Sydney South - Revesby 132kV Underground Feeders

Magnetic Field Assessment

Ausgrid

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Contents

Appendices

Figures

Tables

1 Background and Scope

1.1 Background

It is understood that Ausgrid is proposing to construct a 132kV underground cable feeder connecting its Revesby substation to TransGrid's Sydney South Bulk Supply Point at Picnic Point and is currently preparing a Review of Environmental Factors (REF) report. In connection with that report, Ausgrid has engaged Aurecon to undertake an assessment of the power frequency magnetic fields likely to be associated with the proposed feeder. The proposed cable route is shown in Figure 1.

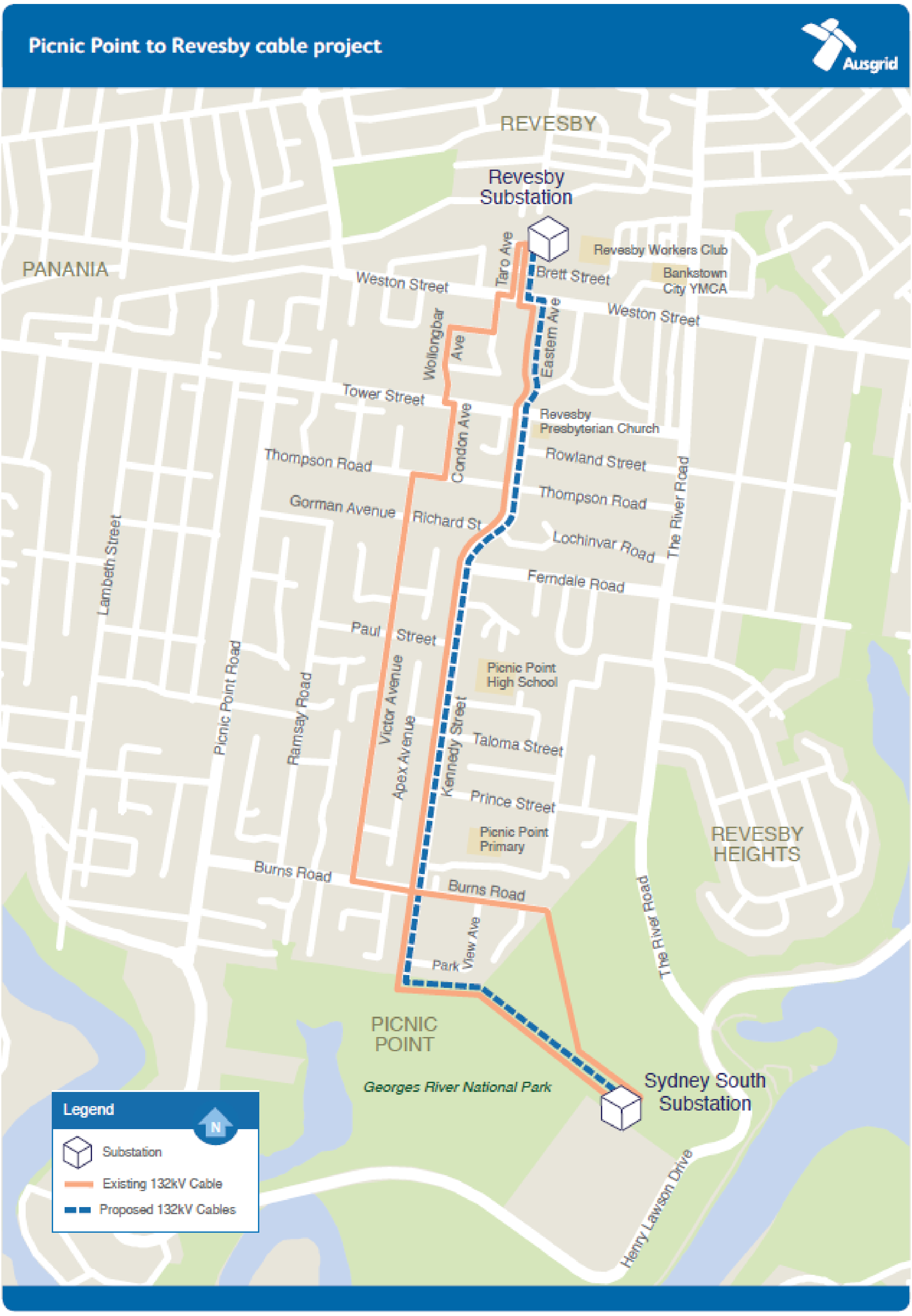

Figure 1 Proposed underground cable route Sydney South – Revesby

1.2 Scope

The scope of Aurecon's assignment covers the following:

- Provide a brief description of the EMF health issue
- Calculate the time weighted magnetic fields likely to be associated with the proposed cables at 1m above ground level and extending up to 25m on each side of the trench centreline as follows:
  - For a typical cable run (representing the bulk of the route)
  - For a typical (flat configuration) joint bay
  - For a typical "narrow" joint bay
- Assess the compliance of the anticipated field levels with the relevant national and international EMF guidelines
- Assess the compliance of the proposed line with precautionary and prudent avoidance principles as defined in the relevant guidelines
- Prepare an EMF assessment report to inform the overall environmental assessment

This report addresses the above scope.

1.3 Structure of Report

Section 2 provides background information on the EMF and human health issue and Section 3 documents the relevant information supplied by Ausgrid. Section 4 contains predictions of the EMF levels associated with the proposed works. Section 5 addresses the proposed design in the context of compliance with EMF guidelines and precautionary/prudent avoidance principles. Conclusions are presented in Section 6. Further information regarding electric and magnetic fields and human health is contained in Appendices A to D.

2 Overview of Electric and Magnetic Fields

2.1 General Description

Whenever electrical equipment is in service, it produces an electric field and a magnetic field. The electric field[1] 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.

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

Further detail on electric and magnetic fields can be found in Appendix A.

2.2 Electric and Magnetic Field/Health Issue

The possibility of adverse health effects due to the EMFs associated with electrical equipment has been the subject of extensive research throughout the world for more than 40 years. To date, while adverse health effects have not been established, the possibility that they may exist cannot be ruled out. Further discussion of the EMF/health issue can be found in Appendix B.

2.3 Health Guidelines

Since late 2015, the relevant Australian regulator, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), has adopted the international guideline published by the International Commission on Non-Ionising Radiation Protection (ICNIRP) in 2010. Details of the current guideline “Reference Levels” for electric and magnetic field exposure can be found in Appendix C. These “Reference Levels” have been used as the principal assessment criteria for this assignment and are reproduced in Table 1 below. The criteria are independent of duration of exposure.

Table 1 ICNIRP Guideline Reference Levels (General Public)

Parameter	Reference Level
Electric Field	5,000 Volts per metre (V/m)
Magnetic Field	2,000 milliGauss (mG)

2.4 Prudent Avoidance

Given the inconclusive nature of the science regarding EMF and human health, it is widely considered that a prudent approach is the most appropriate response under the circumstances. Under this approach, subject to modest cost and reasonable practicality, the owners of electric power infrastructure should design their facilities to reduce the intensity of the fields they generate in frequented areas. Further discussion on this subject can be found in Appendix D.

[1] *The electric field associated with underground cables is contained within the cable and, hence, there is no external electric field.*

3 Input Information and Aspects of Field Predictions

3.1 Information Provided by Ausgrid

The input data required for the calculations on which this assessment is based has been supplied by Ausgrid and is summarised below.

- Details of the proposed route.
- Drawings showing the relative locations and electrical phasing of the individual cables comprising the proposed feeders. (refer Figure 2, Figure 3 and Figure 4)
- Drawings showing the proposed cable arrangements for the joint bays along the route.
- Load duration curves for the proposed cables, together with an instruction to model the ultimate winter load scenario. This resulted in a load current of 290 Amps per phase.

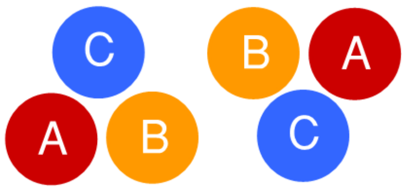

Figure 2 Double Circuit Inverted Trefoil Phasing Arrangement

Figure 3 Double Circuit Joint Bay Phasing Arrangement

Figure 4 Double Circuit Staggered Joint Bay Phasing Arrangement

3.2 Assumptions and Exclusions for Modelling

As instructed by Ausgrid, Aurecon has modelled the magnetic field levels associated with the proposed 132kV underground cables only. The characterisation of the field levels associated with other existing sources which may be found along the routes of the proposed new feeders is beyond the scope of this report.

3.3 Magnetic Field Dependence on Load

The magnetic fields from electrical equipment depend on the loadings at that particular time. Accordingly, in characterising the magnetic fields from an item of electricity infrastructure, it is necessary to make practical assumptions regarding the loadings on the equipment at these sites.

During a typical day, the amount of load current passing through a sub transmission network 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 either summer or winter. Loads may also grow slowly over time, due to a wide variety of factors. It is these various actual loadings which are relevant in the health context, rather than the maximum capacity of an electrical asset, which may only be required for very short periods, under emergency conditions, a few times over its service life.

Given that the epidemiological associations which underpin community interest regarding magnetic fields tend to relate to elevated "*time-weighted average*" magnetic fields, it is logical to select the time weighted average during the most heavily loaded period of the year, in this case winter. The magnetic fields derived under these conditions are the most appropriate for consideration in the context of the magnetic field/health literature, rather than the maximum capacity of the feeder, which may only be required for very short periods, under emergency conditions, a few times over its service life.

It should be noted that, following completion of the proposal, the magnetic fields at any particular time would be dependent on the actual loadings rather than those used for calculation purposes.

4 Characterisation of the Magnetic Field Contribution of the Proposed Works

Based on the available design and loading information, provided by Ausgrid, the magnetic field contribution expected from the proposal has been modelled using established in-house software which has been extensively validated against other comparable software.

Since the same trench and joint bay configurations will be used throughout the route, Aurecon has modelled a typical double circuit section and the two typical joint bay configurations and calculated the magnetic field contribution associated with each. The results of the modelling are presented in Sections 4.1 and 4.2.

The calculated magnetic field contributions are presented as profiles extending 25m either side of the centreline of the cable trench. The magnetic fields have been calculated at a height of 1 m above ground level in accordance with international practice. All calculations have been undertaken using the time-weighted average forecast loads provided by Ausgrid, as noted in Section 3.1. As previously noted, following completion of the proposed works, the magnetic fields would be dependent on the actual loading rather than that used for calculation purposes.

4.1 Double Circuit Trench Configuration

The proposed double circuit trench configuration is shown in Figure 5.

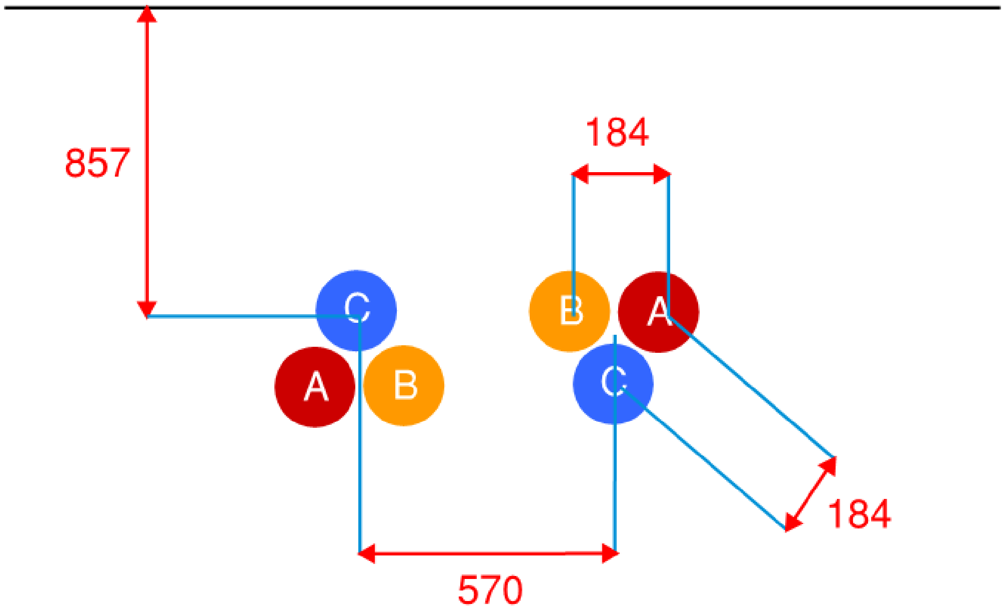

Figure 5 Double Circuit Trench Configuration

The magnetic field contribution of the proposed feeders in the proposed trench configuration is shown in Figure 6.

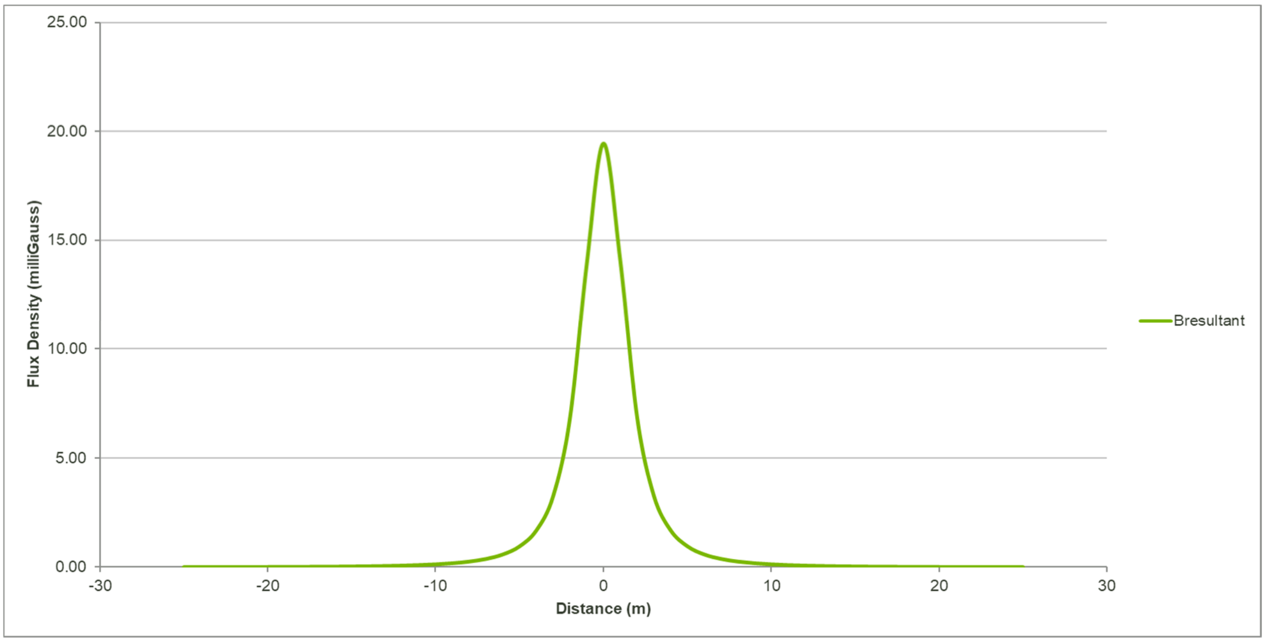

Figure 6 Predicted Magnetic Field Contribution of the Proposed Sydney South to Revesby Cables: Double Circuit Trench Configuration

It can be seen that the predicted time-weighted-average magnetic field contribution directly above the cable trench is 19.4mG. At a distance of 10 metres from the trench centreline, the predicted field decreases to a negligible level.

4.2 Typical Joint Bay Configuration

The detail of the double circuit typical joint bay configuration is shown in Figure 7.

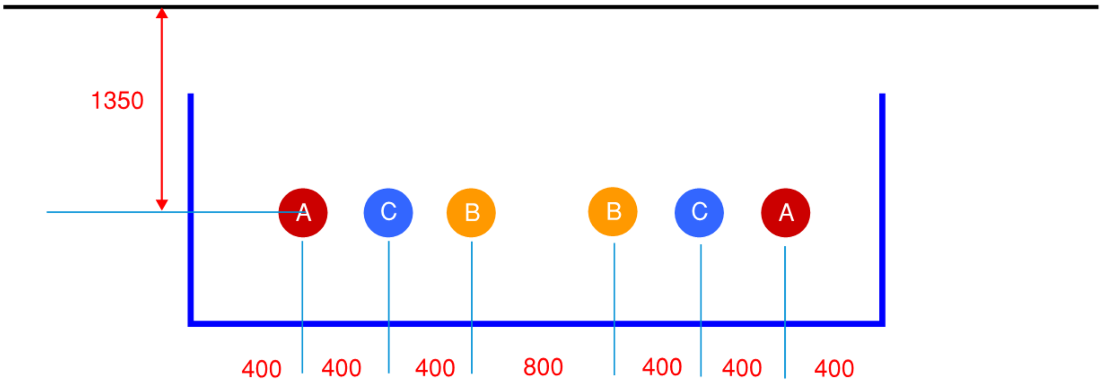

Figure 7 Double Circuit Typical Joint Bay Configuration

The depth below ground of the centres of the cables and coffin boxes in the flat joint bay arrangement is 1350mm.

The magnetic field contribution of the proposed feeders directly above a typical joint bay is shown in Figure 8

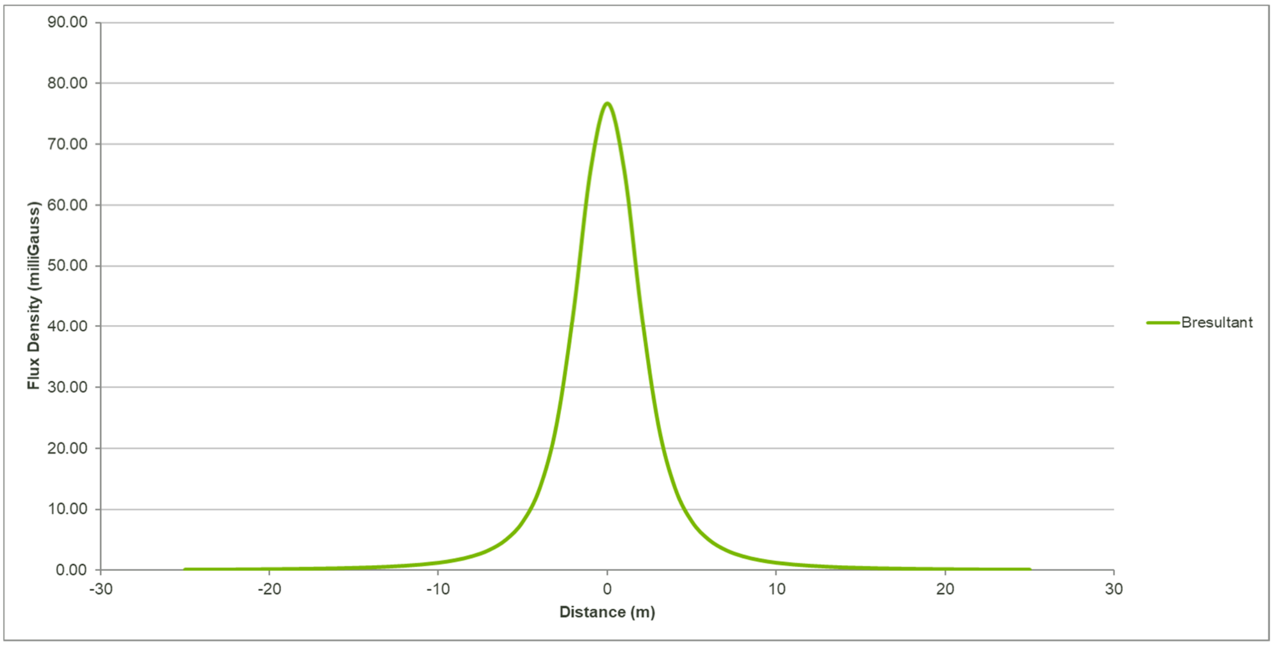

Figure 8 Predicted Magnetic Field Contribution above a Typical Joint Bay Configuration

It can be seen that the peak field contribution above the joint bay under the time-weighted average loading condition is predicted to be 76.7mG, decreasing to less than 1mG within 10m.

4.3 Staggered Joint Bay Configuration

The detail of the staggered joint bay configuration is shown in Figure 9

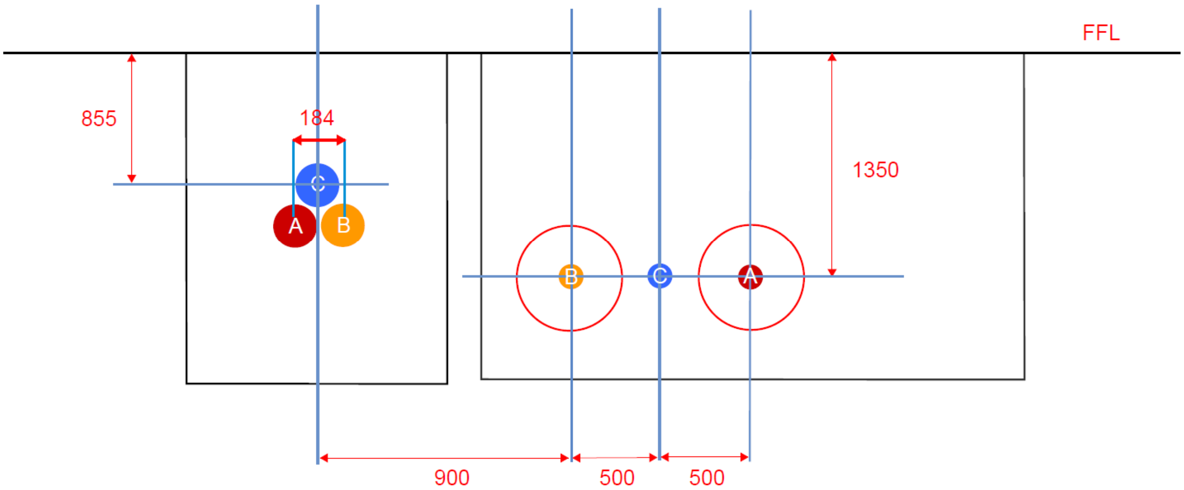

Figure 9 Staggered Joint Bay Configuration

The depth below ground of the centres of the coffin boxes in the flat joint bay arrangement has been taken as 1350 mm.

The magnetic field contribution of the proposed feeders directly above a typical staggered joint bay is shown in Figure 10.

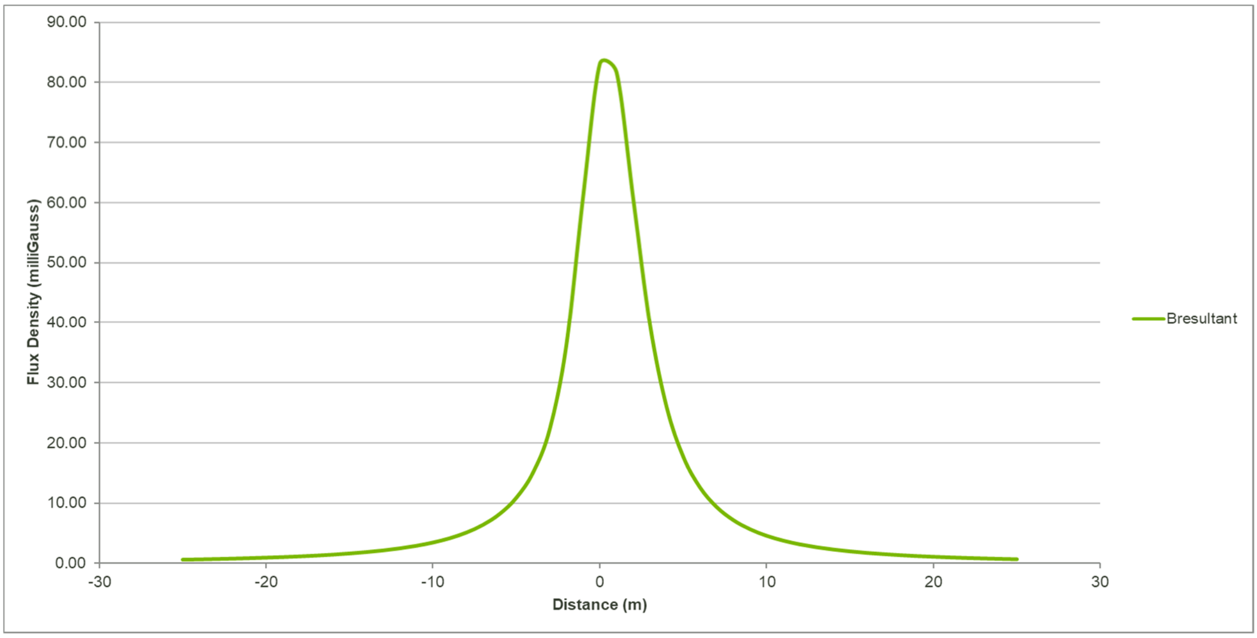

Figure 10 Predicted Magnetic Field Contribution above a typical staggered Joint Bay Configuration

It can be seen that the peak field contribution above the staggered joint bay under time-weighted average loading conditions is predicted to be 83.1mG, decreasing to less than 5mG at a distance of 10m.

4.4 Summary of Magnetic Field Results

As outlined in Sections 4.1, 4.2 and 4.3, the highest predicted magnetic field contribution of the proposed Sydney South to Revesby feeders under the ultimate time-weighted average loading conditions is 19.4mG in the trench sections. This field will occur directly above the cables themselves and the configuration is used for the majority of the route. In highly localised areas above the joint bays, the field contribution is predicted to reach up to 77mG at the typical joint bays and 83mG above the staggered joint bays. At a distance of 10m from the centreline of the cables generally, the field contributions are predicted to reduce to a negligible level. At a distance of 10m from the centreline of the typical and staggered joint bays, the field contributions are predicted to reduce to less than 5mG and a few mG respectively.

4.5 Magnetic Fields Experienced Intermittently

While the field levels presented in Sections 4.1 to 4.3 are the most relevant in the health context, in the broader context of an environmental assessment, it is also appropriate to recognise that, in the longer term, under emergency conditions, magnetic field contributions of up to 5 times those presented above could be experienced in some places for short periods over the life of the feeders. Such situations are only expected to arise rarely, if at all, and if so, would not be expected to be of prolonged duration.

4.6 Magnetic Fields Experienced in Everyday Life

In considering the fact that the predicted field levels associated with the proposed underground feeders are quite localised and will vary, depending on the actual loadings of the feeders, it is important to recognise that life in the modern world involves moving from one source of magnetic fields to another. To put the magnitude of the predicted magnetic fields into perspective, it is worth considering the range of typical magnetic field levels associated with common household appliances at normal user distances and utility infrastructure, shown in Table 4.1. This table is sourced from the Energy Networks Association[2]

[2] *Electric and Magnetic Fields: What We Know. Energy Networks Association, June 2006.*

Table 2 Magnetic Field Levels Associated with Appliances and Utility Infrastructure

Appliances	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
Under Distribution Line	10	2-20
Under Transmission Line	20	10-200
Transmission Line – Edge of Easement	10	2-50

From the above range of field levels, it can be seen that the magnetic field contribution of the proposed feeders typically falls within the range of those normally associated with power lines and some appliances. At a distance of 10m from both the trench and joint bay centrelines, the magnetic field contribution of these feeders is well within the range normally encountered in everyday life.

5 Compliance with EMF Standards and Prudent Avoidance / Precautionary Principles

5.1 Compliance with Health Standards

Magnetic Fields

The highest predicted time-weighted average magnetic field contribution directly above the cable trench is 19.4mG This is less than 1% of the relevant ICNIRP general public exposure guideline level of 2000mG. At a distance of 10m from the centreline, the field contribution is predicted to reduce to a negligible level.

In highly localised areas above the joint bays, the highest predicted time-weighted average magnetic field contribution directly above a staggered joint bay is 83mG. This is less than 5% of the relevant general public exposure guideline level. At a distance of 10m from the joint bays, the field contribution is predicted to reduce to less than 5mG, which is less than 0.3% of the relevant general public exposure guideline level.

Emergency Conditions

As noted in Section 4.5, it is also appropriate to recognise that higher magnetic field contributions could be experienced in some places for short periods under emergency conditions. Even under these conditions, the highest of these field contributions is still predicted to be generally less than 5% of the relevant ICNIRP general public exposure guideline level and less than 20% in the localised areas above the joint bays. Such situations are only expected to arise rarely, if at all, and if so, would not be expected to be of prolonged duration.

Electric Fields

Being of underground construction and contained within cables, the proposed feeders will not produce external electric fields.

5.2 Assessment against Prudent Avoidance Principles

As noted in Section 2.3, given the inconclusive nature of the science, it is considered that a prudent/precautionary approach continues to be the most appropriate response in the circumstances. Under this approach, 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, provided this can be readily achieved without undue inconvenience and at reasonable expense, and are consistent with good engineering and risk minimisation practice.

It is understood that, along with other members of ENA, Ausgrid has adopted the policy of prudent avoidance and there is clear evidence that it is applying it to this project. In this context, Ausgrid, over the course of the project, has:

- Openly shared information regarding the EMF/health issue and the proposed underground cables;
- Where practical, sited the electrical infrastructure in road reserves, away from residential property boundaries, so that the magnetic field contribution at and beyond them will be lower;
- Adopted an underground cable concept rather than less expensive overhead lines;
- Used an innovative double circuit alternative trefoil configuration, which increases the rate at which the magnetic field levels drop off with increasing distance from the source and results in lower field levels at all distances beyond 1 metre from the trench centreline;
- Adopted phasing arrangements for both the double circuit feeders and the joint bays which, in conjunction with the revised trench configuration, result in lower magnetic fields.

While it cannot be said with certainty that any of these measures are beneficial in terms of human health, they represent a fine example of prudent avoidance being applied. Given the relatively low magnetic field levels predicted in frequented areas, further field reduction measures are unlikely to be justified in the name of prudent avoidance.

6 Conclusions

The contribution of the proposed Sydney South to Revesby underground feeder to the electric and magnetic fields along the proposed route has been modelled and assessed on the basis of the information currently available. The predicted field contributions have been assessed against the relevant health guidelines and the principles of prudent avoidance. In summary, our findings are as follows.

Magnetic Fields

- The highest predicted time-weighted average magnetic field contribution above the cables is 19.4mG directly above the centre of the trench. This is less than 1% of the relevant ICNIRP general public exposure guideline level of 2000mG. At a distance of 10m from the centreline, the field contribution is predicted to reduce to a negligible level.
- In highly localised areas above the joint bays, the field contribution is predicted to reach up to 77mG at the typical joint bays and 83mG above the staggered joint bays. These values are both less than 5% of the relevant ICNIRP general public exposure guideline level of 2000mG. At a distance of 10m from the centreline of the typical and staggered joint bays, the field contributions are predicted to reduce to less than 1mG and a few mG respectively, in each case less than 1% of the guideline level.

Electric Fields

- Being of underground cable construction, the proposed feeders will not produce external electric fields.

Prudent Avoidance Measures

Over the course of the project, consistent with the notion of prudent avoidance, Ausgrid has taken the following measures:

- Openly shared information regarding the EMF/health issue and the proposed underground cables;
- Where practical, sited the electrical infrastructure in road reserves, away from residential property boundaries, so that the magnetic field contribution at and beyond them will be lower;
- Adopted an underground cable concept rather than less expensive overhead lines;
- Used an innovative double circuit alternative trefoil configuration, which increases the rate at which the magnetic field levels drop off with increasing distance from the source and results in lower field levels at all distances beyond 1 metre from the trench centreline;
- Adopted phasing arrangements for both the double circuit feeders and the joint bays which, in conjunction with the revised trench configuration, result in lower magnetic fields.

While it cannot be said with certainty that any of these measures are beneficial in terms of human health, they represent a fine example of prudent avoidance being applied. Given the relatively low magnetic field levels predicted in frequented areas, further field reduction measures are unlikely to be justified in the name of prudent avoidance.

Appendix A

General Description of Electric and Magnetic Fields

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

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

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

- The total electric 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

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

Alternating electric and magnetic fields are produced by any electric wiring or equipment carrying alternating current (AC). This current does not flow steadily in one direction, but oscillates backwards and forwards at a frequency[3] of 50Hz and hence the fields produced by AC systems oscillate at the same frequency. This frequency falls into a range referred to as **extremely low frequency** (ELF), so the electric and magnetic fields are referred to as ELF fields.

Electromagnetic Radiation

It is not uncommon for the 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 magnetic waves which oscillate (vibrate) in phase with, and perpendicular to, each other. This is in contrast to EMF, where the electric and magnetic components are essentially independent of one another.

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

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

visible light[4], 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 A-2) as follows:

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

References

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

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

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

Appendix B
Overview of EMF Health Issue

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

Extremely Low Frequency (ELF) Fields

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

While EMFs involve both electric and magnetic components, electric fields are relatively constant over time, are readily shielded and, in the health context, are generally no longer associated with the same level of interest as magnetic fields. Nevertheless, high electric field strengths, such as those associated with high voltage equipment in major substations can approach a level at which “nuisance shocks” can occur and this phenomenon needs to be managed. Magnetic fields are not readily shielded, are more ubiquitous and remain the subject of some debate. Accordingly, much of the remainder of this section is directed towards magnetic fields.

The most recent scientific reviews by authoritative bodies are reassuring for most potential health issues. However, statistical associations[5] between prolonged exposure to elevated magnetic fields and childhood leukaemia have persisted. This led the International Agency for Research on Cancer (IARC) (Ref. B-1) in 2002 to classify magnetic fields as a “possible carcinogen” [6].

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

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

References

B-1. World Health Organisation, International Agency for Research on Cancer, Lyon, France: IARC Monographs on the evaluation of carcinogenic risks to humans. Non-Ionising Radiation Part 1: Static and Extremely Low Frequency (ELF) Electric and Magnetic Fields. (2001)

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

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

[5] *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 – 118 agents are included in the group, including asbestos, tobacco and ultraviolet radiation*
- *Group 2A – the agent is probably carcinogenic – 79 agents have been included in this group, including diesel engine exhaust, creosotes and PCBs*
- *Group 2B – the agent is possibly carcinogenic to humans – 290 agents have been included in this group, including coffee, gasoline, lead, nickel, petrol engine exhaust and extremely low frequency magnetic fields*
- *Group 3 – the agent is not classifiable as to carcinogenicity – 501 agents have been included in this group, including caffeine, coal dust, extremely low frequency electric fields and static electric and magnetic fields*
- *Group 4 – the agent is probably not carcinogenic to humans – only 1 agent (caprolactam) has been included in this group.*

Appendix C
Health Guidelines

Health Guidelines for Extremely Low Frequency Electric and Magnetic Fields

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

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

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

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

In line with the regulator's advice, Aurecon has applied the current international ICNIRP guideline reference levels to this assessment.

The reference levels for both electric and magnetic fields contained in the current ICNIRP guidelines are summarised in Table 3.

Table 3 Health Guideline Reference Levels

Parameter	ICNIRP 2010 Reference Levels
Electric Fields – General Public	5kV/m
Electric Fields – Occupational	10kV/m
Magnetic Fields – General Public	2,000mG
Magnetic Fields – Occupational	10,000mG

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

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

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

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

It is in this context that precautionary measures for ELF magnetic fields such as "Prudent Avoidance" have arisen (see Attachment D).

References

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

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

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

Appendix D
Prudent Avoidance

Extremely Low Frequency Magnetic Fields

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

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

- Adverse health effects have not been established
- The possibility cannot be ruled out
- If there is a risk, it is more likely to be associated with the magnetic field than the electric field

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

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

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

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

The practice of 'prudent avoidance' has been adopted by the (Australian) Energy Networks Association (ENA) and most Australian power utilities, including TfNSW's Asset Standards Authority Division.

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

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

It also states:

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

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

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

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

It also states:

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

References

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

D-4. World Health Organisation: Environmental Health Criteria Vol. 238: Extremely low frequency fields. (2007).

D-5. Energy Networks Association: EMF Management Handbook. (2016).

Appendix E
Tables of EMF Calculation Results

Figure 6 – Double Circuit Trench Configuration

Distance (m)	Bresultant (MilliGauss)
-10	0.1
-9	0.2
-8	0.3
-7	0.4
-6	0.6
-5	1.0
-4	1.7
-3	3.3
-2	6.8
-1	13.9
0	19.4
1	14.1
2	6.9
3	3.3
4	1.7
5	1.0
6	0.6
7	0.4
8	0.3
9	0.2
10	0.1

Figure 8 – Typical Joint Bay Configuration

Distance (m)	Bresultant (MilliGauss)
-10	1.2
-9	1.6
-8	2.3
-7	3.3
-6	5.0
-5	8.0
-4	13.5
-3	24.0
-2	42.6
-1	65.6
0	76.7
1	65.6
2	42.6
3	24.0
4	13.5
5	8.0
6	5.0
7	3.3
8	2.3
9	1.6
10	1.2

Figure 10 – Staggered Joint Bay Configuration

Distance (m)	Bresultant (MilliGauss)
-10	3.5
-9	4.2
-8	5.1
-7	6.4
-6	8.2
-5	10.9
-4	15.1
-3	22.3
-2	36.4
-1	61.1
0	83.1
1	81.7
2	60.7
3	39.8
4	26.0
5	17.7
6	12.6
7	9.4
8	7.2
9	5.7
10	4.6

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