Review of Environmental Factors

Hunter-Central Coast REZ Network Infrastructure

Appendix E - Electric and Magnetic Fields Assessments

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Hunter-Central Coast - Renewable Energy Zone

Transmission Lines Electric and Magnetic Fields Assessment

Ausgrid

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Executive Summary

The Australian energy landscape is transitioning to a greater mix of low-emission renewable energy sources, such as wind and solar. To support this transition, meet our future energy demands and connect Australian communities and businesses to these lower cost energy sources, the national electricity grid needs to evolve.

In delivering Ausgrid's network infrastructure which forms part of the Hunter-Central Coast REZ, formally declared under section 19(1) of the Electricity Infrastructure Investment Act 2020, Ausgrid is proposing to deliver the following energy network infrastructure:

- Construction of a transmission line from Kurri Sub-Transmission Substation (STS) to Singleton STS including,
  - Replacement of the existing 66 kV single circuit line in between Kurri STS and Branxton Zone Substation (ZS) by a new 132 kV double circuit line
  - Replacement of the existing 66 kV single circuit line between Branxton ZS and Mt Thorley ZS by a new 132 kV double circuit line with a 66 kV underbuilt line
  - Replacement of the existing 132 kV single circuit line between Mt Thorley ZS and Singleton STS by two new, side by side 132 kV lines, one single circuit and one double circuit.
- Construction of transmission line from Singleton STS to Antiene Sub Transmission Substation (STSS) Switching Station (SS) including,
  - Replacement of the existing 132 kV single circuit line by two new side by side 132 kV lines, one single circuit and one 132 kV double circuit
- Construction of a transmission line from Muswellbrook SS to Muswellbrook BSP including,
  - Replacement of the existing 132 kV single circuit line by a new 132 kV double circuit line

The scope of Aurecon's assessment relates to the transmission lines encompasses the following:

- Provision of a brief description of electric and magnetic fields (EMF) in relation to human health.
- Calculation of the EMF for the proposed lines at one metre above ground level, extending up to 100 metres on each side of their centrelines and covering the range of structure types, conductor configurations and other relevant parameters associated with the lines.
- An assessment of the compliance of the anticipated field levels with the relevant national and international EMF guidelines.
- An assessment of compliance of the proposed lines with precautionary and prudent avoidance principles as defined in the relevant guidelines.
- Preparation of a report covering the EMF assessment.

The purpose of this assessment is to check the EMF levels of the proposed 66 kV and 132 kV lines against the International Commission on Non-Ionizing Radiation Protection (ICNIRP) public exposure guidelines as recommended by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).

Aurecon has modelled the EMF associated with all of the proposed lines and, based on the modelling results, has arrived at the following conclusions.

Magnetic Fields

The contributions of the proposed transmission lines to the magnetic field environment are predicted to be well within the ICNIRP Guideline Reference Level of 2,000 mG. Results are summarised in Table 1-1.

Table 1-1 | Summarized magnetic field results

Tx. Line Section	Scenario	Directly under the transmission line				At the easement edge			
		For average load		For peak load		For average load		For peak load	
		(mG)	% of ICNIRP Guideline Ref. Level	(mG)	% of ICNIRP Guideline Ref. Level	(mG)	% of ICNIRP Guideline Ref. Level	(mG)	% of ICNIRP Guideline Ref. Level
Section A - A	Existing	< 1	< 0.05%	12	0.6%	< 1	< 0.05%	4	0.2%
	Proposed	33	1.7%	124	6.2%	10	0.5%	37	1.9%
Section B - B	Existing	< 1	< 0.05%	12	0.6%	< 1	< 0.05%	4	0.2%
	Proposed	8	0.4%	34	1.7%	5	0.3%	18	0.9%
Section C - C	Existing	< 1	< 0.05%	83	4.2%	< 1	< 0.05%	9	0.5%
	Proposed	26	1.3%	152	7.6%	5	0.3%	24	1.2%
Section D - D	Existing	69	3.5%	159	8.0%	8	0.4%	19	1%
	Proposed	32	1.6%	96	4.8%	7	0.4%	18	0.9%
Section E - E	Existing	61	3.0%	130	6.5%	7	0.4%	15	0.8%
	Proposed	21	1.1%	146	7.3%	1.2	0.1%	22	1.1%

As can be seen from Table 1-1, the predicted magnetic fields for the proposed line configurations on average load are less than those for the existing configurations for Sections DD & EE. In the case of Sections AA, BB & CC, predicted fields for the proposed line configurations are higher than those for the existing configurations, but still within the range of fields from the other proposed lines.

Predicted maximum magnetic fields for the proposed transmission lines are less than 7.6% of the ICNIRP Guideline Reference Level directly under the lines and less than 1.9% at the easement edges.

Electric Fields

In all locations, the electric fields directly below the proposed lines will be less than the ICNIRP Guideline Level of 5 kV/m. Results are summarised in Table 1-2.

Table 1-2 | Summarized electric field results

Transmission Line Section	Scenario	Directly under the transmission line		At the easement edge	
		(kV/m)	% of ICNIRP Guideline Reference Level	(kV/m)	% of ICNIRP Guideline Reference Level
Section A - A	Existing	0.6	7%	0.3	3%
	Proposed	1.7	18.3%	0.5	5%
Section B - B	Existing	0.6	7%	0.3	3%
	Proposed	0.3	3.5%	0.2	2.6%
Section C - C	Existing	1.9	21.3%	0.2	2.5%
	Proposed	1.7	18.5%	0.1	0.9%
Section D - D	Existing	2	21.9%	0.2	2.6%
	Proposed	1.7	18.5%	0.1	0.9%
Section E - E	Existing	2	21.9%	0.2	2.6%
	Proposed	1.7	18.3%	0.1	0.7%

As can be seen from Table 1-2, calculated maximum electric field values are less than 22% of the ICNIRP Guideline Reference Level directly under the transmission lines and less than 5% at the easement edges.

In practice, due to shielding by vegetation etc, the actual electric fields are likely to be considerably less than those predicted.

Prudent Avoidance

It is widely accepted that, given the inconclusive nature of the science, it is considered that, in the circumstances, a prudent/precautionary approach continues to be the most appropriate response to health concerns regarding EMF. Under this approach, the operators of electricity infrastructure should design their facilities to reduce the intensity of the magnetic fields they generate, and locate them to minimise the fields that people, especially children, encounter over prolonged periods, provided this can be readily achieved without undue inconvenience and at reasonable expense, and be consistent with good engineering and risk minimisation practice.

In the case of the current project;

- Ausgrid has advised that the phases of the parallel circuits will be arranged, as modelled in this report to provide maximum magnetic field cancellation.
- For Sections DD & EE, the magnetic fields associated with the proposed lines will be less than those associated with the existing lines.
- Ausgrid has chosen to locate the new lines along the existing easements, thereby avoiding the proliferation of lines. In doing so, it is noted that, for section CC, DD & EE the chosen corridors are more than 100 m away from the nearest dwellings and other frequented premises. At such distances, the average magnetic fields would be within the range found in typical everyday situations.
- For Section AA, there are approximately 30 dwellings within 100 m of the centre of the transmission line, the nearest being 30 m away and the others ranging between 40 m and 100 m. The maximum average magnetic field due to the transmission line at the nearest dwelling will be 3.3 mG and that for the others will range from less than 1 mG to 2 mG.
- For Section BB, there are approximately 20 dwellings within 100 m of the centre of the transmission line, the nearest being 20 m away and the others ranging between 35 m and 90 m. The maximum magnetic field due to the transmission line at the nearest dwelling will be 5.8 mG and that for others will range from less than 1 mG to 4 mG.

Due to the uncertainty as to the existence or otherwise of adverse health effects, it cannot be said whether the above measures would result in any health benefit, but they are all appropriate and consistent with the principles of prudent avoidance.

Contents

1 Introduction 1
1.1 Background 1
1.2 Key Components of the Project 1
1.3 Purpose and scope of this report 3
1.4 Structure of the report 3

2 Overview of electric and magnetic fields 3
2.1 General description 3
2.2 Electric and magnetic fields and health 3
2.2.1 Summary of health effects 4
2.3 Health guidelines 4
2.4 Prudent avoidance 5
2.5 Medical implants 5
2.6 Animals and plants 6
2.6.1 Gibbs Inquiry 6
2.6.2 United Kingdom EMF National Policy Statement 6

3 Input information and aspects of field predictions 7
3.1 Input information 7
3.2 Approach 7
3.3 Data and assumptions for modelling 8

4 Field characterisation 9
4.1 Approach 9
4.2 Magnetic field results 9
4.2.1 Kurri STS to Branxton Tee line (Section A-A) 10
4.2.2 Branxton TEE to Mt Thorley ZS Line (Section B-B) 12
4.2.3 Mt Thorley ZS to Singleton STS (Section C-C) 13
4.2.4 Singleton STS to Antiene Sub Transmission Substation (STSS) SS (Section D-D) 15
4.2.5 Sandy Creek STSS to Muswellbrook BSP (Section E-E) 16
4.3 Magnetic fields experienced in everyday life 18
4.4 Electric field results 19
4.4.1 Kurri STS to Branxton ZS Line (Section A-A) 19
4.4.2 Branxton TEE to Mt Thorley ZS Line (Section B-B) 20
4.4.3 Mt Thorley ZS to Singleton STS (Section C-C) 21
4.4.4 Singleton STS to Antiene Sub Transmission Substation (STSS) SS (Section D-D) 22
4.4.5 Sandy Creek STSS to Muswellbrook BSP (Section E-E) 23

5 Compliance with EMF guidelines and prudent avoidance principles 24
5.1 Compliance with health guidelines 24
5.1.1 Magnetic fields 24
5.1.2 Electric fields 25
5.2 Assessment against prudent avoidance principles 25

6 References 26

Appendices

Appendix A

General description of electric and magnetic fields

Appendix B

Overview of EMF and health

Appendix C

Health guidelines

Appendix D

Prudent avoidance

Figures

Figure 1-1 | Key components of the project from Kurri STS to Antiene Sub Transmission Substation (STSS) SS
Figure 1-2 | Key components of the project from Muswellbrook SS to Muswellbrook BSP
Figure 4-1 | Section view of the existing and the proposed pole structures
Figure 4-2 | Calculated magnetic field profile for existing 66 kV and proposed 132 kV configuration from Kurri to Branxton
Figure 4-3 | Section view of the existing and the proposed pole structures
Figure 4-4 | Calculated magnetic field profile for existing 66 kV and proposed 132 kV configuration from Branxton to Mt Thorley
Figure 4-5 | Section view of the existing and the proposed pole structures
Figure 4-6 | Calculated magnetic field profile for existing and proposed configuration of line from Mt Thorley to Singleton
Figure 4-7 | Section view of the existing and the proposed pole structures
Figure 4-8 | Calculated magnetic field profile for existing and proposed configuration of line from Singleton to Antiene Sub Transmission Substation (STSS)
Figure 4-9 | Section view of the existing and the proposed pole structures
Figure 4-10 | Calculated magnetic field profile for existing and proposed configuration of 132 kV line from Muswellbrook STS to Muswellbrook BSP
Figure 4-11 | Calculated electric field profile for existing 66 kV and proposed 132 kV configuration from Kurri to Branxton
Figure 4-12 | Calculated electric field profile for existing 66 kV and proposed 132 kV configuration from Branxton to Mt Thorley
Figure 4-13 | Calculated electric field profile for existing and proposed configuration of lines from Mt Thorley to Singleton
Figure 4-14 | Calculated electric field profile for existing and proposed configuration of line from Singleton to Antiene Sub Transmission Substation (STSS)
Figure 4-15 | Calculated electric field profile for existing and proposed configuration of 132 kV line from Muswellbrook STS to Muswellbrook BSP

Tables

Table 1-1 | Summarized magnetic field results
Table 1-2 | Summarized electric field results
Table 1-1 | Structure geometries along different sections of the transmission line route
Table 2-1 | ICNIRP Guideline levels
Table 3-1 | Transmission structures details in different sections
Table 3-2 | Average and maximum loads for the existing and proposed configuration of the transmission lines
Table 4-1 | Magnetic field for the existing 66 kV/proposed 132 kV configuration of line from Kurri to Branxton
Table 4-2 | Magnetic field for the existing 66 kV and proposed 132 kV configurations of the line from Branxton to Mt Thorley
Table 4-3 | Magnetic field for the existing and proposed configuration of 132 kV line from Mt Thorley to Singleton
Table 4-4 | Magnetic field for the existing and proposed configuration of 132 kV line from Singleton to Antiene Sub Transmission Substation (STSS)
Table 4-5 | Magnetic field for the existing and proposed configuration of 132 kV line from Muswellbrook STS to Muswellbrook BSP
Table 4-6 | Typical ELF magnetic field levels associated with appliances and infrastructure
Table 4-7 | Electric field for existing 66 kV/proposed 132 kV configuration of line from Kurri to Branxton
Table 4-8 | Electric field for the existing 66 kV/proposed 132 kV lines from Branxton to Mt Thorley
Table 4-9 | Electric field for the existing and proposed configuration of 132 kV line from Mt Thorley to Singleton
Table 4-10 | Electric field for the existing and proposed configuration of 132 kV line from Singleton to Antiene Sub Transmission Substation (STSS)
Table 4-11 | Electric field for the existing and proposed configuration of 132 kV line from Muswellbrook STS to Muswellbrook BSP
Table 5-1 | Summary of magnetic field results
Table 5-2 | Summary of electric field results

1 Introduction

1.1 Background

The Hunter-Central Coast REZ was formally declared by the Minister for Energy under section 19(1) of the Electricity Infrastructure Investment Act 2020 (the Act) and published in the NSW Gazette on 9 December 2022. The declaration sets out the intended network capacity for network infrastructure in the Hunter-Central Coast REZ. This project would form part of Ausgrid's network infrastructure that would form part of the REZ.

1.2 Key Components of the Project

The proposed works of the project include replacing the existing line construction from Kurri STS to Antiene Sub Transmission Substation (STSS) SS and from Muswellbrook SS to Muswellbrook BSP with new construction, utilising the existing line corridors. Along the proposed route of the transmission lines, there are various permutations of geometries and combinations of circuits. This EMF assessment has focused on the most common permutations which prevail along the proposed transmission line route.

The key components of the proposed works in relation to the EMF assessment are:

- A proposed 132 kV transmission line (~60 km) from the existing Kurri STS located in Kurri Kurri to the existing Singleton STS located in Maison Dieu with several permutations of geometries and combinations of circuits such as 132 kV double circuit; 132 kV double circuit with parallel 132 kV single circuit; and 132 kV double circuit with a 66 kV circuit underbuilt
- A proposed 132 kV double circuit with parallel 132 kV single circuit (~25 km) from the existing Singleton STS to the proposed Antiene Sub Transmission Substation (STSS) SS located at Hebdon.

An overview of the project is shown in Figure 1-1 and Figure 1-2.

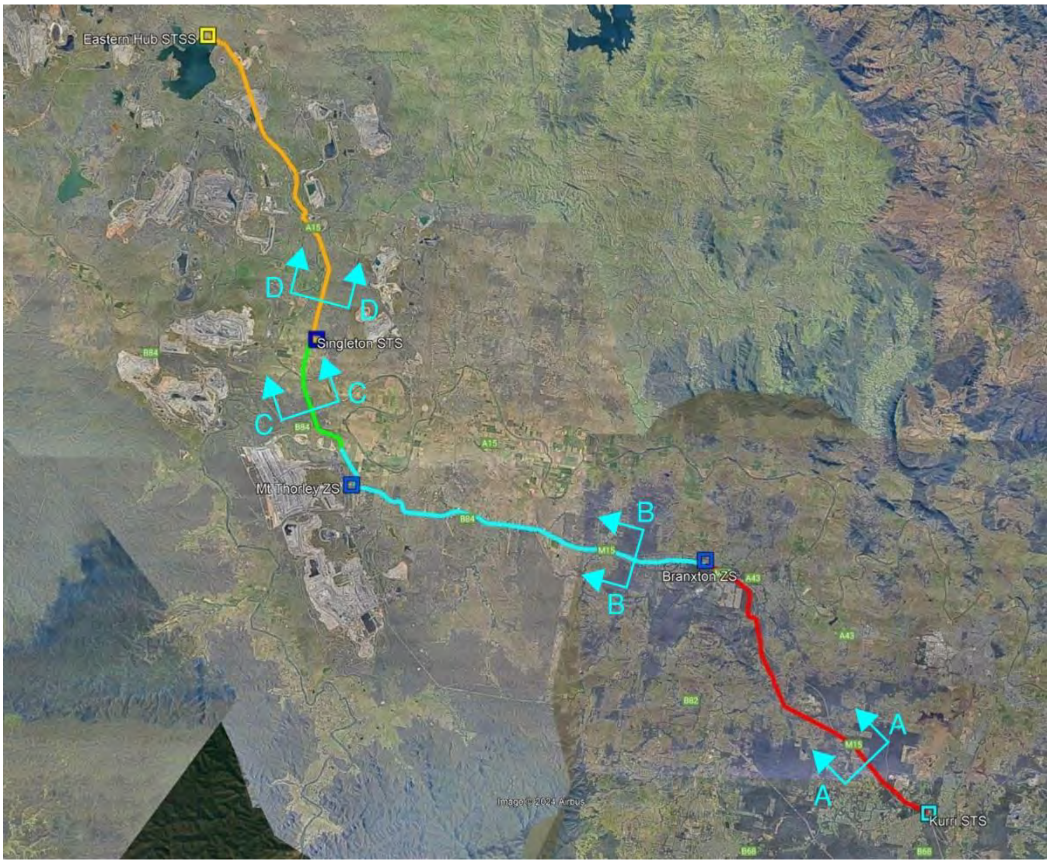

Figure 1-1 | Key components of the project from Kurri STS to Antiene Sub Transmission Substation (STSS) SS

Figure 1-2 | Key components of the project from Muswellbrook SS to Muswellbrook BSP

The approximate lengths of the transmission line route sections are:

- Kurri to Singleton 132 kV transmission line:
  – Kurri STS to Branxton ZS - Section A-A (24 km)
  – Branxton ZS to Mt Thorley ZS - Section B-B (24 km)
  – Mt Thorley ZS to Singleton STS - Section B-B (3 km) & Section C-C (8 km)
- Singleton to Antiene Sub Transmission Substation (STSS) 132 kV transmission line:
  – Singleton STS to Antiene Sub Transmission Substation (STSS) SS- Section D-D (20 km)
- Muswellbrook SS to Muswellbrook BSP - Section E-E (4 km)

New 132 kV transmission line facilities would be constructed along each of the above routes, but the different sections will have different structure geometries and combinations of circuits as shown in Table 1-1.

Table 1-1 | Structure geometries along different sections of the transmission line route

Circuit Name	Section	Existing Structure	Modelled Structure
Kurri to Branxton	A-A	66 kV Single Circuit	132 kV Double Circuit
Branxton to Mt Thorley	B-B	66 kV Single Circuit	132 kV Double Circuit 66 kV Single Circuit Underbuilt
Mt Thorley to Singleton	C-C	132 kV Single Circuit	132 kV Single Circuit 132 kV Double Circuit
Singleton to Antiene Sub Transmission Substation (STSS)	D-D	132 kV Single Circuit	132 kV Single Circuit 132 kV Double Circuit
Sandy Creek STSS to Muswellbrook BSP	E-E	132 kV Single Circuit	132 kV Double Circuit

Aurecon has been engaged to calculate both the electric and magnetic field (EMF) levels associated with the existing line sections and those likely to be produced by the proposed ones, and to assess them against relevant health guidelines as part of the overall environmental impact assessment of the project.

1.3 Purpose and scope of this report

The scope of Aurecon's assessment relates to the transmission lines and is to encompass the following:

- provision of a brief description of EMF in relation to human health.
- calculation of the electric and magnetic fields for the proposed lines at one metre above ground level, extending up to 100 metres on each side of their centrelines and covering the structures mentioned in Table 1-1, using conductor configurations and other relevant parameters associated with the proposed lines.
- an assessment of the compliance of the anticipated field levels with the relevant national and international EMF guidelines.
- an assessment of compliance of the proposed lines with precautionary and prudent avoidance principles in accordance with the relevant guidelines.
- preparation of a report covering the EMF assessment.

1.4 Structure of the report

The structure and content of this report are as follows:

- Chapter 1 (Introduction) - outlines the overview, key components and the purpose and scope of this report.
- Chapter 2 (Overview of electric and magnetic fields) - provides a description of EMF and outlines the key guidelines relating to EMF.
- Chapter 3 (Input information and aspects of field predictions) - provides the approach and assumptions used in the EMF modelling.
- Chapter 4 (Field characterisation) - presents the EMF modelling results.
- Chapter 5 (Compliance with EMF guidelines and prudent avoidance principles) - discusses compliance with the key guidelines relating to EMF and the application of prudent avoidance.

2 Overview of electric and magnetic fields

2.1 General description

Whenever electrical equipment is in service, it produces an electric field and a magnetic field. The electric field is associated with the voltage of the equipment and the magnetic field is associated with the current (amperage). In combination, these fields cause energy to be transferred along electric wires. Being related to voltage, the electric fields associated with high voltage equipment remain relatively constant over time, except where the operating voltage changes. Conversely, being related to current, the magnetic field strength resulting from an electrical installation varies continually with time as the load on the equipment varies.

The electric and magnetic fields associated with electrical equipment, whilst interrelated, are not dependent on each other and as such can exist independently.

Further detail on EMFs can be found in Appendix .

2.2 Electric and magnetic fields and health

It is known that EMFs at magnitudes much higher than those encountered in everyday life can interact with the central nervous system. In addition, the possibility of adverse health effects due to the much lower EMFs associated with electrical equipment has been the subject of extensive research throughout the world for more than 40 years.

To date, adverse health effects due to fields of the levels normally associated with electrical infrastructure, have not been established. However, due to a body of epidemiological evidence, the possibility that such effects may exist has not been ruled out.

2.2.1 Summary of health effects

While EMFs involve both electric and magnetic components, electric fields are relatively constant over time, are readily shielded and, in the health context, are generally no longer associated with the same level of interest as magnetic fields. Nevertheless, high electric field strengths, such as those associated with the highest voltage transmission lines or high voltage equipment in major substations, can approach a level at which “nuisance shocks” can occur and this phenomenon needs to be managed. This can be done via appropriate easement and fencing practices.

Magnetic fields are not readily shielded, are more ubiquitous and remain the subject of some debate. Accordingly, much of the health research has been directed towards magnetic fields.

A large number of studies have been conducted over many years to investigate the possibility of adverse health consequences from extremely low frequency electric and magnetic fields. These studies have addressed a wide range of end points including childhood leukaemia, other childhood cancers, cancers in adults, depression, suicide, cardiovascular disorders, reproductive dysfunction, developmental disorders, immunological modifications, neurobehavioural effects and neurodegenerative disease. The most recent scientific reviews by authoritative bodies are reassuring for most potential health end points. However, statistical associations between prolonged exposure to elevated magnetic fields and childhood leukaemia have persisted. This led the International Agency for Research on Cancer (IARC) (Ref. B-1) in 2002 to classify magnetic fields as a “possible carcinogen”, a categorisation used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals.

The fact that, despite over 30 years of laboratory research, no mechanism for an effect has been established, lends weight to the possibility that the observed statistical associations reflect some factor other than a causal relationship. This point is made in the 2001 report of the UK National Radiological Protection Board’s (NRPB) Advisory Group, chaired by eminent epidemiologist, the late Sir Richard Doll (Ref. B-2)

> *“in the absence of clear evidence of a carcinogenic effect in adults, or of a plausible explanation from experiments on animals or isolated cells, the evidence is currently not strong enough to justify a firm conclusion that such fields cause leukaemia in children.” (page 164)*

Further discussion of the above including footnotes can be found in Appendix B.

2.3 Health guidelines

Since late 2015, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)[1] , has adopted the *Guidelines for Limiting Exposure to Time-varying Electric and Magnetic Fields (1Hz to 100kHz))* published by the International Commission on Non-Ionising Radiation Protection (ICNIRP) in 2010. In adopting the ICNIRP Guidelines ARPANSA noted:

> *“The ICNIRP ELF guidelines are consistent with ARPANSA’s understanding of the scientific basis for the protection of the general public (including the foetus) and workers from exposure to ELF EMF.” (Ref. C-2)*

The ICNIRP Guideline sets ‘Basic Restrictions’, which are derived from the levels at which interactions with the central nervous system (CNS) are established, with a safety factor applied. The Basic Restrictions are expressed in terms of electric field levels within the human body but, as these levels can only be assessed by sophisticated computer modelling of the body, ICNIRP also sets ‘Reference Levels’, expressed in terms of kV/m and microtesla[2] for electric and magnetic fields respectively. These levels are conservatively set such that, provided they are met, the Basic Restrictions would also be met without the need for more

[1] *ARPANSA is the Australian government agency that is charged with the responsibility, inter alia, for protecting the health and safety of people and the environment from EMF.*

[2] *Magnetic fields are often expressed in units of milligauss, where 1 milligauss is equal to 0.1 microtesla. The units used for this report are milligauss.*

comprehensive analysis. The ICNIRP 'Basic Restrictions' and 'Reference Levels' for the general public are reproduced in Table 2-1. As noted above, these criteria apply to both adults and children and are independent of duration of exposure.

Table 2-1 | ICNIRP Guideline levels

Parameter	Basic Restriction (Volts per metre)	Reference Level
Electric Field – General Public	CNS tissue of the head: 0.02 All tissue of head and body: 0.4	5,000 Volts per metre (V/m)
Magnetic Field - General Public	CNS tissue of the head: 0.02 All tissue of head and body: 0.4	2,000 milligauss (mG)

In applying the ICNIRP Guideline, it is important to recognise that the numerical limits, e.g. 2,000 mG, are based on established health effects. In ICNIRP's fact sheet on the guidelines (Ref. C-3), it notes that:

> *"It is the view of ICNIRP that the currently existing scientific evidence that prolonged exposure to low frequency Magnetic Fields is causally related with an increased risk of childhood leukaemia is too weak to form the basis for exposure guidelines. Thus, the perception of surface electric charge, the direct stimulation of nerve and muscle tissue and the induction of retinal phosphenes are the only well-established adverse effects and serve as the basis for guidance."*

Being based on established biological effects (which occur at field levels much higher than those normally encountered in the vicinity of electrical equipment), the (numerical) exposure limits in the guidelines and standards cannot be said to define safe limits for possible health effects, should these exist, from magnetic fields at levels normally encountered in the vicinity of electrical equipment.

The principal compliance criteria used for this assignment are as per Table 2-1.

2.4 Prudent avoidance

Given the inconclusive nature of the science regarding EMF at levels commonly associated with electrical equipment and human health, it is widely considered that a prudent approach is the most appropriate response under the circumstances. Prudent avoidance is a precautionary concept developed to address the possibility of health effects from prolonged exposure to field levels much lower than those for which effects have been established.

Under this approach, subject to modest cost and reasonable practicality, the owners of electric power infrastructure should design their facilities to reduce the intensity of the fields they generate in frequented areas where prolonged[3] exposure is possible. Further general discussion on this subject can be found in Appendix D and the implications for this assessment are discussed in Section 5.2.

2.5 Medical implants

In addition to direct interactions with the human body, EMFs also have the potential to interfere with active implanted medical devices (AIMDs) such as cardiac pacemakers, insulin pumps etc. A wide variety of devices are used in modern medicine and, due to the multiplicity of EMF sources in the modern environment, they are generally subject to standards regarding immunity from interference.

In Europe, the relevant European Directive (90/385/EEC) requires designers and manufacturers of AIMDs to make them immune to interference in "reasonably foreseeable" circumstances. The relevant European Standard (CENELEC 50527-1) interprets this as meaning that devices should be immune from interference up to the ICNIRP general public reference levels. Similar requirements apply in the UK. However, as the magnetic field reference level at the time of the European directive was 1,000 mG, rather than the present

[3] *In this context, prolonged exposure is taken as the time-weighted average exposure, measured over a period of months or years, rather than days or weeks*

2,000 mG, it is customary (and conservative) to assume that AIMDs should be immune to interference from magnetic fields only up to 1,000 mG.

The relevant Australian Standard (AS 45502-1: 2002), which was reproduced from a European Standard (EN 45502-1: 1997), stipulates that AIMDs be immune from risks connected with reasonably foreseeable environmental conditions such as magnetic fields, external electrical influences etc. In that context, as a first guide, the Australian Standard cites a magnetic intensity of 150 Amps/metre[4] (1,885 mG).

Accordingly, as the highest magnetic fields associated with 66 kV and 132 kV transmission lines are of the order of a 'hundred mG', from a practical perspective, AIMDs which comply with the relevant Standards should be immune from transmission line interference. Nevertheless, concerned wearers of AIMDs should consult their treating physician for further information or advice, based on the specific characteristics of their actual device.

2.6 Animals and plants

As well as potential effects on humans, the possibility of EMF effects on plants and various animals, including cows, sheep, pigs and horses has been studied over the years, particularly in the 1970s and 1980s. A smaller number of studies have also been reported since that time.

2.6.1 Gibbs Inquiry

In 1991, the late Sir Harry Gibbs, a former Chief Justice of the High Court of Australia published the findings of an extensive inquiry into community needs and high voltage transmission line development.

As part of the Inquiry, he reviewed the body of research on the possibility of effects on native flora and fauna, farm animals and plants and reported his conclusions in Chapter 6.6 of his report (Ref D-1) as follows:

> *'Bees in hives under or near transmission lines are adversely affected by shocks created by currents induced by the lines but the effect can be mitigated by shielding'*
>
> *'The Magnetic Fields created by power lines do not affect the health or reproductive capacity of farm animals or present a danger to native fauna.'*
>
> *'The growth of trees which are close to a transmission line may be reduced by the effect of corona[5]. In any case, the height of trees on a transmission line easement will be restricted when this is necessary in the interest of safety."*
>
> *'From a practical point of view, the Electric Fields created by transmission lines have no adverse effects on crops, pasture grasses or native flora, other than trees growing under or near to the line.'*

His summary conclusion was:

> *'No reason exists for concern as to the effect of the fields on animals or plants.'*

2.6.2 United Kingdom EMF National Policy Statement

More recently than Sir Harry Gibbs, in July 2011, the UK Government adopted a National Policy Statement (NPS EN-5) for Electricity Networks Infrastructure. This NPS, taken together with the Overarching National Policy Statement for Energy (EN-1), provides the primary basis for decisions taken by the UK Infrastructure Planning Commission (IPC) on applications it receives for electricity networks infrastructure.

In Clause 2.10.8, the NPS states:

> *'There is little evidence that exposure of crops, farm animals or natural ecosystems to transmission line EMFs has any agriculturally-significant consequences.'*

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[4] *In air or human tissue, a magnetic field intensity of 150 A/m is equivalent to a magnetic flux density of 1885 milligauss.*

[5] *For this to happen, the leaves have to be sharp and pointy eg as on conifers, rather than rounded. Due to the nature of Australian vegetation and easement clearing practices, leaf-tip corona has not been an issue in Australia.*

3 Input information and aspects of field predictions

3.1 Input information

The input data listed below, required for the calculations on which this assessment is based, has been provided by Ausgrid,

- Conductor details and ground clearances
- Existing and proposed transmission line loadings
- Transmission line routes
- Easement widths
- Existing and proposed structure dimensions

The transmission line works have been divided into 5 different sections, based on the particular configuration, for analysis. The type of construction for the various sections of the transmission line route shown in Section 1.2 are described separately in Table 3-1:

Table 3-1 | Transmission structures details in different sections

Section	Easement Width (m)	Existing Structure	Existing Conductor	Proposed Structure	Proposed Conductor
A-A from Kurri to Branxton	20	66 kV single circuit single conductor on single pole	Cherry[6]	132 kV dual circuit twin/twin conductor on single pole	Olive
B-B from Branxton to Mt Thorley	20	66 kV single circuit single conductor on single pole	Cherry	132 kV dual circuit twin/twin conductor on single pole and 66 kV Single Circuit Underbuilt single conductor on the same pole	Olive Cherry
C-C from Mt Thorley to Singleton	45	132 kV single circuit single conductor on H pole	Mango and Goat each for 50% of the length	132 kV single circuit single conductor on single pole and 132 kV dual circuit twin/twin conductor on single pole	Olive Olive
D-D from Singleton to Antiene Sub Transmission Substation (STSS)	45	132 kV single circuit single conductor on H pole	Olive	132 kV single circuit single conductor on single pole and 132 kV dual circuit twin/twin conductor on single pole	Olive Olive
E-E from Sandy Creek STSS to Muswellbrook BSP	45	132 kV single circuit single conductor on H pole	Majority Olive Remaining Mango	132 kV dual circuit single/single conductor on single pole	Olive

3.2 Approach

To gain a comprehensive understanding of the EMF contributions from the proposed transmission lines, the predicted EMF levels associated with the various sections of the Hunter-Central Coast REZ transmission lines have been modelled separately as per Table 3-1.

The EMF produced by a double circuit transmission line is influenced, inter alia, by the magnitudes and directions of the currents in the two circuits. In selecting the load conditions to be modelled for this

6 Aluminium conductor steel reinforced (ACSR) conductors have code names which indicate the size, construction and materials of the respective conductor.

assessment, Aurecon has examined the various possible combinations of load currents and, for the purposes of reporting, has selected the case which results in the highest magnetic fields.

The EMF produced by transmission lines is influenced by the phasing arrangements of the lines. In selecting the phasing arrangements, Aurecon has examined various possible combinations of phasing arrangements and for the purposes of reporting, has selected the case which results in the lowest magnetic fields at the edge of the easements. It is understood that Ausgrid will adopt these arrangements.

In all cases, fields have been modelled at a height of one metre above ground level in accordance with international standards.

As noted in Appendix , while EMFs involve both electric and magnetic components, electric fields are relatively constant over time, are readily shielded and, in the health context, are generally no longer associated with the same level of interest as magnetic fields.

3.3 Data and assumptions for modelling

The following assumptions have been made in undertaking the EMF modelling:

- The ground clearance taken for modelling the fields in the report is the minimum design ground clearance i.e. 7.5 m. In most cases, clearances will be greater than this.
- The loadings in the proposed/existing transmission lines have been taken as the average and system normal peak values as applicable and as listed in the Table 3-2 below, derived from comprehensive load records provided by Ausgrid.
- Aurecon has modelled several possible phasing arrangements for each of the line sections to determine the phasing arrangement that provides optimised magnetic fields at the edge of the easements.
- The easement widths for the proposed transmission lines are assumed to be the same as those currently existing.
- System maximum voltage (1.1 times the nominal voltage) has been used for the electric fields assessment

Table 3-2 | Average and maximum loads for the existing and proposed configuration of the transmission lines

Line Section	Load Condition	Existing Load (A)	Proposed Load (A)		
Section A-A		**66 kV Circuit**	**132 kV Circuit 1**	**132 kV Circuit 2**	
	Peak	85.8	1230.1	1217.5	
	Average	7	322.5	319.2	
Section B-B		**66 kV Circuit**	**132 kV Circuit 1**	**132 kV Circuit 2**	**66 kV Circuit**
	Peak	85.8	1230.1	1217.5	13.8
	Average	7	322.5	319.2	3.4
Section C-C		**132 kV Circuit**	**132 kV Circuit 1**	**132 kV Circuit 2**	**132 kV Circuit 3**
	Peak	318	1230.1	1217.5	721
	Average	2	322.5	319.2	176.4
Section D-D		**132 kV Circuit**	**132 kV Circuit 1**	**132 kV Circuit 2**	**132 kV Circuit 3**
	Peak	607.5	1230.1	1217.5	759.7
	Average	265.5	322.5	319.2	277.2
Section E-E		**132 kV Circuit**	**132 kV Circuit 1**	**132 kV Circuit 2**	
	Peak	497.7	695.5	694.9	
	Average	235.2	207.8	207.6	

4 Field characterisation

4.1 Approach

Based on the available design and loading information, the electric and magnetic fields in the vicinity of the proposed transmission lines have been modelled using the CDEGS software package. CDEGS is an internationally recognised software package pioneered by Safe Engineering Services & Technologies (SES) to provide grounding and electromagnetic and conductive interference analysis involving electrical networks. The software has undergone extensive scientific validation using field tests and comparisons with analytical or published results for over twenty years[7].

In all cases, the fields cited apply at a height of one metre above ground, in accordance with international practice.

When more than one conductor type is being used in a given section, only one conductor type has been assessed since magnetic field does not depend on the conductor type. Although the conductor size can affect the electric field at ground level, for the cases involved in the proposed lines, Aurecon's modelling has shown the differences to be insignificant. Accordingly, for the line sections having multiple conductor types, the assessment has been based on the larger conductor only.

4.2 Magnetic field results

The results obtained from the magnetic field modelling of the existing and proposed 66 kV and 132 kV transmission lines are shown in the following sections. The magnetic fields are presented in the form of profiles indicating the magnetic fields along a line across the easement, perpendicular to the existing and proposed overhead conductors.

All profiles are presented as seen by an observer looking along the respective lines in the following directions.

[7] *Safe Engineering Services & Technologies Ltd (SES): CDEGS Software Validation* http://www.sestech.com/products/softwarevalidation.htm

- Section A-A - Kurri to Branxton line: towards Branxton
- Section B-B - Branxton to Mt Thorley: towards Mt Thorley
- Section C-C - Mt Thorley to Singleton: towards Singleton
- Section D-D - Singleton to Antiene Sub Transmission Substation (STSS): towards Antiene Sub Transmission Substation (STSS)
- Section E-E - Sandy Creek STSS to Muswellbrook BSP: towards Muswellbrook BSP

4.2.1 Kurri STS to Branxton Tee line (Section A-A)

The section view of existing and proposed pole structures are shown in Figure 4-1 below.

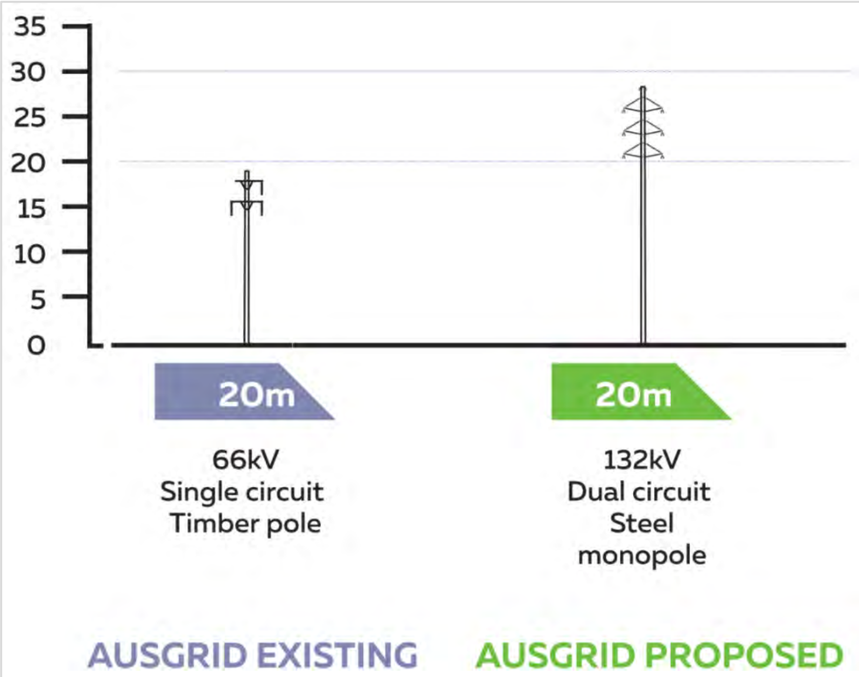

Figure 4-1 | Section view of the existing and the proposed pole structures

The calculated/predicted magnetic fields along the existing 66 kV single circuit configuration and the proposed 132 kV double circuit configuration from Kurri STS to Branxton Tee are shown in Figure 4-2.

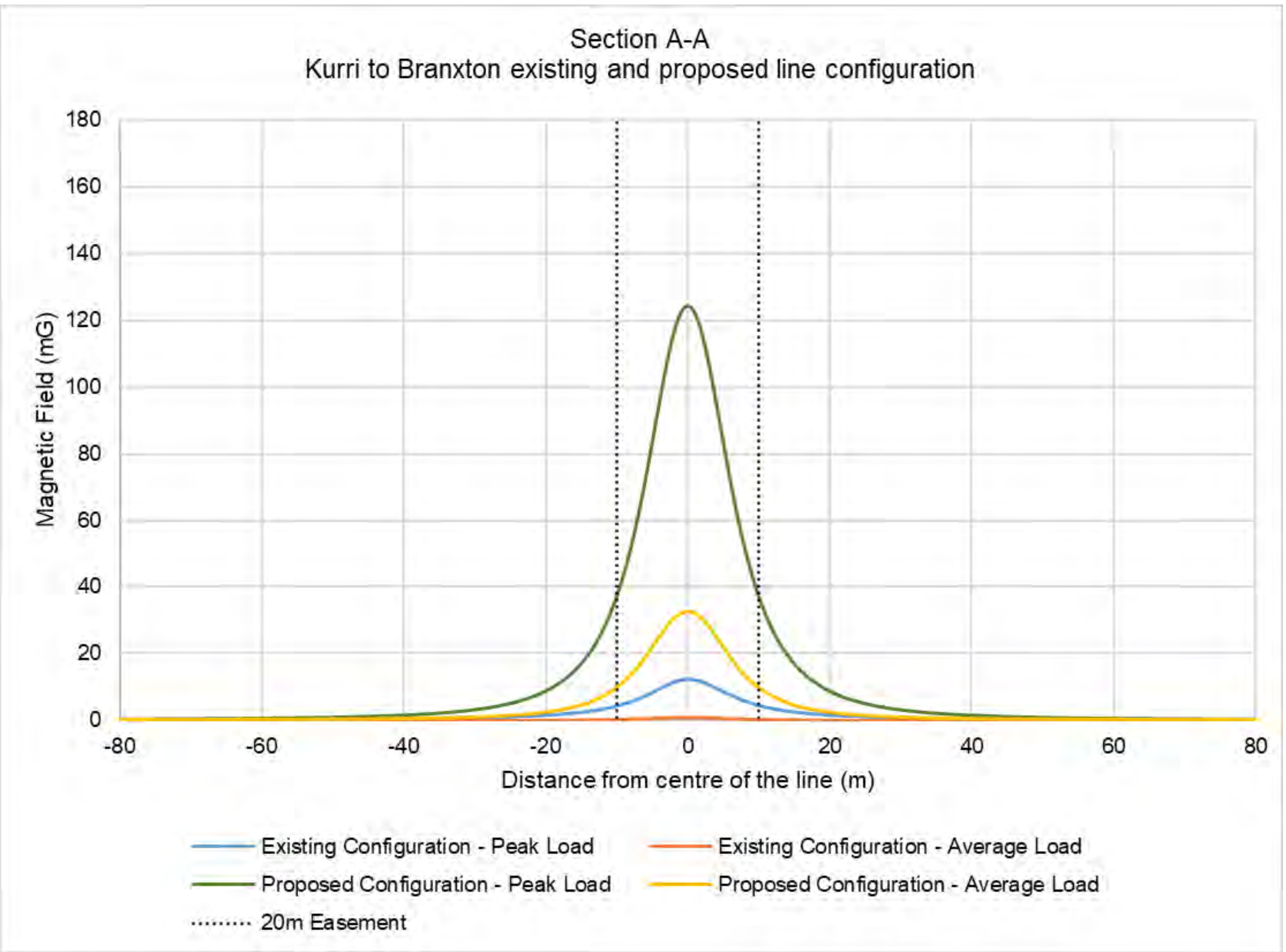

Figure 4-2 | Calculated magnetic field profile for existing 66 kV and proposed 132 kV configuration from Kurri to Branxton

The magnetic fields depicted in Figure 4-2, under various configuration and load conditions, are summarised in Table 4-1.

Table 4-1 | Magnetic field for the existing 66 kV/proposed 132 kV configuration of line from Kurri to Branxton

Loading Condition	Directly under line (mG)		Easement edge – 20 m (mG)		100 m from line (mG)	
	Existing	Proposed	Existing	Proposed	Existing	Proposed
Average Load	< 1	33	< 1	10	< 1	< 1
Peak Load	12	124	4	37	< 1	< 1

From the results above, it can be seen that the magnetic field for proposed configuration is higher than that of existing configuration, due to higher load current in the proposed 132 kV line.

The phasing arrangement that results in the lowest magnetic field for the proposed 132 kV double circuit line looking towards Branxton is as follows,

132 kV Feeder Circuit 1	132 kV Feeder Circuit 2
A	**C**
B	**B**
C	**A**

4.2.2 Branxton TEE to Mt Thorley ZS Line (Section B-B)

Section view of the existing and the proposed pole structures are as shown in Figure 4-3.

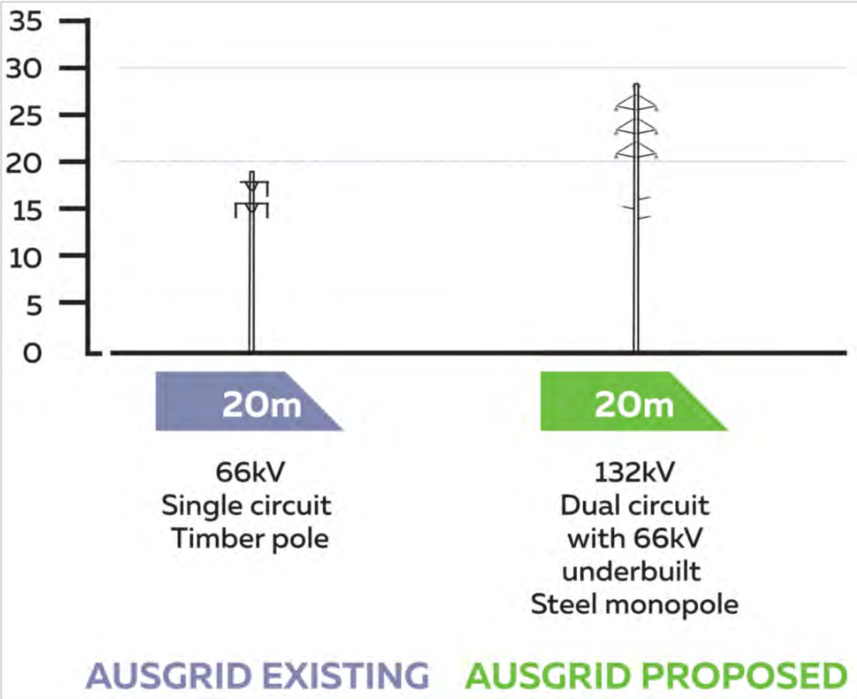

Figure 4-3 | Section view of the existing and the proposed pole structures

The calculated/predicted magnetic fields along the existing 66 kV single circuit configuration and the proposed 132 kV double circuit with 66 kV underbuilt single circuit from Branxton Tee to Mt Thorley are shown in Figure 4-4.

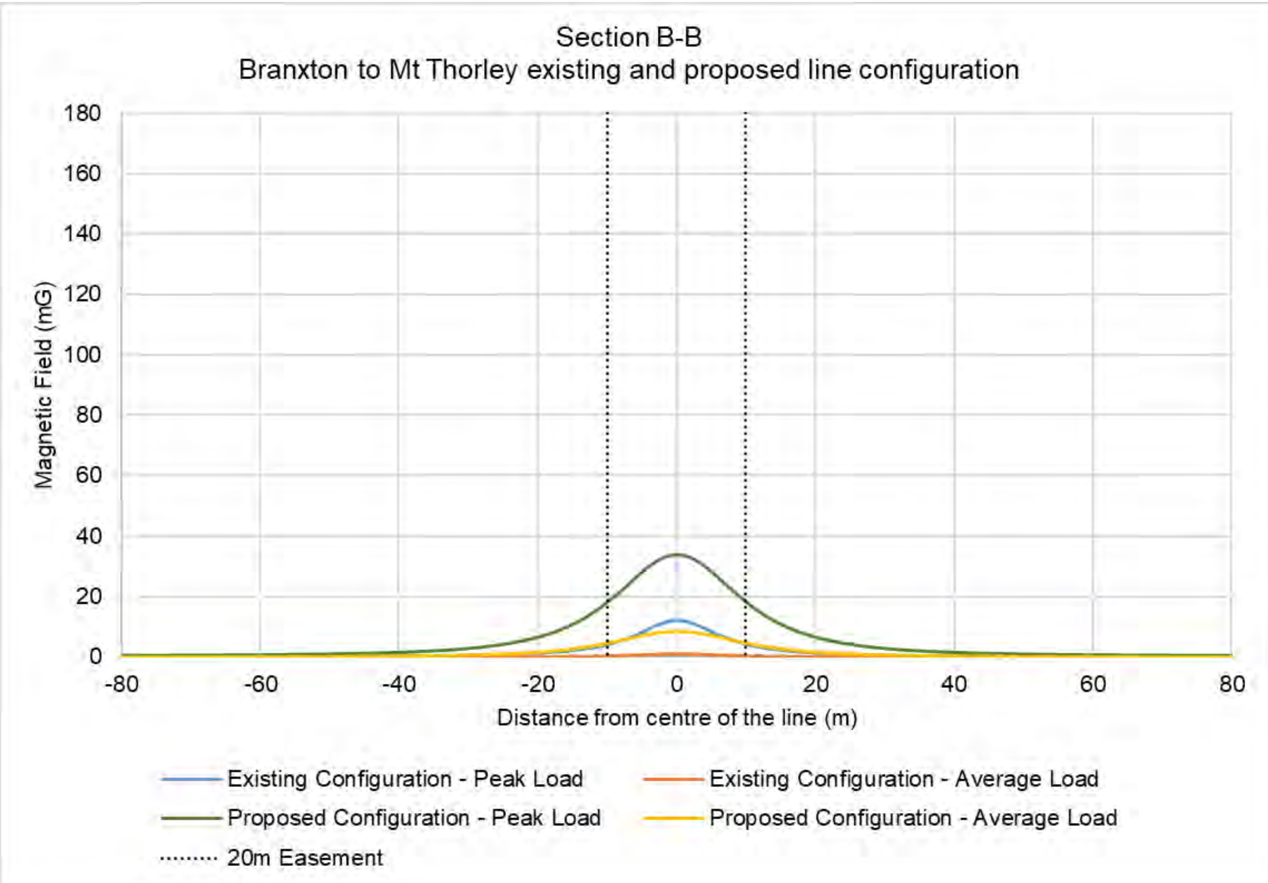

Figure 4-4 | Calculated magnetic field profile for existing 66 kV and proposed 132 kV configuration from Branxton to Mt Thorley

The magnetic fields depicted in Figure 4-4, under various configuration and load conditions, are summarised in Table 4-2.

Table 4-2 | Magnetic field for the existing 66 kV and proposed 132 kV configurations of the line from Branxton to Mt Thorley

Loading Condition	Directly under line (mG)		Easement edge – 20 m (mG)		100 m from line (mG)	
	Existing	Proposed	Existing	Proposed	Existing	Proposed
Average Load	< 1	8	< 1	5	< 1	< 1
Peak Load	12	34	4	18	< 1	< 1

From the results above, it can be seen that, the magnetic field for the proposed line configuration is higher than that of the existing line, due to the higher load current in the proposed 132 kV lines.

In determining the optimal phase arrangement for the three lines, the phase arrangement for the lines in Section A-A that resulted in the lowest magnetic field, as mentioned in section 4.2.1, has been retained. Various phase arrangements have been examined for 66 kV underbuilt line and the phasing arrangement that results in the lowest magnetic field at the easement edge (looking towards Mt Thorley) is as follows:

132 kV Feeder Circuit 1	132 kV Feeder Circuit 2
A	**C**
B	**B**
C	**A**

66 kV Feeder Circuit

    C

A

    B

4.2.3 Mt Thorley ZS to Singleton STS (Section C-C)

Section views of the existing and proposed pole structures are as shown in Figure 4-5.

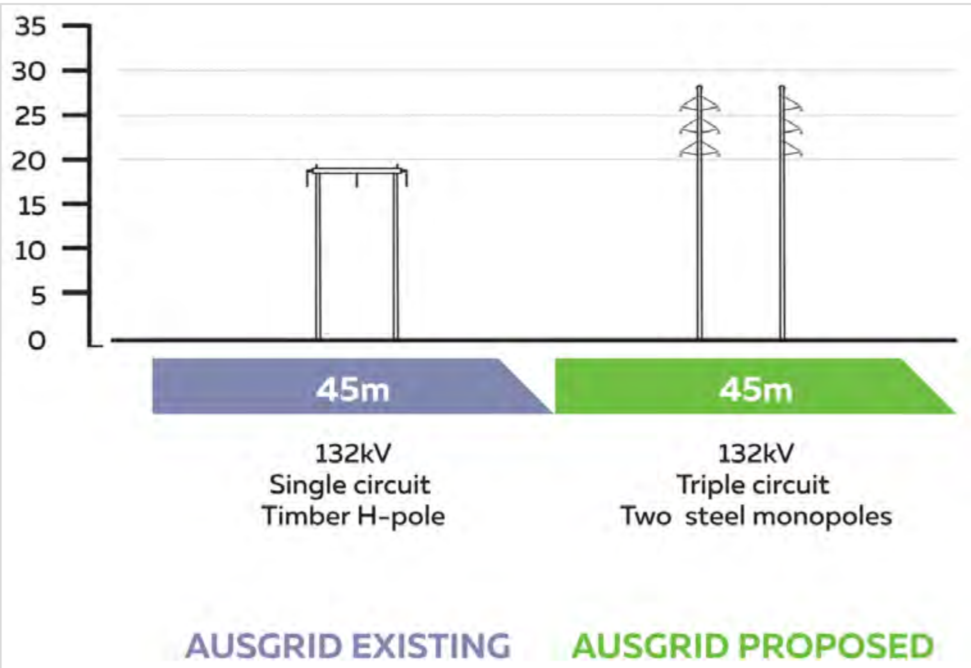

Figure 4-5 | Section view of the existing and the proposed pole structures

The calculated/predicted magnetic fields along the existing 132 kV single circuit and for the proposed configuration with 132 kV double circuit line running adjacent to it from Mt Thorley to Singleton are shown in Figure 4-6.

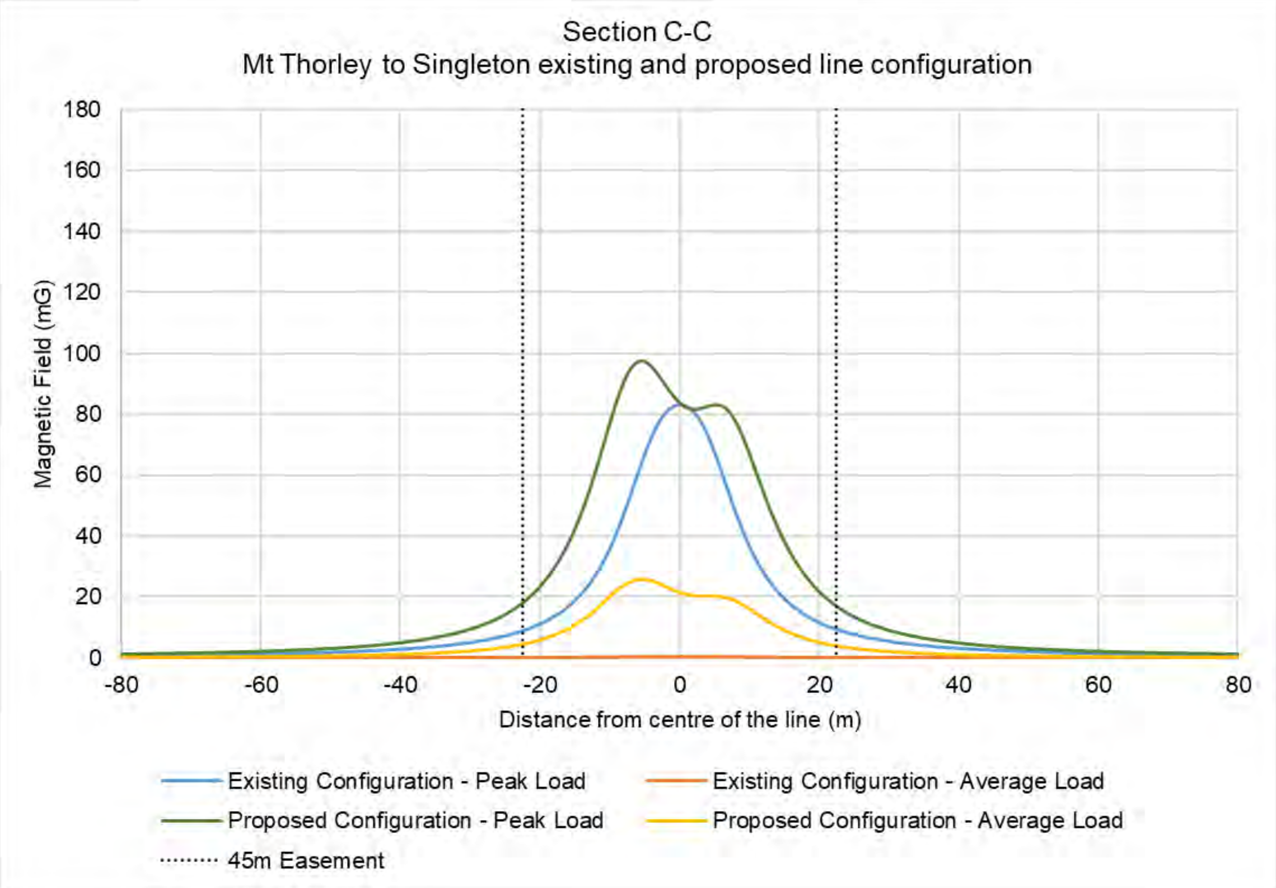

Figure 4-6 | Calculated magnetic field profile for existing and proposed configuration of line from Mt Thorley to Singleton

The magnetic fields depicted in Figure 4-6, under various configuration and load conditions, are summarised in Table 4-3.

Table 4-3 | Magnetic field for the existing and proposed configuration of 132 kV line from Mt Thorley to Singleton

Loading Condition	Directly under line (mG)		Easement edge – 45 m (mG)		100 m from line (mG)	
	Existing	Proposed	Existing	Proposed	Existing	Proposed
Average Load	< 1	26	< 1	5	< 1	< 1
Peak Load	83	97	9	18	< 1	< 1

From the results above, it can be seen that, the magnetic field for the proposed line configuration is higher than that for the existing line, due to the higher load current in the proposed 132 kV lines.

In determining the optimal phase arrangement for the three lines, the phase arrangement for the lines in Section A-A that resulted in the lowest magnetic field, as mentioned in section 4.2.1 has been retained. Various phase arrangements have been examined for the existing line and the phasing arrangement that results in the lowest magnetic field at the easement edge (looking towards Singleton) is as follows:

132 kV New Circuit 1	132 kV New Circuit 2	132 kV Existing Circuit on new pole
A	**C**	**A**
B	**B**	**B**
C	**A**	**C**

4.2.4 Singleton STS to Antiene Sub Transmission Substation (STSS) SS (Section D-D)

Section view of the existing and the proposed pole structures are as shown in Figure 4-7.

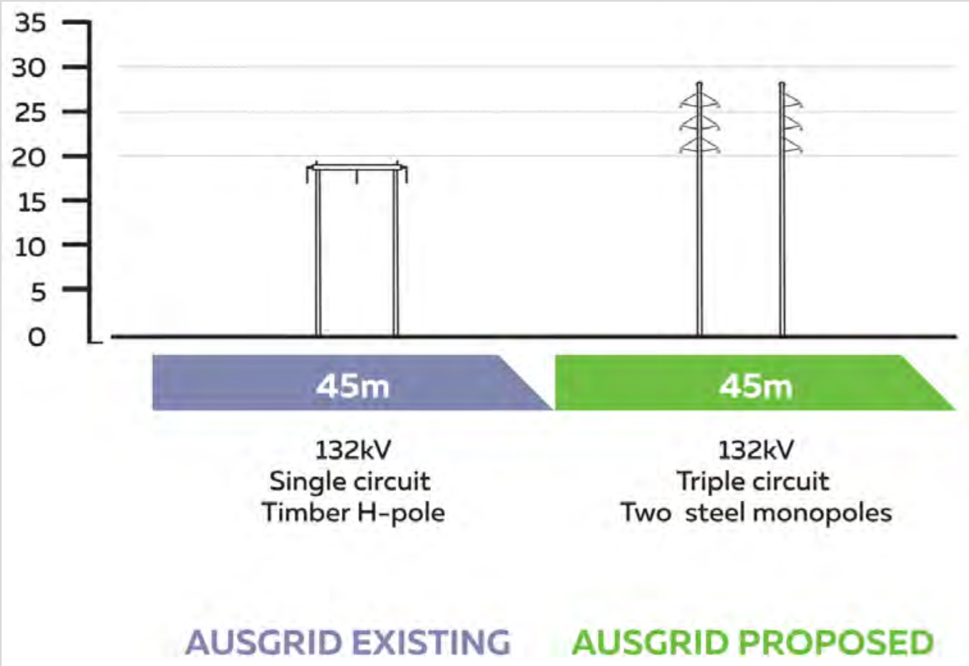

Figure 4-7 | Section view of the existing and the proposed pole structures

The calculated magnetic fields along the existing 132 kV single circuit and for the proposed configuration, with the 132 kV double circuit line running adjacent to it from Singleton to Antiene Sub Transmission Substation (STSS) are shown in Figure 4-8.

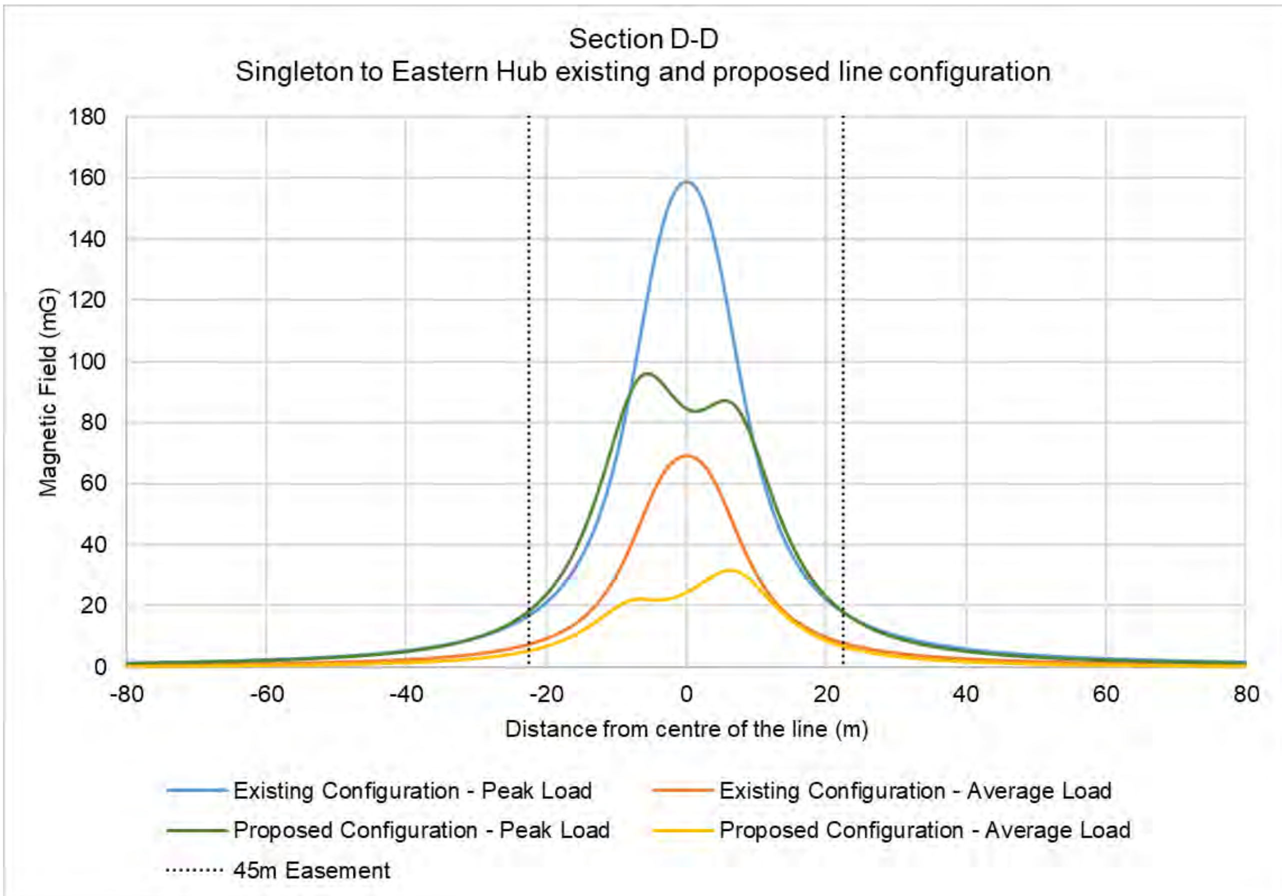

Figure 4-8 | Calculated magnetic field profile for existing and proposed configuration of line from Singleton to Antiene Sub Transmission Substation (STSS)

The magnetic fields depicted in Figure 4-8, under various configuration and load conditions, are summarised in Table 4-4.

Table 4-4 | Magnetic field for the existing and proposed configuration of 132 kV line from Singleton to Antiene Sub Transmission Substation (STSS)

Loading Condition	Directly under line (mG)		Easement edge – 45 m (mG)		100 m from line (mG)	
	Existing	Proposed	Existing	Proposed	Existing	Proposed
Average Load	69	32	8	7	< 1	< 1
Peak Load	159	96	19	18	1	< 1

From the results above, it can be seen that the magnetic fields for the proposed line configuration are less than those for the existing configuration.

Since the structure arrangement of proposed section D-D is similar to that of proposed section C-C, the phase arrangement that gives the least magnetic field in section C-C is recommended for section D-D as well.

4.2.5 Sandy Creek STSS to Muswellbrook BSP (Section E-E)

Section view of the existing and the proposed pole structures are as shown in Figure 4-9.

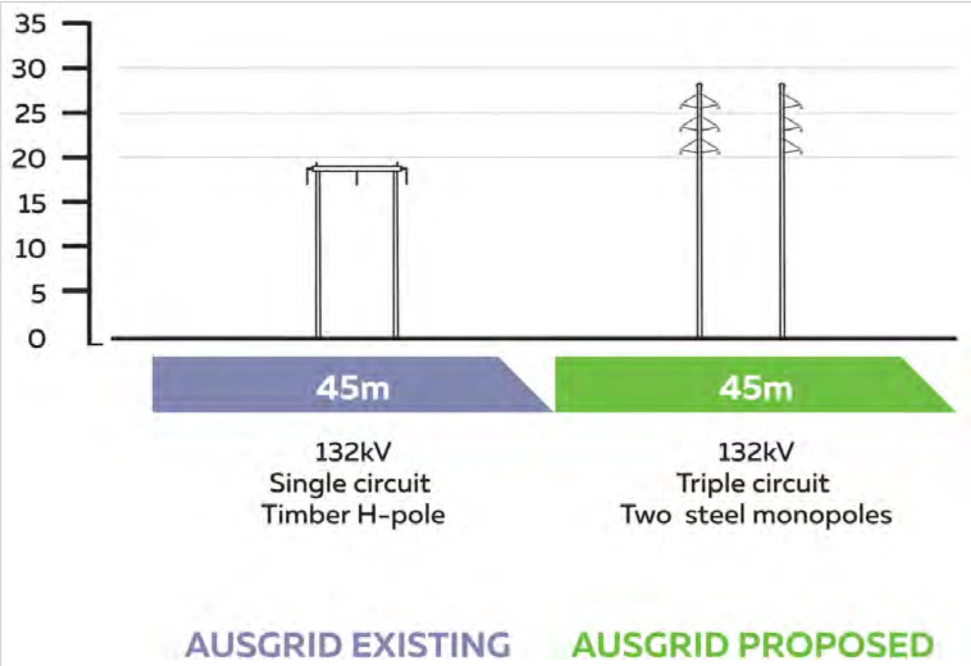

Figure 4-9 | Section view of the existing and the proposed pole structures

The calculated/predicted magnetic fields along the existing 132 kV single circuit and for the proposed 132 kV double circuit configuration from Sandy Creek STSS to Muswellbrook BSP are shown in Figure 4-10.

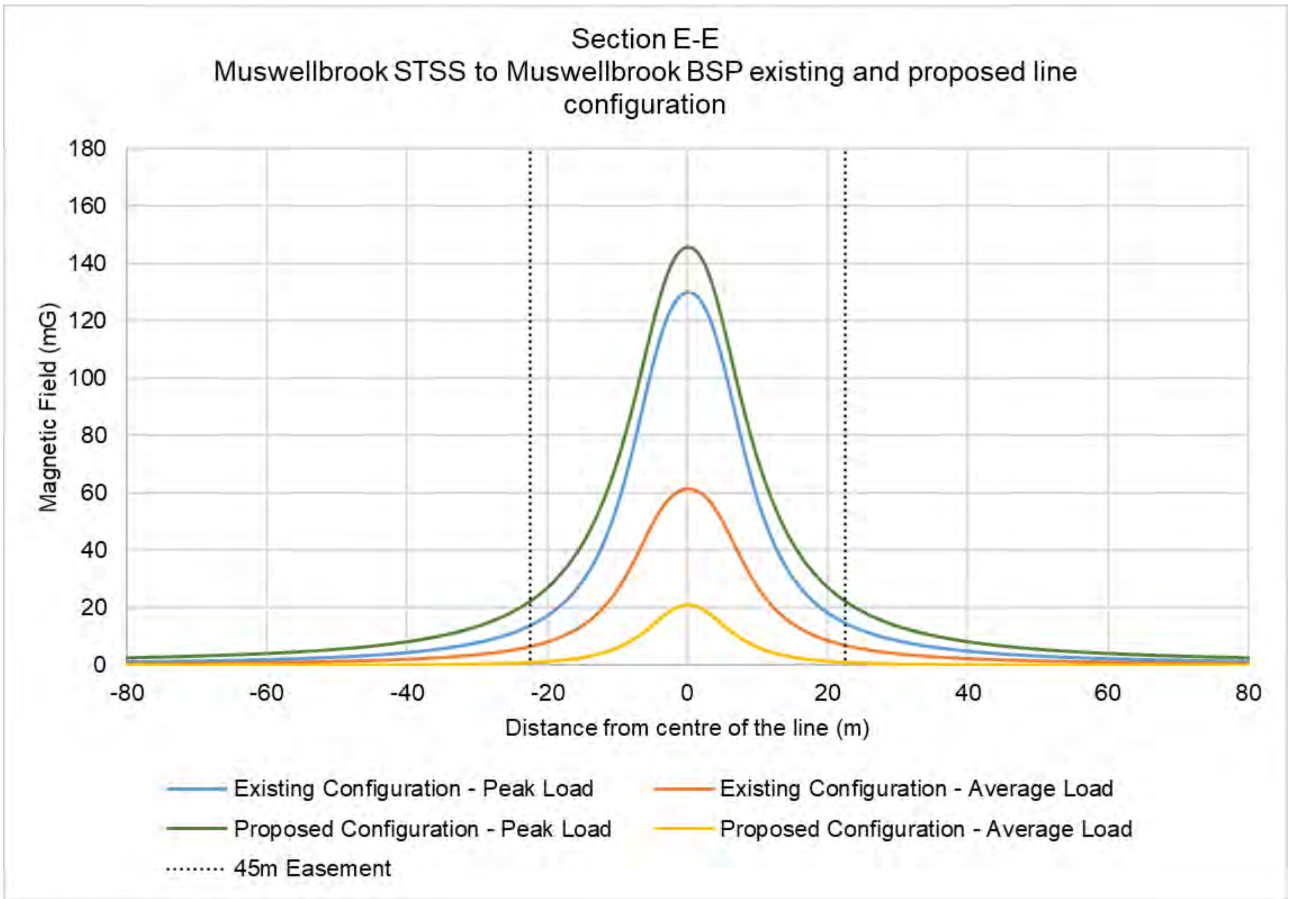

Figure 4-10 | Calculated magnetic field profile for existing and proposed configuration of 132 kV line from Muswellbrook STS to Muswellbrook BSP

The calculated magnetic fields depicted in Figure 4-10, under various load conditions, are summarised in Table 4-5.

Table 4-5 | Magnetic field for the existing and proposed configuration of 132 kV line from Muswellbrook STS to Muswellbrook BSP

Loading Condition	Directly under line (mG)		Easement edge – 45 m (mG)		100 m from line (mG)	
	Existing	Proposed	Existing	Proposed	Existing	Proposed
Average Load	61	21	7	1.2	< 1	< 1
Peak Load	130	146	15	22	< 1	1.9

From the results above, it can be seen that, the magnetic field for the proposed line configuration for average load is less than that of the existing line.

Since the structure arrangement of proposed section E-E is similar to that of proposed section A-A, the phase arrangement that gives the least magnetic field in section A-A is recommended for section E-E as well.

4.3 Magnetic fields experienced in everyday life

In considering the fact that the magnetic fields associated with the proposed transmission lines are quite localised and, due to their location in an easement, are unlikely to be experienced by people, other than intermittently, it is useful to recognise that life in the modern world involves moving from one source of magnetic fields to another. To put this into perspective, the Energy Networks Association has published a series of typical magnetic field levels associated with particular appliances and infrastructure at normal user distance[8]. These are set out in Table 4-6.

Table 4-6 | Typical ELF magnetic field levels associated with appliances and infrastructure [8]

Appliance	Typical Measurement (mG)	Typical range of measurements (mG)[9]
Electric Stove	6	2 – 30
Refrigerator	2	2 – 5
Electric Kettle	3	2 – 10
Toaster	3	2 – 10
Electric Blanket	20	5 – 30
Hair Dryer	25	10 – 70
Pedestal Fan	1	0.2 – 2
Substation		
- Substation Fence	5	1 – 8
Distribution Line		
- Under line	10	2 – 30
- 10 m away	-	0.5 – 10
Transmission Line		
- Under line	20	10 – 200
- Edge of easement	10	2 – 50

From the above range of fields, it can be seen that the predicted magnetic field contributions associated with the proposed transmission lines (in the range 1.2 to 152 mG within the easement) are within the range of fields normally encountered around transmission lines. It is noted that the levels in Table 4-6 are typical only and fields may vary from the ranges shown. It is also noted that the transmission lines would be within an easement and human interaction with magnetic fields would therefore be intermittent and transitory in nature.

[8] *Electric and Magnetic Fields - What we know*, Energy Networks Association (n.d)
[9] *Levels of magnetic fields may vary from the range of measurements shown. Appliance measurements at normal user distance.*

4.4 Electric field results

The results obtained from the electric field modelling of the proposed transmission lines are shown in the following sections and are presented in the form of profiles indicating the electric field along a line across the easement at right angles to the proposed 66 kV and 132 kV overhead conductors. As noted in Section 2.1, electric fields are primarily governed by the transmission line voltage[10] and, accordingly, are less variable than magnetic fields. Electric field results are shown for the phase arrangements set out in section 4.2.

4.4.1 Kurri STS to Branxton ZS Line (Section A-A)

The calculated electric fields along the existing 66 kV single circuit line and the proposed 132 kV double circuit line from Kurri STS to Branxton Tee are shown in Figure 4-11.

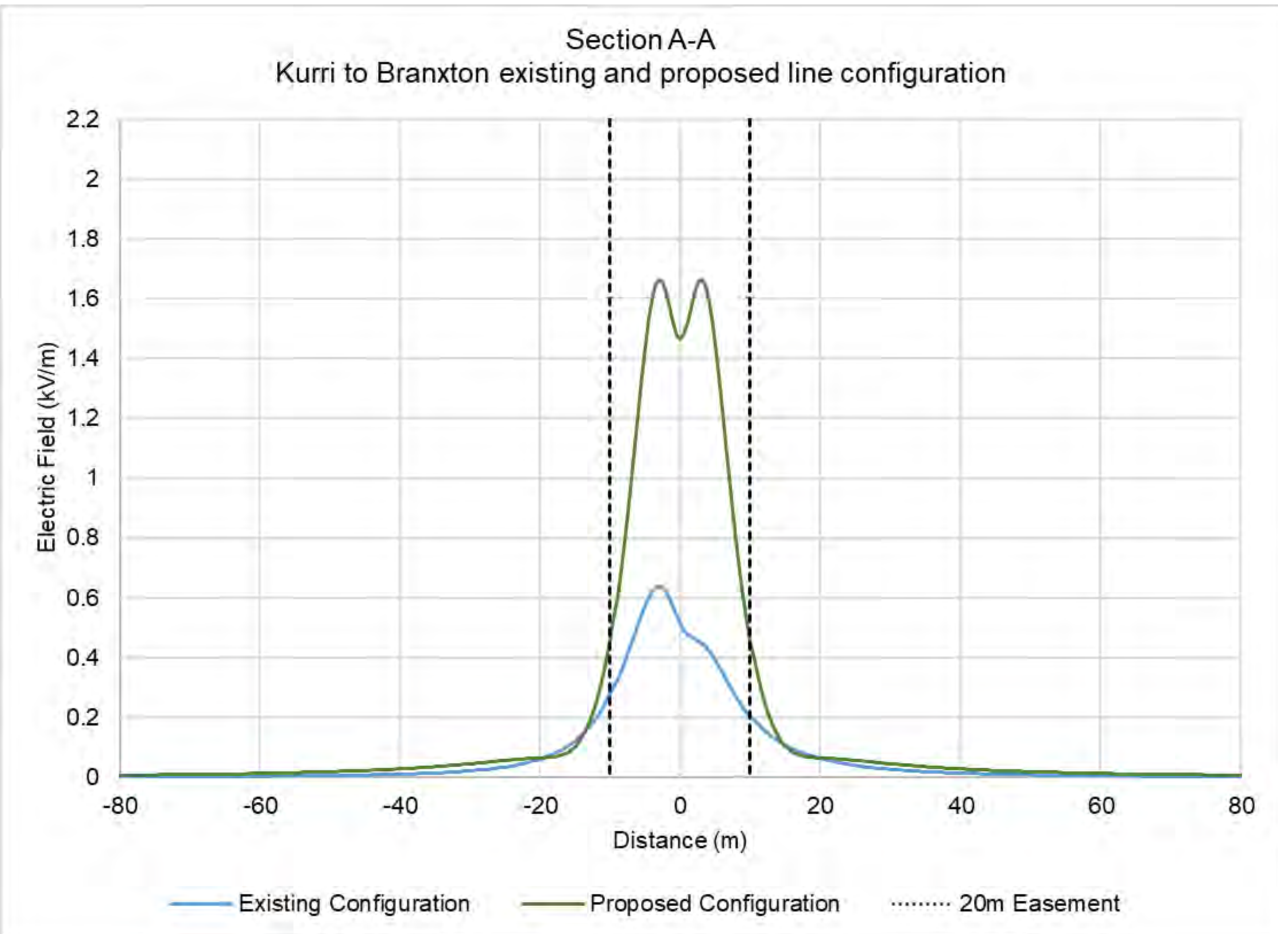

Figure 4-11 | Calculated electric field profile for existing 66 kV and proposed 132 kV configuration from Kurri to Branxton

The electric field results depicted in Figure 4-11, for the existing and proposed line configurations, are summarised in Table 4-7.

Table 4-7 | Electric field for existing 66 kV/proposed 132 kV configuration of line from Kurri to Branxton

Configuration	Directly under the line (V/m)	Easement edge – 20 m (V/m)	100 m away from the line (V/m)
Existing	639	277	2
Proposed	1,666	456	5

[10] *Load current has a secondary influence on electric fields directly under the line, due to its influence on conductor sag.*

4.4.2 Branxton TEE to Mt Thorley ZS Line (Section B-B)

The calculated electric fields along the existing 66 kV single circuit lineand the proposed 132 kV double circuit lines with single circuit 66 kV underbuilt line from Branxton Tee to Mt Thorley are shown in Figure 4-12.

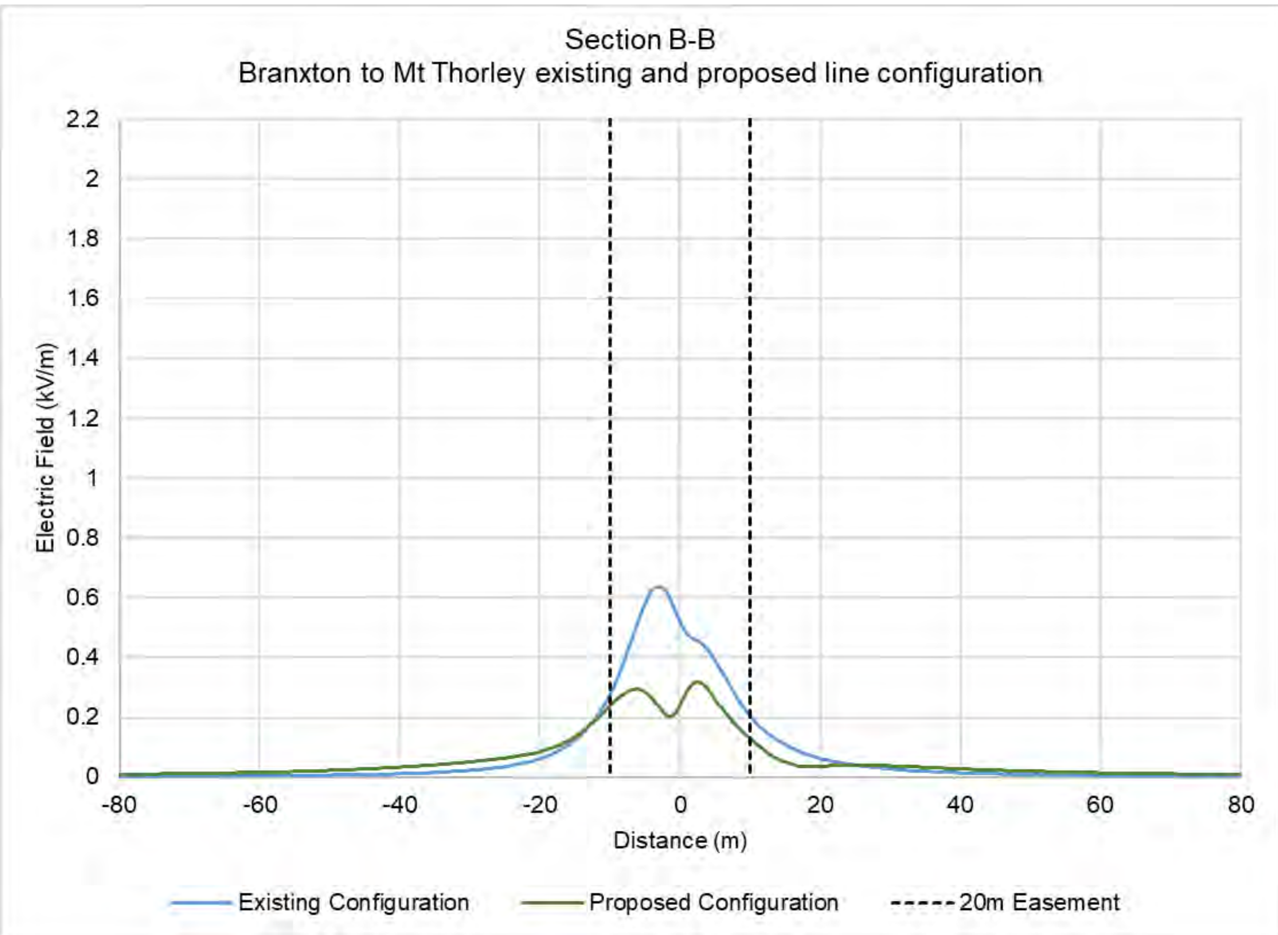

Figure 4-12 | Calculated electric field profile for existing 66 kV and proposed 132 kV configuration from Branxton to Mt Thorley

The electric field results depicted in Figure 4-12, under the existing and proposed lines, are summarised in Table 4-8.

Table 4-8 | Electric field for the existing 66 kV/proposed 132 kV lines from Branxton to Mt Thorley

Configuration	Directly under the line (V/m)	Easement edge – 20 m (V/m)	100 m away from the line (V/m)
Existing	639	277	2
Proposed	319	238	6

As can be seen from the results above, the electric field for the proposed configuration is less than that for the existing line.

4.4.3 Mt Thorley ZS to Singleton STS (Section C-C)

The calculated electric fields along the existing 132 kV single circuit line and for the proposed configuration with a 132 kV double circuit line running adjacent to the existing 132 kV single circuit line from Mt Thorley to Singleton are shown in Figure 4-13.

The existing line has both mango and goat conductors, each for 50% of its length. However, as Aurecon's calculations revealed both the conductors produce similar results, only those for Mango are shown.

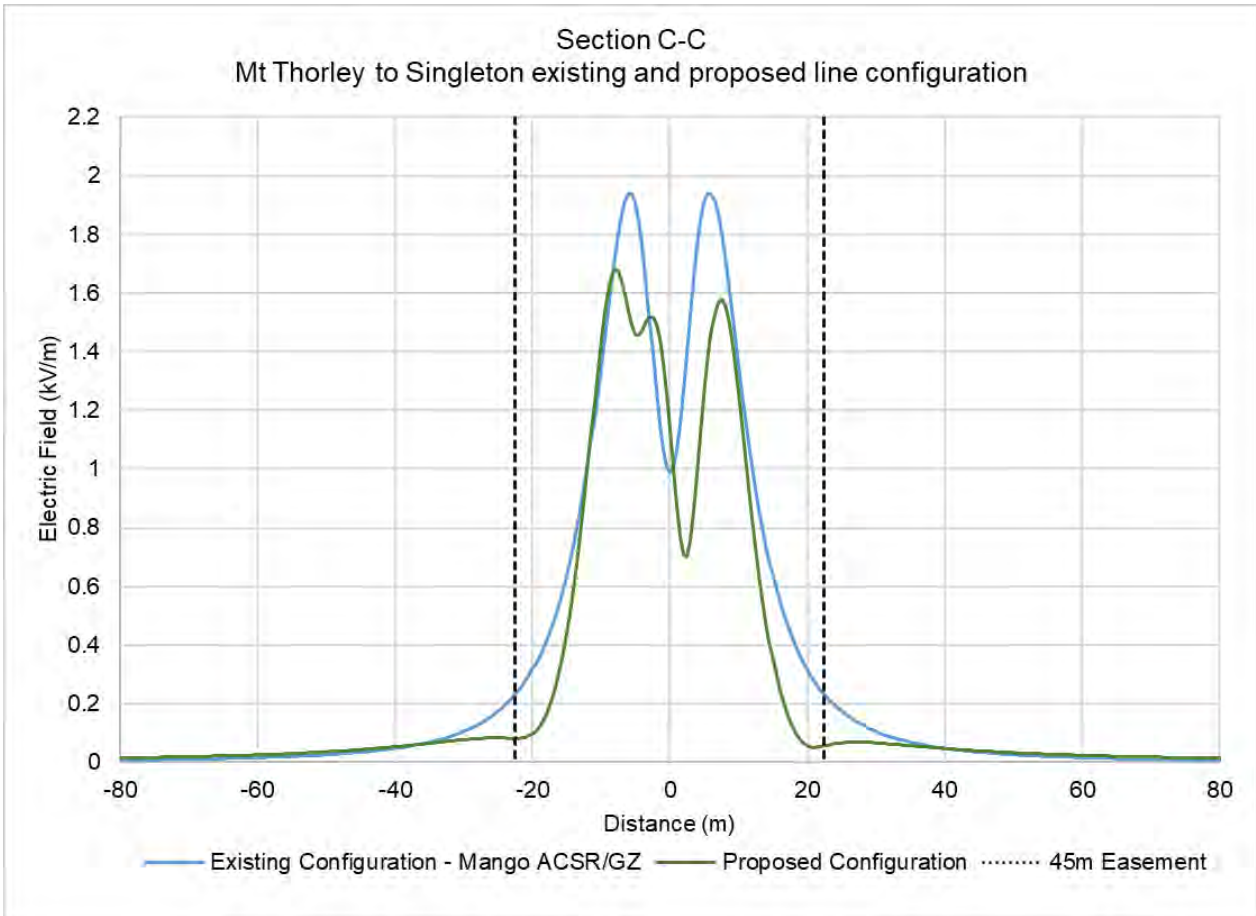

Figure 4-13 | Calculated electric field profile for existing and proposed configuration of lines from Mt Thorley to Singleton

The electric field results depicted in Figure 4-13, under existing and proposed line configuration, are summarised in Table 4-9.

Table 4-9 | Electric field for the existing and proposed configuration of 132 kV line from Mt Thorley to Singleton

Condition Considered	Conductor	Directly under the line (V/m)	Easement edge – 45 m (V/m)	100 m away from the line (V/m)
Existing	Mango ACSR/GZ	1,940	231	4
Proposed	Olive ACSR/GZ	1,681	81	9

As can be seen from the results above, both directly below the lines and at the edge of the easement, the electric fields for the proposed configuration are less than those for the existing line. However, at a distance of 100 m, the electric fields for the proposed configuration are very low, but greater than those for the existing line. This phenomenon is not uncommon for multiple lines in combination.

4.4.4 Singleton STS to Antiene Sub Transmission Substation (STSS) SS (Section D-D)

The calculated electric fields along the existing 132 kV single circuit line and for the proposed configuration with 132 kV double circuit line running adjacent to 132 kV single circuit line from Singleton to Antiene Sub Transmission Substation (STSS) are shown in Figure 4-14.

The proposed transmission line structure arrangement for section D-D is the same as that proposed for section C-C. Therefore, the electric field results are similar to the results given in Figure 4-13.

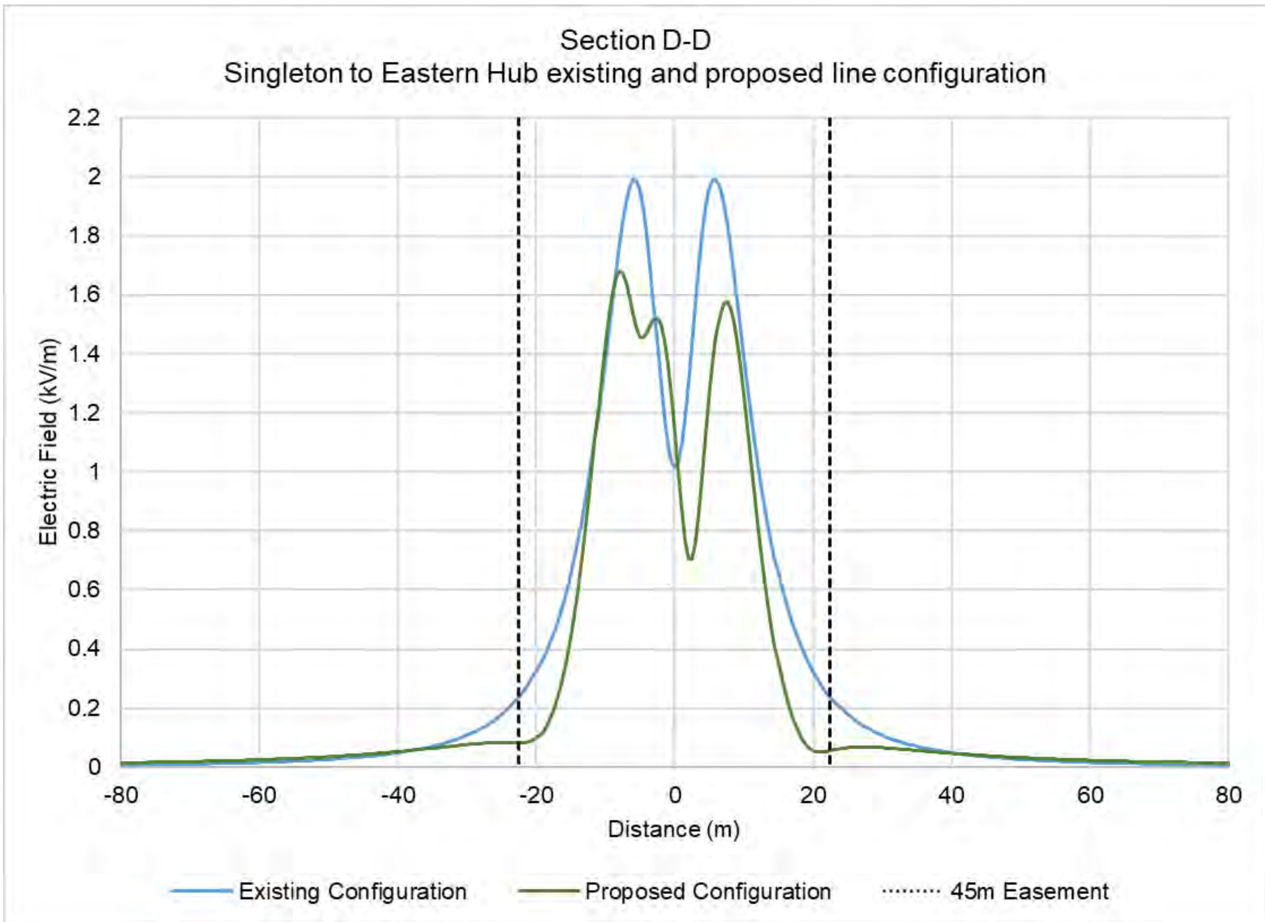

Figure 4-14 | Calculated electric field profile for existing and proposed configuration of line from Singleton to Antiene Sub Transmission Substation (STSS)

The electric field results depicted in Figure 4-14, under existing and proposed line configuration, are summarised in Table 4-10.

Table 4-10 | Electric field for the existing and proposed configuration of 132 kV line from Singleton to Antiene Sub Transmission Substation (STSS)

Configuration	Directly under the line (V/m)	Easement edge – 45 m (V/m)	100 m away from the line (V/m)
Existing	1,990	237	4
Proposed	1,681	81	9

As can be seen from the results above, both directly below the lines and at the edge of the easement, the electric fields for the proposed configuration are less than those for the existing line. However, at a distance of 100 m, the electric fields for the proposed configuration are very low, but greater than those for the existing line. This phenomenon is not uncommon for multiple lines in combination.

4.4.5 Sandy Creek STSS to Muswellbrook BSP (Section E-E)

The calculated electric fields along the existing 132 kV single circuit line and the proposed 132 kV double circuit line from Sandy Creek STSS to Muswellbrook BSP are shown in Figure 4-15.

The existing configuration has Olive ACSR/GZ for the majority of its length and Mango ACSR/GZ for the remaining part of the line. However, as both conductors produce similar results only those for Olive are shown.

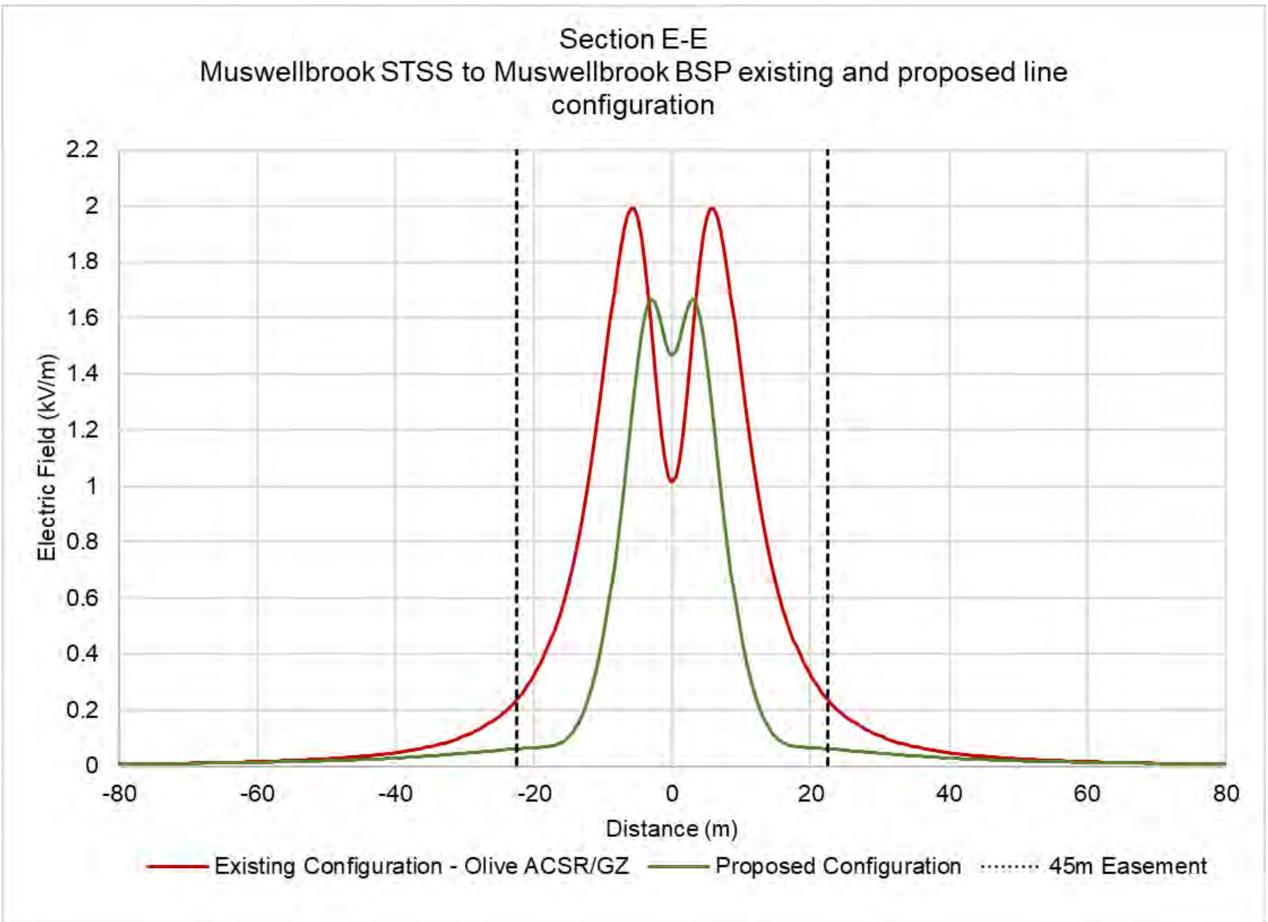

Figure 4-15 | Calculated electric field profile for existing and proposed configuration of 132 kV line from Muswellbrook STS to Muswellbrook BSP

The electric field results depicted in Figure 4-15, for the existing and proposed line configurations, are summarised in Table 4-11.

Table 4-11 | Electric field for the existing and proposed configuration of 132 kV line from Muswellbrook STS to Muswellbrook BSP

Condition Considered	Conductor	Directly under the line (V/m)	Easement edge – 45 m (V/m)	100 m away from the line (V/m)
Existing	Olive ACSR/GZ	1,990	237	4
Proposed	Olive ACSR/GZ	1,666	62	5

As can be seen from the results above, both directly below the lines and at the edge of the easement, the electric fields for the proposed configuration are less than those for the existing line. However, at a distance of 100 m, the electric fields for the proposed configuration are very low, but greater than those for the existing line. This phenomenon is not uncommon for multiple lines in combination.

5 Compliance with EMF guidelines and prudent avoidance principles

5.1 Compliance with health guidelines

5.1.1 Magnetic fields

The contribution of the proposed transmission lines to the magnetic field environment is predicted to be well within the ICNIRP Guideline Reference Level of 2,000 mG. Relevant magnetic field values are summarised in Table 5-1.

Table 5-1 | Summary of magnetic field results

Tx. Line Section	Scenario	Directly under the transmission line				At the easement edge			
		For average load		For peak load		For average load		For peak load	
		(mG)	% of ICNIRP Guideline Ref. Level	(mG)	% of ICNIRP Guideline Ref. Level	(mG)	% of ICNIRP Guideline Ref. Level	(mG)	% of ICNIRP Guideline Ref. Level
Section A - A	Existing	< 1	< 0.05%	12	0.6%	< 1	< 0.05%	4	0.2%
	Proposed	33	1.7%	124	6.2%	10	0.5%	37	1.9%
Section B - B	Existing	< 1	< 0.05%	12	0.6%	< 1	< 0.05%	4	0.2%
	Proposed	8	0.4%	34	1.7%	5	0.3%	18	0.9%
Section C - C	Existing	< 1	< 0.05%	83	4.2%	< 1	< 0.05%	9	0.5%
	Proposed	26	1.3%	152	7.6%	5	0.3%	24	1.2%
Section D - D	Existing	69	3.5%	159	8.0%	8	0.4%	19	1%
	Proposed	32	1.6%	96	4.8%	7	0.4%	18	0.9%
Section E - E	Existing	61	3.0%	130	6.5%	7	0.4%	15	0.8%
	Proposed	21	1.1%	146	7.3%	1.2	0.1%	22	1.1%

As shown in Table 5-1, the predicted maximum magnetic fields for the proposed transmission lines are less than 7.6% of the ICNIRP Guideline Reference Level directly under the transmission lines and less than 1.9% at the easement edges.

Furthermore, it is evident that, for Sections D-D & E-E, the magnetic fields from the proposed transmission lines on average load, are lower than those from the existing lines. In the case of Sections A-A, B-B & C-C, predicted fields are higher than the existing fields but still within the range of fields from the other proposed lines.

5.1.2 Electric fields

From the results shown in Section 4.4, it is evident that the contribution of the existing and proposed 66 kV and 132 kV transmission lines to the electric field environment is predicted to be well within the ICNIRP Guideline Reference Level of 5 kV/m. Relevant electric field values are shown in Table 5-2.

Table 5-2 | Summary of electric field results

Transmission Line Section	Scenario	Directly under the transmission line		At the easement edge	
		(kV/m)	% of ICNIRP Guideline Reference Level	(kV/m)	% of ICNIRP Guideline Reference Level
Section A - A	Existing	0.6	7%	0.3	3%
	Proposed	1.7	18%	0.5	5%
Section B - B	Existing	0.6	7%	0.3	3%
	Proposed	0.3	4%	0.2	3%
Section C - C	Existing	1.9	21%	0.2	3%
	Proposed	1.7	19%	0.1	1%
Section D - D	Existing	2.0	22%	0.2	3%
	Proposed	1.7	19%	0.1	1%
Section E - E	Existing	2.0	22%	0.2	3%
	Proposed	1.7	18%	0.1	1%

As shown in Table 5-2, calculated maximum electric field values are less than 30% of the ICNIRP Guideline Reference Level directly under the transmission lines and less than 5% at the easement edges.

In practice, due to shielding by vegetation etc, the actual electric fields are likely to be considerably less than those predicted.

5.2 Assessment against prudent avoidance principles

As noted in Section 2.4, given the inconclusive nature of the science, it is considered that, in the circumstances, a prudent/precautionary approach continues to be the most appropriate response to health concerns regarding EMF. Under this approach, the operators of electricity infrastructure should design their facilities to reduce the intensity of the magnetic fields they generate, and locate them to minimise the fields that people, especially children, encounter over prolonged periods, provided this can be readily achieved without undue inconvenience and at reasonable expense, and be consistent with good engineering and risk minimisation practice.

In the case of the current project;

- Ausgrid has advised that the phases of the parallel circuits will be arranged, as modelled in this report to provide maximum magnetic field cancellation.
- For Sections D-D & E-E, the magnetic fields associated with the proposed lines on average load will be less than those associated with the existing lines. In the case of Sections A-A, B-B and C-C, the predicted fields will still be within the range of fields from the other proposed lines.
- Ausgrid has chosen to locate the new lines along the existing easements, thereby avoiding the proliferation of lines. In doing so, it is noted that, for section CC, DD & EE the chosen corridors are more than 100 m away from the nearest dwellings and other frequented premises. At such distances, the average magnetic fields would be within the range found in typical everyday situations.
- For Section AA, there are approximately 30 dwellings within 100 m of the centre of the transmission line, the nearest being 30 m away and the others ranging between 40 m and 100 m. The maximum average magnetic field due to the transmission line at the nearest dwelling will be 3.3 mG and that for the others will range from less than 1 mG to 2 mG.

- For Section BB, there are approximately 20 dwellings within 100 m of the centre of the transmission line, the nearest being 20 m away and the others ranging between 35 m and 90 m. The maximum magnetic field due to the transmission line at the nearest dwelling will be 5.8 mG and that for others will range from less than 1 mG to 4 mG.

Due to the uncertainty as to the existence of adverse health effects, it cannot be said whether the above measures would result in any health benefit, but they are all appropriate and consistent with the principles of prudent avoidance.

6 References

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Appendix A
General description of electric and magnetic fields

The electric and magnetic fields associated with electrical equipment, whilst interrelated, are not dependent on each other and can exist independently. The electric field is associated with the voltage of the equipment and the magnetic field is associated with the current (amperage). In combination, these fields cause energy to be transferred along electric wires.

An **electric field** is a region where electric charges experience an invisible force. The strength of this force is related to the voltage, or pressure, which forces electricity along wires. Electric fields are strongest closest to their source, and their strength diminishes rapidly with distance from the source, in much the same way as the warmth of a fire decreases with distance. Many common materials – such as brickwork or metal – block electric fields, so they are readily shielded and, for all practical purposes, do not penetrate buildings. They are also shielded by human skin, such that the electric field inside a human body will be at least 100,000 times less than the external field (Ref A-1). Being related to voltage, the electric fields associated with high voltage aerial lines and electrical substations remain relatively constant over time, except where the operating voltage changes.

A **magnetic field** is a region where magnetic materials experience an invisible force produced by the flow of electricity (known as electric current and measured in Amperes). The strength of a magnetic field depends on the size of the current and decreases as distance from the source increases. The magnetic field strength resulting from an electrical installation varies continually with time and is affected by a number of factors including:

- total electric load
- size and nature of the equipment
- design of the equipment
- layout and electrical configuration of the equipment and its interaction with other equipment.

While electric fields are blocked by common materials, this is not the case with magnetic fields. This is why locating equipment in enclosures or underground will eliminate any external electric field but not the magnetic field.

Alternating electric and magnetic fields are produced by any electric wiring or equipment carrying alternating current (AC). This current does not flow steadily in one direction but oscillates backwards and forwards at a frequency[11] of 50Hz and hence the fields produced by AC systems oscillate at the same frequency. This frequency falls into a range referred to as **extremely low frequency** (ELF), so the electric and magnetic fields are referred to as ELF fields.

Electromagnetic radiation

It is not uncommon for the ELF EMF associated with electrical equipment to be confused with electromagnetic radiation (EMR). The fact that, in many jurisdictions, agencies which regulate the various forms of EMR are also involved in the setting of guidelines/standards for EMF tends to add to this confusion.

Electromagnetic radiation is a term we use to describe the movement of electromagnetic energy through the propagation of a wave. This wave, which moves at the speed of light in a vacuum, is composed of electric and magnetic waves which oscillate (vibrate) in phase with, and perpendicular to, each other. This is in contrast to EMF, where the electric and magnetic components are essentially independent of one another.

Electromagnetic radiation is classified into several types according to the frequency of its wave; these types include (in order of increasing frequency): radio waves, microwaves, terahertz radiation, infra-red radiation,

[11] *Frequency is a measure of the number of times per second a wave oscillates or vibrates. The most common unit of measurement of frequency is the Hertz (Hz) where 1 Hz is equal to 1 cycle per second.*

visible light[12], ultraviolet radiation, x-rays and gamma rays. Whereas EMR causes energy to be radiated outwards from its source e.g. light from the sun or radio-frequency signals from a television transmitter, EMFs cause energy to be transferred along electric wires.

In the context of EMF and health, the distinction between EMF and EMR is addressed by the New Zealand Ministry of Health in its public information booklet "Electric and Magnetic Fields and Your Health" (Ref A-2) as follows:

"The electric and magnetic fields around power lines and electrical appliances are not a form of radiation. The word "radiation" is a very broad term, but generally refers to the propagation of energy away from some source. For example, light is a form of radiation, emitted by the sun and light bulbs. ELF fields do not travel away from their source, but are fixed in place around it. They do not propagate energy away from their source. They bear no relationship, in their physical nature or effects on the body, to true forms of radiation such as x-rays or microwaves."

References

A-1. World Health Organisation: *Environmental Health Criteria Vol. 238*: Extremely low frequency fields. (2007).

A-2. New Zealand Ministry of Health: *Electric and Magnetic Fields and Your Health*. (2008).

[12] *Visible light is a group (spectrum) of frequencies which can be sensed by the eyes of humans and various other creatures.*

Appendix B
Overview of EMF and health

Research into EMFs and health is a complex area involving many scientific disciplines – from biology, physics and chemistry to medicine, biophysics and epidemiology. Many of the health end points of interest to researchers are quite rare. In this context, it is well accepted by scientists that no study considered in isolation will provide a meaningful answer to the question of whether or not EMFs can contribute to adverse health effects. In order to make an informed conclusion from all of the research, it is necessary to consider the science in its totality. Over the years, governments and regulatory agencies around the world have commissioned independent scientific review panels to provide such overall assessments.

Extremely low frequency (ELF) fields

The possibility of adverse health effects due to the ELF EMFs at levels commonly associated with electrical equipment has been the subject of extensive research throughout the world. To date, while adverse health effects have not been established, the possibility that they may exist cannot be ruled out.

While EMFs involve both electric and magnetic components, electric fields are relatively constant over time, are readily shielded and, in the health context, are generally no longer associated with the same level of interest as magnetic fields. Nevertheless, high electric field strengths, such as those associated with the highest voltage transmission lines or high voltage equipment in major substations, can approach a level at which "nuisance shocks" can occur and this phenomenon needs to be managed.

Magnetic fields are not readily shielded, are more ubiquitous and remain the subject of some debate. Accordingly, much of the remainder of this section is directed towards magnetic fields.

The most recent scientific reviews by authoritative bodies are reassuring for most potential health end points. However, statistical associations[13] between prolonged exposure to elevated magnetic fields and childhood leukaemia have persisted. This led the International Agency for Research on Cancer (IARC) (Ref. B-1) in 2002 to classify magnetic fields as a "possible carcinogen"[14].

The fact that, despite over 30 years of laboratory research, no mechanism for an effect has been established, lends weight to the possibility that the observed statistical associations reflect some factor other than a causal relationship. This point is made in the 2001 report of the UK National Radiological Protection Board's (NRPB) Advisory Group, chaired by eminent epidemiologist, the late Sir Richard Doll (Ref. B-2).

"in the absence of clear evidence of a carcinogenic effect in adults, or of a plausible explanation from experiments on animals or isolated cells, the evidence is currently not strong enough to justify a firm conclusion that such fields cause leukaemia in children." (page 164)

Corona ions

Although not strictly ELF fields per se, the phenomenon known as corona ions has been raised in some quarters as an alternative explanation for possible health effects attributed to EMF.

When high voltage conductors are surrounded by air, they can cause some of the air molecules to become electrically charged. In the mid to late 1990s, it was hypothesised by a group at Bristol University that these

[13] *It should be noted that a statistical association does not necessarily reflect a cause and effect relationship*

[14] *IARC publishes authoritative independent assessment by international experts of the carcinogenic risks posed to humans by a variety of agents, mixtures and exposures. These agents, mixtures and exposures are categorised into 4 groups, namely:*

- *Group 1 – the agent is carcinogenic to humans – 129 agents are included in the group, including asbestos, tobacco, diesel engine exhaust and ultraviolet radiation*
- *Group 2A – the agent is probably carcinogenic – 96 agents have been included in this group, including red meat, wood fire emissions, creosotes and PCBs*
- *Group 2B – the agent is possibly carcinogenic to humans – 321 agents have been included in this group, including gasoline, lead, nickel, petrol engine exhaust and extremely low frequency Magnetic Fields*
- *Group 3 – the agent is not classifiable as to carcinogenicity – 497 agents have been included in this group, including caffeine, coal dust, extremely low frequency electric fields and static electric and Magnetic Fields*

charged molecules can attach to pollutant particles, which may also be present in the air. It was further hypothesised that, especially downwind of high voltage power lines, the charged pollutant particles are more likely to be deposited on the skin or in the lungs, thereby increasing the risk of pollution related health effects.

In considering this issue, it is important to note that it is customary to design transmission lines to limit the conductor surface gradients under normal weather conditions to prevent the inception of corona.

The hypothesis has been examined by various independent health authorities over the years as discussed below.

World Health Organisation (WHO)

WHO addressed the corona ion hypothesis in its 2007 monograph on extremely low frequency fields (Ref B-3) as follows:

"High-voltage power lines produce clouds of electrically charged ions as a consequence of corona discharge. It is suggested that they could increase the deposition of airborne pollutants on the skin and on airways inside the body, possibly adversely affecting health. However, it seems unlikely that corona ions will have more than a small effect, if any, on long term health risks, even in the individuals who are most exposed."

(UK) National Radiological Protection Board (NRPB)

In 2004, after having reviewed the issue, the NRPB's Ad Hoc Group on Corona Ions released a report "Particle deposition in the vicinity of power lines and possible effects on health" (Ref B-4). The report concluded that:

"The effects of external fields on deposition of particles in the respiratory tract, if any, are likely to be very small";

"Any health risks from the deposition of environmental particulate air pollutants on the skin appear to be negligible."
and

"…it seems unlikely that corona ions would have more than a small effect on the long-term health risks associated with particulate air pollutants, even in the individuals who are most affected. In public health terms, the proportionate impact will be even lower because only a small fraction of the general population live or work close to sources of corona ions."

References

B-1. World Health Organisation, International Agency for Research on Cancer, Lyon, France: IARC Monographs on the evaluation of carcinogenic risks to humans. Non-Ionising Radiation Part 1: Static and Extremely Low Frequency (ELF) Electric and Magnetic Fields. (2002)

B-2. National Radiological Protection Board, (UK), ELF ElectroMagnetic Fields and the Risk of Cancer, Report of an Advisory Group on Non-Ionising Radiation, Chairman, Sir Richard Doll, NRPB Vol. 12 No. 1, 2001.

B-3. World Health Organisation: Environmental Health Criteria Vol. 238: Extremely low frequency fields. (2007).

B-4. National Radiological Protection Board, (UK), Particle Deposition in the Vicinity of Power Lines and Possible Effects on Health: Report of an independent Advisory Group on Non-ionising Radiation and its Ad Hoc Group on Corona Ions. Volume 15, No. 1, 2004

Appendix C
Health guidelines

Health guidelines for extremely low frequency electric and magnetic fields

The World Health Organisation recognises two international EMF/health guidelines:

- the *Guidelines for Limiting Exposure to Time-varying Electric and Magnetic Fields (1Hz to 100kHz) produced by the International Commission on Non-Ionising Radiation Protection (ICNIRP)* Ref C-1)
- the *IEEE Standard C95.1*, produced by the International Committee on Electromagnetic Safety, Institute of Electrical and Electronics Engineers (IEEE) in the USA.

In July 2015, the relevant Australian regulator (ARPANSA) officially adopted the more conservative of the above two, the ICNIRP 2010 Guidelines, in full, stating:

"The ICNIRP ELF guidelines are consistent with ARPANSA's understanding of the scientific basis for the protection of the general public (including the foetus) and workers from exposure to ELF EMF." (Ref. C-2)

In line with the regulator's advice, Aurecon has applied the provisions of the current international ICNIRP Guidelines to this assessment.

The 'Basic Restrictions' and 'Reference Levels'[15] for both electric and magnetic fields, contained in the current ICNIRP Guidelines' are summarised in the table below.

Table D-1: ICNIRP Guideline levels

Parameter	Basic Restriction (Volts per metre)	Reference Level
Electric field – general public	CNS Tissue of the head: 0.02 All tissue of head & body: 0.4	5,000 Volts per metre (V/m)
Magnetic field – general public	CNS Tissue of the head: 0.02 All tissue of head & body: 0.4	2,000 milligauss (mG)
Electric field – occupational	CNS Tissue of the head: 0.1 All tissue of head & body: 0.8	10,000 Volts per metre (V/m)
Magnetic field – occupational	CNS Tissue of the head: 0.1 All tissue of head & body: 0.8	10,000 milligauss (mG)

In applying the guidelines, it is to be noted that, unlike earlier versions, the various limits are now independent of duration of exposure.

In applying the ICNIRP Guidelines, it is also important to recognise that the numerical limits, eg 2,000 mG, are based on established health effects. In ICNIRP's fact sheet on the guidelines (Ref. C-3), it notes that:

"It is the view of ICNIRP that the currently existing scientific evidence that prolonged exposure to low frequency Magnetic Fields is causally related with an increased risk of childhood leukaemia is too weak to form the basis for exposure guidelines. Thus, the perception of surface electric charge, the direct stimulation of nerve and muscle tissue and the induction of retinal phosphenes are the only well-established adverse effects and serve as the basis for guidance."

Being based on established biological effects (which occur at field levels much higher than those normally encountered in the vicinity of electrical equipment), the (numerical) exposure limits in the guidelines and standards cannot be said to define safe limits for possible health effects, should these exist, from magnetic fields at levels normally encountered in the vicinity of electrical equipment.

[15] *The "Reference Levels" set out in the guideline are derived from the levels at which interactions with the central nervous system are established, with a safety factor applied and a further adjustment to simplify compliance measurement.*

It is in this context that precautionary measures for ELF magnetic fields such as prudent avoidance have arisen (see Appendix D).

References

C-1 International Commission on Non-Ionising Radiation Protection (2010: Guidelines for Limiting Exposure to Time-varying Electric and Magnetic Fields (1Hz to 100kHz): *Health Physics* 99(6):818-836; (2010).

C-2 ARPANSA: *Extremely Low Frequency Electric and Magnetic Fields* – 2015, accessed 10 May 2016.

C-3. ICNIRP Fact Sheet on the guidelines for limiting exposure to time-varying electric, and Magnetic Fields (1Hz-100kHz) published in *Health Physics* 99(6): 818-836; 2010, accessed 10 May 2016, <http://www.icnirp.org/cms/upload/publications/ICNIRPFactSheetLF.pdf>.

Appendix D
Prudent avoidance

Extremely low frequency magnetic fields

Regarding the potential health effects from ELF magnetic fields, while compliance with the relevant guideline is important in protecting people from established health effects, it does not necessarily address possible health effects, should they exist, from fields at levels normally encountered in the vicinity of electrical equipment. The possibility of such effects has been comprehensively studied over several decades worldwide but, to this day, there is no clear understanding of how ELF electric or magnetic fields at low levels could pose a threat to human health.

Since the late 1980s, many reviews of the scientific literature have been published by authoritative bodies. There have also been several inquiries such as those by Sir Harry Gibbs in NSW (Ref. D-1) and Professor Hedley Peach in Victoria (Ref. D-2). These reviews and inquiries have consistently found that:

- adverse health effects have not been established for fields at levels commonly found around electrical equipment and infrastructure
- the possibility cannot be ruled out
- if there is a risk, it is more likely to be associated with the magnetic field than the electric field.

Both Sir Harry Gibbs and Professor Peach recommended a policy of prudence or prudent avoidance, which Sir Harry Gibbs described in the following terms:

"… [doing] whatever can be done without undue inconvenience and at modest expense to avert the possible risk …"

In 1999, the (US) National Institute of Environmental and Health Sciences (NIEHS) (Ref. D-3) found:

"In summary, the NIEHS believes that there is weak evidence for possible health effects from ELF-EMF exposures, and until stronger evidence changes this opinion, inexpensive and safe reductions in exposure should be encouraged." (page 38)

The practice of prudent avoidance has been adopted by the (Australian) Energy Networks Association (ENA) and most Australian power utilities.

The World Health Organisation has also addressed the notion of prudence or precaution on several occasions, including in its 2007 publication *Extremely low frequency fields. Environmental Health Criteria, Vol. 238* (Ref. D-4), which states:

"…the use of precautionary approaches is warranted. However, it is not recommended that the limit values in exposure guidelines be reduced to some arbitrary level in the name of precaution. Such practice undermines the scientific foundation on which the limits are based and is likely to be an expensive and not necessarily effective way of providing protection."

It also states:

"Provided that the health, social and economic benefits of electric power are not compromised, implementing very low-cost precautionary procedures to reduce exposure is reasonable and warranted."

Given the inconclusive nature of the science, it is considered that a prudent approach continues to be the most appropriate response in the circumstances. Under this approach, subject to modest cost and reasonable convenience, power utilities and transport authorities should design their facilities to reduce the intensity of the fields they generate, and locate them to minimise the fields that people, especially children, encounter over prolonged periods. While these measures are prudent, it cannot be said that they are essential or that they will result in any benefit.

In the Australian context, ENA's position, as adopted in their *EMF Management Handbook* (Ref. D-5), states:

"Prudent avoidance does not mean there is an established risk that needs to be avoided. It means that if there is uncertainty, then there are certain types of avoidance (no cost / very low cost measures) that could be prudent."

It also states:

"Both prudent avoidance and the precautionary approach involve implementing no cost and very low cost measures that reduce exposure while not unduly compromising other issues."

References

D-1. Gibbs, Sir Harry, Chairman, *Inquiry into Community Needs and High Voltage Transmission Line Development, Submission to the NSW Government*, February 1991.

D-2. Peach HG, Bonwick WJ and Wyse T (1992). *Report of the Panel on ElectroMagnetic Fields and Health to the Victorian Government (Peach Panel Report)*. Melbourne, Victoria: September 1992.

D-3. National Institute of Environmental Health Sciences, National Institutes of Health, (USA), *NIEHS report on health effects from exposure to power-line frequency electric and Magnetic Fields*, NIH Publication No. 99-4493, 1999.

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Hunter-Central Coast - Renewable Energy Zone

Substation/Switching Station Electric and Magnetic Fields Assessment

Ausgrid

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Executive Summary

The Australian energy landscape is transitioning to a greater mix of low-emission renewable energy sources, such as wind and solar. To support this transition, meet our future energy demands and connect Australian communities and businesses to these lower cost energy sources, the national electricity grid needs to evolve.

In delivering Ausgrid's network infrastructure which forms part of the Hunter-Central Coast REZ, formally declared under section 19(1) of the Electricity Infrastructure Investment Act 2020, Ausgrid is proposing to deliver the following energy network infrastructure:

- Construction of new Antiene Sub Transmission Substation (STSS) Switching Station
- Construction of new Sandy Creek STSS
- Augmentation of Kurri Sub-Transmission Substation (STS)
- Augmentation of Rothbury Zone Substation (ZS)

The scope of Aurecon's assessment relates to these stations and is to encompass the following:

- Provision of a brief description of electric and magnetic fields (EMF) in relation to human health.
- Identification of relevant national and international EMF guidelines to be used for EMF assessment in substations/switching stations.
- An assessment of the EMF from the proposed switching stations and modifications to existing substations, immediately outside their perimeter fences.

The purpose of this assignment is to provide an EMF assessment of the proposed new switching stations and augmentation works at the existing substations.

Aurecon has noted that the switching stations and substations will be enclosed by a 3 m high weldmesh high-security fence around their perimeters and a 1.2 m high post and wire fence around the site boundaries. The switchyard perimeter and site boundary fences will be secured by locked gates with access restricted to authorised persons only. This will limit exposure to EMF for the general public.

The fields outside the switching station boundary, where the general public could potentially be present, are expected to be dominated by the incoming overhead lines. The field levels associated with these lines are expected to be in the same order as those reported in Section 4.2 of *Transmission Lines Electric and Magnetic Fields Assessment 526726- W00001-RPT-PL-0001*.

The nearest potentially frequented sites are located between 190 m and 400 m away from the various high security fences and, accordingly, the likelihood of prolonged human exposure to EMF at these locations is negligible.

Contents

1 Introduction......1
1.1 Background......1
1.2 Key Components of the Project......1
1.3 Purpose and scope of this report......1
1.4 Structure of the report......1

2 Overview of electric and magnetic fields......2
2.1 General description......2
2.2 Electric and magnetic fields and health......2
2.2.1 Summary of health effects......2
2.3 Health guidelines......3
2.4 Medical implants......4
2.5 Animals and plants......4
2.5.1 Gibbs Inquiry......4
2.5.2 United Kingdom EMF National Policy Statement......5

3 Switching Stations......6
3.1 Switching Station Elements......6
3.2 Approach......6
3.3 Magnetic Fields......6
3.3.1 Proposed Antiene Sub Transmission Substation (STSS) 132 kV Switching Station......6
3.3.2 Proposed Sandy Creek 132 kV Switching Station......8

4 Substations......11
4.1 Approach......11
4.2 Magnetic Fields......11
4.2.1 Upgrades to Kurri STS......11
4.2.2 Upgrades to Rothbury Zone Substation......14

5 References......16

Appendices

Appendix A

General description of electric and magnetic fields

Appendix B

Health guidelines

Figures

Figure 3-1 | Proposed location of the Antiene Sub Transmission Substation (STSS) 132 kV switching station
Figure 3-2 | Transmission line connections to the proposed switching station
Figure 3-3 | Proposed location of the Sandy Creek 132 kV switching station
Figure 3-4 | Transmission line connections to the proposed switching station
Figure 4-1 | Location of the existing Kurri STS
Figure 4-2 | Proposed changes to Kurri STS
Figure 4-3 | Location of the existing Rothbury ZS and proposed inductor installation

Tables

Table 2-1 | ICNIRP Guideline levels

1 Introduction

1.1 Background

The Hunter-Central Coast REZ was formally declared by the Minister for Energy under section 19(1) of the Electricity Infrastructure Investment Act 2020 (the Act) and published in the NSW Gazette on 9 December 2022. The declaration sets out the intended network capacity for network infrastructure in the Hunter-Central Coast REZ. This project would form part of Ausgrid's network infrastructure that would make up the REZ.

1.2 Key Components of the Project

The key substation components of the project include:

- Construction of new Antiene Sub Transmission Substation (STSS) Switching Station
- Construction of new Sandy Creek STSS
- Upgrading of the existing Kurri Sub-Transmission Substation
- Augmentation of Rothbury Substation

Aurecon has been engaged to assess the electric and magnetic fields (EMF) associated with the proposed works, immediately outside the perimeter fences and assess them against relevant health guidelines, as part of the overall environmental impact assessment of the project.

1.3 Purpose and scope of this report

The scope of Aurecon's assessment relates to the project key components described in Section 1.2 and encompasses the following:

- Provision of a brief description of EMF in relation to human health
- Identification of relevant national and international EMF guidelines
- An assessment of the EMF from proposed switching stations and modifications to existing substations, immediately outside their perimeter fences.

This report discusses the expected EMF levels with reference to the scope and localities of the proposed works, and their proximity to locations accessible to the public.

1.4 Structure of the report

The structure and content of this report are as follows:

- Chapter 1 (Introduction) - outlines the overview, key components and the purpose and scope of this report.
- Chapter 2 (Overview of electric and magnetic fields) - provides a description of EMF and outlines the key guidelines relating to EMF.
- Chapter 3 (Switching station magnetic fields) - addresses the EMF aspects of the proposed switching stations.
- Chapter 4 (Substation magnetic fields) -addresses the EMF aspects of the proposed changes to existing substations.

2 Overview of electric and magnetic fields

2.1 General description

Whenever electrical equipment is in service, it produces an electric field and a magnetic field. The electric field is associated with the voltage of the equipment and the magnetic field is associated with the current (amperage). In combination, these fields cause energy to be transferred along electric wires. Being related to voltage, the electric fields associated with high voltage equipment remain relatively constant over time, except where the operating voltage changes. Conversely, being related to current, the magnetic field strength resulting from an electrical installation varies continually with time as the load on the equipment varies.

The electric and magnetic fields associated with electrical equipment, whilst interrelated, are not dependent on each other and as such can exist independently.

Further detail on EMFs can be found in Appendix A.

2.2 Electric and magnetic fields and health

It is known that EMFs at magnitudes much higher than those encountered in everyday life can interact with the central nervous system. In addition, the possibility of adverse health effects due to the much lower EMFs associated with electrical equipment has been the subject of extensive research throughout the world for more than 40 years.

To date, adverse health effects due to fields of the levels normally associated with electrical infrastructure, have not been established. However, due to a body of epidemiological evidence, the possibility that such effects may exist has not been ruled out.

2.2.1 Summary of health effects

While EMFs involve both electric and magnetic components, electric fields are relatively constant over time, are readily shielded and, in the health context, are generally no longer associated with the same level of interest as magnetic fields. Nevertheless, high electric field strengths, such as those associated with the highest voltage transmission lines or high voltage equipment in major substations, can approach a level at which “nuisance shocks” can occur and this phenomenon needs to be managed. This can be done via easement and fencing practices.

In the context of the current study, the only significant source of electric fields outside the perimeter fences of the switching stations/substations will be the incoming and outgoing lines, which have been addressed in the report {REFERENCE}. Accordingly, the remainder of this report is directed towards magnetic fields.

Magnetic fields are not readily shielded, are more ubiquitous and remain the subject of some debate. Accordingly, much of the later health research has been directed towards magnetic fields.

A large number of studies have been conducted over many years to investigate the possibility of adverse health consequences from extremely low frequency electric and magnetic fields. These studies have addressed a wide range of end points including childhood leukaemia, other childhood cancers, cancers in adults, depression, suicide, cardiovascular disorders, reproductive dysfunction, developmental disorders, immunological modifications, neurobehavioral effects and neurodegenerative disease. The most recent scientific reviews by authoritative bodies are reassuring for most potential health end points. However, statistical associations between prolonged exposure to elevated magnetic fields and childhood leukaemia have persisted. This led the International Agency for Research on Cancer (IARC) (Ref. B-1) in 2002 to classify magnetic fields as a “possible carcinogen”, a categorisation used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals.

The fact that, despite over 30 years of laboratory research, no mechanism for an effect has been established, lends weight to the possibility that the observed statistical associations reflect some factor other than a causal relationship. This point is made in the 2001 report of the UK National Radiological Protection Board's (NRPB) Advisory Group, chaired by eminent epidemiologist, the late Sir Richard Doll (Ref. B-2)

> *"in the absence of clear evidence of a carcinogenic effect in adults, or of a plausible explanation from experiments on animals or isolated cells, the evidence is currently not strong enough to justify a firm conclusion that such fields cause leukaemia in children." (page 164)*

2.3 Health guidelines

Since late 2015, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)[1] has adopted the *Guidelines for Limiting Exposure to Time-varying Electric and Magnetic Fields (1Hz to 100kHz),* published by the International Commission on Non-Ionising Radiation Protection (ICNIRP) in 2010. In adopting the ICNIRP Guidelines ARPANSA noted:

> *"The ICNIRP ELF guidelines are consistent with ARPANSA's understanding of the scientific basis for the protection of the general public (including the foetus) and workers from exposure to ELF EMF." (Ref. C-2)*

The ICNIRP Guidelines set 'Basic Restrictions', which are derived from the levels at which interactions with the central nervous system (CNS) are established, with a safety factor applied. The Basic Restrictions are expressed in terms of electric field levels within the human body but, as these levels can only be assessed by sophisticated computer modelling of the body, ICNIRP also sets 'Reference Levels', expressed in terms of kV/m and microtesla[2] for external electric and magnetic fields respectively. These levels are conservatively set such that, provided they are met, the Basic Restrictions would also be met without the need for more comprehensive analysis.

The ICNIRP 'Basic Restrictions' and 'Reference Levels' for the general public[3] are reproduced in Table 2-1. As noted above, these criteria apply to both adults and children and are independent of duration of exposure.

Table 2-1 | ICNIRP Guideline levels

Parameter	Basic Restriction (Volts per m)	Reference Level
Electric Field – General Public	CNS tissue of the head: 0.02 All tissue of head and body: 0.4	5,000 Volts per m (V/m)
Magnetic Field - General Public	CNS tissue of the head: 0.02 All tissue of head and body: 0.4	2,000 mG (mG)

In applying the ICNIRP Guideline, it is important to recognise that the numerical limits, e.g. 2,000 mG, are based on established health effects. In ICNIRP's fact sheet on the guidelines (Ref. C-3), it notes that:

> *"It is the view of ICNIRP that the currently existing scientific evidence that prolonged exposure to low frequency Magnetic Fields is causally related with an increased risk of childhood leukaemia is too weak to form the basis for exposure guidelines. Thus, the perception of surface electric charge, the direct stimulation of nerve and muscle tissue and the induction of retinal phosphenes are the only well-established adverse effects and serve as the basis for guidance."*

Being based on established biological effects (which occur at field levels much higher than those normally encountered in the vicinity of electrical equipment), the (numerical) exposure limits in the guidelines and standards cannot be said to define safe limits for possible health effects, should these exist, from magnetic fields at levels normally encountered in the vicinity of electrical equipment.

The principal compliance criteria used for this assignment are as per Table 2-1.

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[1] *ARPANSA is the Australian government agency that is charged with the responsibility, inter alia, for protecting the health and safety of people and the environment from EMF.*

[2] *Magnetic fields are often expressed in units of mG, where 1 mG is equal to 0.1 microtesla. The units used for this report are mG.*

[3] *The general public are individuals of all ages and of differing health statuses, which includes more vulnerable groups or individuals, and who may have no knowledge of or control over their exposure to EMFs. These differences suggest the need to include more stringent restrictions for the general public, members of the general public would not be suitably trained to mitigate harm or may not have the capacity to do so which have been detailed in Section 2.3.*

2.4 Medical implants

In addition to direct interactions with the human body, EMFs also have the potential to interfere with active implanted medical devices (AIMDs) such as cardiac pacemakers, insulin pumps etc. A wide variety of devices are used in modern medicine and, due to the multiplicity of EMF sources in the modern environment, they are generally subject to standards regarding immunity from interference.

In Europe, the relevant European Directive (90/385/EEC) requires designers and manufacturers of AIMDs to make them immune to interference in "reasonably foreseeable" circumstances. The relevant European Standard (CENELEC 50527-1) interprets this as meaning that devices should be immune from interference up to the ICNIRP general public reference levels. Similar requirements apply in the UK. However, as the magnetic field reference level at the time of the European directive was 1,000 mG, rather than the present 2,000 mG, it is customary (and conservative) to assume that AIMDs should be immune to interference from magnetic fields only up to 1,000 mG.

The relevant Australian Standard (AS 45502-1: 2002), which was reproduced from a European Standard (EN 45502-1: 1997), stipulates that AIMDs be immune from risks connected with reasonably foreseeable environmental conditions such as magnetic fields, external electrical influences etc. In that context, as a first guide, the Australian Standard cites a magnetic intensity of 150 Amps/metre[4] (1,885 mG).

Accordingly, as the highest magnetic fields associated with 66 kV and 132 kV transmission lines are of the order of a 'hundred mG', from a practical perspective, AIMDs which comply with the relevant Standards should be immune from transmission line interference. Nevertheless, concerned wearers of AIMDs should consult their treating physician for further information or advice, based on the specific characteristics of their actual device.

2.5 Animals and plants

As well as potential effects on humans, the possibility of EMF effects on plants and various animals, including cows, sheep, pigs and horses has been studied over the years, particularly in the 1970s and 1980s. A smaller number of studies have also been reported since that time.

2.5.1 Gibbs Inquiry

In 1991, the late Sir Harry Gibbs, a former Chief Justice of the High Court of Australia published the findings of an extensive inquiry into community needs and high voltage transmission line development.

As part of the Inquiry, he reviewed the body of research on the possibility of effects on native flora and fauna, farm animals and plants and reported his conclusions in Chapter 6.6 of his report (Ref E-1) as follows:

> *'Bees in hives under or near transmission lines are adversely affected by shocks created by currents induced by the lines but the effect can be mitigated by shielding'*
>
> *'The Magnetic Fields created by power lines do not affect the health or reproductive capacity of farm animals or present a danger to native fauna.'*
>
> *'The growth of trees which are close to a transmission line may be reduced by the effect of corona[5]. In any case, the height of trees on a transmission line easement will be restricted when this is necessary in the interest of safety."*
>
> *'From a practical point of view, the Electric Fields created by transmission lines have no adverse effects on crops, pasture grasses or native flora, other than trees growing under or near to the line.'*

His summary conclusion was:

> *'No reason exists for concern as to the effect of the fields on animals or plants.'*

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[4] *In air or human tissue, a magnetic field intensity of 150 A/m is equivalent to a magnetic flux density of 1885 milligauss.*
[5] *For this to happen, the leaves have to be sharp and pointy e.g. as on conifers, rather than rounded. Due to the nature of Australian vegetation and easement clearing practices, leaf-tip corona has not been an issue in Australia.*

2.5.2 United Kingdom EMF National Policy Statement

More recently than Sir Harry Gibbs, in July 2011, the UK Government adopted a National Policy Statement (NPS EN-5) for Electricity Networks Infrastructure. This NPS, taken together with the Overarching National Policy Statement for Energy (EN-1), provides the primary basis for decisions taken by the UK Infrastructure Planning Commission (IPC) on applications it receives for electricity networks infrastructure.

In Clause 2.10.8, the NPS states:

> *'There is little evidence that exposure of crops, farm animals or natural ecosystems to transmission line EMFs has any agriculturally-significant consequences.'*

3 Switching Stations

A switching station is a facility used to connect two or more transmission lines of the same designated voltage. For the Hunter-Central Coast REZ, the following switching stations are proposed:

- New Antiene Sub Transmission Substation (STSS) 132 kV switching station at Hebdon to provide connections for renewable energy projects
- New Sandy Creek 132 kV switching station to connect the energy hubs to the NSW transmission network

3.1 Switching Station Elements

The proposed switching stations will include the following elements:

- 132 kV feeder bays to connect incoming/outgoing transmission lines
- 132 kV busbar to provide interconnection between those feeder bays
- 2 x 42.5 MVA, 15 kV synchronous condensers depending on the transmission network requirements
- 132/15 kV transformers to connect synchronous condensers to 132 kV busbar
- 3 m high weldmesh high-security fence around the perimeter of the switching station, equipped with danger & do not enter signage and allowing access only to authorised personnel
- 1.2 m high post and wire fence around the site boundary with public access prevented by locked gates.

3.2 Approach

The following approach has been adopted in the assessment of the switching stations:

- Examine and describe relevant aspects of the existing environment.
- Review and describe the security fencing associated with each site, with particular reference to the degree of accessibility to members of the public.
- Examine the major switching station elements and describe the likely magnetic field levels at relevant locations across the site, including those areas potentially accessible to the general public, having regard to the distance from the relevant switching station elements[6].
- Describe the incoming lines and predicted field levels based on the Transmission Lines EMF Assessment (526726- W00001-RPT-PL-0001) and
- Summarise findings in relation to the relevant EMF guidelines.

3.3 Magnetic Fields

This section provides assessment of each of the switching stations proposed as part of the project.

3.3.1 Proposed Antiene Sub Transmission Substation (STSS) 132 kV Switching Station

The Antiene Sub Transmission Substation (STSS) 132 kV switching station is proposed to be built on vacant crown land on the north-eastern banks of Lake Liddell.

The site is located on a peninsula, surrounded by water and swamp land to the west, south and east. To the north lies Hebden Rd and the Great Northern Railway with a dedicated biodiversity conservation area located on the northern side of the railway, approximately 150 m away from the switchyard perimeter fence.

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[6] *Ausgrid's design standards and operating procedures are such that the fields experienced by workers within the proposed facilities will comply with the relevant ICNIRP Occupational Reference Levels.*

To the east is a bare land approximately 175 m away from the switchyard perimeter fence and to the west is the Liddell Recreation Park as shown in Figure 3-1. Hence, the nearest area which could be frequented by members of the public is the Liddell Recreation Park, which is approximately 400 m away from the switchyard perimeter fence.

Figure 3-1 | Proposed location of the Antiene Sub Transmission Substation (STSS) 132 kV switching station

Access to the entire site will be restricted to authorised persons by the following:

- A 3 m high weldmesh high-security fence around the perimeter of the switching station, more than 30 m away from the busbars which are expected to be the dominant EMF source. This fence will be fitted with "Danger - High Voltage - Keep Out" signage and secured by locked gates.
- A 1.2 m high post and wire fence around the site boundary, which will range from about 40 to 275 m outside the high security fences.

Both the switchyard perimeter and site boundary fences will be secured by locked gates.

Ausgrid has advised that the switching station will be designed in accordance with its established practices which have been shown to result in EMF levels at the switchyard perimeter fences, which are well below the ICNIRP Guideline reference levels for the general public.

The infrastructure and equipment proposed to be installed within the new switching station will include:

- Twelve 132 kV feeder bays
- Two 42.5 MVA, 15 kV synchronous condensers
- Two 132/15 kV transformers and associated auxiliary transformers, modular switch room and control room

The major field sources within the switching station are the incoming feeders, the busbars, and the transformers and synchronous condenser connections. The transformers and synchronous condensers will be located approximately 12 m inside the switchyard perimeter fence and 80 m from the site boundary along Hebden Rd. The 132 kV busbars will be connected to the 15 kV synchronous condensers via underground cables minimising the external field levels. Furthermore, the orientation of the busbars is perpendicular to the Liddel Recreation Park boundary, resulting in minimal magnetic field contribution. Overall, since the park is situated approximately 400 m away from the high security fence, it is predicted that the magnetic field levels would be negligible.

Around the switching station boundary, where the general public could potentially be present, the fields are expected to be dominated by the incoming overhead lines. The configuration of the proposed switching station will include four line bays at its southern end to accommodate the proposed line connections to the

Singleton STS, Kurri STS and Sandy Creek BSP. The 132 kV lines from Singleton STS and Kurri STS will enter the site from the southern end and the 132 kV line from Sandy Creek BSP will enter from the northern end of the station as shown in Figure 3-2. The magnetic field levels associated with these lines are expected to be in the same order as those reported in Section 4.2.1 and 4.2.4 of 526726- W00001-RPT-PL-0001, which have been shown to be in the order of 1 mG or less at 100 m.

Figure 3-2 | Transmission line connections to the proposed switching station

Given the above, and that the nearest frequented area i.e. the Liddell Recreation Park is about 400 m away from the switchyard perimeter fence and 240 m from the site boundary fence, the contribution of the proposed switching station to the field levels at the recreation park is expected to be negligible.

3.3.2 Proposed Sandy Creek 132 kV Switching Station

The Sandy Creek 132 kV switching station is proposed to be built to the south of Ausgrid's existing Sandy Creek substation.

To the north lies existing Sandy Creek sub-transmission substation. To the east and south are bare lands for more than 1 km away from the switchyard perimeter fence and to the southwest are residential properties approximately 600 m away from the switchyard perimeter fence. To the west is vacant farming land, which is progressively being subdivided into residential developments as shown in Figure 3-3. Hence, the nearest area which could be frequented by members of the public is residential properties that are being developed approximately 300 m away from the switchyard perimeter fence.

Figure 3-3 | Proposed location of the Sandy Creek 132 kV switching station

Access to the entire site will be restricted to authorised persons by the following:

- A 3 m high weldmesh high-security fence around the perimeter of the switching station, more than 15 m away from the busbars which are expected to be the dominant EMF source. This fence will be fitted with "Danger - High Voltage - Keep Out" signage.
- A 1.2 m high post and wire fence around the site boundary, which will be more than 200 m outside the high security fences.

Both the switchyard perimeter and site boundary fences will be secured by locked gates.

Ausgrid has advised that the switching station will be designed in accordance with its established practices which have been shown to result in EMF levels at the switchyard perimeter fences, which are well below the ICNIRP Guideline reference levels for the general public.

The infrastructure and equipment proposed to be installed within the new switching station will include:

- Ten 132 kV feeder bays
- 132 kV busbar

The major field sources within the switching station are the incoming feeders and the busbars. Two 132 kV feeder bays will connect to transformer bays in the existing Sandy Creek substation via underground cables minimising the external magnetic field levels. Furthermore, the orientation of the busbars is approximately perpendicular to the vacant farmland progressively being subdivided into residential developments, resulting in minimal field contribution from the busbars. Further, since the subdivision area is situated approximately 300 m away from the high security fence, it is predicted that the magnetic field levels would be negligible.

Around the switching station boundary, where the general public could potentially be present, the fields are expected to be dominated by the incoming overhead lines. The configuration of the proposed switching station would include five line bays at its southern end to accommodate connections to the lines to the northeast and south. The magnetic field levels associated with these lines are expected to be in the same order as those reported in Section 4.2.1 and 4.2.4 of 526726- W00001-RPT-PL-0001, which have been shown to be in the order of 1 mG or less at 100 m.

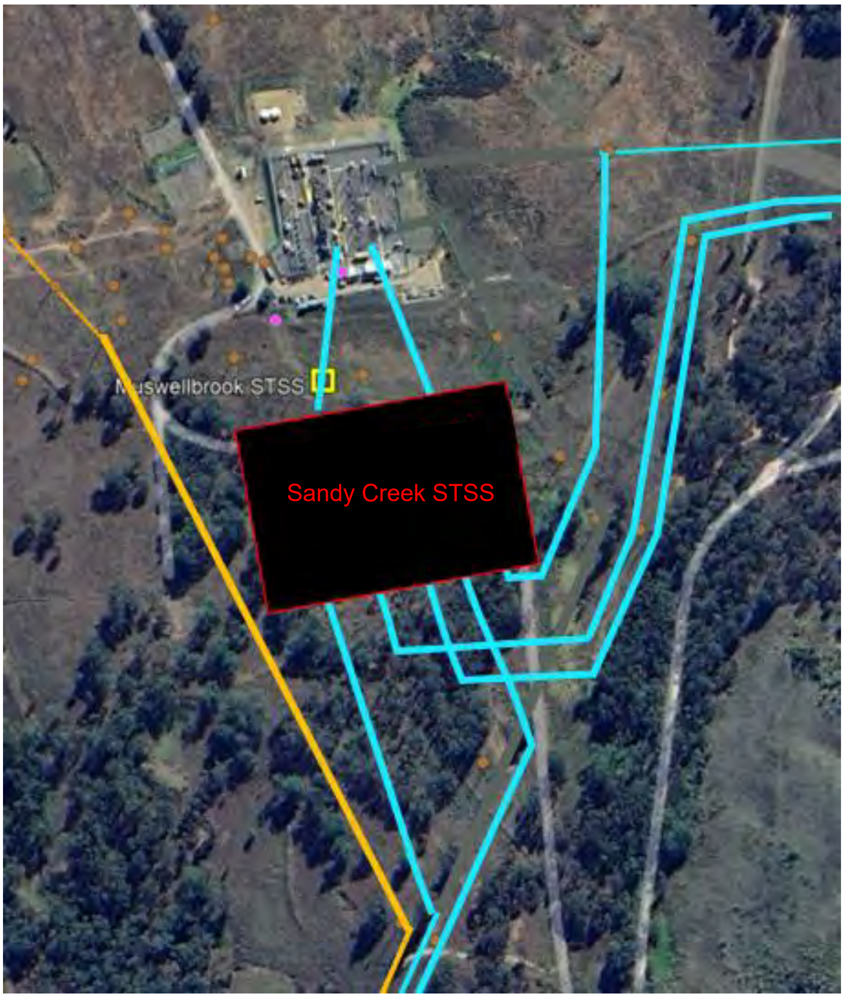

Figure 3-4 | Transmission line connections to the proposed switching station

Given the above, and that the nearest potentially frequented area i.e. the vacant farmland progressively being subdivided into residential developments is about 300 m away from the switchyard perimeter fence, the contribution of the proposed switching station to the field levels at the residential developments is expected to be negligible.

4 Substations

A substation is a facility where more than one voltage is present and step up/down transformers connect them. Hunter-Central Coast REZ will include upgrades to:

- Existing Kurri STS (132/66/33 kV)
- Existing Rothbury ZS (132/11 kV)

4.1 Approach

The following approach has been adopted in the assessment of the upgrades to substations:

- Examine and describe relevant aspects of the existing environment.
- Review and describe the security fencing associated with each site, with particular reference to the degree of accessibility to members of the public.
- Examine the substation elements at the proposed upgrade and describe the likely magnetic field levels at relevant locations across the site, including those areas potentially accessible to the general public having regard to the distance from the relevant substation elements.
- Describe the incoming lines and predicted field levels based on the Transmission Lines EMF Assessment (526726- W00001-RPT-PL-0001) and
- Summarise findings in relation to the relevant EMF guidelines.

4.2 Magnetic Fields

4.2.1 Upgrades to Kurri STS

The existing Kurri STS is located close to the Hunter Expressway at Kurri Kurri and the upgrades will be done at the southwest end of the existing substation.

To the southwest of the substation lies the Hunter Expressway and a factory approximately 250 m away. There are residential properties more than 450 m away to west and southwest of the location of the proposed upgrade. To the northwest and north are forest lands which could be assumed not to be frequented by members of public for at least 600 m from the switchyard perimeter fence. To the south lies bare land and Hunter Expressway and to the east are some fast-food outlets. Hence, the nearest area which could be frequented by members of the public are the fast-food outlets, approximately 190 m away from the existing substation perimeter fence and approximately 275 m away from the proposed upgrade.

Figure 4-1 | Location of the existing Kurri STS

Access to the existing site is currently restricted to authorised persons by the following, which will apply to proposed upgrade as well,

- A 3 m high weldmesh high-security fence around the perimeter of the substation, which will be modified to cover the proposed upgrade, and the fence will be 30 m away from the busbars which are expected to be the dominant EMF source of the upgrade. This fence will be fitted with “Danger - High Voltage - Keep Out” signage.
- A 1.2 m high post and wire fence around the site boundary, which will be 16 m outside the high security fence in the southwest direction.

Both the switchyard perimeter and site boundary fences will be secured by locked gates.

Ausgrid has advised that the upgrade to the existing substation will be designed in accordance with its established practices which have been shown to result in EMF levels at the switchyard perimeter fences, which are well below the ICNIRP Guideline reference levels for the general public.

The infrastructure and equipment proposed to be installed as the upgrade to existing Kurri STS will include:

- Extension of the existing 132 kV outdoor yard to the west including 132 kV busbars to accommodate two 132 kV feeder bays.
- Two new 132 kV overhead lines will be connected to the southern side of the switchyard.

Figure 4-2 | Proposed changes to Kurri STS

The major field sources which will be associated with the upgrade are the incoming feeders and the busbars. The nearest residential building on the southwest side of the substation and the nearest area which could be frequented by members of public i.e. fast-food outlets are approximately 280 m and 190 m respectively away from the high security fence and site boundary fence, accordingly, it is predicted that the magnetic field levels would be negligible.

Around the substation boundary, where the general public could potentially be present, the fields are expected to be dominated by the incoming overhead lines. The configuration of the proposed upgrade will include two line bays at its southern end to accommodate the proposed line connections as shown in Figure 4-2. The magnetic field levels associated with these lines are expected to be in the same order as those reported in Section 4.2.1 and 4.2.4 of 526726- W00001-RPT-PL-0001, which have been shown to be in the order of 1 mG or less at 25 m.

Given the above and that the nearest potentially frequented area, i.e. the fast-food outlets, are approximately 280 m away from the location of proposed upgrade, about 190 m away from the switchyard perimeter fence and 110 m from the site boundary fence, the contribution from the proposed upgrade to the substation to the field levels at the fast-food outlets is expected to be negligible.

4.2.2 Upgrades to Rothbury Zone Substation

The existing Rothbury ZS is located in Rothbury, surrounded mostly by rural lands and the upgrades will be done at the southwest corner of the existing substation.

From south to northeast of the substation lies in bare lands with a few residential buildings approximately 200 m away from the switchyard perimeter fence. From east to south of the substation lie Wine Country Drive and some forest lands with a few residential buildings, the nearest being more than 200 m away from the substation perimeter fence. The nearest location to the proposed upgrade potentially frequented by general public is a residential property towards southwest of the substation, approximately 250 m away.

Figure 4-3 | Location of the existing Rothbury ZS and proposed inductor installation

Access to the existing site is currently restricted to authorised persons by the following measures, which will apply to proposed upgrade as well,

- A 3 m high weldmesh high-security fence around the perimeter of the substation, which will be modified to accommodate the proposed upgrade. The fence will be 20 m away from the inductor, which is expected to be a major EMF source associated with the upgrade. This fence will be fitted with “Danger - High Voltage - Keep Out” signage.
- A 1.2 m high post and wire fence around the site boundary, which will be 30 m outside the high security fence in the southwest direction.

Both the switchyard perimeter and site boundary fences will be secured by locked gates.

Ausgrid has advised that the substation works will be designed in accordance with its established practices which have been shown to result in EMF levels at the switchyard perimeter fences, which are well below the ICNIRP Guideline reference levels for the general public.

The infrastructure and equipment proposed to be installed in the upgrade to existing Rothbury ZS will include:

- One 132 kV inductor bay and associated inductor, and connections to the existing feeder bay

The major field sources of the upgrade are the incoming feeders and the inductor. The nearest place potentially frequented by members of the general public on the southwest side of the substation is approximately 250 m away from the high security fence and, it is predicted that the magnetic field levels would be negligible.

The fields in the areas potentially accessible to the general public, around the substation boundary, are expected to be dominated by the incoming overhead lines. The configuration of the proposed upgrade will not affect the existing 132 kV overhead lines located on the southern side of the site and, accordingly changes to the existing magnetic field levels are not anticipated as a result of the upgrade.

Given the above and that the nearest place potentially frequented by general public is approximately 250 m away from the location of proposed upgrade, about 230 m away from the switchyard perimeter fence and 200 m from the site boundary fence, the contribution from the proposed substation upgrade to the field levels at the nearest residential building is expected to be negligible.

5 References

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Appendix A
General description of electric and magnetic fields

The electric and magnetic fields associated with electrical equipment, whilst interrelated, are not dependent on each other and can exist independently. The electric field is associated with the voltage of the equipment and the magnetic field is associated with the current (amperage). In combination, these fields cause energy to be transferred along electric wires.

An **electric field** is a region where electric charges experience an invisible force. The strength of this force is related to the voltage, or pressure, which forces electricity along wires. Electric fields are strongest closest to their source, and their strength diminishes rapidly with distance from the source, in much the same way as the warmth of a fire decreases with distance. Many common materials – such as brickwork or metal – block electric fields, so they are readily shielded and, for all practical purposes, do not penetrate buildings. They are also shielded by human skin, such that the electric field inside a human body will be at least 100,000 times less than the external field (Ref A-1). Being related to voltage, the electric fields associated with high voltage aerial lines and electrical substations remain relatively constant over time, except where the operating voltage changes.

A **magnetic field** is a region where magnetic materials experience an invisible force produced by the flow of electricity (known as electric current and measured in Amperes). The strength of a magnetic field depends on the size of the current and decreases as distance from the source increases. The magnetic field strength resulting from an electrical installation varies continually with time and is affected by a number of factors including:

- total electric load
- size and nature of the equipment
- design of the equipment
- layout and electrical configuration of the equipment and its interaction with other equipment.

While electric fields are blocked by common materials, this is not the case with magnetic fields. This is why locating equipment in enclosures or underground will eliminate any external electric field but not the magnetic field.

Alternating electric and magnetic fields are produced by any electric wiring or equipment carrying alternating current (AC). This current does not flow steadily in one direction but oscillates backwards and forwards at a frequency[7] of 50Hz and hence the fields produced by AC systems oscillate at the same frequency. This frequency falls into a range referred to as **extremely low frequency** (ELF), so the electric and magnetic fields are referred to as ELF fields.

Electromagnetic radiation

It is not uncommon for the ELF EMF associated with electrical equipment to be confused with electromagnetic radiation (EMR). The fact that, in many jurisdictions, agencies which regulate the various forms of EMR are also involved in the setting of guidelines/standards for EMF tends to add to this confusion.

Electromagnetic radiation is a term we use to describe the movement of electromagnetic energy through the propagation of a wave. This wave, which moves at the speed of light in a vacuum, is composed of electric and magnetic waves which oscillate (vibrate) in phase with, and perpendicular to, each other. This is in contrast to EMF, where the electric and magnetic components are essentially independent of one another.

Electromagnetic radiation is classified into several types according to the frequency of its wave; these types include (in order of increasing frequency): radio waves, microwaves, terahertz radiation, infra-red radiation,

[7] *Frequency is a measure of the number of times per second a wave oscillates or vibrates. The most common unit of measurement of frequency is the Hertz (Hz) where 1 Hz is equal to 1 cycle per second.*

visible light[8], ultraviolet radiation, x-rays and gamma rays. Whereas EMR causes energy to be radiated outwards from its source e.g. light from the sun or radio-frequency signals from a television transmitter, EMFs cause energy to be transferred along electric wires.

In the context of EMF and health, the distinction between EMF and EMR is addressed by the New Zealand Ministry of Health in its public information booklet “Electric and Magnetic Fields and Your Health” (Ref A-2) as follows:

“The electric and magnetic fields around power lines and electrical appliances are not a form of radiation. The word “radiation” is a very broad term, but generally refers to the propagation of energy away from some source. For example, light is a form of radiation, emitted by the sun and light bulbs. ELF fields do not travel away from their source but are fixed in place around it. They do not propagate energy away from their source. They bear no relationship, in their physical nature or effects on the body, to true forms of radiation such as x-rays or microwaves.”

References

A-1. World Health Organisation: *Environmental Health Criteria Vol. 238*: Extremely low frequency fields. (2007).

A-2. New Zealand Ministry of Health: *Electric and Magnetic Fields and Your Health*. (2008).

[8] *Visible light is a group (spectrum) of frequencies which can be sensed by the eyes of humans and various other creatures.*

Appendix B
Health guidelines

Health guidelines for extremely low frequency electric and magnetic fields

The World Health Organisation recognises two international EMF/health guidelines:

- the *Guidelines for Limiting Exposure to Time-varying Electric and Magnetic Fields (1Hz to 100kHz) produced by the International Commission on Non-Ionising Radiation Protection (ICNIRP)* Ref C-1)
- the *IEEE Standard C95.1*, produced by the International Committee on Electromagnetic Safety, Institute of Electrical and Electronics Engineers (IEEE) in the USA.

In July 2015, the relevant Australian regulator (ARPANSA) officially adopted the more conservative of the above two, the ICNIRP 2010 Guidelines, in full, stating:

"The ICNIRP ELF guidelines are consistent with ARPANSA's understanding of the scientific basis for the protection of the general public (including the foetus) and workers from exposure to ELF EMF." (Ref. C-2)

In line with the regulator's advice, Aurecon has applied the provisions of the current international ICNIRP Guidelines to this assessment.

The 'Basic Restrictions' and 'Reference Levels'[9] for both electric and magnetic fields, contained in the current ICNIRP Guidelines' are summarised in the table below.

Table C-1: ICNIRP Guideline levels

Parameter	Basic Restriction (Volts per m)	Reference Level
Electric field – general public	CNS Tissue of the head: 0.02 All tissue of head & body: 0.4	5,000 Volts per m (V/m)
Magnetic field – general public	CNS Tissue of the head: 0.02 All tissue of head & body: 0.4	2,000 mG (mG)
Electric field – occupational	CNS Tissue of the head: 0.1 All tissue of head & body: 0.8	10,000 Volts per m (V/m)
Magnetic field – occupational	CNS Tissue of the head: 0.1 All tissue of head & body: 0.8	10,000 mG (mG)

In applying the guidelines, it is to be noted that, unlike earlier versions, the various limits are now independent of duration of exposure.

In applying the ICNIRP Guidelines, it is also important to recognise that the numerical limits, e.g. 2,000 mG, are based on established health effects. In ICNIRP's fact sheet on the guidelines (Ref. C-3), it notes that:

"It is the view of ICNIRP that the currently existing scientific evidence that prolonged exposure to low frequency Magnetic Fields is causally related with an increased risk of childhood leukaemia is too weak to form the basis for exposure guidelines. Thus, the perception of surface electric charge, the direct stimulation of nerve and muscle tissue and the induction of retinal phosphenes are the only well-established adverse effects and serve as the basis for guidance."

Being based on established biological effects (which occur at field levels much higher than those normally encountered in the vicinity of electrical equipment), the (numerical) exposure limits in the guidelines and

[9] *The "Reference Levels" set out in the guideline are derived from the levels at which interactions with the central nervous system are established, with a safety factor applied and a further adjustment to simplify compliance measurement.*

standards cannot be said to define safe limits for possible health effects, should these exist, from magnetic fields at levels normally encountered in the vicinity of electrical equipment.

References

C-1 International Commission on Non-Ionising Radiation Protection (2010: Guidelines for Limiting Exposure to Time-varying Electric and Magnetic Fields (1Hz to 100kHz): *Health Physics* 99(6):818-836; (2010).

C-2 ARPANSA: *Extremely Low Frequency Electric and Magnetic Fields* – 2015, accessed 10 May 2016.

C-3. ICNIRP Fact Sheet on the guidelines for limiting exposure to time-varying electric, and Magnetic Fields (1Hz-100kHz) published in *Health Physics* 99(6): 818-836; 2010, accessed 10 May 2016, <http://www.icnirp.org/cms/upload/publications/ICNIRPFactSheetLF.pdf>.

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