Appendix B4

Electric & Magnetic Fields Assessment

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Mangoola Coal 500kV Transmission Line Deviation
Umwelt (Australia) Pty Limited

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Appendix A: Submission by Wybong Action Group

1. Introduction

1.1 Background

It is understood that Xstrata Mangoola Pty Limited (trading as Mangoola Coal), on behalf of TransGrid, proposes to relocate a 9 km section of the Bayswater- Mt Piper 500kV Transmission Line in the vicinity of its Mangoola site. The route of the proposed deviation is shown in Figure 1.1 below. Umwelt (Australia) Pty Limited (Umwelt) has been engaged to undertake the necessary environmental assessment of the proposal. One of the issues to be addressed on the overall environmental assessment is electric and magnetic fields (EMF) and Umwelt has engaged Aurecon to undertake the EMF assessment.

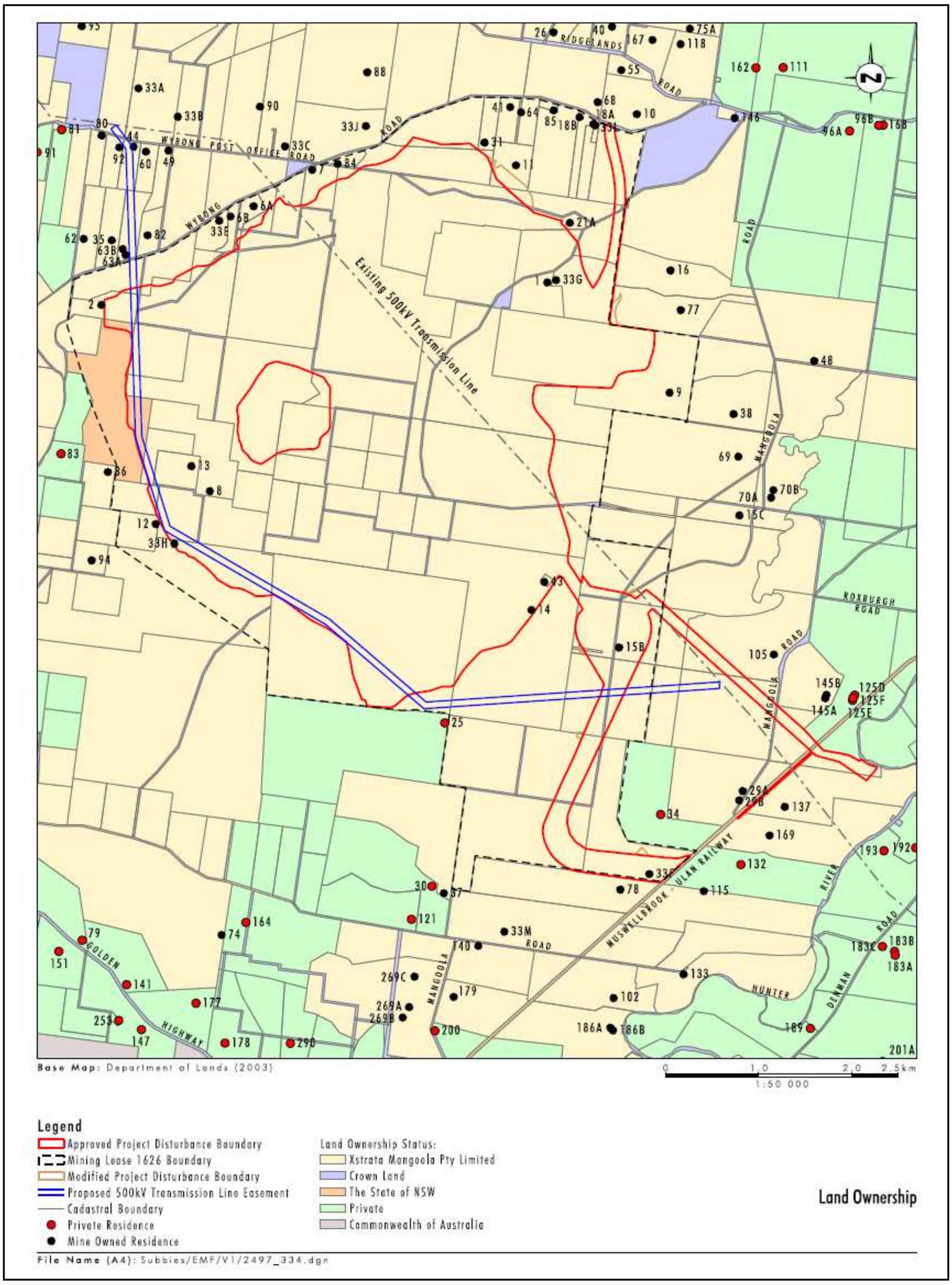

Figure 1.1: Route of proposed deviation

1.2 Scope

In accordance with Umwelt's instruction, the scope of the EMF assessment is to include the following:

- Assessment of identified impacts in accordance with identified standards/guidelines
- Identification of any management controls or mitigation measures which might be required to minimise identified EMF impacts
- A comparison of the EMF impacts created by the existing line with those from the proposed relocated line
- Calculation of EMF impacts on private residences and any other relevant sensitive land uses
- Comment on references to EMF in a document produced by a local community group known as the "Wybong Action Group" (See Appendix A).

The results of the above work are to be used by Umwelt to inform their environmental assessment of the overall project.

1.3 Approach

In undertaking the assignment, the following approach has been taken:

- Relevant background information, supplied by Umwelt or others has been examined
- A site inspection was undertaken and electric and magnetic field measurements made
- The electric and magnetic fields likely to be associated with the existing and proposed lines have been calculated, sufficient to characterise the existing EMF environment and to predict the contribution of the proposed relocated line to the future EMF environment
- The predicted electric and magnetic fields have been assessed against relevant standards and guidelines.

1.4 Information Requested from Client

In order to enable the assignment to be performed, Umwelt were requested to provide or arrange provision of the following relevant information to Aurecon:

- Details of the proposed line route and any easement securing it
- Dimensioned drawings/sketches of the structure top configurations to be used
- Nomination of any specific sensitive sites along the route where customised calculations and/or measurements may be required
- For each nominated site, a dimensioned sketch showing the position of the proposed line in relation to the perceived sensitive receptor(s)
- Details of anticipated loadings on each circuit of the deviated line, shortly after commissioning, and long-term, when an ultimate load is reached
- The maximum rated current for each circuit of the proposed line
- For the relocated line, conductor type and stringing conditions, maximum design temperature and minimum ground clearance at maximum operating temperature
- Details of loadings on the existing lines at the time that any measurements are undertaken.

1.5 Information provided by Umwelt

Pursuant to the request for information as summarised in Section 1.4, the following input information has been provided or arranged by Umwelt. The remainder of this report is predicated on that information. Salient points are set out below:

- The location and route of the proposed deviation are as shown in Figure 1.1

- The line deviation will be constructed using double-circuit steel lattice tower structures, similar to those used on the existing line, as shown in Figure 1.2
- The towers will range from 46 to 66 metres in height
- The line will be strung with quadruple “Orange ACSR” conductors designed to achieve a minimum of 11 metres ground clearance at its maximum operating temperature of 120°C
- The anticipated peak (system normal) loadings in the new section of line, upon commissioning and in the longer term are 1200 Amps and 4000 Amps respectively
- Under abnormal emergency conditions, the line loading could be as high as 5200 Amps
- The 85th percentile load, i.e. the load which will be exceeded for not more than 15% of the time is expected to be some 54% of the annual peak
- Details of the locations of a number of dwellings and caves providing bat habitat within the project area were also provided.

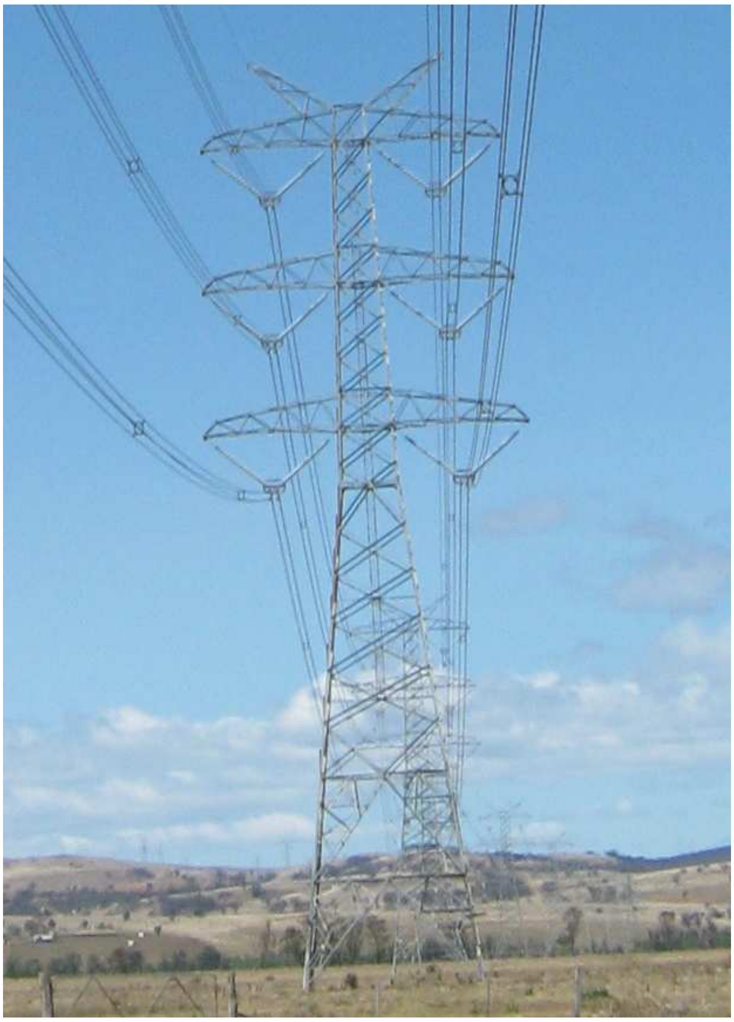

Figure 1.2: Outline of lattice tower structures

1.6 Structure of Report

The remainder of Section 1 provides background information and an overview of the EMF/health issue is provided in Section 2. Section 3 discusses precautionary measures, Section 4 documents our EMF calculations and Section 5 addresses the specific matters to which our attention has been directed. Section 6 discusses the application of prudent avoidance to the project and our conclusions are presented in Section 7.

1.7 General Description of Electric and Magnetic Fields

The electric and magnetic fields associated with electrical equipment are essentially independent of one another. 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. In more detail:

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 (Ref. 6). Being related to voltage, the electric fields associated with transmission lines and electrical equipment in 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 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.
To put this into perspective, the (Australian) Energy Networks Association (ENA) (Ref. 3) has published a series of typical magnetic field levels associated with particular appliances at normal user distance. These are set out in Table 1.1.

MAGNETIC FIELD SOURCE	TYPICAL MEASUREMENT (MILLIGAUSS)	RANGE OF MEASUREMENTS (MILLIGAUSS)
Electric Stove	6	2-30
Computer Screen	5	2-20
Television Screen	1	0.2-2
Electric Blanket	20	5-30
Hairdryer	25	10-70
Refrigerator	2	2-5
Electric Toaster	3	2-10
Electric Kettle	3	2-10
Electric Fan	1	0.2-2
Street Distribution Line (directly under line)	10	2-20
High Voltage Transmission Line directly under line at edge of easement	20 10	10-200 2-50

Table 1.1: Magnetic Field Levels Associated with Appliances

Background magnetic field levels within buildings but remote from particular sources are typicially in the range of 0.1 to 1 milligauss (mG)

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 these fields.

Unlike electric fields, 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.

1.8 Electromagnetic Radiation

It is not uncommon for the electric and magnetic fields (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 a 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[1] of its wave; these types include (in order of increasing frequency): radio waves, microwaves, teraherz radiation, infra red radiation, visible light[2], 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 the EMF/health issue, 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. 1) 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.*”

[1] 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 = 1 cycle per second.

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

2. Overview of the EMF-Health Issue

2.1 General

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 remains that they may exist.

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 compared to some later studies, 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 can 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. 4) in 2001 to classify magnetic fields as a "possible carcinogen".[3]

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[3] 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.

In noting the association between exposure to elevated magnetic field levels[4] and childhood leukaemia, it is important to recognise that a statistical association does not necessarily reflect a cause and effect relationship[5].

The fact that, despite over 20 years laboratory research, no mechanism for an effect has been established, 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, the late Sir Richard Doll (Ref. 5).

> *"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.

2.2 Putting Magnetic Field Levels of 3 - 4 Milligauss into Perspective

The epidemiological studies which have reported associations between elevated magnetic fields and childhood leukaemia generally define “elevated” magnetic fields as average magnetic field exposure of 3 to 4 milligauss or 0.3 to 0.4 microtesla[6] (μT). However, it is important to understand that 3 or 4 milligauss is not an exposure limit or safety level, but rather is a level selected by researchers as part of their study design, as outlined below.

Ideally, epidemiological studies compare the incidence of disease in populations which are exposed to the agent under study and those who are not (e.g. smokers vs non-smokers). However, in the case of EMF, everyone in the modern world is exposed to some level of EMF, so it is not possible to find an unexposed population. Accordingly, in designing a study, the researchers need to select some level of magnetic field and define exposure below that level as “unexposed” and above that level as “exposed”. A further consideration for researchers in selecting an appropriate line of demarcation between “exposed” and “unexposed” is that they need to be able to identify a sufficient number of subjects with exposures above that level to enable valid statistical analysis to be performed. It turns out that average exposures above a few milligauss are relatively rare and, accordingly, in order to ensure a sufficient number of “exposed” subjects, there is little option but to select a level of a few milligauss as the boundary between “exposed” and “non-exposed” for the purposes of the study.

It is not uncommon for individuals unfamiliar with the design of epidemiological studies to misunderstand the significance of 4 milligauss and view it as a threshold between “safe” and “unsafe” rather than as a product of experimental design. Such a position is scientifically untenable.

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[4] In the context of the EMF epidemiological studies, the term “elevated” generally refers to fields in the range of 3 to 4 milligauss. Because the significance of these levels is frequently misunderstood, further explanation is provided in Section 2.2.

[5] Statistical associations between two entities e.g. an association between exposure to an agent and a disease can be due to a variety of factors and should not be confused with a “cause and effect” or “causal” association, where it is established that exposure to the agent in question actually causes the disease. There are many examples of associations which are not causal, e.g. where both the agent of interest and the outcome are both linked to a third factor.

[6] Magnetic fields can be expressed in units of either milligauss (mG) or microteslas (μT), where 1mG = 0.1(μT).

This issue is addressed briefly in the EMF section of the ARPANSA website as follows:

> *"The average level of 0.4 μT referred to in the conclusion to the Doll report [Ref. 5] is not an exposure limit or safe level. This exposure level was arbitrarily selected to distinguish "exposed" and "unexposed" participants in epidemiological studies."*

2.3 World Health Organisation (WHO)

The most recent WHO review is Environmental Health Criteria 238 – Extremely Low Frequency Fields (Ref. 6), which was published in 2007. As well as presenting a comprehensive review of the EMF/health research literature, the document contains a health risk assessment and provides guidance on protective measures including "precautionary measures" (see Section 3 below).

In relation to childhood leukaemia, WHO says:

> *"on balance, the evidence is not strong enough to be considered causal, but sufficiently strong to remain a concern."*

In relation to other diseases, the document says

> *"A number of other diseases have been investigated for possible association with ELF magnetic field exposure. These include cancers in both children and adults, depression, suicide, reproductive dysfunction, developmental disorders, immunological modifications and neurological disease. The scientific evidence supporting a linkage between ELF magnetic fields and any of these diseases is much weaker than for childhood leukaemia and in some cases (for example, for cardiovascular disease or breast cancer) the evidence is sufficient to give confidence that magnetic fields do not cause the disease."*

In relation to Protective measures, the following is said:

> *"It is essential that exposure limits be implemented in order to protect against the established adverse effects of exposure to ELF electric and magnetic fields. These exposure limits should be based on a thorough examination of all the relevant scientific evidence.*
>
> *Only the acute effects have been established and there are two international exposure limit guidelines (ICNIRP, 1998a; IEEE, 2002) designed to protect against these effects.*
>
> *As well as these established acute effects, there are uncertainties about the existence of chronic effects, because of the limited evidence for a link between exposure to ELF magnetic fields and childhood leukaemia. Therefore 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."*

2.4 Health Standards

2.4.1 General

Until relatively recently, (see below) the relevant Australian health standard was the document called 'Interim Guidelines on Exposure to 50/60 Hz Electric and Magnetic Fields' (1989) (Ref. 7). 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. 8). 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 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.

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 (ARPANSA) is currently preparing a Standard to replace them (see below). In addition, the ICNIRP guidelines, upon which the NHMRC guidelines are based, have been reviewed twice (1993 and 1998) and the 24-hour exposure limits for the general public remain 1000 milligauss. A further review of the ICNIRP guidelines is currently in progress and a draft, retaining the 1000 milligauss limit, was recently circulated for comment.

2.4.2 International Health Standards

The World Health Organisation (Ref. 6) notes that:

> *"The best source of guidance for both exposure levels and the principles of scientific review are the international guidelines."*

In this context, it recognises two such guidelines. These are the ICNIRP guidelines (Ref. 8) - see 2.4.1 above) and the IEEE Standard C95.6 for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0–3 kHz (Ref. 9)

The IEEE standard defines exposure levels to protect against adverse effects in humans from exposure to electric and magnetic fields at frequencies from 0–3 kHz. As with the ICNIRP guidelines (Ref. 8), this standard was developed with respect to *established* mechanisms of biological effects in humans from electric and magnetic field exposures. It states:

> *"Established human mechanisms fall within the category of short-term effects. Such effects are understood in terms of recognized interaction mechanisms. Exposure limits defined in this standard are not based on the potential effects of long-term exposure because:*
> *a) There is not sufficient, reliable evidence to conclude that long-term exposures to electric and magnetic fields at levels found in communities or occupational environments are adverse to human health or cause a disease, including cancer.*
> *b) There is no confirmed mechanism that would provide a firm basis to predict adverse effects from low-level, long-term exposure."*

The Subcommittee responsible for the Standard noted:

> *"The Subcommittee will continue to evaluate new research and will revise this standard should the resolution of present uncertainties in the research literature identify a need to limit long-term exposures to values lower than the limits of this standard"*

In February, 2007, the IEEE's International Commission on Electromagnetic Safety reaffirmed the exposure limits in its 2002 Standard for a further 5 years.

2.4.3 Australian Draft Standard

As noted in 2.3.1 above, ARPANSA is currently preparing a Standard to replace the NHMRC Guidelines. In December, 2006, ARPANSA issued a Draft Standard on "Exposure Limits for Electric and Magnetic Fields (0Hz to 3kHz)" for public comment (Ref. 10). Before commenting on the "limits" themselves, it is important to understand that the fundamental limits ("Basic Restrictions") contained in the ARPANSA Draft, as well as other guidelines, relate to conditions within the human body. Because it is difficult to apply these limits in practice or to demonstrate compliance, the Draft also sets

"Reference Levels", which are conservatively based field levels, which are easier to apply and which effectively guarantee compliance with the "Basic Restrictions". It is common to cite these "Reference Levels" as the applicable limits.

The 2006 ARPANSA Draft Standard proposed a 24-hour exposure limit (Reference Level) for the general public of 1000 milligauss - i.e identical to both the previous (Australian) NHMRC Guidelines and the current (International) ICNIRP Guidelines. (It is understood that, as a result of submissions in response to the December, 2006 draft, the Australian Government Radiation Health Committee, at its meeting of 18th July, 2007, resolved, inter alia, to revise the magnetic field limit for the general public upwards to 3000 milligauss (Ref. 11)) .

In the Foreword to the ARPANSA Draft, the CEO of ARPANSA, Dr John Loy notes that:

> *"the incorporation of arbitrary additional safety factors beyond the limits of the Standard is not supported".*

As with IRPA and IEEE, in preparing the draft standard, the ARPANSA Working Group also undertook a review of the EMF/health literature as described below:

> *"The Working Group has especially sought and examined relevant scientific literature with a view to finding evidence that the ICNIRP (1998) exposure guidelines might need revision on grounds that exposure to levels within the limits could lead to adverse health effects.*
>
> *Data for effects of ELF/Static exposure on living organisms was evaluated by considering the evidence of health effects in humans, and the biological effects in humans and other organisms, as well as effects at a cellular level. In establishing the exposure limits the Working Group recognised the need to reconcile a number of differing expert opinions. The validity of scientific reports was evaluated by considering elements such as; the strength of evidence, reproducibility of effect, existence of an established relationship between occurrence of an effect and the magnitude of exposure (i.e. dose response), that the effect follows an understood mechanism, and the extent of peer review prior to publication. In many cases, not all relevant elements could be assessed.*
>
> *In particular, the Working Group has examined relevant scientific reviews (notably those of: Health Council of the Netherlands Report 2000; IEEE C95.6 Standard 2002; NRPB 0 - 300 GHz Review of the Scientific Evidence 2004; NIEHS EMF Rapid Working Group Report 1998; NIEHS Report (K Olden) 1999; NRPB Advisory Group on NIR report 2001; ICNIRP Epidemiology Review 2001, also Greenland et al. 2000; International Agency on Research into Cancer (IARC Vol 80 June 2002; California EMF Program: Policy Options June 2002) and reports on various case studies and focused on the recent literature reports subsequent to the development of the ICNIRP guidelines (i.e. post 2000) and has consulted with researchers and posed specific questions in their area of expertise".*

2.4.4 Comparison of Health Standards (General Public)

For ease of comparison, the general public limits stipulated by the various health standards are set out in Table 2.1 below.

Table 2.1 Comparison of various EMF Health Standards

	Australia			International	
	NHMRC Guidelines (24 hrs/day) (1989)	**ARPANSA Draft (2006)**	**ARPANSA Current Draft (2009)**	**ICNIRP Guidelines (1998)**	**IEEE Standard (2007)**
Magnetic Field (mG)	1000	1000	3000	1000	9040
Magnetic Field (Controlled Circumstance)	N/A	3000	N/A	N/A	N/A
Electric Field (kV/m)	5 kV/m	5 kV/m	5 kV/m	5 kV/m	5 kV/m (10 on ROW)
Electric Field (Controlled Circumstance)	N/A	10 kV/m	10 kV/m	N/A	N/A

3. Precautionary Measures

With regard to the potential health effects from magnetic fields, while compliance with the relevant guideline is important, it does not imply absolute safety. The possibility of health effects being associated with long-term exposure to relatively low EMF levels has been comprehensively studied over several decades worldwide and, while the possibility of adverse health effects remains, much has been learned and, as can be seen from the material presented in Section 2 above, there is a high degree of consensus among the relevant standard setting bodies to the effect that:

- There are established effects related to exposures much higher than normally encountered in the home or the workplace.
- These established effects are sufficiently well understood to enable the setting of scientifically-based protective limits.
- While there is some evidence of possible effects from much lower field levels, particularly magnetic fields, this evidence is insufficient to warrant the setting of protective limits and, in any case, could not provide a rational basis for the setting of such limits[7].

Since the late 1980s, many reviews of the scientific literature have been published by authoritative bodies, including the World Health Organisation (e.g. Ref. 6). There have also been a number of 'Inquiries' such as those in Australia by Sir Harry Gibbs in NSW (Ref. 12) and Professor Hedley Peach in Victoria (Ref. 13). These reviews and inquiries have consistently found that:

- Adverse health effects have not been established.
- The possibility remains open.
- 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 Institutes of Environmental and Health Sciences (Ref. 14) 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 World Health Organisation (Ref. 6) addresses the matter of precaution in these terms:

> *"Implementing other suitable precautionary procedures to reduce exposure is reasonable and warranted. However, electric power brings obvious health, social and economic benefits, and precautionary approaches should not compromise these benefits. Furthermore, given both the weakness of the evidence for a link between exposure to ELF magnetic fields and childhood leukaemia, and the limited impact on public health if there is a link, the benefits of exposure reduction on health are unclear. Thus the costs of precautionary measures should be very low."*

And:

[7] In order to enable rational health limits to be set, it is necessary to understand the following:

1. The mechanism of interaction between the agent under consideration and the human body which produces the health effect to be protected against.
2. The level of "dose" at which the agent produces the effect.

In the case of EMF, the evidence for a link between exposure to ELF magnetic fields and health effects is quite weak and no such mechanism has been established.

> ***"****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."*

In the Australian context, the (2006) Draft ARPANSA Standard (Ref. 10) addresses the matter of "prudent avoidance" in an Annex entitled *"A Public Health Precautionary Approach to ELF Fields".* The Annex states:

> *[Prudent avoidance] "does not imply setting exposure limits at an arbitrarily low level, and requiring that they be achieved regardless of cost, but rather adopting measures to reduce public exposure to ELF fields at modest cost."*

Section 5.7 of the Draft addresses "Protection of the General Public" and relevantly stipulates:

> *"Measures for the protection of the general public who may be exposed to ELF and/or static fields due to their proximity to high ELF and/or static sources must include the following: …… Minimising, as appropriate, ELF and/or static electric and magnetic field exposure, provided this can be readily achieved without undue inconvenience and at reasonable expense. Any such precautionary measures should follow good engineering and risk minimisation practice. ……………The incorporation of arbitrary additional prescriptive safety factors beyond the exposure limits of this Standard is not supported."*

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 such facilities 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 health benefit.

The practice of 'prudent avoidance' has been adopted by the (Australian) Energy Networks Association (ENA) and most Australian power utilities, including TransGrid, the owner of the 500kV transmission line proposed to be deviated under the current project.

Practical guidance on the implementation of "prudent avoidance" is available through the scientific literature e.g. Prudent Avoidance Guidelines for Power Frequency Magnetic Fields (Ref. 2).

4. Field Characterisation

4.1 Line loadings used for modelling

As noted in Section 1.7, magnetic fields vary with load current. During a typical day, the amount of load current in a transmission line 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. Loads also tend to grow slowly over time, due to population growth and other factors. The loads in major transmission lines can also be influenced by the need for inter regional transfer of power as dictated by the National Electricity Market. Accordingly, the magnetic fields from the proposed deviated section of line will vary over time, and also spatially, depending on the loading at the particular time.

In the health context, it is the various actual loadings on a line which are relevant, rather than its maximum capacity, which may only be required for very short periods, under emergency conditions, a few times over its service life. Accordingly, in characterising the magnetic fields, it is necessary to make practical assumptions regarding line loadings.

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, as noted below:

4.2 EMF modelling

Based on the available design and loading information provided by Umwelt, a series of typical field profiles have been calculated to provide an understanding of the electric and magnetic fields likely to be associated with the proposed line.

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 international practice.

Further, in order to demonstrate the validity of the modelling, EMF measurements were made under the existing line (mid-span between Towers 57 & 58) during a site inspection on 28th September, 2009. The line loadings at the time were obtained from TransGrid and the electric and magnetic field levels were calculated using these loadings. The calculated and measured results for both electric and magnetic fields are set out respectively in Table 4.1 and Figure 4.1 below.

Position	Measured Field (kV/m)	Calculated Field (kV/m)
8 m from centre NE side	3.4	3.3
At centre of line	2.5	2.5
8 m from centre SW side	3.2	3.3

Table 4.1: Measured vs Calculated Electric fields - 28 September, 2009

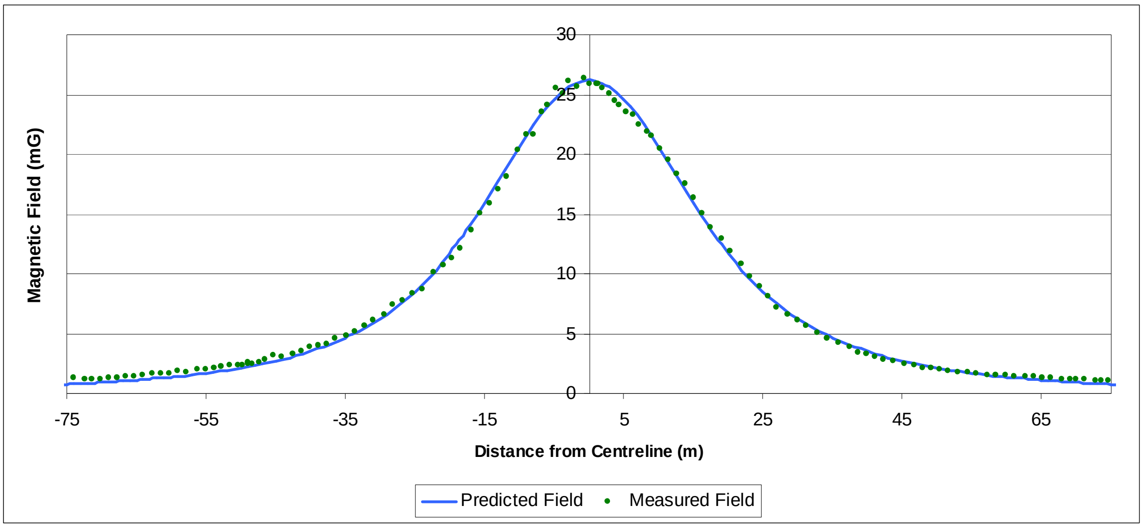

Figure 4.1: Measured vs Calculated Magnetic Fields - 28 September, 2009

It can be seen from Table 4.1 and Figure 4.1 that there is good practical agreement between the measured and modelled results.

Magnetic field levels in the vicinity of the proposed deviated route were also measured during our site inspection on 28th September, 2009. No measurable fields were detected. This was not surprising as no potential magnetic field sources were observed and there was no reason to suppose that any hidden (e.g. underground) sources were present either.

4.3 Modelled magnetic fields under normal operating conditions

The scenarios modelled were:

a) An initial condition (85th percentile) shortly after commissioning of the proposed deviation
b) An "ultimate" condition (85th percentile), possibly many years in the future, when the line load has reached its ultimate level.

The results of the modelling are shown graphically in Figure 4.2:

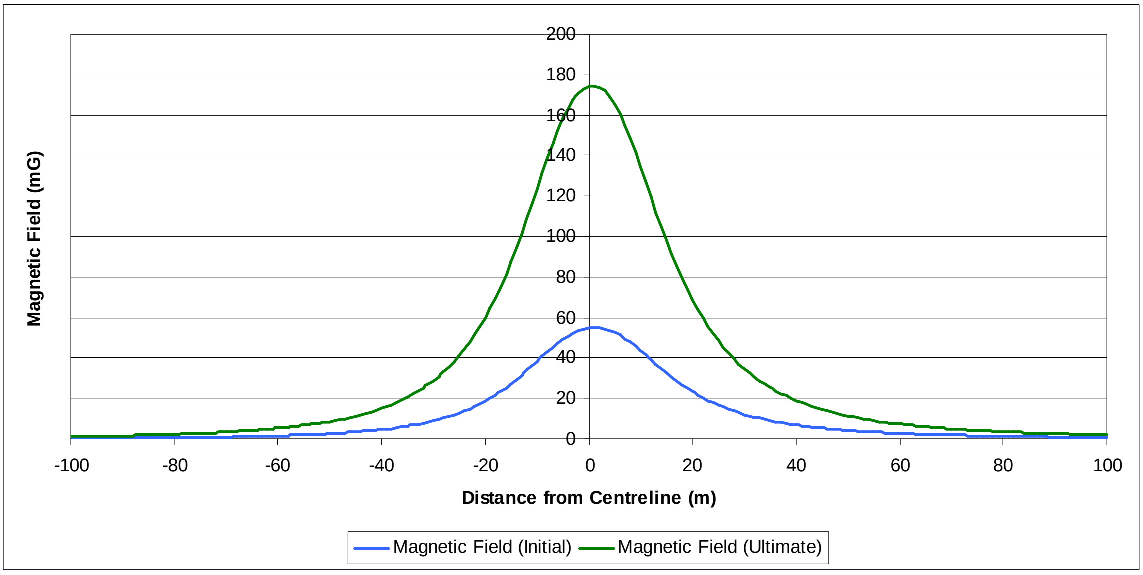

Figure 4.2: Calculated Magnetic Fields

The following observations are made in respect of the results shown in Figure 4.2:

- Shortly after commissioning of the deviation, the magnetic field directly under the line is predicted to be approximately 55 mG. This will decrease to 9 mG at the edge of the easement 35 metres away and 1mG within about 90 metres.

- At some future time, possibly many years hence, when the line has reached its ultimate loading, the magnetic field directly under the line is predicted to reach 175 mG. This will decrease to 25 mG at the edge of the easement 35 metres away and 1mG within about 130 metres.

In considering this matter, as indicated in Section 1.7, 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 an overhead line, are analogous to those we experience intermittently in everyday life.

4.4 Magnetic fields under extreme emergency conditions

While the field levels presented in Section 4.3 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 up to 5 times those shown in Figure 4.2 could be experienced in some places within the easement for short periods over the life of the line, with a similar increase in the distance from the line where fields could be detected. Such situations would rarely arise, if ever, and would not be expected to be of prolonged duration.

4.5 Modelled electric fields

The scenarios modelled were:

a) An initial condition (85th percentile) shortly after commissioning of the proposed deviation;
b) An "ultimate" condition (85th percentile), many years in the future, when the line load has reached its ultimate level;

The results of the modelling are shown graphically in Figure 4.3:

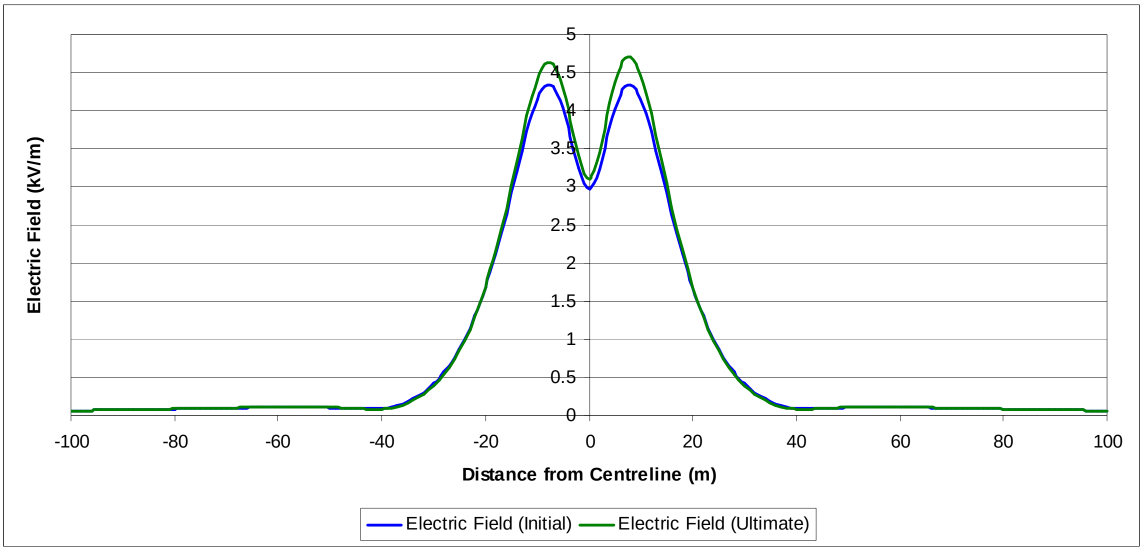

Figure 4.3: Calculated Electric Fields

The following observations are made in respect of the results of the electric field modelling:

As expected, there is little variation in the electric field with line loading. The minor increase in electric field strength directly under the line for the ultimate load case is due to additional sag in the overhead conductors, caused by the heating effect of the increased load current. Under the ultimate load condition, the electric field directly under the line is predicted to be approximately 4.7 kV/m. This will decrease to 0.17 kV/m at the edge of the easement 35 metres away and 0.06kV/m within 100 metres. For those sections of the route through vegetated areas, the electric fields beyond the edge of the clearing are likely to be very low, due to the effects of shielding.

The above levels within the easement area range from 3% to 94% of the relevant guideline level of 5kV/m and, in practice, are likely to be lower, due to the effects of shielding.

4.6 Electric fields under extreme emergency conditions

While the field levels presented in Section 4.5 are a conservative estimate of what is likely to exist under the line for the bulk of the time, in the broader context of an environmental assessment, it also appropriate to recognise the possibility that, fields up to approximately twice those presented in Figure 4.3 could be experienced for short periods in some places (in the vicinity of the low points in spans) over the life of the line. Such situations, which include an extreme "worst case" scenario (emergency conditions with one circuit out of service and the other operating at its maximum rated load) would rarely arise, if ever, and would not be expected to be of prolonged duration. Nevertheless, during such a period, the highest field levels would exceed the 5kV/m general guideline limit (see Table 2.1) but would not exceed the ARPANSA Draft Guideline limit for "controlled circumstances" [8] of 10kV/m. Should the ARPANSA Draft Guidelines become mandatory, it may become necessary for the requirements for "controlled circumstances" to be observed. However, it should be noted that, until the ARPANSA Guidelines are finally issued, it is not possible to be definitive as to the treatment of situations where electric field levels could be between 5kV/m and 10kV/m, particularly when such situations only occur under abnormal operating conditions. Furthermore, as this issue would affect the whole of the Bayswater to Mt Piper line, not just the part being deviated, it is suggested that the proposed course of action be determined in consultation with the owners of the line, TransGrid.

[8] Under the ARPANSA Draft Guidelines, circumstances where electric field levels exceed 5kV/m but do not exceed 10kV/m require signage at suitable entry points and the preparation and maintenance of explanatory documentation.

5. Review of Specific Matters

5.1 General

As well as undertaking an overall assessment, we have been asked to direct our attention to several specific matters as discussed in the following sub-sections:

5.2 Neighbouring Residences

The nearest residence to the proposed route is a farmhouse some 200 metres south of the proposed alignment, between towers 9 & 10.

At this distance, even under the ultimate loading scenario, the sustained magnetic fields will be well below 1 mG and of no consequence. The electric field from the line will be effectively zero.

The fields at other residences, which are further from the proposed alignment will be even less.

Accordingly, following commissioning of the line on the proposed realignment, to the extent that any power frequency fields exist at residences in the area, they are likely be due to sources other than the line.

5.3 Matters Raised by the Wybong Action Group

The submission of the "Wybong Action Group" (Appendix A) proposes an alternative route alignment on a number of grounds, including "effects of EMF on species such as mammals" and we have been asked to provide brief comment on the EMF aspects of that submission.

The Wybong Action Group (WAG) provides no clarification of the nature of the claimed effects of EMF, other than citing four references from the scientific literature (Appendix A, Ref.2.). The following observations are made regarding the four cited references:

- The first reference relates to the electromagnetic emissions from cellular phones and base stations and has no relevance to the power frequency EMFs associated with the subject transmission line.
- The second reference investigates possible effects on kestrels nesting in power frequency fields at the high end of what may be experienced directly under a 745,000 Volt transmission line. (300mG and 10kV/m). The authors reported a seasonal phase-shift of the melatonin profile in adult males and conclude that "*It is likely that the results are relevant to wild raptors nesting within EMFs*". Given the very high fields associated with the study and its claimed relevance to raptors rather than mammals, it appears to have little relevance to the claims advanced by WAG.
- The third reference involved exposure of a well known breed of laboratory rats to magnetic fields ranging from 355 to 516 milligauss, not at the constant 50Hz frequency of power systems, but with a frequency tuned with the local earth's magnetic field to provide a resonance condition for particular ions. The study was conducted in the context of understanding very specific mechanisms of biological interaction at the cellular level for possible therapeutic use and appears to have little relevance to the claims advanced by WAG.
- The fourth reference relates to radar installations and has no relevance to the power frequency EMFs associated with the subject transmission line.

Reference is also made to the creation of an "electromagnetic field barrier". There is no explanation of what the authors mean by such a barrier and we have been unable to find any scientific basis either for its existence or for its biological significance, if any.

5.4 Caves providing bat habitat

It is understood that a number of caves providing bat habitat have been identified in the project area. Although no specific claims have been advanced regarding EMF in relation to the caves, for the sake of completeness, the magnetic field levels predicted to exist at the various caves have been examined. Of the sites nominated, only one (AC38) is within reasonable proximity (67 metres) to the line. The predicted magnetic field at site AC38 is 1.2mG initially, increasing to 4mG over the life of the line. The fields at the remainder of the sites, which range from 293 metres up to almost 2 km from the line, are predicted to be either very low or negligible.

Due to the effects of distance and the shielding effect of the terrain and vegetation, the electric field within all caves is expected to be virtually zero.

6. 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.

Due to the line deviation's relatively remote location away from frequented areas and the low likelihood of any persons spending prolonged periods within the zone of its electric and magnetic fields, It is considered that no additional precautionary measures are warranted. Nevertheless, it is noted that the line design uses a compact geometry and the phases have been configured to afford maximum mutual field cancellation, both of which features are consistent with the notion of prudent avoidance.

7. Conclusions

The transmission line electric and magnetic fields likely to be associated with the proposed Mangoola Coal 500kV Line Deviation Project have been assessed on the basis of the information currently available. The findings of the assessment are:

- Except in the vicinity of the connection points to the existing line, there are currently no detectable electric and magnetic fields along the proposed route.
- The proposed relocated line will be of similar construction to the existing line and will be subject to an identical future loading regime. Accordingly, the electric and magnetic fields produced by the proposed relocated line will be virtually identical to those produced by the existing line.
- Shortly after commissioning of the deviation, the magnetic field directly under the line is predicted to be approximately 55 mG. This will decrease to 9 mG at the edge of the easement 35 metres away and to 1mG within about 90 metres.
- At some future time, possibly many years hence, when the line has reached its ultimate loading, the magnetic field directly under the line is predicted to reach 175 mG. This will decrease to 25 mG at the edge of the easement 35 metres away and to 1mG within about 130 metres.
- Even directly underneath the line, the magnetic fields will normally be less than 20% of the relevant health guideline and will decrease quite rapidly as one moves away from it.
- It is possible that higher magnetic fields could be experienced in some places within the easement for short periods over the life of the line, with a corresponding increase in the distance from the line where fields could be detected. Such situations would rarely arise, if ever, and would not be expected to be of prolonged duration.
- There is little variation in the electric field with line loading. Under the ultimate load condition, the electric field directly under the line is predicted to be approximately 4.7 kV/m. This will decrease to 0.17 kV/m at the edge of the easement 35 metres away and 0.06kV/m within 100 metres.
- For those sections of the route through vegetated areas, the electric fields beyond the edge of the clearing are likely to be very low, due to the effects of shielding.
- The above levels within the easement area range from 3% to 94% of the relevant guideline level of 5kV/m and, in practice, are likely to be even lower, due to the effects of shielding.
- It is possible that electric fields up to approximately twice those noted above could be experienced for short periods in some places (in the vicinity of the low points in spans) over the life of the line. Such situations, which include an extreme "worst case" scenario (emergency conditions with one circuit out of service and the other operating at its maximum rated load) would rarely arise, if ever, and would not be expected to be of prolonged duration. Nevertheless, during such a period, the highest field levels could exceed the 5kV/m general guideline limit (see Table 2.1) but would not exceed the ARPANSA Draft Guideline limit of 10kV per metre for "controlled circumstances". Should the ARPANSA Draft Guidelines become mandatory, it would be necessary for the requirements for "controlled circumstances" to be observed.
- The nearest residence to the proposed route is a farmhouse some 200 metres south of the proposed alignment, between towers 9 & 10. At this distance, even under the ultimate loading scenario, the sustained magnetic fields will be well below 1 mG and of no consequence. The electric field from the line will be effectively zero.
- The line's contribution to the fields at other residences, which are further from the proposed alignment, will be even less.
- To the extent that any power frequency fields exist at residences in the area following commissioning of the line on the proposed realignment, they are likely be due to sources other than the line.
- Only one (AC38) of the caves providing bat habitat as nominated for detailed study is within reasonable proximity (67 metres) to the line. The predicted magnetic field at site AC38 is 1.2mG initially, increasing to 4mG over the life of the line.

- The fields at the remainder of the sites, which range from 293 metres up to almost 2 km from the line, are predicted to be either very low or negligible.
- Due to the effects of distance and the shielding effect of the terrain and vegetation, the electric field within all caves is expected to be virtually zero.
- In the context of the matters raised by the Wybong Action Group, we see no reason for concern regarding the influence of the EMFs associated with the proposed deviation on native fauna in the area.

8. References

1. Electric and Magnetic Fields and Your Health: National Radiation Laboratory, New Zealand Ministry of Health, 2008.
2. Prudent avoidance guidelines for power frequency magnetic fields. Nuttall K, Flanagan PJ & Melik G: Radiation Protection in Australasia, vol. 16, no. 3, pp. 2-12: ARPS 1999.
3. Electric and Magnetic Fields: What we know: Energy Networks Association, June 2006.
4. 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: World Health Organisation, International Agency for Research on Cancer, Lyon, France, 2001.
5. ELF Electromagnetic Fields and the Risk of Cancer, Report of an Advisory Group on Non-ionising Radiation, Chairman, Sir Richard Doll: National Radiological Protection Board, (UK), NRPB Vol 12 No.1, 2001.
6. Environmental Health Criteria 238 – Extremely Low Frequency Fields: World Health Organisation, 2007.
7. Interim Guidelines on Limits of Exposure to 50/60 Hz Electrical and Magnetic Fields: National Health and Medical Research Council: Radiation Health Series No. 30,1989.
8. Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300GHz): International Commission on Non-Ionising Radiation Protection (1998): Health Physics, April 1999, Volume 74, Number 4; pp 4494-5528.
9. IEEE Standard C95.6: Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0–3 kHz : IEEE, 2002.
10. Exposure Limits for Electric & Magnetic Fields – 0 Hz to 3 kHz: ARPANSA - Public Consultation Draft, 7 December 2006.
11. Meeting minutes: Australian Government Radiation Health Committee, 18 July 2007 – Agenda Item 2.4.
12. Inquiry into Community Needs and High Voltage Transmission Line Development, Gibbs, Sir Harry, Chairman: Submission to the NSW Government, September, 1990.
13. Report of the Panel on Electromagnetic Fields and Health to the Victorian Government (Peach Panel Report). Peach HG, Bonwick WJ and Wyse T. Melbourne, Victoria: September, 1992.

14 NIEHS report on health effects from exposure to power-line frequency electric and magnetic fields: National Institute of Environmental Health Sciences, National Institutes of Health, (USA), NIH Publication No. 99-4493, 1999.

Appendix A

Submission by Wybong Action Group

Wybong Action Group Incorporated

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WAG

18 July 2009

Mr Grant Farrar
Operations Manager
Xstrata Mangoola P/L
Muswellbrook NSW 2333

Dear Mr Farrar,
At the Denman Community Information Session, mid April 2009, regarding the Proposal to relocate the 500kV Transmission line Wybong Action Group provided initial feedback regarding negative outcomes associated with the proposed route outlined. This feedback was expanded upon with publication of a draft alternate route on the Wybong Action Group website (www.wag.org.au/mod2) in May 2009 and advice to Xstrata Mangoola P/L and Muswellbrook Shire Council Environment Committee of the Alternate Route Proposal on June 3, 2009.

The attached "Alternate North-East 500kV Transmission Line Relocation Proposal" is based on:

- the primary goal objective and requirement of the Anvil Hill Project by the Director-General of the NSW Department of Planning for "no net loss of flora and fauna values in the medium to long term"[1],
- ESD Principles,
- Appendix 9, Ecological Assessment, Anvil Hill Environmental Assessment August 2006,
- Appendix13, Aboriginal Archaeological Assessment, Anvil Hill Environmental Assessment August 2006,
- Appendix 3, Anvil Hill Coal Project, Independent Hearing and Assessment Panel, Flora & Fauna
- Aboriginal Cultural Heritage Management Plan, Xstrata Mangoola P/L, July 2008
- relevant requirements of:
  - Muswellbrook LEP 1985,
  - Hunter REP 1989,
  - Muswellbrook LEP 2008, Part 1,2 & 3,
  - Section 8, Rural Development Control Plan, Muswellbrook DCP 2008, and
- Effects of EMF on species such as mammals[2],
- Community Input and Feedback received by Wybong Action Group.

The resultant "Alternate North-East 500kV Transmission Line Relocation Route":

- aims to better fulfil the Director-Generals requirement of "no net loss of flora and fauna values in the medium to long term" by avoiding Transmission Line Relocation induced clearing of, and encroachment of EMF fields into pre-European Woodland, Rock Shelters and Escarpment of recognised High Habitat Value previously identified by Peake, HCRCMA, Umwelt & DEC for protection in perpetuity[3] and as *Biodiversity Offset* and *Corridor* in mitigation[4] of the otherwise severe impacts on flora and fauna of the unmitigated Project, acknowledging also that "there are NO reserves on the floor of the Hunter Valley that protect vegetation similar to that occurring on the Permian sediments of the (mine) study area"[5]
- avoids 500 kV Transmission Line encroachment on areas of identified *Aboriginal Cultural Heritage Value*[6] and *High Scenic Value*[7],
- is <u>30% shorter,</u> and
- less costly to construct and maintain.

Documentation consisting of an amended Anvil Hill EA, Maps and Text will be provided Xstrata Mangoola in the near term to validate the reasons for the proposal, promotion and selection by the Wybong Community of the "Alternate North-East 500kV Transmission Line Relocation Route."

The "Alternate North-East 500kV Transmission Line Relocation Route" is proposed to Xstrata Mangoola P/L by Wybong Action Group for, with and on behalf of the Wybong Community for consideration in good faith within the 500 kV Transmission Relocation Modification Proposal and any associated Environmental Assessment.

Wybong Action Group believe the adoption by Xstrata Mangoola P/L of a route, such as the "Alternate North-East 500kV Transmission Line Relocation Route", provides the Community and Xstrata Mangoola a superior environmental, ecological, aboriginal heritage and cost outcome, provides the Director-General of the Department of Planning a less harmful (than otherwise) impact on flora and fauna values in the medium to long term and is to the benefit of all concerned.

We recommend the attached "Alternate North-East 500kV Transmission Line Relocation Route" for your consideration,

Sincerely,

John Shewan

John Shewan
President
Wybong Action Group.

Attached: Alternate North-East 500kV Transmission Line Relocation Route Summary

cc. Phil Jones, Major Projects Assessment, NSW Department of Planning
Mayor Martin Rush, Muswellbrook Shire Council

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[1] p5, Appendix2, Authorities Correspondence, Anvil Hill Environmental Assessment, August 2006

[2] The Precautionary Principle and Risk Perception: Experimental Studies in the EMF Area, Peter M. Wiedemann and Holger Schütz, Research Centre Jülich, Programme Group MUT (Humans, Environment, Technology), Jülich, Germany.
Effects of Electromagnetic Fields on Photophasic Circulating Melatonin Levels in American Kestrels, Kimberly Jan Fernie,1,2 David Michael Bird,1 and Denis Petitclerc3, 1Natural Resource Sciences, McGill University, Quebec, Quebec, Canada; 2Toxicology Centre and Biology, University of Saskatchewan, Saskatoon, Saskatchewan, Canada; 3Agriculture and Agri-Food Canada, Lennoxville, Quebec, Canada
Effects of electromagnetic fields of low frequency and low intensity on rat metabolism, Gabriele Gerardi1, Antonella De Ninno*2, Marco Prosdocimi3, Vanni Ferrari1, Filippo Barbaro3, Sandro Mazzariol4, Daniele Bernardini1 and Getullio Talpo3, 1Department of Veterinary Clinical Sciences, University of Padua, 2ENEA, CR Frascati, Dept. FIM, 3PROMETEO S.r.l., Via Marostica 2, 35100, Padua, Italy and 4Department of Public Health, Comparative Pathology, and Veterinary Hygiene, University of Padua, Italy
Bats Avoid Radar Installations: Could Electromagnetic Fields Deter Bats from Colliding with Wind Turbines? Barry Nicholls, Paul A. Racey, School of Biological Sciences, University of Aberdeen, Aberdeen, United Kingdom

[3] p37, 201, Appendix 9a, Ecological Assessment, Anvil Hill Environmental Assessment, August 2006
p7, 26, 31Appendix 3, Anvil Hill Coal Project, Independent Hearing and Assessment Panel, Flora & Fauna, Jan 2007

[4] p164, 185, 220, Appendix 9a, Ecological Assessment, Anvil Hill Environmental Assessment, August 2006
p17, Appendix 3, Anvil Hill Coal Project, Independent Hearing and Assessment Panel, Flora & Fauna, Jan 2007

[5] p28, Appendix 9a, Ecological Assessment, Anvil Hill Environmental Assessment, August 2006

[6] Fig 9.1, Appendix13a, Aboriginal Archaeological Assessment, Anvil Hill Environmental Assessment August 2006,
Fig 7.1, Aboriginal Cultural Heritage Management Plan, Xstrata Mangoola P/L, July 2008

[7] Muswellbrook LEP 1985, Hunter REP 1989, Muswellbrook LEP 2008, Part 1,2 & 3, Section 8, Rural Development Control Plan, Muswellbrook DCP 2008, Appendix 15, Visual Assessment, Anvil Hill Environmental Assessment August 2006