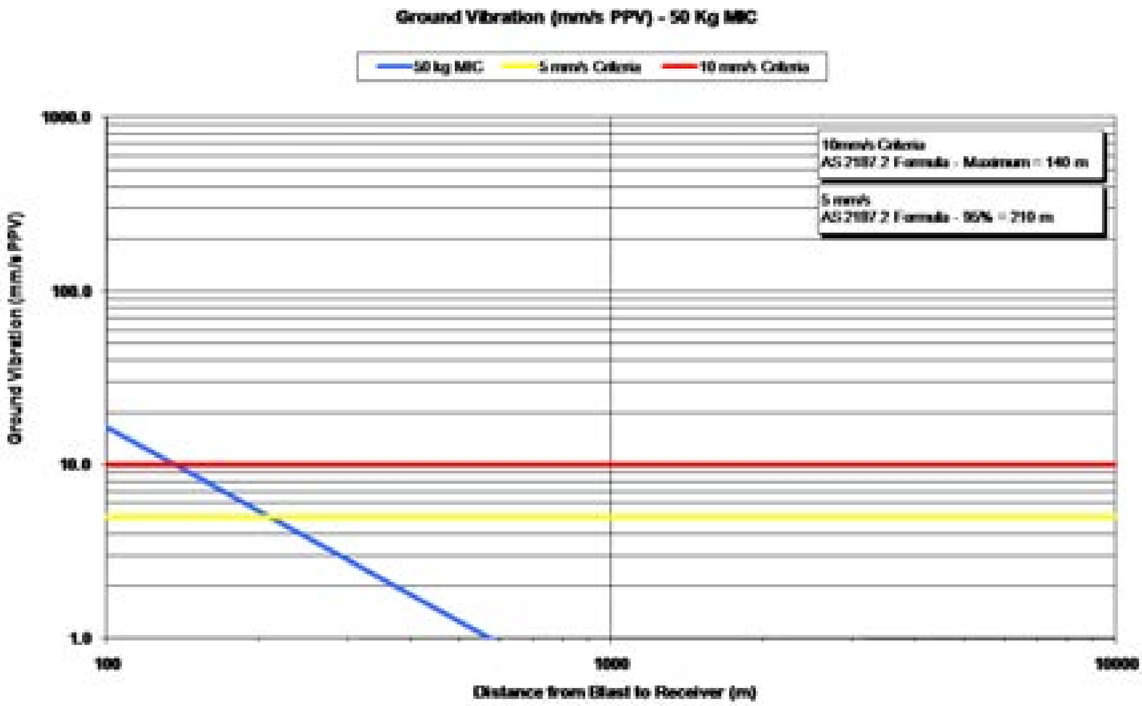


Figure 8 Ground Vibration (mm/s PPV) - 50 kg MIC – Concentrate Pipeline and Main Access Route Construction



The maximum offset distances required to achieve the ground vibration guideline for blasting shown in **Figure 6**, **Figure 7** and **Figure 8** have been summarised in **Table 23**.

Table 23 Predicted Offset Distances to Achieve the Blasting Ground Vibration Guideline

Construction Site	Ground Vibration Guideline (mm/s PPV)		Predicted Offset Distance to Achieve the Vibration Guideline (m)	
	95%	Maximum	95%	Maximum
Open-pit	5	10	1150	750
ISF/ Quarries	5	10	315	205
Concentrate pipeline and main access route construction	5	10	210	140

The nearest sensitive receptor to the open-pit is Wameimin 2 which is approximately 7.5 km from the open-pit and is predicted to experience ground vibrations levels well below the adopted Project vibration guideline for blasting activities.

There will also be some blasting associated with the construction of the ISF embankment wall. The specific blast MIC has not yet been determined; however, the blast MIC is expected to be similar to that of the quarries. The nearest sensitive receptor to the ISF is Paupe located approximately 6.5 km from the ISF, well outside the distance of any blasting related vibration impacts.

The nearest sensitive receptors to any of the quarries are approximately 400 m (Paupe) and 460 m (Temsapmin) from the quarry sites; all other sensitive receptors are located at greater distances from the quarries. No adverse blasting related vibration impacts are therefore anticipated adjacent any of the quarries.

The specific locations for blasting during construction of the concentrate pipeline and main access route have not yet been determined. The distance between any blasting required for the concentrate pipeline and main access route construction and most sensitive receptors is expected to be greater than the 210 m distance at which the blasting vibration guideline is achieved. There are nine (9) potentially sensitive receptors within 210 m of the concentrate pipeline and main access route alignment, including;

- Wokomo 2 (90 m)
- Dioru (20 m)
- Green River Station (30 m)
- Aminii (10 m)
- Itomi (140 m)
- Kilifas (30 m)
- Sumumini (20 m)
- Imbrinis (25 m)
- Vanimo (15 m)

If blasting is required adjacent to these receptors, then specific blast management measures may be required.

There are no other locations where adverse vibration impacts due to blasting associated with road construction are anticipated.

3.5.2 Blasting Vibration - Airblast Overpressure

Blast emission levels have been predicted based on the typical blast design parameters in **Section 3.4.1**.

The applicable airblast overpressure guideline for the Project caters for the inherent variation in emission levels from a given blast design by allowing 5% exceedance of a general guideline (115 dBL Peak) and up to a (never to be exceeded) maximum (120 dBL Peak). Correspondingly, “5% exceedance” and “maximum” predictions were generated for this assessment.

The resulting airblast overpressure predictions for blasting activities at the open-pit, ISF, Quarries and main access route are shown in **Figure 9**, **Figure 10** and **Figure 11**.

Figure 9 Airblast Overpressure (dBL) - 1500 kg MIC - Open-pit

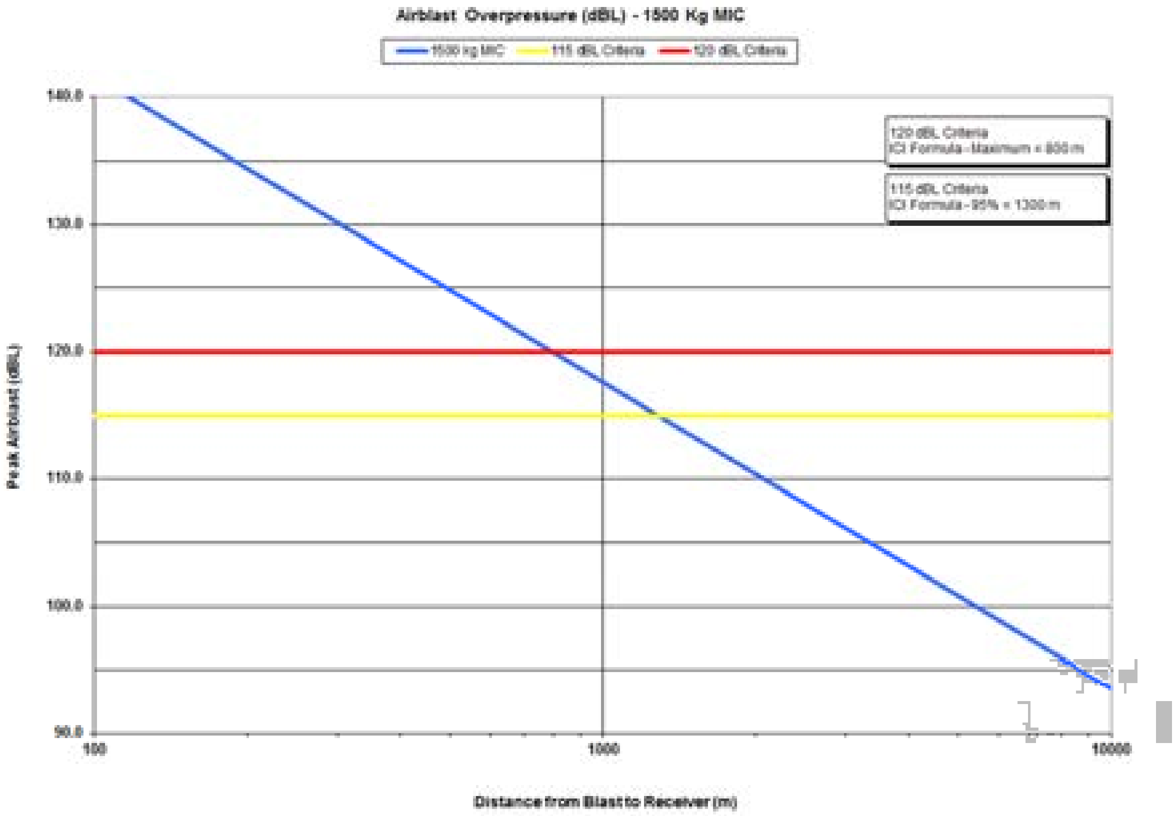


Figure 10 Airblast Overpressure (dBL) - 110 kg MIC – ISF/ Quarries

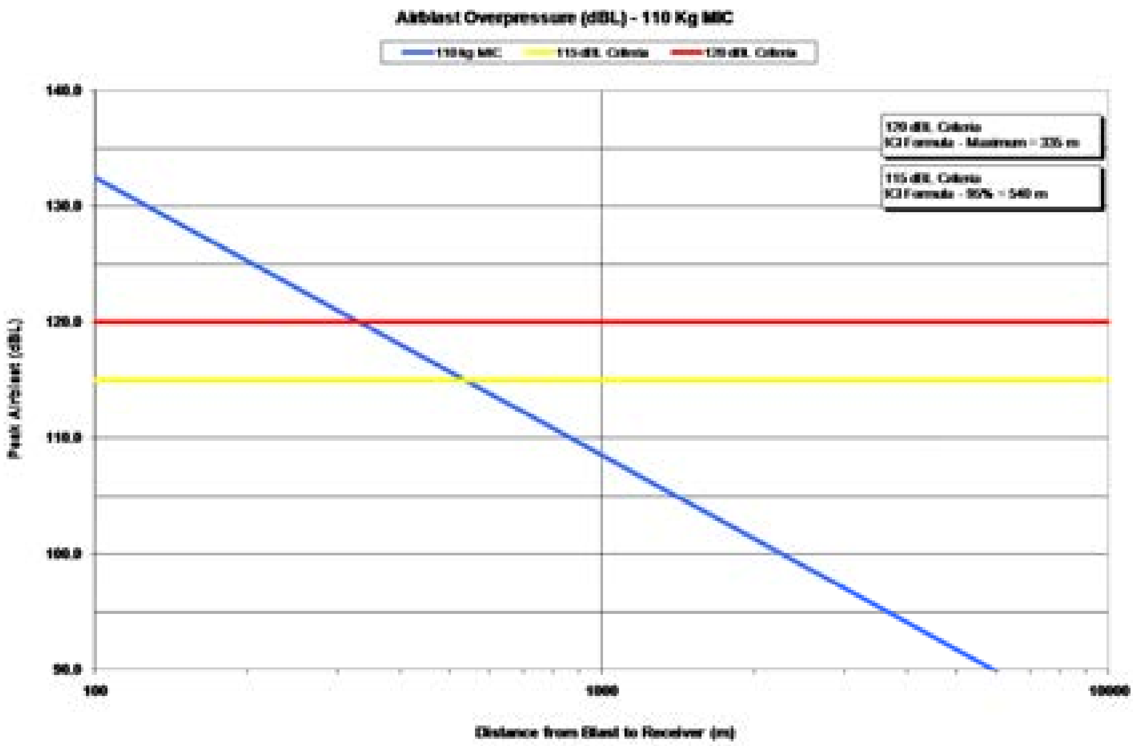
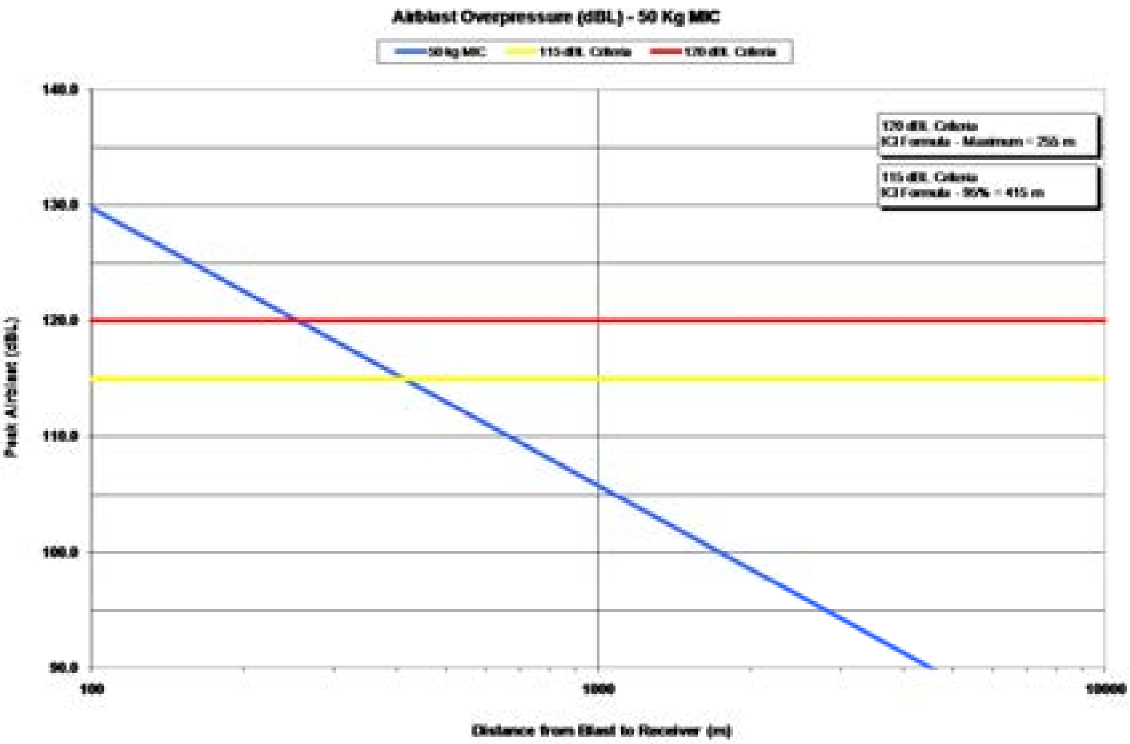


Figure 11 Airblast Overpressure (dBL) - 50 kg MIC – Concentrate Pipeline and Main Access Route Construction



The maximum offset distances required to achieve the airblast overpressure guideline as shown in **Figure 9**, **Figure 10** and **Figure 11** have been summarised in **Table 24**.

Table 24 Predicted Offset Distances to Achieve the Airblast Overpressure Guideline

Construction Site	Airblast Overpressure Guideline (dBL Peak)		Predicted Offset Distance to Achieve the Noise Guideline (m)	
	95%	Maximum	95%	Maximum
Open-pit	5	10	1300	800
ISF/ Quarries	5	10	540	335
Concentrate pipeline and main access route construction	5	10	415	255

The nearest sensitive receptor to the open-pit are Wameimin 2 which is approximately 7.5 km from the open-pit and is predicted to experience airblast overpressure levels well below the adopted Project airblast overpressure guideline for blasting activities.

There will also be some blasting associated with the construction of the ISF. The specific blast MIC has not yet been determined; however, the blast MIC is expected to be similar to that of the quarries. The nearest sensitive receptor to the ISF is Paupe located approximately 6.5 km from the ISF, well outside the distance of any blasting related airblast overpressure impacts.

The nearest sensitive receptors to any of the quarries are 400 m (Paupe) and 460 m (Temsapmin) away; all other sensitive receptors are located at significantly longer distances from the quarries. There is potential for airblast overpressure impacts at the nearest sensitive receptors in Paupe and Temsapmin within 540 m of the nearest quarry. If blasting is required within 540 m of these receptors then specific blast management measures may be required.

No other adverse blasting related airblast overpressure impacts are anticipated adjacent to any of the quarries. If blasting is required within this offset distance at these receptors then specific blast management measures may be required.

The specific locations for blasting during construction of the concentrate pipeline and main access route have not yet been determined. The distance between any blasting required for the concentrate pipeline and main access route construction and any sensitive receptors is expected to be greater than the 415 m distance at which the airblast overpressure guideline is achieved. There are eleven (11) villages with potentially sensitive receptors within this distance, including;

- Hotmin (340 m)
- Wokomo 2 (90 m)
- Dioru (20 m)
- Green River Station (30 m)
- Aminii (10 m)
- Kwomtari (300 m)
- Itomi (140 m)
- Kilifas (30 m)
- Sumumini (20 m)
- Imbrinis (25 m)
- Vanimo (15 m)

If blasting is required within 415 m of any of these sensitive receptors then specific blast management measures may be required.

There are no other locations where adverse airblast overpressure impacts due to blasting associated with road construction are expected.

3.5.3 Non-Blasting Vibration

The following section addresses the potential vibration impacts associated with the construction and operation activities of the Project (excluding blasting activities).

A review of all construction and operation plant and equipment was carried out in order to identify potential sources of vibration emission (excluding blasting). The following vibration sources have been identified for assessment:

- Rock breaking;
- Heavy vehicle movement; and

- Compaction activities (vibratory rollers).
- Impact piling activities.

The typical maximum levels of ground vibration as a function of distance from rock breaking, vibratory rollers and heavy vehicle movements sourced from SLR's vibration measurement data base are shown in **Figure 12**.

Figure 12 Maximum Ground Vibration – Rock Breaking, Vibratory Rollers and Heavy Vehicles

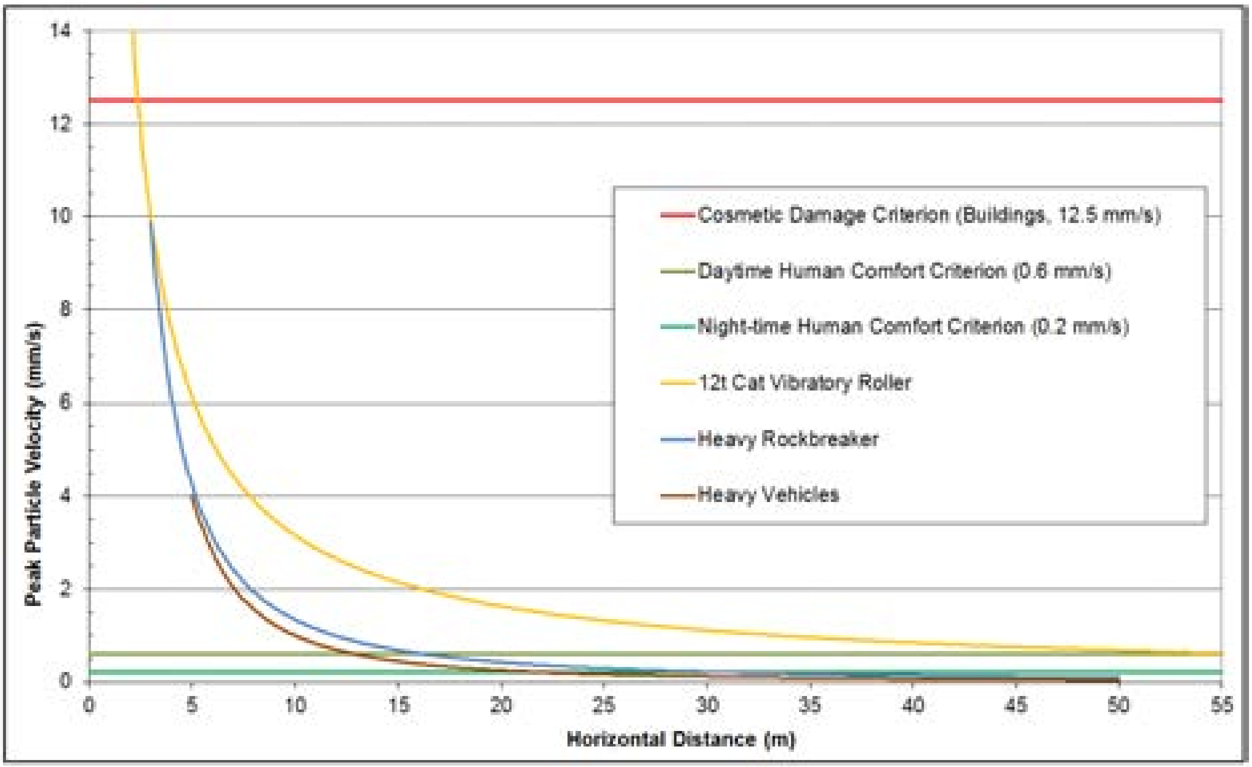


Figure 12 shows that there is no risk for any structural damage to buildings or structures located at distances greater than 3 m from any of these construction activities (rock breaking, vibratory rolling or heavy vehicles).

Vibrations from heavy rock breaking and heavy vehicle movements will achieve the human comfort guideline at a distance of approximately 15 m (daytime) from the activity.

Vibration generated by the heavy vibratory roller will achieve the human comfort guideline at a distance of approximately 55 m (daytime) from the activity. The potential sensitive receptors within 55 m of the concentrate pipeline and main access route are in the seven (7) villages within this distance, including;

- Dioru (20 m)
- Green River Station (30 m)
- Aminii (10 m)
- Kilifas (30 m)
- Sumumini (20 m)
- Imbrinis (25 m)
- Vanimo (15 m)

The nearest sensitive receptor to impact piling works for the Vanimo Ocean Port is 300 m away. Predicted vibration levels at this distance are well below the most stringent Project vibration criterion of 0.2 mm/s.

Due to the large buffer distances between the Project construction sites and Project related infrastructure and the nearest sensitive receptors, compliance with the adopted Project vibration guideline would be readily achieved at all other existing sensitive receptors (for all the above-mentioned sources).

3.5.4 Summary of Vibration Assessment

Blasting Vibration and Airblast

The blast emission predictions summarised in **Table 23** and **Table 24** for the applicable open-pit MIC of 1500 kg and ISF and quarries MIC of 110 kg show that the ground vibration guideline (5 mm/s) and the airblast overpressure guideline (115 dBL peak) are achieved at all existing sensitive receptors.

The concentrate pipeline and main access route construction MIC of 50kg may cause exceedances of the adopted guidelines at potential sensitive receptors which are located within 415 m of the current concentrate pipeline design. If blasting is required adjacent to these receptors (blasting locations have not been determined) then specific blast management measures may be required.

Non-Blasting Vibration

Due to the large buffer distances between the Project construction sites and Project related infrastructure and the nearest existing sensitive receptors, compliance with the applicable vibration guideline would be readily achieved at all sensitive receptors.

The possible exception is Vanimo which is within 55 m of the concentrate pipeline. It should be noted that the concentrate pipeline construction is a short-term event and will only have potential vibration impact as the construction workfront passes very close to sensitive receptors (ie 15 m to 55 m for daytime). This would be adequately managed by consultation with the impacted sensitive receptors (ie within Vanimo).

3.6 Vibration Management Measures

Due to the large buffer distance between the blasting and/or construction activities and the nearest sensitive receptors, there are no predicted vibration impacts (with the possible exception of the eleven (11) sensitive receptors (for blasting) and the seven (7) sensitive receptors (for non-blasting vibration) along the main access route and concentrate pipeline construction alignment) and therefore mitigation management measures are generally not required.

The following mitigation measures are proposed for sensitive receptors in these villages which may potentially be affected by vibration, depending on the location of construction activities relative to each of the receptors:

- Each receptor will be notified as the construction works approach and be kept well informed of scheduled blasting events including the times and duration that they may be affected by emissions from the works. It is proposed that blasting activities will generally only be permitted during the daytime period, in order to minimise impact and annoyance.
- Clear communication methods will be made available so that the affected communities have access to effective communication links to the operational managers, and any substantiated complaints can be addressed appropriately and sensitively.

- If required, the concentrate pipeline and main access route corridor may have some flexibility in design to allow minor deviations to minimise or avoid potential noise impacts at sensitive receptor locations.
- Vibration monitoring of blasting activities may be required at sensitive receptors in the vicinity of blasting activities required for the construction of the concentrate pipeline and main access route. The monitoring program and locations would be determined upon review of the proposed Blast locations and blast design parameters.

3.6.1 Best Practice Vibration Management Strategies

The following discusses the various management/control measures that form best practice management techniques and are able to be implemented to reduce the vibration emissions from blasting and construction activities.

Blast Emissions

It is recommended that the blast management/control measures nominated below be considered as best practice management techniques to ensure blast emissions are minimised as far as practicable.

These measures include:

- Optimising the stemming depth and type of stemming material;
- Generally limiting blasting to daytime;
- Informing any potentially affected residences with a schedule of planned blasting events;
- Ensuring appropriate burden to avoid over or under confinement of the charge;
- Using delay detonation to ensure smaller MICs, decked charges and in-hole delays; and
- Exercising strict control over the spacing and orientation of all blast holes and using the minimum practical sub-drilling which gives satisfactory toe conditions.

Vibration Monitoring

Given the large buffer distances to any existing sensitive receptors from any of the Project work sites (ie open-pit, primary crushing facility, ROM pad, process plant, ISF, hydroelectric power facility, Green River Airport, Frieda River airstrip and Vanimo Ocean Port) no permanent vibration monitoring will be required.

Where vibration generating construction activities (such as vibratory rolling) are carried out within 55 m of receptors, vibration monitoring should be carried out to demonstrate compliance with the adopted Project vibration guideline levels. Any potential vibration impacts (ie where vibration levels are near to guideline levels or compliance cannot be demonstrated) should be managed by consultation with the impacted sensitive receptors.

Vibration (and noise) monitoring of blasting activities may be required at sensitive receptors in the vicinity of blasting activities required for the construction of the concentrate pipeline and main access route and quarries. The monitoring program and locations would be determined upon review of the proposed blasting locations and blast design parameters.

4 Conclusions

4.1 Noise

A comprehensive study of both the construction and operation noise emission levels from the Project was undertaken. The following construction and operational scenarios were identified for assessment via 3D computer modelling, generic offset distance calculations and assessment:

Construction	Operational
Mine area	Mine area
Vanimo Ocean Port	Vanimo Ocean Port
Concentrate pipeline and main access route	Main access route traffic
Green River Airport and Frieda River airstrip	Green River Airport and Frieda River airstrip
Frieda River Port	N/A
Quarries	N/A
Construction Material Barging	N/A
Sepik River bridge	N/A

There are no existing sensitive receptors which are predicted to be adversely impacted by noise from the mine area, ISF, hydroelectric power facility, quarries, and Frieda River airstrip, during the construction or operation phases of the project.

Based on the findings of the noise assessment the only potential for adverse noise impacts from the Project is during the construction and operation of the Vanimo Ocean Port, Green River Airport and the construction of the concentrate pipeline and main access route.

The construction of the concentrate pipeline passes within 300 m of potential sensitive receptors in ten (10) villages which may experience some short-term noise impacts from the concentrate pipeline construction. The pipeline and main access route construction represents a relatively short-term impact.

Noise emissions from these Project related construction activities would be adequately resolved through the management measures detailed in **Section 2.6**.

Based on the noise assessment (see **Section 2.5**), the only potential adverse noise impacts during operational activities are predicted for the Vanimo Ocean Port and Green River Airport. Whilst noise impacts at Vanimo and Green River Station are predicted, the existing noise environment in these areas may not change significantly. There are already industrial activities (ie logging activities) at Vanimo which generate noise emissions with similar characteristics. There are also already aircraft noise emissions generated at Green River Station through the existing operation of the Green River Airport.

This would need to be confirmed prior to commencement of operations to ensure that, where applicable, appropriate noise management measures are incorporated. Operations in Vanimo and at the Green River Airport should be conducted during the daytime period where possible and best practice noise management and mitigation measures implemented wherever practicable.

Although noise mitigation/management measures are not generally required for the Project implementation of relevant best practice noise management strategies will assist in minimising noise emission from the Project sites.

4.2 Vibration

A comprehensive study of vibration emissions (and associated overpressure) from blasting activities and non-blasting construction and operation works associated with the Project has been undertaken.

The vibration study was divided into two categories as follows:

- Blasting activities (ground vibration and airblast overpressure); and
- General construction and operation vibration sources (excluding blasting) such as rock breaking, heavy vehicles, compaction, etc.

Airblast overpressure and vibration were predicted and assessed for blasting associated with the following construction and operation activities:

- ISF – construction;
- Concentrate pipeline and main access route – construction;
- Quarries associated with process plant, ISF, concentrate pipeline and main access route – construction; and
- Open-pit – operation.

The identified existing sensitive receptors are beyond the offset distances required for blasting at the open-pit, ISF and quarries. Therefore, compliance with the adopted Project ground vibration and airblast overpressure guidelines would be achieved at all existing sensitive receptors. There are eleven (11) sensitive receptor areas located within 415 m of the concentrate pipeline and main access route. It is not known whether blasting will be required during the road and pipeline construction near these villages. Appropriate management of blasting impacts will be required should blasting be required at these locations.

Due to the large buffer distances between the construction and operation sites, Project related infrastructure and the nearest existing sensitive receptors, compliance with the adopted Project vibration guidelines would be readily achieved. The possible exception is where the construction of the concentrate pipeline and main access route passes close to existing receptors. It should be noted that this is a short-term construction event and will only have potential vibration impact as the construction work front passes within 15 m to 55 m of the receptors (for daytime). Seven (7) sensitive receptors have been identified as being located within 55 m of the road and concentrate pipeline alignment.

The road construction represents a relatively short-term impact and would be adequately resolved through the following management measures:

- Each receptor will be notified as the construction works approach and be kept well informed of scheduled blasting events including the times and duration that they may be affected by emissions from the works. It is proposed that blasting activities will generally only be permitted during the daytime period, in order to minimise impact and annoyance.

- Clear communication methods will be made available so that the affected communities have access to effective communication links to the operational managers, and any substantiated complaints can be addressed appropriately and sensitively.
- If required, the concentrate pipeline and main access route corridor may have some flexibility in design to allow minor deviations to minimise or avoid potential noise impacts at sensitive receptor locations.

Based on the predicted vibration emissions in this report, it is considered that vibration emissions from the Project are not expected to adversely impact on the surrounding environment.

Although vibration mitigation/management measures are not generally required for the Project (except, if required, for the concentrate pipeline and main access route or quarries), implementation of relevant best practice vibration management strategies will assist in reducing vibration emission from the Project sites.

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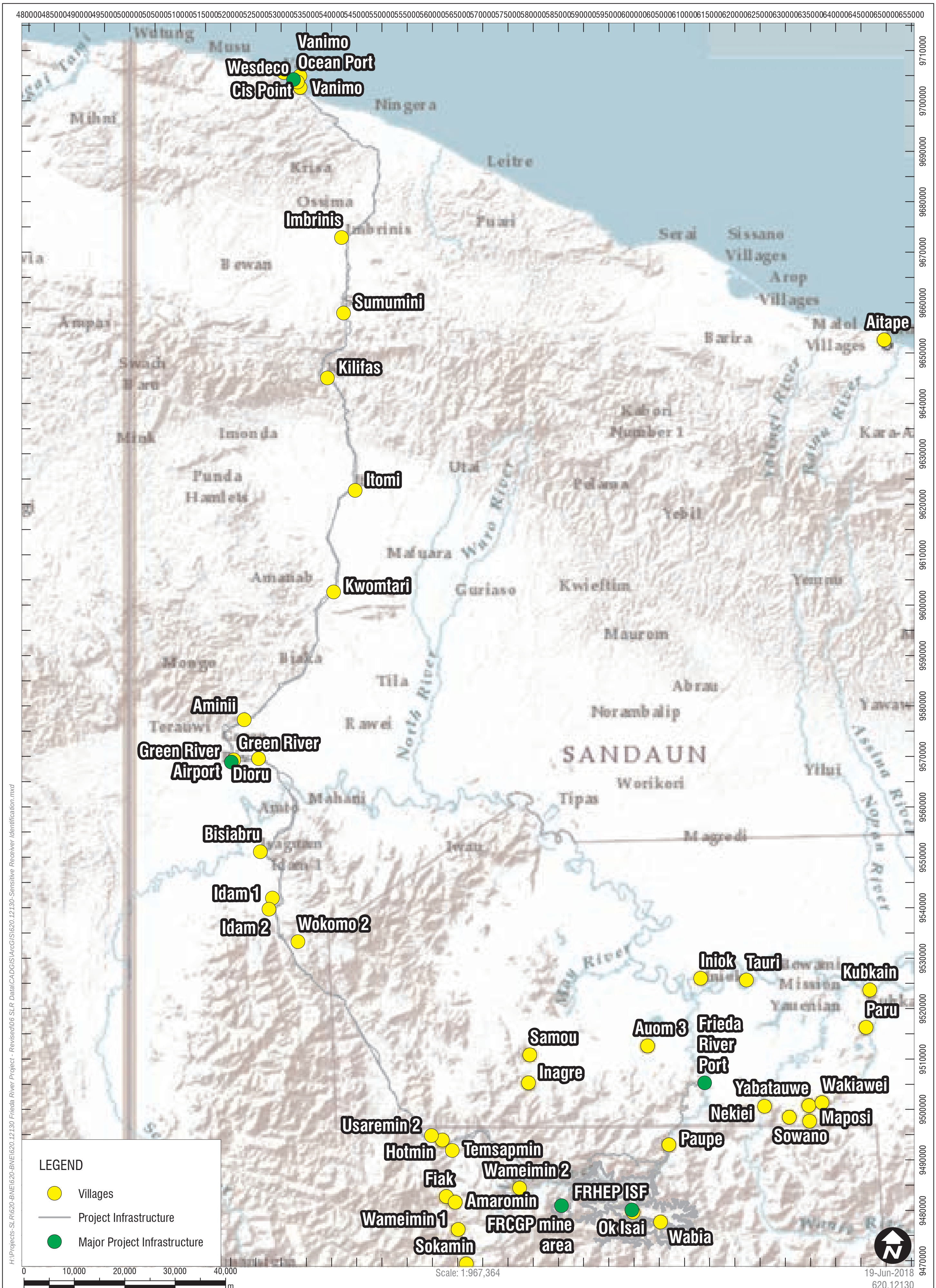
APPENDIX A

Existing Sensitive Receptors



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Sensitive Receivers

Appendix A Figure 1

APPENDIX B

Construction Noise Sources

Table B1 Major Pit and Mining Infrastructure Construction – Dominant Noise Sources (Equipment List)

Equipment	Total Qty of Noise Sources	Source Height (m)	Sound Power Level for a Single Noise Source (dBA L_{Aeq})
Open Pit Clear and Grade Construction			
Earthmoving Equipment			
20T excavator	1	3	101
70T excavator	2	3	101
30T Rock Breaker	8	2	117
980 Front end loader	10	3	98
D9T Dozer	6	3	114
Backhoe	8	3	98
Bobcat	1	3	102
Leveling & Surfacing			
140G Grader	1	3	110
Compactor 825	1	3	114
Trucks			
730E dump truck	2	3	123
777D dump truck	8	3	123
Fuel Truck	1	3	104
150T Low loader	1	3	104
Light Vehicles			
22 seater bus	4	1	102
Utes	2	1	94
Cranes			
Franna 12-20T	2	3	103
Other equipment			
Boomlift/Knuckle	1	3	99
EWP	2	3	99
Generator	1	3	99
Primary Crushing Facility, ROM and Process Plant Construction			
Earthmoving Equipment			
20T excavator	2	3	101
70T excavator	3	3	101
Excavator	3	3	101
980 Front end loader	10	3	98
Backhoe	6	3	98
Bobcat	2	3	102
Leveling & Surfacing			
140G Grader	2	3	110
Compactor 825	2	3	114
Roller	2	3	105
Trucks			
730E dump truck	6	3	123
Concrete Trucks	6	3	104
Flatbed truck with Hiab	2	3	99
Semi-Trailers	5	3	109

Equipment	Total Qty of Noise Sources	Source Height (m)	Sound Power Level for a Single Noise Source (dBA L_{Aeq})
Fuel Truck	2	3	104
Light Vehicles			
22 seater bus	40	1	102
Utes	29	1	94
Cranes			
Franna 12-20T	27	3	103
Crane	2	3	108
Crane 50T	5	3	108
Crane 80T Crawler	2	3	108
Crane 200T Crawler	2	3	108
Other equipment			
Boomlift/Knuckle	19	3	99
EWP	24	3	99
Generator	21	3	99
Gensets	2	3	96
Compressor	22	2	104
Mine Waste Facility			
Dozer	6	3	114
Graders	4	3	110
Excavator	2	3	101
Front End Loader	2	3	98
Compactor/Rollers	20	3	105
Trucks	8	3	103
Water Trucks	2	3	104
Cement Trucks	4	3	103
Site Accommodation Village and Administration Building Construction			
Earthmoving Equipment			
20T excavator	4	3	101
70T excavator	5	3	101
Backhoe	2	3	98
Bobcat	4	3	102
Leveling & Surfacing			
140G Grader	3	3	110
Compactor 825	4	3	114
Trucks			
730E dump truck	5	3	123
Semi-Trailers	3	3	109
Fuel Truck	3	3	104
Light Vehicles			
22 seater bus	8	1	102
Utes	3	1	94
Cranes			
Franna 12-20T	4	3	103
Crane 50T	2	3	108

Equipment	Total Qty of Noise Sources	Source Height (m)	Sound Power Level for a Single Noise Source (dBA L_{Aeq})
Other equipment			
Boomlift/Knuckle	3	3	99
EWP	6	3	99
Generator	3	3	99
Compressor	3	2	104

Note: Sound power levels have been sourced from SLR's noise source database.

Table B2 ISF and Hydroelectric Power Station – Construction Noise Sources (Equipment List)

Equipment	Total Qty of Noise Sources	Source Height (m)	Sound Power Level for a Single Noise Source (dBA L_{Aeq})
Equipment for earth-rock excavation and filling			
High pneumatic drill	8	3	116
Hydraulic drill	2	3	116
Diving drill	20	3	116
Air leg drill	60	3	116
Hydraulic backhoe	14	3	98
Loader	7	3	98
Bulldozer	11	3	114
Smooth drum vibration roller	8	3	105
Small vibrating roller	2	3	105
Concrete Construction equipment			
Mixing plant	1	3	110
Bituminous concrete mixing station	1	3	110
Artificial aggregate processing system	1	3	110
Tower crane	1	3	108
Tower crane	3	3	108
Crawler crane	2	3	108
Spreader	1	3	115
Towed concrete pump	3	3	108
Asphalt distributor	1	3	108
Paver	1	3	115
Concrete truck mixer	9	3	104
Drilling, grouting and supporting facilities			
Guide-rail drill	24	3	114
Engineering drill	14	3	114
Anchor drill	4	3	114
Electrical rock drill	2	3	114
Concrete wet spraying machine	8	3	114
Geological drill	24	3	111
Transportation and hoisting equipment			
Dump truck (100t)	40	3	123
Platform trailer	2	3	104
Platform lorry	5	3	99
Sprinkling Car	9	3	104
Oil tank truck	3	3	104
Mobile crane	7	3	108
Winch	6	3	105
Hydro-power Dam Construction			

Hydraulic Excavators	11	3	101
Wheeled Excavators	2	3	101
Wheel Loaders	4	3	107
Graders	2	3	110
Articulated Trucks	6	3	100
Off-Highway Trucks	8	3	103
Tractors	8	3	108
Mobile Crushers (each with 1 compactor CAT engine)	3	3	122
Drill Rigs	9	3	114
Air Compressor	1	3	104
Concrete batching plant (100 m^3/hr)	2	3	110
Generators (1 MW)	3	3	104
Hydroelectric Power Plant Construction			
Earthmoving Equipment			
20T excavator	1	3	101
70T excavator	1	3	101
Backhoe	2	3	98
Bobcat	2	3	102
Leveling & Surfacing			
Compactor 825	2	3	114
Trucks			
730E dump truck	1	3	123
Concrete Trucks	1	3	104
Semi-Trailers	3	3	109
Fuel Truck	1	3	104
Light Vehicles			
22 seater bus	8	1	102
Utes	3	1	94
Cranes			
Franna 12-20T	3	3	103
Crane 50T	1	3	108
Crane 200T Crawler	1	3	108
Other equipment			
Boomlift/Knuckle	2	3	99
EWP	3	3	99
Generator	1	3	99
Gensets	1	3	96
Compressor	2	2	104

Note: Sound power levels have been sourced from SLR's noise source database.

Table B3 River Port Facility Construction – Dominant Noise Sources (Equipment List)

Equipment	Total Qty of Noise Sources	Source Height (m)	Sound Power Level for a Single Noise Source (dBA L_{Aeq})
4X4 Pickups/SUV	9	1	94
Passenger Bus	5	1	102
Boom Truck (15 T, 18-20 ft Telescopic Crane)	3	3	103
Lube & Fuel/Maintenance Trucks	2	3	104
Garbage Trucks	2	3	104
Water Truck	1	3	104
Flatbed trucks (3.5 Ton)	3	3	99
Tractor (LT9500)	1	3	108
Loader/Backhoe	1	3	98
Bobcat	1	3	102
Cranes	3	3	108
Generator (55 kW)	3	2	92
Generator (20 kW)	4	2	92
Compressor	3	2	104
Crane Truck	2	3	103
Man lift	2	3	99
Scissor platform	2	3	99
Concrete Batching Plant (60 m^3)	1	3	110
Barge (82 m long and 24 m wide)	1	10	110
Tug boat (4000 hp)	1	10	117

Table B4 Access Roads and Pipeline Construction – Dominant Noise Sources (Equipment List)

Equipment	Total Qty of Noise Sources	Source Height (m)	Sound Power Level for a Single Noise Source (dBA L_{Aeq})
Earthmoving Equipment			
20T excavator	5	3	101
70T excavator	5	3	101
Bobcat	5	3	102
Leveling & Surfacing			
140G Grader	3	3	110
Trucks			
730E dump truck	5	3	123
Fuel Truck	1	3	104
Light Vehicles			
22 seater bus	8	1	102
Utes	5	1	94
Cranes			
Franna 12-20T	2	3	103

Note: Sound power levels have been sourced from SLR's noise source database.

Table B5 Green River and Frieda River Airport Construction/Upgrades – Dominant Noise Sources (Equipment List)

Equipment	Total Qty of Noise Sources	Source Height (m)	Sound Power Level for a Single Noise Source (dBA L_{Aeq})
Earthmoving Equipment			
20T excavator	1	3	101
70T excavator	1	3	101
Backhoe	2	3	98
Bobcat	1	3	102
Leveling & Surfacing			
140G Grader	1	3	110
Compactor 825	1	3	114
Trucks			
730E dump truck	1	3	123
Semi-Trailers	1	3	109
Fuel Truck	1	3	104
Light Vehicles			
22 seater bus	2	1	102
Utes	2	1	94
Cranes			
Franna 12-20T	2	3	103
Crane 50T	1	3	108
Other equipment			
Boomlift/Knuckle	1	3	99
EWP	2	3	99
Generator	1	3	99
Compressor	2	2	104

Note: Sound power levels have been sourced from SLR's noise source database.

Table B6 Vanimo Ocean Port Facility Construction – Dominant Noise Sources (Equipment List)

Equipment	Total Qty of Noise Sources	Source Height (m)	Sound Power Level for a Single Noise Source (dBA L_{Aeq})
Earthmoving Equipment			
20T excavator	1	3	101
70T excavator	1	3	101
Backhoe	2	3	98
Bobcat	1	3	102
Leveling & Surfacing			
Compactor 825	2	3	114
Trucks			
730E dump truck	2	3	123
Concrete Trucks	1	3	104
Semi-Trailers	2	3	109
Fuel Truck	1	3	104
Cranes			
Franna 12-20T	4	3	103
Crane 50T	1	3	108
Crane 200T Crawler	1	3	108
Other equipment			
Boomlift/Knuckle	2	3	99
EWP	3	3	99
Generator	2	3	99
Compressor	2	2	104
Piling Rig	1	3	111

Note: Sound power levels have been sourced from SLR's noise source database.

Table B7 Sepik River Bridge Construction – Dominant Noise Sources (Equipment List)

Equipment	Total Qty of Noise Sources	Source Height (m)	Sound Power Level for a Single Noise Source (dBA L_{Aeq})
Impact Piling Equipment			
Hammer piling rig	1	3	122
Sheet piling rig (vibratory)	1	3	116
Drill rig	1	3	112
Compressor	2	3	103
120t mobile crane	1	3	94
30t tracked excavator	3	3	107
Trucks	4	3	103

Note: Sound power levels have been sourced from SLR's noise source database.

APPENDIX C

Operational Noise Sources

Operational Noise Sources

Table C1 Mine Site Year 5 Operations (Open Pit, Primary Crushing, ROM and Process Plant) Operation – Dominant Noise Sources

Equipment	Total Qty of Noise Sources	Source Height (m)	Sound Power Level for a Single Noise Source (dBA L_{Aeq})
Open Pit Mobile Plant Year 5			
Drill Rigs	3	3	114
Hydraulic Shovels and Front End Loaders	5	3	123
Trucks	35	3	124
Bulldozers and wheeldozers	5	3	114
Graders	4	3	110
Primary Crushing Facility	**2**	**10**	**110**
Overland Conveyor Belts	**2**	**--**	**90 dBA/m**
Waste Rock Crushing	**1**	**10**	**110**
Overland Rope Conveyor Belt	**1**	**--**	**90 dBA (at cable supports)**
Process Plant Grinding / Pebble Crushing	**1**	**10**	**132**
Process Plant Concentrator Flotation Plant	**1**	**10**	**136**
Tailings Thickening	**1**	**10**	**110**
Concentrate Feed	**1**	**10**	**85**
Ancillary Equipment (Other)			
Water trucks	1	3	113
Tilt Cab Demolition Machine	2	3	106
Front End Loader	1	3	98
Compactor	3	3	105
Miscellaneous Mining Equipment			
150T Low Loader	1	3	104
Lighting Plants	20	3	88
Water trucks	1	3	113
Miscellaneous Maintenance Equipment			
Lube Truc	4	3	111
Tyre Handler Cat 988K	1	3	113
Service Truck /Hook truck	2	3	111
Service Truck - GET	2	3	111
Service Truck - Welding	2	3	111
Crane - 70-80t All terrain	1	3	108
Crane - 40t - All terrain	1	3	108
Franna 12-20T	1	3	103
Flatbed truck with Hiab	2	3	99
Forklift	2	3	107
Telehandlers - Manitou 4,000t (CAT TH417	2	3	107
Telehandlers - Manitou 2,500t (CATTH336)	2	3	107
Bobcat	1	3	102
Ride on Sweeper	1	3	104
Scissor Lifts/EWP	4	3	99
Boom Lifts	4	3	99

Equipment	Total Qty of Noise Sources	Source Height (m)	Sound Power Level for a Single Noise Source (dBA L_{Aeq})
Portable Crib Room - ATCO TRC 7725	2	3	103
Workshop - General Tooling	1	3	116
Workshop - Specialised Tooling	1	3	116
Workshop - Tyre Handling (Hedweld TH15000)	1	3	116
Workshop - Wheer Motor (Hedweld VWT-XC20E)	1	3	116
Miscellaneous Road Construction Equipment			
Excavators	1	3	101
Articulated Dump Trucks	1	3	118
Rehandling			
Front End Loaders	2	3	98
Pioneering			
Excavators	4	3	101
Articulated Dump Trucks	12	3	118
Dozers	4	3	114
Quarry			
Drill Rig	2	3	114
Excavator	1	3	101
Dump Truck	3	3	123
Front End Loader	2	3	98
Dozer	2	3	114
Mobile Crusher Metso LT120	1	3	118
Mobile Crusher Metso LT300GP	1	3	118
Mobile Crusher Metso LT300HP	1	3	118
Mobile Screen - ST4.8	1	3	122
Dewatering			
Excavator	2	3	101
Front End Loaders	1	3	98
Flat Bed Truck with Hiab	1	3	99
Telehandlers - Manitou 4,000t (CAT TH417	1	3	107
DragFlow Pump HY85 + Power unit	1	3	112
Pioneer - PP64C21	2	3	111
Pioneer - PP108C24	3	3	111
Pioneer - SC108C24	1	3	111
Backhoe	1	3	98
Waste Rock Handling			
5,000 Dwt Barge	3	3	111
Work Boat - Damen Multicat 1908	1	3	117
Crew Boat - Naiad Rib boat (8 pax)	1	3	111

Table C2 Mine Site Year 12 Operations (Open Pit, Primary Crushing, ROM and Process Plant) Operation – Dominant Noise Sources

Equipment	Total Qty of Noise Sources	Source Height (m)	Sound Power Level for a Single Noise Source (dBA L_{Aeq})
Open Pit Mobile Plant Year 12			
Drill Rigs	7	3	114
Hydraulic Shovels and Front End Loaders	8	3	123
Trucks	60	3	124
Bulldozers and wheeldozers	7	3	114
Graders	5	3	110
Compactor	3	3	105
Primary Crushing Facility	**2**	**10**	**110**
Overland Conveyor Belts	**2**	**--**	**90 dBA/m**
Waste Rock Crushing	**1**	**10**	**110**
Overland Rope Conveyor Belt	**1**	**--**	**90 dBA (at cable supports)**
Process Plant Grinding / Pebble Crushing	**1**	**10**	**132**
Process Plant Concentrator Flotation Plant	**1**	**10**	**136**
Tailings Thickening	**1**	**10**	**110**
Concentrate Feed	**1**	**10**	**85**
Ancillary Equipment (Other)			
Water trucks	1	3	113
Tilt Cab Demolition Machine	2	3	106
Front End Loader	1	3	98
Compactor	3	3	105
Miscellaneous Mining Equipment			
150T Low Loader	1	3	104
Lighting Plants	30	3	88
Water trucks	1	3	113
Miscellaneous Maintenance Equipment			
Lube Truc	4	3	111
Tyre Handler Cat 988K	1	3	113
Service Truck /Hook truck	2	3	111
Service Truck - GET	2	3	111
Service Truck - Welding	2	3	111
Crane - 70-80t All terrain	1	3	108
Crane - 40t - All terrain	1	3	108
Franna 12-20T	1	3	103
Flatbed truck with Hiab	2	3	99
Forklift	2	3	107
Telehandlers - Manitou 4,000t (CAT TH417	2	3	107
Telehandlers - Manitou 2,500t (CATTH336)	2	3	107
Bobcat	1	3	102
Ride on Sweeper	1	3	104
Scissor Lifts/EWP	4	3	99

Equipment	Total Qty of Noise Sources	Source Height (m)	Sound Power Level for a Single Noise Source (dBA L_{Aeq})
Boom Lifts	4	3	99
Portable Crib Room - ATCO TRC 7725	2	3	103
Workshop - General Tooling	1	3	116
Workshop - Specialised Tooling	1	3	116
Workshop - Tyre Handling (Hedweld TH15000)	1	3	116
Workshop - Wheer Motor (Hedweld VWT-XC20E)	1	3	116
Miscellaneous Road Construction Equipment			
Excavators	1	3	101
Articulated Dump Trucks	1	3	118
Rehandling			
Front End Loaders	3	3	98
Pioneering			
Excavators	3	3	101
Articulated Dump Trucks	9	3	118
Dozers	3	3	114
Quarry			
Drill Rig	2	3	114
Excavator	2	3	101
Dump Truck	3	3	123
Front End Loader	2	3	98
Dozer	2	3	114
Mobile Crusher Metso LT120	2	3	118
Mobile Crusher Metso LT300GP	2	3	118
Mobile Crusher Metso LT300HP	2	3	118
Mobile Screen - ST4.8	2	3	122
Dewatering			
Excavator	1	3	101
Front End Loaders	1	3	98
Flat Bed Truck with Hiab	1	3	99
Telehandlers - Manitou 4,000t (CAT TH417	1	3	107
DragFlow Pump HY85 + Power unit	1	3	112
Pioneer - PP64C21	3	3	111
Pioneer - PP108C24	6	3	111
Pioneer - SC108C24	2	3	111
Backhoe	1	3	98
Waste Rock Handling			
5,000 Dwt Barge	5	3	111
Work Boat - Damen Multicat 1908	1	3	117
Crew Boat - Naiad Rib boat (8 pax)	1	3	111
Hydroelectric Power Plant			
Hydroelectric generator 68 kw	8	3	90
Hydroelectric generator 17 kw	2	3	83

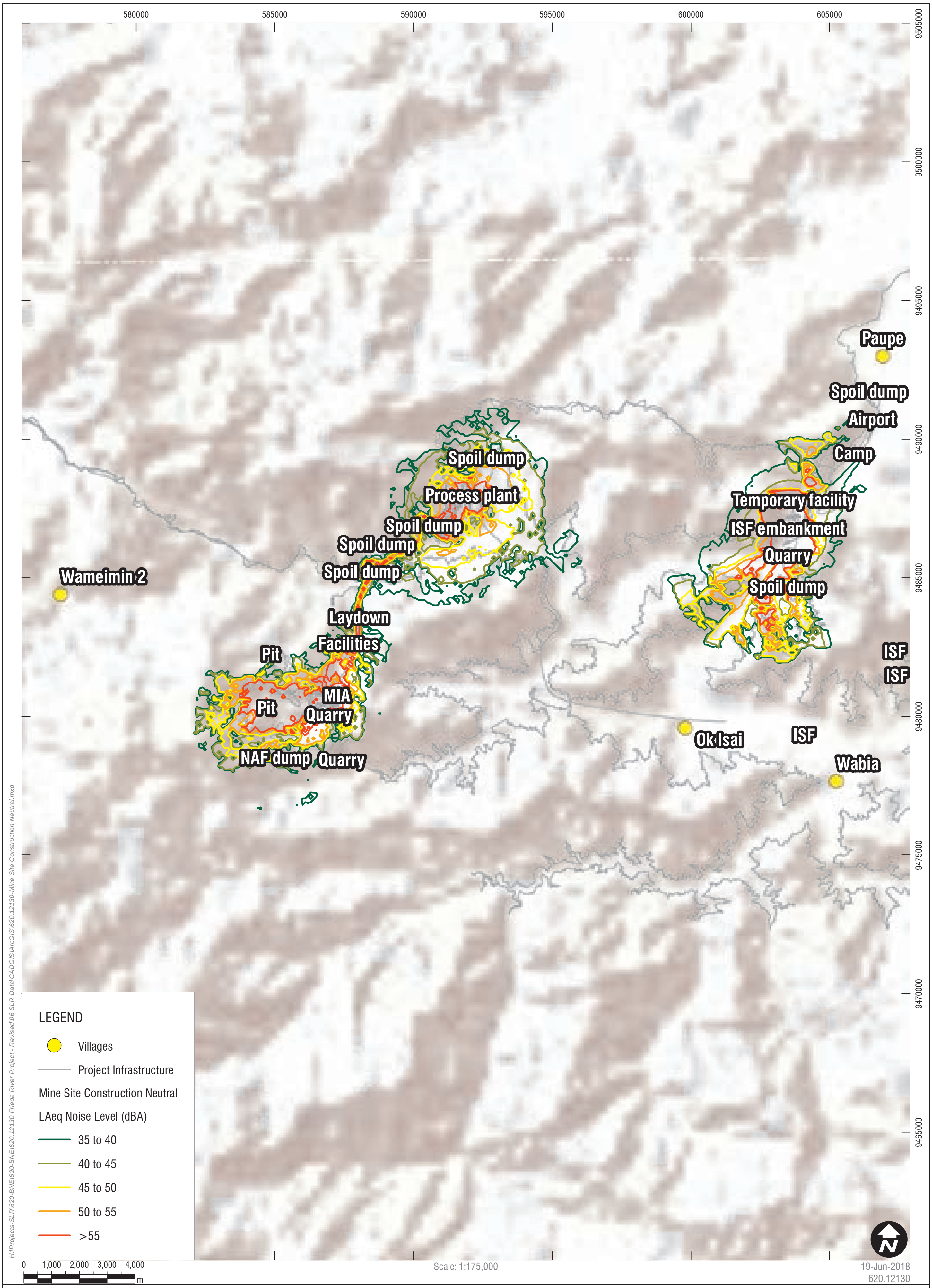
Table C3 Vanimo Ocean Port Operation – Dominant Noise Sources

Equipment	Total Qty of Noise Sources	Source Height (m)	Sound Power Level for a Single Noise Source (dBA L_{Aeq})
Operational Mobile and Fix Plant			
Mobile Harbour Crane 180 tonne	1	3	108
Mobile Harbour Crane 45 tonne	1	3	108
Prime Mover/Trailer	6	3	109
Bobcat	2	3	102
Forklift	2	3	107
Forklift 40 tonne Container Handler	2	3	107
Front End Loader	2	3	98
Concentrate Thickener	1	10	89
Concentrate to Port Conveyor Belt	1	2	90 dBA/m
Operational Nautical Fleet			
Bulk Cargo Ship (docked)	1	10	93
Barge[1]	2	10	111
Tug Boat[1]	2	10	117

Note 1: Maximum 2 barges and 2 tug boats at any one time at the Vanimo Ocean Port.

APPENDIX D

Noise Contour Maps - Mine Area Construction including, Open-pit, Primary Crushing Facility, ROM pad, Process Plant, ISF and Hydroelectric Power Facility



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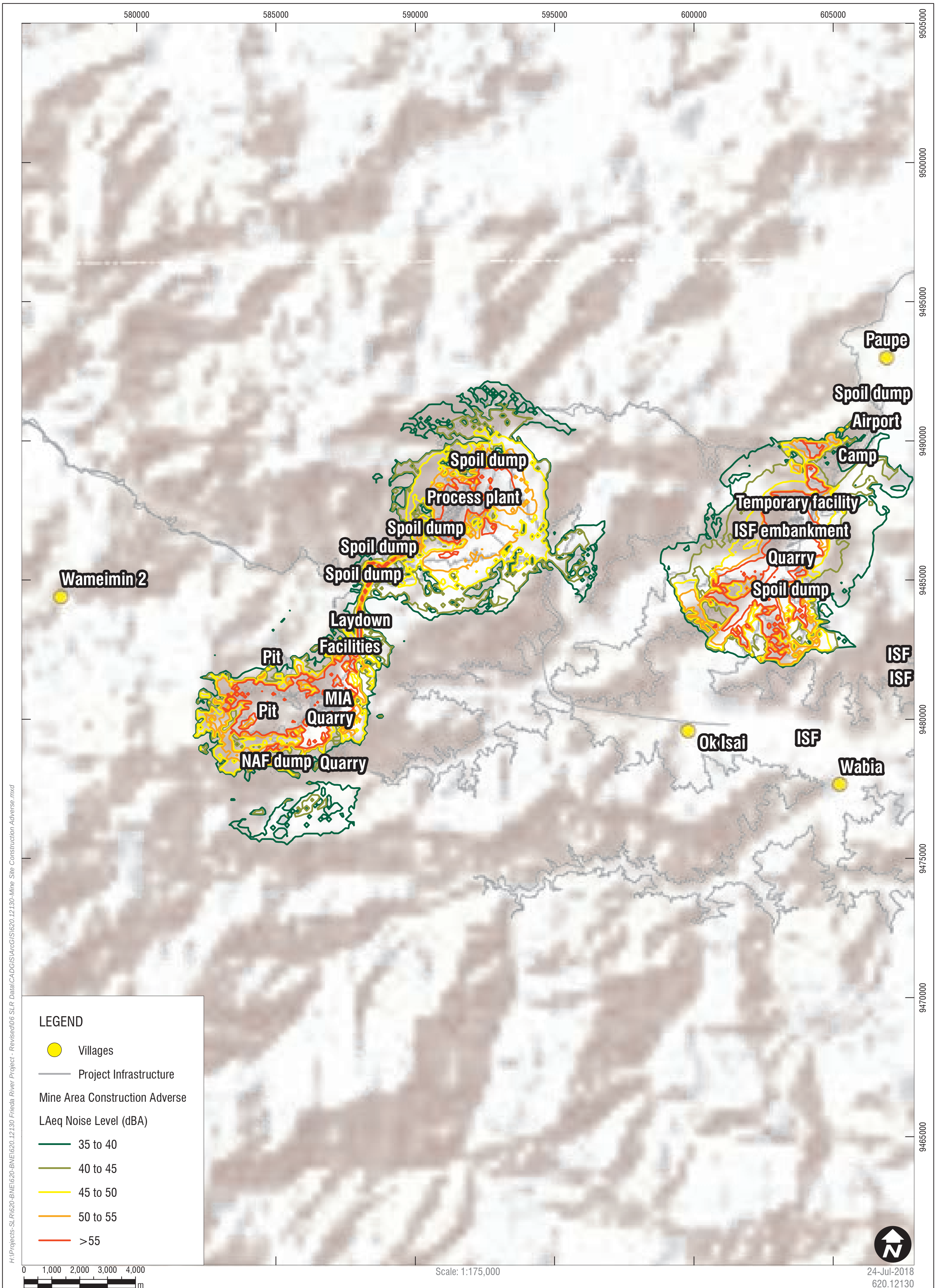
Mine Site Construction Neutral Weather

Appendix D Figure 1



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24-Jul-2018
620.12130

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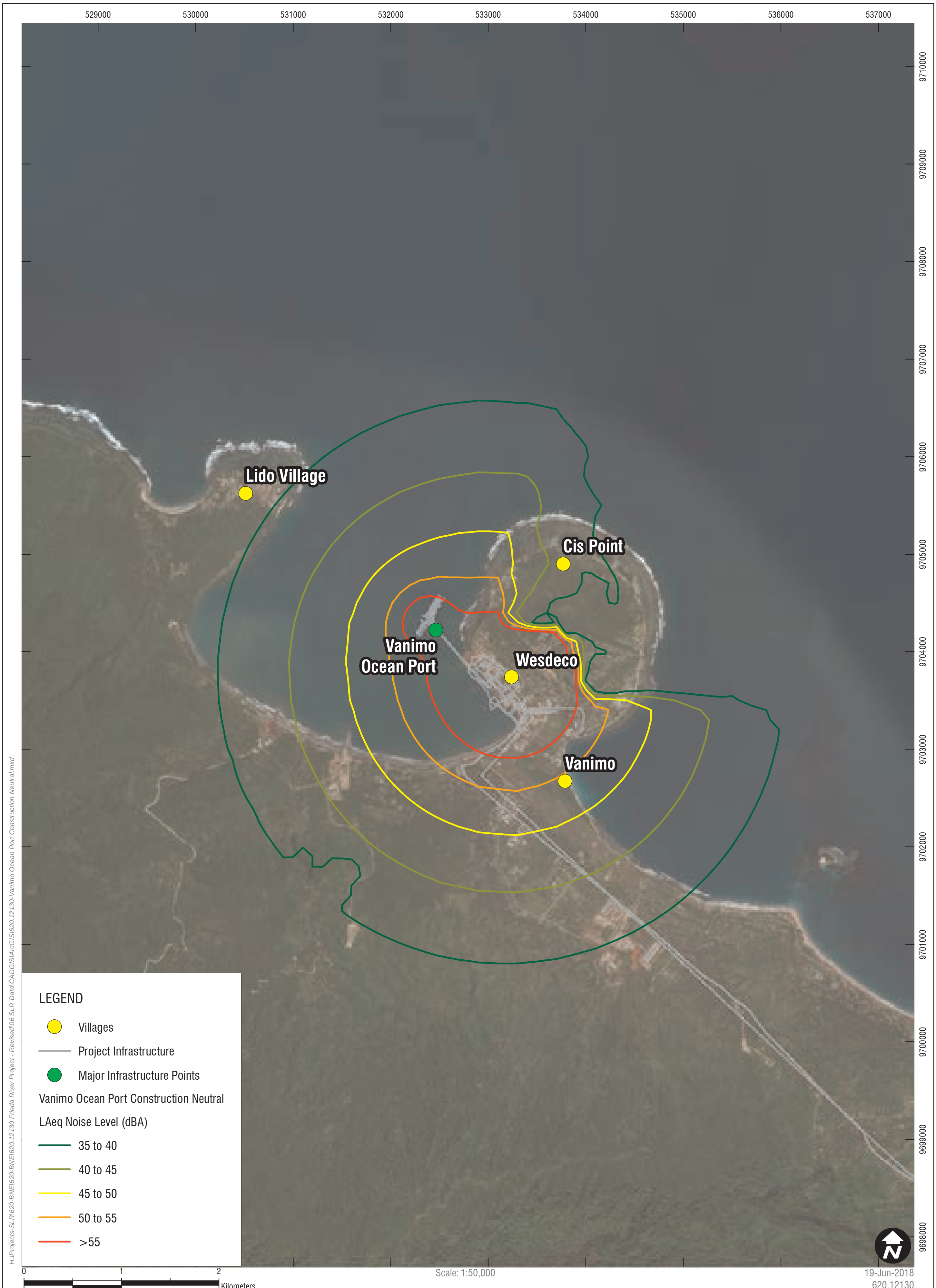
Mine Area Construction Adverse Weather

Appendix D Figure 2

APPENDIX E

Noise Contour Maps - Construction of Vanimo Ocean Port



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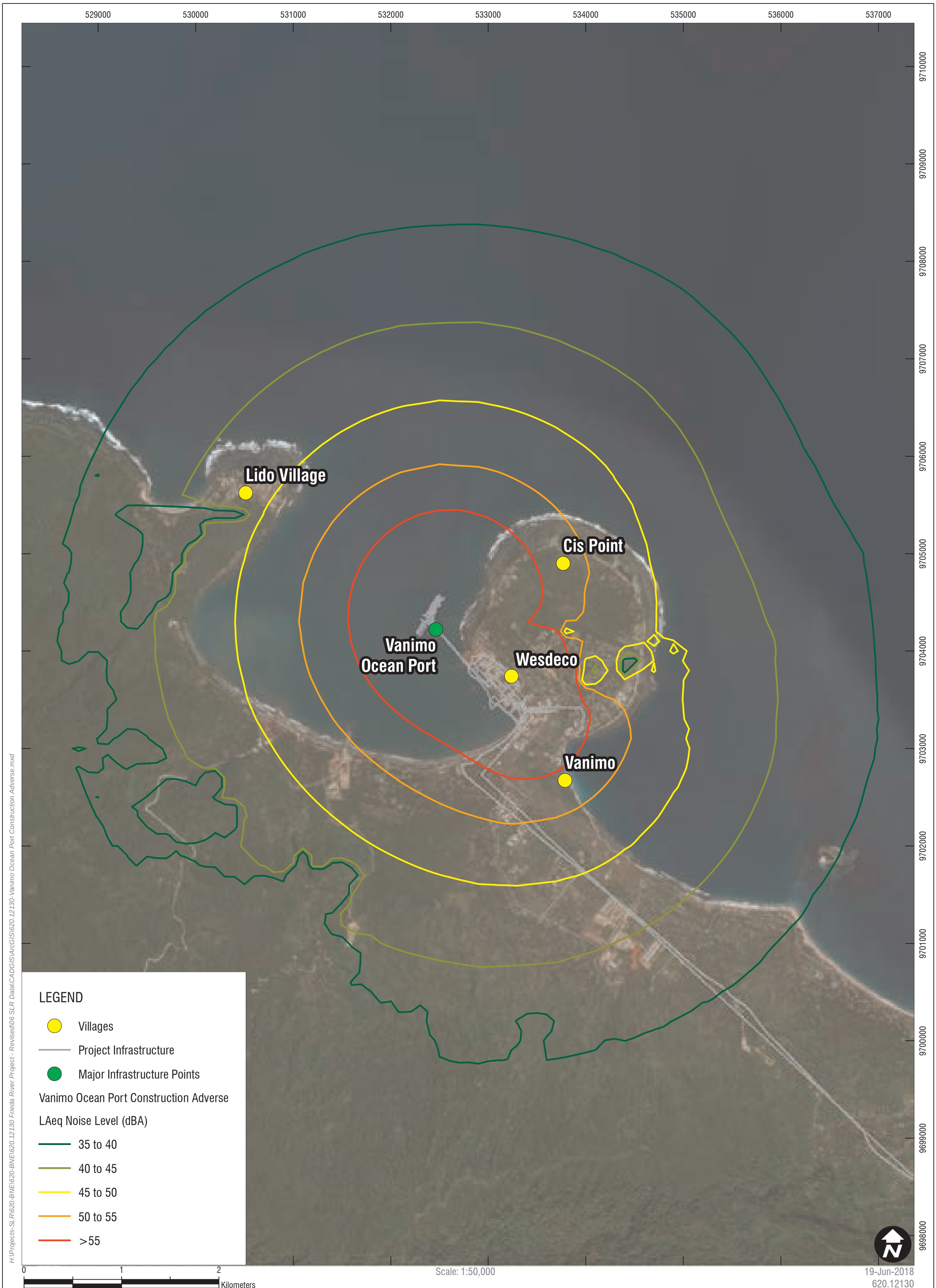
Vanimo Ocean Port Construction Neutral Weather

Appendix E Figure 1



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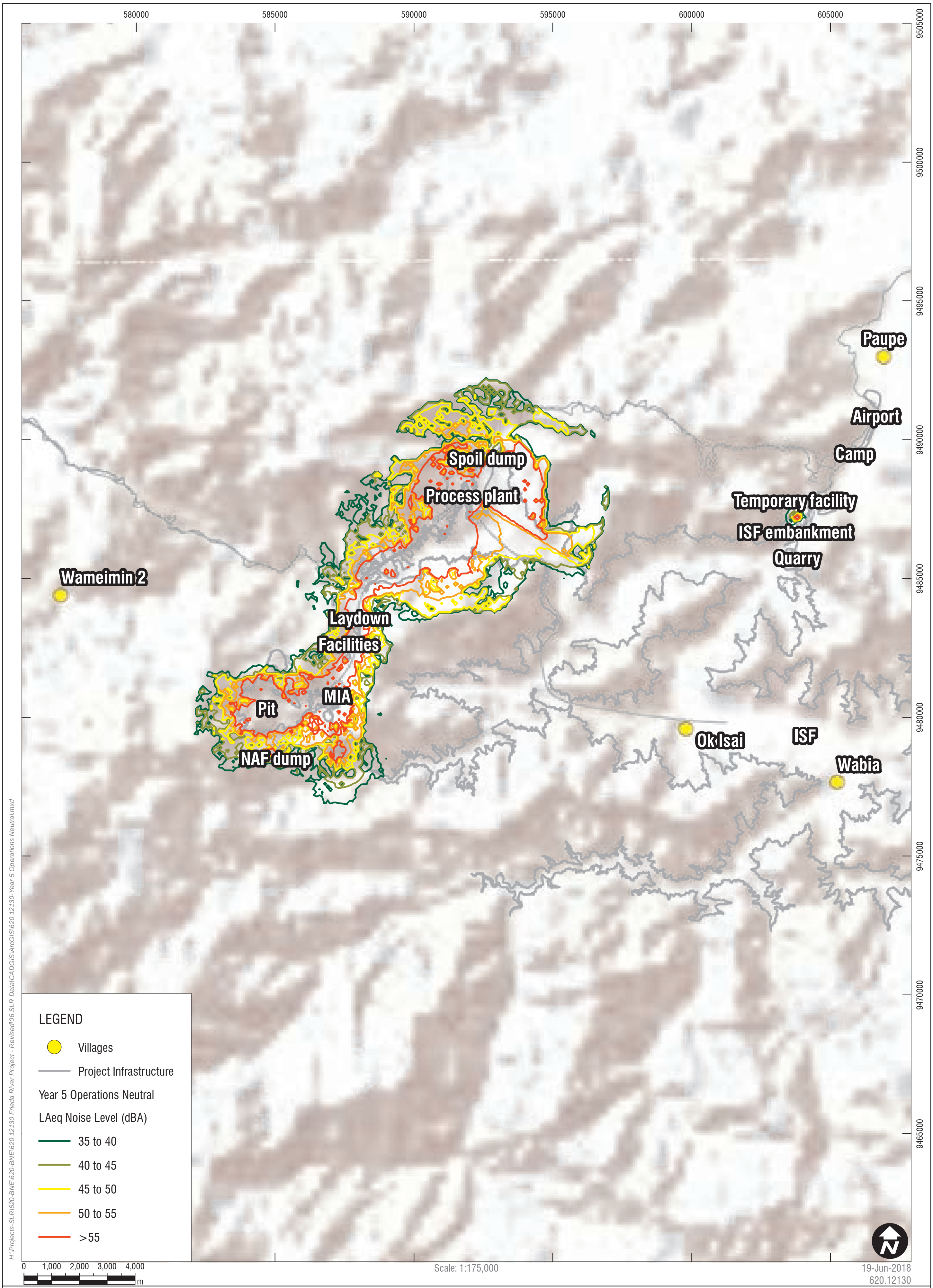
Vanimo Ocean Port Construction Adverse Weather

Appendix E Figure 2

APPENDIX F

Noise Contour Maps - Year 5 Mine Operations



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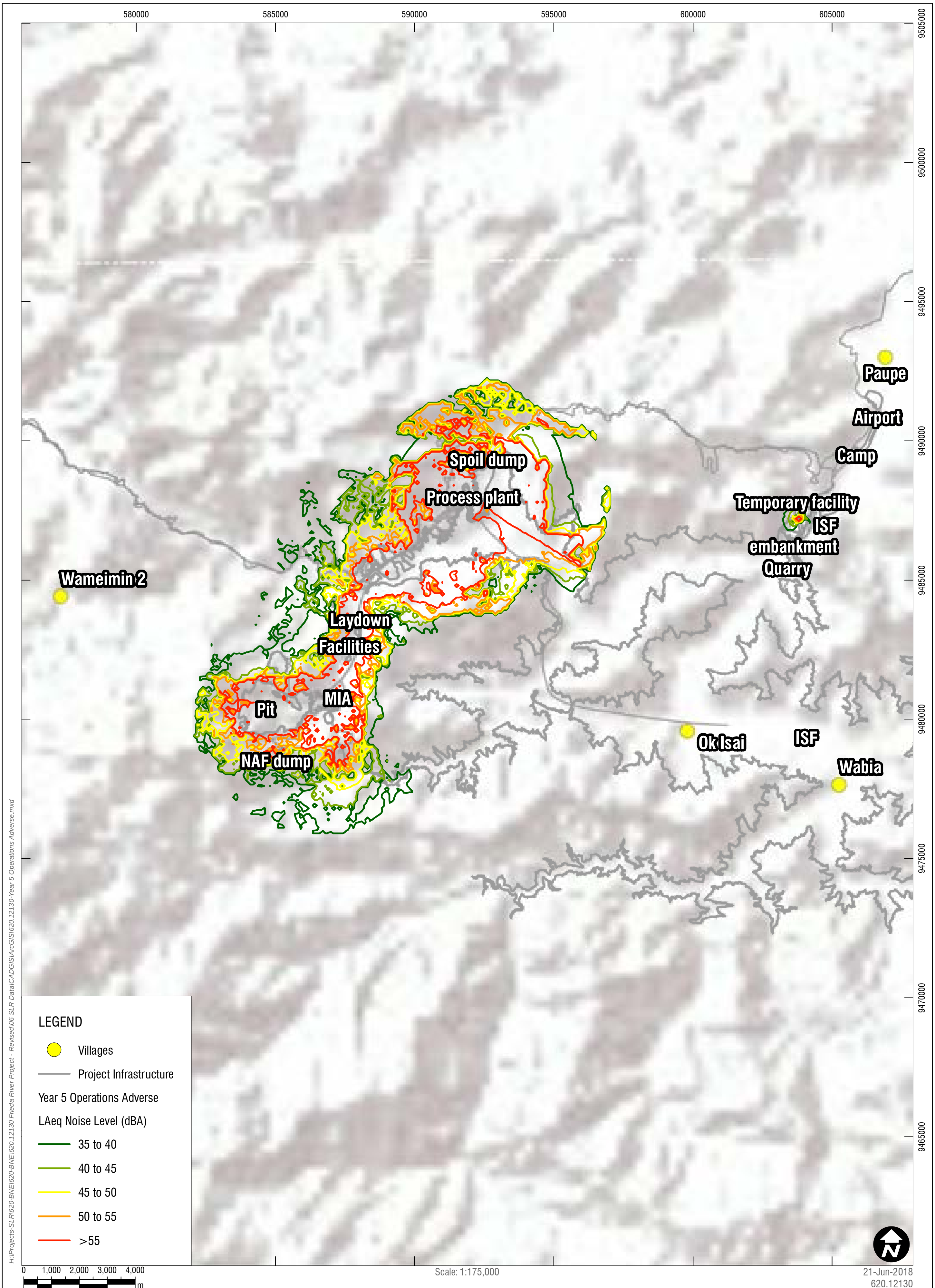
Year 5 Operations Neutral Weather

Appendix F Figure 1



Year 5 Operations Adverse Weather

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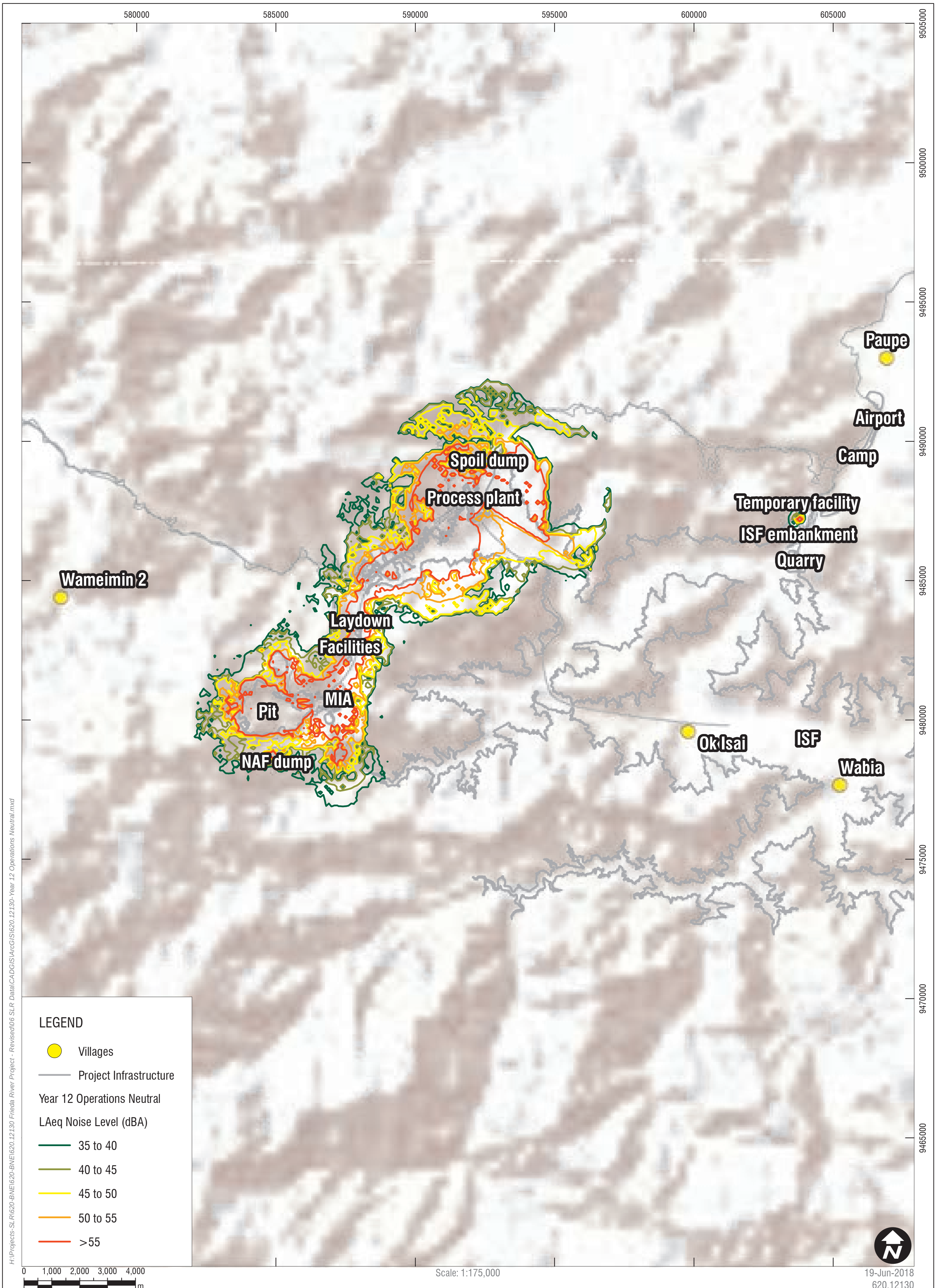
Appendix F Figure 2

APPENDIX G

Noise Contour Maps - Year 12 Mine Operations



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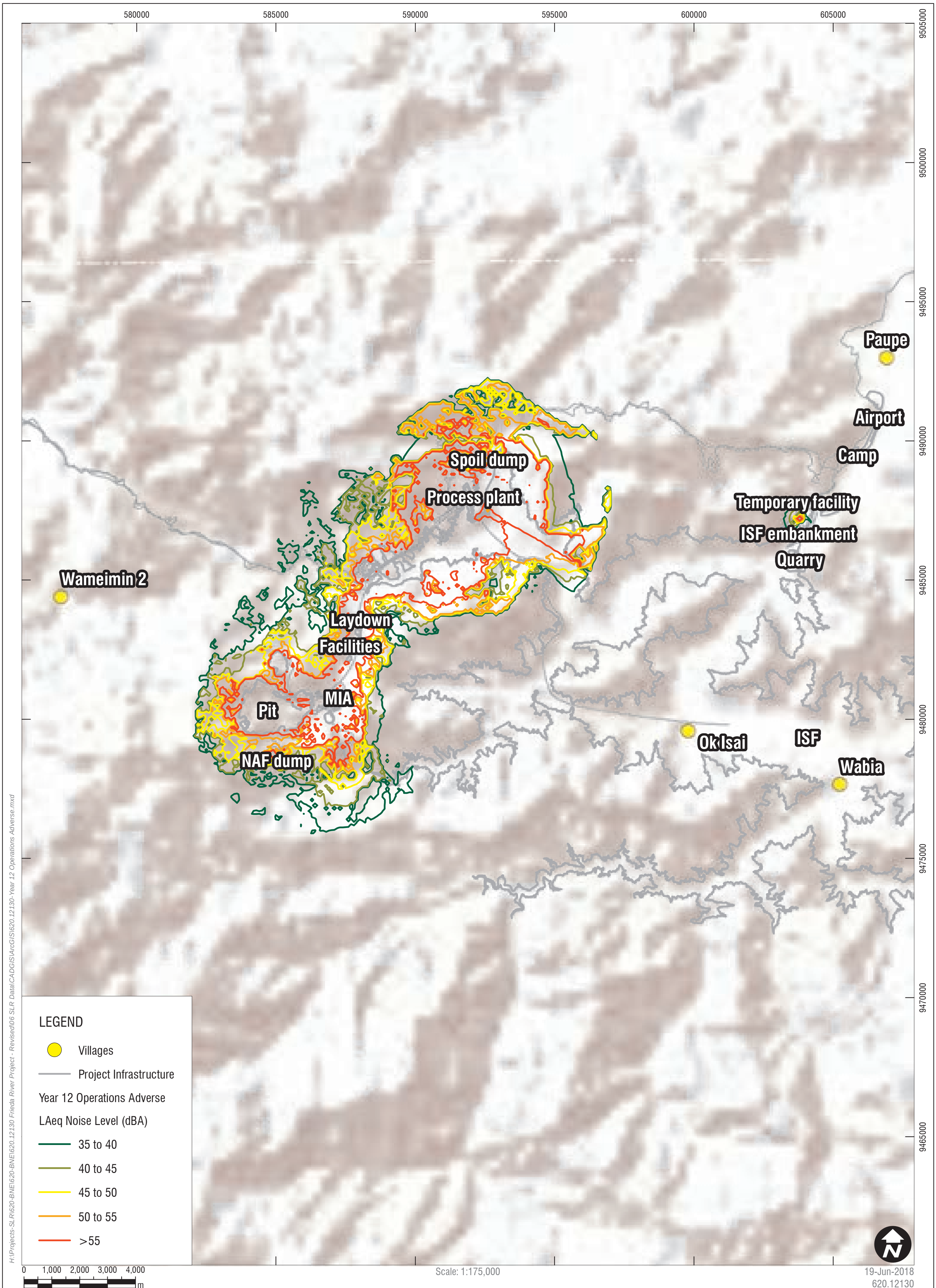
Year 12 Operations Neutral Weather

Appendix G Figure 1



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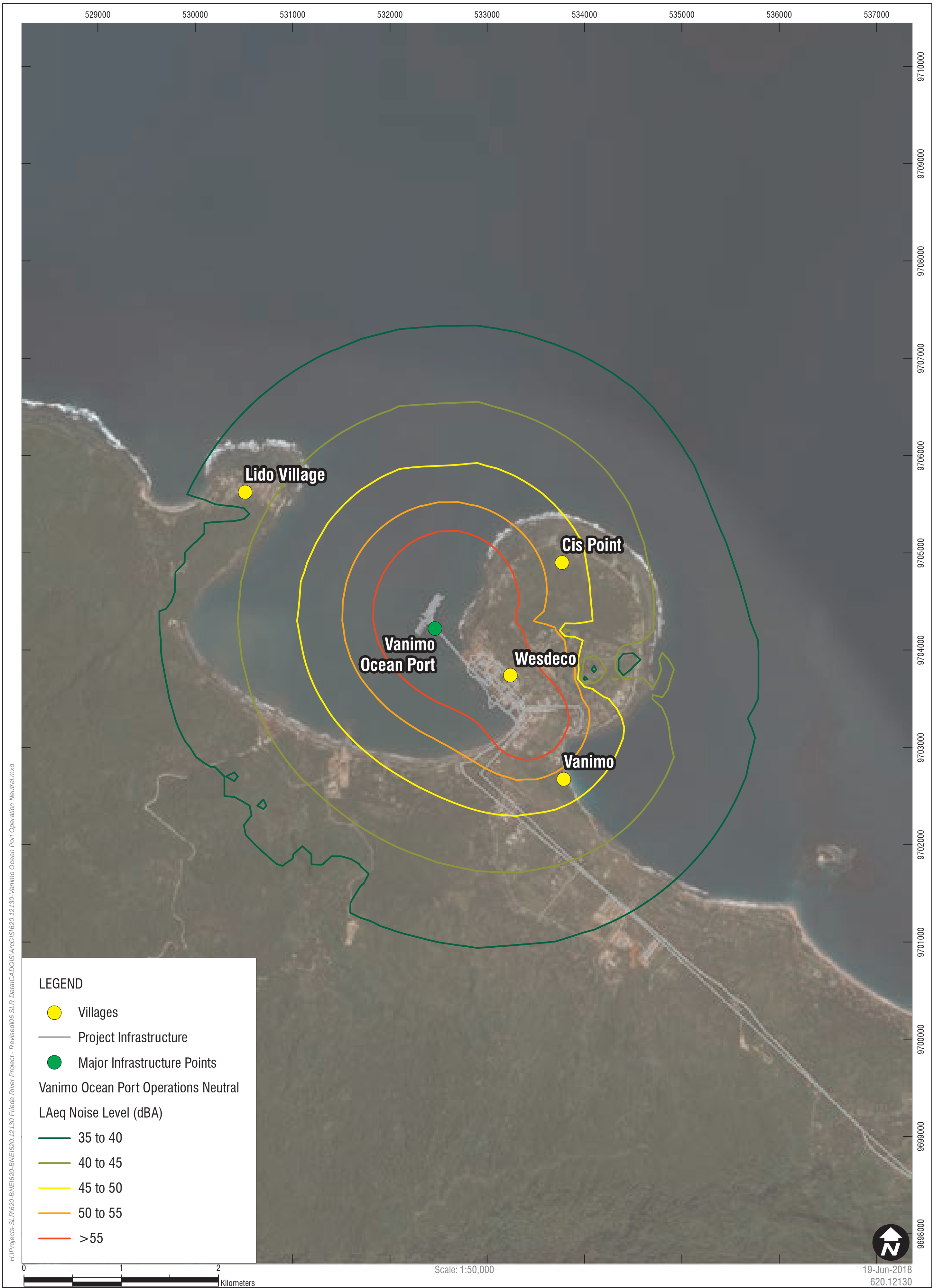
Year 12 Operations Adverse Weather

Appendix G Figure 2

APPENDIX H

Noise Contour Maps - Vanimo Ocean Port Operations



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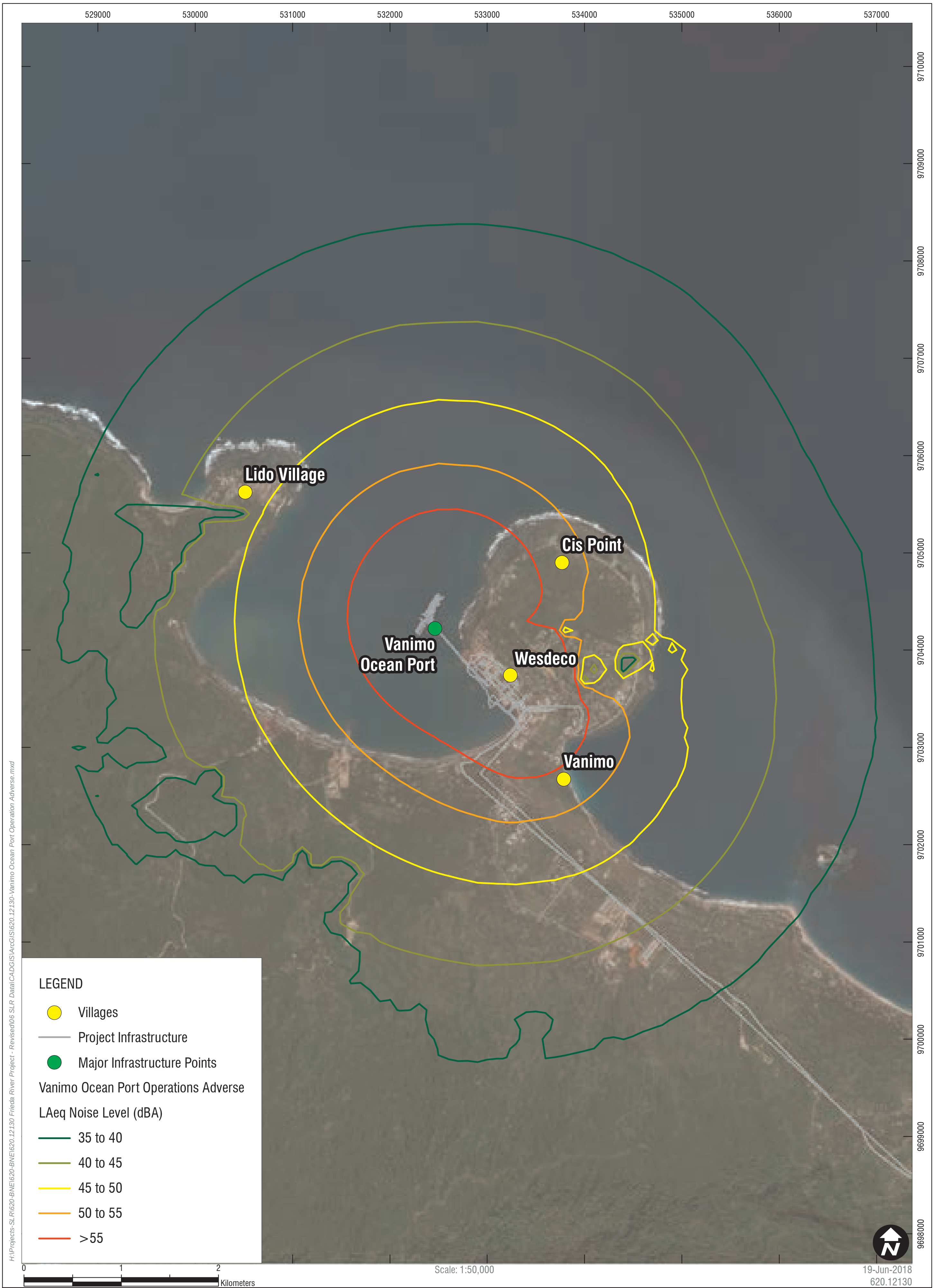
Vanimo Ocean Port Operation Neutral Weather

Appendix H Figure 1



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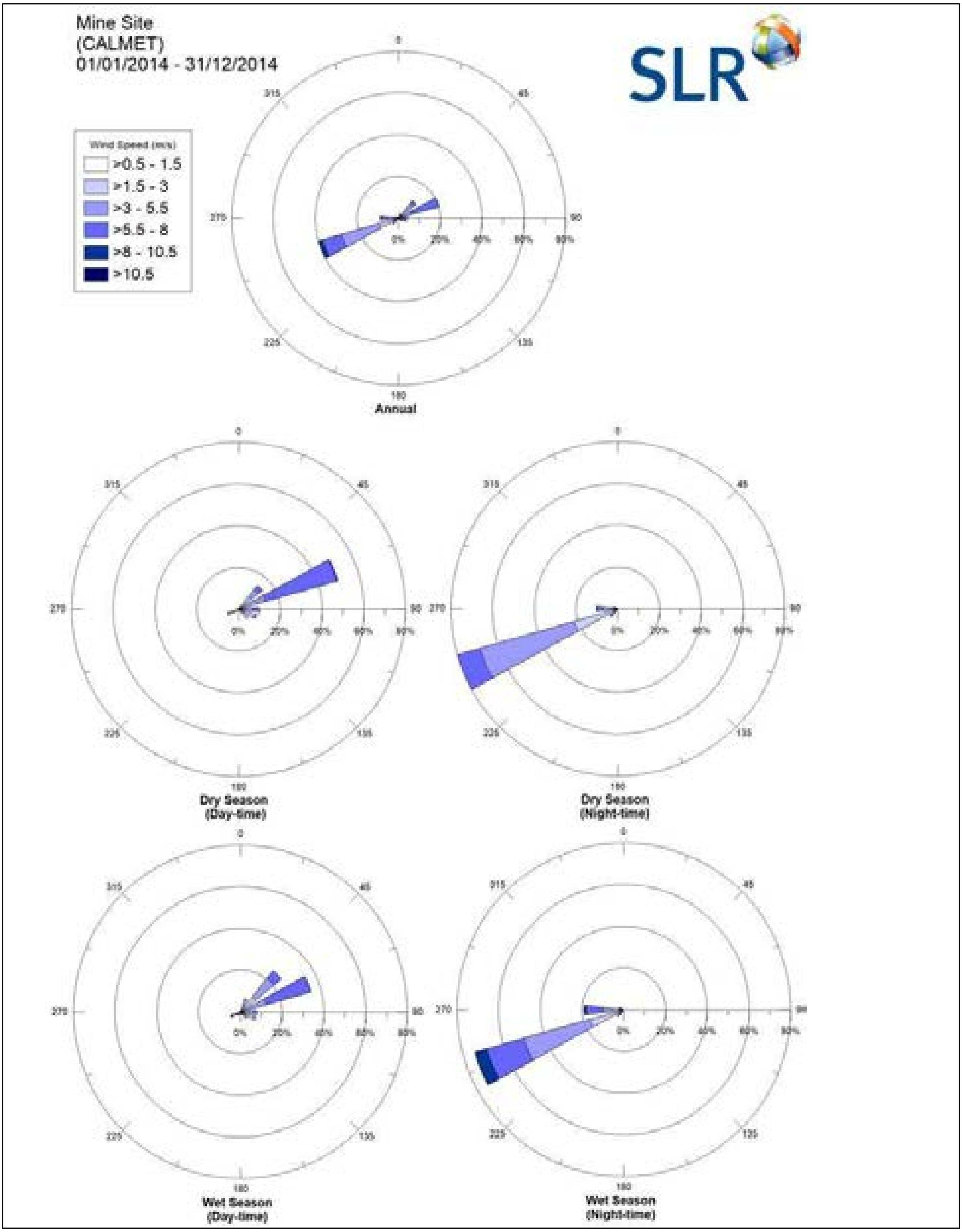
Vanimo Ocean Port Operation Adverse Weather

Appendix H Figure 2

APPENDIX I

Wind Roses

Wind Roses for the Mine Site



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