Appendix I Electric and Magnetic Fields Assessment

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25-Nov-19
Doc No. 60600277-RPT-Wolli Creek T8 EMF Assessment

Wolli Creek Substation & T8 Airport Line Power Upgrade

Electric and Magnetic Fields Assessment

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Electric and Magnetic Fields Assessment

Client: Transport for New South Wales

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Acronyms

A	Ampere
AC	Alternating Current
AIMD	Active Implantable Medical Device
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
CDEGS	Current Distribution, Electromagnetic Fields, Grounding and Soil Structure Analysis Software
CNS	Central Nervous System
DC	Direct Current
EEG	Electroencephalography
ELF	Extremely Low Frequency (taken as 0-3kHz)
EMF	Electric and Magnetic Field
EN	European Standard
ENA	Energy Networks Association
GIS	Gas Insulated Switchgear
HIFREQ	A CDEGS software module that aims to solve electromagnetic problems involving a network of arbitrarily oriented aboveground and buried conductors energized by current and voltage sources
HV	High Voltage (typically 132kV$_{AC}$ or 330kV$_{AC}$, in NSW)
Hz	Hertz
IARC	International Agency for Research on Cancer
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEEE	Institute of Electrical and Electronics Engineers
ISMSB	Installation Supply Main Switchboard
kV	Kilovolt
LV	Low Voltage (<1kV$_{AC}$)
MF	Magnetic Field
mG	Milli-Gauss
mT	Milli-Tesla
MVA	Mega Volt Amp
MW	Megawatt
NER	Neutral Earthing Resistor
OHW	Overhead Wiring
ONAN	Oil Natural Air Natural
ROC	Rail Operations Centre
REF	Review of Environmental Factors
RHS	Radiation Health Series
RMU	Ring Main Unit

RPS	Radiation Protection Series
Std	Standard
TfNSW	Transport for New South Wales
μT	Micro-Tesla
UGOH	Underground to Overhead
V	Volt
W	Watt
WHO	World Health Organisation

1.0 Introduction

1.1 Background

Transport for New South Wales (TfNSW) is proposing capacity improvements on the T8 Airport Line as part of the More Trains More Services program. AECOM has been engaged by TfNSW to provide an electric and magnetic field (EMF) assessment as part of a review of environmental factors (REF) under Division 5.1 of *Environmental Planning and Assessment Act 1979*.

1.2 Project description

The project involves the upgrade of the rail power system near Wolli Creek Station, within the Airport Line tunnel, at Green Square and through to the Chalmers Street Substation near Central Station.

The project would include the key elements outlined below.

1.2.1 Wolli Creek

- construction of a traction substation at Wolli Creek Junction (proposed traction substation), located between the T8 Airport and South Line and residential apartments that front onto Lusty Street, Wolli Creek (5-13 Lusty Street)
- upgrade of an access road at the end of Lusty Street, Wolli Creek to provide access to the proposed traction substation
- demolition of the existing Undercliffe Substation and Wolli Creek Sectioning Hut (to be replaced by the proposed traction substation)
- installation of 33 kV, 11 kV and 1500 V underground feeders to connect the proposed traction substation to the high-voltage and 1500V DC networks and the Wolli Creek portal of the Airport Line tunnel
- installation of a padmount substation(proposed padmount substation)
- removal of overhead wiring (OHW) structures and OHW supported by those structures.

1.2.2 Airport Line Tunnel

- installation of 33 kV and 11 kV feeders mounted on brackets on the side of the tunnel
- installation of five OHW auxiliary feeder upgrades in the tunnel and through Wolli Creek Station
- signalling upgrades in the tunnel – eight new signals, one relocated signal and associated modifications to trackside and relay room infrastructure.

1.2.3 Green Square

- installation of an 11 kV feeder within an existing underground conduit from the Rail Operations Centre (ROC) on Wyndham Street, Alexandria to Green Square Station, including minor trenching works at Green Square Station

1.2.4 Chalmers Street Substation

- installation of 11kV and 33kV feeders between Chalmers Street Substation and the Prince Alfred Park portal of the Airport Line tunnel.

Figure 1.1 shows the general layout of the key elements for the Proposal.

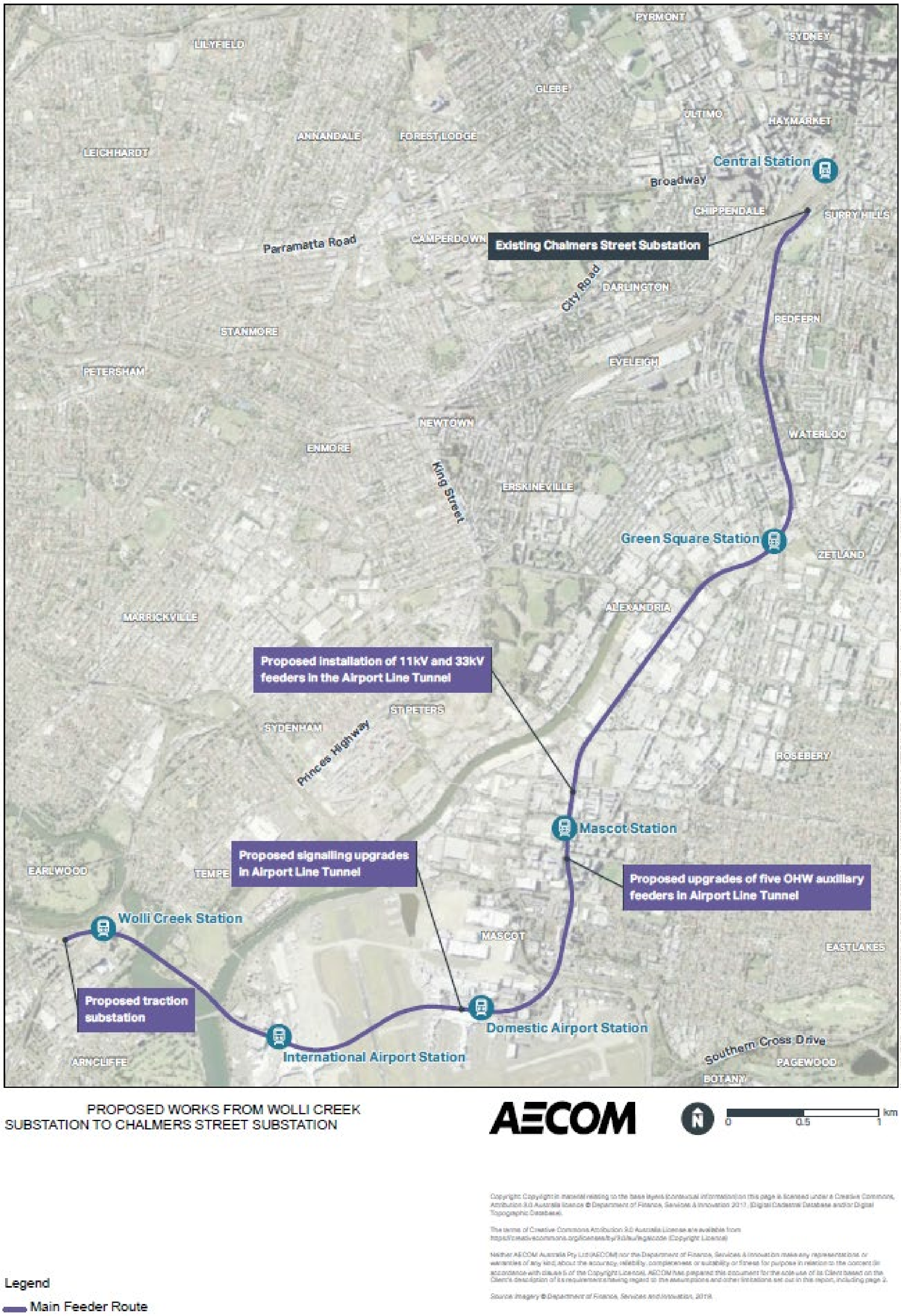

Figure 1.1 Proposed works along the T8 Airport Line from the proposed Wolli Creek traction substation to the Chalmers Street Substation (indicative only, subject to detailed design)

1.3 Site description

1.3.1 Wolli Creek Substation

The proposed substation is to be constructed in the existing rail corridor adjacent to 5-13 Lusty Street, Wolli Creek as shown in Figure 1.2.

Based on the Concept Design report (502128-0005-REP-JJ-0015), the proposed major electrical equipment required for the proposed Wolli Creek Substation is as follows:

- three 33 kV/600 V/600 V AC rectifier transformers
- three 1500 V DC 5 MW rectifiers
- three 600 V/415 V auxiliary transformers
- one 7.5/9 MVA 33/11 kV AC power transformer
- one Neutral Earthing Resistor (NER)
- three indoor 33k V AC gas insulated switchgear (GIS) switchboards
- two indoor 11 kV AC switchboards
- one 1500 V DC 6400 A ONAN reactor
- three 1500 V DC switchboards.

The layout of the proposed traction substation and its associated feeders is based on concept design drawing MTMS-APT-ANG-SB-HV-DWG-743121 (Rev 1).

1.3.2 New 33kV and 11kV AC feeders along the T8 Airport Line

New feeders are proposed to be installed through the existing T8 Airport Line.

The proposed feeders are as follows:

- install brackets in the Airport Line Tunnel for 33 kV and 11 kV feeders
- install 33 kV feeders from Chalmers Street Substation to Prince Alfred Park portal.
- install 33 kV feeders from Prince Alfred Park portal to Wolli Creek portal
- install 33 kV feeders from the proposed traction substation to Wolli Creek portal
- install 11 kV feeders from the proposed traction substation to Wolli Creek Station
- install 11 kV feeders from Chalmers Street Substation to Prince Alfred Park portal
- install 11 kV feeders from Prince Alfred Park portal to Green Square Station
- install 11 kV feeders from Green Square Station to the ROC
- install 33 kV, 11 kV and 1500 V feeders at Wolli Creek.
- In the rail tunnel, the feeders are proposed to be fixed to the walls of the tunnel using brackets
- The feeders are proposed to be installed underground, both within and outside of the rail corridor

Figure 1.2, Figure 1.3 and Figure 1.4 show the proposed feeder upgrade works at Wolli Creek, Chalmers Street Substation and Green Square.

Figure 1.2 Proposed works at Wolli Creek

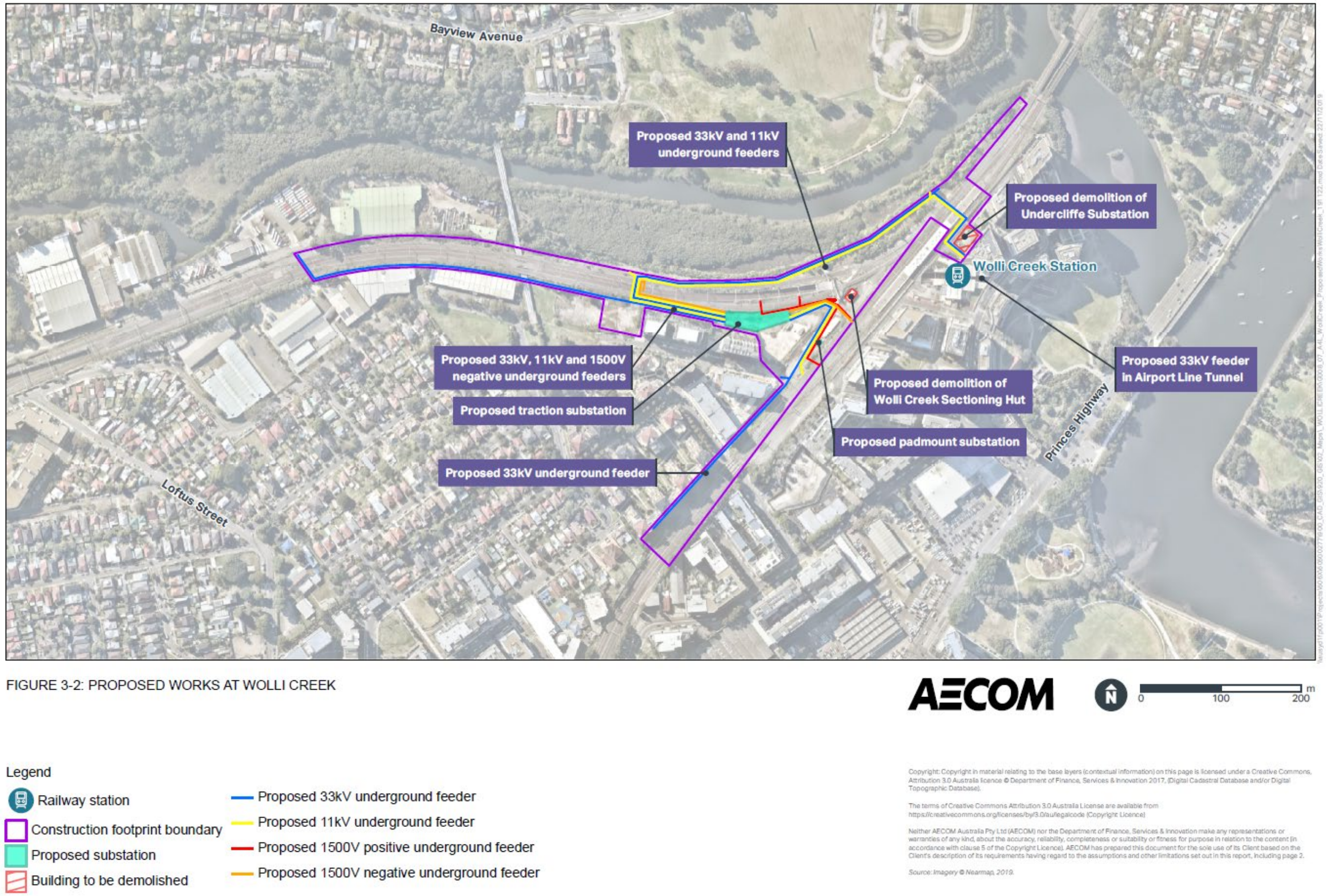

FIGURE 3-2: PROPOSED WORKS AT WOLLI CREEK

PROPOSED WORKS AT GREEN SQUARE

N
0 30 60 m

Legend

- Railway station
- Construction footprint boundary
- Proposed 11kv underground (in new route)
- Proposed 11kv underground (in existing conduit)

Figure 1.3 Proposed works at Green Square Station

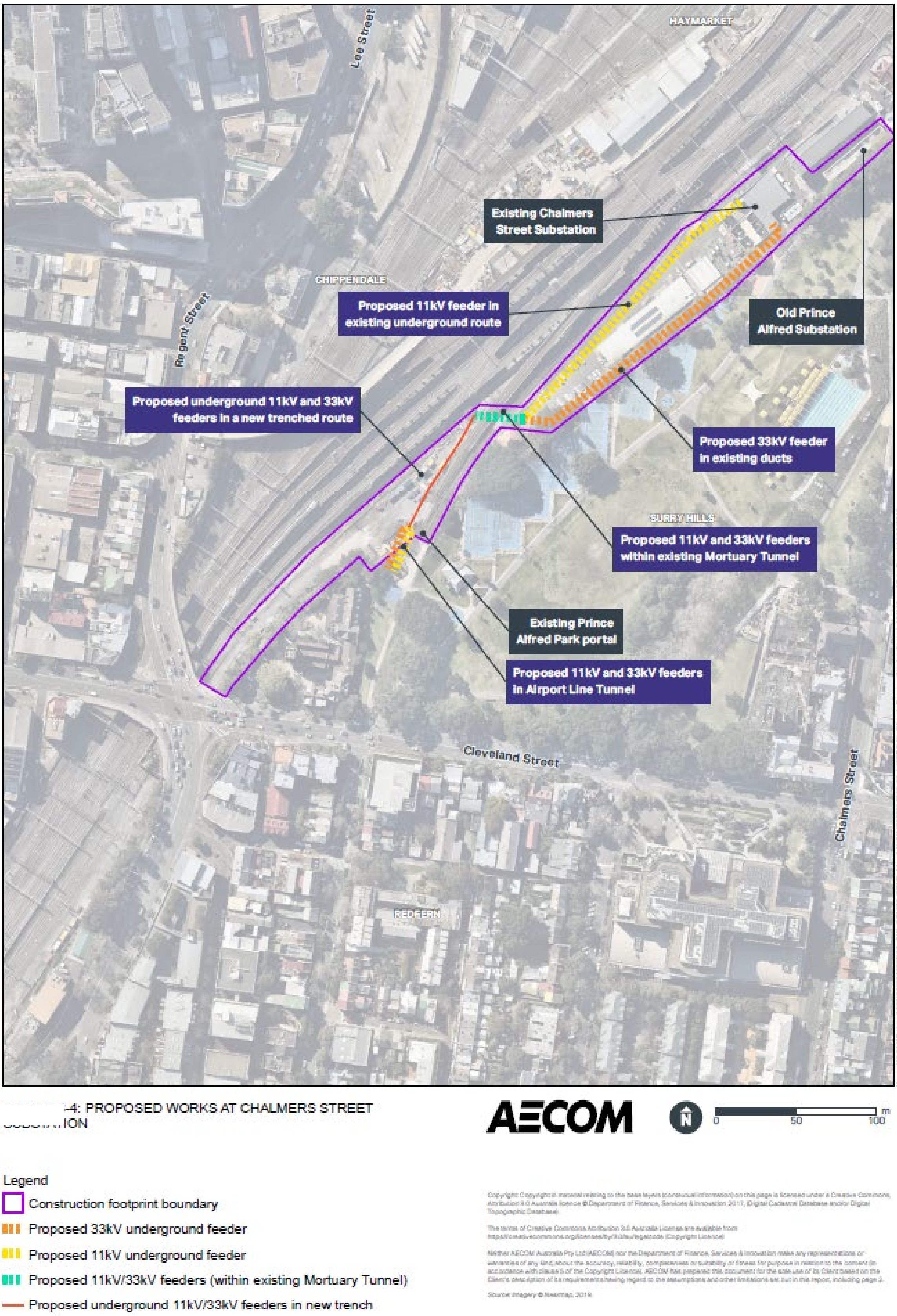

Figure 1.4 Proposed works at Chalmers Street Substation

1.4 Scope

In the context of the REF, the following scope has been developed for the study:

- Provide a brief overview of EMF and relevant guidelines
- Calculate EMF levels of the proposed traction substation under the typical loading conditions
- Calculate EMF of the new 33 kV and 11 kV feeders along the T8 Airport Line, according to typical arrangements
- Assess the proposed design against prudent avoidance (refer to section 2.4) as defined in the relevant guidelines
- Provide a statement of the changes in demolishing the Undercliffe Substation and Wolli Creek Sectioning Hut.

1.5 Limits and exclusions

The following limits and exclusions have been applied in defining the extent of the EMF model:

- The EMF model is based on the proposed traction substation design provided by TfNSW in October 2019
- The proposed traction substation assessment only considers the EMF produced by the equipment inside the proposed traction substation including within the outdoor transformer yard
- Existing HV aerial lines outside the substation or 1500 V DC overhead wiring are not included as part of the assessment
- DC positive and negative feeders inside the substation are not included as part of the assessment
- The loading values summarised and applied in the assessment are relevant to the short-term effects. It is conservative to use these for long-term exposure considerations. However, to accurately assess this (and remove conservatism) would require knowledge of the actual load profiles over the course of one year which is not available.

2.0 Overview of magnetic fields

2.1 Description

Electric and magnetic fields exist wherever electric current flows – in power lines and feeders, residential wiring and electrical appliances. Electricity is widely used in modern life, which means magnetic fields are all around us and exist wherever electricity is used.

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), an Australian Government agency, is responsible for the regulation of EMF. ARPANSA provides the following definition of Extremely Low Frequency (ELF) electric and magnetic fields (EMF):

> *"Extremely low frequency (ELF) electric and magnetic fields (EMF) occupy the lower part of the electromagnetic spectrum in the frequency range 0-3000 Hz. ELF EMF result from electrically charged particles. Artificial sources are the dominant sources of ELF EMF and are usually associated with the generation, distribution and use of electricity at the frequency of 50 Hz in Australia or 60 Hz in some other countries. The electric field is produced by the voltage whereas the magnetic field is produced by the current."*

The strength of the force associated with an electric field is related to the voltage: the higher the force/voltage, the stronger the electric field. The level of electric field is measured in thousands of volts per metre (kV/m). Electric fields are strongest closest to the source but reduce quickly with distance. In addition, most materials act as a barrier to electric fields.

Magnetic fields are produced by the flow of an electric current: the higher the current (measured in Amperes), the greater the magnetic field. The strength of magnetic fields is measured in milliGauss (mG). Like electric fields, magnetic fields are highest closest to the source but also reduce quickly with distance. The magnetic field strength resulting from an electrical installation varies continually with time and is affected by several factors including; the total electrical load, and the layout and arrangements of the conductors.

In October 2005, the World Health Organisation (WHO) convened a Task Group of scientific experts to assess the potential human health risks associated with exposure to electric and magnetic fields in the frequency range 0 to 100,000 Hz (100 kHz) (WHO, 2007). The Task Group concluded that there are no substantive health issues related to electric fields at levels generally encountered by members of the public as most materials act as a barrier to electric fields. However, the Task Group did identify potential for adverse health effects associated with short-term and long-term exposure to magnetic fields (as discussed in Section 2.2). Therefore, magnetic fields are the primary hazard for consideration in an assessment of potential human health risks associated with the Project.

2.2 Magnetic fields and human health

A number of animal and human studies have been undertaken to assess the potential health effects of exposure to magnetic fields, including that published by WHO (2007)[1] and the International Commission on Non-Ionizing Radiation Protection (ICNIRP, 2010)[2]. A summary of the short-term and long-term health effects identified within this assessment and relevant guidelines are discussed below.

ICNIRP (2010) notes that "*the main interaction of magnetic fields is the Faraday induction of electric fields and associated currents in the tissues. Electric fields may also be induced by movement in a static magnetic field*". Potential human health effects are therefore associated with internal electric fields induced by magnetic fields.

It is important to note when reviewing the following information, that ARPANSA has stated that:

- "*The scientific evidence does not establish that exposure to ELF EMF found around the home, the office or near powerlines and other electrical sources is a hazard to human health*"; and

[1] WHO (2007) Extremely Low Frequency (ELF) Fields – Environmental Health Criteria Monograph No. 238
[2] ICNIRP (2010) ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1HZ – 100 kHz)

- "*There is no established evidence that the exposure to magnetic fields from powerlines, substations, transformers or other electrical sources, regardless of the proximity, causes any health effects*".

2.2.1 Short-term effects

At high levels of short-term exposure, ICNIRP (2010) and WHO (2007) reported that there are established health effects including:

- Direct stimulation of nerve and muscle tissue,
- Induction of retinal phosphenes, and
- Changes in nerve cell excitability in the central nervous system (CNS).

There was also indirect scientific evidence that brain functions such as visual processing and motor co-ordination can be transiently affected by induced magnetic fields.

ICNIRP (2010) states that *"the most robustly established effect of electric fields*[3] *below the threshold for direct nerve or muscle excitation is the induction of magnetic phosphenes, the perception of faint flickering light in the periphery of the visual field, in the retinas of volunteers exposed to low frequency magnetic fields. The minimum threshold flux density for the induction of retinal phosphenes is around 5mT (50,000 mG) at 20 Hz, rising at higher and lower frequencies*".

Health guidelines (discussed further in Section 2.3) are based on this effect because ICNIRP (2010) state that "*avoiding retinal phosphenes should protect against any possible effects on brain function. Phosphene thresholds are a minimum around 20 Hz and rise rapidly at higher and lower frequencies, intersecting with the thresholds for peripheral and central nerve stimulation at which point limits on peripheral nerve stimulation should apply. For workers who are not trained and who may be unaware and not in control of their exposure status the basic restriction is set at the phosphene threshold in order to avoid these transient but potentially disturbing effects of exposure".*

2.2.2 Long-term effects

In 2002, International Agency for Research on Cancer (IARC) published a monograph[4] classifying extremely low-frequency magnetic field as Group 2B "possibly carcinogenic to humans". This classification is 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. As stated by the WHO (2007), *"this classification was based on a pooled analyses of epidemiological studies demonstrating a consistent pattern of a two-fold increase in childhood leukaemia associated with average exposure to residential power-frequency magnetic field above 0.3 to 0.4 μT*". However, WHO (2007) noted that the epidemiological evidence is weakened by:

- Potential selection bias,
- There are no accepted biophysical mechanisms that would indicate that low-level exposure leads to cancer development, and
- Animal studies, for the most part, have been negative.

Other potential health effects associated with long-term exposure to magnetic fields have been studied including other childhood cancers, cancers in adults, depression, suicide, cardiovascular disorders, reproductive dysfunction, developmental disorders, immunological modifications, neurobehavioural effects and neurodegenerative disease. WHO (2007) identified that the scientific evidence supporting these other health effects is much weaker (or not at all) than for childhood leukaemia.

In relation to other potential health effects, ICNIRP (2010) concluded:

- The available data do not indicate that low frequency magnetic fields affect the neuroendocrine system in a way that would have an adverse impact on human health.

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[3] i.e. internal electric fields induced by magnetic fields.
[4] International Agency for Research on Cancer. Static and extremely low frequency electric and magnetic fields. Lyon, France: IARC; IARC Monographs on the Evaluation of Carcinogenic Risk to Humans Volume 80; 2002.

- The evidence for the association between low frequency exposure and Alzheimer's disease and amyotrophic lateral sclerosis is inconclusive.
- The evidence does not suggest an association between low frequency exposure and cardiovascular diseases.
- The evidence for an association between low frequency exposure and developmental and reproductive effects is very weak.

A recent review by the European Commission (2015)[5] similarly concluded that overall, existing studies do not provide convincing evidence for a causal relationship between Extremely Low Frequency electric field and magnetic field exposure and self-reported symptoms, and noted the following:

- *"The new epidemiological studies are consistent with earlier findings of an increased risk of childhood leukaemia with estimated daily average exposures above 0.3 to 0.4 μT. As stated in the previous Opinions, no mechanisms have been identified and no support is existing from experimental studies that could explain these findings, which, together with shortcomings of the epidemiological studies prevent a causal interpretation.*
- *Studies investigating possible effects of ELF exposure on the power spectra of the waking EEG are too heterogeneous with regard to applied fields, duration of exposure, and number of considered leads, and statistical methods to draw a sound conclusion. The same is true for behavioural outcomes and cortical excitability.*
- *Epidemiological studies do not provide convincing evidence of an increased risk of neurodegenerative diseases, including dementia, related to power frequency magnetic field (MF) exposure. Furthermore, they show no evidence for adverse pregnancy outcomes in relation to ELF MF. The studies concerning childhood health outcomes in relation to maternal residential ELF MF exposure during pregnancy involve some methodological issues that need to be addressed. They suggest implausible effects and need to be replicated independently before they can be used for risk assessment.*
- *Recent results do not show an effect of the ELF fields on the reproductive function in humans."*

WHO (2007) noted that "*there are uncertainties about the existence of chronic effects, because of the limited evidence for a link between exposure to ELF [Extremely Low Frequency] magnetic fields and childhood leukaemia. Therefore, the use of precautionary approaches is warranted. However, it is not recommended that 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*."

In consideration of the uncertainty regarding long-term effects, WHO (2007) recommended that:

> "*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*"; and
>
> "*Government and industry should monitor science and promote research programmes to further reduce the uncertainty of the scientific evidence on the health effects of ELF field exposure*".

2.3 Health legislation and guidelines

ARPANSA has adopted ICNIRP's 2010 'Guidelines for limiting exposure to time varying electric and magnetic fields (1Hz to 100 kHz)', which it regards as international best practice, for application in Australia. The ARPANSA website states:

> "*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."*

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[5] European Commission (2015) Scientific Committee on Emerging and Newly Identified Health Risks SCENIHR Opinion on Potential health effects of exposure to electromagnetic fields

In line with ARPANSA's advice, the ICNIRP (2010) magnetic field Reference Levels have been adopted for this assessment. Within ICNIRP (2010), limitations of exposure that may lead to established health effects (as discussed in Section 2.2.1) are termed 'Basic Restrictions'. The physical quantity used to specify the 'Basic Restrictions' on EMF exposure is the internal electric field strength, as it is the internal electric field that effects nerve and other cells. However, given the difficulties in assessing internal electric field strength, 'Reference Levels' of exposure were derived from relevant Basic Restrictions using measured and/or computational techniques. Reference Levels are defined by ICNIRP (2010) as "*the electric and magnetic fields and contact currents to which a person may be exposed without an adverse health effect and with acceptable safety factors*". The Reference Levels are described by ICNIRP (2010) as "*practical or "surrogate" parameters that may be used for determining compliance with the Basic Restrictions*" and "*assume an exposure by a uniform (homogenous) field with respect to the spatial extension of the human body*". However, if the Reference Levels are exceeded it does not necessarily mean that a health effect will occur if it can be demonstrated that the Basic Restrictions are not exceeded.

The recommended ICNIRP (2010) magnetic field Reference Levels are provided in Table 2.1. It should be noted that the Reference Levels (ICNIRP, 2010) were based on established short-term health effects only (as discussed in Section 2.2.1). ICNIRP (2010) concluded that "*a causal relationship between magnetic fields and childhood leukaemia has not been established nor have any other long term effects been established. The absence of established causality means that this effect cannot be addressed in the basic restrictions*".

In addition to the ICNIRP guidelines, the WHO also recognises The Institute of Electrical and Electronics Engineers (IEEE) standards including IEEE Standard C95.6:2002 'Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0-3 kHz'. However, the IEEE levels are much higher than the ICNIRP Reference Levels and were specific to certain body parts, rather than to the person as a whole; therefore, the IEEE levels have not been included herein. It should be noted that the ICNIRP *"consider the scientific evidence related to possible health effects from long-term, low-level exposure to ELF fields insufficient to justify lowering these quantitative exposure limits"* (WHO, 2007).

Table 2.1 50Hz Magnetic field reference levels(1)

Publication	Reference Levels(2)	
	General Public(3)	Occupational(4)
ICNIRP (2010)(3)	200μT (2,000mG)	1,000μT (10,000mG)

Table 2.1 Notes:

1. At 50Hz the most sensitive known impact is to the retinal tissue in the form of magneto-phosphenes.
2. The International System of Units (SI) for magnetic field strength is Tesla (T) and another commonly used unit is Gauss (G), where 1μT = 10mG.
3. The general public is defined as individuals of all ages and of differing health statuses, which may include particularly vulnerable groups or individuals, and who may have no knowledge of or control over their exposure to EMF. Note that a foetus is defined as a member of the general public, regardless of exposure scenario, and is subject to the general public restrictions (ICNIRP 2010).
4. Occupationally-exposed individuals are defined as healthy adults who are exposed under controlled conditions associated with their occupational duties. They are trained to be aware of potential EMF risks and to employ appropriate harm-mitigation measures, and who have the capacity for such awareness and harm-mitigation response it is not sufficient for a person to merely be a worker (ICNIRP 2010).

2.3.1 Personal medical devices

As stated in ICNIRP (2010), compliance with the present guidelines may not necessarily preclude interference with, or effects on, medical devices such as metallic prostheses, cardiac pacemakers and implanted defibrillators and cochlear impacts. Interference with pacemakers may occur at levels below the recommended Reference Levels.

For persons wearing Active Implanted Medical Devices (AIMDs), which include pacemakers and implantable defibrillators, the most relevant standard is considered to be European Standard EN 50527-1 (2016) titled ‘Procedure for the assessment of the exposure to electromagnetic fields of workers bearing active implanted medical devices’. Clause 4.1.2 of this standard states that:

> “*AIMDs are expected to function as described in their product standards as long as the General Public Reference levels of Council Recommendation 1999/519/EC (except for static magnetic fields) are not exceeded… and where no specific warnings have been issued to the AIMD-Employee*.”

In regard to AIMD manufacturers, what this means in practice is that the devices need to be designed with an immunity up to the general public reference levels. Based on the date of the referred European Council recommendation, this means that older AIMDs are considered to be immune up to 100μT (1,000mG).

For persons wearing a hearing aid or cochlear implant there is the standard risk of 50Hz magnetic field noise occurring, which will not damage the devices or the ear. Where the device has a loop system receiver, operating the device in this mode will also function correctly as the magnetic field strength of the induction loop transmissions are to be designed with a high enough signal-to-noise ratio over background magnetic fields (as per EN 60118-4).

Whilst modern AIMDs are expected to be designed with consideration of the current published Reference Levels, due to differences between manufacturers and countries of origin, we recommend any persons concerned consult with their physician.

2.4 Prudent avoidance

The practice of Prudent Avoidance has been adopted by the Energy Networks Association and most Australian power utilities and distributors. In accordance with the latest advice from ENA EMF Handbook[6], it states:

> “*Prudent Avoidance does not mean that 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*.”

The application of Prudent Avoidance is addressed in Section 3.7 and Section 4.7.

[6] Energy Networks Association (2016), EMF Management Handbook

2.5 Typical EMF Levels

ARPANSA provides a summary of typical 50 Hz magnetic field levels that may be encountered in daily life:

Table 2.2 Typical Magnetic Field Levels Encountered

Location	Source	Typical Range	
		μT	mG
Home[1]	Television	0.02 - 0.2	0.2 - 2
	Pedestal fan	0.02 - 0.2	0.2 - 2
	Refrigerator	0.2 – 0.5	2 - 5
	Kettle	0.2 - 1	2 - 10
	Toaster	0.2 - 1	2 - 10
	Hairdryer	1 - 7	10 - 70
	Electric stove	0.2 - 3	2 - 30
	Electric blanket	0.5 - 3	5 - 30
Public Streets / Neighbourhood	Directly under LV/MV distribution line	0.2 - 3	2 - 30
	10 m away from LV/MV distribution line	0.05 – 0.1	0.5 - 10
	Directly under HV transmission line	1 - 20	10 - 200
	At the edge of HV transmission line easement	0.2 - 5	2 - 50
	Above underground feeders (voltage not defined)	0.5 - 20	5 - 200

Table 2.2 Notes:

1. The range of typical magnetic field levels associated with common household appliances are at normal user distances.

3.0 Wolli Creek Substation – analysis

3.1 Reference documents

The proposed Wolli Creek traction substation EMF assessment is based on the following documents:

Table 3.1 Reference documents

Document Number	Title
MTMS-APT-ANG-SB-HV-DWG-743121 (Rev 1)	Wolli Creek Substation – Concept Design Layout
502128-0005-REP-JJ-0015	MTMS2 – Wolli Creek Junction Traction Substation – Concept Design Report
EL0232168	General Arrangement 5350kVA 33000/600-600V Transformer
EL0269498 (Rev C)	33kV Rectifier Transformer Basic Configuration Requirements Arrangement
EP 20 10 00 01 SP	1500 Volt DC Cables and Cable Ratings

3.2 Feeder loadings

The loads under normal operation for the 11 kV and 33 kV feeders are as follows:

11kV Feeders

- Feeder 662 = 350 A
- Feeder 688 = 240 A
- Feeder 689 = 240 A
- Feeder 690 = 240 A

33kV Feeders

- Feeder 7A9 = 460 A
- Feeder 702 = 140 A
- Feeder 705 = 530 A
- Feeder 765 = 290 A
- Feeder 767 = 460 A

3.3 Assumptions

The following assumptions have been made in undertaking this EMF assessment:

- Only two 33 kV/600 V/600 V transformers and rectifiers are operating at any time as the third transformer and rectifier are backups
- The equipment in the substation is operating at their rated output
- 11 kV busbars are operating at 1070 A under maximum loading based on the proposed design.

3.4 Areas of interest

The areas of particular interest are identified as places where public or staff could be exposed to the magnetic fields:

- Inside the proposed traction substation yard, i.e. offices in close proximity to the transformers.

- Residential buildings adjacent to the substation, refer to Figure 3-1.

3.5 Magnetic field modelling approach

The magnetic field contributions of the proposed Wolli Creek Substation have been modelled in the HIFREQ module of the CDEGS software package. The purpose of these calculations provides an understanding of the magnetic field contribution likely to be associated with the proposed substation.

In all cases, the field contributions have been calculated at a height of 1m above ground in accordance with international practice. The total field level at any point will be the vector sum of the field contributions of the various underground and above ground sources modelled within the substation.

3.6 Calculated magnetic fields

Figure 3.1 shows a surface contour plot of the magnetic field contribution calculated within and around the substation. The following observations are made with regard to magnetic fields:

- Magnetic field levels in the areas of the 33 kV switchgear may reach approximately 1,000 mG which is below the occupational guideline reference level of 10,000mG but it is potentially an issue for a person with an AIMD
- Magnetic field levels near the 600 V AC feeders are approximately up to 1,000mG which is below the occupational guideline reference level of 10,000 mG but it is potentially an issue for a person with an AIMD
- The highest magnetic field contribution is at the 11 kV switchboard with magnetic field levels approximately up to 2000 mG. These levels are below the occupational guideline reference level of 10,000 mG but it is potentially an issue for a person with an AIMD
- Magnetic field levels at the public boundary adjacent to the retaining walls are approximately up to 50 mG which is below the general public guideline reference level of 2,000 mG. The levels are reduced to a negligible value (less than 2 mG) at 15 metres away from the public boundary.

3.7 Prudent avoidance measures

As noted in Section 2.4, prudent avoidance is to be applied whereby any available low-cost measures can be adopted to reduce magnetic field exposure whilst not resulting in additional constraints.

The summary of the available mitigation measures aimed at further reducing magnetic fields in accordance with the Prudent Avoidance approach are:

- The design has relocated the existing Undercliffe Substation to an area within the railway reserve, where general public access is unlikely
- The design proposed using three-core feeders for 11 kV and three single-core feeders for 33 kV feeders. It is recommended to use all three-core feeders (or trefoil for any single-core feeders that cannot be avoided) to maximise the cancellation of magnetic fields
- Openly share to public and staff the EMF predictions and comparison to the applicable standards and guidelines for the proposed facilities
- Ensure staff awareness of the EMF predictions and field sources within the Proposed Wolli Creek traction substation, and comparison to the applicable standards and guidelines, and required safety protocols
- Staff with medical implants should consult with their physician if working in high EMF exposure (approaching and exceeding 1,000 mG) areas.

Although the benefits of these measures could not be certain, they would still be aligned with the concept of prudent avoidance.

3.8 Post-commissioning survey

It is recommended after installation of the proposed Wolli Creek traction substation that an electromagnetic survey be conducted. The purpose of this survey is to assess the final electromagnetic fields contribution for compliance and compatibility.

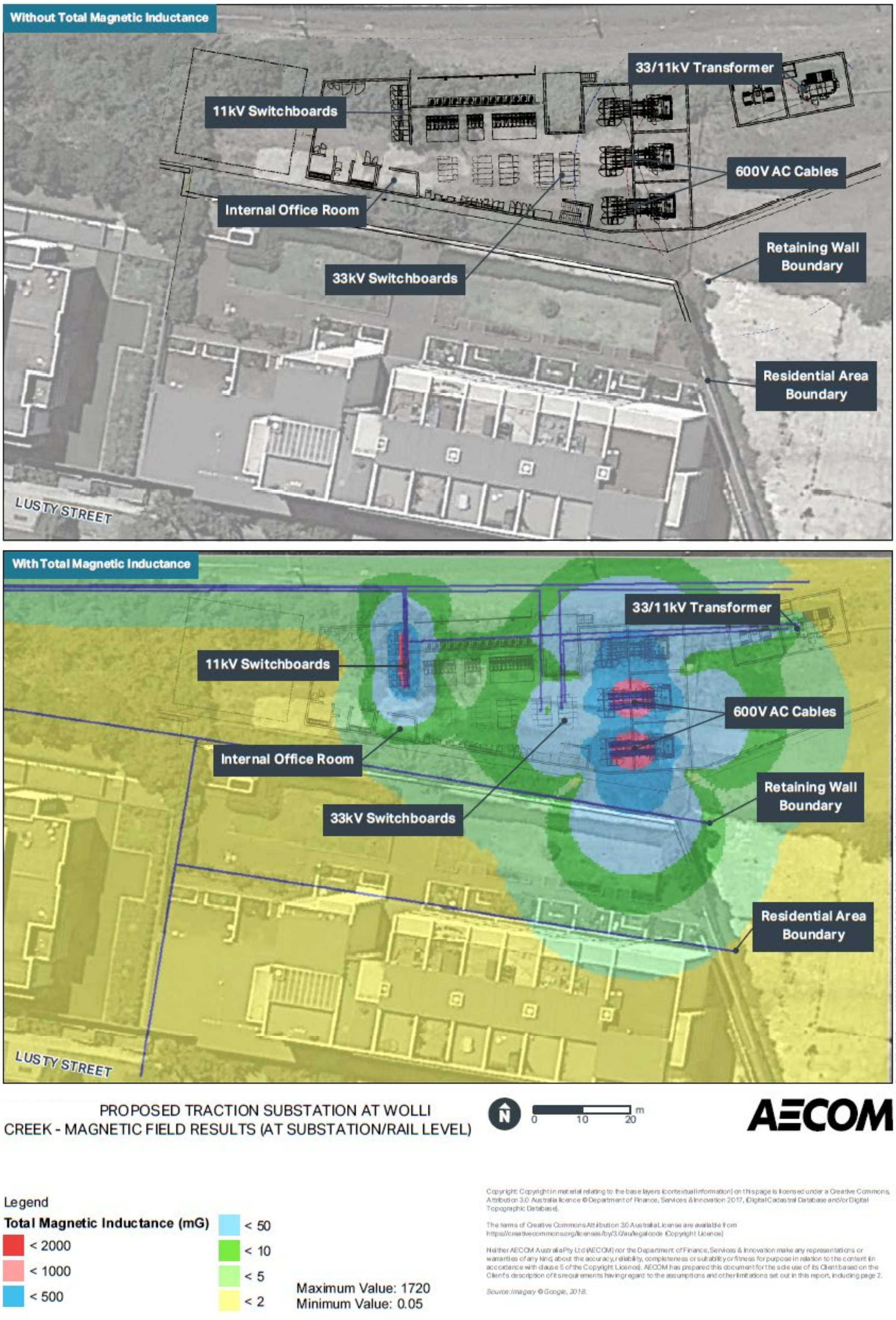

Figure 3.1 Proposed traction substation – magnetic field results (at substation/rail level)

4.0 T8 Airport Line feeder upgrade – analysis

4.1 Reference documents

The EMF assessment for the T8 Airport Line feeder upgrade scope is based on the following document:

Table 4.1 T8 Airport Line feeder upgrade - reference document

Document Number	Title
MTMS-APT-ANG-EL-HV-DWG-743001	MTMS2 – T8 Transformation Electrical – HV Cable Route Design Package

4.2 Assumptions

The following assumptions have been made in undertaking this EMF assessment:

- The calculations are based on the proposed feeder upgrades only. Any existing feeders are excluded from the analysis
- The minimum clearance between the proposed feeders and the train carriage inside the tunnel is estimated to be 1 metre away
- The proposed 11 kV feeder route from Green Square Station to the ROC will be installed under the road at 900 mm below the ground
- Future 11 kV feeders are excluded in this analysis.
- The typical load for a 33kV feeder is 460 A and for an 11 kV feeder is 240 A based on Section 3.2.

4.3 Magnetic field modelling approach

The magnetic field contributions of the T8 Airport Line feeder upgrade have been modelled in the HIFREQ module of the CDEGS software package according to the typical sections.

The field contributions have been calculated at a height of 1 m above standing surface levels.

4.4 Chalmers Street Substation

The installation of the proposed 33 kV and 11 kV feeders is detailed in drawing no. MTMS-APT-ANG-EL-HV-DWG-743041.

The predicted magnetic fields of the proposed underground feeders are shown in Figure 4.1 which has a maximum up to 40 mG directly above the feeders which is below the occupational guideline reference level of 10,000 mG. The magnetic levels are reduced to 2 mG at 4 metres away from the centreline of the feeders.

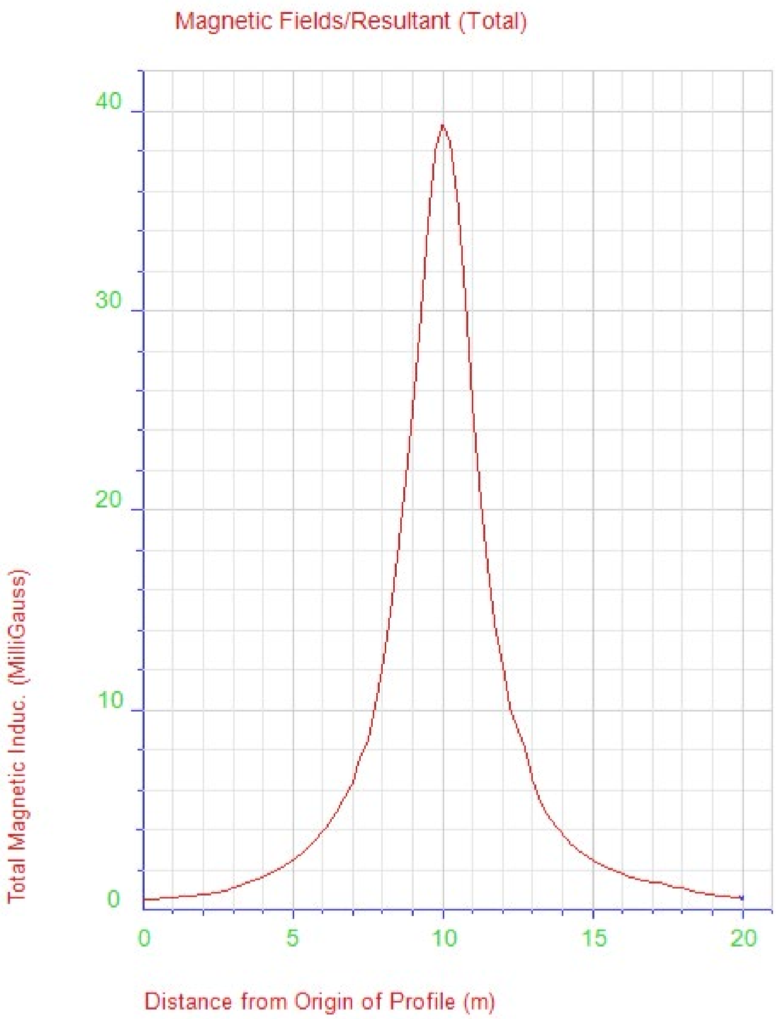

Figure 4.1 Calculated magnetic fields at Chalmers Street Substation proposed feeders

4.5 Typical tunnel sections

Both 33 kV and 11 kV feeders are to be installed on the walls inside the tunnels with different sections based on drawing no. MTMS-APT-ANG-EL-HV-DWG-743071.

4.5.1 Tunnel section at 1.430km (up) from northern portal towards country

33 kV feeder 7A8 and 11 kV feeder 569 are proposed to be installed on one side of the tunnel wall. The predicted magnetic field levels are shown in Figure 4.2 with a level of 32 mG inside the train carriage which is below the general public guideline reference level of 2,000 mG.

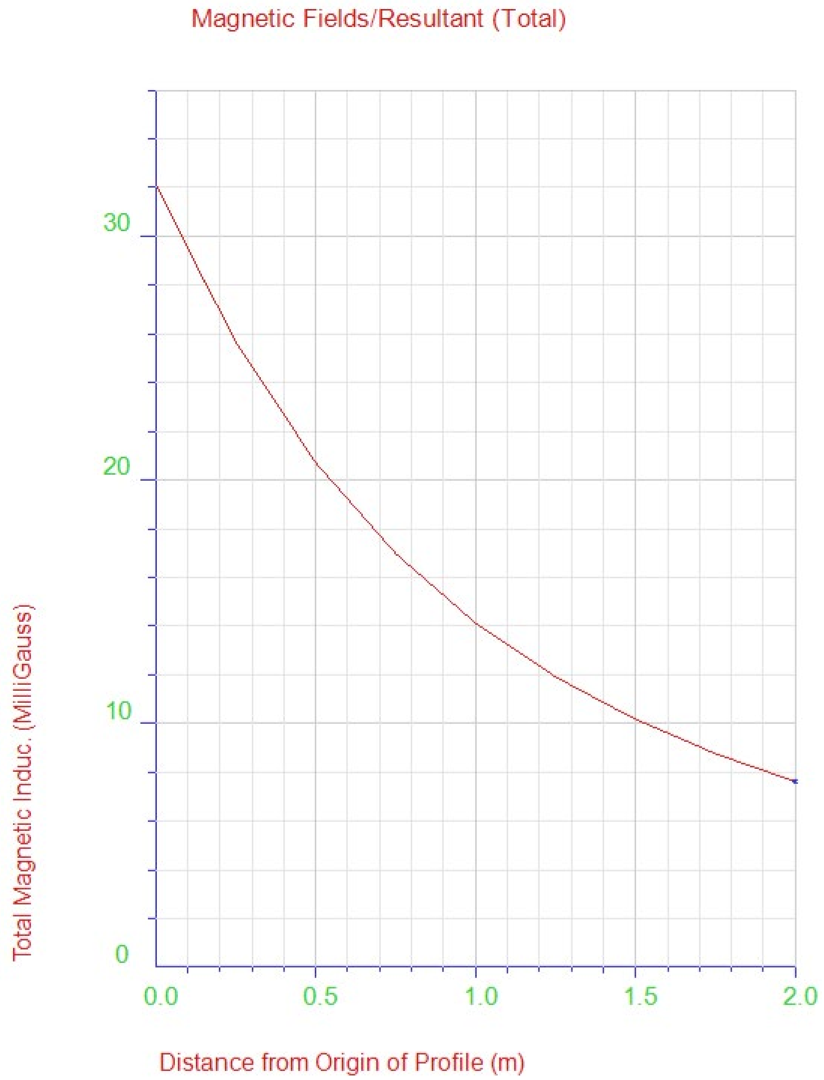

Figure 4.2 Calculated magnetic fields at northern portal tunnel section proposed feeders

4.5.2 Tunnel section at 6.325km (down) from Mascot Station towards country

Only 33 kV Feeder 7A9 is proposed inside the tunnel. The predicted magnetic field levels are shown in Figure 4.3 with a level of 22 mG inside the train carriage which is below the general public guideline reference level of 2,000 mG. This analysis also applies for a section at 9.132 km (Up) from International Airport Station towards the west.

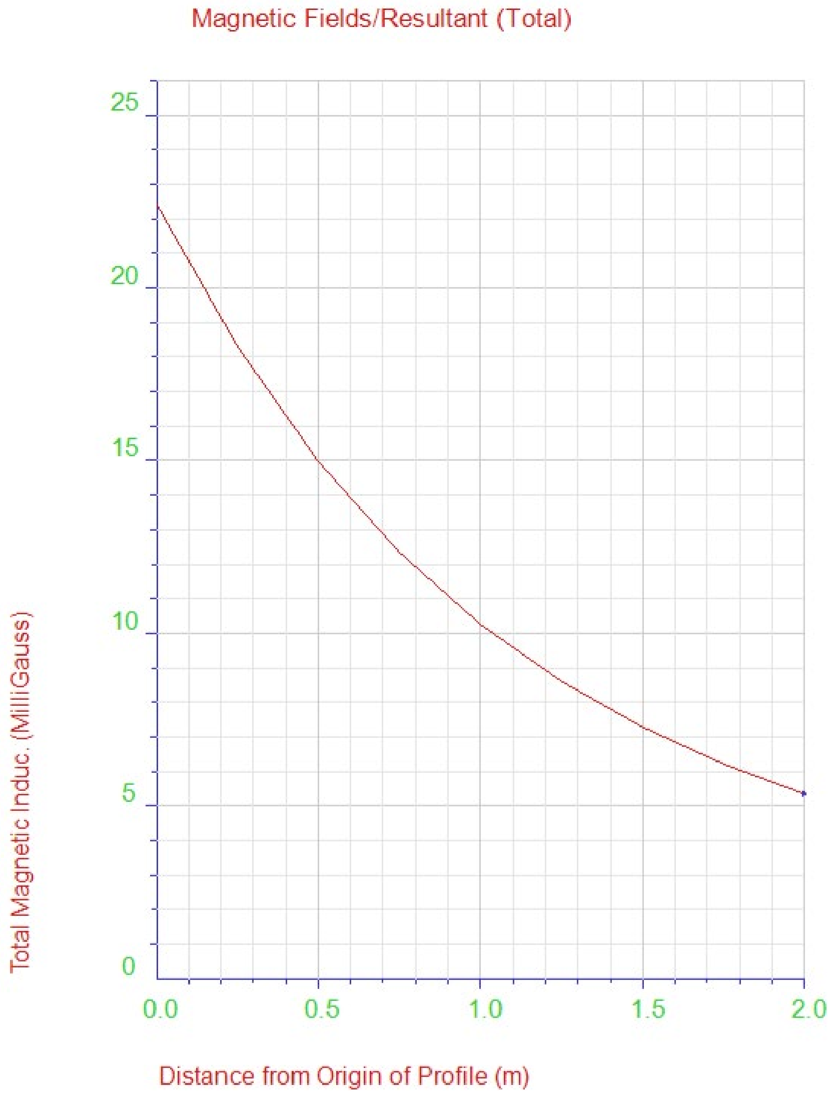

Figure 4.3 Calculated magnetic fields at Mascot Station tunnel section proposed feeders

4.6 Green Square

11 kV Feeder 569 is proposed to be installed from Green Square Station to the ROC under Wyndham Street. The predicted magnetic field levels are shown in Figure 4.4 with a maximum level of 4mG and the levels are reduced to 2 mG at 3 metres away which are below the general public guideline reference level of 2,000 mG.

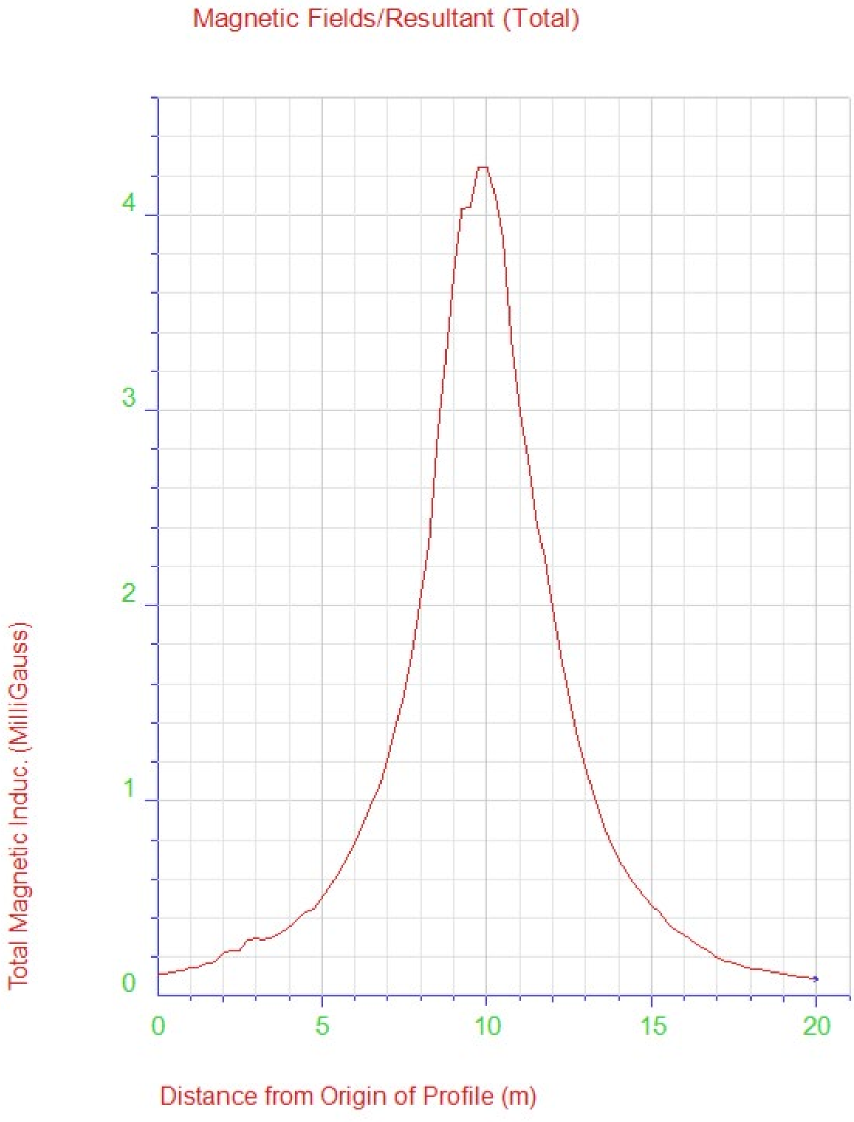

Figure 4.4 Calculated magnetic fields at Green Square Station proposed feeders

4.7 Prudent avoidance measures

As noted in Section 2.4, prudent avoidance is to be applied whereby any available low-cost measures can be adopted to reduce magnetic field exposure whilst not resulting in additional constraints.

The summary of the available mitigation measures aimed at further reducing magnetic fields in accordance with the prudent avoidance approach are:

- The design has incorporated using three-core feeders for 33 kV and 11 kV feeders to maximise magnetic field cancellations
- Inside the tunnels, it is recommended to lay the feeders as close to the tunnel wall as possible to increase the separation between the feeders to the public inside the train
- The feeders under the road are recommended to be installed at a minimum depth of 900 mm.

Although the benefits of these measures could not be certain, they would still be aligned with the concept of prudent avoidance.

5.0 Summary

AECOM has assessed the magnetic field contributions associated with the proposed traction substation and T8 Airport Line Power Supply Upgrade as part of More Trains More Services program against the relevant health guidelines and the principles of prudent avoidance.

The proposed designs in this project have 50 Hz magnetic field sources from the transformers, rectifiers, HV feeders and HV switchboards. The predicted magnetic field in all locations are confirmed to be below the Reference Levels applied to the general public and staff. However, persons with AIMDS should consult with their physicians prior to working inside the substation.

Prudent Avoidance measures are proposed as discussed in Section 3.7 and Section 4.7. AECOM recommends the detailed designer implements all Prudent Avoidance measures along with any of their own, identified as part of the safety in design process. It is also recommended that an EMF survey be undertaken to measure the final magnetic field levels after the installation of the substation.