Attachment 2 - Electric & Magnetic Field (EMF) Assessment (Connell Wagner)

Connell Wagner Pty Ltd
ABN 54 005 139 873
116 Military Road
Neutral Bay
New South Wales 2089 Australia

Telephone: +61 2 9465 5880
Facsimile: +61 2 9465 5881
Email: cwsyd@conwag.com
www.conwag.com

Tweed South Zone Substation: Assessment of Electric and Magnetic Fields

Country Energy

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1. Introduction

1.1 Background

Country Energy proposes to establish a 66/11kV Zone Substation in Kirkwood Road, South Tweed Heads and has submitted a Development Application to Tweed Shire Council. Among the issues raised in submissions was the electric and magnetic fields (EMF) likely to be associated with the facility. The purpose of this report is to document an assessment of those fields.

A plan of the proposed substation is shown in Figure 1.1.

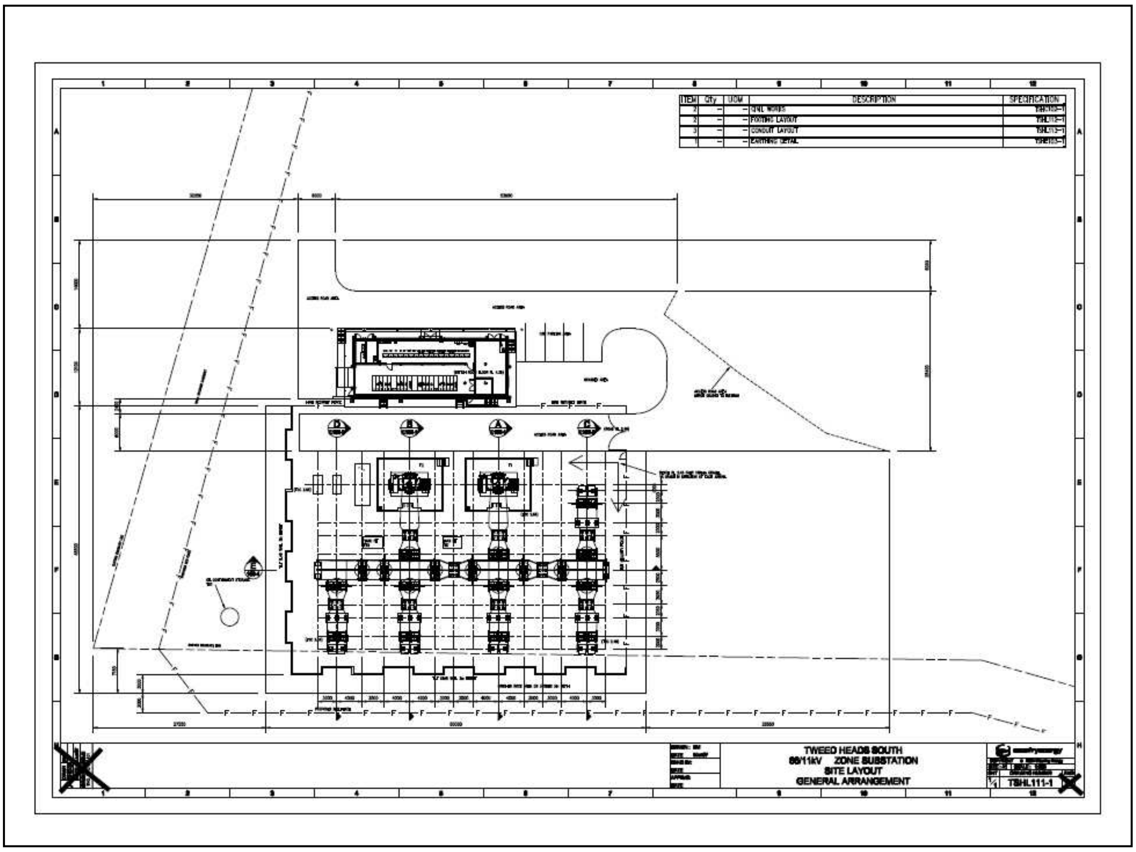

Figure 1.1 - Plan of Proposed Substation

1.2 Project and Site Description

The project involves the establishment of a 66,000 Volt (66kV) to 11,000 Volt (11kV) zone substation on a large block of land, owned by Country Energy and fronting Kirkwood Road, South Tweed Heads.

The substation will consist of an outdoor 66kV switchyard, outdoor transformers and capacitors, together with a building containing control equipment and 11kV switchgear. The transformers will be located between the control building and Kirkwood Road. The outdoor switchyard will be surrounded by an enclosure consisting of a 3 metre high masonry wall on its southern and western sides and a high-security fence on its northern and eastern sides. The entire substation will be within an outer security fence along the boundaries of the Country Energy property.

The substation fronts Kirkwood Road on its southern boundary, while its northern and eastern boundaries are surrounded by a Country Energy Depot. The nearest residential property is a caravan park, the boundary of which is some 10 metres west of the outer security fence and about 25 metres from the nearest piece of electrical equipment.

The substation will be supplied at 66kV by two proposed underground cables, possibly along Kirkwood Road.

It is understood that the proposed underground cable routes associated with the substation are currently in the concept design stage and that community consultation is in progress. Planning approval for these cables will be the subject of a separate formal process and will include environmental impact assessment.

Although, this report is directed to the substation, the proposed underground cables are also addressed.

It is understood that outgoing power will exit the station via multiple 11kV cables in several directions as follows:

- Northwards along Holden Street (Trench 4)
- Northwards along Sunshine Avenue (Trench 5)
- Eastwards along Kirkwood Road (Trenches 1& 2)
- Southwards from Kirkwood Road along Tierneys Road (Trench 3).

Trenches 1 and 4 will carry up to 5 circuits each, Trench 2 will carry 4, Trench 3 will carry three and trench 5 will carry one.

1.3 Structure of Report

The remainder of Section 1 provides background information. Sections 2 and 3 describe and document the calculations and measurements undertaken and Section 4 addresses the matter of "prudent avoidance" and its application to the project. Conclusions are presented in Section 5.

1.4 Overview of Electric and Magnetic Fields

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 close 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.

Because electric fields are related to the voltage of the source, the electric fields in the vicinity of high voltage equipment tend to be higher than those which occur in the vicinity of other electrical equipment and appliances encountered in everyday situations. Also, being voltage dependent, they are relatively constant over time because the system voltage is constant.

A **magnetic field** is a region where magnetic materials experience an invisible force produced by the flow of electricity or the current (amps). Because magnetic fields are related to the current rather than the voltage, high voltage equipment is not the only source of magnetic fields encountered in everyday life. In fact, modern life involves frequent contact with magnetic fields from a variety of sources such as appliances and electrical machinery.

The strength of a magnetic field depends on the size of the current (measured in amps), and decreases with distance from the source. While electric fields are blocked by many common materials, this is not the case with magnetic fields. This is one reason why power lines may contribute to the overall magnetic fields in the environment and why burying power lines will not necessarily eliminate them.

The magnetic field strength resulting from an electrical installation varies continually with time and is affected by a number of factors including:

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

In the case of a substation, the layout of the equipment within the station can have a significant effect on the external magnetic fields.

While the equipment type and design and the substation layout are normally constant throughout the life of a facility, the overall load and the interactions between the various items of equipment will vary and so will the resulting magnetic fields.

1.5 The EMF Health Issue

Over the past 30 years, concerns have been expressed that the EMFs associated with electrical equipment might have adverse health effects. The issue has been the subject of extensive research throughout the world. To date, adverse health effects have not been established but the possibility that they may exist has not been ruled out.

The first studies into possible health effects from EMFs, in the late 1960s, were directed towards *electric fields* and, overall, gave generally reassuring results. In 1979, an epidemiological study of childhood cancers in Denver, Colorado first raised the possibility that there could be a relationship between *magnetic fields* and cancer. Although this study was relatively unsophisticated by today's epidemiological standards, it created interest in the scientific and broader community and, over the following ten years, led to the redirection of research efforts towards magnetic fields.

Since the 1979 study, many thousands of papers have been published on EMFs and human health. However, answering the question *"do EMFs cause illness?"* is not a simple task. Research into EMFs and health is a complex area involving many scientific disciplines - from biology, physics and chemistry to medicine, biophysics and epidemiology. Also, the situation is further complicated by the fact that many of the health issues of interest to researchers are quite rare.

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.

The most recent scientific reviews by authoritative bodies are reassuring for most potential health issues. 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 1) in 2001 to classify magnetic fields as a "possible carcinogen".[1]

In noting the association between exposure to elevated magnetic field levels and childhood leukaemia, it is important to recognise that a statistical association does not necessarily reflect a cause and effect relationship.

The fact that, despite over 25 years' laboratory research, no mechanism for an effect has been identified, lends weight to the possibility that the observed 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, Sir Richard Doll (Ref 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).

The bulk of the electric and magnetic fields/health research over the past 15 years has been directed towards magnetic rather than electric fields.

While EMFs involve both electric and magnetic components, electric fields are driven by the system voltage and are relatively constant over time, are readily shielded and, in the health context, are generally not associated with the same level of interest as magnetic fields. Accordingly, the major focus of the following discussion is on magnetic fields.

1.6 Health Standards

The relevant Australian health standard is the document called 'Interim Guidelines on Exposure to 50/60 Hz Electric and Magnetic Fields' (1989) (Ref 3). The document was issued by the National Health and Medical Research Council (NHMRC) and was based on guidelines developed by the International Non-ionising Radiation Committee of the International Radiation Protection Association (IRPA) (Ref 4). IRPA has since been replaced by the International Commission on Non-ionising Radiation Protection (ICNIRP). While the authors of the above guidelines considered the then epidemiological and laboratory studies regarding electric and magnetic fields and cancer, they considered that the available data did not provide any basis for health risk assessment useful

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[1] *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 5 groups, namely:*

- ***Group 1*** *-the agent is carcinogenic to humans-88 agents are included in the group, including asbestos, tobacco and gamma radiation;*
- ***Group 2A*** *- the agent is probably carcinogenic - 64 agents have been included in this group, including diesel engine exhaust, UV radiation and formaldehyde;*
- ***Group 2B*** *- the agent is possibly carcinogenic to humans - 236 agents have been included in this group, including coffee, gasoline, lead, nickel, engine exhaust and extremely low frequency magnetic fields;*
- ***Group 3*** *- the agent is not classifiable as to carcinogenicity - 496 agents have been included in this group;*
- ***Group 4*** *- the agent is probably not carcinogenic to humans - only 1 agent has been included in this group.*

for the development of exposure limits. The exposure limits in the guidelines are based primarily on established or predicted effects related to the flow of electric current within the body. They are not intended to define safe limits for possible health effects, should these exist, from fields at strengths normally encountered in the vicinity of electrical equipment.

For electric fields, the guidelines stipulate a limit of 5 kV/metre for general public exposure for up to 24 hours per day.

In the case of magnetic fields, the guidelines stipulate a limit of 1000 milligauss for general public exposure for up to 24 hours per day.

Because the NHMRC has not updated its guidelines since their original issue, they have lapsed and the Australian Radiation Protection and Nuclear Safety Agency is currently reviewing them. The ICNIRP guidelines, upon which the NHMRC guidelines are based, have been reviewed twice (1993 and 1999) and the 24-hour exposure limits for the general public remain 1000 milligauss and 5kV/metre respectively.

1.7 Prudent Avoidance

With regard to the potential health effects from magnetic fields, while compliance with the relevant guideline is important, it does not imply a level of 'safety'. The possibility of health effects has been comprehensively studied over several decades worldwide but, to this day, there is no clear understanding of whether or not electric or magnetic fields 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 a number of 'Inquiries' such as those by Sir Harry Gibbs in NSW (Ref 5) and Professor Hedley Peach in Victoria (Ref 6). These reviews and inquiries have consistently found that:

- Adverse health effects have not been established.
- 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 defined as doing what can be done at modest cost and without undue inconvenience to avoid a possible risk.

More recently (1999) the (US) National Institute of Environmental and Health Sciences (Ref 7) 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 Energy Supply Association of Australia (ESAA) and most Australian power utilities, including Country Energy.

Given the inconclusive nature of the science and the ongoing possibility of adverse health effects, it is considered that a prudent avoidance approach continues to be the most appropriate response in the circumstances. Under this approach, subject to modest cost and reasonable convenience, power utilities 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.

Commentary on the application of prudent avoidance to the Tweed South Zone Substation project is contained in Section 4 below.

2. Aspects of Field Predictions

2.1 Dependence on Load

During a typical day, the loading on a substation will vary substantially between a daily minimum, generally in the early hours of the morning and a daily maximum at times of peak demand. Loadings also vary seasonally during the year, generally reaching a peak in summer. It is these various actual loadings which are relevant in the health context, rather than the maximum capacity of the facility, which may only be required for very short periods, under emergency conditions, a few times over its service life.

To establish the substation loadings to be used for the study, the Country Energy System Planning Department provided information on:

- Forecast yearly peak loadings on the substation;
- Daily load profiles;
- The way in which the substation will be configured and operated; and
- Connection and operational arrangements for the incoming supply.

This information served as the basis for the field assessment. Salient points are set out below:

- The substation will be supplied via two underground 66kV connections "cut in" to an existing 66kV overhead line which runs along the old Pacific Highway.
- At this stage, it is expected that the two cables will form part of a "mesh" system. This means that the direction of current flow in the two cables will be in opposite directions.
- The incoming and outgoing load flows will be 19 and 9 MVA respectively in 2008 and 28 and 4 MVA in 2020.
- The initial load on the substation would be about 11 MVA, increasing to about 26MVA by 2020.
- Under abnormal "emergency" conditions, the incoming and outgoing load flows could be 35 and 24 MVA respectively in 2008 and 63 and 38 MVA in 2020.

2.2 Variability of Electric and Magnetic Fields Associated with Electricity Infrastructure

The magnetic fields from substations will vary over time and also spatially, depending on the loadings on the various components of the substation at the particular time.

Accordingly, in characterising the electric and magnetic fields, it is necessary to make practical assumptions regarding the above factors.

Given that the epidemiological associations which underpin concerns regarding EMF tend to relate to elevated "***average***" magnetic fields, of the various hypothetical conditions one could select for magnetic field characterisation, the most meaningful is to take the long term average load and link this to conservative assumptions regarding other factors. The magnetic fields derived under these conditions are the most appropriate for consideration in the context of the magnetic field/health literature. This approach has been followed, with the substation loading assumed to be at 75% of its annual peak for each of the years modelled.

2.3 Incoming and Outgoing Feeder Connection Design and Phasing Arrangements

The physical design and phase arrangement for a section of underground cable, have a significant influence on the resulting EMFs. Accordingly, these have to be specified for the purposes of calculations and, in the case of a circuit which has not yet been designed, assumptions need to be made. As the phasing arrangement is an area where the designer has some flexibility and, given that Country Energy has adopted a policy of prudent avoidance, it has been assumed that, for the incoming and outgoing feeders, the designers will adopt a phase arrangement which results in lower average

EMF levels. Accordingly, such an arrangement has been adopted for the feeder connection calculations in this study, in conjunction with physical design information provided by Country Energy. (It should be noted that, as all of the incoming and outgoing circuits are underground, the fields are quite localised and the phase arrangements are less significant than for overhead lines.)

3. Field Characterisation

3.1 Proposed Substation

As noted in Section 2.2, the magnetic fields from the proposed substation will vary over time and also spatially, depending on the loadings on the various components of the substation at the particular time. Within a substation, there are a multiplicity of sources of varying physical size and electrical characteristics, all interacting with one another. For this reason, the characterisation of the magnetic fields associated with a substation is a complex exercise. While it is theoretically possible to calculate the resulting fields at a particular point for a particular set of circumstances, such calculations are very specific to the point studied and the assumed loading conditions on each item of equipment in the substation. Such calculations are considered to be of little practical value, as the results can vary markedly, depending on the assumptions made.

For this reason, it is both useful and practical to rely on a “similarity-based” approach, whereby the magnetic fields associated with an existing substation of similar design to the one proposed are measured and used as a basis for predicting the range of fields likely to be associated with the proposed substation.

Over the years, Connell Wagner has performed detailed magnetic field measurements at various Zone Substations with a range of plant and equipment similar to that proposed for the Tweed South Zone Substation. Magnetic field profiles (at a height of 1 metre) associated with the transformers, capacitors and switchgear were produced and the loadings at the time were recorded. Fields were also measured around the perimeter of the substation building.

In all cases, the measured fields decreased rapidly with increasing distance from the equipment.

The magnetic fields likely to be generated by the equipment within the proposed Tweed South substation have been estimated, based on measurements made at comparable sites by Connell Wagner.

The specific equipment profiles used for the assessment are summarised in the table below.

Equipment	MF 3 Metres Away	MF 6 Metres Away	MF 10 Metres Away
66/11kV Transformer	30 mG	11.5 mG	6.5 mG
66kV Switchgear	20 mG	5 mG	2 mG
11kV Switchgear	2 mG	1 mG	<1mG
11kV Capacitors	10 mG	2.5 mG	1.5 mG

The magnetic field contribution at the southern and western security fences, due to the substation equipment, is expected to be of the order of a few milligauss or less. There will be localised higher magnetic fields where the underground cables enter the site, as discussed in Section 3.2 below.

Except where the underground cables enter the site, the field at the property boundaries will be negligible and the magnetic fields from the substation are not expected to increase the existing levels at neighbouring residences.

3.2 Incoming and outgoing connections

As well as the substation itself, the incoming and outgoing underground cables will also be a source of electric and magnetic fields. The 66kV cables are expected to be routed along Kirkwood Road, entering the Country Energy site at its south-eastern corner and entering the substation on the southern side. Planning approval for this cable will be the subject of a separate formal process and will include environmental impact assessment. The assessment documented in this report relates only to the substation. Nevertheless, in order to provide a complete assessment of the magnetic fields in the vicinity of the substation, it is necessary to have an appreciation of the fields likely to be associated with both the incoming 66kV connections and the outgoing 11kV cables. Accordingly, based on the currently available design and loading information provided by Country Energy, a series of typical field profiles have been calculated to provide an understanding of the likely contribution of the external connections to the magnetic fields where they enter the substation property and in nearby streets.

The modelling has been carried out using established engineering techniques, which are used internationally, have been validated by field measurements and are known to produce accurate results provided that the underlying assumptions (as discussed above) are valid. In all cases, fields have been calculated at a height of 1 metre above ground in accordance with the international practice.

The scenarios modelled were:

a) In 2008, following commissioning
b) Around 2020, with the substation operated as part of a mesh system, with incoming current equivalent to 28 MVA and outgoing current (to the next substation on the ring) equivalent to 4 MVA.
c) As for scenario b, but with the system operating under abnormal emergency conditions.

The results of the modelling for 2020 are shown graphically in Figure 3.1.

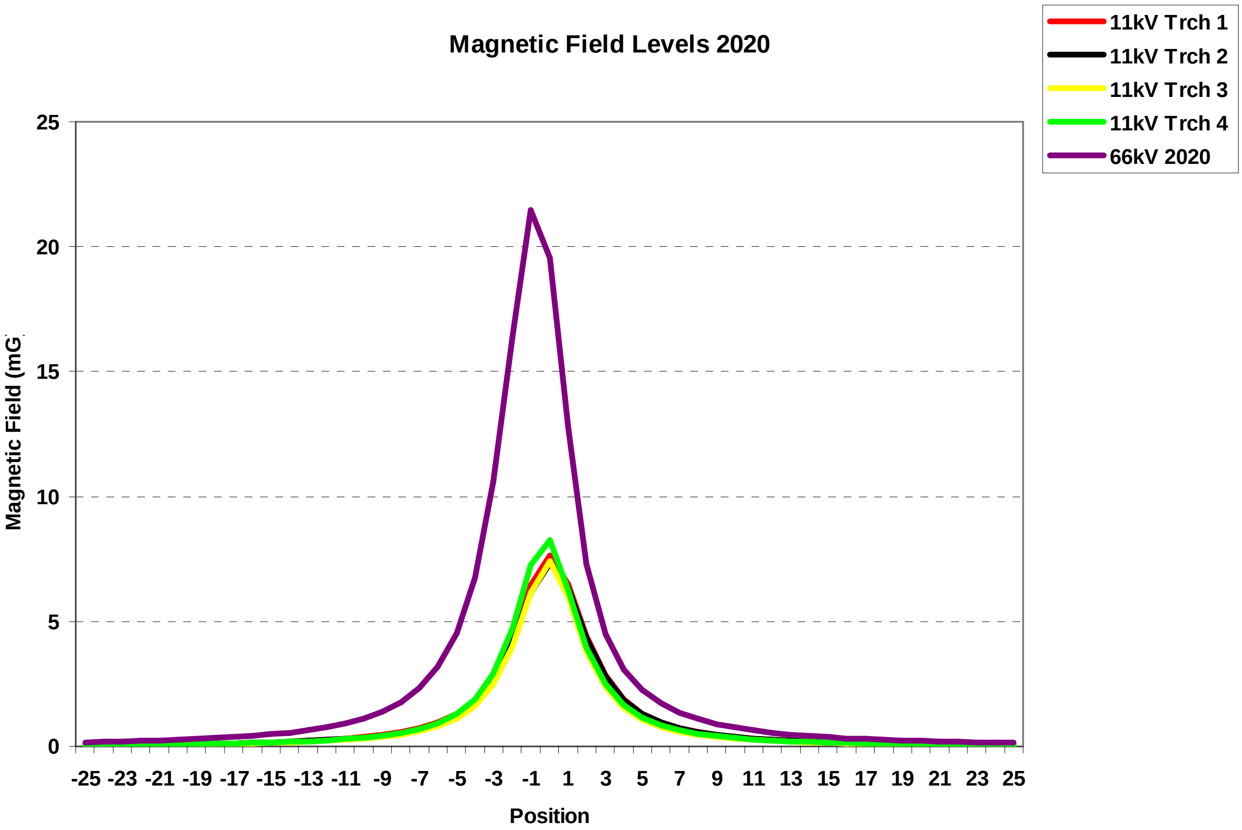

Figure 3.1: Predicted localised magnetic fields associated with underground cables to & from substation

As the results for 2008 are similar, but somewhat lower than those for 2020, for the purpose of clarity, they have not been shown in the Figure. It will be noted that the field strengths for the various sections of 11kV route are relatively similar to one another and less than for the 66kV cables. The results for Trench No. 5 have also been omitted for clarity.

The fields from the 66 kV cables reach 22 milligauss directly above the more heavily loaded cable, decreasing to a few milligauss within 3 to 5 metres and becoming negligible beyond 8 to 10 metres. The fields from the 11 kV cables reach 7 to 8 milligauss directly above the cables, dropping off to a few milligauss within a few metres and becoming negligible beyond about 6 metres.

3.3 Electric Fields

As much of the electrical equipment associated with the substation will be of the indoor variety, it will produce little or no electric field external to the equipment enclosure. The only unenclosed high voltage connections within the substation will be within the outdoor switchyard and would only be accessible to authorised persons. The electric fields in these areas, directly under the connections, have been estimated to be in the range of 1 to 3 kV per metre, based on previous measurements directly beneath high voltage busbars. This is less than one third of the NHMRC occupational guideline for "whole working day" exposure.

The electric field will be localised to the 66kV switchbays and will not extend beyond the station fence.

3.4 Magnetic Fields Experienced Intermittently

While the field levels presented in Sections 3.2 and 3.3 are the most relevant in the health context, in the broader context of an environmental assessment, it also appropriate to recognise the possibility that fields of approximately twice the level of those modelled could be experienced in some places for short periods over the life of the facility. Such a situation would rarely arise over its life, would probably be confined to the 66kV cables and would not be expected to be of prolonged duration.

In considering both this matter and the localised fields directly above the underground cables, it is important to recognise that life in the modern world involves moving from one source of magnetic fields to another. The intermittent fields, which may be experienced for short periods of time in the vicinity of a substation, are analogous to those we experience in everyday life. To put this into perspective, the ESAA (Ref 8) has published a series of typical magnetic field levels associated with particular appliances at normal user distance. These are set out in Table 2 below:

	Typical Measurement (mG)	Range of Measurements (mG)
Stove	6	2-30
Computer	5	2-20
TV	1	0.2-2
Electric Blanket	20	5-30
Hair Dryer	25	10-70
Refrigerator	2	2-5
Toaster	3	2-10
Kettle	3	2-10
Fan	1	0.2-2

Table 2: Magnetic Field Levels Associated with Appliances

From the above range of fields, it can be seen that the magnetic field exposures likely to be experienced intermittently as a result of the proposed substation are consistent with the range encountered in everyday life.

4. Prudent Avoidance

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

The Tweed South Zone Substation proposal has been reviewed against criteria which can be regarded as good practice in the application of prudent avoidance, recognising that, at this stage, the project is in its planning stages and design details have not all been finalised. It is noted that Country Energy has taken the following steps:

- Sited the facility on a much larger parcel of land than would be required merely to accommodate it, thereby providing generous separation from neighbouring properties.
- Selected underground cables for all incoming and outgoing feeders.
- Openly shared information regarding the EMF/health issue and the proposed facility.

Furthermore, consistent with Country Energy's policy of prudent avoidance, it is understood that the proposed underground cable connections will be configured as far as practicable to achieve reduced magnetic fields. It is also understood that, in the case of the 66kV cables, the more heavily loaded cable will be located nearest the road.

Each of these measures is consistent with the notion of prudent avoidance.

5. Conclusions

The magnetic fields likely to be associated with the proposed Tweed South Zone Substation have been assessed on the basis of the information currently available. The findings of the assessment are:

- The magnetic fields at the security fences of the substation will generally be of the order of a few milligauss.
- There will be localised areas of higher magnetic fields at the south-western corner of the Country Energy property, associated with the incoming and outgoing feeder connections. Under normal operation, these fields are unlikely to exceed 30 milligauss and would be localised to the areas a few metres each side of the various cables.
- The magnetic fields from the substation will not increase the existing levels at any neighbouring residences.
- The magnetic fields at and beyond the Country Energy property will be less than 3% of the relevant health guideline.
- The magnetic fields within the internal areas of the substation, which are accessible only to Country Energy staff, will generally be in the range of 0-100 milligauss and will comply with all relevant occupational health guidelines.
- The electric fields within the substation will also comply with all relevant occupational health guidelines.
- There will be no source of external electric fields.

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