Assessment of Environmental Noise Effects

Taheke Geothermal Power Station Project

Assessment of Noise Effects Of Two Geothermal Power Station Options

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Tahi ki whenua he oranga whakatupuranga

Eastland
Generation

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Executive Summary

This report assesses potential environmental noise effects associated with the proposed Taheke Geothermal Project - a project to establish a geothermal power station capable of generating 25 to 40 MWe [net] of electrical power on a rural site within the Taheke 8C Development Area in the Rotorua district.

The assessment covers potential noise emissions associated station construction, on-going station operation, intermittent sound from steam venting or bypass operation, in addition to noise emitted during occasional geothermal well drilling, well testing, and associated works in the steamfield. This assessment considers noise associated with TWO possible geothermal power station generation options, both of which involves a mix of various industrial type noise sources, as described in the report. The assessment involves quantifying expected noise emissions using computer-based modelling methods to calculate noise levels expected in the area. Results are presented as tables of expected levels of noise received at identified receiver sites in the area and in the form of noise contour diagrams showing sound level contours (lines of equal sound pressure).

For each power station option, noise levels predicted for each receiver site are compared to the relevant noise performance standards of the Rotorua District Plan. Noise emitted during the construction phase has been compared to the noise limits recommended within the New Zealand Construction Noise Standard (NZS6803:1999).

The assessment is informed by recent results of measurements of existing ambient sound levels taken at three locations in the local area (including adjacent to sensitive receiver locations). The assessment of potential noise considers existing sound levels and quantifies how these will be relatively unaffected by noise from the operation of the proposed power station. While the assessment is informed by a comparison with ambient sound levels, the primary focus of the assessment is on compliance with the noise standards of the Rotorua District Plan and the New Zealand construction noise standard NZS6803:1999 Acoustics – Construction Noise.

The assessment of noise effects has found:

- *<u>Normal Operation</u> - Levels of noise emitted during normal operation of both power station generation options have been found capable of individually fully complying with both the Rotorua District Plan permitted activity noise standards NOISE-S1 and S2 during both daytime and night time at the relevant noise assessment locations.*
- *<u>Venting / Bypass Noise</u> - A separate assessment of noise emitted by each of the TWO power station options during intermittent steam venting (due to unforeseen circumstances) or operation under 'Bypass mode' have been found to be able to comply with district plan permitted activity noise standards NOISE-S1 and S2 for both daytime and night time at the relevant noise assessment locations.*
- *<u>Construction Noise</u> - Noise emitted during the construction of the power station and ancillary facilities (both options) and steam field development has been found to be able to be controlled and managed to achieve compliance with the New Zealand Construction Noise Standard as required by NOISE-R2 of the Rotorua District Plan.*
- *<u>Well Drilling Noise and Testing</u> – The assessment includes noise emitted during infrequent drilling of geothermal wells associated with the project. These temporary noise emissions have been based on a modern hydraulic drill rig (Rig 31) which has previously operated at Taheke. These noise emissions will be able to comply with the Rotorua District Plan permitted activity noise standards for well drilling.*

In summary, noise emissions associated with various aspects of the proposed Taheke 8C geothermal project have been assessed as likely to result in a 'less than minor' overall noise effect on the environment. During station operation, existing sound levels at the closest noise sensitive locations may be affected in a minor way. This low level of noise effect on the environment is due to precautions taken in siting the station and the low-noise type of activities proposed to be established as part of the Taheke Geothermal Project.

Malcolm Hunt
November 2022

TAHEKE 8C
The Proprietors of Taheke 8C and Adjoining Blocks (Inc)
Toitū te whenua he oranga whakatupuranga

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1 Introduction

The *ROOPU Whakarite Mahi Limited Partnership* (a partnership between The Proprietors of Taheke 8C and Adjoining Blocks Incorporated and Eastland Generation Limited) is the Applicant who is applying to the Rotorua District Council and Bay of Plenty Regional Council for resource consent(s) to construct and operate a 25 to 40 MWe (net) geothermal power station involving an average daily extraction rate of up to 10,000 tonnes of geothermal fluid. The station is proposed to be constructed on a rural site (Rural 1 Zone) within the Taheke 8C Development Area in accordance with the Rotorua District Plan (or the "District Plan"). The District Plan[1] establishes the Taheke 8C Development Area to provide for the establishment and operation of a range of activities including renewable energy, the aim being to enhance the economic and social wellbeing of current and future generations whilst avoiding, remedying or mitigating adverse environmental effects.

Malcolm Hunt Associates (MHA) have carried out an assessment of potential environmental noise effects associated with the proposed power station to be located within the Taheke 8C Development Area in the Rotorua District. The assessments carried out have identified and quantified the relevant noise sources associated with station construction, well drilling and testing, and power station operation. Regarding on-going 24-hour power station operation, this report considers noise emissions associated with TWO different options for utilising underground geothermal resources for power generation. All these results are compared with District Plan noise criteria for the Takahe 8C Development Area and other relevant guideline limits for noise received at representative noise sensitive locations.

The project description, layout and overall concepts are based on the information provided by the Project's Engineer. All maps and diagrams in this report are north facing (unless otherwise noted) and not to scale (unless otherwise noted).

2 Scope of Assessment

This assessment of potential noise effects is based upon:

1. Noise emissions associated with each stage of development – being steam field development (well drilling and testing), infrastructure development, power station construction and on-going operation. Noise emissions during the construction phase of the project fall within the scope of noise criteria set out within New Zealand construction standard *NZS 6803:1999 Acoustics - Construction Noise;*

2. Acoustic modelling and predictions of cumulative sound levels associated with the operation of each of TWO proposed power station options under normal and alternative 'bypass' type operating conditions. Predicted noise levels are assessed under the relevant noise criteria set out in the District Plan and other guiding documents;

3. Measured existing ambient sound levels which are used to define the existing ambient sound environment and assist in understanding the degree of expected changes in the local sound climate that will arise once the project commences;

4. The assessment includes a discussion on design standards and mitigation measures incorporated into the project to ensure noise effects on the environment remain reasonable at all times.

As the power station will operate over the full 24-hour day, night time noise impact is the focus of this noise assessment, particularly in terms of assessing compliance with the District Plan night time noise limits, and in terms of increases in existing ambient sound levels at noise sensitive locations.

3 Project Description

This assessment has considered the following components of the project:

- Drilling of a number of geothermal wells, an activity which has taken place in the area at a number of sites. Noise impacts include well pad preparation, 24-hour drilling and noise associated with flow testing, and other temporary

[1] Part 3 Area A – Specific Matters, Development Areas, Updated August 2022.

works associated with establishing wellhead infrastructure and pipelines. The Project Description outlines how production wells will be located on Taheke land in the area of the existing wells T8CP01 and T8CP02 (these well locations are shown in **Figure 2** below). It is expected that four wells will be required initially with up to another six required over the life of the plant. In addition to new production wells drilled in the vicinity of either P01 or P02 well pads, wells will be drilled at other sites for re-injection purposes. These wells will be located on Taheke land with a number required over the life of the plant. While the exact number and location of wells has yet to be determined, the assessment below provides good guidance on 'worst case' noise effects due to modelled well drilling sites being located relatively close to noise sensitive sites.

- Construction activities on the site over a period of 2 to 3 years including earthworks and site preparation to form building platforms, hard stand areas including access and parking areas, in addition to drainage works. Construction activities include actual station construction and short duration commissioning works (testing).

- On-going 24-hour operation of the Power Station over the life of the consent. This includes noise due to normal operation of pumps, cooling fans, turbine / generators, control valves and separation plants. Noise due to short term venting of geothermal steam under bypass or 'trip' situations has been separately investigated and reported on within the results set out below. The assessment of operational noise effects across the two generation options is mutually exclusive. That is, it is contingent on operational noise emitted by only ONE of two possible power station options as described in ***Section 4.0*** below.

3.1 Site and Local Environment

The power station site is proposed to be located on Taheke 8C land located approximately 18 kilometres north/north-east of Rotorua and 2 kilometres north-east of the Okere village on land that is zoned Rural 1 Zone, Taheke 8C Development Area, in accordance with the Rotorua District Plan. Further, the Taheke geothermal field is located in Geothermal Management Group 3 under the Bay of Plenty Regional Natural Resources Plan. The site itself is accessed off State Highway 3 just north of the Okere Falls settlement. **Figure 1** below illustrates the power station location and wider area.

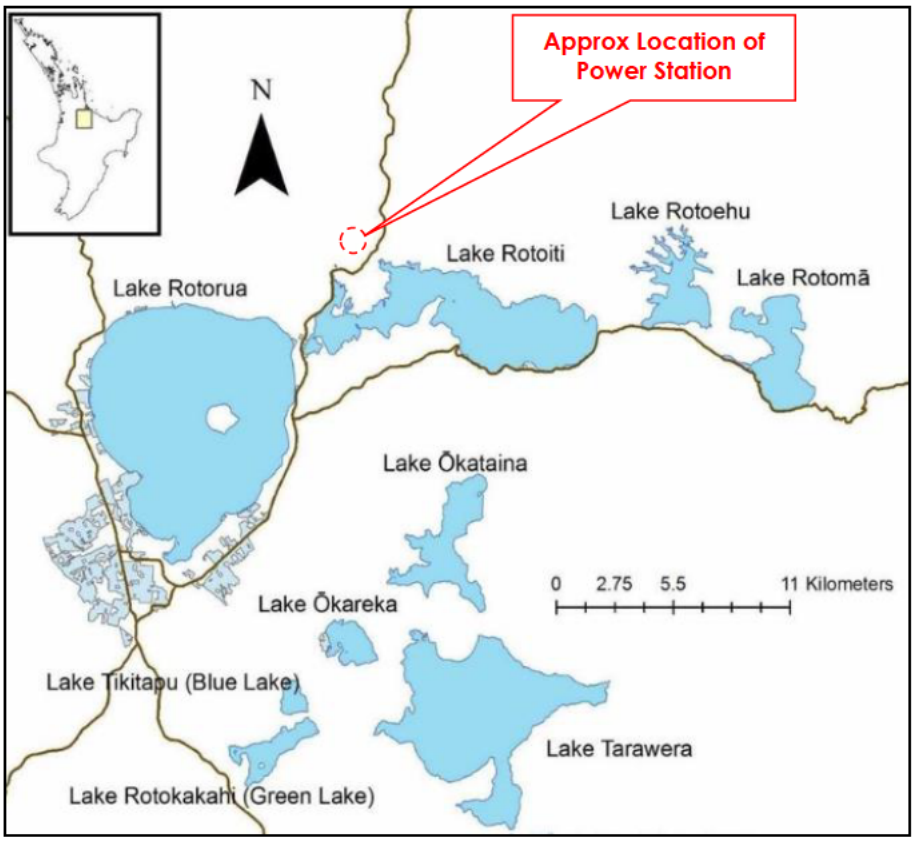

Figure 1: Location map showing the Rotorua Lakes and the approximate power station location.

3.2 Receiver Sites

A number of existing noise-sensitive sites have been identified in the local area. These receiver sites are described in **Table 1** with their corresponding locations shown in **Figure 2**.

Site	Location	District Plan Zone
A	2 Otaramarae Rd	Residential
B	1000A to E, State Highway 3, Okere falls	Rural
C	Manaiatutu Road, Okere falls	Rural
D	6 Otaramarae Road, Okere falls	Residential
E	905 State Highway 3, Okere falls	Rural
F	1108 State Highway 3, Okere falls	Rural
G	811 State Highway 3, Okere falls	Rural
H	Okere Falls Park	Reserve
I	29 Okere Road, Okere Falls	Rural

Table 1: Closest noise sensitive receiver sites identified within the vicinity of the proposed power station site.

Identified noise sensitive receiver sites in the vicinity of the power station site are illustrated in **Figure 2** as follows:

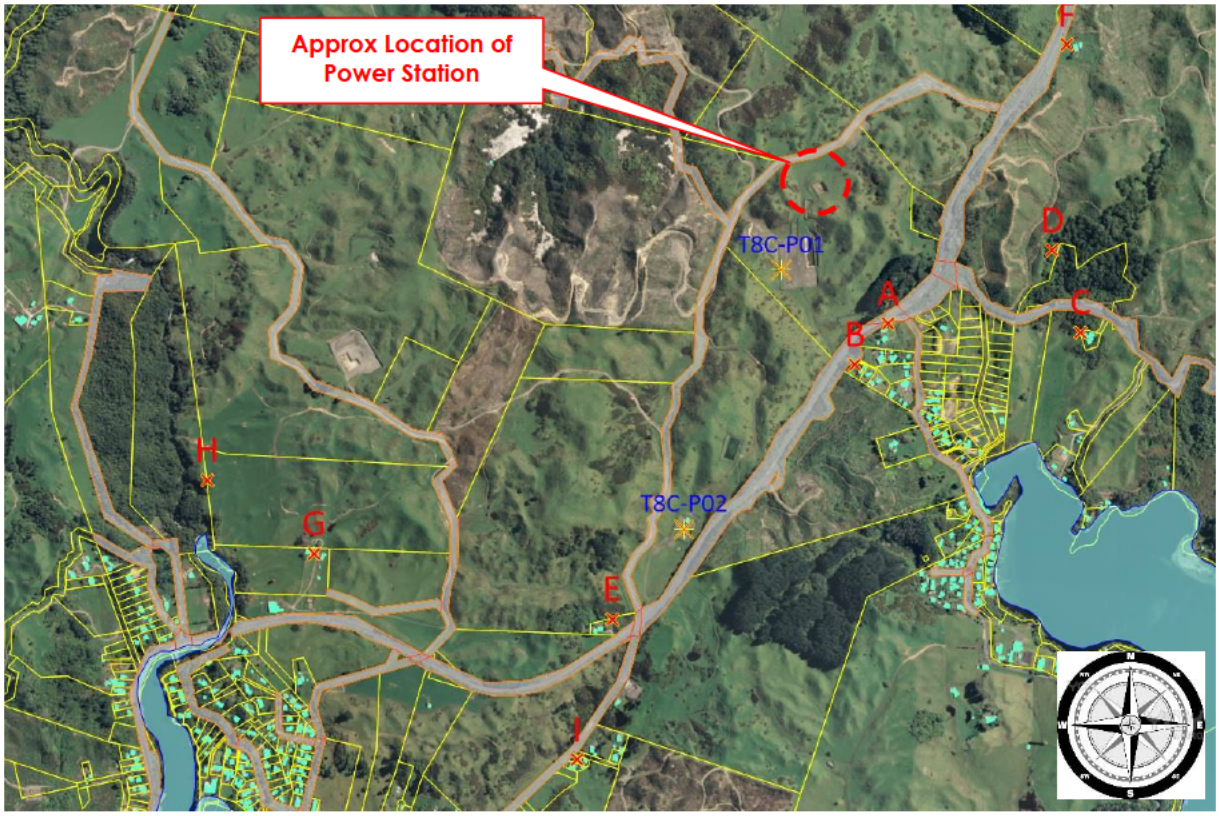

Figure 2: Aerial map showing closest noise sensitive sites (A to I inclusive) located in the vicinity of the proposed Taheke Geothermal Power Station.

Significant buffer distances and undulating terrain exists between the power station site and the identified closest sensitive receiver sites (**Table 1**).

Figure 3 below illustrates a 3d view of the local area and power station site indicating the naturally undulating nature of terrain in the area. As below, predictions of power station noise levels (***Section 5.0***) have taken into account in terms of distance and terrain shielding.

Figure 3: Aerial 3d-map of power station site showing undulating terrain in the surrounding area. NTS. Reference: Google Earth Pro Maps.

4 Noise Sources

4.1 Power Station

The assessment is based on one of two potential options for converting geothermal energy to electrical energy. **Section 5.0** below sets out the predicted noise emission levels during typical operation of ONE of the following options:

1. **Option 1**
   Conventional Condensing Steam Plant (the '**Conventional** Option'). The turbine / generator is housed within a turbine hall building. Cooling is provided by three large (18 m high) wet cell, mechanical draft cooling towers. Most of the steam condensate entering the cooling water circuit is evaporated in the cooling tower while the balance is reinjected to the geothermal reservoir. This plant is similar to the Mercury Kawerau Geothermal Power Station located in the Kawerau industrial area.

2. **Option 2**
   Organic Rankine Cycle Plant (the '**ORC Binary** Option'). This option utilises a series of up to 52 small "fin fan" cooling fans installed on a fan deck about 8 metres above ground level. These fans will be configured on site in two tranches about 30 metres apart. The turbine/generator is housed outdoors. No large buildings are necessary. As this type of plant utilises heat exchangers and "working fluid" for energy exchange, all geothermal steam and fluids (apart from non-condensable gases) are re-injected to the geothermal reservoir. This configuration would be similar to the Te Ahi O Maui geothermal plant installed near Kawerau.

Turbines and generator, condenser, gas ejectors/vacuum pump (where fitted) and cooling mechanisms have the potential to control overall noise levels from the site. Secondary noise sources are represented by the steam separator, lubrication, circulation or reinjection pumps, ventilation fans, transformers and the electricity distribution lines, all of which have less noise output and affect only local sound levels.

As set out within the project description, a powerhouse building will be employed for option 1, which will incorporate noise attenuating internal linings where necessary to reduce emission to the surrounding area. The sound emitted from the electricity transmission system is characterised by a slight hiss or hum typically associated with corona discharge from the conductors. The strength of these sound levels varies according to rainfall and humidity; however, the source strength remains low even under worse case conditions. As such, noise from the electrical system and connection to grid will not be unlikely to cause any noticeable noise effect at any sensitive receiver sites in the area.

Sound power levels for the various power station noise sources have been derived from manufacturer's data, field measurements of similar plant items. The relevant sound power levels for each of the two power station options are set out as follows:

OPTION 1 – Conventional Condensing Steam Turbine Generator		L_{Aw}[2] dB
Steam Turbine Generator	Inside turbine hall	120 dB
Hot Well Pump	Inside turbine hall	108 dB
Air Compressors (rotary & reciprocating)	Inside turbine hall	104 dB
Condenser Unit		110 dB
Separator		99 dB
Main Auxiliary Transformer		92 dB
Generator Step-up Transformer		100 dB
Cooling Tower fans EACH (THREE)		109 dB
Circulating Water Pumps		106 dB
Ventilating Fans Turbine Hall		92 dB
Separator		99 dB
Control Valves		102 dB
Bypass Mode / Venting Under Bypass		118 dB

Table 2: Sound power levels Option 1 - Conventional Condensing Steam Plant.

OPTION 2 – ORC Binary Plant	L_{Aw} dB
Cooling Fin-Fans (SPW EACH) dB (up to 52 Fans)	89 dB
Pumps, etc.	103 dB
Turbine Generator (unshielded) dB	113 dB
Main Auxiliary Transformer	92 dB
Generator Step-up Transformer	100 dB
Separator	99 dB
Control Valves	102 dB
Bypass Mode / Venting Under Bypass	118 dB

Table 3: Sound power levels Option 2 - Organic Rankine Cycle Plant.

4.2 Well Drilling

The geothermal resource is to be extracted using production wells and returned through a re-injection well. Up to six production wells will need to be drilled over the life of the consent with the exact number of re-injection wells required depending upon the conversion technology option employed within the power station.

Production and re-injection wells are proposed to be drilled using a mobile drill rig. Noise levels measured during typical drilling activity[3] have been used to quantify noise emissions during the two to three week well drilling periods expected on the application site. Levels of drilling noise have been modelled based on 'Rig 32' operated by MB Century and shown in **Figure 4** below.

Rig 32 is a modern, hydraulically operated rig with an efficient vertical pipe rack delivery system. The top drive is fully integrated with the vertical pipe rack through an automated pipe handler that rotates within the rack system. The semi-circular pipe rack is assembled around the rig floor and contributes to screening noise from this source. Sound power levels associated with Rig 32 well drilling operations are set out in **Table 4** which includes power generators, pumps and other ancillary equipment. Whilst the rig has a total of four generators and three mud pumps, typically only two generators and one mud pump are used at one time.

[2] L_{Aw} = A-weighted sound power level as used in sound level predictions.

[3] Measurement report by *Marshall Day Acoustics* of the MB Century Drillmec HH350 drilling rig (Rig 32) operating in Taupo. Report ref. "*Lt 001 201211cj SJK Drillmec HH350 Noise Evaluation 19 Dec 12.pdf*"

Figure 4: Photo of Rig 32 which is has hydraulically controlled drill processes and has operated at the Taheke site previously.

The following table summarises the Rig 32 sound power levels adopted as a basis for sound levels predicted received in the area, including at the closest dwellings:

Noise Source (# on-site)	Acoustic Centre Above Ground, m	Sound Power Level, dB L_{WA}	Octave Band Sound Power Level, dB L_w							
			63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Generator (4x)	3m	104	105	106	104	101	99	95	87	78
HPU (1x)	2m	101	102	104	103	98	95	90	87	82
Mud Pump (3x)	2m	110	109	110	106	105	110	103	102	91
Mud Shaker (4x)	4m	88	95	90	87	83	83	77	74	70
Drill Floor Hydraulics (1x)	8m	103	83	87	86	90	94	97	95	92

Table 4: Sound power levels for Rig 32 under normal operation, as per Marshall Day report.

These sound power levels are for a larger production well type rig (Rig 32). Smaller, less noisy rigs are often used for drilling re-injection wells as these are shallower requiring less drilling energy. The drilling process operates 24 hours a day, typically for periods of 10 days to 3 weeks.

Drilling noise assessment in this report is based on the operation of Rig 32 with the above noise output operating 24 hours per day.

The experience to date is that noise from drilling geothermal wells can be managed and reduced by selecting appropriate drilling rigs, careful design and the layout of the drill site, and via the use of quiet equipment. In some cases, drilling contractors are required to further reduce noise emissions using special mufflers or by placing acoustic barriers around plant items. Acoustic barriers can be constructed of suitable materials and appropriately placed for screening noisy parts of the rig (for example, mud pumps and generators) in directions where noise emissions are more important.

Section 6.0 sets out the expected sound levels emitted during well drilling operations. The location of the wells has not been finalised. The arbitrary location adopted within the predictions set out below represents a typical location for a production well near to the site perimeter. Any other wells associated with the project are likely to be further from any existing residential sites.

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4.3 Well Testing

Once a well is drilled, production testing takes place over variable periods of time (days or weeks) making use of portable steam vent silencers that incorporate efficient noise suppression in their design. Production testing is a temporary activity undertaken for a few weeks at most. When vented through adequately designed vent structures, saturated steam is effectively self-silencing compared to dry steam, owing to the interaction of sound with the minute water droplets in the high moisture content of saturated steam. Production testing has been measured at a range of distances at other steam fields and will have a sound power level similar to the operation of a conventional condensing turbine power station. Noise emitted during well testing therefore has similar potential noise effects as Option 1 set out in ***Section 6.0*** below.

Figure 5: Photo of typical well production testing.

5 Acoustic Modelling

5.1 Method

The prediction method utilises specific input variables including sound power levels at source, air absorption values based on temperature and humidity. Sound power data used within the model are the sound power levels presented above in ***Section 4.0***.

The prediction method is based on sound power levels at source propagating over a range of distances to receiving sites in the area. Sound level predictions have been conducted using a computer-based prediction program which has as its base the algorithms set out within ISO 9613-Part 2:1996 [4]. This method predicts equivalent continuous A-weighted sound level (L_{Aeq}) under meteorological conditions favourable to propagation from sources of known sound emission. These meteorological conditions equate to slight downwind conditions, or propagation under a well-developed moderate ground-based temperature inversion as commonly occurs at night.

The ISO 9613-Part 2:1996 method adopted to predict sound levels conforms with the recommendations of NZS6801:2008 *Acoustics – Measurement of Environmental Sound* which states, at clause 7.1.2, that slightly enhanced sound propagation conditions should be adopted for predictions of environmental sound.

Sound attenuation due to acoustic screening caused by undulating terrain (that is, where there is no line of sight between the source and the receiving position) are taken into account using the acoustic barrier principles of Maekawa [5].

Predicted sound levels are output in the form of L_{Aeq} dB sound levels for each 20-metre x 20 metre 'node' across the local area. A contour plotting programme ("Surfer" by Golden Software) is then used to plot sound level contours[6]. In addition,

[4] *ISO 9613-2:1996 Acoustics - Attenuation of sound during propagation outdoors -- Part 2: General method of calculation*. International Organisation for Standardisation 1996, Geneva.
[5] Z. Maekawa, *Noise reduction by screens*, Applied Acoustics, 1 [1968], p.157.
[6] Sound level contours depict lines of equal sound pressure, measured in L_{Aeq} dB.

predicted sound levels are able to be output in terms of expected sound levels for specific locations, such as at the notional boundary to nearby rural dwellings or the closest residential zoned land.

Prediction results set out within in ***Section 6.0*** which outlines predicted sound levels received under enhanced propagation conditions for each of nominated receiver sites. ***Section 7.0*** sets out the results of measurements of existing ambient sound levels found in the local area under calm conditions. ***Section 9.0*** below assesses sound levels predicted for each identified receiver location in terms of compliance with the relevant noise limits adopted from the Rotorua District Plan and relevant guidelines (the relevant noise criteria are described in ***Section 8.0***). The assessment also includes commentary on a comparison of predicted station noise levels with measured ambient daytime and night time ambient sound levels found in the area.

5.2 Sound Propagation Factors

5.2.1 Topography

The terrain surrounding this power station site is undulating and hilly. Screening effects of natural barriers has been taken into account where direct line of sight is blocked by the land form. The modelling adopted terrain data for the area is sourced from Bay of Plenty Regional Council (BOPRC) LIDAR terrain data. The data has been cross referenced and checked with a number of GPS points taken around the station site and in the surrounding area.

The modelling results set out below indicate that terrain has a significant influence on sound levels received in the local area, due to station and steamfield noise sources.

5.2.2 Meteorological Effects

Meteorological factors may influence the propagation sound. Attenuation due to atmospheric absorption of sound has the effect of reducing sound levels over distance in addition to the usual "inverse square" spreading of sound levels over distance. The air absorption effect is frequency dependent and is slightly related to the temperature and humidity of the air. In this case, air absorption has been factored in to the predictions, with temperature and humidity values adopted being the conservative values set out table 2 of ISO9613-2:1996 (12 degrees Celsius and 70% humidity, atmospheric pressure of 101.325 kPa).

5.2.3 Wind Effects

The effects of wind on sound propagating outdoors are to reduce sound levels received 'upwind' and to augment levels downwind. The effect is distance dependent. Predictions carried out are for slight downwind enhancement conditions i.e., adjustment for slightly enhanced propagation due to wind has been included in the modelling. In effect, downwind sound propagation has been included for all directions which is a worst-case situation.

In reality, the actual predominant wind directions experienced in the area are set out in the wind rose diagram shown in **Figure 6**.

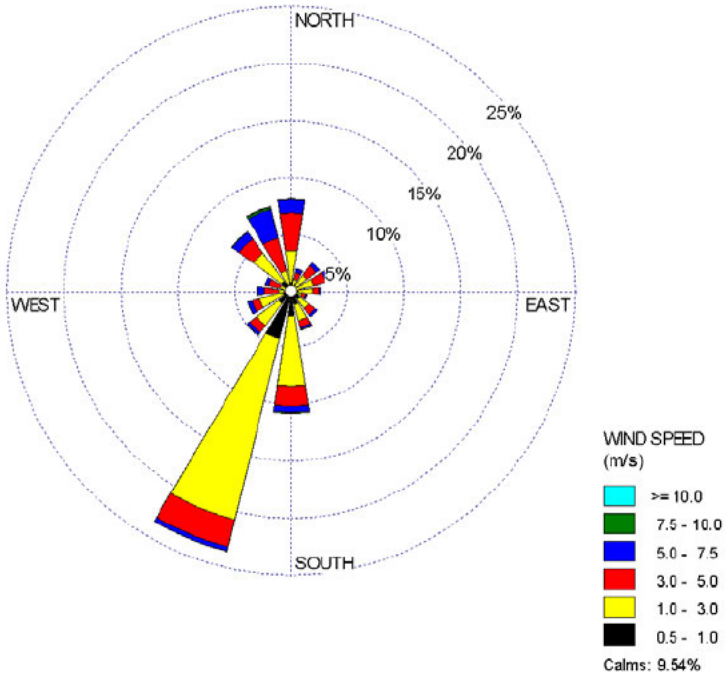

Figure 6: Wind rose diagram for the site showing the predominant wind directions. Based on 2005 meteorological data. Wind Rose Reference; URS TAOM Air Quality Report 2012.

Figure 6 indicates the predominant winds are from the south south west, thus reducing predicted sound levels for receivers located south of the station site. Under predominant wind conditions, downwind (enhanced) propagation will occur to receivers located to the north of the development site, however there are no known sensitive sites located in this direction.

5.3 Accuracy of Modelling Results

The attenuation of sound propagating outdoors between a sound source and receiver location fluctuates due to variations in the meteorological conditions along the propagation path.

Table 5 of ISO 9613-2:1996 (reproduced below as **Table 5**) sets out the estimated accuracy of broadband noise.

	Source-Receiver Distance, *d*	
Mean height of source and receiver, *h*	**0<d<100m**	**100m<d<1000m**
0 < h < 5m	±3 dB	± 3 dB
5 m < h <30m	±1 dB	± 3 dB

Table 5: Accuracy of acoustic modelling. Reference ISO 9613-2:1996.

Modelling results presented with an accuracy ±3 dB based on **Table 8** and the assumptions set out above taking into account typical measurement uncertainty for environmental acoustic measurements.

6 Prediction Results

6.1 Option 1 – Conventional Power Station

The predicted sound level contours (45 to 65 L_{Aeq} dB) for normal operation of Power Station Option 1 are depicted in **Figure 7** below (not showing water pump operations).

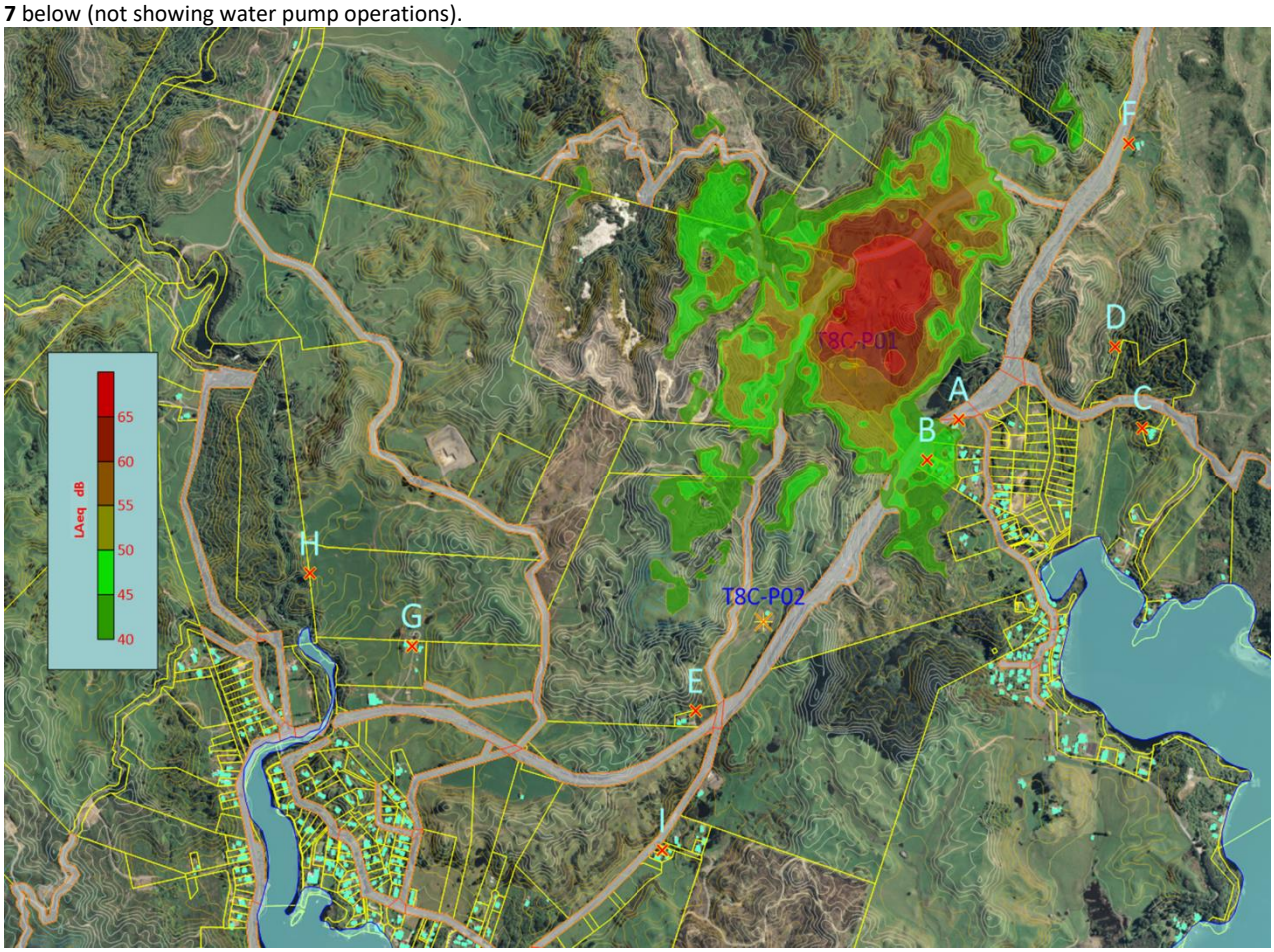

Figure 7: Predicted sound level contours (40 to 70 L_{Aeq} dB) for Option 1 Conventional Option.

6.2 Option 2 – ORC Binary

The predicted sound level contours (40 to 70 L_{Aeq} dB) for normal operation of Power Station Option 2 are depicted in **Figure 8** below.

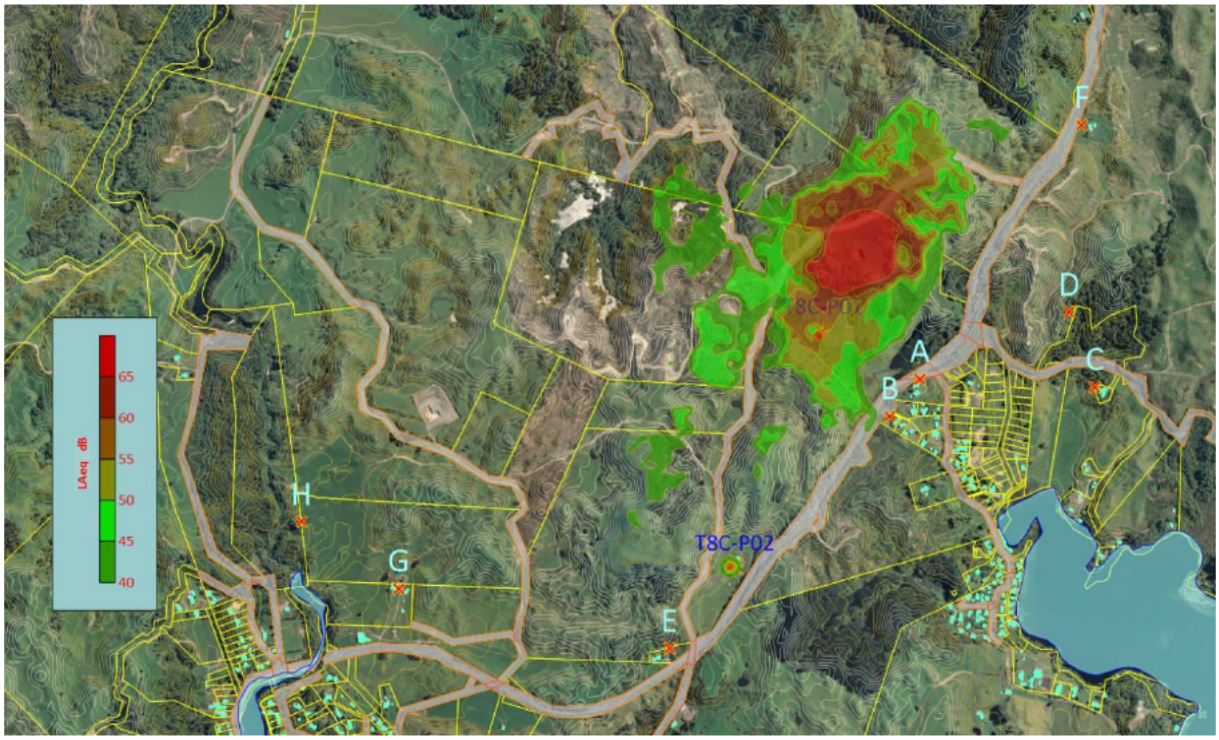

Figure 8: Predicted sound level contours (45 to 65 L_{Aeq} dB) for Option 2, ORC Binary Option, typical maximum station operation.

6.3 Tabulated Results - Two Options - Normal Station Operation

The predicted sound levels for typical station generation at or near its rated electrical output are set out in **Table 6** for identified noise receiver locations (notional boundary position) in units of $L_{Aeq(15\ min)}$ dB. This is for normal station operation, from all station and ancillary sources which includes the steam turbines, condensers, pumps, cooling towers, transformers, separators, re-injection pumps etc as set out above in ***Section 4.0***.

	Noise Receiver Site	Predicted Sound Level **Option 1** LAeq(15 min) dB	Predicted Sound Level **Option 2** LAeq(15 min) dB
A	2 Otaramarae Rd	37	35
B	1000A to E, State Highway 33, Okere falls	43	38
C	Manaiatutu Road, Okere falls	28	27
D	6 Otaramarae Road, Okere falls	30	29
E	905 State Highway 33, Okere falls	23	23
F	1108 State Highway 3, Okere falls	28	28
G	811 State Highway 3, Okere falls	19	18
H	Okere Falls Park	18	17
I	29 Okere Road, Okere Falls	19	18

Table 6: Predicted LAeq(15 min) levels (in dB) received at receiver locations for normal station operation (Option 1 and Option 2).

The above tabulated LAeq(15 min) prediction results are presented in graphical form as follows:

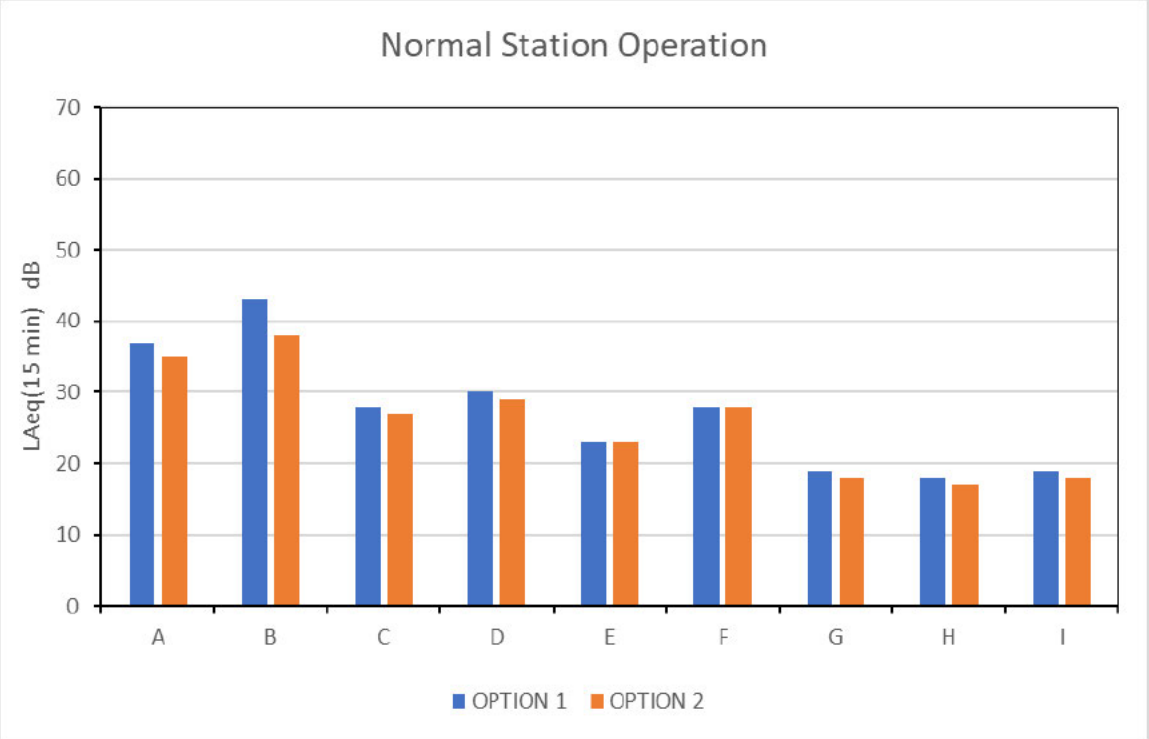

Figure 9: Predicted LAeq(15 min) levels due to normal plant operation, as received at locations A to I.

Received sound levels will be generally broadband in nature without any noticeable tones or impulsive characteristics.

The assessment of the above noise levels due to normal 24-hour station operation are set out in ***Section 9.0*** below.

6.4 Temporary Station By-Pass / Venting Operations - Two Options

Noise Receiver Site		Predicted Sound Level **Option 1** LAeq(15 min) dB	Predicted Sound Level **Option 2** LAeq(15 min) dB
A	2 Otaramarae Rd	39	40
B	1000A to E, State Highway 33, Okere falls	37	42
C	Manaiatutu Road, Okere falls	32	31
D	6 Otaramarae Road, Okere falls	34	34
E	905 State Highway 33, Okere falls	26	26
F	1108 State Highway 3, Okere falls	32	31
G	811 State Highway 3, Okere falls	22	22
H	Okere Falls Park	21	20
I	29 Okere Road, Okere Falls	22	22

Table 6: Predicted LAeq(15 min) dB levels received at identified receiver locations for temporary station by-pass / venting operations.

The above tabulated LAeq(15 min) prediction results are presented in graphical form as follows:

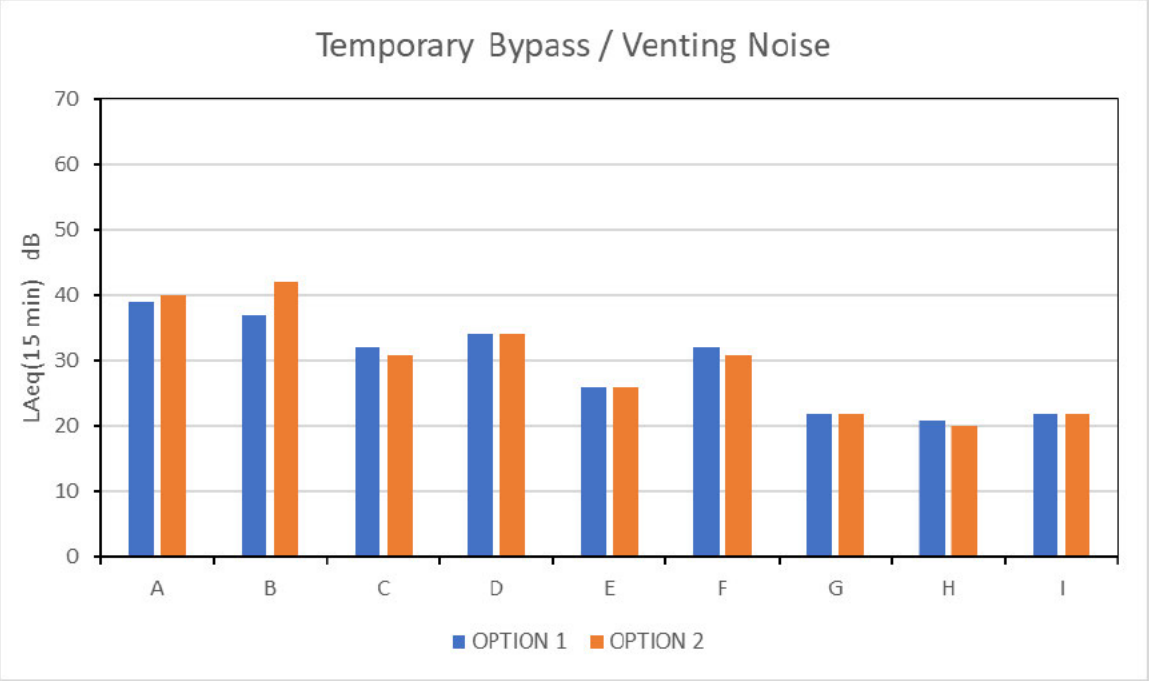

Figure 10: Predicted LAeq(15 min) levels due to temporary station by-pass / venting operations, as received at locations A to I.

Received sound levels will be generally short duration (1 to 4 hours) and will be more likely to occur during daytime. These sound emissions are expected to be broadband in nature without any noticeable tones or impulsive characteristics.

The assessment of the above noise levels due to normal 24-hour station operation is set out in ***Section 9.0*** below.

6.5 Well Drilling Prediction Results

The predicted 40 dBA, 45 dBA, 50 dBA, and 55 dBA contours (LAeq(15 min) dB) for well drilling operations at either P01 or P02 well pads are depicted in **Figures 11 and 12** as follows;

	Noise Receiver Site	Predicted Sound Level **Drilling In Vicinity of P01 Production Well** LAeq(15 min) dB	Predicted Sound Level **Drilling In Vicinity of P02 Production Well** LAeq(15 min) dB
A	2 Otaramarae Rd	40	24
B	1000A to E, State Highway 33, Okere falls	50	26
C	Manaiatutu Road, Okere falls	25	24
D	6 Otaramarae Road, Okere falls	25	18
E	905 State Highway 33, Okere falls	20	53
F	1108 State Highway 3, Okere falls	21	14
G	811 State Highway 3, Okere falls	16	21
H	Okere Falls Park	14	17
I	29 Okere Road, Okere Falls	15	33

Table 7: Predicted LAeq(15 min) dB sound levels for noise sensitive receiving locations from indicative well drilling operations.

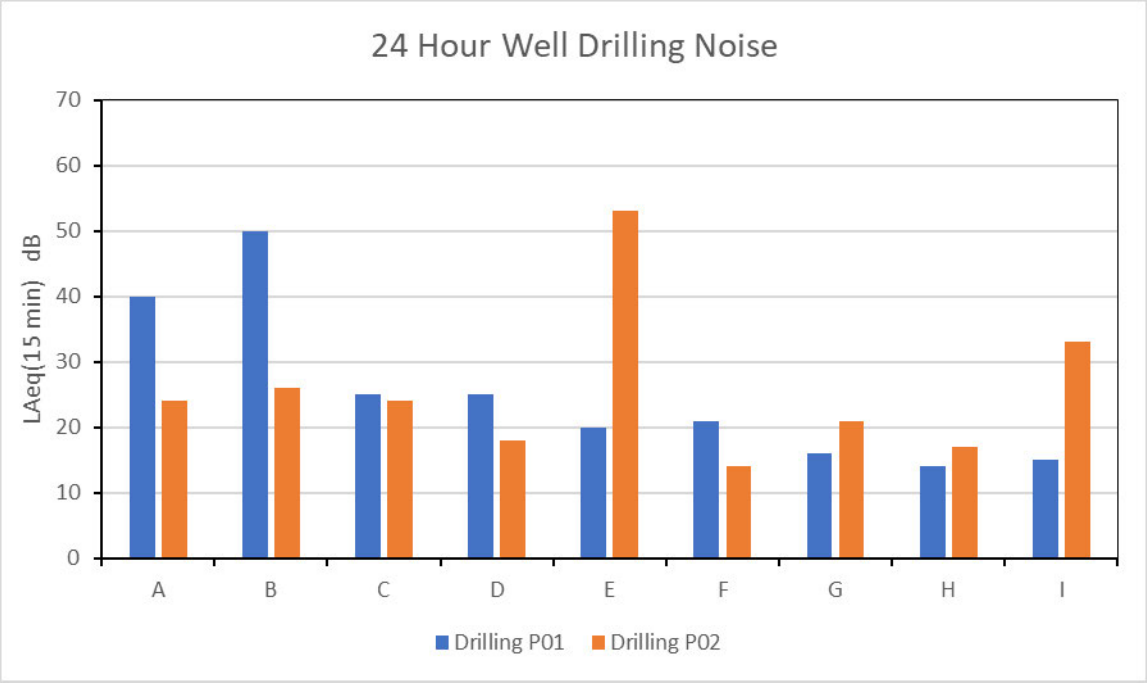

Figure 11: Predicted LAeq(15 min) levels due to 24-hour drilling operation, as receiver at locations A to I.

Received sound levels will be generally broadband in nature without any noticeable tones or impulsive characteristics.

The assessment of the above noise levels due to 24-hour well drilling is set out in ***Section 9.0*** below.

7 Existing Environment: Ambient Sound Level Survey

7.1 Background

Measured existing ambient sound levels found within the receiving environment provide an important context within which future noise effects can be assessed. While a key objective of this report is to assess compliance with specific noise performance standards (for example as set out in the District Plan), information on the current 'day to day' noise environment has been collected at various sites to gain an understanding of the baseline background sound levels existing in the area.

Generally, ambient sound levels in rural areas are low owing to the lack of significant noise sources and the dispersed nature of noise sources that do exist. The readings show existing sound levels in the area are highly affected by:

- Sounds from traffic on state highway 33 and local roads;
- Sounds from animals, birds and insects;
- Farm equipment and machinery;
- Distant sound associated with rural activities.

7.2 Survey Method

The survey involved measurements conducted at various times of the day including at the closest residential sites during the day time periods at nine sites in the local area. A data logging sound level meter was set up at one of these representative sites for a period of approximately seven days (~1,000 ten-minute samples) to collect data under a range of daytime and night time conditions including nil to light winds, with varying weather conditions. There was significant rain (for limited periods) during the first few days of the logging period. Measurements at the remaining sites were conducted during periods of relatively calm winds with nil precipitation.

Measurements were conducted during late August 2022. The measurements included a long-term day/ night measurement site (Site 1) handheld "attended" daytime measurements (Sites 2 to 3). Hand held measurements were collected over a 15-minute sample period.

7.3 Measurement Sites

Monitoring was conducted at sites 1, 2 and 3 as shown within **Figure 12** below. The survey targeted readings taken within relatively quiet areas, away from the state highway, representative of dwellings and noise sensitive sites not immediately adjacent to the highway.

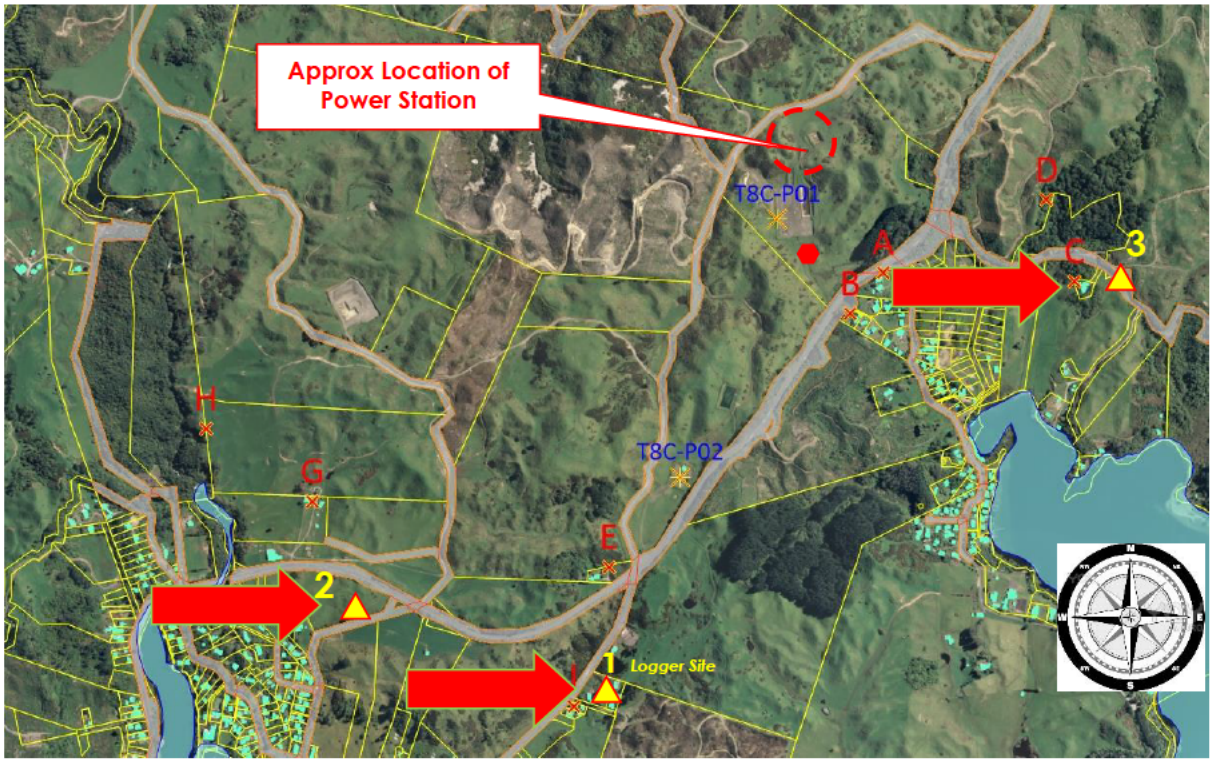

Figure 12: Aerial photo map of ambient sound level monitoring locations 1, 2, and 3 ( ). Reference: Google Earth Pro Maps.

7.4 Measurement Equipment

Equipment sound level measurements were conducted using a Bruel and Kjaer 2260 Investigator Type 1 Sound Level Meter. Field calibration was checked before measurements. The microphone was positioned approx. 1.2 metres above local ground. The microphones had an inner and outer windshield placed over the microphones during all measurements. The following settings were used:

Measurement settings:

- A weighting (dBA), Fast response.
- Linear Frequency Weighting (dB, un-weighted) employed for 3rd octave band analysis.
- Measurement Metrics: L_{Aeq}, L_{A90} and L_{AFMax}

All sound level monitoring was carried out in accordance with the procedures set down in the technical New Zealand Standard, NZS6802:2008 Acoustics - *Measurement of Environmental Sound*. This Standard provides guidance on the technical aspects of noise measurement.

Weather conditions throughout the monitoring survey conducted between 26th and 28th August 2022 were calm with light winds from the South-West wind direction. The mean temperature over this time was 14 ºC.

7.5 Results

7.5.1 Sound Level Logger Results

An automated sound level logger was deployed at SITE 1 for a period of 48 hours in order to measure ambient sound levels under calm daytime and night time conditions. The results are summarised in the following graph;

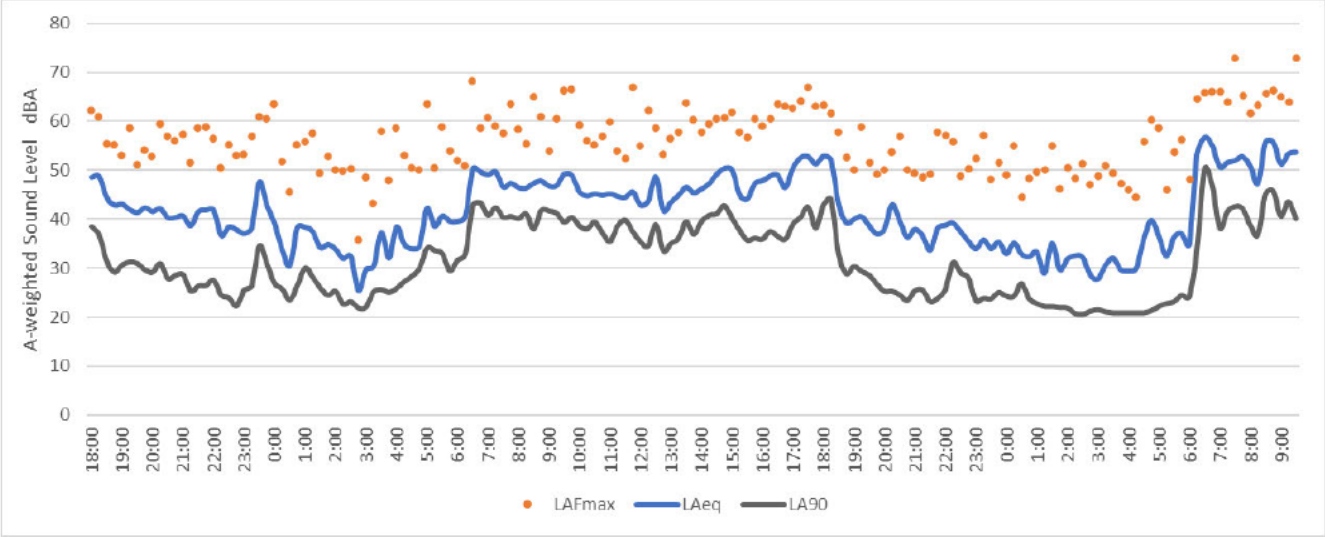

Figure 13: Ambient sound levels (LAeq, LAFMax and LA90) measured at site 1 between 26th and 28th August 2022.

These results reflect the secluded location of Site 1 which, although affected by distant sounds of vehicles using State Highway 33, is a relatively quiet location. Night time LAeq sound levels below 30 dB is indicative of quiet night periods under calm weather conditions.

7.5.2 Short Term Handheld Results

Appendix C contains graphs of one minute by one minute measured ambient sound levels, taken at two sites (Site 2 and Site 3). Separate handheld measurement sampled were collected during daytime and night hours to capture variability in ambient sound levels.

Summary results of ambient sound level readings are presented in **Table 10** below which sets out mean measured ambient sound levels using three relevant descriptors.

Site	Time of Day	L_{Aeq} dB	L_{AFMax} dB	L_{A90} dB
Site 2	Day	48 dB	67 dB	41 dB
	Night	42 dB	68 dB	38 dB
Site 3	Day	56 dB	60 dB	48 dB
	Night	40 dB	57 dB	32 dB

Table 10: Measured overall sound pressure levels for each of the noise descriptors at each site.

These ambient sound levels indicate a generally quiet environment, at least compared to residential sites located within urban parts of the district. Low levels of ambient sound during night time periods are a feature of the existing environment. Natural sounds due to vegetation-induced wind noise and sounds from birds and farm animals were noted as the most common identifiable sound source during surveys. As this rural area supports mainly pastoral farming, rural sounds from farm machinery used for cultivating land or harvesting do not affect ambient sound levels in the area. For much of the time sound levels experienced at receiver sites located within 100m to 150m of State Highway 33 will be considerably affected by sounds of vehicles passing through the area at speed. NZTA records indicate around 7,500 vehicles per day use this part of state highway 33 to traverse through the area with around 15% of these vehicles being heavy vehicles.

The noise effect of vehicles passing through the area is a factor which is discussed below regarding the context within which noise from a future geothermal power station may be experienced.

8 Assessment Criteria

8.1 Resource Management Act

Section 16 of the RMA places a general duty on all occupiers to adopt the best practicable option (BPO) to ensure noise emitted from any site does not exceed a reasonable level.

What constitutes a "reasonable level" is not prescribed by the Act. Noise limits prescribed in the relevant *District Plan* may be used to guide on limits of acceptability. The following sections describe the relevant noise provisions of the Rotorua District Plan.

8.2 Rotorua District Plan

The power station is to be located in the Rural 1 Zone (RURZ1) of the Rotorua District Plan. The introduction to the District Plan Rural Zone Chapter notes the RURZ1 zone predominantly comprises productive rural land used for agriculture and forestry and identifies the following features that contribute to the amenity of the RURZ1 zone:

> *".....the open space, forested landscapes, large lot sizes, low traffic levels, and the low numbers of buildings. The main activities provided for within this zone involve agricultural practices such as farming and forestry as well as infrastructure and network utility operations. Moderate noise levels, odour and other disturbance from agriculture, forestry, network utility infrastructure, rural industries such as mining and quarrying, and geothermal electricity generation activities are an expected element of the working rural environment."*

The district-wide noise provisions of the Rotorua District Plan seek to provide "*A noise environment consistent with the character and amenity expected for the zone*". Noise rules are set out to manage the effects of noise, concentrating on protecting sensitive sites such as residential zones and dwellings in rural areas.

Relevant aspects on the noise provisions of the District Plan are summarised as follows:

- Policy 5 specifically exempts well drilling from the normally applying permitted activity noise limits;
- Construction noise is controlled under NOISE-R2 with a Performance Standard of:
  a. *All construction noise shall comply with the relevant noise levels stated in NZS 6803:1999, and shall be measured and assessed in accordance with NZS 6803:1999 'Acoustics – Construction Noise'.*
- NOISE-R1 Emission of noise imposes two key performance rules:
  a. Noise received at sites within the zone must conform with NOISE-S1;
  b. Noise received within a different zone must conform with NOISES2;
- Noise Standard S1 – Noise Received Within Same Zone: Rural Zone - 8. Taheke 8C Precinct:

  Well Drilling:

  Noise levels shall not exceed the following limits when measured at any point within the notional boundary of any rural ~~dwelling~~ residential unit.

Daytime	7am to 10pm, any day	70 dB $L_{Aeq\ (15\ minutes)}$
Night-time and public holidays	At all other times	60 dB $L_{Aeq\ (15\ minutes)}$ 85 dB L_{Amax}

  Taheke 8C Precinct:

  *8. a. The noise standards for the **Industrial 2 Zone** shall apply to activities associated with geothermal electricity generation activities in in Areas A, C, D, E and G of Taheke 8C Precinct. [emphasis added].*

Industrial 2 Zone noise limits of the Rotorua District Plan are set out as follows:

Industrial Zones

a. Other than that specified below, noise levels shall not exceed the following limits when measured at any point within the boundary of the receiving site:

Daytime	7am to 10pm, any day except public holidays	75 dB $L_{Aeq\ (15\ minutes)}$
Night-time and public holidays	At all other times	70 dB $L_{Aeq\ (15\ minutes)}$ 80 dB L_{Amax}

- Noise Standard S2 - Noise received within a different zone:

  Noise levels from any activity shall not exceed the noise limits specified for the adjoining zone when measured at any point within the receiving site, or at any point within the notional boundary of any residential unit in the Rural zones.

It has been identified that the construction and/or operation of the proposed power station (and ancillary equipment including wells and steamfield equipment) may affect the 'Residential 4' zoned land to the south of State Highway 33 near the development site. Noise levels are specifically assessed for Residential 4 (R4) residentially zoned sites in the area including the group of R4 sites located on the nearby Kaituna Arm of Lake Rotoiti. Thus, power station noise levels received at all relevant residentially zoned locations have been specifically investigated within the current assessment.

Noise performance standards for residential zones are set out in the Rotorua District Plan as follows:

Residential Zones

a. Noise levels shall not exceed the following limits when measured at any point within the boundary of the receiving site:

Daytime	7am to 7pm, any day except public holidays	50 dB $L_{Aeq\ (15\ minutes)}$
Evening	7pm to 10pm any day except public holidays	45 dB $L_{Aeq\ (15\ minutes)}$
Night-time and public holidays	At all other times	40 dB $L_{Aeq\ (15\ minutes)}$ 70 dB L_{Amax}

Note above noise limits apply at various compliance locations. These are summarised as follows:

Noise Standard	Applying to	District Plan Noise Assessment Location
NOISE-R2	Construction noise	At 1 metre from the dwelling
Noise Standard S1	Industrial 2 Zone noise limits applying to *"activities associated with geothermal electricity generation"* located in the Taheke 8C Precinct	At any point within a receiving site.
Noise Standard S1	Drilling Noise	The notional boundary to any residential unit in the Rural Zone
Noise Standard S2	Noise received within a different zone	A. At any point within a Residential Zone; or B. At any point within the Reserve Zone.

Table 11: Compliance assessment locations found within the relevant District Plan noise limits applying to the proposed development.

The Rotorua District Plan requires that measurement and assessment be undertaken in accordance with the requirements of the New Zealand Standards *NZS 6801:2008 - Measurement of Environmental Sound* and *NZS 6802:2008 – Environmental Noise*. The assessment below follows the recommendations of these Standards.

8.3 NZS6802:2008

While NZS6802:2008 sets out procedures for the assessment of noise for compliance with noise limits, it also contains guidelines regarding noise limits that will provide generally acceptable noise outcomes at noise sensitive sites. These guidelines are of use for determining the significance of noise effects where the District Plan noise limits are not complied with by a small margin.

As a guideline the "Table 3" generic noise limits of NZS6802:2008 are considered to provide reasonable protection of health and amenity associated with use of land for residential purposes. Table 3 (Guideline residential upper noise limits) from NZS6802:2008 is reproduced as follows:

Daytime(1)	55 dB $L_{Aeq(15\ min)}$
Evening(1,2)	50 dB $L_{Aeq(15\ min)}$
Night-time(1)	45 dB $L_{Aeq(15\ min)}$
Night-time(1) Lmax	75 dB L_{AFmax}

NOTE –

(1) The definition of times of day are a matter for the relevant local authority and should recognise that a period of not less than 8 hours needs to be provided for sleep to ensure at least the minimum acceptable degree of health protection.

(2) Inclusion of an evening period and its hours of application are a matter for the relevant local authority.

(3) This clause is not framed as a consent condition, rule or national environmental standard and should not be quoted for those purposes. See C8.1.3 for suggested format of consent conditions, rules or national environmental standards.

It can be seen that NZS6802:2008 indicates noise received at sensitive sites up to LAeq 45 dB is likely to result in an acceptable noise outcome. This recommendation indicates the consequences of exceeding the night time noise limit of the Rotorua District Plan (LAeq 40 dB) by up to 5 dB at any existing residential unit in the area would not be likely to generate unreasonable noise effects.

9 Noise Assessment

9.1 Assessment of Operational Power Station Noise

Predictions undertaken and reported on above indicate station sound levels under normal operation will be received at generally low levels at the closest identified receiver sites. Site B (located at 1000A to 1000E State Highway 33, Okere Falls) is the most affected site with operational LAeq sound levels being levels between 40 dB to 45 dB, except for Option 2 noise which would be expected to be received at 38 dB at this receiver location.

Based on a consideration of noise produced by each of the two generation options, Option 1 and Option2 have been compared. At the closest receiver site (site B located at 1000A to E, State Highway 33, Okere Falls) Option 1 is 5 dB noisier than option 2. At all other receiver sites similar noise effects between the two options has been found with the conventional option (Option 1) being, on average, 1 to 2 dB noisier than Option 2 (ORC Binary option). At more remote receiver locations, the differences between options becomes blurred with no clear quieter option indicated within the predictions undertaken.

Noise due to normal operation of both options are predicted to comply with the generic recommended noise limits of NZS6802:2008 (LAeq 45 dB during night time). Comparing the results for predicted station noise under normal station operation received at sensitive receiver sites in the area with the above District Plan noise criteria, we find Options 1 and 2 are both compliant with R1 (industrial zone noise limits) within the zone. The relevant District Plan noise standards applying to noise generated by "*activities associated with geothermal electricity generation*" taking place in the Taheke 8C Precinct are based on meeting a LAeq(15) 70 dB limit within adjacent sites in the zone and do not place requirements on this noise to be controlled to any specific limit at sensitive receiver sites within the Rural Zone.

R2 applies to noise received within adjacent zones. R2 assessed as complied with (LAeq 40 dB night time as measured within any part of a Residential R4 site) even though nearby receivers within the rural zone (Site B) will receive sound levels up to 43 dB for normal station operation.

Overall, noise due to normal operation (all options) is assessed as compliant with all relevant permitted activity noise standards of the Rotorua District Plan.

9.2 Assessment Of Venting /Bypass Noise

Levels of noise emitted under normal operation are increased during venting through purpose-built structures or by re-directing working fluids (option2) directly to the cooling unit to dissipate energy that would otherwise be turned into electricity by the turbine/generator. The additional noise is emitted by the vent structure (and turbulent mixing above) and control valves at which major pressure drop must be managed.

The predictions indicate sound levels will be received at generally low levels at the closest identified receiver sites during venting / bypass mode operation. Site B (located at 1000A to 1000E State Highway 33, Okere Falls) is the most affected site with venting/bypass LAeq sound levels being levels between 37 dB to 42 dB at this receiver location.

Noise emissions due to steam venting/bypass operations received at sensitive receiver sites in the area have been compared with the above noise criteria. In summary, we find:

- R1 (industrial zone noise limits) within the zone - Options 1 and 2 are found to be both compliant.
- R2 (noise received within adjacent zones) is assessed as complied with (LAeq 40 dB night time within any part of a Residential R4 site). Receivers within the rural zone (Site B) will receive station sound levels up to 42 dB however when operating under a venting/bypass operating mode however the District Plan does not limit noise received at sensitive receiver sites where the noise concerned is emitted by geothermal activities undertaken for the purposes of electricity generation within the Taheke 8C Development Area.
- In terms of the generic recommended noise limits of NZS6802:2008 (LAeq 45 dB during night time at the notional boundary to a dwelling), these limits are also predicted to be complied with during normal station operation and during intermittent venting / bypass mode operation (both options).

Overall, noise due to venting / bypass mode operation (all options) is assessed as compliant with the relevant permitted activity noise standards of the Rotorua District Plan.

9.3 Assessment of Well Drilling & Testing Noise

Noise Standard S1 of the District Plan imposes noise limits on drilling activities which, in summary, limit noise from drilling activities to LAeq(15) 70 dB daytime and LAeq(15) min) 60 dB night time, assessed the notional boundary to any residential unit in the Rural Zone. **Table 7** above indicates worst case well drilling noise levels will be received at the closest sensitive sites at levels between 20 dB and 56 dB. The most affected receiver location is Site B (located at 1000A to 1000E State Highway 33, Okere Falls) will receive drilling noise up to LAeq(15 min) 56 dB.

As the maximum noise level does not exceed the more stringent LAeq(15 min) 60 dB limit, 24-hour drilling activity is assessed as compliant with the Rotorua District plan S1 Noise Standard.

10 Construction Noise

Establishing the proposed geothermal power station ancillary works will involve construction noise arising from the following activities:

- Site Clearance, including removal of fences, gates and tracks;
- Removal of vegetation and topsoil from areas of earthworks, road and platform sites;
- Bulk earthworks, roading and site infrastructure;
- Construction of buildings and installation of power generation equipment;
- Construction of geothermal steam and fluid pipelines and associated separator stations; and
- Construction of a new switchyard, associated roadworks, landscaping and connection to the Transpower grid.

The above works will result in the emission of noise of varying levels and durations. Noise from construction of the power station, steam and fluid lines and separation plant will arise from the use of mechanical equipment, machinery, vehicles on the site and hand tools.

Construction activities are generally conducted during daytime only. Based on measurements of similar construction activities including the use of motor-scrapers, back hoe excavators, light and heavy vehicles, compressors and power tools, construction noise levels are assessed cumulatively as likely to result in sound levels of less than L_{Aeq} 55 dB/L_{Amax} 65 dB at the closest noise sensitive site.

As per the Rotorua District Plan noise performance standards, construction noise is assessed according with NZS6803:1999 *Acoustics – Construction Noise*. Table 2 of NZS6803 sets out the L_{Aeq} and L_{Amax} noise limits for construction work received at residential and commercial locations. These as summarised in **Table 12** below. In this case, the 'Long Term' noise limits would apply to a project of this scale.

Time of week	Time period	Duration of work					
		Typical duration (dBA)		Short-term duration (dBA)		Long-term duration (dBA)	
		L_{eq}	L_{max}	L_{eq}	L_{max}	L_{eq}	L_{max}
Weekdays	0630-0730	60	75	65	75	55	75
	0730-1800	75	90	80	95	70	85
	1800-2000	70	85	75	90	65	80
	2000-0630	45	75	45	75	45	75
Saturdays	0630-0730	45	75	45	75	45	75
	0730-1800	75	90	80	95	70	85
	1800-2000	45	75	45	75	45	75
	2000-0630	45	75	45	75	45	75
Sundays and public holidays	0630-0730	45	75	45	75	45	75
	0730-1800	55	85	55	85	55	85
	1800-2000	45	75	45	75	45	75
	2000-0630	45	75	45	75	45	75

Table 12: Recommended upper limits of levels of noise received in residential and commercial areas for construction projects all periods. Reference table 2, NZS6803: 1999.

The above construction noise limits of NZS6803:199 are assessed 1 metre from the most exposed facade of the closest residential dwelling. This assessment location 1 metre from the dwelling façade differs from the assessment locations adopted within other New Zealand Standards or District Plan noise rules where assessment is carried out at the 20m notional boundary to rural dwellings.

Table 12 indicates the relevant New Zealand Standard recommends 'elevated' limits for noise from construction activities during daytime compared to normally acceptable daytime noise limits for permanent activities (such as LAeq(15 min) 50 dB or 55 dB for daytime. The use of elevated daytime noise limits for construction noise is based on the premise that higher than normal noise is usually tolerable if the noise-producing activities are not permanent.

Based on the project information and due to the separation distances involved, the layout of the site, the nature of the proposed construction works, construction methods and hours of operation, cumulative construction noise levels are not predicted to exceed limits set out within New Zealand Standard NZS6803:1999. Depending upon construction activities being undertaken, the closest sensitive receiver sites would be unlikely to receive construction noise at levels exceeding LAeq(15 min) 60 dB.

Noise will arise from vehicles operating on public roads visiting the site daily including for the purposes of delivery of materials and staff vehicles. Given the nature of the project and the existing traffic noise emissions in the area, it is not likely that vehicles associated with the project will give rise to any significant increases in daily road traffic noise levels.

11 Assessment Summary

This assessment has considered the following components of the project:

- Drilling of a number of geothermal wells in the area of the existing wells T8CP01 and T8CP02 and at other sites for re-injection purposes is assessed as an activity that can comply with the District Plan S1 noise standard which applies specifically to noise from geothermal well drilling. While the exact number and location of wells has yet to be determined, the assessment provided guides on likely noise effects due to modelled well drilling sites being located relatively close to noise sensitive sites. On this basis it is reasonable to assume well drilling at sites other than those assessed here would be likely to generate noise effects at levels no greater than already forecast under the two modelled well sites.

- Construction activities on the site over a likely period of 2 to 3 years will generate locally significant noise including noise due to machinery used in site preparation to form building platforms, hard stand areas including access and parking areas, in addition to drainage works. No exceedance of the 'Long Term' noise limits of NZS6803:1999 is expected at any sensitive receiver throughout the construction phase, including the construction of the station building(s) and noise due to limited duration commissioning works (testing).

- On-going 24-hour operation of the Power Station over the life of the consent is assessed as compliant. This includes all noise due to normal of pumps, cooling fans, turbine / generators, control valves and separation plants. This includes compliance with NOISE-R1 (industrial zone noise limits) within the zone (for Options 1 and 2) together with compliance with NOISE-R2 (noise received within adjacent zones) where compliance is achieved with the LAeq 40 dB night time limit applying to noise received within any Residential R4 zoned site.

- Noise due to short term venting of geothermal steam venting or station operation under bypass mode or a 'trip' situation has been separately investigated and reported on within the results set out above as a compliant activity.

Predicted LAeq noise levels set out above (***Section 6.0***) indicate project noise levels at receiver sites at received levels of between 20 dB and 50 dB. As a guide to the potential impact of these outdoor sound levels likely to be experienced around residential units, the following provides a guideline sound level for various typical noise levels found in commonly experienced situations:

- 40 to 50 dBA in a general office situation or outdoors in residential areas during daytime.
- 60 dBA when talking normally to someone 1 to 2 m away.
- 65 to 75 dBA when riding in a car at highway speeds.
- 85 to 95 dBA while cutting the grass with motor mower.

Outdoor predicted noise levels from the Taheke 8C Project are found within the lower range of above reported noise levels due to sounds from typical activities. Comparing noise output among the two generation options, only for the closest site (Site B) was any differentiation noticeable in noise received between the two generation options. At further afield receiver sites noise differences between generation options became small and mostly insignificant.

Power station noise levels under normal operation (both options) will not be likely add significantly to existing outdoor daytime sound levels at any existing sensitive site in the area. If detected at sensitive sites, the sound (if any) would be a characterised as low hum sound, present in an area without sounds from other sources, such as passing road traffic. The assessment of compliance with District Plan noise limits is based on the realistic assumption that noise due the operating power station (including venting /bypass operations) would not be likely to include any noticeable tonal components, impulsiveness, or other "special audible characteristics" as defined within NZS6802:2008. The assessment has found levels of noise emitted during normal operation and venting or bypass mode operation for both power station generation options are capable of individually fully complying with District Plan permitted activity noise standards S1 and S2 for both daytime and night time at the relevant noise assessment locations in the area.

Compared to measured ambient sound levels, noise due to the proposed geothermal development experienced at the closest residential sites will likely cause a decrease in times when sound levels at these sites will measure below 35 dB to 40 dB, depending upon wind direction and other weather effects. The overall effect will be to raise outdoor 'noise floor' currently experienced during quiet periods and under certain rare wind directions. Under these relatively rare conditions the closest receivers will experience slightly elevated background sound levels, however the levels received will be entirely compatible with residential uses.

Traffic passing through the area on State Highway 33 is the most significant noise source identified in the surveys undertaken. The following diagram[7] portrays noise "*Effects Area*" and "*Buffer Area*" identified by Waka Kotahi as areas adjacent to State Highway 33 where noise from passing traffic should be avoided or mitigated, if possible, by the landowner or developer of new or altered sensitive land use activities.

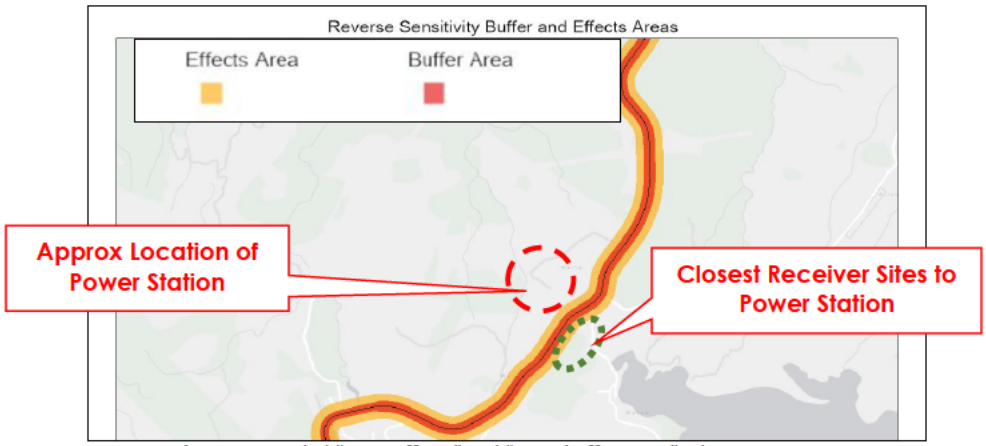

Figure 14: NZTA's recommended "noise effects" and "noise buffer areas" adjacent to SH33.

The two areas shaded red and orange in **Figure 14** are the "buffer area" and "effects area" which are areas where NZTA recommends traffic noise be mitigated (insulated against) or avoided by not establishing sensitive uses in areas near the highway. NZTA have selected these guideline traffic noise levels as they are consistent with the road traffic noise criteria of NZS6806:2010 *Acoustics – Traffic Noise – Noise from New & Altered Roads* being 64 dB LAeq,24h (buffer area) and 57 dB (effects area). The "effects" area (within which NZTA recommends habitable rooms should be insulated against road traffic noise noise) extends 87 metres from the road centreline and encompasses the two closest sensitive receivers to the proposed station site (receiver sites A and B).

[7] NZTA website https://www.nzta.govt.nz/roads-and-rail/highways-information-portal/technical-disciplines/environment-and-sustainability-in-our-operations/environmental-technical-areas/noise-and-vibration/road-traffic-noise-calculator/

Overall, based on the predicted worst case noise emissions from the power station received at noise sensitive sites in the area, our assessment is that there will be no adverse noise effects arising from the construction or operation of the power station on its proposed site together with well drilling, well testing and steamfield works necessary to complete the Taheke Geothermal Development.

12 Noise Mitigation

Section 17 of the Resource Management Act 1991 states that every person has the general duty to avoid, remedy or mitigate potential adverse effects, including noise. Noise mitigation methods described below are consistent with the Best Practical Option (BPO) for managing the potential effects of noise of the proposed upgrade.

The ***best practicable option*** is defined as follows:

"...the best method for preventing or minimising the adverse effects on the environment having regard, among other things, to

a) The nature of the discharge or emission and the sensitivity of the receiving environment to adverse effects; and

b) The financial implications, and the effects on the environment, of that option when compared with other options; and

c) The current state of technical knowledge and the likelihood that the option can be successfully applied."

A range of mitigation measures will ensure noise not only complies with the applicable standards, but is reduced where possible below these limits. Noise mitigation measures forming part of the proposed project include the following;

1. Plant items likely to generate significant noise (e.g., turbines, generator, pumps, motors, etc.) will be specified as being required to meet specific sound power levels as part of the plant procurement and acquisition process and within performance contracts with parties contracted to build the station.

2. Proven technology is available to reduce the noise of venting steam to atmosphere.

3. Due to the location of the power station and the undulating nature of the local terrain, effective noise screening is provided in directions towards all existing residential sites.

4. The turbine hall building will provide effective noise attenuation, reducing the noise emissions from equipment housed within for Option 1.

5. Cooling systems are a predominant source. The approach for both the wet cell and fin fan units is to adopt modern, best practice technology resulting in noise from this source mitigated to a reasonable degree.

13 Summary

MHA have carried out an assessment of environmental noise effects associated with the proposed power station to be located at a rural site within the Taheke 8C Development Area.

The methodology used by MHA has been to identify the relevant noise sources associated with development of the geothermal steam field, well drilling and testing, station construction and power station operation. Sound levels at source (quoted above within this report) have been used to predict noise emissions for two options for the power station. These results have been compared with relevant guideline limits at representative compliance assessment locations. The assessment has found levels of noise emitted during normal operation and venting or bypass mode operation for both power station generation options are capable of individually fully complying with the Rotorua District Plan permitted activity noise standards S1 and S2 for both daytime and night time at the relevant noise assessment locations in the area.

During well drilling, predicted noise levels (see **Table 7** above) indicate worst case well drilling noise levels will be received at the closest sensitive sites at levels between 20 dB and 56 dB with the most affected receiver location (Site B) receiving drilling noise up to LAeq(15 min) 56 dB. As the maximum noise level does not exceed the more LAeq(15 min) 60 dB night time District Plan noise limit, 24-hour drilling activity is assessed as compliant with the District Plan S1 Noise Standard.

Existing sound levels at noise sensitive locations in the area during normal station operation will be virtually unchanged due to the contribution of noise arising during normal station operation.

Overall, it is considered the "di minimis" level of noise effects of the proposed geothermal power station development will affect the local environment to a 'less than minor' degree owing to predicted compliance with the District Plan noise

standards S1 and S2, as set out above. This low scale of noise effects is not unexpected, having regard to size and type of equipment to be installed, the selected station site being located well away from noise sensitive sites and well screened by the natural terrain. The report includes identification of measures incorporated into the project designed to mitigate the effects of noise.

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Assessment of Environmental Noise Effects

Taheke Geothermal Power Station Project

Glossary of Acoustic Terms

A-weighted Sound Level
The sound pressure level of a signal which has been passed through an "A" weighting filter whereby both low and high frequency components are attenuated without affecting the component near 1000 Hz. The unit is the decibel, but it is usual to distinguish between this and other uses of the decibel by writing the unit as dB[A]. A frequency-response adjustment of a sound level meter that makes its reading conform to human response. The sensitivity of the human ear is frequency dependent. At low and high frequencies, the ear is not very sensitive, but between 500 Hz and 6 kHz the ear is very sensitive. The A-weighting filter is a broadband filter that covers the interval from 20 Hz to 20 kHz. The shape of the A-weighting curve approximates the frequency sensitivity of the human ear. So, the A-weighted value of a noise source is an approximation to how the human ear perceives the noise. A sound pressure *level* in dB means that it is calculated relative to the standard reference level of 20 μPa for airborne sound. The word "level" associates that figure with the appropriate standard reference level.

Airborne Sound
Sound that reaches the point of interest by propagation through air.

dB
decibel. A bel (after Alexander Graham Bell) is defined as the logarithm to base ten of the ratios of two acoustical powers, or intensities. One tenth of a bel, the decibel, is the generally used unit.

dBA, dB[A]
A sound-level meter reading with an A-weighting network simulating the human-ear response at a loudness level of 40 phons. The weighting is specified in ANSI Specifications for Sound Level Meter, S1.4-1983

Frequency
Frequency is the reciprocal of time. If an event is periodic in time, that is, if it repeats itself at a fixed time interval, then its frequency is one divided by the time interval. If a vibrating element takes one tenth of a second to complete one cycle and return to its starting point, then its frequency is defined to be 10 cycles per second, or 10 hertz (Hz). Although the SI standard unit of frequency is the Hz, when analysing machinery vibration, it is sometimes more convenient to express frequency in cycles per minute (cpm), which corresponds to rpm. Frequency in cpm is simply frequency in Hz times 60. Another common frequency representation used in machinery monitoring is multiples of turning speed, or "orders". Frequency in orders is frequency in cpm divided by the turning speed of the machine. The second order is then the second harmonic of turning speed, etc. This is especially convenient if the machine is varying in speed, for the frequency representation on a spectrum will be the same regardless of speed. Two spectra from the same machine can therefore more easily be compared if they are both expressed in orders. Conversion of the frequency axis of a spectrum to orders is called "order normalisation", and is done by vibration monitoring analyzers.

Frequency Weighting
Modification of the frequency spectrum of a signal by means of a filter having a conventional characteristic known as A, B, C or D. A-weighting is the most commonly used.

Octave Band Level
The integrated sound pressure level of only those sine-wave components in a specified octave band.

L_{Amax} dB
The single highest sampled sound pressure level.

L_{min} dB
The single lowest sampled sound pressure level.

L_{Aeq} dB
The time averaged sound pressure level (or equivalent sound level) that has the same mean square sound pressure level as the time-varying sound level under consideration. Commonly referred to as an "energy average" measure of sound exposure.

L_{A10} dB
The sound pressure level exceeded for only 10% of the monitoring period. This level of sound therefore equates to an average maximum sound and is used widely in emission limits as the L10 correlates well with the subjective reaction to sound.

L_{A90} dB
The level of sound exceeded for 95% of the monitoring period. This level of sound equates to an average background sound level, and is influenced by constant. It is used as a guide to the general ambient sound level.

Notional Boundary
New Zealand Standard NZS6802:2008 (Section 8.4.7) states where the notional boundary is used, it always related to a building used for a noise sensitive activity, typically residential. The notional boundary is within 20m of any side of a dwelling (or other specified class of building). In this context, the term, façade, is no longer used for legal purposed. If the legal boundary is 20m from the dwelling, then the measurement location is still at any point within the notional boundary.

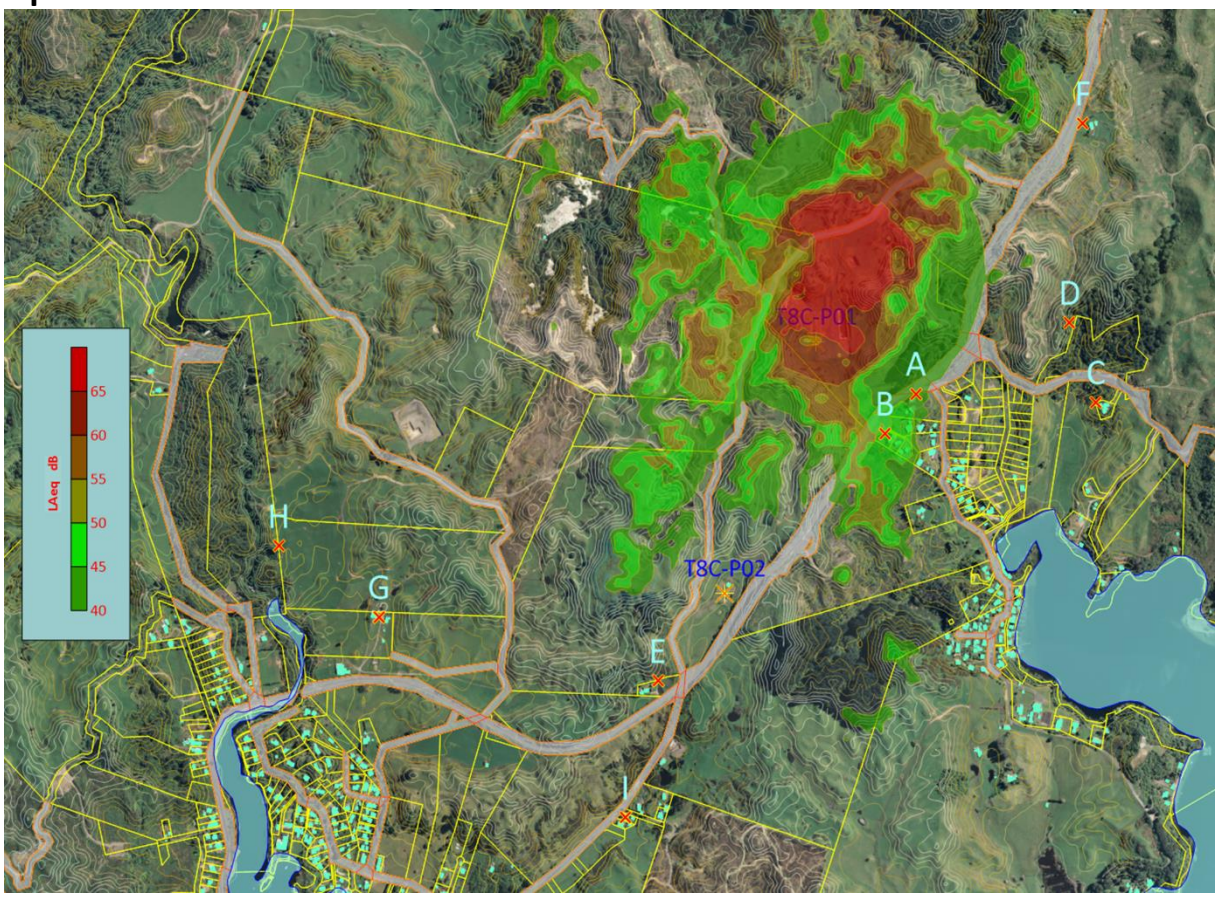
Sound Power Level
The acoustic 'energy' created by a sound is defined as its sound power. The ear cannot hear sound power nor can it be measured directly.

Sound power is not dependent upon its surrounding environment.

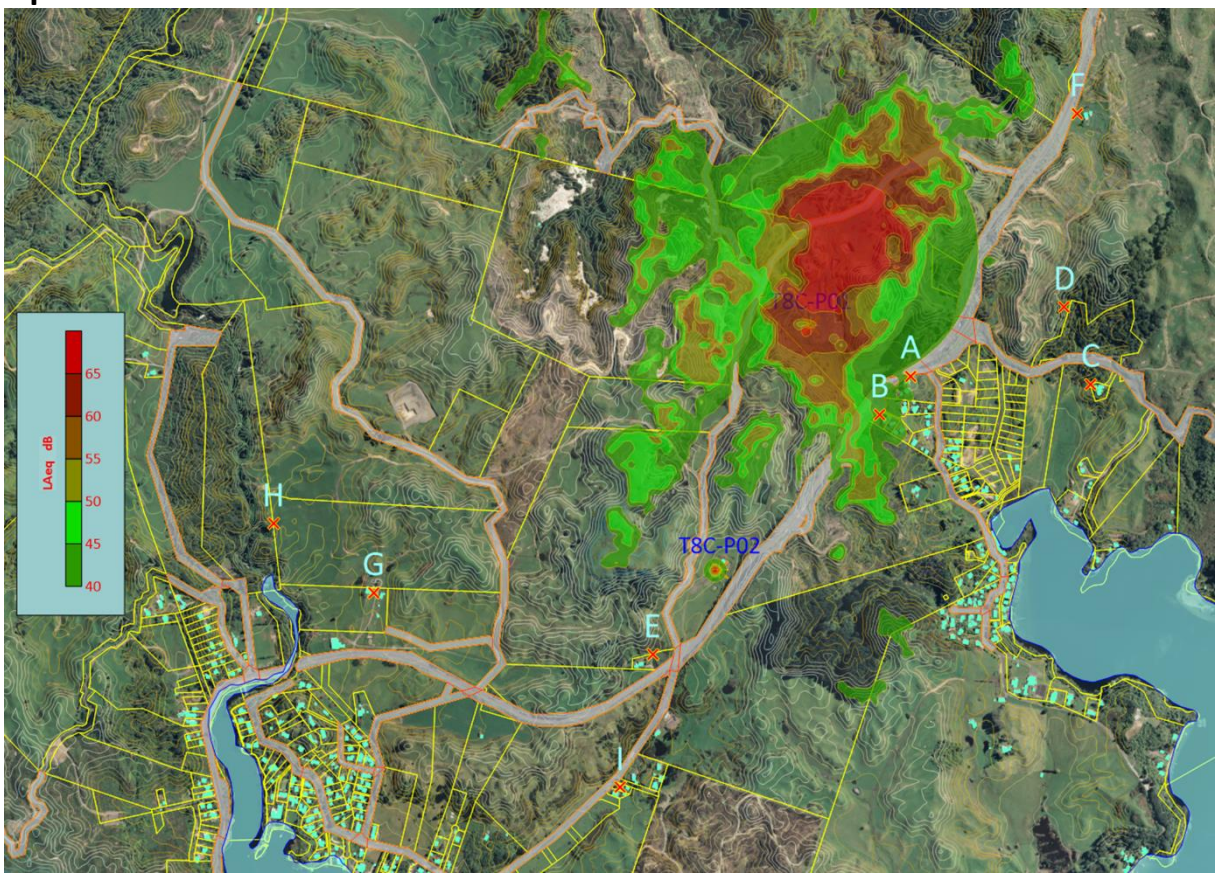
Sound Pressure Level
Sound Pressure Level is defined as varying pressure fluctuations caused by sound waves. The ear converts these fluctuations into what we call audible sound, which is the sensation (as detected by the ear) of very small rapid changes in the air pressure above and below a static value. This "static" value is atmospheric pressure.

Appendix A
Noise Contour Diagrams - Station By-Pass / Venting Operations – Two Options

Option 1



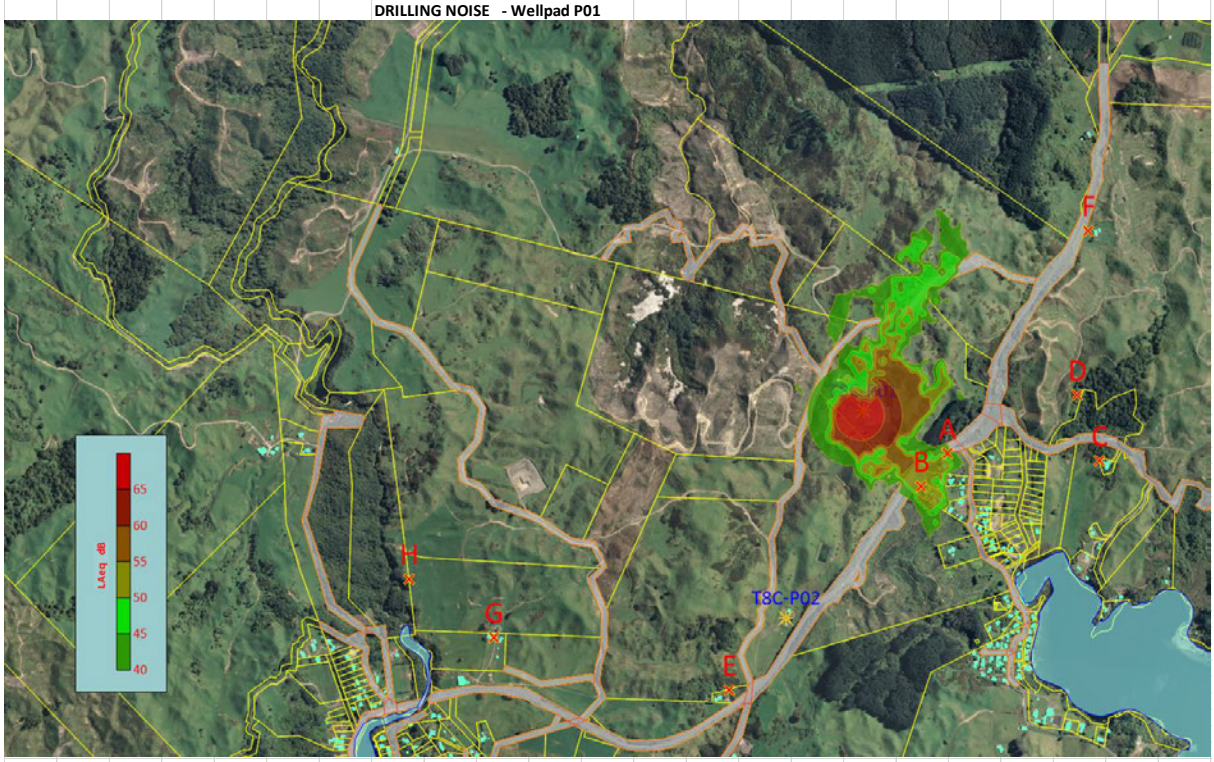
Option 2



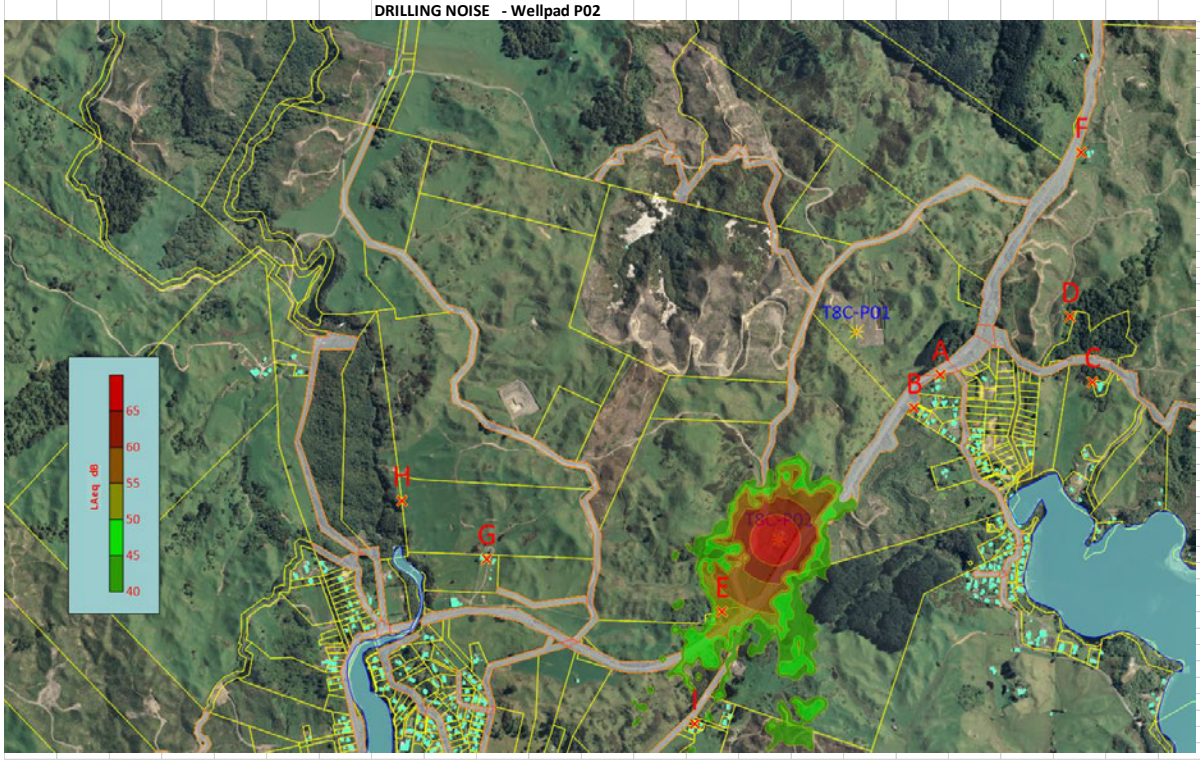
Appendix B

Noise Contour Diagrams – Well Drilling P01 & P02 Wellpads

DRILLING NOISE - Wellpad P01

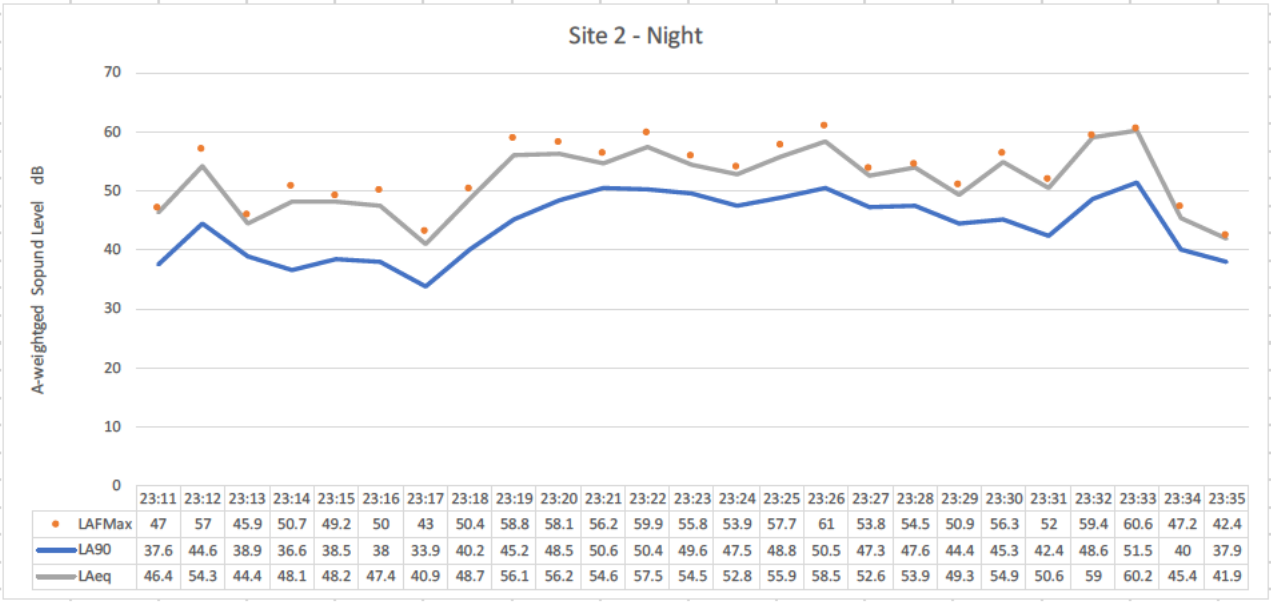


DRILLING NOISE - Wellpad P02

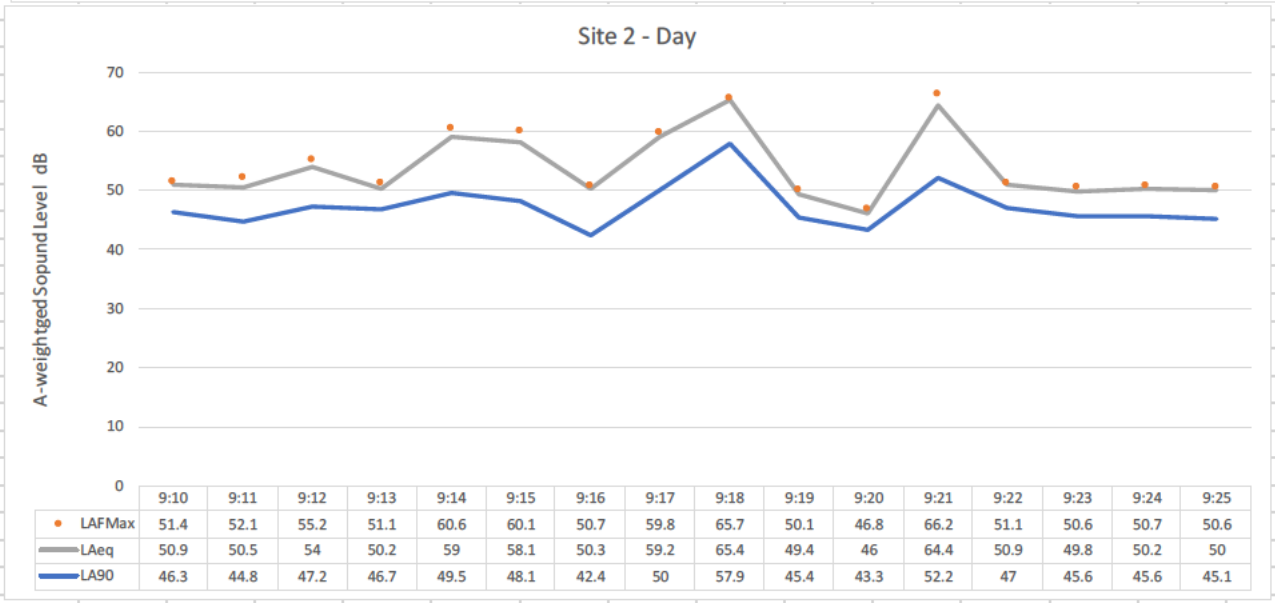


Appendix C

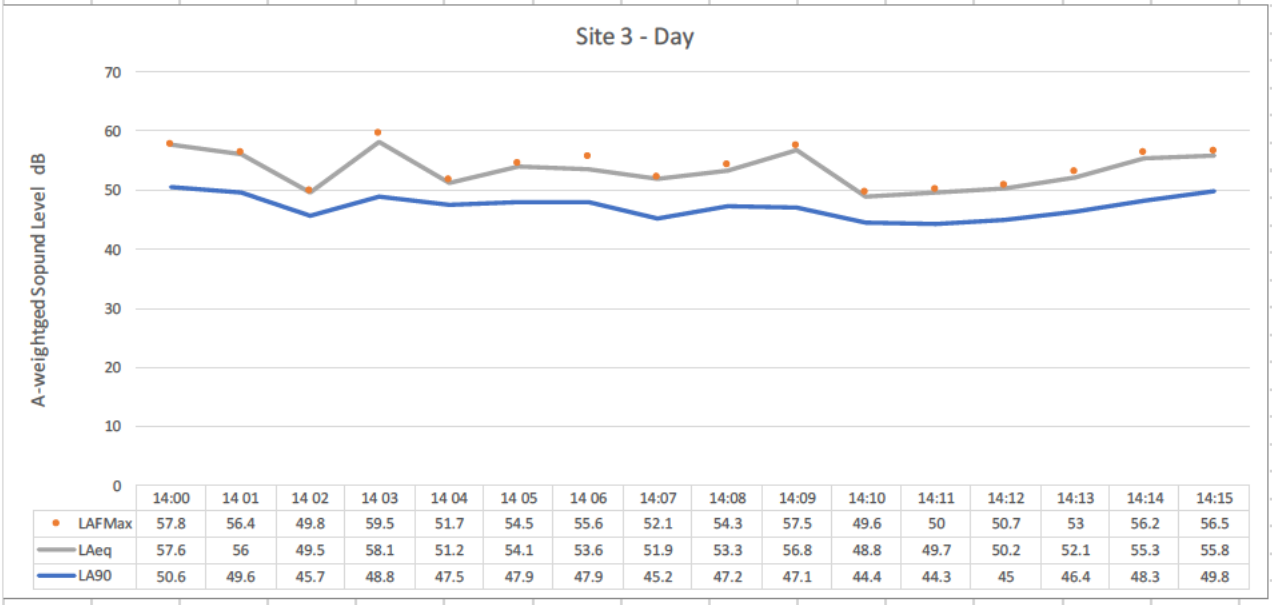
Ambient Sound Levels Measured at Sites 2 & 3



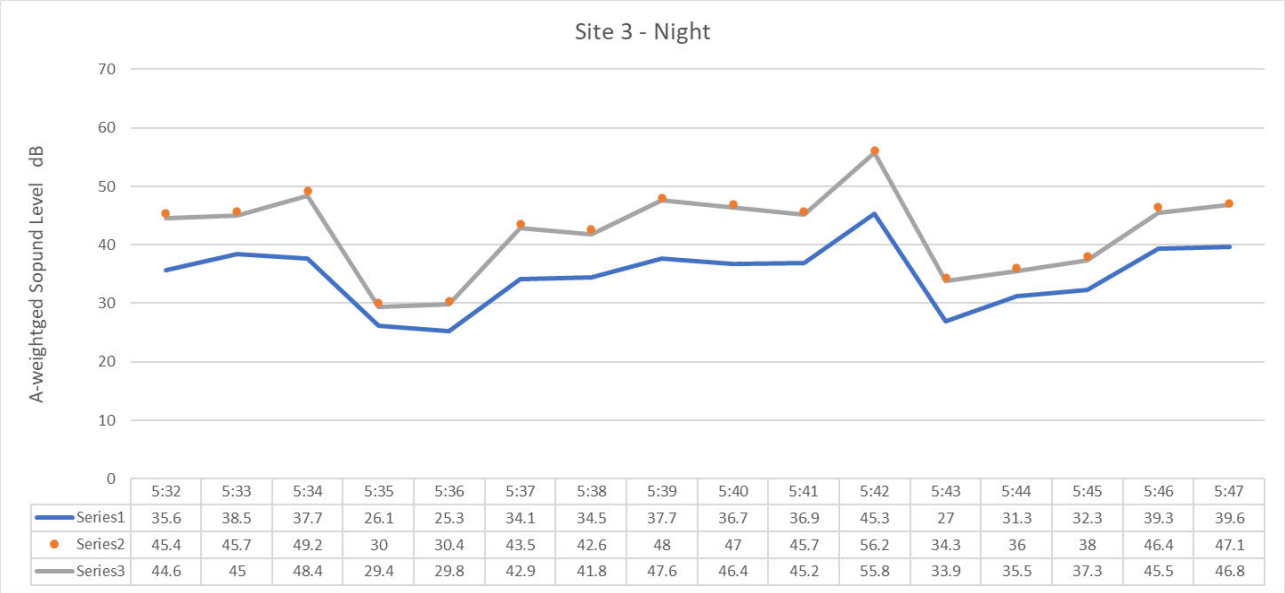
	23:11	23:12	23:13	23:14	23:15	23:16	23:17	23:18	23:19	23:20	23:21	23:22	23:23	23:24	23:25	23:26	23:27	23:28	23:29	23:30	23:31	23:32	23:33	23:34	23:35
LAFMax	47	57	45.9	50.7	49.2	50	43	50.4	58.8	58.1	56.2	59.9	55.8	53.9	57.7	61	53.8	54.5	50.9	56.3	52	59.4	60.6	47.2	42.4
LA90	37.6	44.6	38.9	36.6	38.5	38	33.9	40.2	45.2	48.5	50.6	50.4	49.6	47.5	48.8	50.5	47.3	47.6	44.4	45.3	42.4	48.6	51.5	40	37.9
LAeq	46.4	54.3	44.4	48.1	48.2	47.4	40.9	48.7	56.1	56.2	54.6	57.5	54.5	52.8	55.9	58.5	52.6	53.9	49.3	54.9	50.6	59	60.2	45.4	41.9



	9:10	9:11	9:12	9:13	9:14	9:15	9:16	9:17	9:18	9:19	9:20	9:21	9:22	9:23	9:24	9:25
LAFMax	51.4	52.1	55.2	51.1	60.6	60.1	50.7	59.8	65.7	50.1	46.8	66.2	51.1	50.6	50.7	50.6
LAeq	50.9	50.5	54	50.2	59	58.1	50.3	59.2	65.4	49.4	46	64.4	50.9	49.8	50.2	50
LA90	46.3	44.8	47.2	46.7	49.5	48.1	42.4	50	57.9	45.4	43.3	52.2	47	45.6	45.6	45.1



	14:00	14 01	14 02	14 03	14 04	14 05	14 06	14:07	14:08	14:09	14:10	14:11	14:12	14:13	14:14	14:15
LAFMax	57.8	56.4	49.8	59.5	51.7	54.5	55.6	52.1	54.3	57.5	49.6	50	50.7	53	56.2	56.5
LAeq	57.6	56	49.5	58.1	51.2	54.1	53.6	51.9	53.3	56.8	48.8	49.7	50.2	52.1	55.3	55.8
LA90	50.6	49.6	45.7	48.8	47.5	47.9	47.9	45.2	47.2	47.1	44.4	44.3	45	46.4	48.3	49.8



	5:32	5:33	5:34	5:35	5:36	5:37	5:38	5:39	5:40	5:41	5:42	5:43	5:44	5:45	5:46	5:47
Series1	35.6	38.5	37.7	26.1	25.3	34.1	34.5	37.7	36.7	36.9	45.3	27	31.3	32.3	39.3	39.6
Series2	45.4	45.7	49.2	30	30.4	43.5	42.6	48	47	45.7	56.2	34.3	36	38	46.4	47.1
Series3	44.6	45	48.4	29.4	29.8	42.9	41.8	47.6	46.4	45.2	55.8	33.9	35.5	37.3	45.5	46.8