Environment Effects Statement

Western Renewables Link

TECHNICAL REPORT

L EMI and EMF Impact Assessment

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Western Renewables Link
EES Technical Report L

EMI and EMF Impact Assessment

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Contents

Figures

Tables

Glossary

a.c.	Alternating Current
ACMA	Australian Communications and Media Authority
AM	Radio broadcasting using Amplitude Modulation transmission
AIMD	Active Implantable Medical Device
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
AS	Australian Standard
AS/NZS	Australian/New Zealand Standard
AusNet	AusNet Transmission Group Pty Ltd
Basic Restrictions	EMF exposure thresholds that must be complied with
CDEGS	Current Distribution, Electromagnetic Fields, Grounding and Soil Structure Analysis Software
CFA	Country Fire Authority
CIGRE	International Council on Large Electric Systems
CT	Computed Tomography
DAB	Digital Audio Broadcasting
dB	Decibels – a logarithmic unit used to measure sound level
DEECA	Department of Energy, Environment and Climate Action
DELWP	The former Department of Environment, Land, Water and Planning
DGPS	Differential Global Positioning System
DTP	Department of Transport and Planning
DTV	Digital Television
Environment Effects Act	*Environment Effects Act 1978*
EES	Environment Effects Statement
ELF	Extremely Low Frequency – frequency range between 0 – 3000Hz within the electromagnetic spectrum
EMC	Electromagnetic Compatibility
EMF	Electric and Magnetic Fields
EMI	Electromagnetic Interference
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EPR	Environmental Performance Requirements
ESI	Australian Electricity Supply Industry
FFG Act	*Flora and Fauna Guarantee Act 1988 / Flora and Fauna Guarantee Amendment Act 2019*
FM	Radio broadcasting using Frequency Modulation transmission
GHz	Gigahertz
GPS	Global Positioning System

HF	High Frequency
HV	High Voltage
Hz	Hertz – measurement of frequency
IARC	International Agency for Research on Cancer
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEEE	Institute of Electrical and Electronics Engineers
ITU	International Telecommunication Union
kV	kilovolt
LiDAR	Light Detection and Ranging
MHz	Megahertz
MREH	Melton Renewable Energy Hub
MTI	Medical Treatment Injury
NHMRC	National Health and Medical Research Council
p.u.	Per unit – ratio of actual value to a reference value
Principal Contractor	During the construction stage, there will be multiple principal contractors and sub-contractors involved in the delivery of the different project components. This EES refers to Principal Contractor as a catch all term for the contractor responsible for the works.
Project Area	The Project Area encompasses all areas that would be used to support the construction and operational components of the Project considered in the EES. The Project Area is contained within the Project Land and encompasses the following: ▪ Permanent infrastructure: - Transmission tower structures - Upgrade and connection to the Bulgana Terminal Station - Connection to the Sydenham Terminal Station - An upgrade of Elaine Terminal Station - The new 500kV terminal station near Bulgana - Access tracks required for operation - The Proposed Route. ▪ Temporary construction areas and infrastructure including: - Distribution line crossovers - Hurdles - Laydown areas - Stringing pads - Access tracks - Tower assembly areas - Workforce accommodation facilities.

Project Land	The Project Land encompasses all land parcels that could be used for the purpose of temporary Project construction and permanent operational components. The Project Land corresponds with the extent of the Specific Controls Overlay proposed in the draft Planning Scheme Amendment for the Project. This generally includes the entire land parcel intersected by a Project component.
Proposed Route	The Proposed Route is approximately 100 to 170m wide and encompasses the nominal future easement for the proposed new transmission line (including a buffer either side), and the terminal station areas. The Proposed Route is located within the Project Area.
Reference Levels	Conservative, measurable EMF levels that ensure compliance with the basic restrictions for generic EMF exposure scenarios
RI	Radio Interference
RHC	Radiation Health Committee
RIV	Radio Interference Voltage
RMS	Root Mean Square
SES	Victoria State Emergency Service
SYTS	Sydenham Terminal Station
T	Tesla - measurement of magnetic flux density
UHF	Ultra-High Frequency – radio waves between 300MHz and 3,000MHz
UHF CB	Ultra-High Frequency Citizen Band Radio
VHF CB	Very-High Frequency Citizen Band Radio
WBTS	Waubra Terminal Station
WiFi	Wireless Fidelity
220kV	220kV transmission line
500kV	500kV transmission line

Executive summary

The Western Renewables Link (the Project) proposes a new transmission line starting at Bulgana, near Stawell in Victoria's west, and extending approximately 190km to Sydenham in Melbourne's north-west. The Project will enable the connection of new renewable energy generated in western Victoria into the National Electricity Market and increase the Victorian transmission capacity. The Project is being delivered by AusNet Transmission Group Pty Ltd (AusNet).

This Electromagnetic Interference (EMI) and Electric and Magnetic Fields (EMF) Impact Assessment forms part of the Environment Effects Statement (EES) prepared for the Project in accordance with the *Environment Effects Act 1978*. This report and the methodology applied in preparing this report, responds to the requirements set out in the EES scoping requirements, with a view to assessing potential issues related to EMI and EMF that are associated with the Project.

EMF are invisible, physical fields that surround electrical charges. The moving electrical charges in electrical and electronic equipment found in homes and offices, as well as those in transmission line conductors and associated electrical power infrastructure, generate EMF in the local environment. This EMF may impact the proper functioning of some electrical and electronic equipment.

High electric fields near the surface of the transmission line conductors and associated equipment, devices, and hardware may ionise the air immediately surrounding the conductors, resulting in corona discharges. These discharges generate radio frequency fields that may cause some degree of interference to the reception of radio, television and mobile communication signals in the vicinity of the transmission lines and terminal stations. Transmission line towers and conductors can also impact radio communications by blocking and scattering the electromagnetic fields in the vicinity of a transmission line. These communication interference effects are collectively referred to as EMI.

Overview

This report assesses the potential impact on people and equipment within the study area that may be sensitive to EMI and EMF from transmission lines, terminal stations and associated electrical infrastructure.

The study area for the EMI and EMF Impact Assessment is defined as the Project Area (i.e., the transmission line route, existing terminal stations at Sydenham, Bulgana and Elaine, and a new 500kV terminal station near Bulgana), plus an additional 5km buffer around the Project Area. A buffer of 5km has been used because EMI associated with tall metallic transmission line structures such as signal blocking and scattering effects do not typically affect radio communication reception at distances greater than 5km from the structures.

Existing conditions

Existing EMI and EMF sources are identified within the Project Area. Receptors that may be sensitive to EMI and EMF from transmission lines and associated electrical infrastructure are also identified within the study area. The calculated and measured EMI and EMF levels associated with the existing sources are compared to appropriate limits and reference levels at the sensitive receptor locations.

Impact assessment

The impact assessment has considered the adoption of the following standard design controls to reduce exposure to EMF and reduce electromagnetic field interference effects:

- Diagonal phasing has been adopted for the transmission lines, which maximises magnetic field cancellation and thereby minimises public exposure to magnetic fields at ground level.
- Minimum design heights above ground have been increased above the minimum statutory requirement to maintain EMF levels within acceptable limits directly under the line.
- Maximising separation from sensitive receptors through route selection and terminal station site selection.

The effects of EMI and EMF of the proposed new transmission lines and terminal stations on sensitive receptors were assessed within the study area for the construction, operation and decommissioning of the Project with the standard design controls implemented. The impacts were found to be primarily related to the operation of the Project. The key findings of this impact assessment are:

- Key strategies for the identified EMI and EMF effects primarily entail application of design controls that are prescribed in the AusNet design standards, along with standard AusNet construction and maintenance control measures. In recognising that impacts are largely eliminated through the Project's design controls, operational impacts described and assessed in this report are therefore the post-design control impacts.
- The impact of the EMF from the Project infrastructure on human health will not be significant and additional mitigation is not required.
- The EMF from the Project infrastructure will not have a significant impact on agriculture and additional mitigation is not required.
- The EMF from the Project infrastructure will have a negligible impact on sensitive receptors and additional mitigation is not required.
- The EMI from the Project infrastructure may have a minor impact on AM radio, FM radio and emergency services radio reception during rain conditions. There are no practicable mitigation measures that will reduce this impact to negligible and mitigation is not considered necessary.
- The EMI from the Project infrastructure will have a negligible impact on TV and mobile phone reception and mitigation measures are not required.
- The EMI from the Project infrastructure may have a moderate impact on some point-to-point communication links in the study area. Mitigation measures may be required and will entail a detailed investigation of potential point-to-point communication link performance issues prior to the operation of the transmission line and either an increase in antenna height, increase in transmit power level or relocation of the antenna. The selected mitigation measure will reduce the impact rating to negligible.
- There is a minor impact of EMI on DGPS correction signals for land navigation directly under the proposed 500kV transmission line in heavy rain conditions. The momentary interruption of DGPS correction signals as mobile agricultural equipment passes under the line will not impact autonomous operations as the existing correction will be utilised under the line and updated once the equipment clears the area under the line. Mitigation is therefore not required.

Impacts of the Project on EMI and EMF have been assessed and mitigation measures have been identified in response to the EES evaluation objective to minimise/avoid adverse effects on community health and safety. The impact assessment concluded that it will not be necessary to contain electromagnetic radiation emissions from the Project or to shield or buffer nearby sensitive receptors from such emissions as the expected EMI and EMF from the Project are below levels that would require further mitigation.

Environmental Performance Requirements

One EMI and EMF EPR and one general EPR are recommended to meet the EES evaluation objective relevant to EMI and EMF, namely:

EL1: Undertake an Electric and Magnetic Field and Electromagnetic Interference Assessment

1. Design and construct the Project to reduce electric and magnetic fields (EMF) and electromagnetic interference (EMI) from the Project infrastructure to below the reference levels and limits for the Project, or as low as reasonably practicable to avoid and minimise impacts.
2. The applicable reference levels and limits are defined in EES Technical Report L: EMI and EMF Impact Assessment. The design must be informed by a Project wide EMI and EMF verification assessment for all the proposed infrastructure at the detailed design stage, identifying existing sensitive receptors and committed future developments within the study area.

3. Prior to the commencement of the relevant construction works, the assessment must be documented in a management plan for implementation and includes, but is not limited to:
   a. Outcomes of the Project wide EMI and EMF verification assessment at the detailed design stage and details of the areas assessed
   b. The location of all sensitive receptors that may be impacted by the infrastructure
   c. Where at-receiver mitigation measures to sensitive receptors are required to avoid or minimise adverse impacts
   d. If mitigation measures are identified as per Item 3(c) (e.g., point-to-point communication links), identify what the mitigation works are, and timeline for implementation.
   e. A pre- and post-construction testing strategy to verify design calculations, impacts on sensitive equipment and the efficacy of any specified mitigation measures
   f. Remedial action to be investigated if EMI and EMF limits are not met during the construction, testing, and commissioning.

EM7: Develop and implement a Complaints Management System

1. Prior to commencement of construction, develop and implement a process for recording, managing, and resolving complaints received from affected stakeholders as part of the Communications and Stakeholder Engagement Management Plan (EPR EM5). The complaints management arrangements must be consistent with Australian Standard AS/NZS 10002: 2014 Guidelines for Complaints Management in Organisations and the Essential Services Commission Land Access Code of Practice.

Residual impacts

Residual impacts are defined in the assessment as those construction and operational impacts that remain after the identified mitigation measures that are specified in the EPRs have been implemented.

There were no significant residual impacts identified in the assessment of EMF impacts and mitigation measures were not required.

Only minor and negligible residual impacts were identified in the assessment of EMI impacts. minor residual impacts were identified to AM radio reception, FM radio reception, emergency services radio reception and DGPS correction signals for land navigation near the proposed 500kV transmission line in heavy rain conditions. There will be alternative radio channels available that will not be significantly impacted by the EMI. The momentary interruption of DGPS correction signals as mobile agricultural equipment passes under the transmission line will not impact autonomous operations as the existing correction will be utilised under the transmission line and updated once the equipment clears the area under the line. Other residual EMI impacts to TV reception, point-to-point communications and mobile communications were negligible.

The only mitigation option that will reduce the identified minor residual impacts to negligible is the use of a much larger, heavier phase conductor bundle along the proposed 500kV transmission line. This will require much larger, taller towers and will also increase the EMF levels in the vicinity of the proposed 500kV transmission line. It was therefore concluded that it was not practicable to reduce the minor EMI residual impacts any further and as such, additional mitigation or controls are not deemed necessary, nor recommended.

1. Introduction

1.1 Background

The Western Renewables Link Project (the Project) proposes a new transmission line starting at Bulgana, near Stawell in Victoria's west, and extending approximately 190km to Sydenham in Melbourne's north-west. The Project will enable the connection of new renewable energy generated in western Victoria into the National Electricity Market and increase the Victorian transmission capacity. The Project is being delivered by AusNet Transmission Group Pty Ltd (AusNet).

The Project was originally referred to the former Minister for Planning under the *Environment Effects Act 1978* (Environment Effects Act) on 9 June 2020 by AusNet and it was determined that an Environment Effects Statement (EES) was required. On 22 August 2023, the Minister for Planning determined that the Project has the potential to cause significant environmental effects and that an EES was required to inform decision-makers in the granting of key approvals for the Project. In summary the key changes in the new proposed Project scope are:

- The urgent Sydenham Terminal Station Rebuild will be assessed and approved separately. A connection into the Sydenham Terminal Station forms part of Western Renewables Link scope
- The 220kV portion of the transmission line is proposed to be uprated to 500kV
- The new terminal station north of Ballarat will no longer be required
- A new 500kV terminal station near Bulgana will be required, including a new 220kV connection to the existing Bulgana Terminal Station.

The Commonwealth Government's Department of Agriculture, Water and the Environment (DAWE) — now Department of Climate Change, Energy, the Environment and Water (DCCEEW) — has also confirmed that the Project is a 'controlled action' and will require assessment and approval under the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* (EPBC Act). The Commonwealth has determined that it will use the bilateral assessment agreement and rely on the Victorian Government's assessment process (EES) to inform an approval decision under the EPBC Act.

1.2 Purpose of this report

The purpose of this report is to assess the potential electric and magnetic fields (EMF) and electromagnetic interference (EMI) impacts associated with the Project and to define any Environmental Performance Requirements (EPRs) necessary to determine the environmental outcomes that the Project must meet, to be achieved through the implementation of mitigation measures during construction, operation and decommissioning, and address the EES evaluation objectives.

Extremely low frequency (ELF) EMF induce internal currents and electric fields in the body, which may cause biological effects in people if the internal electric fields exceed certain limits. ELF EMF may also impact the proper functioning of electrical and electronic equipment that is sensitive to such fields.

Large electric fields near the surface of the transmission line conductors cause ionisation of the air near the surfaces of the conductors which generates high frequency electromagnetic fields. These electromagnetic fields can interfere with the reception of radio, television[1] and mobile communication signals near the lines. The metallic transmission line conductors and towers can also cause scattering of the communication signals. The radiated fields and the field scattering effects are collectively referred to as EMI.

The specific objectives of the impact assessment are to assesses the impact on people and equipment within the study area that may be sensitive to EMI and EMF from Project transmission lines, terminal stations and associated electrical infrastructure.

[1] All references to television include satellite television

1.3 Structure of the report

The report is structured in the following way:

- **Introduction** (this section) which provides background details for the Project and outlines the purpose and structure of the EMI and EMF Impact Assessment.
- **Technical background** (Section 2) which provides some background technical information on EMI and EMF.
- **EES scoping requirements** (Section 3) where the EES scoping requirements relevant to EMI and EMF are set out, and an indication of where each component of the EES scoping requirements has been considered and addressed in the EMI and EMF Impact Assessment.
- **Project description** (Section 4), where Project components and activities relevant to the assessment are explained including the locations and activities with the highest associated EMI and EMF impacts.
- **Legislation, policy and guidelines** (Section 5) which lists the Commonwealth, state and other documents relevant to the assessment.
- **Method** (Section 6) where the approach applied to assess potential EMI and EMF impacts associated with the Project is explained.
- **Existing conditions** (Section 0) which identifies background EMI and EMF conditions across the study area.
- **Impact assessment** (Section 8 to Section 11), where initial and residual EMI and EMF impacts during the construction, operation and decommissioning of the Project, including potential cumulative impacts from other nearby developments and projects are evaluated. Measures to mitigate or otherwise effectively manage the potential impacts are also presented here.
- **Environmental Performance Requirements** (Section 12) which set out the environmental outcomes to be achieved through the implementation of mitigation measures during construction, operation and decommissioning. While some EPRs are performance based to allow flexibility in how they will be achieved, others include more prescriptive measures that must be implemented. Compliance with the EPRs will be required as a condition of the Project’s approval.
- **Conclusion** (Section 13) where the objectives, methods, outcomes and recommendations of the assessment are presented.

1.4 Related studies

This report should be read in conjunction with the following related technical reports, from which this report draws specific information:

- **Technical Report H: Agriculture and Forestry Impact Assessment** provides an understanding of the existing agriculture and forestry values in the study area which was used to inform the assessment of agricultural impacts from EMF from the Project infrastructure
- **Technical Report J: Aviation Impact Assessment** describes the nature of aviation operations relevant to the Project and potential impacts to existing aerodromes, helipads and other aviation activity.

Where these technical reports identified similar key issues that require consideration, reference has been made to the study in this report.

2. Technical background

2.1 EMF

EMF are invisible, physical fields that surround moving electric charge and exert forces on nearby objects. The electric charges in transmission line conductors and associated electrical power infrastructure generate the electric fields and the moving charges generate the magnetic fields. The voltages that are applied to the transmission line conductors define the magnitude and distribution of the electric fields in the air gaps between the conductors and the ground. The electrical currents that flow in the transmission line conductors define the magnitude and distribution of the magnetic fields near the line.

Both the voltages and currents associated with the transmission lines and terminal stations considered in this report oscillate between minimum and maximum values at an *"extremely low frequency"* of 50 cycles per second (i.e., 50Hz). The Root Mean Square (RMS) of the oscillating voltage and current waves on the transmission line conductors is used as a measure of how much electrical power is transferred along the transmission line. The RMS voltage applied to a transmission line's conductors, and thereby the RMS electric field under a transmission line, is kept relatively constant by the operator and varies only over a small range, daily or seasonally. The RMS current in a transmission line's conductors, and thereby the RMS magnetic field surrounding a line's conductors, generally varies more widely due to daily and seasonal changes in electrical power demand on the network.

The ELF EMF under a transmission line at ground level are termed "near fields" that are tightly coupled to the conductors and are not radiated "far fields". These electromagnetic fields do not have enough energy to ionize atoms or molecules (i.e., completely remove a charge from an atom or molecule).

Typical measured EMF levels that have been reported by various sources in generic environments are summarised in Table 2.1.

Table 2.1: Typical EMF levels for different types of sources

Source		Typical Range of Magnetic Fields (μT)[2]	Typical Range of Electric Fields (kV/m)[3]
Around the home and office	General areas in the home or office	0.05 to 0.15	0.003 to 0.02
	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
	Television	0.02 to 0.2	Not reported
	Electric heater blanket	0.5 to 3	0.058 to 0.6
	Hair dryer	1 to 7	0.3 to 0.8
Public streets and neighbourhoods	Street-side power lines (directly under the line)	0.2 to 3	0.01 to 0.06
	Street-side power lines (10m from the line)	0.05 to 1	Not reported
	High voltage transmission line (directly under the line)	1 to 20	0.003 to 94
	High voltage transmission line (10m from the line)	0.2 to 5	4.5

Magnetic fields are quantified in terms of the magnetic flux density, which is the total magnetic field that passes through a defined surface area. Magnetic flux density is measured in tesla (T) and commonly stated in units of microtesla (μT), which is one millionth of a tesla.

[2] The typical magnetic field strengths are sourced from ARPANSA: https://www.arpansa.gov.au/understanding-radiation/radiation-sources/more-radiation-sources/measuring-magnetic-fields
[3] The typical electric field strengths are sourced from Transpower New Zealand Ltd, EMF Fact Sheet 3: https://www.transpower.co.nz/resources/factsheet-3-electric-and-magnetic-field-strengths
[4] This range is for a wide range of transmission line voltages, from 110kV through to 500kV.

Electric fields are quantified in terms of the electric field strength, which is measured in units of volts per metre (V/m) and is normally stated in units of kilovolts per metre (kV/m) under a transmission line, which is one thousand volts per metre.

EMF are strongest closest to their source (i.e., the transmission line conductors) and their strengths decrease rapidly with distance from the source. Electric fields are shielded by most common materials, such as brickwork, trees and human skin. Unlike electric fields, magnetic fields are not shielded by most common materials and pass through them mostly unattenuated.

2.1.1 EMF and health

Short-term effects

ELF EMF induce internal electric fields and currents in the body. The World Health Organisation states that at high field levels (well above 100 µT) they can cause “nerve and muscle stimulation and changes in nerve cell excitability in the central nervous system” (World Health Organization 2007). 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.

Exposure guidelines have been defined to protect against these biological effects (Energy Networks Association 2021).

Potential Long-Term Effects

Extensive scientific research examining health risks associated with exposure to ELF EMF have been undertaken since the 1970’s. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) has advised that: “Most of the research indicates that the ELF EMF exposure normally encountered in the environment, including in the vicinity of the powerlines, does not pose a risk to human health” (ARPANSA 2021). In this context, ‘in the vicinity of powerlines’ relates to in the vicinity of publicly accessible areas surrounding 500kV transmission lines and terminal stations. ARPANSA states that: “Background magnetic fields in the home are typically in the order of 0.1 µT” (ARPANSA 2021).

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

There are some epidemiological (population) studies that have reported a statistical association between increased rates of childhood leukaemia and prolonged exposure to ELF magnetic fields at levels below the exposure limits but higher than what is typically encountered in a home environment. 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 research findings, the International Agency for Research on Cancer (IARC) published a monograph that prudently classified ELF magnetic fields as "possibly carcinogenic to humans"[5] – Group 2B[6] and ELF electric fields as "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 is little scientific evidence supporting an association between ELF magnetic field exposure and other adverse health effects (World Health Organization 2007).

2.1.2 Exposure limit guidelines for EMF

The World Health Organization recognises two international guidelines for ELF EMF exposure:

- The Guidelines for Limiting Exposure to Time-varying Electric and Magnetic Fields (1Hz to 100kHz) produced by the International Commission on Non-Ionising Radiation Protection (ICNIRP, 2010)
- IEEE Standard C95.1- Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0Hz to 300GHz produced by the Institute of Electrical and Electronics Engineers (IEEE, 2019)

These guidelines apply to the general public in all areas (i.e., not just under or adjacent to the transmission line and terminal stations) 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 ELF 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 50/60Hz 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 would withdraw the existing NHMRC RHS30 guidance on ELF EMF exposure and recognised that the International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1Hz to100kHz) are consistent with ARPANSA's and the RHC's understanding of the scientific basis for the protection of people from exposure to ELF EMF[7].

The ICNIRP guidelines define general public exposure as exposure of individuals of all ages and of varying health status to EMF and specify basic restrictions, which are limits, and reference levels, which are practical parameters that may be used for determining compliance with the limits, but which are not limits themselves.

The basic restrictions for ELF EMF are exposure limits for internal electric fields in different body tissues. Relating these internal field levels within body tissues to measurable external field levels 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 being assessed for exposure.

It is noted that a conservative reduction factor is used for 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

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

[6] IARC publishes independent assessments 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

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

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 EMF exposure scenarios. The ICNIRP reference levels for general public exposure to 50Hz EMF are summarised in Table 2.2.

Table 2.2: ICNIRP 50Hz EMF reference levels for general public exposure

Exposure Category	Electric Field Strength (kV/m)	Magnetic Flux Density (μT)
General public exposure	5	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 1m 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. Whenever a reference level is exceeded, however, it is necessary to test compliance with the relevant basic restriction and to determine whether additional protective measures are necessary (ICNIRP, 2010).

ARPANSA conducted a series of EMF measurements in Victoria for various types of electrical supply infrastructure to gain an understanding of the typical levels experienced by the general public. Based on these EMF measurements, ARPANSA made the following conclusions (Urban et al., 2014):

> *Measurements of ELF magnetic fields around electricity supply infrastructure were well below (generally less than 1%) the exposure limit of 100 μT. Residential properties (at the boundary) and other public places in close proximity generally had magnetic fields higher than normal however these areas are not considered to represent "prolonged residential exposure". Inside homes in Melbourne, a recent survey conducted by ARPANSA found that only about 2% are likely to have higher than normal magnetic fields. The electric fields at nearby residences and other places of interest were also well below the 5000 V/m limit. The higher electric fields measured at the boundary of residential properties near transmission lines compared to other types of infrastructure are due to the higher voltage.*

The ARPANSA conclusion was made in 2014 with reference to the NHMRC 1989 EMF exposure guidelines, which defined a 100μT magnetic flux density reference level. The ICNIRP 2010 EMF exposure guidelines, which ARPANSA now references, has revised the reference level to 200μT.

2.1.2.1 AusNet's approach to the management of EMF

It is AusNet's policy to comply with the ICNIRP reference levels (as summarised in Table 2.2) where practicable. However, transmission lines operating at 500kV can exceed the electric field reference level in some locations. It is necessary in such cases to assess the electric field exposure against the basic restrictions.

AusNet have commissioned EMF Scientific Limited to define a measurable electric field limit that will achieve compliance with the ICNIRP basic restrictions. This analysis considered three dosimetry[8] studies that were conducted by Dimbylow (1998, 2005) and Findlay (2014). These studies were conducted with anatomically realistic human bodies to determine the induced electric field in the brain, retina and the skin.

The recommended measurable electric field limit derived from dosimetry, taking account of variability between models, is 9kV/m (Appendix H). However, it is further noted by the author that the recommended electric field

[8] Dosimetry is the calculation of internal electric field strength using anatomically realistic body models.

limit does not include an allowance for "dosimetric uncertainty" but that this uncertainty associated with the dosimetric computations has been comprehensively assessed by Magne and Deschamps (Magne and Deschamps, 2016) for occupational exposure situations (Appendix H). As noted in Appendix H:

> *While this cannot be regarded as a definitive assessment, it is the only detailed published result available, and takes account of the multiple different aspects of dosimetric uncertainty in an explicit formulation, as opposed to providing a single overall reduction factor as ICNIRP do*[9].

Allowing for dosimetric uncertainty using the Magne and Deschamps (Magne and Deschamps, 2016) assessment would indicate a range of possible exposure limits between 7kV/m and 9kV/m (Appendix H). Based on this, the Project has adopted a 7kV/m electric field limit for the new 500kV transmission line that shall not be exceeded in all cases. The EMF limits adopted for the Project are summarised in Table 2.3.

Table 2.3: 50Hz EMF limits for general public exposure adopted by AusNet for the Project's 500kV infrastructure

Exposure Category	Electric Field Strength (kV/m)	Magnetic Flux Density (μT)
General public exposure	7	200

The Australian Energy Networks Association (ENA) has produced an EMF management handbook to provide information and guidance to the Australian electricity distribution and transmission industry to address queries in relation to EMF. The ENA recommends demonstrating compliance using the Reference Levels wherever practicable and to manage exposure by engineering or administrative controls and using a higher exposure limit derived from dosimetry when compliance with Reference Levels cannot be demonstrated (Energy Networks Association, 2021). AusNet's approach is in line with the ENA's recommendations and the wider Australian power industry's approach.

The AusNet design limit of 7kV/m, which is based on ICNIRP basic restriction calculations, is adopted for assessing the impacts of the Project's new 500kV transmission line. The ICNIRP reference level of 5kV/m is adopted for assessing the impacts of all other Project infrastructure, given that the AusNet design limit was only derived for a 500kV transmission line.

2.1.3 Prudent avoidance/precautionary principles

Given that adverse health effects from long-term exposure to EMF have not been established but also cannot be ruled out, Sir Harry Gibbs, the former Chief Justice of the High Court of Australia, and Professor Hedley Peach, University of Melbourne, recommended a policy of prudent avoidance (Gibbs, 1991); (Peach et al. 1992) in their reviews of the potential health effects.

Prudent avoidance is a precautionary approach to managing the potential risk which involves doing whatever can be done without undue inconvenience and at modest expense to avert the possible risk. As an example, diagonal phasing, also known as reverse phasing, has been adopted for the double circuit transmission lines as this maximises magnetic field cancellation and thereby minimises public exposure to magnetic fields at ground level.

The World Health Organization endorsed the adoption of precautionary approaches, such as prudent avoidance, but cautioned that "it is not recommended that the limit values in exposure guidelines be reduced to some arbitrary level in the name of precaution. Such practice undermines the scientific foundation on which the limits are based and is likely to be an expensive and not necessarily effective way of providing protection." (World Health Organization 2001).

Furthermore, the World Health Organization noted that electric power brings obvious health, social and economic benefits, and precautionary approaches should not compromise these benefits (World Health Organization 2001). Given that only limited epidemiological studies have suggested a statistical association between exposure to ELF magnetic fields and childhood leukaemia and that no credible theoretical mechanism

[9] Renew, D., An Electric Field Limit for the Western Renewables Link, 18 September 2022

has been proposed to support the possible association, the benefits of exposure reduction on health are unclear. Thus, the costs of precautionary measures should be very low.

The prudent avoidance approach adopted for the Project also addresses AusNet's general environmental duty (GED) under the *Environment Protection Act 2017,* in that, under the approach all practicable measures will be taken to reduce the risk of harm to human health and the environment associated with the operation of the transmission line.

2.1.4 Active implantable medical devices

Active implantable medical devices (AIMDs), such as cardiac pacemakers, may be sensitive to magnetic field exposure up to the public ICNIRP reference levels (Energy Networks Association 2021). Whilst there are many models and manufacturers of AIMDs, more recently manufactured devices are designed to be immune to EMF in accordance with various design standards (e.g., EN 45502, ISO 14117). The EN50527 series of European standards provides advice on assessing exposures for wearers of pacemakers, implantable cardioverter-defibrillators, and spinal cord stimulators. Only a very small proportion have been found to be sensitive to magnetic field levels up to the public ICNIRP reference levels (Energy Networks Association 2021). There have been no known instances of adverse effects on users with pacemakers near power lines (NZ Ministry of Health 2013).

As the susceptibility of medical implants to EMF interference can differ, there is a need for a case-by-case risk management approach in consultation with the wearer's treating physician for public exposure to ELF EMF up to the public ICNIRP reference levels.

2.1.5 EMF and livestock

Large ruminants[10]

Research into the possible health effects of ELF EMF exposure in animals has been reported in numerous peer reviewed publications. In 1974, K. Busby conducted a survey-based study of 18 farms located near a 765kV transmission line in Ohio for the Agricultural Resources Commission of New York. The study specifically considered the possible impact of the ELF EMF from the transmission line on dairy production and the behaviour of grazing herds. The farmers whose livestock grazed near the power line did not report any differences in behaviour. Additionally, no reduction in milk production, as compared to the three years prior to the commissioning of the 765kV line, was reported by any of the farmers (Busby et al. 1974).

During the period 1977 to 1979, two Americans, H.E. Amstutz and D.B. Miller, conducted a two-year clinical study of the health of beef cattle, dairy cows, sheep, pigs, and horses exposed to ELF EMF. They collated data from 11 livestock farms traversed by a 765kV transmission line in Indiana with electric field strength levels up to 12.5kV/m. The study concluded that the power line had no effect on the health, behaviour or productivity of the livestock (Amstutz et al. 1980).

In 1982, B. Algers and K. Hennichs, conducted a study on the fertility of dairy cows exposed to ELF electric fields from a 400kV transmission line in Sweden. The cows were exposed to electric field strength levels up to 5kV/m. The study was conducted in conjunction with 106 farmers and the research concluded that herds showed no reduction in fertility (Algers and Hennichs, 1985).

Comparable research into the effects of ELF EMF from 735kV transmission lines on cattle has been carried out more recently in Canada by the Hydro-Quebec Research Institute, McGill University, the Ministry of Agriculture, Fisheries and Food in Quebec and the Quebec Dairy Committee. The study has similarly concluded that electric fields up to 10kV/m and magnetic fields up to 30μT had no significant impact on the health, behaviour and productivity of cattle (Burchard et al. 1996).

[10] Ruminants are large hoofed herbivorous grazing or browsing mammals, examples include cattle and sheep.

Small ruminants

An investigation into the effects of ELF EMF exposure on the health of sheep was conducted by studying interleukin proteins in ewe lambs (Hefeneider et al., 2001). Interleukin proteins are involved in cell-to-cell communication related to both growth and immunity in the animals and are considered an indicator of general health in sheep. The ewes were exposed to magnetic fields of 3.5 to 3.8μT and electric fields of 5.2 to 5.8kV/m over a course of 27 months. The study showed that there was a significant reduction in interleukin protein (IL-1) in ewe lambs that were 8 to 10 weeks of age in the first study. However, there were no significant differences found between the treated group and the control group in the follow-up study (i.e., the observed effects were not statistically significant).

Another study conducted in 1995, focused on melatonin levels and puberty in female lambs. A group of lambs were exposed to EMF under 500kV transmission lines with nominal magnetic fields levels of 3.77μT and nominal electric field levels of 6.3kV/m. No significant differences were found in either circulating melatonin levels or the age of puberty between the treated group and the respective control group (Lee et al., 1995).

Collectively, these studies, along with other similar studies conducted over the past 50 years, indicate that EMF from transmission lines do not pose a significant risk of adverse health effects or negative impacts on production in livestock.

2.1.6 EMF and apiaries

The Gibbs report (Gibbs, 1991) concluded that bees in hives under or near to transmission lines are adversely affected by shocks created by currents induced by the lines, but that the effect can be mitigated by shielding.

The finding in the report was supported by published research conducted in 1981, which focused on the different biological effects on honeybee colonies under a 765kV transmission line (Greenberg et al. 1981). 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 0.65-0.85kV/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; 5.5kV/m, 2 weeks; and 4.1kV/m, 11 weeks. The two lowest exposure groups had normal weight after 25 weeks. Abnormal propolization of hive entrances did not occur below 4.1kV/m. Queen loss occurred in 6 of 7 colonies at 7kV/m and 1 of 7 at 5.5kV/m, but not below. Foraging rates were significantly lower only at 7 and 5.5kV/m."

Research into the effect of EMF on non-native honeybees, other than the effects of induced shocks, has been subsequently reported on in 2018 (Shepherd, S et al 2018). The study findings noted that reduced learning, altered flight dynamics and altered feeding habits were observed when the bees were subjected to a simulated magnetic field between 100μT and 1000μT, which is typically only encountered in close proximity to the transmission conductors.

Hence, the effects of EMF within the Project Area may therefore impact apiaries if the levels exceed 4.1kV/m and 100μT respectively. Given that native Australian bees are solitary and do not live in colonies, it is concluded that there is no significant impact on native Australian bees. The EMF impact assessment therefore only considers the impact on apiaries.

2.2 EMI

Some electrical and electronic appliances and equipment are susceptible to ELF magnetic field exposure from electrical sources such as transmission lines and terminal stations. They are referred to as sensitive receptors. Exposure to magnetic fields exceeding the immunity limits specified by the manufacturer may cause reduced functionality or malfunction of the equipment.

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 line and can cause interference to the reception of radio, television and mobile communication signals in the vicinity of the transmission line.

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 EMI levels from the transmission line under wet conductor conditions.

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

EMI 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 EMI on transmission lines and terminal stations that is responsible for the majority of reported interference issues are gap (spark) discharges (EPRI, 2005]). 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 EMI 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 EMI 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 conductors 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 receptors and reception of radio, television and mobile communication signals are collectively referred to as EMI.

2.2.1 Radio and television interference

Conductor corona and gap discharges generate interference over a wide frequency range. The limits for EMI from a transmission line are established in Australian Standard 2344 (*Limits of electromagnetic interference from overhead AC powerlines and high voltage equipment installations in the frequency range 0.15MHz to 3000MHz*). 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 falls into ITU region 3, zone C. The applicable emission limits for this zone are summarised in Table 2.4. 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 30MHz and in microvolts per metre (dBµV/m) for frequencies above 30MHz. The specified limits are defined in the standard as the fields measured at 2 metres above ground.

Table 2.4: 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	-
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 3MHz to 30MHz

EMI compliance with the Australian Standard (AS) AS 2344 reference levels is verified by testing in accordance with CISPR TR 18-2, which requires that measured levels must comply with the limits for at least 80% of the time with a confidence level of at least 80%. The measured values are assessed against the AS 2344 reference levels under average rain conditions (i.e., 50th percentile rain or $L50_{wet}$ levels). The radio frequency interference limits are defined for a Quasi Peak detector. As such, the interference level at an observation point is not the addition of individual contribution from the different transmission lines and terminal stations (i.e., proposed and existing transmission lines and terminal stations) but rather from the largest interference source at that location. If the contributions from two lines are within 3dB of each other, the root mean square value for the two contributions is considered.

The AS 2344 reference levels are defined for the protection of radio and television reception against the subjective annoyance caused by transmission line radio interference, specifically for perceived annoyance to music listeners. A protection ratio of 30dB is conservatively adopted for deriving the reference levels in the standard. Higher radio interference emission levels may be tolerable for less sensitive receptors (e.g., receivers located closer to the relevant transmitter or receivers that use more sophisticated modulation techniques) or where there is greater tolerance for reduced intelligibility or increased annoyance (e.g., talk radio or emergency services announcements). International Council on Large Electric Systems (CIGRE) Technical Brochure 20 (Interferences produced by Corona Effect of Electric Systems) defines a radio reception quality scale for assessing the impact of radio interference from transmission lines and terminal stations. The stated subjective impression of the reception quality for a Code 2 protection margin of 12dB is unacceptable for music listening but speech is intelligible. Code 2 radio reception is therefore also considered in the EMI impact assessments for reception of information associated with emergency services broadcasts.

Point-to-point radio communication links are susceptible to scattering effects caused by conductive obstructions such a transmission line conductors and towers. Users of point-to-point radio communication links can include Australian Federal Police, Department of Defence, Australian Emergency Services and land mobile services. The noise source considered will be the coherent multipath signal and not the transmission line radio interference emissions. For this form of interference, it is preferable that the obstacle does not impinge more than 20% into the primary Fresnel zone[11] of the radio communication link and must not impinge more than 40% into it, depending on the material type and coverage of the obstacle.

The extent and impact of signal blocking and scattering effects will depend on the type of service interfered with and the frequency of the signal. Spread spectrum, digital modulation devices (e.g., 3G, 4G and 5G mobile

11 Fresnel zone is an elliptical region between the transmit antenna and the receive antenna

phones) are very immune to the scattering effects caused by tall conductive structures. Fixed frequency, land mobile, point-to-point and point-to-multipoint links (e.g., VHF CB, UHF CB, aeronautical radio and telemetry links) are more susceptible to scattering effects if either the transmitter or receiver are located in close proximity to a transmission line tower. Analogue radio and TV reception are sensitive to signal blocking and scattering effects, particularly at receivers that are close to transmission line towers and remote from the closest transmitter.

2.2.2 Sensitive receptors

Medical and research equipment, such as electron microscopes, atomic force microscopes, Nuclear Magnetic Resonance (NMR), Computed Tomography (CT), Positron Emission Tomography (PET) and X-ray equipment, may be sensitive to 50Hz magnetic fields at levels between 0.03μT and 3.8μT.

Electrical and electronic equipment found more generally in residential, commercial and light industrial environments[12] within the study area are less sensitive to ELF magnetic fields. The required immunity limit for general equipment in this environment is defined in AS/NZS 61000.6.1 as 3.8μT for 50Hz magnetic fields. For equipment in an industrial environment, AS/NZS 61000.6.2 specifies a 38μT magnetic flux density limit.

All forms of radio communication equipment are sensitive to EMI and are considered to be sensitive receptors for the purposes of this impact assessment.

For sensitive receptors 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).

[12] As defined in AS/NZS 61000.6.1, environments can include residential properties, retail outlets, business premises, areas of public entertainment, outdoor and light-industrial locations. Examples include houses, shops, offices, cinemas, petrol stations and workshops.

3. EES scoping requirements

The Scoping Requirements – Western Renewables Link Environment Effects Statement (DTP, 2023) set out in detail the matters to be investigated, assessed and documented in the EES for the Project and are referred to in this report as the EES scoping requirements.

3.1 EES evaluation objectives

The EES scoping requirements specify evaluation objectives which provide a framework to guide an integrated assessment of environmental effects of the Project, in accordance with the Ministerial guidelines for assessment of environmental effects under the Environment Effects Act 1978, Eighth edition, 2023. The evaluation objectives identify desired outcomes in the context of key legislative and statutory policies, as well as the principles and objectives of ecologically sustainable development and environmental protection, including net community benefit.

The evaluation objective relevant to EMI and EMF assessment is set out in Section 4.5 (Community amenity, safety, roads and transport) of the EES scoping requirements:

> *Avoid, or minimise where avoidance is not possible, adverse effects for community amenity, health and safety, with regard to construction noise, vibration, dust, lighting, waste, greenhouse gas emissions, transport network, operational noise, fire risk management and electromagnetic radiation.*

In order to meet the evaluation objective, it is necessary to understand the potential impact of the Project on EMI and EMF in the environment so that impacts can be appropriately avoided or mitigated. Understanding potential impacts requires an impact assessment, for which the starting point is a clear understanding of the existing conditions.

3.2 Assessment of specific environmental effects

The EES scoping requirements set out the key issues that the Project poses to the achievement of the evaluation objective, together with the features and values of the existing environment that are to be characterised – these are referred to as the 'existing conditions'. The scoping requirements also list potential effects of the Project and identify where mitigation measures may be required.

The scoping requirements pertaining to EMI and EMF are set out in Section 4.5 (Community amenity, safety, roads and transport) of the scoping requirements. These are reproduced in Table 3.1, together with directions to the reader as to where these items have been addressed in this report (and other reports as applicable).

Table 3.1: EMI and EMF scoping requirements

Aspect	Scoping requirement	Relevant sections
Key issues	Risks to human health, including due to electromagnetic or other radiation emissions from project construction or operations	Section 7 (Existing conditions), 8 (Construction), 9 (Operations) and 10 (Decommissioning)
	Potential electromagnetic interference with communication or infrastructure systems	
Existing environment	Identify sensitive receptors that could be affected by noise, dust or electromagnetic or similar radiation from project construction or operation	Section 7 (Existing conditions)
Mitigation Measures	Identify measures to minimise or contain electromagnetic radiation emissions from the project or to shield or buffer nearby sensitive receptors from such emissions	Section 8 (Construction) and 9 (Operations)
	Describe and assess potential measures for avoiding, mitigating, or managing impacts of electromagnetic radiation, including on human health and on telecommunications	

Aspect	Scoping requirement	Relevant sections
Likely effects	Identify and assess potential impacts on human health and safety that could result from the project	Section 8 (Construction) and 9 (Operations)
	Identify potential effects of fugitive emissions of electromagnetic or similar radiation from the project on sensitive receptors	
Performance Criteria	Describe proposed measures to manage and monitor effects on amenity values and identify likely residual effects, including compliance with standards and proposed trigger levels for initiating contingency measures	Section 8 (Construction) and 9 (Operations)
	Describe contingency measures for responding to unexpected impacts to amenity values resulting from the project during construction and operation of the project	

4. Project description

4.1 Project overview

The Project aims to address the current constraints of the western Victorian transmission network by providing the additional capacity, reliability and security needed to drive the development of further renewable electricity generation in western Victoria. By doing so, the Project supports the transition from coal-generated electricity to renewables and the efficient connection of renewable electricity into the National Electricity Market.

The Project comprises the construction and operation of a new approximately 190km overhead double circuit 500kV transmission line between Bulgana in Victoria's west and Sydenham in Melbourne's north-west. To support the connection of the new transmission line, the following works are proposed:

- The construction and operation of a new 500kV terminal station near Bulgana, and a 220kV transmission line connection to the existing Bulgana Terminal Station
- Expansion of the existing Bulgana Terminal Station
- Connection works at the Sydenham Terminal Station including the modification of a bay and a bay extension with associated infrastructure
- Upgrade of the existing Elaine Terminal Station, through the diversion of an existing line
- Protection system upgrades at connected terminal stations.

The Project's main features are summarised in Figure 4.1 and the location is shown in Figure 4.2:

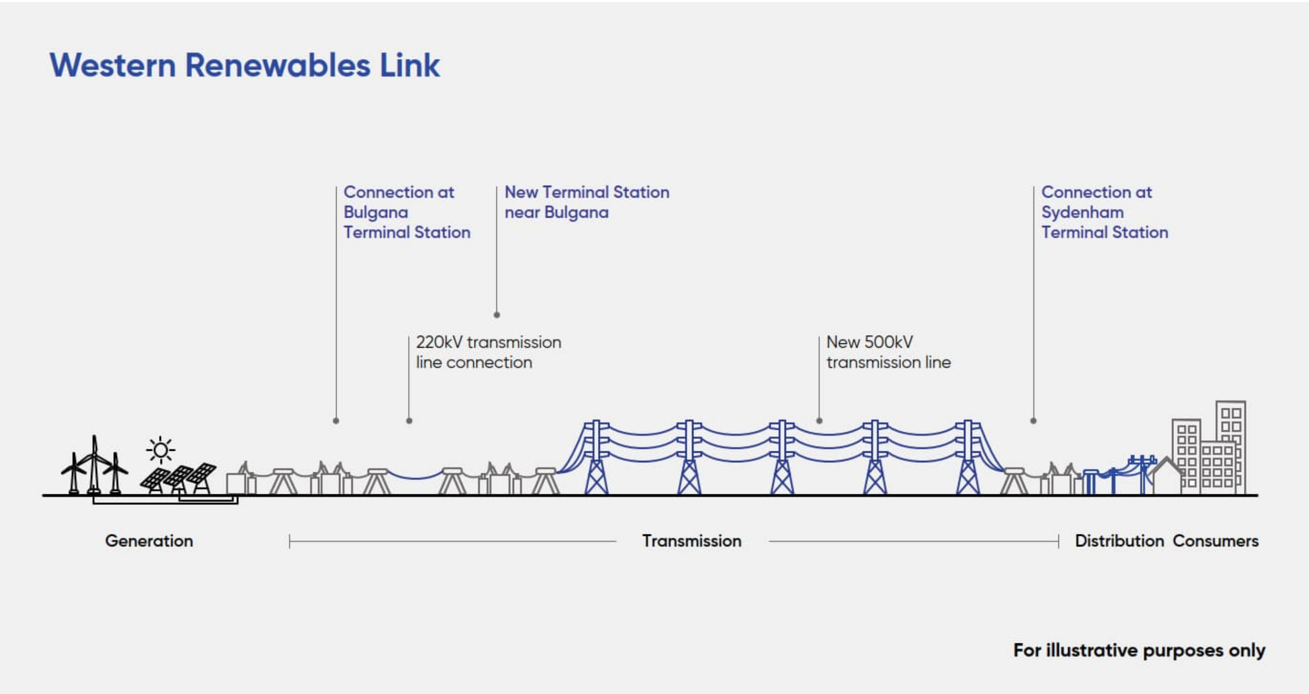

Figure 4.1: Western Renewables Link (Source: AusNet, 2024)

The Project can be described by the following key terms:

- **Project Land**: The Project Land encompasses all land parcels that could be used for the purpose of temporary Project construction and permanent operational components. The Project Land is shown in Figure 4.2:
- **Project Area**: The Project Area is contained within the Project Land and encompasses all areas that would be used to support the construction and operation of the Project. The Project Area is shown in Figure 4.2:

- **Proposed Route**: The Proposed Route is approximately 100 to 170m wide and encompasses the nominal future easement for the proposed new transmission line (including a buffer either side), and the terminal station areas. The Proposed Route is located within the Project Area.

The Proposed Route commences at the existing Bulgana Terminal Station with a 220kV transmission line connection to the new 500kV terminal station approximately 2.3km to the north-east. The Proposed Route then runs from the new 500kV terminal station to the north of the existing Ballarat to Horsham transmission line, where it runs parallel to the existing transmission line for approximately 60km. East of Lexton, the Proposed Route deviates from the Ballarat to Horsham transmission line, passing through the northern section of the Waubra Wind Farm between Mount Bolton and Mount Beckworth. Continuing east, the Proposed Route passes south of the Berry Deep Lead gold mining precinct and north of Allendale and Kingston. North of Kingston the Proposed Route turns south-east to Mount Prospect. From Mount Prospect to near Dean, the Proposed Route is adjacent to the existing Ballarat to Bendigo transmission line. Near Dean, the Proposed Route deviates from the existing transmission line to run south, then east through Bolwarrah, Bunding and Myrniong to Darley. The Proposed Route then continues eastward crossing Merrimu Reservoir north of Long Forest and along the northern boundary of MacPherson Park at Melton, connecting to the existing electricity network at the Sydenham Terminal Station.

The Project crosses six local government areas (LGAs), namely:

- Shire of Northern Grampians
- Shire of Pyrenees
- City of Ballarat
- Shire of Hepburn
- Shire of Moorabool
- City of Melton.

For the purposes of this EMI and EMF Impact Assessment, the 'study area' adopted is based on the Project Area plus an additional 5km buffer applied. This is further discussed in Section 6.2.

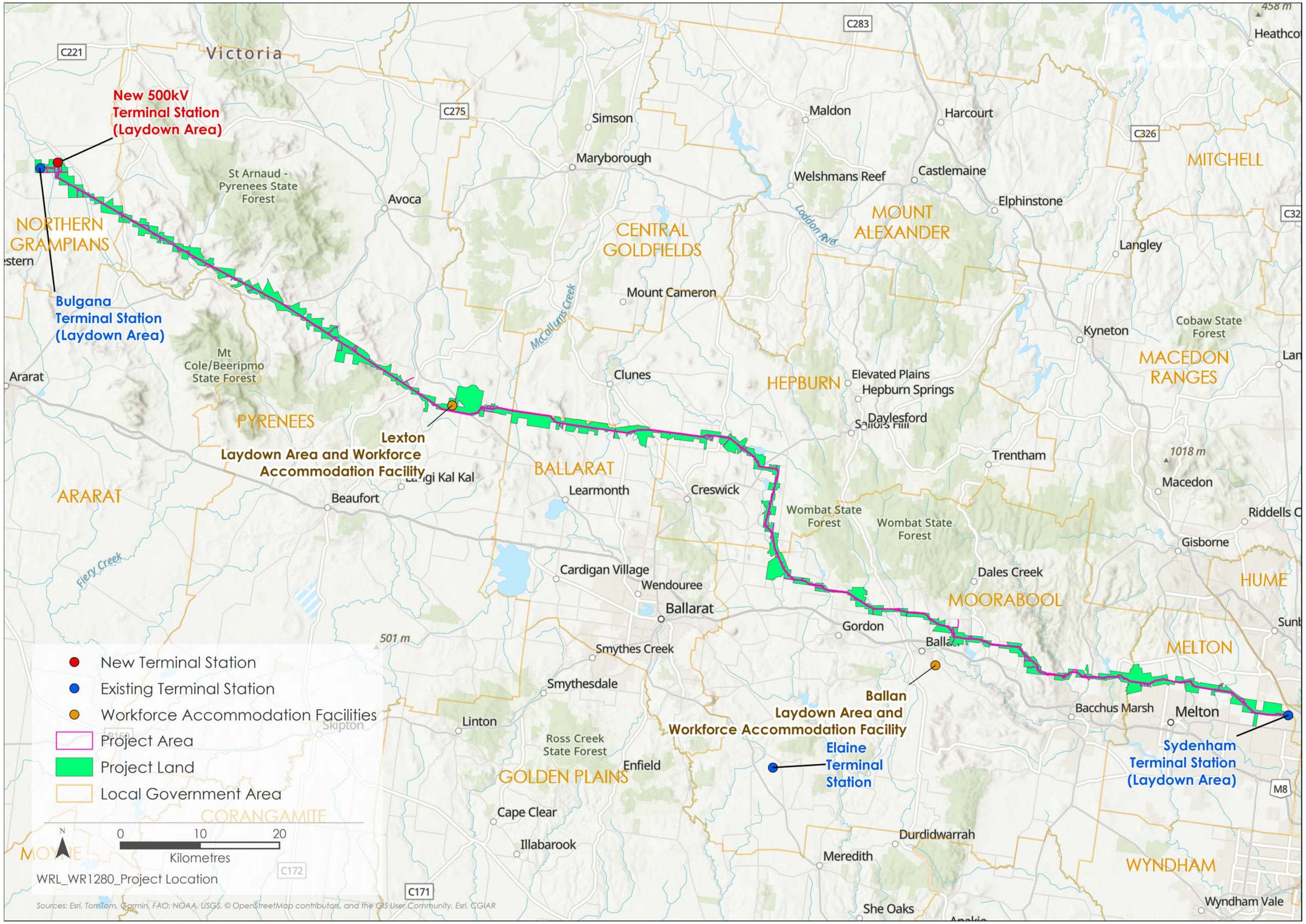

Figure 4.2: Project location (Source: Jacobs, 2025)

4.2 Project infrastructure

The Project includes both permanent and temporary infrastructure, as described in sections 4.2.1 and 4.2.2. The Project has been progressively refined from an initial broad area of interest as described in **EES Chapter 5: Project development**.

4.2.1 Permanent infrastructure

The proposed Project includes the construction of infrastructure listed in Table 4.1. Further detail is provided in **EES Chapter 6: Project description**.

Table 4.1: Project infrastructure – key components*

Double circuit lattice towers	418 double circuit towers
Single circuit lattice towers	36 single circuit towers (18 sets of two side-by-side)
Approximate length of 500kV transmission line route	Approximately 190km, between Bulgana in Victoria's west to Sydenham in Melbourne's north-west.
Approximate length of 220kV transmission line route	Approximately 2.5km, between the existing Bulgana Terminal Station to the new terminal station
Terminal Stations	A new 500kV terminal station and associated infrastructure near Bulgana to be connected to the existing Bulgana Terminal Station via a 220kV connection.
	Expansion of the existing Bulgana Terminal Station to support connection of the new 500kV terminal station near Bulgana.
	A connection to the Sydenham Terminal Station, including the modification of a 500kV bay and a new 500kV bay extension with associated infrastructure
	Relocation and diversion of existing 220kV transmission lines at Elaine Terminal Station.

* Note: These figures are approximate and subject to final detailed design, which will consider further landholder consultation and geotechnical, site and other investigations.

For the safe and reliable operation of the transmission line, an easement is needed for the operation of the transmission line, and other related infrastructure to provide public safety and to provide access for maintenance and repair purposes. The transmission line easements will be typically between 70 and 100m wide for the Project.

The transmission line design requirements are specified by the Australian standard AS/NZS 7000:2016 Overhead Line Design and AusNet's Electricity Safety Management Scheme. Key assumptions and considerations of the transmission towers that will form part of the Project and have been used as the basis of this report are described below.

- Transmission towers (towers) support the overhead conductors (wires or lines) at the required height above the ground to meet regulations and safety requirements. The preferred tower configuration will be a galvanised steel lattice structure similar to those found elsewhere across Victoria and within the national network. The typical tower height for the Project is between 60 to 80m. It is noted that whereas the Electricity Safety (General) Regulations 2019 require a minimum distance of 9m between the energised wires and the ground, the Project has adopted a minimum separation of 15m for the transmission line design. This more onerous design requirement has been adopted specifically to reduce the EMF that people are exposed to at ground level.
- Each tower has four footings which will typically be 1.8m in diameter and 9m deep. The four footings base width will be between 10 to 17m wide. During construction, ground disturbance around each tower will typically be no greater than 50 by 70m.
- The spacing or span length between each tower is determined by the height from the ground that the conductors need to be to achieve the required ground clearance in the middle of the span. Typical span

length is between 450 to 550m for the transmission line. Longer span lengths are possible over sensitive areas or to avoid impacts, however longer spans require taller towers to provide safe ground clearances and wider easements to allow for greater sway of the conductors. Similarly, where it is difficult to achieve the required ground clearance in the middle of the span, due to topography or obstacles, the tower span may be reduced.

- Each span comprises 26 conductors, made up of 12 conductors on each side of the tower cross arms and two ground wires across the top of the tower. Each conductor is approximately 32mm thick and made of aluminium wire strands with a steel core.
- As part of the Project, the existing Bulgana Terminal Station will be expanded to support the connection of the new 500kV terminal station into the existing 220kV switchyard. The new 500kV terminal station will support the connection of the Project transmission line and future connections. The new terminal station will require additional land to the north-east of the existing Bulgana Terminal Station.
- Upgrades required at Elaine Terminal Station will involve the relocation of existing 220kV transmission lines and diversion of an existing 220kV line into the terminal station. The footprint of the terminal station will not change, and all new equipment will be approximately the same height and scale as existing structures and equipment at the Elaine Terminal Station.
- Connection works are proposed at Sydenham Terminal Station. The existing Sydenham Terminal Station will be re-built through the Sydenham Terminal Station Rebuild Project, prior to the Project works. The Project will connect into Sydenham through the modification of a 500kV bay and new 500kV bay extension.

4.2.2 Temporary infrastructure

During construction there will be additional work areas, including vehicle access tracks, temporary tower stringing pads, distribution line crossover points, potential hurdle locations, temporary laydown areas and workforce accommodation facilities.

Temporary laydown areas associated with the terminal stations and the transmission line will be used to sort materials, pre-assemble Project components and store equipment, vehicles and other supplies that support construction activities. Temporary fencing, gates, security systems and lighting will also be installed at the laydown areas. The Project will establish five laydown areas; two of which will be located at existing terminal station sites (Bulgana and Sydenham), one at the new 500kV terminal station near Bulgana, and an additional two sites at intermediate locations between the stations southeast of Lexton and south-east of Ballan. The two intermediate laydown areas are required for the construction of the transmission line. The size of each site (including workforce accommodation facilities) will vary depending on storage requirements. The site south-east of Lexton will be up to approximately 12ha and the site south-east of Ballan will be up to approximately 24ha.

AusNet proposes to utilise temporary construction workforce accommodation facilities to accommodate construction workforce personnel. Two facilities are proposed; one in each of the western and eastern portions of the Project, co-located with each of the intermediate laydown areas. Each facility will have capacity for up to 350 personnel and will provide individual accommodation units, a communal kitchen and meals area, laundry, gym facilities, mobile and Wi-Fi boosters, and serviced cleaning. The layouts of the proposed accommodation facilities will be determined by the Principal Contractor.

4.3 Summary of key Project activities

4.3.1 Construction

Construction of the Project will include preparatory activities (e.g., site investigations, establishment of laydown areas etc.), establishment of temporary infrastructure (such as water and wastewater infrastructure and power supplies), construction of towers and transmission line stringing works; construction works at terminal stations; site rehabilitation works; and pre-commissioning activities. The overall construction duration of the Project is approximately two years. This schedule is dependent on adjustments required to deliver the Project and the granting of approvals within certain timeframes. For tower assembly and transmission line stringing, work will not be constant, with specialist crews following each other along the route doing specific jobs (clearing, site preparation, tower construction, conductor stringing, site rehabilitation, etc). As each work crew leaves a site (or property) there may be days, weeks, or possibly months of inactivity until the next crew arrives. The cumulative duration of construction work at each tower (i.e., time on each property) will be approximately 9 to 22 weeks (over a two year period). Once construction is complete, site rehabilitation will occur and commissioning activities will include final inspections and other safety and pre-operational checks. Construction of the Project is anticipated to commence in late 2026 and be completed by late 2028.

Key activities associated with the construction of towers include:

- Site preparations, including necessary vegetation clearance
- Construction of vehicle access tracks and minor upgrades to existing roads and tracks
- Tower foundation construction
- Tower structure assembly and erection
- Transmission line stringing works
- Commissioning
- Site rehabilitation.

The works proposed at the new 500kV terminal station near Bulgana, the existing Bulgana Terminal Station and Sydenham Terminal Station will be constructed over a period of approximately 20 months, with key activities including:

- Site preparations, access and necessary vegetation clearance
- Earthworks
- Construction of footings, foundations and drainage systems
- Installation of structures and equipment
- Commissioning
- Landscaping and rehabilitation.

4.3.2 Operations

The operation and maintenance of transmission lines are subject to stringent regulatory controls to safeguard public safety and the uninterrupted supply of electricity. All transmission line operators are required to comply with these controls and provide regular reports to the relevant authorities, including Energy Safe Victoria.

The key operation stage activities for the transmission line include:

- Scheduled inspections of the transmission line and easement (either by vehicle patrols or LiDAR/aerial surveys)
- Ongoing vegetation management to maintain safety clearances under the transmission line
- Tower maintenance inspections
- Repairs and maintenance to address issues found in above inspections.

While the terminal stations are operated remotely, staff are present at stations for inspections or maintenance. Routine inspections will occur bi-monthly, with personnel checking the overall condition of the terminal station's assets.

4.3.3 Decommissioning

The Project's transmission line is designed for a service life of 80 years, while the terminal station works have been designed for a minimum life of 45 years. The terminal station works will be maintained and upgraded to enable the terminal stations to remain operational for the service life of the transmission line. At the end of the service life of the transmission line, the infrastructure will either be decommissioned or upgraded to extend its service life to maintain the security and reliability of the transmission network as determined by the network planner at that time. In the event of decommissioning, the key activities may involve:

- Lowering the overhead transmission line and ground wires to the ground and cutting them into manageable lengths to roll onto drums or reels for disposal as scrap metal
- Removing insulators and line hardware from structures at the site and disposal at an approved waste facility
- Dismantling towers in manageable sections, removing from the site and selling steel as scrap
- Excavation of footings below finish surface level
- Decommissioning and removal of terminal stations
- Easement restoration and rehabilitation, where required.

4.3.4 Activities relevant to the EMI and EMF Impact Assessment

Electrical plant and equipment used for Project construction and decommissioning activities will be certified by the supplier as compliant with commercial product EMC standards. Compliance with this certification requirement is managed by the Australian Communication and Media Authority). As such, the plant and equipment do not pose an EMF or EMI risk to people or the environment. The only significant sources of EMI and EMF associated with the Project infrastructure are therefore the energised, operational transmission line and terminal stations.

The following has been incorporated into the Project design to reduce public exposure to EMF and reduce electromagnetic field interference effects associated with the energised, operational transmission line and terminal stations:

- Diagonal phasing has been adopted for the new 500kV transmission line, which maximises magnetic field cancellation and thereby minimises public exposure to magnetic fields at ground level. It may be impracticable to do the same for the short 220kV transmission line between the existing Bulgana Terminal Station and the new 500kV terminal station near Bulgana. Non-diagonal phasing along this short transmission line has therefore been considered in the assessment
- Minimum design heights above ground have been increased above the minimum statutory requirement to 15m to maintain electric field levels within acceptable limits directly under the line
- A quad Olive ACSR/GZ conductor bundle arrangement has been adopted to manage corona effects.
- Maximising separation from sensitive receptors through route selection and terminal station site selection.

The above design controls have been considered in the assessment of potential impacts during the operational stage of the Project.

The decommissioning and removal of the transmission line and terminal stations will remove the only significant sources of EMI and EMF and thereby reduce the associated impacts on the local environment. Accordingly, the following Project impacts will be considered in the EMI and EMF Impact Assessment:

- Long-term impacts during operation
- Human health impacts
- Impact on livestock
- Impact on medical and research facilities

- Impact on AM radio, FM radio, television, point-to-point communication links and mobile phone communication networks (including emergency services communications).

5. Legislation, policy and guidelines

There is currently no applicable legislation or policies that enforce requirements for the impact assessment and management of EMI and EMF. However, the *Environment Effects Act 1978* provides for the assessment of proposed projects that are capable of having a significant effect on the environment, and relevant industry guidance, although not enforceable, has been adopted from the standards and guidelines listed in Table 5.1.

Table 5.1: Legislation, policies and guidelines relevant to EMI and EMF

Legislation, Policies and Guidelines	Relevance to this report
Environment Effects Act 1978	
The *Environment Effects Act 1978* (Environment Effects Act) provides for the assessment of projects that may have a significant effect on the environment by enabling the Minister administering the Act to decide that an EES should be prepared. An EES may be required where: ▪ There is a likelihood of regionally or State significant adverse environmental effects ▪ There is a need for an integrated assessment of social and economic effects of a project or relevant alternatives ▪ Normal statutory processes would not provide a sufficiently comprehensive, integrated, and transparent assessment. The process under the Environment Effects Act is not an approval process in itself; rather it is an assessment process that enables statutory decision-makers to make decisions about whether a project with potentially significant environmental effects should proceed.	On 22 August 2023, the Minister for Planning determined that the Project requires assessment through an EES under the Environment Effects Act, due to matters as set out in the Statement of Decision on Referral No. 2023R-04, and summarised below: ▪ The area of interest for the project supports significant environmental values and other social values, potential aggregate impacts on which are of at least regional significance. ▪ Multiple alignment and design alternatives for the project within the area of interest require rigorous and transparent assessment and refinement. ▪ An EES responds to community interest in project siting, alignment and design alternatives by providing appropriate opportunities for public input. The Minister for Planning issued the EES scoping requirements in November 2023 (Section 3), which have informed this assessment.
International Commission on Non-Ionizing Radiation Protection – 2010: Guidelines for limiting exposure to time-varying electric and magnetic fields (1Hz – 100kHz)	
Since late 2015, the Australian Radiation Protection and Nuclear Safety Agency has adopted the guidelines published by ICNIRP in 2010 as international best practice. The “Reference Levels” set out in the ICNIRP guidelines are derived from the basic restrictions at which interactions with the central and peripheral nervous systems are established, with relevant safety factors applied to account for exposure and analysis of uncertainties. They are defined to simplify compliance testing.	The ICNIRP guidelines define the reference levels for the assessment of ELF EMF impacts on human health.
Australian Standard AS 2344 – 2016: Limits of electromagnetic interference from overhead a.c. powerlines and high voltage equipment installations in the frequency range of 0.15MHz to 3000MHz	
This Australian Standard sets out reference levels for EMI (radio disturbance) from alternating current (a.c.) overhead powerlines and high voltage equipment installations in the frequency range 0.15MHz to 3000MHz.	The standard defines the reference levels for the assessment of EMI to radio, television and communication links.
International Council on Large Electric Systems (CIGRE) Technical Brochure 20 - 1974: Interferences produced by Corona Effect of Electric Systems	
The International Council on Large Electric Systems (CIGRE) guideline defines a radio reception quality scale for assessing the impact of radio interference from transmission lines and terminal stations.	The guideline defines a methodology for assessing the EMI in radio, television and communication links.

Legislation, Policies and Guidelines	Relevance to this report
Energy Networks Association of Australia – 2016: EMF Management Handbook	
The Energy Networks Association of Australia has published an EMF Management Handbook for the Australian electricity supply industry (ESI). The handbook provides up-to-date information for EMF discussions within the ESI and lays out general principles and practical advice to assist Australian utilities with their EMF management approach.	The handbook has been used to provide background information on EMF and overview of the current state of the health debate as discussed in Section 2.
Australian/New Zealand Standard AS/NZS 61000.6.1 – 2006: Electromagnetic Compatibility – Immunity for residential, commercial and light-industrial environments	
This standard applies to apparatus intended to be directly connected to a low-voltage public mains network or connected to a dedicated DC source which is intended to interface between the apparatus and the low-voltage public mains network. The environments encompassed by this standard are residential, commercial and light industrial locations, both indoor and outdoor.	The standard defines the limits for the assessment of EMI to electrical and electronic equipment found more generally in residential, commercial and light industrial environments within the study area.
Australian/New Zealand Standard AS/NZS 61000.6.2 – 2006: Electromagnetic Compatibility – Immunity for industrial environments	
This standard applies to apparatus intended to be connected to a power network supplied from a high or medium voltage transformer dedicated to the supply of an installation feeding manufacturing or similar plant and intended to operate in or in proximity to industrial locations. This standard applies also to apparatus which is battery operated and intended to be used in industrial locations. The environments encompassed by this standard are industrial, both indoor and outdoor.	The standard defines the limits for the assessment of EMI to electrical and electronic equipment found in industrial environments within the study area.

6. Method

6.1 Overview

This section describes the method that was used to assess the potential impacts of the Project. Risk screening was applied to prioritise the key issues for impact assessment. Measures to avoid, minimise and manage potential effects have then been developed to address these impacts. The following sections outline the method adopted for the EMI and EMF Impact Assessment.

6.2 Study area

The study area for the EMI and EMF Impact Assessment is defined as the Project Area (i.e., the transmission line route, the existing terminal stations at Sydenham, Bulgana, and Elaine and the new 500kV terminal station near Bulgana) plus an additional 5km buffer around the Project Area. The Waubra Terminal Station is within this 5km buffer. Therefore, Waubra is factored into the existing conditions assessment, noting that it does not form part of the Project.

EMI associated with tall metallic transmission line structures, such as signal blocking and scattering effects, do not typically affect radio communication reception at distances greater than 5km from the structures. This was the basis of the defined study area. The study area is shown in Figure 6.1.

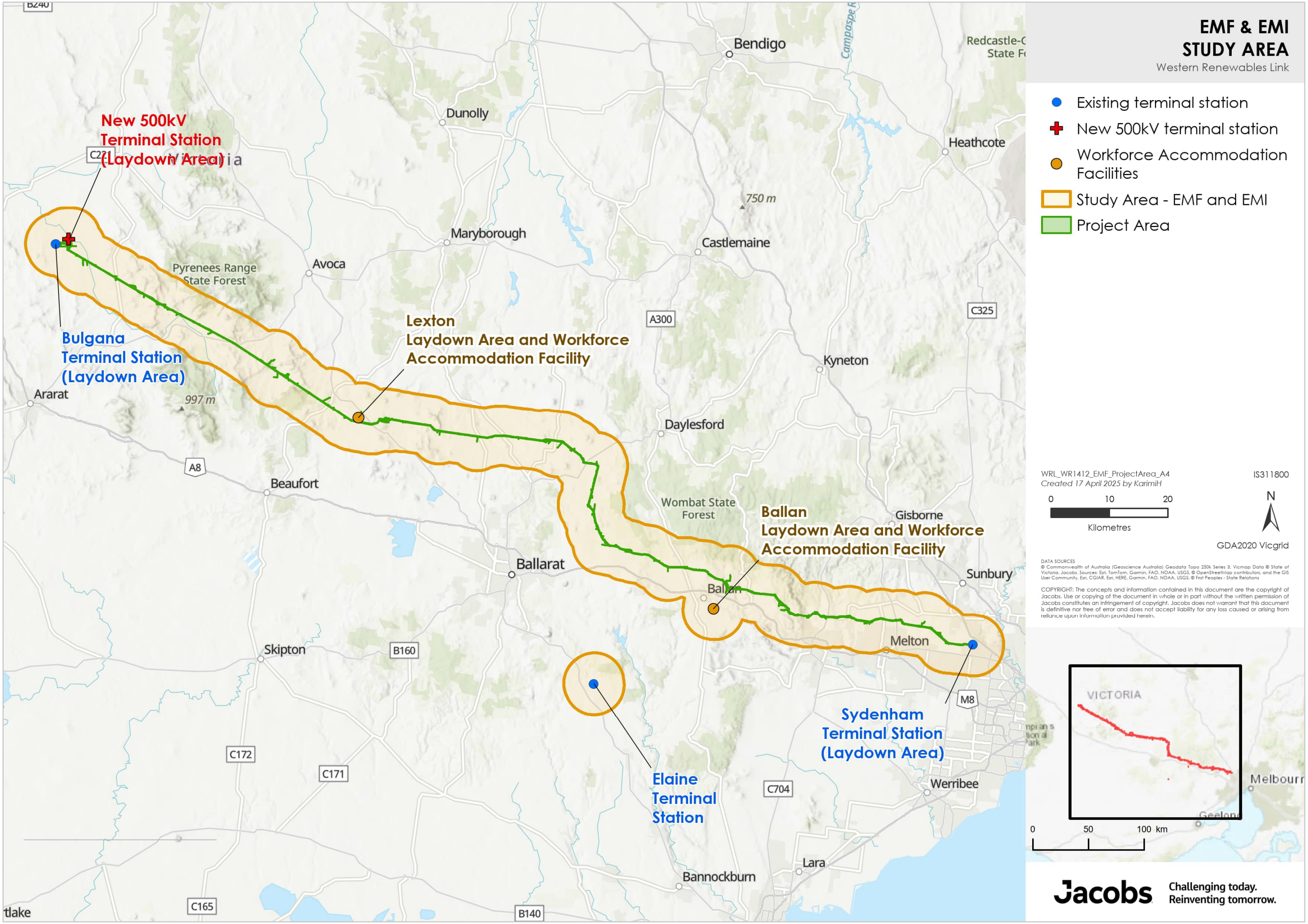

Figure 6.1: Study area (Source: Jacobs, 2025)

6.3 Existing conditions

The existing conditions assessment was used to characterise the current condition of the physical, biological and social environment. The study of the existing EMI and EMF conditions comprised:

- Identification of transmission lines and terminal stations as key sources of EMI and EMF within the Project Area and calculation of the expected worst-case EMI and EMF levels, including:
  - The existing 220kV and 500kV transmission lines within the Project Area were modelled using CDEGS SESEnviro[13], the AusNet circuit data sheets for the existing line assets and the design minimum ground clearances specified in the AusNet Design Manual. The calculated EMI and EMF levels associated with the existing infrastructure are included in Appendix A and Appendix B respectively.
  - EMI and EMF measurements were made near existing 220kV and 500kV transmission lines and terminal stations on 8 – 10 September 2021 and 13 – 15 September 2023. These measurements were made during dry weather conditions and represent the everyday operational levels. The measured EMI and EMF levels associated with the existing infrastructure are included in Appendix C.
  - Identification of any sensitive receptors within the study area that may be sensitive to EMI and EMF at levels that are below the accepted reference levels and limits. This included both existing and known, committed sensitive receptors. The different types of sensitive receptors considered in the EMI impact assessment are described in Section 2.2.2. These included sensitive receptors that are very sensitive to EMI (e.g., hospitals), which are specified in Section 7.3.3, and those that are less sensitive to EMI, such as electrical and electronic equipment in residential houses or temporary workforce accommodation. An initial conservative assessment has considered the impact on such a dwelling at the edge of the easement. This has been refined to the actual location of dwellings near the line, as required.
  - Identification of radio and mobile communication links within the study area. This includes the identification of radio and TV transmitters, point-to-point radio links and mobile phone transmitters.

6.4 Risk screening

A risk screening process was undertaken to identify the EMI and EMF related risks associated with the design, construction, operation and decommissioning of the Project and to provide for the appropriate level of investigation. The outcomes of the risk assessment identified the key issues that were taken forward into the impact assessment stage (see Sections 8.1, 9.1 and 10).

6.5 Impact assessment method

The method for the EMI and EMF Impact Assessment included:

- Identifying key issues (as described in Section 6.4) to be addressed in the impact assessment
- Identifying potential impacts of Project construction, operation, and decommissioning according to the impact ratings developed for the EMI and EMF assessment, which are summarised in Table 6.1. It is noted that the developed impact ratings are limited to impacts on electrical and electronic equipment. The basis for this is that the EMI and EMF levels associated with the new Project infrastructure have been limited to levels that are below the reference levels and limits derived for people and animals within the study area, except for apiaries, which are not present in the EMF impact zones and therefore do not present an impact risk. EPR EL1 (refer to Section 12) involves verification that no new apiaries have been located in the EMF impact zones prior to the operation of the transmission line. If the detailed design assessment does identify new apiaries with the EMF impact zones, they will be relocated outside the impact zones. Therefore no impact ratings are required to be defined for people and animals.

[13] CDEGS SESEnviro is a software package developed by Safe Engineering Services (SES). The software is industry recognised and is commonly used locally and internationally to perform electromagnetic environmental impact assessment analysis.

- Potential impacts of the Project were measured against the existing conditions by assessing the significance of the impacts, taking into consideration mitigation measures. Mitigation measures to reduce the potential impacts have been recommended in accordance with the mitigation hierarchy (avoid, minimise, manage, rehabilitate and offset) and these have then informed the development of Environmental Performance Requirements (EPRs).
- Identifying any other potential developments that could lead to cumulative impacts when considered together with the Project.
- Prepare EPRs to define the environmental outcomes to be achieved through the implementation of mitigation measures during construction, operation and decommissioning. While some EPRs are performance based to allow flexibility in how they will be achieved, others include more prescriptive measures that must be implemented. Compliance with EPRs will be required as a condition of the Project's approval.
- Determining the residual impacts associated with the construction, operation, and decommissioning of the Project, and evaluating their significance in accordance with the criteria described above.

Table 6.1 shows the specific ratings applied when assessing relevant aspects of potential EMI and EMF impacts. These criteria were used to assess the overall residual impact of Project activities on EMI and EMF.

Table 6.1: Discipline specific impact ratings for EMI and EMF

Rating	EMI and EMF impact rating criteria
Negligible	Electromagnetic fields do not interfere with proper functioning of sensitive receptors.
Minor	Electromagnetic fields may exceed equipment sensitivity ratings but will not impact on proper function.
Moderate	Electromagnetic fields exceed sensitive receptor immunity ratings resulting in minor to moderate impact on proper system functioning. These impacts can be overcome through operational controls such as recalibration or restart processes or the accuracy of the device is downgraded.
Major	Electromagnetic fields exceed sensitive receptor immunity ratings to the extent that degrades the performance of the receiver, in turn negatively impacting on operational processes that rely on that receiver. Sensitive receptor may require complex restart or recalibration process or cannot be used during certain times of day.
Severe	Electromagnetic fields exceed sensitive receptor immunity ratings to the extent that the receiver is rendered inoperable until repair, recalibration or adjustment of the receiver. Severe impact on operational processes that rely upon the receiver.

The EMI and EMF Impact Assessment followed a systematic approach to identify, assess and manage potential environmental effects. The assessment of environmental effects was based on best practice, including a risk-based approach, so the extent of the investigation, and therefore assessment, was proportionate to the risk of adverse effects. The assessment was peer reviewed throughout the assessment process. The impact assessment has:

- Undertaken field measurements of present-day EMI and EMF levels within the study area. These values were compared with the identified impact assessment criteria to determine if they are currently within the reference levels and design limits. They will also be used to benchmark measured post-construction levels. The measured EMI and EMF levels associated with the existing infrastructure are included in Appendix C.
- Undertaken a desktop analysis to assess expected EMI and EMF levels from the proposed assets:
  - The proposed electrical assets were modelled in CDEGS SESEnviroPlus software to determine the worst case EMI and EMF.
  - Results have been plotted to show field levels in proximity to the proposed assets. The calculated EMI and EMF levels associated with the proposed infrastructure are included in Appendix D and Appendix E respectively.
  - EMF results were assessed against the reference levels and design limits. A Project design limit was established for electric fields at the start of the impact assessment. This was deemed necessary because the general guidance for electric field exposure was based on conservative assumptions and

not aligned with the prudent avoidance principles specified in the ENA EMF guidelines for the proposed 500kV transmission lines. The adopted design limit for electric field levels was based on international practice, as described in the technical paper included in Appendix H.

  - EMI levels were assessed against the manufacturer's specifications, where available, or the relevant standard limits. The EMI level calculations are included in Appendix F and Appendix G.

- Undertaken an assessment of the possible effects of construction and operation / maintenance of the Project, with regards to the applicable EES scoping requirements within the study area. These effects have been assessed considering standard controls and the identified mitigation measures:
  - Impacts to human health due to electromagnetic emissions from Project construction or operation.
  - Potential EMI with communication or infrastructure systems.
  - Community concerns raised during the consultation process including impacts on Active Implantable Medical Devices, livestock and apiaries, and GPS.
- Identified mitigation and management measures and drafted Environmental Performance Requirements (EPRs) to define the performance outcomes to avoid, minimise or manage EMI and EMF related impacts.

6.6 Stakeholder engagement

Stakeholders and the community were consulted to support the preparation of this report and to inform the development of the Project and understanding of its potential impacts.

Table 6.2 lists specific engagement activities that have occurred in relation to the EMI and EMF assessment, with more general engagement activities occurring at all stages of the Project. Feedback received during community consultation sessions is summarised in Section 6.7 relevant to the EMI and EMF Impact Assessment.

Table 6.2: Stakeholder engagement undertaken for EMI and EMF

Activity	Matters discussed
Feedback from Moorabool Shire Council on EMI and EMF existing conditions report	Much of the surrounding areas in Moorabool are high fire danger areas. During a fire, the number of communication channels are reduced, and the community relies on other channels of communication such as AM radio. The Council have an interest on impacts of the Project on the different forms of communication or staying connected to relevant information during fire movements and other emergency events.
Feedback from Southern Rural Water on EMI and EMF existing conditions report	Southern Rural Water is responsible for managing irrigation districts, the regulation of surface water and groundwater licensing, and storage dams across the southern third of Victoria. The Project traverses besides the Merrimu reservoir dam. Southern Rural Water have an interest in any potential impacts of the Project on Merrimu reservoir dam equipment and operations.

6.7 Community feedback

In addition to consultation undertaken with specific stakeholders, consultation has been ongoing with the community throughout the design development and the EES process. Feedback relevant to the EMI and EMF Impact Assessment is summarised in Table 6.3, along with where and how those topics are addressed in this report.

Table 6.3: Community consultation feedback for the EMI and EMF Impact Assessment

Matter raised	Where matter has been addressed
Several identical comments about human health impacts and impacts to Active Implantable Medical Devices.	Section 9.2.1.1
Several comments about livestock and animal health impacts.	Section 9.2.1.2
Impacts to mobile agricultural equipment which may utilise Global Positioning System	Section 9.2.2.7

The Social Pinpoint data was provided via an online mapping tool, which asked stakeholders to provide feedback on what is important to individuals and communities in their local area. The online mapping tool was available between June 2020 and October 2020.

In total, there were four Social Pinpoints that were relevant to the EMI and EMF Impact Assessment. Two of these Social Pinpoints were related to human health concerns with these Social Pinpoints located approximately 600m and 1.3km from the transmission line route in Darley. The third one was related to apiaries impacted by the powerlines with this Social Pinpoint located approximately 6.5km from the transmission line route in Wattle Flat. The last one that relates to the EMI and EMF Impact Assessment was related to interference to Telstra and NBN communication towers, with this Social Pinpoint located approximately 16km from the transmission line route in Parwan. The two human health concerns are summarised in Section 9.2.1.1, apiaries in Section 2.1.6 and 9.2.1.2 and interference to Telstra and NBN communication towers in Section 9.2.2.

6.8 Assumptions, limitations and uncertainties

The following assumptions, limitations and uncertainties apply to this impact assessment:

- ACMA communication sites – This dataset was generated at the time of writing this report. Any communication links and sites added post this date are not captured in the assessment documented 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.
- The line design parameters and operating conditions used for the calculations of the EMI and EMF of the new transmission line is provided in Table 6.4.
- The Project infrastructure, as described in Section 4.2 (Table 4.1), includes 36 single circuit towers, 18 sets of two, side-by-side. Of these 36 towers, 12 are located near MacPherson Park. These single circuit towers are used in this location to reduce the height of the transmission line infrastructure near Melton Aerodrome. The line design parameters and operating conditions used for the calculations of the EMI and EMF of the new transmission line along the single circuit tower sections are provided in Table 6.5.
- The Project infrastructure, as described in Section 4.2 (Table 4.1), includes two 220kV connections between the existing Bulgana Terminal Station and the new 500kV terminal station near Bulgana, along with the associated infrastructure. AusNet have advised that these connections will be facilitated by two short 220kV single circuit transmission lines. The lines will utilise the 500kV single circuit tower geometry and 500kV phase conductor type and bundle. The line design parameters and operating conditions used for the EMI and EMF calculations for the 220kV connections are provided in Table 6.6.

Table 6.4: Design and operating conditions used for calculations of the EMI and EMF – 500kV double circuit towers

Parameter	New 500kV transmission line
Earth wire geometry at midspan	X = ±8.4m, Y = 47.1m
Top phase geometry at midspan	X = ±8.4m, Y = 36.0m
Middle phase geometry at midspan	X = ±8.6m, Y = 25.5m
Bottom phase geometry at midspan	X = ±9.0m, Y = 15m
Minimum ground clearance	15m
Electrical phase order	RYB/BYR
Phase conductor diameter	31.5mm
Bundle type and size	Quad, 520x520mm
Earth conductor diameter	18.0mm
Current used for calculations	3118A (2700MVA)
Nominal System Voltage	500kV
Highest Permissible System Voltage	550kV

Table 6.5: Design and operating conditions used for calculations of the EMI and EMF - 500kV single circuit towers

Parameter	New 500kV transmission line
Earth wire geometry at midspan	X = ±7.85m, Y = 29.045m
Left phase geometry at midspan	X = -12.8m, Y = 15m
Middle phase geometry at midspan	X = 0m, Y = 15m
Right phase geometry at midspan	X = +12.8m, Y = 15m
Minimum ground clearance at midspan	15m
Distance between parallel lines	40m (centreline to centreline)
Electrical phase order	RYB/RYB (parallel SC flat, horizontal arrangement, left to right)
Phase conductor diameter	31.5mm
Bundle type and size	Quad, 520x520mm
Earth conductor diameter	18.0mm
Current used for calculations	3118A (2700MVA)
Nominal System Voltage	500kV
Highest Permissible System Voltage	550kV

Table 6.6: Design and operating conditions used for calculations of the EMI and EMF - 220kV tie line at BGTS

Parameter	New 220kV tie line (transmission line)
Earth wire geometry at midspan	X = ±7.85m, Y = 29.045m
Left phase geometry at midspan	X = -12.8m, Y = 15m
Middle phase geometry at midspan	X = 0m, Y = 15m
Right phase geometry at midspan	X = +12.8m, Y = 15m
Minimum ground clearance	15m
Electrical phase order	40m (centreline to centreline)
Phase conductor diameter	RYB/RYB (parallel SC flat, horizontal arrangement, left to right)
Bundle type and size	31.5mm
Earth conductor diameter	Quad, 520x520mm
Current used for calculations	2625A (1000MVA)
Nominal System Voltage	220kV
Highest Permissible System Voltage	245kV

6.9 Data sources

Data sources used in the preparation for this report are listed in Table 6.7 and Table 6.8.

Table 6.7: Assessment input data sources

Data	Source
Radio communication sites	Australian Communications and Media Authority (ACMA) https://web.acma.gov.au/rrl/site_proximity.main_page - See Figure 7.2.
Existing transmission line details	Circuit Data Sheets – Extracted from AusNet's Objective[14] database – See Figure 7.1:

Table 6.8: Existing transmission line details within the Project Area. Source: AusNet Circuit Data Sheets

Existing Transmission Lines	Phase to Phase Voltage (kV[15])	Rated Maximum Current Per Circuit as per Circuit Data Sheet (A[16])
220kV transmission line between Horsham Terminal Station and Ballarat Terminal Station, comprising: ▪ Horsham - Bulgana section ▪ Bulgana - Crowlands section ▪ Crowlands - Ararat section ▪ Ararat - Waubra section ▪ Waubra - Ballarat section	220	1540
500kV transmission line between Moorabool Terminal Station and Sydenham Terminal Station circuits 1 and 2	500	4840
220kV transmission line between Ballarat Terminal Station and Bendigo Terminal Station	220	1075

6.10 Independent review

An independent review of this assessment has been completed by David Renew of EMF Scientific. The independent reviewer's scope included an assessment of this report's methodology and assumptions, the impact assessment's findings, the suitability of any EPRs, and if the report adequately addresses if the Project can meet the relevant evaluation objective in the EES scoping requirements. Any matters in this assessment which they disagreed with were also considered for inclusion in this report.

[14] AusNet Objective database is a content management system that stores drawings and technical documents
[15] V – Volts – Unit of voltage (1kV = 1000V)
[16] A – Amperes – Unit of electrical current

7. Existing conditions

7.1 Introduction

The existing conditions for the Project Area have been described in two geographical areas:

- Western area, which covers the area between the existing Bulgana Terminal Station and the Newlyn area (the approximate mid-way point between Bulgana and Sydenham). The area includes the existing Waubra Terminal Station, which is not within the Project Area but falls within the 5km buffer around the proposed new transmission line and has therefore been included in the EMI and EMF study area.
- Eastern area, which covers the area from the Newlyn area to the end of the transmission line at the Sydenham Terminal Station.

A plan of the Project Area showing relevant existing transmission and sub-transmission lines is provided in Figure 7.1.

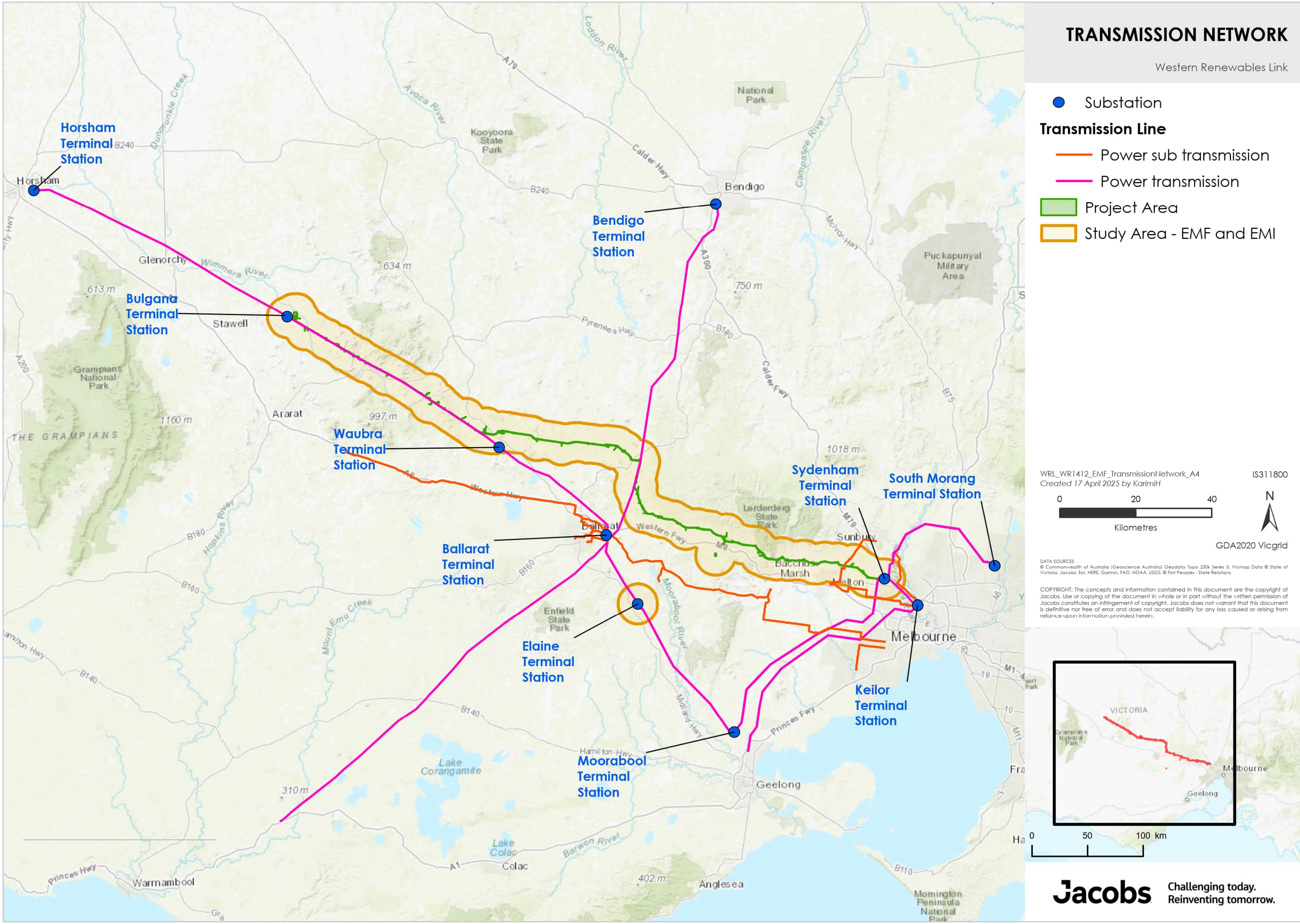

Figure 7.1: Existing transmission and sub-transmission lines that interface with the study area (Source: Jacobs, 2025)

7.2 Western area

7.2.1 EMF – existing transmission lines

The electric field strength and magnetic flux density levels associated with the existing transmission lines in the western area were calculated at 1m above ground using the maximum rated line voltages and currents. These values represent the worst-case EMF levels associated with the lines. The calculation results are included in Appendix A. The electric field strength and magnetic flux density levels were also measured under the existing lines and represent the everyday field levels under the transmission lines during normal operating voltages and currents. The measured data are included in Appendix C. The calculated and measured levels are summarised in Table 7.1 and Table 7.2. It is evident from both the calculated and measured data that the EMF levels are largest directly below the line and decrease quickly with increased distance away from the transmission line.

Table 7.1: Calculated and measured electric field strength levels associated with the existing 220kV transmission lines in the western area

Assessment	Exposure Scenario	General Public Exposure Reference Level (kV/m)	Maximum electric field strength (kV/m)
Calculated (worst case)	Directly under the line	5	4.40
	20m from centreline (edge of easement)	5	0.90
Measured (everyday)	Directly under the line	5	0.77
	20m from centreline (edge of easement)	5	0.45

Table 7.2: Calculated and measured magnetic flux density levels associated with the existing 220kV transmission lines in the western area

Assessment	Exposure Scenario	General Public Exposure Reference Level (μT)	Maximum Magnetic Flux Density (μT)
Calculated (worst case)	Directly under the line	200	32.2
	20m from centreline (edge of easement)	200	4.40
Measured (everyday)	Directly under the line	200	2.56
	20m from centreline (edge of easement)	200	1.83

The calculated EMF levels are based on the minimum design ground clearance that is associated with the maximum current rating of the transmission line conductor bundles. This high current flow through the conductors will heat up the conductors and cause them to sag closer to the ground. Since the EMF levels increase quickly with reduced distance between the observation point and the conductors, both the electric field strength and the magnetic flux density levels will increase significantly under maximum operating current conditions.

The measured EMF levels are associated with the typical, everyday load current conditions along the lines, which is generally much lower than the maximum possible current rating. The conductors are therefore not operating at the maximum rated temperature, which results in less conductor sag and increased separation between the measurement point and the conductors. That is why the measured, everyday electric field strength and magnetic flux density levels are much lower than the worst-case calculated levels.

The worst case and everyday electric field strength and magnetic flux density levels associated with the existing 220kV transmission lines in the western area are below the ICNIRP public reference levels, which are appropriate for the public areas under and adjacent to the 220kV transmission lines.

7.2.2 EMF – existing terminal stations

Field measurements were also carried out at terminal stations in the western area and are representative of the everyday EMF levels adjacent to the Project terminal stations, including Elaine Terminal Station. The measured data is included in Appendix C and a summary of the results is provided in Table 7.3 and Table 7.4.

Table 7.3: Measured electric fields associated with the existing terminal stations in the western area

Terminal Station	Exposure Scenario	General Public Exposure Reference Level (kV/m)	Maximum Measured Electric Field Strength (kV/m)
Bulgana Terminal Station	At the perimeter fence line	5	0.060
Waubra Terminal Station	At the perimeter fence line	5	0.005

Table 7.4: Measured magnetic fields associated with the existing terminal stations in the western area

Terminal Station	Exposure Scenario	General Public Exposure Reference Level (μT)	Maximum Measured Magnetic Flux Density (μT)
Bulgana Terminal Station	At the perimeter fence line	200	0.16
Waubra Terminal Station	At the perimeter fence line	200	0.03

It is concluded from the comparisons of the measured data with the reference levels that the everyday EMF levels associated with the terminal stations in the western area are well below the ICNIRP public reference levels, which are appropriate for the public areas adjacent to the terminal stations. These measured field levels are typical of public areas near terminal stations as the steel security fencing surrounding the terminal station significantly reduces the electric field levels outside the fenced area and the power equipment associated with strong magnetic fields are typically not located near the public boundary of a terminal station (i.e., the magnetic field levels in public areas are low due to the large separation between the power equipment and the accessible areas).

7.2.3 EMI – existing transmission lines

The radio interference from the existing 220kV transmission lines was calculated at 500kHz, 2m above ground level at the edge of an assumed minimum 40m wide easement. It was also calculated at the standard horizontal distance of 15m from the outermost phase conductor that is specified in AS 2344. The radio interference reference levels specified in AS 2344 are defined at a 500kHz centre frequency. The radio interference emissions from the line were assessed under average wet and dry conditions. The calculated radio interference levels at 500kHz under both average dry and average rain conditions are included in Appendix B.

The radio interference from the existing 220kV transmission lines was also measured at 500kHz, 2m above ground level at the edge of the assumed minimum 40m wide easement and compared to the calculated values and reference levels in Table 7.5 Where the calculated “wet” values are larger (i.e., more positive) than the reference values, the impact on radio listening is higher (i.e., has a higher impact rating) during rain conditions. Similarly, where the calculated “dry” values are larger (i.e., more positive) than the reference values, the impact on radio listening is higher (i.e., has a higher impact rating) during dry weather conditions. The CIGRE Code 2 reference levels are specific to radio broadcasts in the study area, whereas the AS 2344 reference levels are general limits (i.e., not specific to the study area environment). All measurements were made under dry weather conditions. The measured data are included in Appendix C.

Table 7.5: Summary of the calculated and measured radio interference levels at 500kHz for the existing 220kV transmission lines within the western area

EMI	Calculated Radio Interference (dBµA/m)				Measured Radio Interference @ 500kHz (dBµA/m)	Reference Levels (dBµA/m)	
	20m from centreline (edge of easement)		At 15m from outer most conductor		20m from centreline (edge of easement)		
	Wet	Dry	Wet	Dry	Dry	AS 2344	CIGRE Code 2
Radio Interference @ 500kHz	4.8	-12.7	3.5	-14	-25.8	-15.5	2.5

FM radio and terrestrial TV reception are more immune to radio interference from a transmission line, as compared to AM radio reception. The radio interference and television interference emissions from the transmission lines at typical broadcast frequencies were calculated and measured near the existing transmission lines and compared to the reference levels in Table 7.6 for average dry and wet conditions. It is noted that the measured levels are actually the background noise level of the test meter. The calculated levels under dry weather conditions are so low, they are not detectable at a sensitive receptor.

It is evident from the comparisons of the calculated worst case interference levels and the applicable reference levels in Table 7.6 that interference is only likely to AM radio reception under certain weather and operating conditions under the line and in close proximity to the transmission line easement.

Table 7.6: Summary of the calculated radio and television interference levels at typical AM and FM radio and terrestrial TV broadcast frequencies for the existing 220kV transmission lines in the western area

EMI	Calculated Radio Interference (dBµV/m)		Measured Radio Interference (dBµV/m)	Reference Levels (dBµV/m)	
	Wet	Dry	Dry	AS 2344	CIGRE Code 2
AM radio interference @ 500kHz	3.5	-14	-25.8	-15.5	2.5
FM radio interference @ 90MHz	16.2	-1.3	17	30	48
Terrestrial TV interference @ 600MHz	-0.3	-17.8	18	37	55

A desktop review was carried out to identify medical and research equipment that may be particularly sensitive to EMF within the western area. The Ochre Medical Centre Creswick was identified approximately 7km from the existing transmission lines. This identified sensitive receptor is not located near the existing transmission lines and the calculated magnetic field levels from the existing transmission lines were below 0.03µT (i.e., the most onerous limit discussed in Section 2.2.2) at this distance.

The generic 50Hz magnetic field immunity limit for electrical and electronic equipment and appliances in a residential, commercial or light industrial environment was identified as 3.8µT. Electrical and electronic equipment associated with farm sheds and residential dwellings may be impacted by 50Hz magnetic fields that exceed this level. The worst case calculated magnetic flux density level associated with the existing transmission lines in the Western area are below the immunity limit at distances greater than 28m from centre of the transmission line. Houses and sheds within this potential impact zone were therefore considered for potential EMI impacts. A plan showing the location of point-to-point communication links in the western area is provided in Figure 7.2.

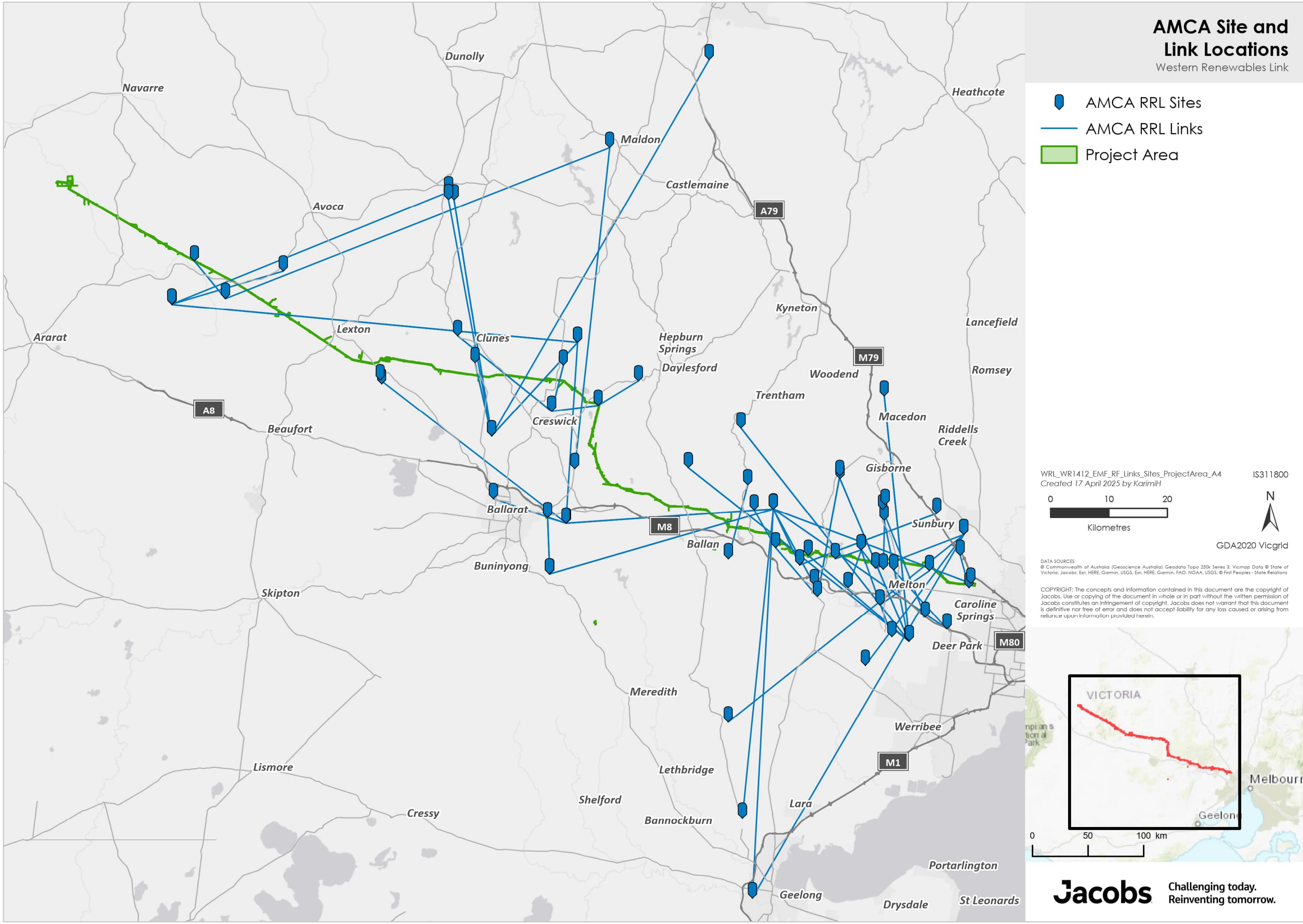

Figure 7.2: Point-to-point radio links extracted from the ACMA database (Source: https://web.acma.gov.au/rrl/site_proximity.main_page, 2023)

7.2.4 EMI – existing terminal stations

Field measurements were also carried out at the terminal stations in the western area under dry conditions. The measured data is summarised in Table 7.7 and included in Appendix C.

Table 7.7: Summary of the measured radio interference levels at 500kHz for the existing terminal stations in the western area

Terminal Station	Interference Scenario	Measured Radio Interference @ 500kHz (dBµA/m)	Reference Level (dBµA/m)	
			AS 2344	CIGRE Code 2
Bulgana Terminal Station	At the perimeter fence line	21.85	-15.5	2.5
Waubra Terminal Station	At the perimeter fence line	22.62	-15.5	2.5

As was the case for the transmission lines, the dry weather corona noise (see Section 2.2) was so low, it could not be detected at the receiver.

7.3 Eastern area

7.3.1 EMF levels – existing transmission lines

The electric field strength and magnetic flux density levels associated with the existing transmission lines in the eastern area were calculated at 1m above ground using the maximum rated line voltages and currents. These values represent the worst-case EMF levels associated with the lines. The calculation results are included in Appendix A. The electric field strength and magnetic flux density levels were also measured under the existing lines and represent the everyday field levels under the transmission lines during normal operating voltages and currents. The measured data are included in Appendix C. The calculated and measured levels are summarised in Table 7.8 and Table 7.9.

The comparisons in Table 7.8 and Table 7.9 illustrate that the magnetic flux density levels associated with the existing transmission lines within the Eastern area are below the general public exposure reference level of 200µT. The measured electric field strength under the existing 500kV transmission line is also below the AusNet 7kV/m design limit, which was derived from the ICNIRP basic restrictions for the new 500kV transmission lines. The electric field strength will therefore not exceed the ICNIRP basic restrictions in a person standing directly under the line during the worst-case operating scenario and is therefore within the acceptable limit.

The measured EMF levels are associated with the typical, everyday load current along the lines, which is generally much lower than the maximum possible current rating. The conductors are therefore not operating at the maximum rated temperature, which results in less conductor sag and increased separation between the measurement point and the conductors. This is why the measured, everyday electric field strength and magnetic flux density levels are much lower than the worst-case calculated levels.

Table 7.8: Calculated and measured electric field strength levels associated with the existing 500kV transmission line in the eastern area

Assessment	Exposure Scenario	Design Limit (kV/m)	Maximum electric field strength (kV/m)
Calculated (worst case)	Directly under the line	7	6.7
	30m from centreline (edge of easement)	7	2.5
Measured (everyday)	Directly under the line	7	3.7
	30m from centreline (edge of easement)	7	1.9

Table 7.9: Calculated and measured magnetic flux density levels associated with the existing 500kV transmission line in the eastern area

Assessment	Exposure Scenario	Public Reference Levels (μT)	Maximum Magnetic Flux Density (μT)
Calculated (worst case)	Directly under the line	200	56.6
	30m from centreline (edge of easement)	200	21.1
Measured (everyday)	Directly under the line	200	0.4
	30m from centreline (edge of easement)	200	0.2

Transmission lines (or sub-transmission lines) operating at a lower voltage of 66kV and distribution lines operating at voltages below 66kV also traverse the eastern area and contribute lower levels of EMF to the local environment. The EMF levels associated with a typical 66kV transmission line are summarised in Table 7.10.

Table 7.10: Calculated and measured electric field strength and magnetic flux density levels associated with a typical 66kV transmission line

Electric Field Strength			Magnetic Flux Density		
General Public Exposure Reference Level (kV/m)	Maximum Calculated Electric Field Strength (kV/m)	Maximum Measured Electric Field Strength (kV/m)	General Public Exposure Reference Level (μT)	Maximum Calculated Magnetic Flux Density (μT)	Maximum Measured Magnetic Flux Density (μT)
5	0.5	0.005	200	11.7	0.005

The comparisons in Table 7.10 illustrate that the typical EMF levels associated with a 66kV transmission line are well below the ICNIRP public reference levels for EMF.

7.3.2 EMF levels – existing terminal station

Field measurements were also carried out at the terminal station in the eastern area and are representative of the everyday EMF levels adjacent to the terminal station. The measured data is included in Appendix C and a summary of the results is provided in Table 7.11 and Table 7.12.

Table 7.11: Measured electric fields associated with the existing terminal station in the eastern area

Terminal Station	Exposure Scenario	General Public Exposure Reference Level (kV/m)	Maximum Measured Electric Field Strength (kV/m)
Sydenham Terminal Station	At the perimeter fence line	5	0.187

Table 7.12: Measured magnetic fields associated with the existing terminal station in the eastern area

Terminal Station	Exposure Scenario	General Public Exposure Reference Level (μT)	Maximum Measured Magnetic Flux Density (μT)
Sydenham Terminal Station	At the perimeter fence line	200	0.32

It is concluded from the comparisons of the measured data with the reference levels that the everyday EMF levels associated with the terminal stations in the Eastern area are well below the ICNIRP public reference levels, which are appropriate for the public areas adjacent to the terminal stations. These measured field levels are typical of public areas near terminal stations as the steel security fencing surrounding the terminal station significantly reduces the electric field levels outside the fenced area and the power equipment associated with strong magnetic fields are typically not located near the public boundary of a terminal station (i.e., the magnetic field levels in public areas are low due to the large separation between the power equipment and the accessible areas).

7.3.3 EMI – existing transmission lines

The radio interference from the existing 500kV transmission lines was calculated at 500kHz, 2m above ground level at the edge of an assumed 60m wide easement. It was also calculated at the standard horizontal distance of 15m from the outermost phase conductor that is specified in AS 2344. The radio interference reference levels specified in AS 2344 are defined at a 500kHz centre frequency. The radio interference emissions from the line were assessed under average wet and dry conditions. The calculated radio interference levels at 500kHz under both average dry and average rain conditions are included in Appendix B.

The radio interference from the existing 500kV transmission lines were also measured at 500kHz, 2m above ground level at the edge of the assumed 60m wide easement and compared to the calculated values and reference levels in Table 7.13. All measurements were made under dry weather conditions and are therefore considered everyday values. The measured data are included in Appendix C.

Table 7.13: Summary of the calculated and measured radio interference levels at 500kHz for the existing 500kV transmission lines within the eastern area

<table>
<tr><th rowspan="3">EMI</th><th colspan="4">Calculated Radio Interference (dBμA/m)</th><th>Measured Radio Interference @ 500kHz (dBμA/m)</th><th colspan="2">Reference Levels (dBμA/m)</th></tr>
<tr><th colspan="2">30m from centreline (edge of easement)</th><th colspan="2">At 15m from outer most conductor</th><th colspan="3">30m from centreline (edge of easement)</th></tr>
<tr><th>Wet</th><th>Dry</th><th>Wet</th><th>Dry</th><th>Dry</th><th>AS 2344</th><th>CIGRE Code 2</th></tr>
<tr><td>Radio Interference @ 500kHz</td><td>18</td><td>0.5</td><td>19</td><td>3</td><td>3.33</td><td>-15.5</td><td>2.5</td></tr>
</table>

FM radio and terrestrial TV reception are more immune to radio interference from a transmission line, as compared to AM radio reception. The radio interference and television interference emissions from the transmission lines at typical broadcast frequencies were calculated near the existing lines and compared to the limits in Table 7.14 for average dry and wet conditions. It is noted that the measured levels are actually the background noise level of the test meter. The calculated levels under dry weather conditions are so low, they are not detectable at a sensitive receptor.

It is evident from the comparisons of the calculated worst case interference levels and the applicable reference levels in Table 7.13 and Table 7.14 that interference is likely to AM radio reception under certain weather and operating conditions under the line and in close proximity to the line easement.

Table 7.14: Summary of the calculated radio and television interference levels at typical AM and FM radio and terrestrial TV broadcast frequencies for the existing 500kV transmission lines within the eastern area

EMI	Calculated Radio Interference (dBµV/m)		Measured Radio Interference (dBµV/m)	Reference Levels (dBµV/m)	
	Wet	Dry	Dry	AS 2344	CIGRE Code 2
AM radio interference @ 500kHz	19	3	3.33	-15.5	2.5
FM radio interference @ 90MHz	27.1	9.6	17	30	48
Terrestrial TV interference @ 600MHz	10.6	-6.9	18	37	55

A desktop review was carried out to identify medical and research equipment that may be particularly sensitive to EMF within the eastern area. The identified sensitive receptors of this type are not located near the existing transmission lines and the calculated magnetic field levels from the existing transmission lines were below 0.03µT (i.e., conservative reference limit discussed in Section 2.2.2) at these distances. The following locations were identified:

- The Capital Radiology Sydenham – approximately 2km from the existing transmission lines.
- Health Scan Specialist Imaging Melton – approximately 4km from the existing transmission lines.
- Lake Imaging Melton – approximately 3km from the existing transmission lines.
- Lake Imaging Bacchus Marsh Hospital – approximately 5km from the existing transmission lines.
- Ballan District Health & Care – Hospital – approximately 23km from the existing transmission lines (outside the study area, requested via stakeholder engagements).

The generic 50Hz magnetic field immunity limit for electrical and electronic equipment and appliances in a residential, commercial or light industrial environment was identified as 3.8µT. Electrical and electronic equipment associated with farm sheds and residential dwellings may be impacted by 50Hz magnetic fields that exceed this level. The worst case calculated magnetic flux density level associated with the existing transmission lines in the eastern area are below the immunity limit at distances greater than 103m from the centre of the transmission line. Houses and sheds within this potential impact zone were therefore considered for potential EMI impacts.

It is assumed that existing point-to-point communication links operate satisfactorily in the existing environment (i.e., the existing transmission lines do not significantly obstruct or interfere with reception). A plan showing the location of point-to-point communication links in the eastern area is provided in Figure 7.2.

7.3.4 EMI – existing terminal station

Field measurements of the EMI from the terminal station were also carried out at the terminal station in the eastern area under dry conditions. The measured data is summarised in Table 7.15 and included in Appendix C.

Table 7.15: Summary of the measured radio interference levels at 500kHz for the existing Sydenham Terminal Station within the eastern area

Terminal Station	Interference Scenario	Measured Radio Interference @ 500kHz (dBµA/m)	Reference Levels (dBµA/m)	
			AS 2344	CIGRE Code 2
Sydenham Terminal Station	At the perimeter fence line	21.55	-15.5	2.5

As was the case for the transmission lines, the dry weather corona noise (see Section 2.2) was so low, it could not be detected at the receiver.

8. Construction impact assessment

8.1 Key issues

Potential impacts for EMI and EMF in relation to the construction activities of the Project are summarised in Table 8.1. Community issues that have been addressed are also summarised. An overview of the significance of impacts is described in the following section.

Table 8.1: Construction impact assessment – Project activities related to EMI and EMF impacts

Project component	Project activity	Potential for impact from EMI and EMF and associated consequence	Standard controls
Project-wide	All activities related to construction of the transmission line and terminal stations (including the intermediate laydown areas and workforce accommodation facilities).	The heavy equipment, trucks, and light vehicles used for construction activities can potentially generate EMF (i.e., moving metal mass through the earth's static magnetic field) and EMI. There is therefore a potential to impact sensitive receptors, including human health, and to cause interference to radio frequency.	Construction areas and access roads will not be located near very sensitive receptors such a medical and scientific research equipment. The electrical and electronic equipment used during construction must have appropriate regulatory Electromagnetic Compatibility (EMC) compliance labelling.
		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 interferences that can impact sensitive receptors such as DGPS.	The radiocommunication equipment used during construction must have appropriate Regulatory Compliance Mark labelling.
Terminal station	Construction works at existing terminal stations (Bulgana and Sydenham) – including laydown areas	Temporary construction staging arrangements may increase EMI and EMF emissions from the terminal stations. There is, therefore, a potential to impact human health and create radio frequency interferences.	All construction staging arrangements will be designed to comply with design standards, thereby ensuring EMI and EMF levels are below the Project limits and reference levels.

8.2 Significance of impacts

During construction of the new 500kV transmission line, the line will not be electrified and it will therefore not produce any EMI or EMF emissions or impacts.

Construction of the Project infrastructure involves commercial plant and electrical equipment that will have appropriate EMC certification. This provides assurance that EMI and EMF emissions from the construction site are below the limits specified in applicable ACMA and product safety standards for a construction environment. When assessing the significance of impacts, this standard control is considered to be implemented as an inherent part of the Project, similar to Project design controls (see Section 4.3.4). This results in negligible EMI impacts for the construction stage of the Project.

Construction workers may need to work at closer distances to live transmission line conductors than the general public are permitted. This includes the time spent near existing operational 220kV transmission lines, in the laydown areas at the existing Bulgana and Sydenham Terminal Stations and at the new 500kV terminal station near Bulgana. They will therefore be exposed to higher EMF levels. To prevent public access to work sites, sites will be restricted with appropriate fencing, and construction workers occupational exposure to EMI and EMF 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).

Considering the above discussion, it is therefore expected that construction of the Project, when assessed with design and standard controls, will have no significant EMF impacts.

9. Operations impact assessment

9.1 Key issues

The potential impacts of EMI and EMF associated with the operation activities of the Project are summarised in Table 9.1. Community issues that have been addressed are also summarised. An overview of the significance of impacts is described in the following sections.

Table 9.1: Operations impact assessment – Project activities related to EMI and EMF impacts

Project component	Project activity	Potential for impact due to EMI and EMF and associated consequence	Standard controls
Project-wide	Operation of the transmission line and terminal stations	Potential for the new transmission line and terminal stations to exceed the electric field strength and magnetic field strength reference levels specified in the ICNIRP guidelines and/or 7kV/m electric field strength limit adopted for the Project, resulting in human health impacts.	Undertake EMI and EMF assessments as part of detailed design. Standard design controls, which were identified in Section 4.3.4, are to be applied during the detailed design process to achieve compliance with the identified assessment criteria. Where compliance with these requirements is not practicable, mitigation measures must be implemented to reduce the risk so far as is reasonably practicable. Refer to **Section 9.3** and **Section 9.4** for details of the mitigations.
		Potential for the new transmission line and terminal stations to interfere with EMF sensitive equipment and general electronic equipment installed in residential, commercial and light industrial environments within close proximity to the Project.	
		Potential for the new transmission line and terminal stations to impact AM radio reception.	
		Potential for the new transmission line (as a form of obstacle) to interfere with point-to-point radio communication links.	
		Potential for the new transmission line and terminal stations to impact agriculture, including livestock, apiaries and GPS.	

9.2 Significance of impacts

Design controls applied to the Project infrastructure (see Section 4.3.4) provide assurance that EMI and EMF emissions from the operational infrastructure are below the limits specified in applicable ACMA and safety standards and guidelines for an operating environment. These design controls are an inherent part of the Project. When discussing the significance of impacts in the sections below, the assessment therefore focuses on the impact after the application of all design controls.

This section provides a detailed assessment of each potential impact identified in Table 9.1.

9.2.1 Estimated EMF levels associated with the Project

As was discussed in the existing conditions section (refer to Sections 7.2.2 and 7.3.2), the EMF in public areas adjacent to terminal stations is lower than that directly under the transmission line entering the terminal station. This is because of the electric field shielding provided by the metal perimeter security fence and the distance between power equipment and the public access areas. The worst-case EMF levels will therefore be within the transmission line easement.

The EMF from the new transmission line were calculated at 1m above ground using the maximum rated transmission line voltages and currents. All calculations were performed using modelling assumptions to provide calculated values that represent the maximum expected values for each of the specified parameters. Plots of the EMF levels are included in Appendix D and the details of the transmission line configuration, voltages and currents used for these calculations are summarised in Table 6.5. The calculated levels are summarised in Table 9.2 and Table 9.3. The EMF from the new transmission line were calculated for both double circuit and single circuit operating states.

Table 9.2: Calculated electric field strength levels associated with the proposed transmission line

Transmission Line	Operating State	Exposure Scenario	Design Limit (kV/m)	Maximum calculated electric field strength (kV/m)	Reference
New 500kV transmission line (sections with double circuit towers)	Double Circuit	Directly under the line	7	5.51	Figure D.1
		30m from centreline (edge of easement)	7	0.94	
	Single Circuit	Directly under the line	7	6.43	Figure D.3
		30m from centreline (edge of easement)	7	0.90	
Existing 220kV transmission line co-located with new 500kV transmission line within a common easement between Bulgana and Waubra	Double Circuit	Directly under the line	7	5.70	Figure D.5
		At edge of assumed easement	7	0.95	
	Single Circuit	Directly under the line	7	6.58[17]	Figure D.7
		At edge of assumed easement	7	0.97[18]	
New 500kV transmission line (sections with two adjacent single-circuit towers)	Double Circuit	Directly under the line	7	6.61	Figure D.9
		At edge of assumed easement	7	2.91	
	Single Circuit	Directly under the line	7	6.52	Figure D.11
		At edge of assumed easement	7	2.86	
New 220kV connections	Double Circuit	Directly under the line	5	2.90	Figure D.13

[17] Sensitivity analysis performed for various circuits out-of-service. Worst case field level is reported.

Transmission Line	Operating State	Exposure Scenario	Design Limit (kV/m)	Maximum calculated electric field strength (kV/m)	Reference
between the existing Bulgana Terminal Station and the new 500kV terminal station near Bulgana		At edge of assumed easement	5	0.35	
	Single Circuit	Directly under the line	5	2.90	Figure D.15
		At edge of assumed easement	5	0.35	

The calculated values are based on the maximum possible voltage and current ratings of the transmission line conductor bundles and represent the maximum possible field levels under any future operating condition. The actual, everyday operating EMF levels are expected to be lower than these worst-case values. In particular, the everyday magnetic field levels are expected to be much lower than worst case values since the typical load currents in the conductors are usually much lower than the load currents under worst case operating conditions. Furthermore, the minimum ground clearances assumed for the calculations occurs when the current is a maximum, which is the rated current used for the calculations. If during normal operation the current is lower, then the conductor sag would decrease so that the ground clearance would increase from the minimum, resulting in lower EMF at 1m above ground level.

The worst-case calculated electric field strength levels are also below the AusNet design limits, which were derived from the ICNIRP basic restrictions. The electric field strength will therefore not exceed the ICNIRP basic restrictions in a person standing directly under the line during the worst-case operating scenario, anywhere along the Project.

The worst-case calculated magnetic field strength levels are also below the ICNIRP reference levels for public exposure (Table 9.3).

Table 9.3: Calculated magnetic flux density levels associated with the proposed transmission line

Transmission Line	Operating State	Scenario	General Public Exposure Reference Level (μT)	Maximum Calculated Magnetic Flux Density (μT)	Reference
New 500kV transmission line (sections with double circuit towers)	Double Circuit	Directly under the line	200	28.3	Figure D.2
		30m from centreline (edge of easement)	200	7.68	
	Single Circuit	Directly under the line	200	23.9	Figure D.4
		30m from centreline (edge of easement)	200	10.9	
Existing 220kV transmission line co-located with new 500kV transmission line within a common easement between Bulgana and Waubra	Double Circuit	Directly under the line	200	31.0	Figure D.6
		At edge of assumed easement	200	7.6	
	Single Circuit	Directly under the line	200	32.6	Figure D.8

Transmission Line	Operating State	Scenario	General Public Exposure Reference Level (µT)	Maximum Calculated Magnetic Flux Density (µT)	Reference
		At edge of assumed easement	200	11	
New 500kV transmission line (sections with two adjacent single-circuit towers)	Double Circuit	Directly under the line	200	39.6	Figure D.10
		At edge of assumed easement	200	16.56	
	Single Circuit	Directly under the line	200	43.5	Figure D.12
		At edge of assumed easement	200	14.2	
New 220kV connections between the existing Bulgana Terminal Station and the new 500kV terminal station near Bulgana	Double Circuit	Directly under the line	200	33.4	Figure D.14
		At edge of assumed easement	200	6	
	Single Circuit	Directly under the line	200	36.6	Figure D.16
		At edge of assumed easement	200	4.6	

9.2.1.1 Human health impacts

It is not expected persons other than AusNet employees or contractors would spend significant periods of time within or close to the transmission infrastructure. AusNet employees and contractors working within the easement will do so in accordance with relevant health, safety and environmental guidelines and procedures.

As the Project traverses through rural properties, it is likely that landholders engaged in land management or agricultural activities will spend time adjacent to or under the transmission line. Such persons may be subjected temporarily to a higher EMF than they might experience in their home. These EMF levels do not however exceed the conservative field strength limit defined for the Project. In areas where the electric field strength may exceed 5kV/m during worst-case operating scenarios, people may experience micro-shocks to metalwork directly under the line (e.g., farm fences). In such cases, the metalwork will be earthed, relocated outside the area subject to elevated electric field or replaced with a non-conductive equivalent.

Electric field exposure outside of transmission line easements are significantly lower (2.91kV/m) than the levels directly underneath the line and well below the 7kV/m AusNet design limit and the 5kV/m limit used to assess the risk of micro-shocks under all operating conditions. Similarly, the magnetic field strength exposure outside of transmission line easements are significantly lower (14.2µT) than the levels directly underneath the line and well below the ICNIRP reference levels (200µT) under all operating conditions. The transmission line, therefore, does not pose any health impacts to the general public, residents or workers outside the transmission line easement.

Furthermore, the worst-case calculated EMF levels are below the indicated references levels associated with Active Implantable Medical Devices and do not pose a risk to people with such devices.

Based on the impact assessment presented in this section for potential impacts on human health, it is concluded that the EMF from the Project infrastructure will not have a significant impact on human health. Additional mitigation is not required to meet the scoping requirement in Section 3.2.

9.2.1.2 Potential for impact on agriculture

The local and international studies discussed in Section 2.1.5 concluded that EMF levels comparable with the calculated values presented in this section do not pose any impacts to the general health or production in small/large ungulates.

As discussed in Section 2.1.6, apiaries may be impacted if the electric field is greater than 4.1kV/m or the magnetic field exceeds 100µT for an extended period of time. The worst case calculated electric field directly under the new 500kV transmission line may exceed 4.1kV/m at 1m above ground level in areas where the minimum ground clearance to the line's conductors approaches the 15m limit. The worst case calculated magnetic field strength under any operating condition is 43.5µT. Impacts on apiaries located directly under the new 500kV transmission line are therefore possible but unlikely as the extent of the areas subjected to an electric field strength exceeding 4.1kV are very limited along the proposed lines and existing apiaries were not identified in these areas in the desktop assessment. Prior to construction, any apiaries that are identified in areas subjected to the elevated electric fields, will be relocated outside the transmission line easement to eliminate all known effects on the health of the apiaries (EPR EL1). Magnetic field levels under the transmission line do not exceed 100µT and therefore are not expected to impact apiaries.

The Australian Government's National Standard for Organic and Bio-Dynamic Produce (Edition 3.7, 2016) does not specifically mention transmission lines or EMF (Department of Agriculture and Water Resources, 2016). 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." The Project is not located within close proximity of any known organic or bio-dynamic produce storage areas and will therefore not impact organic or bio-dynamic certification at existing facilities.

Based on the impact assessment presented in this section for potential impacts on agriculture and the desktop audit that identified no apiaries along the Proposed Route, it is concluded that the EMF from the Project infrastructure will not have a significant impact on agriculture. Additional mitigation is not required to meet the scoping requirement in Section 3.2. However, as defined in EPR EL1, the impact assessment must be verified during detailed design and mitigation, which would be relocation of impacted apiaries away from the line, must be implemented as required.

9.2.1.3 Sensitive receptors

A desktop review was carried out to identify medical and research equipment that may be particularly sensitive to magnetic fields. The following locations were identified, these are shown in Figure 9.1:

- The Ochre Medical Centre Creswick – approximately 6.8km from the proposed transmission line route
- Capital Radiology Sydenham – approximately 1.9km from the proposed transmission line route
- Health Scan Specialist Imaging Melton – approximately 3.5km from the proposed transmission line route
- Lake Imaging Melton - approximately 3.3km from the proposed transmission line route
- Lake Imaging Bacchus Marsh Hospital - approximately 4.9km from the proposed transmission line route
- Ballan District Health & Care Hospital – approximately 3.4km from the proposed transmission line route

The identified sensitive receptors of this type are not located near the proposed transmission line route and the calculated magnetic field levels from the proposed transmission route were below 0.03µT (i.e., the conservative reference limit discussed in Section 2.2.2) at these distances.

Southern Rural Water's Merrimu Reservoir dam is located approximately 230m south of the new transmission line route. There are no radio telemetry links at the reservoir and any equipment in the site should be specified for an industrial environment. The industrial limit of 37.6μT that is defined in AS/NZS 61000.6.2 therefore applies. The calculated 50Hz magnetic field strength associated with the proposed transmission line is below this level during worst case operating conditions underneath the conductors and at any point away from the line. It is also below the 3.8μT magnetic field limit specified in AS/NZS 61000.6.1 should non-industrial rated equipment be installed at the reservoir. Mitigation will therefore not be required.

Electrical and electronic equipment found more generally in residential, commercial and light industrial environments within the study area may be less immune to magnetic fields than the industrial equipment. The required immunity limit for general equipment in this environment is defined in AS/NZS 61000.6.1 as 3.8μT for 50Hz magnetic fields. The calculated 50Hz magnetic field strength associated with the proposed transmission line are below this level at distances greater than 48m from centre of the transmission line during worst case operating conditions. No sensitive receptors were identified along the Proposed Route within the identified impact zone. Under normal operating conditions, the magnetic field will not exceed this level outside the easement. Dwellings and farm buildings will not be permitted within a transmission line easement, therefore any residential electrical and electronic equipment will not be affected.

Based on the impact assessment presented in this section for potential impacts on sensitive receptors and the desktop audit in the study area, it is concluded that the magnetic fields from the Project infrastructure will have a negligible impact on sensitive receptors. Additional mitigation is not required to meet the scoping requirement in Section 3.2.

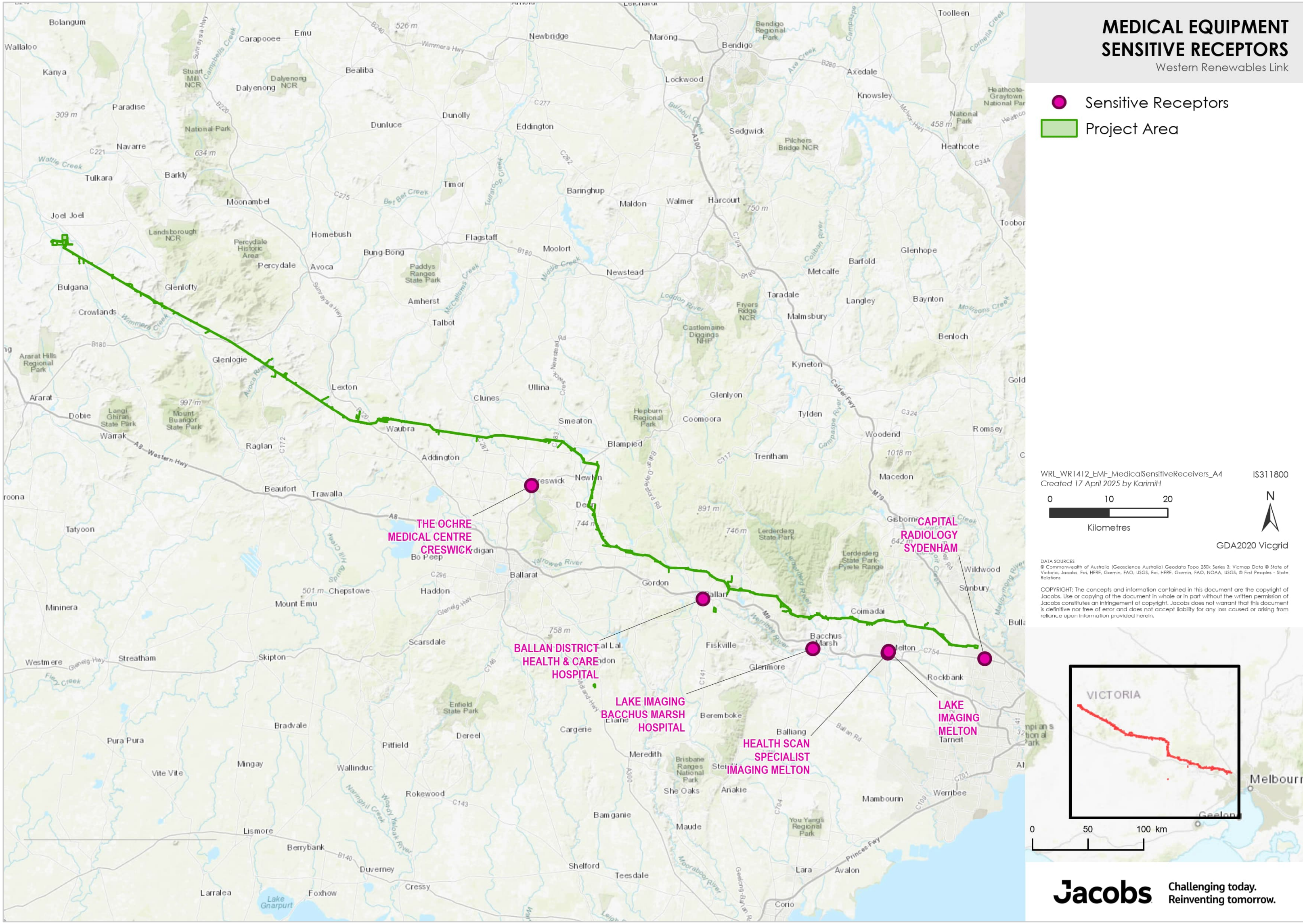

Figure 9.1: Medical Sensitive receptors in close proximity to the Project Area (Source: Jacobs, 2025)

9.2.2 Estimated EMI associated with the Project

The radio interference from the proposed transmission line was calculated using the semi-empirical method defined by the Electric Power Research Institute (EPRI) at 500kHz, 2m above ground level at the edge of an assumed easement (EPRI, 2005 [23]). Empirical correction factors developed by both CIGRE and BPA were also applied to derive the EMI levels at frequencies other than 500kHz, as is appropriate for the receiver type and broadcast frequency band. The assumed easement width for the proposed 500kV transmission line is 60m. The radio interference emissions from the proposed transmission line were assessed under heavy rain, average rain (wet conductor) and average fair weather (dry conductor) conditions. The heavy rain levels represent the worst-case radio interference from the transmission line and the average dry levels represent the most likely EMI emission from the proposed transmission line. The radio interference calculation plots are included in Appendix E. The results are summarised in Table 9.4.

Table 9.4: Summary of the calculated radio interference levels for the proposed transmission line

Transmission Lines	Operating State	Calculated Radio Interference @ 500kHz (dBµA/m)			Reference Levels (dBµA/m)	
		Dry	Wet	Heavy Rain	AS 2344	CIGRE Code 2
New 500kV transmission line (sections with double circuit towers)	Double Circuit	-2.96	14.5	23.3	-15.5	2.5
	Single Circuit	-5.20	12.3	21.6	-15.5	2.5
Existing 220kV transmission line co-located with new 500kV transmission line (between Bulgana to Waubra)	Double Circuit	-1.57	15.93	24.6	-15.5	2.5
	Single Circuit	-1.48	16.06	24.7	-15.5	2.5
New 500kV transmission line (sections with two adjacent single-circuit towers)	Double Circuit	-4.14	13.36	22.77	-15.5	2.5
	Single Circuit	-5.42	12.08	21.57	-15.5	2.5
New 220kV connections between the existing Bulgana Terminal Station and the new 500kV terminal station near Bulgana	Double Circuit	n/a*	n/a*	n/a*	-15.5	2.5
	Single Circuit	n/a*	n/a*	n/a*	-15.5	2.5

* The calculated value is negligible due to the very low surface voltage gradient

9.2.2.1 Impact on AM Radio Reception

The study area has multiple AM radio transmitters providing coverage to the general public. Only AM radio stations with reasonable received signal strength within the study area are considered in the assessment. Reception of other AM radio stations would already be an issue in the study area (i.e., an existing condition) and AS 2344 doesn't require that reception of these stations be considered in the interference assessment. The calculated Radio Interference from the proposed transmission line is compared to both the AS 2344 and CIGRE Code 2 reference levels in Table 9.5 for the relevant AM radio stations.

The radio interference calculation plots are included in Appendix E and the broadcast strength plots are included in Appendix G. The calculated radio interference levels at the edge of the transmission line easement will exceed the AS 2344 reference levels for AM radio reception under dry and wet conditions. However, the average signal strength for AM radio reception in the study area is good and it is unlikely that the worst-case radio interference from the proposed transmission line will significantly impact the quality of radio reception near the line easement in areas currently experiencing good radio reception. In areas where the existing quality of radio reception is poor, the negative impact of the radio interference from the new transmission line on the quality of AM radio reception may be pronounced under rain conditions.

Table 9.5: Radio Interference assessment for AM radio reception within the study area

AM Radio Station	Transmitter Location	Site ID	Frequency (kHz)	Minimum Signal Strength at Easement (dBμA/m)	Calculated Radio Interference (dBμA/m)		Reference Levels (dBμA/m)	
					Wet	Dry	AS2344	CIGRE Code 2
ABC Radio Melbourne (Figure G.6)	Delahey	140387	774	63	12.1	-5.4	-15.5	51
ABC RN (Figure G.7)	Delahey	140388	621	63	13.4	-4.1	-15.5	51
ABC Wimmera (Figure G.8)	Horsham	40474	594	68	15.1	-2.4	-15.5	56

Based on the impact assessment presented in this section for potential impacts on AM radio reception, it is concluded that the EMI from the Project infrastructure may have a minor impact on AM radio reception during rain conditions. There are no practicable mitigation measures that will reduce this impact (refer to Section 9.4) to negligible and mitigation is not considered necessary to meet the scoping requirement in Section 3.2.

9.2.2.2 Impact on FM Radio Reception

Commercial FM radio services in the study area are provided by multiple transmitters. A summary of the calculated signal strength and radio frequency interference emissions associated with these transmitters is provided in Table 9.6. Major radio transmission sites within the study area include a site at Harcourt North (Site ID 11742), Ballarat (Site ID 36240) and Ararat (Site ID 11729).

The radio interference calculation plots are included in Appendix E and the broadcast strength plots are included in Appendix G. The calculated radio interference levels at the edge of the transmission line easement will be below the AS 2344 reference levels for FM radio under dry and wet conditions. There are some FM radio stations that currently have poor average broadcast signal strength in the study area and the quality of reception of these radio stations may be impacted. There are however alternative radio stations with strong broadcast signal strength that will not be significantly impacted by the radio interference under any weather and operating conditions.

Table 9.6: Radio Interference assessment for FM radio reception within the study area

FM Radio Station	Transmitter Location	Site ID	Frequency (MHz)	Minimum Signal Strength at Easement (dBμV/m)	Calculated Radio Interference (dBμV/m)		Reference Levels (dBμV/m)	
					Wet	Dry	AS2344	CIGRE Code 2
ABC Central Victoria (Figure G.11)	Bendigo	11742	91.1	22	27.24	9.74	30	10
ABC News Radio (Figure G.12)	Bendigo	11742	89.5	17	27.39	9.89	30	5
979fm – Community radio (Figure G.9)	Mt Kororoit	35081	97.9	60	25.2	7.75	30	48
Bacchus Marsh Community Radio (Figure G.10)	Bacchus Marsh	152917	98.5	68	25.16	7.7	30	56
Radio Technologies Site (Figure G.13)	Bacchus Marsh	41707	162.6	57	20.96	3.46	30	45

Based on the impact assessment presented in this section for potential impacts on FM radio reception, it is concluded that the EMI from the Project infrastructure may have a minor impact on FM radio reception during rain conditions. There are no practicable mitigation measures that will reduce this impact to negligible (refer to Section 9.4) and mitigation is not considered necessary to meet the scoping requirement in Section 3.2.

9.2.2.3 Impact on emergency services

The study area has coverage for various community broadcast services, including Health, Police and Emergency Services, summarised in Table 9.7, and Country Fire Authority (CFA) services, summarised in Table 9.8. The radio interference calculation plots are included in Appendix E and the broadcast strength plots are included in Appendix G. The calculated radio interference levels at the edge of the transmission line easement will be below the AS 2344 reference levels for Health, Police and Emergency Services radio broadcasts under dry and wet conditions. There are some High Frequency (HF) radio channels that may be impacted under rain conditions. These broadcasts generally have strong signal strength within the study area, and it is unlikely any EMI effects will be significant in these channels under any weather and operating conditions.

Table 9.7: Radio Interference assessment for Health, Police and Emergency Services radio broadcasts with coverage within the study area

Service	Transmitter Location	Site ID	Frequency (MHz)	Minimum Signal Strength at Easement (dBµV/m)	Calculated Radio Interference (dBµV/m)		Reference Levels (dBµV/m)	
					Wet	Dry	AS2344	CIGRE Code 2
Western Health (Figure G.17)	St Albans	42653	40.75	70.8	32.83	15.37	30	58.8
Department of Justice and Community Safety (Figure G.18)	St Albans	42653	148.6875	80.8	21.59	4.13	30	68.8
Coburns Road Airfield (Figure G.20)	Melton	47875	124.2	87	23.15	5.69	30	75
Victoria SES (Figure G.14)	Melton	43867	2.5705	105	52.33	34.87	34.8	93
Victoria SES (Figure G.15)	Melton	43868	3.7335	100.8	47.5	30.04	34.2	88.8
Victoria SES (Figure G.16)	Bacchus Marsh	43914	2.5705	95.8	52.33	34.87	34.8	83.8
Department of Justice and Community Safety (Figure G.21)	Melton	50618	164.85	57	20.84	3.34	30	45
Department of Justice and Community Safety (Figure G.22)	Melton	300276	148.69	57	21.73	4.23	30	45
Department of Justice and Community Safety (Figure G.23)	Sydenham	10010678	421.475	57	12.68	-4.82	37	45

Table 9.8: Radio Interference assessment for Country Fire Authority radio broadcasts with coverage within the study area

Service	Transmitter Location	Site ID	Frequency (MHz)	Minimum Signal Strength at Easement (dBμV/m)	Calculated Radio Interference (dBμV/m)		Reference Levels (dBμV/m)	
					Wet	Dry	AS2344	CIGRE Code 2
CFA (Figure G.24)	Elmhurst	45999	161.075	97	20.86	3.46	30	85
CFA (Figure G.47)	Mt Lonarch	42198	161.075	52	20.86	3.46	30	40
CFA (Figure G.51)	Smeaton Hill	44049	161.025	67	20.86	3.46	30	55
CFA (Figure G.43)	Melton	45914	161.05	72	20.86	3.46	30	60
CFA (Figure G.28)	Bacchus Marsh	45918	161.05	67	20.86	3.46	30	55
CFA (Figure G.44)	Melton	45933	161.05	27	20.86	3.46	30	15
CFA (Figure G.48)	Myrniong	45937	161.05	67	20.86	3.46	30	55
CFA (Figure G.50)	Rocklyn	45981	161.025	67	20.86	3.46	30	55
CFA (Figure G.42)	Lexton	46002	161.075	72	20.86	3.46	30	60
CFA (Figure G.33)	Clunes	46139	161.025	72	20.86	3.46	30	60
CFA (Figure G.37)	Greendale	46142	161.025	72	20.86	3.46	30	60
CFA (Figure G.41)	Learmonth	45145	161.2	72	20.85	3.45	30	60
CFA (Figure G.35)	Creswick	46294	161.025	57	20.86	3.46	30	45
CFA (Figure G.25)	Greendale	46386	161.025	62	20.86	3.46	30	50
CFA (Figure G.38)	Greendale	137895	161.025	77	20.86	3.46	30	65
CFA (Figure G.49)	Newlyn	137985	161.025	72	20.86	3.46	30	60
CFA (Figure G.40)	Kingston	138156	161.025	77	20.86	3.46	30	65
CFA (Figure G.32)	Burnbank	140910	161.075	72	20.86	3.46	30	60
CFA (Figure G.27)	Ascot	140919	161.025	77	20.86	3.46	30	65
CFA	Melton	141937	162.375	72	20.79	3.39	30	60

Service	Transmitter Location	Site ID	Frequency (MHz)	Minimum Signal Strength at Easement (dBμV/m)	Calculated Radio Interference (dBμV/m)		Reference Levels (dBμV/m)	
					Wet	Dry	AS2344	CIGRE Code 2
(Figure G.45)								
CFA (Figure G.31)	Bunding	302624	161.025	97	20.86	3.46	30	85
CFA (Figure G.36)	Diggers Rest	303127	161.05	37	20.86	3.46	30	25
CFA (Figure G.29)	Bacchus Marsh	303130	161.05	37	20.86	3.46	30	25
CFA (Figure G.39)	Greenvale	10009936	161.05	72	20.86	3.46	30	60
CFA (Figure G.30)	Bulla	10011129	161.05	72	20.86	3.46	30	60
CFA (Figure G.52)	Toolern Vale	10011130	161.05	72	20.86	3.46	30	60
CFA (Figure G.46)	Melton South	10011131	161.05	72	20.86	3.46	30	60
CFA (Figure G.26)	Aintree	10023351	162.375	57	20.79	3.39	30	45
CFA (Figure G.34)	Cobblebank	10024989	162.375	57	20.79	3.39	30	45

Based on the impact assessment presented in this section for potential impacts on emergency services radio reception, it is concluded that the EMI from the Project infrastructure may have a minor impact on emergency services radio reception during rain conditions. There are no practicable mitigation measures that will reduce this impact to negligible (refer to Section 9.4) and mitigation is not considered necessary to meet the scoping requirement in Section 3.2.

9.2.2.4 Impact on TV reception

Commercial TV services in the area comprise Digital TV (DTV) broadcasts from the Ballarat East (36762) transmission tower. A summary of the calculated DTV signal strength and Television interference emission levels from the proposed transmission line at the broadcast frequencies associated with these transmitters is provided in Table 9.9. The television interference calculation plots are included in Appendix E and the broadcast strength plots are included in Appendix G.

The calculated television interference levels at the edge of the transmission line easement will be below the AS 2344 reference levels under dry and wet conditions. EMI effects to television broadcast reception within the study area will not be significant under any weather and operating conditions.

Based on the impact assessment presented in this section for potential impacts on TV reception, it is concluded that the EMI from the Project infrastructure will have a negligible impact on TV reception. Mitigation measures are not required to meet the scoping requirement in Section 3.2.

Table 9.9: Radio frequency interference assessment for DTV broadcast reception within the study area

Coverage Area	TV Station	Transmitter Location	Frequency (MHz)	Station Site ID	Minimum Signal Strength at Easement (dBµV/m)	Calculated Radio Interference (dBµV/m)		Reference Level (dBµV/m)
						Wet	Dry	AS2344
Ballarat East (Figure G.2)	SBS	Ballarat East	613.5	36762	22	9.27	-8.19	37
Ballarat East (Figure G.1)	ABC	Ballarat East	620.5	36762	22	9.18	-8.28	37
Ballarat East (Figure G.3)	Seven	Ballarat East	627.5	36762	22	9.08	-8.38	37
Ballarat East (Figure G.4)	Nine	Ballarat East	634.5	36762	22	8.98	-8.48	37
Ballarat East (Figure G.5)	Ten	Ballarat East	641.5	36762	22	8.89	-8.57	37

9.2.2.5 Impact on point-to-point communications

The communication installations identified in Table 9.10are located within the transmission line easements. As discussed in Section 2.2.1, the new line conductor should not penetrate more than 40% into the primary Fresnel Zone as this may impact the performance of the communication channel. While the conductors would be within the primary Fresnel Zone of these links, it is still considered unlikely that it would significantly impact the link signal to such an extent as needing any at-receiver mitigations (e.g., in order of application: increasing transmit power level, increasing the antenna height, or the relocation of the antenna). As such, while it is possible that at-receiver mitigations could be required, final verification of impact (per EPR EL1) will be necessary to confirm approach.

Table 9.10: Point to Point radio links with an antenna located within the transmission line easement

ID	Name	Distance to Centreline (m)	Asset Owner/Operator
49810	Met Bureau site LERDERDERG	5.42	Bureau of Meteorology
9026397	Ararat Terminal Station Easter Brooks Lane ELMHURST	16.10	Powercor

There are also a number of point-to-point radio links that are located outside the line easements but intercept the study area and may be impacted by the transmission line conductors and towers. Details of these links and the EMI risk assessment are summarised in Table 9.11. The EMI calculation plots are included in Appendix F.

It is noted that the horizontal conductors and steel lattice towers do not present significant coverage as an obstacle to radio waves at VHF and higher frequencies or for transmitters and receivers outside the transmission line easement. The EMI assessments in Table 9.11 are therefore conservative. As per EPR EL1, a detailed investigation of potential communication link performance issues is required at the detailed design stage to confirm if any at-receptor mitigation is required.

Based on the impact assessment presented in this section for potential impacts on point-to-point communication links, it is concluded that the EMI from the Project infrastructure, though unlikely, has the potential to have a moderate impact on some point-to-point communication links in the study area. It is possible that mitigation measures are required to meet the scoping requirement in Section 3.2. The key mitigation of a detailed investigation of potential point-to-point communication link performance issues prior to the operation of the transmission line (EPR EL1) will be required to confirm if there is any significant impact. If at that time a significant impact is found to have occurred, then further mitigation, such as (in order of application) an increase in transmit power level, an increase in antenna height, or the relocation of the antenna may be applied. The selected mitigation measures will reduce the impact rating to negligible.

Table 9.11: Impact of proposed transmission line on point-to-point radio links within the study area

Site 1		Site 2		Lowest Frequency (MHz)	Potential impact on performance of communication link	Penetration into 1st Fresnel Zone (%)
Address	Site ID	Address	Site ID			
Fire Tower Ben Nevis Road, Ben Nevis (Figure F.16)	300696	Mid-State Foods 56 Loch Street, Maryborough	300697	6063.8	No	0
Green Hill Creek Road (Eureka Concrete Quarry), Amphitheatre (Figure F.39)	10009554	Fire Tower Ben Nevis Road, Ben Nevis	300696	7866.3	No	0
Powercor Site Keith Road, Glenlogie (Figure F.28)	9026396	Fire Tower 1.7km W of Maldon Mt Tarrengower	11748	1438.5	No	0
Air Services Australia / CFA Site Smeaton Hill (Figure F.2)	46213	Air Services Australia Site, Ben Nevis	49290	7431.5	No	0
Passive Reflector Quoin Hill, Waubra (Figure F.37)	9004445	Waubra Terminal Station Troys Road, Waubra	9004444	7821.825	No	0
Old SEC tower Powernet site 9km E of Ballarat, Mt Warrenheip (Figure F.36)	11724	Passive Reflector Quion Hill, Waubra	9004445	7821.825	No	0
Water Storage Tank Ballarat Maryborough Road, Clunes (Figure F.19)	9015847	Central Highlands Water Radio Site 14km NNW of Ballarat, Mt Hollowback	305907	404	Yes	100
Water Tower Stoneham Drive, Maryborough (Figure F.10)	306085	Central Highlands Water Radio Site 14km NNW of Ballarat, Mt Hollowback	305907	404.075	No	30
Vic-TV Site 14km NNW of Ballarat, Mt Hollowback (Figure F.8)	11722	Telstra RT, Maryborough	36747	5945.2	No	0
Telstra Site 14km NNW of Ballarat, Mt Hollowback (Figure F.46)	11723	Telstra RT, Maryborough	36747	7463	No	0
Clunes Golf Course Road, Clunes (Figure F.32)	10006169	Optus Site Alcorns Road, Creswick	303691	7866.3	No	0

Site 1		Site 2		Lowest Frequency (MHz)	Potential impact on performance of communication link	Penetration into 1st Fresnel Zone (%)
Address	Site ID	Address	Site ID			
TXU Networks/CFA Site Mt Herbert off Calder Highway, Ravenswood (Figure F.12)	36862	Central Highlands Water Radio Site 14km NNW of Ballarat, Mt Hollowback	305907	404.65	Yes	70
Central Highlands Water site, Smeaton Hill (Figure F.11)	44049	Central Highlands Water Radio Site 14km NNW of Ballarat, Mt Hollowback	305907	404.075	No	0
NBN Co Site 37 White Hills Road, Smeaton (Figure F.29)	9015337	Optus Site Alcorns Road, Creswick	303691	10815	No	0
Central Highlands Water Site, Smeaton Hill (Figure F.1)	44049	Vertel Tower Mt Warrenheip Lot 2045, Mt Warrenheip Road, Dunnstown	11727	404.15	No	0
Clarks Hill Daylesford Ballarat Road south of Church Road, Ballarat (Figure F.7)	305522	Fire Tower 1.7km W of Maldon, Mt Tarrengower	11748	1430.5	No	0
NBN Co Site Lot 1 Telegraph Road, Newlyn North (Figure F.47)	9017513	NBN Co Site 90 Old Main Road, Eganstown	10004765	11075	No	0
Old SEC tower Powernet site 9km E of Ballarat, Mt Warrenheip (Figure F.33)	11724	Fire Watch Tower 15km NNW of Bacchus Marsh, Mt Blackwood	11706	7762.525	No	0
Telstra Site 12km SE of Ballarat, Mt Buninyong (Figure F.17)	11717	Telstra Pole 15km NNW of Bacchus Marsh, Mt Blackwood	11707	7459.5	No	0
Inglison Lot 1 Ingliston Road, Ballan (Figure F.44)	10010444	NBN Co Site Struck Oil Track, Greendale	9027029	7866.3	No	0
Moorabool Terminal Station Anakie Road, Lovely Banks (Figure F.34)	47904	Fire Watch Tower 15km NNW of Bacchus Marsh, Mt Blackwood	11706	7821.825	No	0
NBN Co Site 90 Mt Blackwood Road Myrniong (Figure F.43)	9027033	NBN Co Site Crown Allot. 2003 Parish of Blackwood, Greendale	9027031	10915	Yes	100
Telstra Pole 15km NNW of Bacchus Marsh, Mt Blackwood (Figure F.20)	11707	Tower Montpellier Service Basin, Highton	11681	450.76875	No	0
Bureau of Meteorology site, Mt Hope (Figure F.22)	49803	Bureau of Meteorology, Mt Cottrell	305446	151.5	Yes	100

Site 1		Site 2		Lowest Frequency (MHz)	Potential impact on performance of communication link	Penetration into 1st Fresnel Zone (%)
Address	Site ID	Address	Site ID			
Crown Castle Site Bald Hill off Swans Road, Darley (Figure F.21)	51030	Fire Watch Tower 15km NNW of Bacchus Marsh, Mt Blackwood	11706	18332.5	No	0
Telstra Pole 15km NNW of Bacchus Marsh, Mt Blackwood (Figure F.15)	11707	Telstra Exchange Gell Street, Bacchus Marsh	50537	10815	No	5
Bureau of Meteorology, Lerderderg (Figure F.23)	49810	Bureau of Meteorology, Mt Cottrell	305446	151.5	No	0
NBN Co Site 1011 Bacchus Marsh Road Bullengarook (Figure F.45)	9027030	NBN Co Site 4494 Geelong-Bacchus Marsh Road Maddingley	9027032	6640	No	0
Crown Castle Site Bald Hill off Swans Road, Darley (Figure F.41)	51030	Burkes Hill Reservoir Road, Sunbury	570406	6019.325	No	0
Fire Watch Tower 15km NNW of Bacchus Marsh Mt Blackwood (Figure F.18)	11706	Vodafone Site Old Lion Park, 1611-1781 Western Highway, Rockbank	130382	6004.5	No	0
Met Bureau Site, Blue Mountain (Figure F.24)	49802	Bureau of Meteorology site, Mt Cottrell	305446	151.5	No	0
Treatment Plant Diggers Rest Coimadai Road, Toolern Vale (Figure F.14)	303439	Dodemaide Ct, Merrimu	305057	404.9	Yes	100
Treatment Plant Diggers Rest Coimadai Road Toolern Vale (Figure F.42)	303439	Telstra/Optus Site cnr Western Highway / Long forest Road, Bacchus Marsh	301321	18305	Yes	100
Water Tank Diggers Rest Coimadai Road, Merrimu (Figure F.48)	9020838	Western Water Butlers Road, Mt Cottrell	303440	18332.5	Yes	100
Treatment Plant Diggers Rest - Coimadai Road, Toolern Vale (Figure F.13)	303439	Minns Road Tank Tower, Melton	305601	404.825	Yes	100
Met Bureau Site, Mt Bullengarook (Figure F.26)	53497	Bureau of Meteorology, Mt Cottrell	305446	151.5	No	0
Optus Site 559 Coburns Road Toolern (Figure F.38)	305670	Telstra Site 273 Gisborne - Melton Road Toolern Vale	9007557	7866.3	No	0
Met Bureau Site Toolern Vale (Figure F.25)	49768	Bureau of Meteorology, Mt Cottrell	305446	151.5	Yes	80

Site 1		Site 2		Lowest Frequency (MHz)	Potential impact on performance of communication link	Penetration into 1st Fresnel Zone (%)
Address	Site ID	Address	Site ID			
AirServices Tower, Mt Cottrell (Figure F.3)	46253	Air Services Tower, Mt Macedon	11736	7431.5	No	0
Telstra Site Rockbank Exchange 16 Old Leakes Road ROCKBANK (Figure F.31)	37273	Telstra CMTS Toolern Vale 273 Gisborne-Melton Road, Toolern Vale	9003405	7866.3	No	0
Victoria Police Site Circular Drive, Sunbury (Figure F.6)	41442	Police & Ambulance Site Mt Anakie	11694	7477	No	0
Jacksons Hill Storage Tank The Heights, Sunbury (Figure F.40)	305058	Green Hill Water Storage Tank Site Off Mount Mary Road, Eynesbury	9016906	404.5	Yes	100
Elevated Tank Hillview Court, Hillside (Figure F.30)	300651	CMTS Site 1376 Calder Highway, Diggers Rest	300951	21868	Yes	100
Victoria Road, Sydenham (Figure F.35)	53016	Fire Watch Tower 15km NNW of Bacchus Marsh, Mt Blackwood	11706	7821.825	No	0
Powercor Site Keith Road, Glenlogie (Figure F.27)	9026396	Ararat Terminal Station Easter Brooks Lane, Elmhurst	9026397	1434.5	No	0

9.2.2.6 Impact on mobile phone communications

There are multiple Optus, Telstra and Vodafone operated transmitter stations within the study area. The National Broadband Network also has transmitter stations associated with but separate from these service providers. The EMI assessment for these transmitters is summarised in Table 9.12. The shadowing and scattering effects of the steel lattice transmission line towers will be negligible at these higher mobile frequencies. The transmission line structures and conductors do not therefore impact mobile phone or WiFi reception.

The calculated EMI levels at the edge of the transmission line easement will be below the AS 2344 reference levels for mobile phone and WiFi broadcast reception under dry and wet conditions. Therefore, EMI effects to mobile phone and WiFi broadcast reception within the study area will not be significant under any weather and operating conditions in areas currently experiencing good reception.

Table 9.12: Radio Interference assessment for mobile phone communications within the study area

Service Provider	Station Site ID	Transmitter Location	Frequency (MHz)	Minimum Signal Strength at Easement (dBµV/m)	Calculated Radio Interference (dBµV/m)		Reference Level (dBµV/m)
					Wet	Dry	AS2344
Optus	10002141	Ballan	762	82	7.39	-10.07	37
Vodafone	303691	Creswick	872.5	82	6.22	-11.24	37
Telstra	3350019	Ballarat	700	82	8.13	-9.33	37
Optus	51728	Taylors Lakes	763	57	7.53	-9.97	37
Optus	206097	Sydenham	763	57	7.53	-9.97	37
TPG Internet	300748	Melton West	795.5	57	7.17	-10.33	37
Optus	301329	Taylors Lakes	763	57	7.53	-9.97	37
Optus	301469	Hillside	763	57	7.53	-9.97	37
Optus	302961	Bacchus Marsh North	763	57	7.53	-9.97	37
Optus	9004194	Sydenham	763	57	7.53	-9.97	37
Optus	9015616	Sydenham	763	57	7.53	-9.97	37
Optus	9024297	Melton	763	57	7.53	-9.97	37
Optus	9026099	Melton West	763	57	7.53	-9.97	37
Optus	10000253	Ballan	763	57	7.53	-9.97	37
Optus	10002141	Water Gardens	763	57	7.53	-9.97	37
Optus	10021234	Keilor North	763	57	7.53	-9.97	37
Telstra	10022825	Taylors Lake	778	57	7.36	-10.14	37
Optus	10026244	Plumpton	763	57	7.53	-9.97	37
Optus	10029538	Delahey	763	57	7.53	-9.97	37

Based on the impact assessment presented in this section for potential impacts on mobile phone (or WiFi) communications, it is concluded that the EMI from the Project infrastructure will have a negligible impact on mobile phone communications. As such, mitigation measures are not required to meet the scoping requirement in Section 3.2.

9.2.2.7 Impact on agricultural equipment

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 1GHz and 2GHz. A study conducted by J.M. Silva and R.G. Olsen on the use of GPS receivers under power-line conductors found that no degradation in receiver performance was attributed to electromagnetic emissions from transmission lines under normal or foul weather (Silva and Olsen [25]). There is a risk that damaged transmission line insulators or fittings may cause some interference to GPS systems (refer to Section 9.4).

The DGPS systems used in Australia for land navigation broadcast correction signals in a commercial FM radio band. It was concluded in Section 9.2.2.2 that the operation of the new transmission line will produce Radio Interference at levels below the AS 2344 reference level for commercial radio bands under all weather and operating conditions. Compliance with the AS 2344 reference levels, however, is not assessed directly under the line.

There is a minor impact of EMI on DGPS correction signals for land navigation directly under the proposed 500kV transmission line in heavy rain conditions. The momentary interruption of DGPS correction signals as mobile agricultural equipment passes directly under the line will not impact autonomous operations as the existing correction will be utilised under the line and updated once the equipment clears the area under the line. Additional mitigation measures are therefore not required to meet the scoping requirement in Section 3.

There are no practicable mitigation measures that will reduce this impact to negligible (refer to Section 9.4). Additional mitigation is therefore not considered necessary to meet the scoping requirement in Section 3.2.

9.3 Mitigation of impacts

The EMI and EMF impact assessments presented in the previous section considered standard design controls that are effective for reducing exposure to EMF (Section 4.3.4). Other mitigations and controls discussed in the impact assessment sections above that could be included in the detailed design, construction and maintenance of the transmission line and terminal stations, with references to the relevant Environmental Performance Requirements in Section 12, are:

1. Verification of EMFs and EMI emission levels (EPR EL1 in Table 12.1) within and outside the transmission line easement and at identified sensitive receptors as part of the detailed design for the transmission line and terminal stations.
2. Prior to commencement of the relevant construction works, prepare and implement a management plan (EPR EL1 in Table 12.1) that includes the following (but is not necessarily limited to):
    a. Outcomes of the Project wide EMI and EMF verification assessment at the detailed design stage and details of the areas assessed.
    b. The location of all sensitive receptors that may be impacted by the infrastructure.
    c. Where at-receptor mitigation measures to sensitive receptors are required to avoid or minimise adverse impacts.
    d. Detailed investigation of potential point-to-point communication link performance issues prior to the operation of the transmission line and if required either increase transmit power level, increase antenna height, or relocate of the antenna.
    e. A pre- and post-construction testing strategy to verify design calculations, impacts on sensitive equipment and the efficacy of any specified mitigation measures.
    f. Remedial action to be investigated if EMI and EMF limits are not met during the construction, testing, and commissioning.
3. Provide a means for the general public, residents or workers to report concerns or observations of EMI, such as impacts to reception of radio, television, mobile, internet (EPR EM7 in Table 12.1). This can be achieved through communication of an AusNet Project hotline for receiving and responding to complaints.

9.4 Residual impacts

Residual impacts are defined in the assessment as those construction and operational impacts that remain after the mitigation measures identified in Section 9.3 and specified in the Environmental Performance Requirements (EPRs) in Section 12 have been implemented.

There were no significant residual impacts identified in the assessment of EMF impacts and mitigation measures were not required.

- Only minor and negligible residual impacts were identified in the assessment of EMI impacts. Minor residual impacts were identified to AM radio reception, FM radio reception, emergency services radio reception and DGPS correction signals for land navigation near the proposed 500kV transmission line in heavy rain conditions. There will be alternative radio channels available that will not be significantly impacted by the EMI. The momentary interruption of DGPS correction signals as mobile agricultural equipment passes under the transmission line will not impact autonomous operations as the existing correction will be utilised under the line and updated once the equipment clears the area under the line. Other residual EMI impacts to TV reception, point-to-point communications and mobile communications were negligible.

- The only at-source mitigation option that will reduce the identified minor residual impacts to negligible is the use of a much larger, heavier phase conductor bundle along the proposed 500kV transmission line. This will require much larger, taller towers and will also increase the EMF levels in the vicinity of the proposed 500kV transmission line. There are other types of conductors that claim improved EMI performance (e.g., trapezoidal wire conductors and polyurethane coated conductors) but there is no consensus or verifiable operational evidence that they deliver improved performance. The only at-source mitigation option that will reduce the identified minor residual impacts to negligible is to replace the existing radio communication channels that are impacted by the EMI with channels at higher frequencies. This would require a new license and extensive hardware changes throughout the broadcast area and is not considered practicable.
- It was therefore concluded that it was not practicable to reduce the minor EMI residual impacts any further and as such, additional mitigation or controls are not deemed necessary, nor recommended.

10. Decommissioning impact assessment

As per the construction stage, there are no Project activities described in the decommissioning stage that are considered to have potential for EMI and EMF impacts on the environment.

All decommissioning requirements for the Project would be managed via the Decommissioning Management Plan (EPR EM11).

11. Cumulative impacts

A cumulative impact assessment considers the impacts of a project together with the impacts of other relevant projects that may interact spatially and temporally to change the level of impact on environmental, social or cultural values. **EES Chapter 4: EES assessment framework and approach** identifies relevant future projects that are proportionate to the scale and potential significance of the impacts of Western Renewables Link Project (WRL); that have sufficient information publicly available in an EES or an environmental approvals application; and that have a spatial and temporal relationship to the Western Renewables Link. Cumulative impacts may occur when incremental, successive and combined effects of actions or projects are added to other proposed actions or projects.

Cumulative EMI and EMF impacts may arise from the interaction of construction, operational and decommissioning activities of WRL, and other developments and projects in the area, both current and future. When considered in isolation, specific WRL impacts may be considered manageable. These manageable impacts may, however, be more substantial, when the impact of multiple projects on the same receptors are considered.

Of the 23 shortlisted projects identified in **EES Chapter 4: EES assessment framework and approach**, the following have been considered as potentially relevant to EMI and EMF are presented in Table 11.1.

Table 11.1: Summary of relevant future projects considered for cumulative impacts on EMI and EMF

Project Name	Address	Description
Delahey Urban Development	250a Taylors Road, Delahey, Victoria	Housing and complimentary mixed-uses development
Beaufort Bypass (Western Highway)	4129 Western Hwy, Victoria 5066 Western Hwy, Victoria 353 Beaufort–Lexton Road, Victoria	A new 11-kilometre duplicated section of the Western Highway to bypass Beaufort, linking completed sections of the Western Highway duplication to the east and west of Beaufort
Watta Wella Renewable Energy Project	465 Vineyard Road, Concongella, Victoria	The proposed Watta Wella Renewable Energy Project consists of three co-located renewable energy projects - a wind farm, solar farm and battery energy storage facility. The proposed location for the Project is approximately 16 kilometres north-east of Stawell, in north-west Victoria.
Western Irrigation Network (WIN) Scheme	Melton and Bacchus Marsh to Parwan-Balliang agricultural district	A large-scale irrigation project that will deliver a new, secure source of Class C recycled water for irrigation of farmland in the Parwan-Balliang agricultural district in Melbourne’s outer west via a new 28km pipeline.
Brewster Wind Farm	7 Pin Oak Court, Trawalla, Victoria 54 Kayleys Road, Brewster, Victoria 295 Trawalla Road, Trawalla, Victoria	A proposed windfarm consisting of up to seven wind turbine generators and a total combined capacity of approximately 40MW. The wind farm will connect into the electrical distribution network via an existing 66kV transmission line which runs along the Western Highway directly adjacent the site.
Merrimu Precinct Structure Plan (PSP)/Bacchus Marsh Urban Growth Framework	Merrimu Precinct, Moorabool Shire Council	Bacchus Marsh Urban Growth Framework identifies new areas for jobs, housing and infrastructure, while protecting valuable cultural and environmental assets. It sets out a vision to support a proposed 7,200 lot residential precinct near Bacchus Marsh, north-west of Melbourne as part of the Merrimu Precinct Structure Plan (PSP).
Sand quarry, Lot 8 Seereys Road, Coimadai, Vic	8 Seereys Road, Coimadai, Victoria	Re-establishment of a quarry and associated infrastructure the purposes of extracting mineral resources (sand and gravel).

Project Name	Address	Description
West Gate Tunnel (formerly the Western Distributor Project)	West of Melbourne CBD	A proposed new tunnel and elevated motorway connecting the West Gate Freeway with the Port of Melbourne, CityLink and the western edge of the CBD to provide an alternative river crossing to the existing West Gate Bridge. The Project also involves the widening of the existing West Gate Freeway from the M80 Western Ring Road to the West Gate Bridge to boost capacity, and associated road linkages to the M80 Western Ring Road and Princes Freeway.
2022 Melbourne Airport Master Plan	Melbourne Airport, Victoria	The 2022 Melbourne Airport Master Plan is a document detailing plans for development in the following 5 years coupled with a 20-year strategic direction for the airport. Major Projects include the development of the third runway, the T4 Express Link, and connecting elevated road and forecourt.
Sydenham Terminal Station Rebuild	67 Victoria Road, Plumpton, Victoria	Previously encompassed within the WRL Project this rebuild includes the construction of a new 500kV terminal station north of the existing Sydenham Terminal Station. This was removed from the Project EPBC Referral in August 2023 and is being completed as a standalone project due to its urgency to ensure network reliability.
Lerderderg-Wombat National Park	Anticipated to be the area between and including: Lerderderg State Park, Victoria Wombat State Forest, Victoria	Lerderderg – Wombat National Park will be created by linking existing Lerderderg State Park and much of the existing Wombat State Forest to create a new national park covering more than 44,000 hectares between Daylesford and Bacchus Marsh. The Government is investing in facility upgrades throughout the region, including upgrading campgrounds and new and upgraded walking trails and facilities.
Lerderderg River Nature Trail	Lerderderg State Park, Victoria	Lerderderg River Nature Trail proposes a new 5km trail that would extend the Aqualink hike and bike network through to MacKenzies Flat picnic area. The proposed reserve is to protect an internationally significant outcrop of Permian glacial rocks.
Victoria to New South Wales Interconnector West (VNI)	Between Bulgana, Victoria and Dinawan, NSW	A proposed future double circuit 500kV transmission line connecting Victoria and NSW to increase transfer capacity between states.
Melbourne Renewable Energy Hub, Plumpton, Victoria	77-347 Holden Rd, Plumpton, Victoria 67 Victoria Road, Plumpton 77 Victoria Road, Plumpton	An energy storage project that will store up to 1.6GWh wind, hydro and solar energy from regional Victoria and will connect into the adjacent Sydenham Terminal Station. It includes a 12.5MW solar farm to recover battery efficiency losses and ensure low cost and 'net-zero emission' operations of the Battery Energy Storage System.
Outer Metropolitan Ring Road/E6 (OMR)	Between the west and north regions of the Melbourne outer metropolitan area	Development of a new four-lane (bi-directional) freeway, linking Werribee with Thomastown, via Melton, Tullamarine, Craigieburn, and Epping. The proposal includes a freight and high-speed passenger rail line in the median strip.
Nyaninyuk Wind Farm	Between Evansford, Clunes and Waubra	A proposed windfarm consisting of up to 58 wind turbine generators with a total combined capacity of up to 330MW.

Project Name	Address	Description
Navarre Green Power Hub	North of Navarre, approximately 15km north of Project Land	A proposed wind farm and battery project, with a proposed capacity of approximately 600MW. The wind farm is proposed to be focused within the Barkly Range and Kenya Range to the north of Navarre.
Elaine Solar Farm	South-West of Elaine Terminal Station, approximately 2km from Project Land	A 150 megawatt (MW) solar project and a 250MWh battery. Approved by the state on 3 May 2024, the Project involves the construction of a substation on property neighbouring the Elaine Terminal Station.
Akaysha (Elaine) BESS	225 Elaine-Blue Bridge Road, Elaine, Victoria	A 311MW Battery Energy Storage System (BESS) proposed to be developed adjacent the existing Elaine Terminal Station. The development will include battery units, associated infrastructure, grid connection, access roads, vegetation screening and security fencing.
Melbourne Airport Business Park (MABP) – Sky Road West Warehouse Developments	66 Sky Road, Melbourne Airport VIC 3045	Development of 25ha of land to construct manufacturing, logistics, and industrial warehouse units within the Melbourne Airport Business Park - Sky Road area.
Powercor Mt Cottrell Zone Substation	535-601 Troups Road, Truganina	Construction and operation of the Powercor Mt Cottrell Zone Substation.
Sunbury Line Level Crossing Removals (Calder Park Drive and Holden Road Level Crossing Removal Project)	377 Calder Freeway, Calder Park	The level crossings at Calder Park Drive, Old Calder Highway, Holden Road and Watsons Road will be removed by building a new road bridge over the rail line. This project sits within a larger suite of works aimed at making the Sunbury Line level crossing free in 2025.
Toolern Vale Solar Farm	1375-1415 Holden Road, Diggers Rest,	Proposed use and development of the land for the purposes of a 12.5MW solar farm and utility installation, associated infrastructure, earthworks, access and removal of native vegetation.

Only three of the future, committed power projects in Table 11.1 may have cumulative impacts on the EMI and EMF in the local environment. They are the Melbourne Renewable Energy Hub, Sydenham Terminal Station rebuild and the Victoria to New South Wales Interconnector projects. These projects were identified on the basis of 1) their proximity to the Project and thus their potential to cause cumulative EMF impacts at the same receptors (if both are not effectively managed); 2) their projected timings such that they may overlap with the Project; and 3) the nature of their EMF being similar to the Project which could lead to cumulative effects.

The Melbourne Renewable Energy Hub (MREH) is a battery and solar farm project adjacent to the Sydenham terminal station. Given that the Melbourne Renewable Energy Hub project is an approved project with approved plans and incorporated documentation, the detailed design of Western Renewables Link will consider the cumulative effect of the new MREH and Western Renewables Link infrastructure, where these are located in close proximity to each other.

The detailed design of the Sydenham Terminal Station rebuild project will allow for the connection of the Western Renewable Link to the terminal station. The detailed design of Western Renewables Link infrastructure will also consider the cumulative effects of the existing transmission lines terminating at Sydenham Terminal Station.

The Victoria to New South Wales Interconnector project connects to the Project near the existing Bulgana Terminal Station. The detailed design of the new 500kV terminal station near Bulgana, as part of the Project, will allow for the connection of the proposed Victoria to New South Wales Interconnector to the terminal station. The Project's EPR EL1 account for cumulative impact assessment requirements for all existing and future committed developments.

Although the potential for cumulative EMI and EMF effects at surrounding sensitive receptors would depend on the timings and sequencing of the Project and these other projects listed in Table 11.1, it has been assessed as unlikely that their EMI and EMF contributions would be significant enough to influence the outcomes of this assessment. Care and co-ordination should be applied to avoid circumstances where the same receptors are affected by the Project, as well as these surrounding projects. However, it is concluded from this assessment that any cumulative impacts with the Project are expected to be negligible based on the physical separation between infrastructure.

12. Environmental Performance Requirements

Environmental Performance Requirements (EPRs) set out the environmental outcomes to be achieved through the implementation of mitigation measures during construction, operation and decommissioning. While some EPRs are performance based to allow flexibility in how they will be achieved, others include more prescriptive measures that must be implemented. Compliance with the EPRs will be required as a condition of the Project's approval.

To meet the EES objective of avoiding, or minimising where avoidance is not possible, adverse effects for community amenity, health and safety, with regard to electromagnetic radiation, the following EPRs outlined in Table 12.1 are recommended.

Table 12.1: EMI and EMF Environmental Performance Requirements

EPR code	Environmental Performance Requirements	Project component	Stage
EL1	**Undertake an Electric and Magnetic Field and Electromagnetic Interference Assessment** 1. Design and construct the Project to reduce electric and magnetic fields (EMF) and electromagnetic interference (EMI) from the Project infrastructure to below the reference levels and limits for the Project, or as low as reasonably practicable to avoid and minimise impacts. 2. The applicable reference levels and limits are defined in EES Technical Report L: EMI and EMF Impact Assessment. The design must be informed by a Project wide EMI and EMF verification assessment for all the proposed infrastructure at the detailed design stage, identifying existing sensitive receptors and committed future developments within the study area. 3. Prior to the commencement of the relevant construction works, the assessment must be documented in a management plan for implementation and includes, but is not limited to: a. Outcomes of the Project wide EMI and EMF verification assessment at the detailed design stage and details of the areas assessed. b. The location of all sensitive receptors that may be impacted by the infrastructure. c. Where at-receiver mitigation measures to sensitive receptors are required to avoid or minimise adverse impacts. d. If mitigation measures are identified as per Item 3(c) (e.g., point-to-point communication links), identify what the mitigation works are, and timeline for implementation. e. A pre- and post-construction testing strategy to verify design calculations, impacts on sensitive equipment and the efficacy of any specified mitigation measures. f. Remedial action to be investigated if EMI and EMF limits are not met during the construction, testing, and commissioning.	All	Design, Construction, and Operation
EM7	**Develop and implement a Complaints Management System** 1. Prior to commencement of construction, develop and implement a process for recording, managing, and resolving complaints received from affected stakeholders as part of the Communications and Stakeholder Engagement Management Plan (EPR EM5). The complaints management arrangements must be consistent with Australian Standard AS/NZS 10002: 2014 Guidelines for Complaints Management in Organisations and the Essential Services Commission Land Access Code of Practice.	All	Construction and Operation

13. Conclusion

13.1 Existing conditions

Existing EMI and EMF sources are identified within the Project Area. Receptors that may be sensitive to EMI and EMF from transmission lines and associated electrical infrastructure are also identified within the study area. The calculated and measured EMI and EMF levels associated with the existing sources are compared to appropriate limits and reference levels at the sensitive receptor locations.

13.2 Impact assessment

The impact assessment has considered the adoption of the following standard design controls to reduce exposure to EMF and reduce electromagnetic field interference effects:

- Diagonal phasing has been adopted for the transmission line, which maximises magnetic field cancellation and thereby minimises public exposure to magnetic fields at ground level.
- Minimum heights above ground have been increased to maintain EMF levels within acceptable limits directly under the line.
- Maximising separation from sensitive receptors through route selection and terminal station site selection.

The effects of EMI and EMF of the proposed new transmission line and terminal stations on sensitive receptors were assessed within the study area for the construction, operation and decommissioning of the Project with the standard design controls implemented. The impacts were found to be primarily related to the operation of the Project. The key findings of this impact assessment are:

- Key strategies for the identified EMI and EMF effects primarily entail application of design controls that are prescribed in the AusNet design standards, along with standard AusNet construction and maintenance control measures. In recognising that impacts are largely eliminated through the Project's design controls, operational impacts described and assessed in this report are therefore the post-design control impacts.
- The impact of the EMF from the Project infrastructure on human health will not be significant and additional mitigation is not required.
- The EMF from the Project infrastructure will not have a significant impact on agriculture and additional mitigation is not required.
- The EMF from the Project infrastructure will have a negligible impact on sensitive receptors and additional mitigation is not required.
- The EMI from the Project infrastructure may have a minor impact on AM radio, FM radio and emergency services radio reception during rain conditions. There are no practicable mitigation measures that will reduce this impact to negligible and mitigation is not considered necessary.
- The EMI from the Project infrastructure will have a negligible impact on TV and mobile phone reception and mitigation measures are not required.
- The EMI from the Project infrastructure may have a moderate impact on some point-to-point communication links in the study area. Mitigation measures may be required and will entail a detailed investigation of potential point-to-point communication link performance issues prior to the operation of the transmission line and either an increase in antenna height, increase in transmit power level or relocation of the antenna. The selected mitigation measures will reduce the residual impact rating to negligible.
- There is a minor impact of EMI on DGPS correction signals for land navigation directly under the proposed 500kV transmission line in heavy rain conditions. The momentary interruption of DGPS correction signals as mobile agricultural equipment passes under the line will not impact autonomous operations as the existing correction will be utilised under the line and updated once the equipment clears the area under the line. Additional mitigation measures are not required.

Impacts of the Project on EMI and EMF have been assessed and mitigation measures have been identified in response to the EES evaluation objective to minimise/avoid adverse effects on community health and safety. The impact assessment concluded that it will not be necessary to contain electromagnetic radiation emissions from the Project or to shield or buffer nearby sensitive receptors from such emissions as the expected EMI and EMF from the Project are below levels that would require further mitigation.

13.3 Environmental Performance Requirements

One EMI and EMF EPR and one general EPR are recommended to meet the EES evaluation objective relevant to EMI and EMF, namely:

- EL1: Undertake an Electric and Magnetic Field and Electromagnetic Interference Assessment
- EM7: Develop and implement a Complaints Management System

13.4 Residual impacts

Residual impacts are defined in the assessment as those construction and operational impacts that remain after the identified mitigation measures that are specified in the EPRs have been implemented.

There were no significant residual impacts identified in the assessment of EMF impacts and mitigation measures were not required.

Only minor and negligible residual impacts were identified in the assessment of EMI impacts. Minor residual impacts were identified to AM radio reception, FM radio reception, emergency services radio reception and DGPS correction signals for land navigation near the proposed 500kV transmission line in heavy rain conditions. There will be alternative radio channels available that will not be significantly impacted by the EMI. The momentary interruption of DGPS correction signals as mobile agricultural equipment passes under the transmission line will not impact autonomous operations, as the existing correction will be utilised under the line and updated once the equipment clears the area under the line. Other residual EMI impacts to TV reception, point-to-point communications and mobile communications were negligible.

The only at-source mitigation option that will reduce the identified minor residual impacts to negligible is the use of a much larger, heavier phase conductor bundle along the proposed 500kV transmission line. This will require much larger, taller towers and will also increase the EMF levels in the vicinity of the proposed 500kV transmission line. There are other types of conductors that claim improved EMI performance (e.g., trapezoidal wire conductors and polyurethane coated conductors) but there is no consensus or verifiable operational evidence that they deliver improved performance. The only at-source mitigation option that will reduce the identified minor residual impacts to negligible is to replace the existing radio communication channels that are impacted by the EMI with channels at higher frequencies. This would require a new license and extensive hardware changes throughout the broadcast area and is not considered practicable.

It was therefore concluded that it was not practicable to reduce the minor EMI residual impacts any further and as such, additional mitigation or controls are not deemed necessary, nor recommended.

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World Health Organization, June 2007. *Exposure to extremely low frequency fields*. [online] Available at: <https://www.who.int/teams/environment-climate-change-and-health/radiation-and-health/non-ionizing/elff> [Accessed 7 July 2021].

Appendix A. Existing conditions – calculated EMF results

The following plots show the calculated EMF profiles for the existing transmission lines in the study area. The x-axis defines the horizontal position at which the EMF was calculated with respect to the line, with the centre of the transmission line located at x = 0m. The y-axis defines the calculated electric field strength and magnetic flux density levels at a height of 1m above ground level.

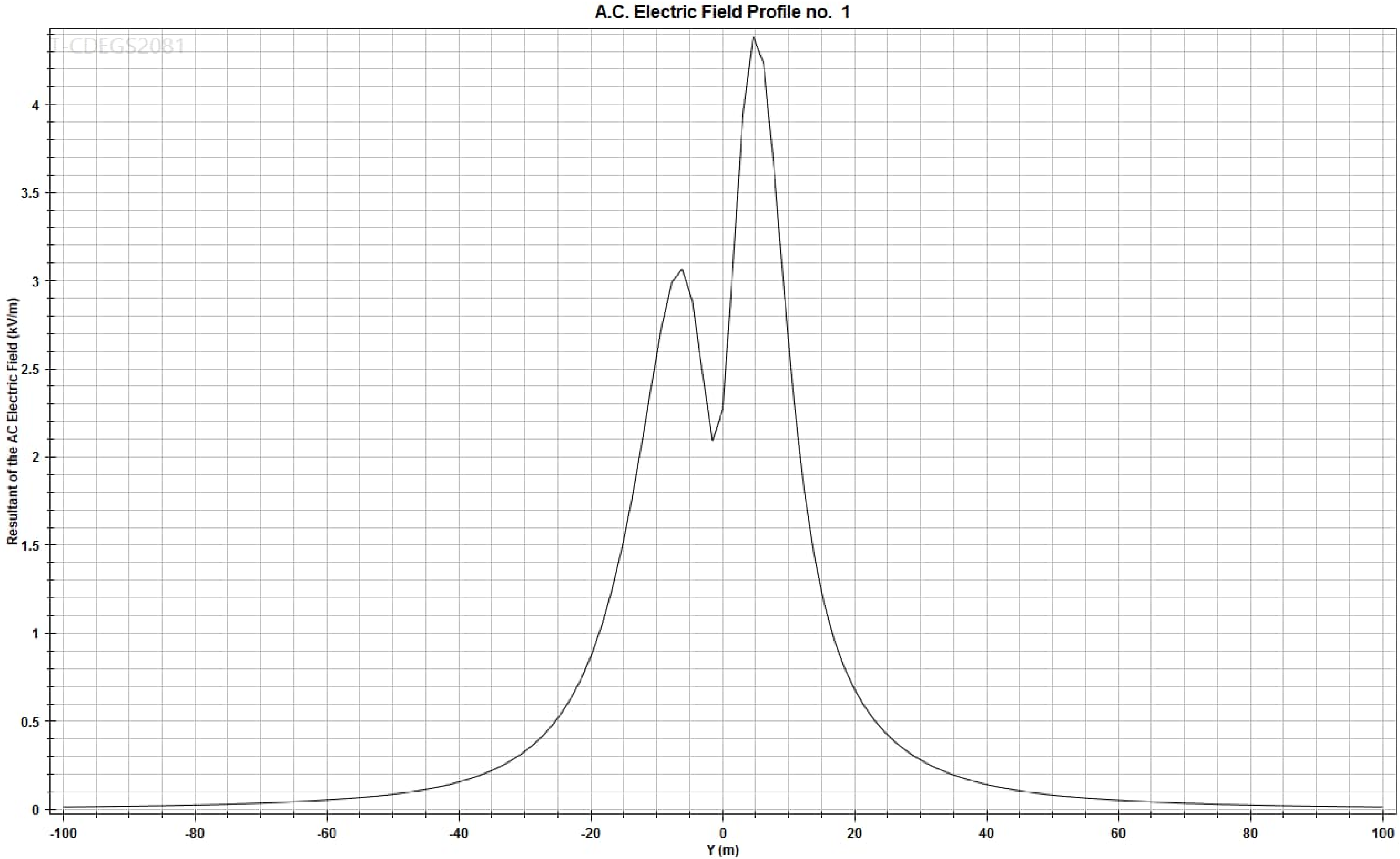

Figure A.1: Calculated Electric Field Strength associated with the existing Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line (Source: Jacobs, 2022)

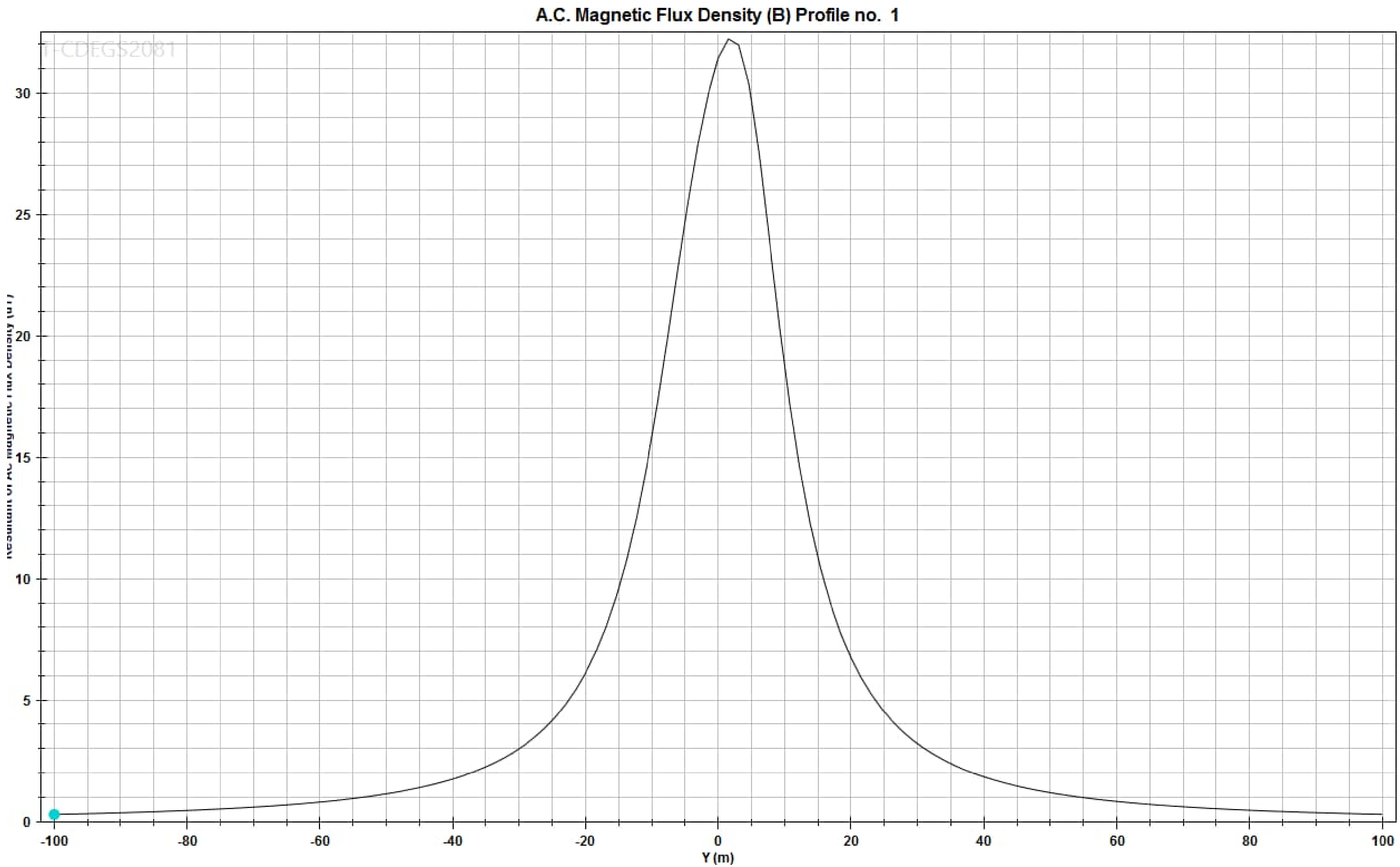

Figure A.2: Calculated Magnetic Flux Density associated with the existing Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line (Source: Jacobs, 2022)

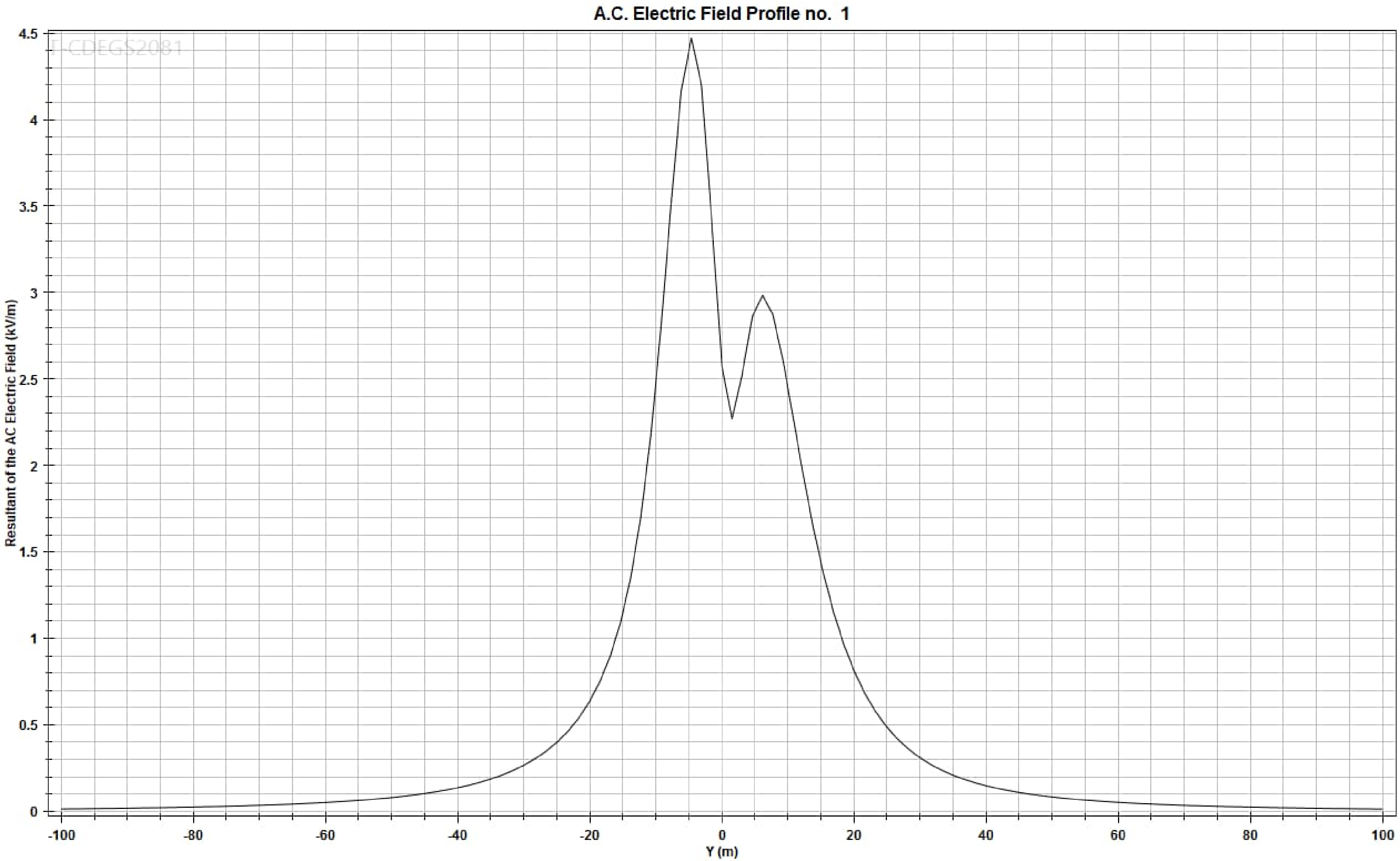

Figure A.3: Calculated Electric Field Strength associated with the existing Ballarat Terminal Station to Bendigo Terminal Station 220kV transmission line (Source: Jacobs, 2022)

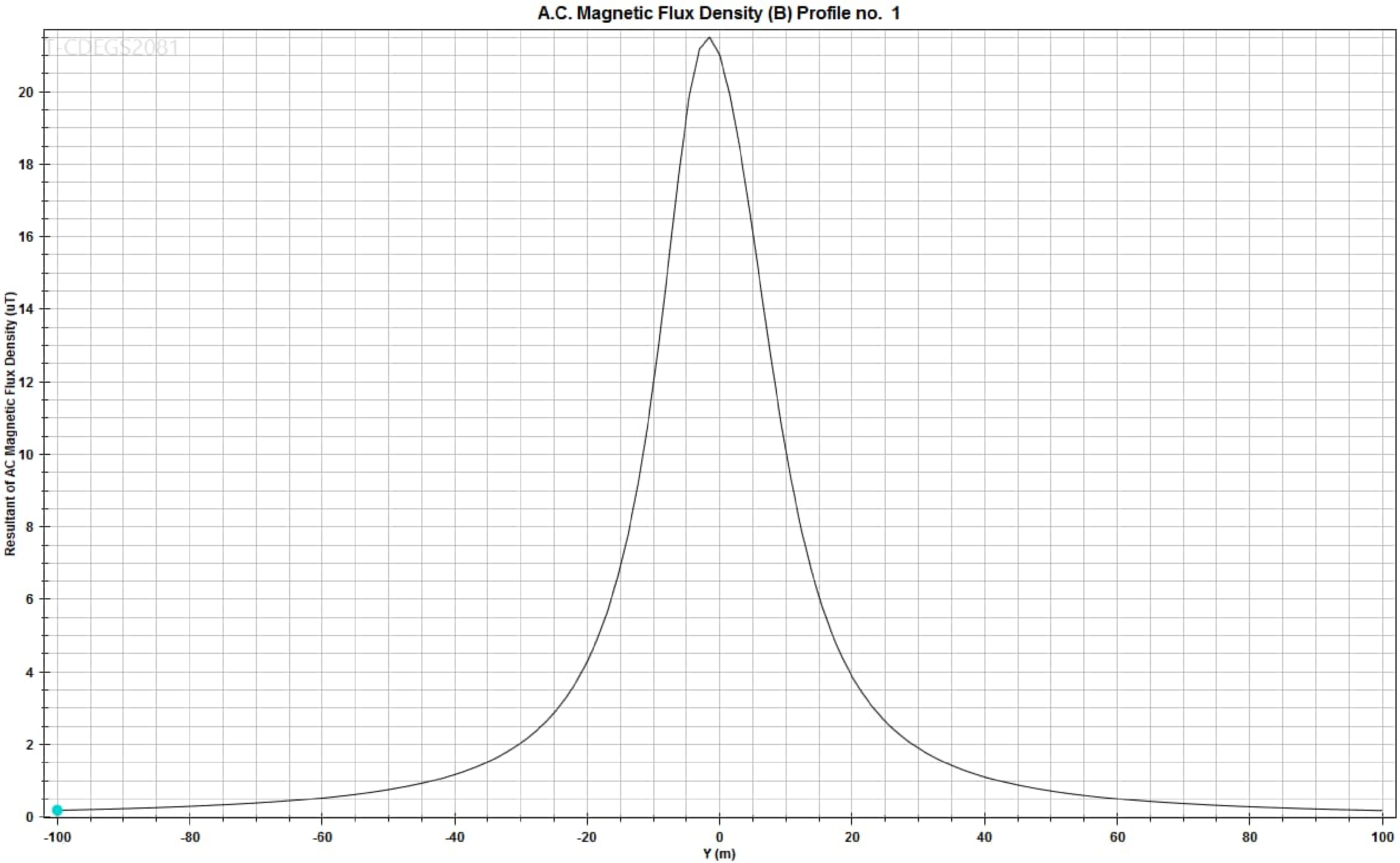

Figure A.4: Calculated magnetic Flux Density associated with the existing Ballarat Terminal Station to Bendigo Terminal Station 220kV transmission line (Source: Jacobs, 2022)

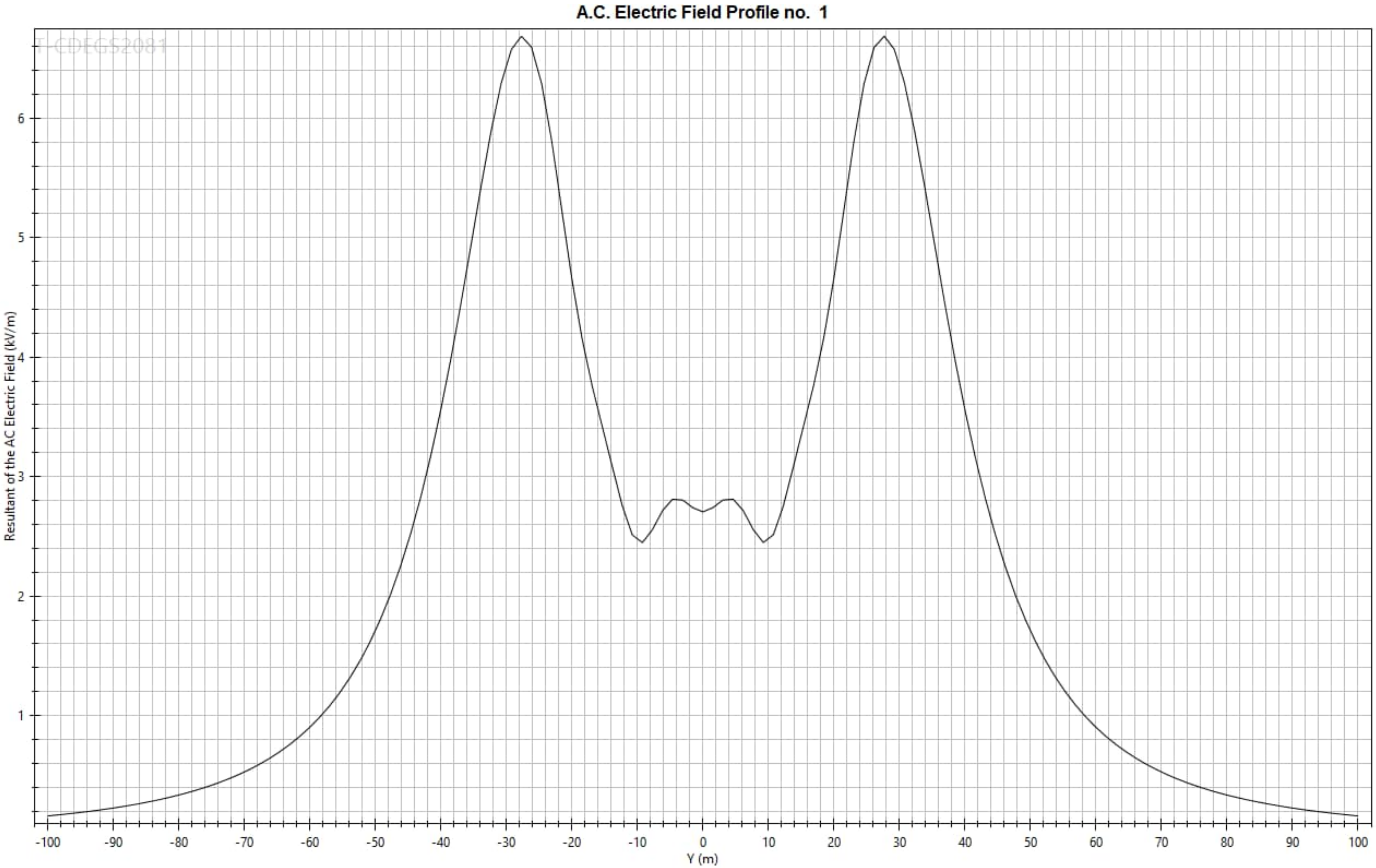

Figure A.5: Calculated Electric Field Strength associated with the existing Moorabool Terminal Station to Sydenham Terminal Station circuits 1 and 2 500kV transmission lines (Source: Jacobs, 2022)

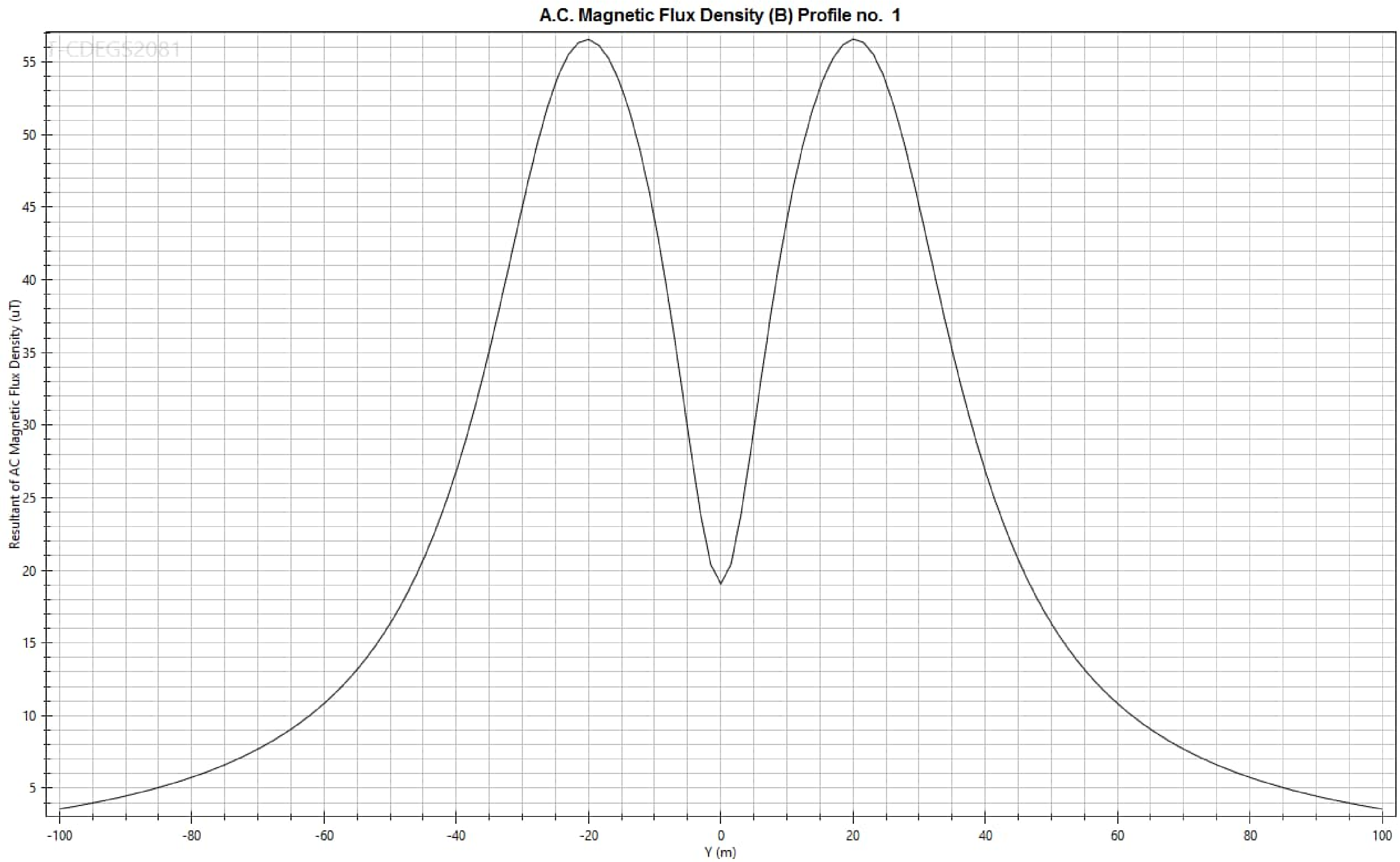

Figure A.6: Calculated Magnetic Flux Density associated with the existing Moorabool Terminal Station to Sydenham Terminal Station circuits 1 and 2 500kV transmission lines (Source: Jacobs, 2022)

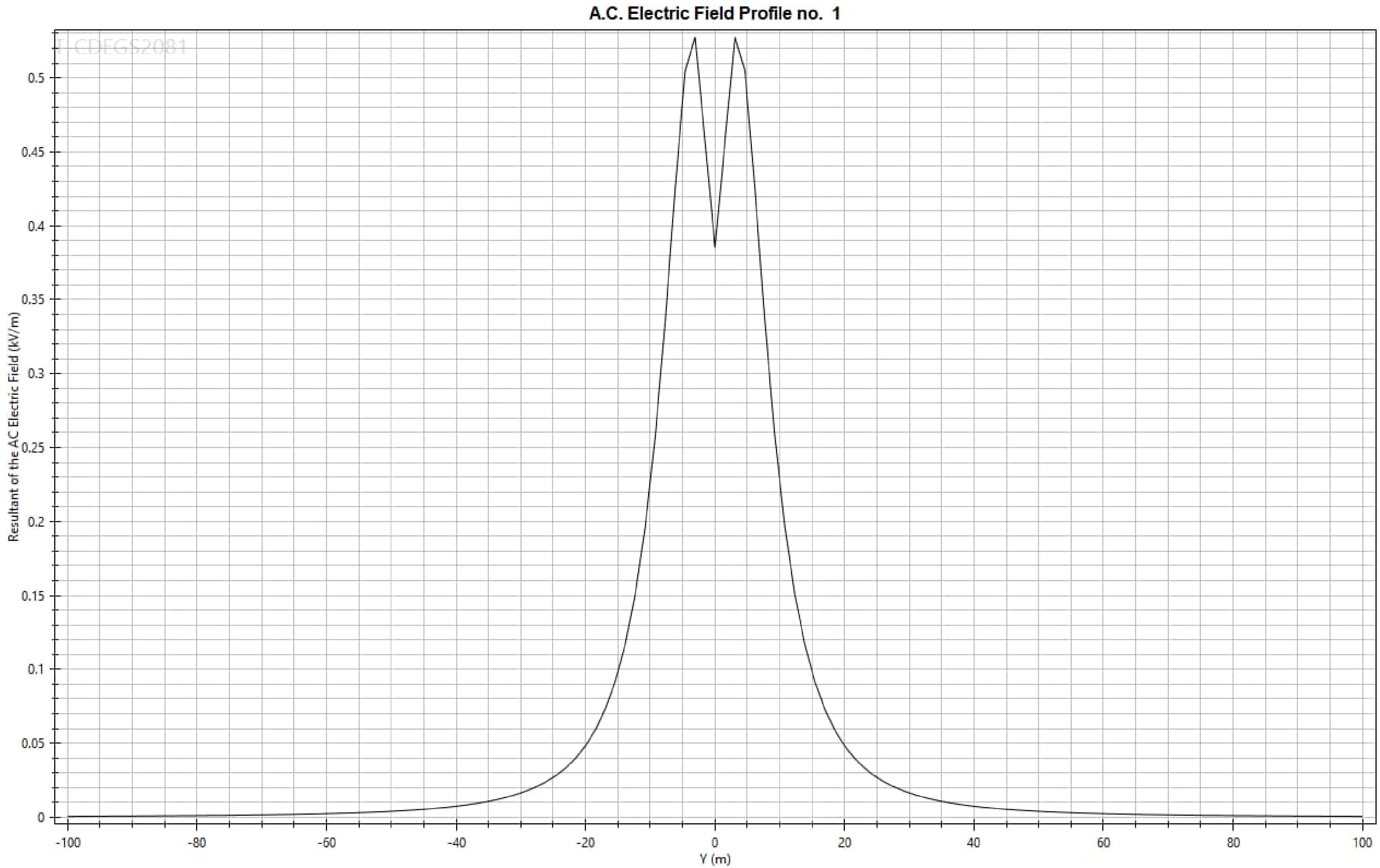

Figure A.7: Calculated Electric Field Strength associated with a typical existing 66kV sub-transmission lines (Source: Jacobs, 2022)

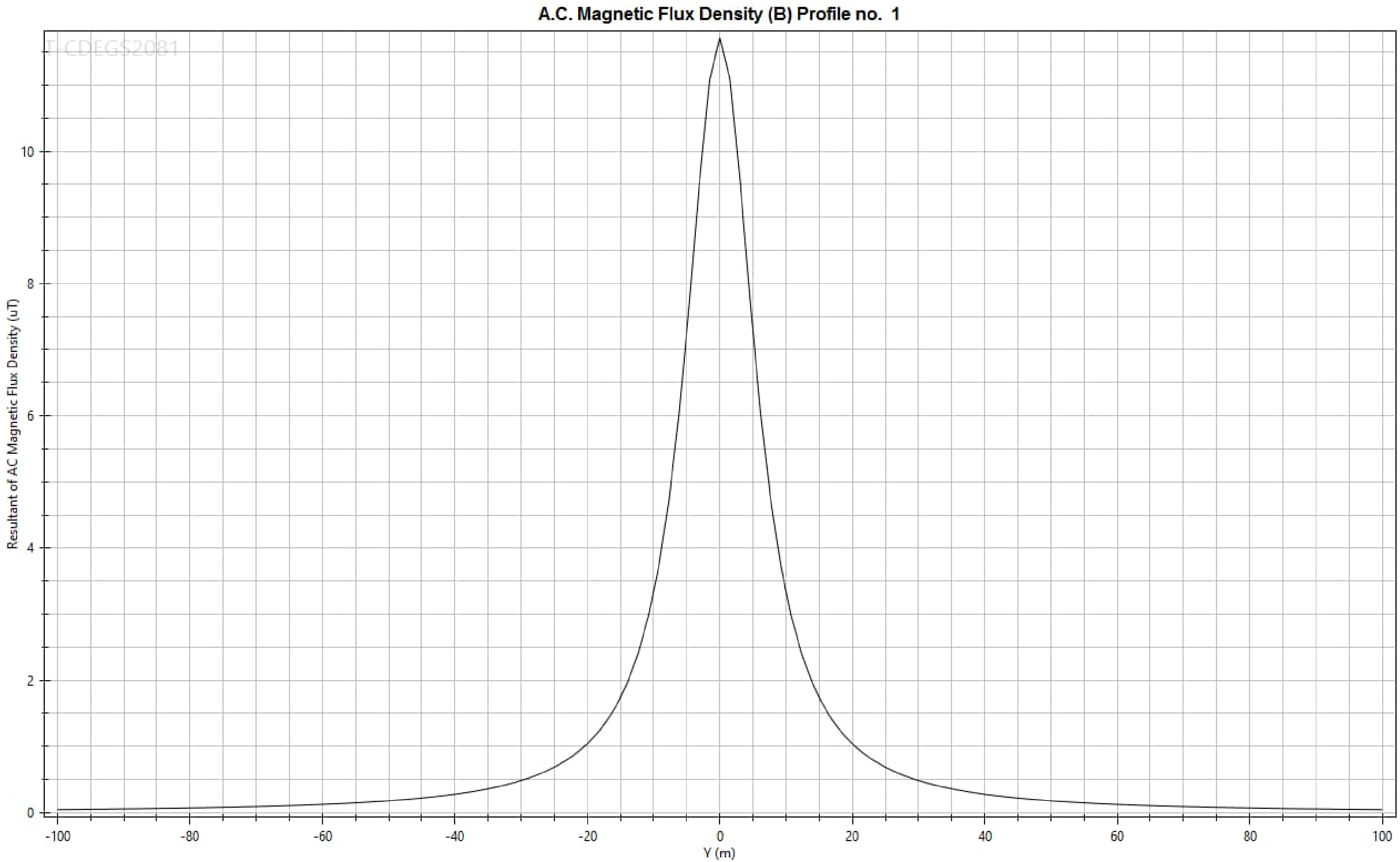

Figure A.8: Calculated Magnetic Flux Density associated with typical existing 66kV sub-transmission lines (Source: Jacobs, 2022)

Appendix B. Existing conditions – calculated EMI results

The following plots show the radio interference levels due to the existing transmission lines in the study area under dry and wet conditions. The x-axis refers to the distance from centre of the line (the centre is taken as 200m), the y-axis depicts the electric field measured in dBμV/m. The applicable reference levels are shown in **Section 2**.

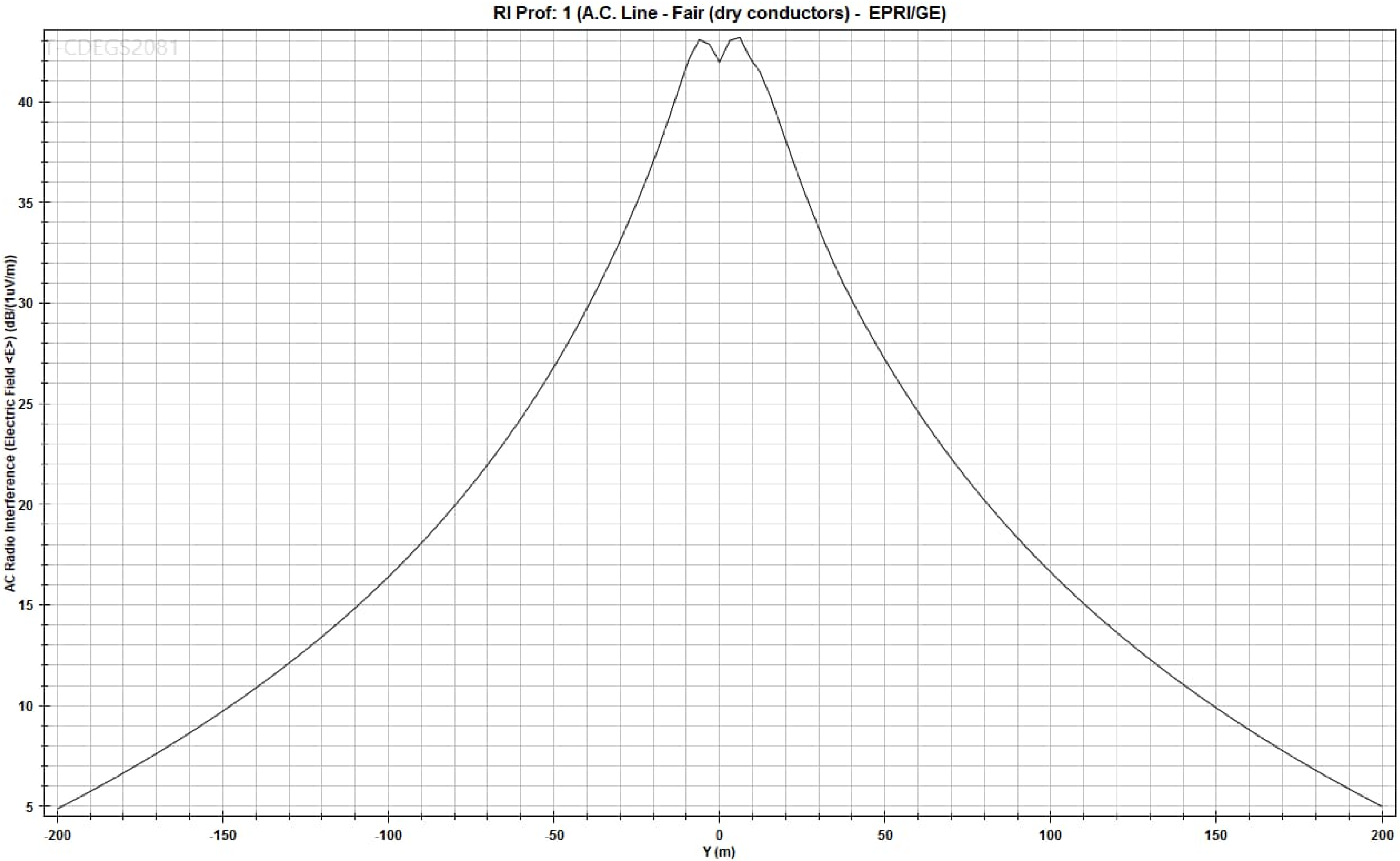

Figure B.1: Calculated Radio Interference at 500kHz associated with the existing Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line (dry conditions) (Source: Jacobs, 2022)

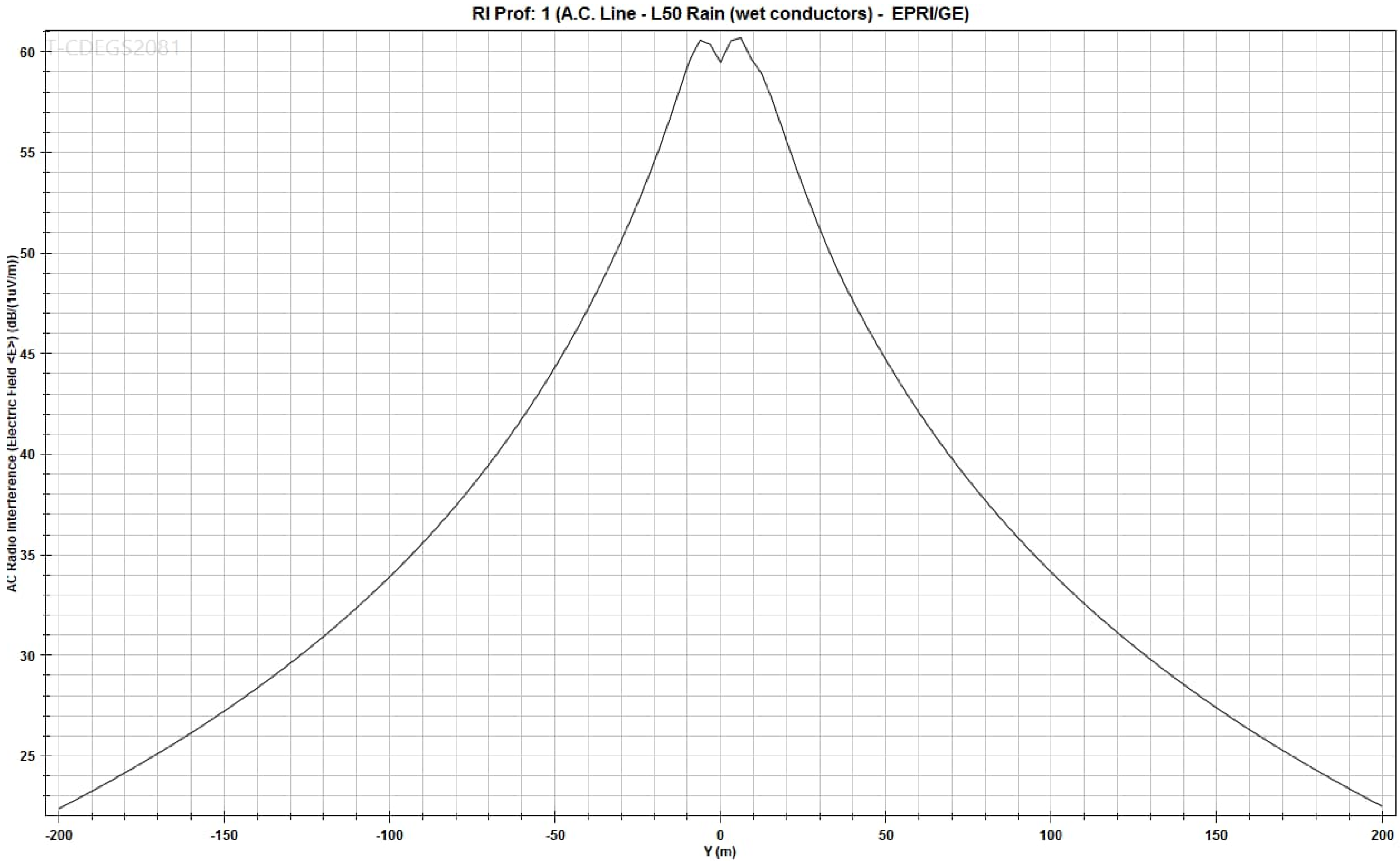

Figure B.2: Calculated Radio Interference at 500kHz associated with the existing Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line (average wet conditions) (Source: Jacobs, 2022)

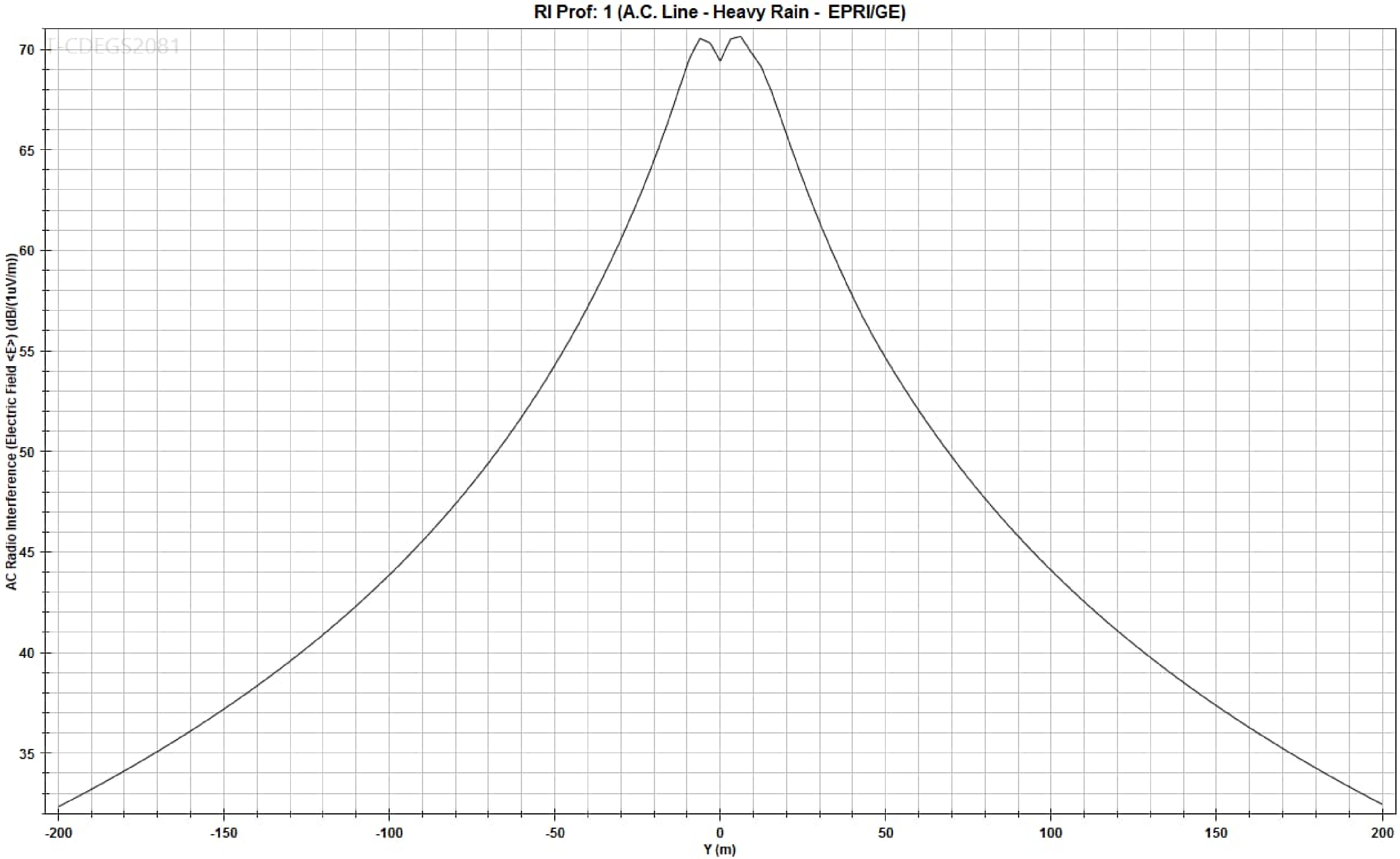

Figure B.3: Calculated Radio Interference at 500kHz associated with the existing with the existing Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line (heavy rain conditions) (Source: Jacobs, 2022)

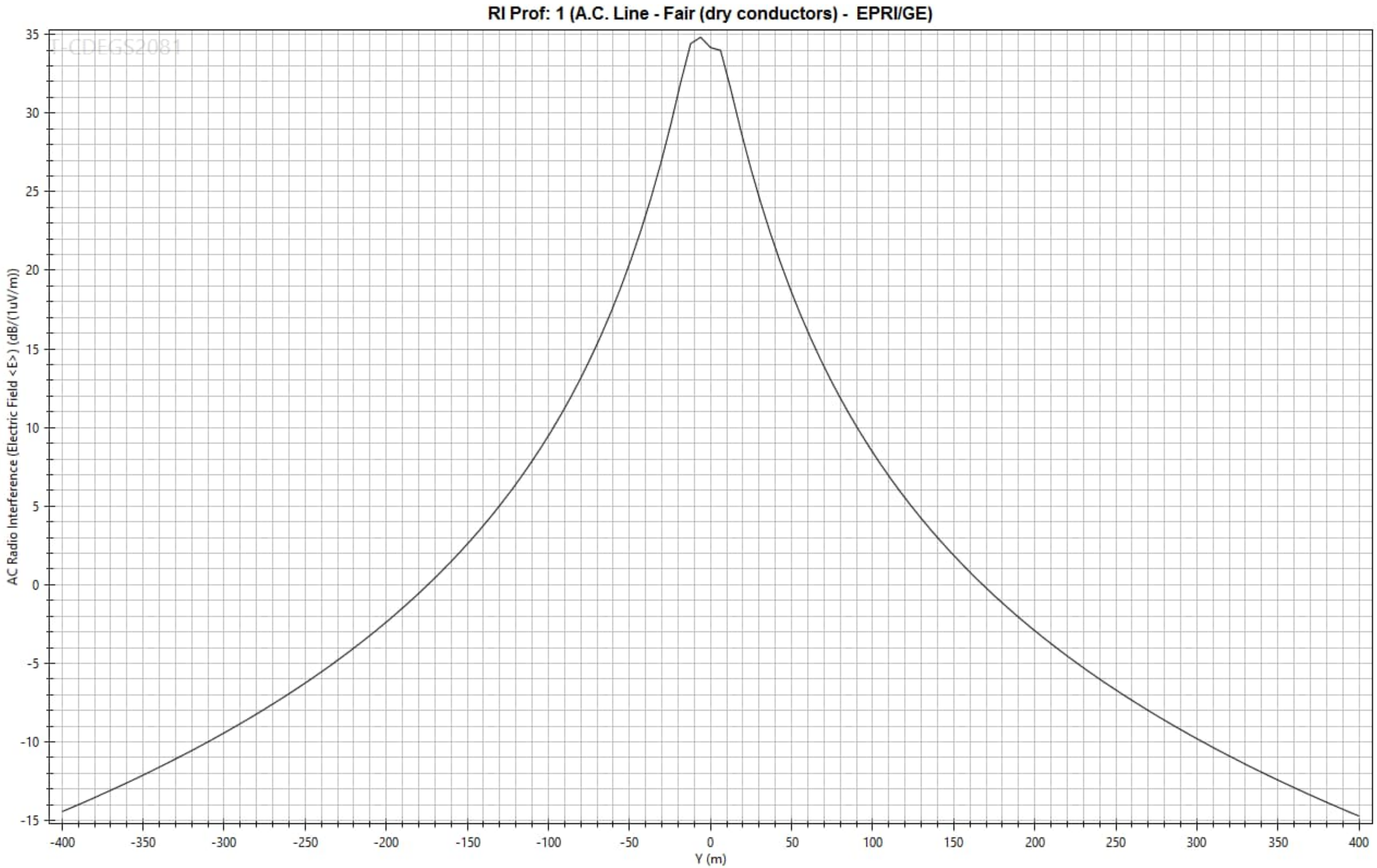

Figure B.4: Calculated Radio Interference at 500kHz associated with the existing with the existing Ballarat Terminal Station to Bendigo Terminal Station 220kV transmission line (dry conditions) (Source: Jacobs, 2022)

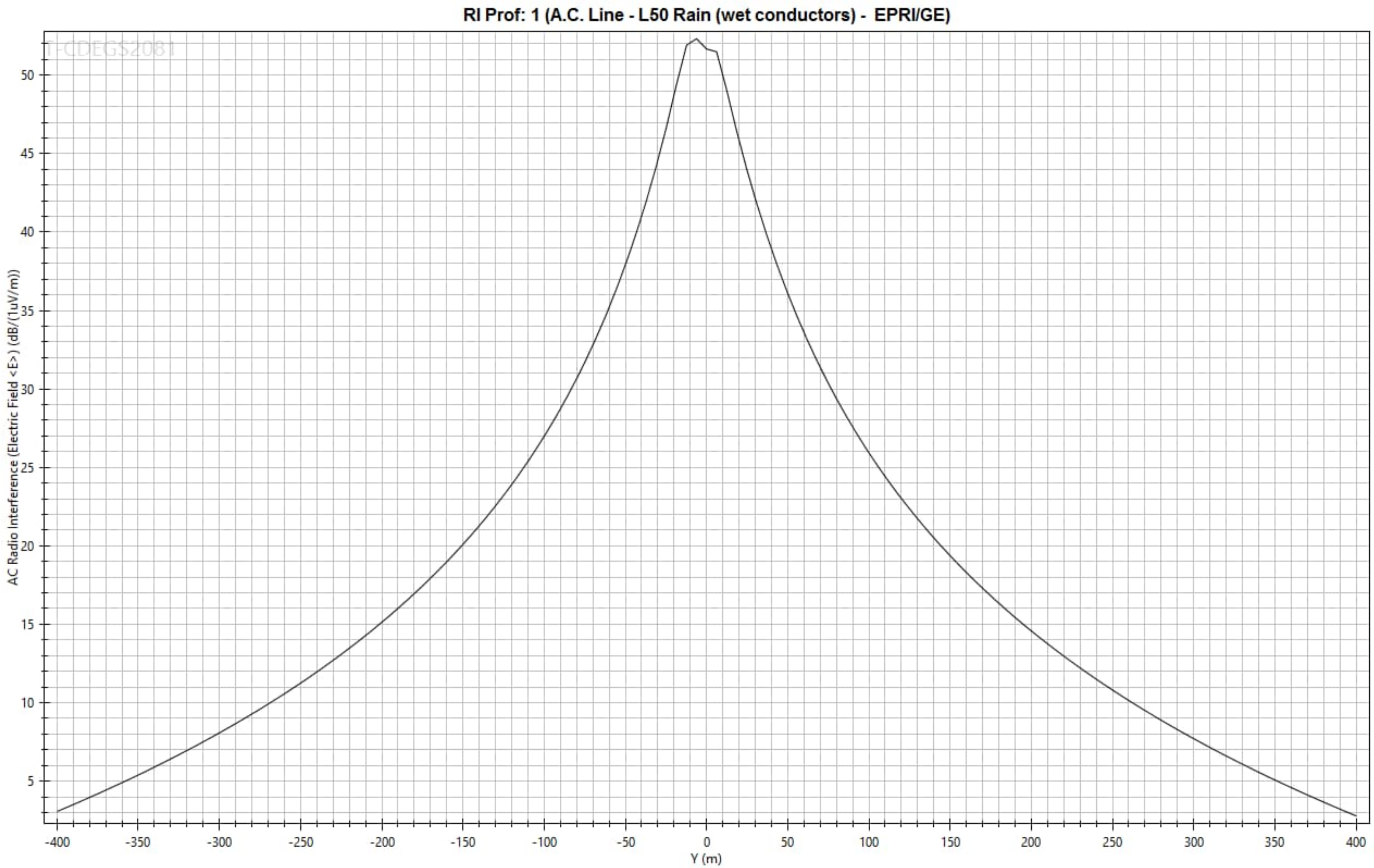

Figure B.5: Calculated Radio Interference at 500kHz associated with the existing with the existing Ballarat Terminal Station to Bendigo Terminal Station 220kV transmission line (average wet conditions) (Source: Jacobs, 2022)

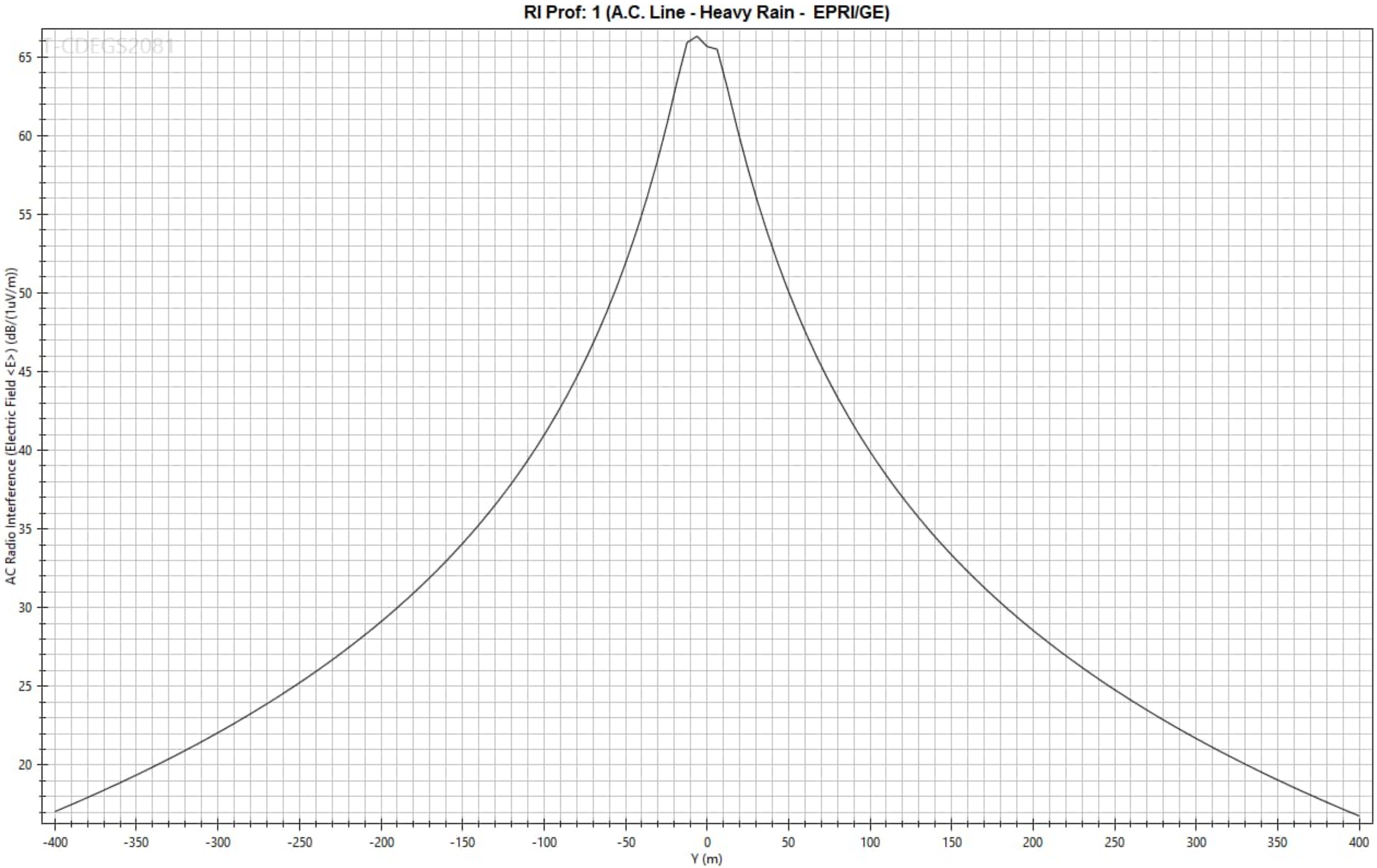

Figure B.6: Calculated Radio Interference at 500kHz associated with the existing with the existing Ballarat Terminal Station to Bendigo Terminal Station 220kV transmission line (heavy rain conditions) (Source: Jacobs, 2022)

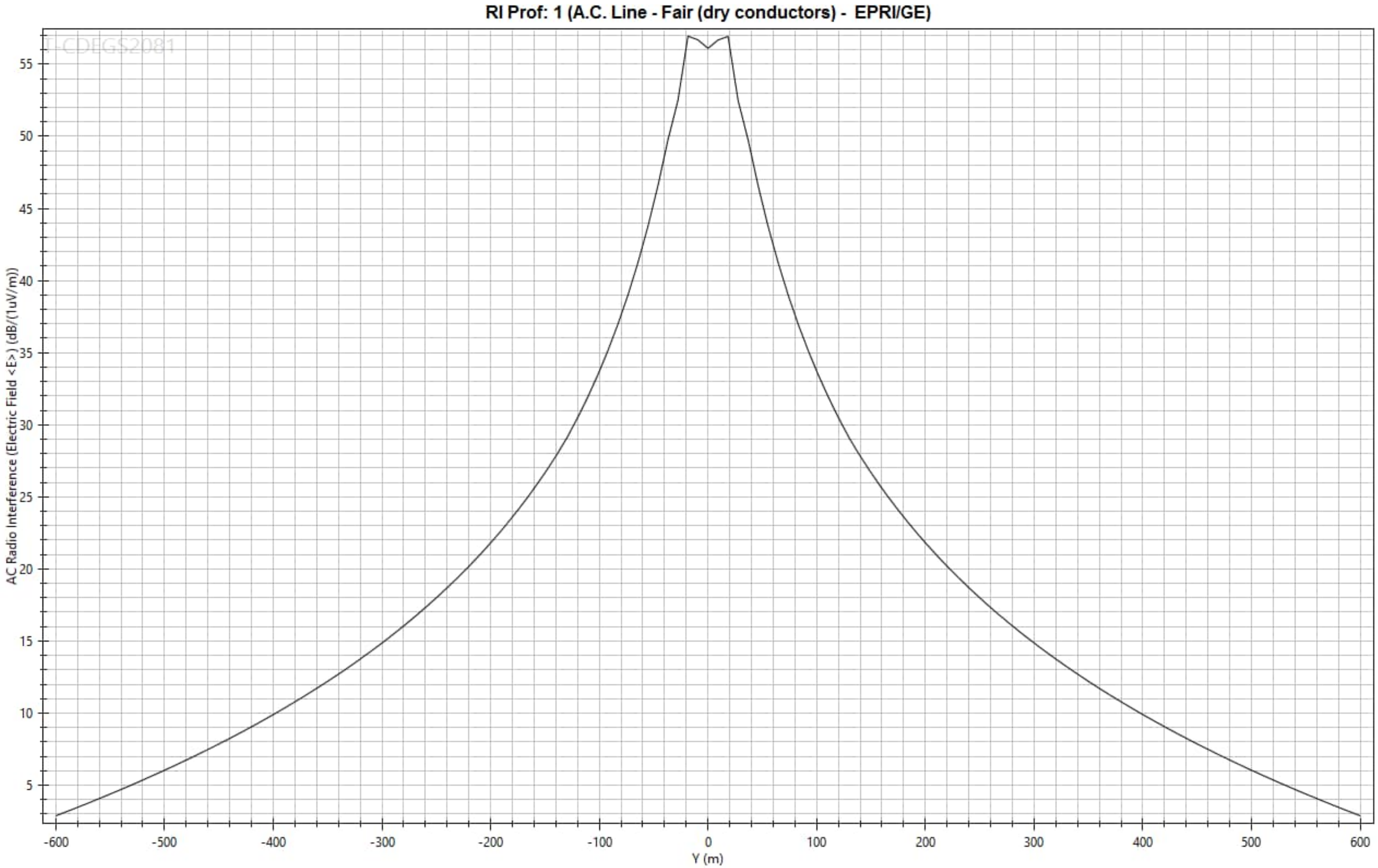

Figure B.7: Calculated Radio Interference at 500kHz associated with the existing with the existing Moorabool Terminal Station to Sydenham Terminal Station circuits 1 and 2 - 500kV transmission lines (dry conditions) (Source: Jacobs, 2022)

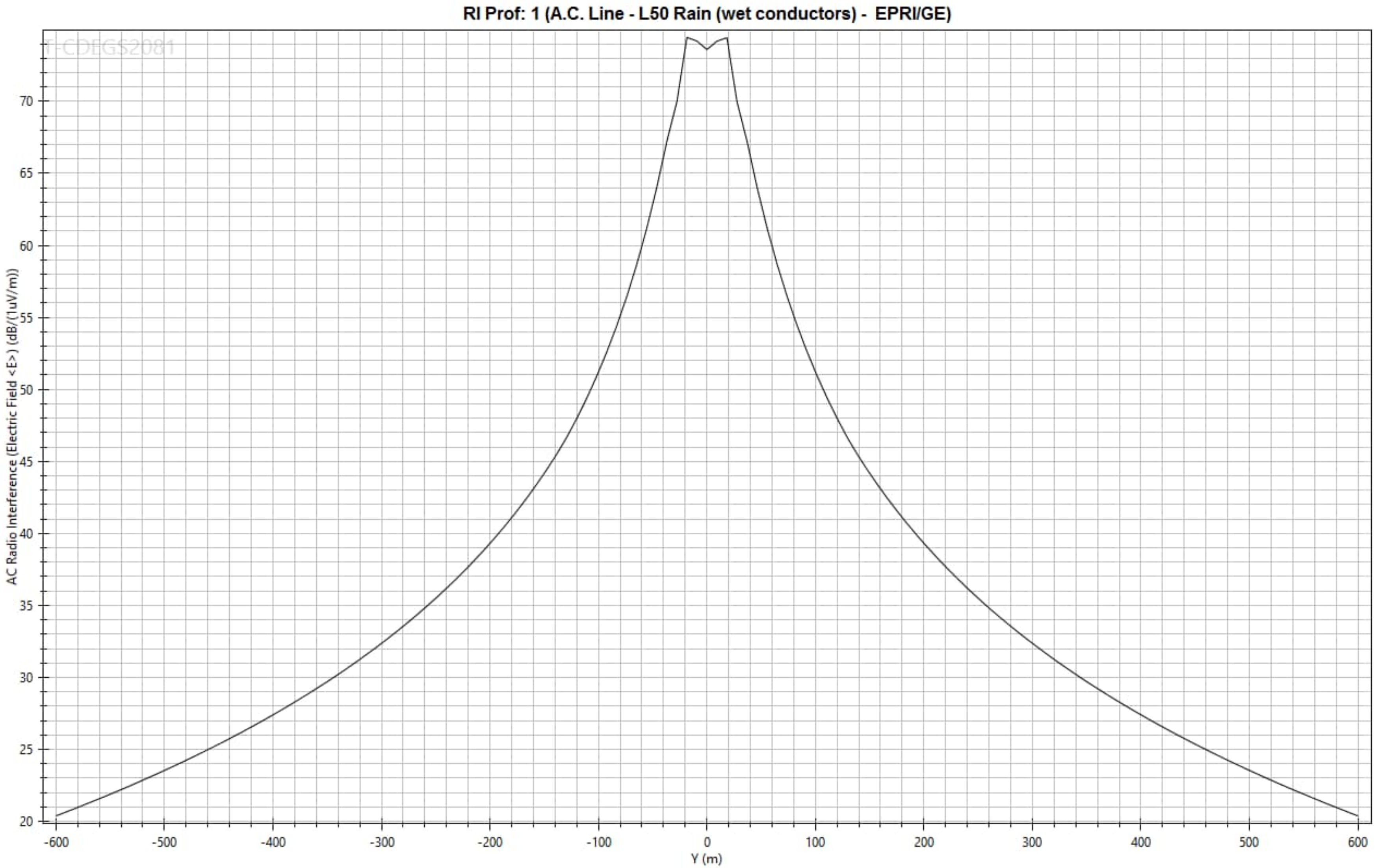

Figure B.8: Calculated Radio Interference at 500kHz associated with the existing with the existing Moorabool Terminal Station to Sydenham Terminal Station circuits 1 and 2 - 500kV transmission lines (average wet conditions) (Source: Jacobs, 2022)

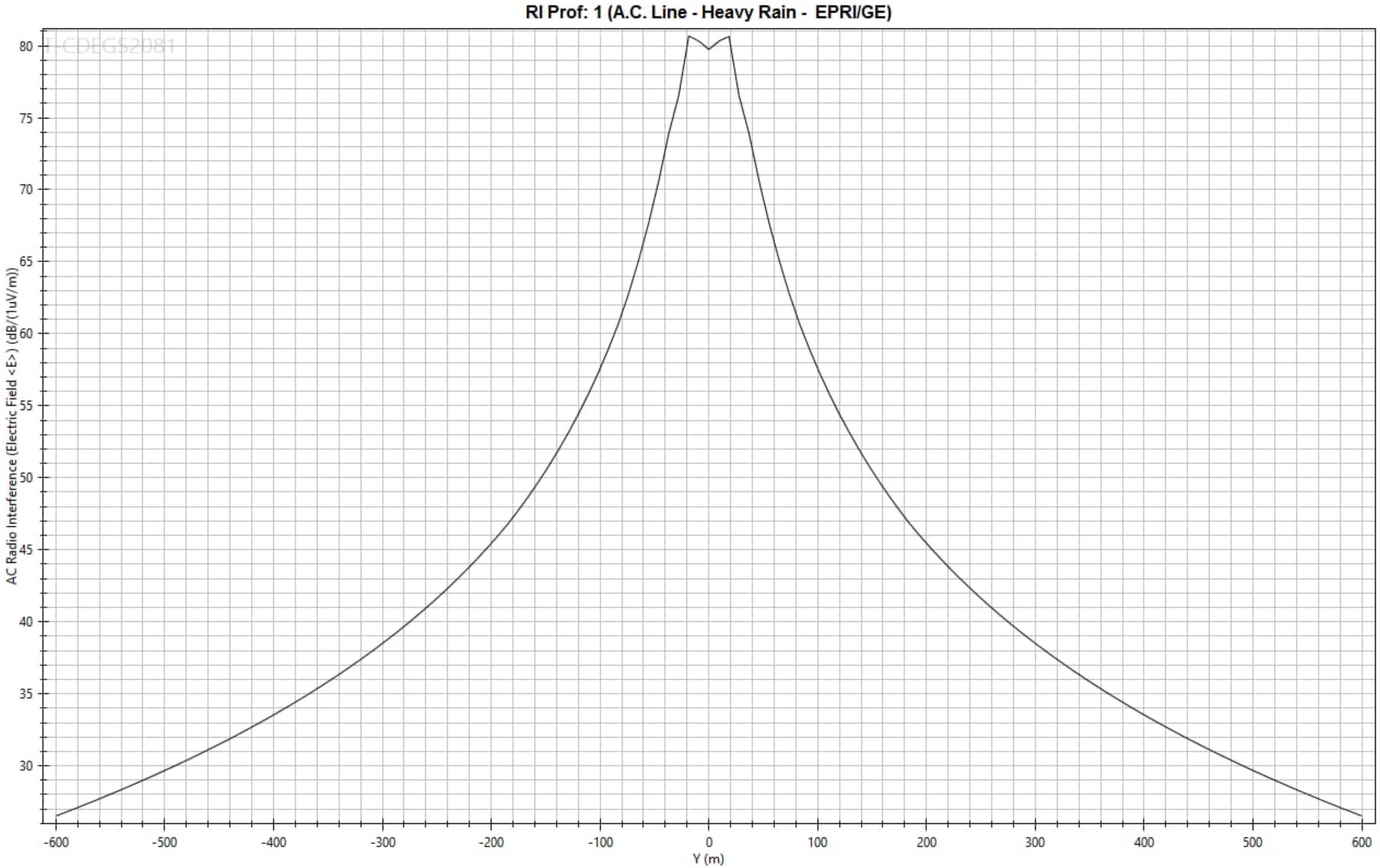

Figure B.9: Calculated Radio Interference at 500kHz associated with the existing with the existing Moorabool Terminal Station to Sydenham Terminal Station circuits 1 and 2 - 500kV transmission lines (heavy rain conditions) (Source: Jacobs, 2022)

Appendix C. Existing conditions – measured EMI and EMF results

C.1 EMI and EMF measurements for Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line – Location 1

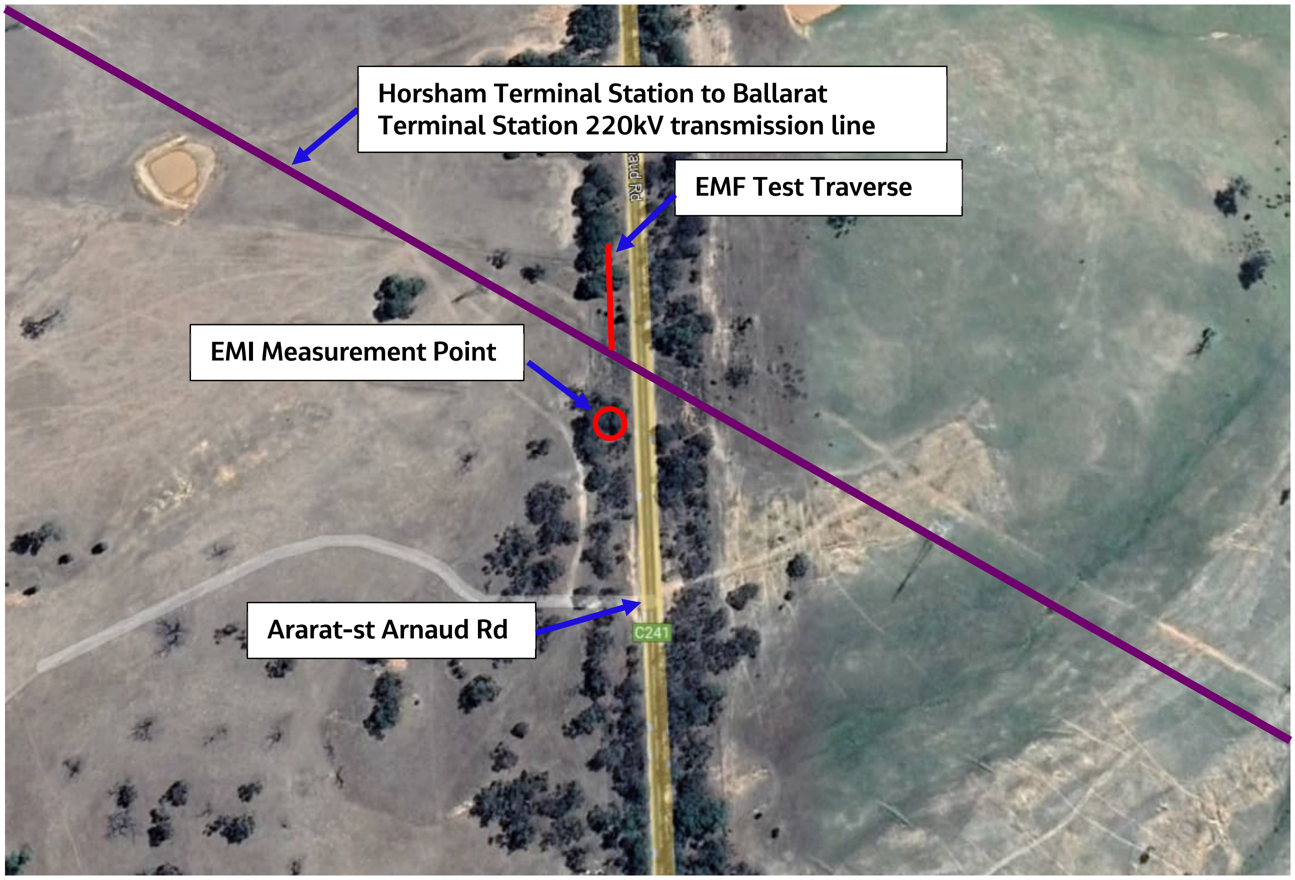

Figure C.1: Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line EMI and EMF measurement Location 1 (Source: Jacobs, 2023)

Table C.1: Measured EMF levels for Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line – Location 1

Distance from centre of transmission line (m)	Magnetic Flux Density (μT)	Electric Field Strength (V/m)
0	2.04	555.1
10	1.77	812.1
20	1.18	448.1
30	0.72	67.4
40	0.45	8.9

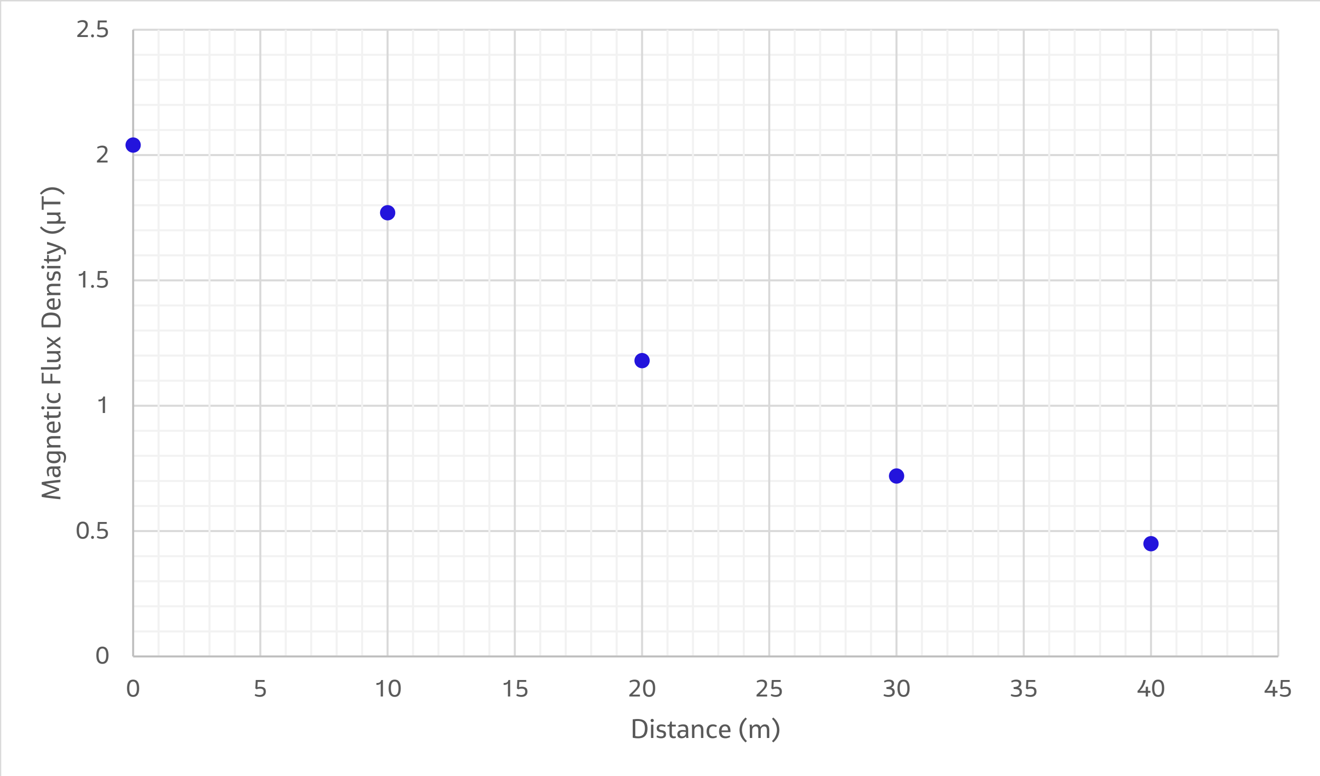

Figure C.2: Measured magnetic flux density for Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line – Location 1 (Source: Jacobs, 2023)

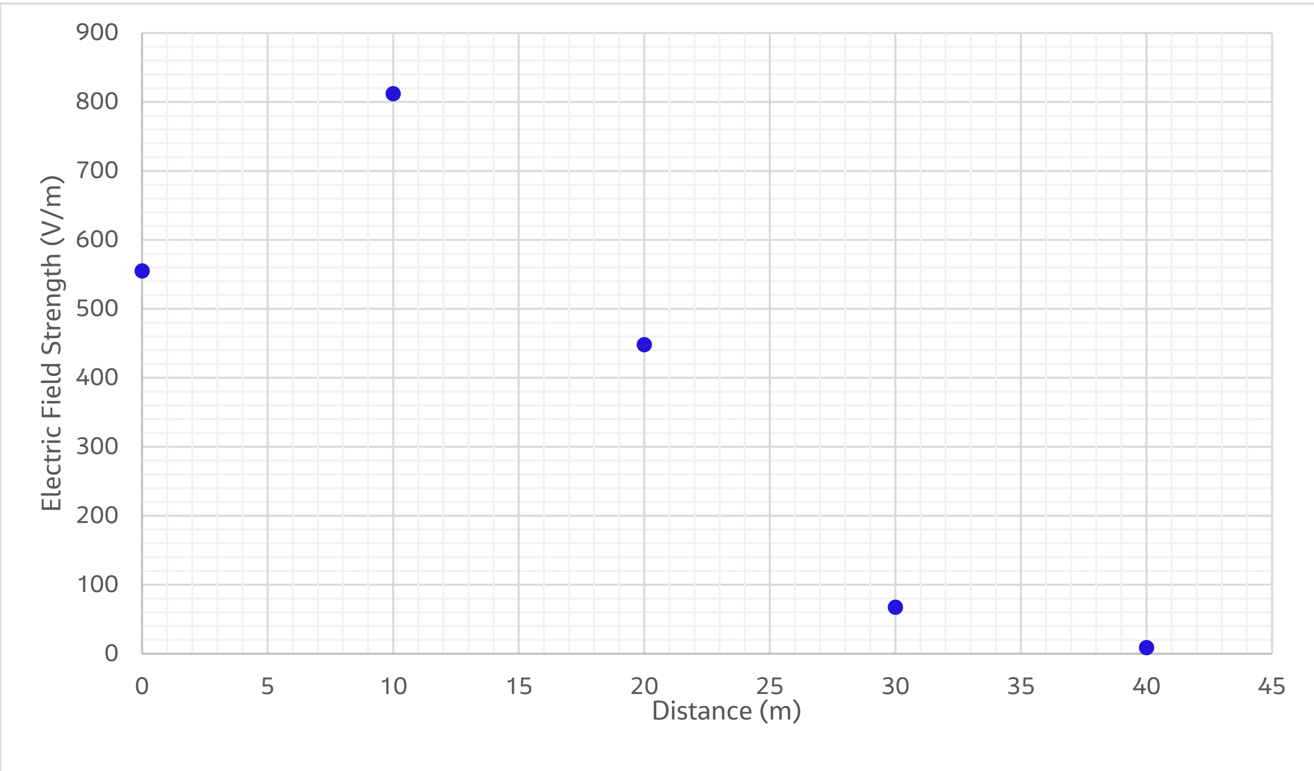

Figure C.3: Measured electric field strength for Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line – Location 1 (Source: Jacobs, 2023)

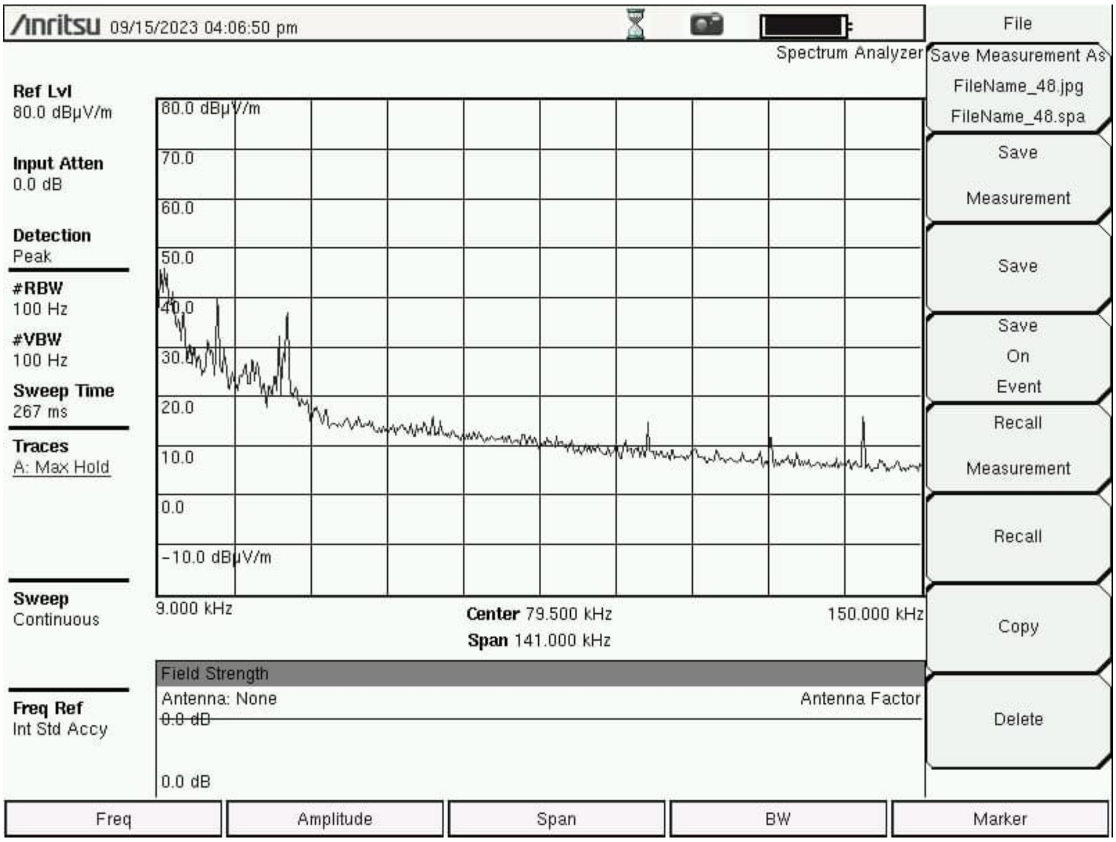

Figure C.4: EMI measurement for Horsham Terminal Station to Ballarat Terminal Station - 220kV transmission lines - 20m from centreline – 9kHz to 150kHz - Location 1 (Source: Jacobs, 2023)

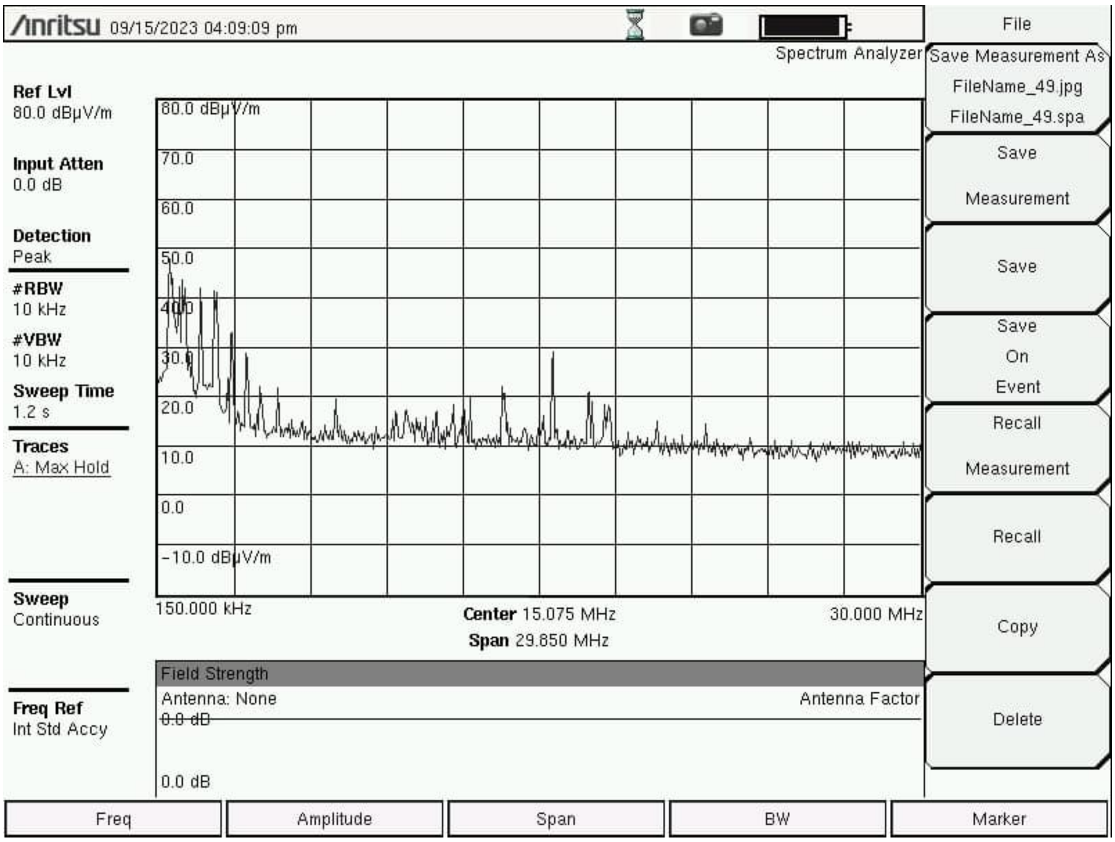

Figure C.5: EMI measurement for Horsham Terminal Station to Ballarat Terminal Station - 220kV transmission lines - 20m from centreline – 150kHz to 30MHz - Location 1 (Source: Jacobs, 2023)

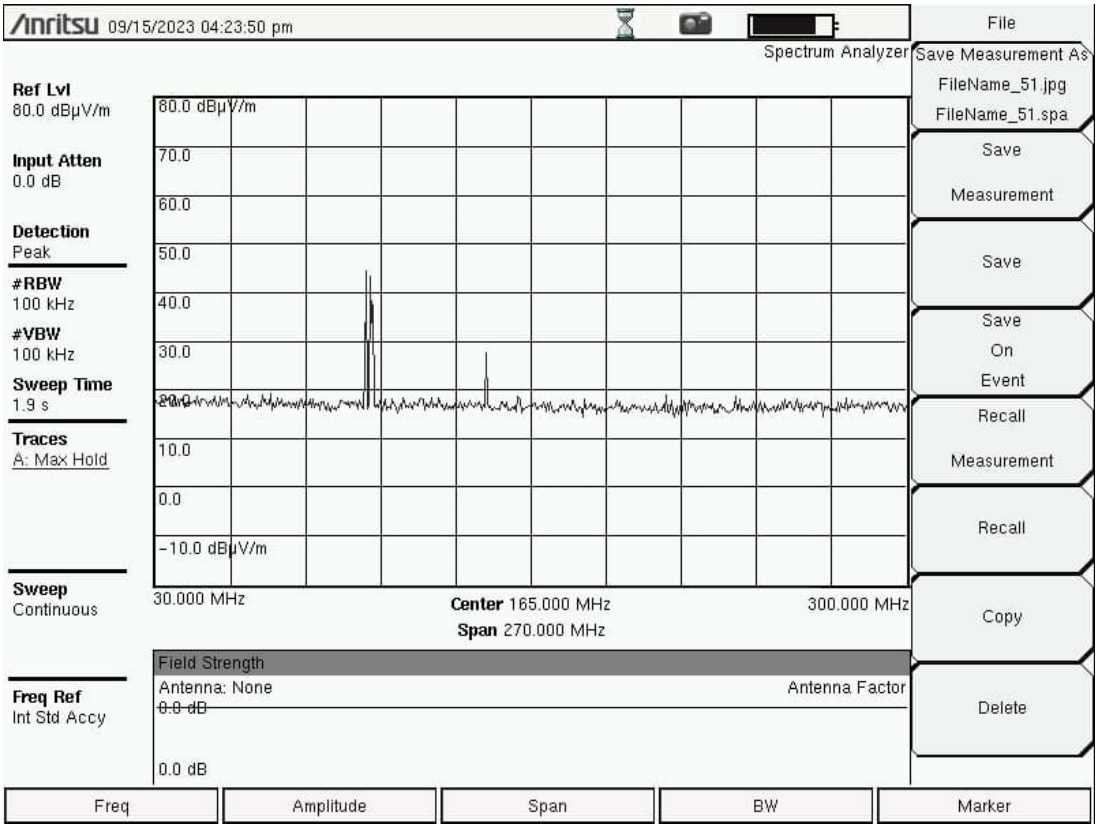

Figure C.6: EMI measurement for Horsham Terminal Station to Ballarat Terminal Station - 220kV transmission lines - 20m from centreline – 30MHz to 300MHz - Location 1 (Source: Jacobs, 2023)

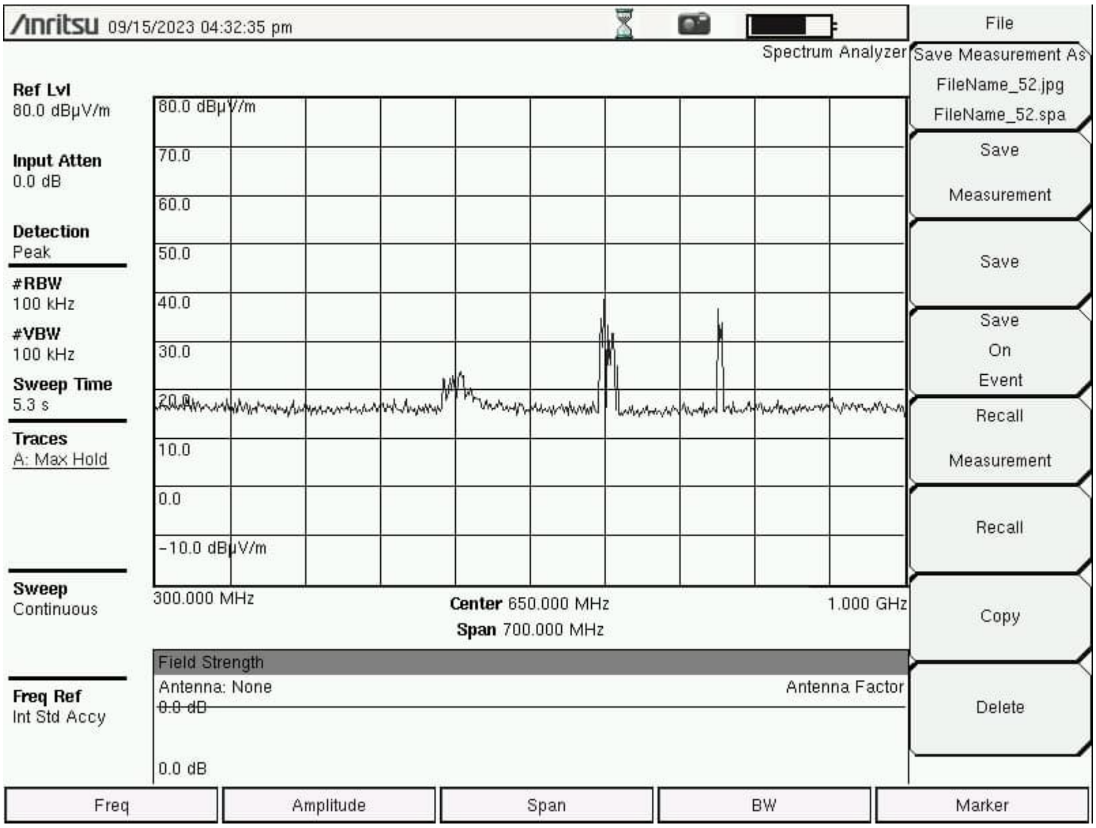

Figure C.7: EMI measurement for Horsham Terminal Station to Ballarat Terminal Station - 220kV transmission lines - 20m from centreline – 300MHz to 1GHz - Location 1 (Source: Jacobs, 2023)

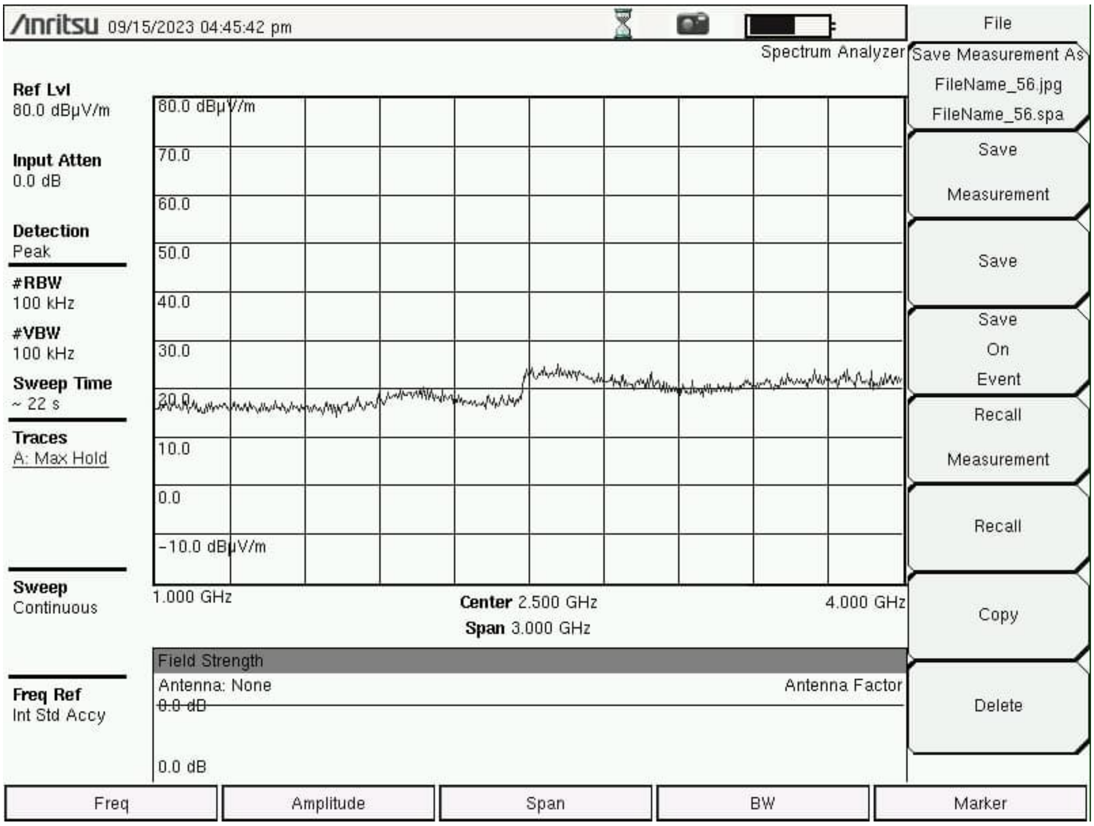

Figure C.8: EMI measurement for Horsham Terminal Station to Ballarat Terminal Station - 220kV transmission lines - 20m from centreline – 300MHz to 1GHz - Location 1 (Source: Jacobs, 2023)

C.2 EMI and EMF measurements for Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line – Location 2

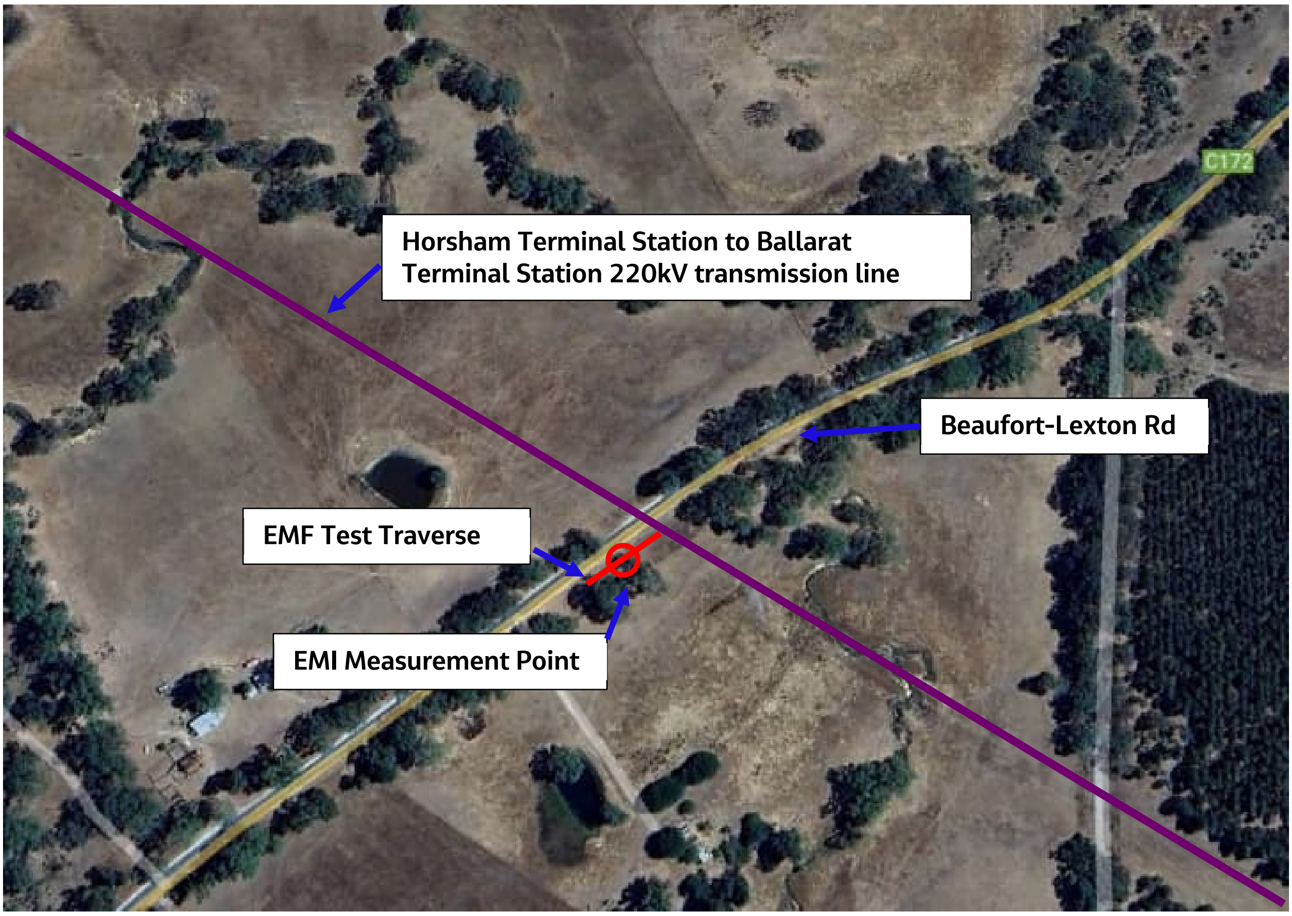

Figure C.9: Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line EMI and EMF measurement Location 2 (Source: Jacobs, 2023)

Table C.2: Measured EMF levels for Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line – Location 2

Distance from centre of transmission line (m)	Magnetic Flux Density (μT)	Electric Field Strength (V/m)
0	2.56	772.3
10	2.26	683.3
20	1.83	58
30	1.21	10.6
40	0.76	4.4
50	0.51	6.9

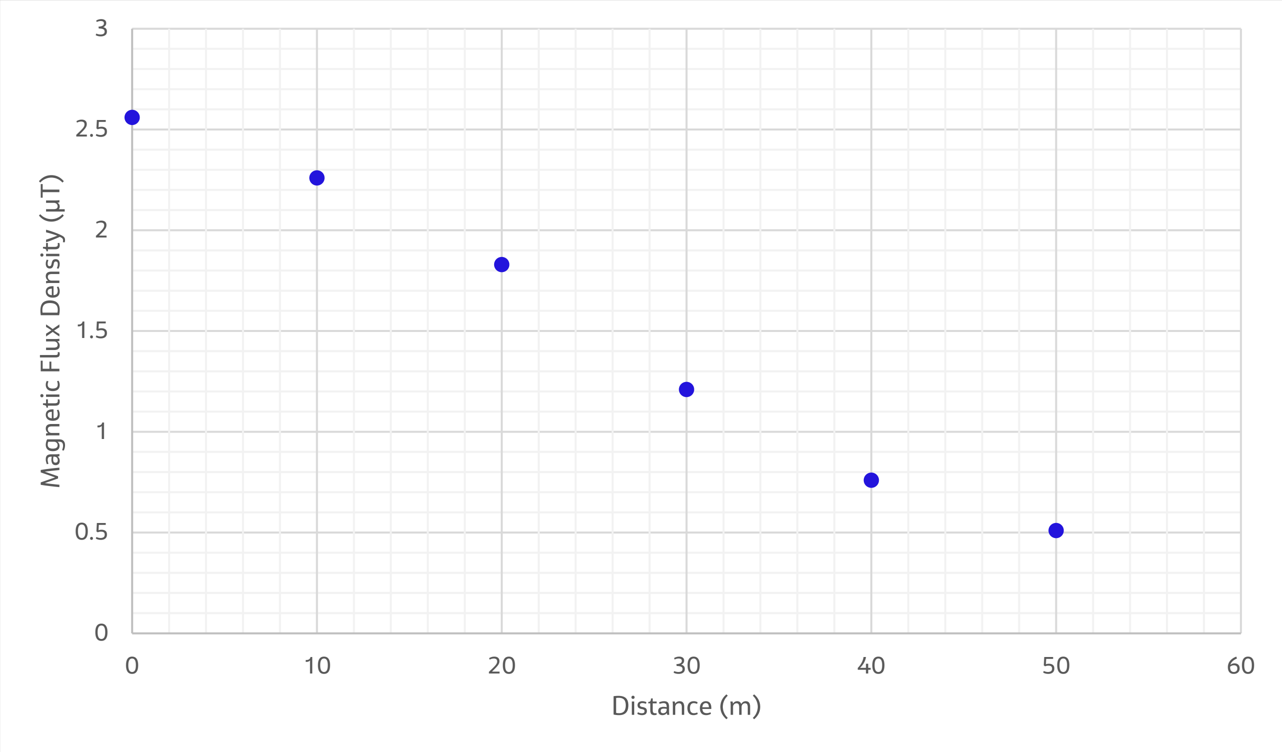

Figure C.10: Measured magnetic flux density for Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line – Location 2 (Source: Jacobs, 2023)

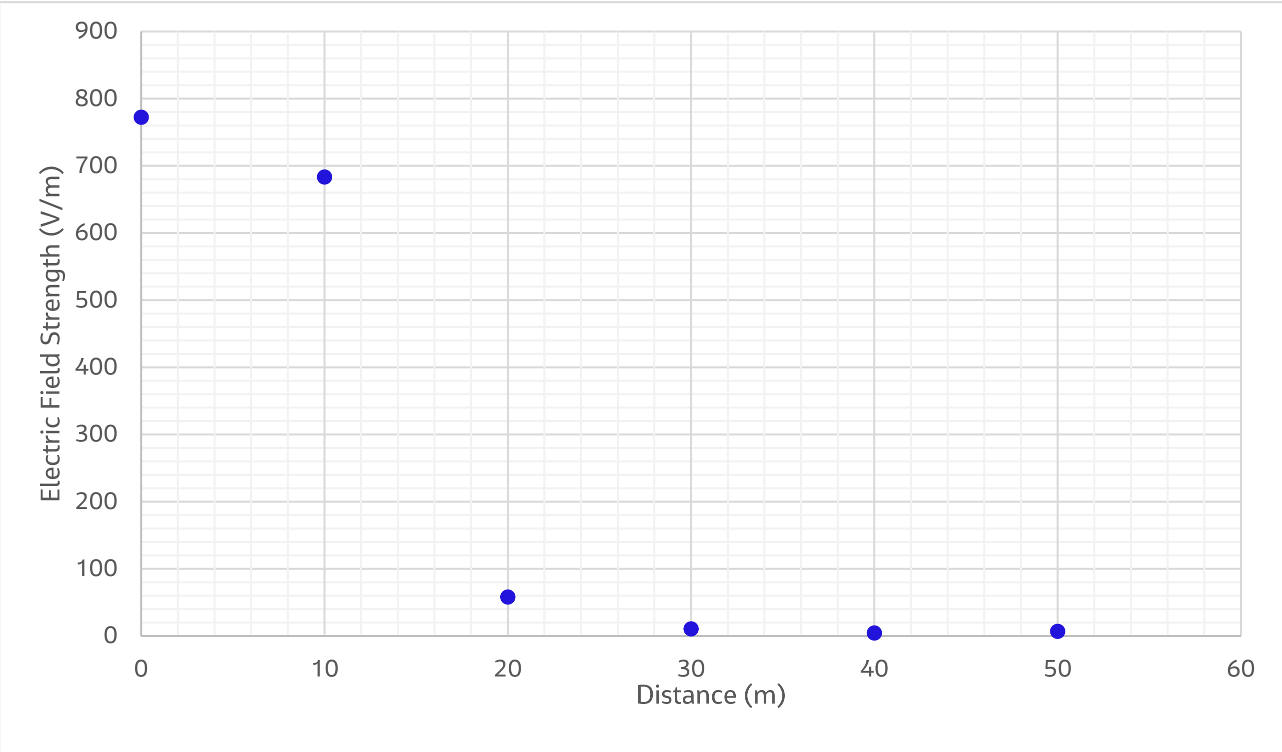

Figure C.11: Measured electric field strength for Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line – Location 2 (Source: Jacobs, 2023)

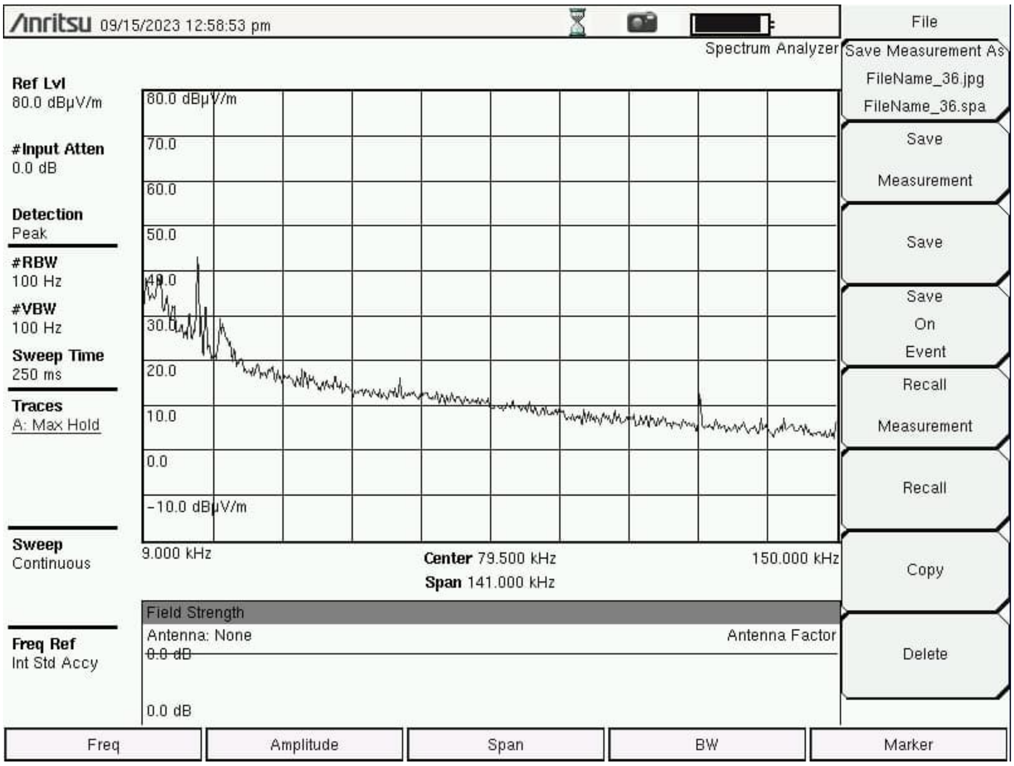

Figure C.12: EMI measurement for Horsham Terminal Station to Ballarat Terminal Station - 220kV transmission lines - 20m from centreline – 9kHz to 150kHz - Location 2 (Source: Jacobs, 2023)

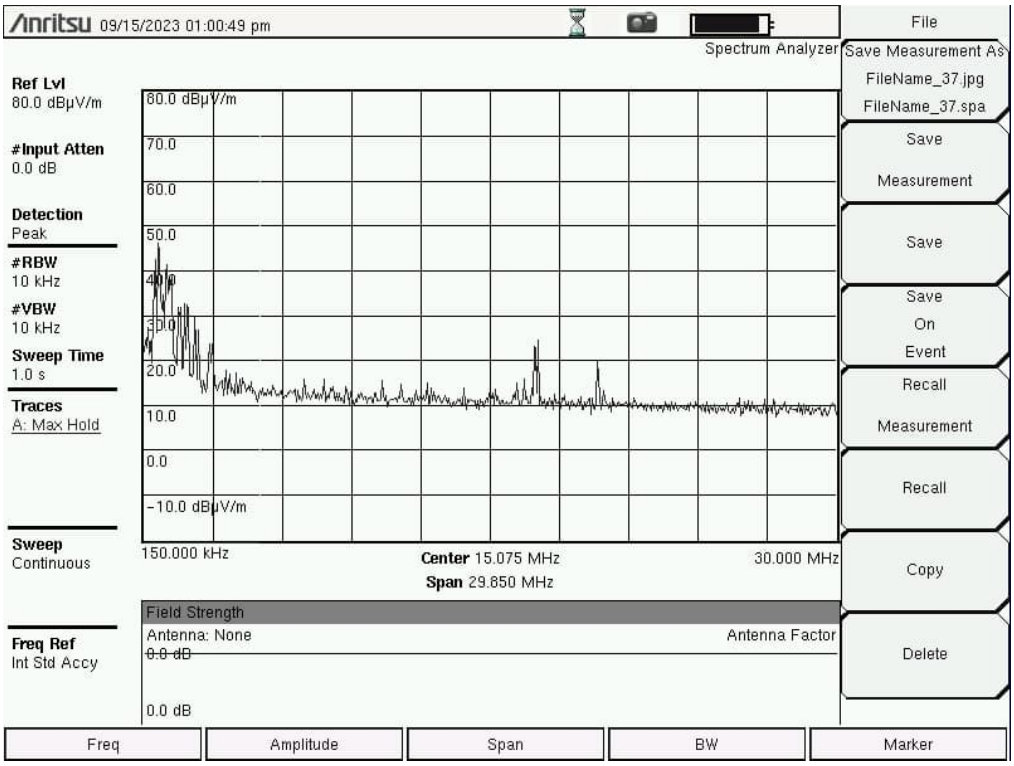

Figure C.13: EMI measurement for Horsham Terminal Station to Ballarat Terminal Station - 220kV transmission lines - 20m from centreline – 150kHz to 30MHz - Location 2 (Source: Jacobs, 2023)

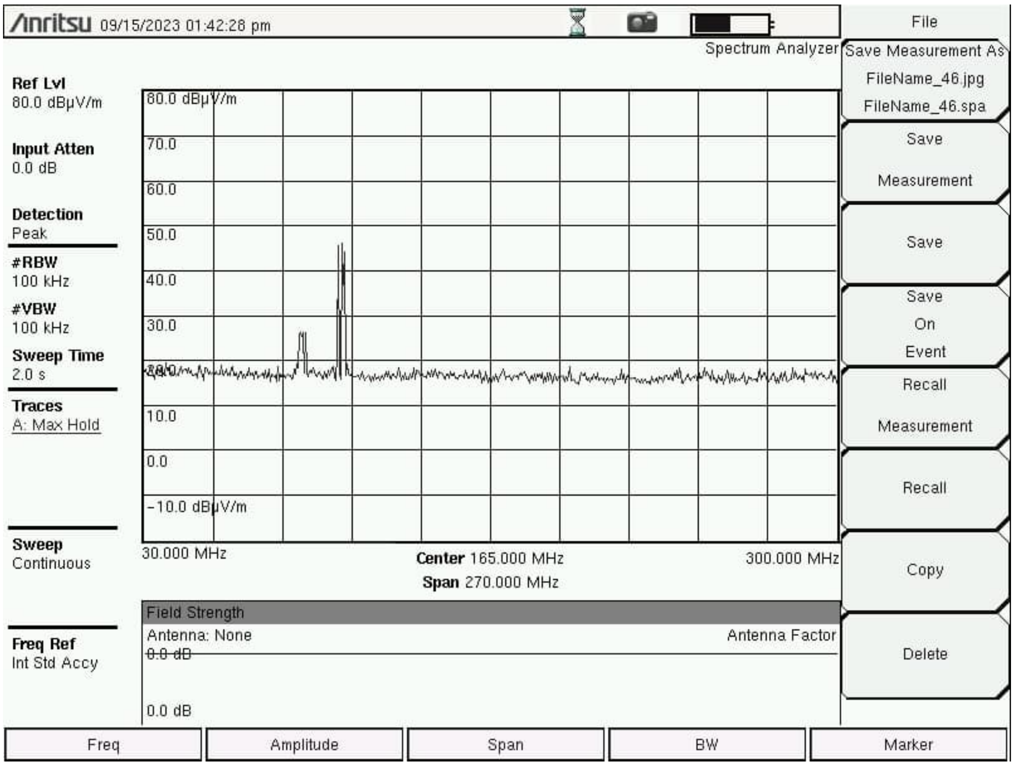

Figure C.14: EMI measurement for Horsham Terminal Station to Ballarat Terminal Station - 220kV transmission lines - 20m from centreline – 30MHz to 300MHz - Location 2 (Source: Jacobs, 2023)

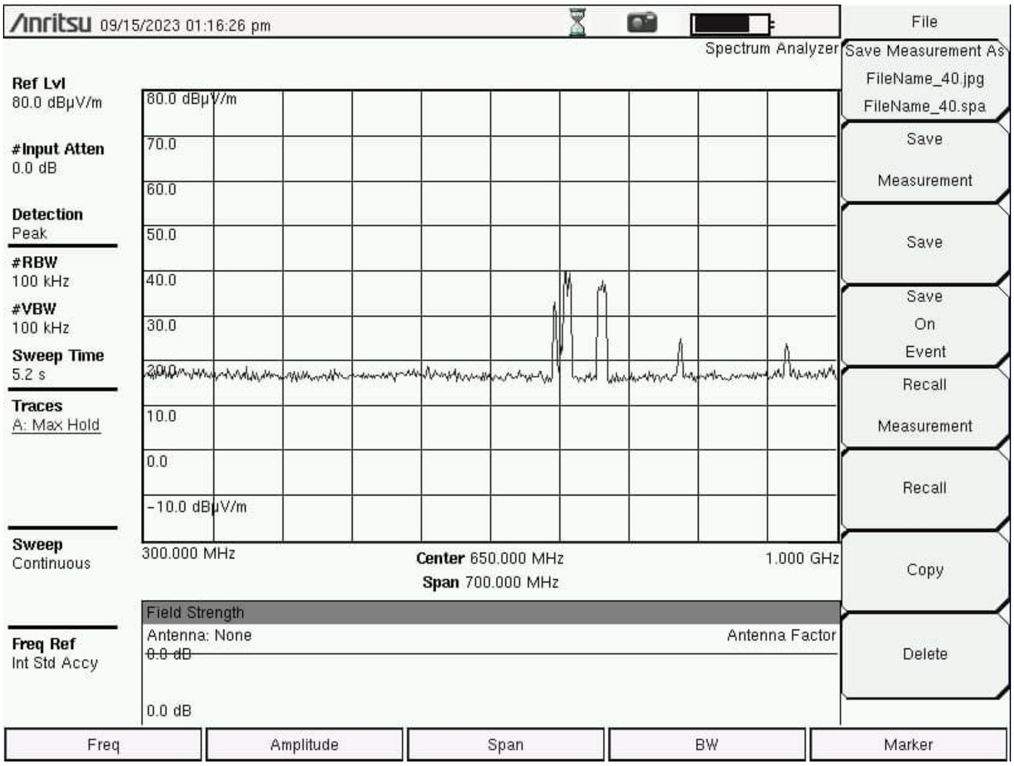

Figure C.15: EMI measurement for Horsham Terminal Station to Ballarat Terminal Station - 220kV transmission lines - 20m from centreline – 300MHz to 1GHz - Location 2 (Source: Jacobs, 2023)

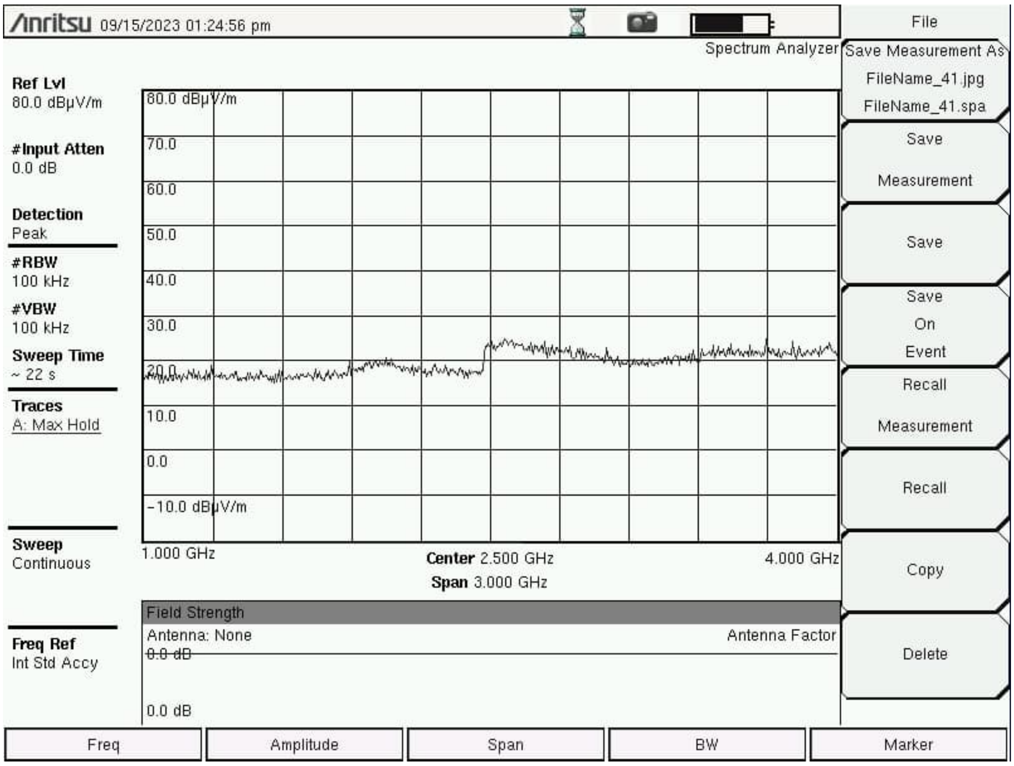

Figure C.16: EMI measurement for Horsham Terminal Station to Ballarat Terminal Station - 220kV transmission lines - 20m from centreline – 1GHz to 4GHz - Location 2 (Source: Jacobs, 2023)

C.3 EMI and EMF measurements for Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line – Location 3

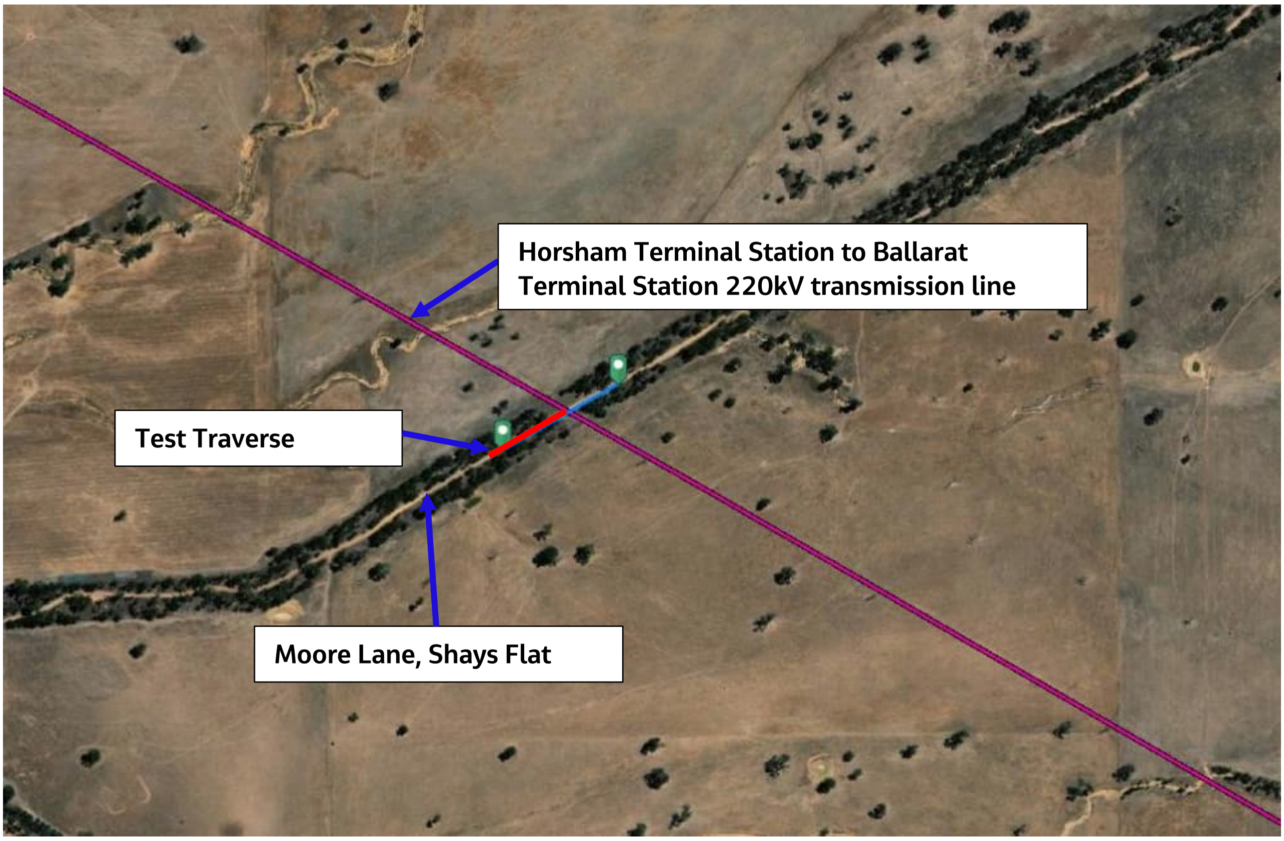

Figure C.17: Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line EMI and EMF measurement Location 3 (Source: Jacobs, 2022)

Table C.3: Measured EMF levels for Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line – Location 3

Distance from centre of transmission line (m)	Magnetic Flux Density (μT)	Electric Field Strength (V/m)
0	2.51	1067
12.5	1.48	720.7
25	0.65	24.72
37.5	0.42	5.97
50	0.26	4.55
62.5	0.17	1.31
75	0.13	4.86
87.5	0.14	2.71
100	0.11	0.98

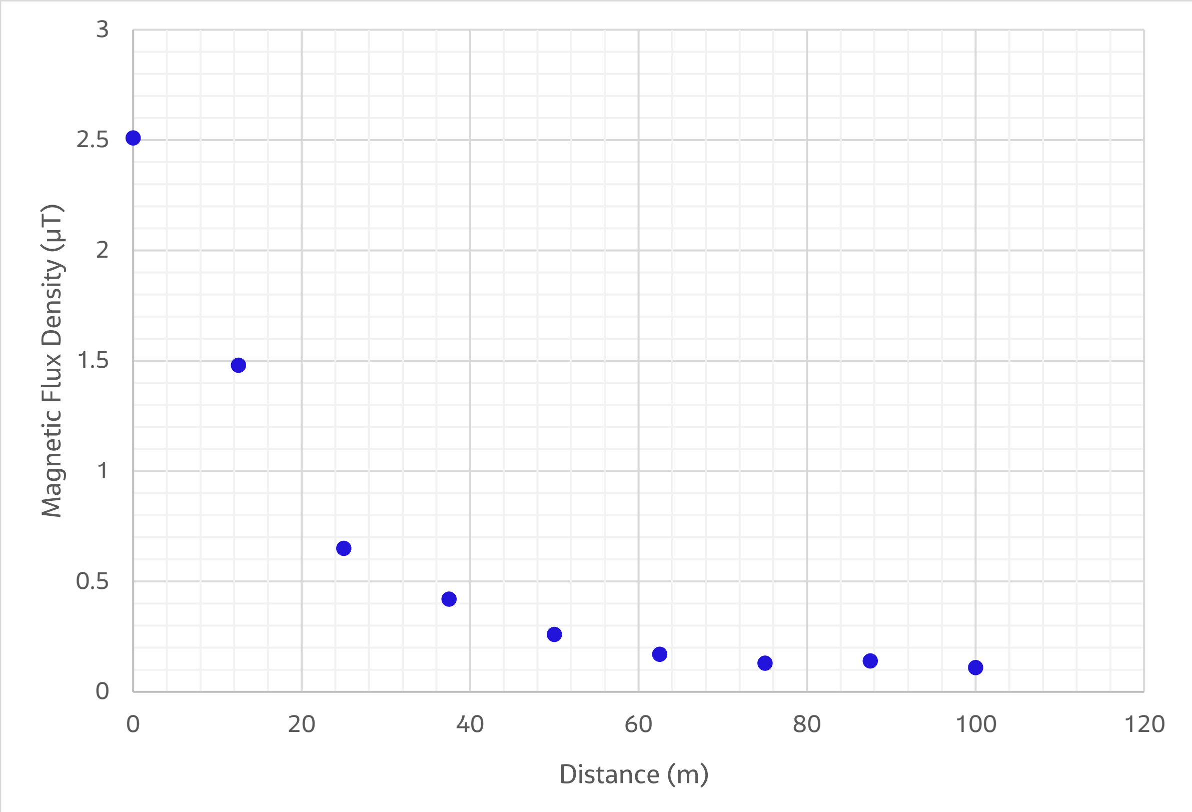

Figure C.18: Measured magnetic flux density for Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line – Location 3 (Source: Jacobs, 2022)

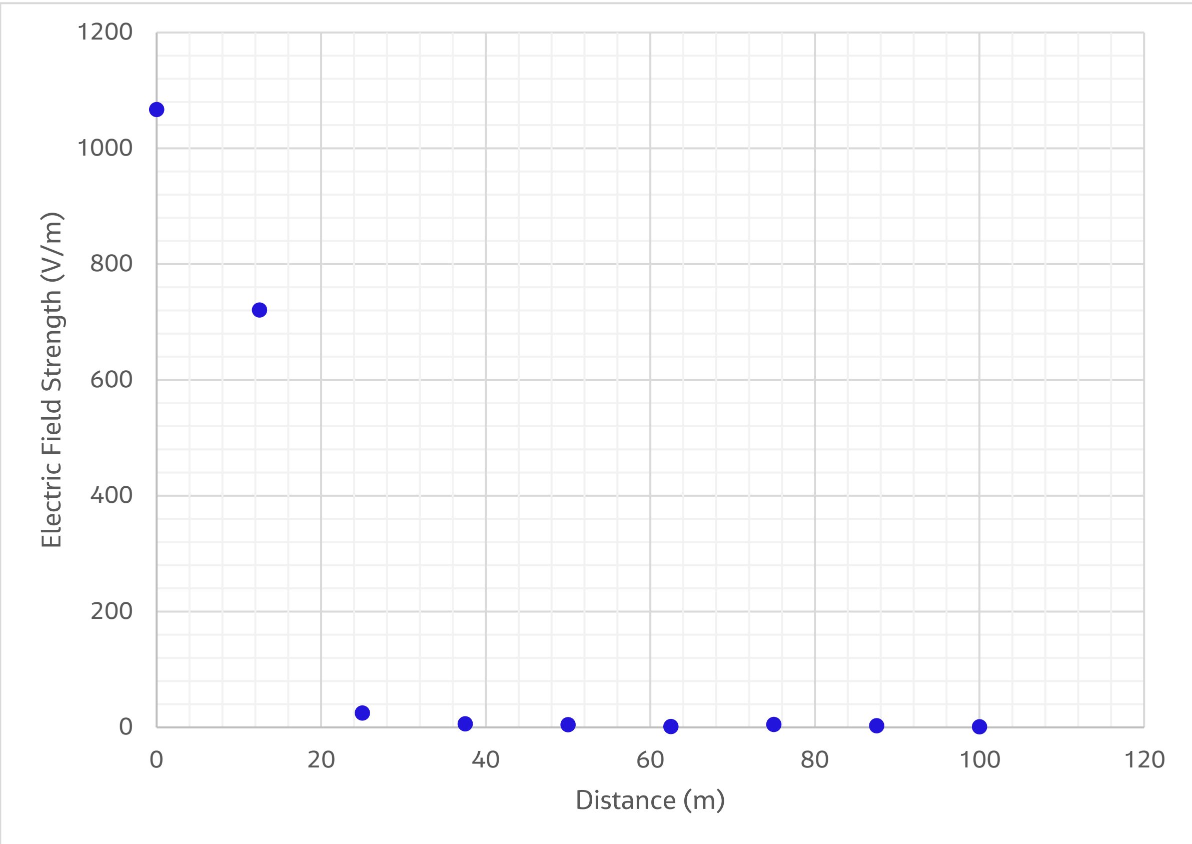

Figure C.19: Measured electric field strength for Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line – Location 3 (Source: Jacobs, 2022)

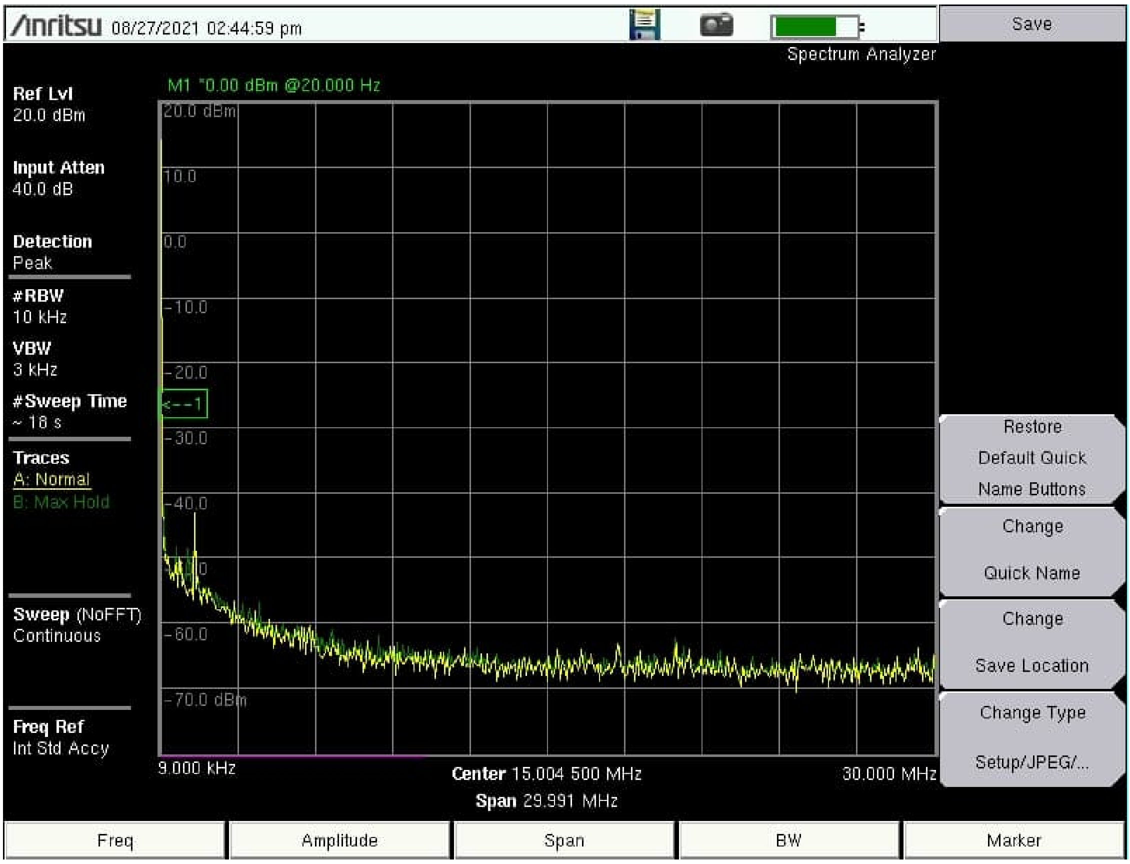

Figure C.20: EMI measurement for Horsham Terminal Station to Ballarat Terminal Station 220kV transmission line – Location 3 (Source: Jacobs, 2022)

C.4 EMI and EMF measurements at the new 500kV terminal station near Bulgana

Figure C.21: The new 500kV terminal station near Bulgana EMI and EMF measurement location (Source: Jacobs, 2022)

Table C.4: Measured EMF levels at the new 500kV terminal station near Bulgana

Distance from terminal station fence line (m)	Magnetic Flux Density (μT)	Electric Field Strength (V/m)
0	0.16	64.68
12.5	0.05	55.82
25	0.04	35.6
37.5	0.04	22.55
50	0.04	18.4
62.5	0.04	16.45
75	0.04	14.74
87.5	0.04	14.2
100	0.04	13.1

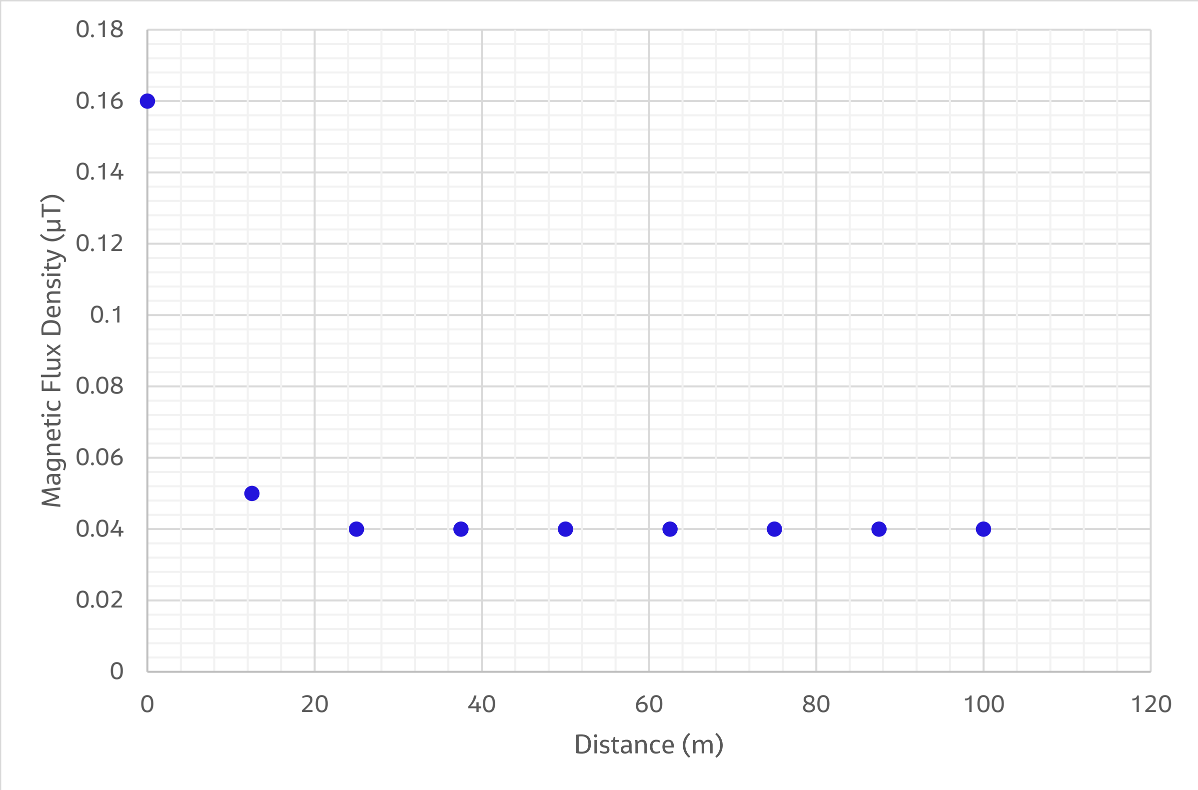

Figure C.22: Measured magnetic flux density at the new 500kV terminal station near Bulgana (Source: Jacobs, 2022)

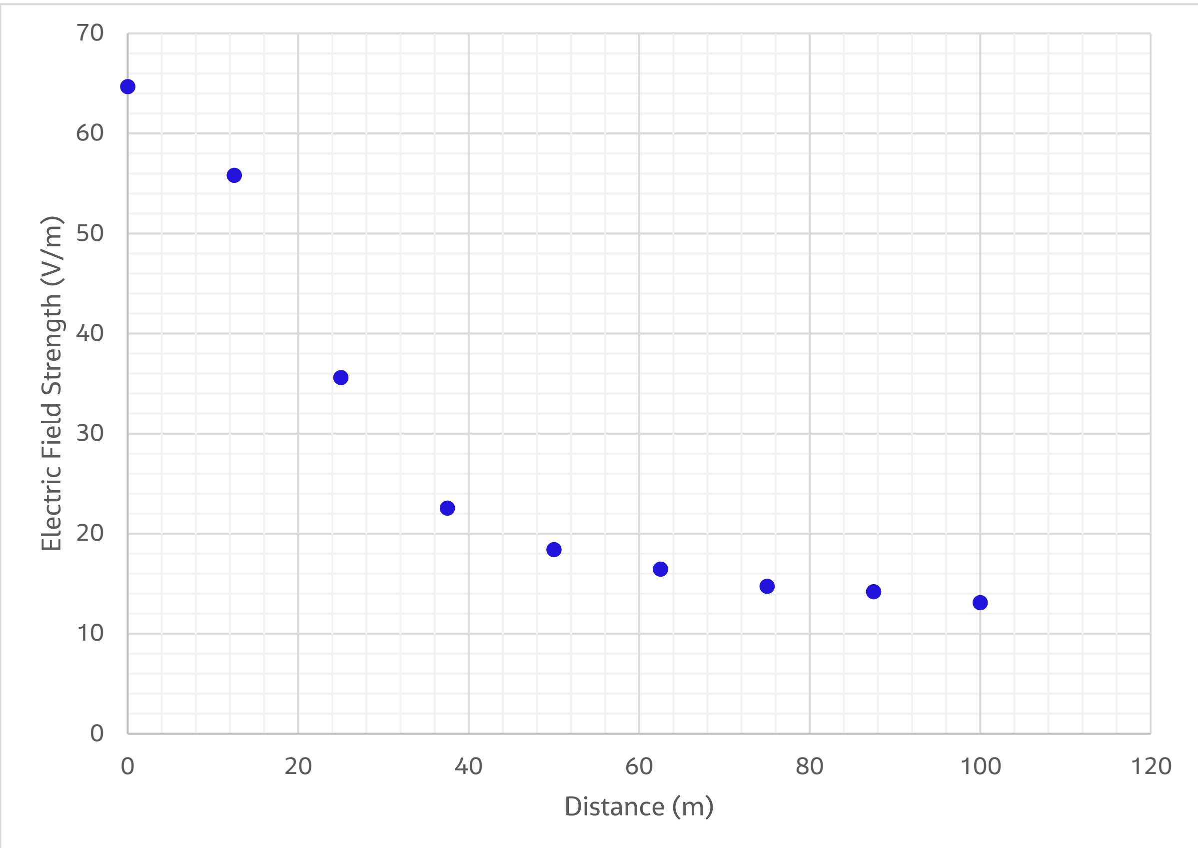

Figure C.23: Measured electric field strength at the new 500kV terminal station near Bulgana (Source: Jacobs, 2022)

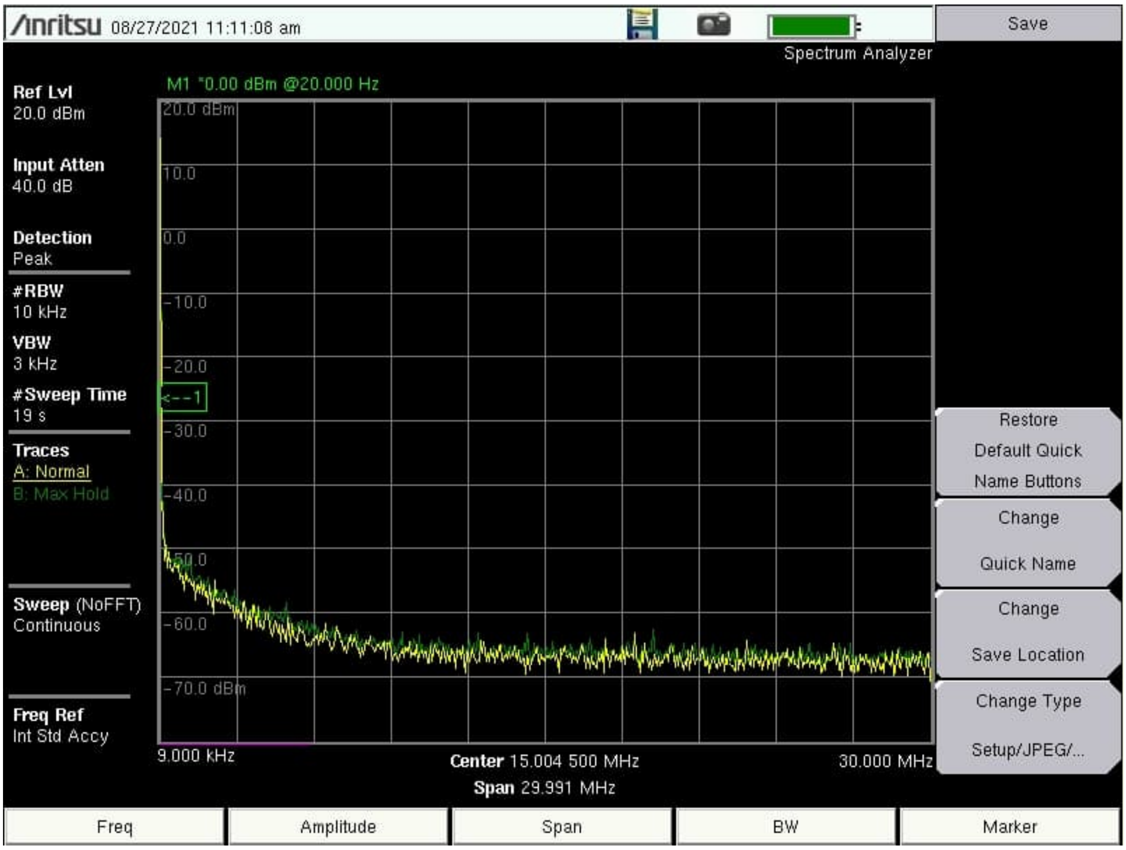

Figure C.24: EMI measurement at the new 500kV terminal station near Bulgana (Source: Jacobs, 2022)

C.5 EMI and EMF measurements at Waubra Terminal Station

Figure C.25: Waubra Terminal Station EMI and EMF measurement location (Source: Jacobs, 2022)

Table C.5: Measured EMF levels at Waubra Terminal Station

Distance from terminal station fence line (m)	Magnetic Flux Density (μT)	Electric Field Strength (V/m)
0	0.03	4.71
12.5	0.03	2.33
25	0.03	1.49
37.5	0.03	1.11
50	0.03	1.58
62.5	0.03	4.1
75	0.03	9.56

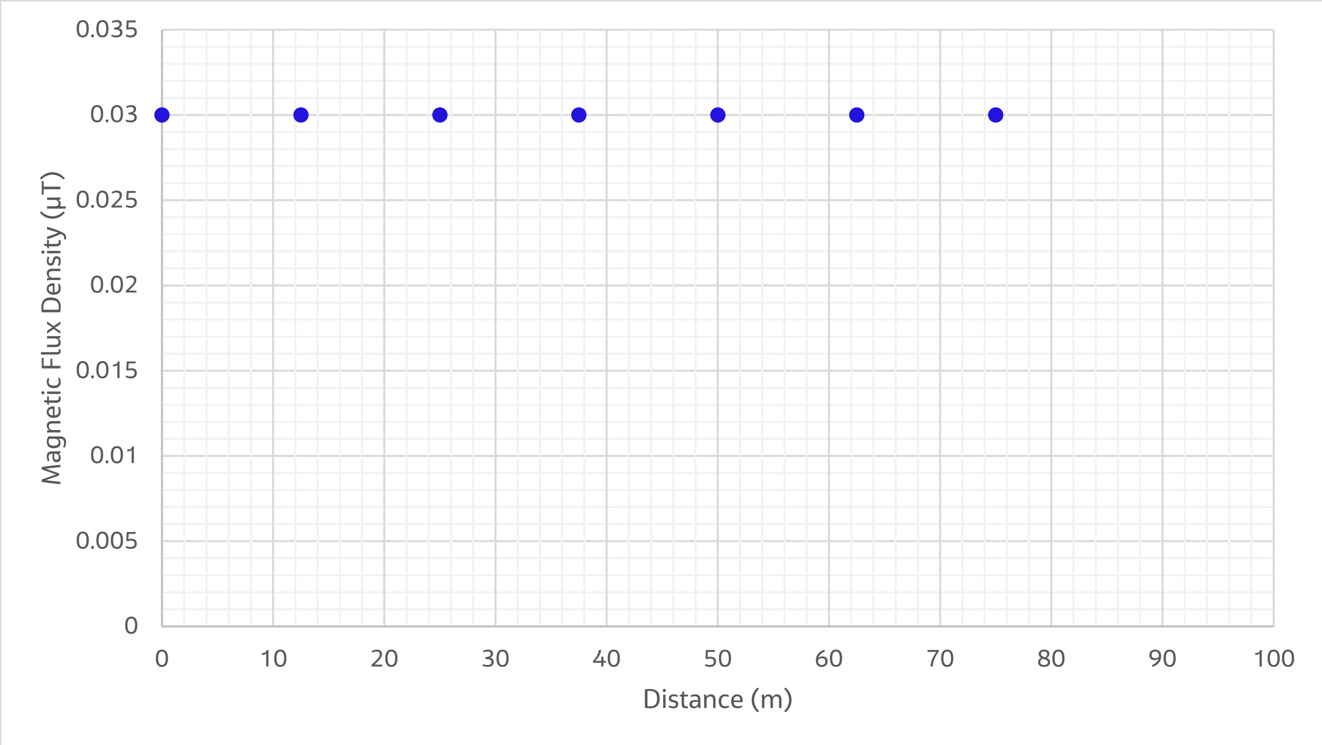

Figure C.26: Measured magnetic flux density at Waubra Terminal Station (Source: Jacobs, 2022)

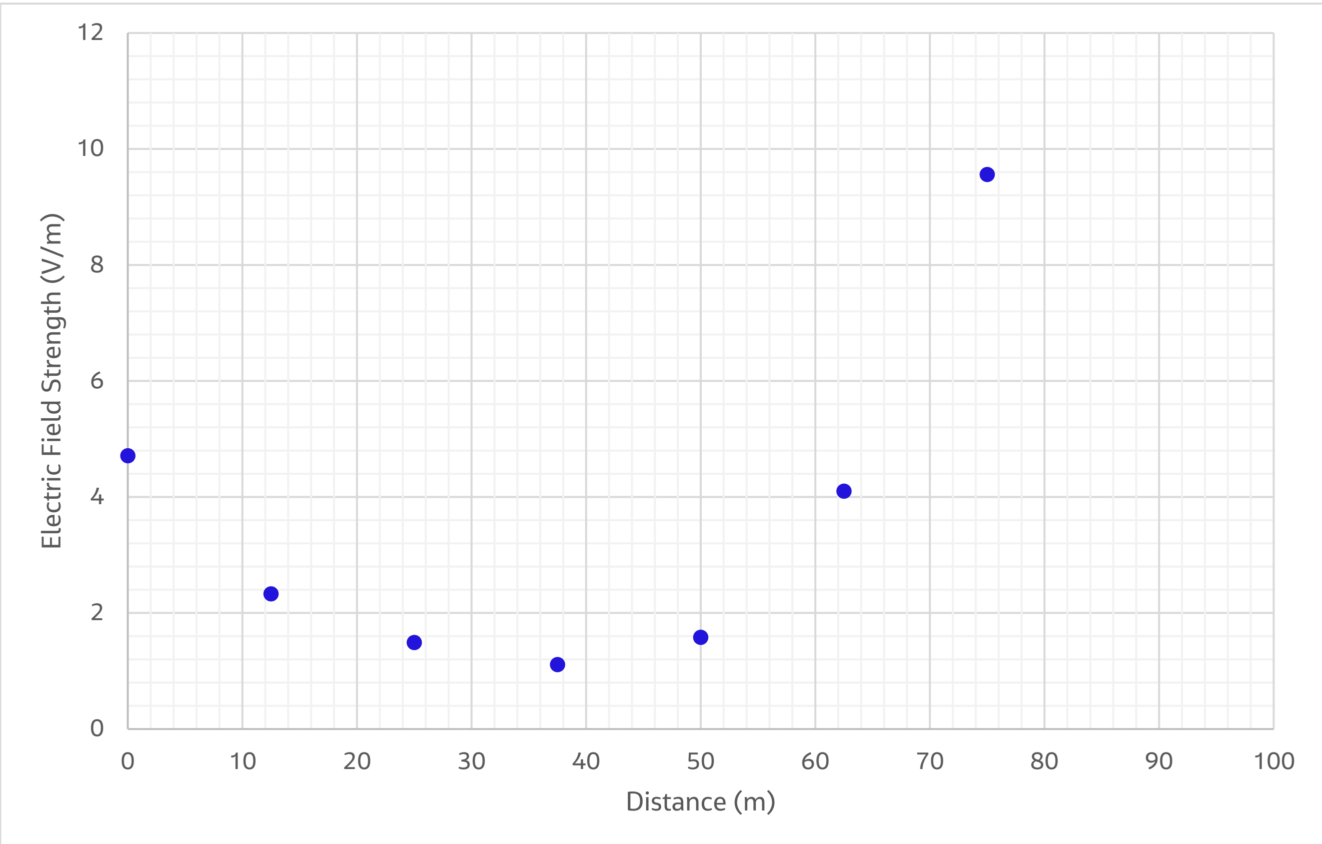

Figure C.27: Measured electric field strength at Waubra Terminal Station (Source: Jacobs, 2022)

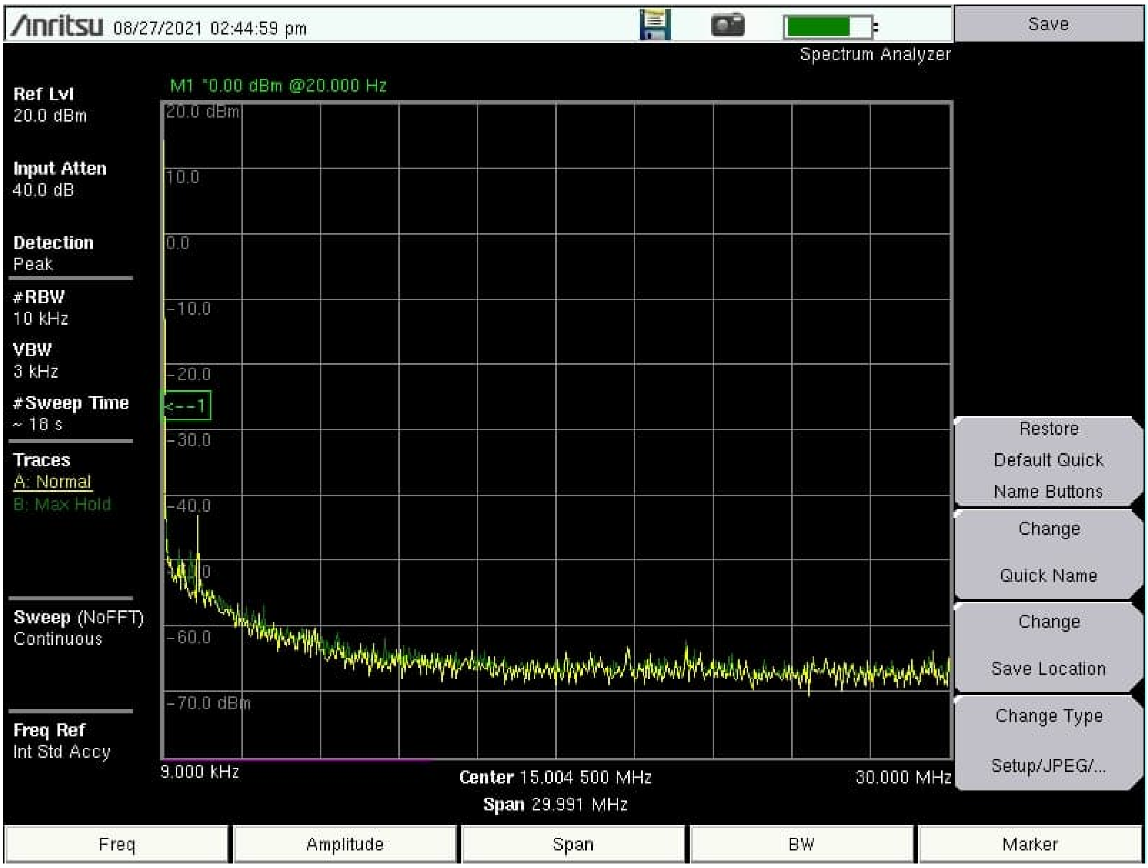

Figure C.28: EMI measurement at Waubra Terminal Station (Source: Jacobs, 2022)

C.6 EMI and EMF measurements at Sydenham Terminal Station

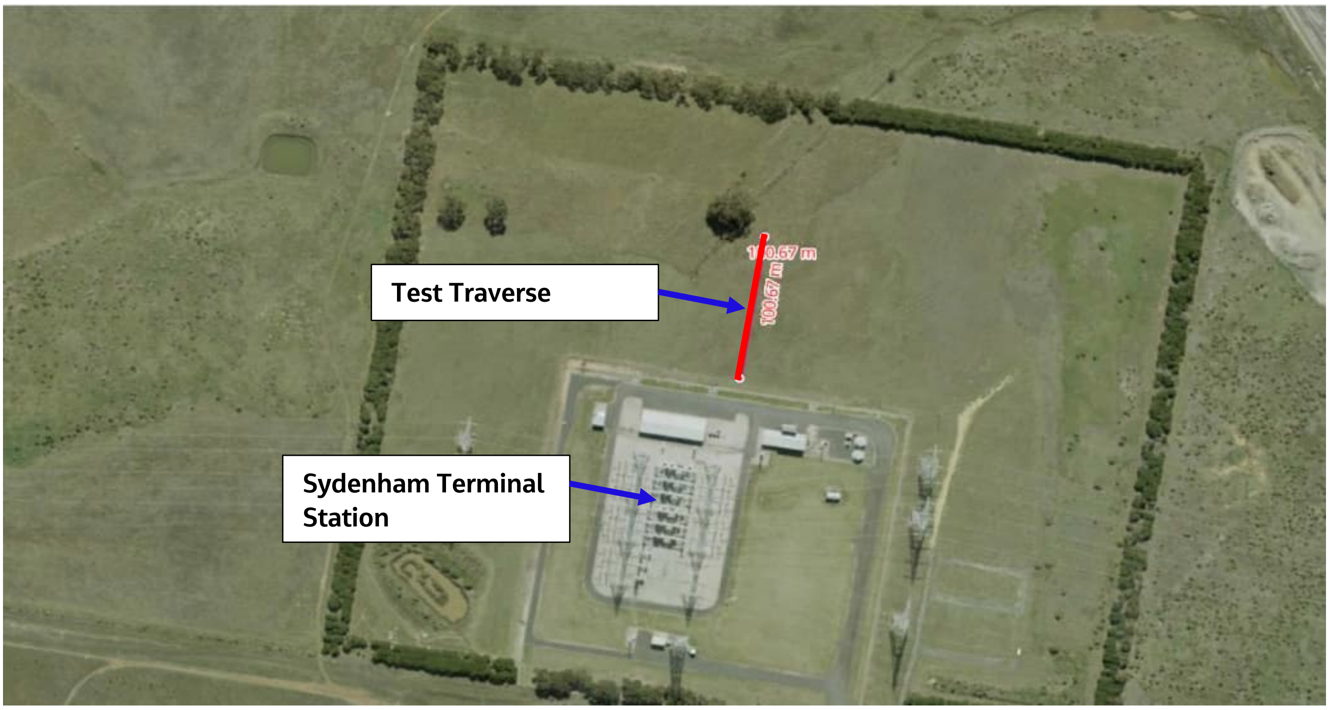

Figure C.29: Sydenham Terminal Station EMI and EMF measurement location (Source: Jacobs, 2022)

Table C.6: Measured EMF levels at Sydenham Terminal Station

Distance from terminal station fence line (m)	Magnetic Flux Density (μT)	Electric Field Strength (V/m)
0	0.32	187.2
12.5	0.26	231.5
25	0.2	165.9
37.5	0.15	123.1
50	0.11	93.89
62.5	0.09	75.01
75	0.07	58.21
87.5	0.06	46.25
100	0.06	39.12

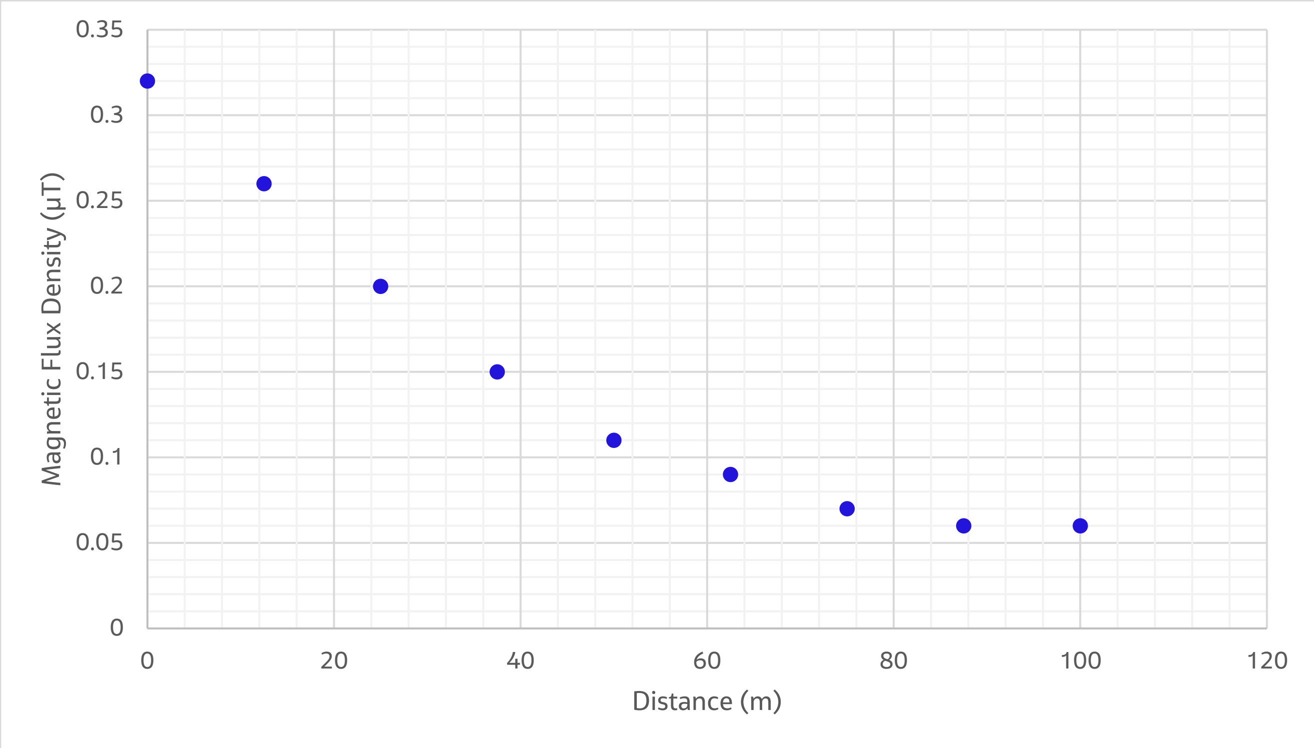

Figure C.30: Measured magnetic flux density at Sydenham Terminal Station (Source: Jacobs, 2022)

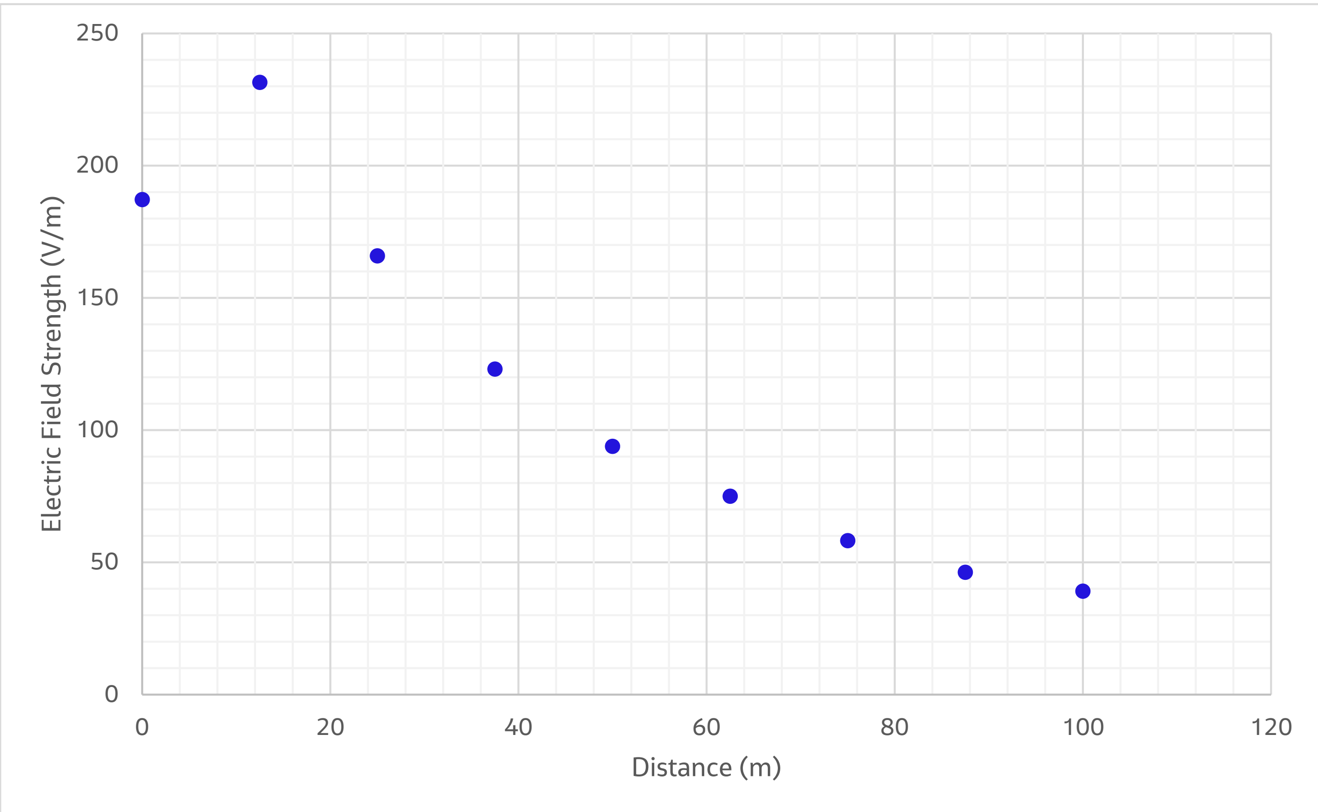

Figure C.31: Measured electric field strength at Sydenham Terminal Station (Source: Jacobs, 2022)

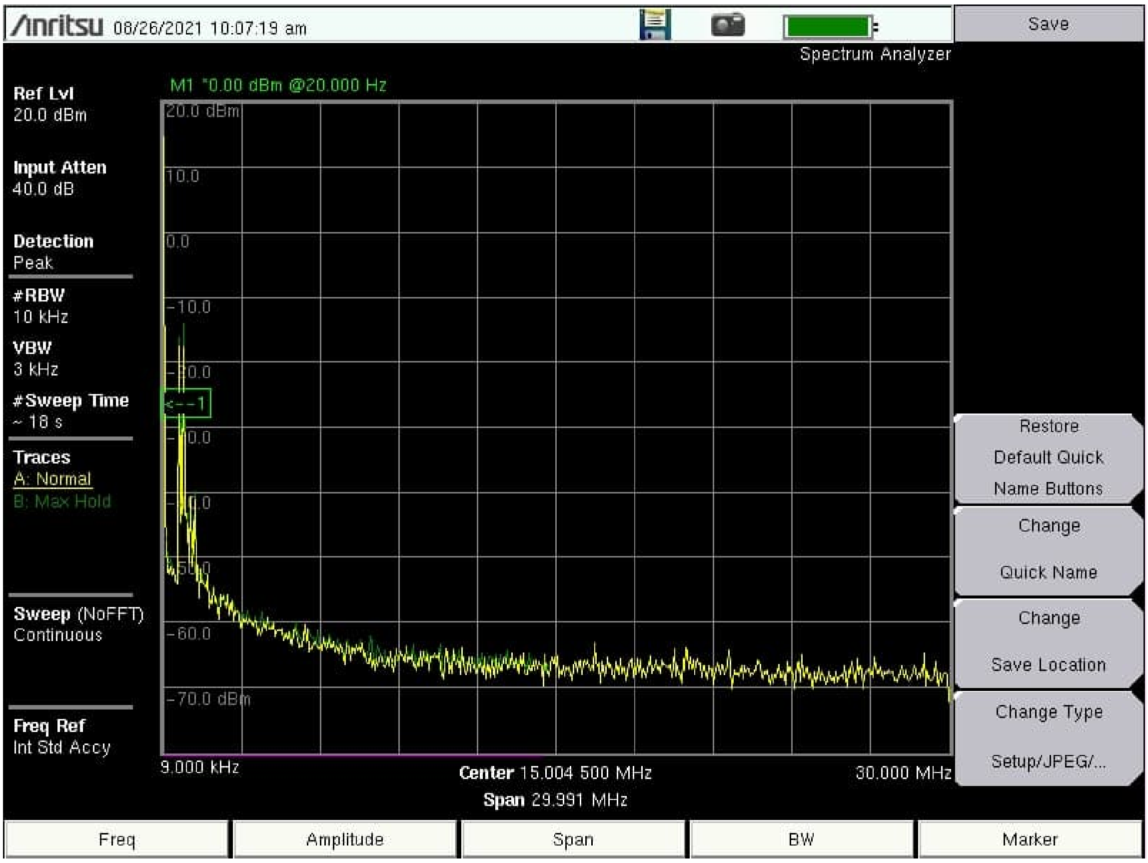

Figure C.32: EMI measurement at Sydenham Terminal Station (Source: Jacobs, 2022)

C.7 EMI and EMF measurement for Moorabool Terminal Station to Sydenham Terminal Station circuits 1 and 2 - 500kV transmission lines

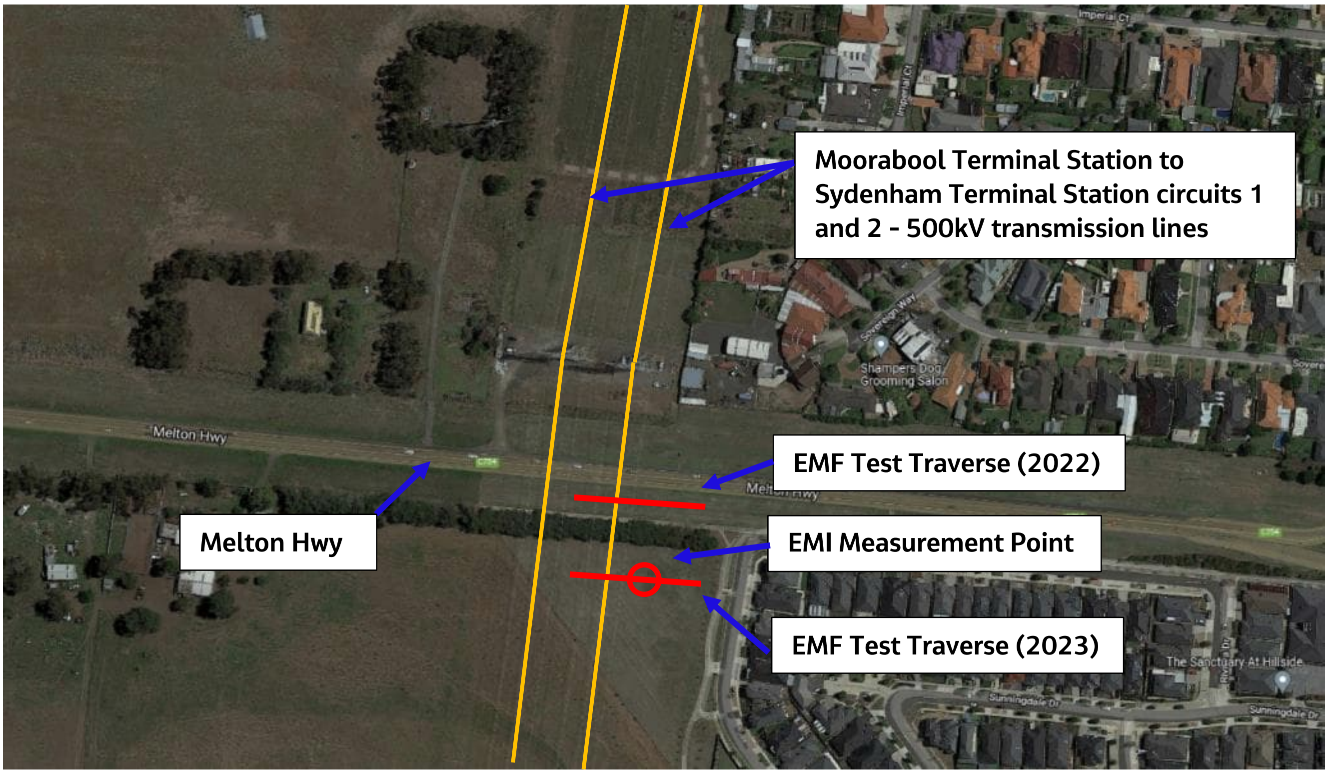

Figure C.33: Moorabool Terminal Station to Sydenham Terminal Station circuits 1 and 2 - 500kV transmission lines EMI and EMF measurement location (Source: Jacobs, 2023)

Table C.7: Measured EMF levels for Moorabool Terminal Station to Sydenham Terminal Station circuits 1 and 2 - 500kV transmission lines (Source: Jacobs, 2022)

Distance from centre of transmission line (m)	Magnetic Flux Density (μT)	Electric Field Strength (V/m)
0	1.35	1538
12.5	0.95	1484
25	0.67	878.8
37.5	0.49	530.8
50	0.33	394.5
62.5	0.26	255.2
75	0.21	174.9
87.5	0.15	120.3
100	0.13	85.41

Table C.8: Measured EMF levels for Moorabool Terminal Station to Sydenham Terminal Station circuits 1 and 2 - 500kV transmission lines (Source: Jacobs, 2023)

Distance from centre of transmission line (m)	Magnetic Flux Density (μT)	Electric Field Strength (V/m)
0	0.43	1208
10	0.42	3573
20	0.32	3669
30	0.21	1916
40	0.16	1353
50	0.12	591

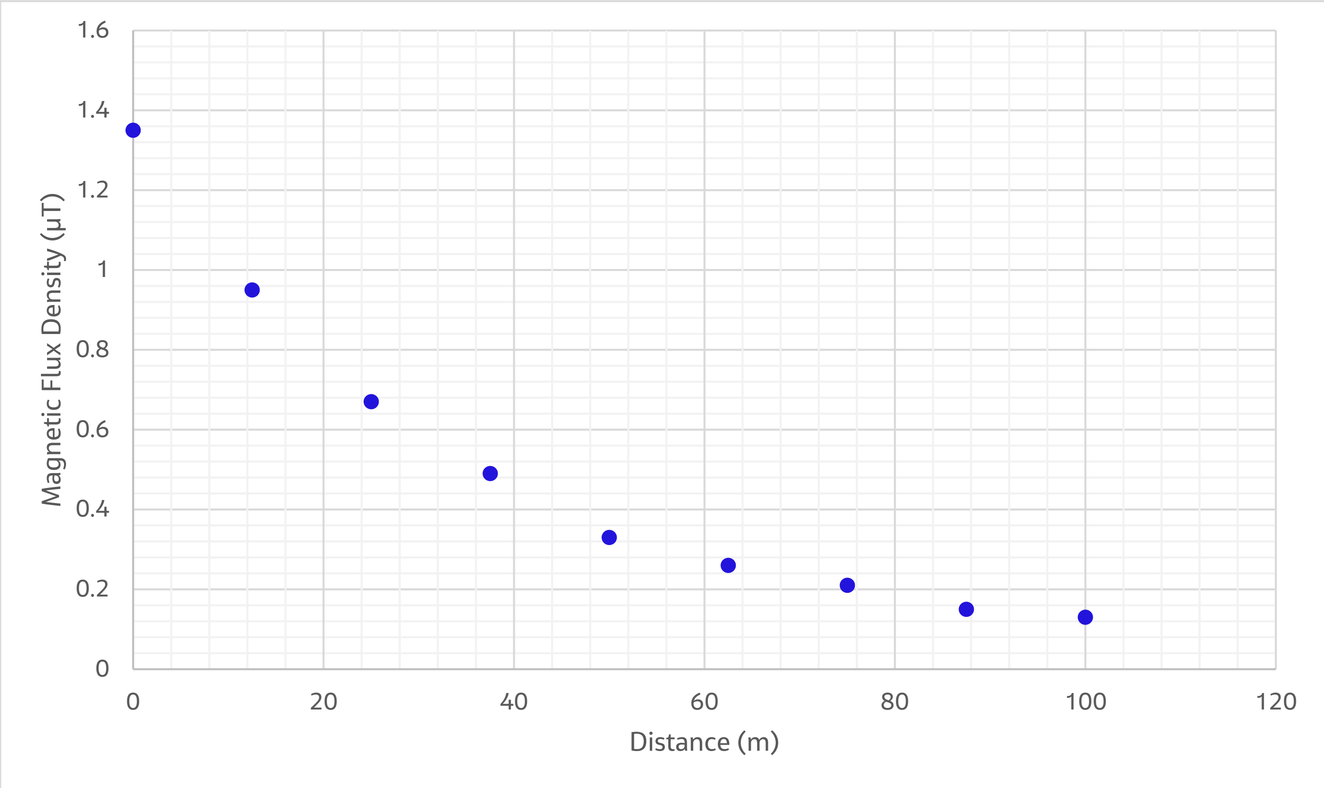

Figure C.34: Measured magnetic flux density for Moorabool Terminal Station to Sydenham Terminal Station circuits 1 and 2 - 500kV transmission lines (Source: Jacobs, 2022)

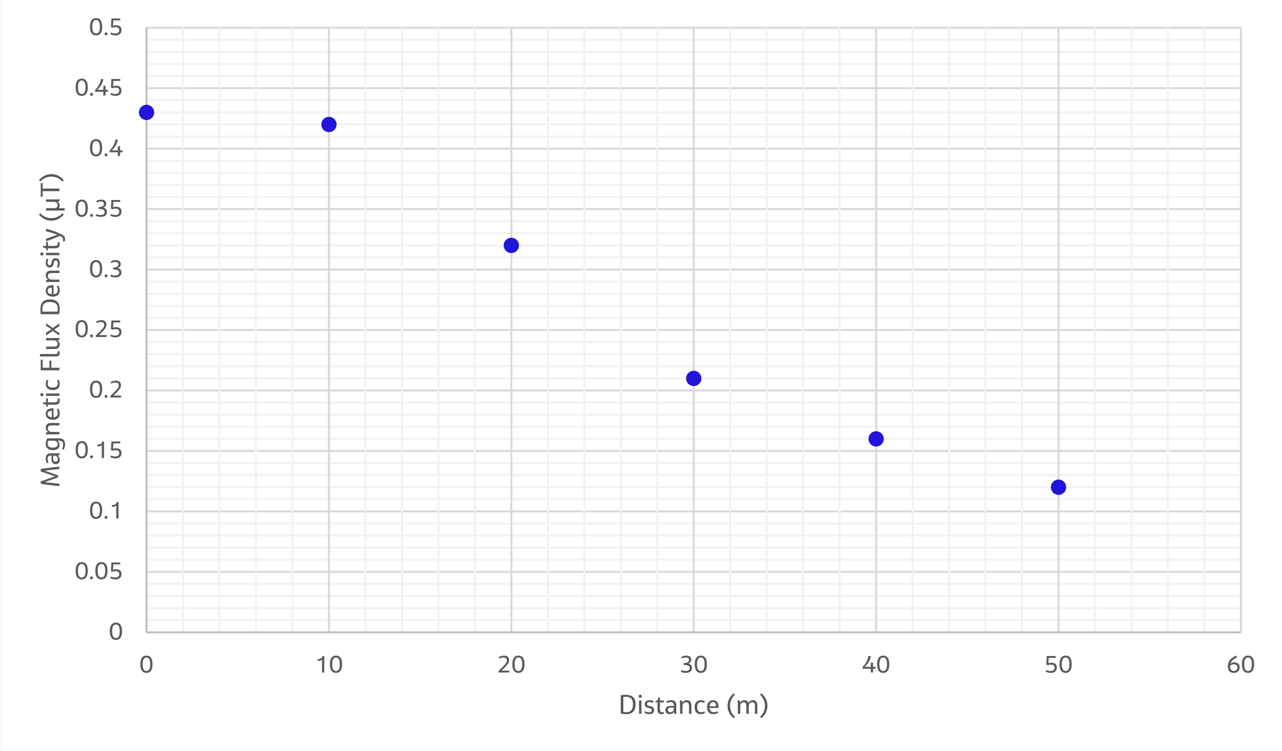

Figure C.35: Measured magnetic flux density for Moorabool Terminal Station to Sydenham Terminal Station circuits 1 and 2 - 500kV transmission lines (Source: Jacobs, 2023)

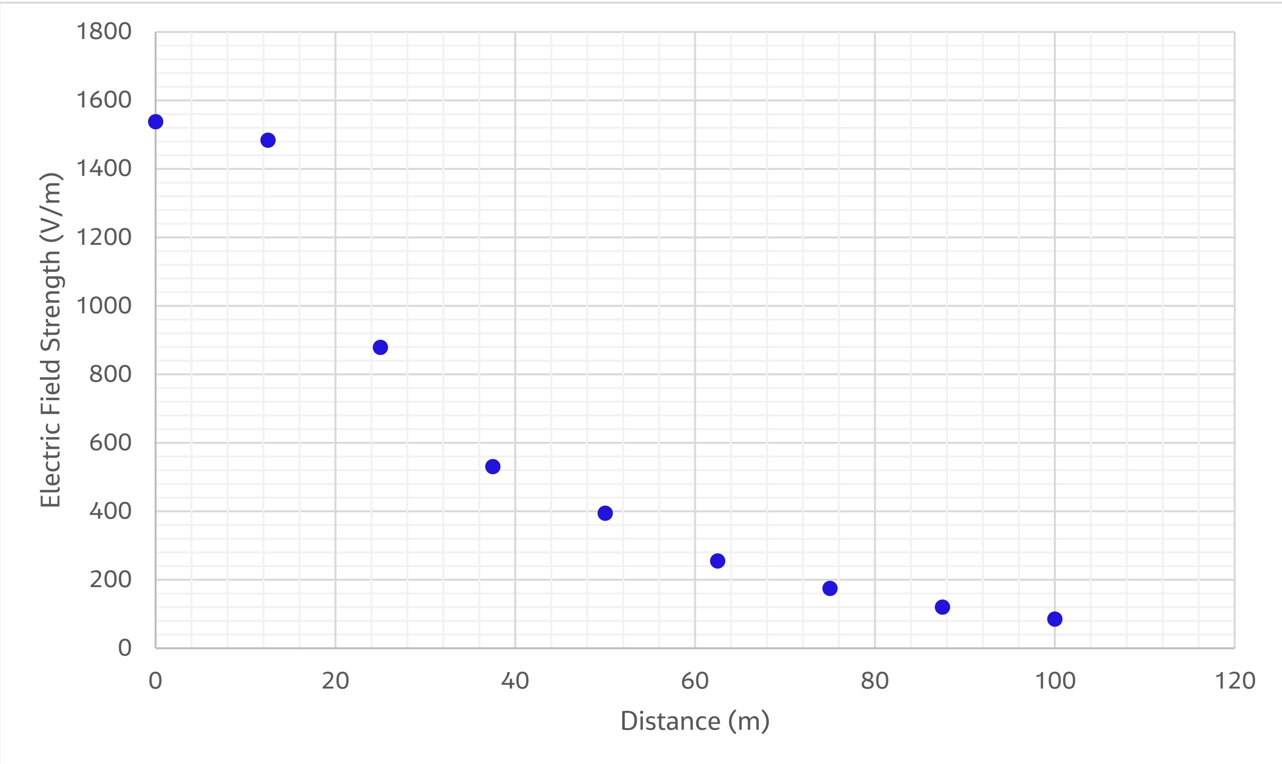

Figure C.36: Measured electric field strength for Moorabool Terminal Station to Sydenham Terminal Station circuits 1 and 2 - 500kV transmission lines (Source: Jacobs, 2022)

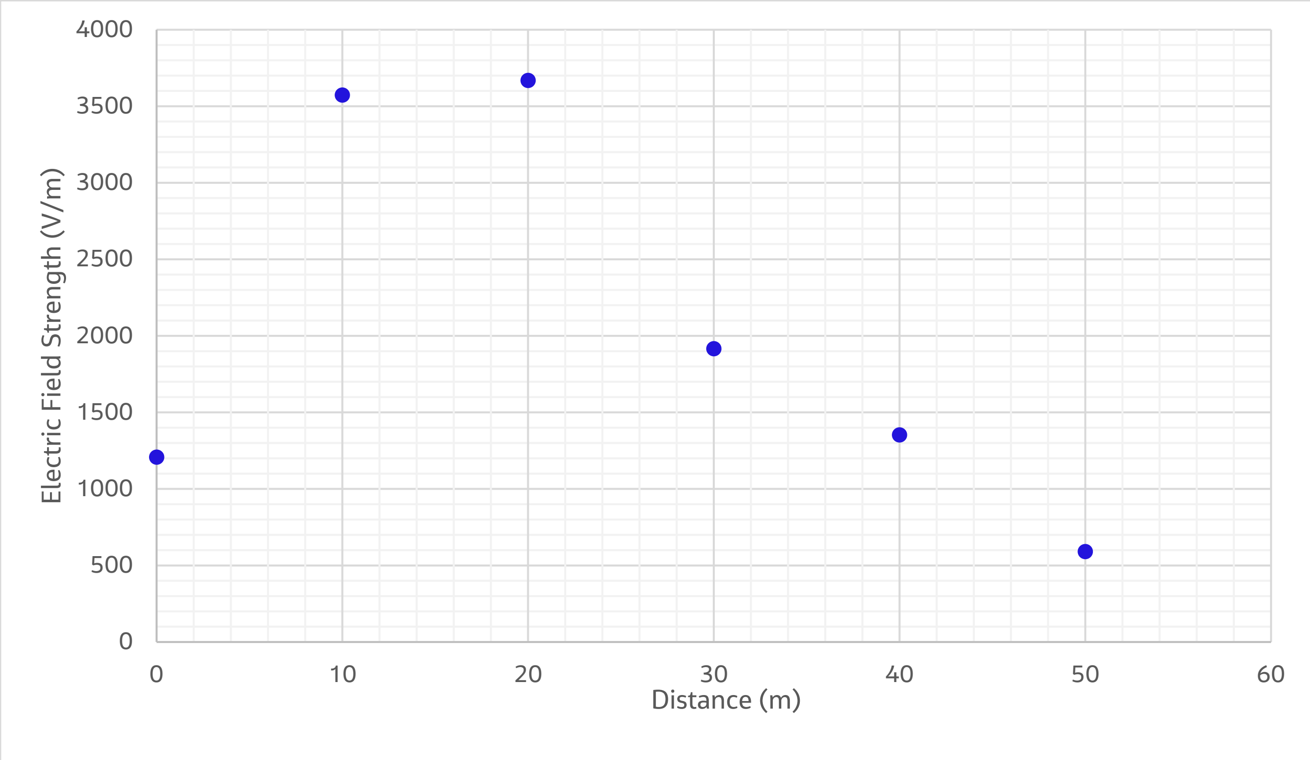

Figure C.37: Measured electric field strength for Moorabool Terminal Station to Sydenham Terminal Station circuits 1 and 2 - 500kV transmission lines (Source: Jacobs, 2023)

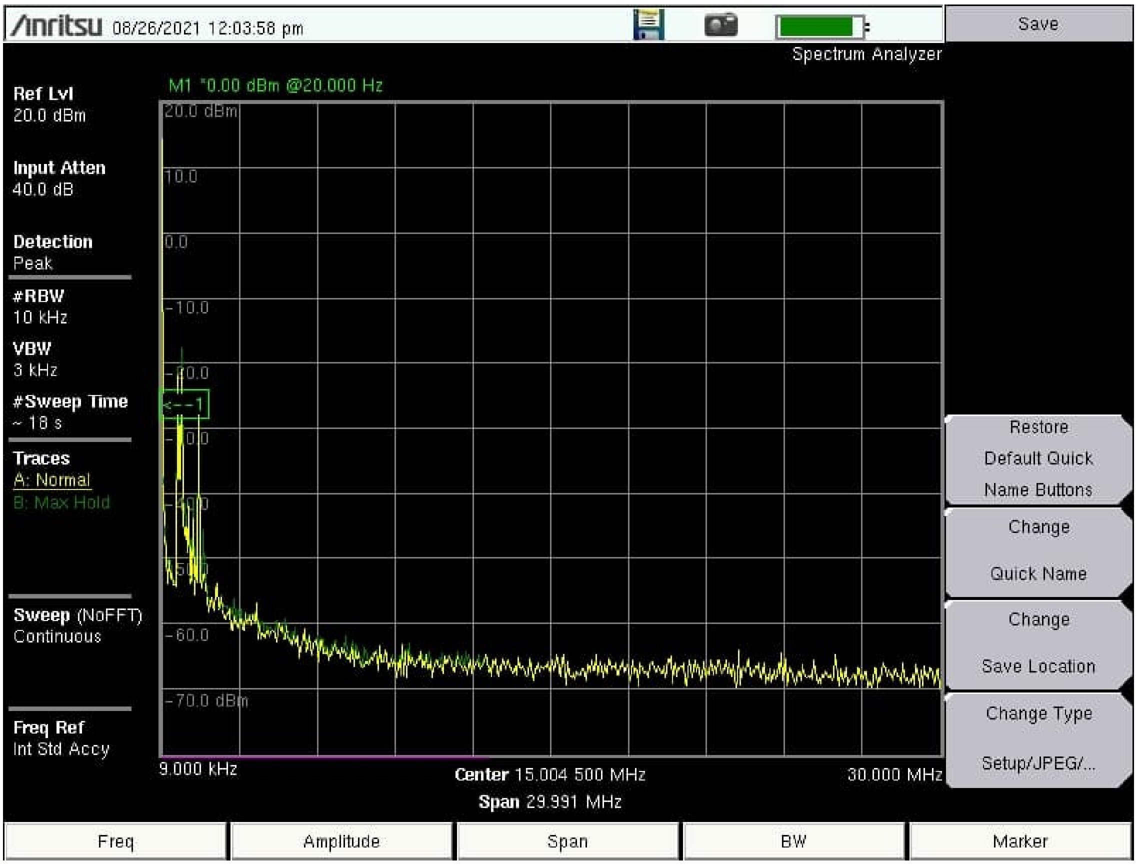

Figure C.38: EMI measurement for Moorabool Terminal Station to Sydenham Terminal Station circuits 1 and 2 - 500kV transmission lines (Source: Jacobs, 2022)

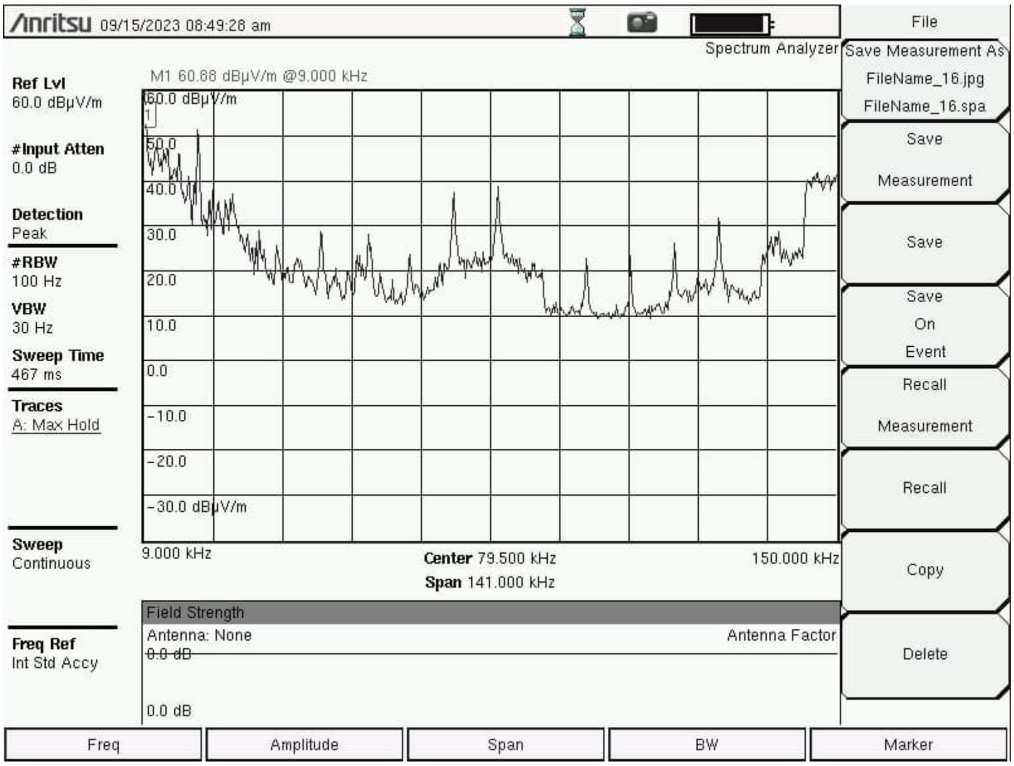

Figure C.39: EMI measurement for Moorabool Terminal Station to Sydenham Terminal Station circuits 1 and 2 - 500kV transmission lines - 30m from centreline – 9kHz to 150kHz (Source: Jacobs, 2023)

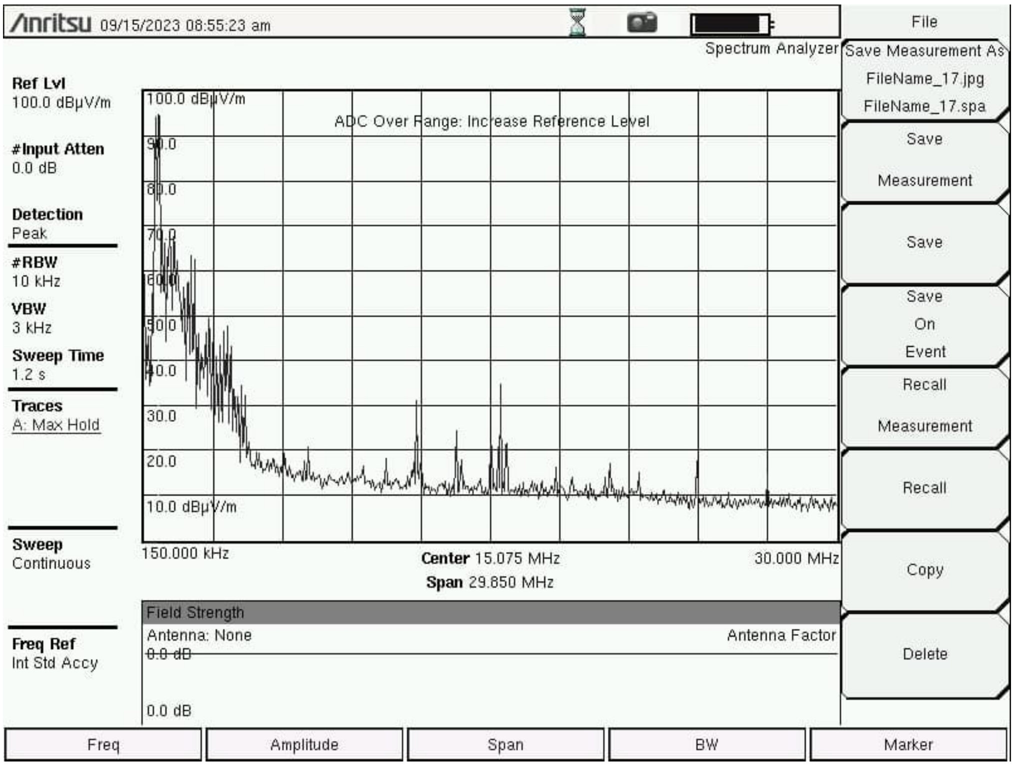

Figure C.40: EMI measurement for Moorabool Terminal Station to Sydenham Terminal Station circuits 1 and 2 - 500kV transmission lines - 30m from centreline – 150kHz to 30MHz (Source: Jacobs, 2023)

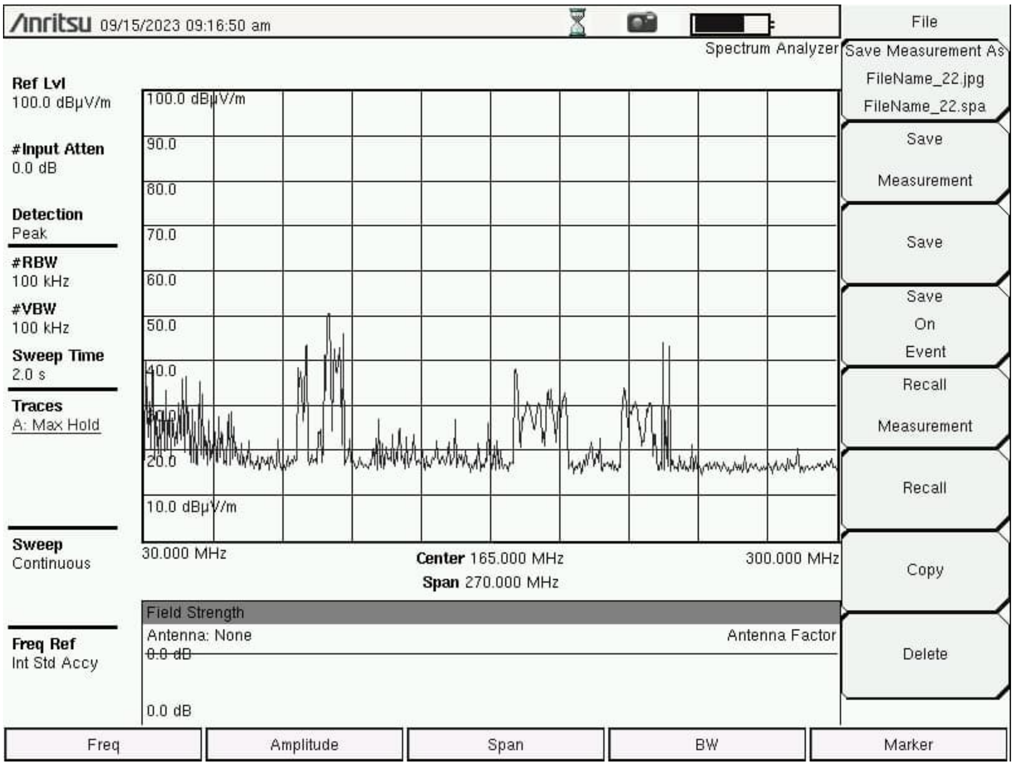

Figure C.41: EMI measurement for Moorabool Terminal Station to Sydenham Terminal Station circuits 1 and 2 - 500kV transmission lines - 30m from centreline – 30MHz to 300MHz (Source: Jacobs, 2023)

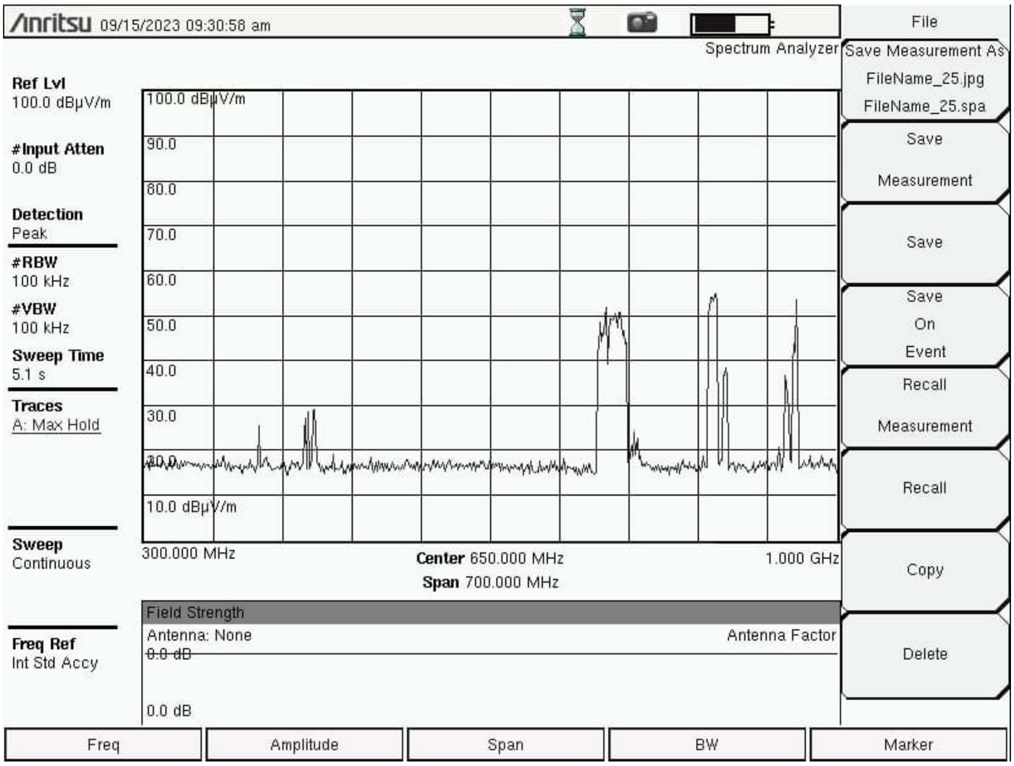

Figure C.42: EMI measurement for Moorabool Terminal Station to Sydenham Terminal Station circuits 1 and 2 - 500kV transmission lines - 30m from centreline – 300MHz to 1GHz (Source: Jacobs, 2023)

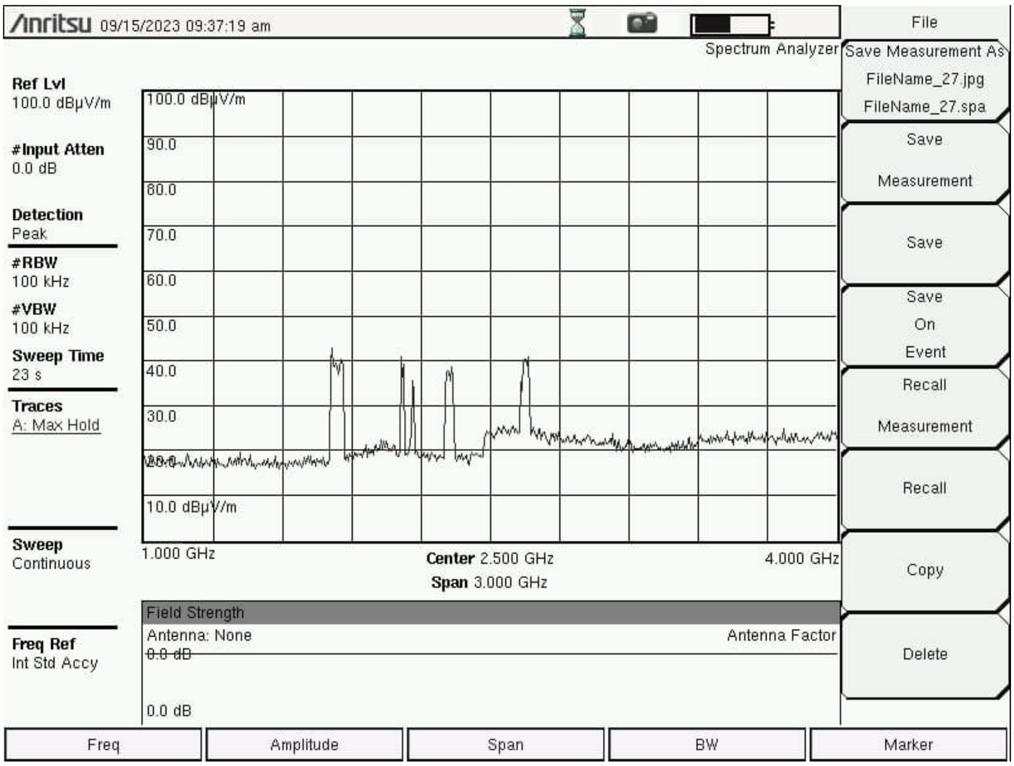

Figure C.43: EMI measurement for Moorabool Terminal Station to Sydenham Terminal Station circuits 1 and 2 - 500kV transmission lines - 30m from centreline – 1GHz to 4GHz (Source: Jacobs, 2023)

C.8 EMI and EMF measurements for Ballarat Terminal Station to Bendigo Terminal Station 220kV transmission line

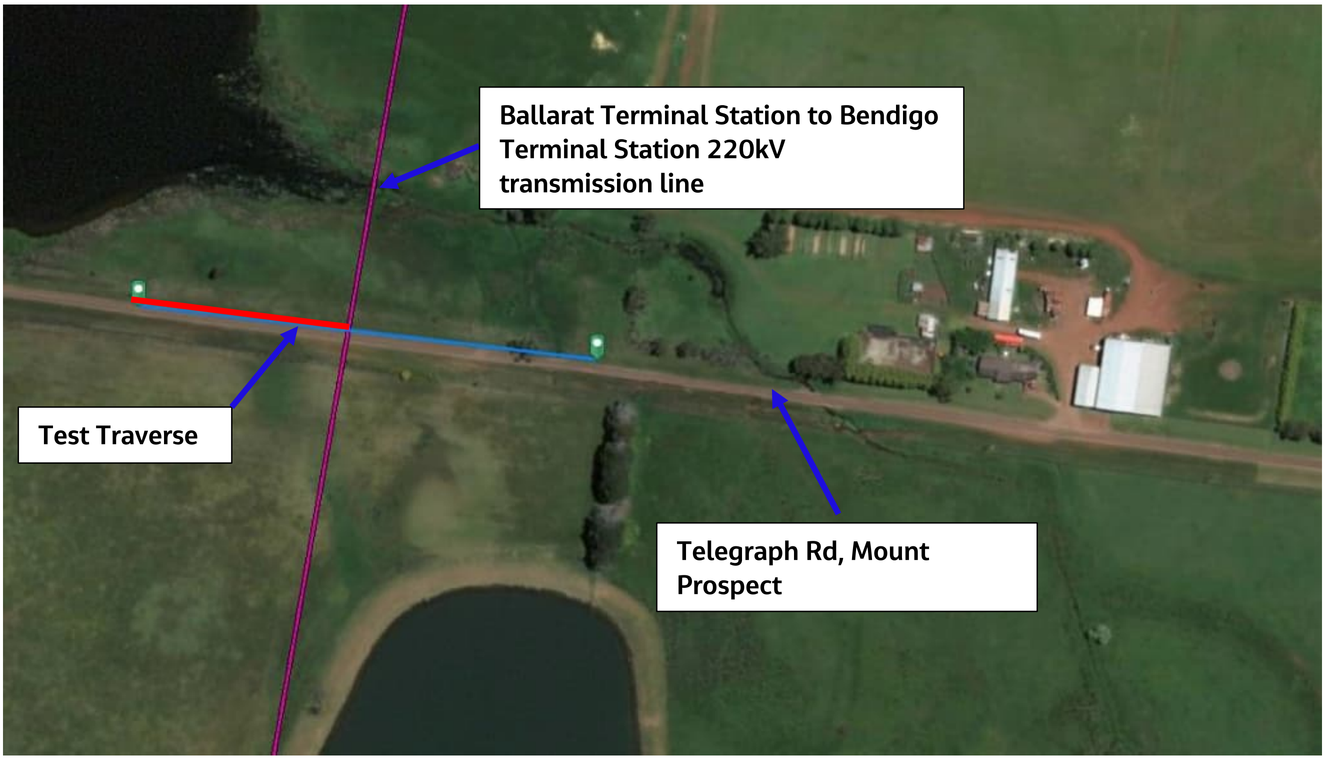

Figure C.44: Ballarat Terminal Station to Bendigo Terminal Station 220kV transmission line EMI and EMF measurement location (Source: Jacobs, 2022)

Table C.9: Measured EMF levels for Ballarat Terminal Station to Bendigo Terminal Station 220kV transmission line

Distance from centre of transmission line (m)	Magnetic Flux Density (µT)	Electric Field Strength (V/m)
0	0.87	1354
12.5	0.45	679.4
25	0.2	222.3
37.5	0.1	114.8
50	0.06	57.89
62.5	0.04	31.79
75	0.03	17.28
87.5	0.02	5.58
100	0.02	11.65

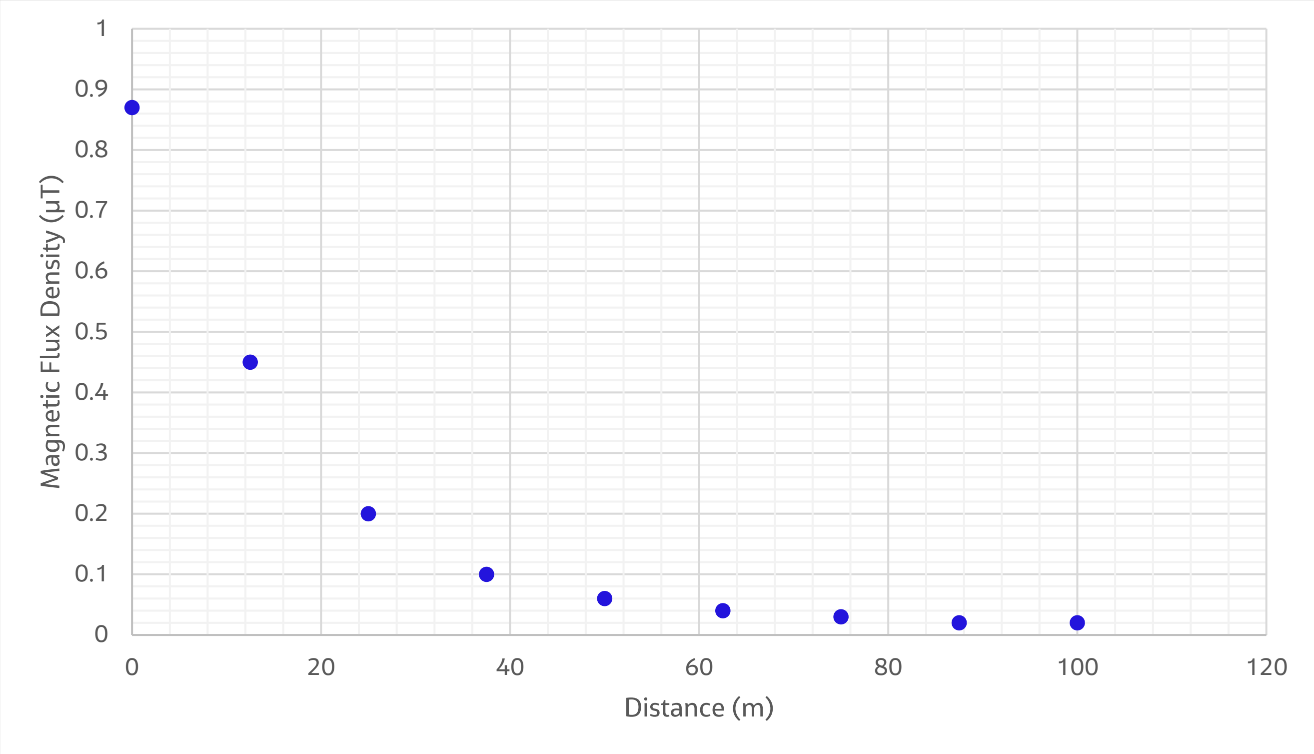

Figure C.45: Measured magnetic flux density for Ballarat Terminal Station to Bendigo Terminal Station 220kV transmission line (Source: Jacobs, 2022)

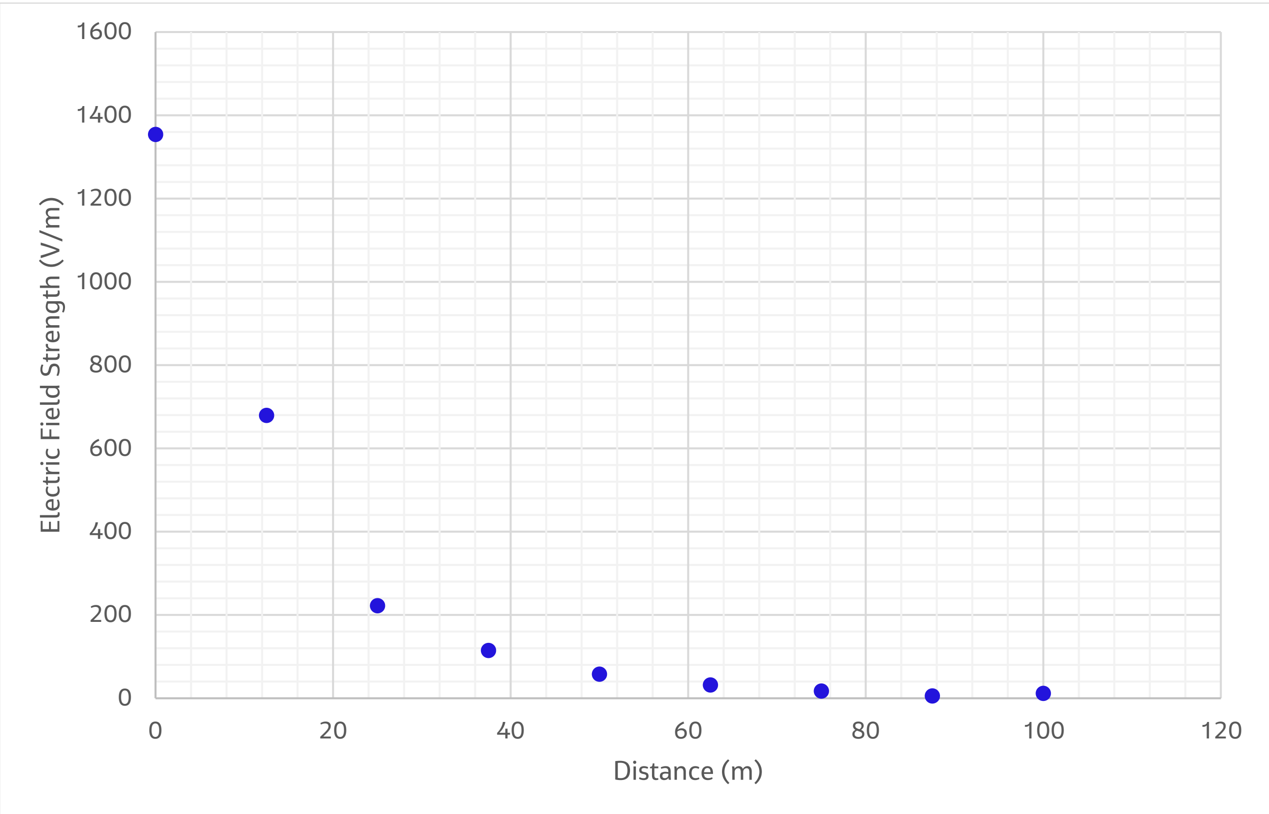

Figure C.46: Measured electric field strength for Ballarat Terminal Station to Bendigo Terminal Station 220kV transmission line (Source: Jacobs, 2022)

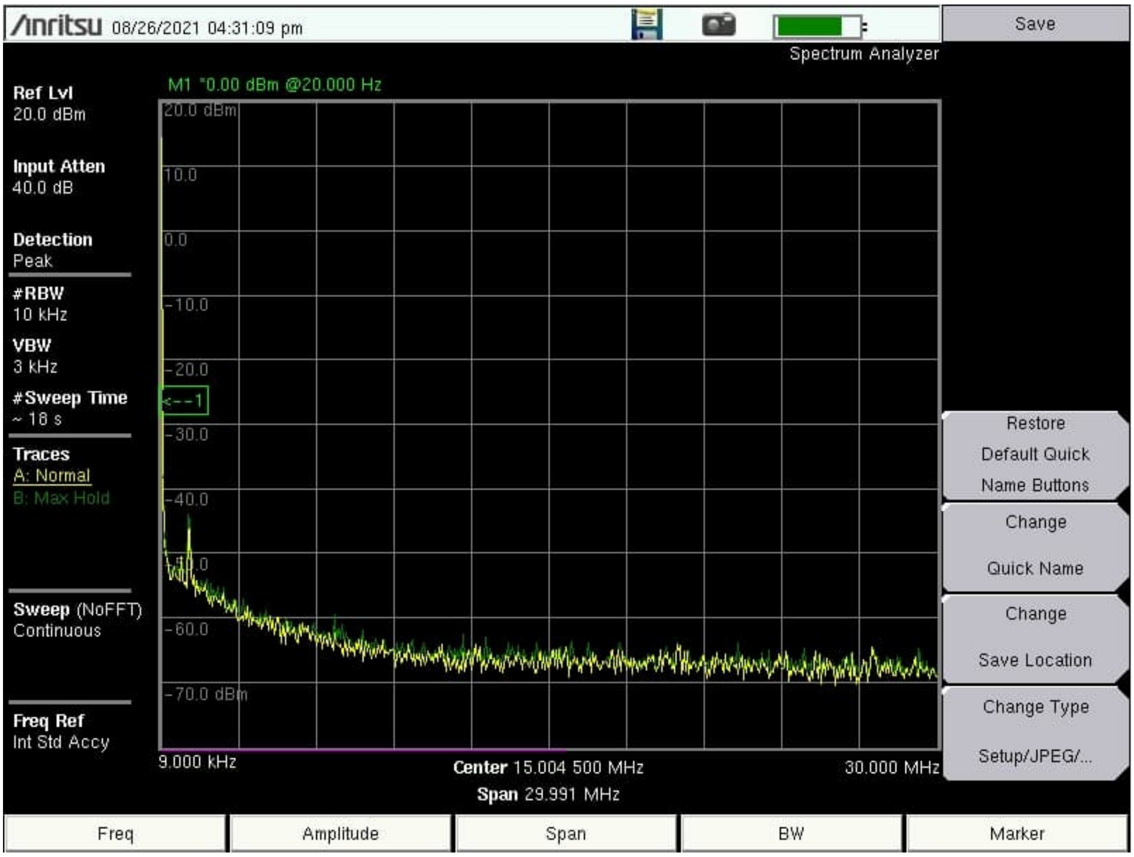

Figure C.47: EMI measurement for Ballarat Terminal Station to Bendigo Terminal Station 220kV transmission line (Source: Jacobs, 2022)

C.9 EMI and EMF measurements for sub-transmission line

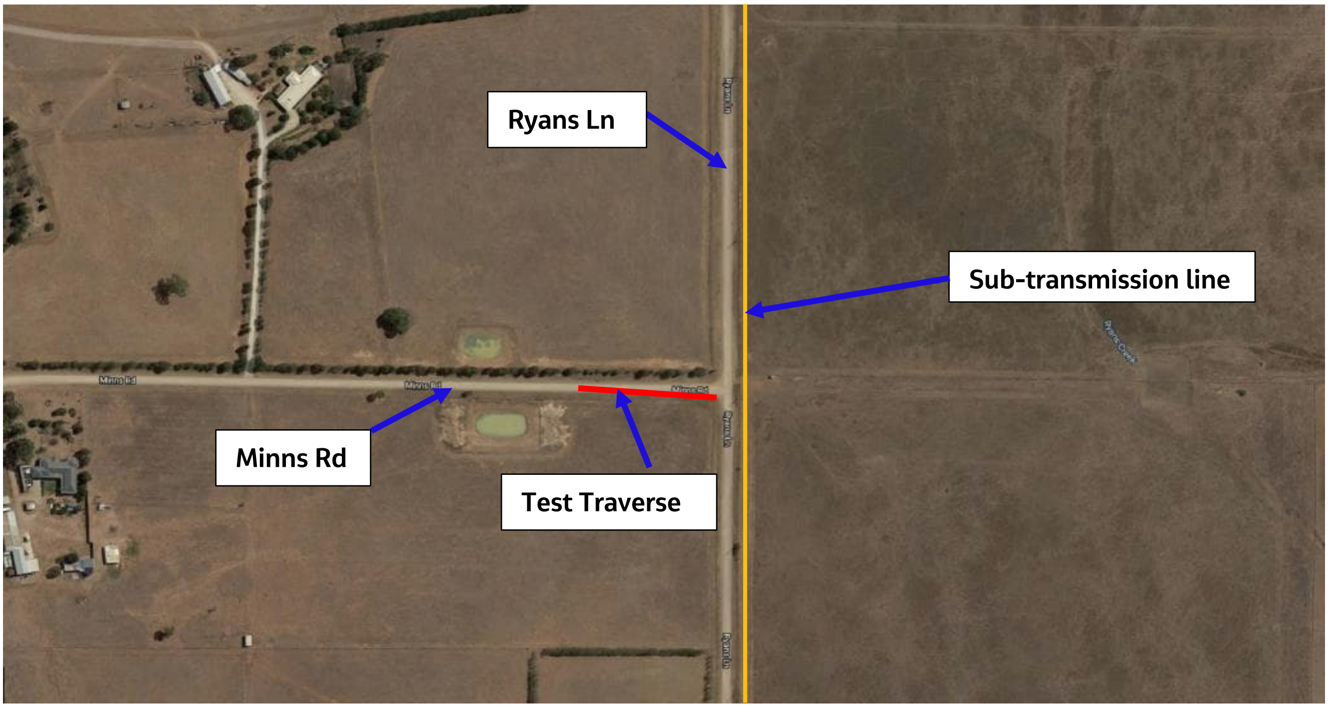

Figure C.48: Sub-transmission line EMI and EMF measurement location (Source: Jacobs, 2022)

Table C.10: Measured EMF levels for sub-transmission line

Distance from centre of transmission line (m)	Magnetic Flux Density (µT)	Electric Field Strength (V/m)
0	0.005	5.09
12.5	0.004	1.88
25	0.005	0.83
37.5	0.004	0.39
50	0.004	0.23
62.5	0.004	0.14
75	0.005	0.12
87.5	0.004	0.11
100	0.005	0.12

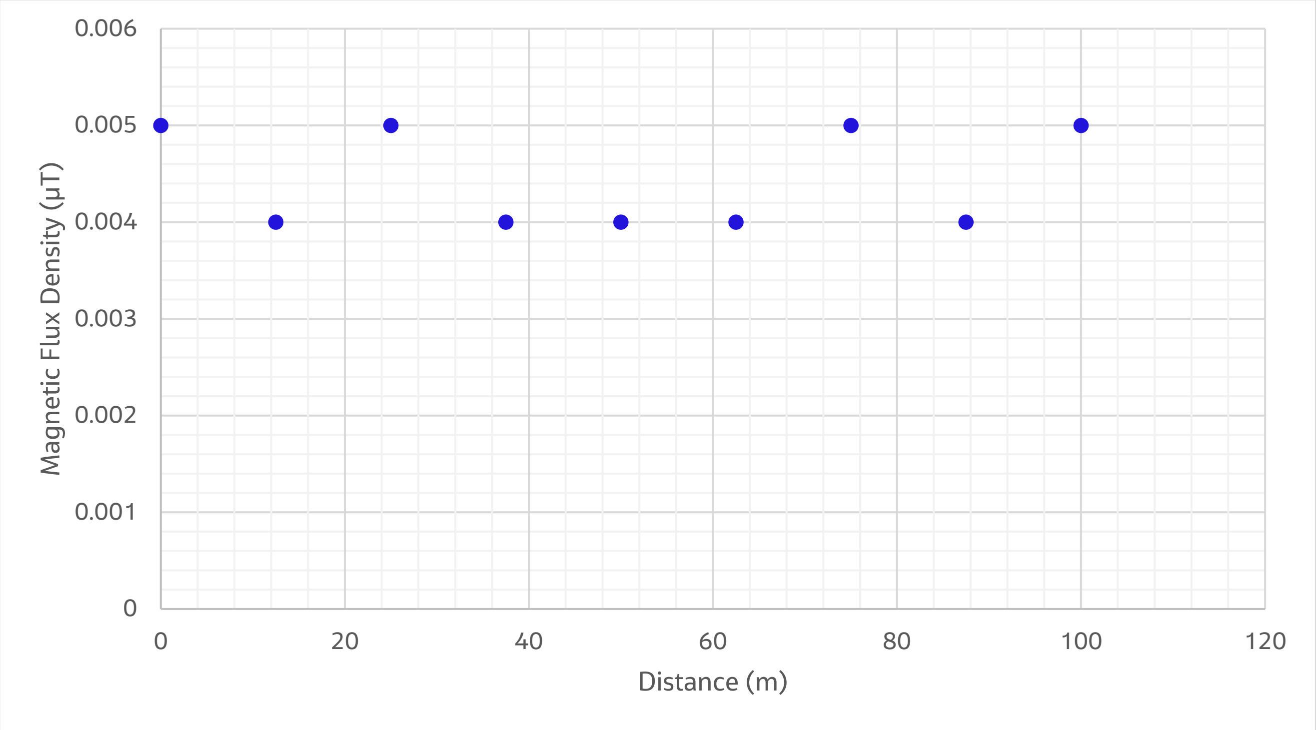

Figure C.49: Measured magnetic flux density for sub- transmission line (Source: Jacobs, 2022)

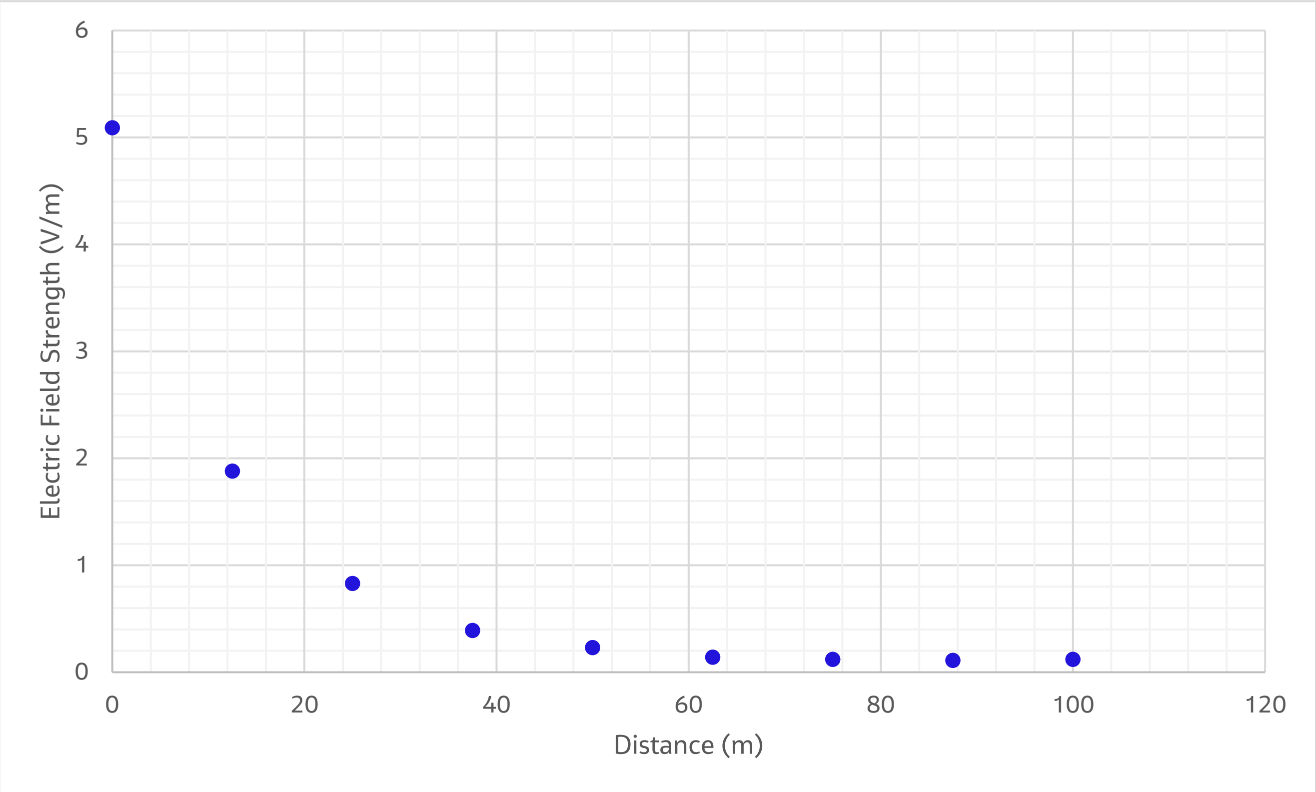

Figure C.50: Measured electric field strength for sub- transmission line (Source: Jacobs, 2022)

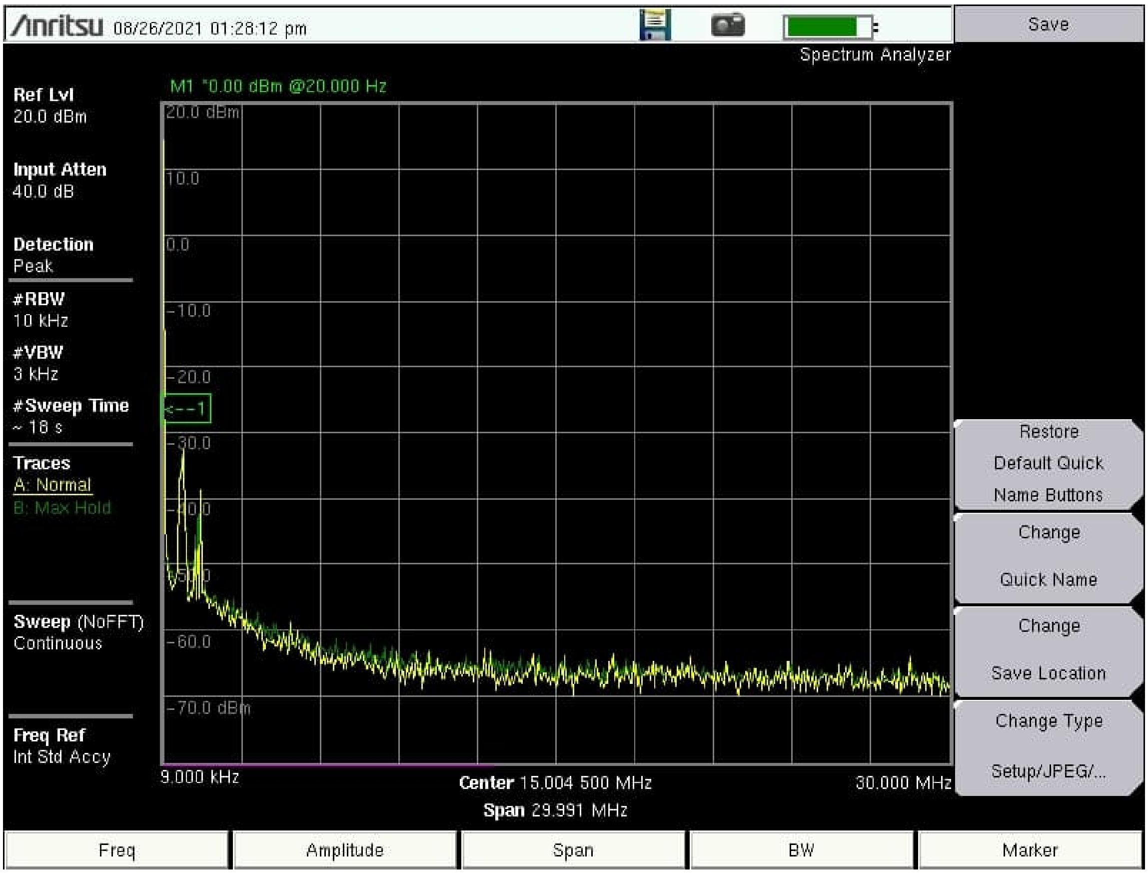

Figure C.51: EMI measurement for sub-transmission line (Source: Jacobs, 2022)

Appendix D. Impact assessment – calculated EMF results

D.1 New 500kV line – both circuits in service

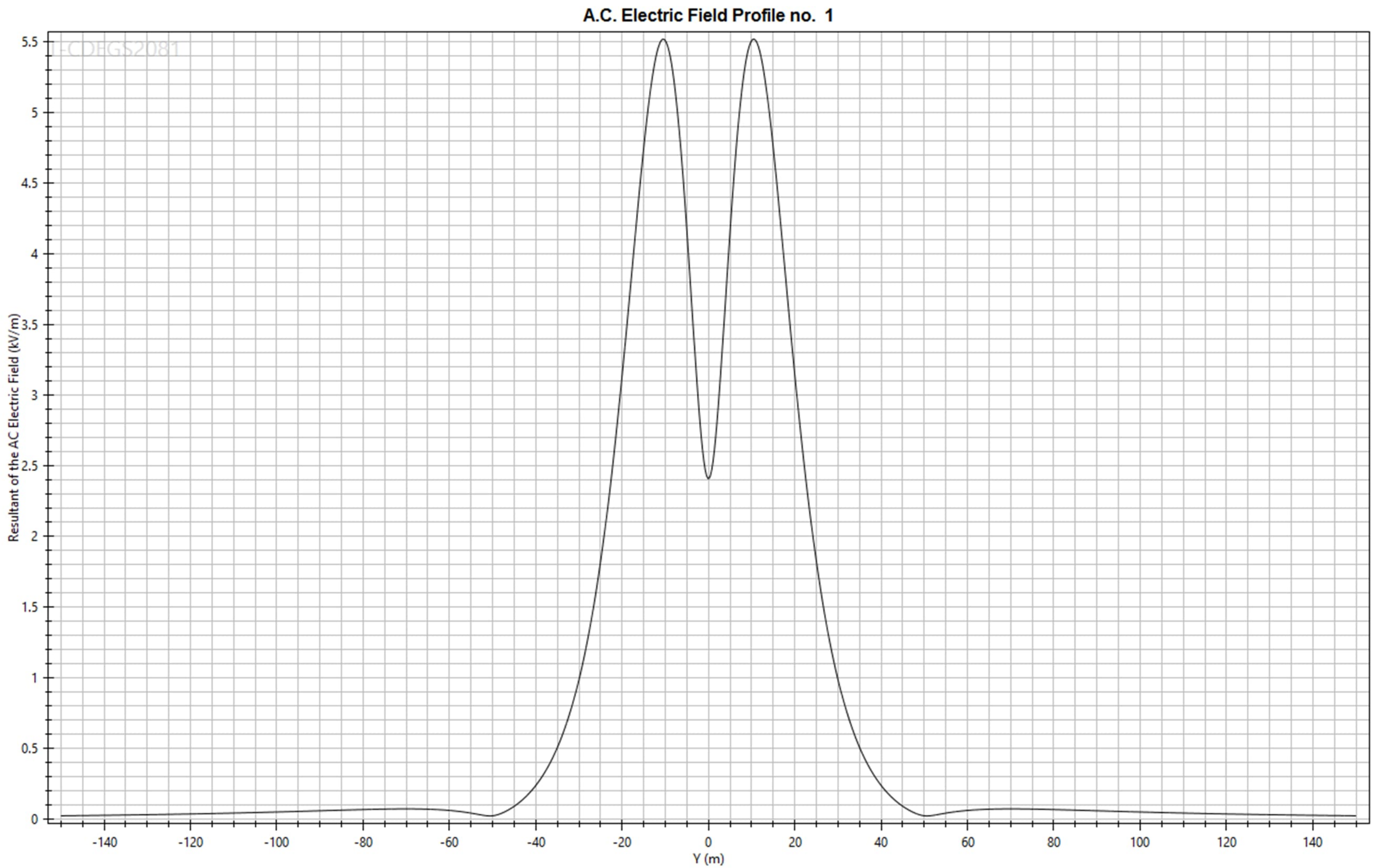

Figure D.1: New 500kV line AC Electric Field Profile, both circuits in service (Source: Jacobs, 2023)

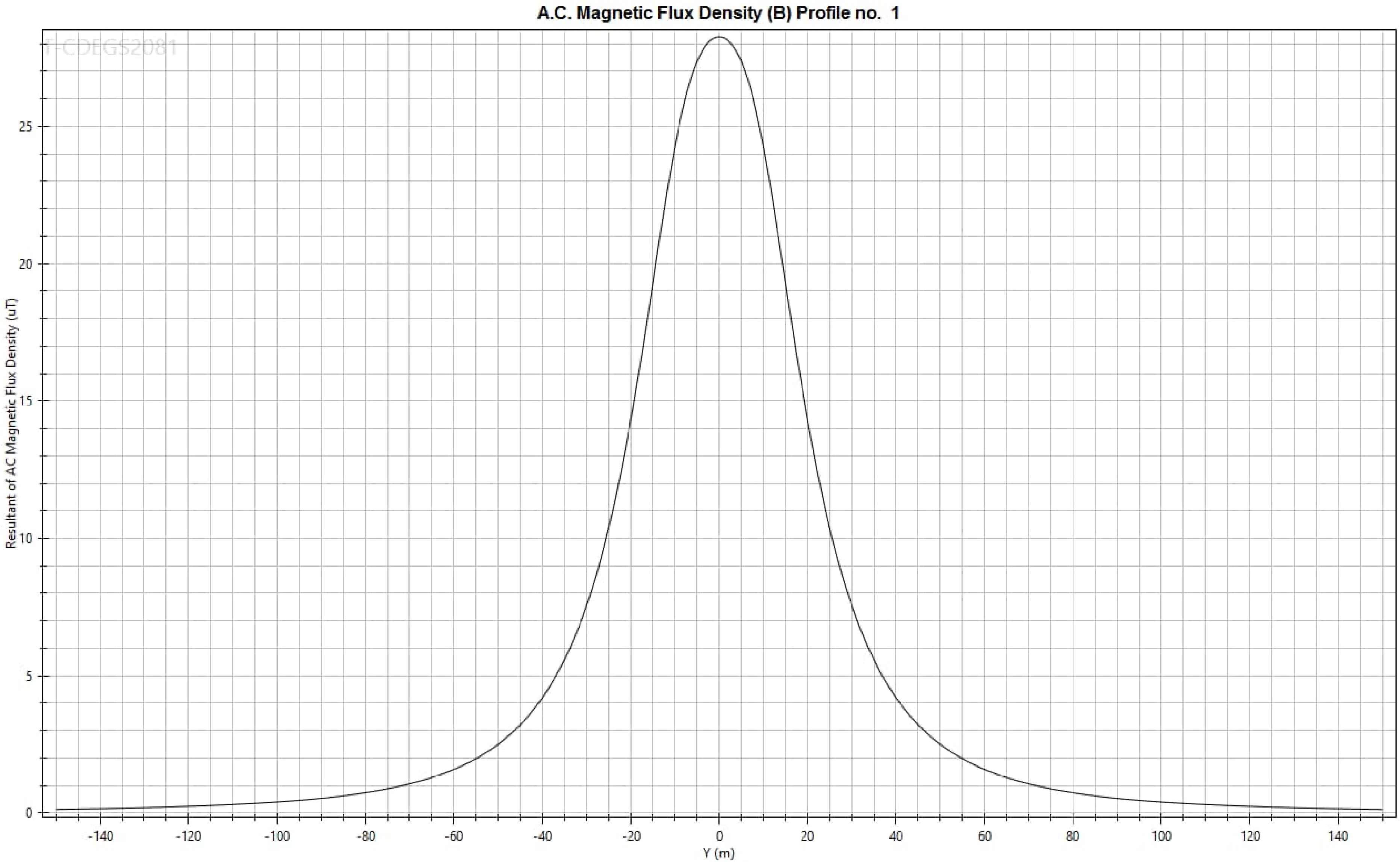

Figure D.2: New 500kV line AC Magnetic Flux Density (B) Profile, both circuits in service (Source: Jacobs, 2023)

D.2 New 500kV line – single circuit operation

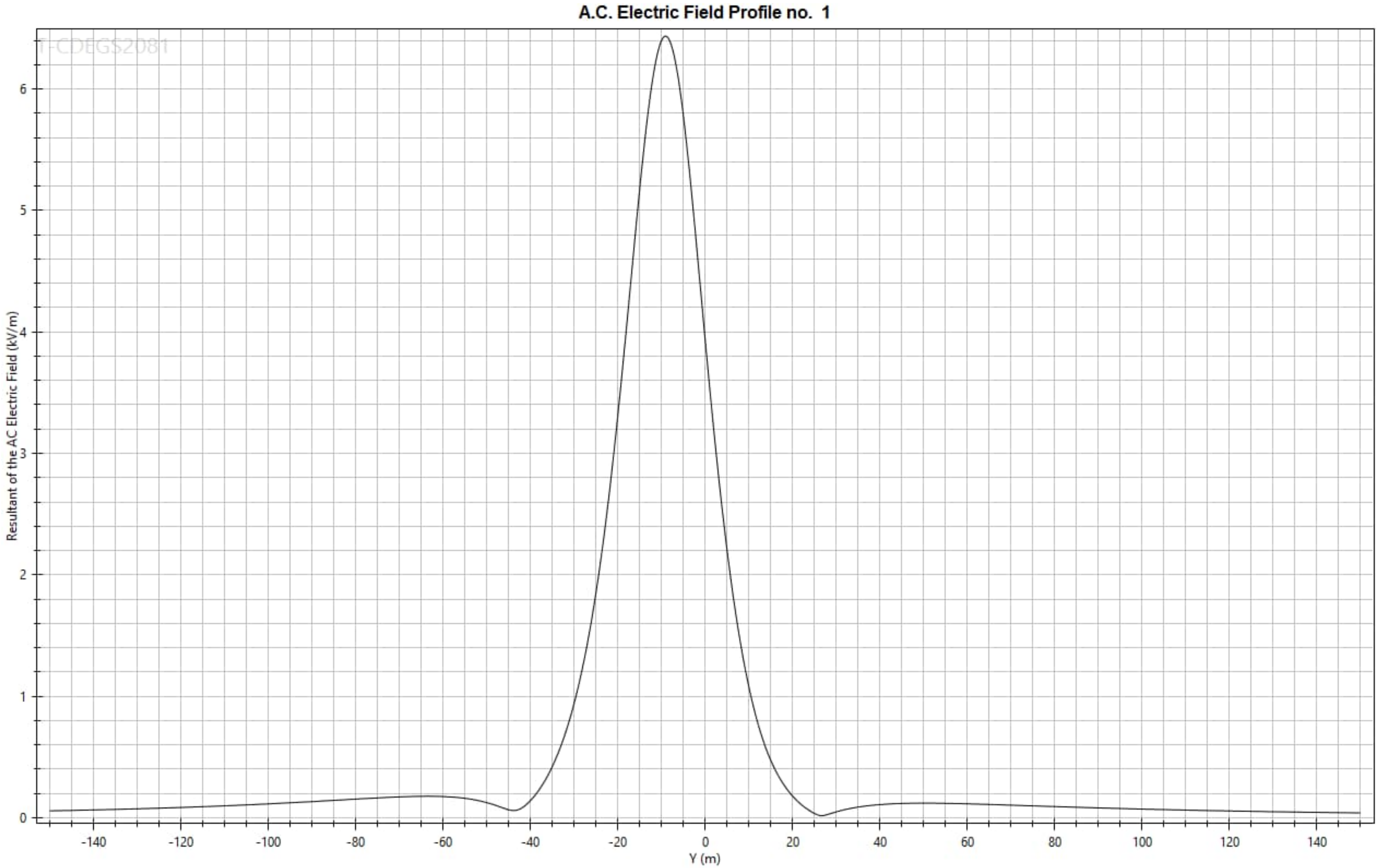

Figure D.3: New 500kV line AC Electric Field Profile, single circuit operation (Source: Jacobs, 2023)

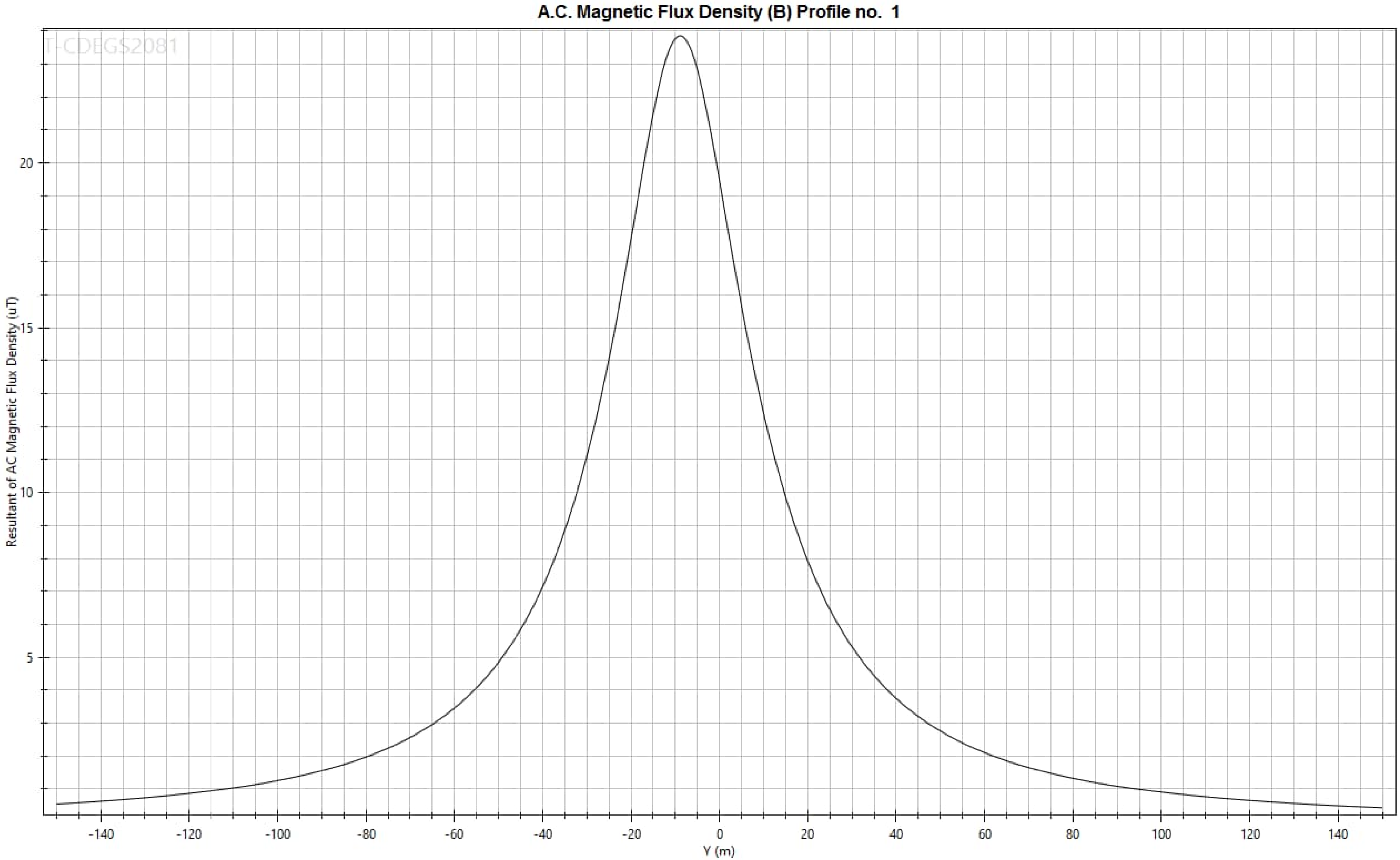

Figure D.4: New 500kV line AC Magnetic Flux Density (B) Profile, single circuit operation (Source: Jacobs, 2023)

D.3 New 500kV line and existing 220kV line – all circuits in service

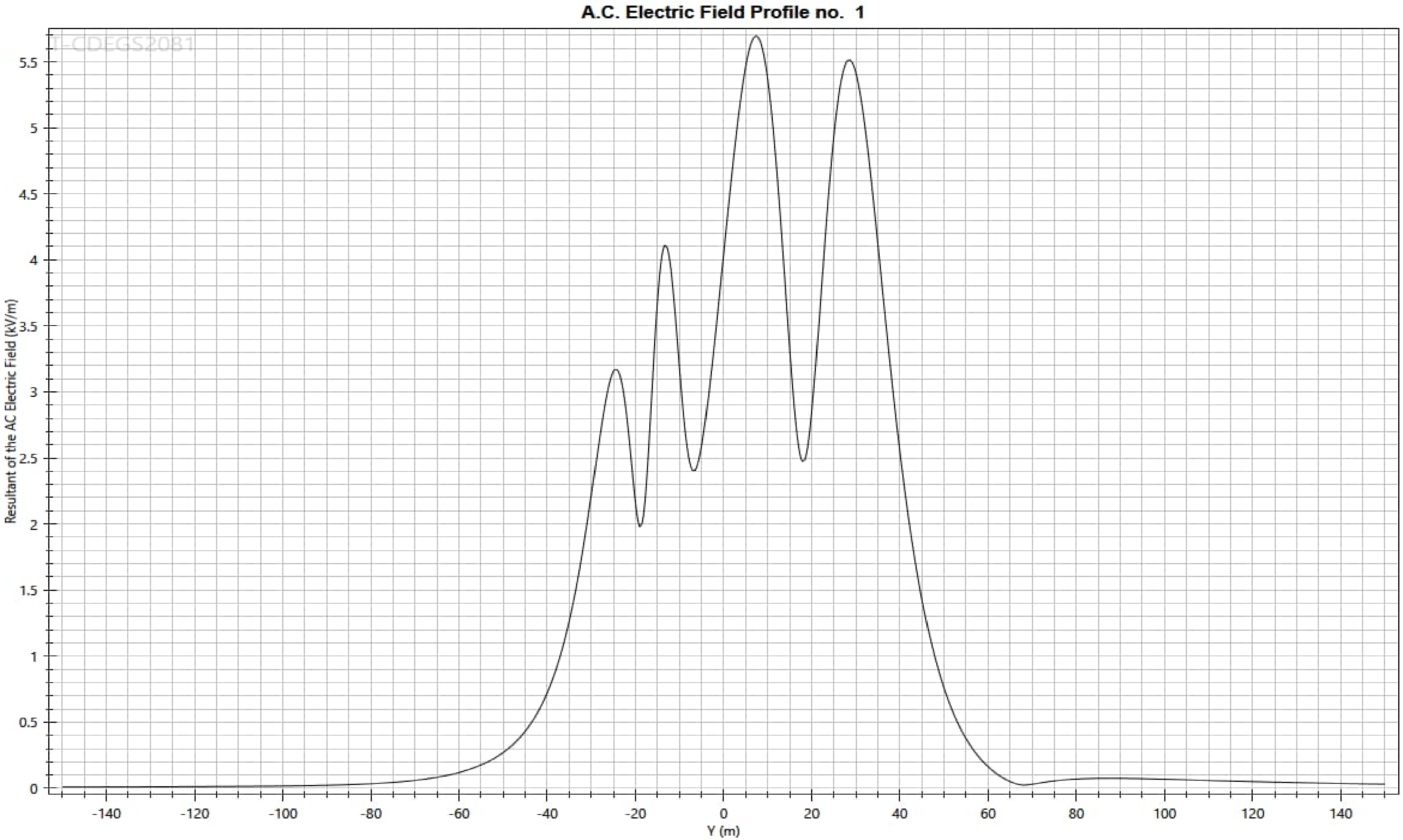

Figure D.5: New 500kV line with existing 220kV line AC Electric Field Profile, all circuits in service (Source: Jacobs, 2023)

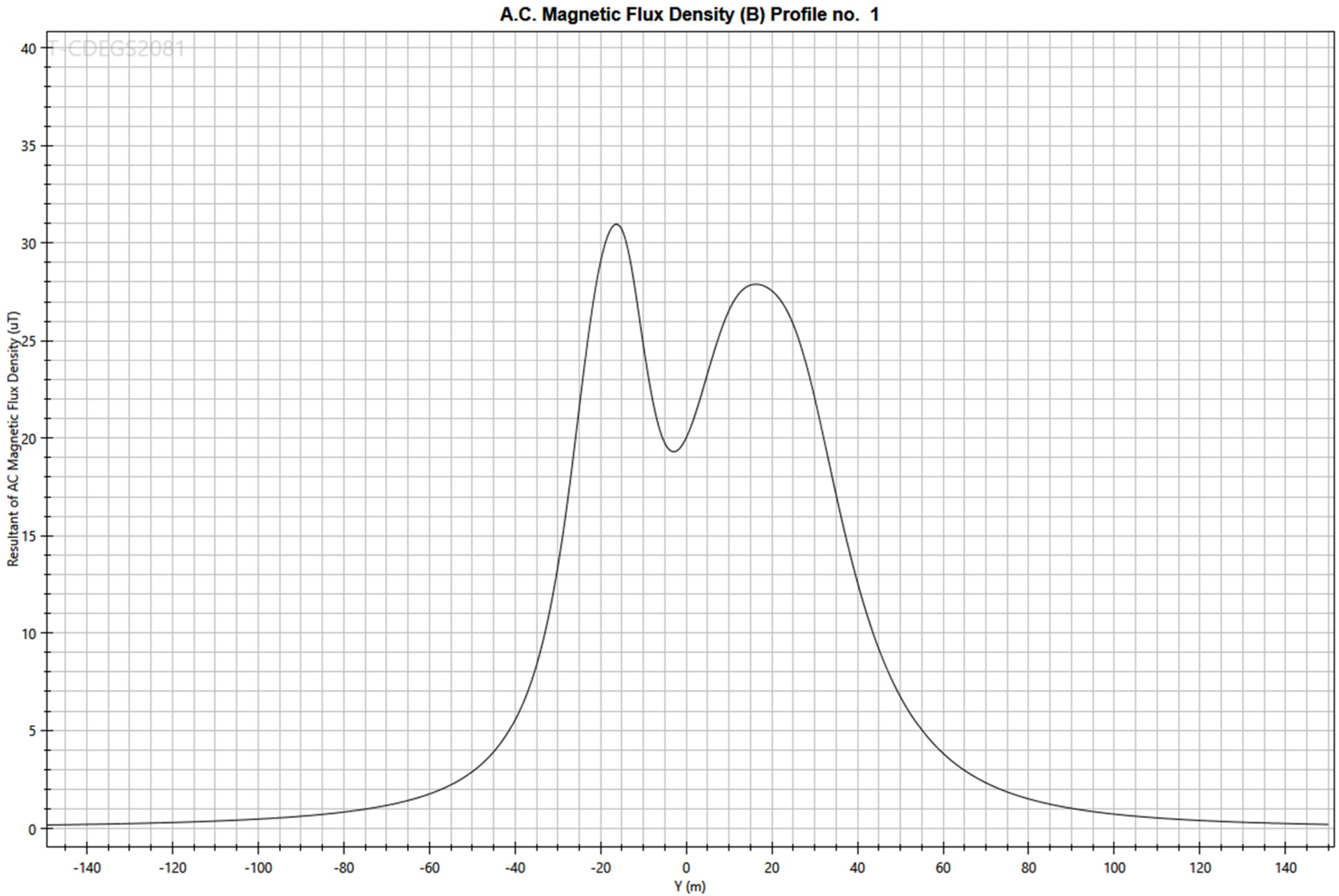

Figure D.6: New 500kV line with existing 220kV line AC Magnetic Flux Density (B), all circuits in service (Source: Jacobs, 2023)

D.4 New 500kV line and existing 220kV line – One new circuit out of service

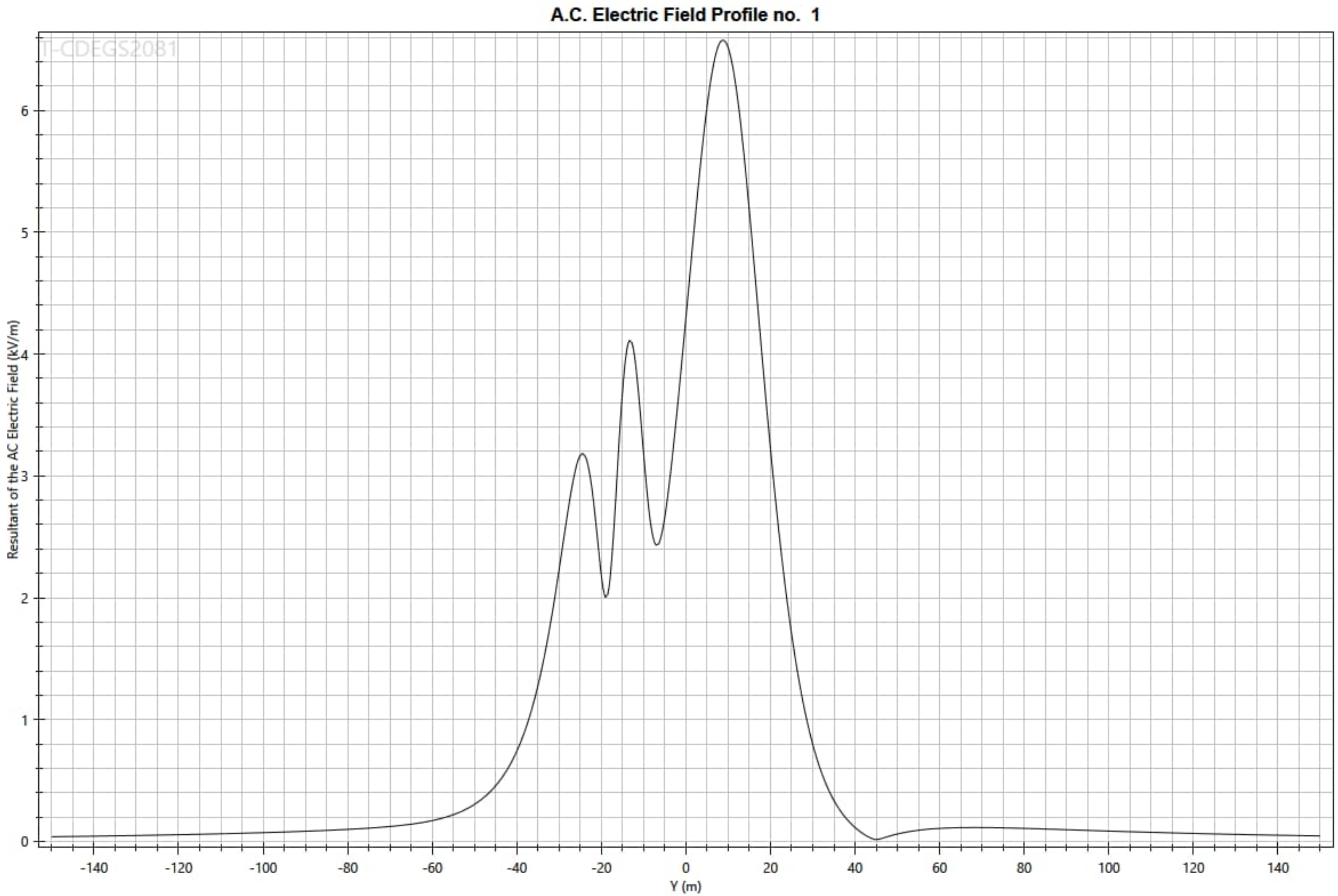

Figure D.7: New 500kV line and existing 220kV lines AC Electric Field Profile, one circuit out of service (Source: Jacobs, 2023)

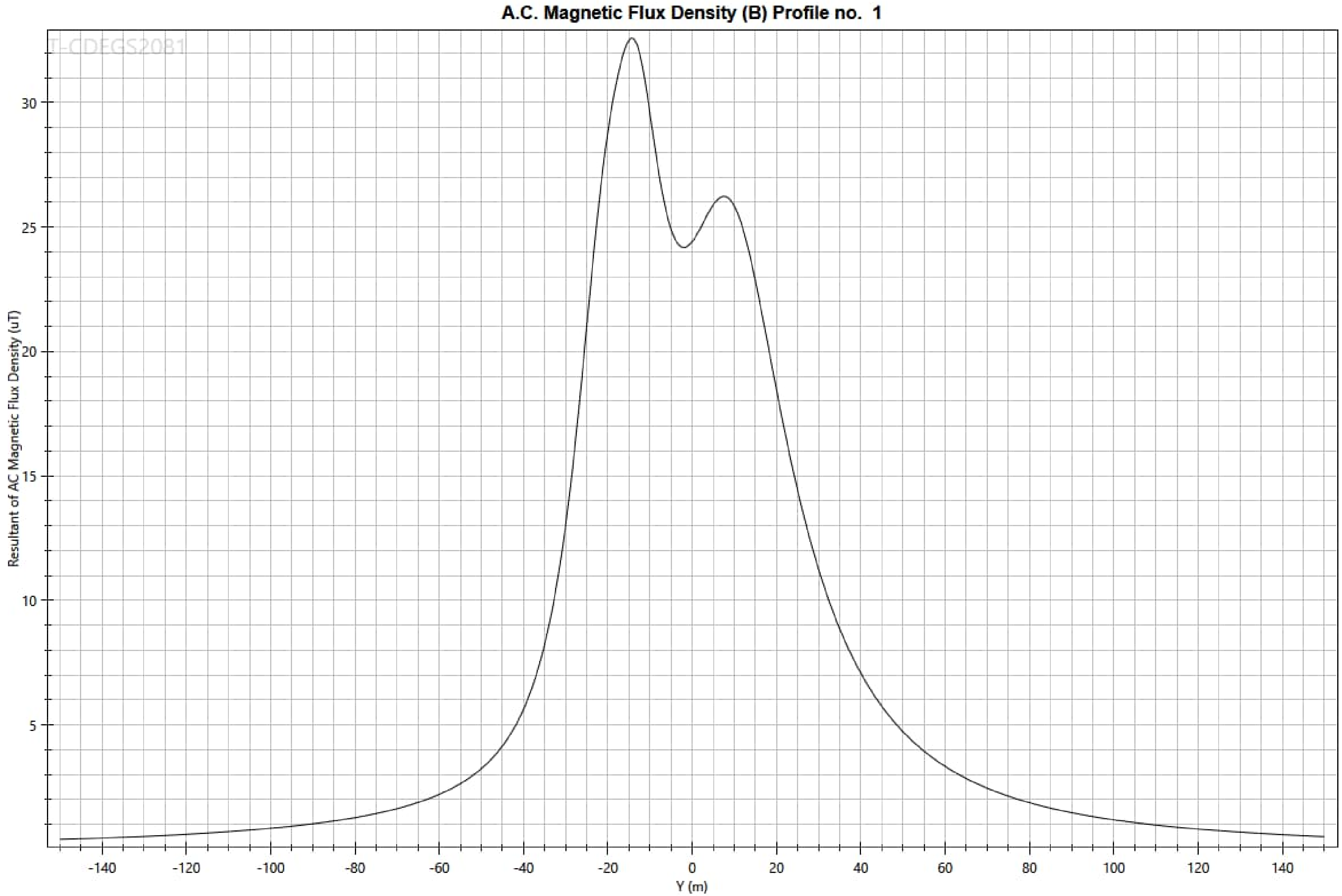

Figure D.8: New 500kV line with existing 220kV line AC Magnetic Flux Density (B), one circuit out of service (Source: Jacobs, 2023)

D.5 New 500kV line – Single Circuit Structures – both circuits in service

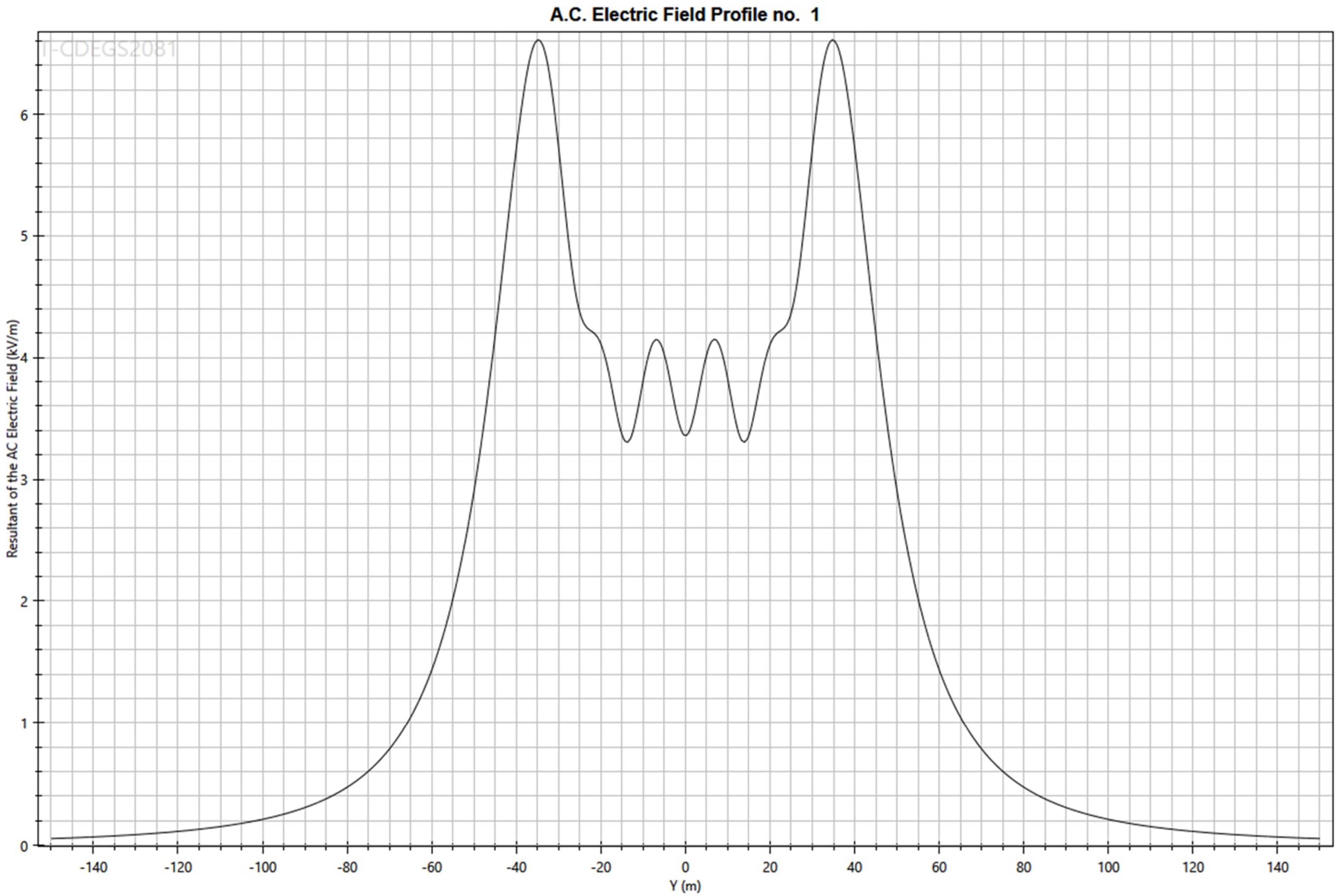

Figure D.9: New 500kV line single circuit structures AC Electric Field Profile, all circuits in service (Source: Jacobs, 2023)

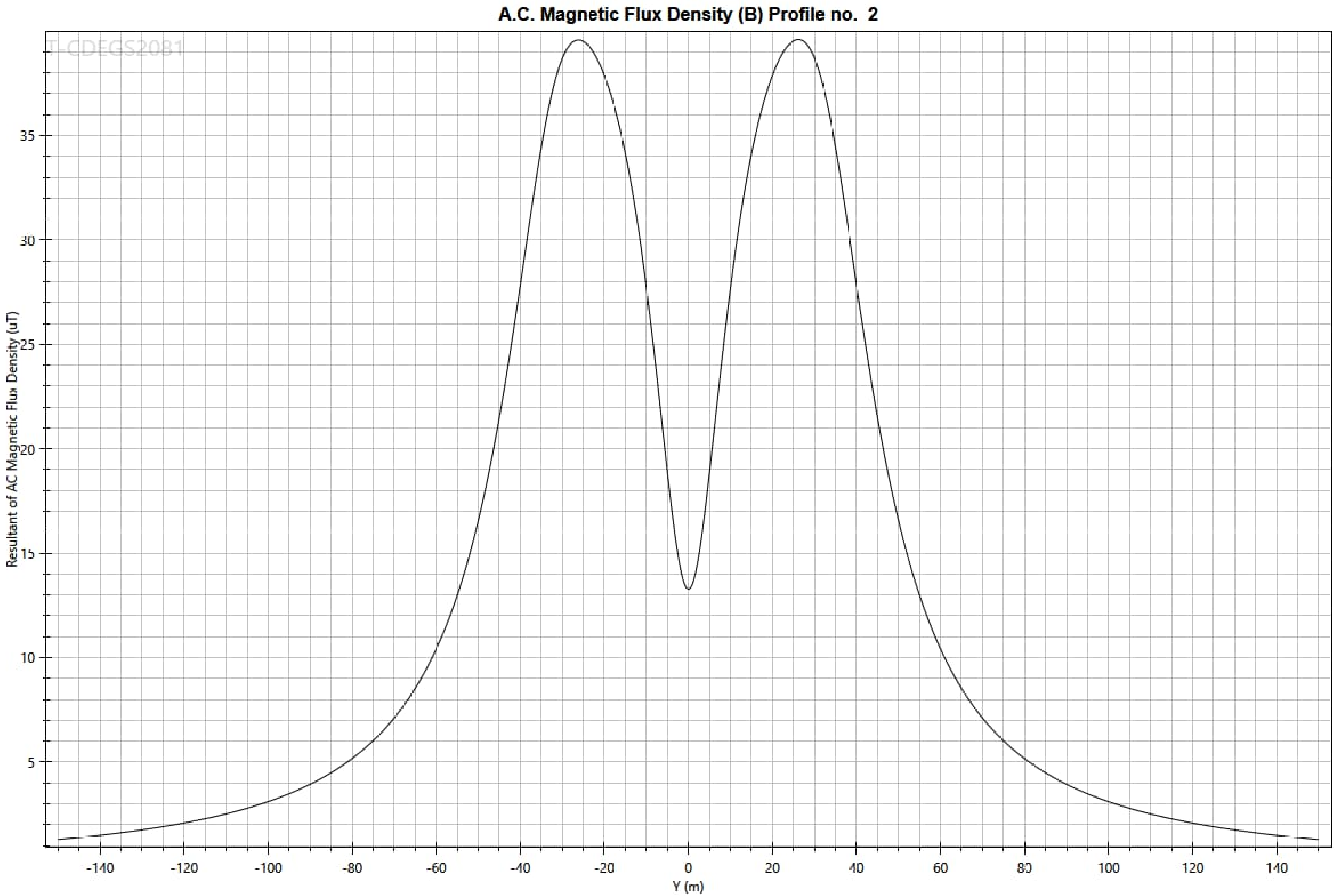

Figure D.10: New 500kV line single circuit structures AC Magnetic Flux Density (B), all circuits in service (Source: Jacobs, 2023)

D.6 New 500kV line – Single Circuit Structures – one circuit out of service

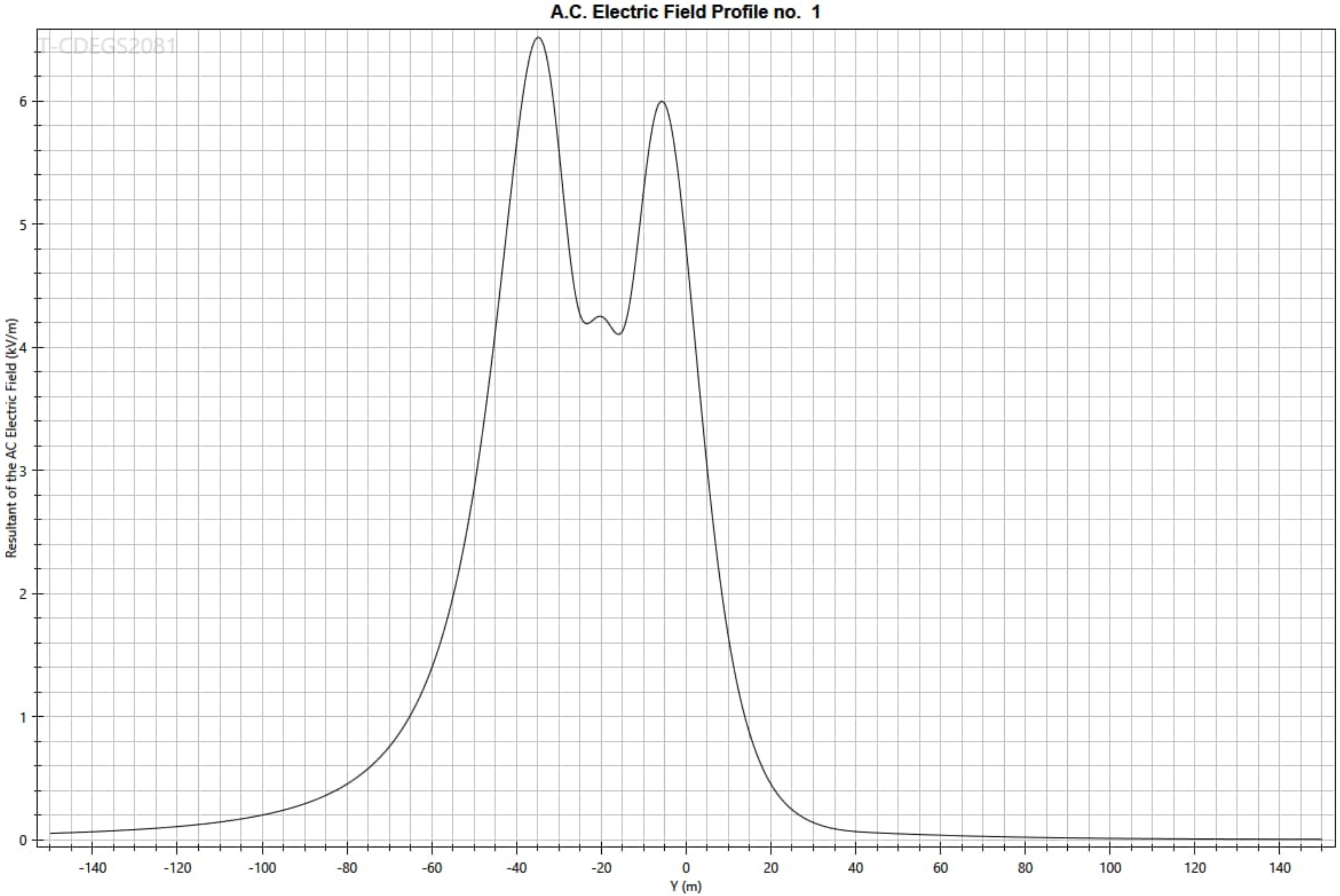

Figure D.11: New 500kV line single circuit structures AC Electric Field Profile, one circuit out of service (Source: Jacobs, 2023)

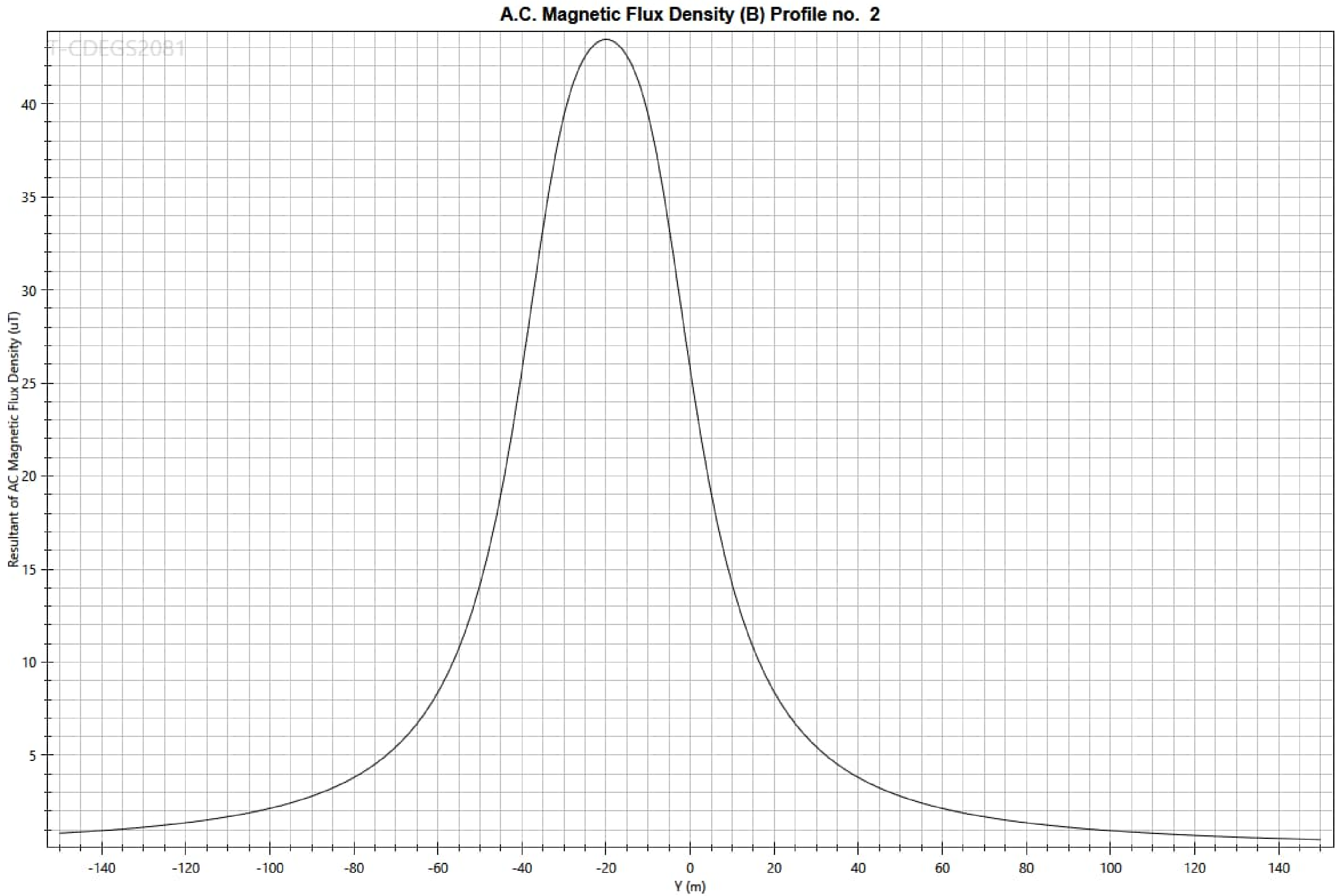

Figure D.12: New 500kV line single circuit structures AC Magnetic Flux Density (B), one circuit out of service (Source: Jacobs, 2023)

D.7 New 220kV line connections at BGTS – both circuits in service

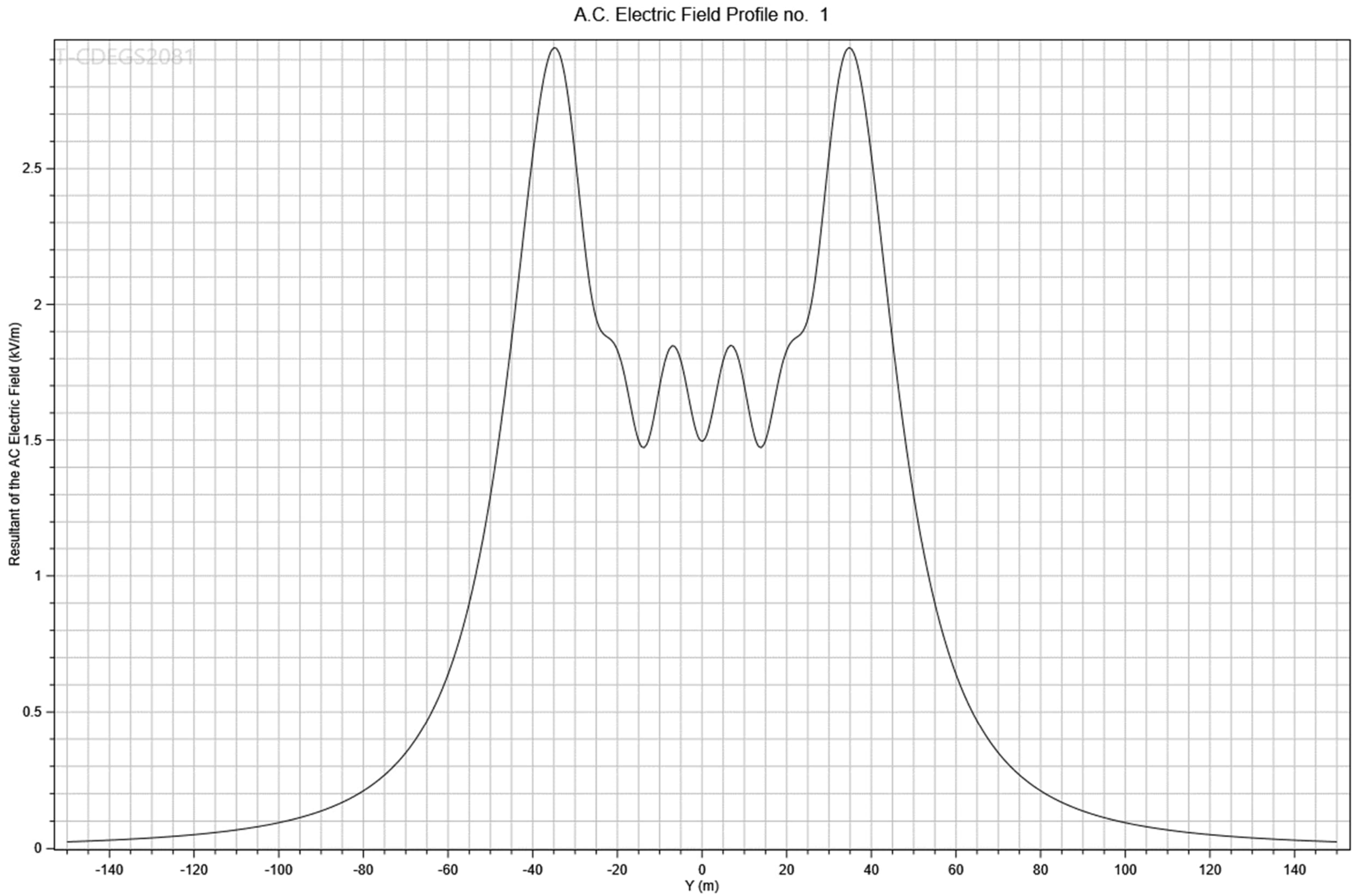

Figure D.13: New 220kV line connections at BGTS AC Electric Field Profile, all circuits in service (Source: Jacobs, 2023)

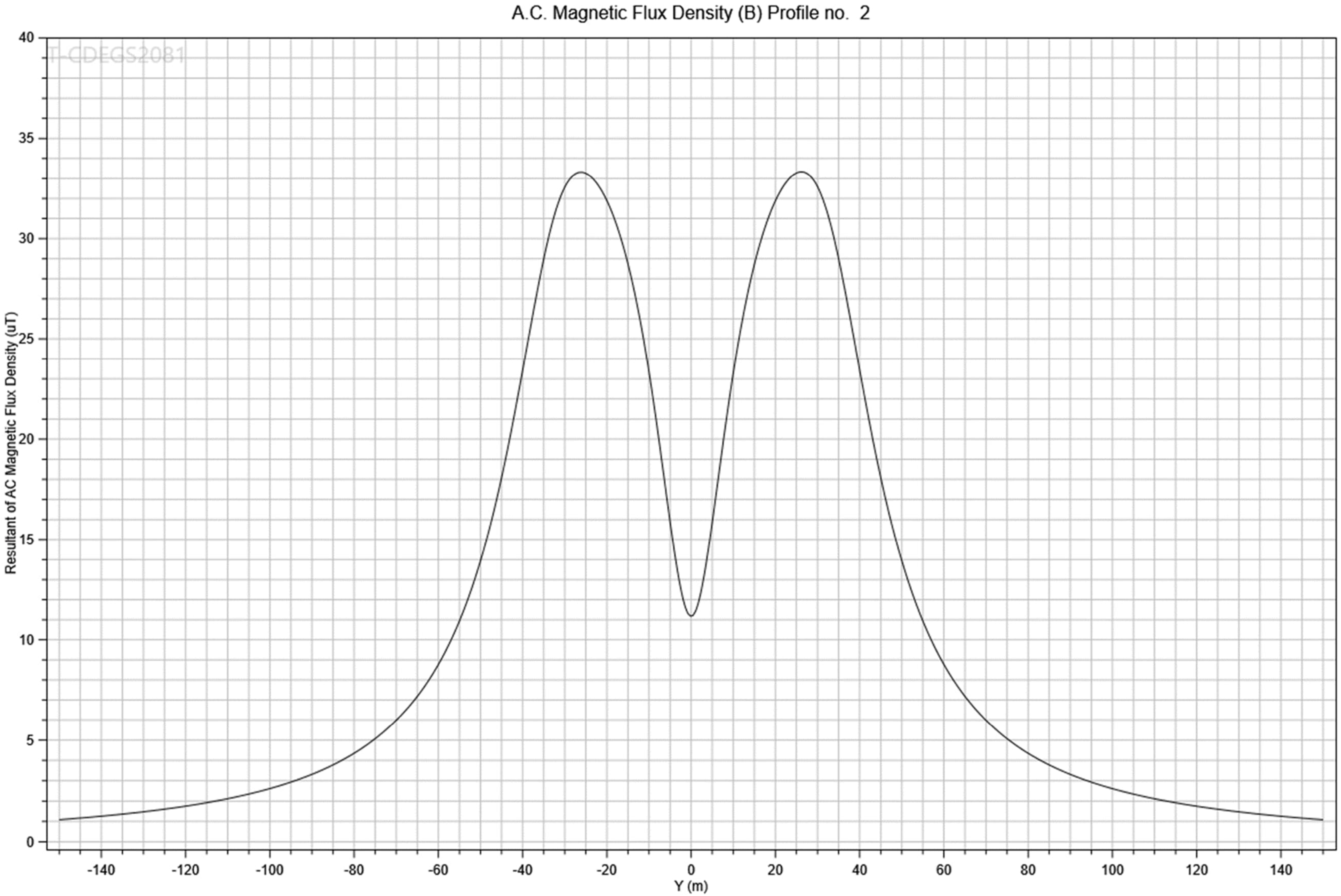

Figure D.14: New 220kV line connections at BGTS AC Magnetic Flux Density (B), all circuits in service (Source: Jacobs, 2023)

D.8 New 220kV line connections at BGTS – one circuit out of service

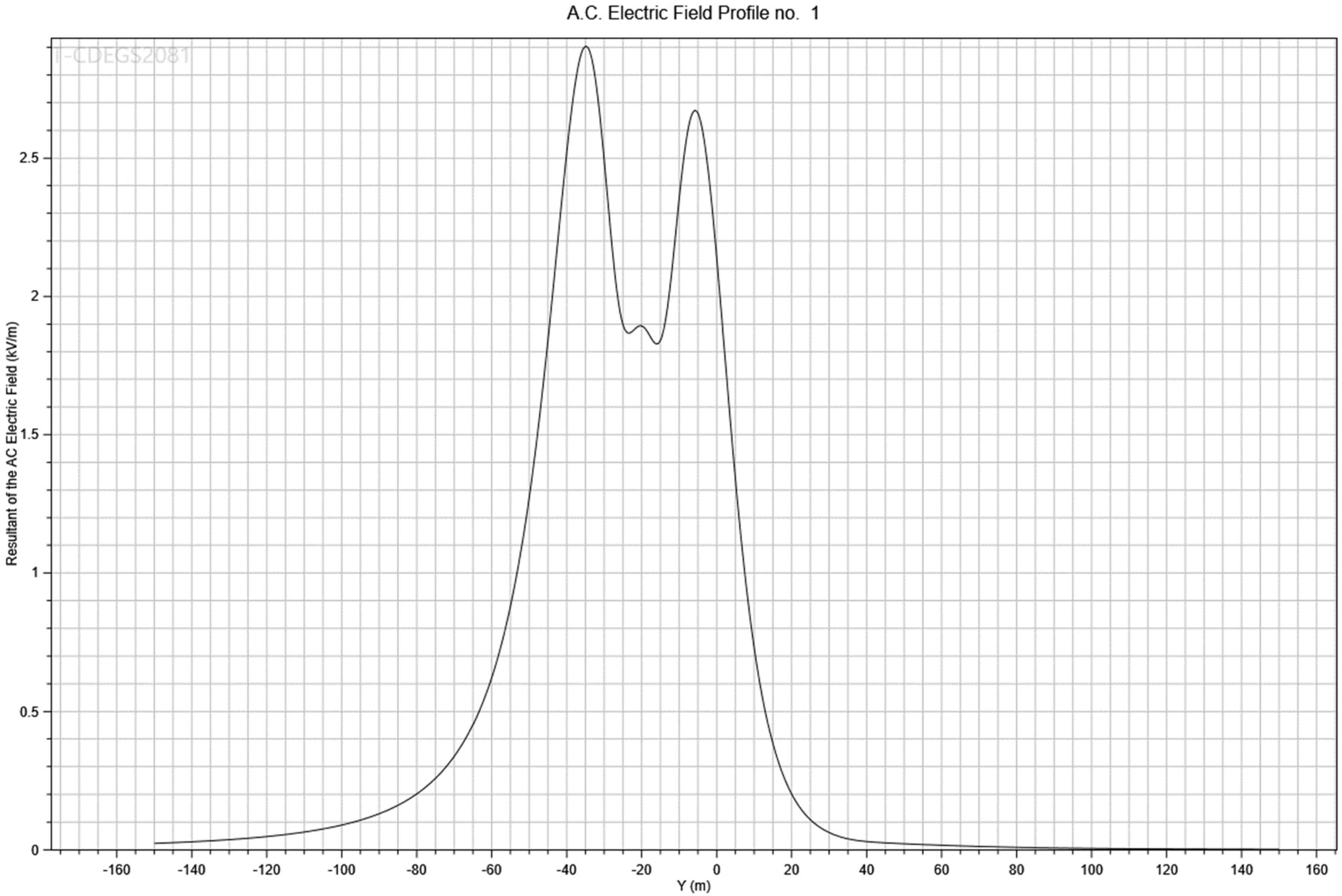

Figure D.15: New 220kV line connections at BGTS AC Electric Field Profile, one circuit out of service (Source: Jacobs, 2023)

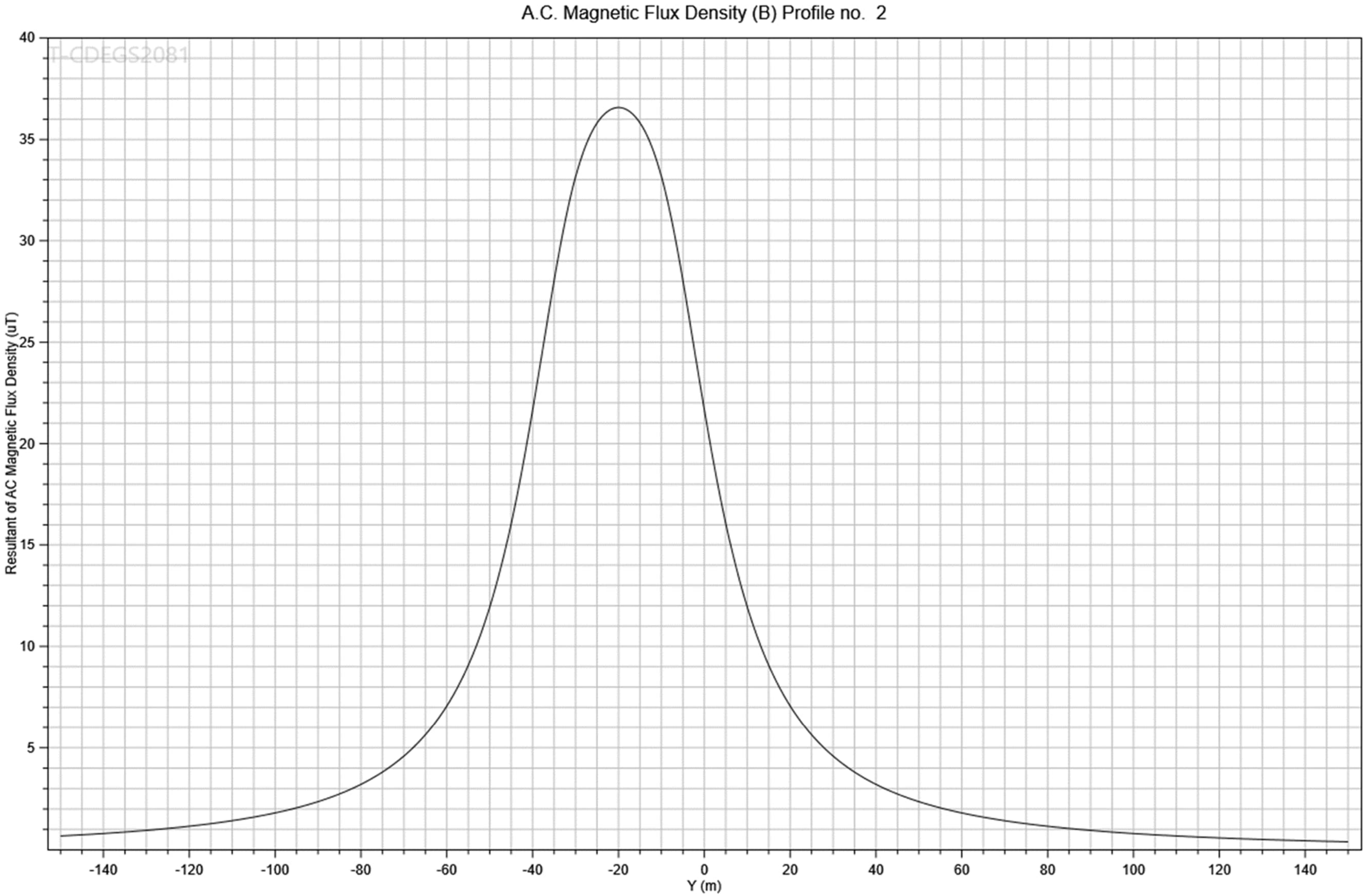

Figure D.16: New 220kV line connections at BGTS AC Magnetic Flux Density (B), one circuit out of service (Source: Jacobs, 2023)

Appendix E. Impact assessment - calculated EMI results

E.1 New 500kV line – both circuits in service

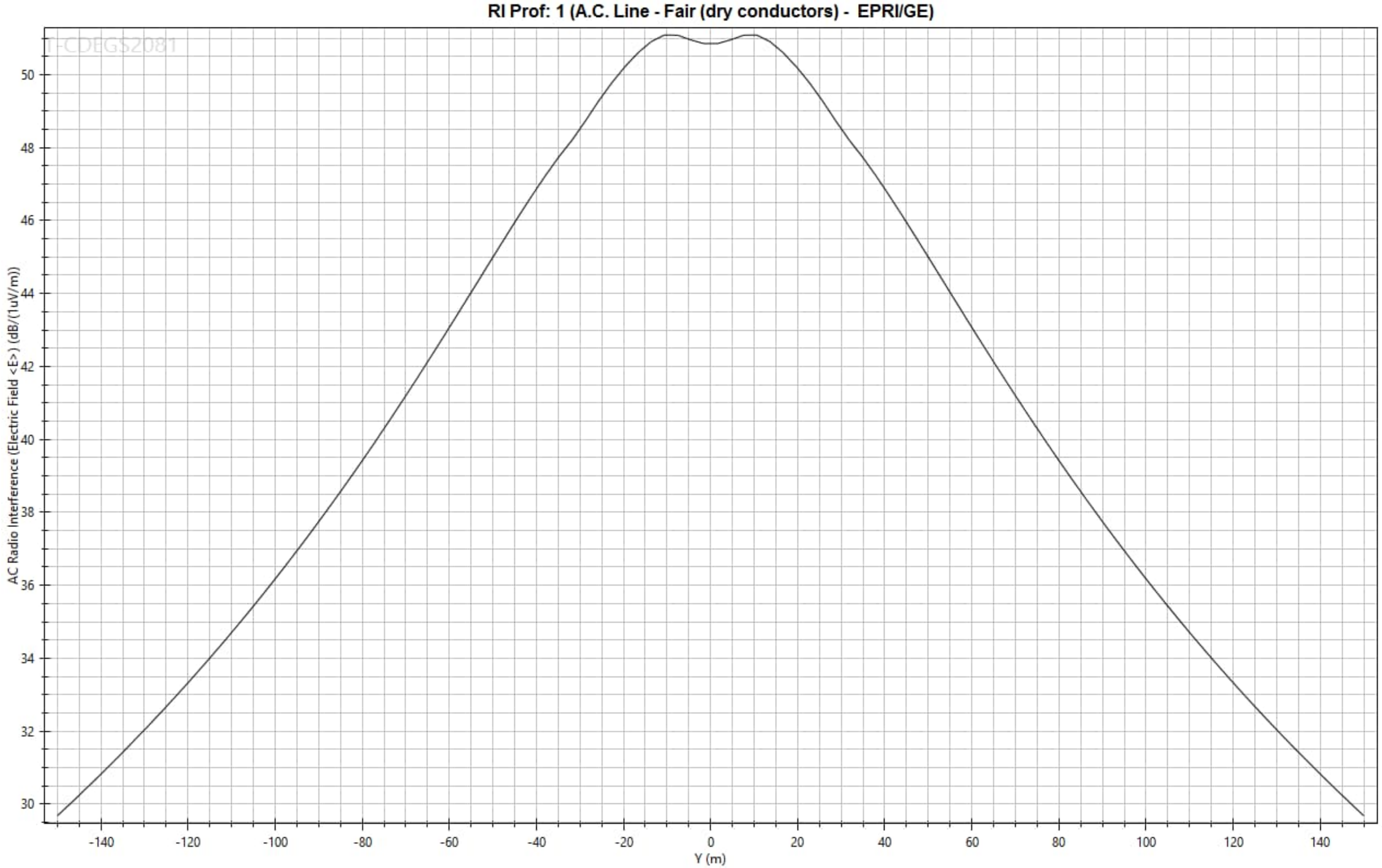

Figure E.1: New 500kV line - RI Electric Field - Fair (dry conductors), both circuits in service (Source: Jacobs, 2023)

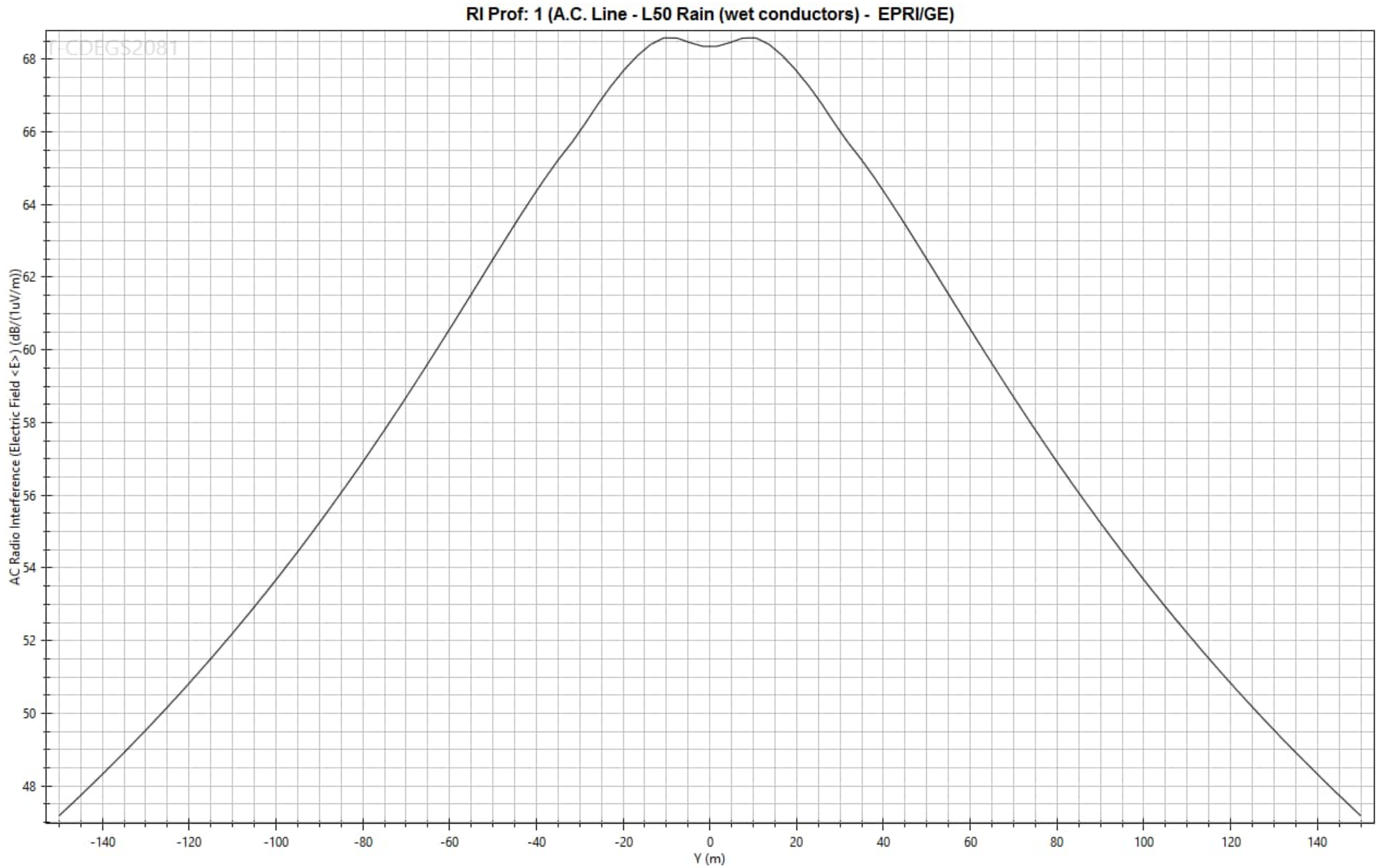

Figure E.2: New 500kV line - RI Electric Field - L50 Rain (wet conductors), both circuits in service (Source: Jacobs, 2023)

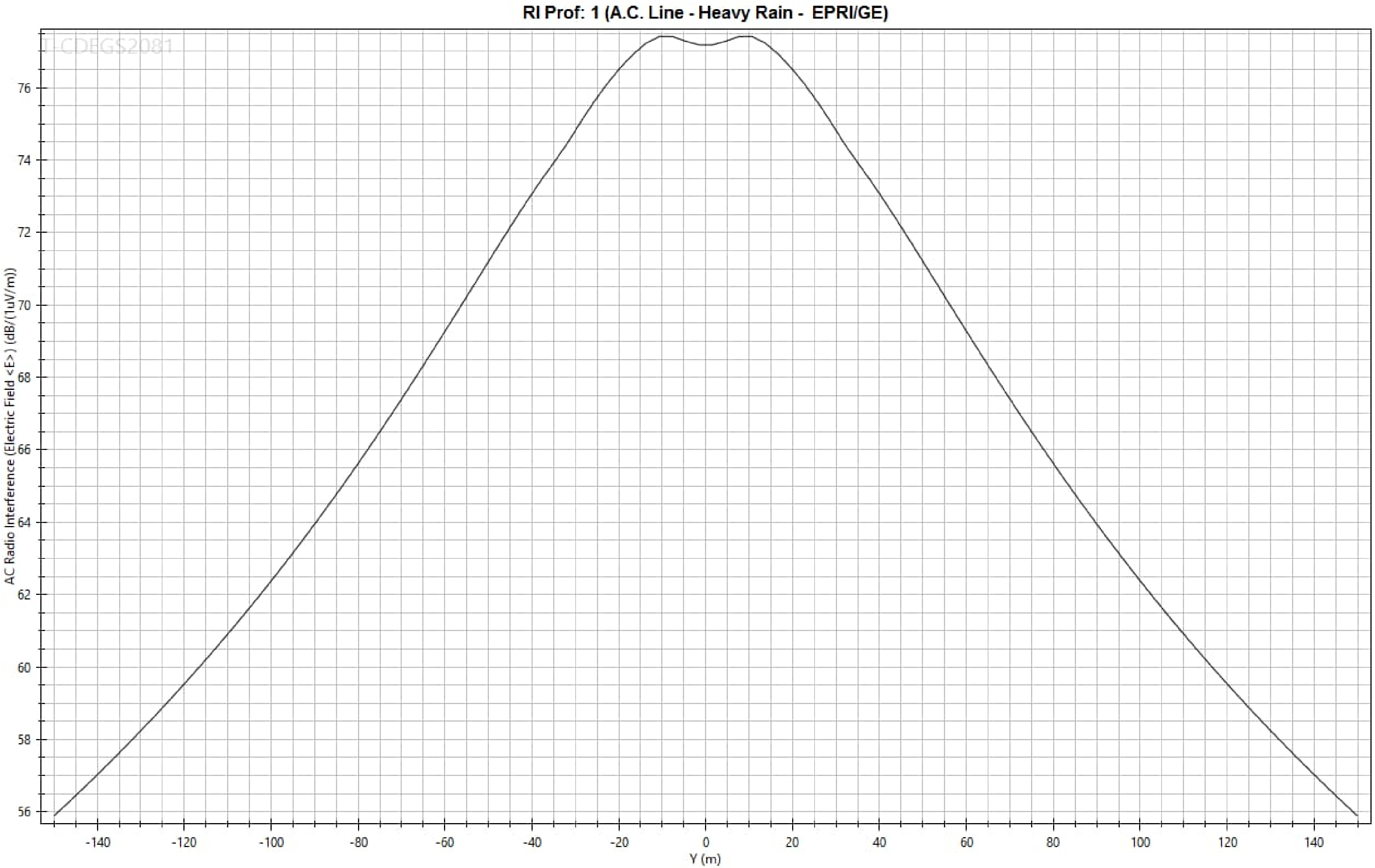

Figure E.3: New 500kV line - RI Electric Field - Heavy Rain, both circuits in service (Source: Jacobs, 2023)

E.2 New 500kV line – single circuit operation

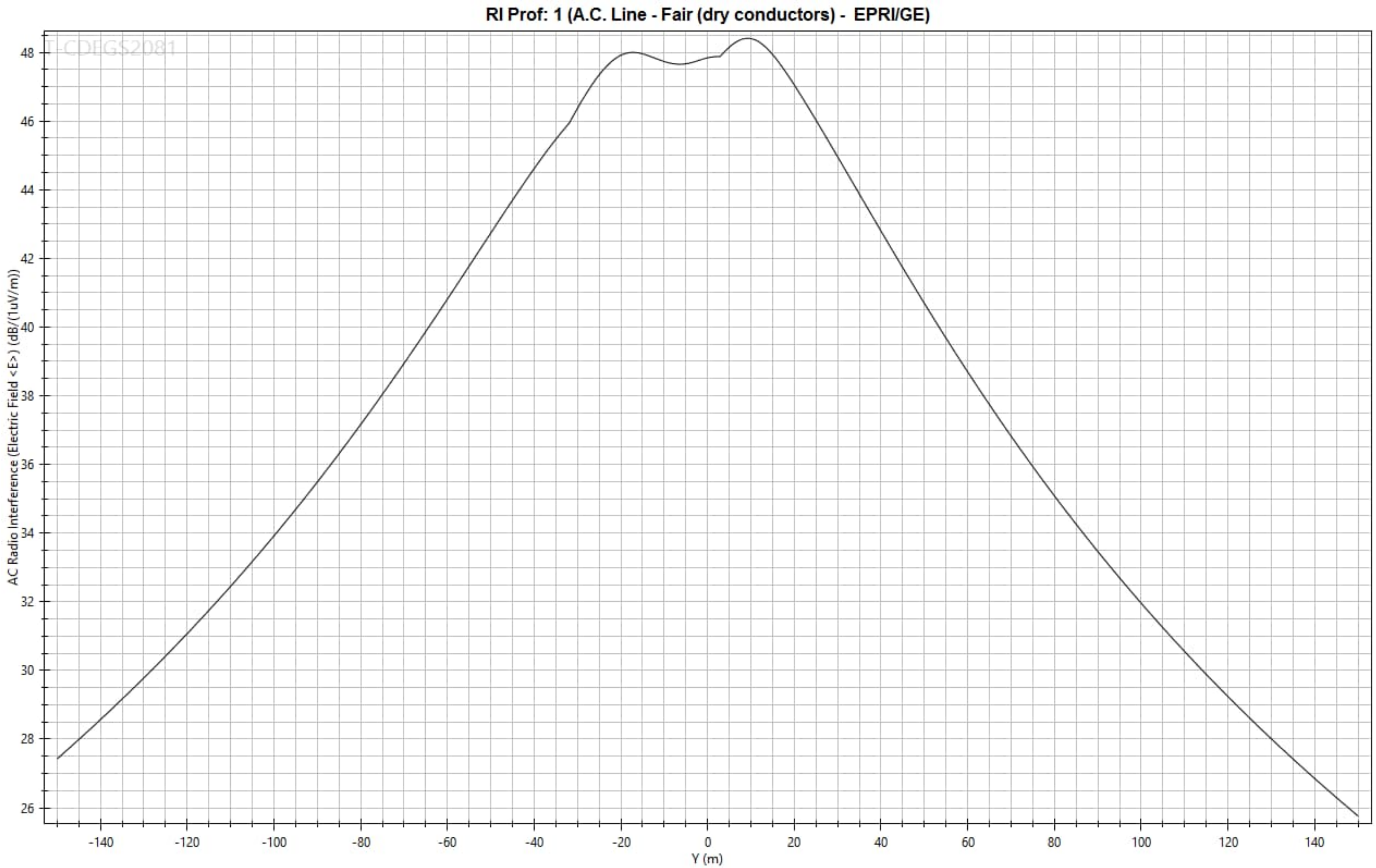

Figure E.4: New 500kV line - RI Electric Field - Fair (dry conductors), single circuit operation (Source: Jacobs, 2023)

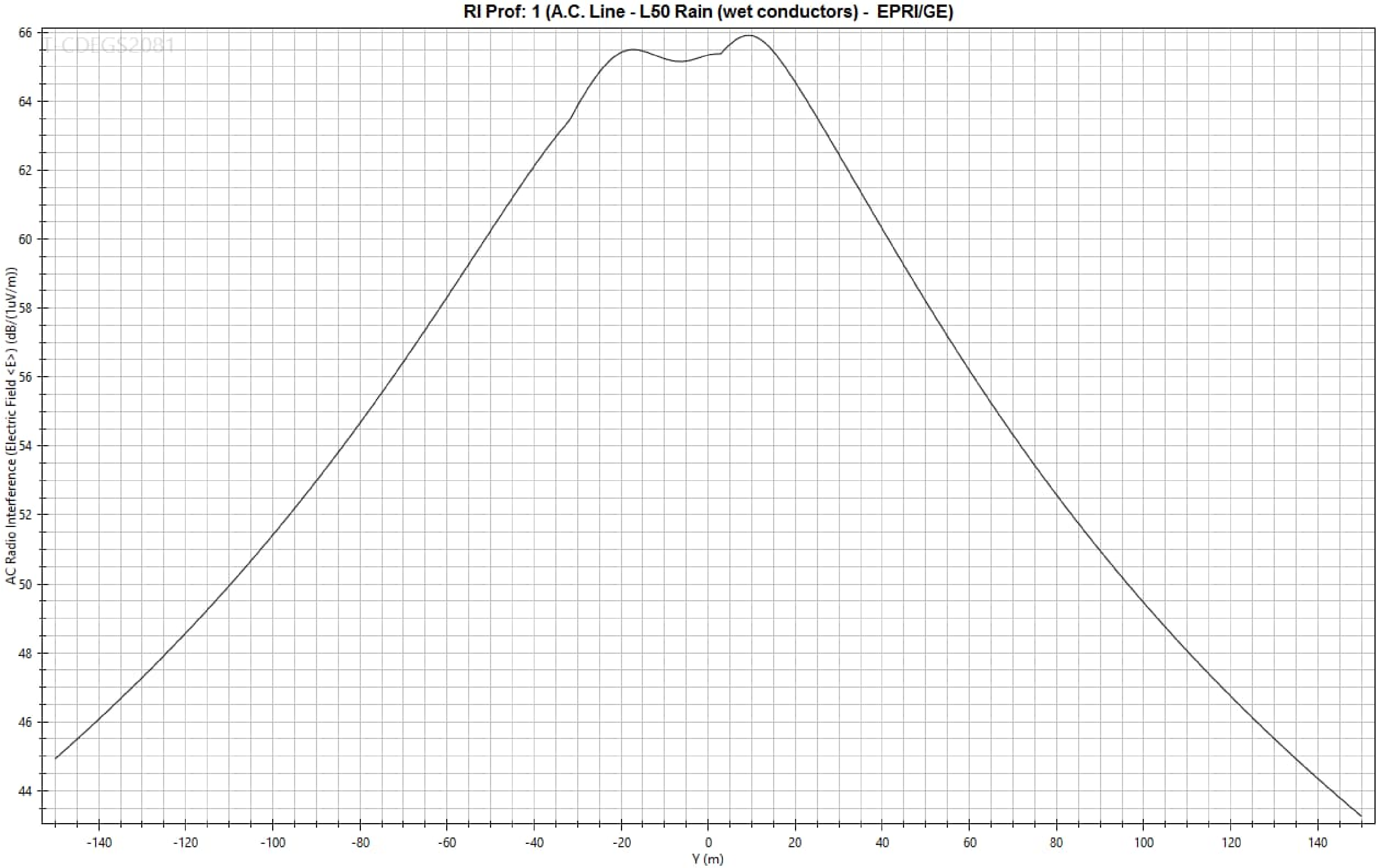

Figure E.5: New 500kV line - RI Electric Field - L50 Rain (wet conductors), single circuit operation (Source: Jacobs, 2023)

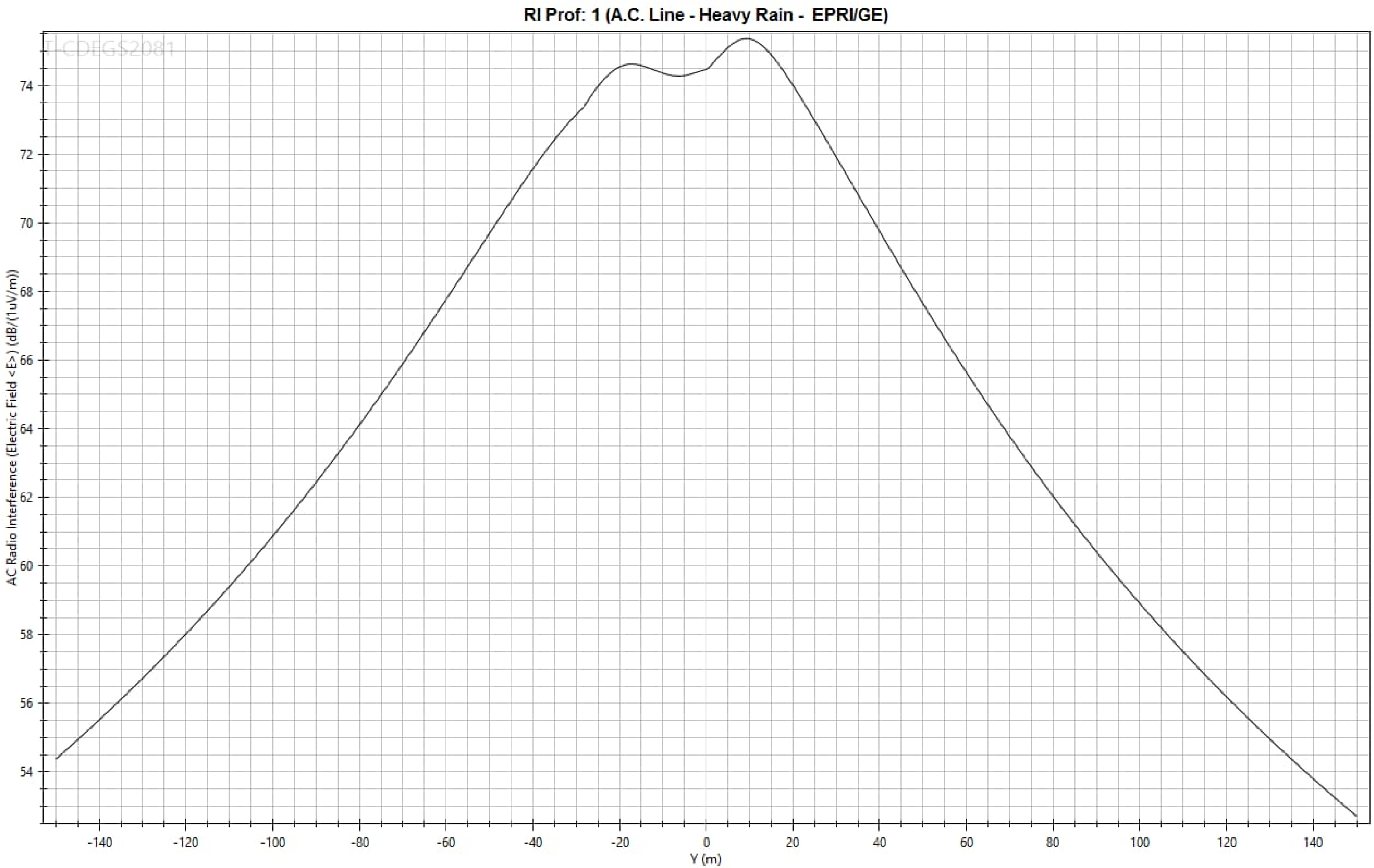

Figure E.6: New 500kV line - RI Electric Field - Heavy Rain, single circuit operation (Source: Jacobs, 2023)

E.3 New 500kV line and existing 220kV line – all circuits in service

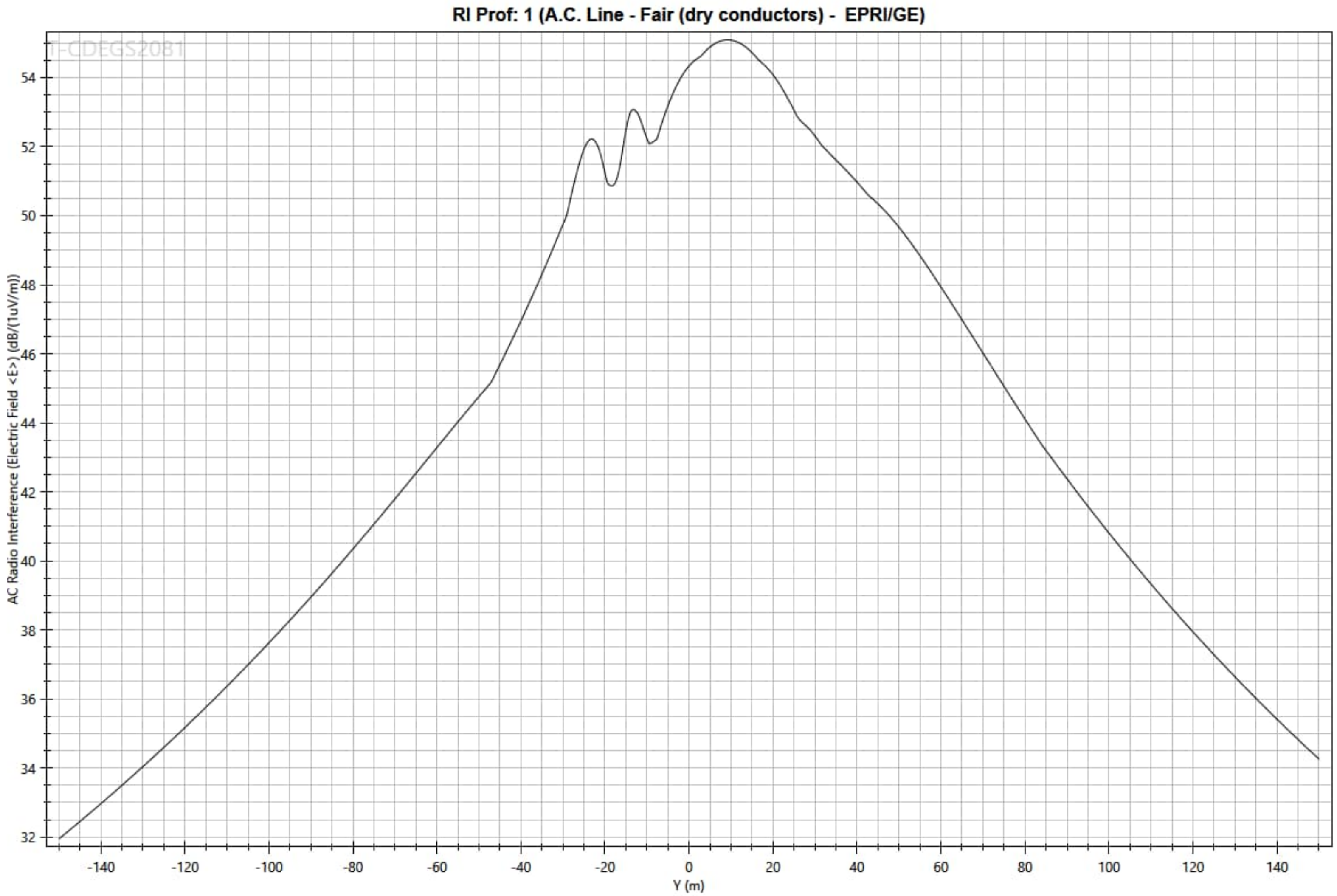

Figure E.7: New 500kV line and existing 220kV line - RI Electric Field - Fair (dry conductors), all circuits in service (Source: Jacobs, 2023)

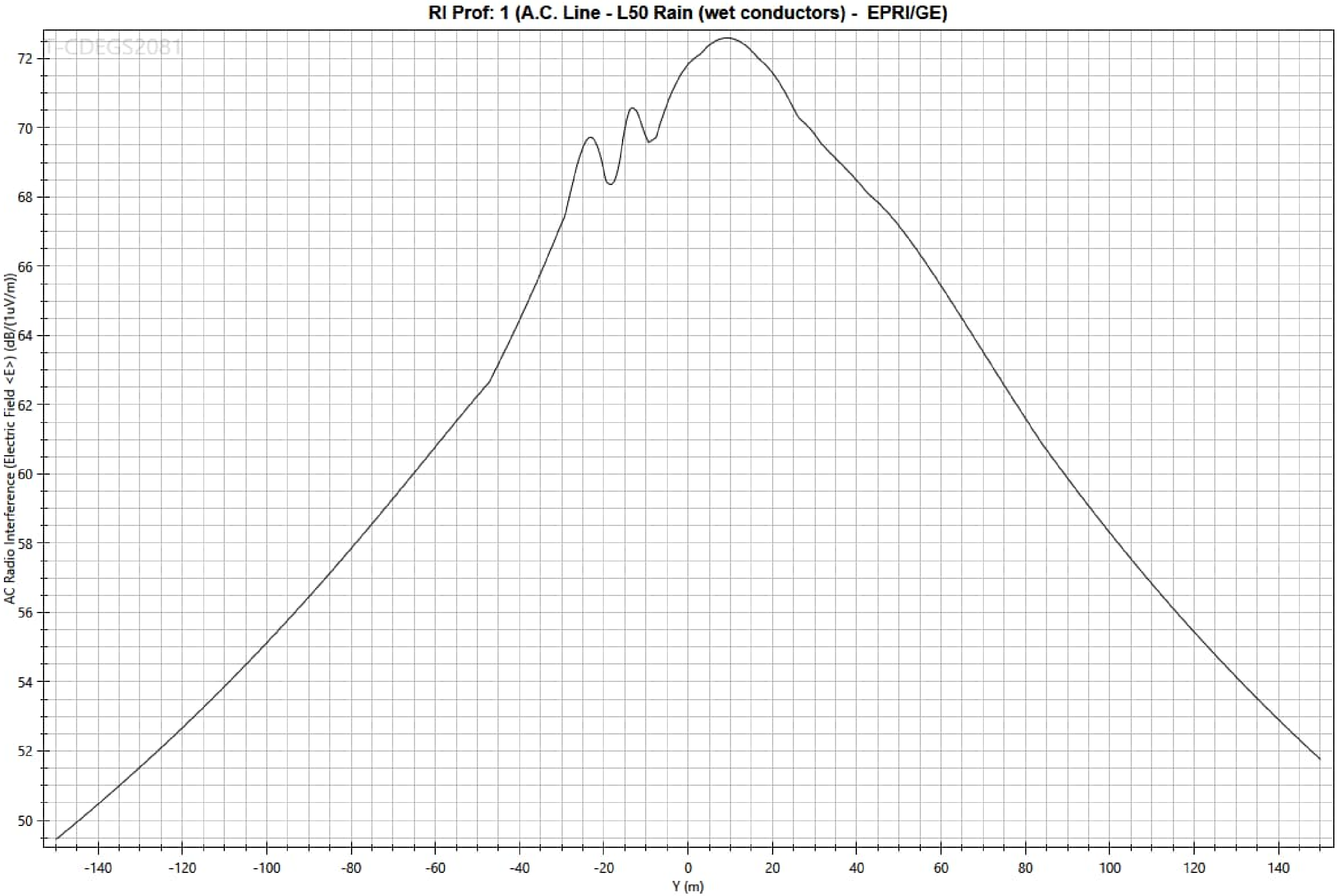

Figure E.8: New 500kV line and existing 220kV line - RI Electric Field - L50 Rain (wet conductors), all circuits in service (Source: Jacobs, 2023)

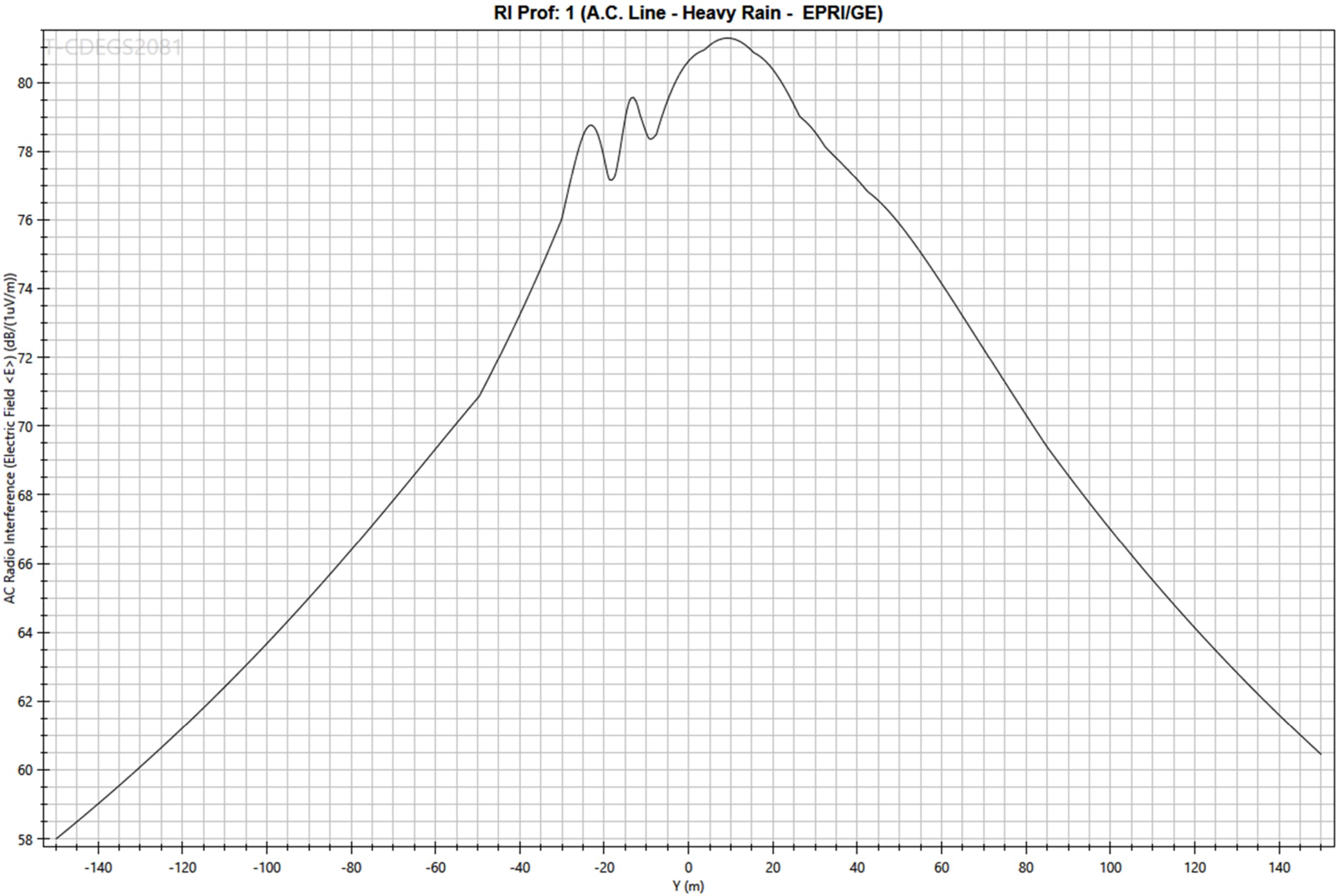

Figure E.9: New 500kV line and existing 220kV line - RI Electric Field - Heavy Rain, all circuits active (Source: Jacobs, 2023)

E.4 New 500kV line and existing 220kV line – One new circuit out of service

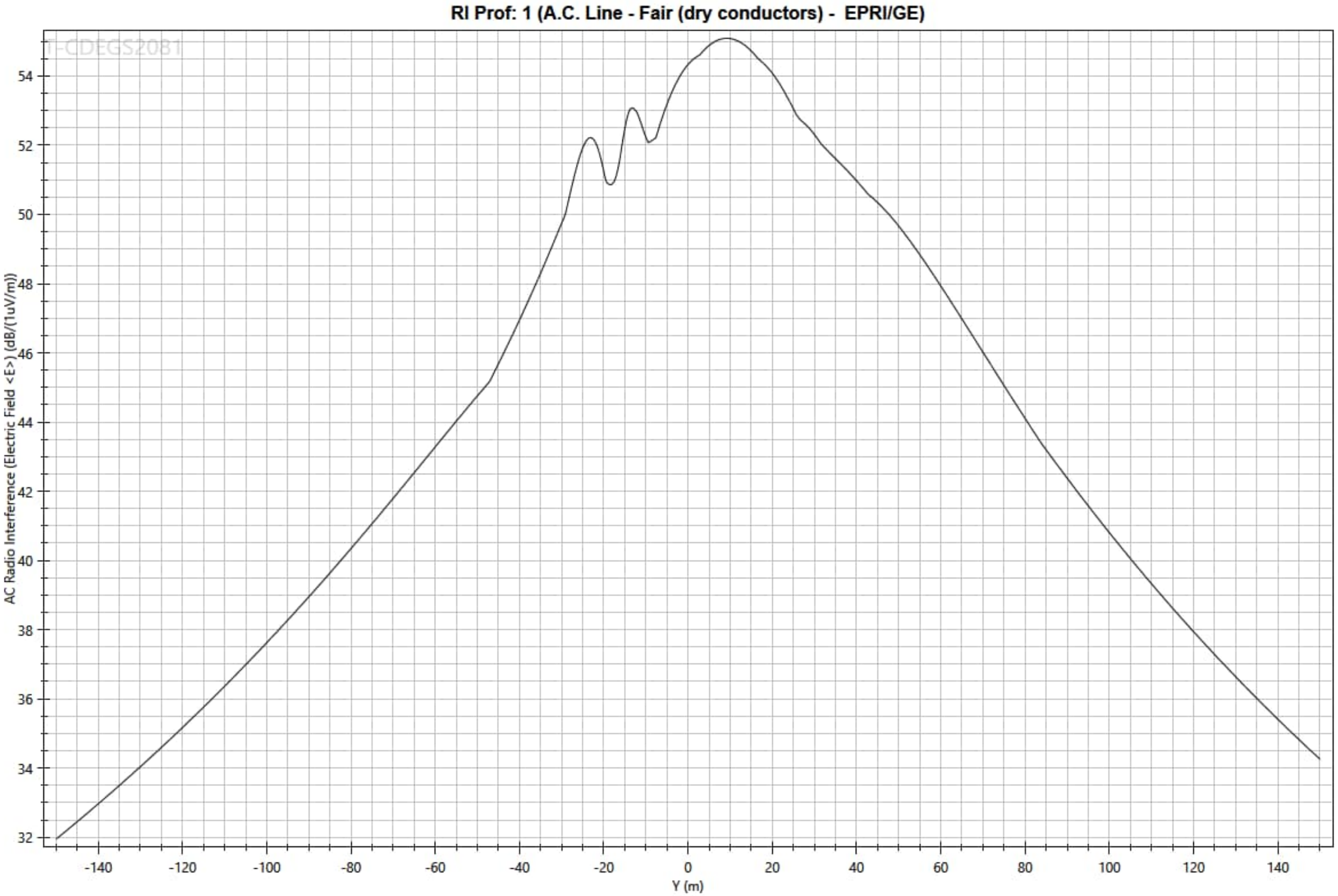

Figure E.10: New 500kV line and existing 220kV line - RI Electric Field - Fair (dry conductors), one circuit out of service (Source: Jacobs, 2023)

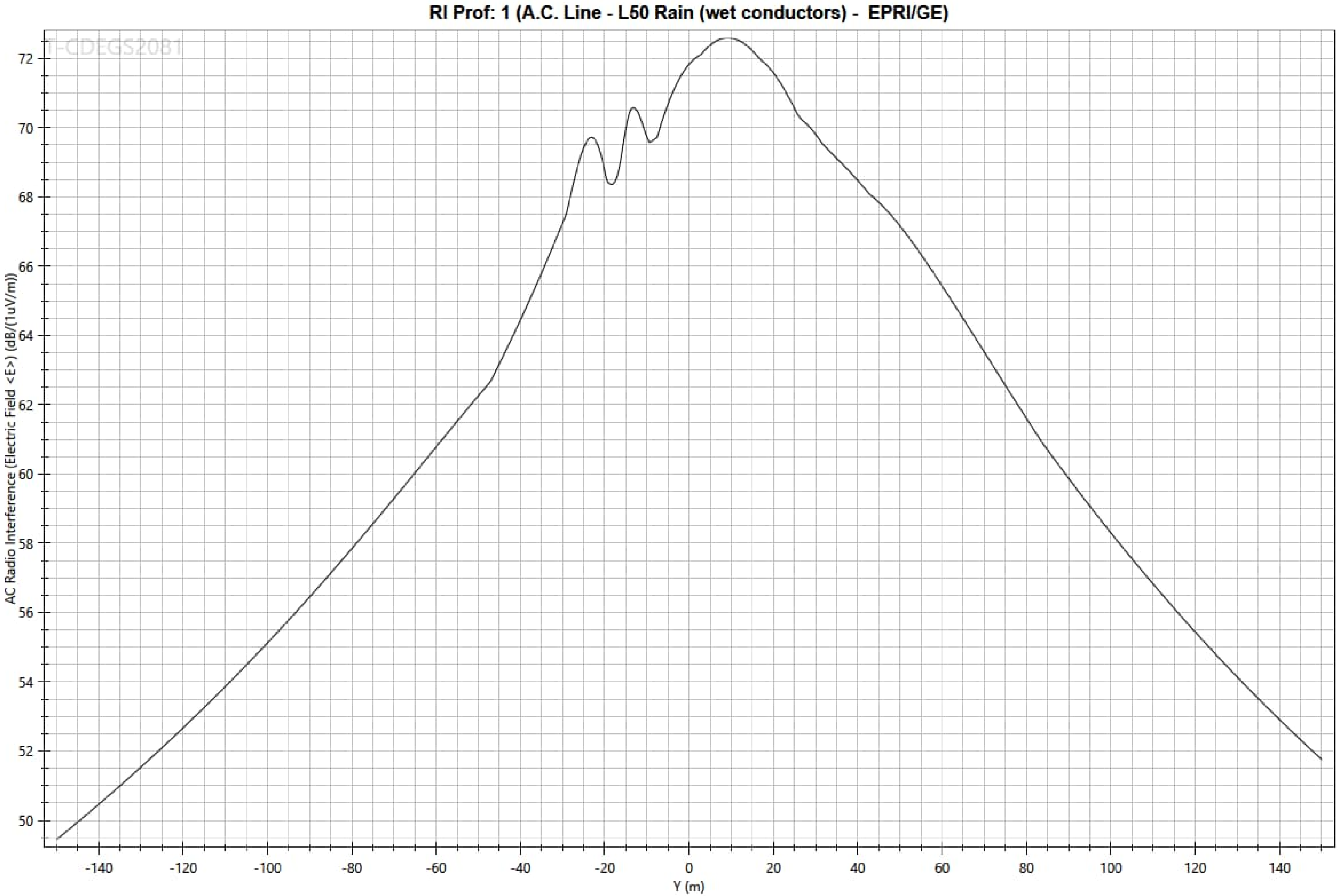

Figure E.11: New 500kV line and existing 220kV line - RI Electric Field - L50 Rain (wet conductors), one circuit out of service (Source: Jacobs, 2023)

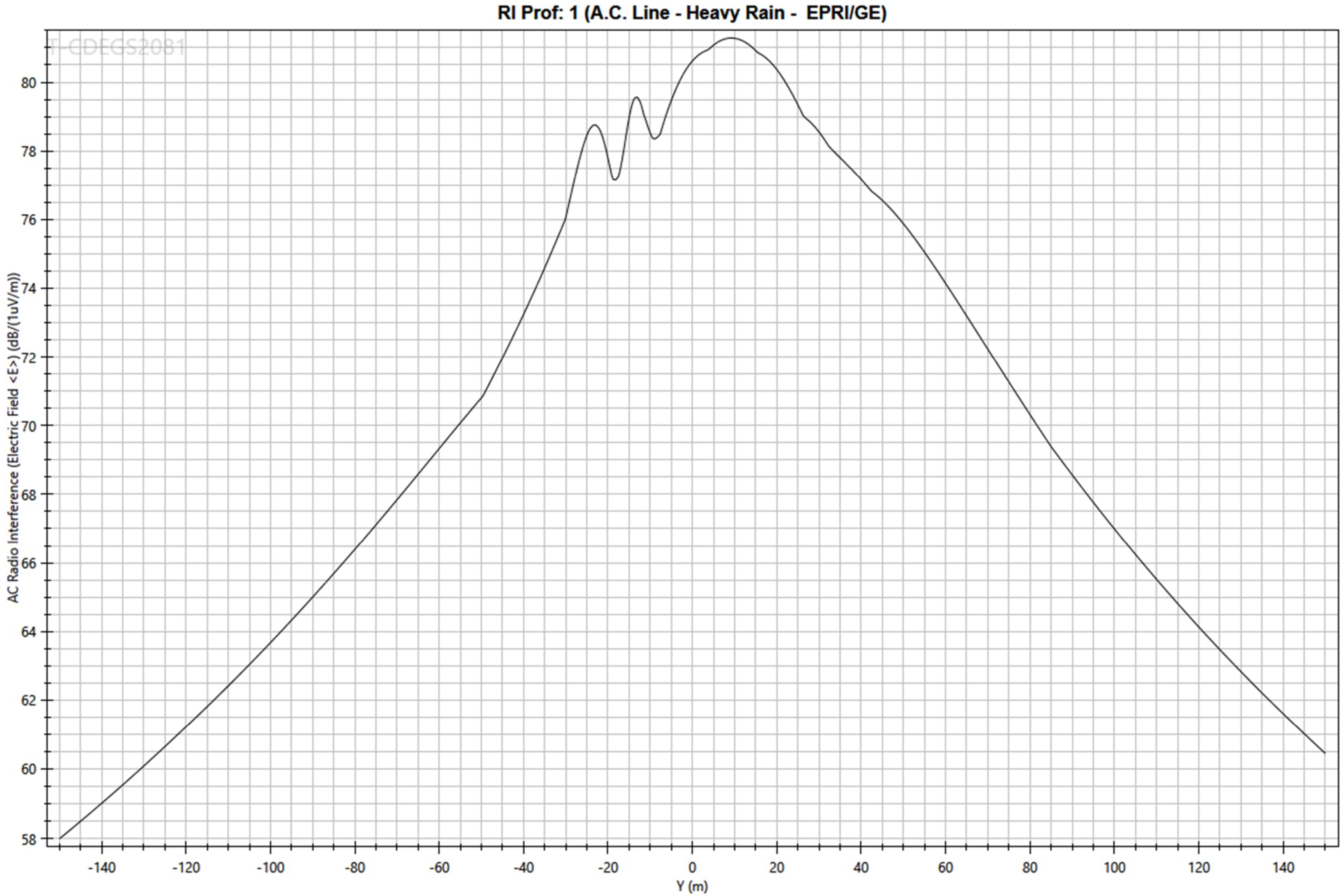

Figure E.12: New 500kV line and existing 220kV line - RI Electric Field - Heavy Rain, one circuit out of service (Source: Jacobs, 2023)

E.5 New 500kV line – Single Circuit Structures – all circuits in service

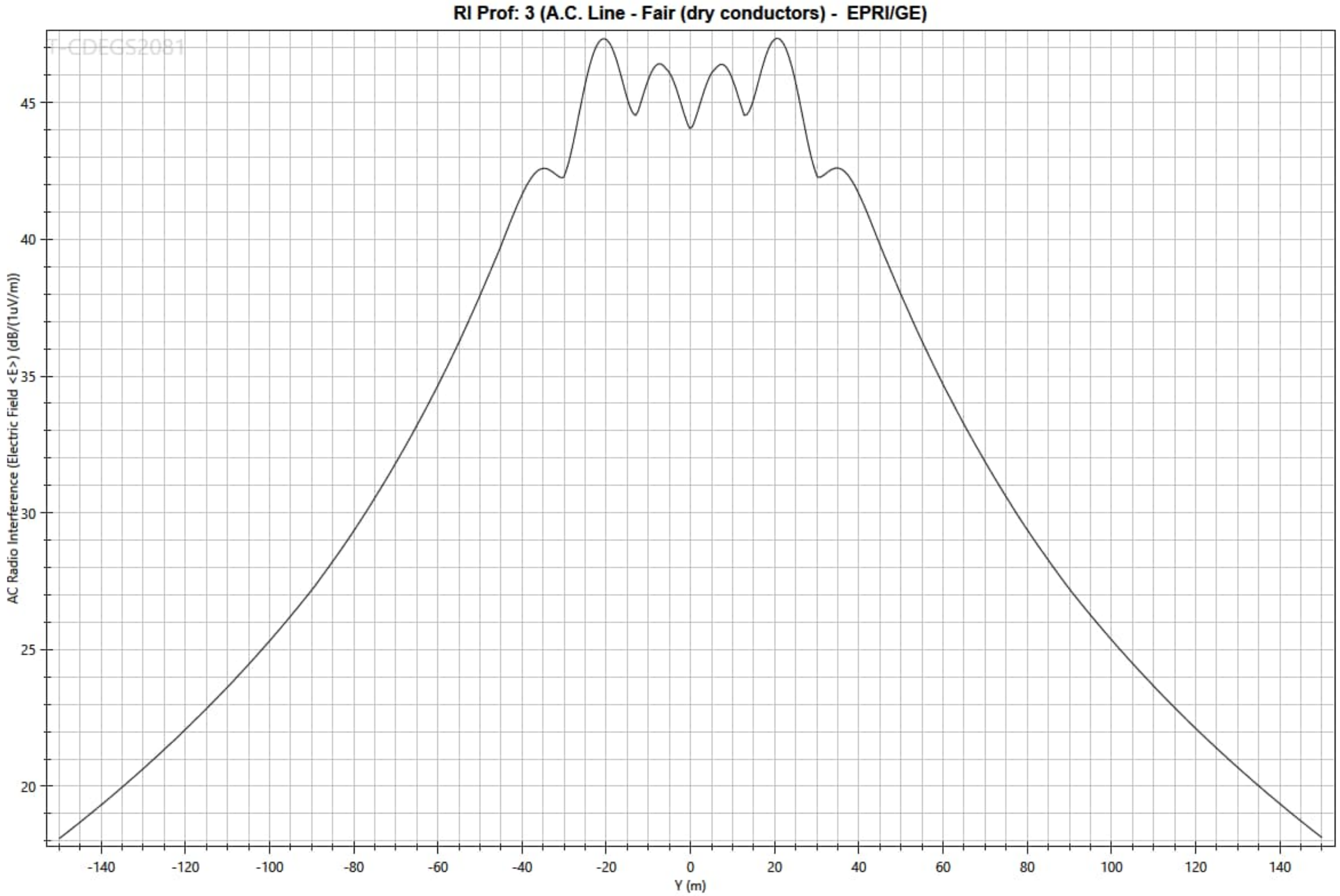

Figure E.13: New 500kV line single circuit structures - RI Electric Field - Fair (dry conductors), all circuits in service (Source: Jacobs, 2023)

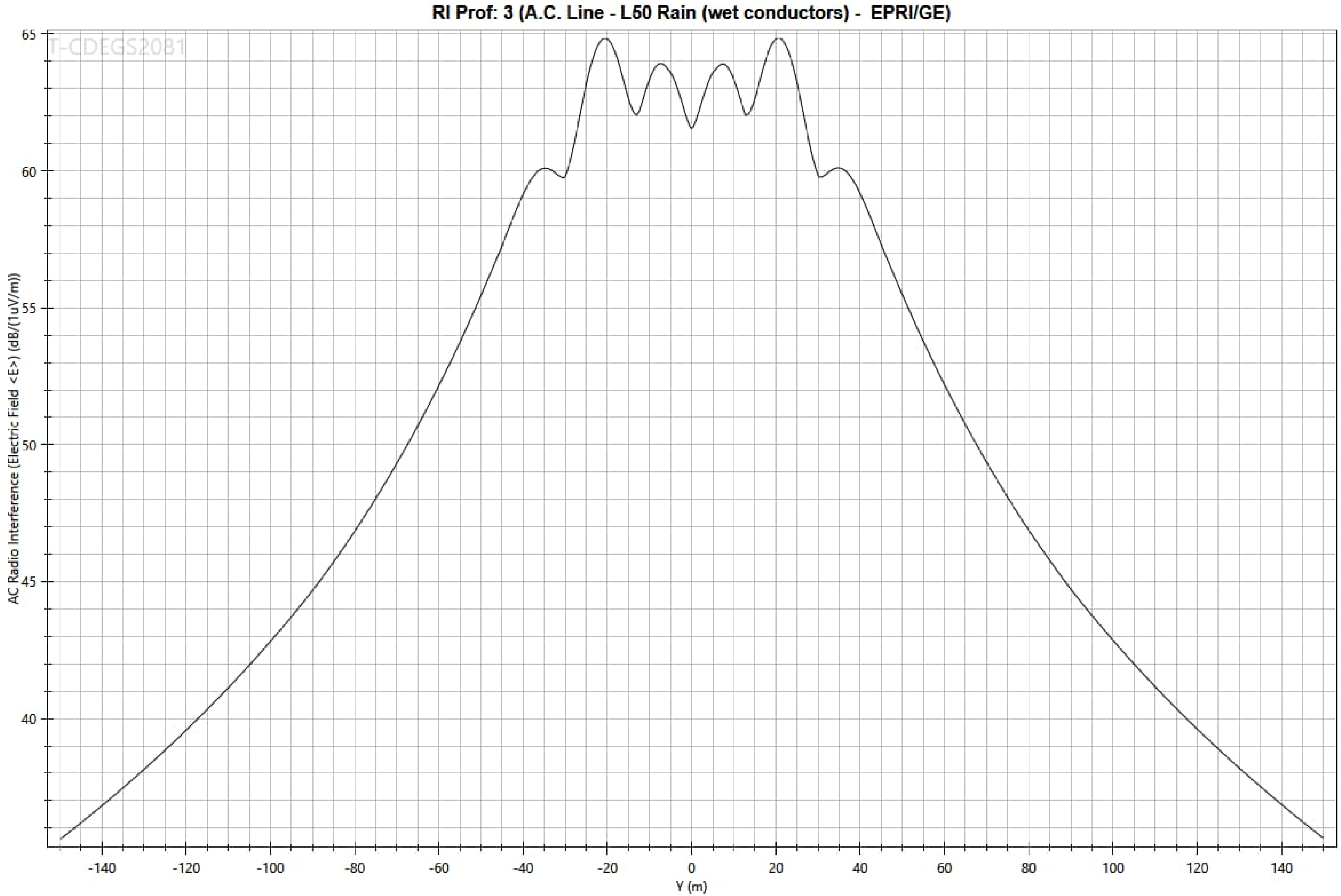

Figure E.14: New 500kV line single circuit structures line - RI Electric Field - L50 Rain (wet conductors), all circuits in service (Source: Jacobs, 2023)

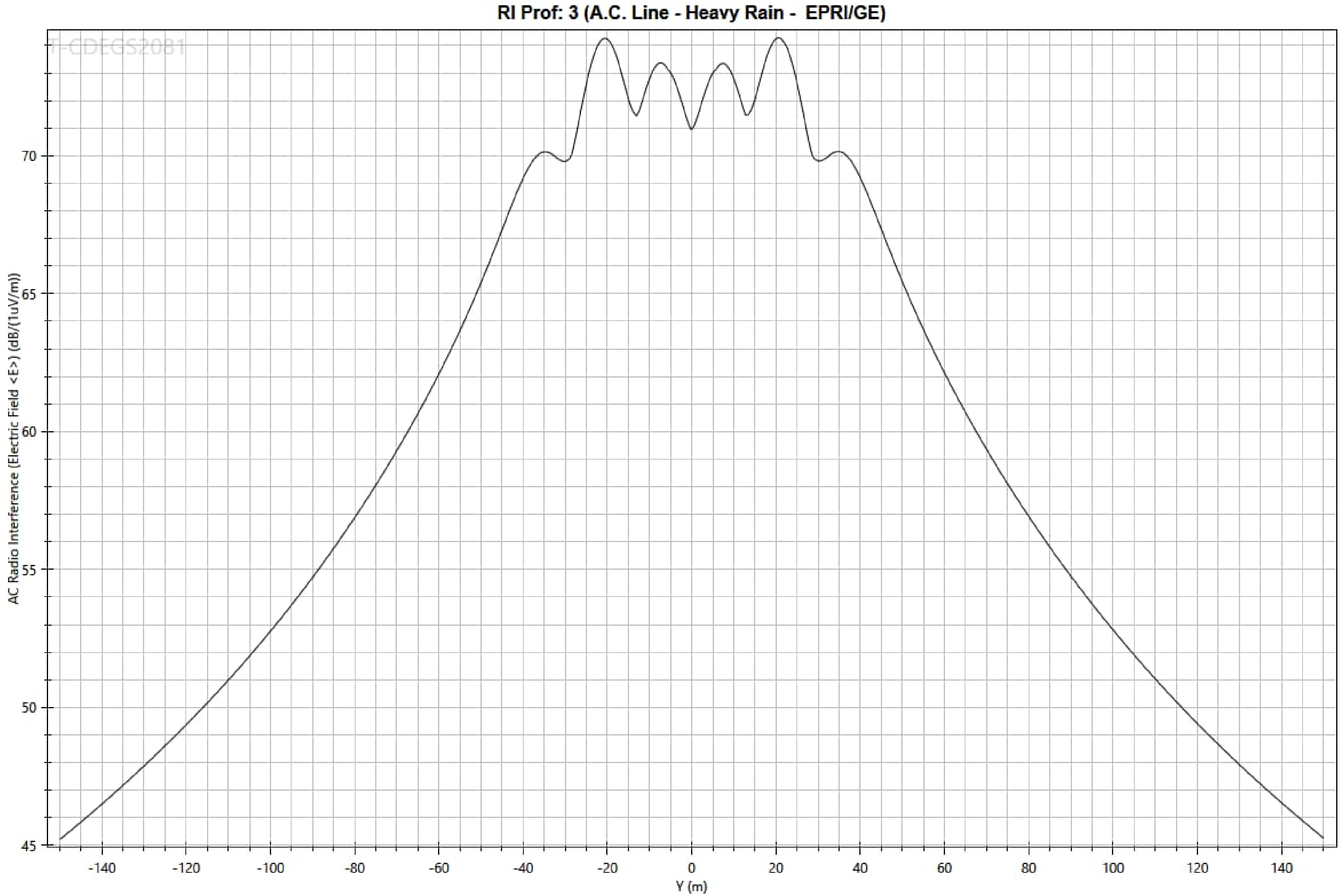

Figure E.15: New 500kV line single circuit structures - RI Electric Field - Heavy Rain, all circuits active (Source: Jacobs, 2023)

E.6 New 500kV line – Single Circuit Structures – one circuit out of service

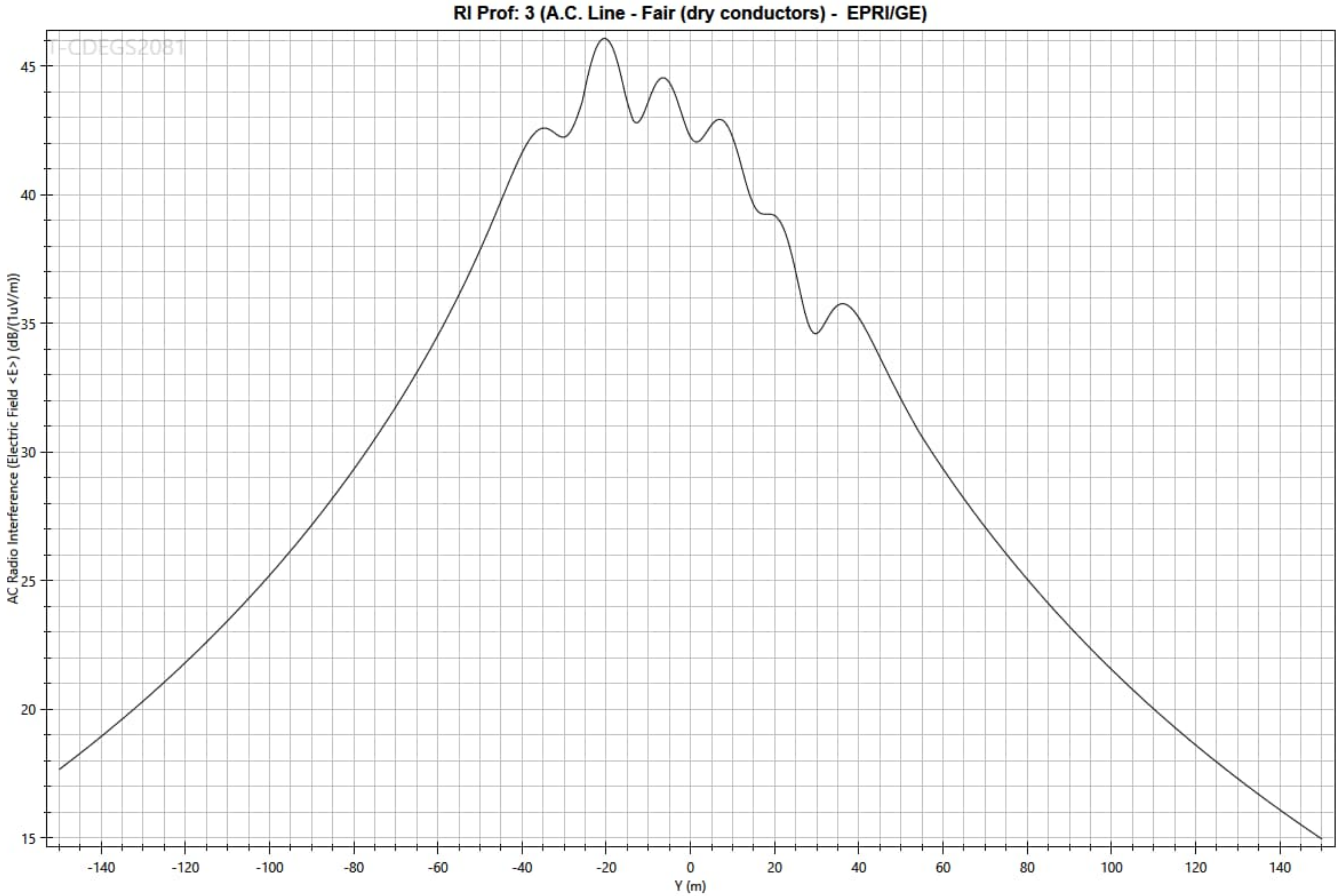

Figure E.16: New 500kV line single circuit structures - RI Electric Field - Fair (dry conductors), one circuit out of service (Source: Jacobs, 2023)

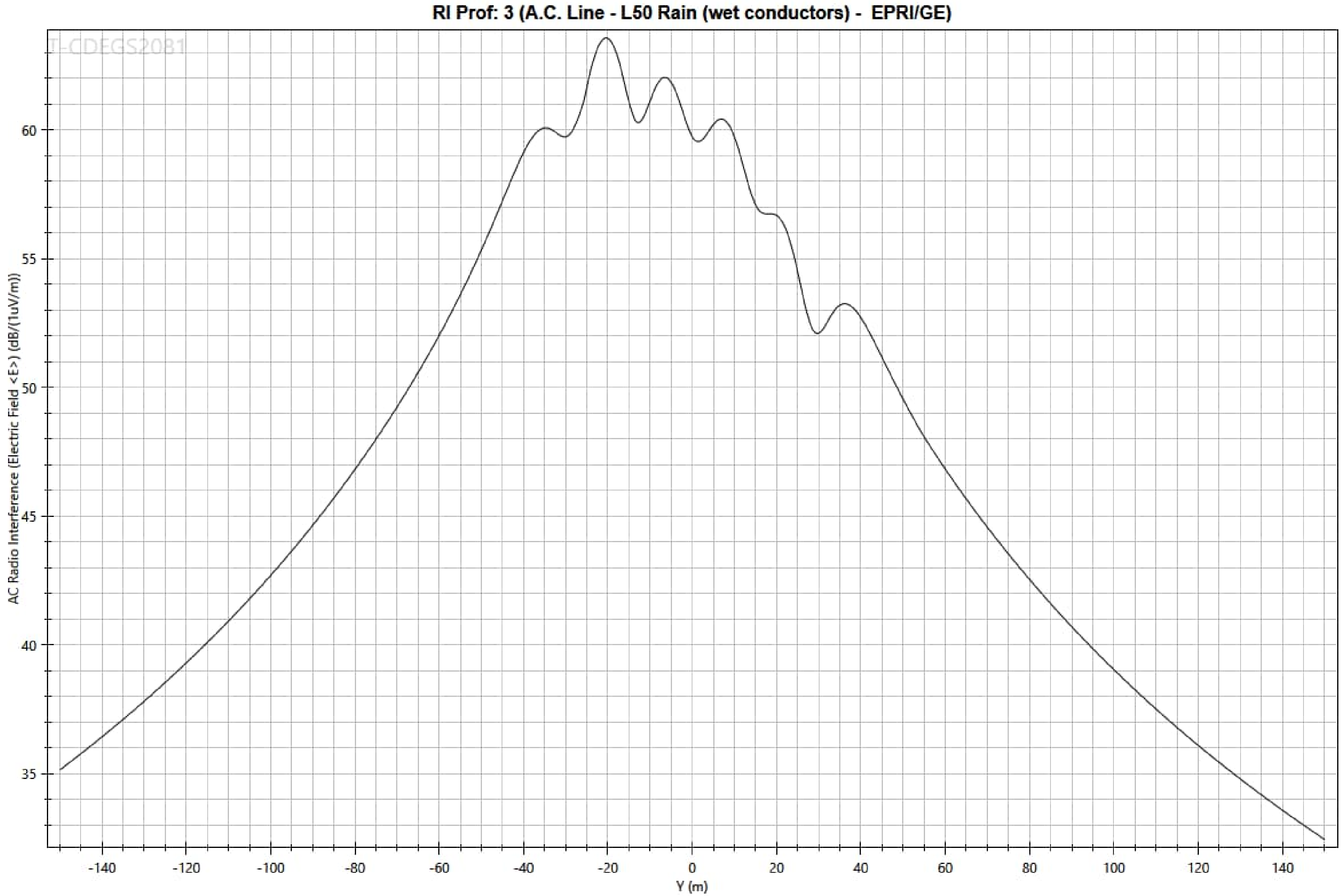

Figure E.17: New 500kV line single circuit structures line - RI Electric Field - L50 Rain (wet conductors), one circuit out of service (Source: Jacobs, 2023)

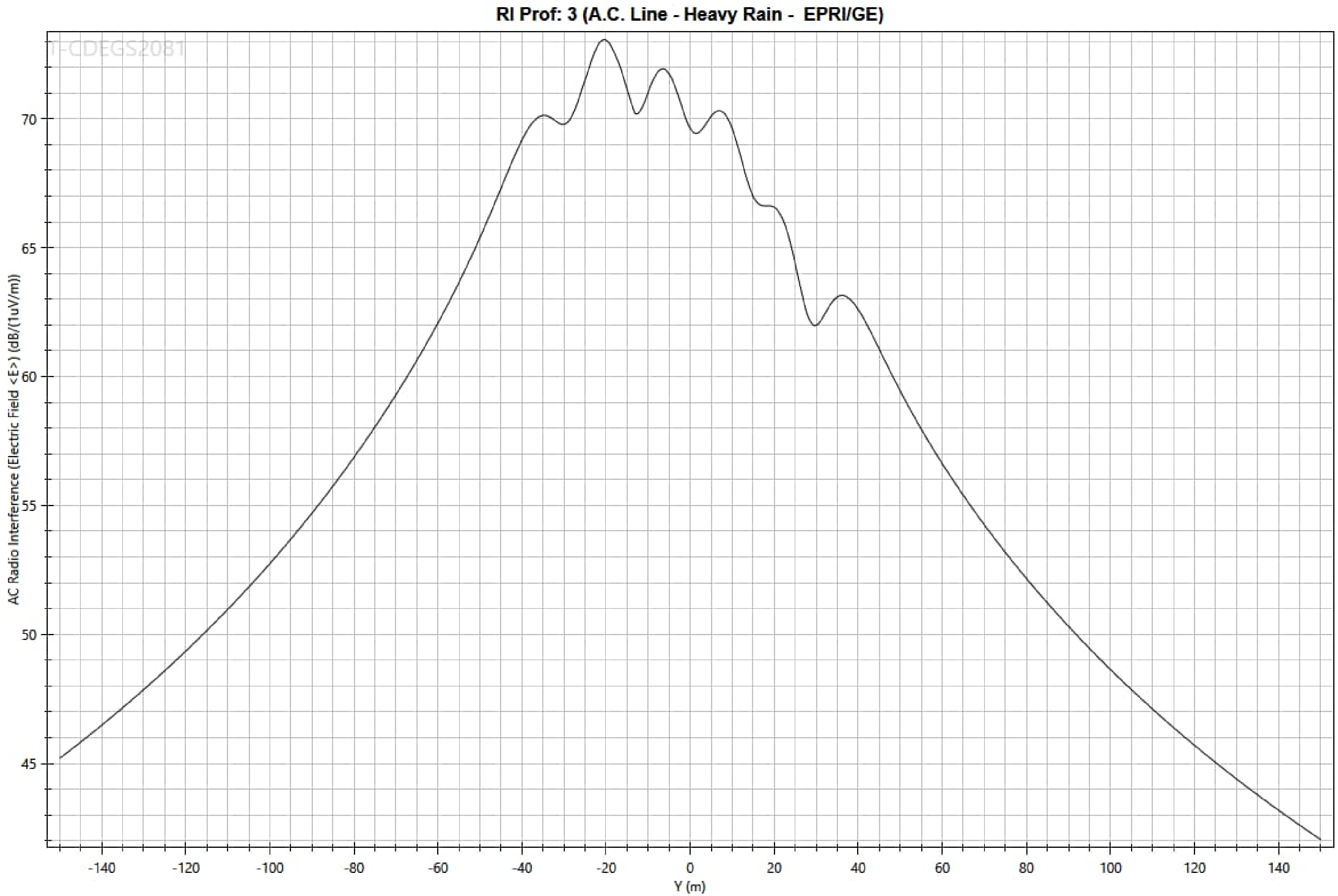

Figure E.18: New 500kV line single circuit structures - RI Electric Field - Heavy Rain, one circuit out of service (Source: Jacobs, 2023)

Appendix F. Existing RF point-to-point services path profiles

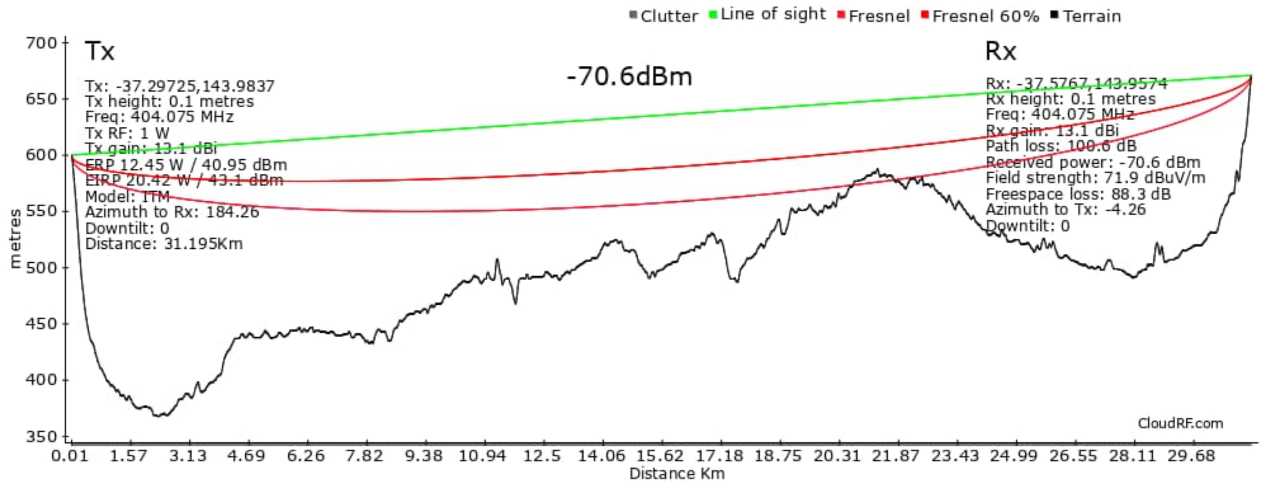

Figure F.1: Path profile for Cloud RF System ID 50835, Smeaton Hill (715988) to Dunnstown (715989) (Source: Jacobs, 2022)

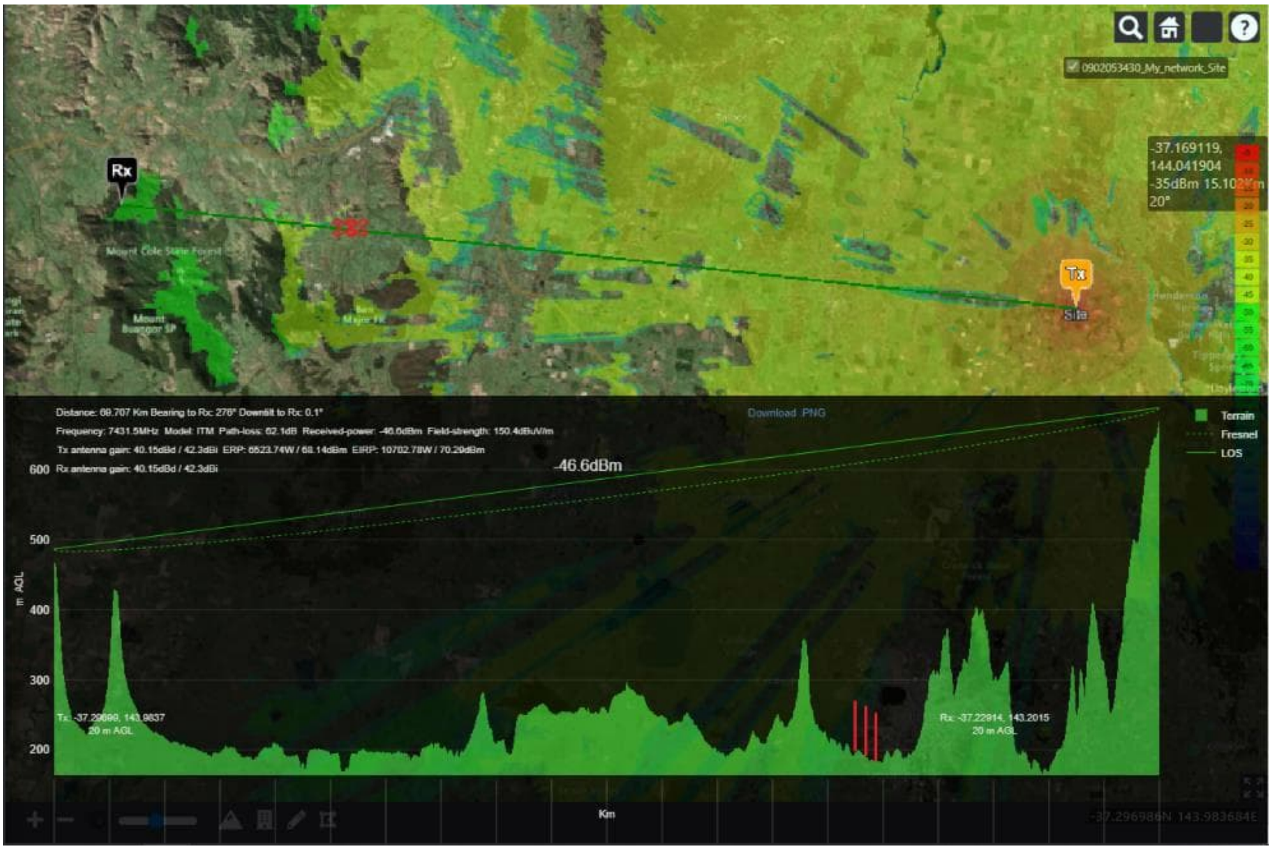

Figure F.2: Path Profile for Cloud RF System ID 110805, Smeaton Hill (738701) to Ben Nevis (738702) (Source: Jacobs, 2022)

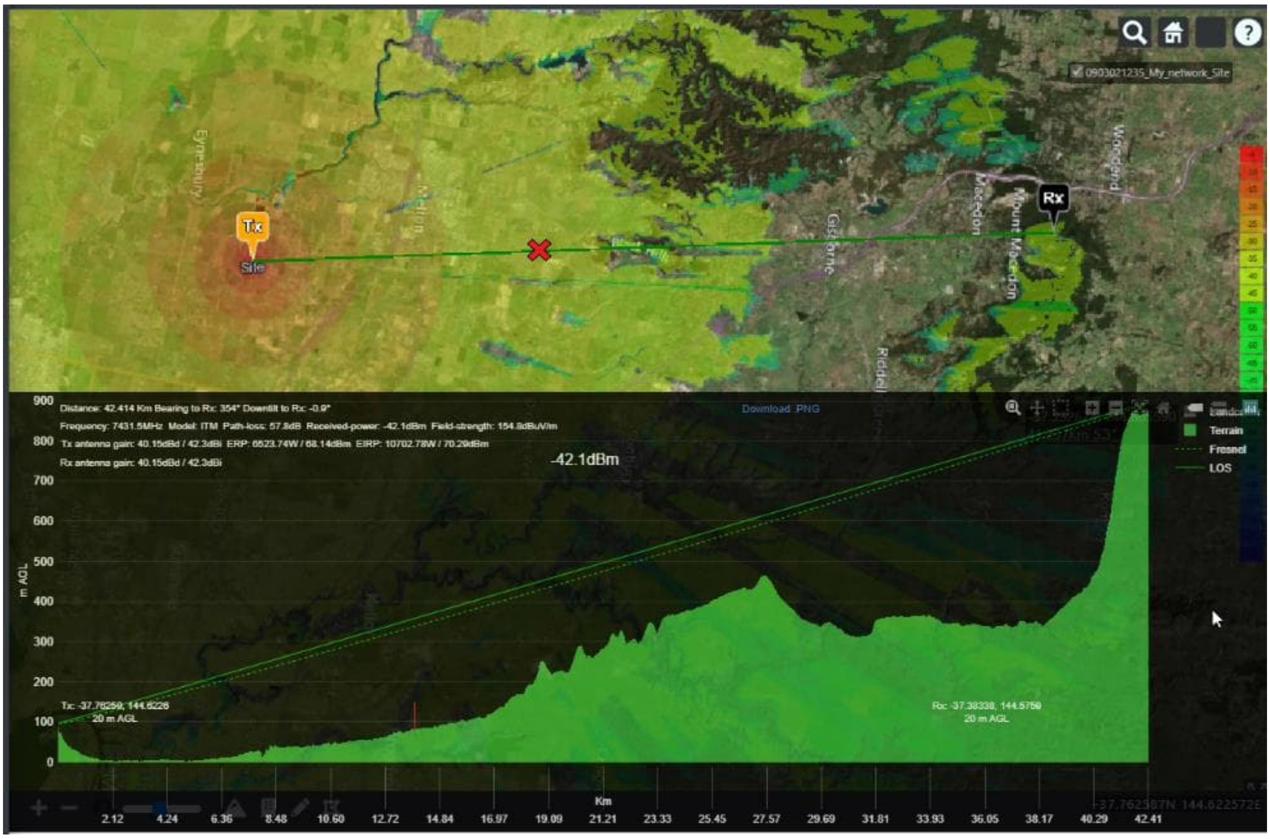

Figure F.3: Path Profile for Cloud RF System ID 110814, MT Cottrell (738759) to Mt Macedon (738760) (Source: Jacobs, 2022)

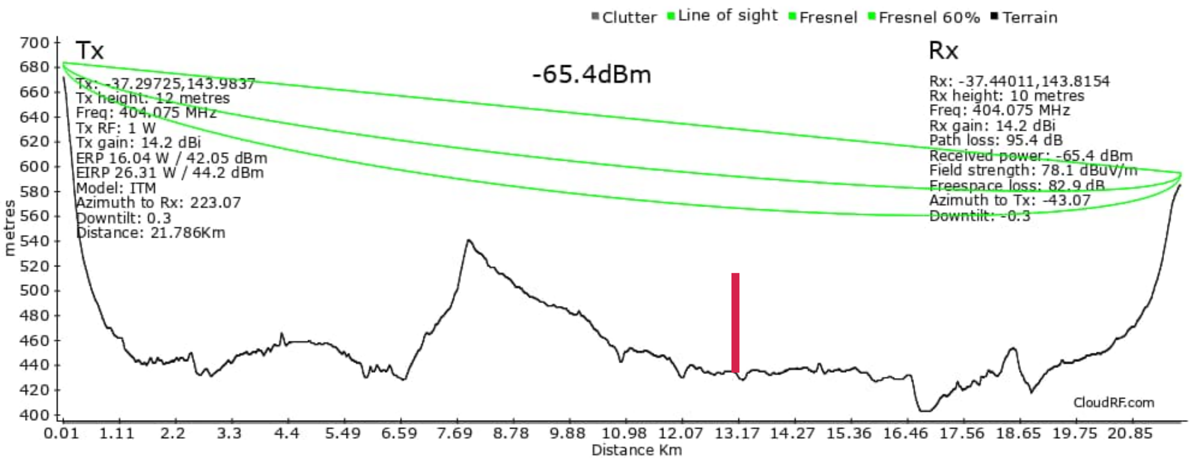

Figure F.4: Path Profile for Cloud RF System ID 303230, Mt Hollowback (750908) to Smeaton Hill (750907) (Source: Jacobs, 2022)

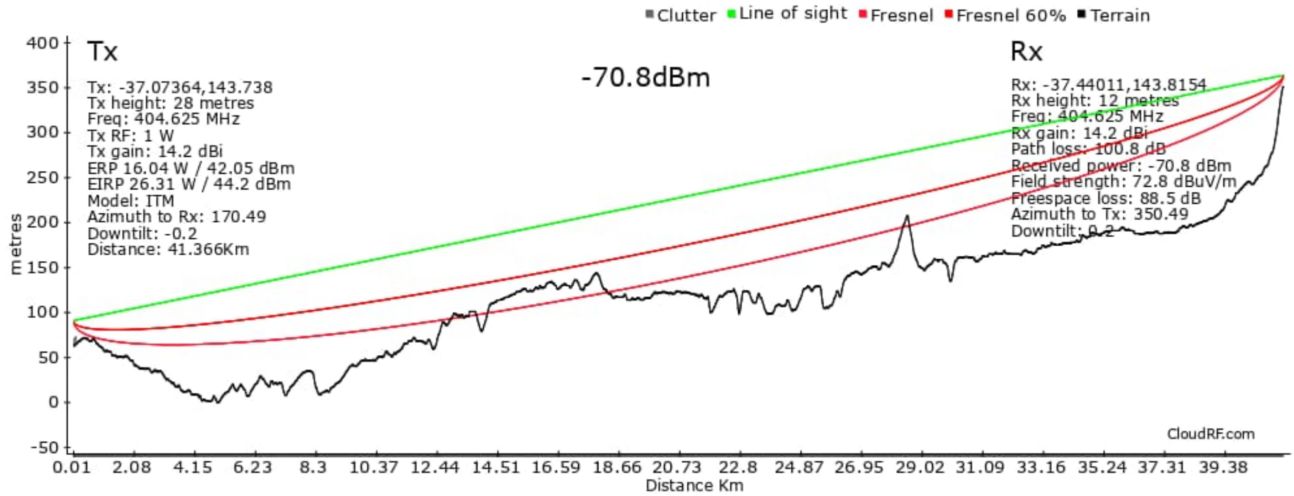

Figure F.5: Path Profile for Cloud RF System ID 303228, Maryborough (750911) to Mt Hollowback (759012) (Source: Jacobs, 2022)

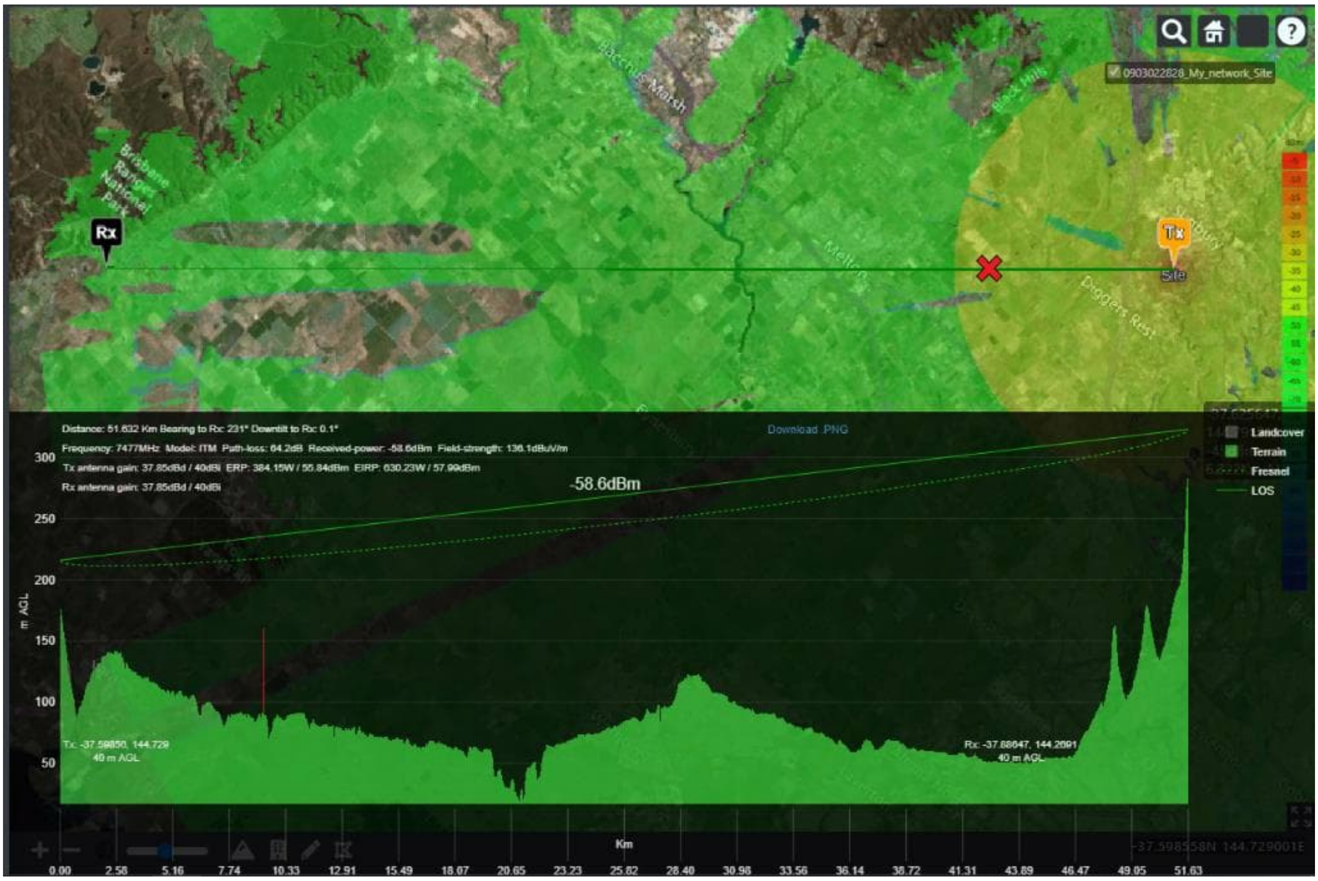

Figure F.6: Path Profile for Cloud RF System ID 184323, Sunbury (787330) to Mt Anakie (787331) (Source: Jacobs, 2022)

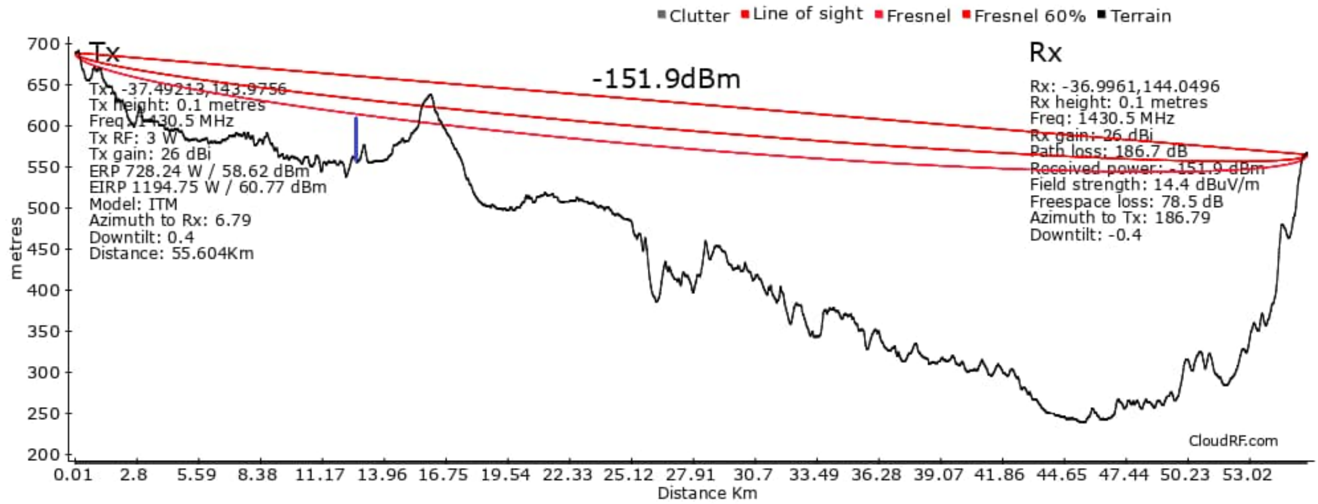

Figure F.7: Path Profile for Cloud RF System ID 242682, Ballarat (791242) to Mt Tarrengower (791243) (Source: Jacobs, 2022)

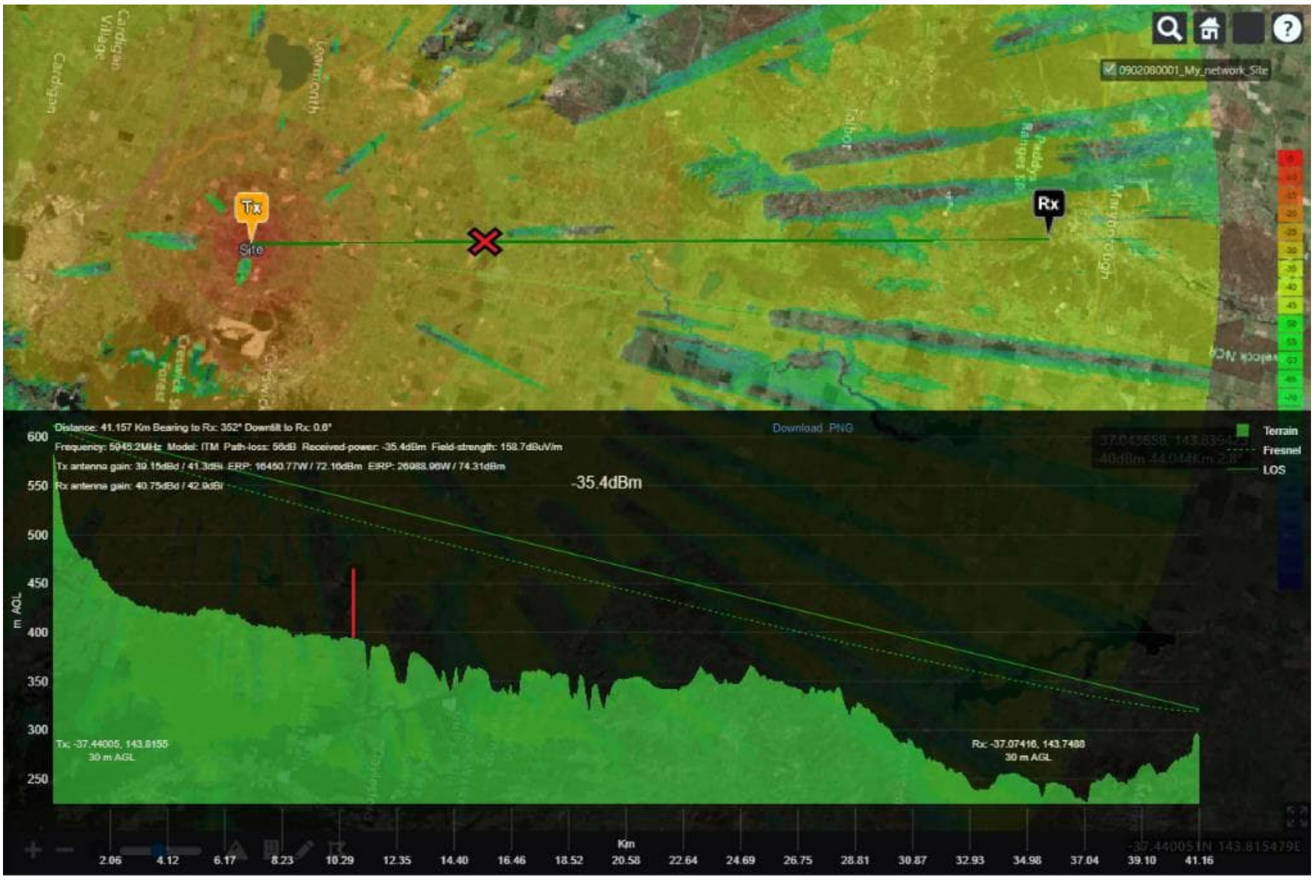

Figure F.8: Path Profile for Cloud RF System ID 211753, Mt Hollowback (827235) to Maryborough (827236) (Source: Jacobs, 2022)

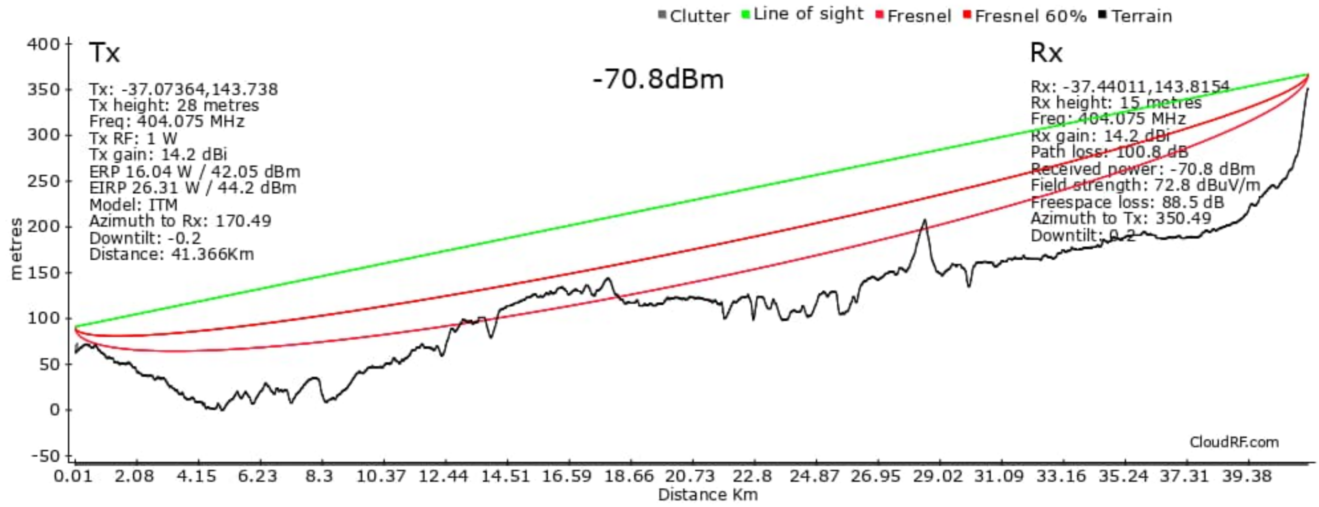

Figure F.9: Path Profile of Cloud RF System ID (327757), Maryborough (832950) to Mt Hollowback (832951) (Source: Jacobs, 2022)

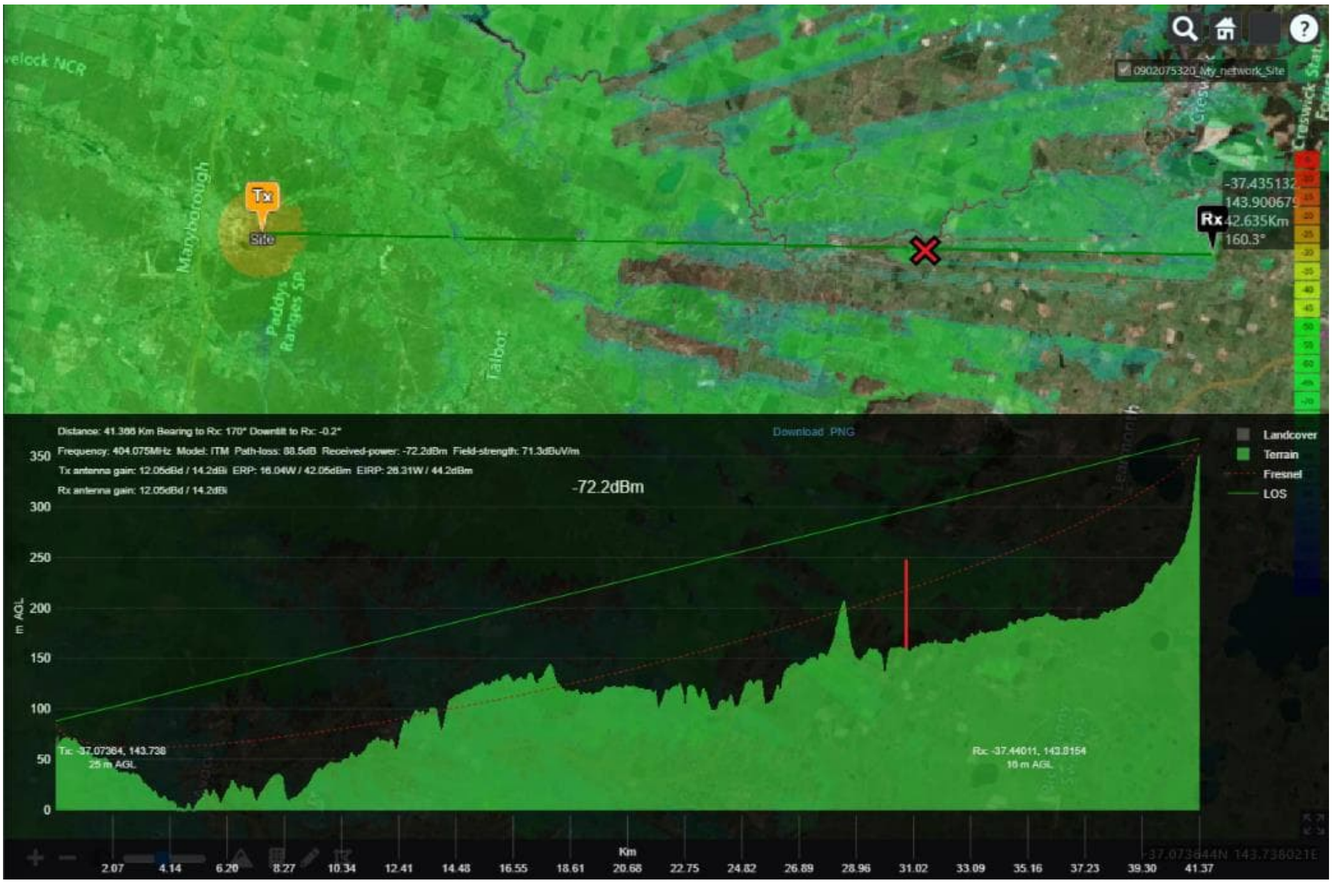

Figure F.10: Path Profile of Cloud RF System ID (328242), Maryborough (832994) to Mt Hollowback (832995) (Source: Jacobs, 2022)

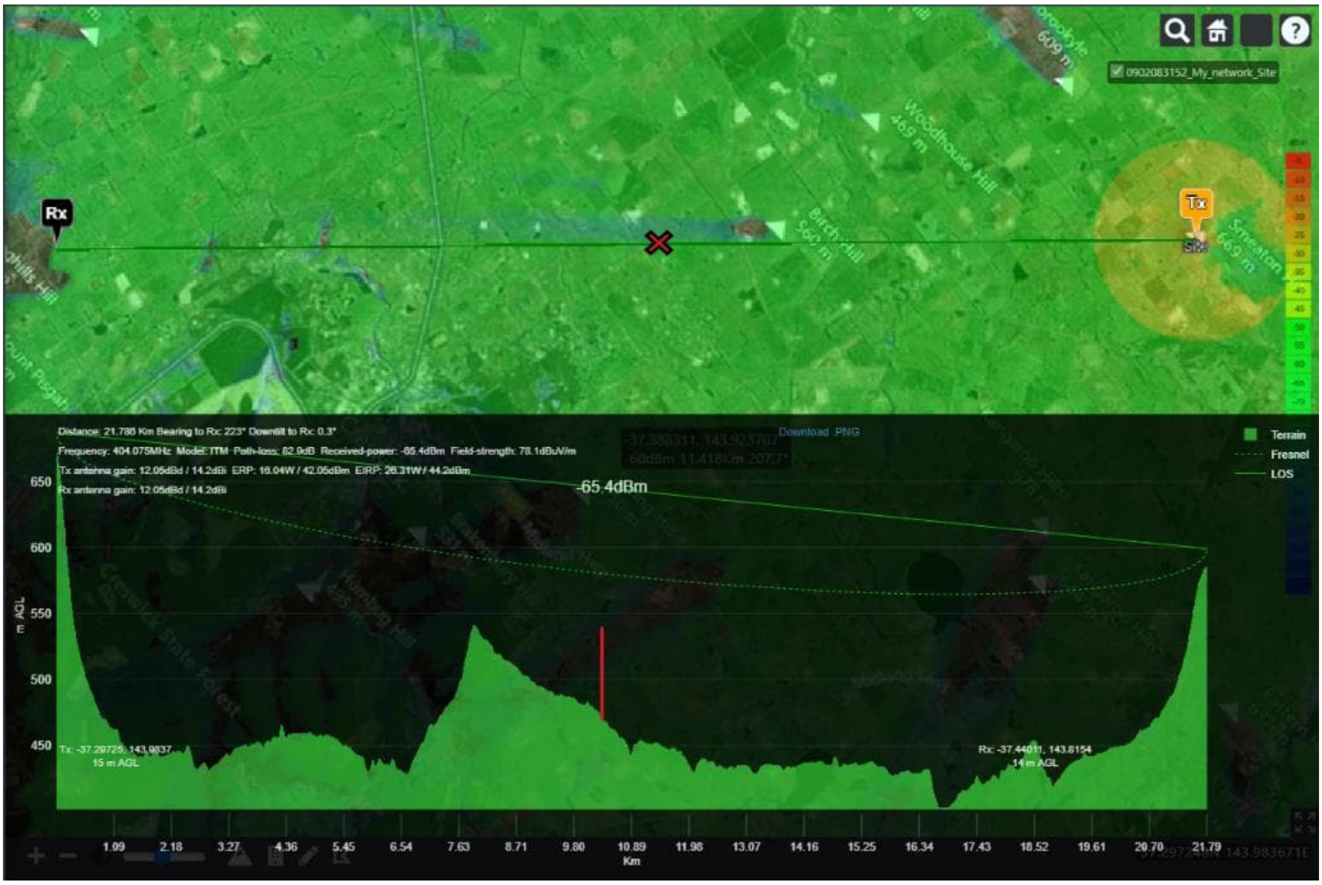

Figure F.11: Path Profile of Cloud RF System ID (328241), Smeaton Hill (833002) to Mt Hollowback (833003) (Source: Jacobs, 2022)

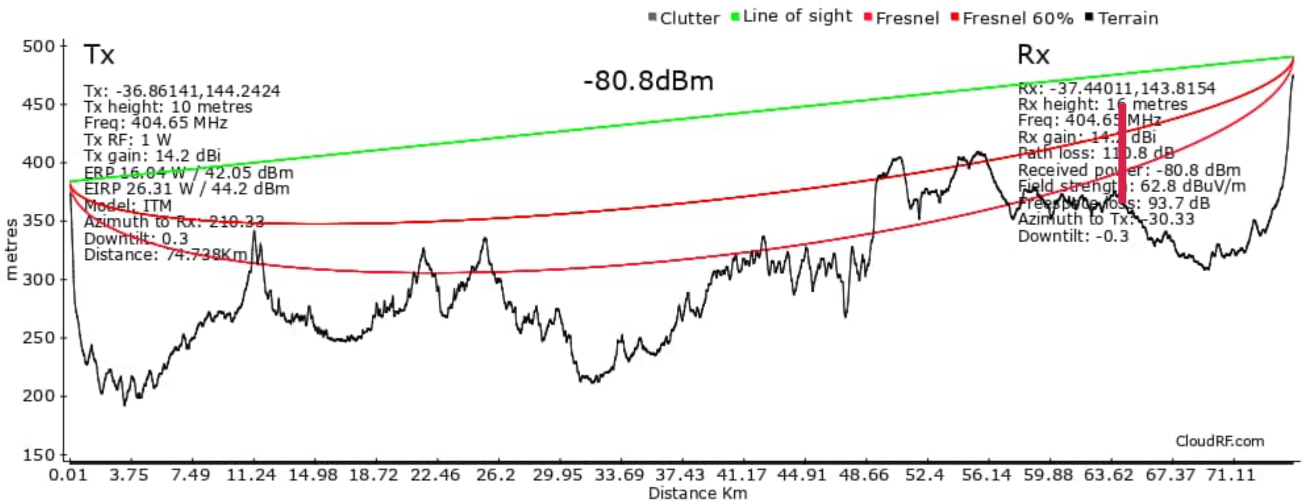

Figure F.12: Path Profile of Cloud RF System ID (328249), Ravenswood (833026) to Mt Hollowback (833027) (Source: Jacobs, 2022)

Figure F.13: Path Profile of Cloud RF System ID (517294), Toolern Vale (922597) to Melton (922598) (Source: Jacobs, 2022)

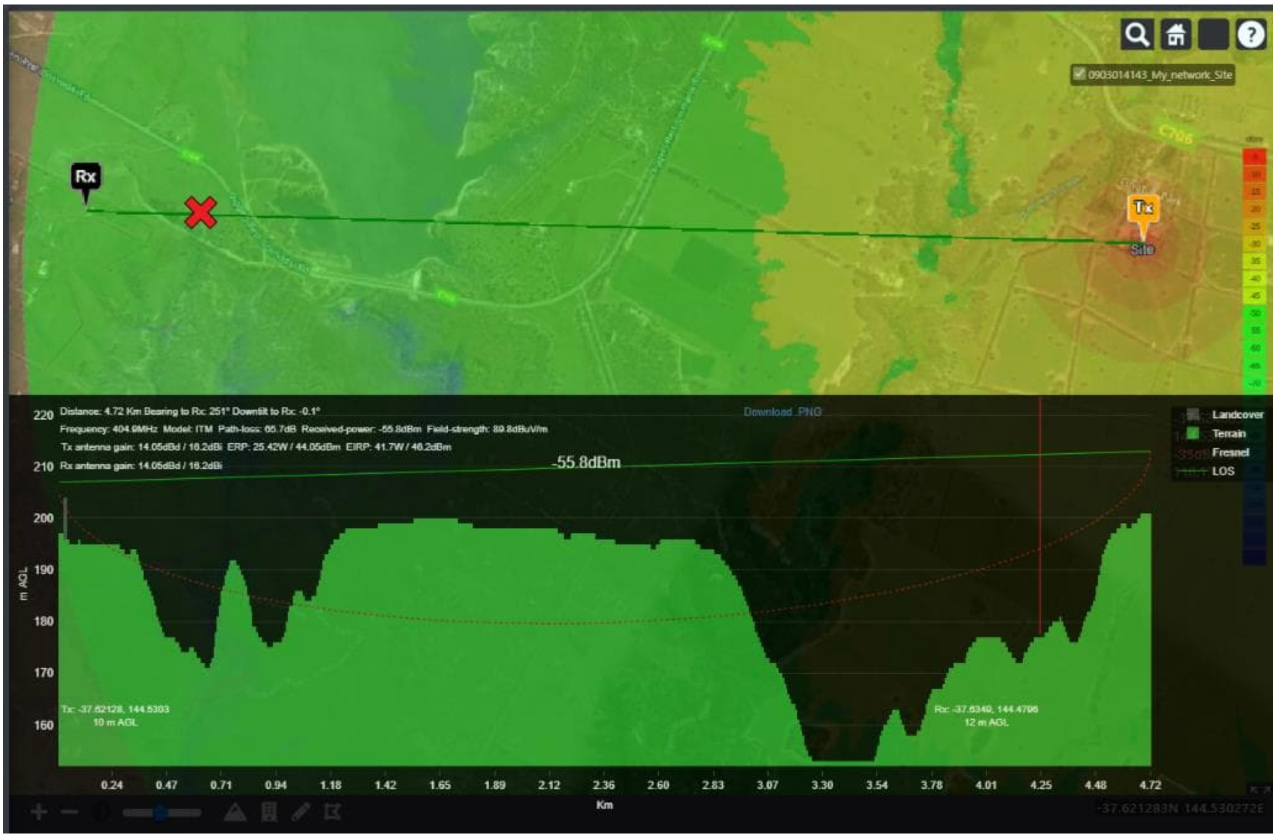

Figure F.14: Path Profile of Cloud RF System ID (517925), Toolern Vale (922605) to Merrimu (922606) (Source: Jacobs, 2022)

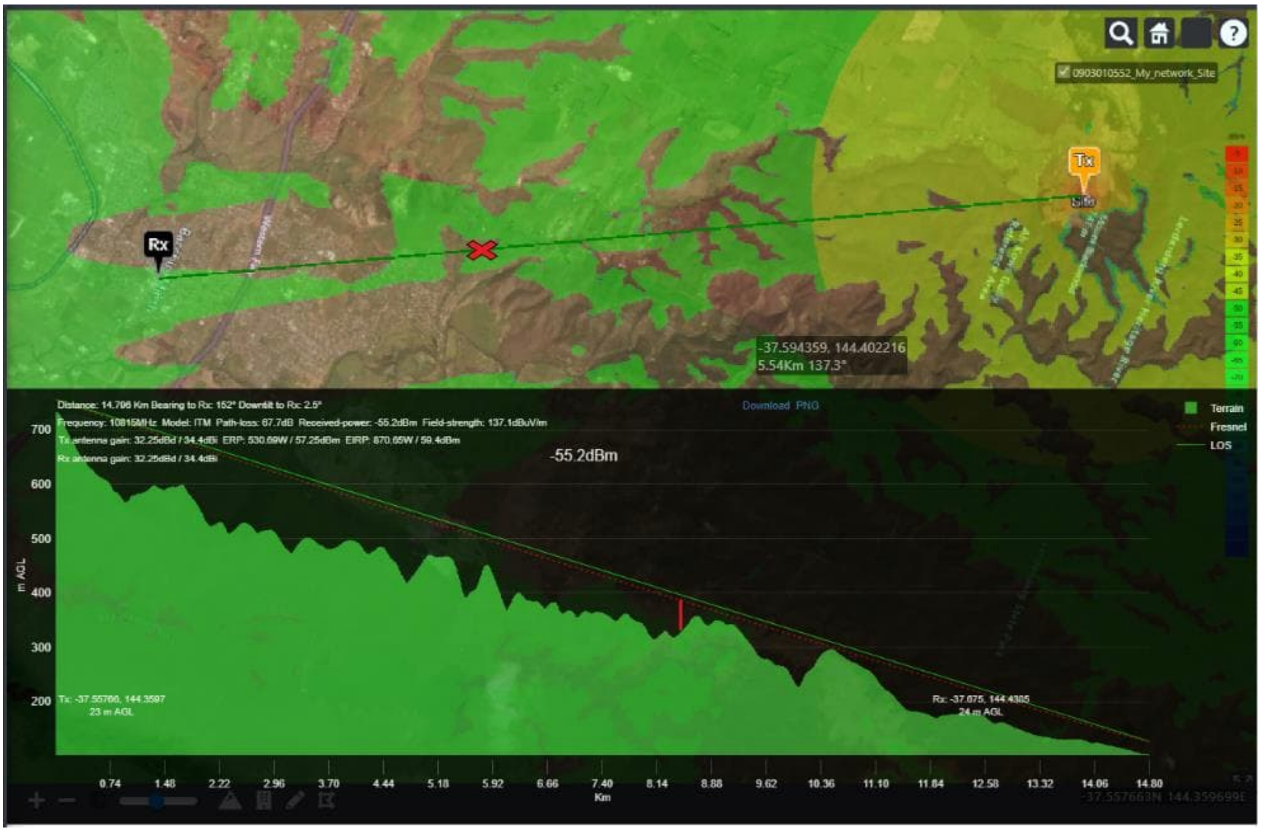

Figure F.15: Path Profile of Cloud RF System ID (545046), Mt Blackwood (926830) to Bacchus Marsh (926831) (Source: Jacobs, 2022)

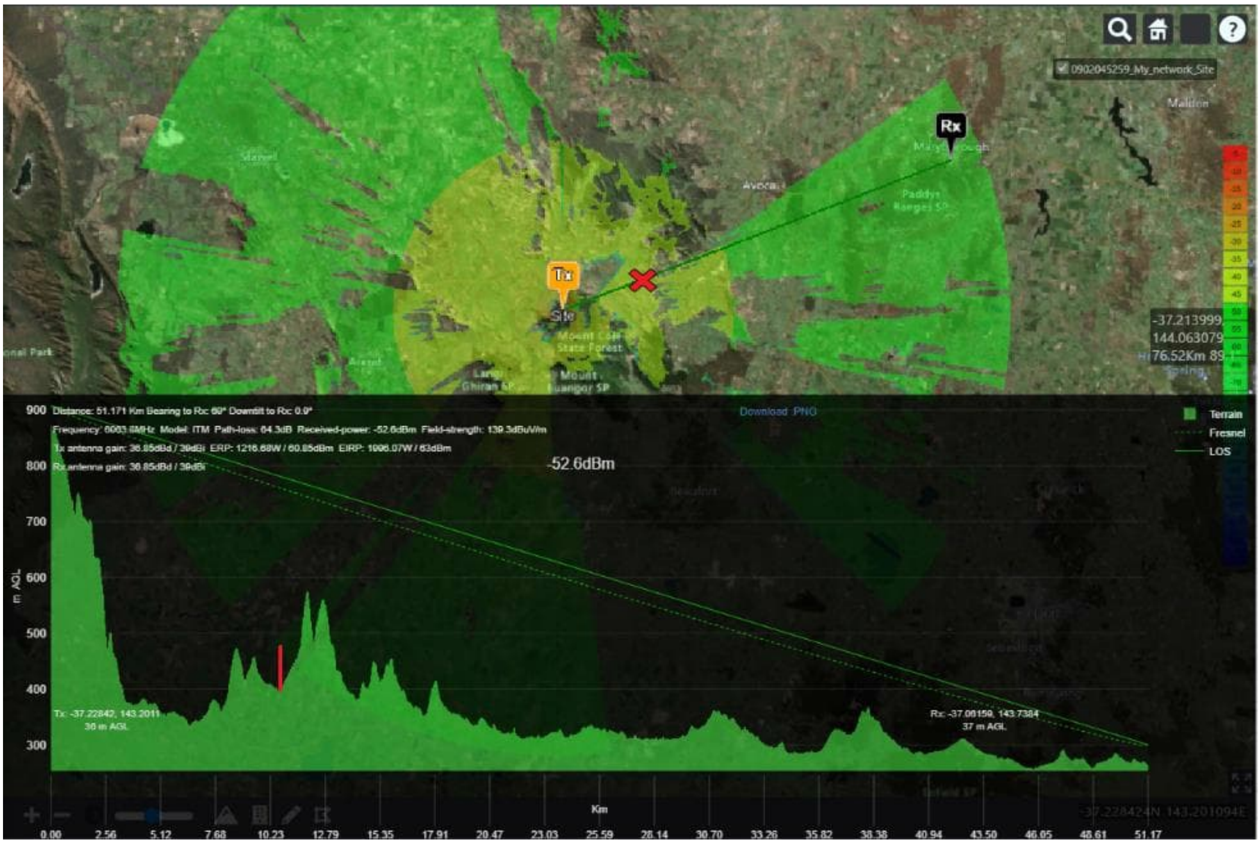

Figure F.16: Path Profile of Cloud RF System ID (601842), Ben Nevis (926858) to Maryborough (926859) (Source: Jacobs, 2022)

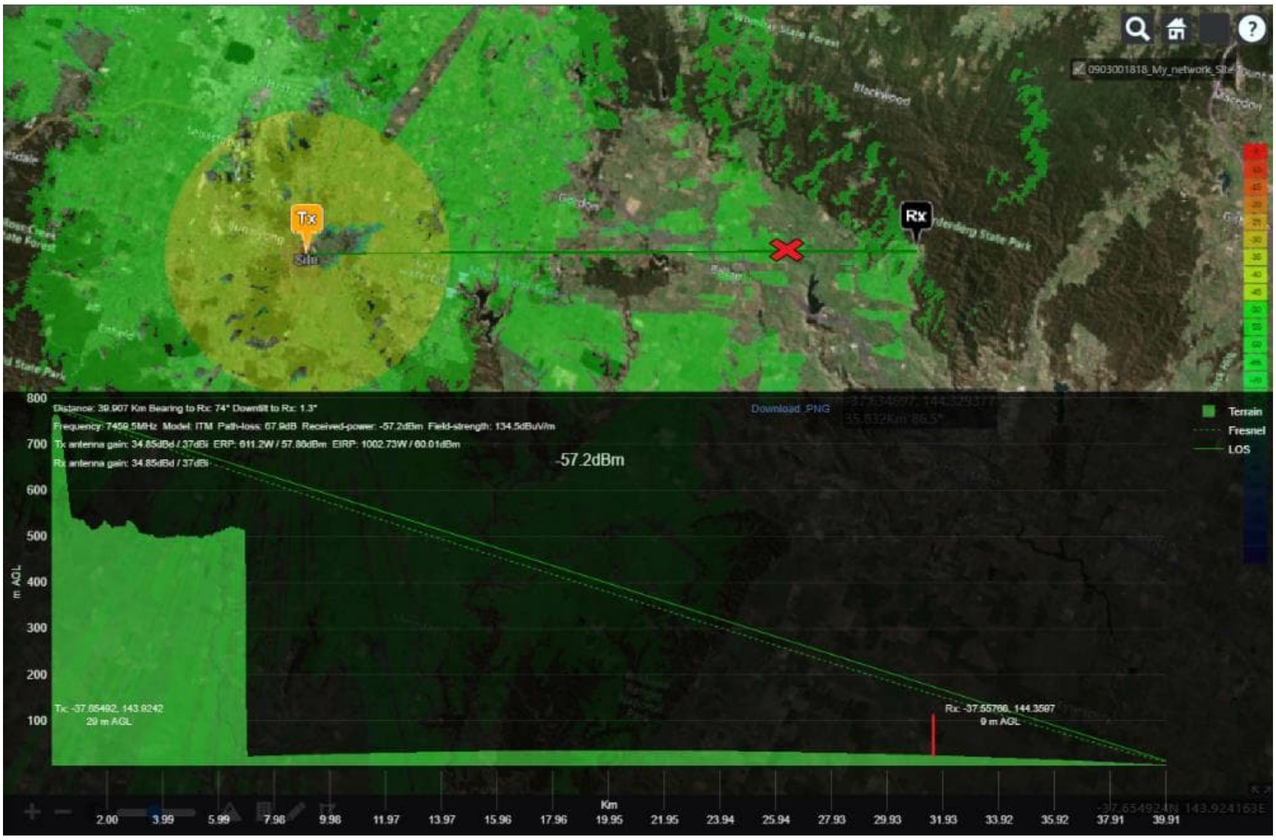

Figure F.17: Path Profile of Cloud RF System ID (545263), Mt Buninyong (927236) to Mt Blackwood (927237) (Source: Jacobs, 2022)

Figure F.18: Path Profile of Cloud RF System ID (556514), Mt Blackwood (928985) to Rockbank (928986) (Source: Jacobs, 2022)

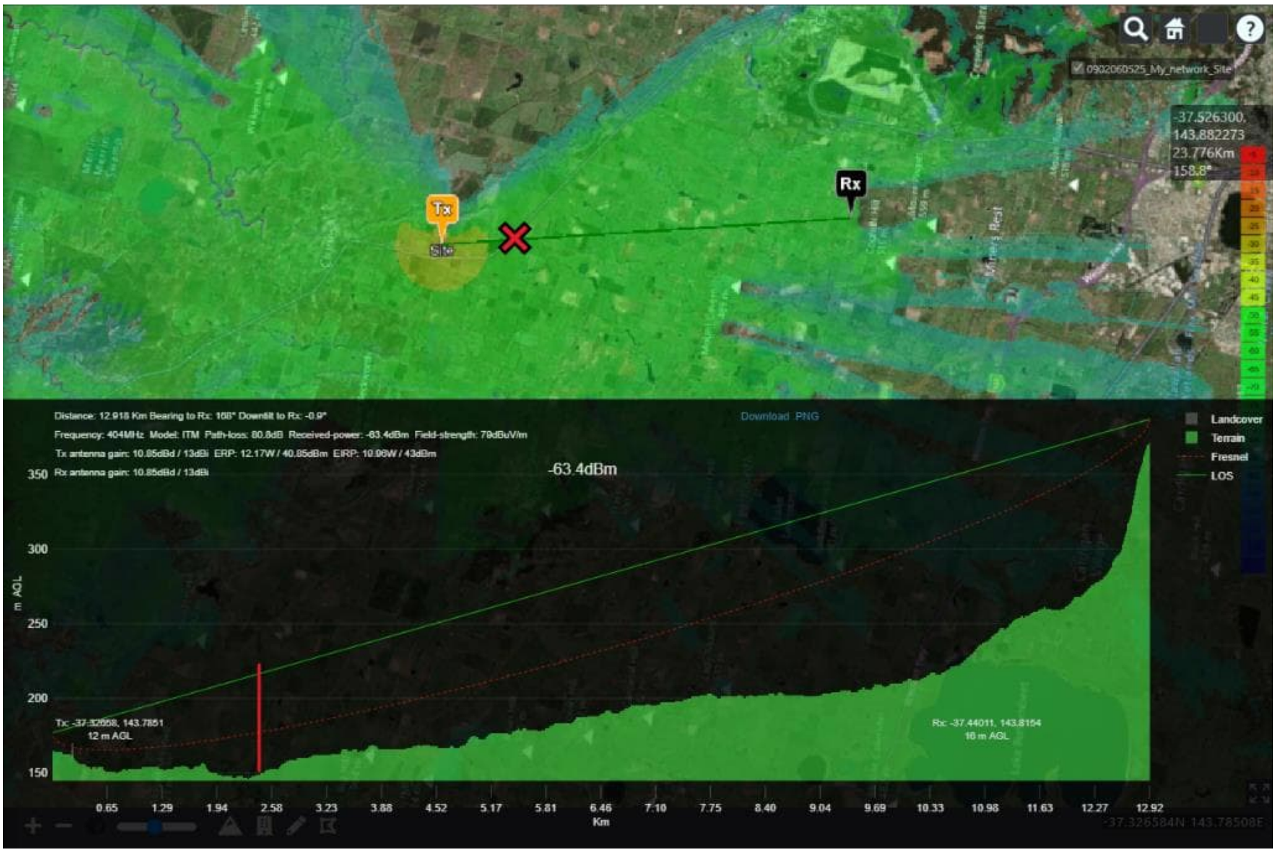

Figure F.19: Path Profile of Cloud RF System ID (560345), Clunes (930123) to Mt Hollowback (930124) (Source: Jacobs, 2022)

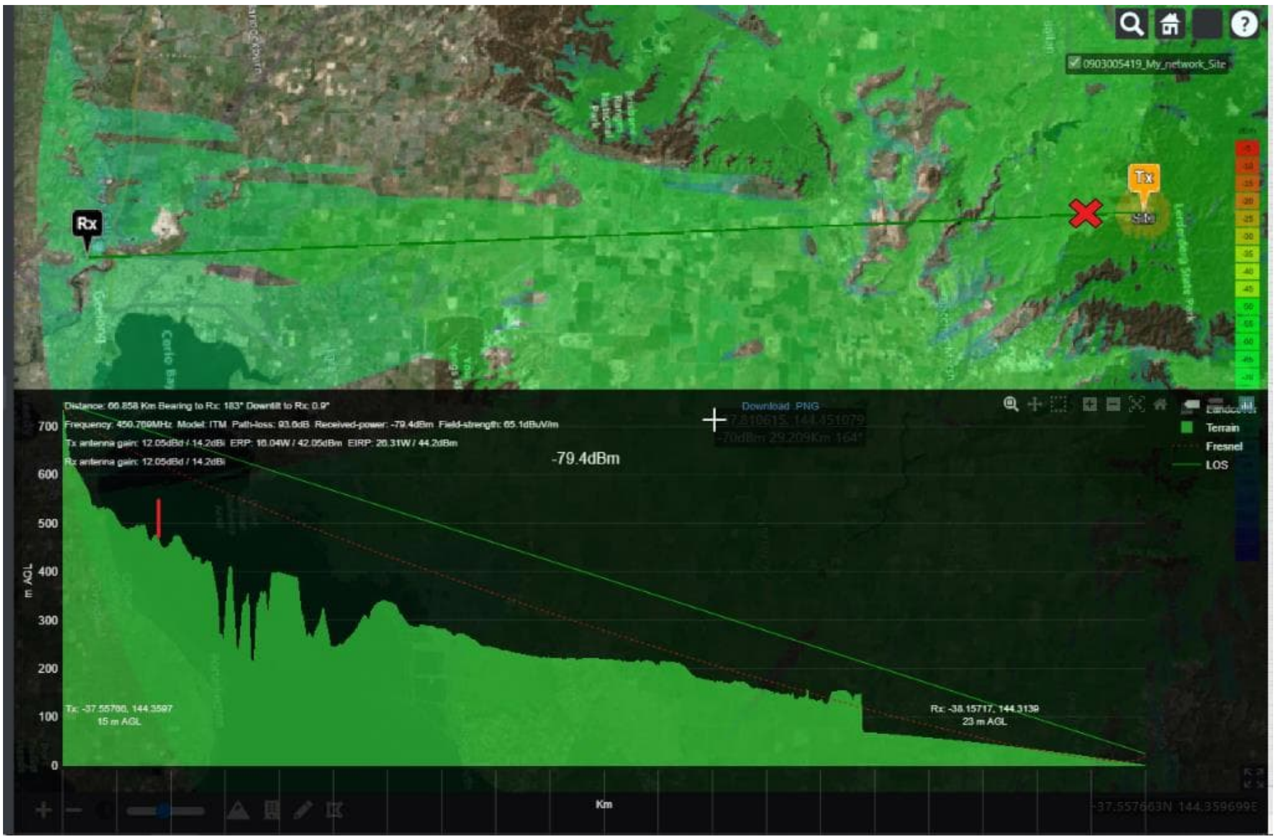

Figure F.20: Path Profile of Cloud RF System ID (603764), Mt Blackwood (942446) to Highton (942447) (Source: Jacobs, 2022)

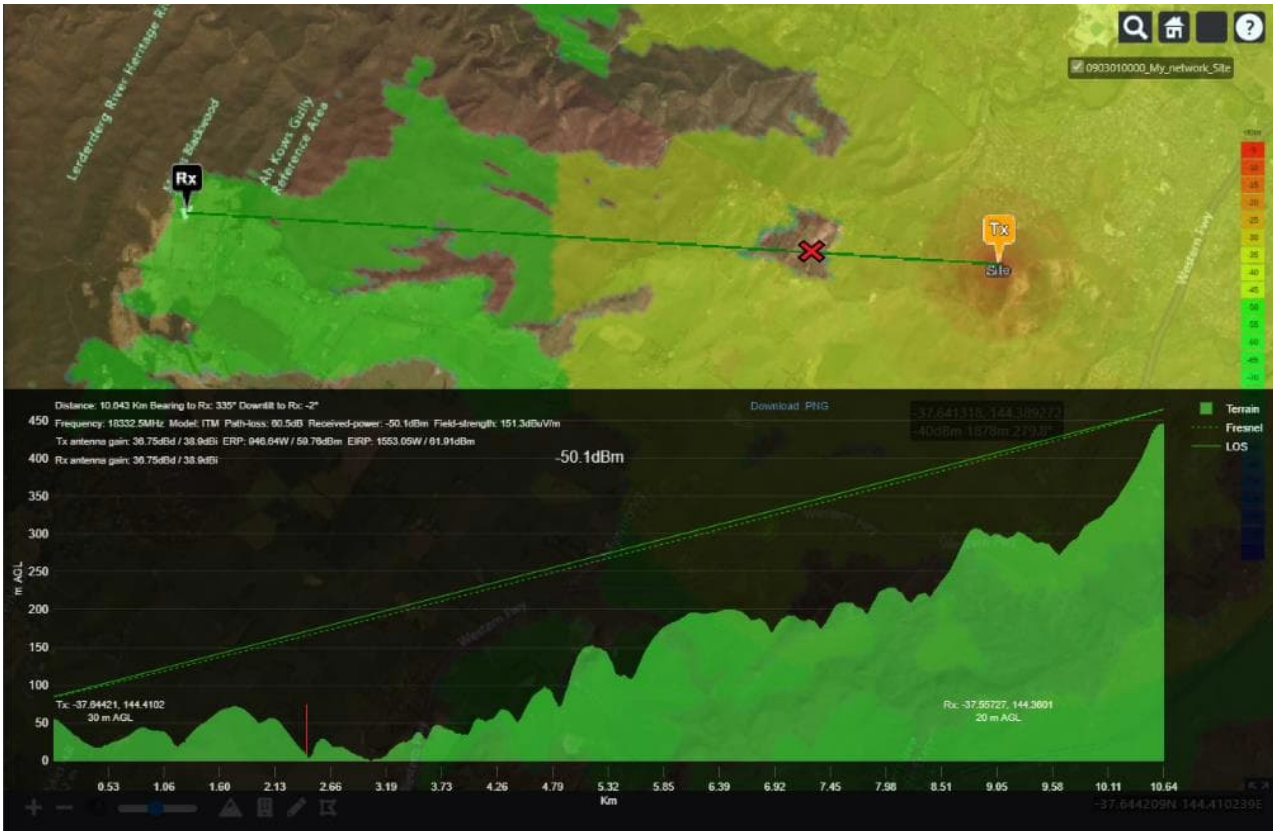

Figure F.21: Path Profile of Cloud RF System ID (634675), Darley (958596) to Mt Blackwood (958597) (Source: Jacobs, 2022)

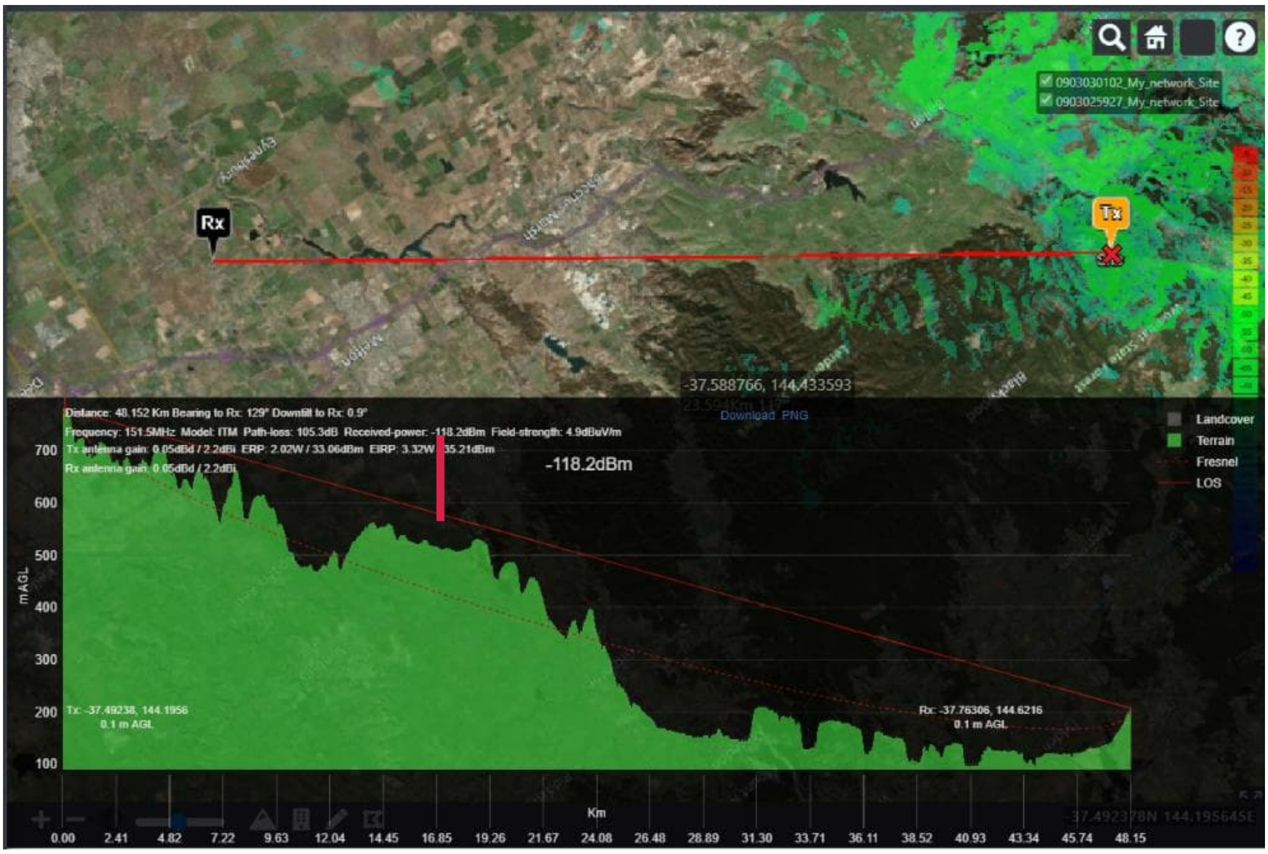

Figure F.22: Path Profile of Cloud RF System ID (79978), Mt Hope (1305380) to Mt Cottrell (1305381) (Source: Jacobs, 2022)

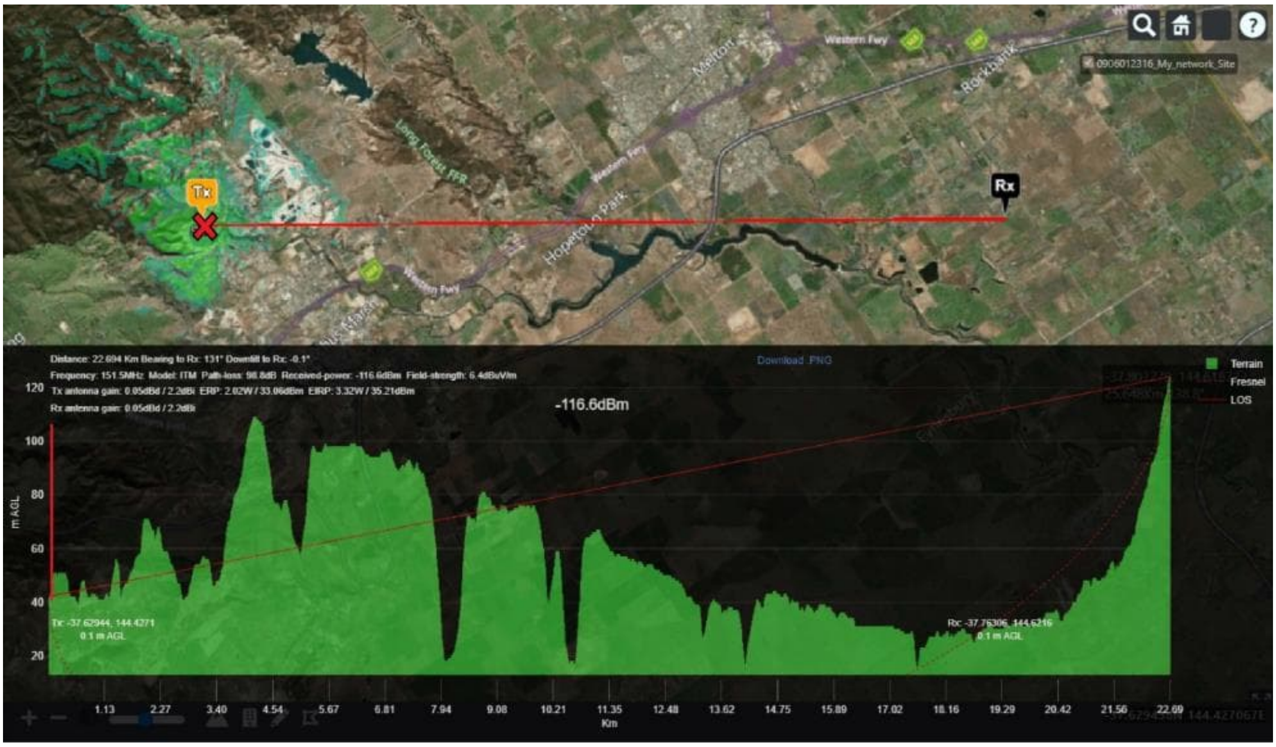

Figure F.23: Path Profile of Cloud RF System ID (79980), Lerderderg (1305384) to Mt Cottrell (1305385) (Source: Jacobs, 2022)

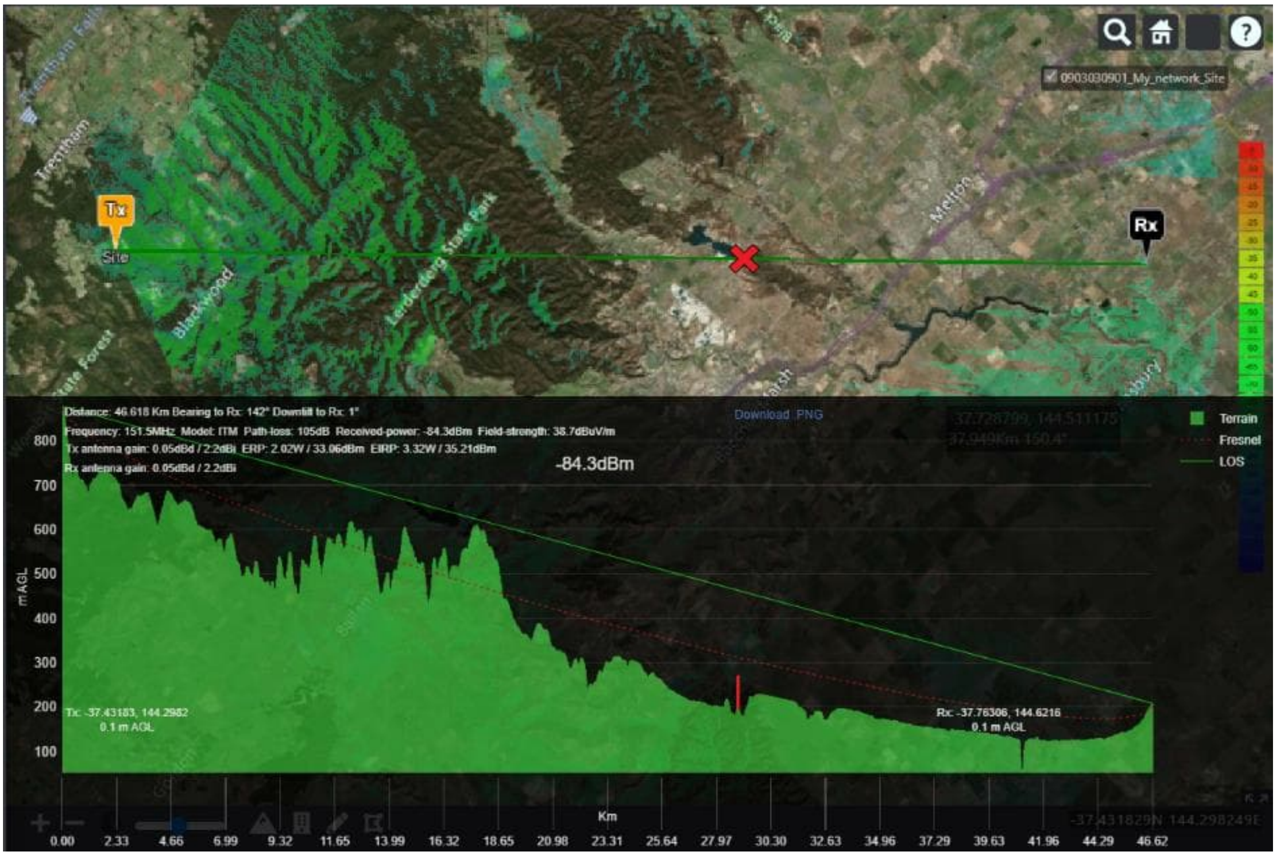

Figure F.24: Path Profile of Cloud RF System ID (79981), Blue Mountain (1305386) to Mt Cottrell (1305387) (Source: Jacobs, 2022)

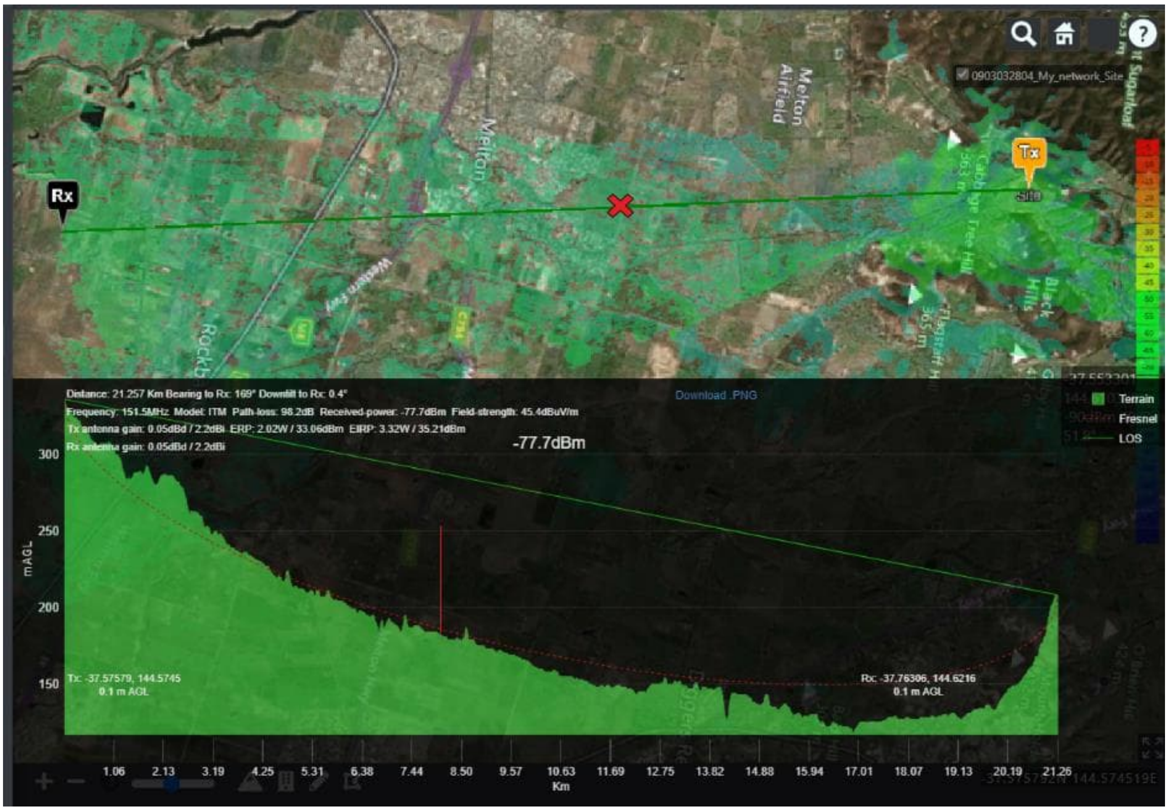

Figure F.25: Path Profile of Cloud RF System ID (79982), Toolern Vale (1305388) to Mt Cottrell (1305389) (Source: Jacobs, 2022)

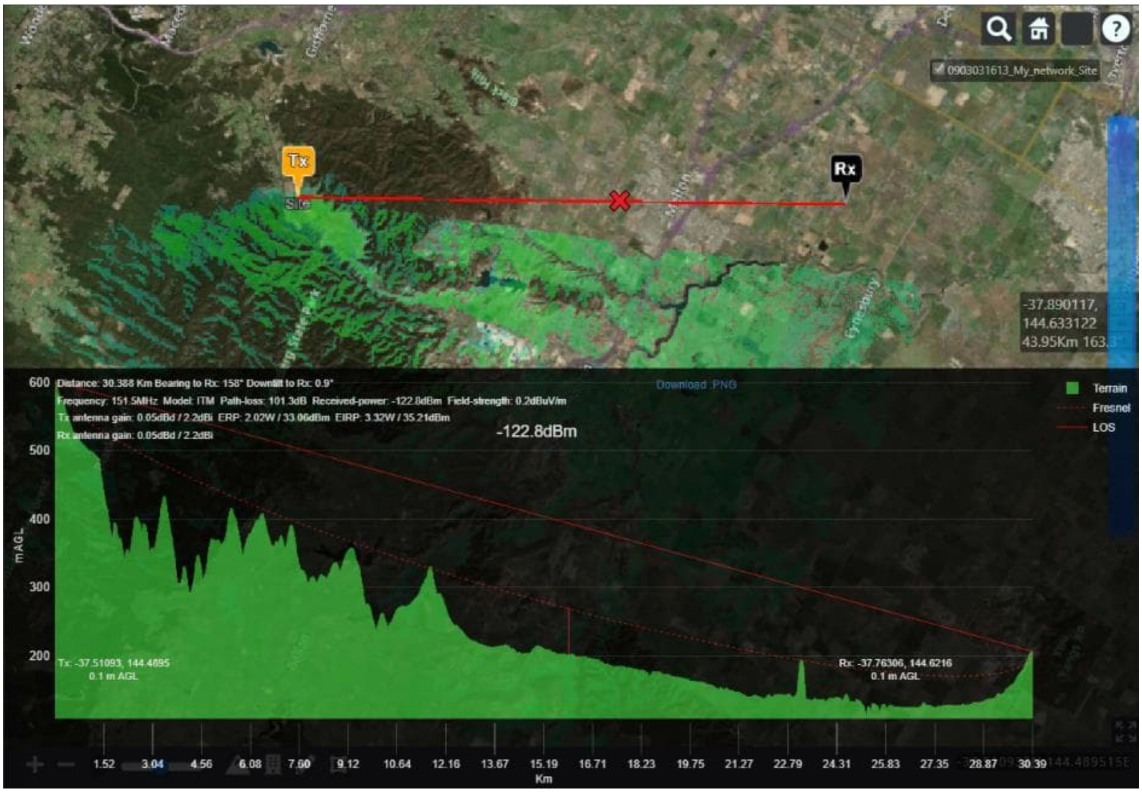

Figure F.26: Path Profile of Cloud RF System ID (95777), Bullengarook (1305390) to Mt Cottrell (1305391) (Source: Jacobs, 2022)

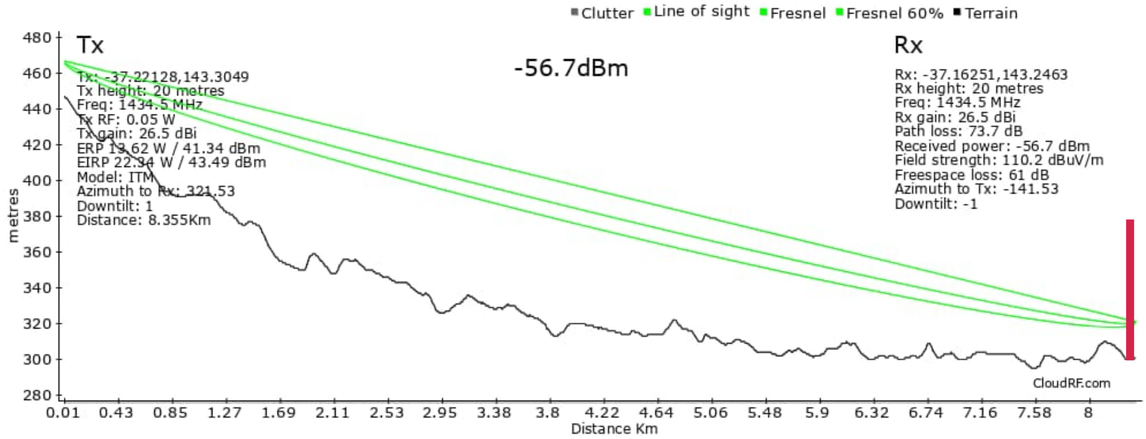

Figure F.27: Path Profile of Cloud RF System ID (1038350), Glenlogie (1375723) to Elmhurst (1375724) (Source: Jacobs, 2022)

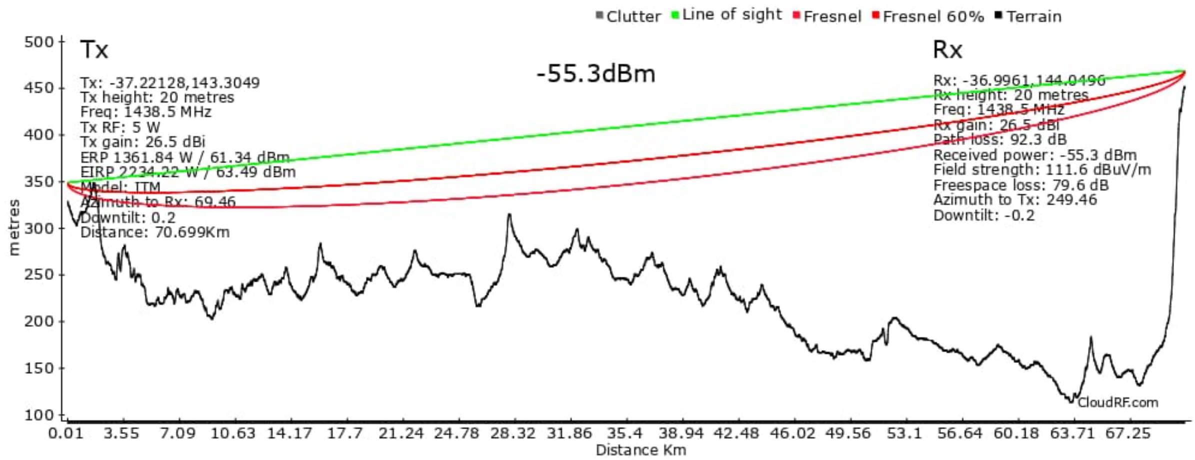

Figure F.28: Path Profile of Cloud RF System ID (1038349), Glenlogie (1375727) to Mt Tarrengower (1375728) (Source: Jacobs, 2022)

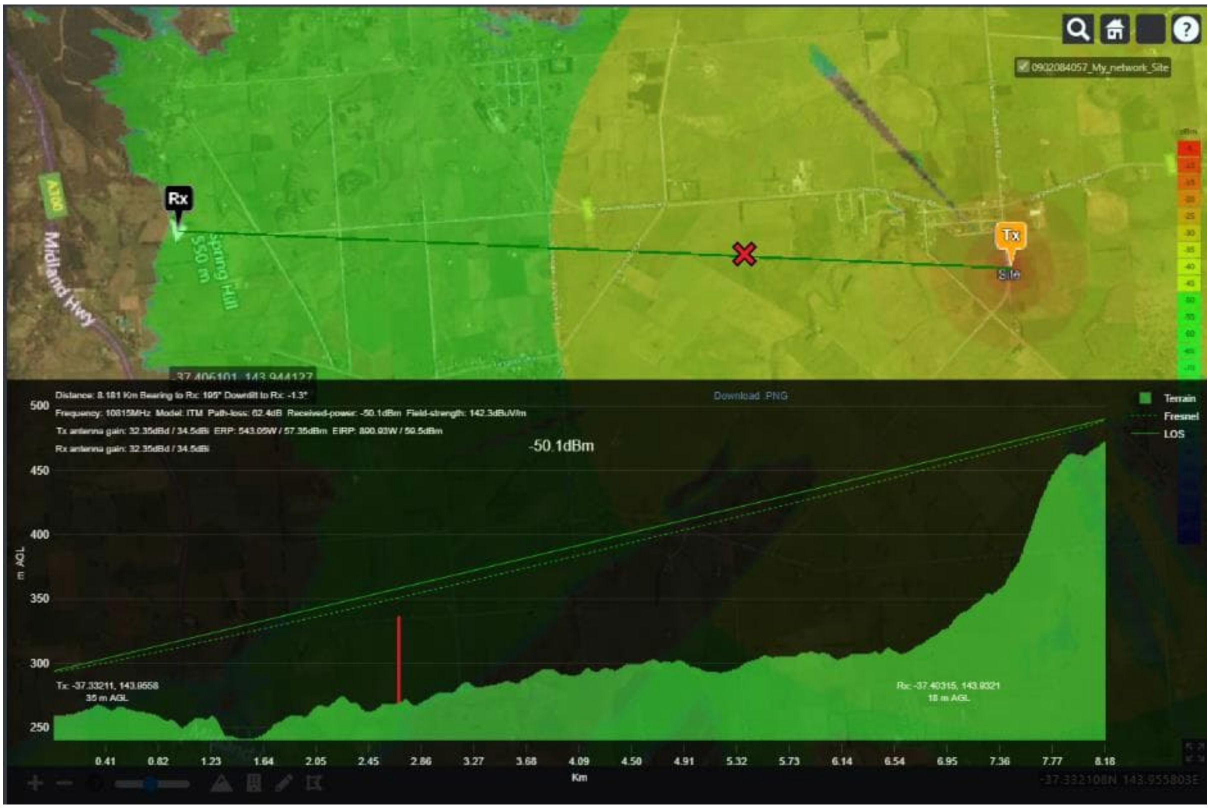

Figure F.29: Path Profile of Cloud RF System ID (1524462), Smeaton (2466939) to Creswick (2466940) (Source: Jacobs, 2022)

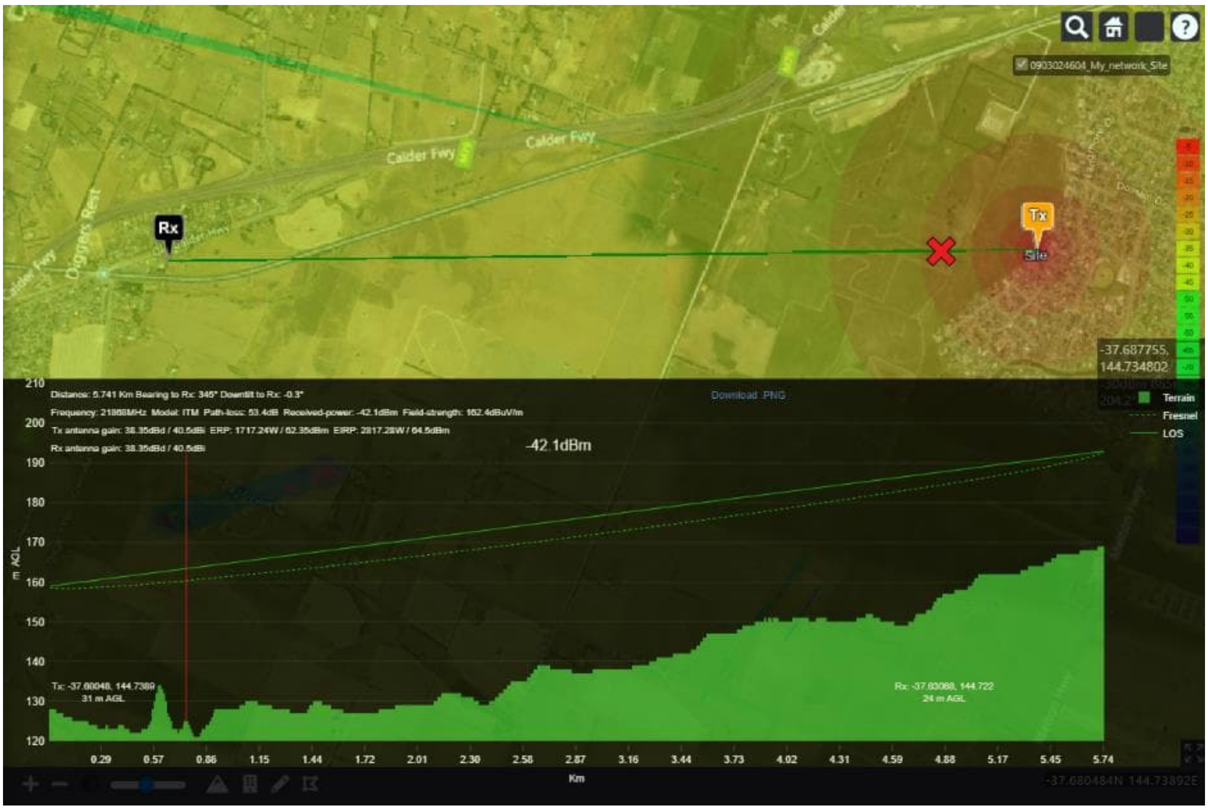

Figure F.30: Path Profile of Cloud RF System ID (1550425), Hillside (2506429) to Diggers Rest (2506430) (Source: Jacobs, 2022)

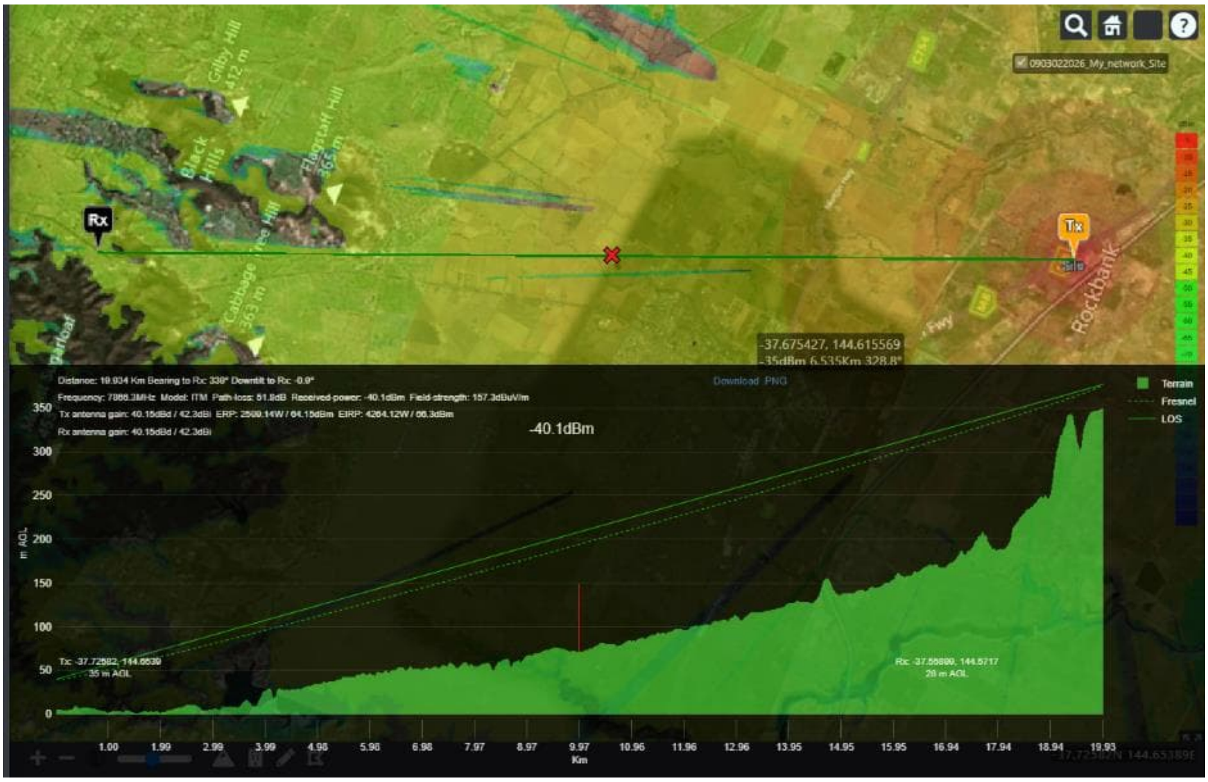

Figure F.31: Path Profile of Cloud RF System ID (1604076), Rockbank (2627302) to Toolern Vale (2627303) (Source: Jacobs, 2022)

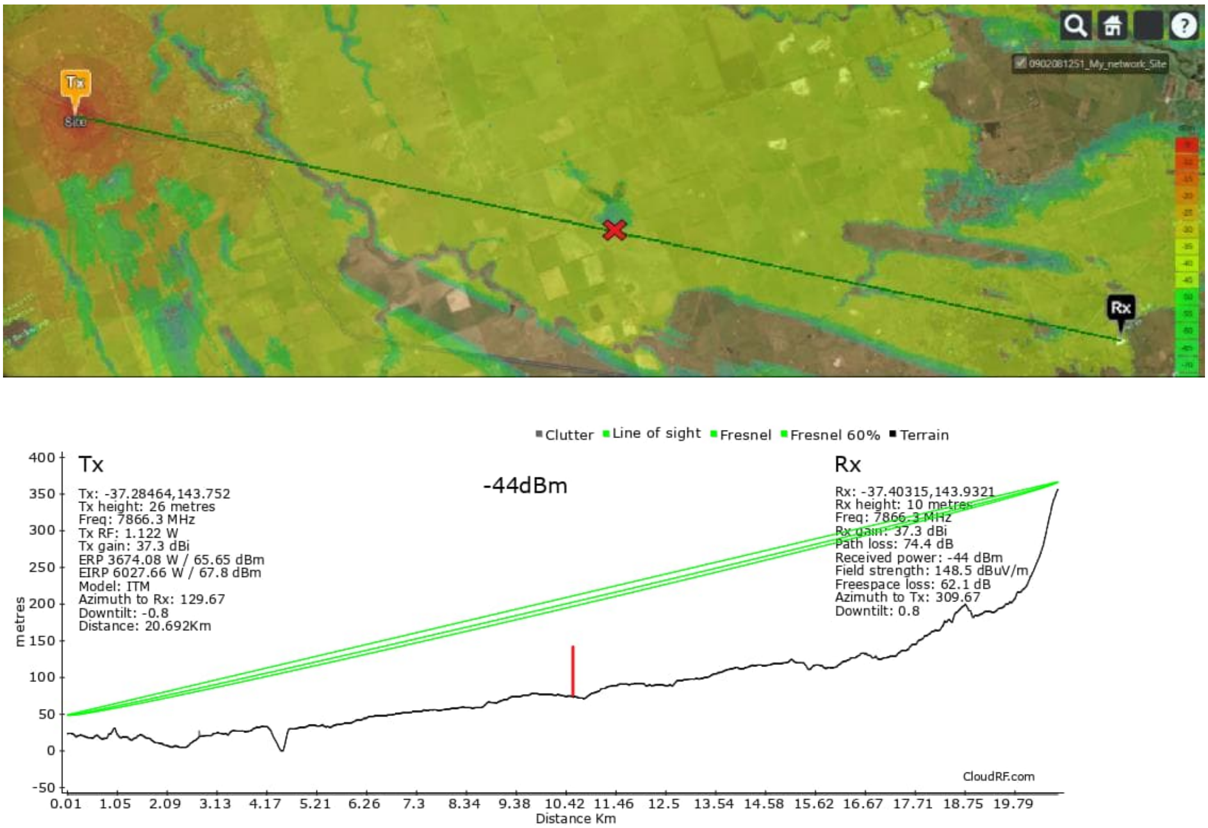

Figure F.32: Path Profile of Cloud RF System ID (1676299), Clunes (2765830) to Creswick (2765831) (Source: Jacobs, 2022)

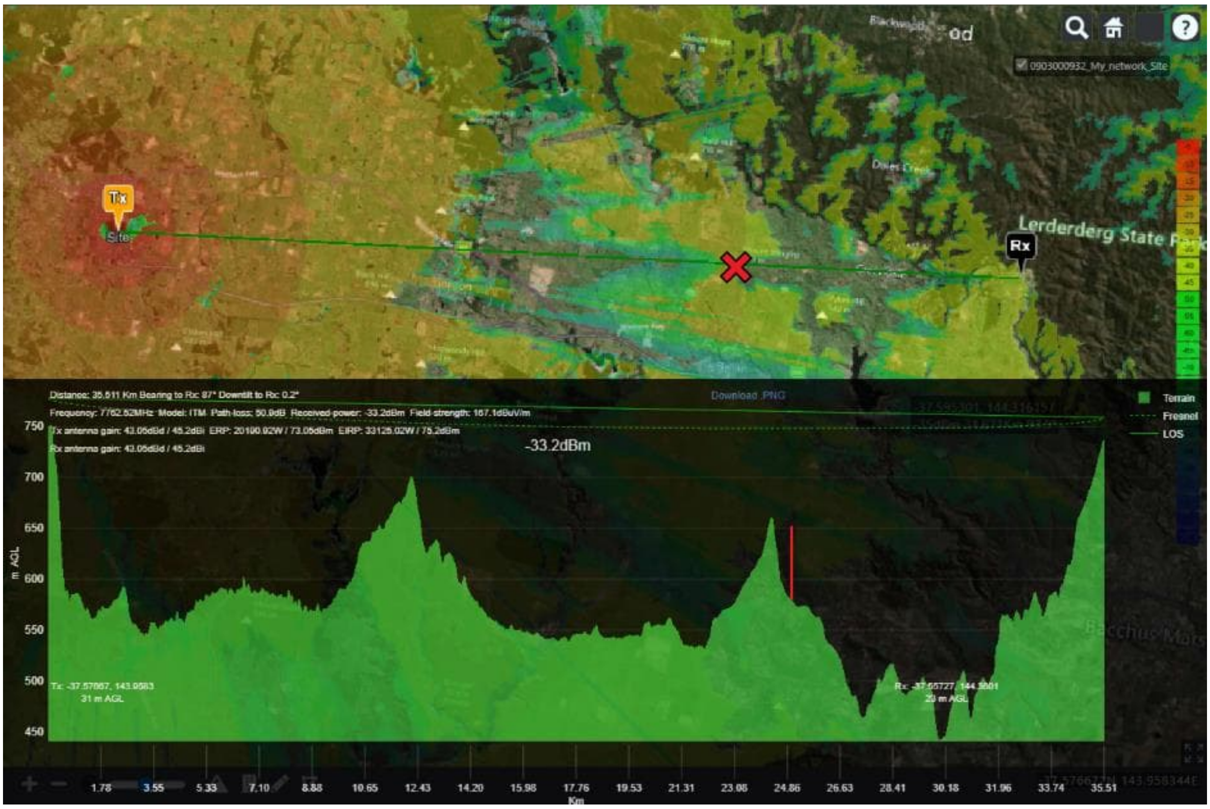

Figure F.33: Path Profile of Cloud RF System ID (1807616), Mt Warrenheip (3062521) to Mt Blackwood (3062522) (Source: Jacobs, 2022)

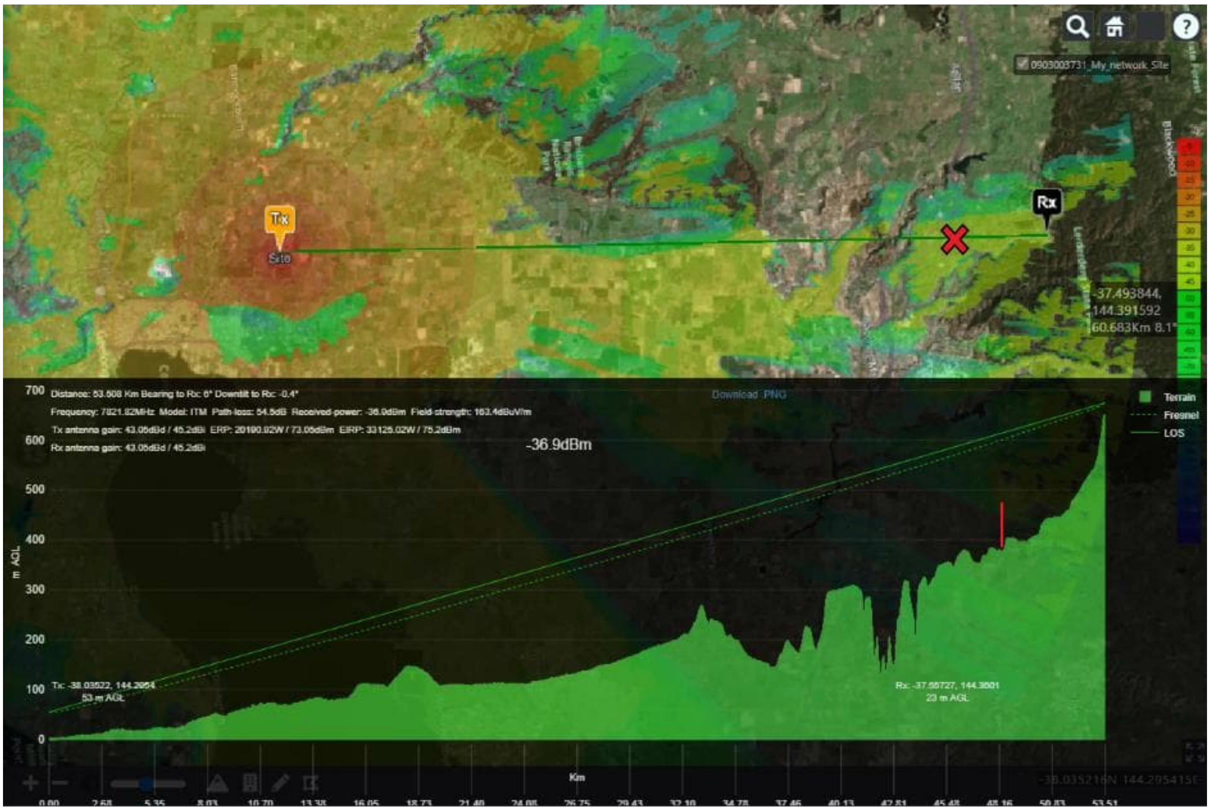

Figure F.34: Path Profile of Cloud RF System ID (1807617), Mt Blackwood (3062525) to Lovely Banks (3062526) (Source: Jacobs, 2022)

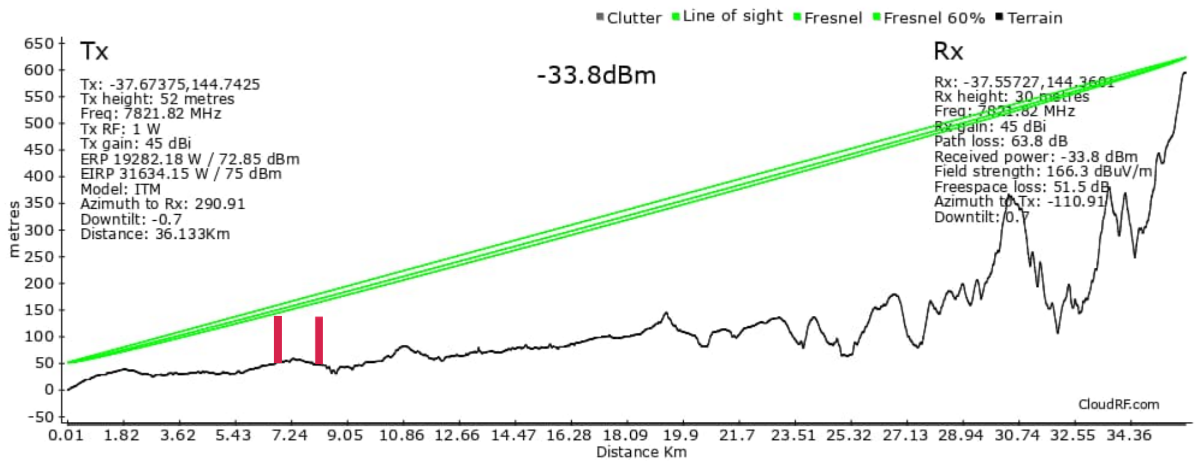

Figure F.35: Path Profile of Cloud RF System ID (1807624), Sydenham (3062829) to Bacchus Marsh (3062830) (Source: Jacobs, 2022)

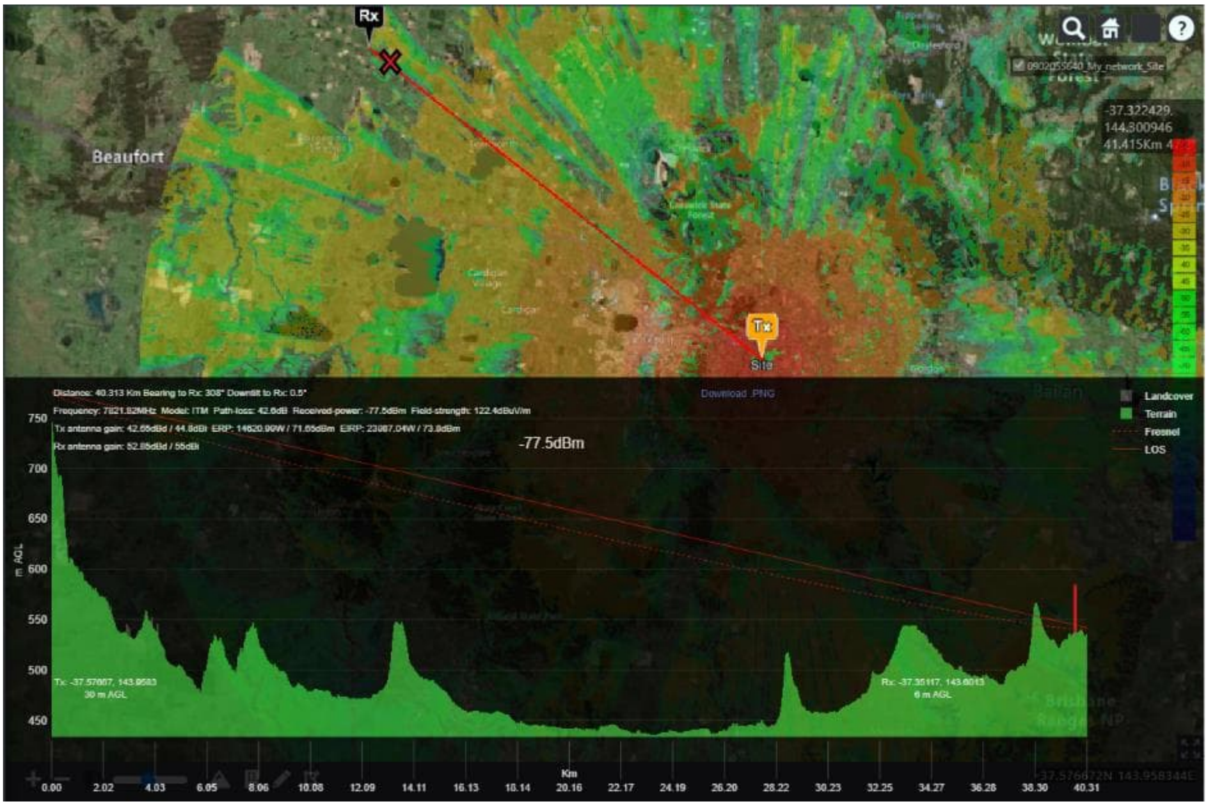

Figure F.36: Path Profile of Cloud RF System ID (1808582), Mt Warrenheip (3064985) to Waubra (3064986) (Source: Jacobs, 2022)

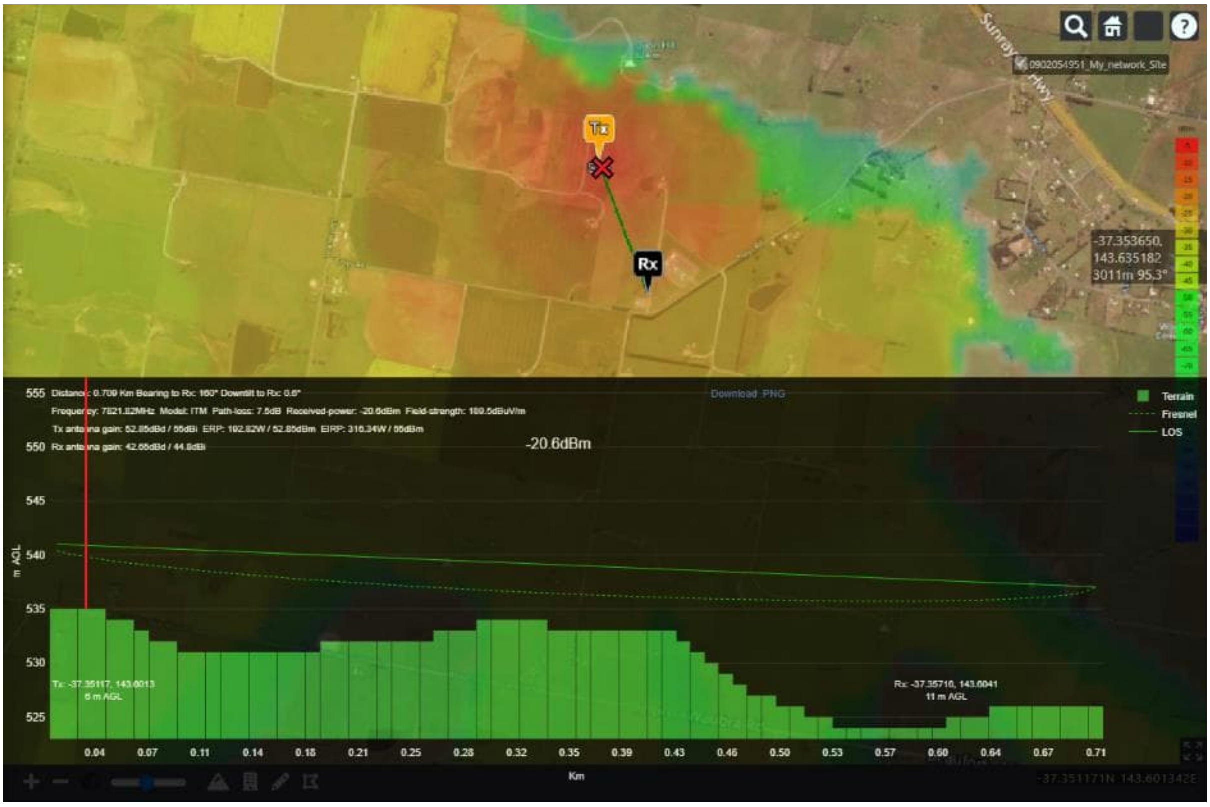

Figure F.37: Path Profile of Cloud RF System ID (1814296), Waubra (3076651) to Waubra (3076652) (Source: Jacobs, 2022)

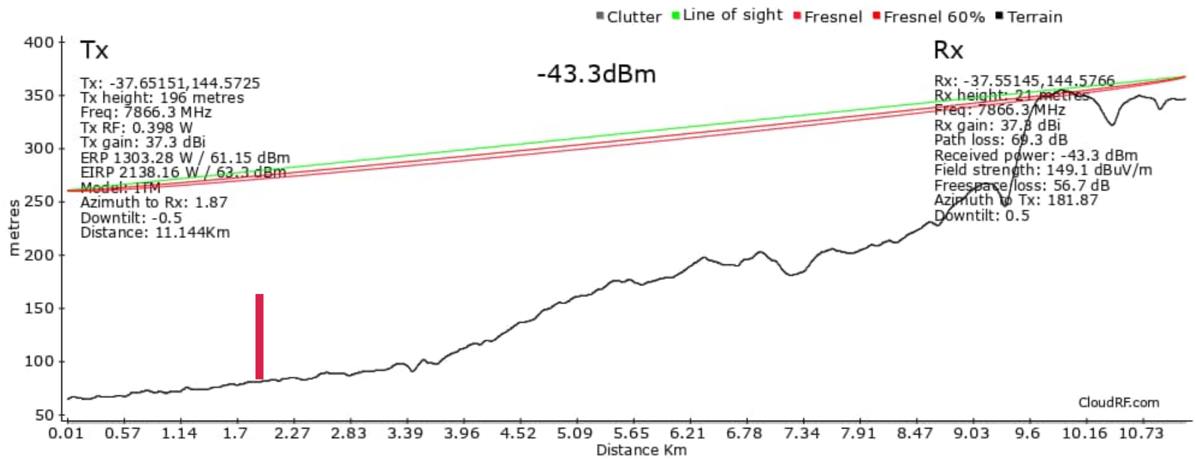

Figure F.38: Path Profile of Cloud RF System ID (1960404), Toolern (3397332) to Toolern (3397333) (Source: Jacobs, 2022)

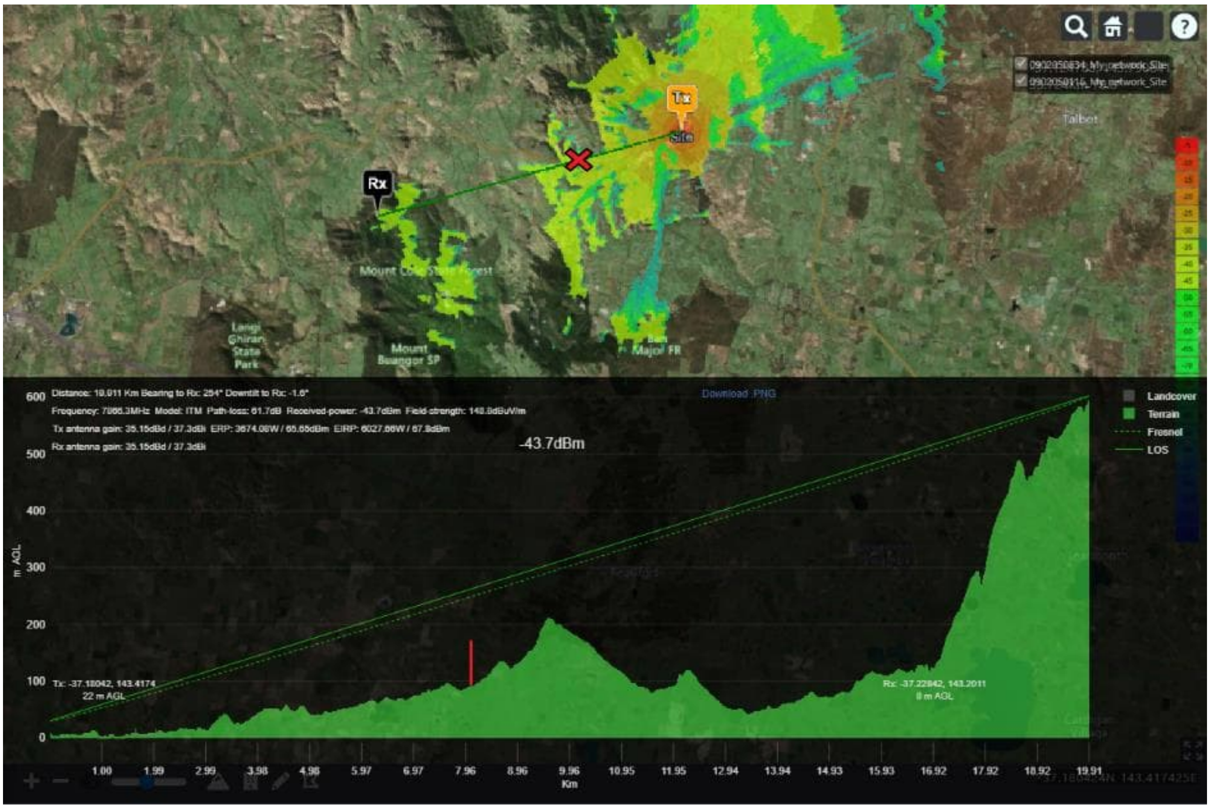

Figure F.39: Path Profile of Cloud RF System ID (2052129), Amphitheatre (3578203) to Ben Nevis (3578204) (Source: Jacobs, 2022)

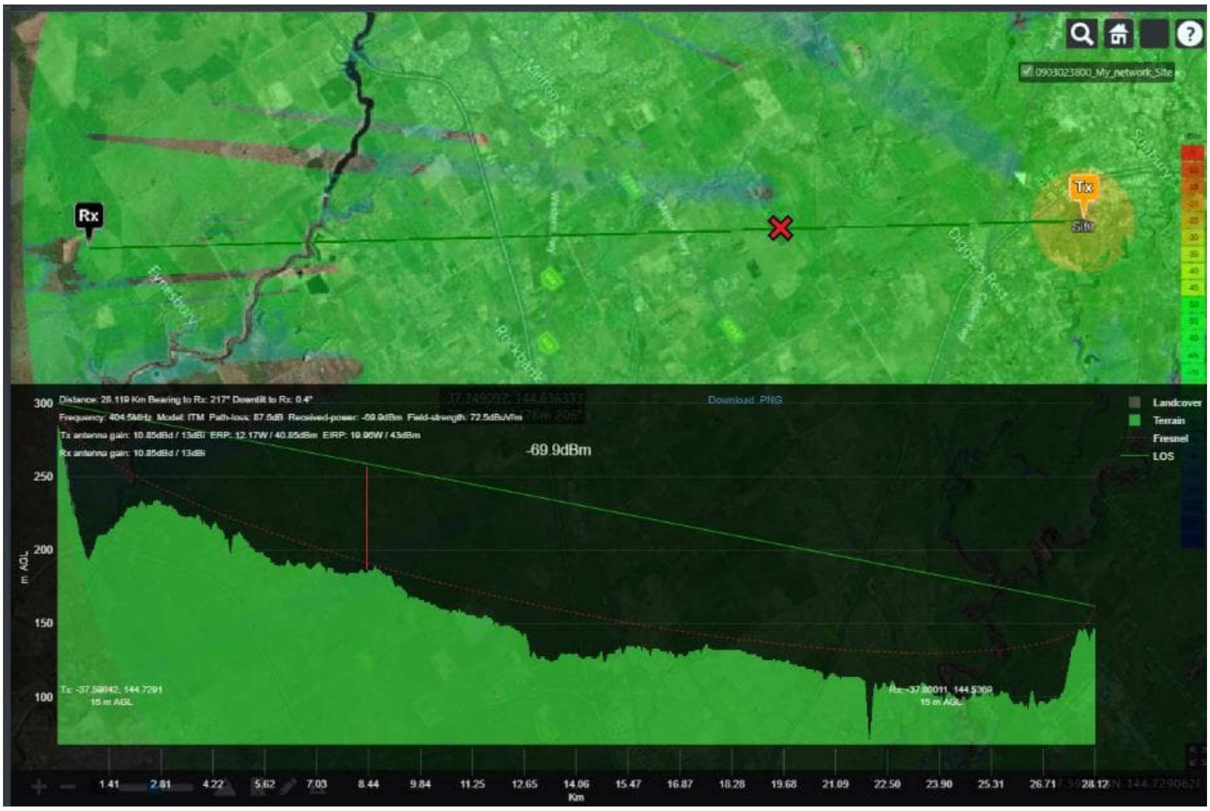

Figure F.40: Path Profile of Cloud RF System ID (2176136), Sunbury (3830307) to Eynesbury (3830308) (Source: Jacobs, 2022)

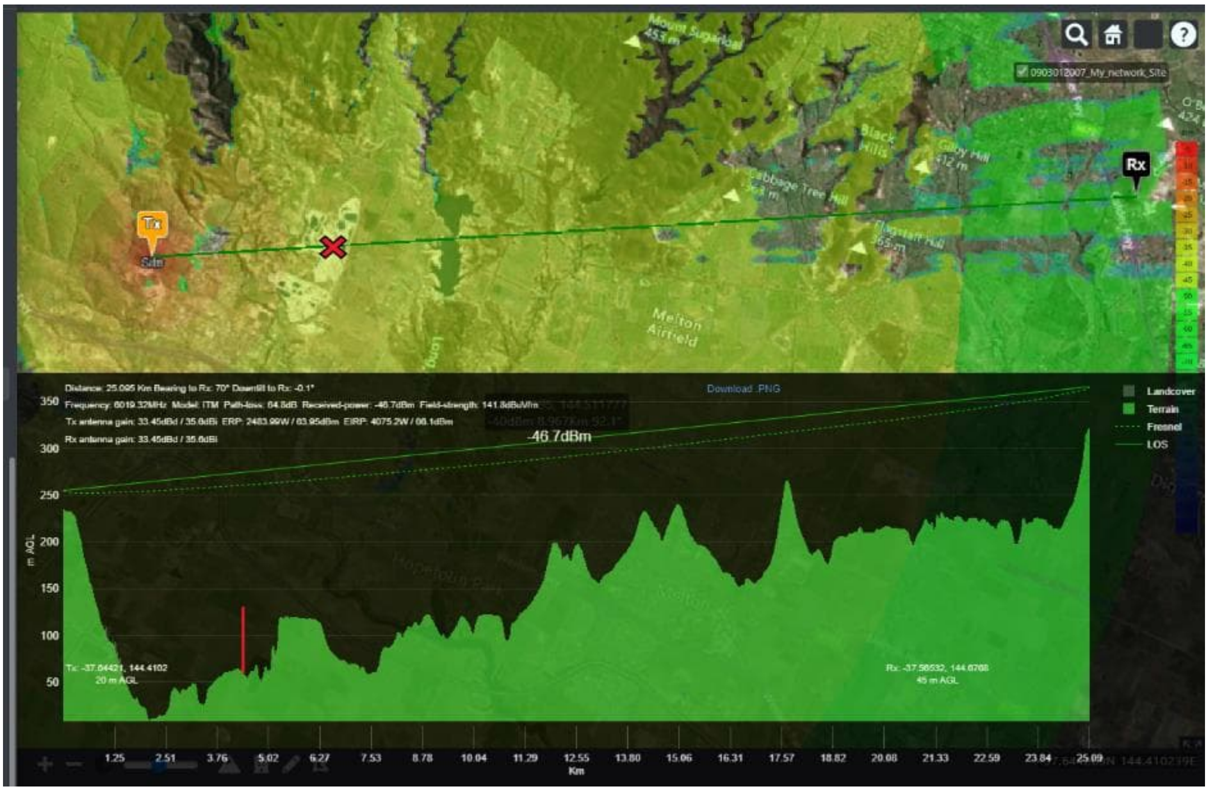

Figure F.41: Path Profile of Cloud RF System ID (2202170), Darley (3889459) to Sunbury (3889460) (Source: Jacobs, 2022)

Figure F.42: Path Profile of Cloud RF System ID (2375559), Toolern Vale (4265678) to Bacchus Marsh (4265679) (Source: Jacobs, 2022)

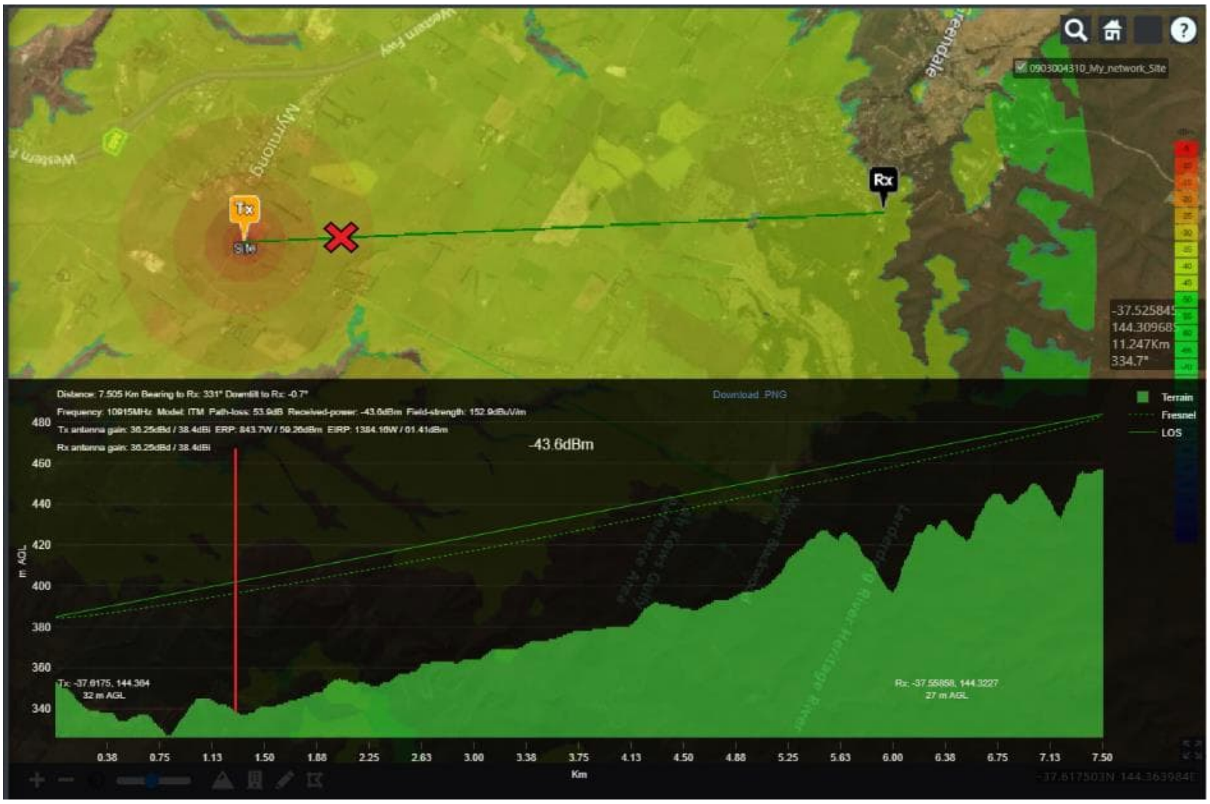

Figure F.43: Path Profile of Cloud RF System ID (3467872), Myrniong (6348226) to Greendale (6348227) (Source: Jacobs, 2022)

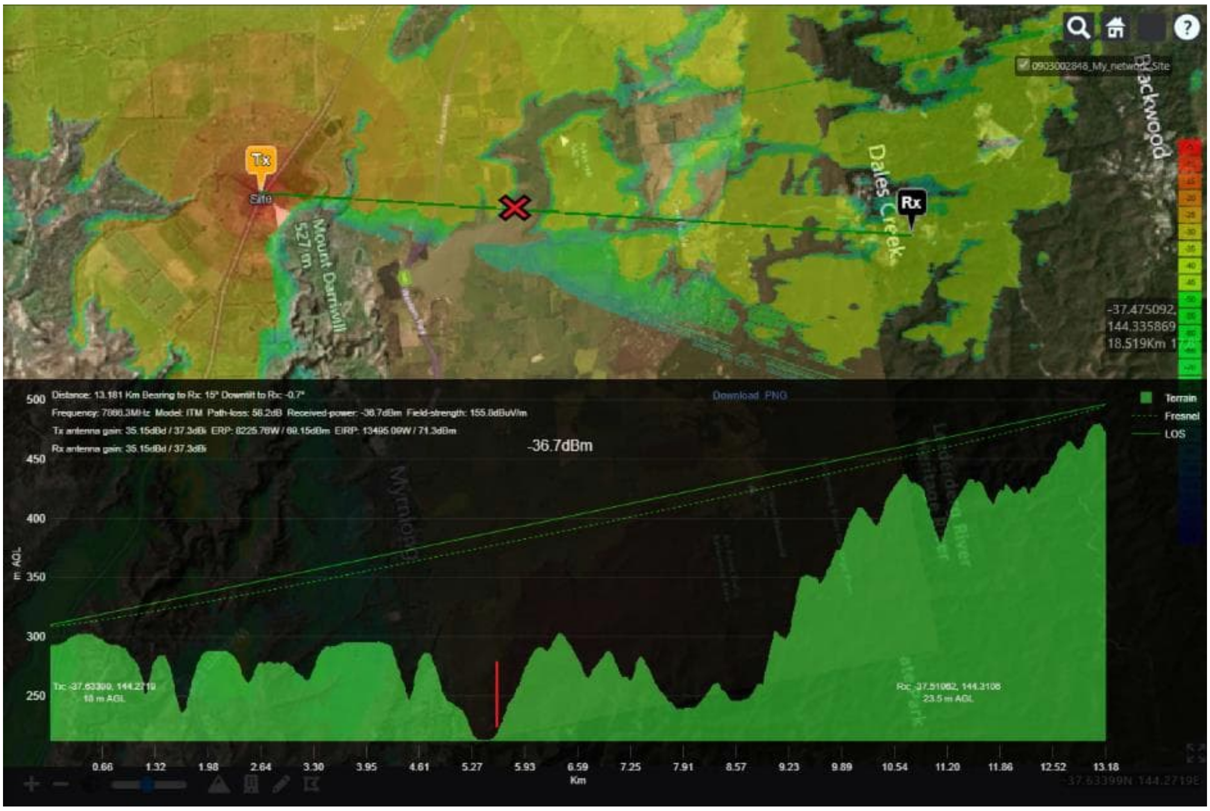

Figure F.44: Path Profile of Cloud RF System ID (4109570), Ballan (7645406) to Greendale (7645407) (Source: Jacobs, 2022)

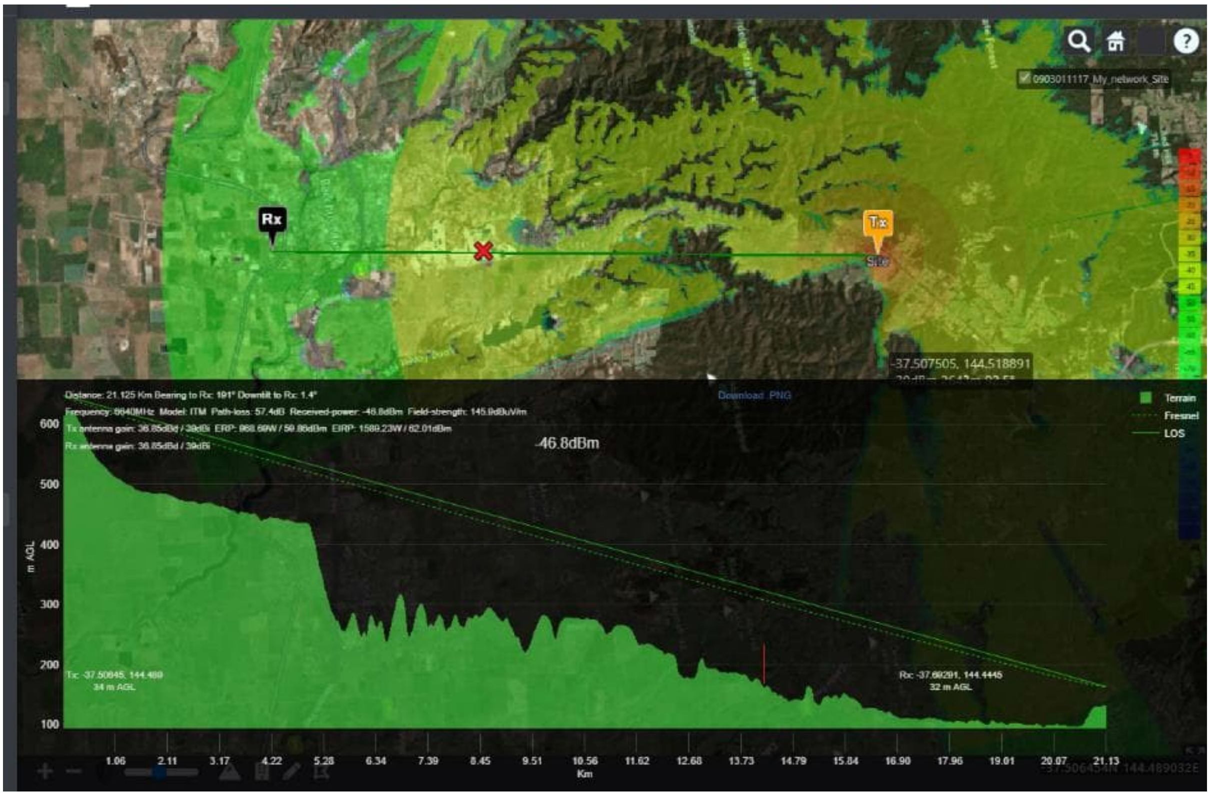

Figure F.45: Path Profile of Cloud RF System ID (4079247), Bullengarook (7790190) to Maddingley (7990191) (Source: Jacobs, 2022)

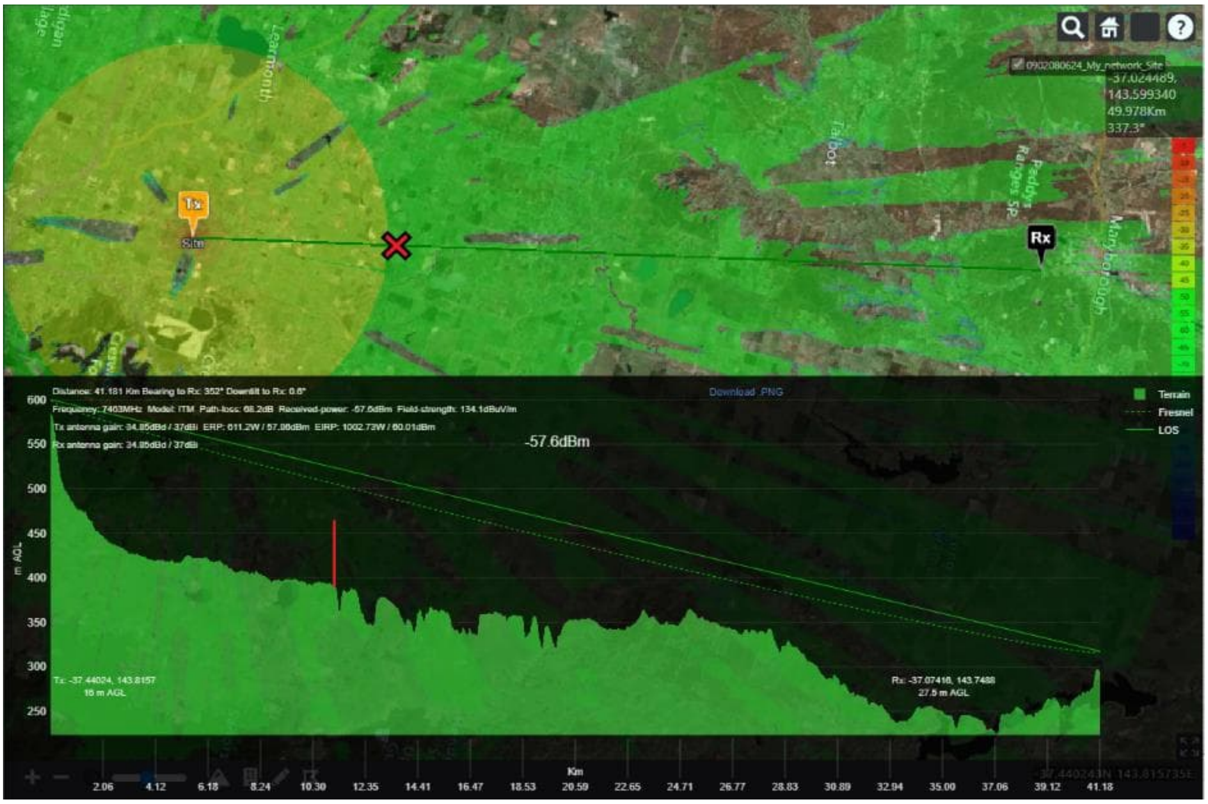

Figure F.46: Path Profile of Cloud RF System ID (4246389), Mt Hollowback (7916409) to Maryborough (7916410) (Source: Jacobs, 2022)

Figure F.47: Path Profile of Cloud RF System ID (4291838), Newlyn North (7989219) to Eganstown (7989220) (Source: Jacobs, 2022)

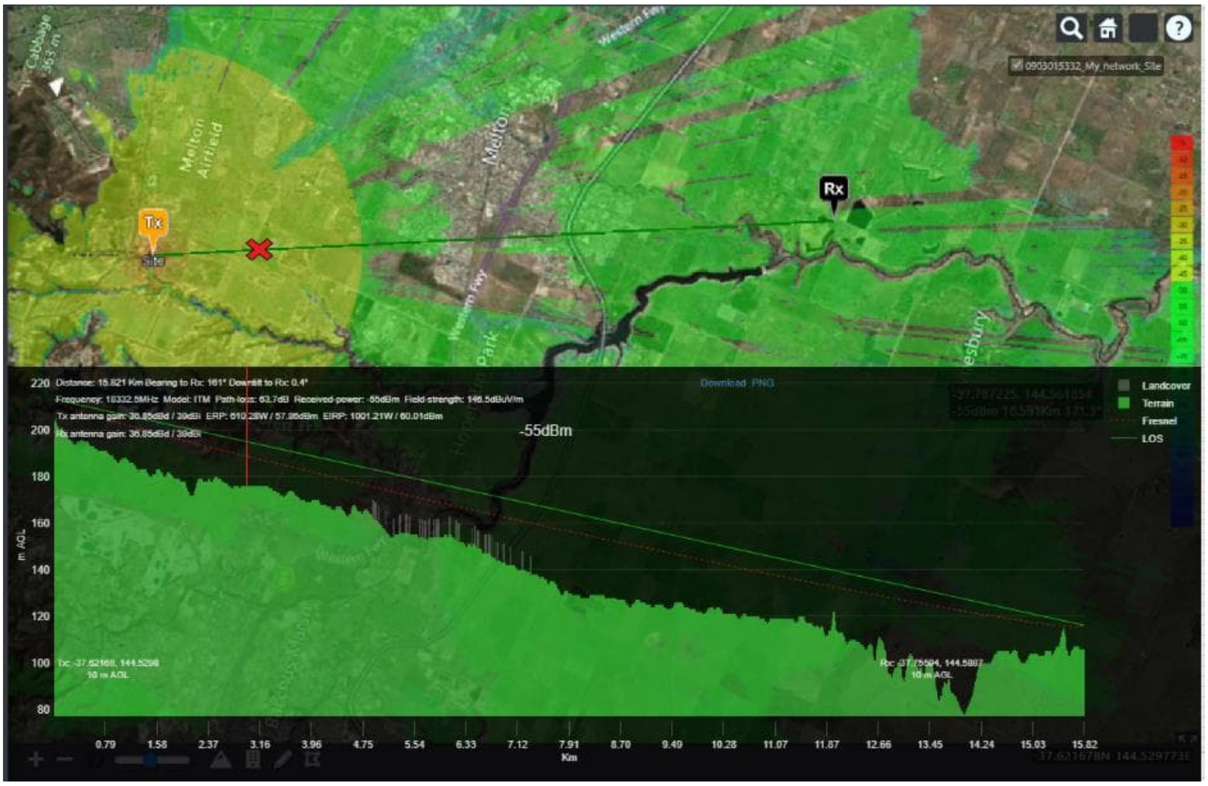

Figure F.48: Path Profile of Cloud RF System ID (4391999), Merrimu (8208956) to Mt Cottrell (8208957) (Source: Jacobs, 2022)

Appendix G. Cloud RF calculation plots

G.1 Digital TV

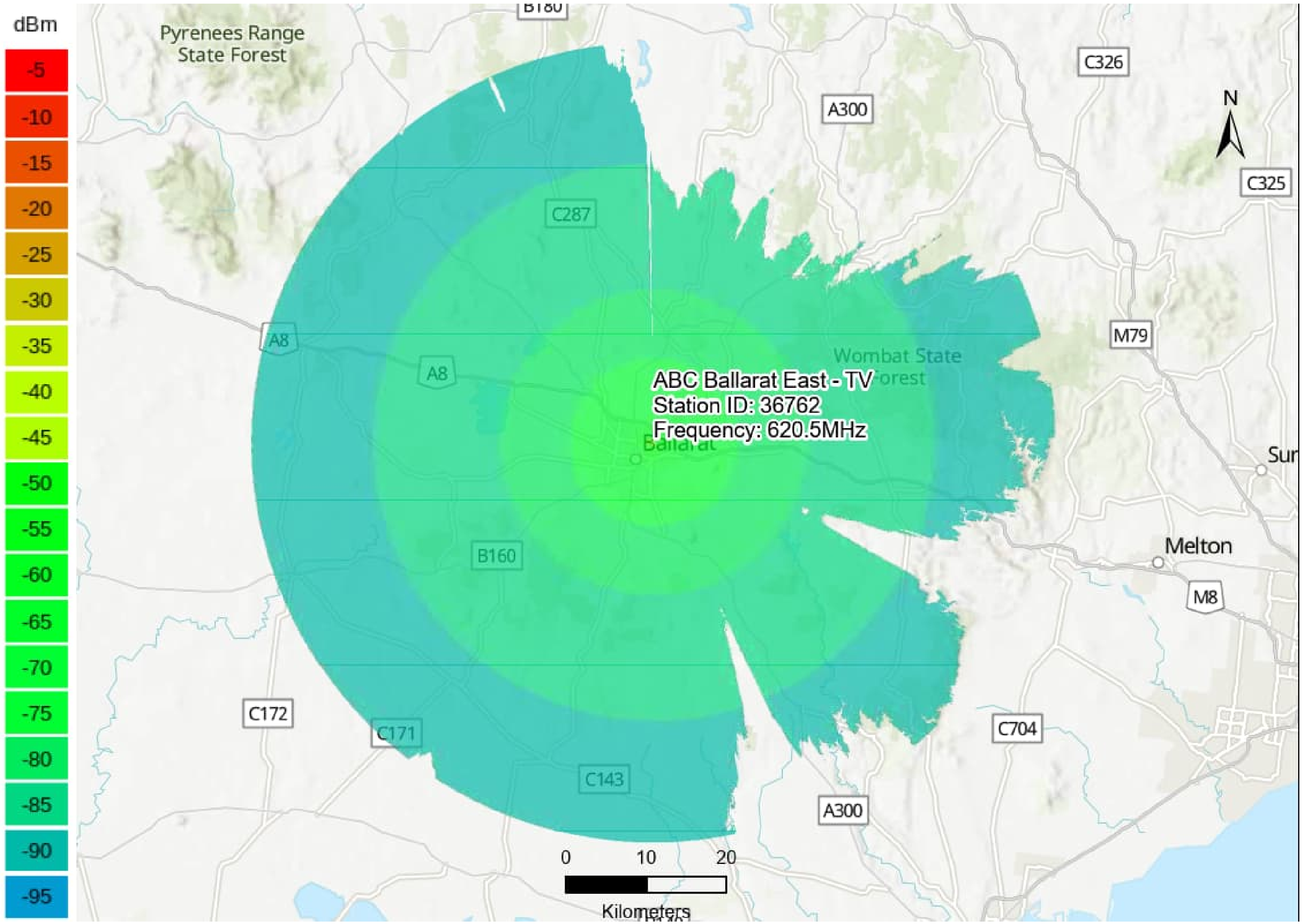

Figure G.1: Cloud RF Signal Strength for Station 36762, ABC Ballarat East (Source: Jacobs, 2022)

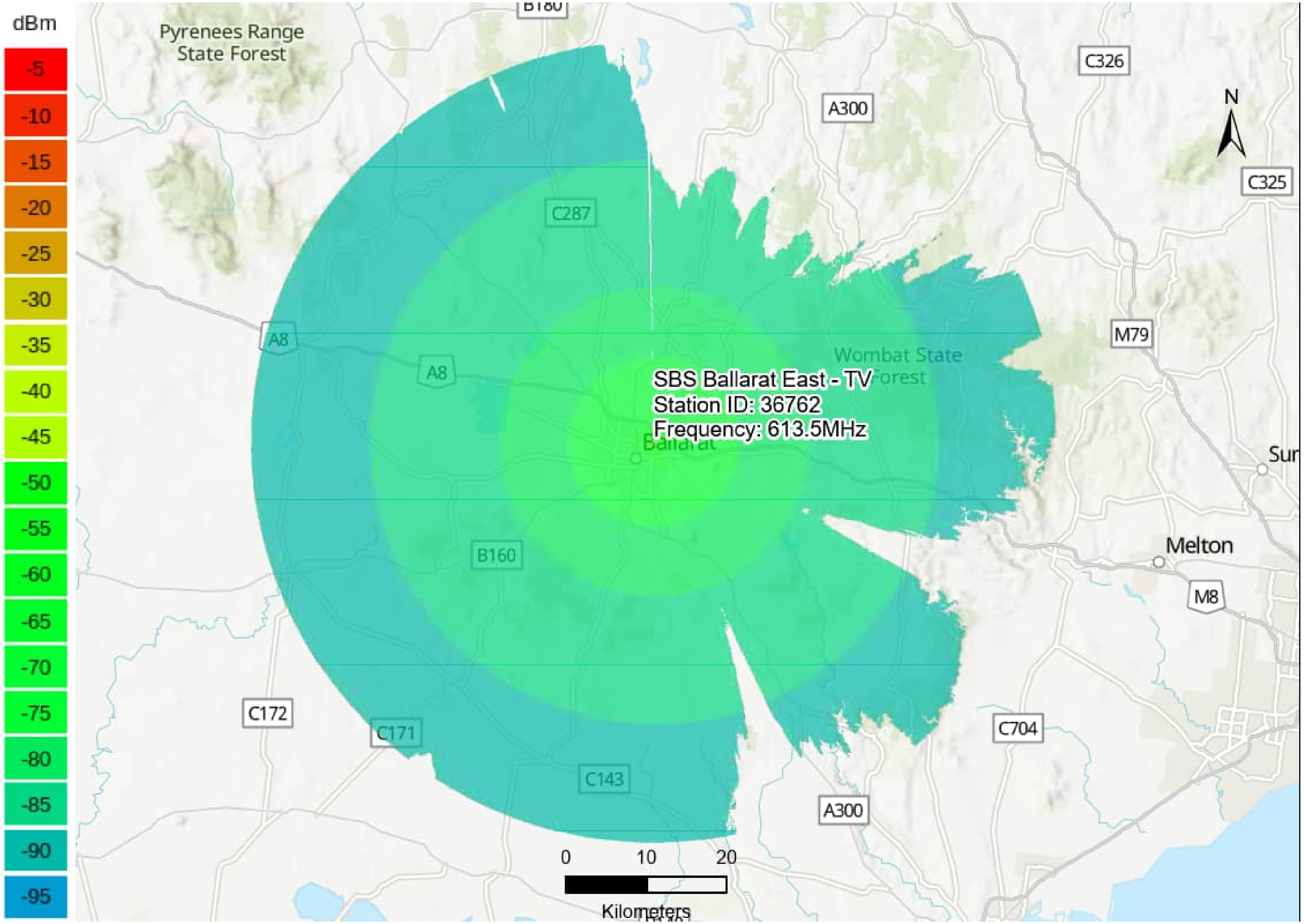

Figure G.2: Cloud RF Signal Strength for Station 36762, SBS Ballarat East (Source: Jacobs, 2022)

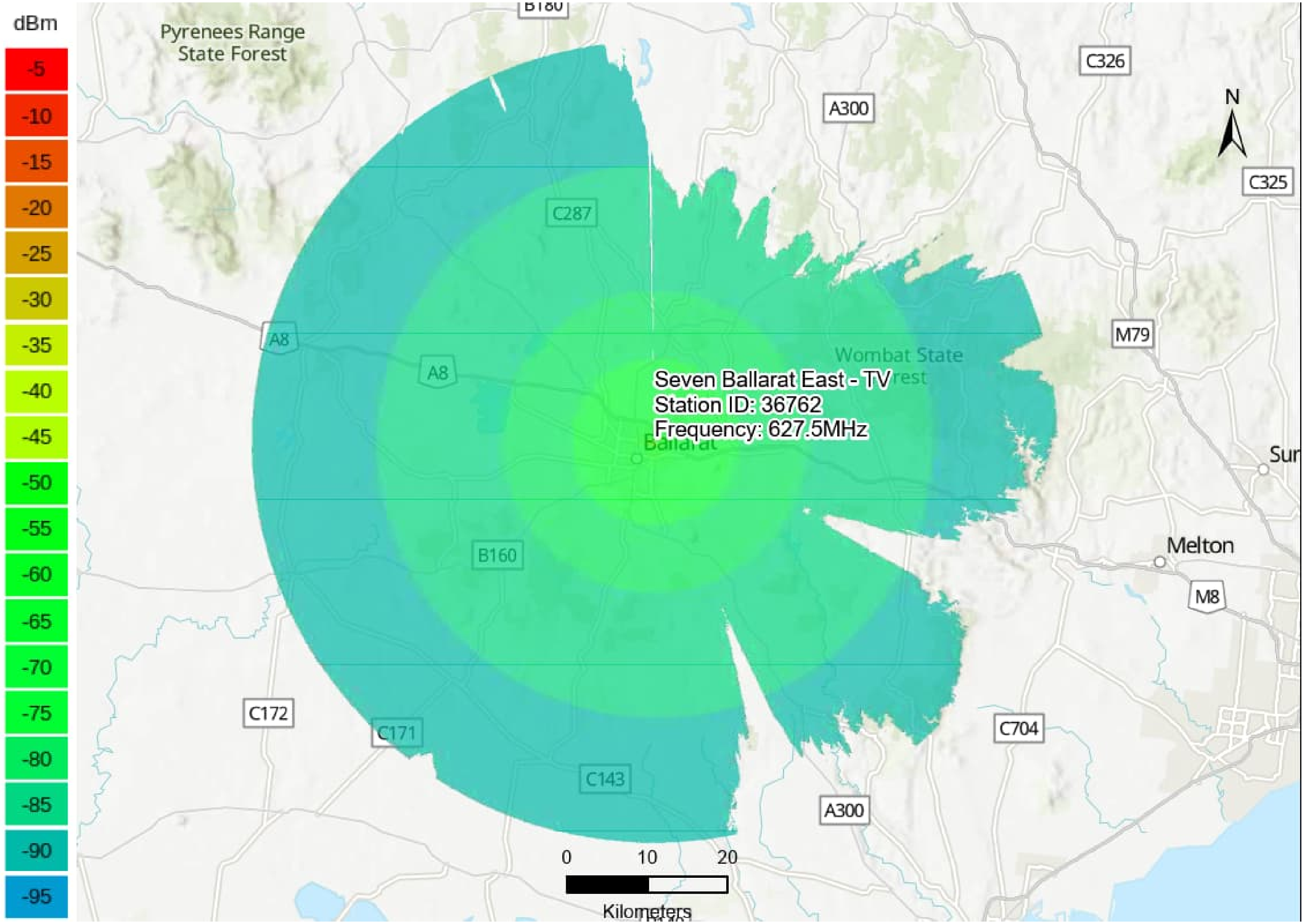

Figure G.3: Cloud RF Signal Strength for Station 36762, Seven Ballarat East (Source: Jacobs, 2022)

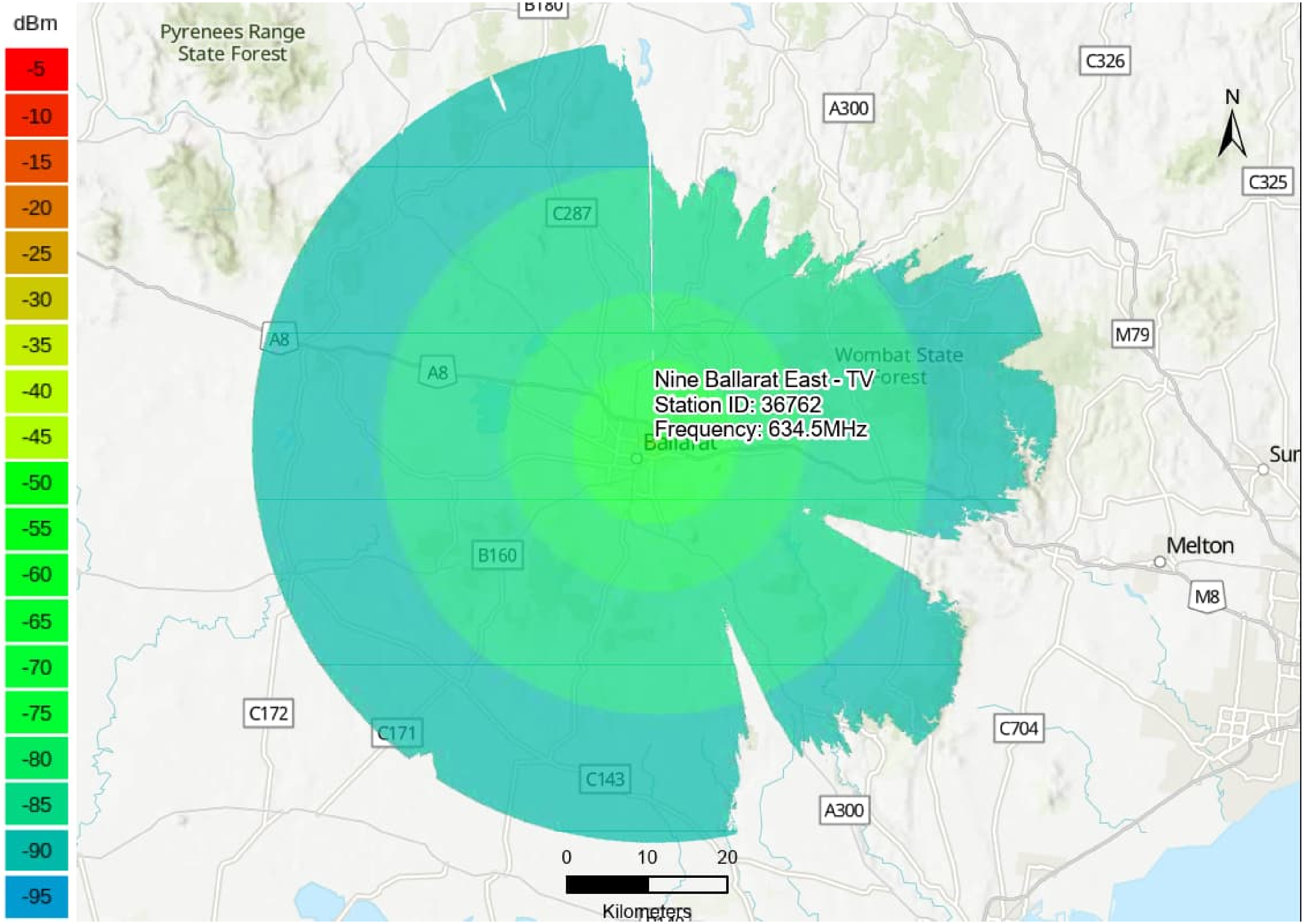

Figure G.4: Cloud RF Signal Strength for Station 36762, Nine Ballarat East (Source: Jacobs, 2022)

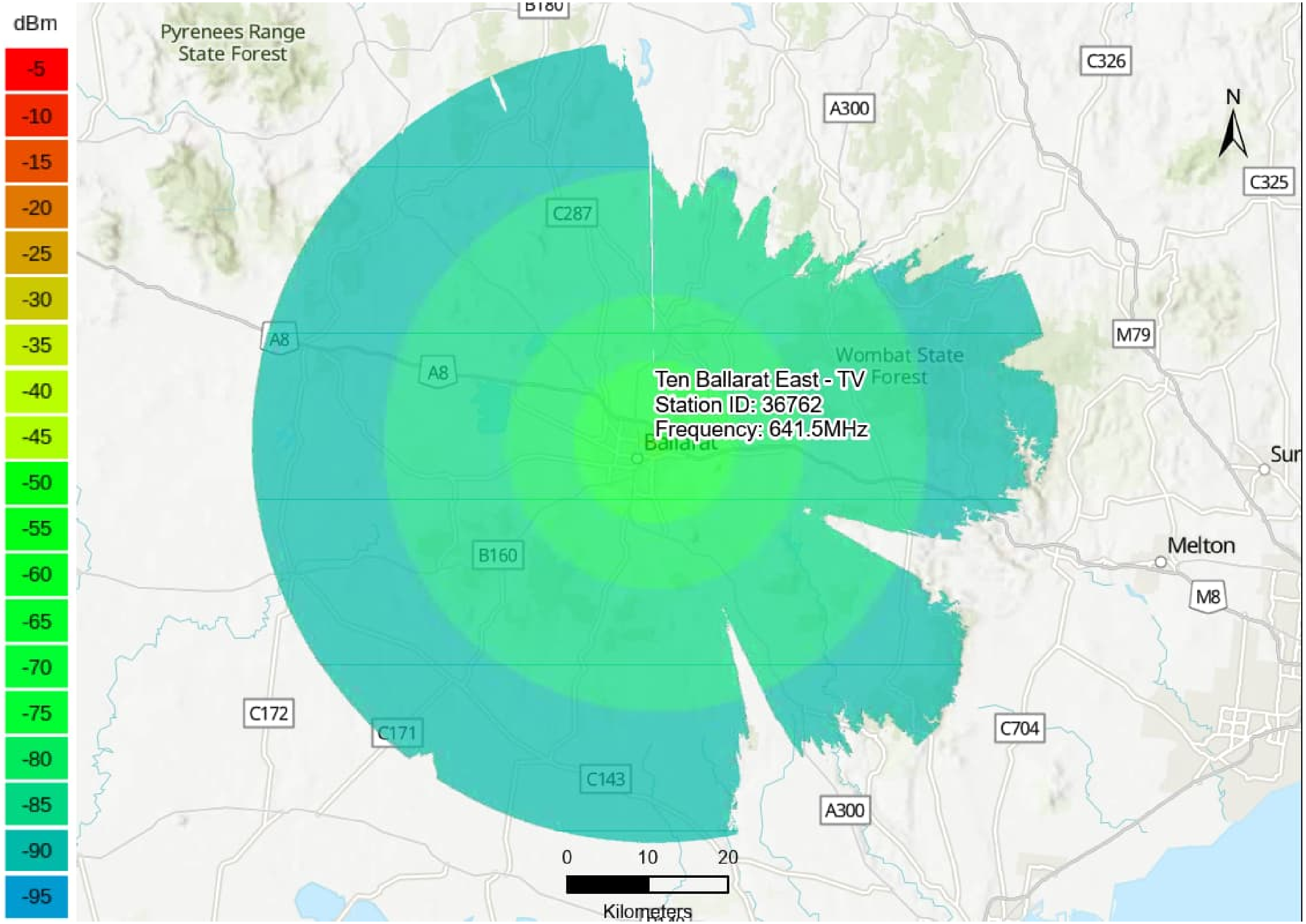

Figure G.5: Cloud RF Signal Strength for Station 36762, Ten Ballarat East (Source: Jacobs, 2022)

G.2 AM and FM Radio

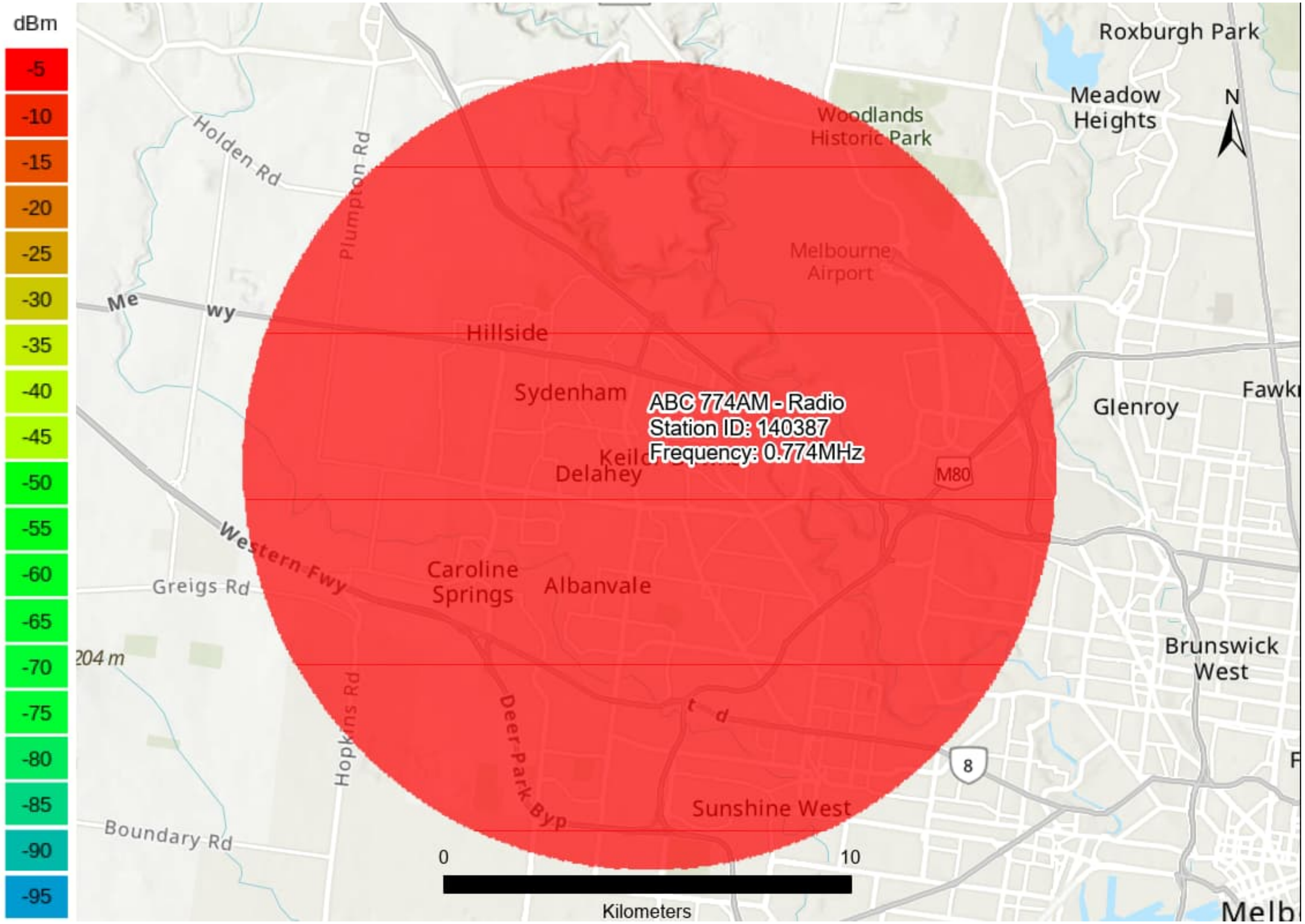

Figure G.6: ABC Radio Delahey, Station ID 140387 (Source: Jacobs, 2022)

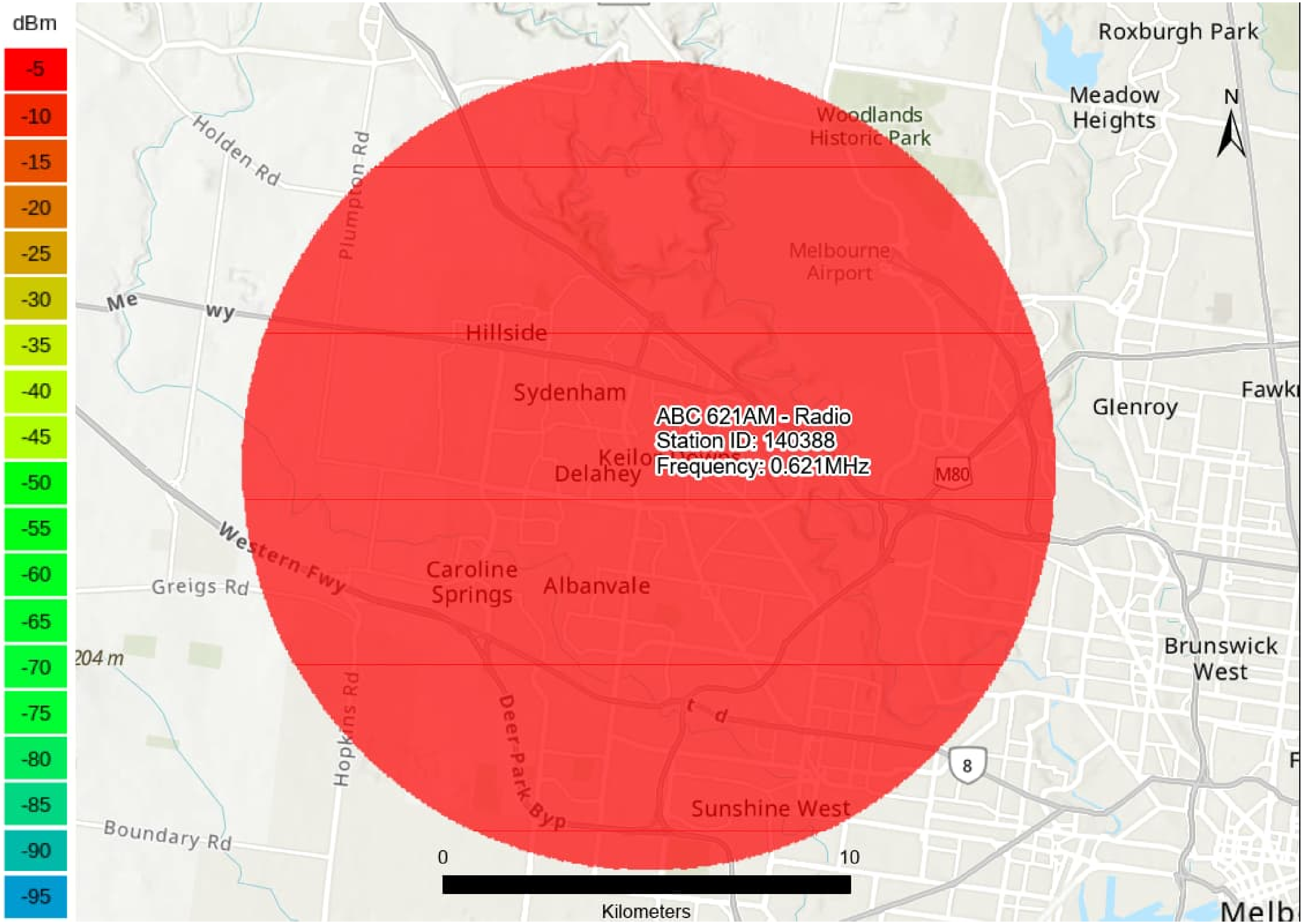

Figure G.7: ABC Delahey, Station ID 140388 (Source: Jacobs, 2022)

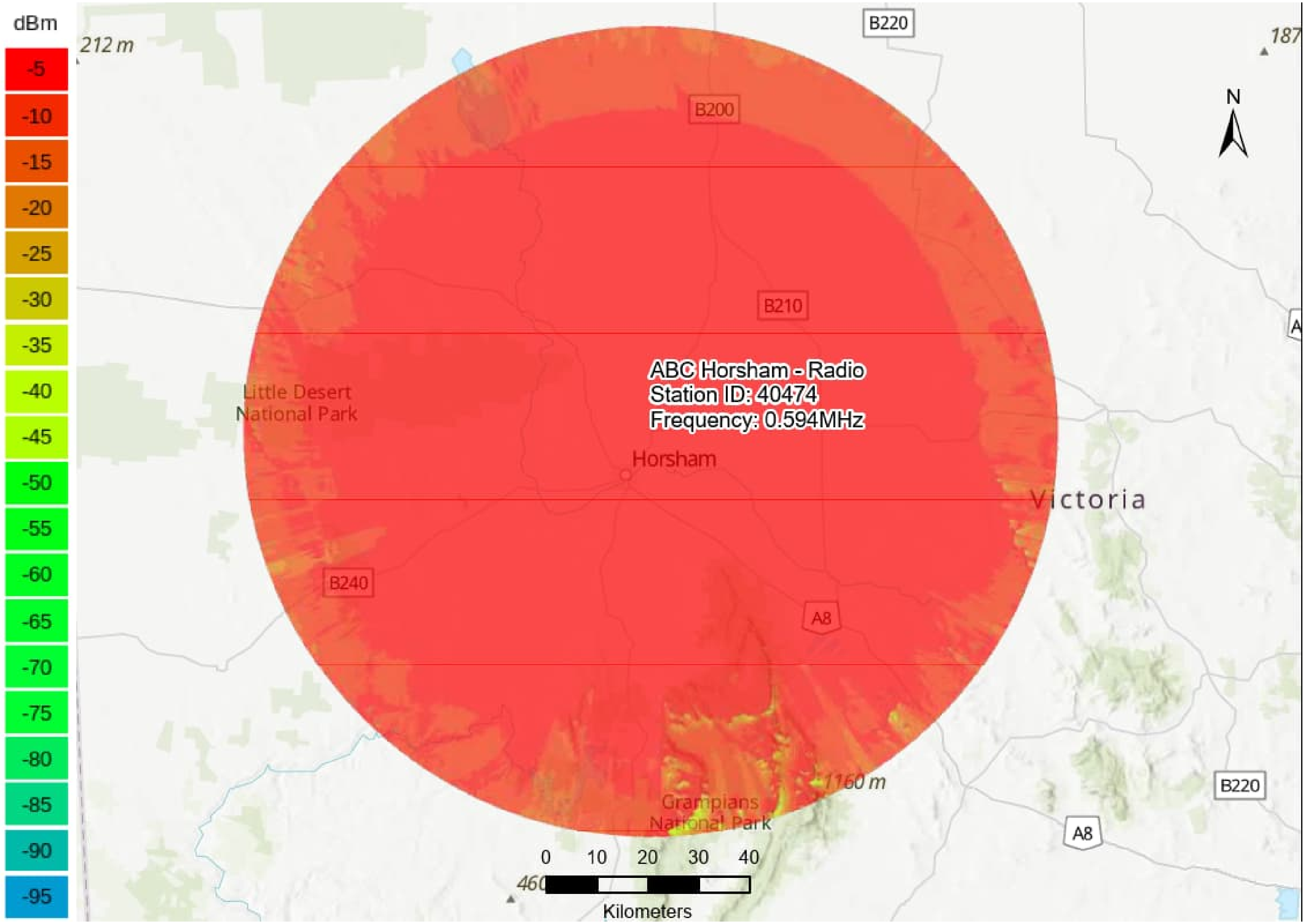

Figure G.8: ABC Horsham, Station ID 40474 (Source: Jacobs, 2022)

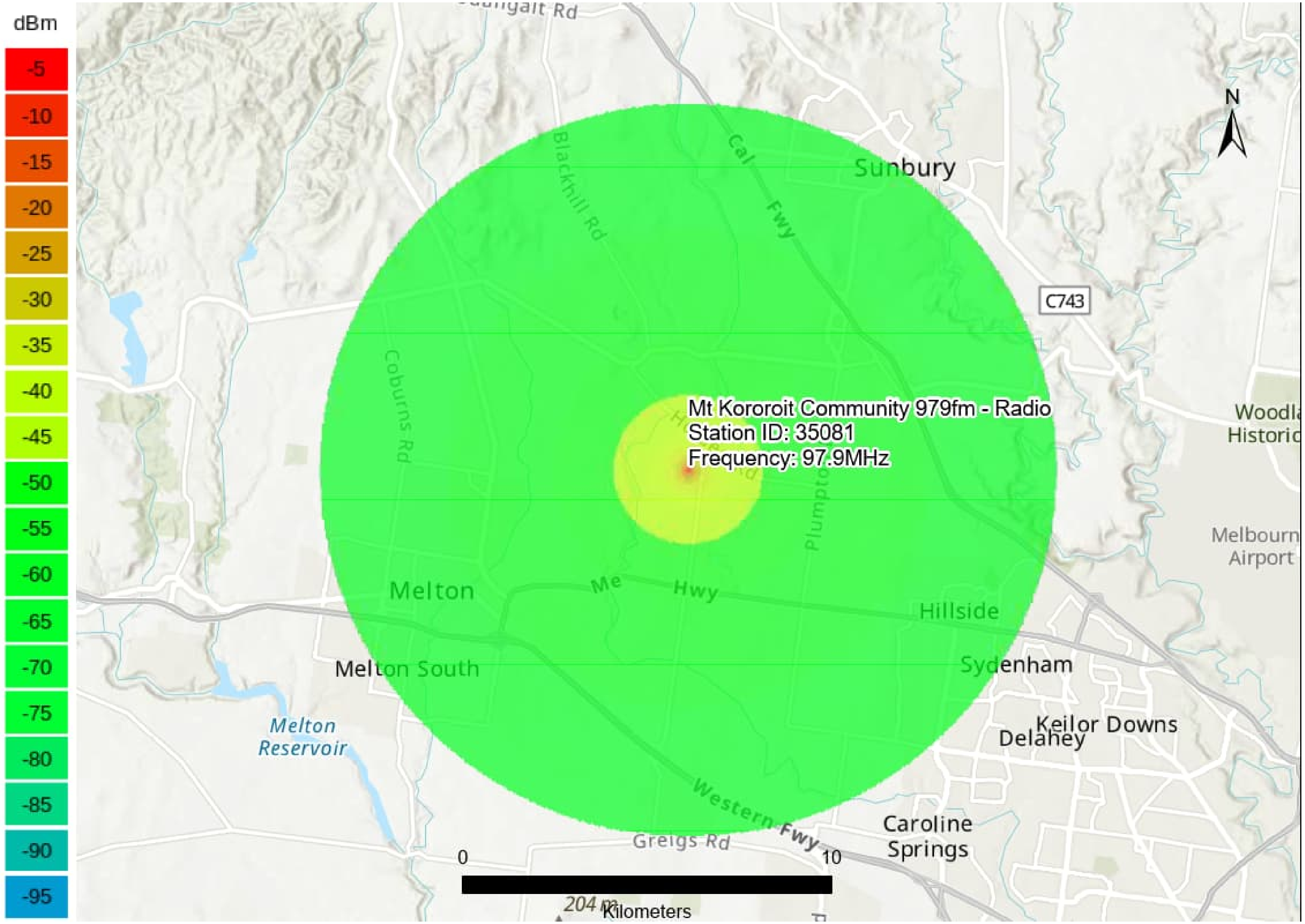

Figure G.9: 979fm – Community radio, Station ID 35081 (Source: Jacobs, 2022)

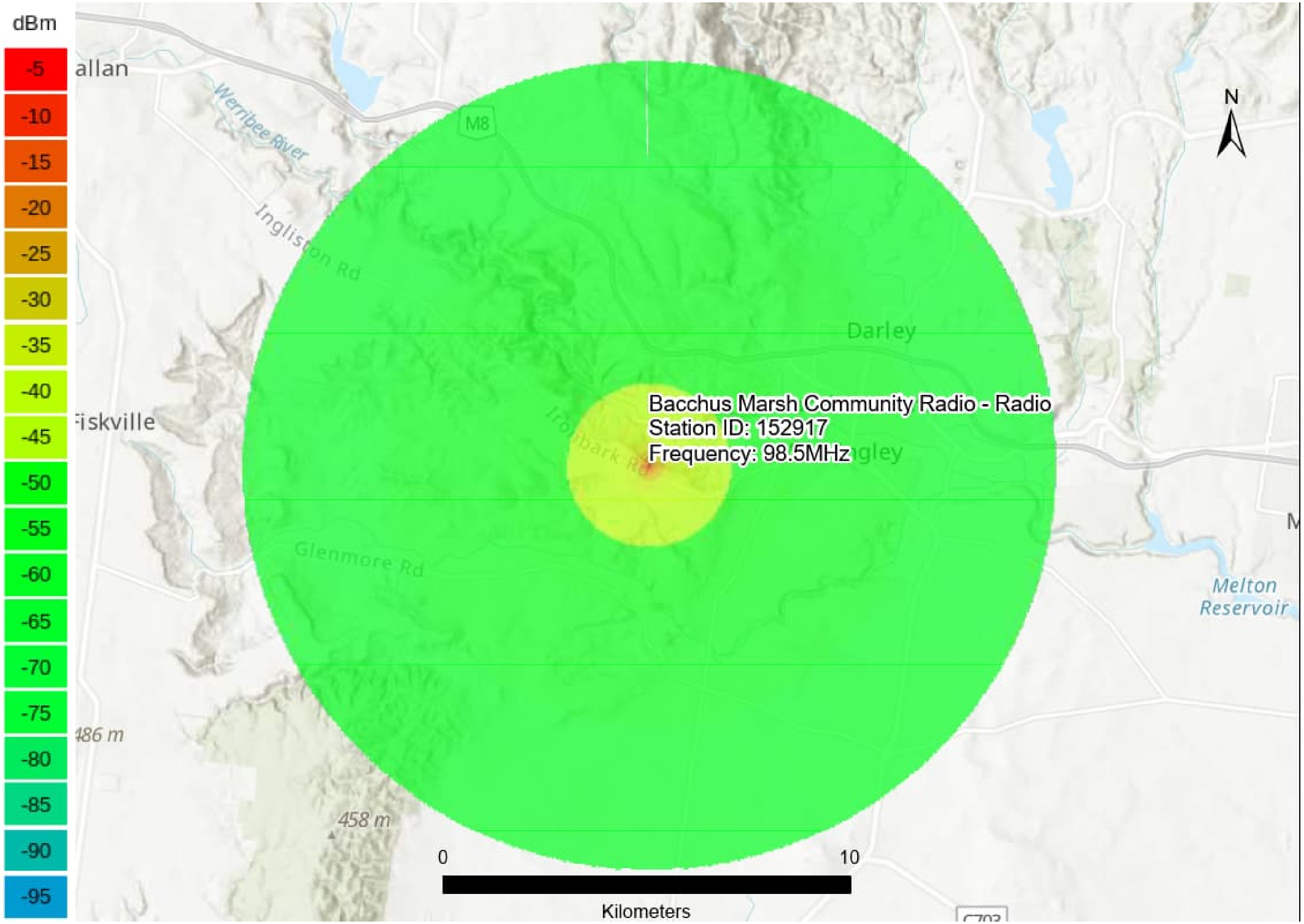

Figure G.10: Bacchus Marsh Community Radio, Station ID 152917 (Source: Jacobs, 2022)

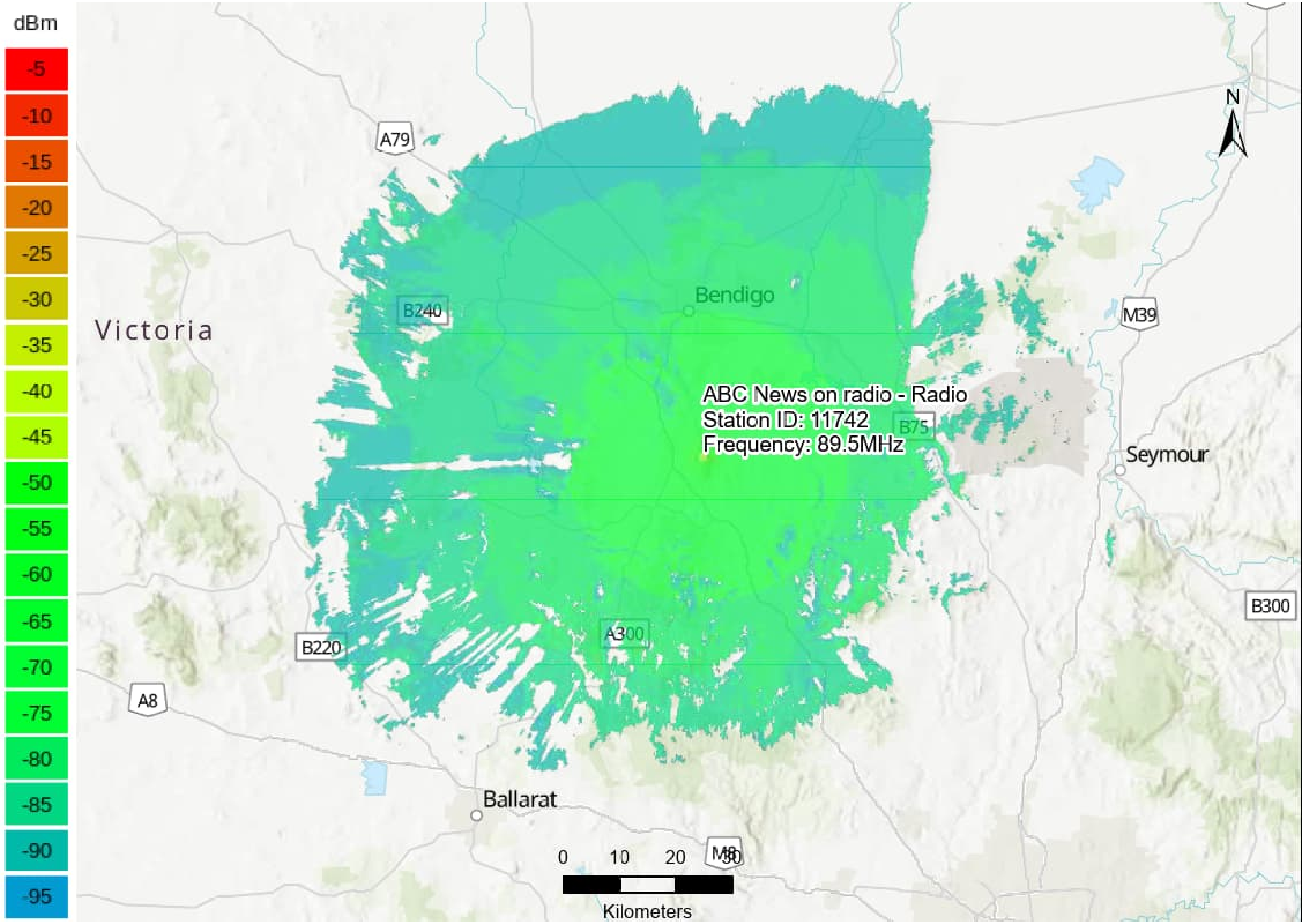

Figure G.11: ABC Central Victoria, Station ID 11742 (Source: Jacobs, 2022)

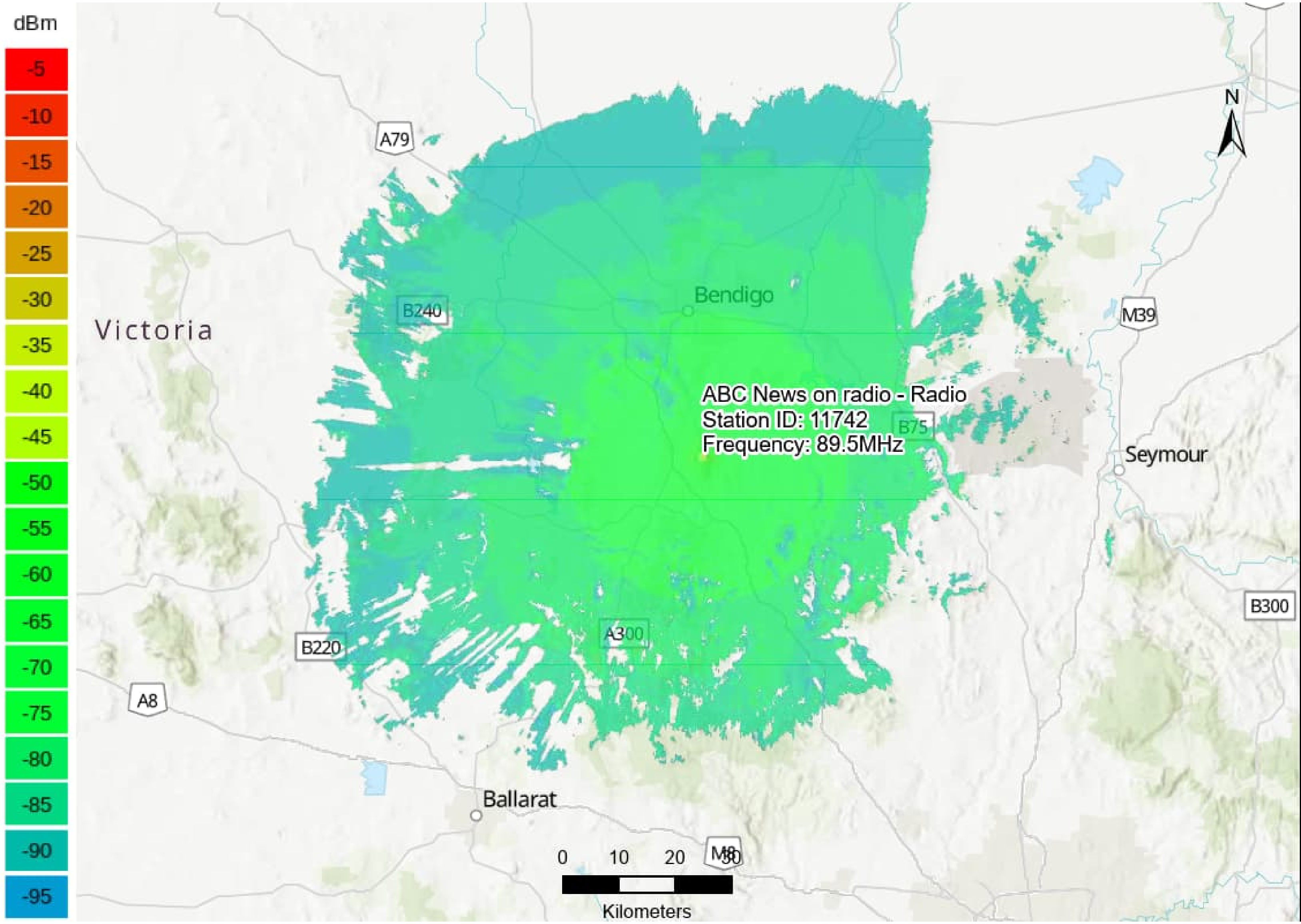

Figure G.12: ABC News One Radio, Station ID 11742 (Source: Jacobs, 2022)

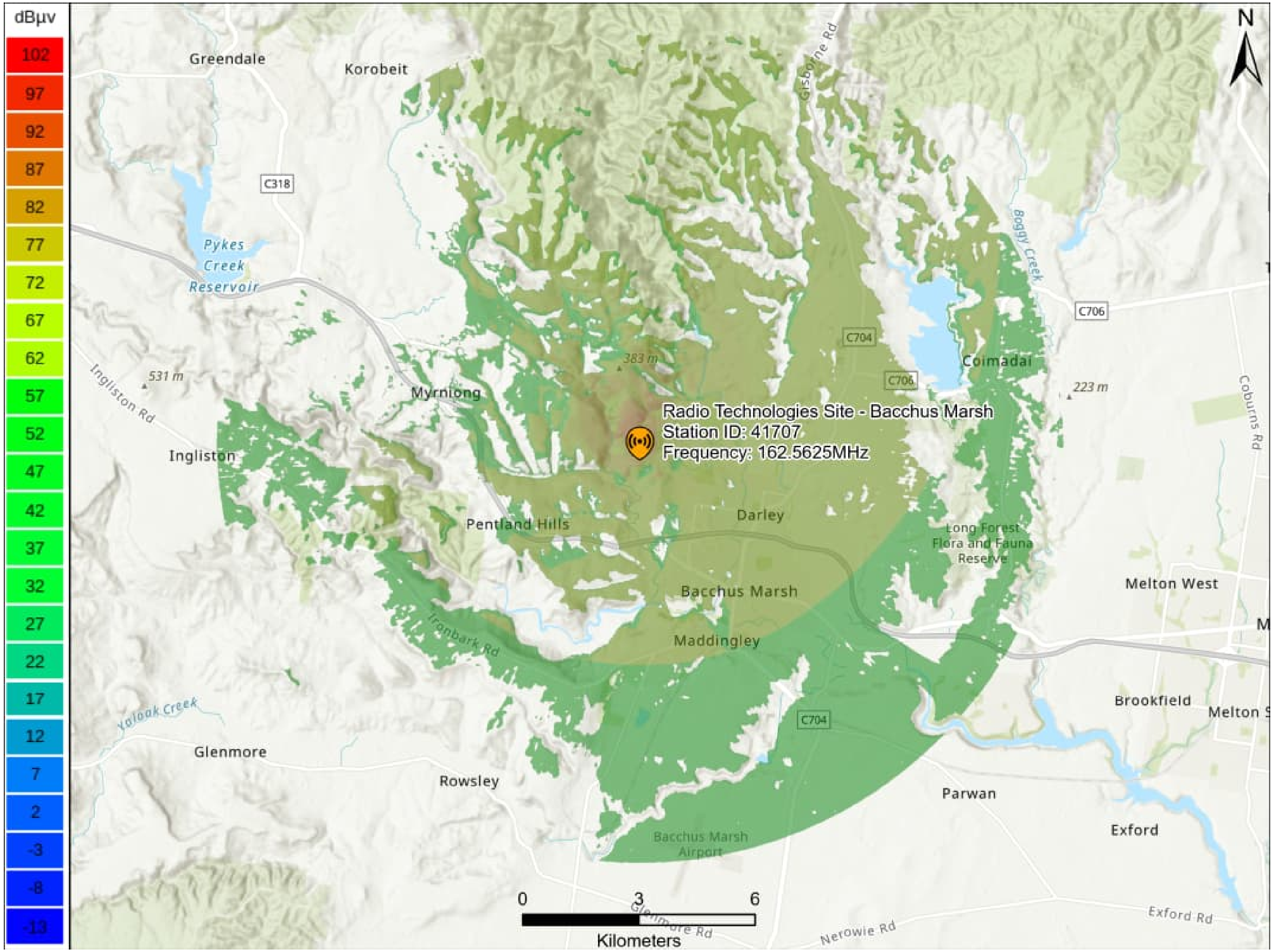

Figure G.13: Radio Technologies Site, Station ID 41707 (Source: Jacobs, 2022)

G.3 SES

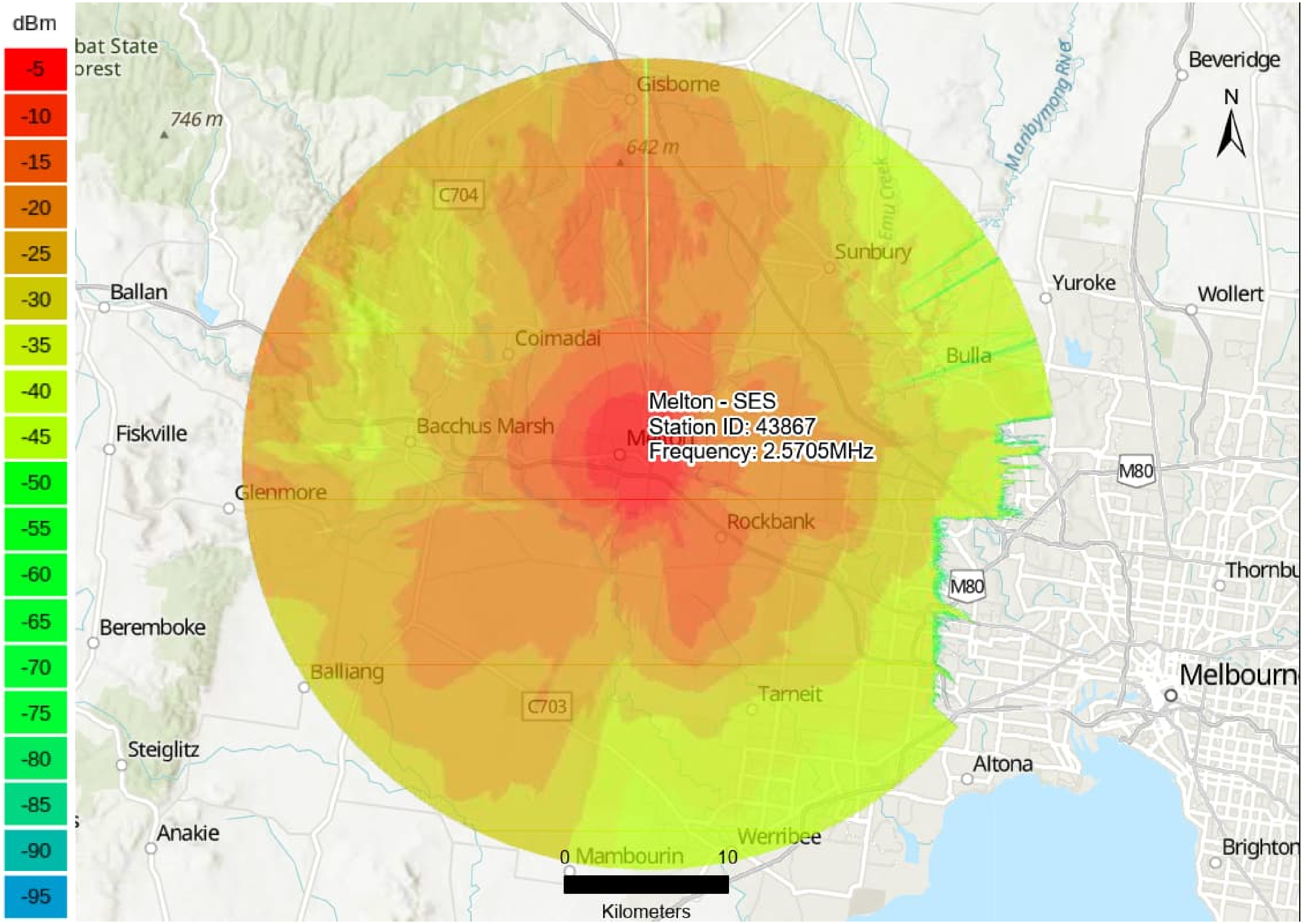

Figure G.14: SES Melton Station 43867 (Source: Jacobs, 2022)

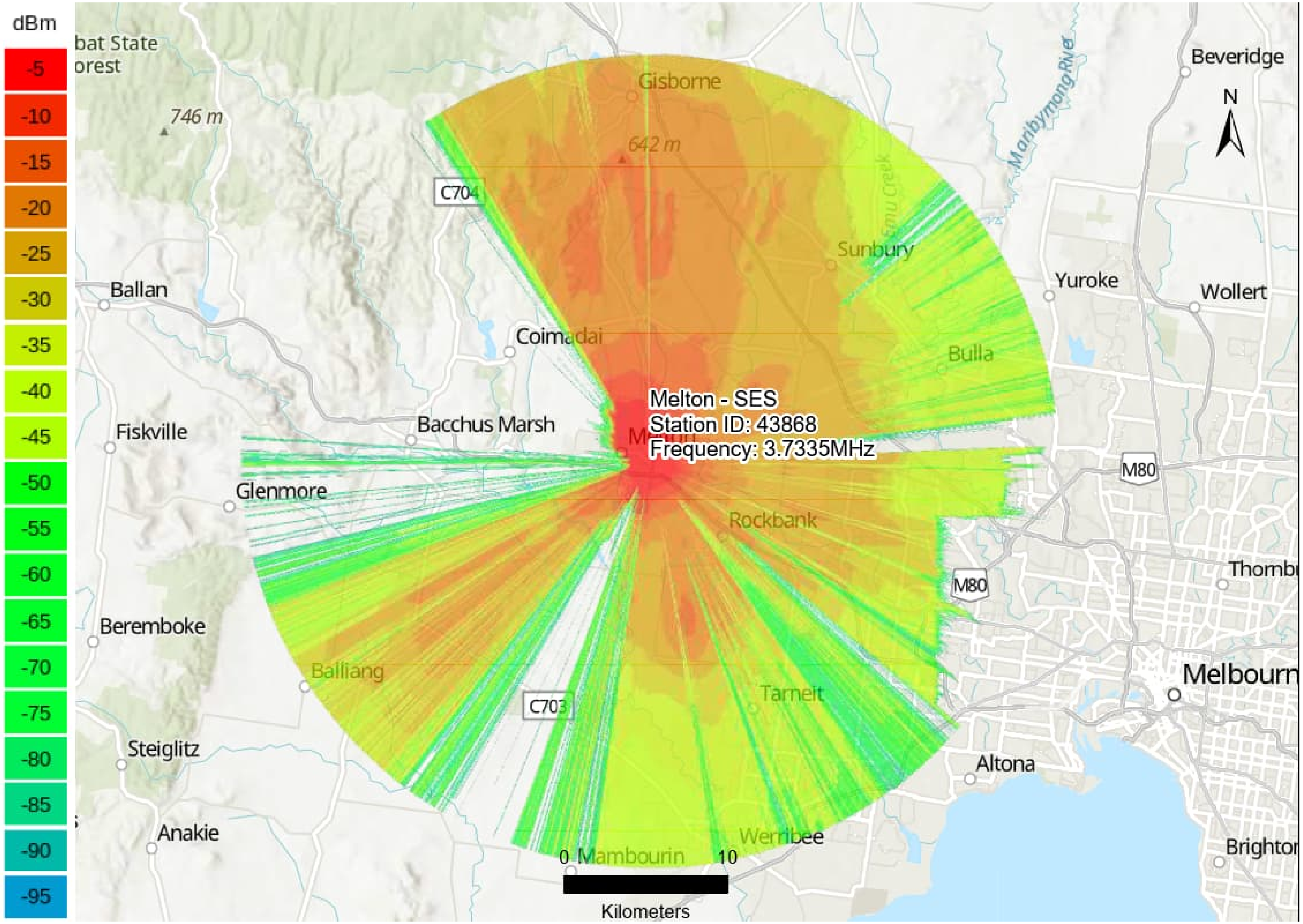

Figure G.15: SES Melton 43868 (Source: Jacobs, 2022)

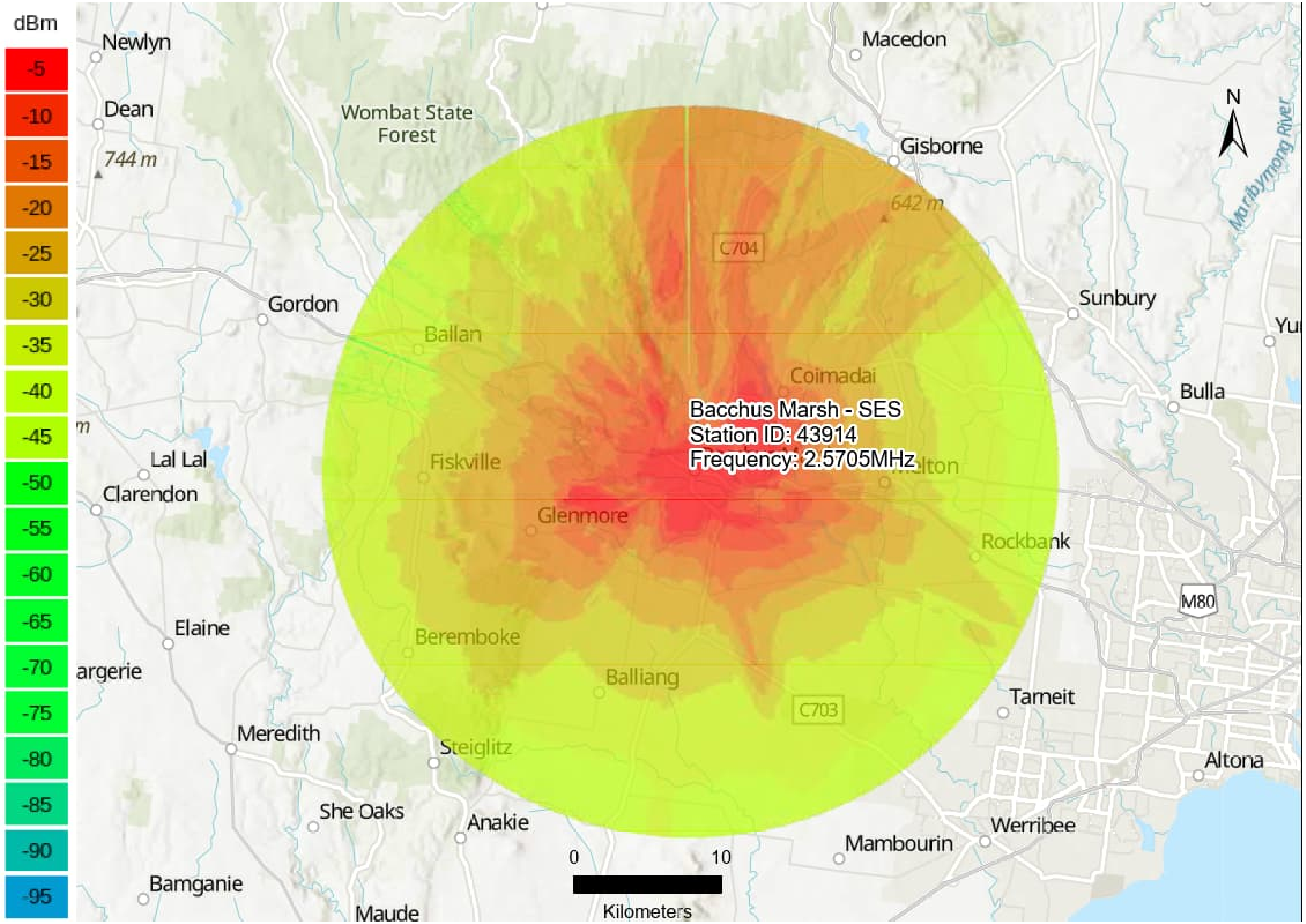

Figure G.16: SES Bacchus Marsh 43914 (Source: Jacobs, 2022)

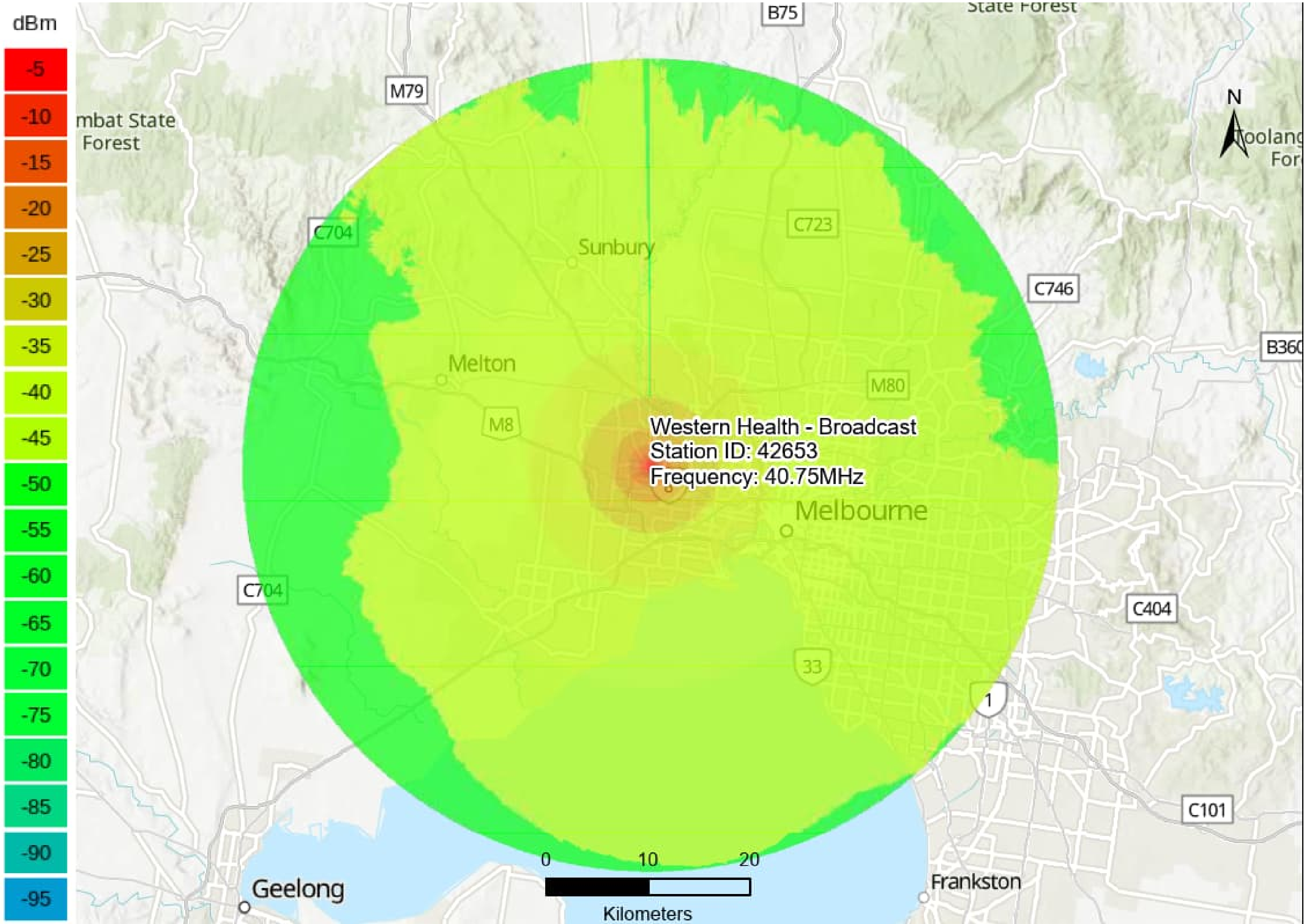

Figure G.17: Western Health St Albans Station 42653 (Source: Jacobs, 2022)

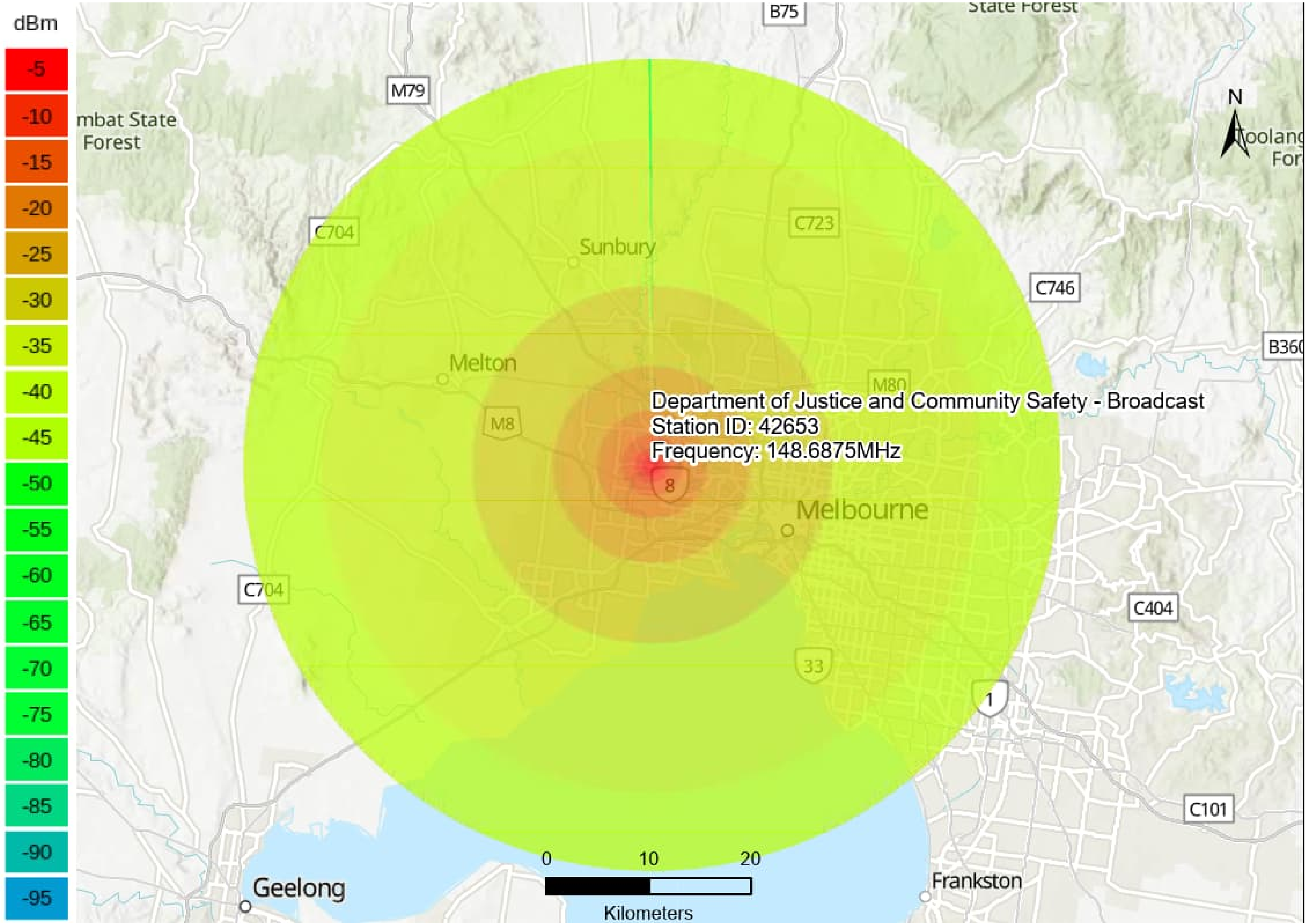

Figure G.18: Department of Justice and Community Safety St Albans Station 42653 (Source: Jacobs, 2022)

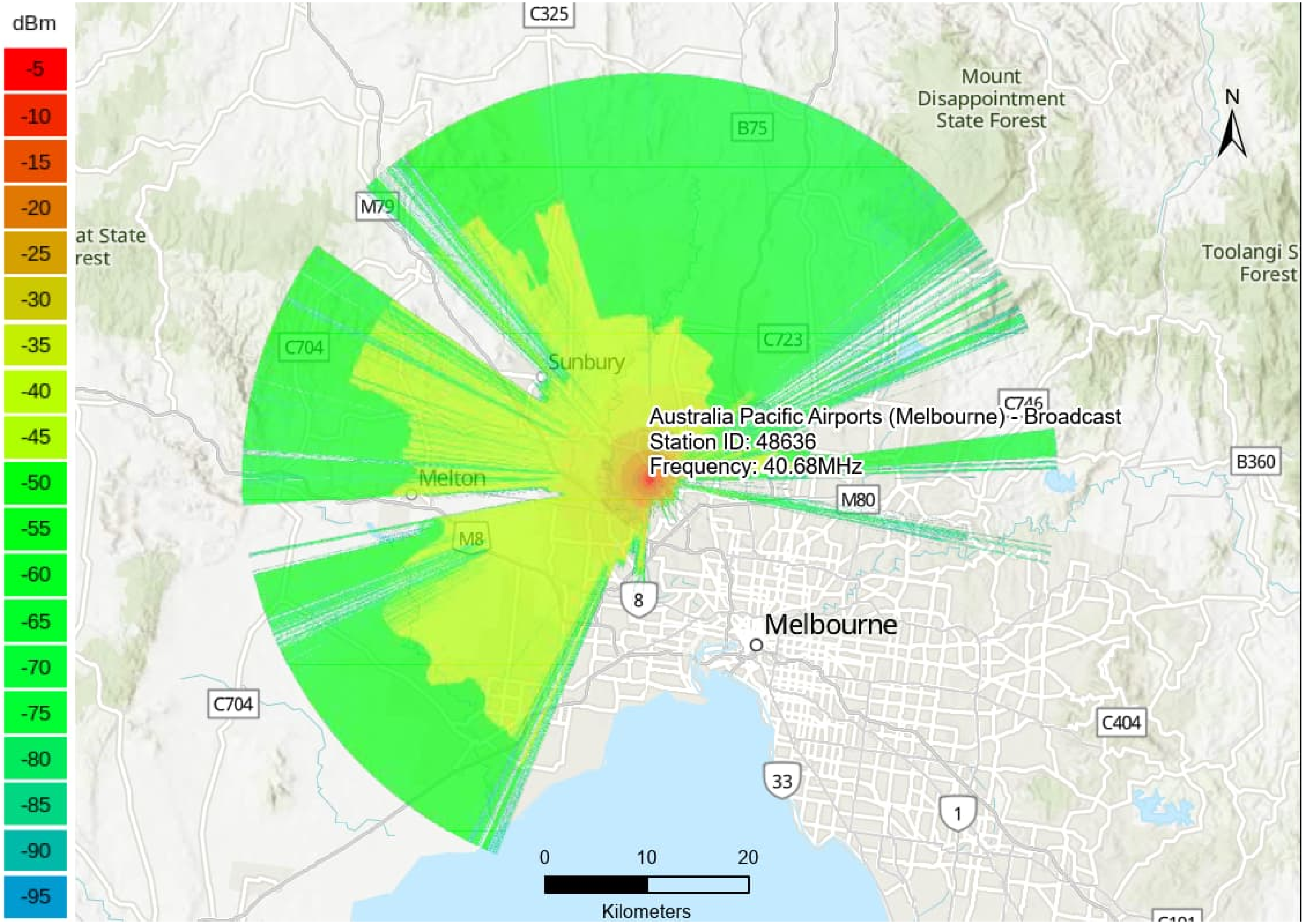

Figure G.19: Australian Pacific Airports (Melbourne) Station 48636 (Source: Jacobs, 2022)

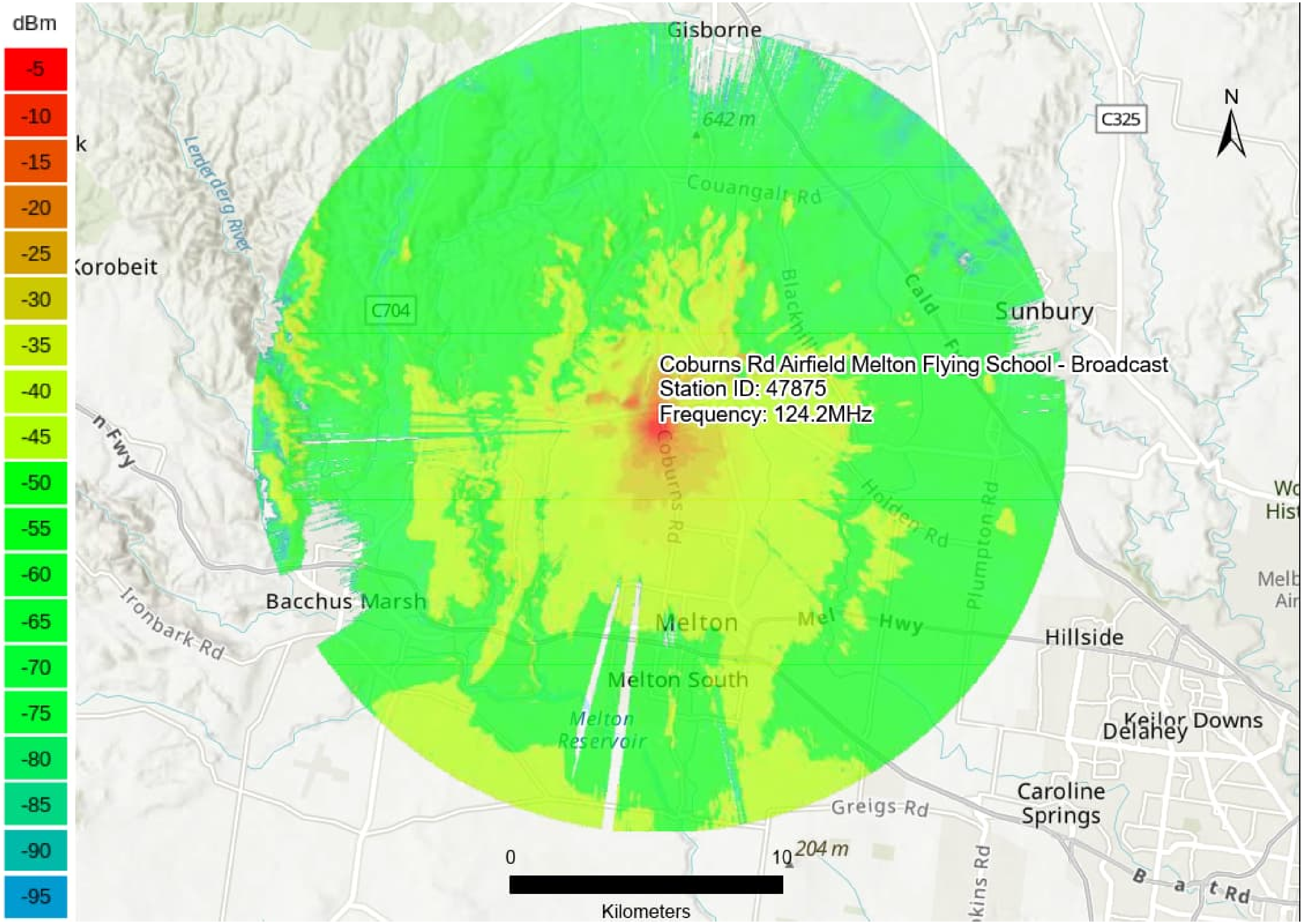

Figure G.20: Flight School 47875 (Source: Jacobs, 2022)

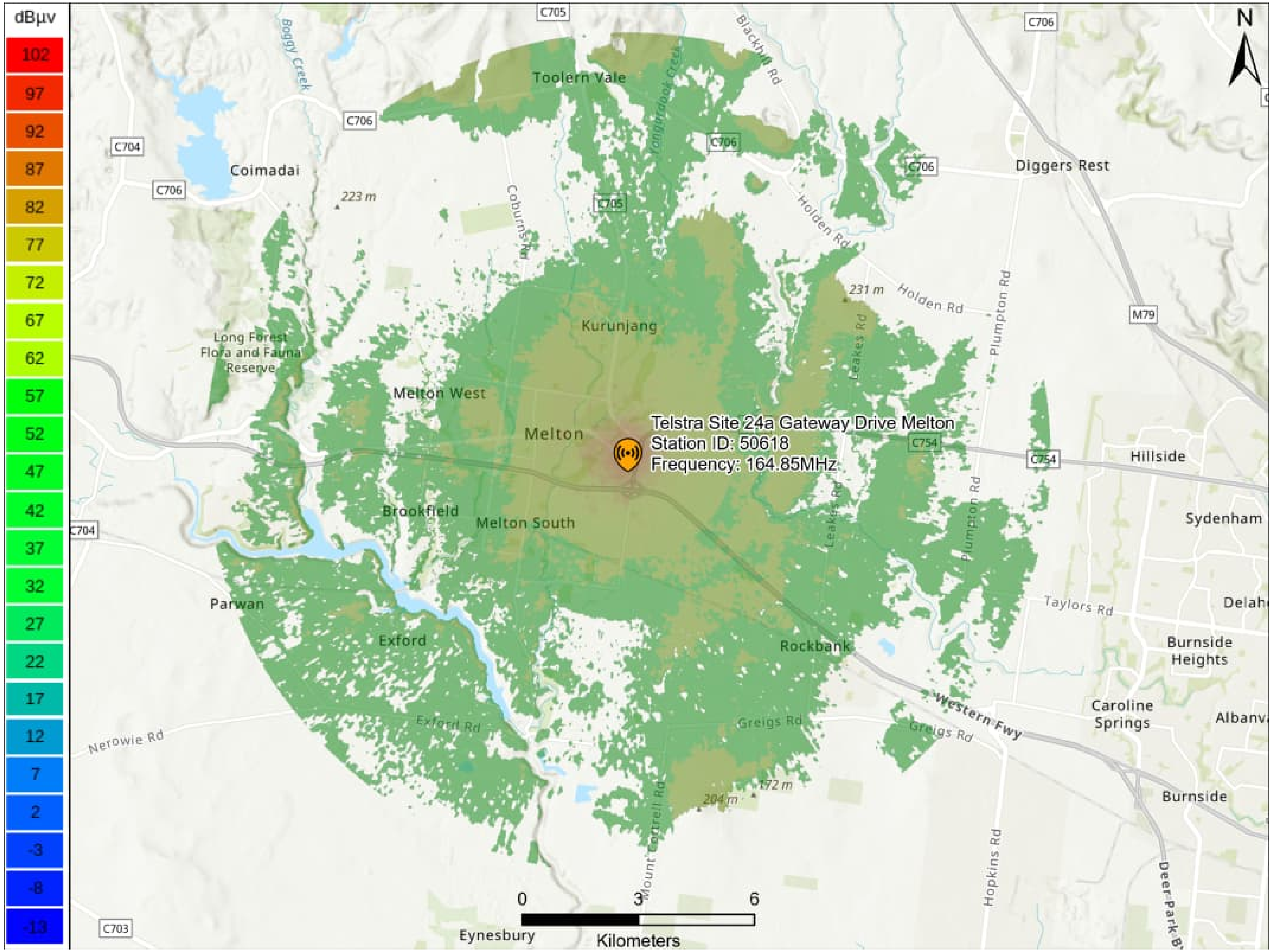

Figure G.21: Department of Justice and Community Safety – Telstra Site 24A Gateway 50618 (Source: Jacobs, 2022)

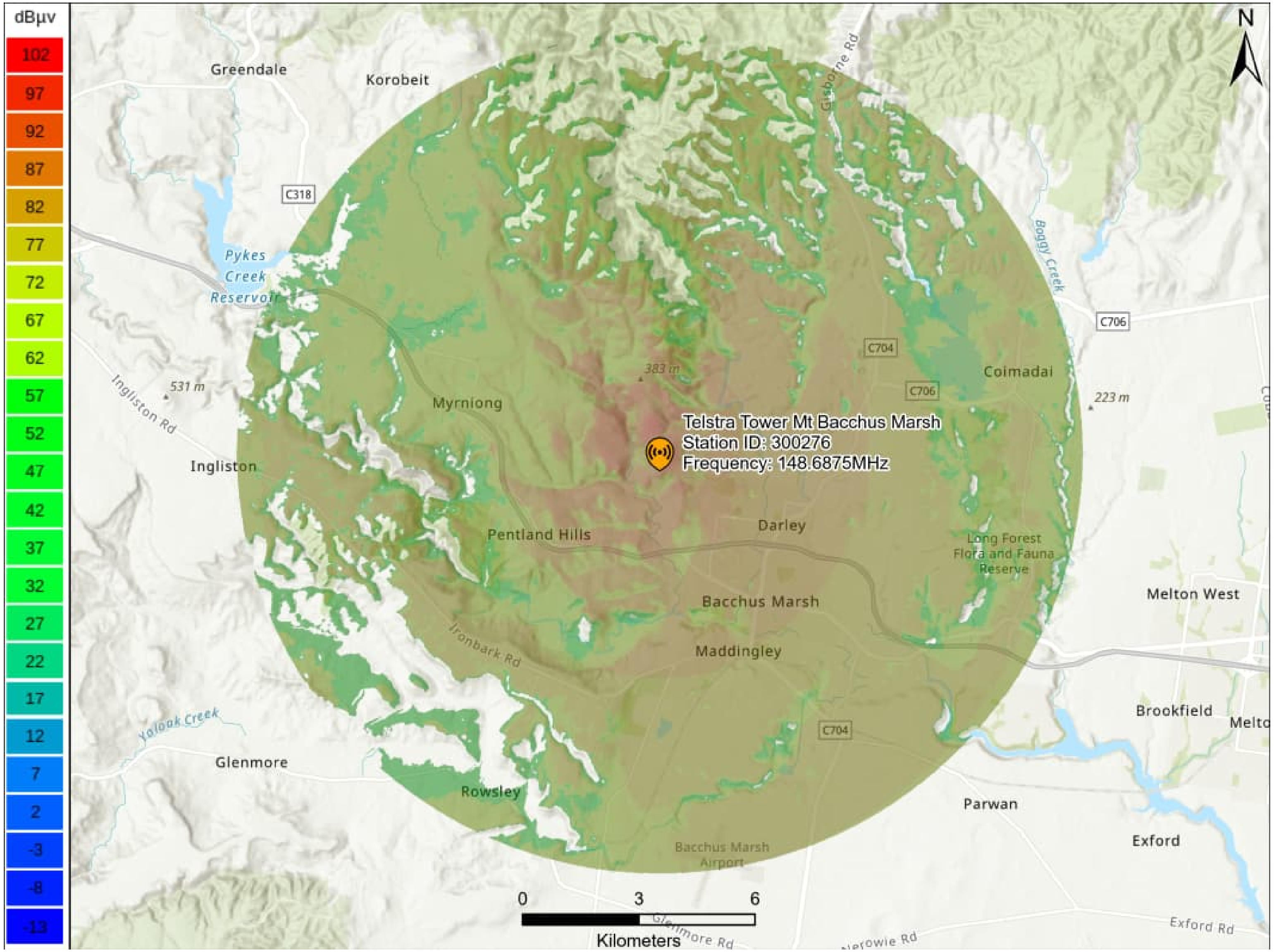

Figure G.22: Department of Justice and Community Safety – Telstra Tower Mt Bacchus Marsh 300276 (Source: Jacobs, 2022)

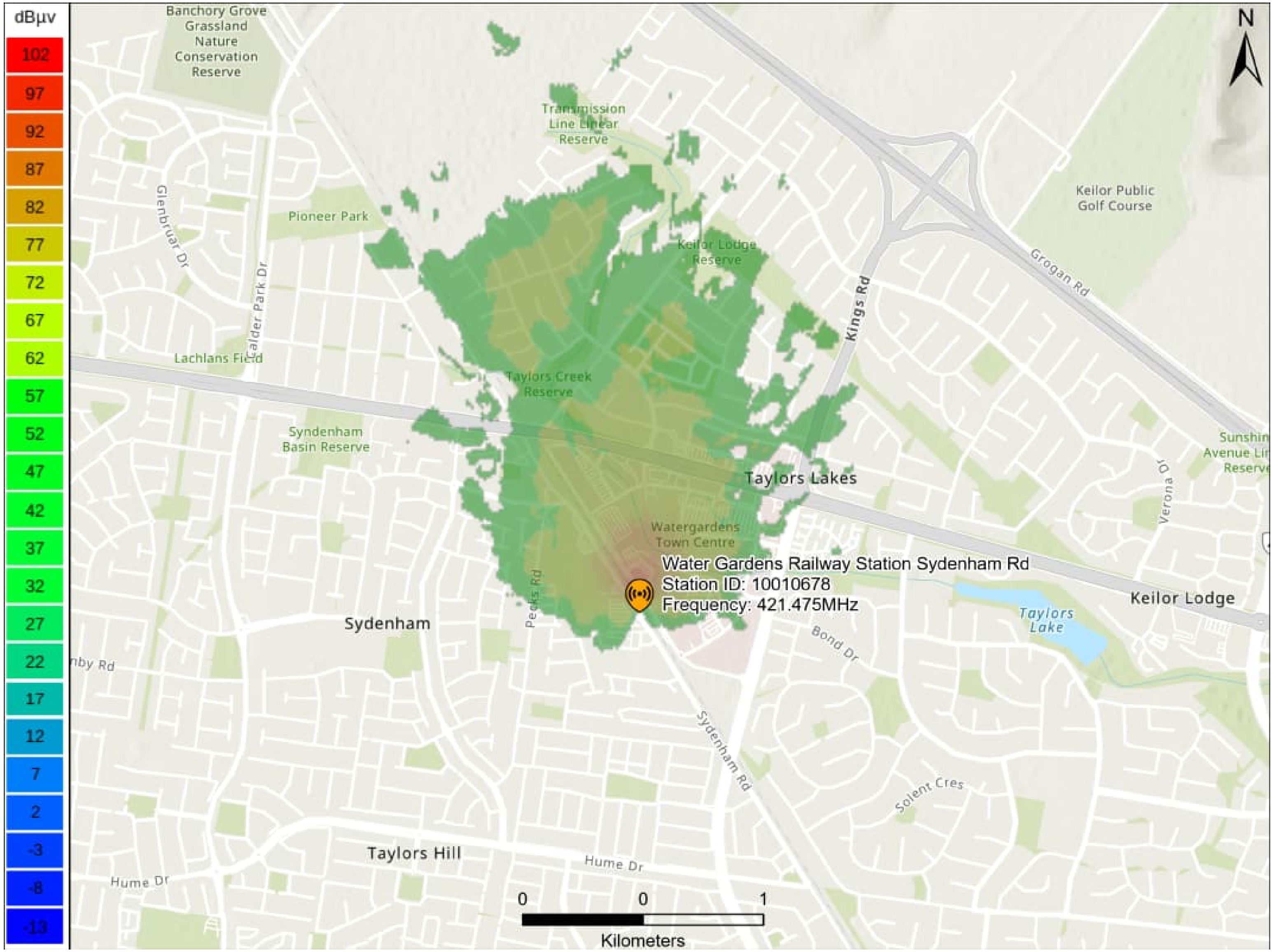

Figure G.23: Department of Justice and Community Safety – Water Gardens Railway Station Sydenham Rd 10010678 (Source: Jacobs, 2022)

G.4 CFA

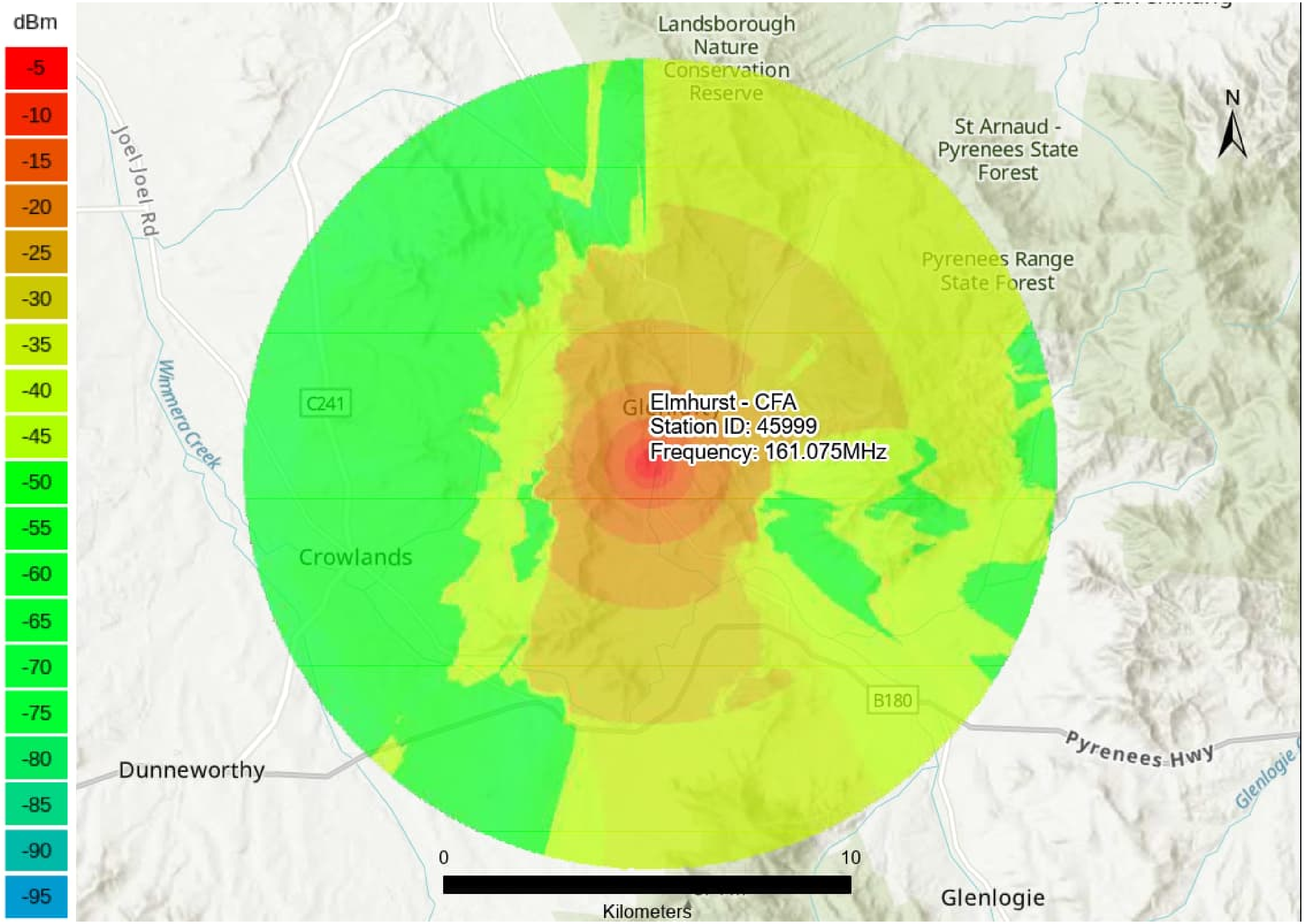

Figure G.24: CFA Elmhurst Broadcast Station 45999 (Source: Jacobs, 2022)

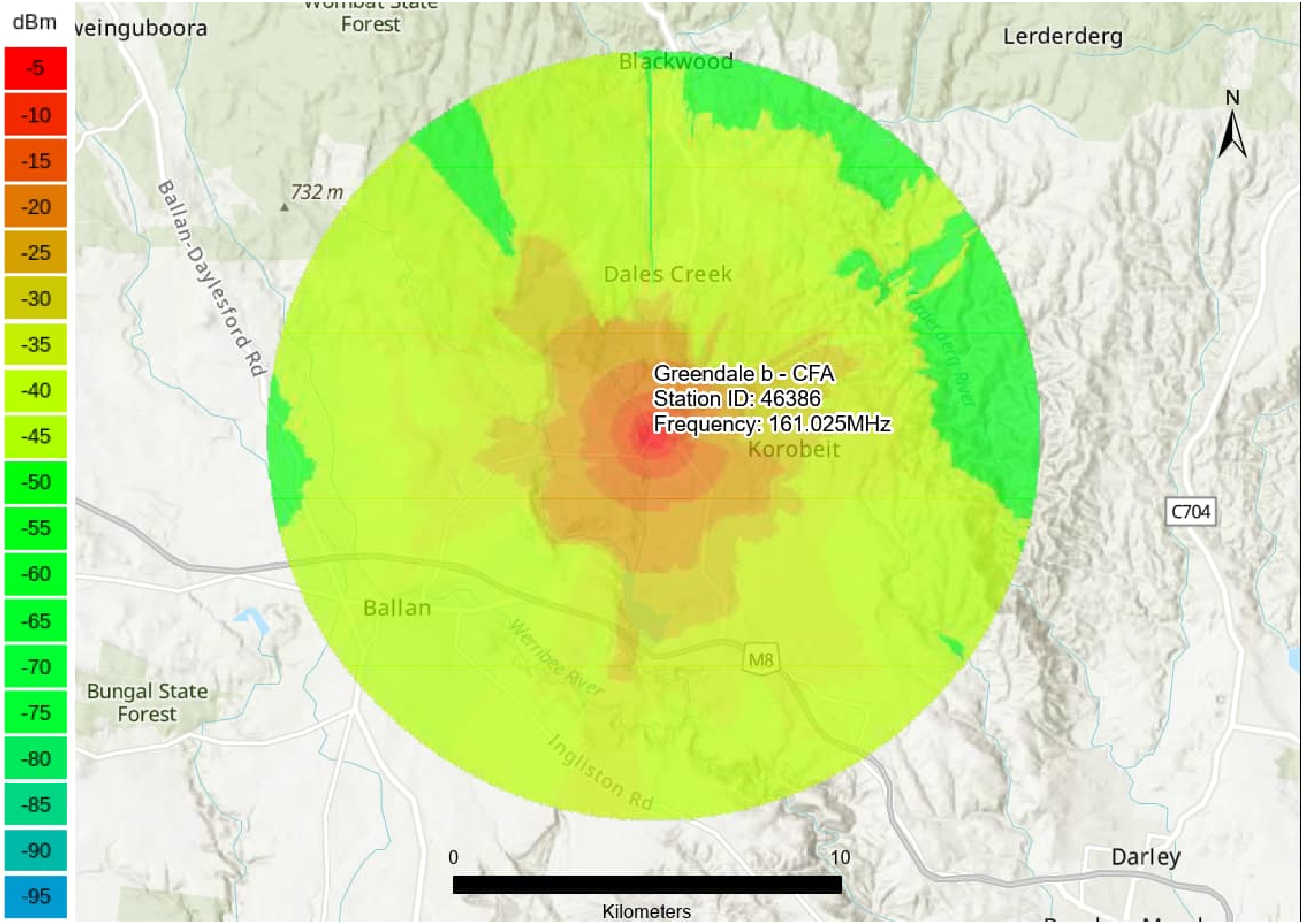

Figure G.25: CFA Greendale Broadcast Station 46386 (Source: Jacobs, 2022)

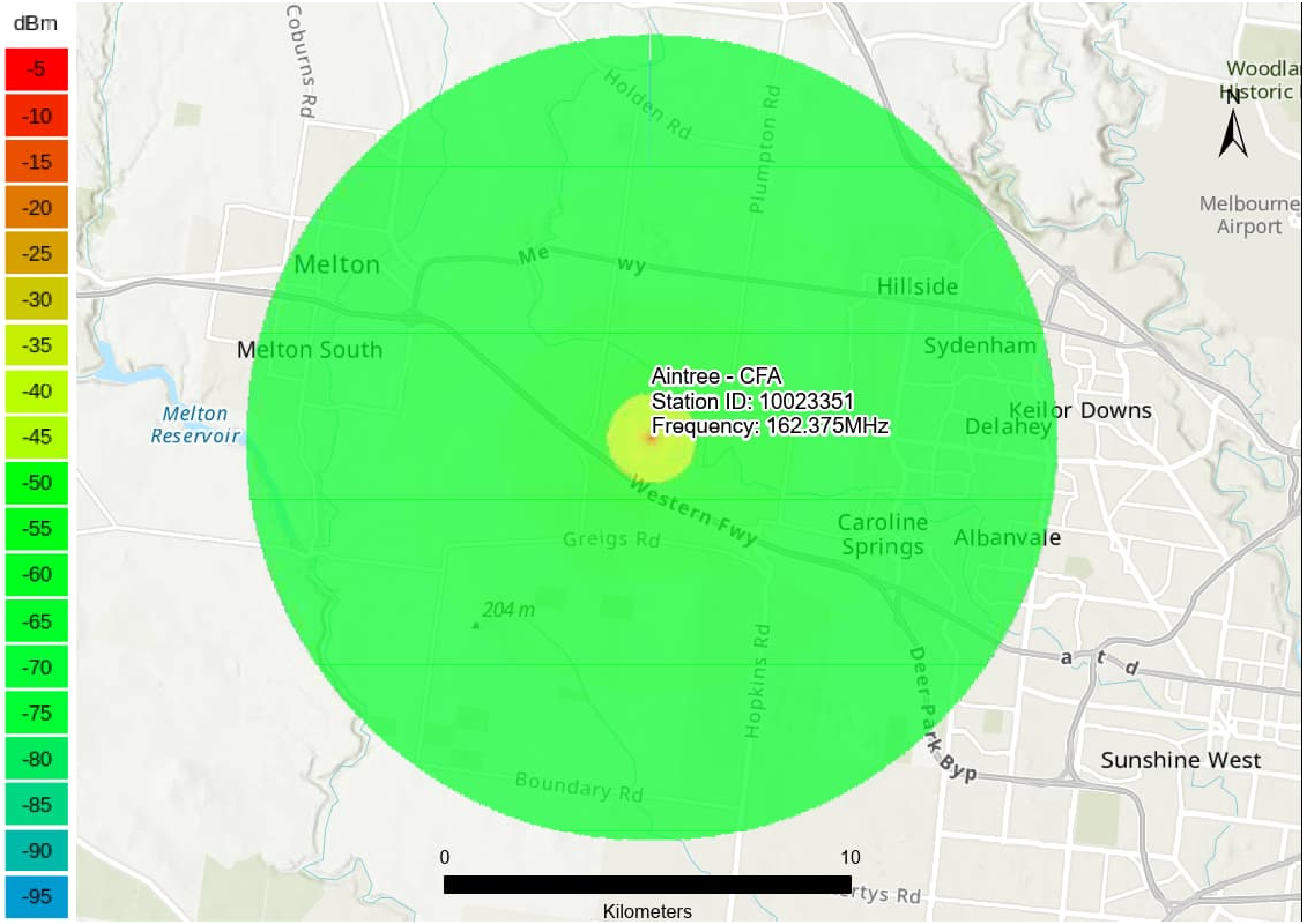

Figure G.26: CFA Aintree Broadcast Station 10023351 (Source: Jacobs, 2022)

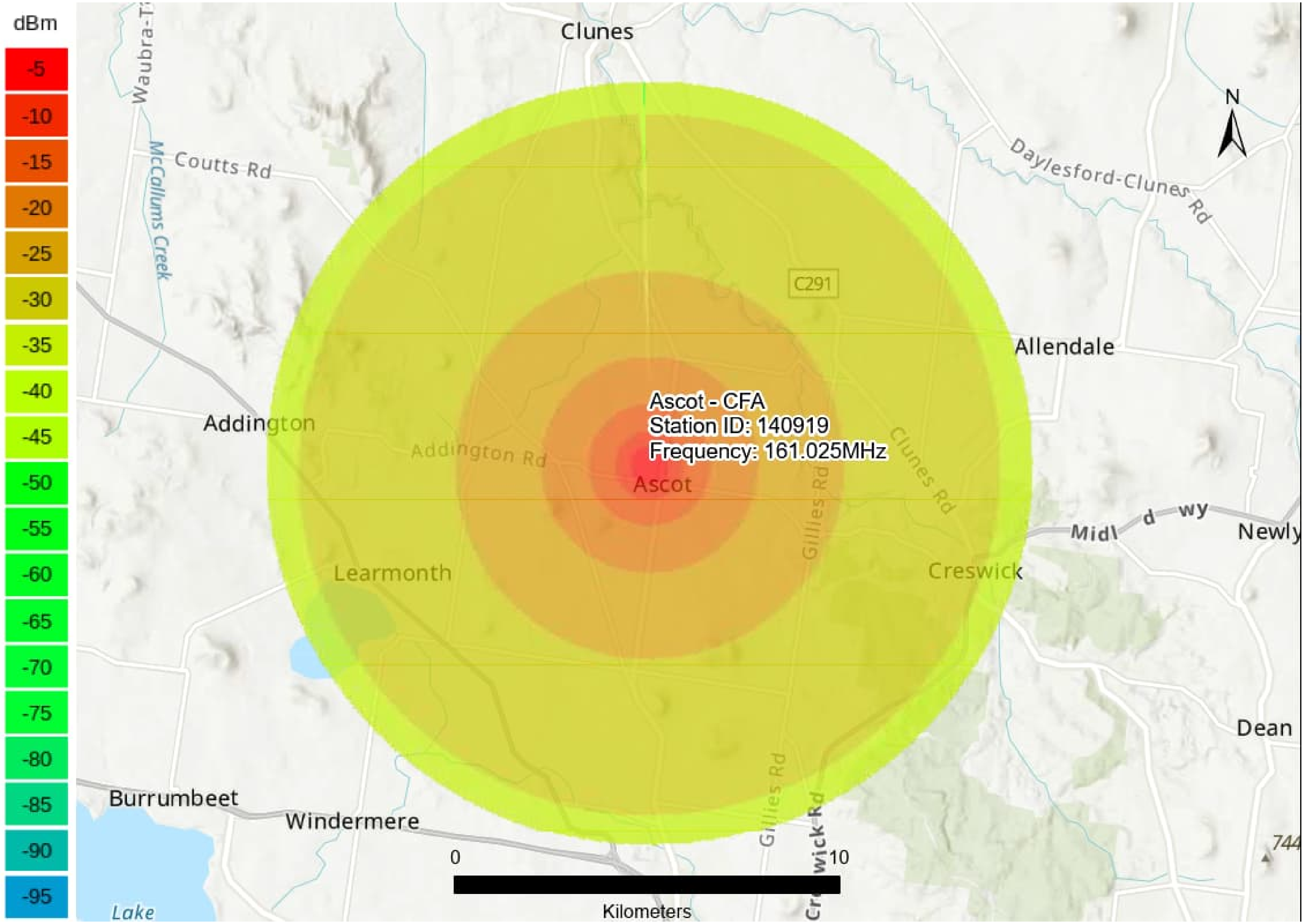

Figure G.27: CFA Ascot Broadcast Station 140919 (Source: Jacobs, 2022)

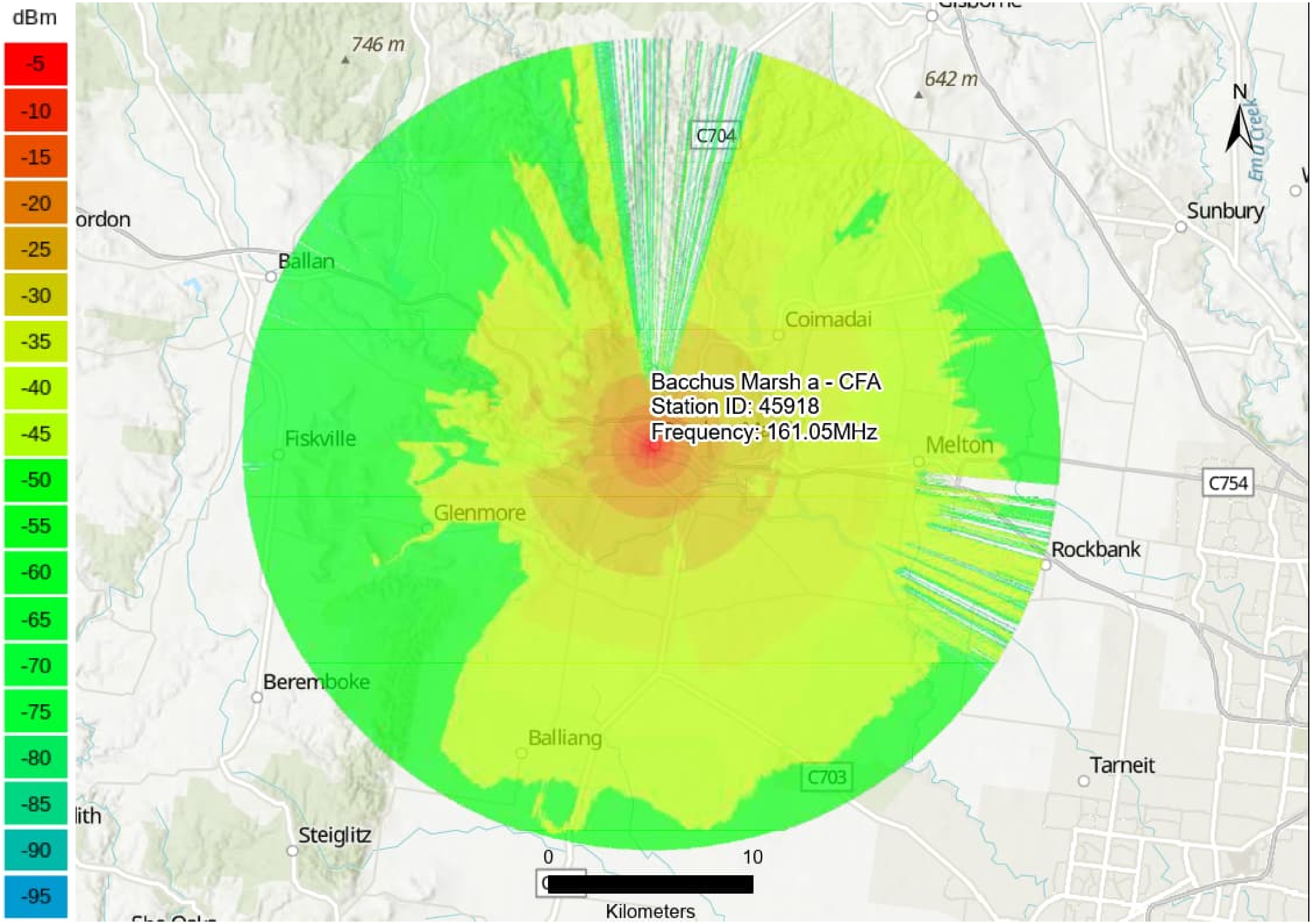

Figure G.28: CFA Bacchus Marsh Broadcast Station 45918 (Source: Jacobs, 2022)

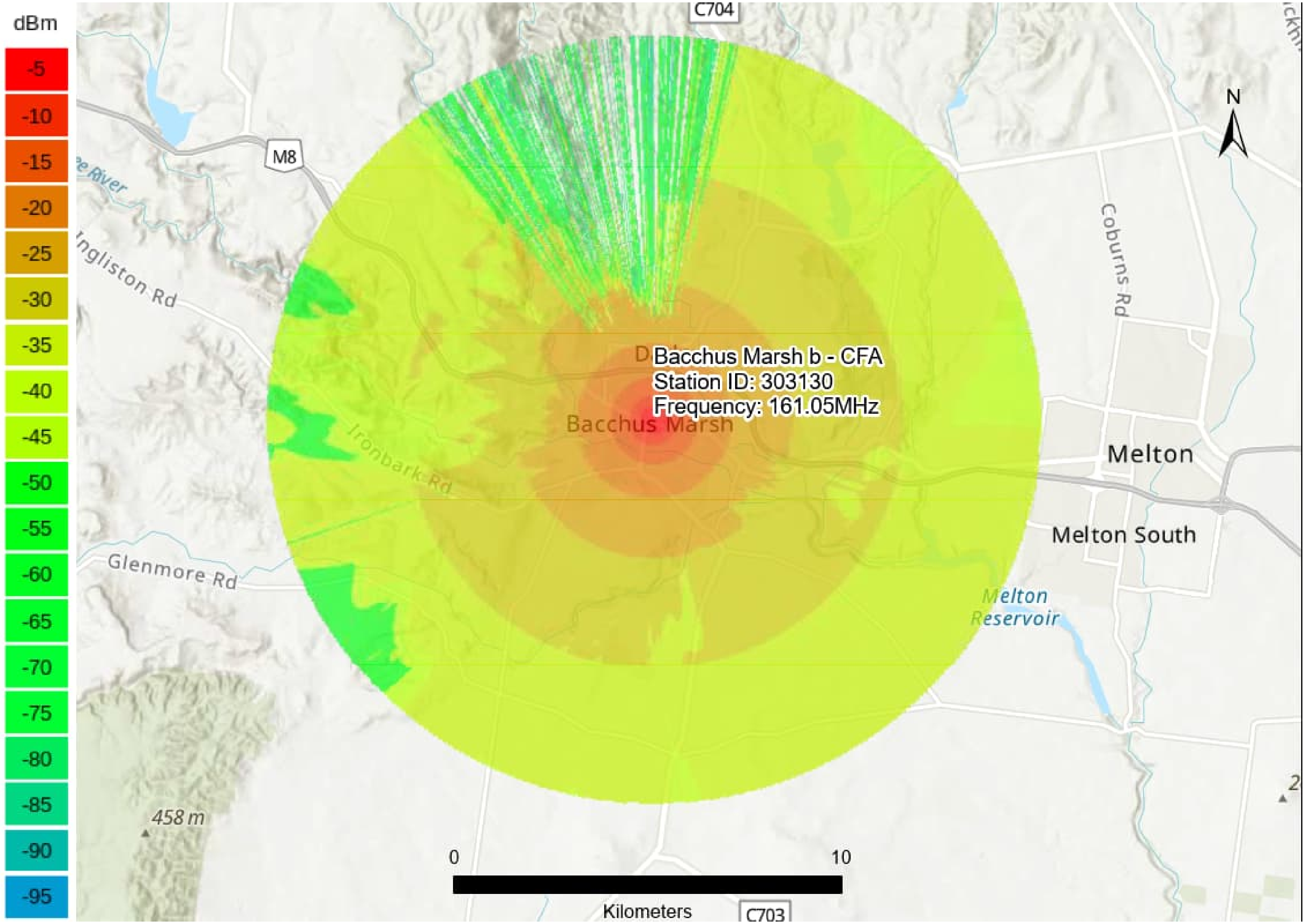

Figure G.29: CFA Bacchus Marsh Broadcast Station 303130 (Source: Jacobs, 2022)

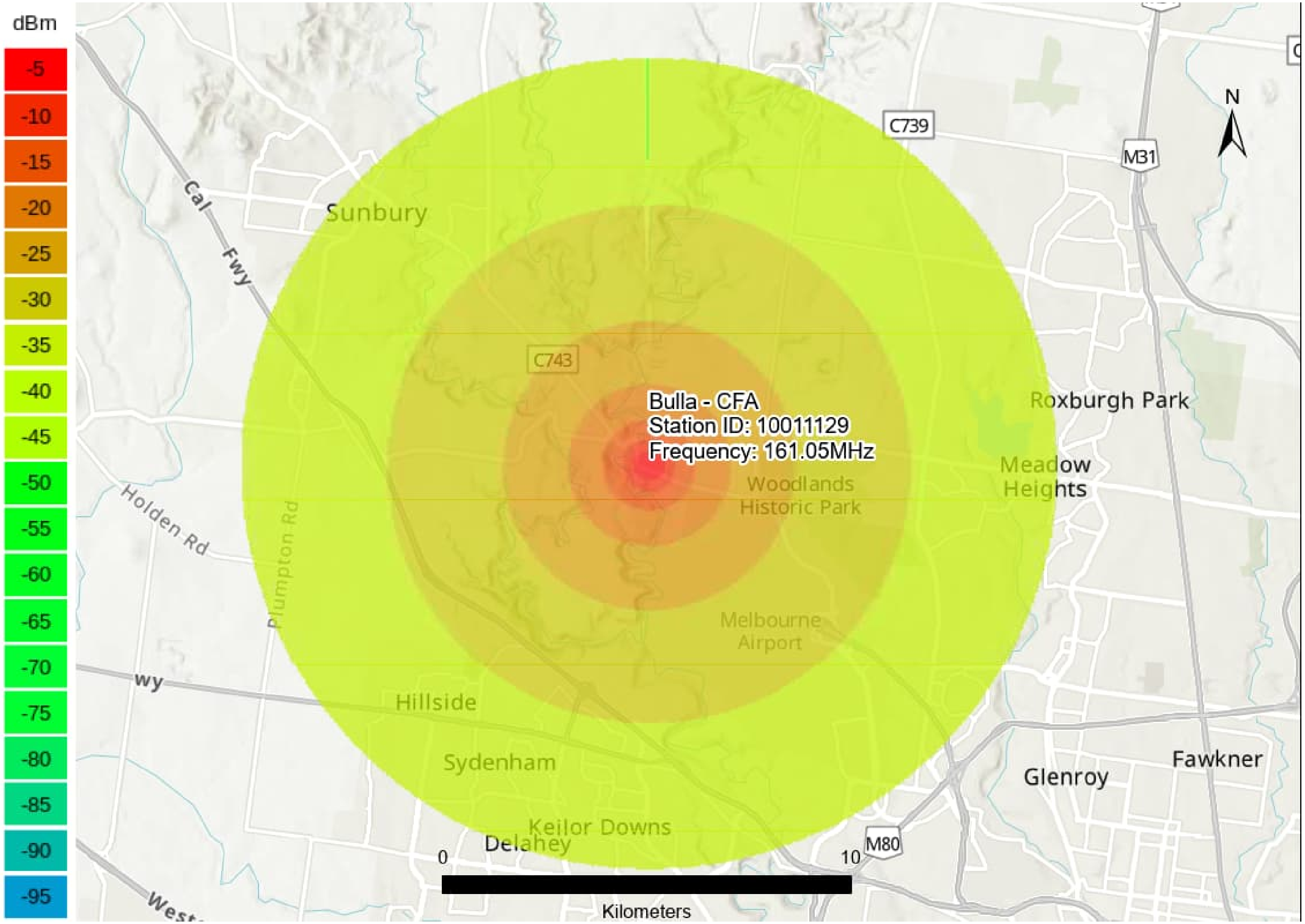

Figure G.30: CFA Bulla Broadcast station 10011129 (Source: Jacobs, 2022)

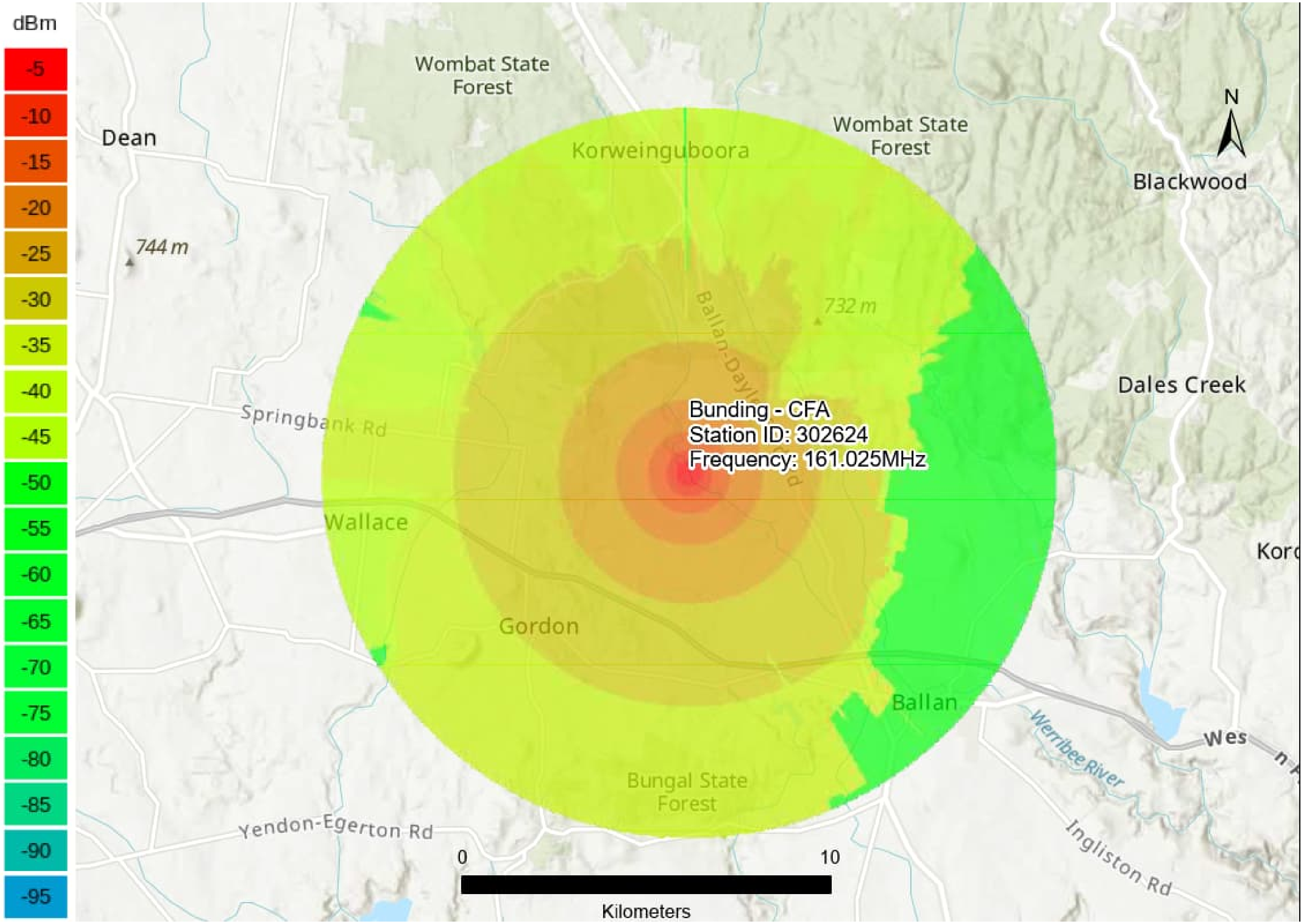

Figure G.31: CFA Bunding Broadcast Station 302624 (Source: Jacobs, 2022)

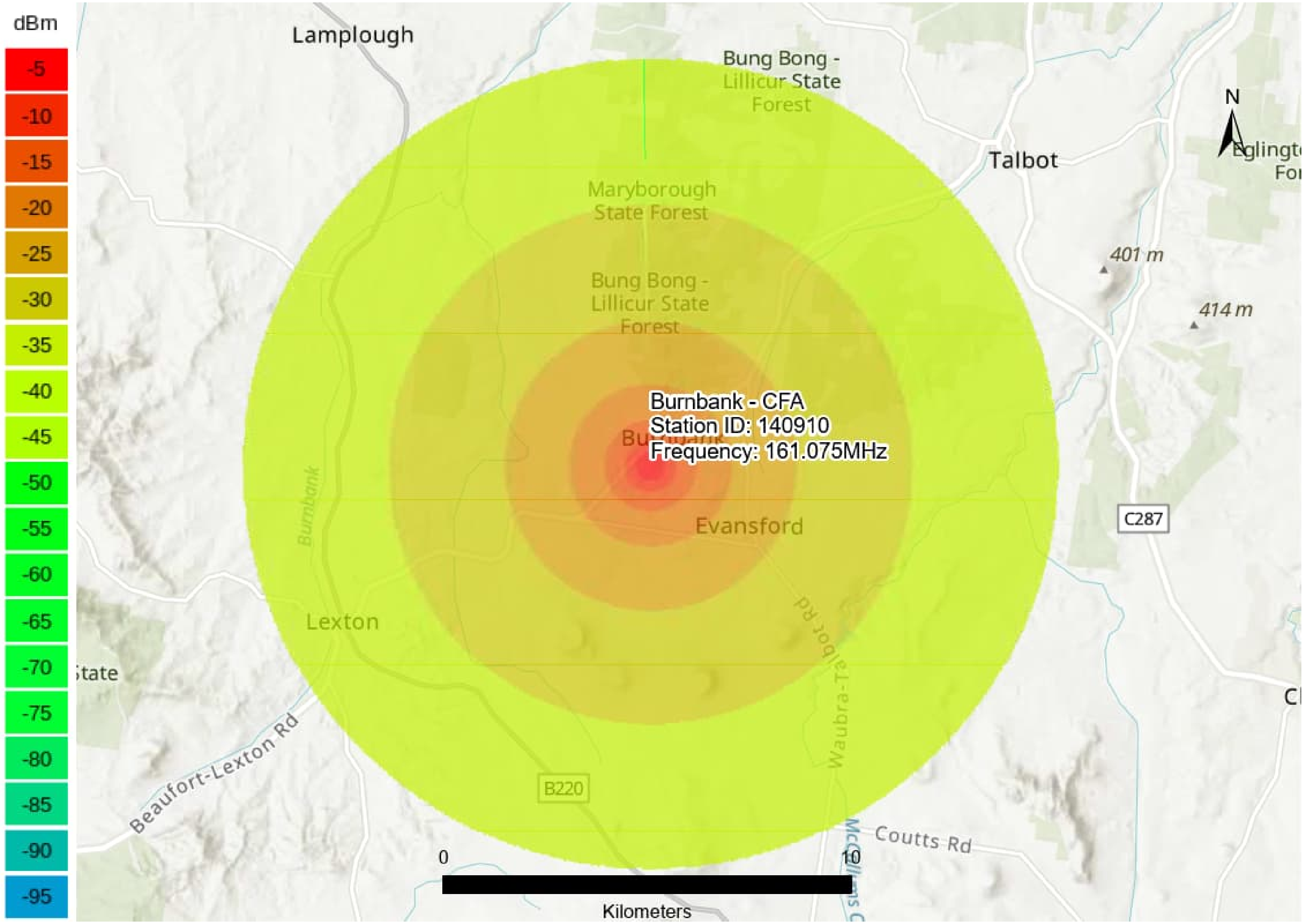

Figure G.32: CFA Burnbank Broadcast Station 140910 (Source: Jacobs, 2022)

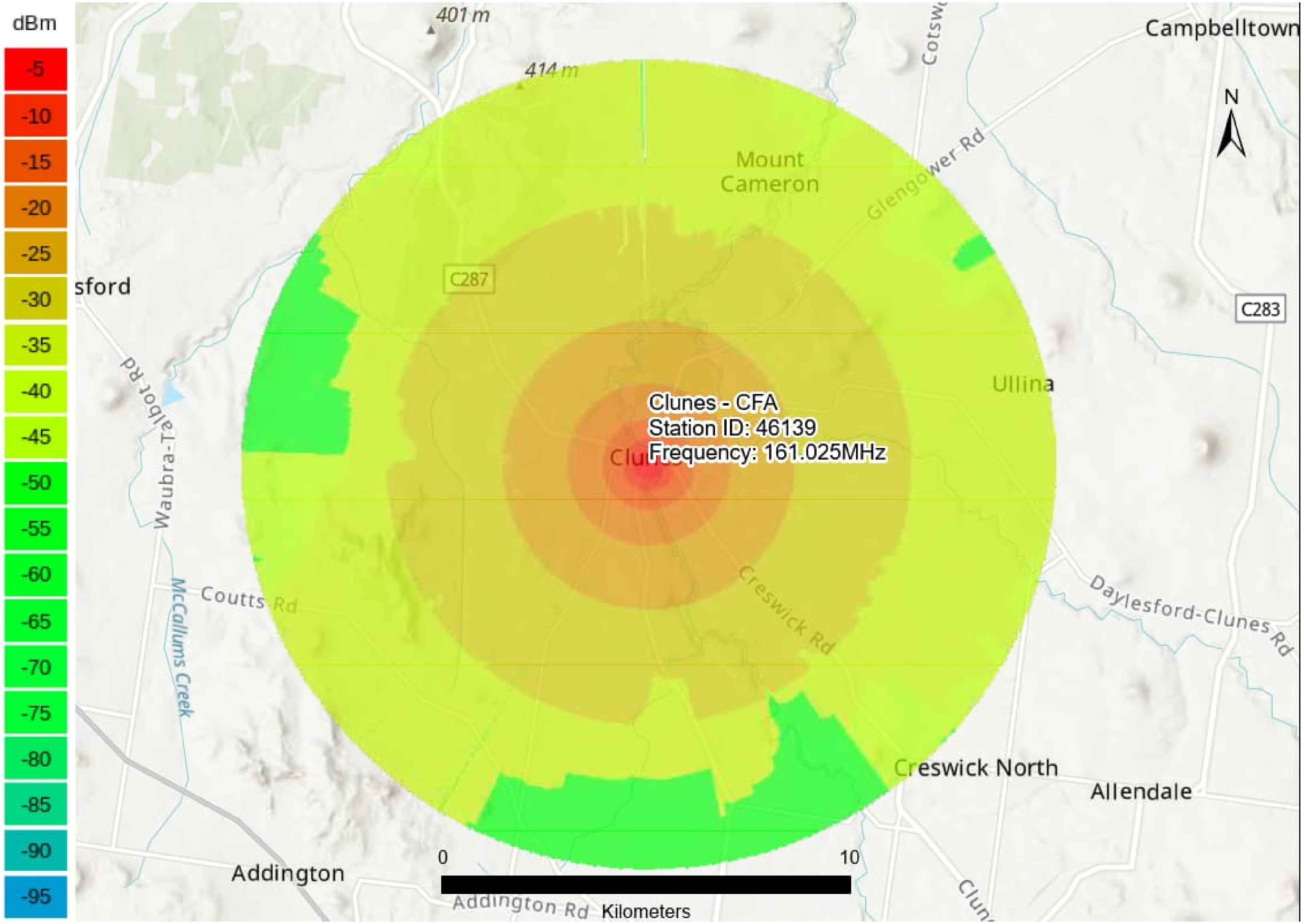

Figure G.33: CFA Clunes Broadcast Station 46139 (Source: Jacobs, 2022)

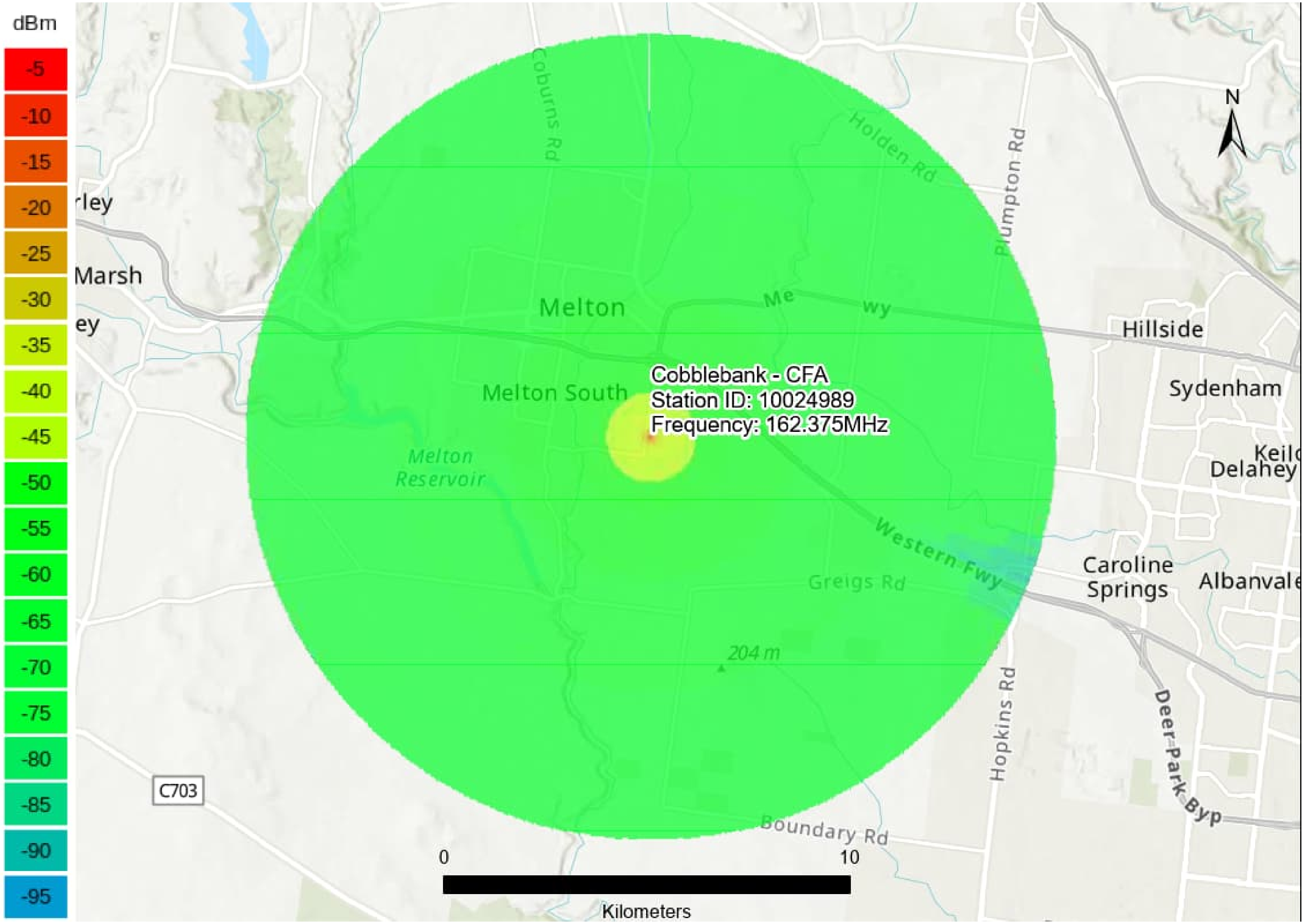

Figure G.34: CFA Cobblebank Broadcast Station 10024989 (Source: Jacobs, 2022)

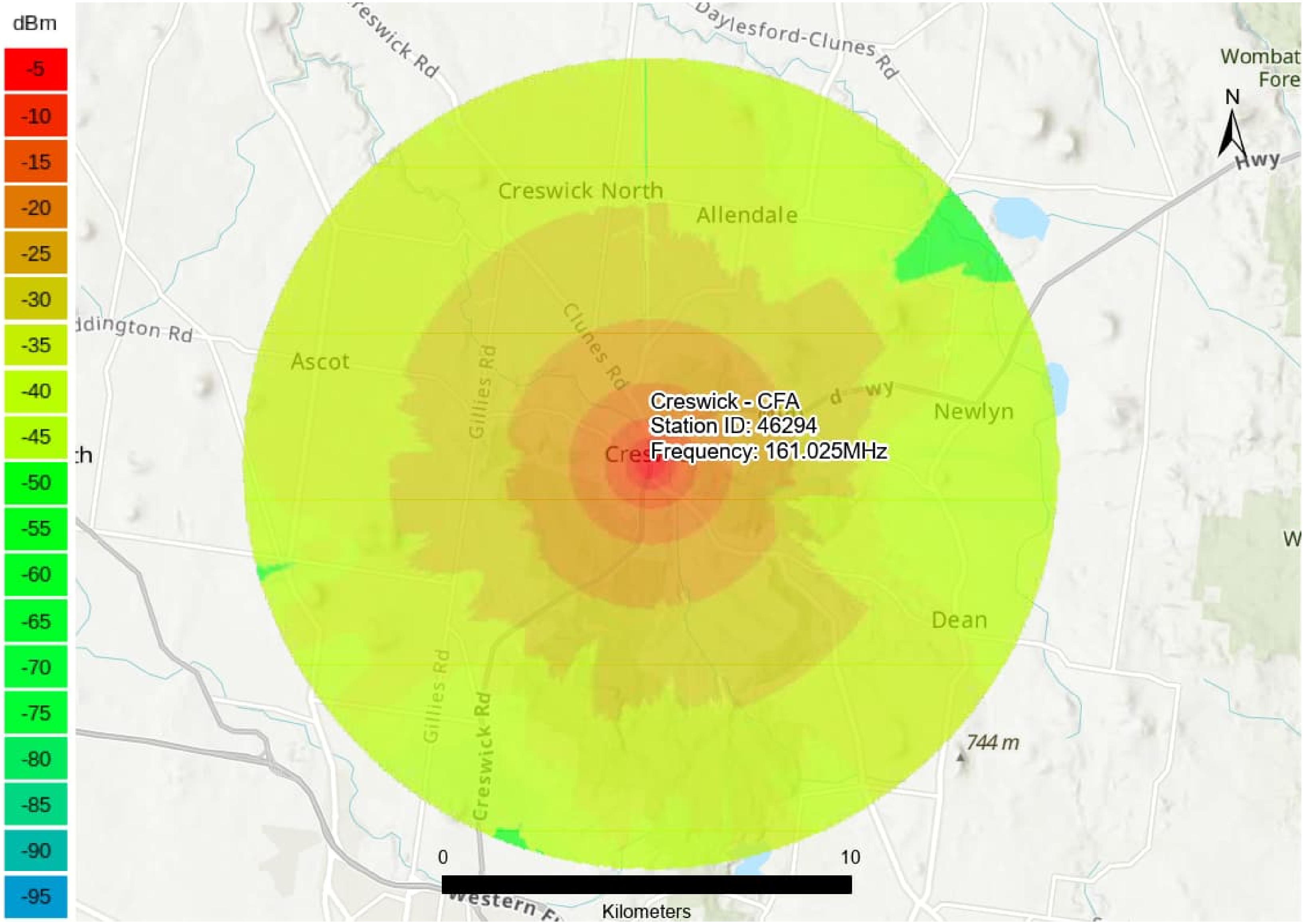

Figure G.35: CFA Creswick Broadcast Station 46294 (Source: Jacobs, 2022)

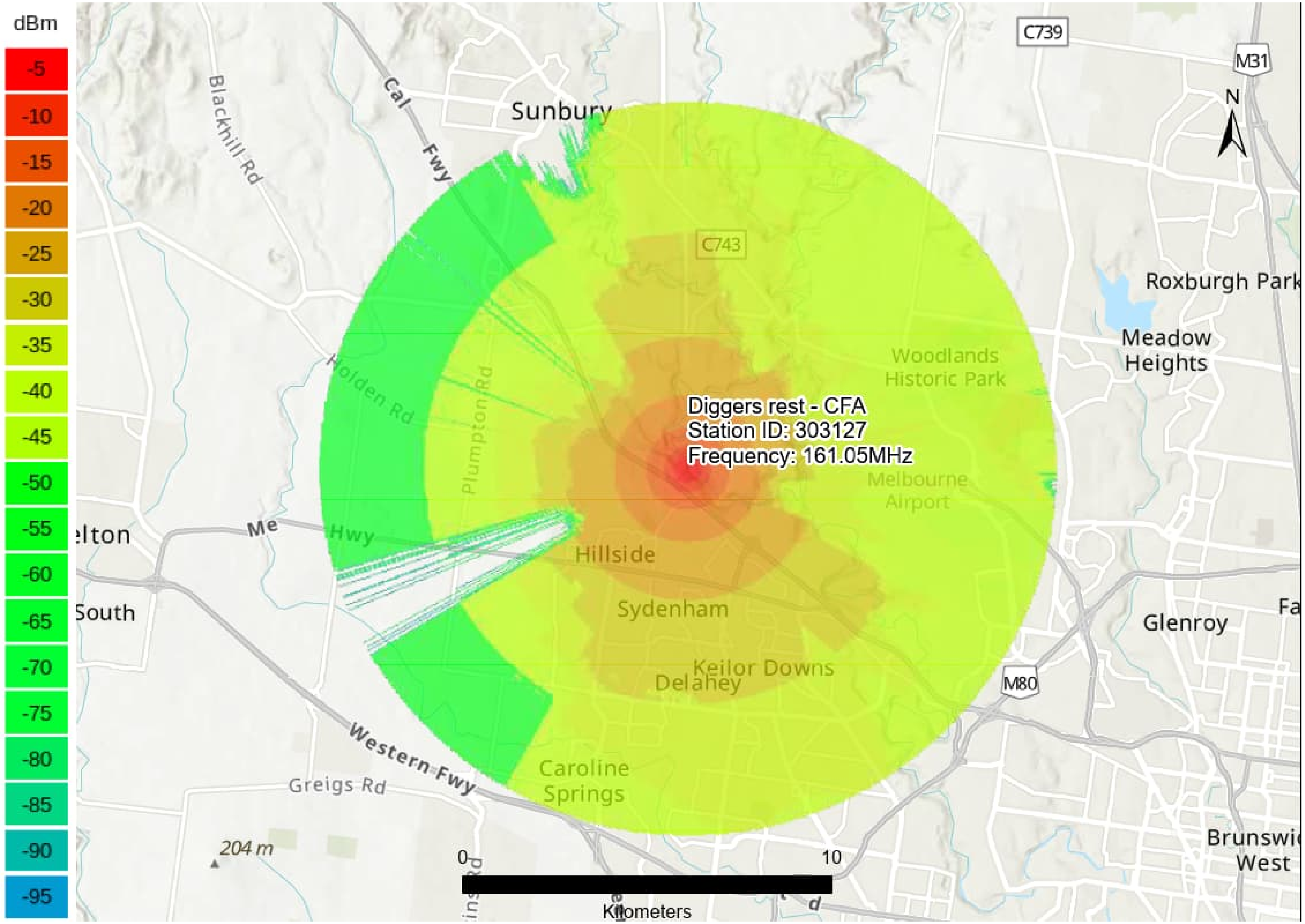

Figure G.36: CFA Diggers Rest Broadcast Station 303127 (Source: Jacobs, 2022)

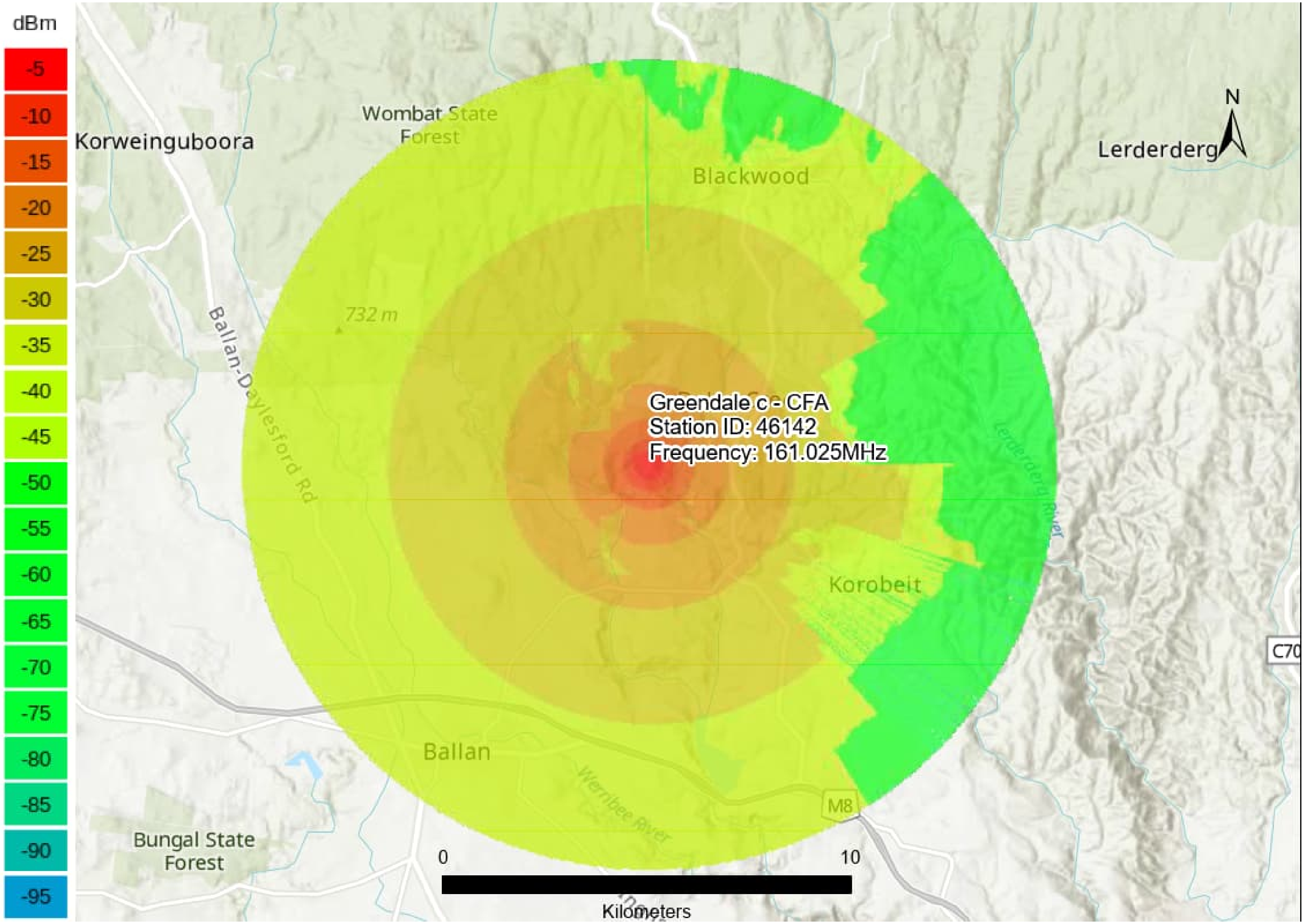

Figure G.37: CFA Greendale Broadcast Station 46142 (Source: Jacobs, 2022)

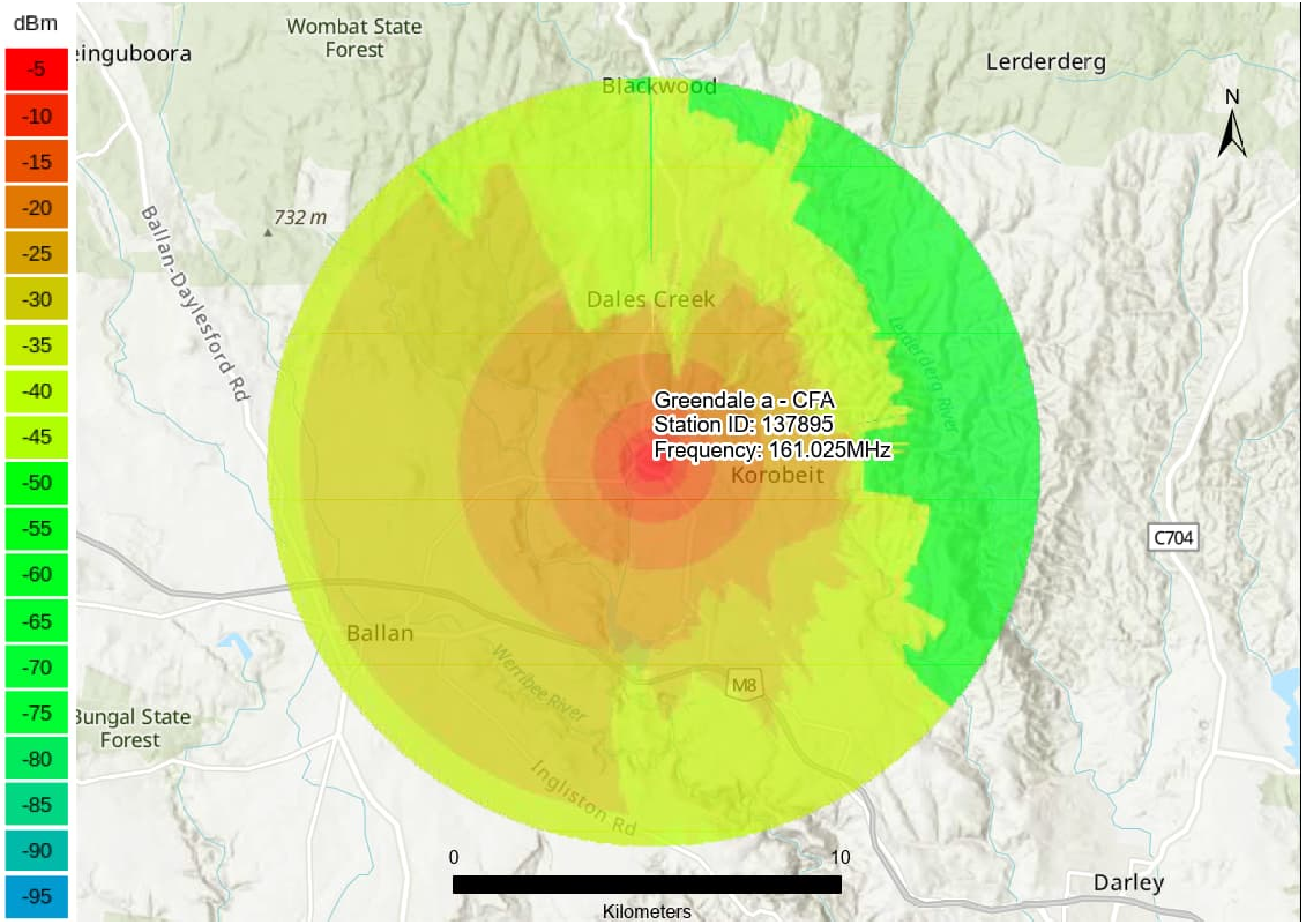

Figure G.38: CFA Greendale Broadcast Station 137895 (Source: Jacobs, 2022)

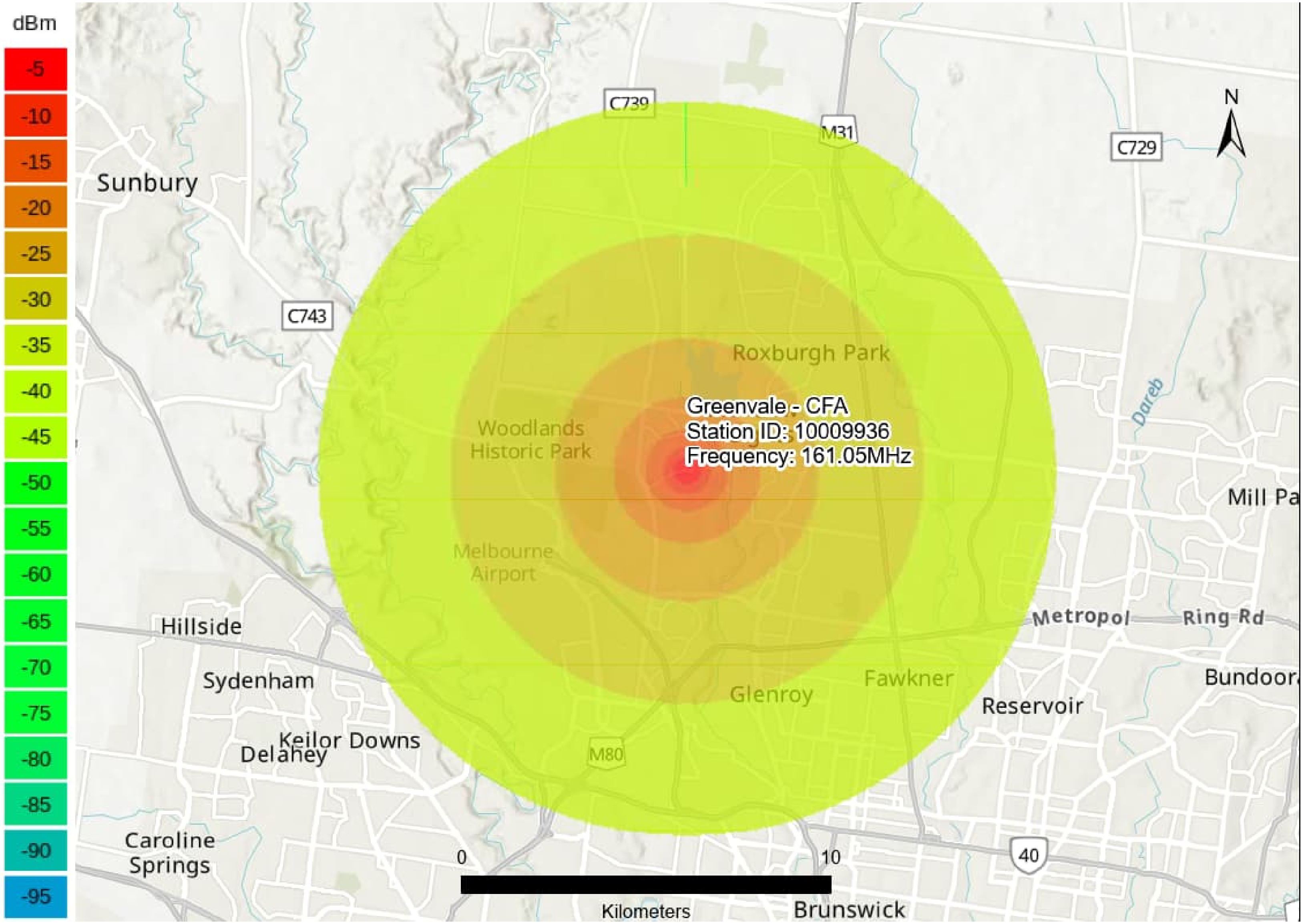

Figure G.39: CFA Greenvale Broadcast Station 10009936 (Source: Jacobs, 2022)

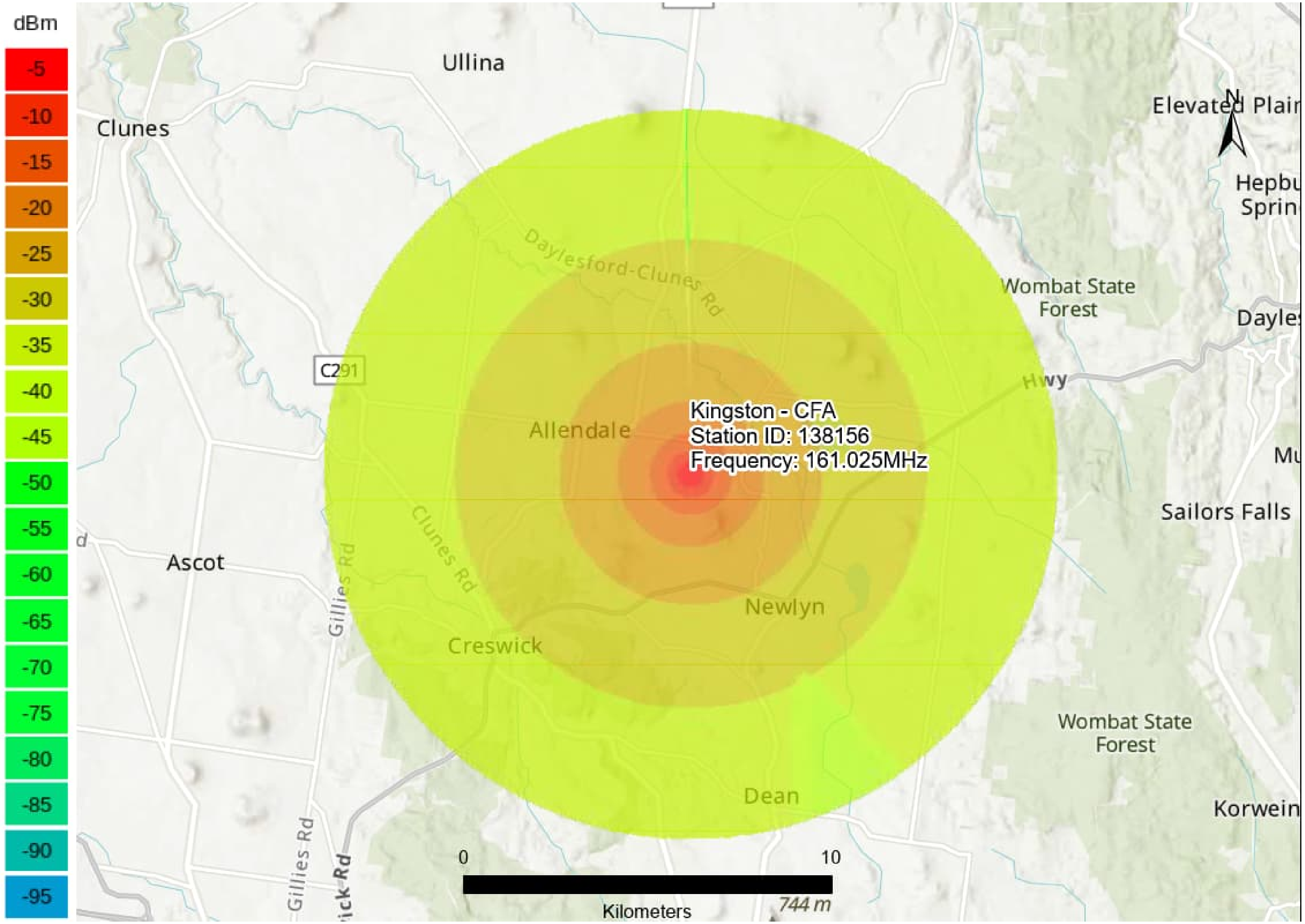

Figure G.40: CFA Kingston Broadcast Station 138156 (Source: Jacobs, 2022)

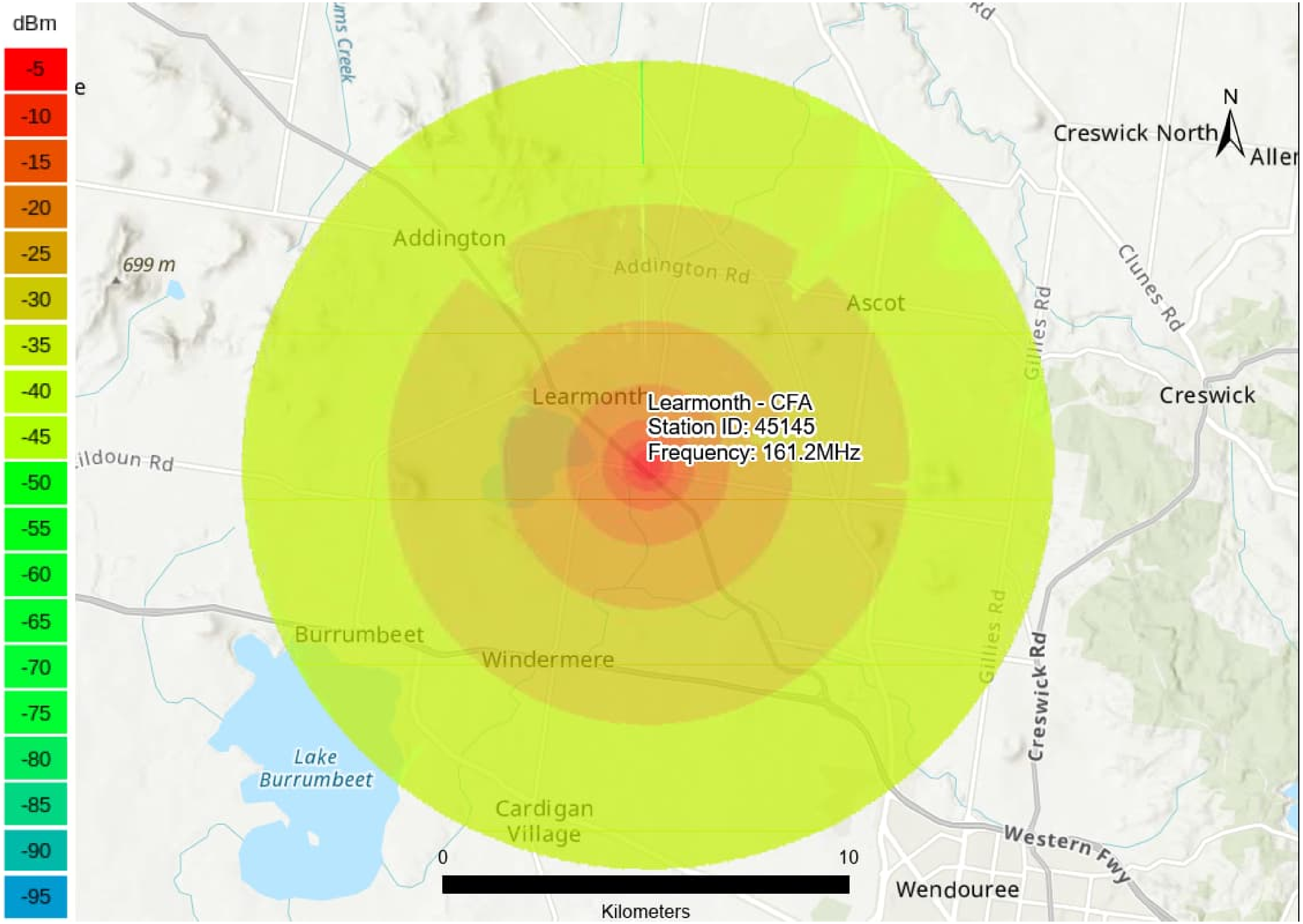

Figure G.41: CFA Learmonth Broadcast Station 45145 (Source: Jacobs, 2022)

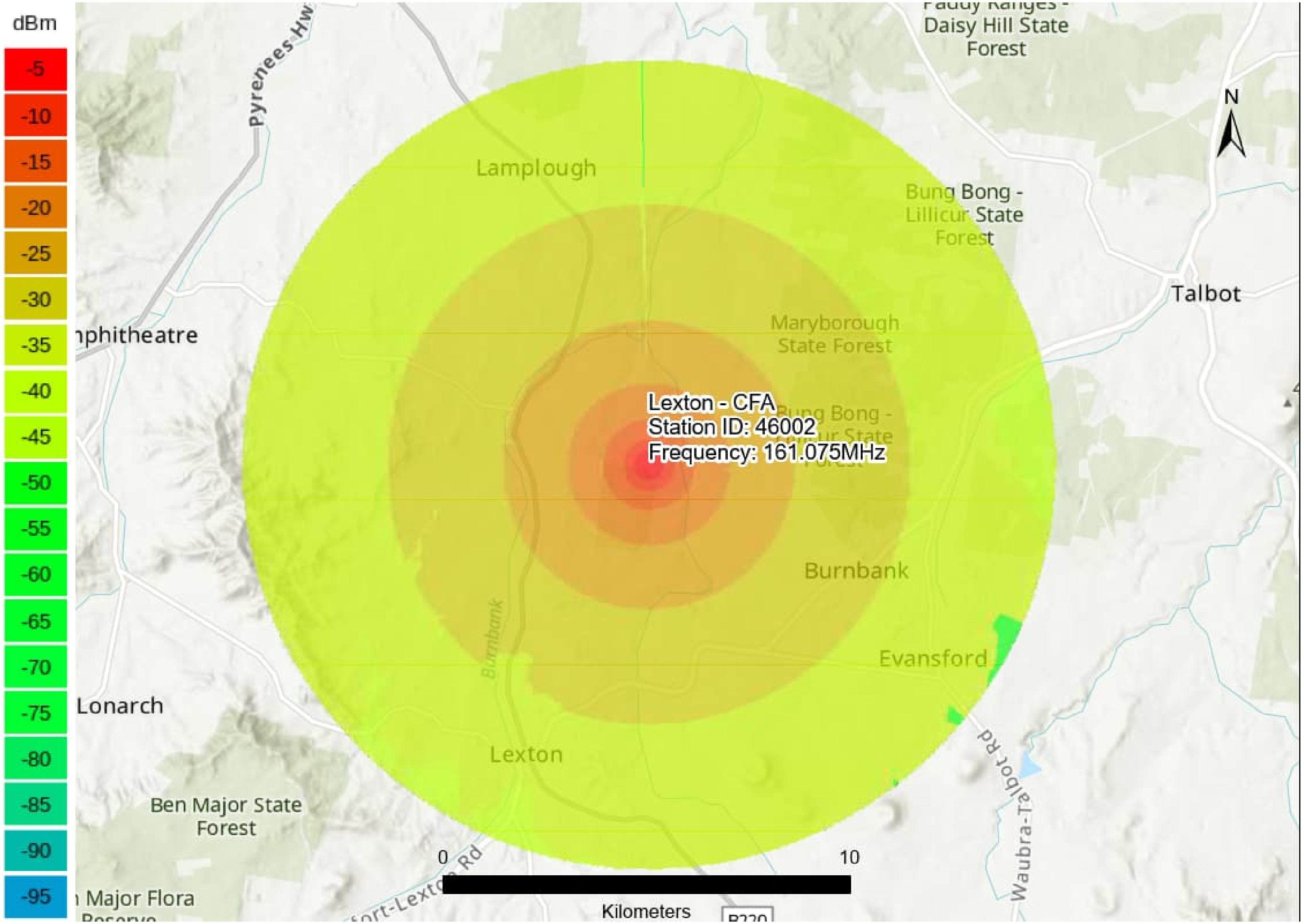

Figure G.42: CFA Lexton Broadcast Station 46002 (Source: Jacobs, 2022)

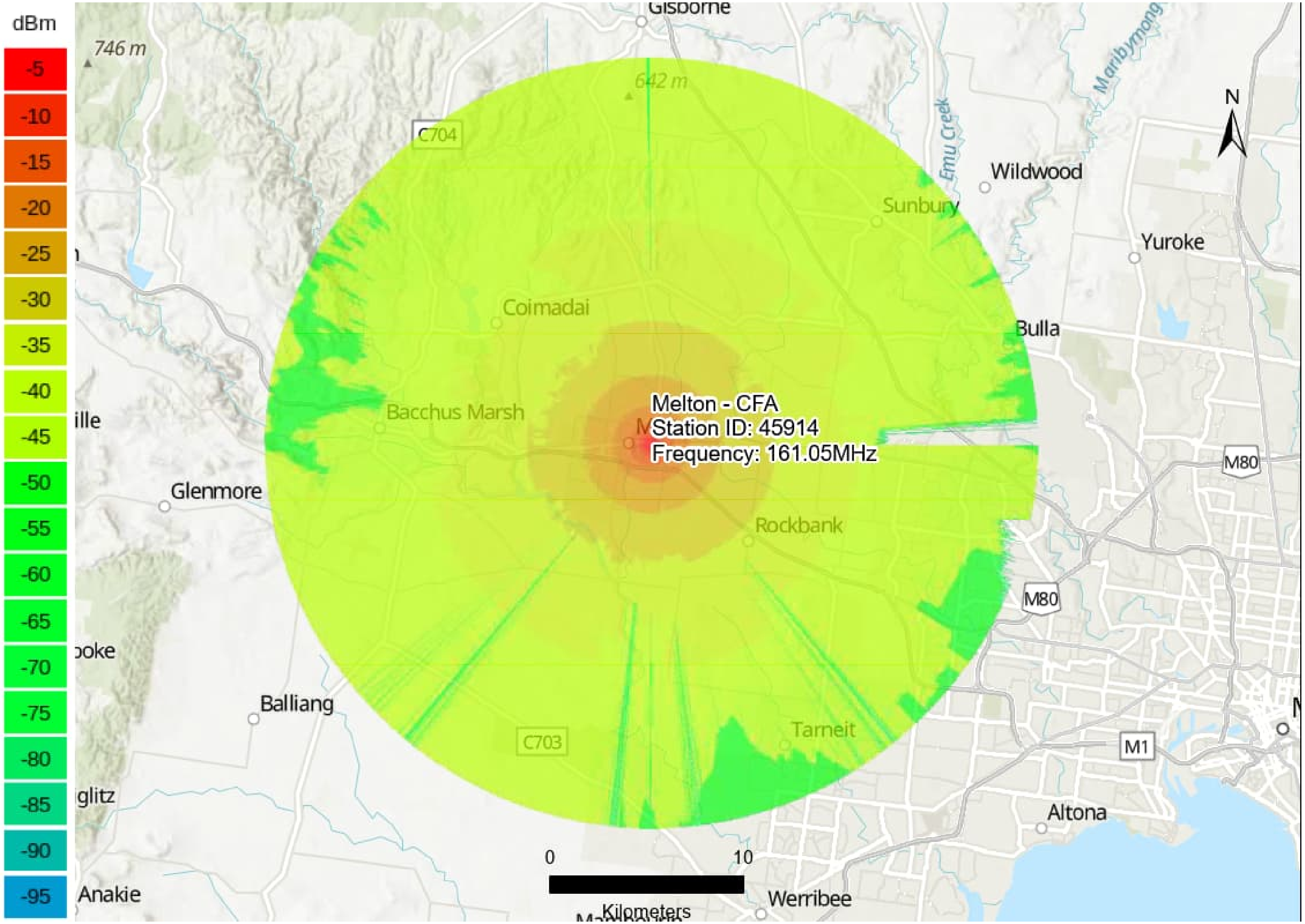

Figure G.43: CFA Melton Broadcast Station 45914 (Source: Jacobs, 2022)

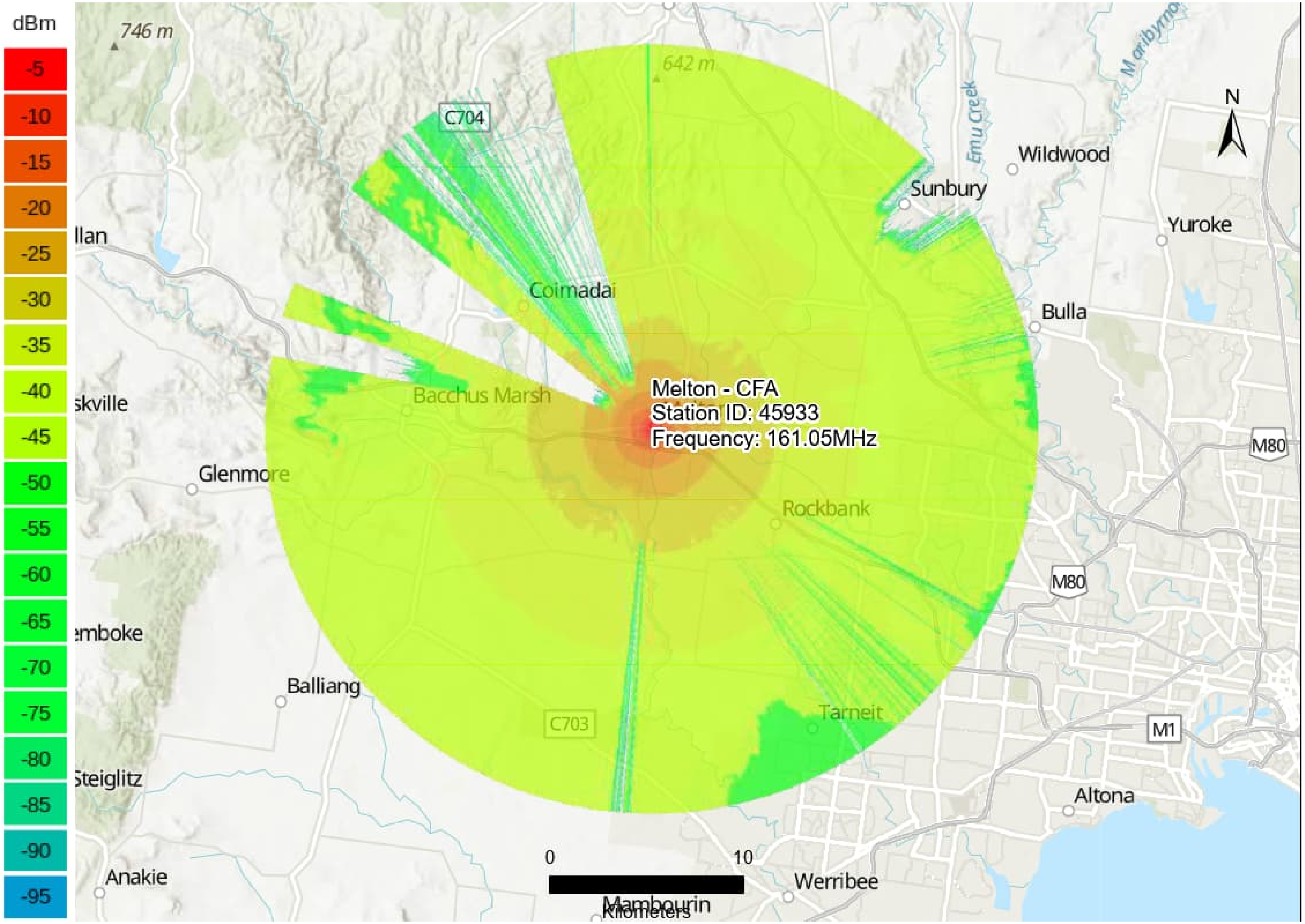

Figure G.44: CFA Melton Broadcast Station 45933 (Source: Jacobs, 2022)

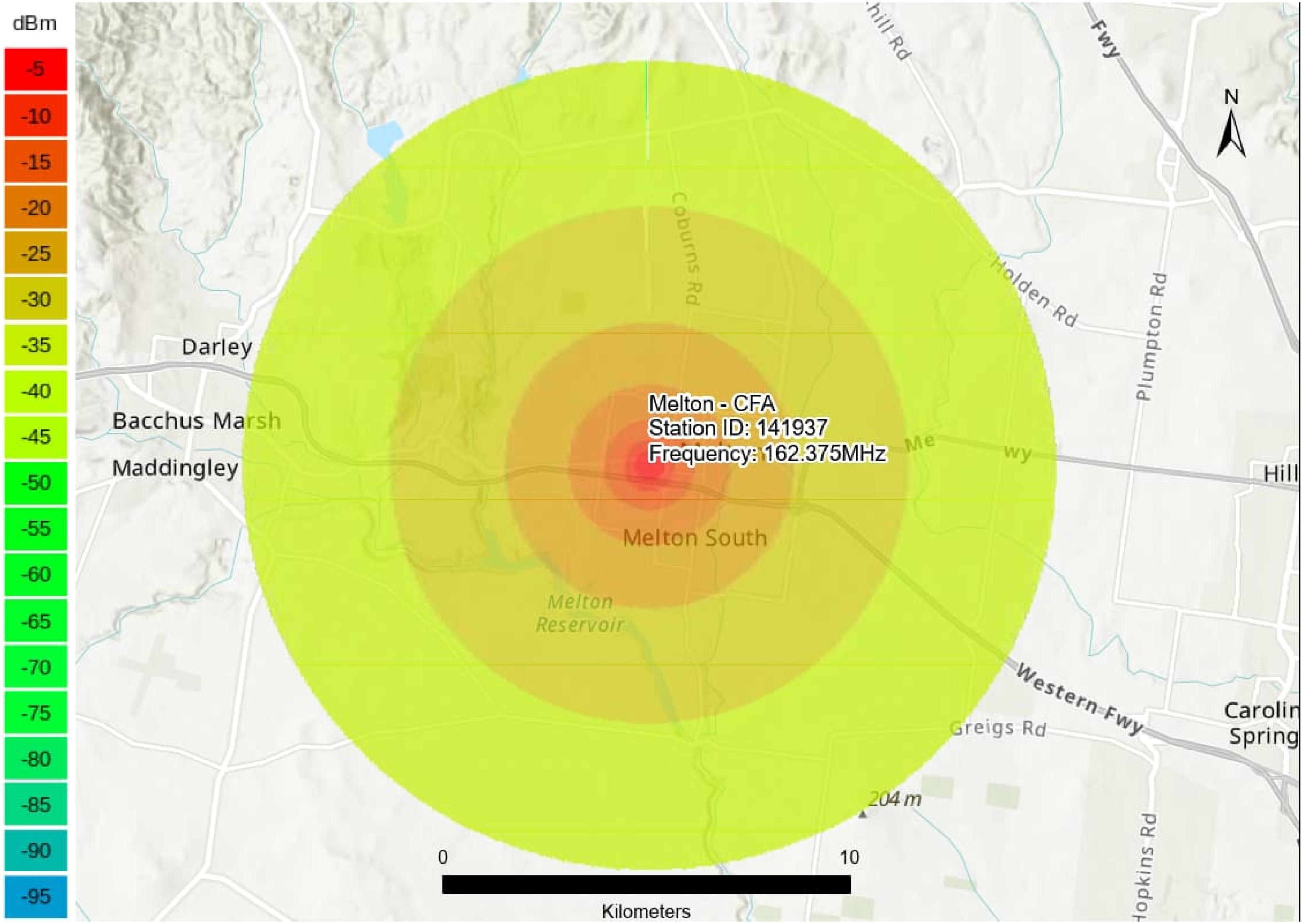

Figure G.45: CFA Melton Broadcast Station 141937 (Source: Jacobs, 2022)

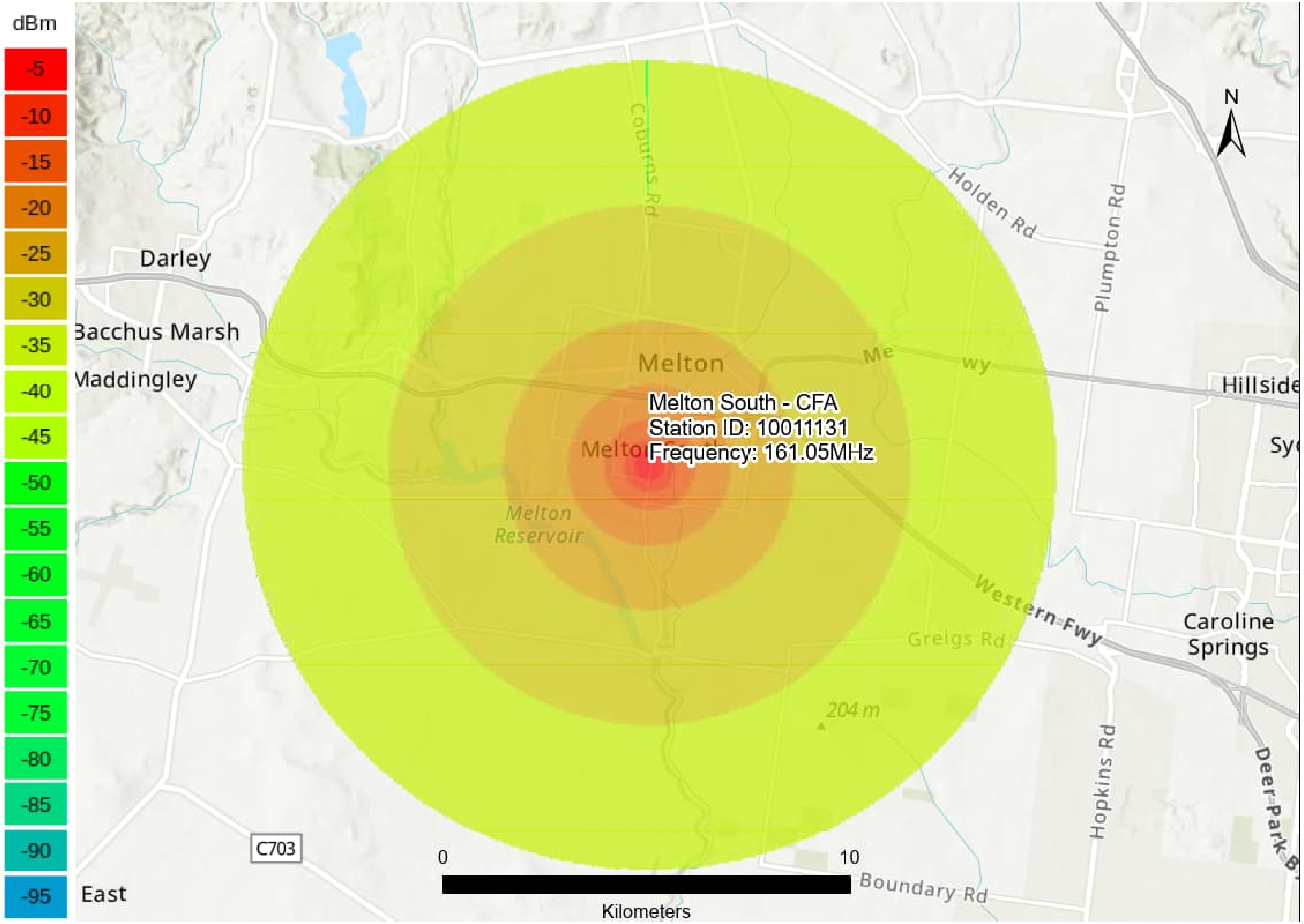

Figure G.46: CFA Melton South Broadcast Station 10011131 (Source: Jacobs, 2022)

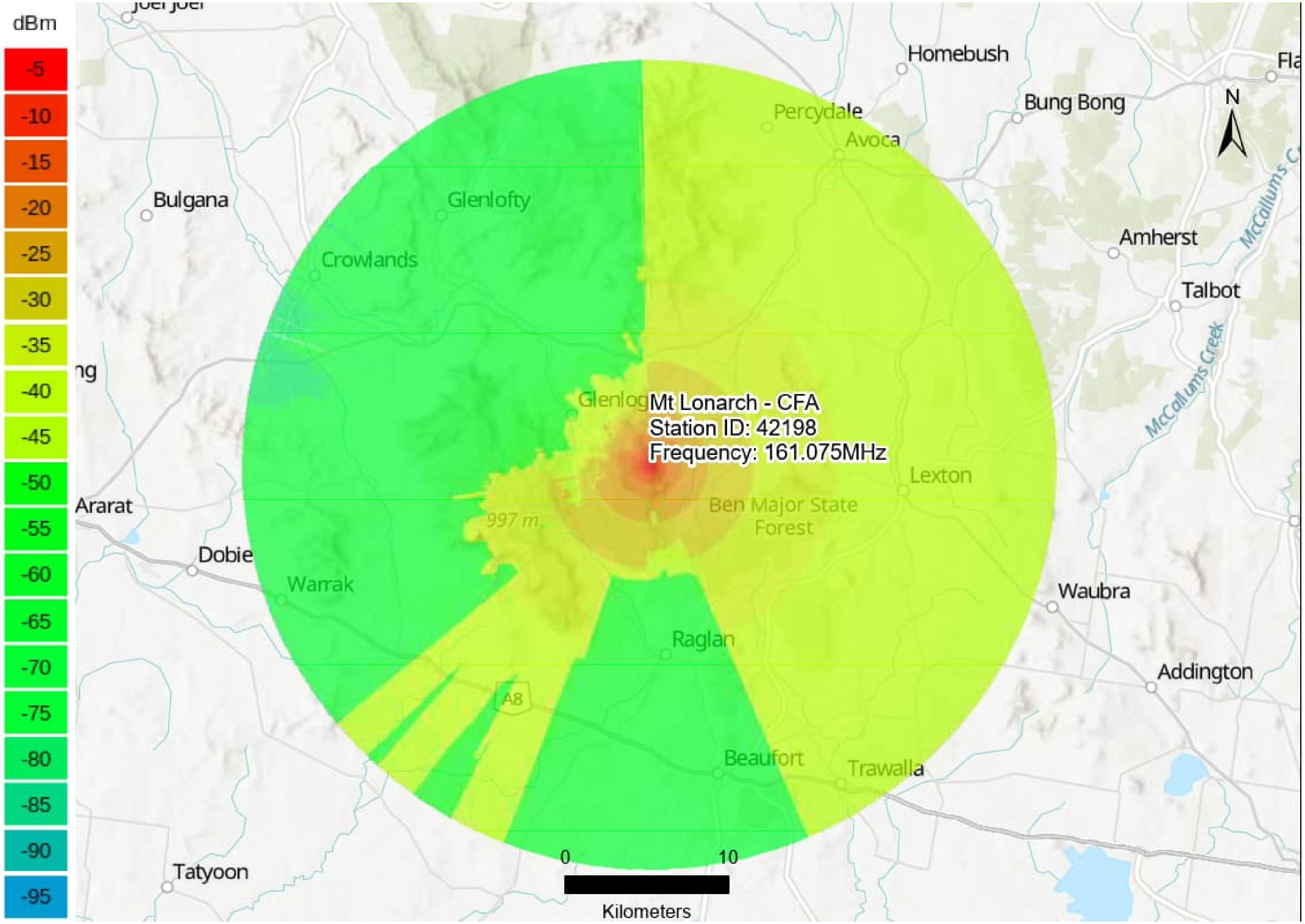

Figure G.47: CFA Mt Lonarch Broadcast Station 42198 (Source: Jacobs, 2022)

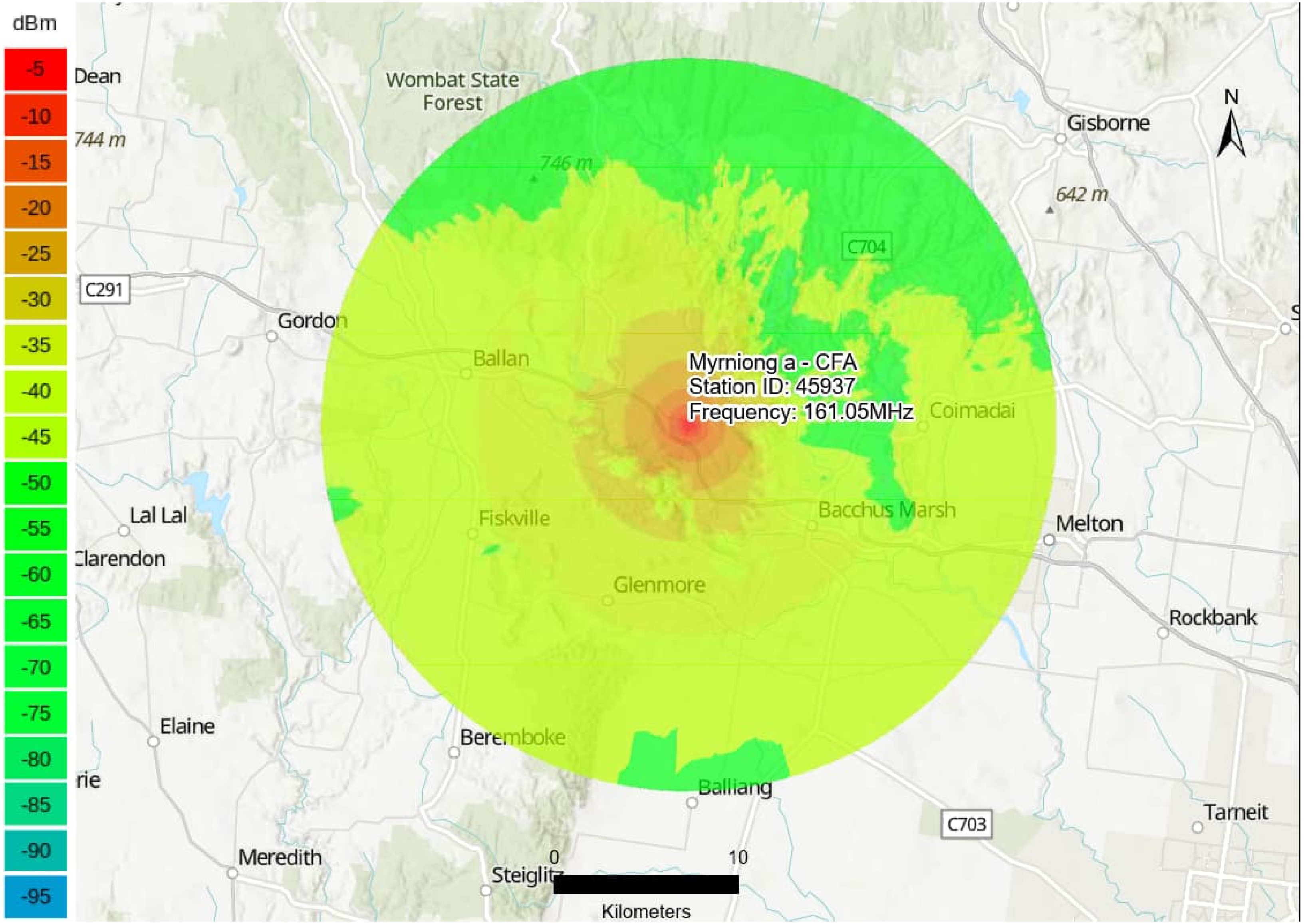

Figure G.48: CFA Myrniong Broadcast Station 45937 (Source: Jacobs, 2022)

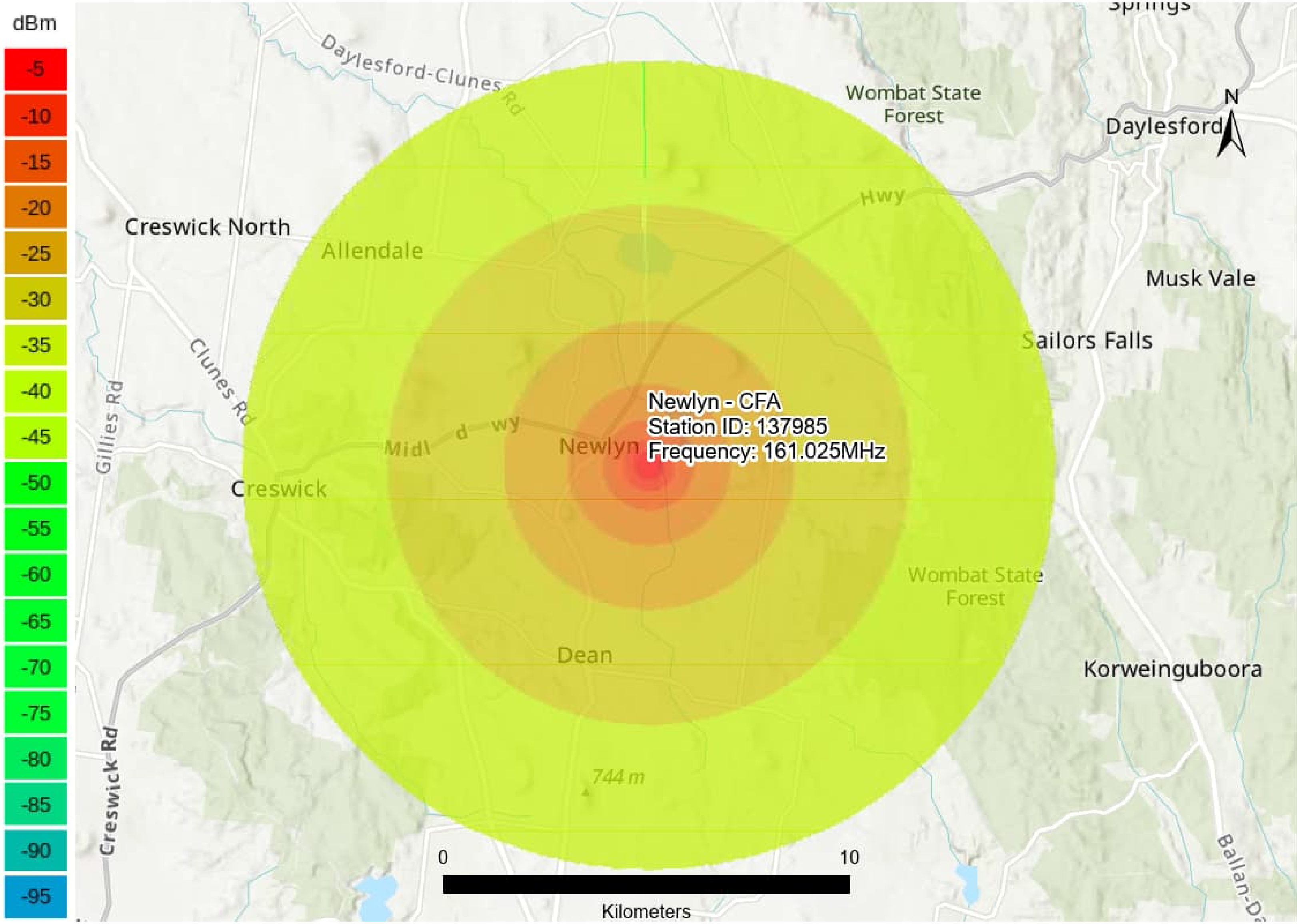

Figure G.49: CFA Newlyn Broadcast Station 137985 (Source: Jacobs, 2022)

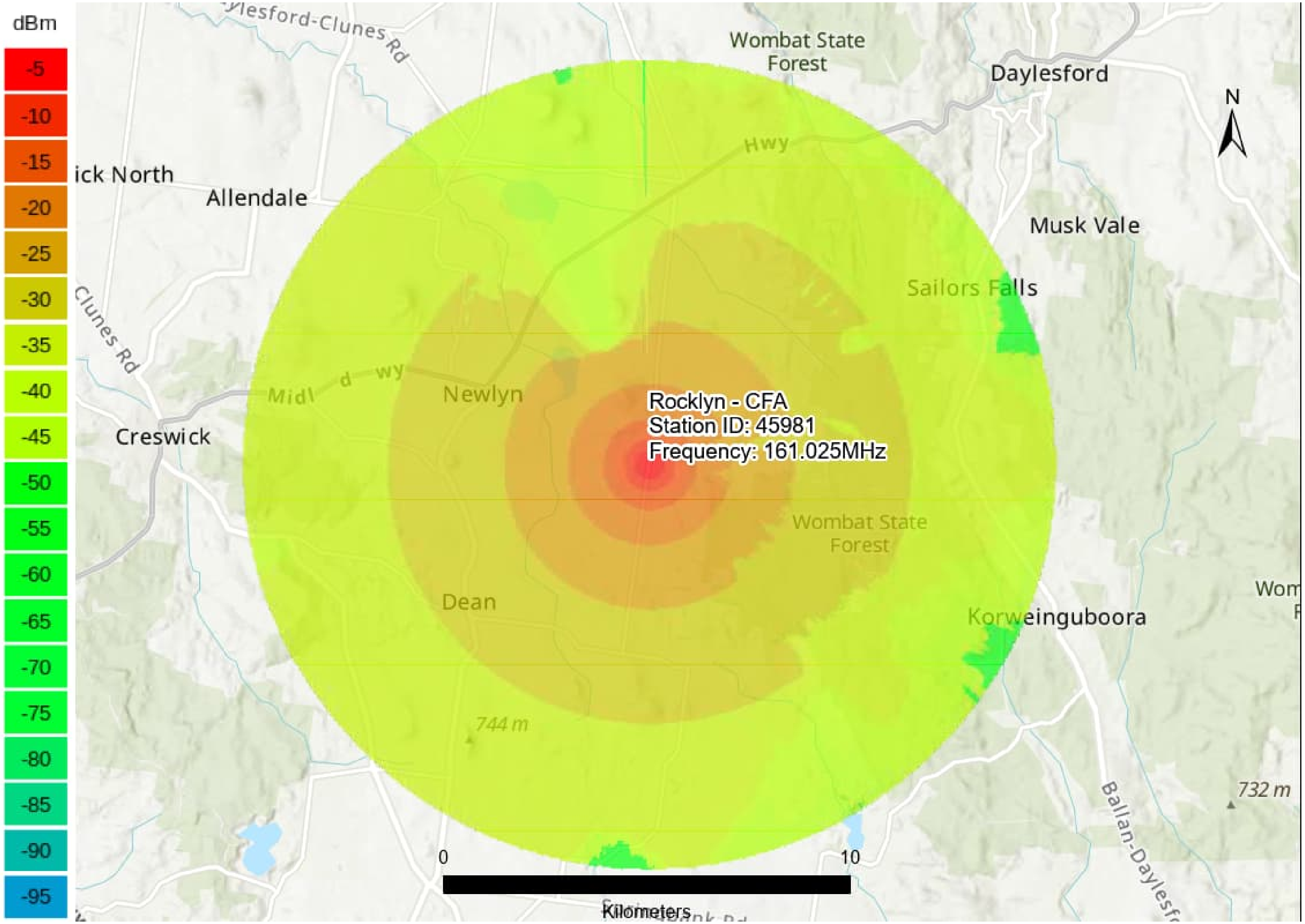

Figure G.50: CFA Rocklyn Broadcast Station 45981 (Source: Jacobs, 2022)

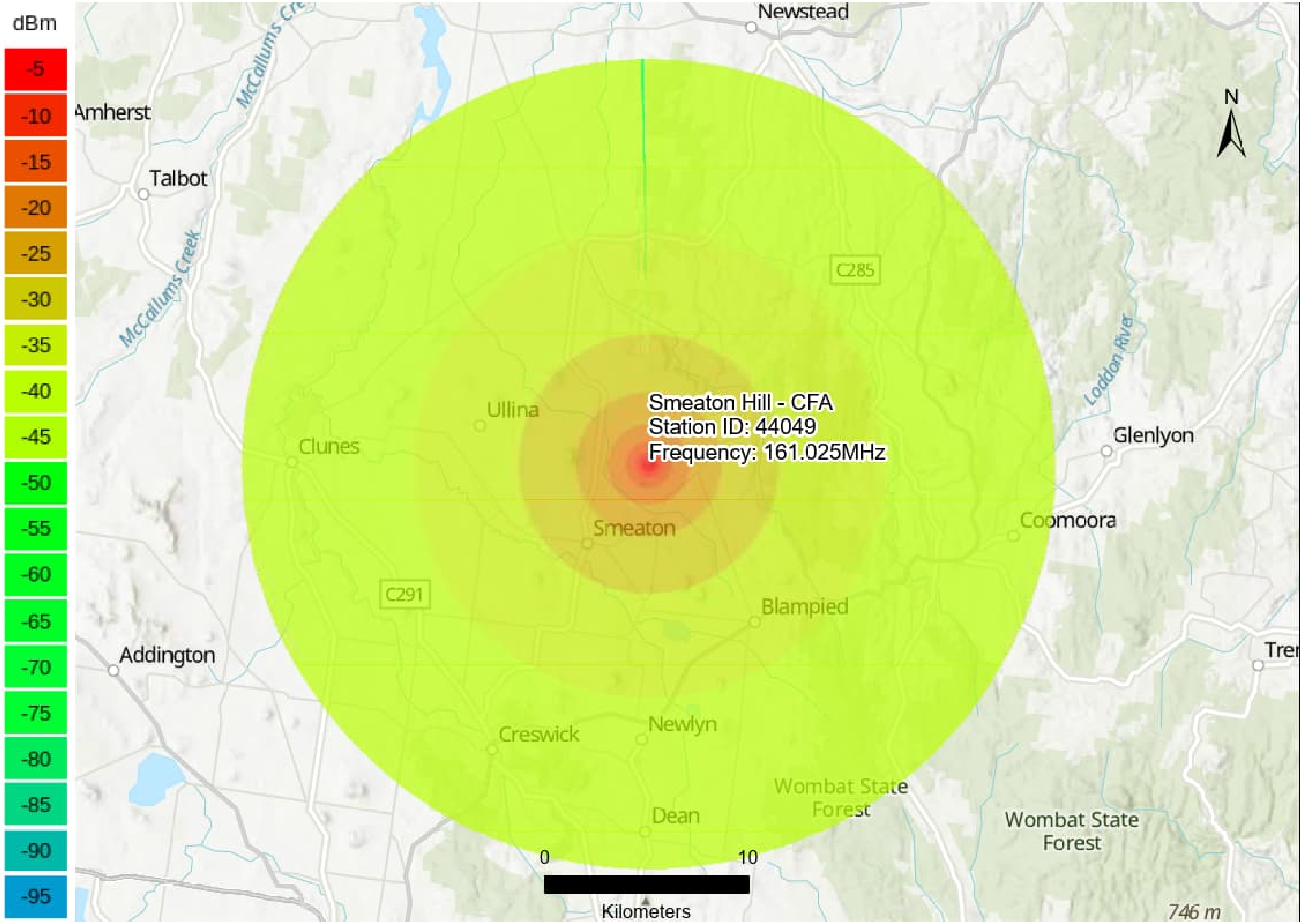

Figure G.51: CFA Smeaton Hill Broadcast Station 44049 (Source: Jacobs, 2022)

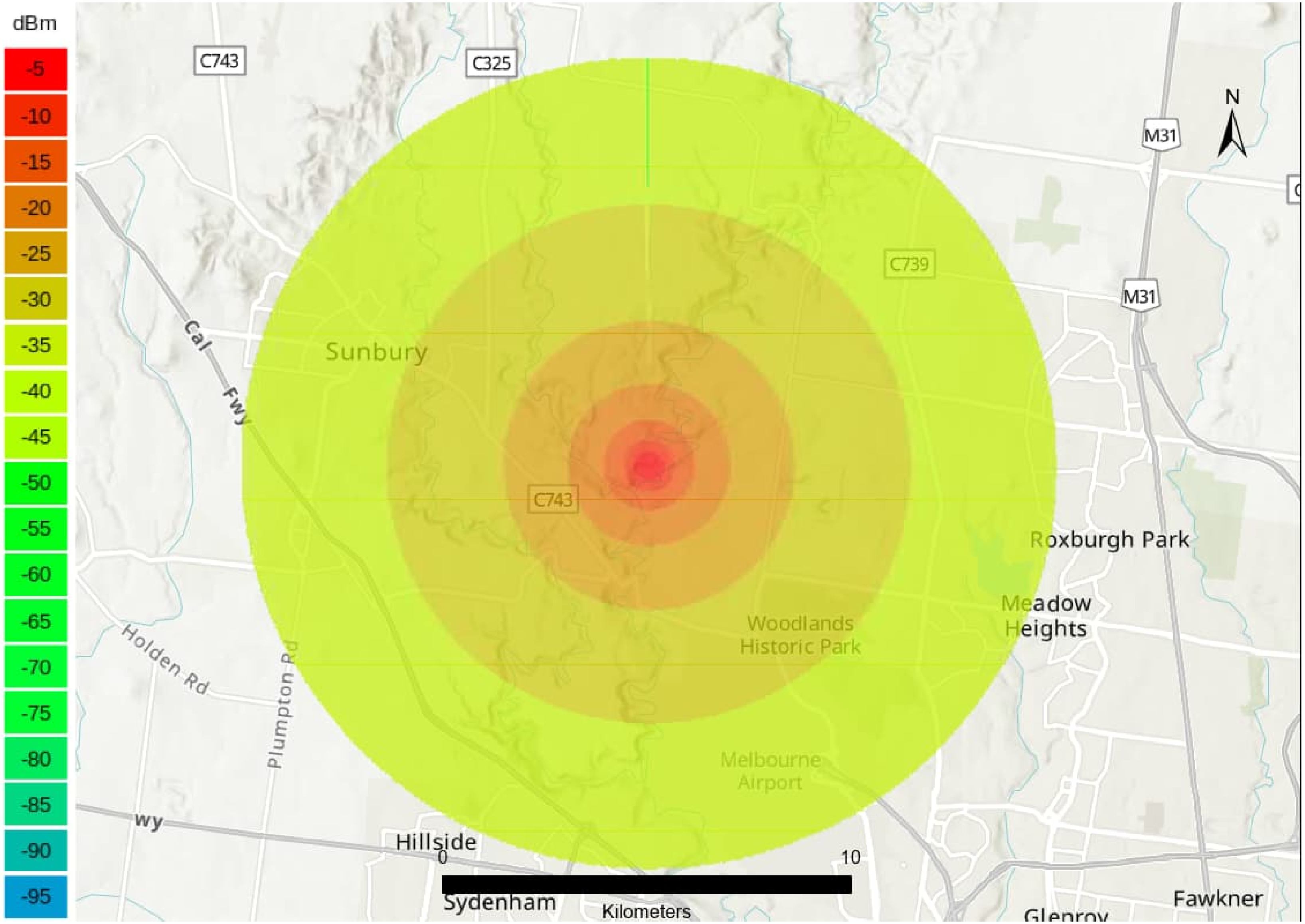

Figure G.52: CFA Toolern Vale Broadcast Station 10011130 (Source: Jacobs, 2022

Appendix H. Referenced Papers

EMF Scientific

AN ELECTRIC FIELD LIMIT FOR THE WESTERN RENEWABLES LINK

by
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EMF Scientific Ltd

12 November 2023

EMF Scientific

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Contents

1 INTRODUCTION

When designing a power line one of the factors that has to be considered is the production of electric and magnetic fields in the vicinity of the power line where the general public have access.

The Western Renewables Link project in Victoria comprises the construction of a new 500 kV double circuit overhead transmission line from Bulgana in western Victoria to Sydenham in Melbourne's north-west. This report has been prepared to give advice on the applicable electric field limit for the project.

The strength of the electric field in the vicinity of a power line depends on the geometrical details of the overhead line conductors and the voltages on those conductors when they are energised.

The design of the line, in particular the minimum ground clearance of the conductors, ensures that the maximum values of the electric and magnetic field are below the limits set by the guidelines provided in 2010 by the applicable body, the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

Section 2 describes the background to using the ICNIRP 2010 guidance, and the Basic Restrictions and Reference Levels established in those guidelines are presented.

For magnetic fields in the vicinity of the power line, the fields are consistently lower than the Reference Levels set by ICNIRP for general public exposure so there is no need to apply the Basic Restrictions for assessing compliance.

However, for electric fields, in some situations in the vicinity of the power line, the field can exceed the Reference Level. The purpose of this report is to provide advice on a suitable electric field limit to use to ensure compliance with the guidelines where the electric field exceeds the electric field Reference Level, and this is explored in Sections 3 and 4.

The findings are discussed, and conclusions are drawn in Section 5.

References here to electric field are always to the unperturbed electric field. That is the electric field in the absence of the person whose exposure is being considered. Exposure limits are set, and assessments performed, for the unperturbed field.

Furthermore, it is assumed that the unperturbed electric field under the line in the space occupied by people under the line is uniform in that it does not vary significantly with height over that region.

2 EMF GUIDELINES

2.1 ARPANSA

ARPANSA, the Australian Radiation Protection and Nuclear Safety Agency, are the primary authority in Australia on radiation protection and nuclear safety, and their responsibilities include extremely low frequency electric and magnetic fields (ELF EMF).

Previously they had provided their own guidance and limits of exposure to ELF EMF in their Radiation Health Series as RHS No 30, in the form of interim guidance, but withdrew that in June 2015 with a statement that:

> *"The Radiation Health Committee agreed at its 24 June 2015 meeting that it would withdraw the existing NHMRC RHS30 guidance on ELF exposure. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has issued Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz -100 kHz) which are aimed at preventing the established health effects resulting from exposure to ELF EMF. The ICNIRP ELF guidelines are consistent with ARPANSA's and the RHC's understanding of the scientific basis for the protection of people from exposure to ELF EMF. Details about ICNIRP and a link to the ICNIRP ELF guidelines are available from the ARPANSA website at International Best Practice."*

Where the ICNIRP Guidelines is referred to in the third and fourth line, there is a link to the ICNIRP guidance published in 2010. Following the link to the webpage on International Best Practice leads to an endorsement of ICNIRP and the statement:

> *"You can view the publications of the International Commission on Non-Ionizing Radiation Protection on their website. Such documents should be considered for implementation in the Australian context and may be relied on by ARPANSA in our regulatory assessments."*

The use here of "should be considered" and "may be relied on by ARPANSA" indicate that ARPANSA are not prescriptive about following ICNIRP but that this is advisory.

2.2 The Guidelines of ICNIRP (2010)

2.2.1 Overview

As ICNIRP explain in the introduction to their 2010 guidance, the guidance is designed to avoid acute, that is short term, effects of the fields:

> *"The restrictions in these guidelines were based on established evidence regarding acute effects; currently available knowledge indicates that adherence to these restrictions protect workers and members of the public from adverse health effects from exposure to low frequency, EMF."*

They give details of the acute effects that can occur if the fields are high enough:

> *"There are a number of well-established acute effects of exposure to low-frequency EMFs on the nervous system: the direct stimulation of nerve and muscle tissue and the induction of retinal phosphenes. There is also indirect scientific evidence that brain functions such as visual processing and motor co-ordination can be transiently affected by induced electric fields. All these effects have thresholds below which they*

> *do not occur and can be avoided by meeting appropriate basic restrictions on electric fields induced in the body."*

They go on to say, about chronic effects of the field which would result from long-term exposure to the field, that:

> *"The epidemiological and biological data concerning chronic conditions were carefully reviewed and it was concluded that there is no compelling evidence that they are causally related to low-frequency EMF exposure."*

Furthermore, they say:

> *"The literature on chronic effects of low frequency fields has been evaluated in detail by individual scientists and scientific panels. WHO's cancer research institute, IARC (International Agency for Research on Cancer), evaluated low frequency magnetic fields in 2002 and classified them in category 2 B, which translates to "possibly carcinogenic to humans." The basis for this classification was the epidemiologic results on childhood leukemia.*
>
> *It is the view of ICNIRP that the currently existing scientific evidence that prolonged exposure to low frequency magnetic fields is causally related with an increased risk of childhood leukemia is too weak to form the basis for exposure guidelines. In particular, if the relationship is not causal, then no benefit to health will accrue from reducing exposure."*

2.2.2 The Basic Restrictions

We now focus on the Basic Restrictions on electric fields induced in the body referred to in the second quote from ICNIRP above, and on the system they have provided to enable them to be met.

ICNIRP provide values for Basic Restrictions that cover the whole extremely low frequency (ELF) range from 1 Hz to 100 kHz. Since power lines in Australia operate at 50 Hz the discussion that follows deals with only the values for 50 Hz.

There are two Basic Restrictions, referred to as for the central nervous system (CNS) and peripheral nervous system (PNS). The former, CNS, relates to the induction of retinal phosphenes and possible effects on some aspects of brain function. The latter, PNS, relates to peripheral and central myelinated nerve stimulation.

At 50 Hz		Effect threshold mV/m	Basic Restriction for general public mV/m
CNS		100	20
PNS		4,000	400
Ratio to effect threshold	CNS	1	5
	PNS	1	10

Table 1 Basic Restrictions at 50 Hz for general public exposures

Table 1 gives the values of the four Basic Restrictions.

Also shown in the table are the threshold for the effects and the ratio between the basic restrictions and the effect thresholds. The Basic Restrictions are set a factor of 5 (CNS) and 10 (PNS) below the effect threshold.

ICNIRP explain that the CNS Basic Restriction is intended to prevent the induction of retinal phosphenes and possible effects on some aspects of brain function, and that these restrictions should also prevent any possible transient effects on brain function. However, they say, "*these effects are not considered to be adverse health effects*."

2.2.3 Reference Levels

The internal electric field strength cannot be readily measured and so the Basic Restrictions are difficult to assess. Therefore, for practical exposure assessment purposes, Reference Levels of field are provided by ICNIRP which are expressed as field quantities that can be measured.

Reference Levels were derived by ICNIRP from the two Basic Restrictions using measurement and/or computational techniques. In the case of electric field, Reference Levels also address perception of the field.

Because the directions of induced electric field in the body from electric and magnetic fields are unlikely to be aligned, it is standard practice internationally to consider the two effects independently.

At 50 Hz	General public
Electric field	5 kV/m
Magnetic field	200 µT (2,000 mG)

Table 2 Reference Levels at 50 Hz for general public exposures

Table 2 gives the General Public Reference Levels at 50 Hz. When considering exposures to the general public in the vicinity of an overhead line, wherever the electric field is less than the Reference Level of 5 kV/m and the magnetic field is less than the Reference Level of 200 µT, then the ICNIRP Basic Restrictions are automatically met.

ICNIRP 2010 states:

> *"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."*

Levels of magnetic field in the vicinity of proposed overhead lines are everywhere well below the 200 µT Reference Level. Calculations of the electric field in the vicinity of the same lines are mostly less than 5 kV/m but exceed the Reference Level under some circumstances. Therefore, it is necessary to test compliance with the Basic Restrictions. How to do this is the topic of the Section 3 that follows, but first we give an overview of the derivation of the ICNIRP Reference Levels.

2.3 Derivation of Reference Levels by ICNIRP

ICNIRP give information about how they derived their Reference Levels from the Basic Restrictions using body models and reduction factors.

The calculation of internal electric field strength using anatomically realistic body models is referred to as dosimetry. ICNIRP (2010, page 826) say that the reference levels were derived from the published dosimetry studies of Dimbylow (2005 and 2006).

ICNIRP 2010 refer to dosimetric uncertainty saying:

> *"In view of the uncertainties in the available dosimetry as well as the influence of body parameters in the derivation of reference levels, ICNIRP is taking a conservative approach in deriving the reference levels from the basic restrictions."*

They say that for magnetic field a reduction factor of 3 was applied "*to allow for dosimetric uncertainty*". For electric field they do not give explicitly the reduction factor to allow for dosimetric uncertainty that they used, but it can be inferred from the calculation results from Dimbylow (2005), which would result in a level of 9.9 kV/m for general public exposure. This Reference Level is 5 kV/m suggesting a reduction factor of just under 2 was used.

The choices of reduction factors for dosimetric uncertainty used by ICNIRP in setting the Reference Levels are ultimately somewhat arbitrary. They were selected by ICNIRP to make sufficient provision, or more than sufficient provision for uncertainties in the computational methods used to determine the induced electric field in the relevant tissues from the external field.

2.4 Assumption of Small Spatial Variation of Field

There is a statement that "the reference levels assume an exposure by a uniform (homogeneous) field with respect to the spatial extension of the human body".

For the Western Renewables Link, at a minimum ground clearance of 15 m this variation is approximately 10%, decreasing with increasing ground clearance of the line.

Various international standards specify measuring or calculating the fields at a height of 1 m, which is approximately the mid height for a tall person or above the mid height for a shorter person.

3 DETERMINATION OF A MEASURABLE E-FIELD LIMIT

3.1 The Dosimetry Studies

The determination of a measurable electric field limit corresponding to the Basic Restrictions of ICNIRP 2010 begins with a dosimetric study of the electric field induced inside an anatomically realistic model the human body. For this we refer to induced electric field dosimetry studies by Dimbylow (2005) and Findlay (2014).

Dimbylow developed the anatomically realistic male human body model, NORMAN (Dimbylow 1998), for earlier studies of induced current density, and then added the female NAOMI (Dimbylow 2005) and later used both for induced electric field computations (Dimbylow 2005). Both these models discretised the body into 2 mm cubes whose conductivities were defined according to their tissue type.

Findlay (2014) developed a similar male human body model MAXWEL, which was more advanced in that the surfaces of the organs were represented by smoothed surfaces which avoided steps and consequent singularities resulting from the voxelization.

	ICRP 2002 male	ICRP 2002 female
Mass, kg	73	60
Height, m	1.76	1.63

Table 3 ICRP (2002) reference values for body mass and height used for the body models

All three were normalised to the reference heights and masses of ICRP (2002) (International Commission on Radiological Protection) given in Table 3.

3.2 Determination of Electric Field Limit from Dosimetry Studies

To apply the ICNIRP 2010 basic restrictions, values of induced electric field are needed in the brain and retina (for the CNS basic restriction) and the skin (for the PNS basic restriction). These are given per 1 kV/m of external field in Table 4.

	NORMAN male	NAOMI female	MAXWEL male
Brain, mV/m	1.65	2.02	1.87
Retina, mV/m	0.514	0.552	0.604
Skin, mV/m	not given	33.1	14.8
Corresponding external electric field limit, kV/m	12.1	9.9	10.7

Table 4 Induced electric field calculated for the three body models, grounded.

In each case values shown are for the body grounded. The values of induced electric field in the body that arise when the body is isolated from the ground are always lower.

The PNS Basic Restriction alone would result in a much higher electric field limit, so it is the CNS Basic Restriction that determines the electric field limit. For the CNS, values of induced electric field for retina are shown, but because they are much lower than the value for the brain, they do not contribute to setting the field limit.

The corresponding electric field is derived by dividing the Basic Restrictions by the induced electric field and the lowest value is shown in the bottom row of Table 4.

The values derived for the female NAOMI (9.9 kV/m) is lower than for male NORMAN (12.1 kV/m). The difference results from the various anatomical differences between the two models including the overall height and mass.

There is no female version of MAXWEL but if there were one, it is likely that the electric field limit would also be lower than for the male version (10.7 kV/m) as low as 9.5 kV/m or 9 kV/m.

Taking all these results together indicates an electric field limit, from dosimetry, of 9.5 or 9.0 kV/m. This taking account of variability between the studies considered including the variability between male and female.

3.3 Reduction Factor for Dosimetric Uncertainty

The inclusion of the word “conservative” in the quote from ICNIRP (2010) in Section 2.3 implies that the Reference Levels are lower than they otherwise need to be, suggesting that the reduction factor that they used was more than it needed to be.

Establishing the appropriate reduction factor to use is an inexact process.

Magne and Deschamps (2016) made a comprehensive assessment of the appropriate reduction factor in connection with applying the occupational exposure limits of the European EMF Directive, which are derived from ICNIRP 2010 and therefore present the same issues for dosimetry. They reviewed published dosimetry studies to obtain estimates of the different sources of uncertainty in these calculation methods and thereby to improve on the conversion of the occupational Basic Restrictions into measurable field limits. Their conclusion resulted in a measurable electric field limit of 35 kV/m for occupational exposures.

The same method can be applied to the Basic Restrictions for the general public (which are lower than the occupational basic restrictions by factors of 5 for CNS and 2 for PNS) with the result that the measurable electric field limit becomes, after rounding, 7 kV/m.

While this cannot be regarded as a definitive assessment, it is the only detailed published result available and takes account of the multiple different aspects of dosimetric uncertainty in an explicit formulation, as opposed to providing a single overall reduction factor as ICNIRP do.

3.4 Microshocks and Contact Currents

Small electrical discharges, variously called “microshocks” or “spark discharges”, occur when a conducting person or object in an elevated electric field is charged to a different voltage to surrounding objects, resulting in electric discharges when they come close (within a fraction of a millimetre) to those objects. Such effects can be discernible when a person touches a grounded object in electric fields as low as 1 or 3 kV/m and are likely to be described as annoying at 5 kV/m, though the effects are found to vary with the climatic conditions and other factors. They become increasingly uncomfortable with increasing electric field and, in fields higher than about 5 kV/m, precautions including grounding are sometimes needed.

For ungrounded objects which are larger than people, microshocks will be more problematic Examples are ungrounded cars or larger vehicles such as farm machinery, vans or busses when parked in a region of high electric field, from which uncomfortably large contact currents and microshocks can be experienced.

Microshocks can also affect larger animals such as horses and cattle, when they come into contact with other animals, with people or, for example with fences which are ungrounded.

Therefore, where the ICNIRP Reference Level of 5 kV/m is exceeded, consideration needs to be given to the possible occurrence of microshocks, particularly in homes, other land in residential use and schools. UK DECC (2013) is a voluntary code of practice, agreed between the UK government and the electricity industry, on the characteristics of microshocks and ways to deal with them, which are through local interventions, rather than through designing the line to produce low enough fields to avoid them.

4 INTERNATIONAL PRACTICES

There is no definitive source of information on national practice worldwide, but from the best available information, the only countries apart from Australia where national requirements have adopted or applied ICNIRP 2010 are Germany and Japan and in both these cases this is to a limited extent. In the majority of countries which are known to have limits at all, the limits are based on the earlier ICNIRP 1998 guidelines rather than the ICNIRP 2010 guidelines.

More information on limits applied internationally can be found in a report by Stam (2018) and on the EMFs.info website at www.emfs.info/limits/world/

4.1 ICNIRP 1998 vs 2010

ICNIRP originally published their guidelines in 1998, covering all frequencies from 1 Hz to 300 GHz, and then in 2010 revised their guidelines covering the frequencies from 1 Hz to 100 kHz.

There are strong similarities between the two versions though there are some differences that affect their application.

- The change from giving the basic restrictions as values of induced current density in the body to giving it as values of induced electric field in the body. As the two are directly related by the tissue conductivity this is not a fundamental change of approach, it is simply a change to the calculation method.
- The parts of the body to which the low frequency basic restrictions apply:
  - 1998: Nervous tissue of the head and trunk (which includes the spinal cord)
  - 2010: CNS tissue of the head (brain and retina but not the spinal cord), and the addition of the PNS basic restriction.
- The implied requirement in the 2010 guidance to allow for dosimetric uncertainty, that was not mentioned in the 1998 guidance.

4.2 Europe

The European Union established their EMF Recommendation (1999/519/EC) in 1999, which applies the 1998 ICNIRP Guidelines for exposures to the general public throughout the European Union. The EMF Recommendation is a recommendation to National States of the European Union to implement the EMF limits given, and as a consequence, their implementation varies from country to country.

The EU did not revise the EMF Recommendation when ICNIRP published their new guidance in 2010. Requirement based on ICNIRP 1998 are therefore still in widely in use.

Separately, the European Union established their EMF Directive (2013/35/EU) in 2013 for occupational exposures. This applies a development of the 2010 ICNIRP Guidance for occupational exposures throughout the European Union.

4.3 In UK

In the UK, following the guidance of the Health Protection Agency at the time, an electric field limit of 9.0 kV/m was adopted as part of the implementation of the EMF Recommendation in the UK. See UK DECC (2012). This is based on the Basic Restrictions of ICNIRP (1998) and on the induced current density dosimetry reported by Dimbylow (2005), with only minimal allowance for variability between dosimetry studies.

4.4 In Australia

The Australian Energy Networks Association (ENA) have produced an EMF Management Handbook (2016) which includes sections on EMF exposure guidelines and limits including ICNIRP 2010, and on assessing compliance with exposure limits, for both the public and workers.

Dosimetry is discussed in section 6.5 and results derived from Dimbylow (2005) are given in Table 6-2 including the value of 9.9 kV/m for electric field for general public exposures, which is based on the value of 2.02 mV/m per kV/m in the brain for the female model NAOMI. They say that this confirms that the Reference Levels are conservatively formulated.

ENA (2016) make no comment about making allowance for uncertainty associated with the dosimetry calculations.

They go on to say that:

> *"the first step should always be to demonstrate compliance with the exposure limits by conventional means and where practicable, manage exposure by engineering or administrative controls. When compliance with the exposure limits cannot be demonstrated by conventional calculations and measurements means, then the Dimbylow method could be considered."*

It would seem that they are recommending keeping things simple by demonstrating compliance using the Reference Levels wherever practicable and to manage exposure by designing lines to not exceed those levels [engineering controls] or by restricting access to places where those levels are exceeded [administrative controls], and to use a higher electric field limit derived from dosimetry where the simpler means are not achievable.
In the case of overhead lines of voltages of 500 kV the only way to comply the 5 kV/m Reference Level would be by building it with a larger-than-usual minimum ground clearance.

TransGrid are seeking permission for their EnergyConnect project to build a new interconnector to connect the electricity grids of South Australia and New South Wales. The project is in two parts, the NSW-Eastern Section and the NSW-Western Section and includes sections of 500 kV overhead line. Their Technical Papers on electric field and magnetic field studies, associated with Environmental Impact Statement, indicate they have adopted electric field limits of 7.8 kV/m for the Western section and 9.1 kV/m for the eastern section, based on a dosimetry study they commissioned.

5 DISCUSSION and CONCLUSIONS

1. ARPANSA, referring to ICNIRP 2010 state that "*such documents should be considered for implementation in the Australian context".*
2. In preparing this report, three dosimetry studies were considered, the male and female models from Dimbylow, and the male model from Findlay, all normalised to ICRP 2002. The results indicate values for the electric field limit at 50 Hz derived from dosimetry ranging from 9.9 kV/m to 12.1 kV/m. Additionally, making an allowance for a female equivalent to the model from Findlay, extends to range down to around 9 kV/m.
3. The recommended electric field limit derived from dosimetry taking account of variability between models is therefore 9 kV/m.
4. This is the same as the 50 Hz electric field limit that is agreed for use in the UK, which is based on the earlier 1998 version of the ICNIRP guidelines.
5. The 2010 version of the ICNIRP guidelines gives an electric field Reference Level of 5 kV/m. They obtain this through the application of a reduction factor of almost 2 to the value of 9.9 kV/m obtained from dosimetry studies, to make what they describe as conservative allowance for dosimetric uncertainty.
6. This recommended electric field limit does not include an allowance for "dosimetric uncertainty". This uncertainty associated with the dosimetric computations has been comprehensively assessed by Magne and Deschamps (2016) for occupational exposure situations. While this cannot be regarded as a definitive assessment, it is the only detailed and published result available, which takes account of the multiple different aspects of dosimetric uncertainty in an explicit formulation. Allowing for dosimetric uncertainty using their assessment would indicate a range of possible exposure limits between 7 kV/m and 9 kV/m.
7. Small electric discharges, microshocks, may occur where electric fields exceed 2 or 3 kV/m. Provision to manage these may be needed on a local basis rather than through line design.

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