Environmental Impact Statement/Environment Effects Statement

# TECHNICAL APPENDICES

MARINUS LINK

# Appendix A

Electromagnetic fields

MARINUS LINK

Jacobs

# Marinus Link

Marinus Link EMF & EMI Impact Assessment

IS360328-SO28-EE-RPT-0002

May 2024

Marinus Link Pty Ltd

| | |
|---|---|
| Document Title: | Marinus Link EMF & EMI Impact Assessment |
| Document No.: | IS360328-SO28-EE-RPT-0002 |
| Revision: | 0 |
| Document Status: | First Issue |
| Date: | May 2024 |
| Client Name: | Marinus Link Pty Ltd |
| Client No: | - |
| Project Manager: | HK |
| Author: | TL |
| File Name: | Marinus Link EMF & EMI Impact Assessment |



### Issue history and status

| Revision | Date | Description | Author | Reviewer | Approver |
|---|---|---|---|---|---|
| 0 | May 2024 | Final Report for First Issue | TL | RU | HK |

Contents

# Executive Summary

## Overview

Marinus Link is a proposed 2 x 750 megawatt (MW) high voltage direct current (HVDC) electricity interconnector between Heybridge in northwest Tasmania and the Latrobe Valley in Victoria. Marinus Link will provide a second link between the Tasmanian renewable energy resources and the Victorian electricity grids enabling efficient energy trade, transmission and distribution from a diverse range of generation sources to where it is most needed and will increase energy capacity and security across the National Electricity Market (NEM).

The interconnector will comprise a 255 km long subsea cable link across the Bass Strait and a 90 km long land cable link through eastern Victoria, with converter stations at both ends. The proposed new HVDC link will initially operate at 750 MW capacity in Stage 1 and will be increased to 1,500 MW in Stage 2 with the addition of a second HVDC circuit.

The scope of works documented in this study report comprises desktop assessments of the Electric and Magnetic Fields (EMF) and Electromagnetic Interference (EMI) associated with the proposed new Marinus HVDC Link. The key components of the HVDC link are the ±320 kV subsea and land cable circuits, a 220 kV converter station at Heybridge (Tasmania) and a 500 kV converter station at either Driffield or Hazelwood (Victoria).

This report documents the impact assessments for people, livestock, wildlife and equipment within the Study area that may be sensitive to electric and magnetic fields and electromagnetic interference from the proposed electrical power infrastructure. It does not consider the impact of EMF and EMI on workers inside the converter stations as there are regulated compliance requirements defined in occupational health and safety standards for these exposure scenarios. Compliance with these requirements will be verified by the contractor during detailed design of the infrastructure.

## Existing Conditions

The only measurable sources of EMF and EMI within the subsea study area are the earth's geomagnetic fields. The cumulative impact of the proposed new electrical power infrastructure and the geomagnetic fields will only be measurable at the shore crossings of the subsea HVDC cables.

There are no measurable cumulative effects between any existing and proposed new HVDC cables within the subsea study area.

The only measurable sources of EMF and EMI within the mainland Tasmania and mainland Victoria study areas are the earth's geomagnetic fields and the AC electric and magnetic fields generated by operational high voltage power lines and substation equipment. There are existing 500 kV AC power lines that will parallel and cross-over the Marinus HVDC land cables. The physical and biological mechanisms by which DC and AC fields impact people, fauna, flora and equipment are distinct. As such, cumulative impact limits for DC and AC fields are not defined in the relevant standards and guidelines, and the cumulative impact of DC and AC fields on the environment within the study area are considered acceptable if they are below the respective limits and reference levels defined in the relevant standards and guidelines.

## Impact Assessment

Research and analysis of sensitive receivers that could potentially be impacted by the EMF and EMI generated by the proposed project's electrical power infrastructure have been undertaken. Limits and reference levels have been derived from applicable state, national and international standards and research reports/studies to evaluate the possible operational impact of the electrical power infrastructure on the local environment within the defined study area.

Besides the impact of electric and magnetic fields on people, plants and animals, generic household electrical and electronic equipment may also be impacted by AC magnetic fields that exceed 3.8 μT and radio frequency fields. DC magnetic field limits are not specified for generic equipment as the equipment is significantly more immune to DC fields, as compared to AC fields, in the general case. Specialised medical and scientific research equipment may however be sensitive to lower-level AC and also DC magnetic fields, which can interfere with the normal operation and functionality of the equipment.

#### Converter Stations and Surrounding Areas

Sensitive receivers that could be impacted by EMF and EMI associated with the proposed converter stations, and were considered in the impact assessment, include people, active implantable medical devices, generic electrical & electronic equipment, very sensitive medical and scientific research equipment, farm equipment, livestock and local flora and fauna.

The maximum calculated EMF at the Heybridge, Driffield and Hazelwood converter stations will be below the reference levels for people, livestock and wildlife at the property boundary for each site. The operating impacts of the converter stations on human health, livestock and wildlife will therefore be negligible. Mitigation and controls will not be required at the installations.

The maximum calculated EMI, specifically the AC magnetic field strength, will be below 3.8 μT (i.e. the generic equipment interference limit) in all areas outside the converter station properties. A desktop study of the area surrounding the three converter station sites was conducted and it was confirmed that there are no fixed sensitive electrical or electronic equipment or system installations that could be impacted by the EMI from the converter stations. The operating impacts of the converter stations on all nearby sensitive receivers will be negligible. Mitigation and controls will not be required at the installations.

#### Land HVDC Cables

Sensitive receivers that could be impacted by EMF and EMI associated with the proposed land HVDC cables, and were considered in the impact assessment, include people, active implantable medical devices, generic electrical & electronic equipment, very sensitive medical and scientific research equipment, farm equipment, livestock (dairy & beef cattle, sheep, horses, pigs, and poultry), honeybees, fruit trees, feeding grasses, vegetables, local flora and fauna (e.g. birds, reptiles, frogs, mammals).

The magnetic field distribution was calculated along the land HVDC project alignment. The maximum calculated EMF along the land HVDC cables will be below the reference levels for people throughout the study area. It was concluded from these calculations that the land cables will have no operating impacts on human health. Mitigation and controls will not be required at the installations.

Similarly, the land cables will not impact the general health of livestock, wildlife and the normal functioning of RFID tags or other farm equipment or machinery along the project alignment.

The HVDC land cables could have some impact on the behaviour of honeybees within 5 m of the cable trench. It is recommended that any apiaries located within 5 m of the trench be relocated outside the impact zone during the construction of the HVDC land cable. The impact of the HVDC cables will then be limited to temporary loss of direction sense for bees foraging within the very localised impact zone above the cable trench. Given the very limited extent of the impact zone and that the impact is momentary disorientation within the impact zone only, it is concluded that the HVDC cable will have negligible impact on bee colonies where the apiary has been relocated outside the impact zone.

A desktop study of the area along the land HVDC project alignment was carried out and it was confirmed that there will be no specialised medical and scientific research equipment near the land HVDC cables that could be impacted by the DC magnetic fields associated with the cables.

**Subsea HVDC Cables – Shore Crossings**

Sensitive receivers that could be impacted by EMF and EMI associated with the proposed subsea HVDC cables in the shore crossing areas, and were considered in the impact assessment, include fish, marine mammals, turtles, marine vessels (e.g. ships and boats), and other marine fauna and flora.

The potential effects of EMF exposure to Marine Flora and Fauna are addressed in the Marine Ecology and Resource Use (MERU) report (EIS/EES Appendix P). This report identifies applicable reference levels and potential effects of EMF exposure on Marine Flora and Fauna, including benthic species, epibenthic species, and those listed as threatened under the Threatened Species Protection Act 1995.

The highest DC magnetic field levels occur on the sea floor at the shore crossings. This is because the cables will be unbundled and spaced a few meters apart along these sections. The maximum calculated EMF along the shore crossing HVDC cables will be below the reference levels for people throughout the study area. It was concluded from the shore crossing cable impact assessment that the calculated field levels are below the applicable reference levels and there will be no operating impacts on human health. Mitigation and controls will not be required at the installations. Similarly, the shore crossing cables will not impact the normal functioning of marine vessels and systems in the study area.

**Subsea HVDC Cables - Bass Strait**

Sensitive receivers that could be impacted by EMF and EMI associated with the proposed subsea HVDC cables in the Bass Strait, and were considered in the impact assessment, include fish, marine mammals, turtles, marine vessels (e.g. ships and boats), and other marine fauna and flora.

The potential effects of EMF exposure to Marine Flora and Fauna are addressed in the Marine Ecology and Resource Use (MERU) report (EIS/EES Appendix P). This report identifies applicable reference levels and potential effects of EMF exposure on Marine Flora and Fauna, including benthic species, epibenthic species, and those listed as threatened under the Threatened Species Protection Act 1995.

The magnetic field distribution was calculated along the subsea HVDC project alignment across Bass Strait. The cables in each circuit will be bundled together within the Bass Strait trench section, which greatly reduces the external magnetic fields associated with the cables. The magnetic fields will be strongest directly above the cables and decrease quickly at increasing distance from the cables. Fluctuations in sea water conductivity were considered in the modelling but were found to have negligible impact on the intensity of the static magnetic fields. The static electric field produced by the cables in the conductive water will be negligible for all reasonable water salinities and ocean current velocities.

The maximum calculated EMF along the subsea HVDC cables will be below the reference levels for people throughout the study area. It was concluded from the subsea cable impact assessment that the calculated field levels are below the applicable reference levels and there will be no operating impacts on human health. Mitigation and controls will not be required at the installations. Similarly, the subsea cables will not impact the normal functioning of marine vessels and systems in the study area.

A desktop study of the area along the subsea HVDC project alignment within the Bass Strait was carried out and it was confirmed that there will be no specialised medical and scientific research equipment near the subsea cables that could be impacted by the DC magnetic fields associated with the cables.

**Cable Heating Assessment**

The heat generated by the subsea and land HVDC cables has been considered in the impact assessment. It is concluded from conservative soil heating calculations that it is unlikely that the operation the HVDC cables will impact plant life, specifically pasture grass, in the vicinity of the cable trench along any section of the cable. The cable system design will provide assurance that any impact on plant health is negligible.

Negligible heating of the seawater near the seabed is expected due to the operation of the subsea HVDC cables. The temperature rise at the seabed surface due to the subsea HVDC cables is indistinguishable from the ambient temperature.

## Monitoring and Review

It is recommended that post-construction and commissioning EMF and EMI tests be conducted near key locations within the project area to verify the calculations presented in this impact assessment and those that will be carried out during the detailed design stage.

## Environmental Performance Requirements

Two Environmental Performance Requirements (EPRs) are recommended as controls to ensure the EIS/EES evaluation objectives relevant to EMF and EMI are met. They are as follows:

| EPR ID | Environmental Performance Requirement | Project Stage |
|---|---|---|
| EPR EMF01 | **Design the project to reduce EMF/EMI emissions**<br>Design and construct the project to reduce electric and magnetic fields (EMF) and electromagnetic interference (EMI) for the project alignment onshore to below the reference levels or as low as reasonably practicable to avoid and minimise impacts. The applicable reference levels are defined in EIS/EES Technical Appendix A: Electromagnetic Fields Section 7 of the EMI impact assessment prepared for the EIS/EES. The design must be informed by a project wide EMF and EMI assessment for all the proposed infrastructure, identifying existing sensitive receptors and committed future developments within the study area. The assessment must be documented in a management plan that includes, but is not limited to:<br>• Outcomes of the project wide EMF and EMI assessment and details of the areas assessed.<br>• The location of all sensitive receptors including beehives within 5 m of the infrastructure. The location of beehives must also be documented in the property management plans (EPR A02).<br>• Where at-receiver mitigation works to sensitive equipment are required to avoid or minimise adverse impacts.<br>• A pre- and post-construction testing strategy to verify design calculations, impacts on sensitive equipment and the efficacy of any specified mitigation measures.<br>• Remedial action to be undertaken if EMF and EMI limits are not met during the construction, testing, and commissioning.<br>The EMF and EMI management plan must be prepared to inform the design and commissioning of the project.<br>EMF and EMI emissions of the subsea cable are addressed in EPR MERU 12. | Design<br>Construction<br>Commissioning |
| EPR EMF02 | **Investigate and resolve complaints regarding EMF and EMI during operation**<br>As part of the OEMP, develop a protocol for investigating and resolving complaints regarding EMF and EMI during operation. The protocol must outline requirements for working with landholders to assess impacts on sensitive equipment and implement reasonably practicable measures to address impacts. | Operation |

## Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to outline the methodology and present the results of an *EMF and EMI impact assessment of the Marinus Link* in accordance with the scope of services set out in the contract between Jacobs and the Client. That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Client (if any) and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

This report has been prepared on behalf of, and for the exclusive use of, Jacobs' Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

# Glossary and Abbreviations

| Abbreviation | Definition |
|---|---|
| AC | Alternating Current |
| ACMA | Australian Communications and Media Authority |
| AIMD | Active Implantable Medical Device |
| AM | Amplitude Modulation |
| ARPANSA | Australian Radiation Protection and Nuclear Safety Agency |
| AS | Australian Standard |
| AS/NZS | Joint Australian New Zealand Standard |
| CDEGS | Current Distribution, Electromagnetic Fields. Grounding and Soil Structure Software |
| CYMCAP | Power Cable Installation Ampacity and Temperature Rise Calculation Software |
| DC | Direct Current |
| DGPS | Differential Global Positioning System |
| EES | Environmental Effects Statement |
| EIS | Environmental Impact Statement |
| ELF | Extremely Low Frequency |
| EMF | Electric and Magnetic Fields |
| EMI | Electromagnetic Interference |
| EN | European Normalised Standard |
| ENA | Energy Networks Australia |
| FM | Frequency Modulation |
| GPS | Global Positioning System |
| HDD | Horizontal Directional Drilling |
| HV | High Voltage |
| HVAC | High Voltage Alternating Current |
| HVDC | High Voltage Direct Current |
| IARC | International Agency for Research on Cancer |
| ICNIRP | International Commission on Non-Ionising Radiation Protection |
| ITU | International Telecommunication Union |
| MLPL | Marinus Link Pty Ltd |
| MNES | Matters of National Environmental Significance |
| MRI | Magnetic Resonance Imaging |
| NEM | National Electricity Market |

| Abbreviation | Definition |
|---|---|
| NHMRC | National Health and Medical Research Council |
| RFI | Radio Frequency Interference |
| RFID | Radio Frequency Identification |
| RHC | Radiation Health Committee |
| RHS | Radiation Health Series |
| RIV | Radio Influence Voltage |
| RMS | Root Mean Square |
| XLPE | Cross-linked Polyethylene |

# 1. Introduction

The proposed Marinus Link (the project) comprises a high voltage direct current (HVDC) electricity interconnector between Tasmania and Victoria, to allow for the continued trading and distribution of electricity within the National Electricity Market (NEM).

The project was referred to the Australian Minister for the Environment 5 October 2021. On 4 November 2021, a delegate of the Minister for the Environment determined that the proposed action is a controlled action as it has the potential to have a significant impact on the environment and requires assessment and approval under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act) before it can proceed. The delegate determined that the appropriate level of assessment under the EPBC Act is an environmental impact statement (EIS).

On 12 December 2021, the former Victorian Minister for Planning under the *Environment Effects Act 1978* (Vic) (EE Act) determined that the project requires an environment effects statement (EES) under the EE Act, to describe the project's effects on the environment to inform statutory decision making.

In July 2022 a delegate of the Director of the Environment Protection Authority Tasmania determined that the project be subject to environmental impact assessment by the Board of the Environment Protection Authority (the Board) under the *Environmental Management and Pollution Control Act 1994* (Tas) (EMPCA).

As the project is proposed to be located within three jurisdictions, the Victorian Department of Transport and Planning (DTP), Tasmanian Environment Protection Authority (Tasmanian EPA) and Australian Department of Climate Change, Energy, Environment and Water (DCCEEW) have agreed to coordinate the administration and documentation of the three assessment processes. One EIS/EES is being prepared to address the requirements of DTP and DCCEEW. Two EISs are being prepared to address the Tasmanian EPA requirements for the Heybridge converter station and shore crossing.

This report has been prepared by Jacobs to address all jurisdictions as part of the EIS/EES being prepared for the whole project.

## 1.1 Purpose of this Report

The objective of Electric and Magnetic Field (EMF) and Electromagnetic Interference (EMI) studies for the project is to identify potential EMF and EMI effects to sensitive receivers and assess the impact caused by the construction and operation of the Marinus Link. The impact of EMF and EMI on workers inside the converter stations are not considered in the studies as there are regulated compliance requirements defined in occupational health and safety standards for these exposure scenarios. Compliance with these requirements will be verified by the contractor during detailed design.

An integrated approach is used to assess the EMF and EMI impacts that could occur as a result of the project. Receivers identified in either the other technical studies or a desktop audit of the proposed alignment were grouped by sensitivity to EMF and EMI, immunity limits were derived for each group from published standards or research papers and finally these assessment criteria were used to assess calculated EMF and EMI that will be generated by the construction and operation of the project.

## 1.2 Project Overview

The project is a proposed 1500 megawatt (MW) HVDC electricity interconnector between Heybridge in northwest Tasmania and the Latrobe Valley in Victoria (Figure 1-1). Marinus Link is proposed to provide a second link between the Tasmanian renewable energy resources and the Victorian electricity grids enabling efficient energy trade, transmission and distribution from a diverse range of generation sources to where it is most needed, and will increase energy capacity and security across the National Electricity Market (NEM).

Marinus Link Pty Ltd (MLPL) is the proponent for the project and is a wholly owned subsidiary of Tasmanian Networks Pty Ltd (TasNetworks). TasNetworks is owned by the State of Tasmania and owns, operates and maintains the electricity transmission and distribution network in Tasmania.

Tasmania has significant renewable energy resource potential, particularly hydroelectric power and wind energy. The potential size of the resource exceeds both the Tasmanian demand and the capacity of the existing Basslink interconnector between Tasmania and Victoria. The growth in renewable energy generation in mainland states and territories participating in the NEM, coupled with the retiring of baseload coal-fired generators, is reducing the availability of dispatchable generation that is available on demand.

Tasmania's existing and potential renewable resources are a valuable source of dispatchable generation that could benefit electricity supply in the NEM. Marinus Link will allow for the continued trading, transmission and distribution of electricity within the NEM. It will also manage the risk to Tasmania of a single interconnector across Bass Strait and complement existing and future interconnectors on mainland Australia. Marinus Link is expected to facilitate the reduction in greenhouse gas emissions at a state and national level.

Interconnectors are a key feature of the future energy landscape. They allow power to flow between different regions to enable the efficient transfer of electricity from renewable energy zones to where the electricity is needed. Interconnectors can increase the resilience of the NEM and make energy more secure, affordable and sustainable for customers. Interconnectors are common around the world including in Australia. They play a critical role in supporting Australia's transition to a clean energy future.

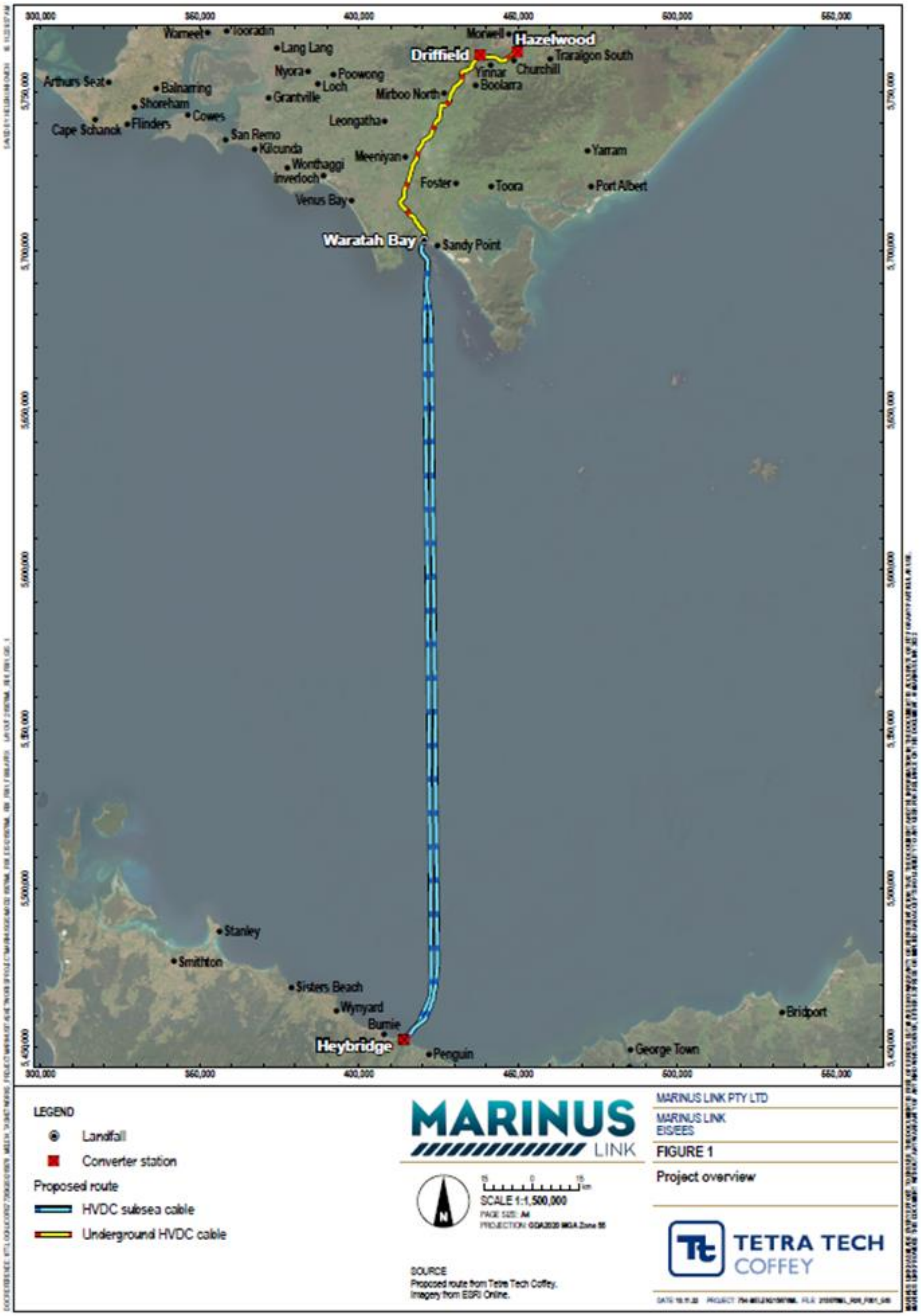


*Figure 1-1: Project Overview*

## 1.3 Assessment Context

Electric and magnetic fields (EMF) are invisible, physical fields that surround electrical charges and exert forces on all charged particles and objects in the field. All electrical and electronic equipment and appliances therefore generate EMF. The magnitude of the EMF generated by equipment is proportional to the magnitude of the voltage and current used to power the equipment and inversely proportional to the distance between the equipment and the sensitive receiver.

The project infrastructure utilises high voltages and currents and will therefore generate significant EMF. Furthermore, a wide range of sensitive receivers will be exposed to these EMFs along the extensive alignment and will come into close proximity to the insulated cables (i.e. within a few metres of the buried cables).

The EMF is also characterised by the frequency at which the fields oscillate between positive and negative peaks, described in cycles per seconds in units of Hertz (Hz). Extremely low frequency fields, such as those generated by the 0 Hz DC equipment and 50 Hz power infrastructure, are not radiated from the power cables and equipment and reduce to very low levels further away from the project infrastructure. At higher frequencies, the cables and equipment radiate electromagnetic fields that only reduce in magnitude with very large distances from the power infrastructure.

Some electrical and electronic equipment is very sensitive to extremely low frequency fields and radiated high frequency fields, which can interfere with the normal operation and functionality of the equipment. These interfering fields are called electromagnetic interference (EMI).

The assessment of EMF and EMI impacts on the large number of sensitive receivers forms an important part of a single consolidated EIS/EES that is being prepared to address the requirements of the Commonwealth and Victorian jurisdictions (including the requirement for an EES) given the large extent of the proposed alignment and the significant amount of electrical power that will be transmitted over the link. Potential sensitive receivers include, but are not limited to: humans, marine life, fauna, wildlife, crops, vegetation, communications equipment, and very sensitive medical and scientific research equipment.

# 2. Assessment Guidelines

The EMF and EMI assessment associated with the project spans all jurisdictions. It considers impacts on sensitive receivers from the converter stations in Tasmania and Victoria, and the subsea and land HVDC cables in between the converter stations. The Commonwealth, Tasmanian, and Victorian scoping requirements and guidelines are therefore applicable. The subsections below (2.1, 2.2, and 2.3) detail the EMF and EMI requirements applicable to the project for each jurisdiction. Moreover, the relevant section of the report which addresses each requirement is also identified in the summary.

## 2.1 Commonwealth

*Table 2-1: Commonwealth EIS Guidelines*

| Section | Definition | Report Section |
|---|---|---|
| 5<br>Relevant Impacts | Any technical data and other information used or needed to make a detailed assessment of the relevant impacts, including but not limited to:<br>• modelling (or other scientifically sound method for making predictions) of electromagnetic disturbance during the construction and operation stages of the action. Modelling should be relevant to the project area, installation methods and noise sources, | 5 & 7.5 |
| 5.3<br>Underwater disturbance (noise, heat, vibrations, and electromagnetic fields) impacts | The EIS must include an assessment of the potential direct and indirect impacts to listed marine, migratory, and threatened species and communities, and including impacts to prey species arising from electromagnetic fields generated during the construction, commissioning, operation, and decommissioning of the subsea cable. The following will be required:<br>• details of the electromagnetic fields to be generated during all stages of the action including:<br>  ○ The intensity and frequency of any underwater disturbance generated from all relevant activities associated with the proposed action;<br>  ○ the expected geographic extent of disturbance, and the length of the disturbance period;<br>• details of the heat generation from the operation of the subsea cable, on the surface of the cable and to the surrounding ambient environment of the water;<br>• the impacts of electromagnetic fields associated with the construction and ongoing operations of the action on all MNES, including:<br>  ○ an assessment of short-term, long-term and cumulative impacts, compared with baseline environmental conditions;<br>  ○ the consequences for the disruption of migration, resting, breeding (including calving and nursing), or foraging behaviours of listed species, as a result of underwater disturbance including consideration of requirements in relevant statutory documents; and<br>  ○ the potential for the activity to impede the recovery of a listed species.<br>  ○ the potential for impacts to commercially important species of the Commonwealth Marine Area | 7.4 & 7.5 |

## 2.2 Tasmania

### 2.2.1 Heybridge Shore Crossing & Coastal Waters

*Table 2-2: EPA EIS Guidelines applicable to the Heybridge shore crossing and coastal waters*

| Scoping Section | Definition | Report Section |
|---|---|---|
| 10.3 Marine Natural Values | In discussion of impacts on flora and fauna, including consideration of:<br>• Heat and electromagnetic radiation, including whether it will have any potential impacts on benthic ecosystems, fish or mammals, and their migratory behaviors, e.g., through impact on movement of seawater, magnetic characteristics of marine sediments or other potential impacts. | 7.2 |
| 10.4 Marine Water Quality | Discuss potential impacts of construction and operation of the proposal on marine water quality, including:<br>• As available, other relevant information for assessing potential impacts such as electromagnetic data,<br>Consideration of operational impacts on water quality, including electromagnetic fields (noting that electromagnetic radiation is within the definition of 'pollutant' under the EMPC). | 7.2.12 |

### 2.2.2 Heybridge Converter Station

*Table 2-3: EPA EIS Guidelines applicable to the Heybridge Converter Station*

| Scoping Section | Definition | Report Section |
|---|---|---|
| 6.8 Electric and magnetic fields | Discuss the potential risks or impacts of electromagnetic fields associated with the proposal, including:<br>• A desktop study of the Electromagnetic Fields (EMF) associated with the new converter station, including calculations of the EMF levels likely to be generated at the edge of the site,<br>• A comparison against levels recommended by the Australian Radiation Protection and Nuclear Safety Agency and the human exposure guideline limits recommended by the International Commission on Non-Ionizing Radiation Protection, | 7.4 & 7.5 |

## 2.3 Victoria

The EES Scoping Requirements issued by the Minister for Planning (February 2023) outline the specific matters to be assessed across a number of environmental and social disciplines relevant to the project, and to be documented in the EES for the project.

The EES Scoping Requirements inform the scope of the EES technical studies and define the EES evaluation objectives. The EES evaluation objectives identify the desired outcomes to be achieved and provide a framework for an integrated assessment of the environmental effects of a proposed project.

### 2.3.1 EES Evaluation Objective – Biodiversity and Ecological Values

"Avoid, and where avoidance is not possible, minimise adverse effects on terrestrial, aquatic and marine biodiversity and ecology, including native vegetation, listed threatened species and ecological communities, other protected species and habitat for these species, and to address offset requirements consistent with state policies."

### 2.3.2 EES Evaluation Objective – Amenity, Health, Safety and Transport

"Avoid and, where avoidance is not possible, minimise adverse effects on community amenity, health and safety, with regard to noise, vibration, air quality including dust, the transport network, greenhouse gas emissions, fire risk and electromagnetic fields."

### 2.3.3 EES Scoping Requirements

*Table 2-4: DEECA EES Scoping Requirements*

| Section | Definition | Report Section |
|---|---|---|
| 3.2 Content and Style | Conclusions on the significance of impacts on local, regional and state matters | 7.5 |
| 3.7 Environmental Management Framework | The Environmental Management Framework should describe proposed objectives, indicators and monitoring requirements, where relevant, for electromagnetic fields | 7.7, 7.8, & 7.9 |
| 4.1 Biodiversity and ecological values | Key Issues<br>• Potential for indirect effects on biodiversity values including those effects associated with changes in coastal processes, noise, vibration, electromagnetic fields, heat, vessel movements and water quality.<br>Likely Effects<br>• Potential for indirect effects on biodiversity values including those effects associated with changes in coastal processes, noise, vibration, electromagnetic fields, heat, vessel movements and water quality.<br>• Assess the direct and indirect effects of the project during construction and operation on biodiversity values, including disturbance through noise, vibration, electromagnetic fields and heat. | 7.2 & 7.5 |
| 4.5 Amenity, safety and transport | Key Issues<br>• Potential for adverse effects resulting from project-related electromagnetic fields at sensitive receivers during construction and operation.<br>Existing Environment<br>• Identify sensitive receivers that could be affected by electromagnetic fields<br>Likely Effects<br>• Identify potential effects of electromagnetic fields from the project on sensitive receivers<br>Mitigation<br>• Describe and assess potential measures for avoiding, mitigating or managing impacts of electromagnetic fields, including on human health | 7.2, 7.5 & 7.7 |

## 2.4 Linkages to Other Reports

This report is informed by, or informs, the technical studies identified in Table 2-5.

*Table 2-5: Linkages to other reports*

| Technical Study | Relevance to this Assessment |
|---|---|
| Agriculture | • Description of the farms and animals present along the project alignment that are potentially exposed to EMF and EMI from the project |
| Marine ecology and resource use | • Identification of marine species and environment exposed to EMF and EMI from the subsea cables<br>• The potential effects of EMF exposure to Marine Flora and Fauna are to be addressed in the Marine Ecology and Resource Use (MERU) report (EIS/EES Appendix P). This report will document potential effects of EMF exposure, and applicable reference levels that relate to Marine Flora and Fauna including benthic species, epibenthic species, and those listed as threatened under the Threatened Species Protection Act 1995. References to the MERU report are made in this report where applicable. |
| Social impact assessment | • People will be exposed to EMF generated by the subsea cables, land cables, and converter stations. Moreover, the general environmental impacts of EMF and EMI will have social implications |

# 3. Legislation, Policy and Guidelines

The scope of works covered in the study comprises desktop assessments of the EMF and EMI associated with the proposed new Marinus HVDC Link. The key components of the HVDC link will be the ±320 kV subsea and land cable circuits, a 220 kV converter station at Heybridge (Tasmania) and a 500 kV converter station at Driffield or Hazelwood (Victoria).

The proposed HVDC link will be arranged as a symmetric monopole with no earth return. The specifications for the indoor HVDC power equipment located within the converter station (e.g. rectifiers, filters, transformers, etc) will be confirmed during the subsequent stages of the project. The EMF and EMI from this equipment is therefore not modelled in the study but the appropriate requirements will be identified in this study and will inform the procurement of the equipment and requirement of the detailed design.

The EMF calculations documented in this report were carried out in the HIFREQ module of CDEGS, Ver. 17. The cable heating calculations documented in this report were carried out using CYMCAP Ver. 7.3. The EMF and EMI assessments documented in this report have been carried out in accordance with the Australian and international standards and industry guidelines specified Table 3-1.

*Table 3-1: Standards and guidelines referenced in the EMF and EMI study*

| Number | Revision | Title |
|---|---|---|
| ICNIRP | 2010 | International Commission on Non-Ionising Radiation Protection – Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz-100 kHz) |
| ICNIRP | 2014 | International Commission on Non-Ionising Radiation Protection – Guidelines for limiting exposure to electric fields induced by movement of the human body in a static magnetic field and by time-varying magnetic fields below 1 Hz |
| EN 45502-2-1 | 2003 | Active implantable medical devices – Particular requirements for active implantable medical devices intended to treat bradyarrhythmia (cardiac pacemakers) |
| EN 45502-2 | 2008 | Active implantable medical devices – Particular requirements for active implantable medical devices intended to treat tachyarrhythmia (includes implantable defibrillators) |
| EN 50527-1 | 2016 | Procedure for the assessment of the exposure to electromagnetic fields of workers bearing active implantable medical devices |
| AS/NZS 61000.6.1 | 2006 | Electromagnetic compatibility (EMC) - Generic standards - Immunity for residential, commercial and light-industrial environments |
| AS 2344 | 2016 | Limits of electromagnetic interference from overhead a.c. powerlines and high voltage equipment installation in the frequency range 0.15 MHz to 3000 MHz |
| ENA | 2016 | EMF Management Handbook |

# 4. Project Description

## 4.1 Overview

Marinus Link is proposed to be implemented as two 750 MW circuits to meet transmission network operation requirements in Tasmania and Victoria. Each 750 MW circuit will comprise two power cables and a fibre-optic communications cable bundled together in Bass Strait and laid in a horizontal arrangement on land. The two 750 MW circuits will be installed in two stages with the western circuit being laid first as part of stage one, and the easter cable in stage two.

The key project components for each 750 MW circuit, from south to north, are:

- HVAC switching station and HVAC-HVDC converter station at Heybridge in Tasmania. This is where the project will connect to the North West Tasmania transmission network being augmented and upgraded by the North West Transmission Developments (NWTD).
- Shore crossing in Tasmania adjacent to the converter station.
- Subsea cable across Bass Strait from Heybridge in Tasmania to Waratah Bay in Victoria.
- Shore crossing at Waratah Bay approximately 3 km west of Sandy Point.
- Land-sea cable joint where the subsea cables will connect to the land cables in Victoria.
- Land cables in Victoria from the land-sea joint to the converter station site in the Driffield or Hazelwood areas.
- HVAC switching station and HVAC-HVDC converter station at Driffield or at Hazelwood, where the project will connect to the existing Victorian transmission network.

A Transition Station at Waratah Bay may also be required if there are different cable manufactures or substantially different cable technologies adopted for the land and subsea cables. The location of the transition station will also house the fibre optic transition station in Victoria. However, regardless of whether a transition station is needed, a fibre optic terminal station will still be required in the same location.

Approximately 255 km of subsea HVDC cable will be laid across Bass Strait. The preferred technology for Marinus Link is two 750 MW symmetrical monopoles using ±320 kV, cross-linked polyethylene insulated cables and voltage source converter technology. Each symmetrical monopole is proposed to comprise two identical size power cables and a fibre-optic communications cable bundled together. The cable bundles for each circuit will transition from approximately 300m apart at the HDD (offshore) exit to 2 km apart in offshore waters.

In Victoria, the shore crossing is proposed to be located at Waratah Bay with the route crossing at the Waratah Bay–Shallow Inlet Coastal Reserve. From the land-sea joint located behind the coastal dunes, the land cable will extend underground for approximately 90 km to the converter station. From Waratah Bay the cable will run northwest to the Tarwin River Valley and then travel to the north to the Strzelecki Ranges. The route crosses the ranges between Dumbalk and Mirboo North before descending to the Latrobe Valley where it turns northeast to Hazelwood. The Victorian converter station will be at either a site south of Driffield or Hazelwood adjacent to the existing terminal station.

The land cables will be directly laid in trenches or installed in conduits in the trenches. A construction area of 20 to 36 m wide will be required for laying the land cables and construction of joint bays. Temporary roads for accessing the construction area and temporary laydown areas will also be required to support construction. Where possible, existing roads and tracks will be used for access, for example, farm access tracks or plantation forestry tracks.

Land cables will be installed in ducts under major roads, railways, major watercourses and substantial patches of native vegetation using trenchless construction methods (e.g., HDD, where geotechnical conditions permit. A larger area than the 36m construction area will be required for the HDD crossings.

The assessment is focused on the Victorian / Tasmanian / marine section of the project. The EMF and EMI assessment covers the Victorian / Tasmanian / marine sections of the project. This report will inform the EIS/EES being prepared to assess the project's potential environmental effects in its entirety across each jurisdiction in accordance with the legislative requirements of the Commonwealth, Tasmanian and Victorian governments (see Figure 4-1).

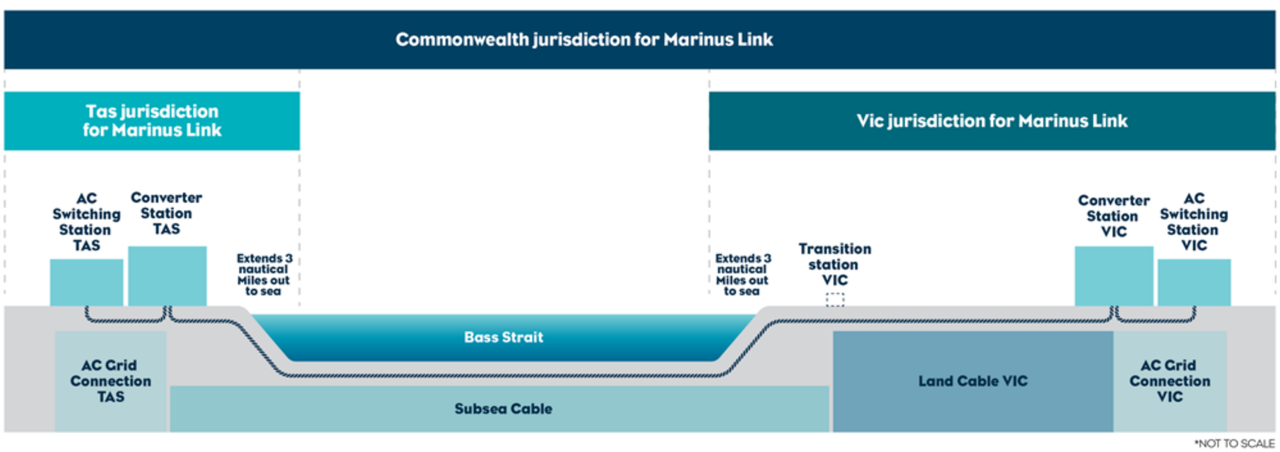


*Figure 4-1: Project components considered under applicable jurisdictions (Marinus Link Pty Ltd 2022, Consultation Plan).*

Marinus Link is proposed to be constructed in two stages over approximately five years following the award of works contracts to construct the project. On this basis, Stage 1 of the project is expected to be operational by 2030, with Stage 2 to follow, with final timing to be determined by market demand. The project will be designed for an operational life of at least 40 years.

## 4.2 Construction, Operation, and Decommissioning

The EMF and EMI assessment of the project is focussed on the operational phase of the project, as this phase will generate the only significant levels. EMF and EMI generated by construction, commissioning and decommissioning activities are discussed but will not be significant.

# 5. Assessment Methodology

The EMF and EMI assessment considers the impact of power and radio frequency electric and magnetic fields and electromagnetic interference on people, animals, plants and electrical and electronic equipment and systems, which are collectively referred to as sensitive receivers in the context of varying degrees of susceptibility to health or functional effects caused by exposure to EMF and EMI. Some specialised medical and scientific research equipment is susceptible to EMI at levels that are much lower than the level typically generated by power infrastructure. This equipment is referred to in the assessment as very sensitive receivers and special consideration must be given to citing power infrastructure near existing equipment that is classified as very sensitive.

An integrated approach is used to assess the potential EMF and EMI impacts that could occur as a result of the project. This involves the following steps:

- A desktop survey of the study area is first conducted to identify sensitive receivers that could be impacted by EMF and EMI associated with the proposed power infrastructure. The survey comprises an audit of online aerial imagery of the study area, followed by an online search for public information regarding the likely residential, commercial or industrial use of identified buildings and installations, and electrical and electronic equipment that may be installed at those locations.
- The basic mechanisms by which EMF and EMI can impact sensitive receivers are then introduced and cause-effect relationships established for the various receivers identified within the study area.
- Limits and reference levels are then confirmed for the identified impacts, based on state, national and international standards, guidelines and published research.
- The power infrastructure is then modelled in an appropriate software package and typical and worst-case EMF and EMI levels are calculated at the sensitive receiver locations for comparison with the impact assessment criteria.
- Finally, mitigations and management methods are assessed, and the residual risk established for the identified impacts.

## 5.1 Study Area

In general, sensitive receivers more than 500 m from the proposed power cables and equipment will not be impacted by EMF and EMI. This is because at a distance of 500 m from the proposed power cables and equipment, the generated EMF and EMI will most likely be indistinguishable from the background ambient levels. This is evidenced in the graphical plots presented in the Operation Impact Assessment (Section 7.5) of this document.

Some very sensitive receivers can however be impacted at greater distances and these will be identified by receiver type, in addition to a general source for sensitive receivers within a 500 m study area around the electrical power installations. In general, very sensitive receivers are receivers that can be affected by magnetic field levels in the nanotesla range. This is as opposed to sensitive receivers which in general, can be affected by magnetic fields in the microtesla range. No very sensitive receivers have been identified near the study area that will be impacted by the project.

## 5.2 Electrical Power Infrastructure

The Marinus Link Reference Design information was used as inputs for the EMF and EMI modelling for the impact assessment. As built data was provided by AusNet for the existing Hazelwood Terminal Station installations. These are discussed in this section along with all other critical input parameters used for the system modelling.

The Marinus HVDC link will comprise two converter stations and interconnecting cables. The two converter stations will be located at Heybridge (Tasmania) and Driffield or Hazelwood (Victoria). Heybridge is a 220 kV converter station, the supply to Heybridge will be via two double circuit transmission lines that utilise twin Sulphur phase conductors. The existing HWTS-CBTS and HWTS-ROTS 500 kV lines will be deviated into the Driffield converter station.

### 5.2.1 HVDC System

The HVDC link is proposed to operate as a symmetrical monopole arrangement with each circuit capable of transferring 750 MW across the Bass Strait. Only one circuit will operate initially during Stage 1 operation, followed by operation of the second circuit during Stage 2 operation. The general arrangement of each circuit is illustrated in Figure 5-1. The nominal voltage is proposed to be ± 320 kV with a maximum continuous rated current of 1,250 A. The maximum overload rated current is 1,480 A. The bundle for each circuit will comprise a positive (sending), negative (return) and a fibre optic cable. The cable sheaths will either be earthed at one or both converter stations, to be confirmed during detailed design.

Both cable arrangements were modelled in the study. Both Stage 1 and Stage 2 operation were also modelled in the study. Only the worst case field levels for all operating stages and arrangements are reported in the impact assessment.

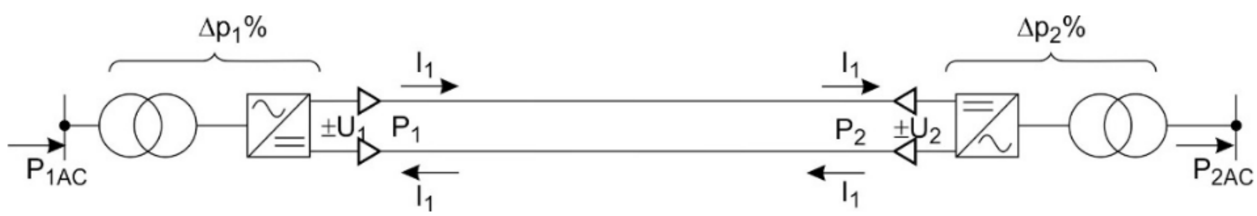


*Figure 5-1: Symmetrical monopole arrangement*

The bundle geometry through the Bass Strait is yet to be confirmed but will either be a horizontal flat or vertical stacked geometry. Both geometries were considered in the study. For the purposes of calculating the worst case magnetic flux density levels, it was assumed that for the three cables per circuit, the top and bottom cables will be the current carrying cables, and the middle cable is the fibre optic cable; providing the smallest degree of magnetic field cancellation.

The geometry of the cable will be sparse and non-uniform where the cable traverses the shore at both the Tasmanian and Victorian ends, as illustrated in Figure 5-2.

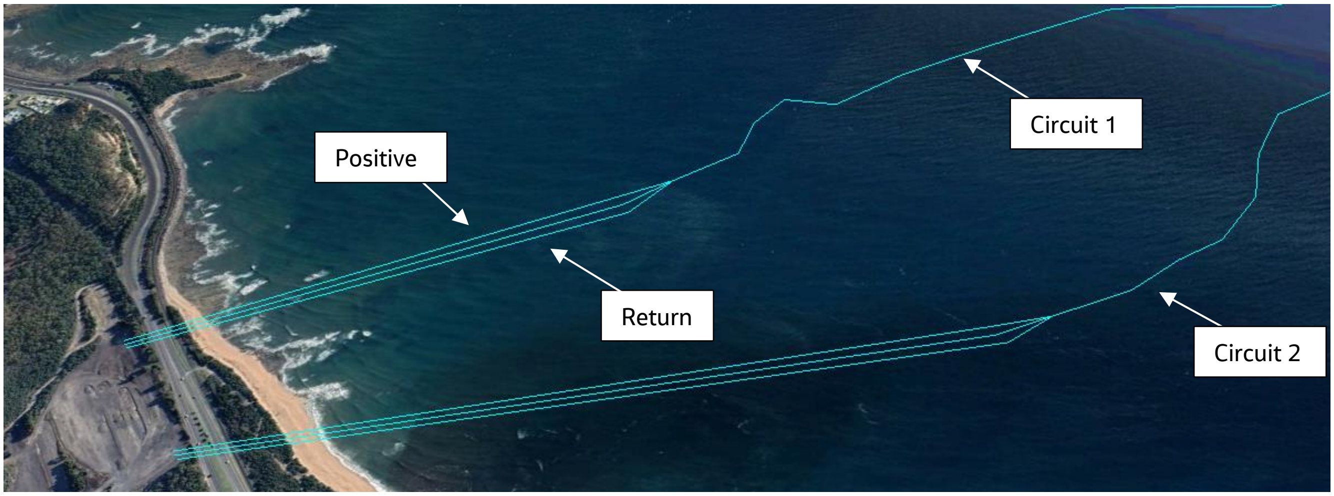


*Figure 5-2: Non-uniformity of cables at the Tasmanian shoreline*

The HVDC subsea cables have been modelled as 1,000 MW-rated submarine cables, comprising a 2,500 $mm^2$ stranded copper core with an extruded lead alloy metallic sheath and an overall nominal diameter of 135 mm. Where the cables transition from the Bass Strait to the land cable to Driffield/Hazelwood, the cables transition to 1,000 MW-rated underground cables; the key differences being the stranded copper wire screen and an overall nominal diameter of 117 mm.

### 5.2.2 Cable Modelling – Subsea Cable

The areas of the project alignment where the cables are spread out and their separation in non-uniform (i.e. the shore crossings at both the Tasmanian and Victorian ends) will produce the largest EMF levels. The two cable transitions between land and sea are shown in Figure 5-3. These sections are:

1. Cable transition from the Heybridge converter station to the Bass Strait (approximately 20 km)
2. Cable transition from the Bass Strait to the land cable (approximately 25 km)

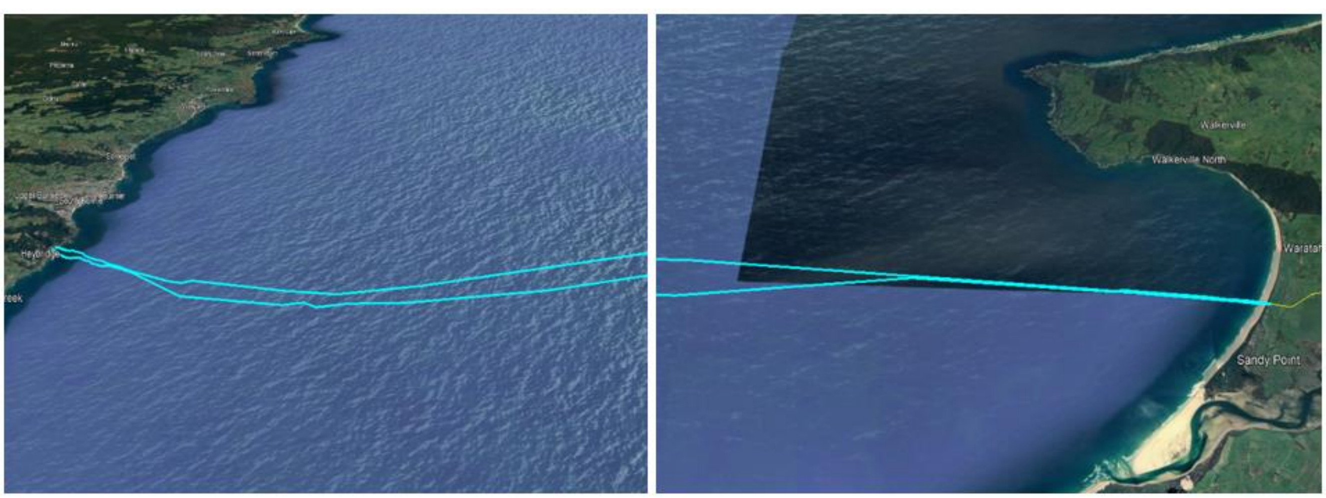


*Figure 5-3: Cable transitions between land and sea*

The preferred cable installation type for shore crossings is horizontal directional drilling (HDD) to about 10 m water depth, at which point they will be trenched where geotechnical conditions permit. The HDD sections comprise ducted cables separated by up to 50 m (see Figure 5-4). The largest EMF will be produced in the areas where the positive and negative cables have the largest separation from each other. This is because the magnetic fields produced by both cables don't cancel each other out to the same degree as in the trench where they will be separated by maximum 50 mm. The magnetic fields will also be reinforced at sharp bends in the cable. The detailed EMF and EMI modelling conducted for the study takes into account these magnetic field cancellation and reinforcement effects.

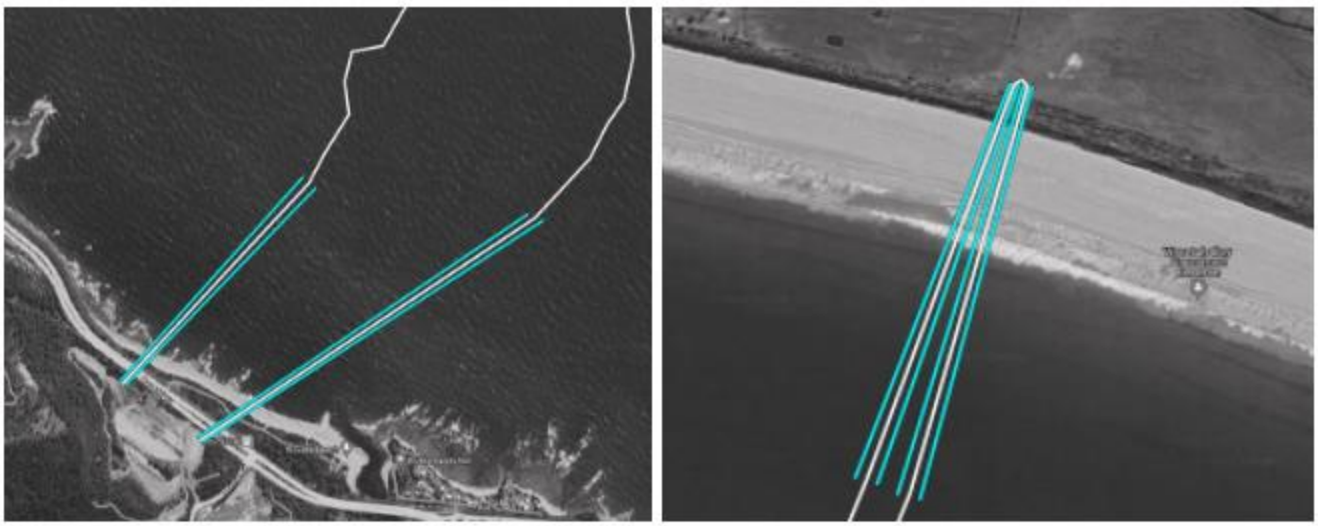

*Figure 5-4: Cable transitions between land and sea – HDD cable ducts*

The final geometry of the positive and return cables will only be confirmed during detailed design. For either horizontal of vertical final arrangements, the modelling conducted in this study has considered a flat arrangement with maximum 50 mm separation as this will produce the largest magnetic field levels for the trenched sections of the cable. The calculated magnetic field levels presented in this study are therefore conservative and allow for variations in final design arrangements. The average separation between the two HVDC circuits is 2 km along the Bass Strait. It is assumed that the cables will be buried a minimum of 1 m beneath the sea floor.

### 5.2.3 Cable Modelling – Land Cable

The proposed route of the land cable is shown in Figure 5-5. It has been assumed that the separation between circuits (cable trenches) will be 8.5 m, the cables will be trenched in a horizontal flat formation with nominal 0.5 m separation, at a minimum buried depth of 1.2 m below ground level.

There will be areas where the inter-cable spacing for the land cables is required to increase from 0.5 m for HDD road and river crossings. At these locations, the EMF modelling presented in this study has consider a maximum cable spacing of 4 m.

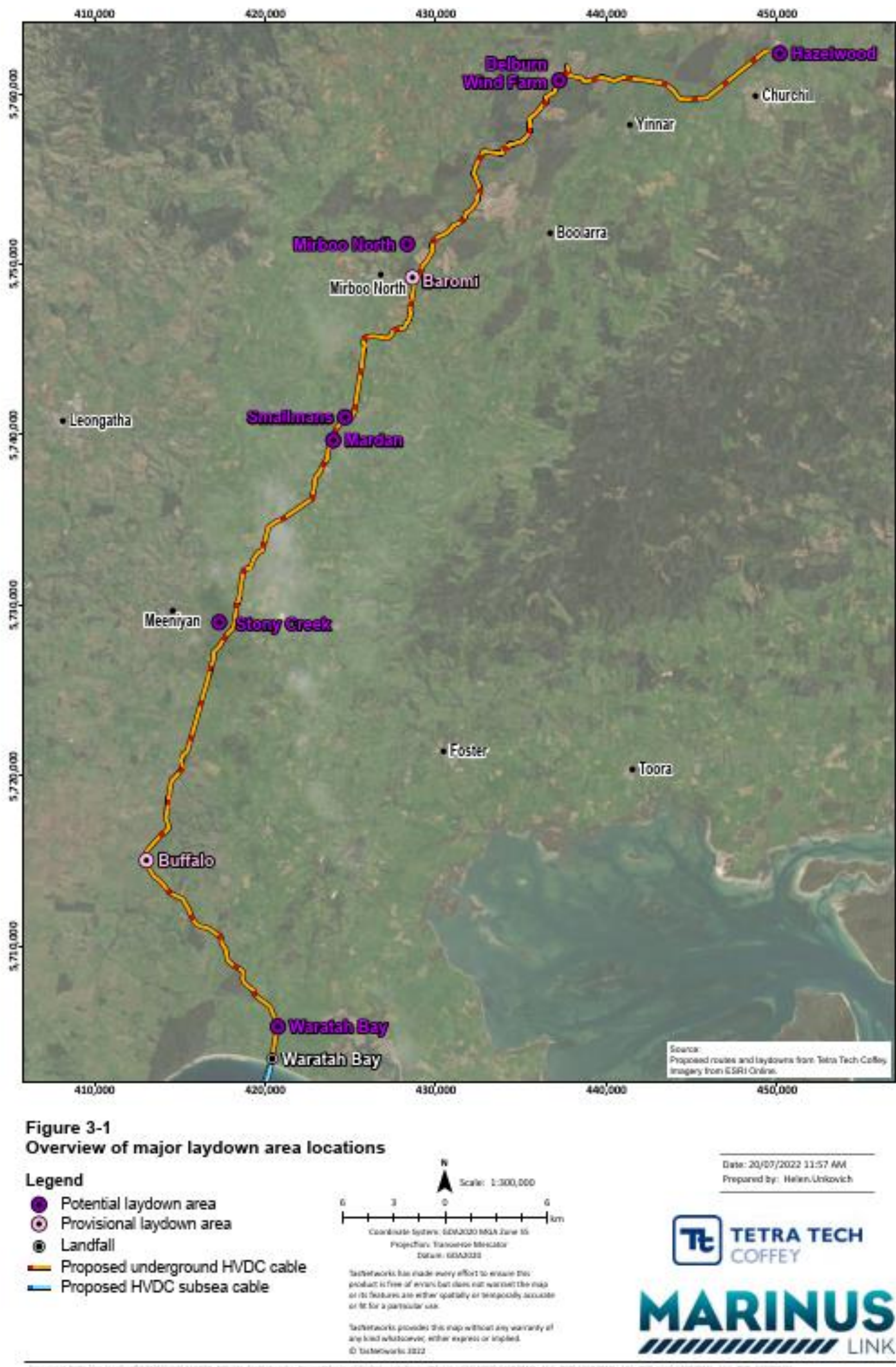


*Figure 5-5: Proposed land project alignment*

### 5.2.4 Converter Station Modelling

The electrical power is converted between AC and DC at converter station either side of the link. The primary AC flexible and rigid conductors within the converter station have been modelled to determine the extremely low frequency (ELF) EMF levels at the boundary of the converter stations, including the landing spans of the incoming/outgoing transmission lines.

Details of large power quality filters and power transformers will only be confirmed at the detailed design stage. Requirements have however been placed on the detailed design to comply with all relevant EMF and EMI environmental and human health standards (refer to EPR EMF01, which is described in Section 7.9). The DC equipment is also proposed to be located indoors, away from the converter station boundary. The building enclosure will shield the outside environment from electric fields generated by the indoor power equipment and the position of the indoor equipment with respect to the boundary will minimise the impact of magnetic fields on nearby sensitive receivers. Furthermore, the highest levels of EMF and EMI generated by DC equipment at the fenceline of the converter stations will be directly above the incoming HVDC cables. The modelling of the EMF/EMI generated by the HVDC cables is performed separately to the converter stations. The conclusions of the HVDC cable EMF/EMI modelling are however applicable to the HVDC cables entering/leaving the converter stations and constitute the worst-case EMF/EMI levels around the boundary of the converter station.

The 220 kV Heybridge site has been modelled based on the Reference Design layout and standard values of minimum ground clearance. Similarly, the 500 kV Driffield and Hazelwood sites have been modelled using the Reference Design layout and standard values of minimum ground clearance.

The Hazelwood converter station will form an extension of the existing Hazelwood terminal station. The extent of the modelling undertaken in this assessment with respect to the Hazelwood site is the modelling of the converter station air insulated switchgear (i.e. the existing terminal station equipment is not modelled). This is because the EMF/EMI levels generated by the existing equipment at the Hazelwood terminal station will have a negligible impact on calculated EMF levels at the fence line of the converter station. The EMF/EMI levels generated by the converter station equipment and connections will be the dominant contributor of EMF/EMI levels at the converter station fence line. Not modelling the existing Hazelwood terminal station equipment will not materially impact the EMF/EMI levels at the converter station site.

All converter station modelling considers only the Air Insulated Switchgear (AIS). Whilst the Heybridge converter station is proposed to include Gas Insulated Switchgear (GIS) inside the building, this equipment is located further away from the boundary fence and will produce lower EMF/EMI levels. As such, the additional GIS equipment will not have a material impact on the reported EMF/EMI levels.

The detailed design of the Heybridge, Driffield and Hazelwood converter stations will include an earthing assessment and mitigation design for safety impacts of earth potential rise on nearby sensitive receivers during HVAC and HVDC earth fault scenarios in accordance with AS/NZS 7000:2016 and AS 2067:2016.

### 5.2.5 Basslink

The Basslink HVDC submarine cable was laid in 2005, forming an electrical connection between Tasmania and Victoria across the Bass Strait. The subsea asymmetric monopole cable link comprises a high voltage cable, a low voltage metallic current return cable and fibre optic cable, which are bundled together. The continuous rated capacity of the link is 500 MW at either +400 kV or -400 kV, depending on the direction of power flow, and a dynamic rating of 630 MW. The nominal rated current of the link is therefore 1,250 A per cable.

A report was published in 2016 by the Journal of Ocean Engineering and Science [1]. It describes the observed impact of the Basslink subsea cable on the Bass Strait environment. The study concluded:

- Over 95% of the cable was directly laid into a wet-jetted trench
- Magnetic field measurements indicate that the intensity of the earth's geomagnetic field in the Bass Strait is 61.6 μT along the ocean bed.
- Sections of the cable were monitored over a 3.5-year period using remote towed video surveys and diver-based survey methods
- Magnetic field measurements were taken when the cable was transferring between 121 MW and 237 MW
- Observations of epibiota near the Victorian shore, at the first dive site, indicated no sedentary epibiota on the sandy seabed. At the dive site, swimming anemones were attached to rock associated with the cable trench
- In the deeper waters of the Bass Strait the following biological effects were noted:
    - Habitat modification where a trench was still detectable
    - Accumulation of drift biological material within the shallow depression where the presence of the cable trench was still detectable
    - Growth of some epibenthic species on the biological material accumulating in the trench
- Levels of biota comprising the seaweeds, bryozoans, ascidians, small sponges and sea urchins that covered the cable conduit shell or occupied the seabed beneath the shell at the Tasmanian end of the cable by 2009 were similar to those of the surrounding area

The study concluded that the ecological effects of the cable installation on epibiota have been minor and transient in nature for soft sediments along the sea floor. Moreover, the armoured half-shell substrate installed at the Tasmanian end of the cable has become a new habitat for reef species and is colonisable. The impact of the electric and magnetic fields generated by the cable do not affect this process.

## 5.3 Impact Assessment

The EMF and EMI impact assessment is performed using an industry specific methodology. Appropriate exposure and immunity limits and reference levels are identified in standards, guidelines and research publications. These are adopted as the assessment criteria in the study. If the calculated EMF and EMI levels are below the applicable criteria, the impact on sensitive receivers is considered acceptable but Environmental Performance Requirements are identified Section 7.9 to manage the impact of any residual effects. For instances where the calculated levels exceed the limits or reference levels, a risk assessment is carried out and mitigation options are considered.

Standard design practices and the additional mitigation and control measures described throughout the study will reduce the significance of the impacts of EMF and EMI from the project construction and operation activities to negligible under most circumstances. Residual impacts that are not negligible will be highlighted in the study.

The aforementioned mitigation measures can be broken down into two categories: at-source and at-receiver mitigations. Generally, at-source mitigations are inherent in standard design practices to reduce the magnitude of electric and magnetic fields produced by high voltage electrical equipment. These at-source mitigations include reduced spacing between adjacent phase conductors in an AC system, and reduced spacings between positive and negative poles in a DC system. At-receiver mitigations can include relocation of the sensitive equipment away from the source, passive shielding, or active shielding. The at-source mitigations have potentially limited efficacy, given the performance requirements of the link. The selection of at-receiver mitigation options depends on the magnitude of the source fields, the immunity of the limit of the sensitive receiver and the associated cost for each option.

### 5.3.1 Cumulative Impact Assessment

The EIS guidelines and EES scoping requirements both include requirements for the assessment of cumulative impacts. Cumulative impacts result from incremental impacts caused by multiple projects occurring at similar times and within proximity to each other.

To identify possible projects that could result in cumulative impacts, the International Finance Corporation (IFC) guidelines on cumulative impacts have been adopted. The IFC guidelines (IFC, 2013) define cumulative impacts as those that 'result from the successive, incremental, and/or combined effects of an action, project, or activity when added to other existing, planned, and/or reasonably anticipated future ones.'

The approach for identifying projects for assessment of cumulative impacts considers:

- Temporal boundary: the timing of the relative construction, operation and decommissioning of other existing developments and/or approved developments that coincides (partially or entirely) with Marinus Link.

- Spatial boundary: the location, scale and nature of the other approved or committed projects expected to occur in the same area of influence as Marinus Link. The area of influence is defined at the spatial extent of the impacts a project is expected to have.

Proposed and reasonably foreseeable projects were identified based on their potential to credibly contribute to cumulative impacts due to their temporal and spatial boundaries. Projects were identified based on publicly available information at the time of assessment. The projects considered for cumulative impact assessment in Tasmania /Bass Strait / Victoria are:

- Delburn Windfarm

- Star of the South Offshore Windfarm
- Offshore wind development zone in Gippsland including Greater Gippsland Offshore Wind Project (BlueFloat Energy), Seadragon Project (Floatation Energy), Greater Eastern Offshore Wind (Corio Generation).
- Remaining North West Transmission Developments

The projects relevant to this assessment have been determined based on the potential for cumulative impacts to EMF/EMI values. Projects assessed as relevant to this assessment are:

- Delburn Windfarm
- Star of the South Offshore Windfarm
- Offshore wind development zone in Gippsland including Greater Gippsland Offshore Wind Project (BlueFloat Energy), Seadragon Project (Floatation Energy), Greater Eastern Offshore Wind (Corio Generation).
- Remaining North West Transmission Developments

Each of these projects contain high voltage electrical equipment that carry electrical current. The voltage and currents associated with the high voltage equipment generate electric and magnetic fields that will have the potential to constructively or destructively summate with the electric and magnetic fields that will be generated by the Marinus Link infrastructure.

Other projects that are not included in the list above have been omitted because either they do not contain high voltage electric equipment and therefore will not generate significant electric and magnetic fields, or the projects are located a significant distance away so that any potentially generated electric and magnetic fields will be indistinguishable from background levels.

Cumulative EMF and EMI impacts have been considered for the proposed electrical power infrastructure and describe the total or net EMF & EMI impacts that will be generated by the project’s cables and other sources of potential EMF and EMI (i.e. the summation of EMF and EMI levels from multiple sources). These impacts include the cumulative effects of the proposed project infrastructure on the ambient geomagnetic field and also on the magnetic fields generated by the operational Basslink cables and other high voltage electrical projects and infrastructure.

The Delburn Windfarm project is the closest windfarm to the proposed Marinus Link infrastructure. Therefore, the cumulative impacts from this project are analysed first in detail. This is because if cumulative impacts from this windfarm project are deemed to be negligible, it stands to reason that the cumulative impacts from other windfarm projects, located further away, will also be negligible.

## 5.4 Assumptions and Limitations

The screened HVDC cables and indoor HVDC power equipment will not produce significant electric fields in the surrounding environment.

The subsea and land cable arrangements will only be confirmed during the detailed design process. Conservative assumptions have been described in Section 5.2. These are conservative and will result in worst-case EMF and EMI levels.

The modelling and results presented in Section 7.5 consider the nominal rating of the link (i.e. 1,500 MW). However, the impact of the overload rating for the proposed cables has also been considered in the impact assessment.

The overload rating is a temporary scenario and it has been assumed, for the purposes of this assessment, to apply to both Stage One and Stage Two cables simultaneously. The overload scenario and emergency current rating is assumed to be 150 MW per stage (i.e. Stage One overload rating is 900 MW and Stage Two overload rating is also 900 MW).

# 6. Existing Conditions

## 6.1 Geomagnetic Field Characterisation

There is a background geomagnetic field at the surface of the earth and in the oceans that is generated by four main natural sources. The EMF and EMI study will consider the cumulative effect of the DC magnetic field generated by the subsea and land cables and the ambient geomagnetic field that fluctuates geographically and also with time.

The primary source of the ambient geomagnetic field is the core field, which varies between 20 μT and 70 μT at the earth's surface. A map of the distribution of typical core field strengths across the globe is illustrated in Figure 6-1. The core field is generated by the flow of a hydrodynamic dynamo operating in the earth's fluid outer core. Convection of molten iron in the outer liquid core and the Coriolis effect caused by the earth's rotation causes the flow of charges across an existing magnetic field, inducing electric currents, which creates another magnetic field that reinforces the existing field (i.e. a dynamo that sustains itself). As is noted that the core field is relatively intense in the Bass Strait region, which is near the earth's magnetic south pole. The core field varies geographically but only varies very slowly with time (i.e. over the course of years, rather than days).

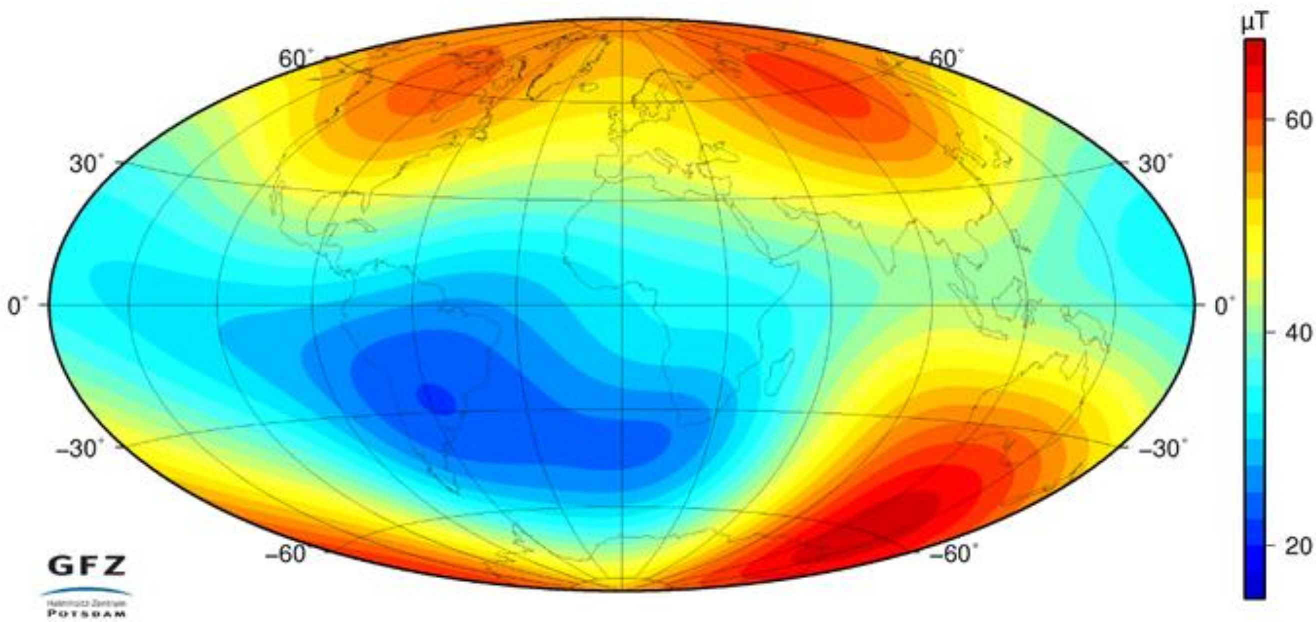


*Figure 6-1: Intensity of the core magnetic field at the earth's surface [GFZ Modell[1]]*

The second contribution to the ambient geomagnetic field at a location within the study area is due to the lithospheric field, which is caused by close proximity to magnetised rocks. The magnetic field strength associated with this contribution gives rise to localised variations in the total geomagnetic field at the earth's surface in the order of 0.1 μT. The lithospheric field anomalies within the study area

[1] Source: GFZ Helmholtz Zentrum Potsdam (https://www.gfz-potsdam.de/en/section/geomagnetism/topics/sources-of-the-earths-magnetic-field/core-field/)

will vary with geographic position due to changes in geology but only varies slowly with time in response to changes in the core field. The iron-rich, volcanic rock that makes up the ocean floor within the Bass Strait contains significant concentrations of magnetite that results in higher field levels near the ocean floor. Relatively large magnetic anomalies are therefore expected along the subsea cable.

The third contribution to the geomagnetic field is from disturbances above the earth's surface. Induced electric currents in the magnetosphere and ionosphere, created by solar radiation and thermospheric winds, cause localised variations in the magnetic field at the earth's surface. During periods of low induced current activity, the strength of these fields is typically in the order of 0.02 μT but can increase very quickly to values as high as 2 μT (e.g. during solar flares). The atmospheric field fluctuations vary geographically and also over relatively short time periods (i.e. is a transient field).

The fourth contribution is a result of the ocean's tidal dynamo but typically has a very low magnitude. Ocean currents cause the steady flow of conductive water and thereby generate magnetic fields through motional induction. The intensity of these magnetic fields is only in the order of 0.001 μT at the earth's surface. These contributions are typically defined in nanotesla (0.001 μT = 1 nT). The map of the oceanic tidal field intensity in Figure 6-2 indicates only a small variation in the geomagnetic field in the Bass Strait due to currents in the Tasman Sea and will have negligible impact on the magnetic anomalies within the study area.

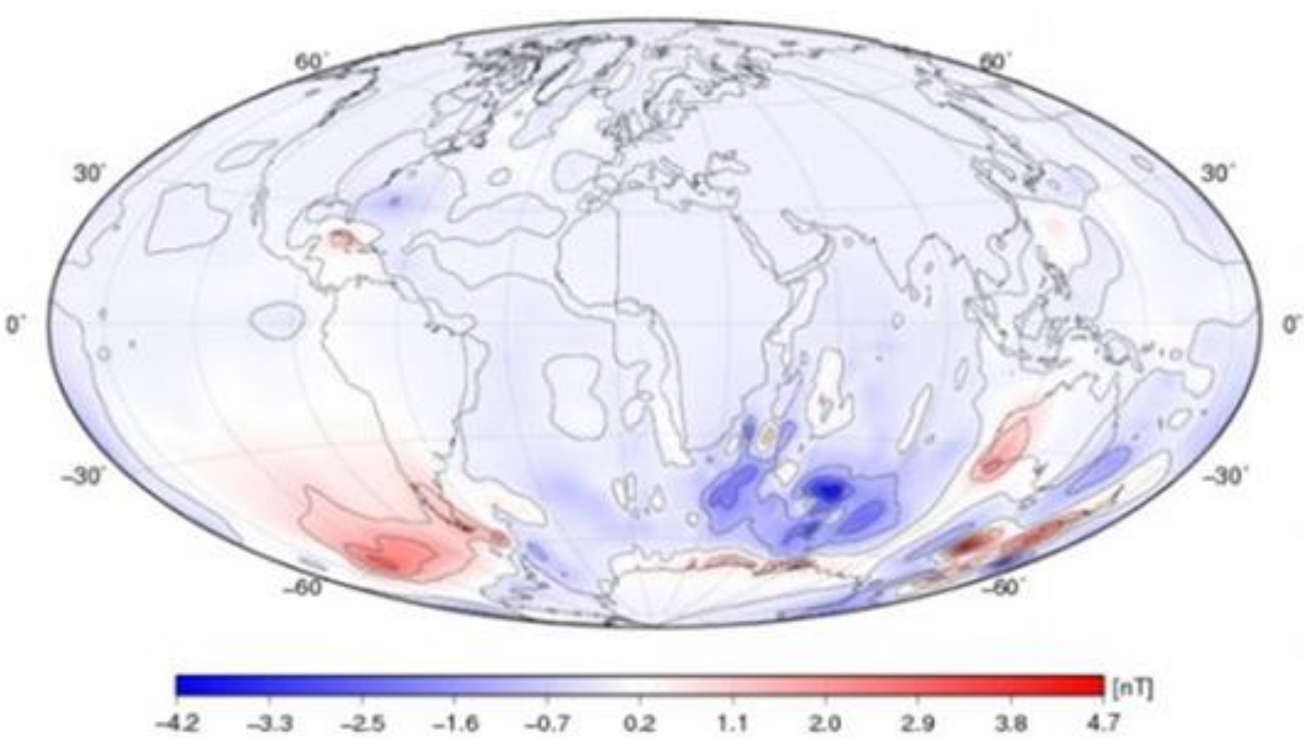


*Figure 6-2: Intensity of the oceanic tidal magnetic field at the earth's surface [GFZ Potsdam[2]]*

[2] Source: GFZ Helmholtz Zentrum Potsdam (https://www.gfz-potsdam.de/en/section/geomagnetism/topics/sources-of-the-earths-magnetic-field/core-field/)

A magnetic anomaly map of the Bass Strait is included in Figure 6-3, with the project's proposed subsea project alignment indicated in the black, dotted polygon. The map describes the average variation in the ambient geomagnetic field at a moment in time due to variations in the core and lithospheric fields. The magnetic anomaly map is derived from measurements taken by aircraft and describes anomalies above and below a nominal, ambient geomagnetic field.

It is concluded from Figure 6-1 and Figure 6-3 that the steady-state geomagnetic field along the subsea project alignment is approximately 60 +1.8/-0.9 µT. Atmospheric geomagnetic storms can also cause transient fluctuations of up to ± 2 µT in the ambient magnetic field in the study area.

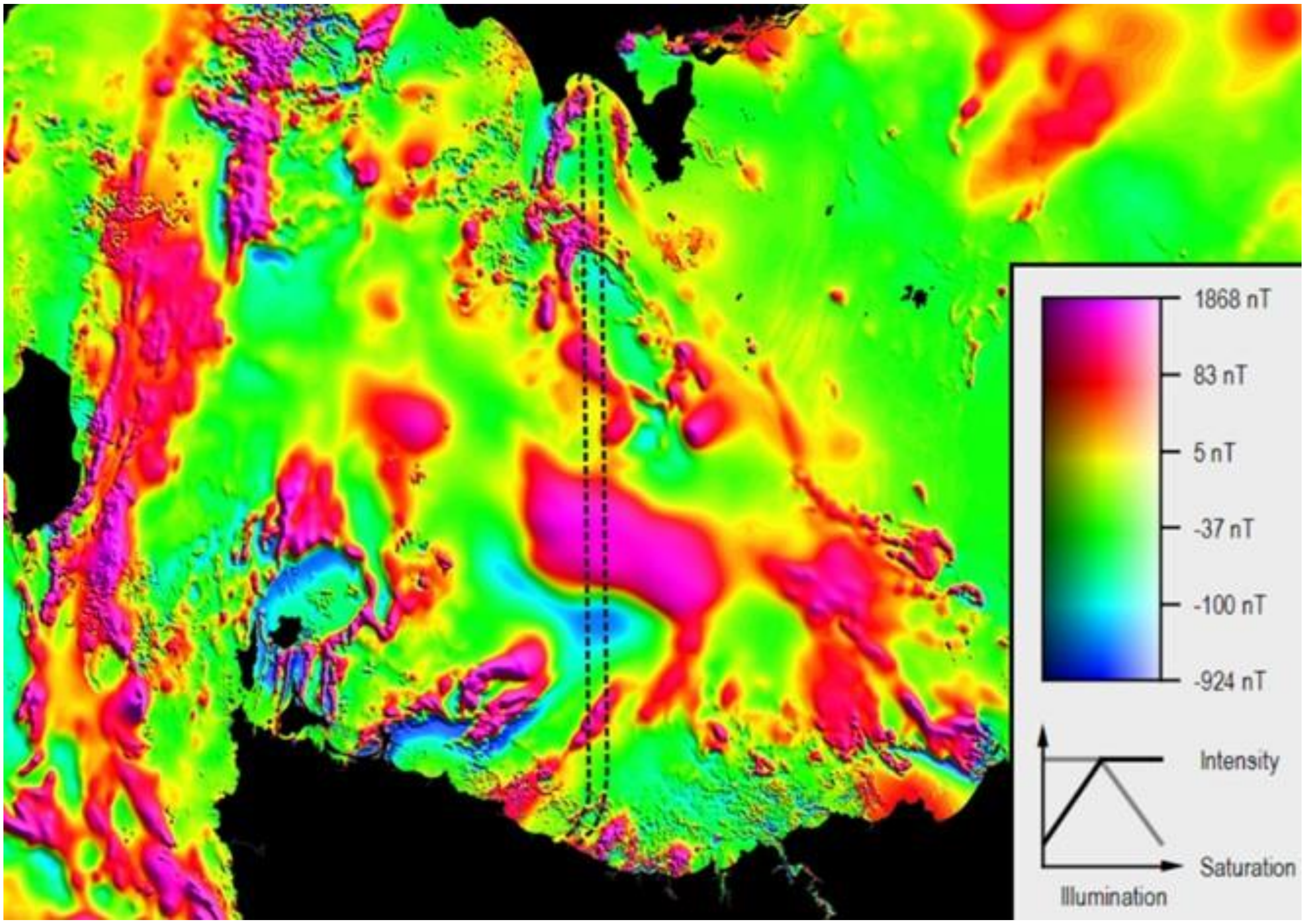


*Figure 6-3: Magnetic anomaly map of Bass Strait (subsea project alignment) [2]*

A similar magnetic anomaly map is included in Figure 6-4 for the land project alignment. The route exhibits a greater degree of geomagnetic field uniformity than the subsea project alignment. The steady-state geomagnetic field along the land project alignment is approximately 60 +1.8/-0.1 µT. Atmospheric geomagnetic storms can also cause transient fluctuations of up to ± 2 µT in the ambient magnetic field in the study area.

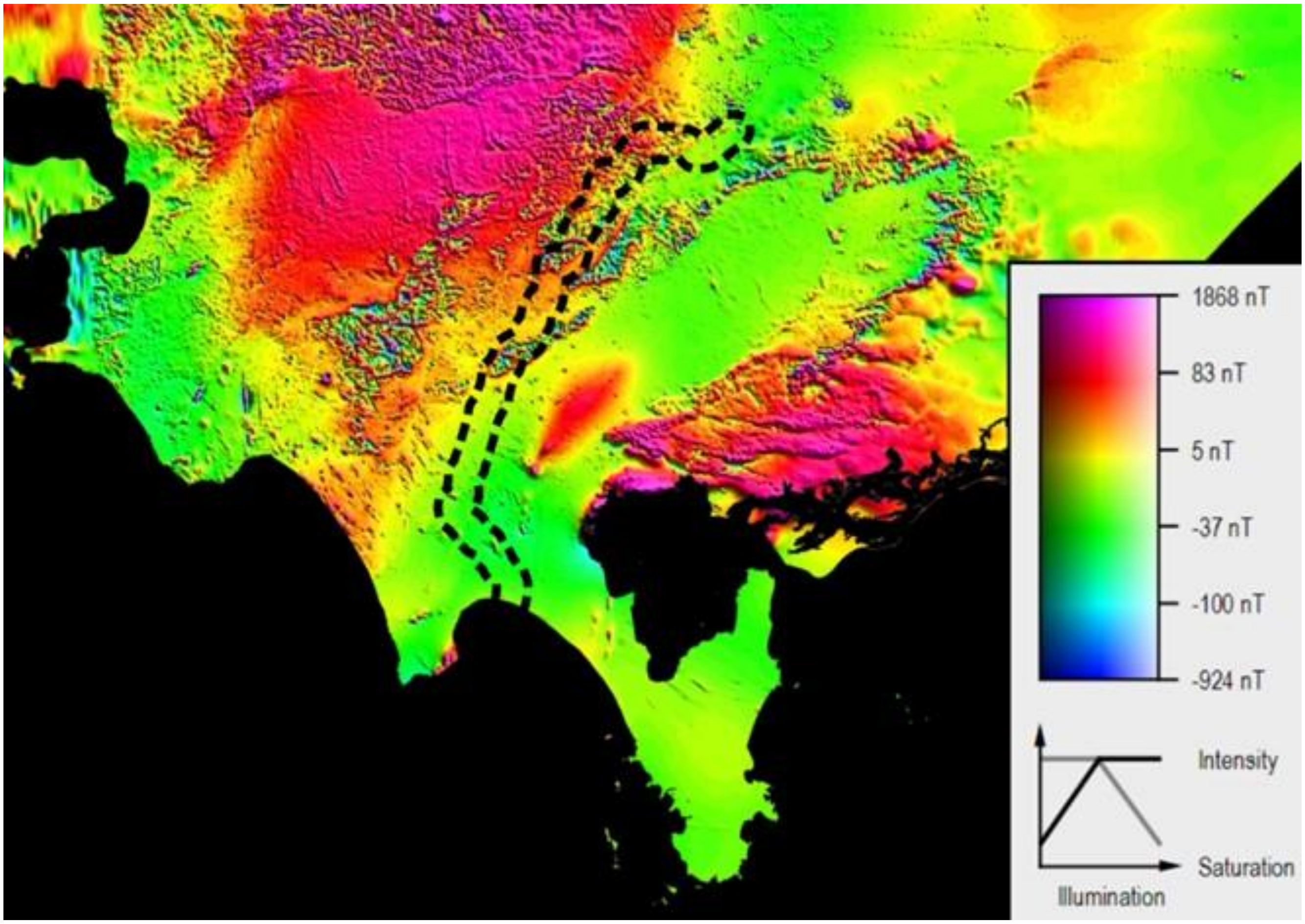


*Figure 6-4: Magnetic anomaly map of south-east Victoria (land project alignment) [2]*

## 6.2 Thermal Characterisation

EMF and EMI cause heating of body tissue and conductive objects by induction. For the DC magnetic fields associated with the proposed subsea and land HVDC cables, the only significant source of heating will be due to ohmic losses in the core of each cable, which will conduct through the cable insulation and screens to the outside environment. The EMF & EMI assessment has therefore also considered the impact of this form of heating on the local environment during normal operation of the cables. As part of this assessment, the thermal characteristics of the local environment are defined in this section.

Materials are characterised by their thermal resistivity, which is a measure of how easily they conduct heat. The thermal resistivity of the seabed and ground in which the subsea and land HVDC cables are buried respectively, has a significant impact on the temperature of the cable and the surrounding soil. Electrical power cables are generally installed in engineered backfill that facilitates the dissipation of heat into the surrounding soil, thereby protecting the cables from thermal damage.

The maximum measured ambient temperatures along key sections of the HVDC project alignment are summarised in Table 6-1 and the measured thermal resistivity of the soil and rock that will surround the HVDC cables in these areas are summarised in Table 6-2. This information has been sourced from the Marinus Link Cable Technical Specification document and has been used in the study to calculate the thermal conduction to the surrounding environment.

*Table 6-1: Measured ambient sea and soil temperatures along key sections of the proposed project alignment*

| Location | Temperature ($^oC$) |
|---|---|
| Heybridge (soil temperature at 1 m depth) | 25 |
| Hazelwood (soil temperature at 1 m depth) | 25 |
| Bass Strait (sea water temperature above seabed) | 18 |

*Table 6-2: Measured thermal resistivity of the material surrounding the HVDC cables along key areas of the project alignment*

| Thermal Resistivity Medium | Location | Thermal Resistivity ($^oK$ m/W) |
|---|---|---|
| Natural Soil | Heybridge | 1.2 |
| Natural Soil | Mainland Victoria<br>Waratah Bay - Smallmans Rd | 1.2 |
| Natural Soil | Mainland Victoria<br>Smallmans Rd - Darlimurla Rd | 3.0 |
| Natural Soil | Mainland Victoria<br>Darlimurla Rd - Strzelecki Hwy | 1.2 |
| Natural Soil | Mainland Victoria<br>Strzelecki Hwy - Hazelwood | 2.0 |
| Seabed | Submarine section – Bass Strait | 1.0 |
| Thermally stable backfilling material | Mainland Victoria<br>Installed in cable trench along route | 1.0 |

# 7. Impact Assessment

## 7.1 Technical Background

Electric and magnetic fields (EMF) are invisible, physical fields that surround electrical charges and exert forces on all charged particles and objects in the field. All electrical and electronic equipment and appliances therefore generate electric and magnetic fields. The electrical charge that provides power to the equipment and appliances produces EMF and some equipment and appliances also intentionally and unintentionally generate electromagnetic emissions as part of their normal functioning (e.g. the radio wave emissions from a CB radio transmitter and the microwaves that heats food in a microwave oven). Most generated fields fluctuate between minimum and maximum peaks at a fixed rate per second, called the frequency, with units of Hertz (Hz). Examples of everyday sources of EMF are illustrated in Figure 7-1. The EMF from these sources is characterised by the magnitude and frequency of the generated electric and magnetic fields.

The ELF electric and magnetic fields under a transmission line, above a cable or near a power equipment connection are non-ionising in that they do not have enough energy to ionize atoms or molecules (i.e., completely remove a charge from an atom or molecule). The fields are strongest near the conductors and decrease exponentially with increasing distance from the conductors.

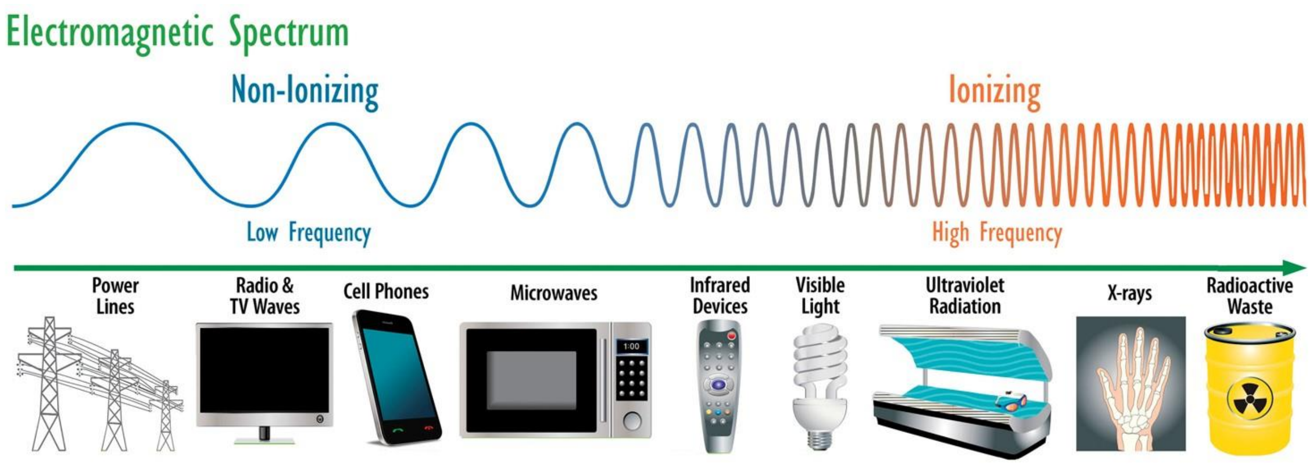


*Figure 7-1: Everyday sources of EMF and EMI*[3]

Electric Field Strength (EFS) is measured in volts per metre (V/m). The large fields associated with high voltage electrical infrastructure are typically expressed in kilovolts per metre (kV/m), with 1 kV/m = 1,000 V/m. Magnetic fields are normally measured in either gauss (G) or Tesla (T) and are commonly expressed in units of milligauss (mG) or microtesla (μT), with 10 mG equal to 1 μT. For the purposes of this EMF and EMI study, electric field strengths will be expressed in kilovolts per metre and magnetic fields will be expressed in units of microtesla. Typical, measured electric and magnetic field levels associated with everyday electrical and electronic equipment are summarised in Table 7-1:

[3] Source: National Institute of Environmental Health Sciences (https://www.niehs.nih.gov/health/topics/agents/emf/index.cfm)

*Table 7-1: Measured EMF levels associated with everyday electrical and electronic equipment and appliances*

| EMF Source | Typical Range of Magnetic Field Strength (μT)[4] | Typical Range of Electric Field Strength (kV/m)[5] |
|---|---|---|
| Electric stove | 0.2 to 3 | 0.07 to 0.1 |
| Refrigerator | 0.2 to 0.5 | Not reported |
| Electric kettle | 0.2 to 1 | Not reported |
| Toaster | 0.02 to 0.2 | Not reported |
| Television | 0.02 to 0.2 | Not reported |
| Personal computer | 0.2 to 2 | Not reported |
| Electric blanket | 0.5 to 3 | 0.058 to 0.6 |
| Hair dryer | 1 to 7 | 0.3 to 0.8 |
| Pedestal fan | 0.02 to 0.2 | Not reported |
| Substation fence | 0.1 to 0.8 | Not reported |
| Distribution line – under the line | 0.2 to 3 | 0.06 to 0.01 |
| Distribution line – 10 m from line | 0.05 to 1 | Not reported |
| Transmission line – under the line | 1 to 20 | 0.003 to 4.1 |
| Transmission line – edge of easement | 0.2 to 5 | Not reported |

The electrical charges in aerial transmission line conductors and underground cables generate both electric and magnetic fields. The voltages that are applied to the aerial conductors define the magnitude and distribution of the electric fields in the air gaps between the conductors and the ground. In underground cables, the metal screen that surrounds the cable's core contains the electric field within the cable, shielding all areas surrounding the cables from the electric field. The electrical currents that flow in the aerial line conductors and underground cable cores define the magnitude and distribution of the magnetic fields near the conductors. The metallic cable screens in underground cables do not however significantly shield the magnetic fields.

Both the voltages and currents associated with converter stations in this study oscillate between minimum and maximum values at an "extremely low frequency" (ELF) of 50 cycles per second (i.e., 50 Hz) and are referred to collectively as Alternating Current (AC). The voltages and currents associated with the land and subsea cables do not oscillate at a set frequency and only vary very slowly in magnitude due to fluctuating electrical loads and are referred to collectively as Direct Current (DC). The instantaneous magnitudes of the DC voltages and currents and the Root Mean Square (RMS) of the AC voltages and currents are used to quantify the amount of electrical power that is transferred along the link.

[4] Source: Australian Radiation Protection and Nuclear Safety Agency: https://www.arpansa.gov.au/understanding-radiation/radiation-sources/more-radiation-sources/measuring-magnetic-fields
[5] Source: Transpower New Zealand Ltd: https://www.transpower.co.nz/resources/factsheet-3-electric-and-magnetic-field-strengths

Some electrical and electronic appliances and equipment are susceptible to ELF magnetic field exposure from electrical power sources. They are referred to as sensitive receivers. Exposure to magnetic fields exceeding the immunity limits specified by the manufacturer may cause reduced functionality or malfunction of the equipment. This is referred to as electromagnetic interference (EMI).

The electric field levels between transmission line conductors and the ground are much larger near the surface of the conductors, as compared to the electric field level to which people are exposed at ground level. These very large conductor surface electric fields are able to ionise the air immediately surrounding the conductors, creating corona discharges that radiate high frequency electromagnetic fields away from the conductors and can cause interference to the reception of radio, television and mobile communication signals.

Water droplets that form on the surface of the conductors during rain increase the electric field strength near the surface of the conductors due to their shape and thereby increasing the radiated electromagnetic interference levels from the transmission lines under wet conductor conditions.

High electric fields around the sharp edges of converter station fittings can also cause corona discharges and electromagnetic interference under both wet and dry conditions. However, the fittings are Radio Interference Voltage (RIV) tested as part of the type of approval process for installation on to the electrical supply network to ensure that the electromagnetic interference from the fittings is below the applicable limits.

Electromagnetic interference from corona discharges on transmission lines and terminals stations is therefore limited to discharges on the conductors during wet weather by design.

The source of electromagnetic interference on transmission lines that is responsible for the majority of reported interference issues are gap (micro-spark) discharges. They are complete electrical discharges between electrodes across two dissimilar dielectrics, floating components and loose or damaged fittings. An example of this is the air gap that forms between a metal bolt and a timber distribution line pole due to a loose fitting. This creates very large electric field gradients across the air gaps, which results in the total, momentary breakdown of the dielectric air insulation. This form of electromagnetic interference source is found on lines of every voltage classification but tend to be most prevalent on distribution line wood pole where hardware has a greater probability of becoming loose as the wooden poles and crossarms dry out.

Dry band arcing along contaminated insulator surfaces generally produces the highest electromagnetic interference levels. This occurs on polluted insulators during fog or dew conditions, or after the cessation of light rain that does not clean the pollution off the insulators. The leakage current across the wet, polluted insulator surface heats the surface and creates small dry bands due to the evaporation of the water along the surface. The voltage across the dry bands results in very high surface voltage gradients and sparking. This can be very severe for heavily polluted insulators. Dry-band arcing is primarily a problem on ceramic and glass insulators and not polymer insulators, which have a hydrophobic surface that mitigates the formation of continuous moisture films along the insulator surface and also facilitate natural cleaning of pollution from the insulator surface during rain.

Transmission line towers and wires also have the potential to interfere with radio communication signal paths, thereby degrading radio reception in the vicinity of the line. The radiated fields and the field scattering effects that interfere with the functionality of sensitive receivers and reception of radio, television and mobile communication signals are collectively referred to as electromagnetic interference (EMI).

## 7.2 Sensitive Receiver Impacts

### 7.2.1 Limits and Reference Levels

Limits for EMF and EMI exposure are defined for some scenarios where a clear cause-effect has been identified and a value of exposure derived from experiments that confirm an acceptable level of confidence for mitigating the unwanted effect.

For exposure scenarios where the cause-effect is not definitive, experimental data is limited or where the verification of compliance with the limits is too complex, conservative, measurable field levels that ensure compliance with the limits are defined.

Limits and/or reference levels are defined in the proceeding sections for all sensitive receivers that may be impacted by EMF and EMI in the study area.

### 7.2.2 Human Biological Impacts

The potential sensitive receivers identified in this subsection are humans. In particular, the assessment considers biological impacts on people exposed to DC and power frequency AC electric and magnetic fields. The exposure scenarios involve DC magnetic fields from HVDC cables and AC electric and magnetic fields from converter stations.

Extremely low frequency electric and magnetic fields induce internal electric fields and currents in the body. The World Health Organisation states that at high field levels (well above 100 μT), it can cause "nerve and muscle stimulation and changes in nerve cell excitability in the central nervous system" [6]. Established biological effects caused by acute exposure to high field strengths include magneto-phosphene effect and micro-shocks:

- Magneto-phosphene effect - the sensation of flashes of light caused by induced electric currents stimulating the retina.
- Micro-shock - a sensation caused by a small electric spark discharge or arc when a person touches an earthed metallic object. Provisions such as proper earthing methods or working procedures are made for activities within the easement to minimise the impacts of micro shocks.

The ENA EMF Management Handbook defines mitigation measures for these biological effects.

Extensive scientific research examining health risks associated with exposure to extremely low frequency electric and magnetic fields have been undertaken since the 1970's. The Australian

[6] Source: World Health Organisation (https://www.who.int/health-topics/electromagnetic-fields#tab=tab_1)

Radiation Protection and Nuclear Safety Agency (ARPANSA) has advised that: “Most of this research indicates that the ELF EMF exposure normally encountered in the environment, including in the vicinity of transmission lines, does not pose a risk to human health” [7].

ARPANSA is the Australian Government’s agency responsible for regulating Commonwealth Government radiation protection practices. The Victorian Department of Health and Tasmanian Department of Health are the state regulatory agencies tasked with protecting people and the environment from the harmful effects of ionising and non-ionising radiation.

There are some epidemiological (population) studies that have reported a statistical association between increased rates of childhood leukaemia and prolonged exposure to extremely low frequency magnetic fields at levels below the exposure limits but higher than what is typically encountered. A statistical association does not necessarily indicate a cause-effect relationship and ARPANSA has concluded, on the balance of the published research, that the statistical association reported in some research is not supported by laboratory or animal studies and no credible theoretical mechanism has been proposed to support the statistical association.

Based largely on the limited evidence, the International Agency for Research on Cancer (IARC) published a monograph that prudently classifies ELF magnetic fields as a “possibly carcinogenic to humans”[8] – Group 2B[9] and ELF electric fields as a “not classifiable as to carcinogenicity” – Group 3.

Extensive studies have also been carried out into other possible health effects of magnetic field exposure, including cancers in adults, depression and suicide. The World Health Organization concluded that there’s little scientific evidence supporting an association between extremely low frequency magnetic field exposure and other adverse health effects[10].

Static and slowly varying magnetic field induce much lower electric fields and currents in the human body. The biological effects described previously for extremely low frequency EMF only occur at much higher DC field exposure levels. It’s only at slowly varying magnetic field intensities greater than 2,000,000 μT that nausea, magneto-phosphenes and other biological effects are perceivable [3].

Blood electrolysis and spin chemistry changes (i.e. changes to an electron’s momentum and spin about a reference axis) can impact chemical reactions within the body when subjected to a static magnetic field but these effects are not considered to have a significant health effect for magnetic field intensities below 7,000,000 μT. Exposure to static and slowly varying magnetic fields of such a large

[7] Source: Australian Radiation Protection and Nuclear Safety Agency: (https://www.arpansa.gov.au/understanding-radiation/radiation-sources/more-radiation-sources/electricity)

[8] List of classifications by the IARC monographs can be found in: https://monographs.iarc.who.int/list-of-classifications

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

- Group 1 – the agent is carcinogenic to humans – 121 agents are included in the group, including asbestos, tobacco and UV radiation
- Group 2A – the agent is probably carcinogenic – 89 agents are included in the group, including lead compounds and creosotes
- Group 2B – the agent is possibly carcinogenic to humans – 319 agents are included in the group, including gasoline and dry cleaning
- Group 3 – the agent is not classifiable as to carcinogenicity – 500 agents are included in this group, including caffeine and tea

[10] Source: World Health Organisation (https://www.who.int/health-topics/electromagnetic-fields#tab=tab_1)

magnitude are generally only associated with medical treatment/diagnosis areas involving magnetic resonance imaging (MRI) [4].

### 7.2.3 Active Implantable Medical Devices

The potential sensitive receivers identified in this subsection are people with active implantable medical devices fitted. The exposure scenarios involve DC magnetic fields from HVDC cables and AC electric and magnetic fields from converter stations.

Static, slowly varying and extremely low frequency magnetic fields can interfere with Active Implantable Medical Devices (AIMD). However, according to the International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines, EU Directive 2013/35/EU and various European Normalised standards and guidelines, exposure to static magnetic fields intensities below 1,000 μT can be regarded as safe in terms of interference to AIMDs. A conservative 500 μT limit is recommended by ICNIRP for the general exposure case.

It is further noted that devices such as cardiac pacemakers are generally designed to be able to withstand static magnetic fields up to 10,000 μT. As a precautionary measure, magnetic fields over magnitudes of 1,000 μT should be avoided by people with pacemakers since electromagnetic fields beyond this limit pose the risk of initiating an asynchronous pacing mode in the AIMD. The potential impact of static and slowly varying magnetic fields on AIMDS, as defined in the EU Directive, is summarised in Table 7-2.

For ELF magnetic fields (e.g. 50 Hz), the EN 45502-2 standard requires manufacturers of AIMDs to immunise such their products from exposure to 50 Hz EMF up to the general public reference levels indicated in the ICNIRP 2010 guidelines. EN 50527-1 provides a procedure for assessing the risk to workers with AIMDs fitted from exposure to EMF in the workplace, where EMF levels approaching the occupational limits indicated in the ICNIRP guidelines are expected. Precautions may need to be taken in such areas to alert or exclude workers with AIMDs.

*Table 7-2: Effects of magnetic fields on Active Implantable Medical Devices defined in the EU Directive 2013/35/EU*

| Static and Slowly Varying Magnetic Field (μT) | Biological Effects | Impact on Pacemakers |
|---|---|---|
| 0 to 500 | None | Generally safe. |
| 500 to 1,000 | None | Relatively safe, subject to formal assessment in accordance with the recommendations of EU Directive 2013/35/EU or other appropriate standards or guidelines. |
| 1,000 to 10,000 | None | Not recommended. May initiate asynchronous pacing modes, albeit not a life-threatening event. |
| > 10,000 | None | Pacemaker may be damaged causing life-threatening event. |

### 7.2.4 Electrical and Electronic Equipment

The potential sensitive receivers identified in this subsection are electrical and electronic equipment installed in residential, commercial, industrial, medical and scientific research environments. The exposure scenarios involve DC magnetic fields from HVDC cables and AC electric and magnetic fields, and electromagnetic interference from converter stations.

The magnetic field immunity limits for sensitive equipment are specified in generic immunity standards. For very sensitive equipment, the manufacturer defines the immunity limits. The immunity limits specified in Table 7-3 are derived from EMI standards for generic equipment and typical manufacturer specifications for very sensitive medical and scientific research equipment.

All forms of radio communication equipment are sensitive to electromagnetic interference and are considered to be sensitive receivers for the purposes of this impact assessment.

For sensitive receivers that form part of critical safety systems during adverse weather conditions (e.g., aeronautical VHF radio communications), the EMI assessment shall consider the most onerous operating and maintenance scenarios (e.g., heavy rain and damaged insulator EMI levels).

*Table 7-3: Typical EMI immunity levels for different equipment and appliances*

| Equipment | Magnetic Field Limit (μT) | | Standard/Specification |
|---|---|---|---|
| | Static/slowly varying | Extremely low frequency | |
| Electrical & electronic equipment in a residential, commercial or light industrial environment | Not defined | 3.8 | AS/NZS 61000-6-1 |
| Electrical & electronic equipment in an industrial environment | Not defined | 38 | AS/NZS 61000-6-2 |
| Electron microscopes | 0.03 to 0.3 | | Typical specification |
| Atomic force microscope | 0.03 to 0.3 | | Typical specification |
| Nuclear magnetic resonance | 0.2 to 0.5 | | Typical specification |
| Computed Tomography | 100 | 1 | Typical specification |
| Positron Emission Tomography | 100 | 3.8 | Typical specification |
| X-ray | Not defined | 3.8 | Typical specification |
| Mass Spectrometer | Not defined | 38 | Typical specification |
| Magnetic Resonance Imaging | 1.2 | | Typical specification |

### 7.2.5 Livestock

The potential sensitive receivers identified in this subsection are livestock. In particular, dairy and beef cattle, sheep, horses, pigs and poultry. The exposure scenarios involve DC magnetic fields from HVDC cables and AC electric and magnetic fields from converter stations.

Considerable research has been conducted on the possible effects of EMF on livestock from HVAC transmission lines ( [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16]) and HVDC transmission lines ( [17] [18] [19] [20]) since the 1970's. These studies have investigated the possible impact of DC and ELF EMFs on the general health, productivity, fertility, reproduction and behaviour of livestock. The studies included exposure of livestock to EMFs under operational transmission lines and also exposure to acute EMF levels in carefully controlled environments.

Collectively, these studies indicate that electric and magnetic fields from transmission lines and cables do not pose a significant risk of adverse health effects or negative impacts on production in livestock. Hydro Quebec, which operates both AC and DC transmission lines in Canada, and conducted an extensive review of the available literature concluded: "At this time, every indication is that no biological disorder can be attributed to the exposure of livestock to EMFs generated by high-voltage lines. Analysis of data collected to date has not made it possible to identify any harmful effect on the health, productivity, fertility, reproduction or behaviour of livestock exposed to EMFs" [21].

Radio-frequency identification (RFID) tags are increasingly used to uniquely identify and store information about an animal or farm object. Passive RFID tags receive radio signals, which also power the transponder device, and transmit the applicable data to a nearby receiver via radio signals. They operate in the kHz frequency range. Active RFID tags are powered and transmit information in wider bandwidths in the MHz frequency range, over larger distances. Passive RFID tags that operate in the kHz frequency range are typically used for cattle and other farm animals.

A study conducted on human patients wearing passive RFID tags with an operating frequency of 13.56 MHz, involved exposure to static and transient magnetic fields associated with the operation of 1,500,000 μT and 3,000,000 μT MRIs [22]. The study concluded that no data loss or corruption occurred in the RFID tags.

### 7.2.6 Apiaries

The potential sensitive receivers identified in this subsection are honeybees. The exposure scenarios involve DC magnetic fields from HVDC cables and AC electric and magnetic fields from converter stations.

A number of factors may cause the bee population of a hive to dwindle or cease to exist, such as sickness, weather conditions, pesticides or intruders. However, the term known as evaporation (Aikin, 1897), was given to describe the phenomenon where evidence of typical reasons for bee population reduction were not present, including: absence of sick or dead bees, non-existence of an egg-laying queen, a lack of fit and young adults, and where the condition does not appear to be contagious [23].

The Gibbs report [24] concluded that honeybees in hives under or near to transmission lines are adversely affected by shocks created by currents induced by HVAC lines, but that the effect can be mitigated by shielding.

The finding in the report was supported by published research conducted by Greenberg et al. [25], which focused on the different biological effects on honeybee colonies under a 765 kV AC transmission line. The observed effects included increased motor activity with transient increase in hive temperature, abnormal propolization, impaired hive weight gain, queen loss and abnormal production of queen cells, decreased sealed brood and poor winter survival.

The study stated, "When colonies were exposed at 5 different electric fields (7, 5.5, 4.1, 1.8, and 0.65-0.85 kV/m) at incremental distances from the line, different thresholds for biologic effects were obtained. Hive net weights showed significant dose-related lags at the following exposures: 7kV/m, one week; 5.5 kV/m, two weeks; and 4.1 kV/m, 11 weeks. The two lowest exposure groups had normal weight after 25 weeks. Abnormal propolization of hive entrances did not occur below 4.1 kV/m. Queen loss occurred in 6 of 7 colonies at 7 kV/m and 1 of 7 at 5.5 kV/m, but not below. Foraging rates were significantly lower only at 7 and 5.5 kV/m."

It is noted that the above-described impact is related only to AC electric fields. The static magnetic fields associated with land HVDC cables will not induce significant currents in a hive and therefore do not pose a risk to the health of a honeybee colony from the described impact.

Behavioural scientists have accumulated decades of experimental evidence regarding honeybees' ability to perceive and utilise the earth's static magnetic field as a form of navigation, this ability is often referred to as magnetoreception [26]. This area of research gives rise to the possibility that if a honeybee uses the earth's magnetic field as a form a navigation, then disruptions and disturbances in this ambient field in a honeybee's environment may affect their ability to locate food sources and their colony. The results of the study described in [23] indicate that exposure of honeybees to static magnetic fields of ≥ 2 μT may inhibit their ability to return to their hives.

It was concluded in Section 6 that the steady-state geomagnetic field along the land project alignment is approximately 60 +1.8/-0.1 μT and that atmospheric geomagnetic storms can also cause transient fluctuations of up to ± 2 μT in the ambient magnetic field in the study area. The impact threshold for DC magnetic fields that is proposed by the research therefore appears to correspond to the limit of the naturally occurring fluctuations in the ambient geomagnetic field.

Prolonged exposure (i.e. > 1 minute) to ELF magnetic fields has a negative impact on a bee's proboscis extension response (i.e. its ability to learn), increases their wingbeat frequency, and decreases their ability to successfully feed, all of which are shown to increase as the intensity level of the ELF AC magnetic field increases [27]. Moreover, honeybees have also exhibited a larger aggression score, by means of a sting extension response, towards bees introduced to their hives after exposure to ELF AC magnetic fields at levels greater than 100 μT, compared to bees that had not been exposed to such fields [28].

Based on the reviewed research, it is concluded that where exposure to static magnetic fields that exceed 2 μT, but do not exceed 100 μT, is very localised and remote from the hive (i.e. not prolonged), the impact on individual bees will be momentary disorientation and will have negligible impact on the colony as a whole.

### 7.2.7 Crops and Orchards

The potential sensitive receivers identified in this subsection are fruit trees, feeding grasses, vegetables and local flora. The exposure scenarios involve DC magnetic fields from HVDC cables and AC electric and magnetic fields from converter stations.

There are many reasons as to why crop and orchard yields and plant health may suffer, including environmental conditions, soil health, pesticides and adverse weather conditions. Research into the effects of EMF on plant health may therefore be inconclusive due to the numerous possible causes for the observed effects.

A report to the New South Wales Minister for Minerals and Energy dated 28 February 1991, commonly known as the "The Gibbs Report", references research into the effects of AC EMF to animals and plants and concludes [24]:

- Crops may suffer leaf damage when located close enough to overhead transmission lines, such that corona discharges are produced on the sharp tips and edges of the tree's leaves and branches. Damage cause by corona discharges may reduce the height and growth of the tree, but not affect the growth of low-growing vegetation or crops
- There was inconclusive evidence to suggest that exposure to a 5 kV/m electric field reduced the rate of germination of sunflower seeds
- Corn grown under 500 kV lines showed lower yields than those not exposed to the EMF. Other crops (cotton, soy beans and clover) and trees showed no effects. The data from the corn yields was deemed inconclusive
- Field studies in Indiana and Oregon, under 765 kV AC and 1200 kV AC (prototype) lines found no evidence of any long-term effects on the growth or germination of a variety of plants, except those affected by the aforementioned corona discharge issue
- Pasture grass beneath HV lines was unaffected

Certain types of trees that have sharp, pointed leaves and branch buds can be impacted by the electric field if they approach too close to the power line conductors. Research indicates that high electric field levels may negatively impact the growth in these tree types (e.g. pine trees). This is due to ionisation of the air, in the form of corona discharges, at the sharp points. These corona discharges damages leaf and branch cells. Corona damage is mainly caused by positive corona, whose inception occurs at space potentials greater than 30 to 40 kV. The research indicates that broadleaf trees don't suffer this form of damage and all trees are not significantly impacted by lower-level electric fields.

The AC EMF levels adjacent to the proposed converter stations will be lower than the levels under AC lines considered in the above research. It is therefore not expected that the EMF from the converter stations will have any effect on plant health. Furthermore, it is noted that the only possible effects identified in the Gibbs Report, albeit inconclusive evidence, was associated with electric field effects on plants and trees, not magnetic field effects. The EMF associated with the project's land HVDC cables will comprise DC magnetic fields only. The underground cables will not generate measurable electric fields.

While the root structure of the plants and trees remain stationary, the movement of the above-ground structure, primarily under the influence of air movement, in a DC magnetic field will induce electric currents in the plant. This is the only mechanism by which the DC magnetic field could cause behavioural responses in plants. Direct, adverse effects of DC magnetic fields on plant health have however not been identified in the available research [29]. It is therefore not expected that the DC magnetic fields from the HVDC cables will have any effect on plant health, or yields associated with orchards or crops.

The underground land HVDC cables will also cause heating of the soil surrounding the cables and this could dry out the soil surrounding the cables. The soil drying effect will impact plant health in the immediate vicinity of the cable trench. A temperature increase of more than 3$^{o}$C at 0.1 m beneath ground level can cause drying of pasture grass immediately above buried HV cables (i.e. in the root zone). The root zone of plants is the area of soil and oxygen surrounding the roots of a plant. Cable heating calculations are presented in Section 7.5.6, along with an assessment of the potential impact on pasture grass in the vicinity of the HVDC cables.

Exposure of fruit and vegetables to high electric field potentials via the application of pulsed electric fields, is commonly used in food preservation as a preferred method over traditional thermal treatments as it does not alter the physical and sensory properties of the foods [30]. The use of electric fields to kill microorganisms associated with fruit and vegetables and research into the effect of magnetic field exposure of plants to a greater intensity than the geomagnetic field [31], suggest that EMF exposure could have positive effects on germination, root & leaf yields, regeneration, and preservation.

The Australian Government's National Standard for Organic and Bio-Dynamic Produce (Edition 3.7, 2016) does not specifically mention transmission lines or electric and magnetic fields. However, Section 1.25.2 of the Standard states that "Bio-dynamic Preparations are to be stored in a suitable container away from fumes, electricity, contamination sources." There are no Bio-dynamic Preparations storage facilities in the vicinity of the proposed power infrastructure and therefore no impact on certification of produce from land adjacent to the proposed infrastructure.

### 7.2.8 Farm Equipment

The potential sensitive receivers identified in this subsection are electrical and electronic equipment used for farming. The exposure scenarios involve DC magnetic fields from HVDC cables and AC electric and magnetic fields, and electromagnetic interference from converter stations.

Modern mobile agricultural equipment may utilise Global Positioning System (GPS) and/or Differential Global Positioning System (DGPS) communications for autonomous operations.

All GPS and DGPS systems utilise communication signals in the L-band, between 1 GHz and 2 GHz. A study conducted by J.M. Silva and R.G. Olsen [32] on the use of GPS receivers under power-line conductors found that no degradation in receiver performance were attributed to electromagnetic emissions from transmission lines under normal or foul weather. There is however a residual risk that damaged transmission line insulators or fittings may cause some interference to GPS systems in close proximity to the electrical power installations.

The DGPS systems used in Australia for land navigation broadcast correction signals in a commercial FM radio band. Converter stations that comply with the Radio Interference limits specified in AS 2344 under all weather conditions will not interfere with a correctly installed DGPS system. This may require higher transmitted DGPS signal strength or repositioning of the reference stations to avoid interference during heavy rain conditions.

### 7.2.9 Wildlife

The potential sensitive receivers identified in this subsection are birds, frogs, mammals and local fauna. In particular, albatrosses, petrels and reptiles are considered. Further, identified threatened wildlife species present in both Tasmania and Victoria, in the vicinity of the project’s HV infrastructure have been identified for the purpose of this assessment.

The land-based threatened wildlife that may be present within 5 km of the proposed Heybridge converter station include the Black-browed albatross, Eastern barred bandicoot, Eastern Quoll, Fairy Tern, Grey Goshawk, Little Tern, Shy Albatross, Southern Fairy Prion, Spotted-tailed Quoll, Swift Parrot, Tasmanian Azure Kingfisher, Tasmanian Devil, Wedge-tailed Eagle, and White-bellied Sea-Eagle.

The land-based threatened fauna in Victoria that may be present along the land HVDC project alignment and around the proposed Driffield or Hazelwood converter station include the Baw Baw Frog, Brush-tailed, Rock-wallaby, Eastern Barred Bandicoot, Greater Glider, Helmeted Honeyeater, Hooded Plover, Leadbeater's Possum, Macquarie Perch, Mountain Pygmy-possum, Orange-bellied Parrot, Plains-wanderer, and Regent Honeyeater.

The exposure scenarios involve DC magnetic fields from HVDC cables and AC electric and magnetic fields from converter stations.

The degree to which different species of wildlife will be exposed to static and ELF EMFs depends on the animal species and the type of installation (i.e. converter station outdoor equipment versus underground cable). Ground dwelling fauna may be exposed to higher magnetic fields if traversing across or burrowing near a buried cable. The Gibbs report [24] found that the fields generated by transmission lines do not have a harmful effect on the health or behaviour of local fauna.

Manitoba Hydro issued a report in 2010 after investigating the effect of transmission lines on wildlife, concluding “Research has not shown a relationship between EMF and the health or behaviour of animals” [33]. Moreover, research on the effect of static and ELF EMF on biological effects such as genetic effects, cell growth, and reproduction and development, from multiple studies, have not indicated adverse effects [34].

For wildlife in general, EMF impacts can be classified as follows:

- Animals that have electroreceptors for predation/foraging (primary) and navigation (secondary);
- Animals that have magnetoreceptors for navigation;
- Animals that have neither electro- nor magnetoreceptors.

Animals that have electroreceptors are the smallest group. They are primarily aquatic as the insulating properties of air doesn't facilitate electric current flow that the ampullae of Lorenzini (the electric field receptor organ) requires for detection. The group mostly comprises fish, amphibians and monotremes (platypus and echidna). Some dolphins have hairless "whisker" cells on their beak that sense electric fields and bees can also sense the electric charge on flowers using specialized hairs on their body. Interference to these receptors directly impacts the health of these animals, as it impacts predation and foraging success, and EMF effects can be significant.

There are many animals that can sense low-level static magnetic fields using many different mechanisms. In birds, there are two main mechanisms for sensing magnetic fields. Migratory birds use cryptochrome protein in the eye to perceive magnetic fields (quantum radical pair mechanism). Some birds have iron-containing materials in their upper beaks and can sense magnetic fields using the trigeminal nerve.

There are no experimental or epidemiological field studies that have concluded that the low-level, localised 50 Hz magnetic fields from power lines could have an impact on magneto-sensitive animals. As birds only use magnetic field sensing for navigation, the low-level, localised magnetic fields from power lines and cables that are below the ambient geomagnetic field and transient fluctuations in this field, are very unlikely to have any effect on the behaviour of birds in the area, including birds nesting on the ground near the land cables. Furthermore, the quantum radical pair mechanism that most birds use for sensing magnetic fields is more sensitive to interference from radio frequency fields than slowly varying or ELF fields.

### 7.2.10 Marine Animals

The potential effects of EMF exposure to Marine Flora and Fauna are to be addressed in the Marine Ecology and Resource Use (MERU) report (EIS/EES Appendix P). This report will document potential effects of EMF exposure, and applicable reference levels that relate to Marine Flora and Fauna including benthic species, epibenthic species, and those listed as threatened under the Threatened Species Protection Act 1995.

### 7.2.11 Marine Vessels

The potential sensitive receivers identified in this subsection are electrical and electronic equipment installed on all forms of marine vessels. The exposure scenarios involve DC magnetic fields from subsea HVDC cables.

Ships and boats not equipped with GPS may rely on compass readings for navigation. Localised disturbances in the geomagnetic field can disrupt the accuracy of the compass reading. However, the compass will need to be located very close (within 10 m) to the source of the disturbance to have any significant impact [35]. Therefore, the impact to ships and boats relying on compass-based navigation in the Bass Strait will be negligible as the vessels will not be close enough to the generated fields from the cables to be impacted. Moreover, only small vessels (e.g. recreational crafts) will be impacted near shore crossings in very shallow water. Any impact to the compass reading on these vessels near the shoreline will not impact navigation or safety as visual navigation will assist. The magnetic fields generated by the proposed Marinus HVDC subsea cables will not impact GPS or gyrocompass navigation.

### 7.2.12 Water Quality

The average water temperature in the Bass Strait ranges from 13.7°C (winter) and 18°C (summer) [11]. The salinity in the Bass Strait ranges from 35-36 ppt with the higher salinity regions located in the northern parts of the Bass Strait[12].

The project's cables will generate heat near the outer surfaces of the cables due to resistive losses in the cable centre conductors. For the trenched cables, the majority of the heating will be limited to the rock and sand immediately surrounding the cables. The thermally insulating ducts will also limit the transfer of heat to the rock and sand. The impact of this heating on the marine fauna and flora will therefore depend on the buried depth of the cables and the thermal resistivity of the sand and sea water.

For cables buried on the seabed and surrounded by sea water, the heating of the water above the ambient is generally limited to water within a few centimetres of the cable [36]. Ocean currents are expected to dissipate the heat and negate any such water heating effects, such that it is only the outer surface of the cable that will be at a temperature above the ambient [37]. The cable heating assessment calculations presented in Section 7.5.6 discuss this in further detail.

The electrical conductivity of seawater and the sand immediately surrounding the cable is a function of temperature and salinity. An increase in electrical conductivity of seawater in the presence of a magnetic field will increase the electric field present in the water. This may impact marine animals. Increases in the salinity and temperature of the seawater will increase the conductivity of the water. The salinity through the Bass Strait does not vary by more than 1 parts per thousand (ppt)[13] on average and this variance will not result in a significant impact on marine life near the Marinus HVDC subsea cables where the magnetic field is strongest. It is therefore only an increase in the temperature of the seawater near the subsea cables that may impact the water quality and thereby the marine life. Only the outer surface of the cable that will be at a temperature above the ambient resulting in a small region of increased conductivity around the cables that is readily dispersed by the strong sea currents in the Bass Strait. The effect of a water temperature rise due to the Marinus HVDC subsea cables on the surrounding environment will therefore be negligible.

[11] Source: https://seatemperature.info/bass-strait-water-temperature.html

[12] http://www.cmar.csiro.au/datacentre/cmar_public/ocean_2004/maps/CARS/sal_0.pdf

[13] http://www.cmar.csiro.au/datacentre/cmar_public/ocean_2004/maps/CARS/sal_0.pdf

The study of the existing Basslink cable indicated that the ecological effects of the cable installation on epibiota have been minor and transient in nature for soft sediments along the sea floor, Epibenthic specie growth had occurred on the biological material accumulating in the cable trench and the armoured half-shell substrate installed at the Tasmanian end of the cable has become a new habitat for reef species and is colonisable. The impact of cable heating does not affect this process. Similarly heat generated by the Marinus subsea cables will not have a significant impact on benthic ecosystems, fish or mammals.

## 7.3 Assessment Criteria

### 7.3.1 Human Health

The World Health Organization recognises two international ELF EMF exposure 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
- IEEE Standard C95.1- Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0Hz to 300GHz produced by Institute of Electrical and Electronics Engineers

These guidelines apply to people in all areas (i.e., not above underground cables) and no distinction is made in the guidelines for the duration of exposure (i.e., the limits and reference levels are specified as maximum instantaneous levels).

There are currently no national guidelines or regulations in Australia for extremely low frequency EMF. The Australian Radiation Laboratory, on behalf of the National Health and Medical Research Council (NHMRC), published the “Interim Guidelines on Limits of Exposure to 50/60 Hz Electric and Magnetic Fields” in December 1989 as part of its Radiation Health Series, No. 30 (RHS30).

ARPANSA’s Radiation Health Committee (RHC) agreed at its 24 June 2015 meeting that it will withdraw the existing NHMRC RHS30 guidance on extremely low frequency electric and magnetic fields exposure and recognised that the International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz -100 kHz) are consistent with ARPANSA’s and the RHC's understanding of the scientific basis for the protection of people from exposure to ELF electric and magnetic field[14].

The basic restrictions for ELF electric and magnetic fields are exposure limits for internal electric fields in different body tissues. Relating these internal field levels within body tissues to measurable external field levels above a buried cable or under a transmission line is a complex undertaking requiring detailed dosimetry analysis. ICNIRP has therefore also defined reference levels, which are the external, measurable field levels that equate to internal field levels within body tissues that are below the basic restrictions. The ICNIRP reference levels are defined for uniform fields over the body whose exposure is being assessed.

[14] https://www.arpansa.gov.au/regulation-and-licensing/regulatory-publications/radiation-health-series

It is noted that a conservative reduction factor is used in deriving reference levels from the basic restrictions to account for uncertainties in the available dosimetry as well as the influence of body parameters on the derived values. It is further noted that a safety factor is applied to occupational exposure limits to derive the general public exposure limits that account for exceptionally sensitive individuals, uncertainties concerning threshold effects due to pathological conditions or drug treatment, uncertainties in reaction thresholds and uncertainties in induction models.

The basic restrictions are therefore the exposure thresholds that must be complied with, and the reference levels are conservative, measurable field levels that ensure compliance with the basic restrictions for generic electric and magnetic field exposure scenarios. The ICNIRP reference levels for general public exposure to 50 Hz electric and magnetic fields are summarised in Table 7-4.

*Table 7-4: ICNIRP EMF reference levels and AIMD limits*

| Exposure Scenario | Electric Field Strength Reference Level (kV/m) | | Magnetic Field Strength Reference Level (μT) | |
|---|---|---|---|---|
| | Static/ slowly varying | ELF | Static/ slowly varying | ELF |
| People – all areas | 5 | 5 | 400,000 | 200 |
| Active implantable medical devices | 5 | 5 | 500 | 200 |

The reference levels specified in the ICNIRP guidelines are defined as spatially averaged values within the volume occupied by a person's body. As such, the reference levels are compared to measured levels at 1 m above the normal standing surface of a person under or near the line.

The ICNIRP guidelines note that compliance with the reference level will ensure compliance with the relevant basic restriction but that if the measured or calculated value exceeds the reference level, it does not necessarily follow that the basic restriction will be exceeded. However, whenever a reference level is exceeded it is necessary to test compliance with the relevant basic restriction and to determine whether additional protective measures are necessary.

Given that adverse health effects from long-term exposure to EMF have not been established but also cannot be ruled out, Sir Harry Gibbs [24], the former Chief Justice of the High Court of Australia, and Professor Hedley Peach [38], University of Melbourne, recommended a policy of prudent avoidance in their reviews of the potential health effects.

Prudent avoidance is a precautionary approach to managing the potential risk which involves implementing no cost and very low-cost measures that reduce exposure (i.e., reasonable efforts to minimise the potential risks are taken when the actual magnitude of the risks is unknown). Under this approach, power utilities must design their assets to reduce the fields generated and locate the assets so as to minimise the long-term exposure of people to these fields, especially children.

### 7.3.2 Fauna and Flora

Reference levels for land fauna and flora impacts are summarised in Table 7-5 and have been derived from the research summarised in Section 7.2.10.

*Table 7-5: Land fauna and flora EMF reference levels considered in the study*

| Exposure Scenario | Electric Field Strength Reference Level (kV/m) | | Magnetic Field Strength Reference Level (μT) | |
|---|---|---|---|---|
| | Static/ slowly varying | ELF | Static/ slowly varying | ELF |
| RFID tags | n/a | n/a | 3,000,000 | 3,000,000 |
| Livestock | 5* | 5* | 400,000* | 200* |
| Apiaries | n/a | 4.1 | 2 | 100 |
| Wildlife | 5* | 5* | 400,000* | 200* |

* Conservative assumed value

### 7.3.3 Electrical and Electronic Equipment

The typical immunity limits for electrical and electronic equipment that are summarised in Table 7-3 have been adopted for the EMI impact assessment in this study.

Conductor corona and other electrostatic effects generate interference over a wide frequency range. The limits for electromagnetic interference from a converter station outdoor switchyard are established in Australian Standard AS 2344. A satisfactory level of radio reception, as defined by the International Telecommunication Union (ITU), can be expected for broadcast, navigation, safety-of-life and other radio communication services in areas where the radio frequency emissions from the line are below these limits. These limits are generally applied at the boundary of the transmission line easement.

Victoria and Tasmania fall into ITU region 3, zone C. The applicable emission limits for this zone are summarised in Table 7-6. Magnetic field strength and electric field strengths associated with emission limits are commonly measured on a decibel scale in microamperes per metre (dBμA/m) for frequencies below 30 MHz and in microvolts per metre (dBμV/m) for frequencies above 30 MHz. The specified limits are defined in the standard as the fields measured at μmetres above ground.

*Table 7-6: Radio and television interference limits as defined in Australian Standard 2344*

| Frequency (MHz) | Magnetic Field Strength (dBμA/m) | | Electric Field Strength (dBμV/m) |
|---|---|---|---|
| | Urban Areas[1] | All Other Areas | |
| 0.15 to 0.30 | -1.5 | -1.5 | - |
| 0.30 to 0.50 | -15.5 | -15.5 | - |
| 0.50 to 1.70 | -1.5 | -15.5 | - |
| 1.70 to 3.00 | -15.5 | -15.5 | - |
| 3.00 to 30.0[2] | -15.5 to -28.5 | -15.5 to -28.5 | - |

| Frequency (MHz) | Magnetic Field Strength (dBµA/m) | | Electric Field Strength (dBµV/m) |
|---|---|---|---|
| | Urban Areas[1] | All Other Areas | |
| 30.0 to 230 | - | - | 30 |
| 230 to 1,000 | - | - | 37 |
| 1,000 to 3,000 | - | - | 60 |

[1] Applicable to areas having a population of greater than 2000 people that are serviced by local broadcast stations
[2] The limit decreases linearly with the logarithm of the frequency from 3 MHz to 30 MHz

## 7.4 Construction Impact Assessment

### 7.4.1 Key Issues

Potential impacts for electric and magnetic fields and electromagnetic interference in relation to the construction activities of the project are summarised in Table 7-7. An overview of the significance of construction impacts is described in the following section.

*Table 7-7: Radio and television interference limits as defined in Australian Standard 2344*

| Project component | Project activity | Potential for impact to electric and magnetic fields and electromagnetic interference and associated consequence | Standard controls |
|---|---|---|---|
| Project-wide | All activities related to construction of the HVDC cables and converter stations. | Radiocommunication equipment used for construction activities (e.g., mobile telephones and Citizens Band radios) will generate radio frequency emissions during construction. There is therefore a potential to create radio frequency interference to nearby sensitive receivers. | The radiocommunication equipment used during construction must have appropriate Regulatory Compliance Mark labelling. |

### 7.4.2 Significance of impacts

Construction of the project infrastructure involves commercial plant and electrical equipment that will have appropriate EMC certification. This provides assurance that EMF and EMI from the construction site will be below the limits specified in applicable Australian Communications and Media Authority (ACMA) and product safety standards for a construction environment. When discussing the significance of impacts, this therefore implies post-mitigation or residual impacts.

Construction workers may need to work at closer distances to live transmission line conductors than the general public are permitted. They will therefore be exposed to higher EMF levels. Public access to work sites will be restricted with appropriate fencing and occupational exposure to EMF and EMI will be managed as part of safe work method planning in accordance with occupational health and safety requirements (e.g. access controls and/or appropriate warning signages).

## 7.5 Operation Impact Assessment

### 7.5.1 Heybridge Converter Station

The HIFREQ model of the AC Air Insulated Switchgear (AIS) equipment and associated structural components at Heybridge converter station, including the landing span, is shown below in Figure 7-2. The electric and magnetic fields around the fence line are plotted in Figure 7-3 and Figure 7-4. The results are summarized in Table 7-8 and Table 7-9. The AC equipment has been modelled as air-insulated equipment. The calculated electric and magnetic field intensities are below the permissible limits for people and other sensitive receivers at the fence line.

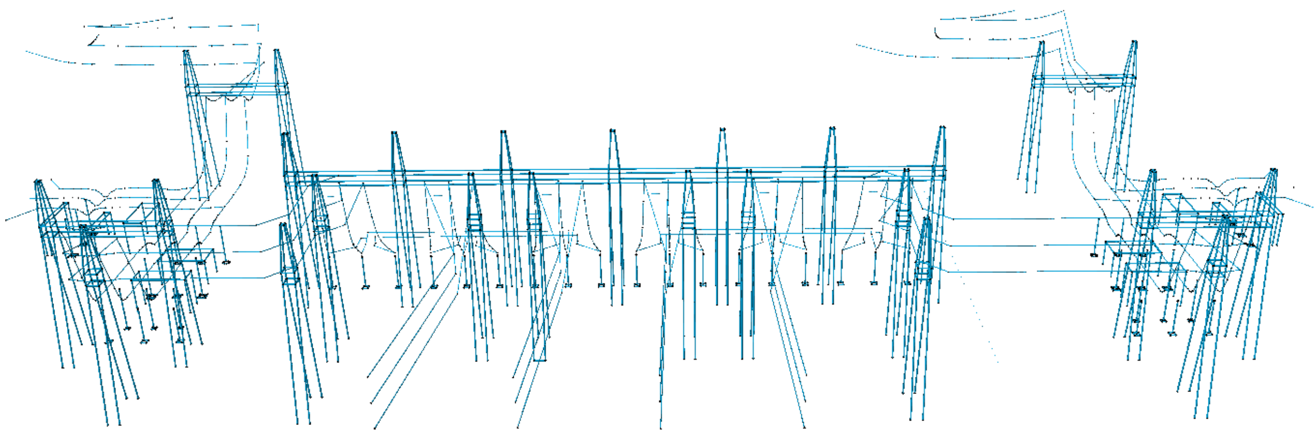

*Figure 7-2: HIFREQ model - AC equipment and supporting structures at the Heybridge Converter Station*

*Table 7-8: Human health impact assessment for the Heybridge converter station*

| EMF | General Public Reference Level | Maximum Calculated Value |
|---|---|---|
| Electric Field Strength (kV/m) | 5 | 3.5 |
| Magnetic Flux Density (μT) | 200 | 14.2 |

*Table 7-9: Farming and wildlife impact assessment for the Heybridge converter station*

| Exposure Scenario | Electric Field Strength (kV/m) | | Magnetic Field Strength (μT) | |
|---|---|---|---|---|
| | Reference Level | Maximum Calculated Value | Reference Level | Maximum Calculated Value |
| Livestock | 5* | 3.5 | 200* | 14.2 |
| Apiaries | 4.1 | 3.5 | 100 | 14.2 |
| Wildlife | 5* | 3.5 | 200* | 14.2 |

* Conservative assumed value

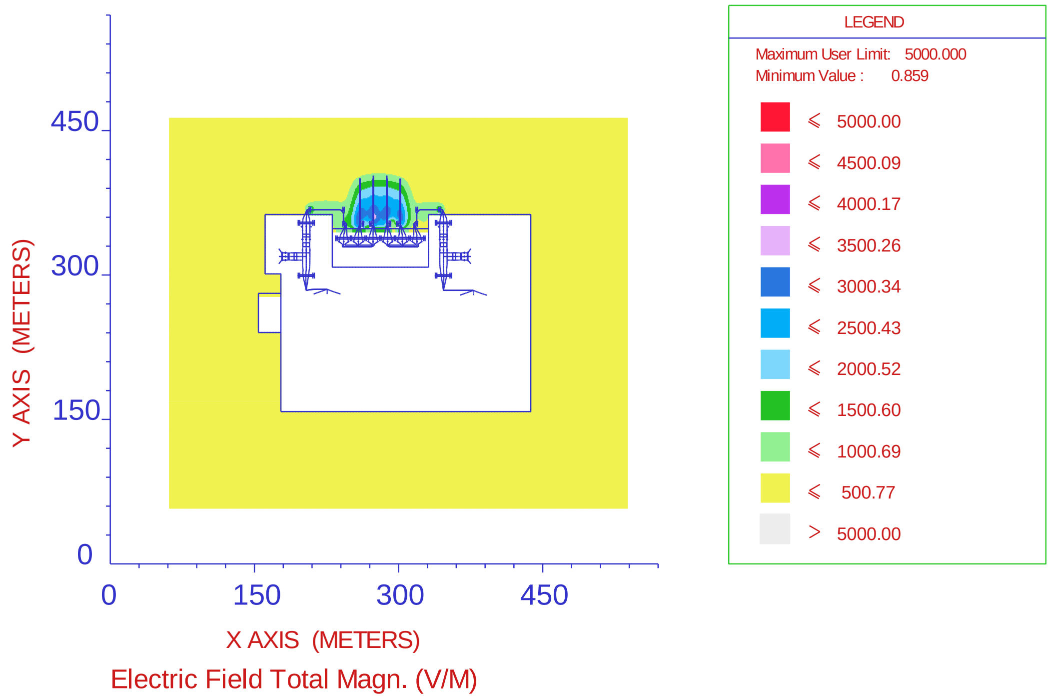


*Figure 7-3: Calculated electric field strength around the fence line of Heybridge Converter Station*

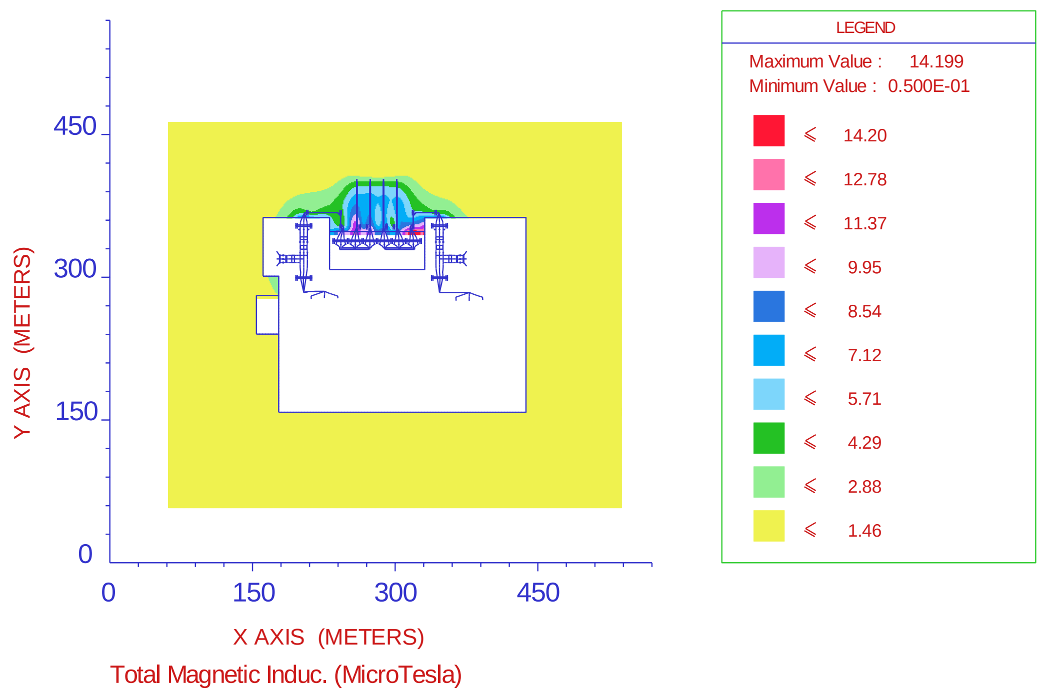


*Figure 7-4: Calculated magnetic flux density around the fence line of Heybridge Converter Station*

A desktop study of the area surrounding the Heybridge converter station was carried out and it was confirmed that there are no sensitive electrical or electronic equipment or systems that could be impacted by the EMI from the converter station. Furthermore, the maximum calculated magnetic field strength was below the 3.8 μT limit for generic household electrical and electronic equipment in all areas outside the converter station property.

The surface voltage gradient on the flexible connections and rigid bus sections within the Heybridge converter station were calculated using the HIFREQ model. The maximum calculated surface voltage gradient within the converter station is less than 16 kV/cm, as is evidenced in Figure 7-5. This is the benchmark value specified in AS/NZS 7000 for acceptable transmission line corona performance. All fittings, insulators and equipment bushings will be RIV tested as part of the type approval process and will therefore produce RFI levels under below the acceptable EMI limits for the converter station environment.

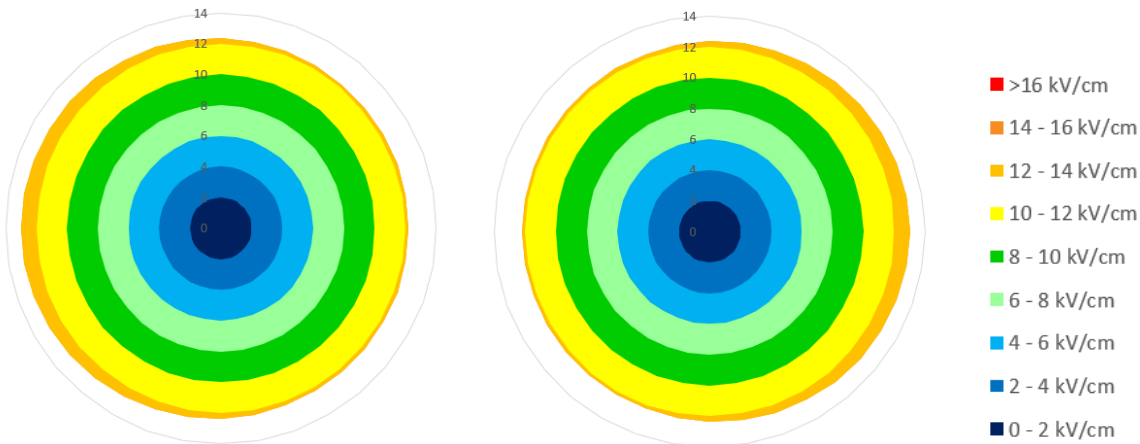


*Figure 7-5: Calculated surface voltage gradient on flexible connections at the Heybridge Converter station*

### 7.5.2 Driffield Converter Station

The HIFREQ model of the AC Air Insulated Switchgear (AIS) equipment and associated structural components at Driffield converter station, including the landing spans for both the incoming and outgoing circuits, is shown below in Figure 7-6. The calculated electric and magnetic fields around the fence line are plotted in Figure 7-7 and Figure 7-8. The results are summarized in Table 7-10 and Table 7-11. The calculated electric and magnetic field intensities are below the permissible limits for people and other sensitive receivers at the fence line.

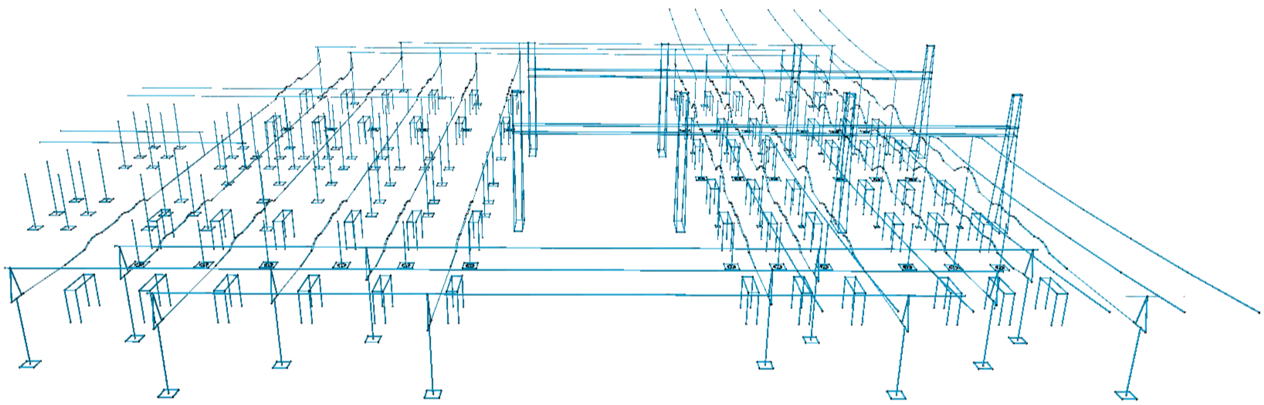

*Figure 7-6: HIFREQ model - AC equipment and supporting structures at the Driffield Converter Station*

*Table 7-10: Human health impact assessment for the Driffield converter station*

| EMF | General Public Reference Level | Maximum Calculated Value |
|---|---|---|
| Electric Field Strength (kV/m) | 5 | 1.8 |
| Magnetic Flux Density (μT) | 200 | 3.4 |

*Table 7-11: Farming and wildlife impact assessment for the Driffield converter station*

| Exposure Scenario | Electric Field Strength (kV/m) | | Magnetic Field Strength (μT) | |
|---|---|---|---|---|
| | Reference Level | Maximum Calculated Value | Reference Level | Maximum Calculated Value |
| Livestock | 5* | 1.8 | 200* | 3.4 |
| Apiaries | 4.1 | 1.8 | 100 | 3.4 |
| Wildlife | 5* | 1.8 | 200* | 3.4 |

* Conservative assumed value

A desktop study of the area surrounding the Driffield converter station was carried out and it was confirmed that there are no sensitive electrical or electronic equipment or systems that could be impacted by the EMI from the converter station. Furthermore, the maximum calculated magnetic field strength was below the 3.8 μT limit for generic household electrical and electronic equipment in all areas outside the converter station property.

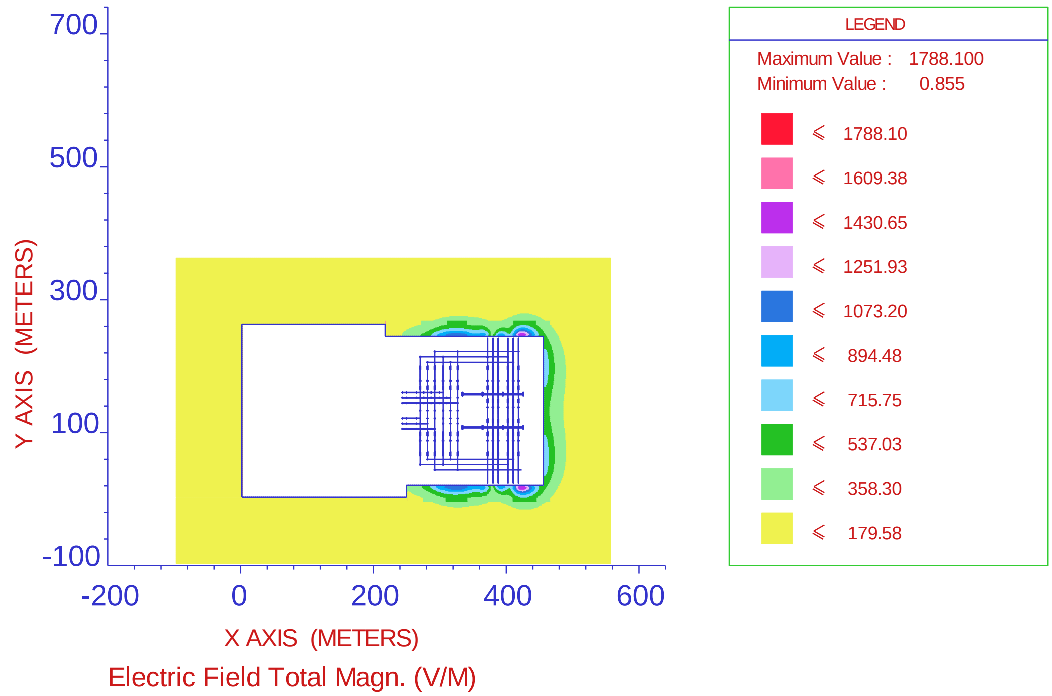


*Figure 7-7: Calculated electric field strength around the fence line of the Driffield Converter Station*

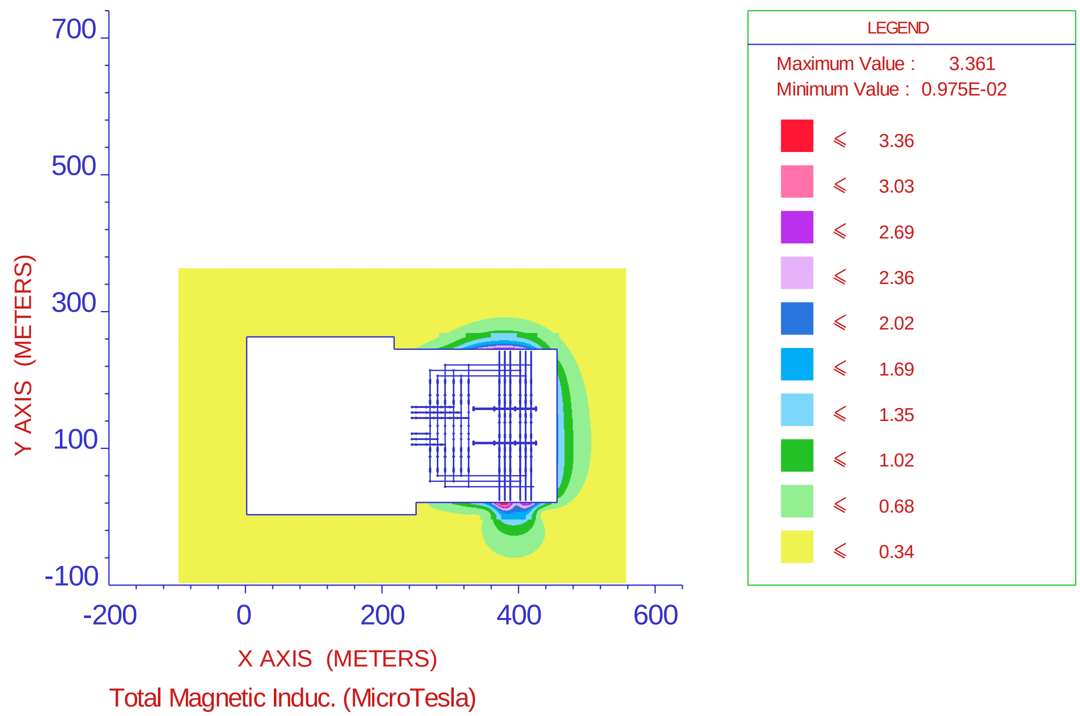


*Figure 7-8: Calculated magnetic flux density around the fence line of the Driffield Converter Station*

The surface voltage gradient on the flexible connections and rigid bus sections within the Driffield converter station were also calculated. The maximum calculated surface voltage gradient within the converter station is 16 kV/cm on the landing span at maximum possible voltage, as evidenced in Figure 7-9 and Figure 7-10. At normal operating voltages it will be below the 16 kV/cm benchmark value specified in AS/NZS 7000 for acceptable transmission line corona performance. All fittings, insulators and equipment bushings will be RIV tested as part of the type approval process and will therefore produce RFI levels under below the acceptable EMI limits for the applicable environment.

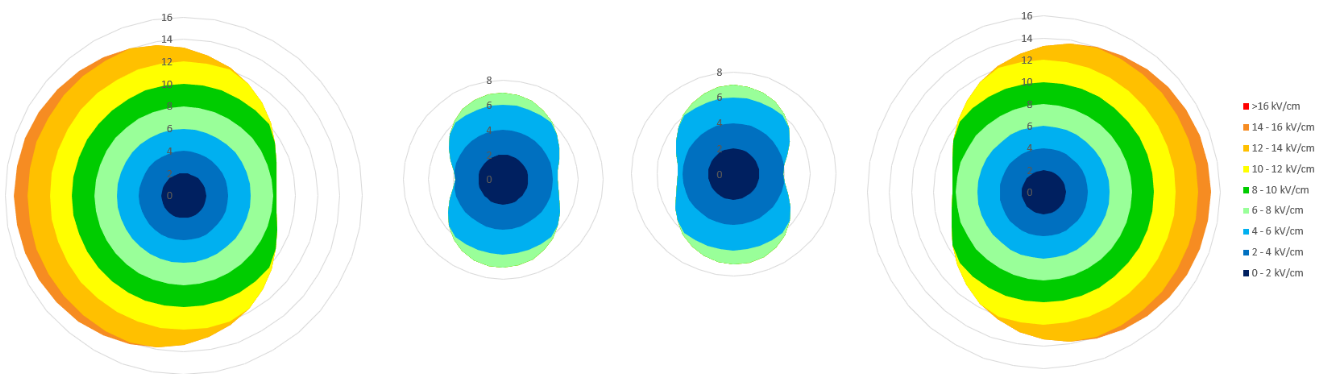


*Figure 7-9: Calculated surface voltage gradient on the flat-arranged flexible connections at the Driffield Converter station*

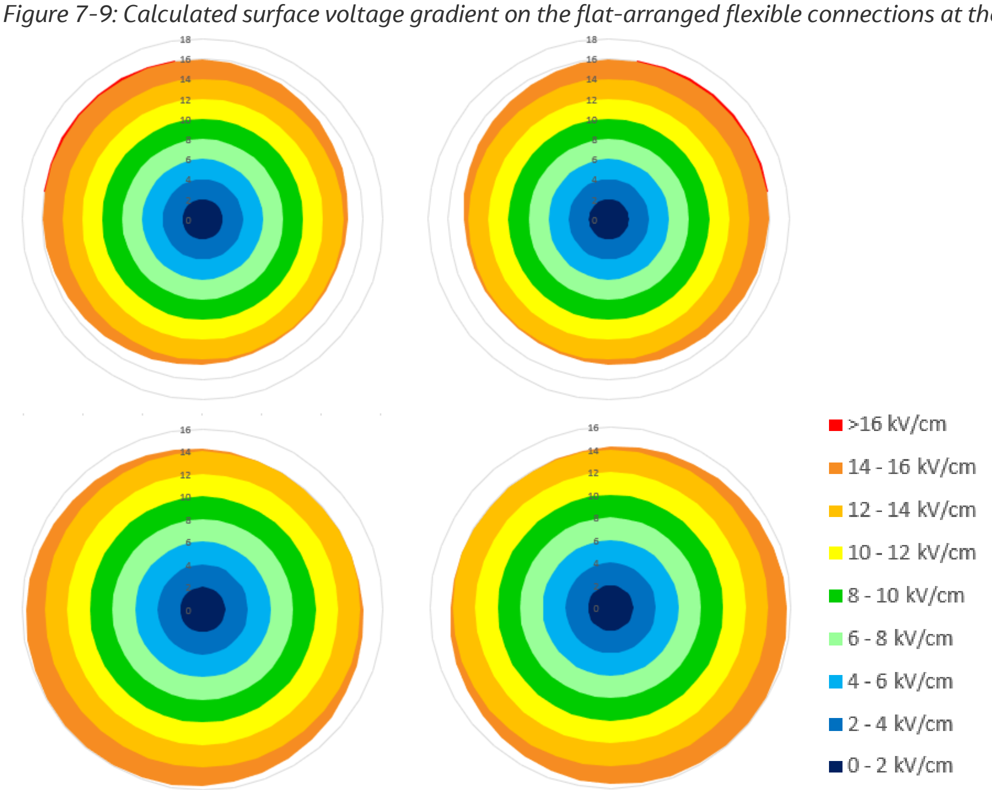


*Figure 7-10: Calculated surface voltage gradient on the square -type flexible connections at the Driffield Converter station*

### 7.5.3 Hazelwood Converter Station

The HIFREQ model of the AC Air Insulated Switchgear (AIS) equipment and associated structural components at Hazelwood converter station, including the landing spans for both the incoming and outgoing circuits, is shown below in Figure 7-11. The calculated electric and magnetic fields around the fence line are plotted in Figure 7-12 and Figure 7-13. The results are summarized in Table 7-12 and Table 7-13. The calculated electric and magnetic field intensities are below the permissible limits for people and other sensitive receivers at the fence line.

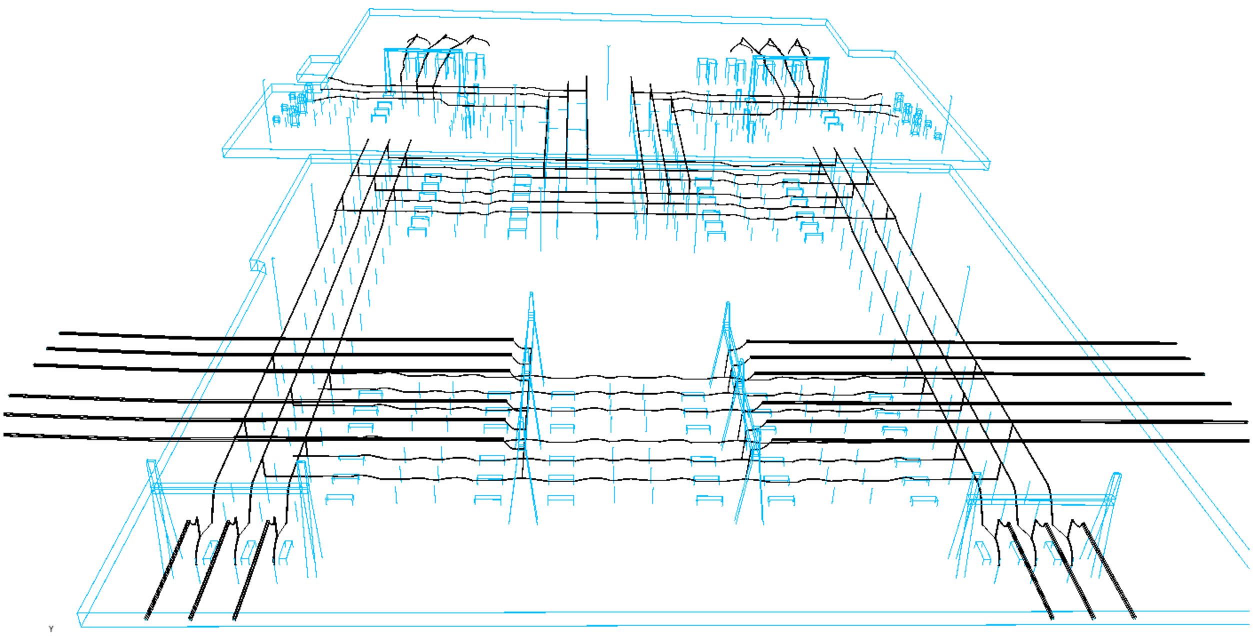

*Figure 7-11: HIFREQ model - AC equipment and supporting structures at the Hazelwood Converter Station*

*Table 7-12: Human health impact assessment for the Hazelwood converter station*

| EMF | General Public Reference Level | Maximum Calculated Value |
|---|---|---|
| Electric Field Strength (kV/m) | 5 | 3.2 |
| Magnetic Flux Density (μT) | 200 | 10.7 |

*Table 7-13: Farming and wildlife impact assessment for the Hazelwood converter station*

| Exposure Scenario | Electric Field Strength (kV/m) | | Magnetic Field Strength (μT) | |
|---|---|---|---|---|
| | Reference Level | Maximum Calculated Value | Reference Level | Maximum Calculated Value |
| Livestock | 5* | 3.2 | 200* | 10.7 |
| Apiaries | 4.1 | 3.2 | 100 | 10.7 |
| Wildlife | 5* | 3.2 | 200* | 10.7 |

* Conservative assumed value

A desktop study of the area surrounding the Hazelwood converter station was carried out and it was confirmed that there are no sensitive electrical or electronic equipment or systems that could be impacted by the EMI from the new equipment at the converter station. Furthermore, the maximum calculated magnetic field strength was below the 3.8 μT limit for generic household electrical and electronic equipment in all areas outside the converter station property.

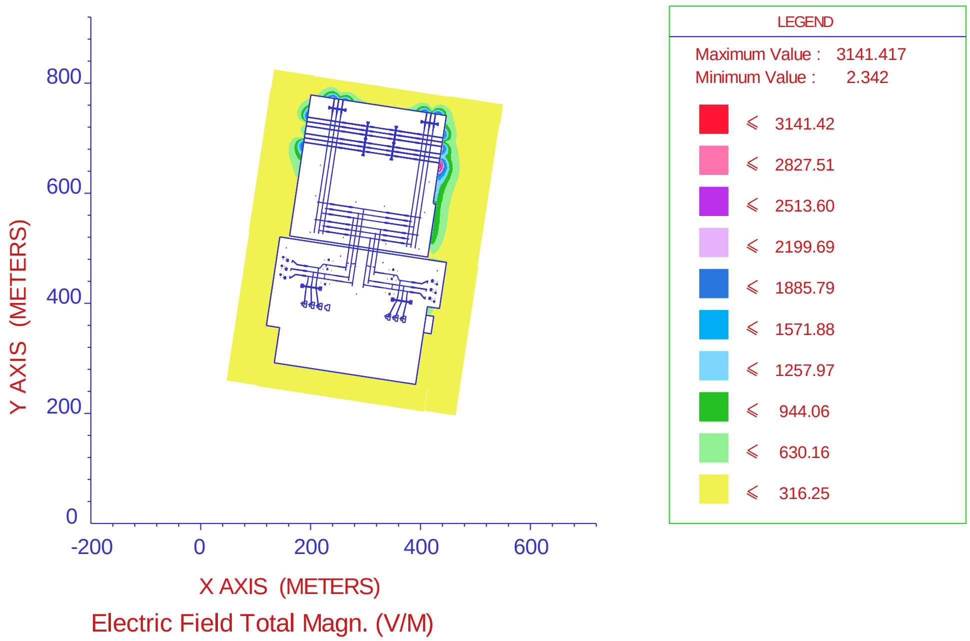


*Figure 7-12: Calculated electric field strength around the fence line of the Hazelwood Converter Station*

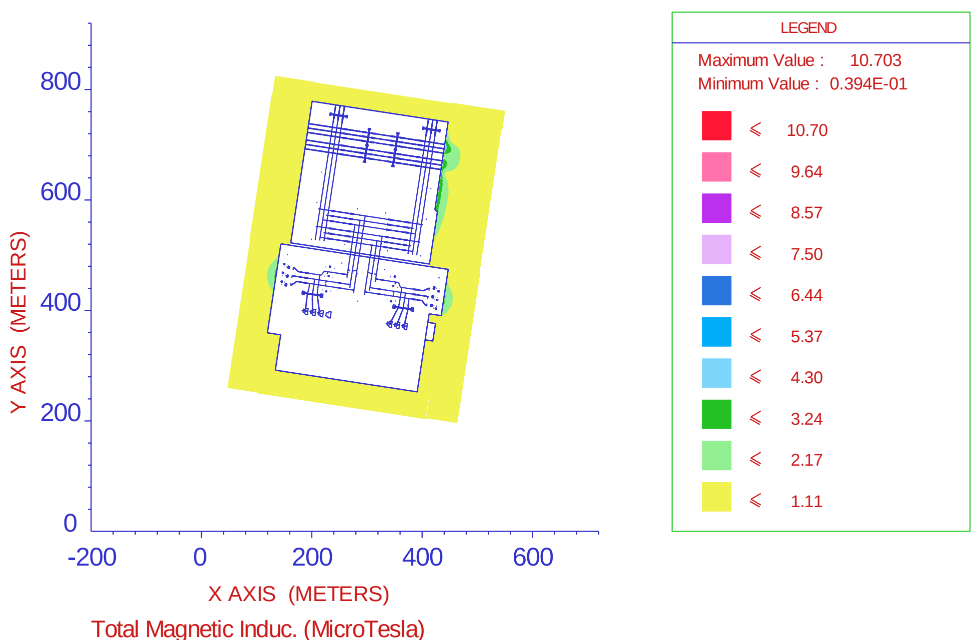


*Figure 7-13: Calculated magnetic flux density around the fence line of the Hazelwood Converter Station*

The surface voltage gradient on the flexible connections and rigid bus sections within the Hazelwood converter station were also calculated. The maximum calculated surface voltage gradient within the converter station is 16 kV/cm on the landing span at maximum possible voltage, as evidenced in Figure 7-14 and Figure 7-15. At normal operating voltages it will be below the 16 kV/cm benchmark value specified in AS/NZS 7000 for acceptable transmission line corona performance. All fittings, insulators and equipment bushings will be RIV tested as part of the type approval process and will therefore produce RFI levels under below the acceptable EMI limits for the applicable environment.

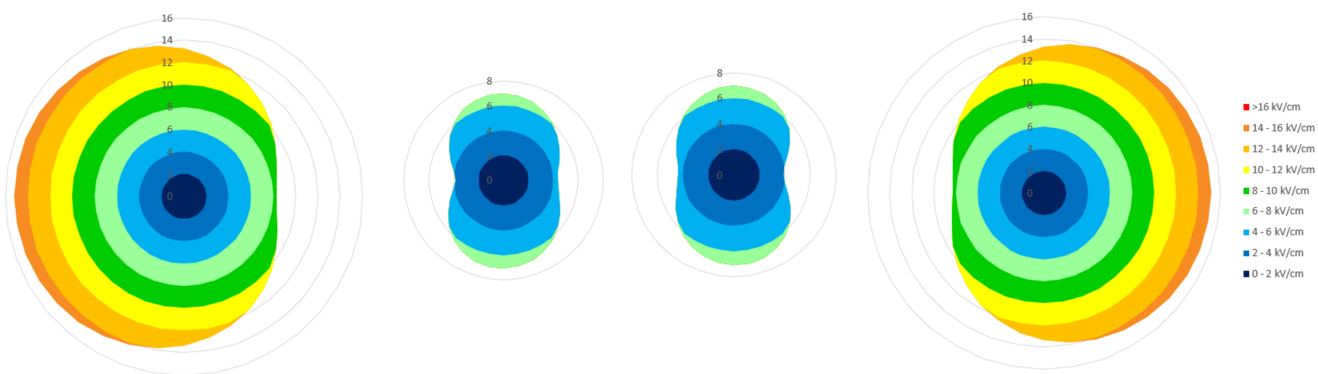


*Figure 7-14: Calculated surface voltage gradient on the flat-arranged flexible connections at the Hazelwood Converter station*

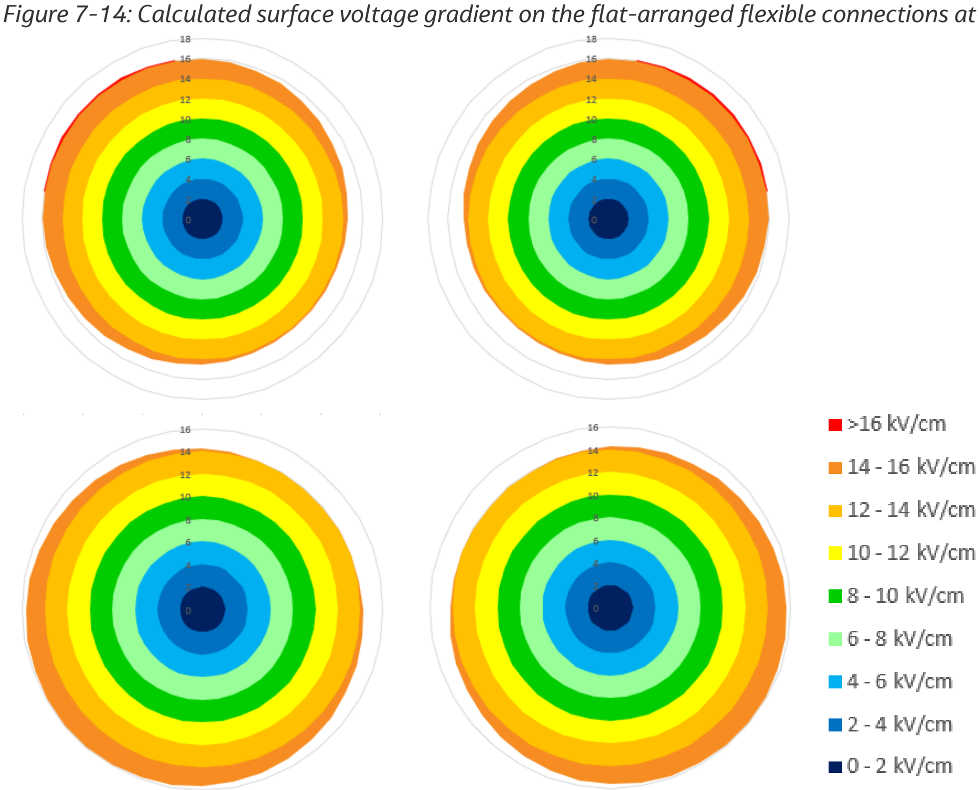


*Figure 7-15: Calculated surface voltage gradient on the square -type flexible connections at the Hazelwood Converter station*

### 7.5.4 Subsea HVDC Cables

The magnetic field levels were calculated in different areas along the subsea HVDC cables to verify the worst-case impact on the marine environment. The results are plotted in Figure 7-16 to Figure 7-27. The highest magnetic field levels occur at ground level as the cables transition from the Heybridge converter station to the Bass Strait (i.e. the Heybridge shore crossing) and at the Waratah Bay shore crossing. The cables will be unbundled and spaced a few metres apart in these HDD sections.

The cables in each circuit will be bundled together within the Bass Strait trench section, which greatly reduces the magnetic fields. The magnetic fields will be strongest directly above the cables and decrease quickly at increasing distance from the cable. Both vertically and horizontally arranged cables have been considered.

Fluctuations in sea water conductivity were considered in the modelling but were found to have negligible impact on the intensity of the static fields, which is consistent with Figure 6-2. The static electric field produced by the cable in the conductive water is negligible for all reasonable water salinities and ocean current velocities.

The largest generated magnetic field strength is 194 μT at the shore crossings (Figure 7-16 to Figure 7-23). The separation between adjacent circuits in these areas range from 20 m to 600 m. The magnetic field strength drops to below 5 μT at a distance of 50 m from the closest cable along the shore crossings.

If there will be locations where the cable cannot be buried at the modelled depth, the magnetic flux density at the seabed level will change. At the 1 m minimum value of the proposed burial depth range, the maximum magnetic flux density at seabed level will increase by up to 150%.

During the worst case possible overload scenario (considered to be where both Stage One and Stage Two are overloaded at the same time) the maximum magnetic flux density at seabed level will increase by up to 12.5%.

The two HVDC circuits will be separated by a nominal distance of 2 km along the majority of the Bass Strait crossing. Both a horizontal and vertical separation between positive and negative cables per circuit have been considered along this section. The EMF produced by vertically separated cables are plotted in Figure 7-24 and Figure 7-25. The EMF produced by horizontally separated cables are plotted in Figure 7-26 and Figure 7-27. The largest magnetic field strength is 24 μT for the horizontally arranged cables. This reduces to 21 μT for the vertically arranged cables. It is however noted that the magnetic field associated with the horizontally arranged cables drops off more quickly with horizontal distance from the cables along the seabed. The calculated magnetic field strength reduces to less than 5 μT at a distance of 3 m from the centre of each cable trench, irrespective of the cable bundle geometry.

The worst case calculated magnetic field strengths are compared to the derived reference levels for human health impacts in Table 7-14.

A desktop study of the area surrounding the subsea cables was carried out and it was confirmed that there are no sensitive electrical or electronic equipment or systems near the HVDC cables.

Furthermore, the XLPE insulated cables will be not subject to corona discharges and will therefore not emit radio frequency interference.

*Table 7-14: Human health impact assessment along the HVDC subsea project alignment*

| Exposure Scenario | Cable Area | Magnetic Field Strength (μT) | |
|---|---|---|---|
| | | Reference Level | Calculated Level |
| People – All areas | Heybridge shore crossing | 400,000 | 193 |
| | Bass Strait – Vertical | 400,000 | 21 |
| | Bass Strait – Horizontal | 400,000 | 24 |
| | Waratah Bay shore crossing | 400,000 | 194 |
| Active implantable medical devices | Heybridge shore crossing | 500 | 193 |
| | Bass Strait – Vertical | 500 | 21 |
| | Bass Strait – Horizontal | 500 | 24 |
| | Waratah Bay shore crossing | 500 | 194 |

It is evident from the impact assessments above that the calculated field levels are below the applicable reference levels and there will be no operating impacts on human health for people near the cables and mitigation is not required.

The potential effects of EMF exposure to Marine Flora and Fauna are to be addressed in the Marine Ecology and Resource Use (MERU) report (EIS/EES Appendix P). This report will document potential effects of EMF exposure, and applicable reference levels that relate to Marine Flora and Fauna including benthic species, epibenthic species, and those listed as threatened under the Threatened Species Protection Act 1995.

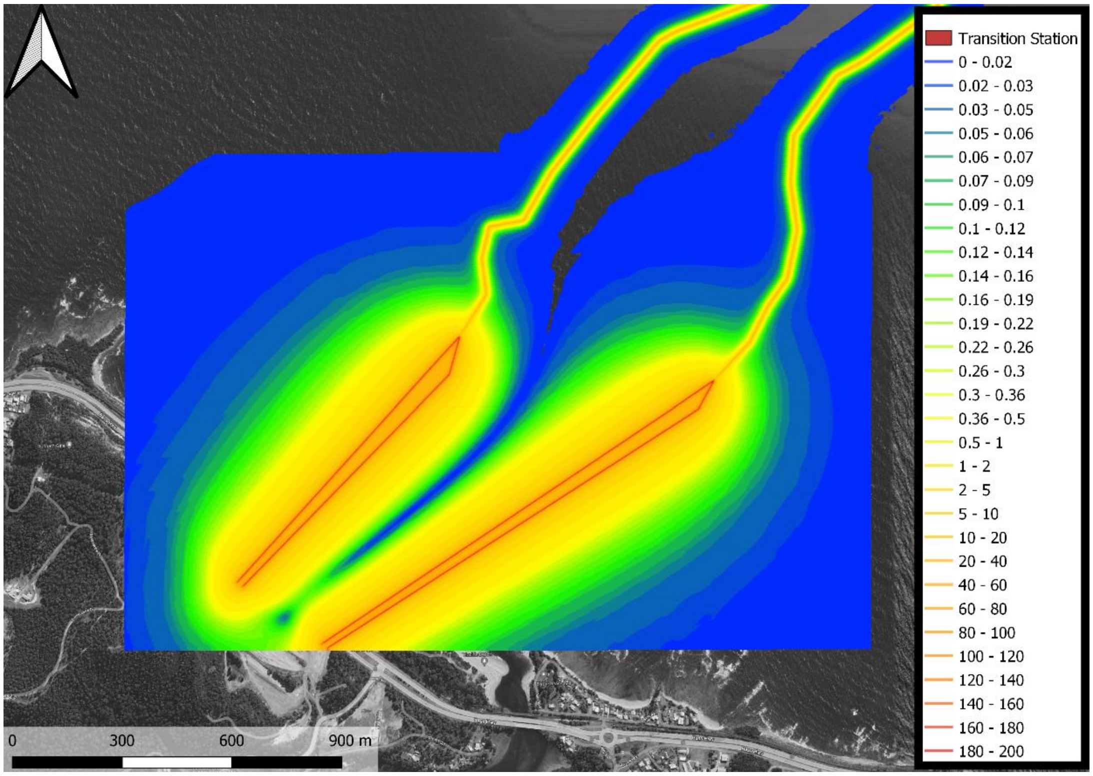


*Figure 7-16: Calculated magnetic field distribution on the seabed at the Heybridge shore crossing (μT)*

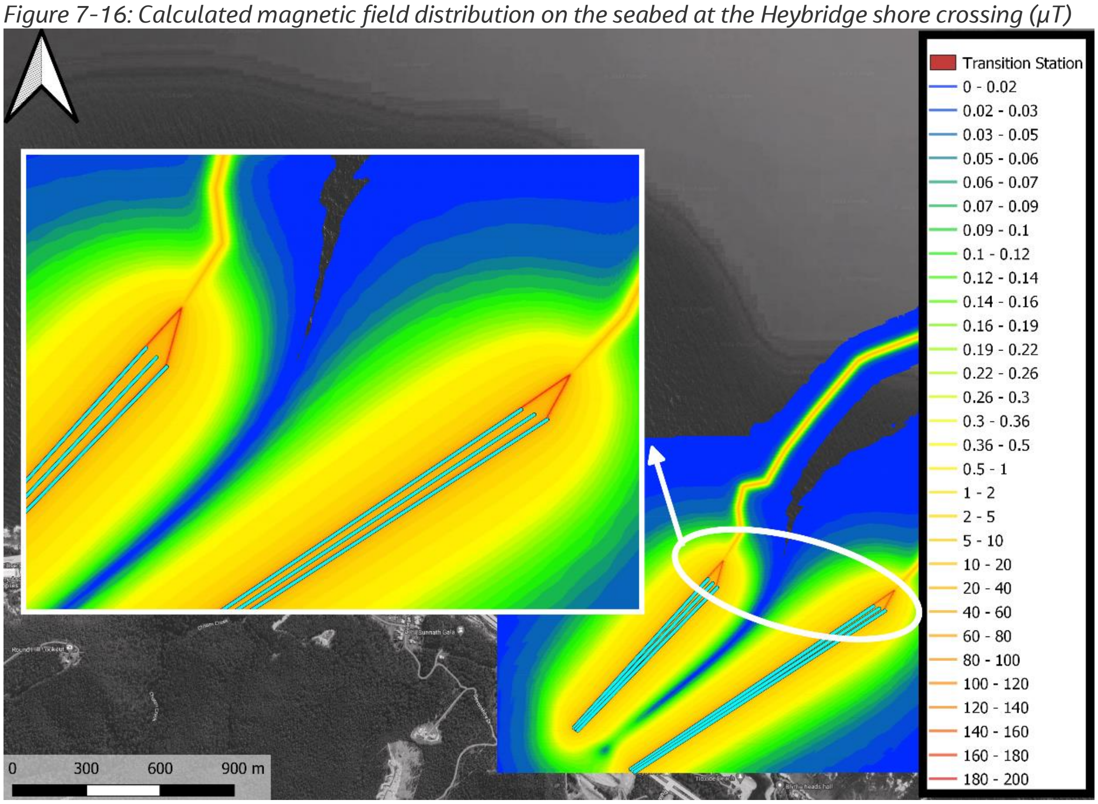


*Figure 7-17: Calculated magnetic field distribution on the seabed at the Heybridge shore crossing (μT)*

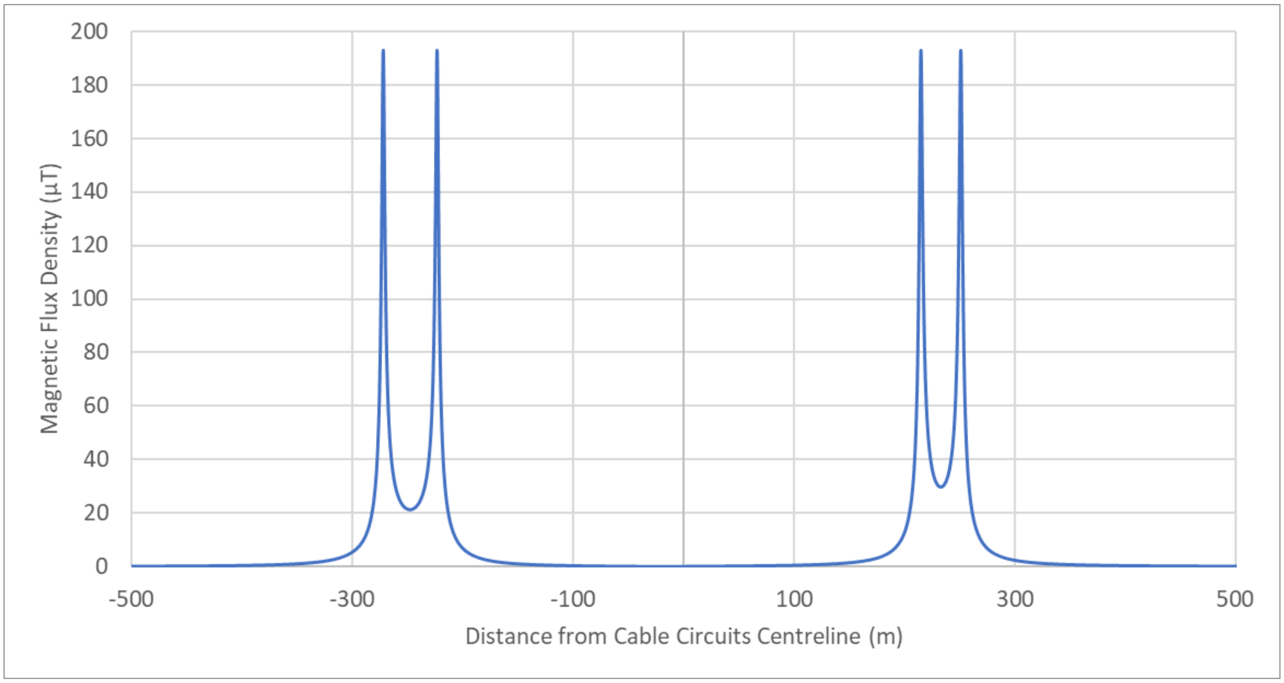


*Figure 7-18: Calculated magnetic field profile across the Heybridge shore crossing cable ducts (both circuits)*

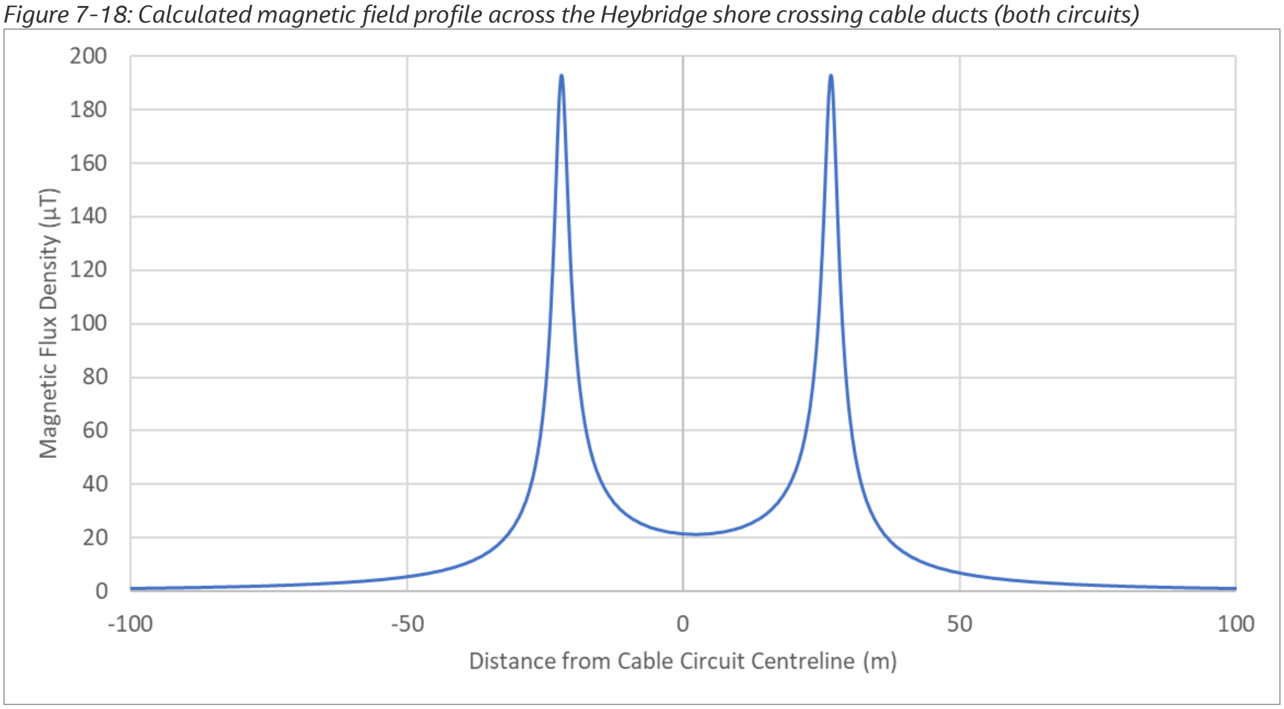


*Figure 7-19: Calculated magnetic field profile across the Heybridge shore crossing cable ducts (one circuit)*

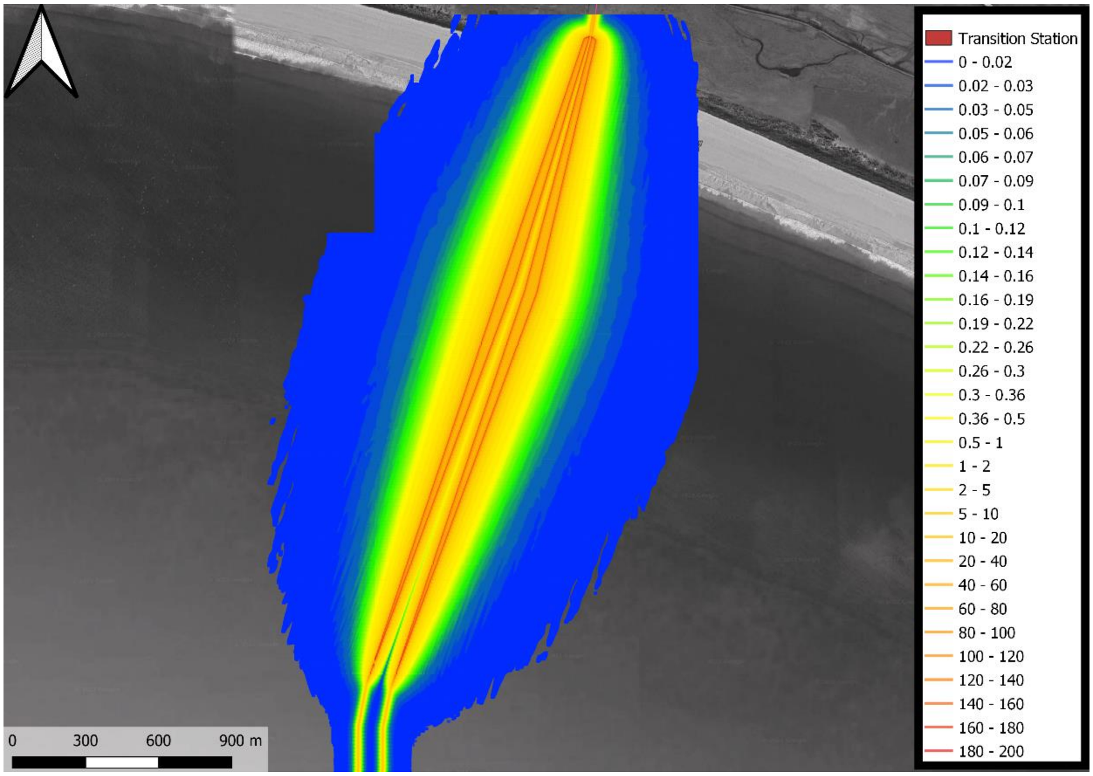


*Figure 7-20: Calculated magnetic field distribution on the seabed at the Waratah Bay shore crossing (μT)*

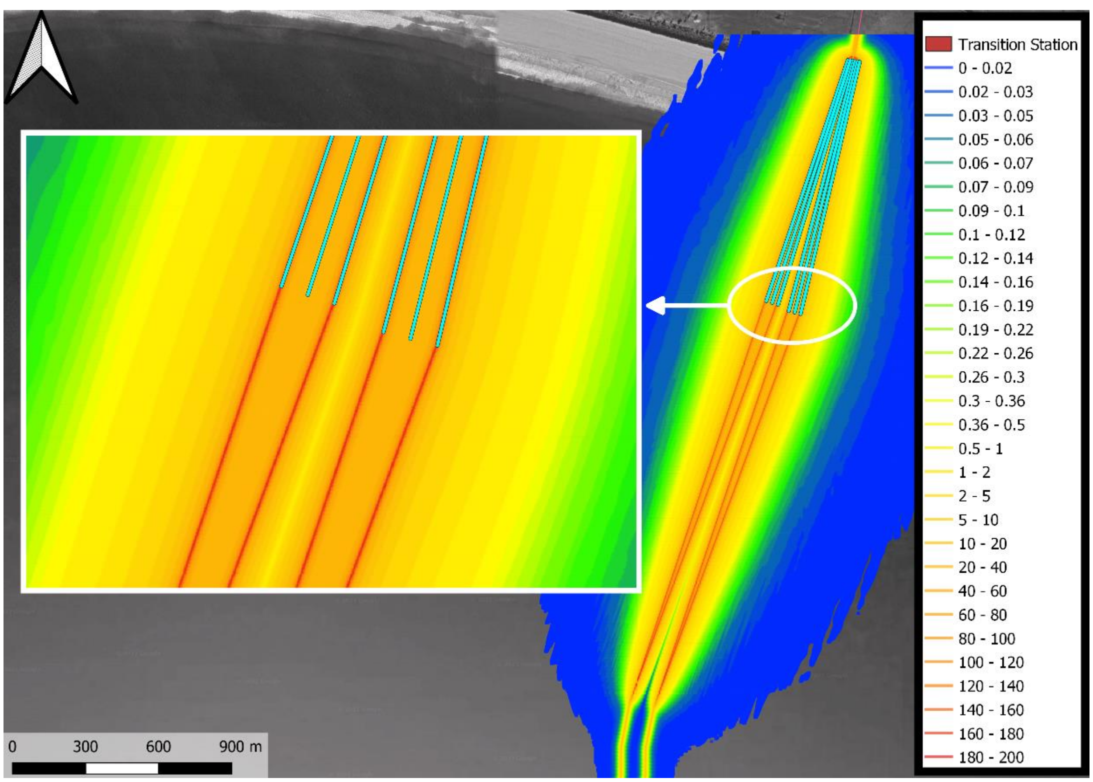


*Figure 7-21: Calculated magnetic field distribution on the seabed at the Waratah Bay shore crossing (μT)*

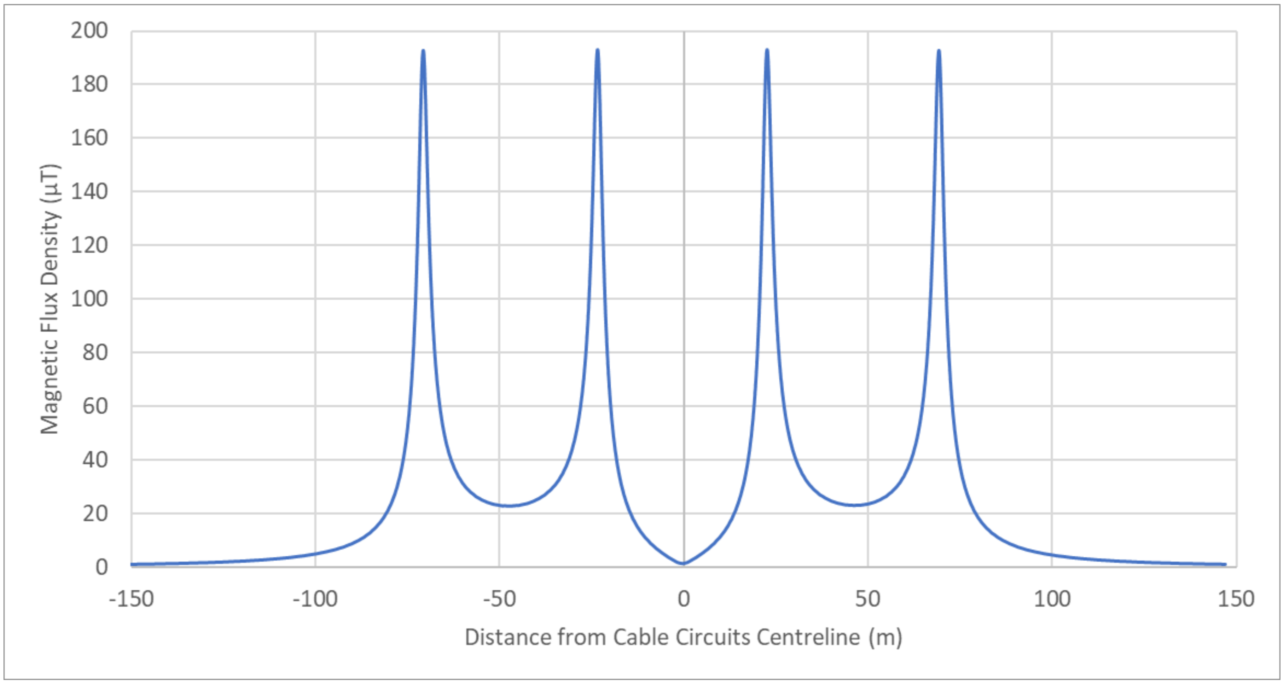


*Figure 7-22: Calculated magnetic field profile across the Waratah Bay shore crossing cable ducts (both circuits)*

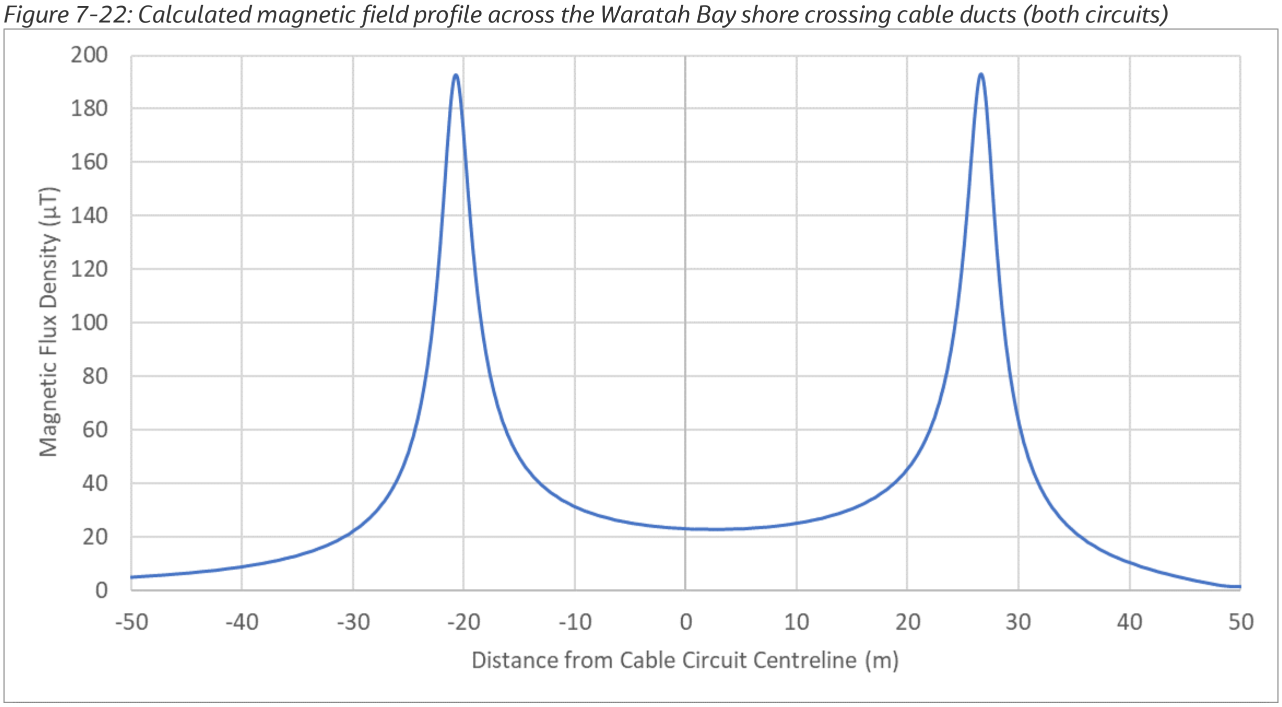


*Figure 7-23: Calculated magnetic field profile across the Waratah Bay shore crossing cable ducts (one circuit)*

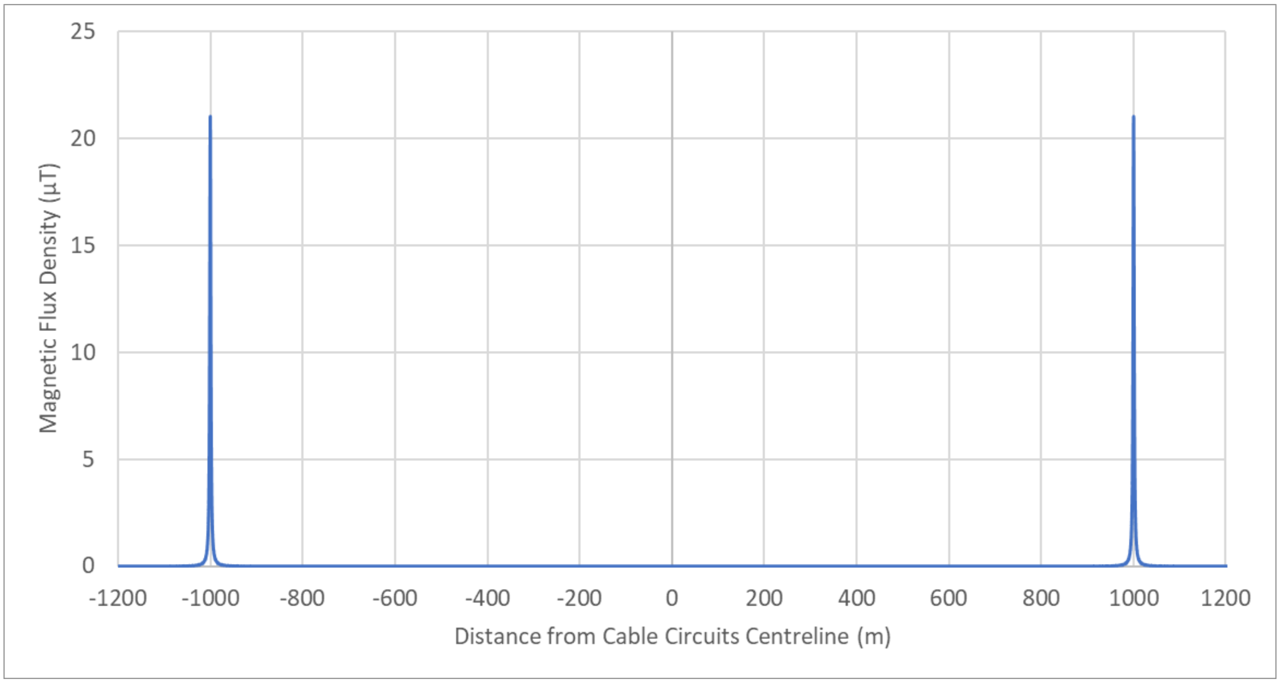


*Figure 7-24: Calculated magnetic field profile across the Bass Strait cables at sea floor level (both circuits) - Vertical*

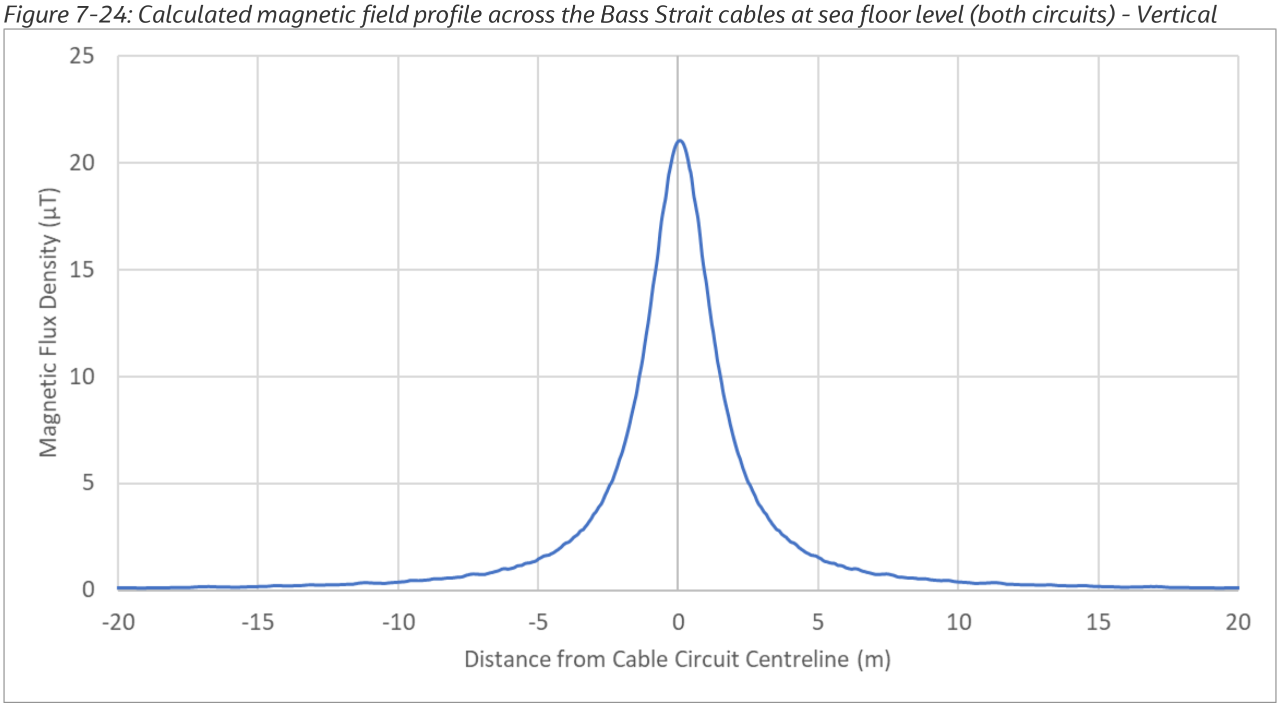


*Figure 7-25: Calculated magnetic field profile across the Bass Strait cables at sea floor level (one circuit) - Vertical*

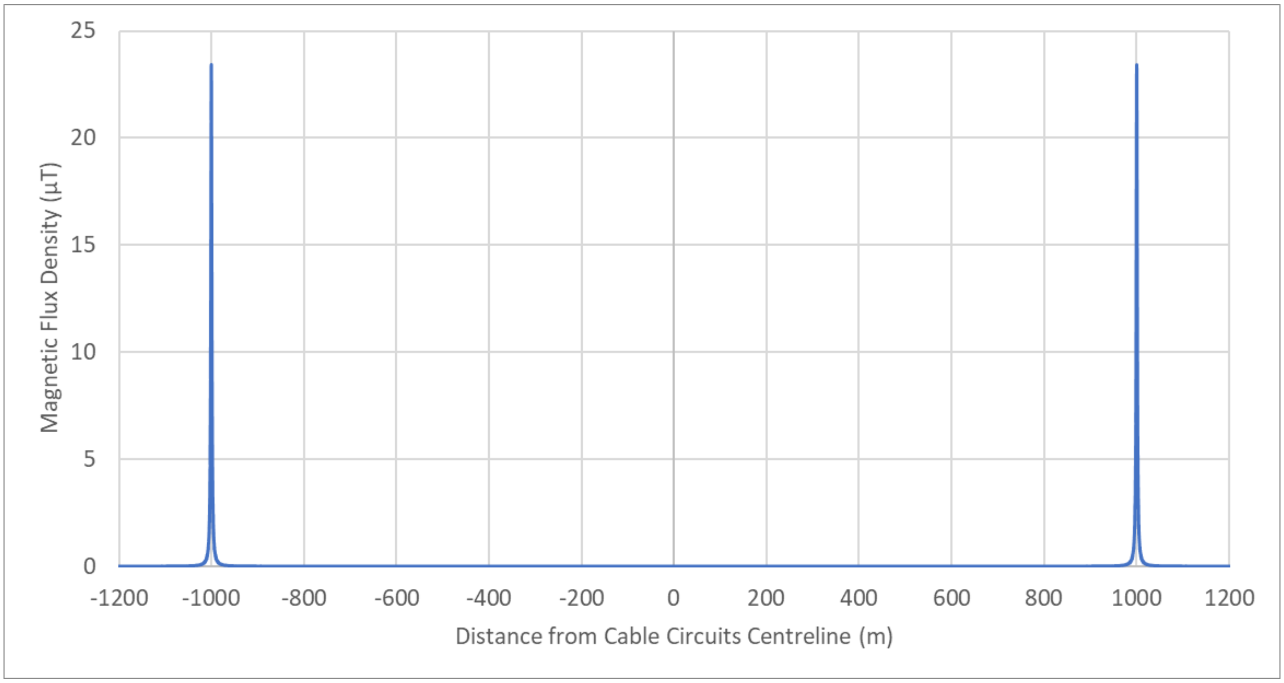


*Figure 7-26: Calculated magnetic field profile across the Bass Strait cables at sea floor level (both circuits) - Horizontal*

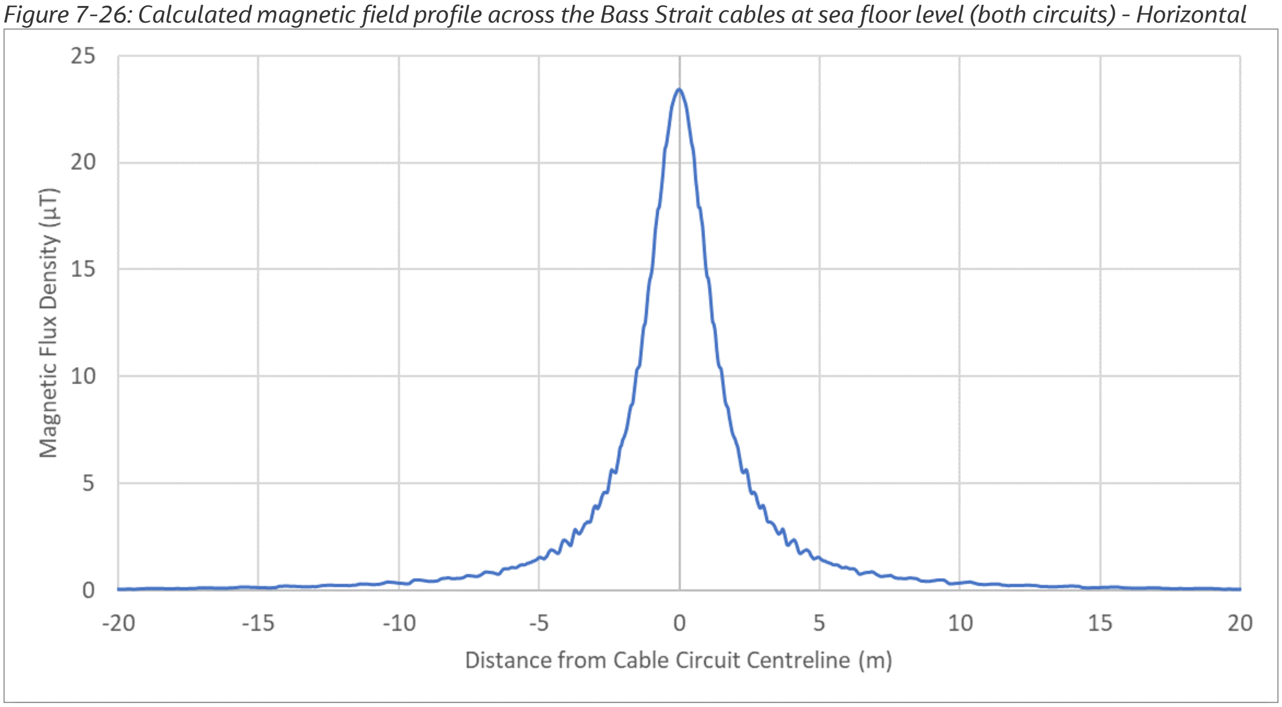


*Figure 7-27: Calculated magnetic field profile across the Bass Strait cables at sea floor level (one circuit) - Horizontal*

### 7.5.5 Land HVDC Cables

The magnetic field distribution was calculated along the HVDC land project alignment. The results indicated that the worst-case magnetic field levels at 1 m above ground level will be present within the first 3 km of land cable after the Waratah Bay shore crossing section.

The nominal horizontal spacing between the trenched positive and negative cables in each circuit will be 0.5 m, with an 8.5 m nominal separation between adjacent circuits, but could increase to 4 m for HDD installations at road and river crossings.

The calculated magnetic field distribution and profile along this land cable section are plotted in Figure 7-28 - Figure 7-35 for different cable spacings between 0.5 m and 4 m. The calculated magnetic field profiles above the HVDC land cable with different cable spacings are compared with each other in Figure 7-36. It is clear from this comparison that the cable spacing has a significant impact on the magnitude of the magnetic field near the HVDC land cables.

The worst case calculated magnetic field strengths are compared to the derived reference levels for human health, sensitive electrical and electronic equipment, fauna and flora impacts in Table 7-15 and Table 7-16 respectively.

During the worst case possible overload scenario (considered to be where both Stage One and Stage Two can be overloaded at the same time) the maximum magnetic flux density will increase by up to 12.5%.

A desktop study of the area surrounding the land cables was carried out and it was confirmed that there will be no sensitive electrical or electronic equipment or systems near the HVDC cables. Furthermore, the XLPE insulated cables will be not subject to corona discharges and will therefore not emit radio frequency interference.

*Table 7-15: Human health impact assessment along the HVDC land project alignment*

| Exposure Scenario | Inter-cable Spacing (m) | Magnetic Field Strength (μT) | |
|---|---|---|---|
| | | Reference Level | Calculated Level |
| People | 0.5 | 400,000 | 25 |
| | 1 | 400,000 | 49 |
| | 2 | 400,000 | 86 |
| | 4 | 400,000 | 124 |
| Active implantable medical devices | 0.5 | 500 | 25 |
| | 1 | 500 | 49 |
| | 2 | 500 | 86 |
| | 4 | 500 | 124 |

*Table 7-16: Sensitive receiver impact assessment along the HVDC land project alignment*

| Exposure Scenario | Inter-cable Spacing (m) | Magnetic Field Strength (μT) | |
|---|---|---|---|
| | | Reference Level | Calculated Level |
| RFID tags | 0.5 | 3,000,000 | 25 |
| | 1 | 3,000,000 | 49 |
| | 2 | 3,000,000 | 86 |
| | 4 | 3,000,000 | 124 |
| Livestock | 0.5 | 400,000* | 25 |
| | 1 | 400,000* | 49 |
| | 2 | 400,000* | 86 |
| | 4 | 400,000* | 124 |
| Apiaries | 0.5 | 2 | 25 |
| | 1 | 2 | 49 |
| | 2 | 2 | 86 |
| | 4 | 2 | 124 |
| Wildlife | 0.5 | 400,000* | 25 |
| | 1 | 400,000* | 49 |
| | 2 | 400,000* | 86 |
| | 4 | 400,000* | 124 |

* Conservative assumed value

It is evident from the impact assessments above that the calculated field levels are below the applicable reference levels and there will be no operating impacts on human health along the land cable. Similarly, the land cables will not impact the general health, foraging behaviour, or habitat of livestock, wildlife and the normal functioning of RFID tags or other farm equipment or machinery along the project alignment. Mitigation will not be required.

The HVDC land cables could have some impact on the behaviour of honeybees within 5 m of the cable trench. This is because directly above the buried cables, and within 5 m of the cable trench, the calculated field levels are above 2 μT. It is recommended that any apiaries located within 5 m of the trench be relocated outside the cable easement during the construction of the HVDC land cable. Publicly available information indicates that there are currently no existing apiaries within 5 m of the proposed land project alignment.

If different cable types will be selected for the subsea and land cables, a transition station could be required. It may also be required for the fibre optic cable termination. The site of the possible transition station is proposed to be 1 km inland from the Waratah Bay shore crossing. The indoor, gas-insulated installation will generate no significant electric fields or radio interference. The magnetic fields generated by the site will be comparable with that of the land cable.


*Figure 7-28: Calculated magnetic field distribution in the vicinity of the HVDC land cable – 0.5 m inter-cable spacing*

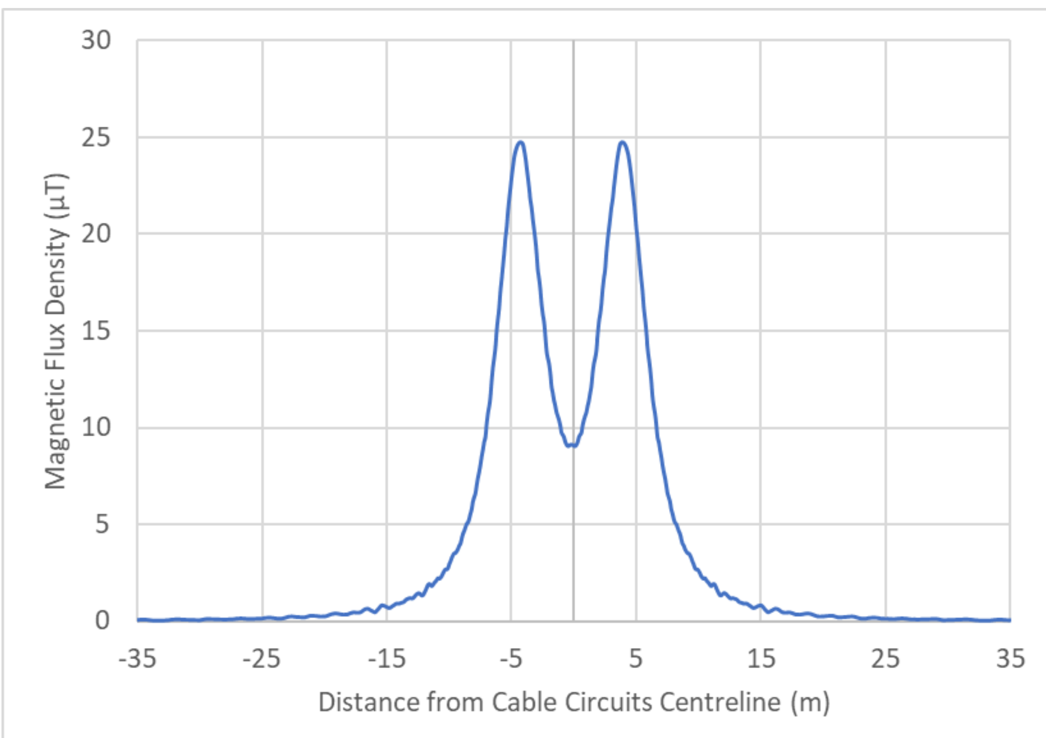


*Figure 7-29: Calculated magnetic field profile above the HVDC land cable – 0.5 m inter-cable spacing*

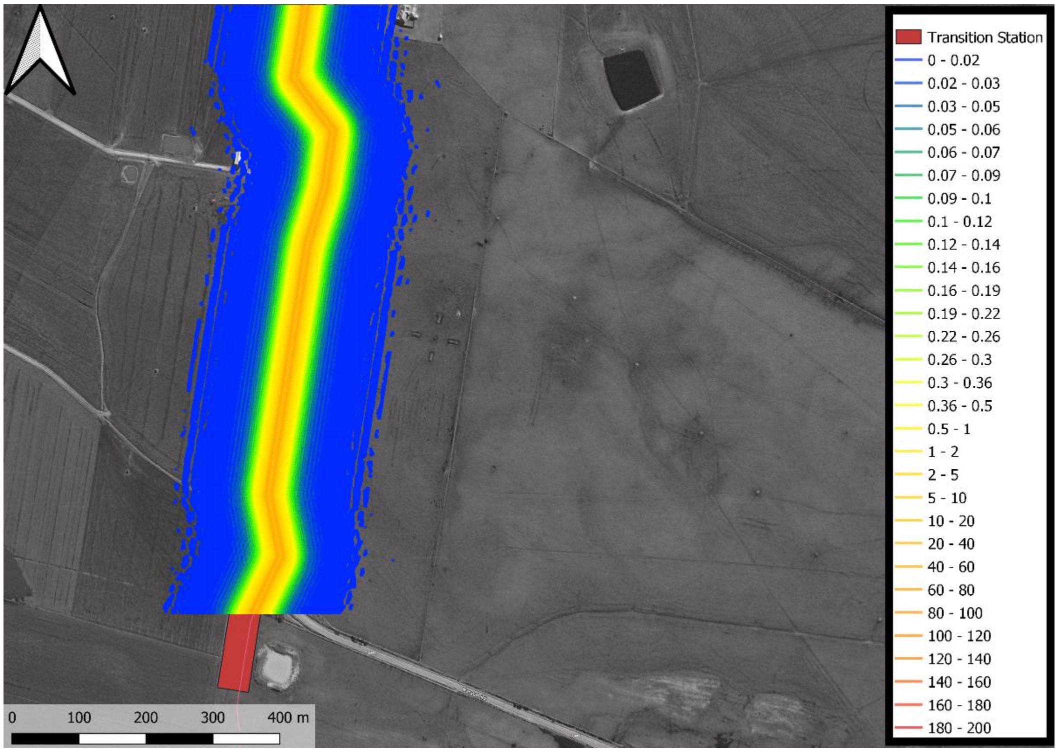


*Figure 7-30: Calculated magnetic field distribution in the vicinity of the HVDC land cable – 1 m inter-cable spacing*

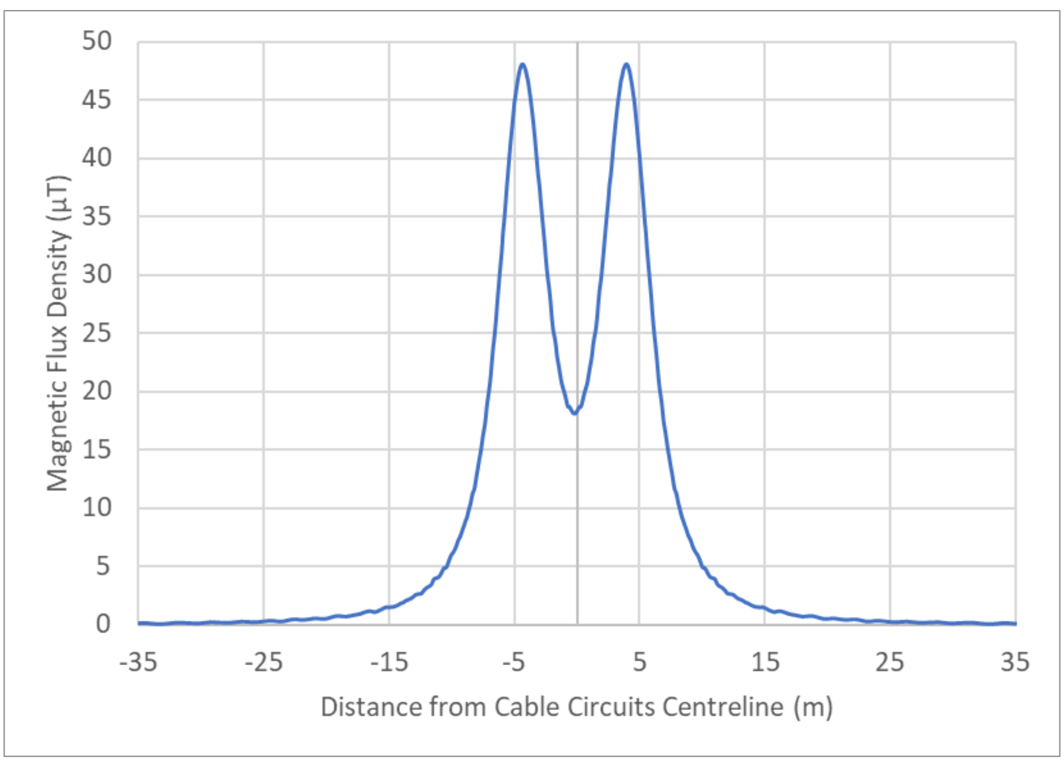


*Figure 7-31: Calculated magnetic field profile above the HVDC land cable – 1 m inter-cable spacing*

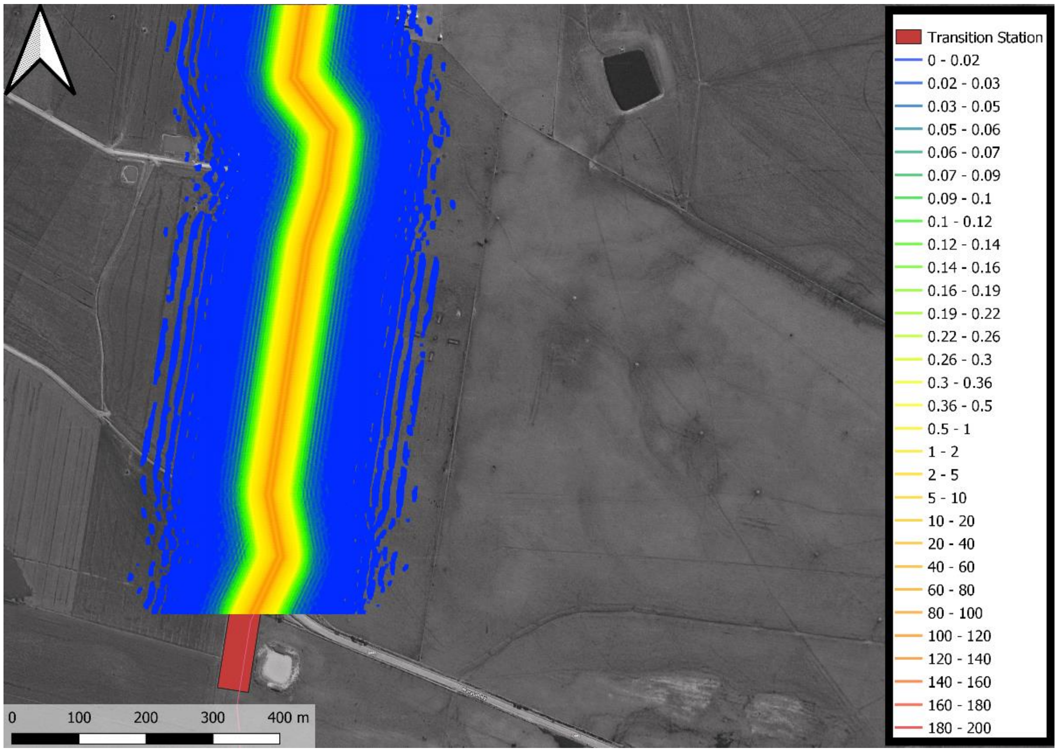


*Figure 7-32: Calculated magnetic field distribution in the vicinity of the HVDC land cable – 2 m inter-cable spacing*

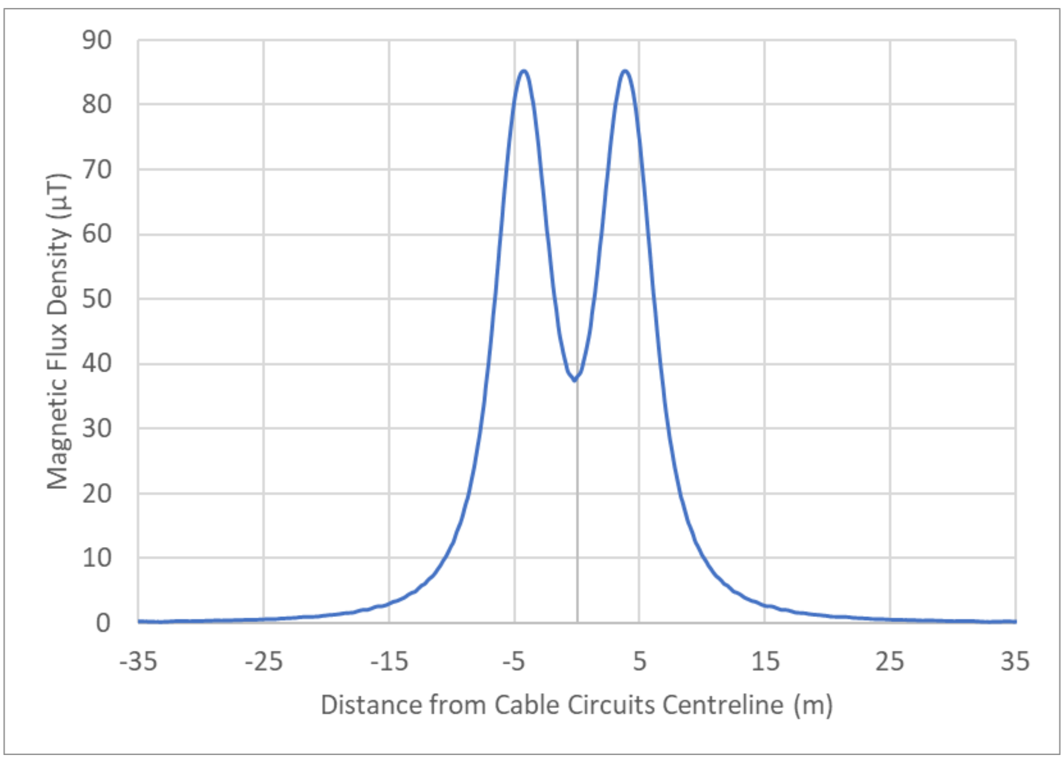


*Figure 7-33: Calculated magnetic field profile above the HVDC land cable – 2 m inter-cable spacing*

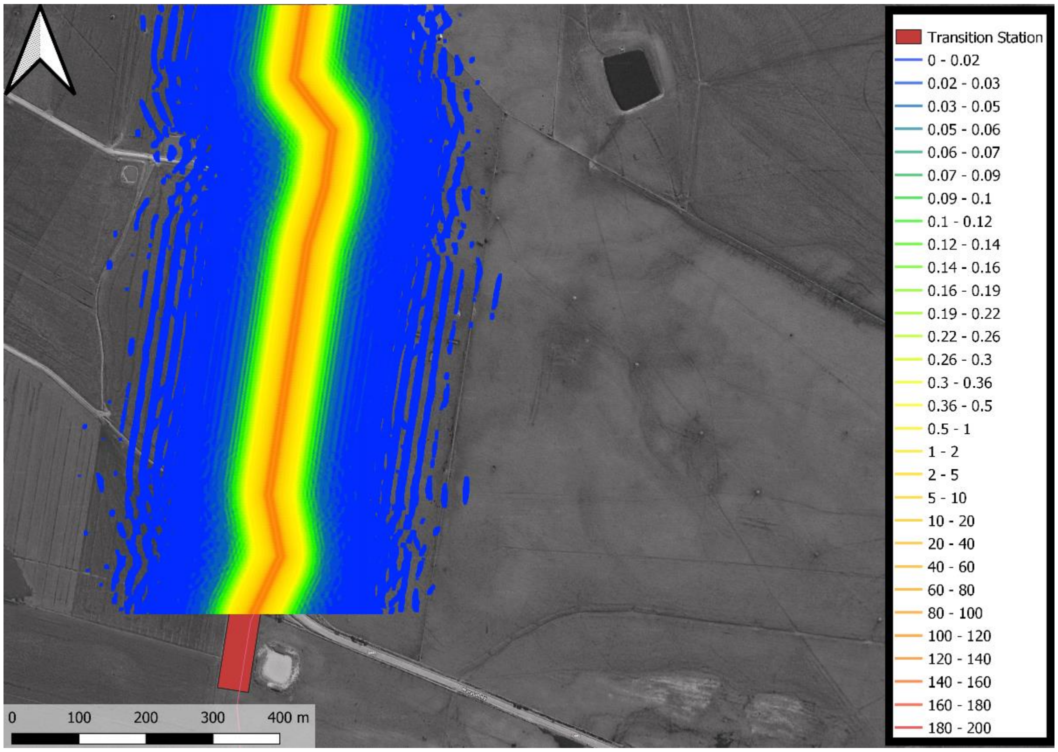


*Figure 7-34: Calculated magnetic field distribution in the vicinity of the HVDC land cable – 4 m inter-cable spacing*

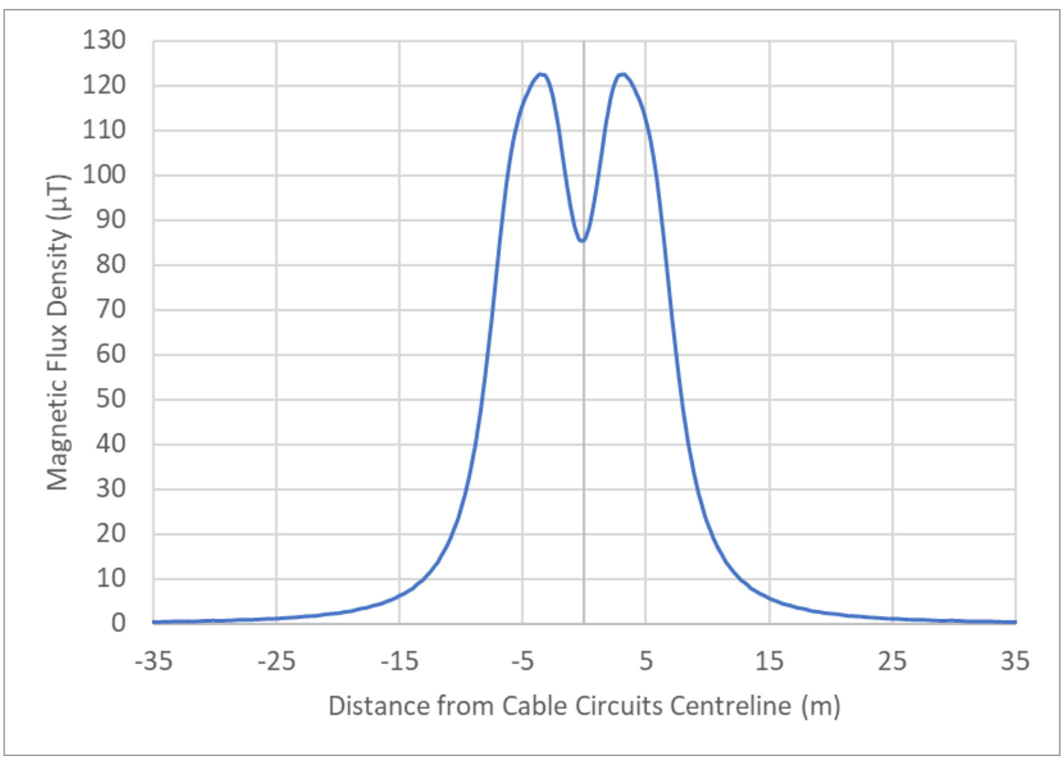


*Figure 7-35: Calculated magnetic field profile above the HVDC land cable – 4 m inter-cable spacing*

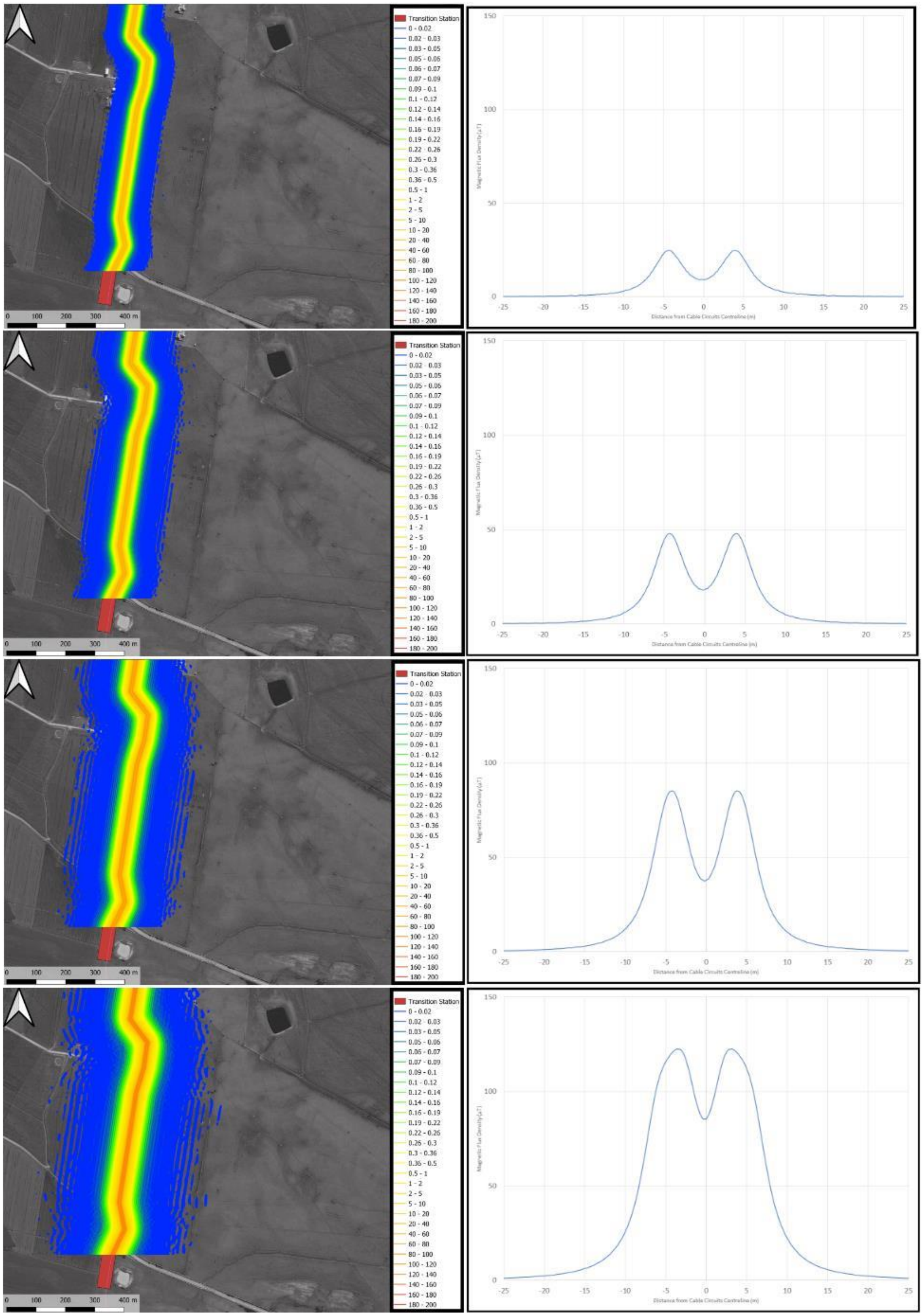

*Figure 7-36: Comparison of calculated magnetic fields for different HVDC land cable separations (0.5 m, 1 m, 2 m, and 4 m)*

### 7.5.6 Cable Heating Assessment

Soil temperature rise contours have been calculated for various operating scenarios for the subsea and land HVDC cables in different areas along the proposed project alignment as part of the impact assessment.

The assumed cable geometry used for the EMF and EMI assessment detailed previously in this section has also been used for the cable heating assessment. Only the horizontal flat cable formation has been considered for the subsea cable heating assessment.

Several CYMCAP models were created to analyse the different sections of the project alignment. Each model contained the relevant ambient temperature and thermal resistivity of the soil and backfill, where applicable. A typical CYMCAP simulation plot is presented in Figure 7-37. The plot presents a cross-sectional view of the modelled buried cables, with horizontal and vertical axis dimensions in meters, and the calculated temperature rise contours in the surrounding soil, colour coded in degrees Celsius.

The land HVDC cables have been modelled in PVC ducts, whilst the subsea cables have been modelled as direct buried. It is assumed that the land HVDC cables will be buried in Thermally Stable Backfilling Material (TSBM) with nominal cross-sectional dimensions of 1 m wide by 0.4 m deep.

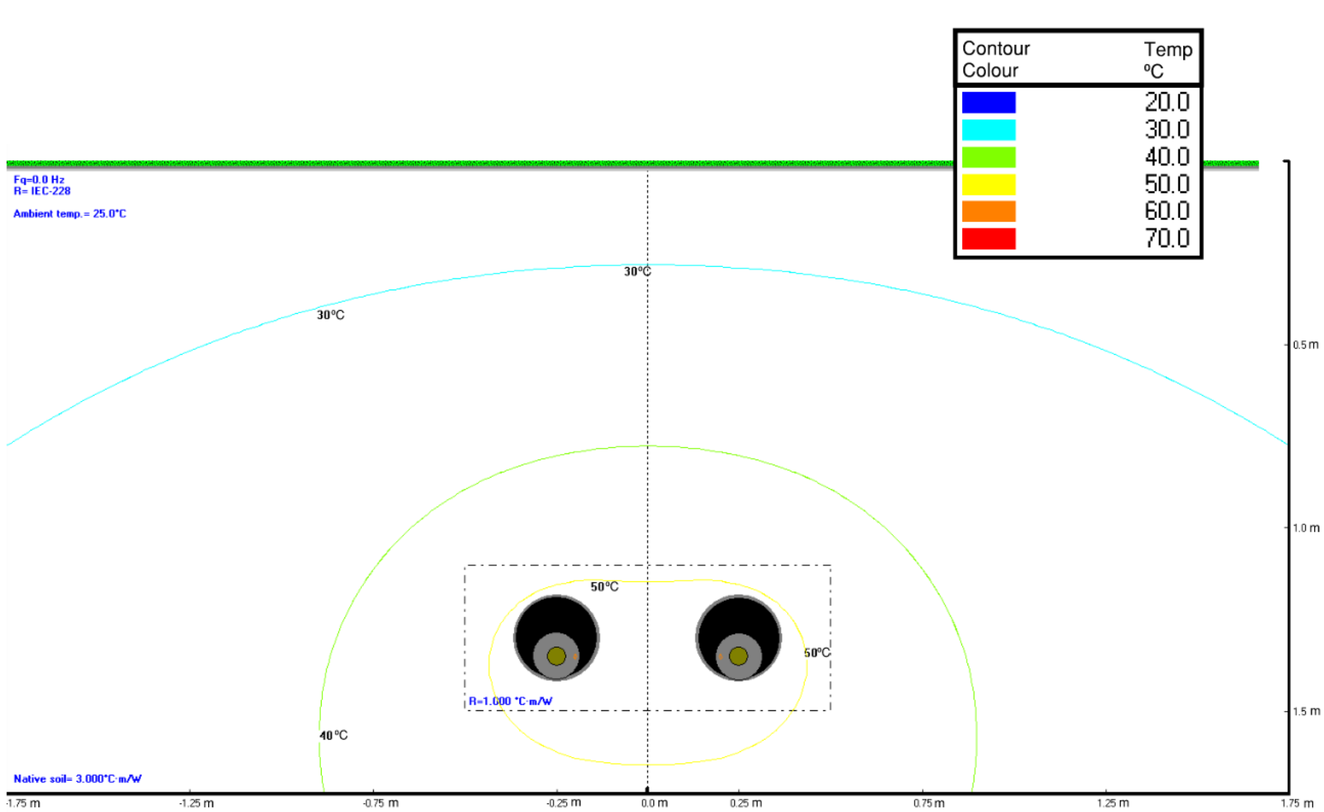


*Figure 7-37: Typical CYMCAP calculation plot*

Cable and soil heating calculations were performed for the following three operating scenarios:

1. The cables operating at the proposed steady-state current
2. The cables operating at a temperature of 70°C
3. The cables operating at a temperature of 90°C

The scenarios where the cables are operating at 70°C and 90°C correspond to the maximum operating temperatures for typical cables. The results of the cable and soil heating calculations are summarised in Table 7-17 at depths of 0.1 m, 0.5 m and 1 m below the surface of the ground or seabed.

The nominal ambient temperature of the soil surrounding the buried HVDC cables is 25°C. If the temperature rise of this soil will exceed 50°C (i.e. an increase of 25°C above the ambient temperature), the soil will lose significant moisture and its thermal resistivity will increase, resulting in possible thermal damage to the cables. The project cable specification document therefore requires that the volume of native soil within the calculated 50°C contour be replaced with Thermally Stable Backfilling Material (TSBM). This is an engineered material that does not dry out at temperatures exceeding 50°C and thereby protects the HVDC cables from thermal damage during maximum loading scenarios.

A temperature increase of more than 3°C above the ambient 25°C at a depth of 0.1 m or less below the surface of the ground, can impact the health of pasture grass. This volume of soil is called the root zone and contains the roots and aerated soil that facilitates healthy growth of the plants. Any drying out of the soil in the root zone will impact the health of the plants.

The calculated soil temperature rise values at the nominal depth of the HVDC cables (i.e. at 1 m depth) and at the maximum depth of the root zone (i.e. at 0.1 m depth) are summarised in Table 7-17. These are the values of temperature rise above the nominal 25°C ambient soil temperature. For all values exceeding 25°C along the proposed land project alignment in Table 7-17, additional thermal backfill was included in the CYMCAP model.

The temperature rise in the root zone only exceeds the 3°C limit along the Smallmans Rd – Darlimurla Rd section. With additional thermal backfill applied, the temperature rise in the root zone can be limited to less than 3°C as is evidenced in the calculation results summarised in Table 7-17.

In the HVDC cable sections where the soil temperature rise at 1 m depth exceeds 25°C, additional excavation and backfill may be required. The environmental impact is therefore limited to the construction phase only and is not considered significant. However, along sections where the soil temperature rise at 0.1 m depth exceeds 3°C, mitigation will be required to address the operational impact on the health of the pasture grass above the HVDC cables. This will be in the form of additional Thermally Stable Backfilling Material (TSBM) in the cable system design. The soil temperature rise calculations presented in this section do however indicate that the worst case soil temperature rise at 0.1 m depth does not exceed 3°C. It is therefore unlikely that the operation of the HVDC cables will impact the health of the pasture grasses in the vicinity of the cables and additional mitigation measures will not be required.

*Table 7-17: Cable heating assessment results with thermal backfill mitigation applied, where required*

| Operating Condition | Increase in Soil Temperature above Ambient for various cable sections | | | | | |
|---|---|---|---|---|---|---|
| | Heybridge Converter Station | Submarine Section | Waratah Bay - Smallmans Rd | Smallmans Rd - Darlimurla Rd[15] | Darlimurla Rd - Strzelecki Hwy | Strzelecki Hwy - Hazelwood |
| **Steady state current 1.0 m depth** | +8°C | +7°C | +8°C | +20°C | +8°C | +14°C |
| **Conductor temp 70°C 1.0 m depth** | +11°C | +22°C | +11°C | +25°C | +11°C | +17°C |
| **Conductor temp 90°C 1.0 m depth** | +15°C | +30°C | +15°C | +35°C | +15°C | +25°C |
| **Steady state current 0.5 m depth** | +3°C | +2°C | +3°C | +9°C | +3°C | +6°C |
| **Conductor temp 70°C 0.5 m depth** | +5°C | +9°C | +5°C | +12°C | +5°C | +8°C |
| **Conductor temp 90°C 0.5 m depth** | +6.5°C | +12°C | +6.5°C | +16°C | +6.5°C | +11°C |
| **Steady state current 0.1 m depth** | +0°C | +0°C | +0°C | +1°C | +0°C | +1°C |
| **Conductor temp 70°C 0.1 m depth** | +1°C | +0°C | +1°C | +2°C | +1°C | +1.5°C |
| **Conductor temp 90°C 0.1 m depth** | +1.5°C | +1°C | +1.5°C | <3°C | +1.5°C | +2°C |

It is noted that the CYMCAP modelling does not take into account the thermal mass of the water and the strong ocean currents in the Bass Strait. These factors will attenuate the thermal contours and result in negligible heating of the seawater near the seabed. It is evident from the values presented in Table 7-17 for the submarine section that the temperature rise of the seabed surface due to the subsea HVDC cables is indistinguishable from the ambient temperature.

## 7.6 Cumulative Impacts

Cumulative EMF and EMI impacts have been considered for the proposed electrical power infrastructure. Cumulative EMF and EMI impacts describe the total or net EMF & EMI impacts that will be generated by the project's cables and other sources of potential EMF and EMI (i.e. the summation of EMF and EMI levels from multiple sources).

These impacts include the cumulative effects of the proposed project infrastructure on the ambient geomagnetic field and also on the magnetic fields generated by the operational Basslink cables and other high voltage electrical projects and infrastructure.

[15] Modelled with additional thermal backfill to encapsulate the 50°C contour

The ambient geomagnetic field is vertically polarised near the surface of the earth (i.e. the field strength in the vertical direction away from the earth's surface is much larger than the field strength in the horizontal direction along the earth's surface). The calculated magnetic fields that will be generated by the new infrastructure will be almost entirely horizontally polarised above the cables, where the fields are largest (i.e. the field strength in the horizontal direction along the earth's surface is much larger than the field strength in the vertical direction away from the earth's surface). Sensitive receivers will experience the resultant magnetic field, which is the vector summation of the ambient and generated fields. Given the difference in field orientation near the cables, the cumulative effect is not significant other than at the shore crossings where the fields generated by the cables are much larger than the ambient geomagnetic field, as summarised in Table 7-18.

The magnetic field generated by the shore crossing cables reduce exponentially with increased horizontal distance away from the cable alignment. The significant magnetic field anomalies in an area of the shore crossings due to the fields generated by the HVDC cables will extend only up to about 5 m horizontal distance from the HDD cable sections. Beyond that distance, the cumulative impact of the proposed infrastructure will not be significant. The identified magnetic field anomaly within 5 m horizontal distance of the shore crossing cables will impact compass readings in very shallow waters, as described in Section 7.2.11. This is not considered a significant impact on maritime safety as the extent of the impact zone is limited to very shallow waters at the shore crossing only. Cumulative impacts on other sensitive electrical and electronic equipment, human health, livestock and wildlife will not be significant.

*Table 7-18: Cumulative impacts of the background geomagnetic field and the subsea HVDC cable magnetic fields*

| **Subsea Location** | **Average Geomagnetic Field Intensity (μT)** | **Maximum Magnetic Field Generated by the subsea HVDC cables (μT)** | **Cumulative Effect of Geomagnetic and Subsea Cable Fields (μT)** |
|---|---|---|---|
| Waratah Bay Shore Crossing (Victoria) | 60.35 | 194 | 203.4 |
| Off-shore | 60.87 | 24 | 65.5 |
| Heybridge Shore Crossing (Tasmania) | 61.39 | 193 | 202.8 |

Based on the worst-case calculated distribution of magnetic field levels near the shore crossing cables for the proposed Marinus project, it is concluded that the cumulative effect of other subsea HVDC cables in the vicinity of the proposed Marinus project will not be significant at a distance greater than 50 m from the Marinus subsea project alignment.

The proposed project subsea project alignment is located a minimum distance of 63 km from the Basslink cable. The magnetic field that will be generated by the project's cables at this distance will not be detectable above the magnetic field generated by the Basslink cables and the ambient geomagnetic fields and will not impact the local marine environment. Accordingly, the magnetic field generated by the Basslink cables will have negligible cumulative effect on the proposed Marinus cables marine environment. Furthermore, any impact on magneto-sensing will be transitory, present only for the duration in which the animals are within the impact zone near the cables, with no remnant effects when they move out of the impact zone. There is therefore no cumulative impact of the proposed project's cables and the existing Basslink cable due to sequential movement of sealife from the Marinus Link impact zone to the Basslink impact zone, and vice versa.

Offshore windfarms have been proposed in the Bass Strait. These wind farms will have subsea power export cables in the Bass Strait to transfer the generated power to the onshore electrical grid. The only proposed Bass Strait offshore wind farms near the Marinus project alignment are the Bass Offshore Wind Energy (BOWE) project and Great Southern Offshore Wind project. The BOWE project will be located 20-30 km off the coast of north-eastern Tasmania. The cumulative effects on Marinus Link from BOWE will be negligible. The cumulative effects on Marinus Link from the Great Southern Offshore Wind project will be negligible. It is further noted that neither of the proposed offshore wind farm projects have been referred and as such are excluded from the scope of the cumulative impact assessment due to lack of information.

Based on the worst-case calculated distribution of magnetic field levels near the land cables for the proposed Marinus project, it is concluded that the cumulative effect of other HVDC land cables in the vicinity of the proposed Marinus cables will not be significant at a distance greater than 10 m from the Marinus land project alignment. However, other projects are most likely to install HVAC cables. The effects of simultaneous exposure to DC and AC magnetic fields are not cumulative as regards interference to active implantable medical devices. Furthermore, humans and animals are far more immune to DC fields than AC fields. The cumulative effects of AC and DC magnetic fields are negligible and exposure to each can be assessed separately.

The proposed Marinus HVDC land project alignment between the transition station and Driffield/Hazelwood converter station runs along the Strzelecki Highway (B460) north-east of Delburn and south-west of Driffield. The proposed Delburn Wind Farm is to be located in this area and comprises 33 wind turbines in the HVP plantation that straddles the Strzelecki Highway. It is evident in Figure 7-38 that the proposed Marinus HVDC land cables will be located in close proximity to a number of proposed wind turbines. The power cables associated with the wind turbines and wind farm power collection system will be HVAC cables. There will therefore be negligible cumulative effects in the area.

There are also existing 500 kV AC power lines that will parallel and cross-over the Marinus HVDC land cables in the vicinity of the proposed windfarm. It is also indicated on Figure 7-38.

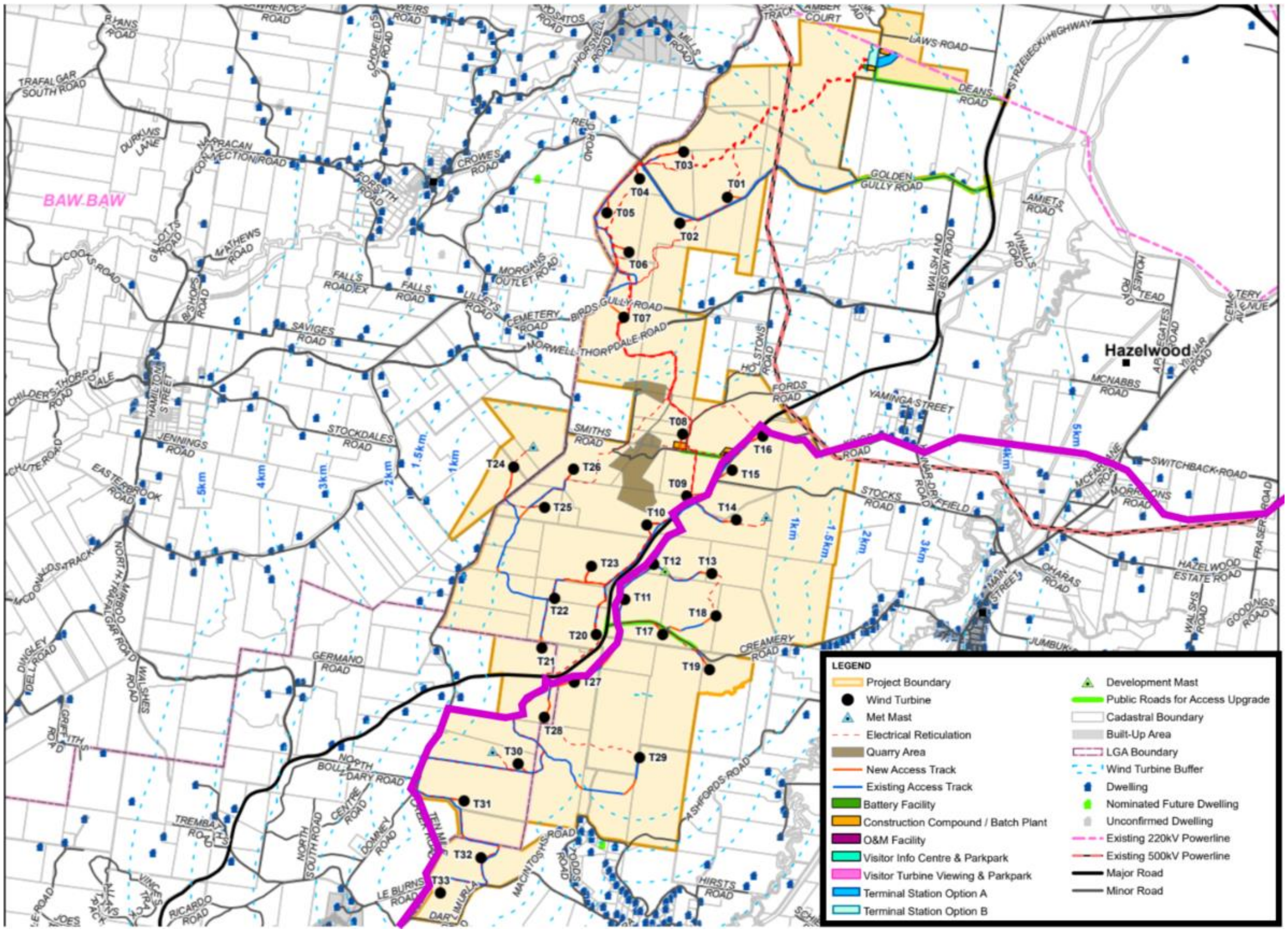


*Figure 7-38: Delburn Wind Farm project area with the proposed Marinus Link HVDC land project alignment overlaid in purple*[16]

There will not be significant cumulative effects from the AC magnetic fields associated with the 500 kV transmission line and the DC magnetic fields generated by the Marinus HVDC land cables. The AC magnetic fields will induce an AC voltage on the sheath and core conductors of each HVDC cable. This may present a safety risk to maintenance staff during work on the out-of-service cables. Safety precautions will be developed to manage this occupational safety risk as part of the detailed design of the HVDC land cables.

## 7.7 Mitigation

The EMF assessment identified a potential impact of the land HVDC cables on the behaviour of honeybees within 5 m of the cable trench. It is recommended that any apiaries located within 5 m of the trench be relocated outside the impact zone during the construction of the HVDC land cable. The identified mitigation requirement will be confirmed and managed by EPR EMF01.

[16] Delburn Wind Farm information and image taken from publicly available information available at: https://osmi.com.au/frequently-asked-questions/#about-the-project . The imaging available at this location has been enhanced around the Marinus Link project alignment for demonstration and explanatory purposes only in this report and does not replace the original.

## 7.8 Monitoring and Review

There were no significant residual EMF or EMI hazards identified in this environmental impact assessment for the proposed project. As such, ongoing monitoring of electric and magnetic fields at sensitive receivers is not considered necessary and has not been recommended.

However, as part of the verification of the analysis conducted as part of this impact assessment and the subsequent detailed design stage, it is recommended that post-construction and commissioning EMF and EMI tests be conducted near key locations within the project area.

## 7.9 Environmental Performance Requirements

The recommended Environmental Performance Requirements (EPRs) identified as a result of the electric and magnetic fields and electromagnetic interference impact assessment are outlined in Table 7-19.

*Table 7-19: EMF and EMI Environmental Performance Requirements (EPRs)*

| EPR ID | Environmental Performance Requirement | Project Stage |
|---|---|---|
| EPR EMF01 | **Design the project to reduce EMF/EMI emissions**<br>Design and construct the project to reduce electric and magnetic fields (EMF) and electromagnetic interference (EMI) for the project alignment onshore to below the reference levels or as low as reasonably practicable to avoid and minimise impacts. The applicable reference levels are defined in EIS/EES Technical Appendix A: Electromagnetic Fields Section 7 of the EMI impact assessment prepared for the EIS/EES. The design must be informed by a project wide EMF and EMI assessment for all the proposed infrastructure, identifying existing sensitive receptors and committed future developments within the study area. The assessment must be documented in a management plan that includes, but is not limited to:<br>• Outcomes of the project wide EMF and EMI assessment and details of the areas assessed.<br>• The location of all sensitive receptors including beehives within 5 m of the infrastructure. The location of beehives must also be documented in the property management plans (EPR A02).<br>• Where at-receiver mitigation works to sensitive equipment are required to avoid or minimise adverse impacts.<br>• A pre- and post-construction testing strategy to verify design calculations, impacts on sensitive equipment and the efficacy of any specified mitigation measures.<br>• Remedial action to be undertaken if EMF and EMI limits are not met during the construction, testing, and commissioning.<br>The EMF and EMI management plan must be prepared to inform the design and commissioning of the project.<br>EMF and EMI emissions of the subsea cable are addressed in EPR MERU 12. | Design<br>Construction<br>Commissioning |
| EPR EMF02 | **Investigate and resolve complaints regarding EMF and EMI during operation**<br>As part of the OEMP, develop a protocol for investigating and resolving complaints regarding EMF and EMI during operation. The protocol must outline requirements for working with landholders to assess impacts on sensitive equipment and implement reasonably practicable measures to address impacts. | Operation |

# 8. Conclusions & Recommendations

## Existing Conditions

The only measurable sources of EMF and EMI within the subsea study area are the earth's geomagnetic fields. The cumulative impact of the proposed new electrical power infrastructure and the geomagnetic fields will only be measurable at the shore crossings of the subsea HVDC cables.

Cumulative effects between any existing and proposed new HVDC cables within the subsea study area will be negligible.

The only measurable sources of EMF and EMI within the mainland Tasmania and mainland Victoria study areas are the earth's geomagnetic fields and the AC electric and magnetic fields generated by operational high voltage power lines and substation equipment. There are existing 500 kV AC power lines that will parallel and cross-over the Marinus HVDC land cables. The physical and biological mechanisms by which DC and AC fields impact people, fauna, flora and equipment are distinct. As such, cumulative impact limits for DC and AC fields are not defined in the relevant standards and guidelines, and the cumulative impact of DC and AC fields on the environment within the study area are considered acceptable if they are below the respective limits and reference levels defined in the relevant standards and guidelines.

## Impact Assessment

Research and analysis of sensitive receivers that could potentially be impacted by the EMF and EMI generated by the proposed project's electrical power infrastructure have been undertaken. Limits and reference levels have been derived from applicable state, national and international standards and research reports/studies to evaluate the possible operational impact of the electrical power infrastructure on the local environment within the defined study area.

Besides the impact of electric and magnetic fields on people, plants and animals, generic household electrical and electronic equipment may also be impacted by AC magnetic fields that exceed 3.8 μT and radio frequency fields. DC magnetic field limits are not specified for generic equipment as the equipment is significantly more immune to DC fields, as compared to AC fields, in the general case. Specialised medical and scientific research equipment may however be sensitive to lower-level AC and also DC magnetic fields, which can interfere with the normal operation and functionality of the equipment.

### Converter Stations and Surrounding Areas

Sensitive receivers that could be impacted by EMF and EMI associated with the proposed converter stations, and were considered in the impact assessment, include people, active implantable medical devices, generic electrical & electronic equipment, very sensitive medical and scientific research equipment, farm equipment, livestock and local flora and fauna.

The maximum calculated EMF at the Heybridge, Driffield and Hazelwood converter stations will be below the reference levels for people, livestock and wildlife at the property boundary for each site. The operating impacts of the converter stations on human health, livestock and wildlife will therefore be negligible. Mitigation and controls will not be required at the installations.

The maximum calculated EMI, specifically the AC magnetic field strength, will be below 3.8 μT (i.e. the generic equipment interference limit) in all areas outside the converter station properties. A desktop study of the area surrounding the three converter station sites was conducted and it was confirmed that there are no sensitive electrical or electronic equipment or systems that could be impacted by the EMI from the converter stations. The operating impacts of the converter stations on nearby sensitive receivers will be negligible. Mitigation and controls will not be required at the installations.

**Land HVDC Cables**

Sensitive receivers that could be impacted by EMF and EMI associated with the proposed land HVDC cables, and were considered in the impact assessment, include people, active implantable medical devices, generic electrical & electronic equipment, very sensitive medical and scientific research equipment, farm equipment, livestock (dairy & beef cattle, sheep, horses, pigs, and poultry), honeybees, fruit trees, feeding grasses, vegetables, local flora and fauna (e.g. birds, frogs, mammals).

The magnetic field distribution was calculated along the land HVDC project alignment. The HVDC cables will only be subject to partial discharges that are contained wholly within the layers of insulation inside the cables and radio frequency interference emitted from these partial discharges within the cable will be much lower than the immunity limits of electrical and electronic equipment.

The maximum calculated EMF along the land HVDC cables will be below the reference levels for people throughout the study area. It was concluded from these calculations that the land cables will be no operating impacts on human health. Mitigation and controls will not be required at the installations.

Similarly, the land cables will not impact the general health of livestock, wildlife and the normal functioning of RFID tags or other farm equipment or machinery along the project alignment.

The HVDC land cables could have some impact on the behaviour of honeybees within 5 m of the cable trench. It is recommended that any apiaries located within 5 m of the trench be relocated outside the impact zone during the construction of the HVDC land cable. The impact of the HVDC cables will then be limited to temporary loss of direction sense for bees foraging within the very localised impact zone above the cable trench. Given the very limited extent of the impact zone and that the impact is momentary disorientation within the impact zone only, it is concluded that the HVDC cable will have negligible impact on bee colonies where the apiary has been relocated outside the impact zone.

A desktop study of the area along the land HVDC project alignment was carried out and it was confirmed that there will be no specialised medical and scientific research equipment near the land HVDC cables that could be impacted by the DC magnetic fields associated with the cables.

**Subsea HVDC Cables – Shore Crossings**

Sensitive receivers that could be impacted by EMF and EMI associated with the proposed subsea HVDC cables in the shore crossing areas, and were considered in the impact assessment, include fish, marine mammals, turtles, marine vessels (e.g. ships and boats), and other marine fauna and flora.

The potential effects of EMF exposure to Marine Flora and Fauna are addressed in the Marine Ecology and Resource Use (MERU) report (EIS/EES Appendix P). This report identifies applicable reference levels and potential effects of EMF exposure on Marine Flora and Fauna, including benthic species, epibenthic species, and those listed as threatened under the Threatened Species Protection Act 1995.

The highest DC magnetic field levels occur on the sea floor at the shore crossings. This is because the cables will be unbundled and spaced far apart along these sections. The maximum calculated EMF along the shore crossing HVDC cables will be below the reference levels for people throughout the study area. It was concluded from the shore crossing cable impact assessment that the calculated field levels are below the applicable reference levels and there will be no operating impacts on human health. Mitigation and controls will not be required at the installations. Similarly, the shore crossing cables will not impact the normal functioning of marine vessels and systems in the study area.

**Subsea HVDC Cables - Bass Strait**

Sensitive receivers that could be impacted by EMF and EMI associated with the proposed subsea HVDC cables in the Bass Strait, and were considered in the impact assessment, include fish, marine mammals, turtles, marine vessels (e.g. ships and boats), and other marine fauna and flora.

The potential effects of EMF exposure to Marine Flora and Fauna are addressed in the Marine Ecology and Resource Use (MERU) report (EIS/EES Appendix P). This report identifies applicable reference levels and potential effects of EMF exposure on Marine Flora and Fauna, including benthic species, epibenthic species, and those listed as threatened under the Threatened Species Protection Act 1995.

The magnetic field distribution was calculated along the subsea HVDC project alignment across Bass Strait. The cables in each circuit will be bundled together within the Bass Strait trench section, which greatly reduces the external magnetic fields associated with the cables. The magnetic fields will be strongest directly above the cables and decrease quickly at increasing distance from the cables. Fluctuations in sea water conductivity were considered in the modelling but were found to have negligible impact on the intensity of the static magnetic fields. The static electric field produced by the cables in the conductive water will be negligible for all reasonable water salinities and ocean current velocities.

The maximum calculated EMF along the subsea HVDC cables will be below the reference levels for people throughout the study area. It was concluded from the subsea cable impact assessment that the calculated field levels are below the applicable reference levels and there will be no operating impacts on human health. Mitigation and controls will not be required at the installations. Similarly, the subsea cables will not impact the normal functioning of marine vessels and systems in the study area.

A desktop study of the area along the subsea HVDC project alignment within the Bass Strait was carried out and it was confirmed that there will be no specialised medical and scientific research equipment near the subsea cables that could be impacted by the DC magnetic fields associated with the cables.

**Cable Heating Assessment**

The heat generated by the subsea and land HVDC cables has been considered in the impact assessment. It is concluded from conservative soil heating calculations that it is unlikely that the operation the HVDC cables will impact plant life, specifically pasture grass, in the vicinity of the cable trench along any section of the cable. The cable system design will provide assurance that any impact on plant health is negligible.

Negligible heating of the seawater near the seabed is expected due to the operation of the subsea HVDC cables. The temperature rise at the seabed surface due to the subsea HVDC cables is indistinguishable from the ambient temperature.

## Monitoring and Review

It is recommended that post-construction and commissioning EMF and EMI tests be conducted near key locations within the project area to verify the calculations presented in this impact assessment and those that will be carried out during the detailed design stage.

# 9. References


[1] J. Sherwood, S. Chidgey, P. Crockett, D. Gwyther, P. Ho, S. Stewart, D. Strong, B. Whitely and A. Williams, "Installation and operational effects of a HVDC submarine cable in a continental shelf setting: Bass Strait, Australia," *Journal of Ocean Engineering and Science,* vol. 1, pp. 337-353, 2016.

[2] "Geophysical Acquisition & Processing Section 2020. Magnetic Anomaly Map of Australia, Seventh Edition, 2020 - Enhanced Products Package - pseudogravity grid. Geoscience Australia, Canberra," [Online]. Available: http://pid.geoscience.gov.au/dataset/ga/144748.

[3] W. H. Organization, "Static fields," *Environmental Health Criteria 232,* vol. Geneva: WHO, 2006.

[4] I. C. o. N.-I. R. Protection, "Medical magnetic resonance (MR) procedures: protection of patients," *Health Phys,* vol. 87, pp. 197-216, 2004.

[5] B. Algers and J. Hultgren, "Effects of Long Term Exposure to a 400 kV, 50 Hz Transmission Line on Oestrous, Fertility and Diurnal Rhythm in Cows," Swedish University of Agricultural Sciences, Department of Animal Hygiene, Skara, Sweden, 196.

[6] H. E. Amstutz and D. B. Miller, *A Study of Farm Animals near 765 kV Transmission Lines,* North Liberty, Indiana: Indiana and Michigan Electric Company and Electric Power Service, 1980.

[7] B. J.F., D. H. Nguyen, L. Richard and E. Block, "Biological effects of electric and magnetic fields on productivity of dairy cows," *J Dairy Sci,* no. 79, pp. 1549-1554, 1996.

[8] B. J. F., D. H. Nguyen and E. Block, "Progesterone concentrations during oestrous cycle of dairy cows exposed to electric and magnetic fields," *Bioelectromagnetics,* no. 19, pp. 438-443, 1998.

[9] K. Busby, D. Driscoll and W. E. Washbon, "A Field Survey of Farmer Experience with 765 kV Transmission Lines," Agricultural Resources Commission State Campus, Albany, New York, 1974.

[10] K. Hennichs, "Cows exposed to 400 kV lines. Inventory and Fertility Study," Swedish University of Agricultural Sciences, Department of Animal Hygiene with Farrier's School, Skara, Sweden, 1982.

[11] J. M. Lee, F. Stormshak, J. M. Thompson, P. Thinesen, L. J. Painter, E. G. Olenchek, D. L. Hess, R. Forbes and D. L. Foster, "Melatonin secretion and puberty in female lambs exposed to environmental electric and magnetic fields," *Biol Reprod,* no. 49, pp. 857-864, 1993.

[12] J. M. Lee, F. Stormshak, J. M. Thompson, D. L. Hess and D. L. Foster, "Melatonin and puberty in female lambs exposed to EMF: A replicate study," *Bioelectromagnetics,* no. 16, pp. 119-123, 1995.

[13] A. A. Mahmoud and D. R. Zimmerman, “High voltage transmission and environmental effects,” *Right of Way,* pp. 15-19, December 1983.

[14] “Cortisol secretion and growth in ewe lambs chronically exposed to electric and magnetic fields of a 60 Hertz 500 kilovolt AC transmission line,” *J Anim Sci,* no. 73, pp. 3274-3280, 1995.

[15] B. J. Ware, “Effects of 765 kV Transmission Lines on Animal Grazing Habits,” American Electric Power Service Corp, New York, 1974.

[16] J. H. Williams and E. J. Beiler, “An Investigation of Dairy Farm Operations in Association with 765 kV Transmission in Ohio,” Ohio Power Sitting Commission and Cleveland Electric Illuminating Company, Cleveland, Ohio, 1979.

[17] R. F. Angell, M. R. Schott, R. J. Raleigh and T. D. Bracken, “Effects of high-voltage direct-current transmission line on beef cattle production,” *Bioelectromagnetics,* no. 11, pp. 273-282, 1990.

[18] D. Ganskopp, R. J. Raleigh, M. R. Schott and T. D. Bracken, “Behaviour of cattle in pens exposed to 500 kV DC transmission lines,” *Applied Anim Behav Sci,* no. 30, pp. 1-16, 1991.

[19] F. B. Martin, A. Bender, G. Steuernagel, R. A. Robinson, R. Revsbech, D. Sorensen, N. Williamson and A. Williams, “Epidemiologic study of Holstein dairy cow performance and reproduction near a high voltage direct current powerline.,” *J Toxicol Environ Health,* no. 19, pp. 325-336, 1986.

[20] R. J. Raleigh, “Joint HVDC Agricultural Study : Final Report,” Oregon State University, Portland, Oregon, 1988.

[21] F. Renaud and G. Daniel, “Effects of Electric and Magnetic Fields on Livestock Health and Productivity,” Hydro Quebec, Quebec, Canada, 1999.

[22] T. Steffen, R. Luechinger and S. Wildermuth, “Safety and reliability of radio frequency identification devices in magnetic resonance imaging and computed tomography,” *Patient Saf Surg,* vol. 4, p. 2, 2010.

[23] T. E. Ferrari, “Magnets, magnetic field fluctuations and geomagnetic disturbances impair the homing ability of honey bees (Apis mellifera),” *Journal of Apicultural Research,* vol. 53:4, pp. 452-465, 2014.

[24] S. H. Gibbs, “Inquiry into community needs and high voltage transmission line development. Report to the New South Wales Minister for Minerals and Energy.,” Department on Minerals and Energy, Sydney, NSW, 1991.

[25] B. Greenberg, V. P. Bindokas and J. R. Gauger, “Biological effects of a 765-kV transmission line exposures and thresholds in honeybee colonies,” *Bioelectromagnetics,* 1981.

[26] E. Wajnberg, D. Acosta-Avalos, O. Cambraia Alves, . J. Ferreira de Oliveira, R. B. Srygley and D. M. S. Esquivel, “Magnetoreception in eusocial insects: an update,” *Journal of the Royal Society Interface,* vol. 7, pp. S207-S225, 2010.

[27] S. Shepherd, M. Lima and E. Oliveira et al., “Extremely Low Frequency Electromagnetic Fields impair the Cognitive and Motor Abilities of Honey Bees,” *Sci Rep,* vol. 8, p. 7932, 2018.

[28] . S. Shepherd, G. Hollands, V. Godley, S. Sharkh and C. Jackson et al., “Increased aggression and reduced aversive learning in honey bees exposed to extremely low frequency electromagnetic fields,” *PLOS ONE,* vol. 14(10), no. e0223614, 2019.

[29] K. Schmiedchen, A.-K. Petri, S. Driessen and W. H. Bailey, “Systematic review of biological effects of exposure to static electric fields. Part II: Invertebrates and plants,” *Environmental Research,* vol. 160, pp. 60-76, 2018.

[30] D. Quass, “Pulsed electric field processing in the food industry. A status report on pulsed electric field.,” Electric Power Research Institute, Palo Alto, CA, 1997.

[31] M. E. Maffei, “Magnetic field effects on plant growth, development, and evolution,” *Frontiers in Plant Science ,* vol. 5, p. 445, 2014.

[32] J. M. Silva and R. G. Olsen, “Use of global positioning system (GPS) receivers under power-line conductors.,” *IEEE transactions on power delivery,* vol. 17, no. 4, pp. 938-944, 2002.

[33] Manitoba Hydro, “Fur, Feathers, Fins & Transmission Lines,” Manitoba Hydro, Manitoba, Canada, 2010.

[34] W. H. Bailey, D. E. Weil and J. R. Stewart, “HVDC power transmission environmental issues review,” Oak Ridge National Lab. (ORNL), Oak Ridge, TN (United States), United States, 1997.

[35] K. J. Lohmann, C. M. F. Lohmann and C. S. Endres, “The sensory ecology of ocean navigation,” *J Exp Biol ,* vol. 11, no. 211, pp. 1719-1728, 2008.

[36] G. W. Boehlert and A. B. Gill, “Environmental and ecological effects of ocean renewable energy development: A current synthesis,” *Oceanography,* vol. 23, no. 2, pp. 68-81, 2010.

[37] T. Worzyk, Submarine Power Cables, Karlskrona, Sweden: Springer Dordrecht Heidelberg London New York, 2009.

[38] H. Peach, W. J. Bonwick and T. Wyse, “Report of the panel on electromagnetic fields and health,” The Victorian Government, Melbourne, Australia, 1992.

[39] Z. Hutchison, A. Gill and P. Sigray, “Anthropogenic electromagnetic fields (EMF) influence the behaviour of bottom-dwelling marine species,” *Sci Rep,* no. 10, p. 4219, 2020.

[40] W. Irwin and K. Lohmann, “Disruption of magnetic orientation in hatchling loggerhead sea turtles by pulsed magnetic fields.,” *J Comp Physiol A Neuroethol Sens Neural Behav Physiol.,* vol. 191, no. 5, pp. 475-80, 2005.

[41] W. Irwin and K. Lohmann, “Magnet-induced disorientation in hatchling loggerhead sea turtles,” *The Journal of Experimental Biology,* vol. 206, no. 3, pp. 497-501, 2003.

[42] H. Westerberg and M. L. Begout-Anras, “Orientation of silver eel (Anguilla anguilla) in a,” *Advances in Fish Telemetry. Proceedings of the Third Conference on Fish Telemetry (Eds. A. Moore and I. Russel),* pp. 149-158, 2000.

[43] S. W. N. W. R. e. a. Greenleaf, “Bee foraging ranges and their relationship to body size.,” *Oecologia,* vol. 153, pp. 589-596, 2007.