Valley of the Winds

APPENDIX J
EMI AND EMF HEALTH IMPACT ASSESSMENT

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VALLEY OF THE WINDS WIND FARM

EMI and EMF Health Impact Assessment

UPC Renewables Australia Pty Ltd

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Objective: Valley of the Winds Wind Farm EMI and EMF Health Impact Assessment

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EXECUTIVE SUMMARY

DNV has been commissioned by UPC Renewables Australia Pty Ltd, operating as UPC\AC Renewables Australia (UPC\AC) (the Proponent) to independently assess potential electromagnetic interference (EMI) impacts and electromagnetic field (EMF) health impacts associated with the development and operation of the proposed Valley of the Winds Wind Farm (the Project) in the central western slopes region of New South Wales (NSW). The results of the EMI and EMF assessments are described in this document.

Background and methodology

DNV has assessed the potential EMI impacts for the Project in accordance with the Secretary's Environmental Assessment Requirements (SEARs) [1], NSW Wind Energy Guideline [2], and Draft National Wind Farm Development Guidelines [3]. The methodology used in this study has been informed by these guidelines and various standard industry practices.

DNV has also evaluated the potential health impacts of EMF associated with the Project as required by the SEARs [1], based on internationally recognised guidelines.

A Project layout consisting of 148 wind turbines with a rotor diameter of 180 m and tip height of 250 m has been considered. These dimensions represent the maximum overall tip height within the maximum rotor and tower hub height dimensions.

190 dwellings have been identified within 5 km of the Project, 28 of which are participating dwellings.

Outcomes of the assessment

Potential EMI impacts

The results of the EMI assessment are summarised in the table that follows these paragraphs.

Three turbines at the Project are located within the calculated diffraction exclusion zones for fixed point-to-point links passing over the wind farm site and therefore are likely to cause interference to those links through diffraction of the signals. DNV recommends consulting with the operators of the links to confirm the potential for impact and identify any mitigation options. This may result in the relocation of turbines to be outside of agreed clearance zones around the affected links.

Turbines at the Project may interfere with point-to-area style services such as mobile phone signals and terrestrial television broadcasting, particularly in areas with poor or marginal signal coverage. Dwellings in the vicinity of the Project may experience interference to digital television broadcast signals from the Central Western Slopes and Coolah towers, although the coverage maps suggest that many of the dwellings located in the potential interference zones may not currently be receiving signals from these towers. However, there is some potential for interference to signals from the Central Western Slopes tower to be experienced outside the identified zones, if dwellings in those areas receive a reflected signal from the turbines that is stronger than the direct signal. Mobile phone services may be susceptible to interference in areas that are currently receiving a weak signal, but the overall likelihood of interference is low and previous advice received from the network operators has generally indicated that they do not expect wind farm developments to interfere with their services. If interference to these services is experienced, a range of options are available to rectify difficulties.

Impacts to satellite television and internet signals that may be received at dwellings in the vicinity of the Project are considered unlikely. The proposed turbines are not expected to interfere with any satellite television or internet services intended for Australian audiences. Interference is possible for signals from satellites that do not provide services designed for Australian audiences, however these are unlikely to be used by nearby residents.

While the Project may cause interference to point-to-multipoint links and meteorological radar, further information from the operators of those services is required to determine the likely impacts. Potential EMI impacts on other services considered in this assessment, including wireless internet services, broadcast radio, citizens band radio, and trigonometrical stations, are considered minor.

DNV notes that the Project is located in the Central-West Orana REZ, which is likely to become an area of high wind farm development activity, with the approved Liverpool Range Wind Farm located nearby. Based on the relative locations of the wind farms, there is some potential for increased interference to mobile phone and FM radio signals in areas where there may be multiple wind turbines between the user and the transmission tower. Cumulative impacts to other services are considered unlikely or, in the case of point-to-multipoint links and meteorological radar, can be assessed through consultation with the relevant operators.

There is potential for the proposed overhead transmission lines to cause interference to fixed point-to-point and point-to-multipoint links crossing the transmission line route through diffraction, reflection, or scattering of signals. Interference to NBN fixed wireless internet signals may also occur if the transmission lines intersect the line of sight from an NBN tower to a nearby dwelling. DNV recommends that this assessment be reviewed once the likely heights for the transmission line are known, and that the potential for interference be further assessed through consultation with the relevant operators. Interference caused by electromagnetic noise produced by the proposed transmission lines is not expected to be an issue for the Project.

Potential EMF health impacts

The risks to human health from EMF associated with the Project are considered low. Simulation of the EMF produced by the proposed medium-voltage underground cabling network has shown that the EMF at ground level will be within the exposure limits recommended for the protection of the general public. EMF from other equipment at the Project is also expected to be compliant with the relevant guidelines. The EMF levels produced by the Project are therefore expected to be within the recommended exposure limits at all publicly accessible locations in and around the wind farm site, and indistinguishable from background levels at nearby dwellings.

Summary of EMI assessment results for the proposed Project

Licence or service type	Assessment findings	Expected impact			Stakeholder feedback (to date)	Potential mitigation options
		Wind farm in isolation	With neighbouring wind farms	Transmission lines		
Radio-communication towers	No towers within 2 km of proposed turbine locations or 1 km of proposed transmission line route	None	No cumulative impact	No impact	Consultation not considered necessary	None required
Fixed point-to-point links	42 links over 11 link paths crossing wind farm site, operated by Essential Energy, NBN Co Limited (NBN Co), New South Wales Government Telecommunications Authority (NSW Telco Authority), NSW Police Force, NSW Rural Fire Service (NSW RFS), Telstra Corporation Limited (Telstra), Warrumbungle Shire Council 27 links over 5 link paths crossing transmission line route, operated by Essential Energy, NBN Co, NSW Telco Authority, and Telstra Diffraction effects: 3 turbines in exclusion zones established by DNV for links operated by NBN Co, NSW Police Force, and Warrumbungle Shire Council; transmission lines may impact links operated by Essential Energy and NBN Co Reflection/scattering effect: turbines are sufficiently far from towers to avoid any impacts; transmission lines may impact links operated by Essential Energy and NBN Co Near-field effects: turbines and transmission lines are sufficiently far from towers to avoid impacts	Likely to cause interference to links operated by NBN Co, NSW Police Force, and Warrumbungle Shire Council through diffraction of signals	No cumulative impact	Potential for interference to links operated by Essential Energy and NBN Co through diffraction, reflection, or scattering of signals	Consultation recommended but not undertaken	Reroute affected links, install additional towers, replace affected links with alternative technologies, relocate turbines to be outside clearance zones

Summary of EMI assessment results for the proposed Project (continued)

Licence or service type	Assessment findings	Expected impact			Stakeholder feedback (to date)	Potential mitigation options
		Wind farm in isolation	With neighbouring wind farms	Transmission lines		
Fixed point-to-multipoint links	64 assignments within 75 km of wind farm site One base station within 20 km of wind farm site, operated by Ulan Coal Mines Ltd	Potential for interference if link paths cross the wind farm site near turbines	Potential for cumulative impact if link paths cross both wind farms	Potential for interference if link paths cross the transmission line route	Consultation recommended but not undertaken	If required – reroute affected links, install additional towers, replace affected links with alternative technologies
Other licence types	Point-to-area style communications: see findings for emergency services, mobile phones, radio broadcasting, and television broadcasting	-	-	-	-	-
Emergency services	Point-to-point links: 3 NSW Telco Authority links, 1 NSW Police Force link, and 2 NSW RFS links crossing wind farm site (see above); no links crossing transmission line route Mobile telephony systems: unlikely to be affected	Likely to cause interference to point-to-point link operated by NSW Police Force Unlikely to cause interference to mobile telephony systems	No cumulative impact to point-to-point links Very low potential for cumulative impact to mobile telephony systems	No impact to point-to-point links Unlikely to cause interference to mobile telephony systems	Consultation recommended but not undertaken	Point-to-point links: as above Mobile telephony systems: if required – increase signal strength from affected tower or alternative towers, install signal repeater, install additional tower
Meteorological radar	Nearest radar: "Namoi", 106 km from Project	Potential for interference if turbines at the Project can be detected by radars	Potential for cumulative impact if turbines at both wind farms can be detected by radars	Unlikely to cause interference	Consultation recommended but not undertaken	To be determined through consultation with the Bureau of Meteorology

Summary of EMI assessment results for the proposed Project (continued)

Licence or service type	Assessment findings	Expected impact			Stakeholder feedback (to date)	Potential mitigation options
		Wind farm in isolation	With neighbouring wind farms	Transmission lines		
Trigonometrical stations	Trigonometrical stations: unlikely to be affected	Unlikely to cause interference	Very low potential for cumulative impact	Unlikely to cause interference	Consultation recommended but not undertaken	None required
Citizen's band radio	Unlikely to be affected	Unlikely to cause interference	Very low potential for cumulative impact	Unlikely to cause interference	Consultation not considered necessary	None required
Mobile phones	Optus and Telstra networks: unlikely to be affected in areas with good coverage, may experience interference from turbines in areas with marginal coverage away from populated areas around Coolah and Dunedoo Vodafone network: unlikely to be used by nearby residents due to existing poor coverage	Low likelihood of interference	Low potential for cumulative impact	Unlikely to cause interference	Consultation recommended but not undertaken	If required – increase signal strength from affected tower or alternative towers, install additional tower
Wireless internet	Likely service providers: Optus, Telstra, NBN Co NBN: available as a fixed wireless and satellite service in areas surrounding the Project	Low likelihood of interference to mobile internet services Unlikely to cause interference to NBN services	Low potential for cumulative impact to mobile internet services No cumulative impact to NBN services	Unlikely to cause interference to mobile internet services Potential for interference to NBN services if transmission lines intersect line of sight from tower to dwelling	Consultation recommended but not undertaken	Mobile phone networks: as for mobile phones NBN: none required

Summary of EMI assessment results for the proposed Project (continued)

Licence or service type	Assessment findings	Expected impact			Stakeholder feedback (to date)	Potential mitigation options
		Wind farm in isolation	With neighbouring wind farms	Transmission lines		
Satellite television and internet	Services intended for Australian audiences: unlikely to be affected Services intended for international audiences: signals from 16 satellites intercepted by turbines at 40 dwellings	Unlikely to cause interference to services intended for Australian audiences Low likelihood of interference to services intended for international audiences	No cumulative impact	Unlikely to cause interference	Consultation with operators not considered necessary Current usage of potentially affected services could be confirmed by engaging with residents of identified dwellings	If required – redirect satellite dish to alternative satellite, install larger or higher-quality satellite dish, change location or height of satellite dish

Summary of EMI assessment results for the proposed Project (continued)

Licence or service type	Assessment findings	Expected impact			Stakeholder feedback (to date)	Potential mitigation options
		Wind farm in isolation	With neighbouring wind farms	Transmission lines		
Radio broadcasting	AM and FM signals: may experience interference in close proximity to turbines Digital radio signals: Project is outside the intended coverage area	Low likelihood of interference to AM and FM signals	Low potential for cumulative impact	Unlikely to cause interference	Consultation not considered necessary	AM and FM signals: if required – install higher-quality antenna at affected location Digital radio signals: none required
Television broadcasting	May experience interference in areas with poor or marginal reception					If required – re-align antenna at affected dwelling to existing tower, re-direct antenna to alternative tower, install more directional or higher gain antenna, change location of antenna, install cable or satellite television, install relay transmitter
	Central Western Slopes tower: 'variable' to 'poor' or non-existent coverage across the Project site, with small areas of 'good' coverage to the north and southwest 52 dwellings in potential interference zone	Low likelihood of interference at identified dwellings, as dwellings may not currently be receiving signals Potential for interference outside identified zone if dwellings receive a reflected signal that is stronger than the direct signal	Low potential for cumulative impact	Unlikely to cause interference	Consultation recommended but not undertaken	
	Coolah tower: 'variable' to 'good' coverage to the northeast of the Project site, 'poor' or non-existent coverage elsewhere 32 dwellings in potential interference zone	Low likelihood of interference at identified dwellings, as dwellings may not currently be receiving signals	Low potential for cumulative impact	Unlikely to cause interference	Consultation recommended but not undertaken	

1 INTRODUCTION

1.1 Project information

The following information has been supplied by the Proponent.

1.1.1 Project overview

UPC Renewables Australia Pty Ltd, operating as UPC\AC Renewables Australia (UPC\AC) (the Proponent), proposes to construct and operate the Valley of the Winds Wind Farm (the Project).

The Project would consist of approximately 148 wind turbines and supporting infrastructure, including a high voltage transmission line which would run approximately 13 kilometres (km) from the Girragulang Road cluster to a connection point with the Central-West Orana REZ Transmission line proposed by TransGrid and the NSW Government. The project would supply approximately 800 megawatts (MW) of electricity into the National Electricity Market (NEM).

The wind farm would be located close to the townships of Coolah and Leadville, with the transmission line running generally south to its connection with the Central-West Orana REZ Transmission line. The project would be entirely within the Warrumbungle Local Government Area (LGA).

The Project would involve the construction, operation and decommissioning of three clusters of wind turbines, that would be connected electrically. These are:

- Mount Hope cluster – approximately 76 turbines
- Girragulang Road cluster – approximately 51 turbines
- Leadville cluster – approximately 21 turbines.

The Project includes the following key components:

- approximately 148 wind turbines with a maximum tip height of 250 metres (m) and a hardstand area at the base of each turbine
- electrical infrastructure, including:
  - substations in each cluster and a step-up facility at the connection to the Central-West Orana REZ Transmission line
  - underground 33 kilovolt (kV) electrical reticulation connecting the turbines to the substations in each cluster
  - overhead transmission lines (up to 330 kV) dispatching electricity from each cluster
  - other electrical infrastructure as required including a potential battery energy storage system (BESS)
  - a high voltage transmission line (up to 500 kV) connecting the wind farm to the Central-West Orana Transmission line
- other permanent on-site ancillary infrastructure:
  - permanent operation and maintenance facilities
  - meteorological masts (up to 13)
- access track network:
  - access and egress points to each cluster from public roads
  - operational access tracks and associated infrastructure within each cluster on private property
- temporary construction ancillary facilities:
  - potential construction workforce accommodation on site

- construction compounds
- laydown areas
- concrete batching plants
- quarry sites for construction material (rock for access tracks and hardstands).

At the end of its practical life, the wind farm would be decommissioned, and the site returned to its pre-existing land use in consultation with the affected landholders.

1.1.2 Site context

The Project location is shown in Figure 4. Land surrounding the wind farm site is characterised by rolling pastoral hills, open flat valleys and ridgelines with scattered vegetation. The hill slopes are generally gentle in gradient and predominantly cleared of vegetation, except for patches of denser remnant vegetation on steeper terrain, near rocky outcrops and between saddles.

The townships of Coolah and Leadville are the closest population centres to the proposed site. These townships are located on gently sloping to level land within valleys near creeks. Most built structures are of low to moderate scale. The main street of Coolah is the focus for local retail and community services in the local area.

Land uses within the locality include:

- **farming** – predominantly grazing cattle and sheep, with small patches of cropping (cereal and fodder)
- **rural living** – scattered rural dwellings and sheds present throughout the landscape, with a higher density of dwellings in the townships.

1.1.3 Purpose of this report

The capital value of the Project would be more than $30 million. Accordingly, the Project is a State Significant Development (SSD) under the *State Environmental Planning Policy (State and Regional Development) 2011* (SEPP SR&D) and Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). Under Section 4.12(8) of the EP&A Act, a development application (DA) for SSD must be accompanied by an environmental impact statement (EIS) that is lodged with the NSW Department of Planning, Industry and Environment for Development Consent.

The Project was also referred to the Commonwealth Department of Agriculture, Water and the Environment for potential impacts to matters of national environmental significance protected by the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). On 13 July 2020, a delegate of the Federal Minister for the Department of Agriculture, Water and the Environment determined that the Project was a controlled action under section 75 of the EPBC Act and therefore requires assessment and approval under the EPBC Act. This assessment is to be undertaken under the *Amended Bilateral Agreement* between the Department of Agriculture, Water and the Environment and the Department of Planning, Industry and Environment.

This report has been prepared to inform the environmental impacts statement (EIS) and development application (DA) for the Project.

1.2 Overview of this report

In accordance with the Secretary's Environmental Assessment Requirements (SEARs) provided by the NSW Department of Planning, Industry and Environment on 9 June 2020 [1], the NSW Wind Energy Guideline for State significant wind energy development (NSW Wind Energy Guideline)

prepared by the NSW Department of Planning and Environment in December 2016 [2], and the National Wind Farm Development Guidelines – Draft (Draft National Guidelines) prepared by the Environment Protection and Heritage Council (EPHC) in July 2010 [3], the assessment described in this report investigates the potential electromagnetic interference (EMI) impact of the Project on:

- fixed point-to-point links
- fixed point-to-multipoint links
- radiocommunication assets belonging to emergency services
- meteorological radars
- trigonometrical stations
- citizens band (CB) radio and mobile phones
- wireless internet
- satellite television and internet
- broadcast radio and television.

"Radiocommunications" is used as a broad term in this report to encompass all services that rely on microwave or radio frequency electromagnetic waves to transfer information, including those listed above.

This assessment also includes an evaluation of the potential health hazards and risks associated with electromagnetic fields (EMF) produced by the Project, as required by the SEARs.

2 REGULATORY REQUIREMENTS

2.1 EMI impacts

The SEARs [1] outline the following requirements for the assessment of interference to telecommunication services:

> *"Telecommunications – identify possible effects on telecommunication systems, assess impacts and mitigation measures including undertaking a detailed assessment to examine the potential impacts as well as analysis and agreement on the implementation of suitable options to avoid potential disruptions to radio communication services; which may include the installation and maintenance of alternative sites."*

In addition, the NSW Wind Energy Guideline [2] currently states:

> *"…the consent authority will give consideration to the risk of electromagnetic interference with telecommunication services in the area, and the adequacy of the measures proposed to ensure the level of service is maintained."*

Although both the SEARs and the NSW Wind Energy Guideline describe the requirements for assessing EMI related impacts, they do not provide detailed methodologies for these assessments.

The EPHC, in conjunction with Local Governments and the Planning Ministers' Council released a draft version of the National Wind Farm Development Guidelines in July 2010 (Draft National Guidelines) [3]. The Draft National Guidelines cover a range of issues across the different stages of wind farm development.

In relation to EMI, the Draft National Guidelines provide advice and methodologies to identify likely affected parties, assess EMI impacts, consult with affected parties and develop mitigation steps to address the likely EMI impacts.

DNV considers that the recommendations of the Draft National Guidelines meet, if not exceed, the requirements of the SEARs and the NSW Wind Energy Guideline, and therefore the Draft National Guidelines have been used to inform the methodology adopted for this assessment.

2.2 EMF health impacts

The SEARs [1] also outline the following requirement for the assessment of health impacts arising from EMF:

> *"Health – consider and document any health issues having regard to the latest advice of the National Health and Medical Research Council [NHMRC], and identify potential hazards and risks associated with electric and magnetic fields (EMF) and demonstrate the application of the principles of prudent avoidance."*

Current advice from the NHMRC states that *"there is no direct evidence from which to draw any conclusions on an association between electromagnetic radiation produced by wind farms and health effects"* [4]. However, research commissioned by the NHMRC acknowledges that there are possible mechanisms by which EMF produced by the flow of electrical current in wind turbines and associated electrical cabling and infrastructure could impact on human health [5].

The Australian Energy Networks Association (ENA) has published an EMF Management Handbook, which recommends that electricity generation, transmission, and distribution systems be designed

and operated in compliance with recognised international EMF exposure guidelines [6]. The ENA Handbook also provides advice and guidance on using a prudent avoidance approach to minimise the possible risks of adverse health effects associated with EMF from generation, transmission, and distribution of electricity. In this context, the ENA defines prudent avoidance as the precautionary act of *"implementing low cost or very low cost measures that reduce exposure while not unduly compromising other issues."*

In relation to EMF exposure guidelines, both the ENA and the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) refer to the exposure limits set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [7] while the NHMRC refers to limits proposed by the World Health Organisation (WHO). For EMF produced by electric currents at a frequency of 50 Hz, the ICNIRP guidelines recommend that general public exposure be limited to an electric field strength of 5 kV/m, a magnetic field strength of 16 mA/m, and a magnetic flux density of 200 μT. Conversely, the WHO guidelines recommend a limit of 100 μT for general public exposure. While alternative limits also exist, as discussed in [5] and [6], the ICNIRP guidelines are internationally recognised and *"consistent with ARPANSA's understanding of the scientific basis for the protection of the general public"* from exposure to EMF.

For the purposes of this assessment, DNV has compared the predicted EMF levels for the Project to the general public exposure limits recommended by the ICNIRP [7] and the WHO [4].

3 METHODOLOGY AND RESULTS – EMI IMPACTS

If not properly designed, wind farms have the potential to interfere with radiocommunication services. Two services that are most likely to be affected are television broadcast signals and fixed point-to-point signals. Terrestrial broadcast signals are commonly used to transmit domestic television, while point-to-point links are used for line-of-sight connections for data, voice, and video. The interference mechanisms are different for each of these and, hence, there are different ways to avoid interference.

The Proponent has asked DNV to complete this assessment based upon a layout provided for the Project consisting of 148 wind turbines. A map of the site showing the proposed turbine layout is shown in Figure 5, and the coordinates of the proposed turbine locations are presented in Table 10.

The Proponent has also asked DNV to consider the potential for cumulative impacts from the Project in conjunction with nearby wind farms, and the potential for the proposed 220/330 kV and 330/500 kV transmission lines to cause interference to radiocommunication signals and services. The proposed electrical infrastructure and transmission line routes are also shown in Figure 5.

For the purpose of the EMI assessment, a hypothetical turbine with a rotor diameter of 180 m and a tip height of 250 m has been considered. These dimensions represent the maximum tip height and rotor diameter under consideration for the Project. The results generated based on this turbine configuration will be conservative for all turbine configurations with dimensions that remain inside the turbine envelope by satisfying all of the following criteria:

- a rotor diameter of 180 m or less
- an upper tip height of 250 m or less.

The locations of dwellings in the vicinity of the Project have been provided by the Proponent. For the purposes of this assessment, DNV has considered all identified dwellings within 5 km of the wind farm site. There are 190 dwellings located within 5 km of the wind farm site, 28 of which are associated dwellings. The coordinates of these dwellings are presented in Table 11, and the dwellings and site boundaries considered in this assessment are also shown in Figure 5.

DNV has not carried out a detailed and comprehensive survey of building locations in the area and is relying on information provided by the Proponent. For the purposes of this assessment, DNV has assumed that all listed dwellings are inhabited.

The Draft National Guidelines recommend that a radial distance of 50 km to 60 km from the centre of a wind farm would normally capture all of the potentially affected services in the area. However, the methodology for assessing the potential radiocommunications interference used in this assessment is to locate all of the radiocommunication towers within approximately 75 km of the proposed wind farm site, and then assess the radiocommunication licences attached to these towers. This reduces the likelihood that radiocommunication links crossing the site are inadvertently excluded from the assessment.

To conduct the EMI assessment, information regarding radiocommunications licences in the vicinity of the Project was obtained from a downloaded copy of the Australian Communication and Media Authority (ACMA) Register of Radiocommunications Licences (RRL) database dated 14 December 2021 [8].

Other services with the potential to experience interference from the Project have also been identified, and the potential for interference to those services assessed. These services include

meteorological radars, trigonometrical stations, CB radio and mobile phones, wireless internet, broadcast radio, satellite television and internet, and broadcast television.

The Draft National Guidelines recommend that consultation with the relevant operator be undertaken if a turbine is located within 2 km of a radiocommunication site, within the second Fresnel zone of a point-to-point link, or within 250 nautical miles of an aeronautical or meteorological radar site. DNV recommends consulting with organisations operating services that may be impacted by the development and operation of the Project, to disseminate basic information on the Project and request responses from the organisations regarding whether they foresee any potential EMI-related impacts on their operations and services.

The radiocommunication licences and services with potential to experience EMI-related impacts from the proposed Project are considered in Sections 3.1 to 3.14. Each section contains a brief overview of the relevant technology, followed by an assessment of the identified licences and services in the area around the Project and the expected potential for interference from the proposed turbines. Details of any feedback obtained from the service operators and potential mitigation options are also included where appropriate. The potential for cumulative impacts and for impacts from the proposed transmission line infrastructure are addressed in Sections 3.15 and 3.16 respectively.

3.1 Radiocommunication towers

Wind turbines located close to radiocommunication sites have the potential to cause interference through near-field effects or reflection or scattering of the signals. According to the Draft National Guidelines [3], the near-field zone for a transmission tower can vary from several metres to approximately 720 m depending on the service type. The Draft National Guidelines therefore recommend that any radiocommunication site within 1 km of a proposed turbine location be considered as a having the potential to be impacted by near-field effects. The potential for a turbine to cause reflection or scattering of signals also depends on a number of factors, including the service type, the required signal-to-noise ratio for the service, and the distances between the user, transmission tower, and turbine. Since there is no single criterion for potential impact on radiocommunication services due to near-field effects and reflection or scattering, the Draft National Guidelines recommend consulting with the service operator if any turbine is to be located within 2 km of a radiocommunication site.

3.1.1 Locations of radiocommunication towers and potential for interference

From the ACMA RRL database, there are 295 radiocommunication towers within a nominal 75 km of the wind farm site. The locations of these radiocommunication towers relative to the Project are shown in Figure 6.

There are no radiocommunication towers located within 2 km of the proposed turbine locations. The closest tower is located within the wind farm site approximately 4.1 km from the nearest proposed turbine location. Therefore, it is not expected that the Project will cause interference to the signals from this tower through reflection or scattering of signals or near-field effects.

3.2 Fixed licences of point-to-point type

Point-to-point links are often used for line-of-sight connections for data, voice, and video. Such links often exist on mobile phone and television broadcast towers. The frequency of common microwave signals varies from approximately 1 GHz to 30 GHz.

Wind turbines can potentially cause interference to point-to-point microwave links and, in some cases, point-to-point ultra high frequency (UHF) links through three mechanisms: diffraction of the signal, reflection or scattering of the signal, and near-field effects. It is generally possible to design around these issues as the link paths and potential interference zones for these signals can be determined.

3.2.1 Locations of point-to-point links and potential for interference

DNV has analysed the registered licences for each radiocommunication tower according to the ACMA RRL database to determine the transmission paths of the licenced links. For this analysis, DNV has used a wider and more conservative frequency range of 0 GHz to 50 GHz.

Each individual link was given a unique identifier or "Assignment ID" so that it could be readily distinguished. This Assignment ID was taken as either the Device Registration ID (for spectrum licences associated with the use of certain frequency band within a particular geographic area) or the EFL ID (for apparatus licences associated with the use of a particular device).

The links paths associated with the analysed towers are shown in Figure 7. It can be seen that not all of the identified transmission towers have a fixed licence of point-to-point type transmission vector. Some towers have no active licences associated with them, and some towers are used solely for point-to-area style transmissions, such as some emergency services towers.

There are 42 point-to-point links over 11 link paths recorded in the ACMA RRL database that pass over the proposed wind farm site, operated by Essential Energy, NBN Co Limited (NBN Co), New South Wales Government Telecommunications Authority (NSW Telco Authority), NSW Police Force, NSW Rural Fire Service (NSW RFS), Telstra Corporation Limited (Telstra), and Warrumbungle Shire Council. The details of the links are provided in Table 12, and the link paths are shown in greater detail in Figure 8.

The potential interference mechanisms and interference zones established by DNV for these links are described in Sections 3.2.1.1, 3.2.1.2, and 3.2.1.3.

3.2.1.1 Interference caused by diffraction

The potential for interference to a fixed point-to-point link through diffraction or obstruction of the signal can usually be avoided by keeping clear of an exclusion zone of circular cross-section around the link path from the transmitter to the receiver [3, 9, 10], typically defined in terms of the Fresnel zones for the link. The *n*th Fresnel zone is comprised of all points for which, if the signal travelled in a straight line from the transmitter to the point and then to the receiver, the additional length compared to the straight transmitter-receiver path equals $\frac{n-\lambda}{2}$, where λ = wavelength.

The radius of the *n*th Fresnel zone varies along the length of the signal, and is given by:

$$R_{Fn} = \sqrt{\frac{n\lambda d_1 d_2}{D}}$$

where d_1 is the distance from the transmitter
d_2 is the distance from the receiver
D is the distance from the transmitter to receiver, such that $d_1+d_2 = D$

To avoid interference to point-to-point links caused by signal diffraction, wind turbines, including the blades, should be kept outside of an exclusion zone based on either the second Fresnel zone as recommended in [9], or potentially 60% of the first Fresnel zone for links below 1,000 MHz with a

clear line of sight as suggested in [11] (although DNV understands that this zone is under review by the authors of that document). For each of the links crossing the proposed wind farm site, DNV has established a diffraction exclusion zone based on the second Fresnel zone for that link.

It is common practice to have multiple Assignment IDs for the same physical link to cover practicalities such as licensing for sending or receiving signals. Accordingly, the second Fresnel zone for each link has been calculated based on the Assignment ID with the lowest frequency.

The potential diffraction exclusion zones in the horizontal plane are shown in Figure 8. Each exclusion zone includes the rotor radius for turbines with a 180 m rotor diameter, and an additional buffer of 25 m on either side to account for potential inaccuracies in the tower locations given in the ACMA RRL database.

For each point-to-point link where there are turbines located within the diffraction exclusion zone in the horizontal plane, DNV has also assessed the potential for the turbine blades to intersect with the diffraction exclusion zone in the vertical plane. This was achieved by examining the elevation and antenna heights at the ends of the link, as well as the approximate elevation of areas within the wind farm site over which the link crosses.

The results of this analysis are summarised in Table 1.

There are turbines located within the exclusion zones in the horizontal and vertical planes for point-to-point links operated by NBN Co, NSW Police Force, and Warrumbungle Shire Council. Therefore, it is likely that the Project will cause interference to these point-to-point links through diffraction of the signals.

Table 1 Details of turbines located within the diffraction exclusion zones established by DNV for point-to-point links crossing the proposed wind farm site

Link no.	Operator	Turbines within potential diffraction exclusion zone	
		Horizontal plane	Vertical plane
1	Essential Energy	None	Not assessed[1]
2	NBN Co Limited	None	Not assessed[1]
3	NBN Co Limited	None	Not assessed[1]
4	NBN Co Limited	1 turbine (LV7)	1 turbine (LV7)
5	NBN Co Limited	1 turbine (LV7)	1 turbine (LV7)
6	NBN Co Limited	1 turbine (LV7)	1 turbine (LV7)
7	NBN Co Limited	1 turbine (LV7)	1 turbine (LV7)
8	NBN Co Limited	1 turbine (LV7)	1 turbine (LV7)
9	NBN Co Limited	1 turbine (LV7)	1 turbine (LV7)
10	NBN Co Limited	1 turbine (LV7)	1 turbine (LV7)
11	NBN Co Limited	1 turbine (LV7)	1 turbine (LV7)
12	NBN Co Limited	None	Not assessed[1]
13	NBN Co Limited	None	Not assessed[1]

Table 1 Details of turbines located within the diffraction exclusion zones established by DNV for point-to-point links crossing the proposed wind farm site (continued)

Link no.	Operator	Turbines within potential diffraction exclusion zone	
		Horizontal plane	Vertical plane
14	NBN Co Limited	None	Not assessed[1]
15	NBN Co Limited	None	Not assessed[1]
16	NBN Co Limited	None	Not assessed[1]
17	NBN Co Limited	None	Not assessed[1]
18	NBN Co Limited	None	Not assessed[1]
19	NBN Co Limited	None	Not assessed[1]
20	NBN Co Limited	1 turbine (LV7)	1 turbine (LV7)
21	NBN Co Limited	1 turbine (LV7)	1 turbine (LV7)
22	NBN Co Limited	1 turbine (LV7)	1 turbine (LV7)
23	NBN Co Limited	1 turbine (LV7)	1 turbine (LV7)
24	NBN Co Limited	None	Not assessed[1]
25	NBN Co Limited	None	Not assessed[1]
26	NBN Co Limited	None	Not assessed[1]
27	NBN Co Limited	None	Not assessed[1]
28	NBN Co Limited	1 turbine (LV7)	1 turbine (LV7)
29	NBN Co Limited	1 turbine (LV7)	1 turbine (LV7)
30	NBN Co Limited	1 turbine (LV7)	1 turbine (LV7)
31	NBN Co Limited	1 turbine (LV7)	1 turbine (LV7)
32	NBN Co Limited	1 turbine (LV7)	1 turbine (LV7)
33	NBN Co Limited	None	Not assessed[1]
34	New South Wales Government Telecommunications Authority	None	Not assessed[1]
35	New South Wales Government Telecommunications Authority	None	Not assessed[1]
36	New South Wales Government Telecommunications Authority	None	Not assessed[1]
37	NSW Police Force	1 turbine (MH47)	1 turbine (MH47)
38	NSW Rural Fire Service	None	Not assessed[1]
39	NSW Rural Fire Service	None	Not assessed[1]
40	Telstra Corporation Limited	None	Not assessed[1]
41	Warrumbungle Shire Council	2 turbines (MH47, MH48)	2 turbines (MH47, MH48)
42	Warrumbungle Shire Council	None	Not assessed[1]

1. Turbines are sufficiently clear of the diffraction interference zone in the horizontal plane, and so clearance in the vertical plane was not assessed.

3.2.1.2 Interference caused by reflection or scattering

Interference due to reflection or scattering of a fixed point-to-point link can occur when the signal produced by the transmitting antenna is reflected, scattered, or re-radiated by an intervening object into the corresponding receiver antenna. If the reflected or scattered signal is sufficiently strong that the ratio of the direct signal to the indirect signal is lower than the required carrier-to-interference (C/I) ratio, or protection ratio, for the link, the link performance can be degraded. The extent to which an object such as a wind turbine will reflect or scatter electromagnetic waves is characterised by its radar cross section [9].

Reference [9] describes a methodology for calculating the C/I ratio that might be expected at a receiver in the presence of a reflected or scattered signal from a wind turbine at a specified location. By evaluating the C/I ratio for incremental changes in the distances between the transmitter, receiver, and wind turbine, and comparing this to the required C/I ratio, a potential interference zone can be defined.

The potential for interference due to reflection or scattering effects may be greater for low frequency links, as the direct path between the transmitter and the receiver is often obstructed by terrain. In this situation, a signal that has been reflected or scattered from a wind turbine with a clear line of sight to the transmitter or receiver may be considerably stronger than the direct signal and therefore have greater potential to cause interference [11]. This is most likely to be a problem if the turbines are located within approximately 5 km of the transmission tower at either end of the link. Conversely, the increased antenna directionality (or gain) and narrower scatter regions typically associated with high frequency links can make the signal for those links less susceptible to interference caused by reflection or scattering regardless of where the turbines are located [11].

DNV considers that the transmission towers for the low frequency point-to-point links crossing the wind farm site are sufficiently far from the proposed turbine locations to avoid reflection or scattering effects. The transmission towers for the high frequency links crossing the Project are closer to the proposed turbine locations but, as noted above, these links are considered less likely to be affected by reflection or scattering of the signals. Therefore, it is not expected that the Project will cause interference to the point-to-point links through this mechanism.

3.2.1.3 Interference caused by near-field effects

The potential for interference to fixed point-to-point links caused by near-field effects can generally be avoided by keeping clear of the near-field zone for the transmitting or receiving antenna. Within the near-field zone, local inductive and capacitive effects are significant and it is difficult to predict the potential impacts of other objects on the transmitted or received signal. Although the near-field distance typically varies with direction relative to the link path, for most practical purposes the near-field zone can be approximated as a sphere centred on the transmitting or receiving antenna.

Reference [9] presents an equation for estimating the radius of the near-field zone for a point-to-point link from the properties of the transmitting or receiving antenna.

DNV considers that the transmission towers for all the point-to-point links crossing the wind farm site are sufficiently far from the proposed turbine locations to avoid near-field effects. Therefore, it is not expected that the Project will cause interference to the point-to-point links through this mechanism.

3.2.2 Stakeholder consultation

DNV recommends contacting the operators of the point-to-point links crossing the proposed wind farm site to determine the likelihood that the proposed Project will cause interference to their operations and services through diffraction, reflection or scattering, or near-field effects.

3.2.3 Mitigation options

Mitigation options would need to be identified in consultation with the relevant operators, but may include upgrading the equipment for the link, re-routing the link via an existing or new tower, or replacing the link with an alternative communication technology. Depending on the availability of suitable mitigation options, this could result in turbines being moved outside of agreed clearance zones around the affected links.

3.3 Fixed licences of point-to-multipoint type

Fixed licences of the point-to-multipoint type are a variation of the point-to-point type. The difference between them is administrative. A point-to-point licence permits communication between two static sites, where the locations of the sites are detailed in the ACMA RRL database. A point-to-multipoint licence allows communication between one or more static sites and multiple points or between the points, and is usually licensed for a defined operational area.

Administratively, the ACMA RRL database details the location of the static station for a fixed licence of the point-to-multipoint type but does not include the remote stations that communicate with the static station. Hence, the paths of the transmission vectors are not readily identifiable.

3.3.1 Locations of point-to-multipoint licences and potential for interference

From the ACMA RRL database, DNV has identified 64 point-to-multipoint Assignment IDs within approximately 75 km of the proposed wind farm site. These licences are shown in Figure 9. The details of the licence holders as given in the ACMA database are provided in Table 13.

There is one point-to-multipoint base station within 20 km of the wind farm site. This station is operated by Ulan Coal Mines Ltd. There are also several point-to-multipoint base stations located more than 20 km from the site.

Wind turbines can cause interference to point-to-multipoint links through the same mechanisms as described for point-to-point links in Section 3.2.1. However, as it is not possible to know the link paths in a point-to-multipoint network without obtaining further information about the locations of each station in the network, consultation with the relevant operators is needed to determine the potential for interference.

3.3.2 Stakeholder consultation

DNV recommends contacting the operators of all potentially affected base stations within 60 km of the Project to identify the associated link paths and determine the likelihood that the proposed Project will cause interference to their services.

3.3.3 Mitigation options

If interference to point-to-multipoint links is experienced, mitigation options may include re-routing the links, installing additional towers, or replacing the affected links with alternative communications infrastructure.

3.4 Other licence types

Besides fixed point-to-point and point-to-multipoint licences, other licence types recorded in the ACMA RRL database include spectrum licences that permit a range of radiocommunications in a specific geographic area and frequency band, private mobile radio and public telecommunications service (PTS) licences, television and radio broadcasting licences, amateur apparatus licences, and aeronautical licences for ground to aircraft communications.

3.4.1 Locations of other licences and potential for interference

DNV has identified a number of other licences in the ACMA RRL database within 75 km of the proposed wind farm site. The locations of these licences and number of associated Assignment IDs for each licence type are shown in Figure 10 and Table 14.

Most of the licences identified can be broadly described as base to mobile station or point-to-area style communications, including commercial and private mobile telephony and radio and television broadcasting. These licence types are generally not affected by the presence of wind turbines any more than other effects such as terrain, vegetation, and other forms of signal obstruction.

The potential for interference to emergency services signals and commercial mobile telephony signals is discussed further in Sections 3.5 and 3.10 respectively, while the potential for interference to radio and television broadcasting services is considered in Sections 3.13 and 3.14.

A number of aeronautical licences, and radiodetermination licences which may be used for aircraft navigation, have been identified. DNV expects that potential impacts to these services will be considered as part of an aviation impact study. DNV notes that there is an aeronautical license to the north of the site which may require consideration as part of the aviation impact study.

3.5 Emergency services

Licence types operated by emergency services such as state ambulance, police, fire, and rescue services typically comprise fixed point-to-point link and mobile radio communications.

3.5.1 Locations of emergency services licences and potential for interference

DNV has reviewed the ACMA RRL database to identify emergency services with licences for radiocommunication assets operating in the vicinity of the Project. The groups identified are listed in Table 15 along with their contact details. The nearest licence is associated with a tower located within the wind farm site, approximately 4.1 km from the nearest proposed turbine location.

The potential for the turbines at the Project to interfere with emergency services point-to-point links crossing the proposed wind farm site is discussed in Section 3.2.

All other licences operated by emergency services in the vicinity of the Project are mobile telephony licences used for mobile radio and paging systems. As discussed in Section 3.4, mobile telephony systems are generally not affected by the presence of wind turbines any more than other forms of signal obstruction. Reference [11] provides general guidance regarding the potential for interference with mobile radio systems, and suggests that a clearance of 500 m from the tower is sufficient to avoid significant impacts to these systems. Other references recommend that turbines be kept outside of clearance zones ranging from a distance of 200 m to 1200 m from the tower for point-to-area style services [12].

Given the distance of the emergency services mobile telephony licences from the proposed turbine locations, DNV considers it unlikely that the Project will cause interference to mobile radio and paging systems operated by emergency services.

3.5.2 Stakeholder consultation

DNV recommends contacting the operators of all potentially affected stations within approximately 60 km of the Project to seek feedback regarding any potential impact that the Project could have on their operations and services.

3.5.3 Mitigation options

Potential mitigation options for impacts to emergency services point-to-point links crossing the wind farm site are discussed in Section 3.2.3.

As noted above, interference with mobile telephony services is considered unlikely. If localised interference to mobile radio or paging system signals is experienced, this can often be mitigated by the user moving a short distance to a new or higher location to receive a clearer signal or by using an external antenna to improve the signal reception. Other mitigation options may include increasing the signal strength from the affected tower or alternative towers, or installing a signal repeater or additional tower on the opposite side of the Project.

3.6 Aircraft navigation systems and radar

DNV expects that a separate aviation impact study will be undertaken to assess the impact of the Project on nearby aviation navigation systems and radar.

3.7 Meteorological radar

The Bureau of Meteorology (BoM) operates a network of weather radars across Australia consisting of high-resolution Doppler radars and standard weather watch or weather surveillance radars. Operation of the BoM's part-time wind finding radar installations ceased in August 2019 [13].

Standard weather watch radars emit pulsed microwave radiation and use reflections or "echoes" of that radiation from water particles in the atmosphere to detect rain and storm activity. Doppler radar installations operate in the same way but are also able to measure the speed of the moving water particles, and therefore can provide information about wind speed and direction [14, 15].

While the uninhibited operation of meteorological radars may not be as critical as aviation radar, there are implications for public safety if severe weather is not predicted or if its approach is masked due to EMI. Because radar installations monitor the current weather situation over a wide area, the information they provide can be used to indicate the possibility and approach of severe storms, tropical cyclones, and flooding events. Wind profile measurements are also used to ensure the safe and economical operation of aircraft and provide an important source of data for the BoM's general weather forecasting system.

The optimal coverage area for a weather radar generally extends approximately 200 km from the radar installation at a height of around 3000 m [16, 17], and approximately 100 km at a height of 1000 m [17]. Therefore, wind farms can theoretically impact on weather radar operations when located within several hundred kilometres of an installation. However, due to the curvature of the earth and intervening terrain, the range at or near ground level is generally less.

The World Meteorological Organisation (WMO) currently states that wind turbines should not be located within 5 km of a meteorological radar site, due to the high potential for complete or partial

blockage of the radar signal and subsequent loss of weather data [18, 19]. For wind farms located between 5 km and 20 km of a radar, the WMO recommends consultation and analysis to assess the likelihood of turbines causing reflection or scattering of the radar signals or interfering with Doppler velocity measurements. At distances of between 20 km and 45 km, the presence of a wind farm may produce radar echoes or signal clutter that can cause loss of data or be mistaken for rain. Significant impacts are generally not expected for wind farms located more than 45 km from a meteorological radar since, in most cases, the turbine will be below the radar scan line of sight. However, the WMO notes that these guidelines are only applicable to typical radar installations in flat terrain and may need to be modified for higher-powered radars or specific situations.

Recent advice received from the BoM also suggests that there may be potential for interference to meteorological radar operations from wind farms over much greater distances than indicated by the WMO guidelines, depending on the relative elevations of the radar and the wind farm and the intervening terrain. Due to electromagnetic wave propagation behaviour, radar frequency signals may be subject to diffraction or 'bending' over terrain obstructions and may therefore be reflected by turbines even if the wind farm is located below the radar line of sight or is obstructed by terrain. In such cases, reflected signals from the turbines could potentially return to the radar with sufficient strength to cause measurable interference. The BoM has also advised DNV of situations where measurable interference from wind turbines has been experienced at radar scanning angles where the unobstructed signal beam would normally be expected to pass clearly over the wind farm.

According to the Draft National Guidelines, operators of weather radars within 250 nautical miles (463 km) of the proposed Project should be consulted [3].

3.7.1 Locations of meteorological radars and potential for interference

DNV has identified that the BoM operates 10 weather radars within 250 nautical miles of the proposed Project, with the closest radar, "Namoi", located approximately 106 km northeast of the wind farm site. The locations of these radars are shown in Figure 11 and the details of each radar are given in Table 16.

The distance between the Project and the nearest BoM radar is considerably greater than the distances at which the WMO suggests impact may occur. However, as noted above, previous advice received from the BoM has indicated that there may be a potential for interference over greater distances than suggested by the WMO and in situations where the turbines are not within direct line of sight of the radar. Consultation with the BoM is therefore needed to determine whether there is any potential for interference.

3.7.2 Stakeholder consultation

DNV recommends contacting the BoM regarding the Project, as recommended by the Draft National Guidelines, to seek feedback on whether interference to their operations and services is likely.

3.7.3 Mitigation options

According to the WMO, there are currently no automated signal processing techniques available that can be used to effectively filter radar data to remove interference caused by wind farms [19], However, if analysis indicates there is a potential for the wind farm to cause reflection or scattering of radar signals, the WMO suggests it may be possible to reduce the likely impact through the relocation of individual turbines prior to construction. In situations where the expected interference

is limited to signal clutter, the radar operator may also be able to mask these effects in the data or train the users to take the locations of the wind farms into account.

3.8 Trigonometrical stations

A trigonometrical station, also known as a trig point or a trig beacon, is an observation mark used for surveying or distance measuring purposes.

Some trig points may host surveying equipment such as Global Positioning System (GPS) antennas and electronic distance measuring (EDM) devices. EDM devices measure the distance from the trig point to the target object by means of a beam of known velocity which is reflected back to the unit from the target object. Most EDM devices require the target object to be highly reflective and, accordingly, a reflective prism is placed on the target object being surveyed.

The effective range of EDM devices depends on the wavelength bands used. Light wave and infrared systems have an effective range of 3 km to 5 km, and could be intercepted or obstructed by the presence of turbines. However, the potential for impact is considered low as it is likely to be possible to relocate the target to obtain an unobstructed view of the trig point. Microwave systems can measure distances up to 150 km, but such systems are not limited by the line of sight or affected by visibility [20].

Global navigation satellite system (GNSS) technology is also commonly used for surveying and distance measurements, as it enables users to accurately determine their geographic location using positioning and timing information received from satellite signals. Geoscience Australia currently operates several GNSS networks across Australia, including the Australian Regional GNSS Network (ARGN) and the AuScope GNSS network [21]. The ARGN is comprised of 20 permanent GNSS Continuously Operating Reference Stations (CORS) which provide the geodetic framework for the spatial data infrastructure in Australia and its territories. Eight stations from the ARGN form the Australian Fiducial Network (AFN) [22], through which the Geocentric Datum of Australia (GDA) is defined. The ARGN also provides information for the measurement of geological processes and contributes data to the International GNSS Service. Additional geospatial information aimed at enhancing the accuracy and resolution of the National Geospatial Reference System is provided by In New South Wales, NSW Spatial Services also operates a state-wide GNSS CORS network, known as CORSnet-NSW, which is used to provide positioning data for mapping, surveying, agriculture, and industry [23]. the AuScope GNSS network of around 100 CORS strategically distributed across the country. GNSS stations are typically equipped with EDM devices and GPS receivers, and transmit data to Geoscience Australia or the relevant state authority via phone lines, internet, or satellite communications.

3.8.1 Locations of trigonometrical stations and potential for interference

According to Geoscience Australia [24], there are 26 trig points within 20 km of the wind farm site. Three trig points are located inside the wind farm site, with the closest trig point, Collier, located approximately 197 m north of the nearest proposed turbine location. The details of these trig points are provided in Table 17 and their locations are illustrated in Figure 12.

DNV has reviewed the primary geodetic network of Australia [25] and observed that the Project is located within the first-order or second-order triangulation region. First-order triangulation depends on trigonometrical stations of known positions, baselines and heights, with the highest degree of accuracy. Points determined from first-order triangulation are then used for the second-order

triangulation network and so forth, with the degree of accuracy decreasing for subsequent networks.

The closest GNSS station is located approximately 2.9 km northeast of the Project, at Coolah [24]. Due to the relatively small distance between the Project and the GNSS station, DNV recommends contacting Geoscience Australia to seek feedback regarding the potential for the Project to cause interference to the GNSS network.

3.8.2 Stakeholder consultation

Although it is unlikely that the trig points in close proximity to the Project host EDM devices or other equipment that may be subject to EMI, DNV recommends contacting Geoscience Australia and NSW Spatial Services to inform them of the Project, and seek feedback regarding whether interference to their systems is possible.

3.9 Citizens band radio

Citizens band radio, also known as CB radio, is a class-licensed two-way, short distance communication service that can be used by any person in Australia for private or work purposes. It is commonly used in rural areas for emergency communications, road safety information, communication between recreational travellers, and general conversation. The class licence implies that all users of the CB radio operate within the same frequency range on a shared basis and no individual licence is required.

The CB radio service can be used for voice communication activities, telemetry, and telecommand applications. The radio service operates on two frequency bands, namely the high frequency (HF) band between 26.965 MHz and 27.405 MHz and the ultra-high frequency (UHF) band between 476.425 MHz and 477.400 MHz.

The HF CB radio service was legalised in Australia in the 1970s as a temporary move to switch to UHF CB over the following five years, and transmits signals in either AM (amplitude modulation) or SSB (single side band) transmission mode. The actual range over which the signal is transmitted depends on the antenna used, the terrain, and the interference levels. Over the last decade, the use of the HF CB radio service has declined and has been replaced by UHF CB radio service.

The UHF CB radio service is unique in Australia and uses the FM (frequency modulation) transmission mode. It provides clear communication over 5–20 km and is less susceptible to power line noise. However, the UHF CB radio service requires a clear line-of-sight for a strong signal and is easily hindered by hilly terrain and forested areas. Even in the absence of physical obstructions, UHF CB radio signals generally cannot travel beyond the effective radio horizon, which depends on elevation, antenna height, weather, and atmospheric conditions. If located on a hilltop, CB radio signals can be transmitted over at least 50 km. However, under normal conditions on flat ground, signal range is typically limited to around 5 km. CB repeater stations are often set up on hilltops by community groups and commercial organisations to transmit signals from one channel to another.

No individual or organisation owns or has the right to use a channel exclusively. However, out of the 40 channels available, some of them will be allocated to emergency, telemetry, or repeater inputs.

3.9.1 Locations of CB radio devices and potential for interference

Since users of CB radio services do not require a licence, there is no record of users of the service and their locations and the channels are shared among the users and the repeater stations without

a right of protection from interference. Given the limitations of UHF radio signals, CB radio services are typically only intended for local or short-range communications. CB radio signals passing through the wind farm site are likely to be intercepted by existing obstructions such as terrain and vegetation, and there is little evidence in the literature to suggest that wind turbines pose a particular risk of interference to these systems. Therefore, the impact of the Project on CB radio services is expected to be minimal.

3.9.2 Mitigation options

If interference to CB radio signals is experienced, simple steps such as moving a short distance to a new or higher location until the signal strength improves may help to mitigate the impact. CB radio users can also increase their signal range and improve reception by switching their equipment to a higher power setting, using a longer antenna, or increasing the antenna mounting height.

3.10 Mobile phones

Mobile phone networks typically operate at frequencies of either between 700 and 900 MHz, or between 1800 MHz and 2600 MHz, however some new services may operate at up to 3500 MHz. At such frequencies, signals may be affected by physical obstructions such as buildings and wind turbines. However, mobile phone networks are designed to operate in such conditions and in most cases, if there is sufficient mobile network coverage and signal strength, the presence of wind turbines is unlikely to cause any interference.

In rural areas, the mobile network coverage may be more susceptible to physical obstructions due to the large distance between the phone towers and the mobile phone user. In that case, it is theoretically possible that wind turbines could cause some interference to the signal. However, there is little evidence in the literature of wind turbines interfering with mobile phone signals, and DNV notes that previous advice received from mobile phone network operators in Australia has generally indicated that they do not expect wind farm developments to interfere with their services.

3.10.1 Availability of mobile phone services and potential for interference

DNV has reviewed the locations of mobile phone towers in the vicinity of the proposed Project. The locations of these towers are shown in Figure 13. The nearest mobile phone tower is located within the wind farm site, approximately 4.1 km from the nearest proposed turbine location.

Mobile phone network coverage maps have been obtained for Optus, Telstra, and Vodafone.

Figure 14 and Figure 15 show the Optus Mobile network coverage for the Project area [26]. Outdoor 3G and 4G coverage is available in areas around Coolah and Dunedoo to the northeast and southwest of the wind farm site, respectively. In most other locations across the wind farm site and the surrounding area, coverage is either not available or requires the use of an external antenna.

Figure 16 and Figure 17 show the Telstra network coverage for the Project area [27]. 3G and 4G coverage is available in many locations across the wind farm site and the surrounding area, although there are some areas to the east, south, and northwest where coverage is not available.

Figure 18 shows the Vodafone network coverage for the Project area [28]. Signal coverage is very limited across most of the wind farm site and surrounding area. Only small areas in the north of the site and to the northwest, and some isolated locations elsewhere, are able to receive outdoor 3G coverage. 4G and 5G signal coverage is not available in the area.

In general, for areas with good coverage, interference to mobile phone signals is unlikely. However, for areas where the reception is likely to be marginal, such as those where an external antenna is required, the possibility for interference exists if a wind turbine intercepts the signal between a mobile phone and the tower. For the Optus and Telstra networks, this may be more likely to occur in locations with reduced signal coverage away from the more populated areas around Coolah and Dunedoo. Given the poor coverage of Vodafone signals in the area around the Project, it is considered relatively unlikely that residents will be using this service compared to the Optus and Telstra networks.

3.10.2 Stakeholder consultation

DNV recommends contacting Optus, Telstra, and Vodafone to inform them of the proposed Project and to seek feedback on any potential impact that the Project could have on their services.

3.10.3 Mitigation options

As noted above, interference with mobile phone signals is generally considered unlikely. If localised interference is experienced by mobile phone users, this can often be rectified by the user moving a short distance to a new or higher location until the signal improves, or using an external antenna to improve the signal reception. For interference over a larger area, or in cases where it would not be possible or practical for the user to change their location, mitigation options may include increasing the signal strength from the affected tower or alternative towers, or installing an additional tower on the opposite side of the Project.

3.11 Wireless internet

Wireless internet services in Australia include wireless broadband provided by mobile phone network operators and other internet service providers, and fixed wireless or satellite internet services through the National Broadband Network (NBN).

3.11.1 Wireless broadband services

Wireless broadband services allow the user to connect to the internet without the need for a phone line or cable connection. The wireless signals may operate by line of sight between a base station and the user's antenna as part of a point-to-multipoint network, or may use point-to-area style transmissions such as mobile phone networks.

3.11.1.1 Availability of wireless broadband services and potential for interference

Residents in the vicinity of the Project may use wireless broadband services provided by Optus and Telstra. These wireless broadband services use the same networks as mobile phone services for those providers, and therefore the comments made in Section 3.10.1 are applicable here. Specifically, there is a low theoretical likelihood of interference in areas with marginal reception if a wind turbine intercepts the signal between a receiver and the tower.

3.11.1.2 Stakeholder consultation

As noted in Section 3.10.2, DNV recommends contacting Optus and Telstra to inform them of the proposed Project and to seek feedback on any potential impact that the Project could have on their services.

3.11.1.3 Mitigation options

As noted above, interference with wireless broadband services is generally considered unlikely. If interference to the wireless broadband services provided by mobile phone networks occurs, the mitigation options given in Section 3.10.3 may be applicable. Specifically, localised interference can

often be rectified by the user moving a short distance or using an external antenna to improve signal reception. For interference over a larger area, or in cases where it would not be possible or practical for the user to change their location, mitigation options may include increasing the signal strength from the affected tower or alternative towers, or installing a signal repeater or additional tower on the opposite side of the Project.

3.11.2 National Broadband Network

The NBN is a national wholesale broadband access network, which consists of fixed line, fixed wireless, and satellite internet services.

NBN fixed line services use wired connections to provide internet signals directly to the user. This technology is typically only available in urban areas and is not expected to be affected by wind farm developments.

NBN fixed wireless services are available in many rural and regional areas. The signals operate by line of sight between an NBN tower and the user's antenna, with a maximum range of 14 km [29]. Consequently, the signals may be affected by physical obstructions such as terrain, vegetation, and wind turbines [30].

NBN satellite internet signals are available to rural and remote users in areas that are not able to receive fixed line or fixed wireless services. The potential for interference to satellite internet signals from the NBN Sky Muster I and II satellites is considered in Section 3.12.

3.11.2.1 Availability of NBN services and potential for interference

The National Broadband Network (NBN) website [31] indicates that the network is currently available as a fixed wireless and satellite internet service in the area surrounding the Project. It is therefore likely that some residents are currently accessing the internet via the NBN and that the network will also be available to other residents in the vicinity of the Project in the near future. The locations of NBN fixed wireless towers within 75 km of the wind farm site are shown in Figure 13, and a map of NBN service coverage in the vicinity of the Project is shown in Figure 19.

The NBN fixed wireless towers servicing the Project area are located at Coolah in the northeast and Dunedoo in the southwest. Based on the relative positions of the NBN towers and nearby dwellings, and the fixed wireless coverage areas shown in Figure 19, it is considered unlikely that the Project will impact residents who are currently using the NBN fixed wireless service.

3.11.2.2 Stakeholder consultation

Although the NBN coverage map suggests that interference to NBN fixed wireless internet signals is unlikely, DNV recommends contacting NBN Co to seek feedback on whether there is potential for the Project to cause interference to their services and to allow them to take the presence of the Project into account in their coverage planning maps.

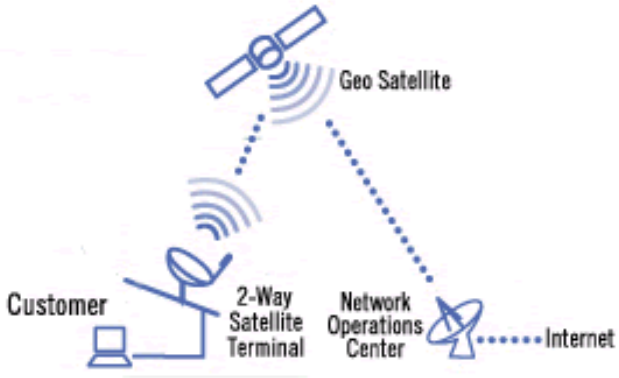
3.12 Satellite television and internet

In some rural or remote areas, television and internet access can only be provided through satellite signals.

Satellite television is delivered via a communication satellite to a satellite dish connected to a set-top box. Satellite television signals are typically transmitted to the user's antenna in one of two frequency bands: the C-band between 4 GHz and 8 GHz, or the Ku-band between 12 GHz and 18 GHz. Signals in the C-band are susceptible to interference due to radio relay links, radar

systems, and other devices operating at a similar frequency. Signals in the Ku-band are most likely to be affected by rain which acts as an excellent absorber of microwave signals at this frequency. The main satellites that transmit Australian free-to-air or subscription television channels are the Optus C1, D1, and D3 satellites and the Intelsat 19 satellite [32, 33].

In the case of satellite internet, the user's computer is connected to a satellite modem which is in turn linked to a satellite dish or antenna mounted on the building roof. When the user accesses the internet, a request is sent to the operation centre of the satellite internet provider via the satellite antenna. Data is then sent back to the user's computer via the same path as shown in the figure below. Satellite internet signals are typically transmitted in the Ku-band, as for satellite television, or the Ka-band, with frequencies ranging from 26.5 GHz to 40 GHz. Like signals in the Ku-band, signals in the Ka-band are susceptible to deterioration caused by moisture in the air, but newer satellites contain technologies that help to minimise the loss of signal quality associated with rain and other weather conditions. The main satellites for providing satellite internet in Australia are the IPSTAR (THAICOM-4) and Optus D2 satellites, and the NBN SkyMuster I and II satellites.



Two-way connection to the internet via satellite [34]

3.12.1 Locations of satellite vectors and potential for interference

Due to marginal coverage of some communication services, some residents in the vicinity of the Project may use satellite television and internet.

A number of satellites transmit television and internet signals that can be received in Australia. DNV has analysed the line-of-sight to dwellings in the vicinity of the Project for satellites which provide any television or internet services to eastern Australia. Although only a small number of satellites are likely to be providing services specifically intended for Australia, all theoretically viewable satellites have been considered.

The results of the analysis are shown in Table 2. Based on these results, turbines at the Project may intercept signals from 16 satellites at 40 nearby dwellings, 14 of which are associated dwellings.

DNV understands that all the potentially affected satellites shown in Table 2 provide television signals intended for international audiences, and considers it unlikely that residents in the vicinity of the Project will currently be receiving signals from these satellites. Many of the satellites have a low angle of elevation above the horizon at the wind farm site location, and so degradation caused

by atmospheric effects or interference from terrain or other obstacles may already prevent the signals from being received at the affected dwellings. For some of these satellites, the programs transmitted on the beam footprints that cover Australia may also be available through other satellite services which have a higher angle of elevation above the horizon and are not expected to be intercepted by turbines at the Project. If residents are not currently receiving signals from the satellites identified in Table 2, either by choice or because those signals are not available due to existing degradation or interference, there will be no potential for the Project to impact on those services.

Table 2 Satellite vectors with potential to be intercepted by the proposed Project

Intercepted satellite	Services provided [35]	Affected dwellings[1]
Eutelsat 70B (E70B, W5A, Eutelsat W5A)	Programs intended for international audiences	236, *250*, *297*
Intelsat 22 (IS-22)	Programs intended for international audiences	22, 30, 81, 82, 84, 88, 189, 190, 236, *250*, *252*, *253*, *254*, 277, 283, *284*, 285, 286, 291, 293, 357, 497, 505
G-Sat 7 (Insat 4F, Rukmini), G-Sat 11, G-Sat 14, G-Sat 18	Programs intended for international audiences	81, 84, 87, 88, 139, 140, 144, 190, *251*, *252*, *256*, *276*, 277, *279*, *284*, 285, *304*, 357, 497, 505
ABS 2 (ST 3, Koreasat 8, Condosat 2), ABS 2A (Mongolosat-1)	Programs intended for international audiences	25, 81, 82, 84, 87, 190, *252*, *254*, *256*, 285, *304*, 357, 505
Apstar 7	Programs intended for international audiences	25, 81, 82, 84, 87, 189, 190, *256*, *279*, *304*, 318, 505
Thaicom 6 (Africom 1), Thaicom 8	Programs intended for international audiences	25, 83, 84, 87, 189, *251*, *252*, *253*, *254*, *256*, *304*
Express 80	Programs intended for international audiences	25, 189, *251*, *253*, *254*, *256*, *280*, *304*
G-Sat 10, G-Sat 6 (Insat 4E), G-Sat 12, G-Sat 30	Programs intended for international audiences	25, 85, 88, *256*, *257*, *281*

1. Associated dwellings are indicated by *underlined italic text*.

3.12.2 Stakeholder consultation

As discussed in Section 3.12.1, it is unlikely that nearby residents are currently receiving signals from satellites that may be affected by interference from turbines at the Project. If desired by the Proponent, the potential for impact could be confirmed by engaging with the residents of the dwellings identified in Table 2 prior to construction of the Project to determine if any are currently receiving signals from the potentially affected satellites and to establish an understanding of how any impact to these services may be mitigated.

3.12.3 Mitigation options

If interference to satellite television signals is experienced at dwellings in the vicinity of the Project, several mitigation options may be available. If an alternative source of the same programming is available, it may be possible for the satellite dishes at affected dwellings to be re-directed to receive signals from the other satellite. In some cases, residents may also be able to access the

affected programs directly over the internet. If an alternative source of programming is not available, it may be possible to rectify interference by installing a larger or higher-quality satellite dish, or by changing the height or location of the dish to obtain a stronger signal.

3.13 Radio broadcasting

Radio stations typically broadcast using one of two forms of transmission: either amplitude modulation (AM) or frequency modulation (FM). In Australia, AM radio operates in the medium wave (MW) band at frequencies between 520 kHz and 1610 kHz, while FM radio operates in the very high frequency (VHF) band between 87.5 MHz and 108 MHz.

3.13.1 AM radio

AM radio signals are diffracted by the ground as they propagate, such that they follow the curvature of the earth, and are also reflected or refracted by the ionosphere at night. This means that AM radio waves are able to travel significant distances under the right conditions. Due to their long wavelength, they can readily propagate around physical obstructions on the surface of the earth (such as wind turbines), however they do not propagate easily through some dense building materials such as brick, concrete, and aluminium.

The distance over which AM radio signals can travel means that the signal may be weak and susceptible to interference by the time it reaches a receiver. Some of the possible sources of interference to AM radio waves include changes in atmospheric conditions, signals from distant AM broadcasters operating on a similar frequency, electrical power lines, and electrical equipment including electric motors.

However, as noted above, the presence of physical obstructions such as turbines is unlikely to cause significant interference to AM radio signals. Due to the long wavelength of the signal, interference is only likely in the immediate vicinity of a turbine [36].

3.13.1.1 Locations of AM transmitters and potential for interference

The locations of AM broadcast transmitters in the vicinity of the Project were determined from the ACMA Broadcast Transmitter Database [37], and are shown in Figure 20.

It is unlikely that any permanent AM radio receivers will be located sufficiently close to the Project to be affected by interference to the radio signals from the turbines.

3.13.1.2 Mitigation options

In the event that localised interference to AM radio signals is experienced, this can potentially be rectified by installing a high-quality antenna or amplifier at the affected residence.

3.13.2 FM radio

FM radio signals are better suited to short range broadcasting. Unlike lower frequency signals (such as AM signals), they are not reflected or refracted off the ionosphere. The waves are slightly refracted by the atmosphere and curve back towards the earth, meaning they can propagate slightly beyond the visual horizon. However, they may be blocked by significant terrain features. FM radio stations therefore tend to have only local coverage, which means that signals are less susceptible to interference from distant FM broadcasters. FM signals are also less susceptible to interference from changes in atmospheric conditions and electrical equipment than AM signals.

FM radio signals are susceptible to interference from buildings and other structures, although they are less vulnerable than higher frequency signals. Interference to FM signals can occur by two

mechanisms: reflection or scattering of the radio waves, or physical obstruction and attenuation of the broadcast signal.

Reflection or scattering of radio waves by physical structures such as wind turbines can reduce the signal strength at a receiver or can cause multi-path errors through reception of a reflected signal in addition to the primary signal from the transmitter. This can result in hissing, fluttering, or distortion being heard by the listener [38]. However, this type of interference is typically only experienced in the immediate vicinity (within several tens of metres) of a wind turbine, where the signal-to-noise ratio is low [36, 39].

Wind turbines located close to an FM transmission tower may also present a physical obstruction to the radio signal. If the line-of-sight between the tower and a radio receiver is blocked by a turbine, this can cause a noticeable decrease in signal quality or may lower the signal strength below the threshold of the receiver's sensitivity [38]. In these situations, the attenuation of the signal may be as great as 2.5 dB in the direction of the obstructing wind turbine. However, this type of interference is generally only a problem near the edges of the FM signal coverage area, where the broadcast signal is already weak. For commercial FM broadcast signals, physical obstruction of the signal may occur if the turbines are located within approximately 4 km of the transmission tower [40].

3.13.2.1 Locations of FM transmitters and potential for interference

The locations of FM broadcast transmitters in the vicinity of the Project were determined from the ACMA Broadcast Transmitter Database [37], and are shown in Figure 20.

The closest FM broadcast transmission tower is located approximately 3.4 km northeast of the proposed wind farm site or 5.7 km from the nearest wind turbine. Due to the distance between the transmission tower and the turbine locations, it is not expected that the Project will cause interference to the FM radio signals from this tower.

It is unlikely that any permanent FM radio receivers will be located sufficiently close to the Project to be affected by reflection or scattering of the radio signals from the turbines.

3.13.2.2 Mitigation options

In the event that localised interference to FM radio signals is experienced, this can potentially be rectified by installing a high-quality antenna or amplifier at the affected residence.

3.13.3 Digital radio

Digital radio services were introduced in metropolitan licence areas in Australia in July 2009. The digital radio services offered use an updated version of the digital audio broadcasting (DAB) digital radio standard, DAB+, to broadcast digital radio to Adelaide, Brisbane, Perth, Melbourne, and Sydney [41]. Digital radio broadcasts in Australia operate in the VHF band at frequencies between 174 MHz and 230 MHz, and therefore tend to have only local coverage within the visual horizon.

3.13.3.1 Availability of digital radio services and potential for interference

According to the digital radio coverage search functions available on the ABC website [42] and Digital Radio Plus website [43], the Project is outside the intended service area for digital radio broadcasts. Since it is therefore unlikely that residents in the vicinity of the Project are currently receiving digital radio signals, it is not expected that the Project will cause interference to these services.

3.14 Terrestrial television broadcasting

Terrestrial television is broadcast in Australia by a number of networks, both public and commercial. As of December 2013, all television broadcasts in Australia are now digital broadcasts [44]. Digital television (DTV) signals are typically more robust in the presence of interference than analogue television signals, and are generally unaffected by interference from wind turbines. DNV has experience in situations where dwellings were able to receive adequate DTV reception in an area of adequate signal strength where the DTV signal was passing through a wind farm.

The susceptibility of DTV signals to interference from wind turbines is discussed further in Section A.1 of Appendix A.

3.14.1 Availability of DTV broadcasting and potential for interference

The locations of DTV broadcast transmitters in the vicinity of the Project were determined from the ACMA Broadcast Transmitter Database [44], and are shown in Figure 20. The main DTV transmitter used by residents in the vicinity of the Project is the Central Western Slopes transmitter at Mt Cenn Cruaich. However, according to the Australian Government mySwitch website [45], it is also possible that residents to the northeast of the site are able to receive DTV signals from the Coolah transmitter. Coverage maps for these broadcast transmitters are reproduced in Figure 21 to Figure 22.

Figure 21 shows that the signal coverage from the Central Western Slopes transmitter is generally 'variable' to 'poor' across most of the wind farm site and surrounding area, with no signal available in some regions across the centre of the site and to the east and southeast. There are smaller areas of 'good' signal coverage from this tower across the north of the wind farm site and to the immediate southwest. The signal coverage from the Coolah retransmission tower is highly localised in the northeast of the site, as shown in Figure 22, with 'good' coverage in the area immediately around the tower and 'variable' coverage extending south of the tower across the wind farm site.

3.14.1.1 Interference caused by large scale effects

For broadcast signals, large scale interference can generally be avoided by placing the wind turbines distant from the broadcast tower. Broadcast transmitters may be either relay or primary transmitters. Relay transmitters are more commonly found in rural areas. Primary transmitter towers are higher power and are more commonly located near large urban areas. A clearance of at least 1 km is recommended for relay transmitters, while a clearance of at least 6 km is recommended for primary transmitters [10].

The closest DTV transmitter to the Project is the Coolah transmitter, which is approximately 7.2 km away. Therefore, it is considered unlikely that the Project will cause large scale interference to signals from this transmitter.

3.14.1.2 Interference caused by reflection or scattering

Although DTV signals are generally unlikely to be susceptible to interference from wind turbines in areas of adequate coverage, interference could be encountered in areas where coverage is marginal and antennas at dwellings may receive a reflected signal from a turbine that is of sufficient power to interfere with the signal received directly from the transmitter. Based on the coverage maps for the area around the Project, it is possible that some areas could be deemed to have marginal reception and interference could be encountered.

Due to the lack of an accurate theoretical scattering model, DNV has not performed detailed scatter calculations to predict DTV interference. Instead, dwellings that have increased potential to receive

back-scattered or forward-scattered signals from a turbine at the Project (assuming an antenna with a sufficiently narrow beam width and sufficiently high front-to-back ratio is being used) have been highlighted using the 'keyhole' approach described in Section A.3 of Appendix A, with a forward-scatter distance of 5 km and a back-scatter distance of 500 m.

The results of the analysis can be seen in Table 18 and Figure 21 to Figure 22. The dwellings most likely to be susceptible to interference include those within the potential interference zones, as summarised in Table 3.

Note that if the signal received at a dwelling from the transmitter is sufficiently weak, or an antenna with insufficient directional discrimination is installed (i.e., a low gain or omni-directional antenna), interference may still occur at dwellings outside of the identified interference zones. Circumstances under which interference may occur outside the interference zones typically established using the 'keyhole' approach are discussed further in Section A.2 of Appendix A. In particular, although DNV has considered the potential for interference to DTV signals at dwellings within 5 km of the proposed turbine locations, previous advice received from BAI Communications, who are responsible for broadcasting of national public television services in Australia, has indicated that interference to DTV broadcasting may be experienced at distances of up to 10 km from turbines. For comparison, Figure 21 and Figure 22 also show the area within 10 km of the proposed turbine locations, although a more detailed assessment would be required to determine whether there is any potential for interference to DTV signals received at dwellings outside the 'keyhole' interference zones.

Based on this assessment, dwellings located within the wind farm site and to the south and east of the Project have increased potential to experience interference to DTV signals from the Central Western Slopes tower. Coverage from this tower is marginal or non-existent across much of the affected area, with the exception of small areas to the north and southwest of the wind farm site, and so it is possible that many of the dwellings in the potential interference zones are not currently receiving signals from this tower. Additionally, dwellings located through the centre of the wind farm site and to the northeast may be able to receive a stronger signal from the Coolah retransmission tower, which would not be affected by interference from the Project. However, based on the local terrain and coverage map, there is potential for dwellings outside the identified interference zone that are currently receiving DTV signals from the Central Western Slopes tower to receive a reflected signal from the turbines at the Project which is stronger than the direct signal and to therefore experience interference.

Interference to DTV signals from the Coolah tower may also be experienced at dwellings in the vicinity of the Project, although the coverage map suggests that most of the dwellings located in the potential interference zone are unlikely to be receiving signals from this tower. For dwellings currently receiving DTV signals from the Coolah tower outside the identified interference zone, signal coverage is good close to the tower and the direct signal in this area is likely to be stronger than any potential reflected signals from the turbines at the Project. However, dwellings located outside the identified interference zone to the north of the Project and between the northern and eastern clusters of turbines may be currently receiving a weak signal from the Coolah tower that could be susceptible to interference.

Table 3 Number of dwellings located within potential interference zones for digital television broadcast transmitters in the vicinity of the wind farm site

Digital television broadcast tower	Number of dwellings in potential interference zone	Signal coverage in potential interference zone
Central Western Slopes (Mt Cenn Cruaich)	52 (22 associated dwellings)	'Good' to 'variable' for dwellings within the wind farm site to the north and southwest of the site, limited for dwellings in other areas
Coolah	32 (11 associated dwellings)	Limited – dwellings in the potential interference zone are unlikely to be receiving signals from this tower

The method used here to assess the potential interference to television signals from the Project represents a simplified approach which is expected to capture locations where interference is most likely to occur. This simplified analysis is deemed appropriate in most cases as the implications of potential television interference are typically low. If reception difficulties are encountered, there are a number of mitigation options available as discussed in further detail in Section 3.14.3.

3.14.2 Stakeholder consultation

DNV recommends contacting BAI Communications, who are responsible for broadcasting of national public television services in Australia, to inform them of the proposed Project and seek feedback on any potential impact that the Project could have on DTV signals in the surrounding area.

3.14.3 Mitigation options

In the event that television interference is an issue during construction or after commissioning of the Project, there are several mitigation options available:

1. Realigning the user's television antenna more directly towards their existing transmitter.
2. Tuning the user's antenna into alternative sources of the same television signal or a substitute signal.
3. Installing a more directional or higher gain antenna at the affected dwelling.
4. Relocating the antenna to a less affected position.
5. Installing cable or satellite television at the affected dwelling.
6. Installing a television relay station.

In the event of significant interference in the backscatter region, realigning the antenna or installing a more directional antenna should ensure a stronger signal from the transmitter since the backscattered signal will originate from a different direction. However, the effectiveness of this mitigation may be reduced if there is no clear line of sight from the antenna to the transmitter. In these cases, it may be more effective to move the antenna to a location where there is a clearer line of sight to the transmitter or to tune the antenna into an alternative or substitute signal (if one is available).

In the case of forward scatter, the antenna will be pointed towards both the original and scattered signal and hence a more aligned or directional antenna may not alleviate a forward scatter issue. Alternative mitigation measures to resolve issues caused by forward scatter could include turning the antenna into an alternative signal (if one is available) or installing cable or satellite television at the affected dwelling. However, as noted in [46], DVB-T reception quality may not be substantially affected in the forward scatter region.

The ITU [47] identified that the receiver height can also affect interference. In areas that are relatively flat and free of vegetation, reflections can enhance or decrease the received signal strength relative to the free path signal strength. The ITU found that the received signal strength may not increase monotonically with receiver height. In other words, lowering the receiver height can improve reception in some cases.

In the event that terrestrial DTV reception cannot be improved, satellite television represents another potential amelioration option. Satellite based television comprises of both free to air and subscription based broadcasts. Residents in areas which are unable to receive DTV through their normal television antenna due to local interference, terrain, or distance from the transmitter in their area may be eligible to access the Australian Government funded Viewer Access Satellite Television (VAST) service [48].

3.15 Cumulative impacts

DNV notes that the Project is located in the Central-West Orana REZ, which is likely to become an area of high wind farm development activity. Consequently, it is possible that some radiocommunication services could experience cumulative impacts from the proposed Project.

3.15.1 Locations of nearby wind farms and potential for cumulative impacts

The nearest wind farm currently under development is the approved Liverpool Range Wind Farm, located approximately 10 km northeast of the Project. The location of the Liverpool Range Wind Farm in relation to the Project is shown in Figure 23, based on a 288-turbine layout obtained from publicly available sources [49]. However, DNV understands that Development Consent for the Liverpool Range Wind Farm was granted based on a 267-turbine layout and that the developer is currently seeking a modification to the Development Consent based on a 223-turbine layout and larger turbine dimensions [50].

Other proposed wind farm developments in the Central-West Orana REZ include the Barneys Reef Wind Farm and Spicers Creek Wind Farm, located approximately 15 km and 45 km southwest of the Project respectively. Both these wind farms are in the very early stages of development and have not yet entered the NSW development assessment process. Therefore, very little information is available about these developments and they are not considered further in this assessment.

Table 4 summarises the anticipated EMI-related impact of the Project in isolation, as discussed in Sections 3.1 to 3.14 and the potential for cumulative impacts from the Project in conjunction with the neighbouring Liverpool Range Wind Farm. The cumulative impact assessment presented here is based on the relative locations of the turbines at the Project and the turbines in the 288-turbine layout for the Liverpool Range Wind Farm shown in Figure 23. The potential for cumulative impact generally increases as the number of turbines located close to the signal path (for point-to-point and point-to-multipoint style services) or between transmitting tower and the user (for point-to-area style services) increases. Therefore, the results of this assessment are also expected to be representative of the potential cumulative impacts for the Project in conjunction with the proposed 223-turbine layout for the Liverpool Range Wind Farm. For services where impact from the Project itself is considered either unlikely or non-existent, it is generally expected that there will be no cumulative impact.

Table 4 Potential for cumulative EMI-related impacts from the Project and neighbouring wind farms

Licence or service type	Anticipated impact from the Project in isolation	Potential for cumulative impact from the Project and neighbouring Liverpool Range Wind Farm
Radiocommunication towers	No impact expected (see Section 3.1)	No cumulative impact
Fixed point-to-point links	Likely to cause interference to links operated by NBN Co, NSW Police Force, and Warrumbungle Shire Council crossing the wind farm site (see Section 3.2)	No cumulative impact, as the link paths do not cross both wind farms in the vicinity of turbines
Fixed point-to-multipoint links	Potential for interference if link paths cross the wind farm site near turbines (see Section 3.3)	Potential for cumulative impact if link paths cross both wind farms
Other licence types	Point-to-area style communications: see findings for emergency services, mobile phones, radio broadcasting, and television broadcasting	
Emergency services	Likely to cause interference to point-to-point link operated by NSW Police Force (see Section 3.2) Unlikely to cause interference to mobile telephony systems (see Section 3.5)	No cumulative impact to point-to-point links, at the link paths do not cross both wind farms in the vicinity of turbines Very low potential for cumulative impact to mobile telephony systems
Meteorological radar	Potential for interference if turbines at the Project can be detected by radars (see Section 3.7)	Potential for cumulative impact if turbines at both wind farms can be detected by radars
Trigonometrical stations	Unlikely to cause interference (see Section 3.8)	Very low potential for cumulative impact
Citizens band radio	Unlikely to cause interference (see Section 3.9)	Very low potential for cumulative impact
Mobile phones	Low likelihood of interference in areas with marginal coverage (see Section 3.10)	Low potential for cumulative impact where there are multiple turbines between the tower and the user
Wireless internet	Low likelihood of interference to services provided by mobile phone networks (see Section 3.11.1) Unlikely to cause interference to NBN fixed wireless internet signals (see Section 3.11.2)	Low potential for cumulative impact to services provided by mobile phone networks where there are multiple turbines between the tower and the user No cumulative impact to NBN fixed wireless signals, as the signal lines of sight do not cross both wind farms
Satellite television and internet	Low likelihood of interference to services intended for international audiences only (see Section 3.12)	No cumulative impact
Radio broadcasting	Low likelihood of interference to AM and FM signals received in close proximity to turbines (see Section 3.13)	Low potential for cumulative impact where there are multiple turbines between the tower and the user
Television broadcasting	Likely to cause interference to signals from the Central Western Slopes tower at some dwellings, low likelihood of interference to signals from the Coolah tower (see Section 3.14)	Low potential for cumulative impact

There is potential for cumulative impacts to point-to-multipoint links if the link paths pass over the Project and the Liverpool Range Wind Farm in the vicinity of the turbines at both sites. However, as discussed in Section 3.2, consultation with the operators of nearby point-to-multipoint licences is needed to identify the associated link paths in relation to the proposed turbine locations and hence determine the potential for cumulative impacts. Similarly, as discussed in Section 3.7, consultation with BoM is needed to determine whether the turbines at either wind farm will have the potential to be detected by meteorological radars.

There is some potential for increased interference to point-to-area style services such as mobile phone and radio broadcasting signals in areas with marginal coverage, or where there may be multiple wind turbines between the user and the transmission tower. Based on the coverage maps shown in Figure 14 to Figure 18, and the relative locations of the mobile phone towers shown in Figure 13, cumulative impacts are considered unlikely for the Optus and Telstra mobile phone networks. Vodafone mobile phone signals may be more susceptible to cumulative impacts than the Optus and Telstra networks, due to the small number of towers servicing the area and existing poor coverage, although it is less likely that residents will be using this service.

Given the distance between the Liverpool Range Wind Farm and the Project, and the relative locations of the broadcast towers servicing the area, cumulative impacts to broadcast DTV signals is also considered unlikely. Figure 24 shows the potential DTV interference zones for both the Project and the Liverpool Range Wind Farm, based on the 'keyhole' approach described in Section 3.14.1.2 and Section A.3 of Appendix A with a forward-scatter distance of 5 km and a back-scatter distance of 500 m. There are no dwellings located within the potential interference zones for both wind farms. Although there are a number of dwellings located within 10 km of the proposed turbine locations at both wind farms, a more detailed assessment would be required to determine whether there is any potential for cumulative impacts to the DTV signals received at these dwellings.

Cumulative impacts to point-to-point links crossing the proposed Project are not expected, as none of these links pass over the Project and the Liverpool Range Wind Farm in the vicinity of the turbines at both sites. The only link that passes over both sites is the link operated by the NSW Rural Fire Service, which is well clear of turbines at the Project. Similarly, the locations of the NBN fixed wireless towers and coverage areas in the vicinity of the Project, as shown in Figure 19, suggest that the signal lines of sight from those towers to nearby dwellings will not pass over both wind farm sites. Therefore, cumulative impacts to the NBN fixed wireless internet service are also not expected.

3.15.2 Stakeholder consultation

DNV recommends contacting the operators of nearby point-to-multipoint licences to identify the associated link paths and hence determine the potential for cumulative impact to those links. DNV also recommends contacting the BoM to seek feedback on whether cumulative impact to their operations and services and services is likely. Consultation with the operators of other potentially affected services, such as mobile phone networks, radio broadcasting, and DTV broadcasting, may also help to confirm whether there is any likelihood of cumulative EMI-related impacts to these services.

3.15.3 Mitigation options

For most radiocommunication services, cumulative impacts from the Project in conjunction with other nearby wind farms are either not expected or are expected to be minimal. In the event that interference to mobile phone signals, radio broadcasting, or DTV broadcasting is experienced as a

result of cumulative impacts after construction of the Project, the mitigation options given in Sections 3.10.3, 3.13.2, and 3.14.3 may be applicable. Mitigation options to resolve cumulative impacts for other services, such as point-to-multipoint links or meteorological radar, may include the options outlined in the previous sections or can be developed through consultation with the relevant operator if required.

3.16 Impacts from transmission line infrastructure

Electrical transmission lines and transmission line infrastructure can potentially cause EMI to radiocommunication signals in two ways:

- the physical presence of the transmission lines and infrastructure causing diffraction or obstruction of the signals, reflection or scattering of the signals, or near field effects
- electromagnetic noise produced by the transmission lines causing radio frequency interference (RFI).

The presence of transmission lines and infrastructure can cause interference to radiocommunication signals and services through the same mechanisms as for other physical obstacles such as wind turbines. Diffraction or obstruction of signals by transmission line infrastructure may decrease the signal strength or quality at the receiving antenna. Similarly, reflection, scattering, or re-radiation of signals by transmission lines can reduce the strength of the received signal or cause multi-path errors that result in degradation or distortion of the primary signal from the transmitter [51, 52]. Near-field effects may also occur if the transmission line infrastructure is located too close to a transmitting or receiving antenna. The potential for interference depends primarily on the signal characteristics and the location of the transmission line in relation to the transmitting and receiving antennas, but may also be influenced by factors such as the physical configuration of the line and the directivity of the antennas [52]. The susceptibility of different radiocommunication signals and services to EMI from physical obstructions is discussed in the previous sections. However, since transmission lines and transmission line infrastructure are predominantly static structures and considerably smaller than modern wind turbines, the potential for a transmission line to cause EMI through its physical presence is likely to be less than for a turbine.

Electromagnetic noise (also called radio noise) is defined as a natural or unintended emission of electromagnetic radiation with frequencies in the radio frequency range, which can interfere with desired signals by being superimposed on, or combined with, those signals [53]. Electromagnetic noise is produced by power lines when electricity is discharged from the line into the surrounding air through either corona effects or gap-type discharges.

Corona is an electrical discharge from the surface of a power line caused by the ionization of air, and subsequent partial breakdown of the insulating properties of the air around the line, in the presence of a strong electric field [54, 51]. When this discharge occurs, it may be accompanied by audible noise, visible light, and electromagnetic radiation. For high-voltage transmission lines (above a nominal voltage of 220 kV in Australia), the resulting electromagnetic noise occurs at a frequency that has potential to interfere with radio and television broadcasting signals and may affect other communications systems or sensitive receivers such as radio telescopes [54, 51, 55]. However, such RFI is generally associated with transmission lines operating at voltages of 345 kV or higher (often described as extra-high-voltage lines) and is less likely to be an issue at lower voltages [51, 54]. Besides varying with the line voltage and current, the occurrence and strength of corona discharges is also influenced by the physical configuration of the line, the shape and size of the conductors, and the height of the line above ground. Corona activity is more likely to occur

during wet weather conditions and at higher altitudes, and can be exacerbated by degraded or damaged insulators, surface contamination of the line, and loose or improperly installed hardware [54, 55]. Since corona discharges correspond to a loss of electrical energy, they are considered undesirable from an operational perspective and modern transmission lines are normally designed to minimise these effects.

Gap-type discharges occur when there is a complete breakdown of the air insulation between two conducting components that are separated by a very small physical gap. Such discharges are commonly caused by loose or broken hardware or wires on low-voltage and medium-voltage power lines, and are not normally an issue for high-voltage transmission lines due to the use of modern equipment and maintenance procedures that reduce the potential for unintended gaps and electrical losses to occur [55, 54].

3.16.1 Locations of transmission lines and potential for interference

3.16.1.1 Interference caused by physical presence

The potential for interference to point-to-point links through diffraction, reflection or scattering, or near-field effects can usually be avoided by keeping clear of an appropriate exclusion zone around the link path or the transmitting or receiving antenna, as described in Section 3.2. Studies have shown that, to avoid interference to point-to-point links caused by signal diffraction or reflection or scattering of signals, transmission lines should be kept outside of the first Fresnel zone [52].

As described in Section 3.2.1, DNV has determined the transmission paths of the registered point-to-point licences for radiocommunication towers in the vicinity of the Project according to the ACMA RRL database. There are 27 links over five link paths recorded in the ACMA RRL database that pass over the proposed 220/330 kV transmission line route, operated by Essential Energy, NBN Co, NSW Telco Authority, and Telstra. No point-to-point links pass over the proposed 330/500 kV transmission line route. The details of the links passing over the 220/330 kV transmission line route are provided in Table 19 and the link paths are shown in relation to the proposed transmission lines in Figure 25.

For each point-to-point link crossing the 220/330 kV transmission line route, DNV has assessed the potential for the transmission line to intersect with the first Fresnel zone in the vertical plane. This was achieved by examining the elevation and antenna heights at the ends of the link, as well as the elevation of the location at which the link intersects with the transmission line route. Specific information about the intended line height and configuration for the proposed 220/330 kV transmission line is not currently available. However, typical line heights for 220/330 kV overhead lines in NSW range from 15 m to approximately 57 m at the supporting towers, depending on the style of the tower and whether the line is a single or double circuit configuration [56]. Assuming a maximum sag in the line of 1 m between the supporting towers, it is expected that the proposed 220/330 kV transmission line could occupy the region between 14 m and 57 m above ground level.

The results of this analysis are summarised in Table 5.

Table 5 Potential for impact to point-to-point links crossing the proposed transmission line routes

Link no.	Operator	Clearance of the first Fresnel zone in the vertical plane relative to the proposed transmission line	Expected impact
1	Essential Energy	Clear at the northern location where the link crosses the transmission line route Potentially intersected at the southern location where the link crosses the transmission line route	Potential for interference
2	NBN Co	Potentially intersected	Potential for interference
3	NBN Co	Potentially intersected	Potential for interference
4	NBN Co	Potentially intersected	Potential for interference
5	NBN Co	Potentially intersected	Potential for interference
6	NBN Co	Potentially intersected	Potential for interference
7	NBN Co	Potentially intersected	Potential for interference
8	NBN Co	Potentially intersected	Potential for interference
9	NBN Co	Clear	None
10	NBN Co	Clear	None
11	NBN Co	Clear	None
12	NBN Co	Clear	None
13	NBN Co	Clear	None
14	NBN Co	Clear	None
15	NBN Co	Clear	None
16	NBN Co	Clear	None
17	NBN Co	Potentially intersected	None
18	NBN Co	Potentially intersected	None
19	NBN Co	Potentially intersected	None
20	NBN Co	Potentially intersected	None
21	NBN Co	Potentially intersected	None
22	NBN Co	Potentially intersected	None
23	NBN Co	Potentially intersected	None
24	NBN Co	Potentially intersected	None
25	NBN Co	Potentially intersected	None
26	New South Wales Government Telecommunications Authority	Clear	None
27	Telstra Corporation Limited	Clear	None

There is potential for the 220/330 kV transmission line to intersect with the first Fresnel zone in the vertical plane for point-to-point links operated by Essential Energy and NBN Co. Therefore, there is potential for the transmission lines to cause interference to these point-to-point links through diffraction, reflection, or scattering of the signals. DNV recommends that this assessment be reviewed once the likely line heights for the 220/330 kV transmission line are known, and that the potential for the transmission lines to cause interference to the point-to-point links be further assessed through consultation with the relevant operators, as discussed in Section 3.16.2.

Transmission lines can potentially cause interference to point-to-multipoint links through the diffraction, reflection, or scattering of the signals as described above for point-to-point links. However, as discussed in Section 3.3, consultation with the operators of nearby point-to-multipoint licences is needed to identify the associated link paths in relation to the proposed transmission line route and hence determine the potential for interference.

DNV considers that the proposed transmission lines are sufficiently far from all radiocommunication towers in the vicinity of the Project to avoid near-field effects. The nearest radiocommunication tower is located approximately 1.6 km from the proposed transmission line route. Therefore, it is not expected that the transmission lines will cause interference to the point-to-point links or other radiocommunication signals through this mechanism.

Based on the relative locations of the transmission lines and nearby dwellings, and the NBN fixed wireless towers and service coverage areas shown in Figure 19, it is possible that some dwellings in the vicinity of the Project may be receiving NBN fixed wireless internet signals from a tower on the opposite side of the proposed transmission line route. There is potential for the transmission lines to interfere with NBN fixed wireless internet signals if the lines intersect with the line of sight from an NBN tower to a dwelling in the vertical plane, although a more detailed assessment would be required to determine the likelihood of such impacts.

Transmission lines and infrastructure may also theoretically cause interference to point-to-area style services such as radio and DTV broadcasting or mobile phone services through physical obstruction or reflection or scattering of the signals [54]. However, as discussed in the previous sections, these services are typically designed to operate in the presence of obstructions and are therefore unlikely to be affected by the presence of transmission lines. The potential for interference to point-to-area signals from the physical presence of transmission lines depends on the locations of the line and receiving antenna with respect to the transmitted signal. The nearest dwelling to the proposed transmission line infrastructure is located approximately 590 m from the 220/330 kV transmission line route, at which distance impacts to television and radio broadcasting are generally considered unlikely [54]. The proposed transmission line routes are sufficiently far from transmission towers for DTV, radio, and mobile phone signals to avoid any large-scale interference.

DNV is not aware of any evidence in the literature of the physical presence of transmission lines causing significant interference to other types of services such as meteorological radar, GNSS signals, and satellite television or internet signals. Therefore, impacts to these services from the proposed transmission lines and transmission line infrastructure are considered unlikely.

3.16.1.2 Interference caused by electromagnetic noise

For the high-voltage overhead transmission lines proposed for the Project, corona discharges are expected to be the primary source of electromagnetic noise [51]. Such discharges have the potential to cause RFI to television and radio broadcasting signals and could impact on other

sensitive radiocommunications. However, DNV notes that RFI is most likely to be an issue for signals in the AM frequency band (520 kHz to 1610 kHz) and the higher frequency signals used for FM radio, DTV, and mobile phone services are not typically affected [57, 54]. As for interference caused by the physical presence of transmission lines, RFI is generally only experienced within close proximity of the lines [54]. Given that the nearest dwelling is located more than 500 m from the transmission line routes, it is considered unlikely that RFI will be experienced at any dwellings in the vicinity of the Project. Additionally, since the voltages proposed for the transmission lines are lower than those normally associated with significant RFI, any interference caused by the lines is not likely to be significant. It is also expected that the proposed transmission lines will be designed and maintained to minimise the potential for both corona and gap-type discharges, in order to reduce the associated electrical losses, and will be no more likely to cause RFI than other transmission lines operating at similar voltages.

3.16.2 Stakeholder consultation

DNV recommends contacting the operators of the point-to-point links crossing the proposed transmission line route to determine the likelihood that the transmission line will cause interference to their operations and services through diffraction, reflection, or scattering of the signals. DNV also recommends contacting the operators of nearby point-to-multipoint licences to identify the associated link paths and hence determine the likelihood that the transmission line will cause interference to their operations and services.

3.16.3 Mitigation options

If interference to point-to-point or point-to-multipoint links caused by the physical presence of the proposed transmission lines and infrastructure is experienced, potential mitigation options may include upgrading the equipment for the links, re-routing the links, installing additional towers, or replacing the affected links with alternative communications infrastructure.

Interference caused by electromagnetic noise is considered unlikely but can be avoided by designing and installing the transmission lines using equipment that minimises the potential for corona and gap-type discharges, and performing regular maintenance to identify and repair loose or broken hardware and wires [54]. In the event that interference caused by electromagnetic noise is experienced after the transmission lines are operational, the mitigation options outlined in the previous sections for the relevant signal or service may be applicable.

4 METHODOLOGY AND RESULTS – EMF HEALTH IMPACTS

An EMF is a physical field produced by a moving electric charge that consists of both an electric field component and a magnetic field component. The effect of each field component at any given location depends on the magnitude of the voltage or current, the distance from the EMF source, any shielding around the source, and the frequency of the source.

The strength of an electric field is proportional to the voltage of the EMF source, while the strength of a magnetic field is proportional to the current. The strengths of both electric and magnetic fields decrease with increasing distance from the source. Electric fields are shielded by opaque objects such as building materials, vegetation, and human skin, whereas magnetic fields can pass through most materials without attenuation.

EMF associated with the generation, distribution, and use of electricity is classified as extremely low frequency (ELF) EMF. In Australia, ELF EMF is often called power frequency EMF and corresponds to a frequency of 50 Hz. Since the amount of energy transported by EMF is proportional to its frequency, ELF EMF contains very little energy. In comparison, radio frequency EMF ranges from approximately 100 kHz to 300 GHz and contains enough energy to heat tissues. Although high-level exposure to ELF EMF has the potential to cause biological effects in humans, there is currently no conclusive evidence linking ELF EMF to any long-term adverse health effects [4].

In wind farms, ELF EMF is produced by transmission lines, electrical transformers, underground network cabling, any overhead cabling, and electrical cabling and equipment within the turbines themselves. At ground level, the EMF generated by transmission lines, underground cabling, overhead cabling, and wind turbines is generally comparable to background EMF levels experienced in a modern home. Other electrical components are typical of similar equipment used in other installations and do not pose a unique risk of EMF. Although there are no Australian standards or regulations governing EMF from electrical equipment, it is expected that this equipment would be designed, installed, and operated in accordance with standard industry practices, which apply the ICNIRP guidelines for EMF exposure based on the concept of prudent avoidance as discussed in Section 2.2 [6, 58, 59].

4.1 Electric and magnetic field strength modelling

DNV has conducted an assessment to characterize the EMF in terms of the electric and magnetic field strengths in the vicinity of the Project, to address the SEARs requirement to identify potential hazards and risks to human health associated with EMF.

For the purposes of this assessment, only the EMF produced by the medium-voltage 33 kV electrical infrastructure within the wind farm site has been modelled. The design details for the substations and step-up facility have not yet been finalised, and so it is not possible to characterize the likely EMF for these components of the Project at this stage of development. However, it is expected that the production of EMF will be considered in the detailed design process, and that the substations and step-up facility will be designed in accordance with standard industry practices to ensure appropriate electrical grounding and EMF levels, consistent with the ICNIRP guidelines and concept of prudent avoidance. Additionally, it is expected that the substations and step-up facility will be fenced off from public access, and that the clearances from the electrical equipment to the outer fencing will be sufficient to ensure that the EMF levels at the boundary are within the recommended exposure limits. Similarly, the high-voltage 220/330 kV and 330/500 kV

transmission lines are expected to be designed in accordance with the ICNIRP guidelines for EMF exposure and installed at a height that will mitigate any risks for people at ground level. Therefore, the potential risks associated with EMF produced by the proposed substations, step-up facility, and high-voltage transmission lines are expected to be low or negligible at publicly accessible locations in and around the Project and are not considered further in this assessment.

For the 33 kV underground electrical cables within the wind farm site, simulations of the magnetic field strength in the vicinity of the cables were performed. Simulations of the electric field strength were not conducted as, due to the cables being buried and the resulting attenuation effects, the electric field strength at ground level for such cables is expected to be negligible. Moreover, research into the potential health impacts of EMF suggests that if there is a risk of adverse health effects "it is more likely to be associated with the magnetic field than the electric field" [6]. The results were then compared to EMF limits for public exposure recommended by the relevant guidelines [7].

The assessment was performed by modelling the underground cable in COMSOL Multiphysics 5.6 [60]. Considering that the magnetic field strength due to the cables depends on the current flowing through the cable and the distance from the cable to the point where the field is measured, several assumptions were used in the modelling as summarised in Table 6.

Table 6 Assumptions made in the simulation of magnetic field strengths for the Project

Assumption			Comment
Cable rating	Voltage	33 kV	Based on information provided by the Proponent
	Cross-section	800 mm^2	Assumed for the purposes of the assessment
Cable layout	Burial depth	800 mm	Based on information provided by the Proponent
	Formation	Trefoil	Assumed for the purposes of the assessment
Maximum current	1000 A		Worst-case condition, assumed for the purposes of the assessment
One cable per phase			Worst-case condition, assumed for the purposes of the assessment and discussed further in Section 4.2
Screens single-point bonded at one end only			Worst-case condition, assumed for the purposes of the assessment
Cables in a balanced phase loading condition			Normal operating condition for a cable in trefoil formation, assumed for the purposes of the assessment and discussed further in Section Section 4.2

Table 7 shows the magnetic field exposure limits recommended by the ICNIRP [7] and WHO [5] and considered in this assessment.

Table 7 Recommended magnetic field exposure limits

Exposure	ICNIRP 2010 reference level [7]		WHO recommendation [5]
	General public	Occupational[1]	General public
Magnetic field	200 μT	1000 μT	100 μT

1. Occupational exposure refers to adults exposed to EMF at their workplaces, generally under known conditions, and as a result of performing their regular or assigned job activities. Occupational exposure has not been considered in this assessment.

4.2 EMF due to underground cabling

The underground cabling was modelled as a single cable per phase under balanced phase loading conditions, with a maximum current of 1000 A taken for the magnetic field calculations.

These modelling parameters represent the worst-case conditions and are expected to correspond to the largest magnetic field strengths for the underground cabling. One cable per phase was assumed as it represents the worst-case condition compared to two cables per phase, where the interaction between the magnetic fields produced by each phase typically results in a cancellation effect. Consequently, the overall magnetic field strength of a single cable per phase configuration is higher than that of a two cable per phase configuration [6]. The assumption of balanced phases corresponds to the normal operating condition for a cable in trefoil formation. Although unbalanced phases may occur under fault conditions, it is expected that any such fault would be detected and cleared by the nearby switchgear soon after occurrence and is unlikely to persist for any reasonable length of time. Therefore, the magnetic field strengths calculated here are expected to be conservative for all underground cabling configurations proposed for the Project.

The trefoil arrangement of the cable in COMSOL Multiphysics 5.6 is shown in Figure 1. Figure 2 shows the modelled magnetic field distribution around the cable, for magnetic fields in the range of 0 μT to 200 μT (being the maximum recommended magnetic field exposure limit for the general public presented in Table 7). The area in which the magnetic field strength is higher than 200 μT, indicated by the dark red region around the cable in Figure 2, falls well below ground level and so there is no risk of people above ground being exposed to magnetic fields greater than 200 μT.

As may be expected, the highest magnetic field strength at ground level due to the underground cabling occurs directly above the cable. Based on the magnetic field contours around the cable shown in Figure 3, the magnetic field strength at this location is approximately 20 μT, which is below the exposure limits specified in Table 7. Since the magnetic field strength decreases as the distance from the cable increases, the magnetic field strength due to the underground cabling at ground level at all other locations will be less than 20 μT Table 7and therefore also well below the relevant exposure limits.

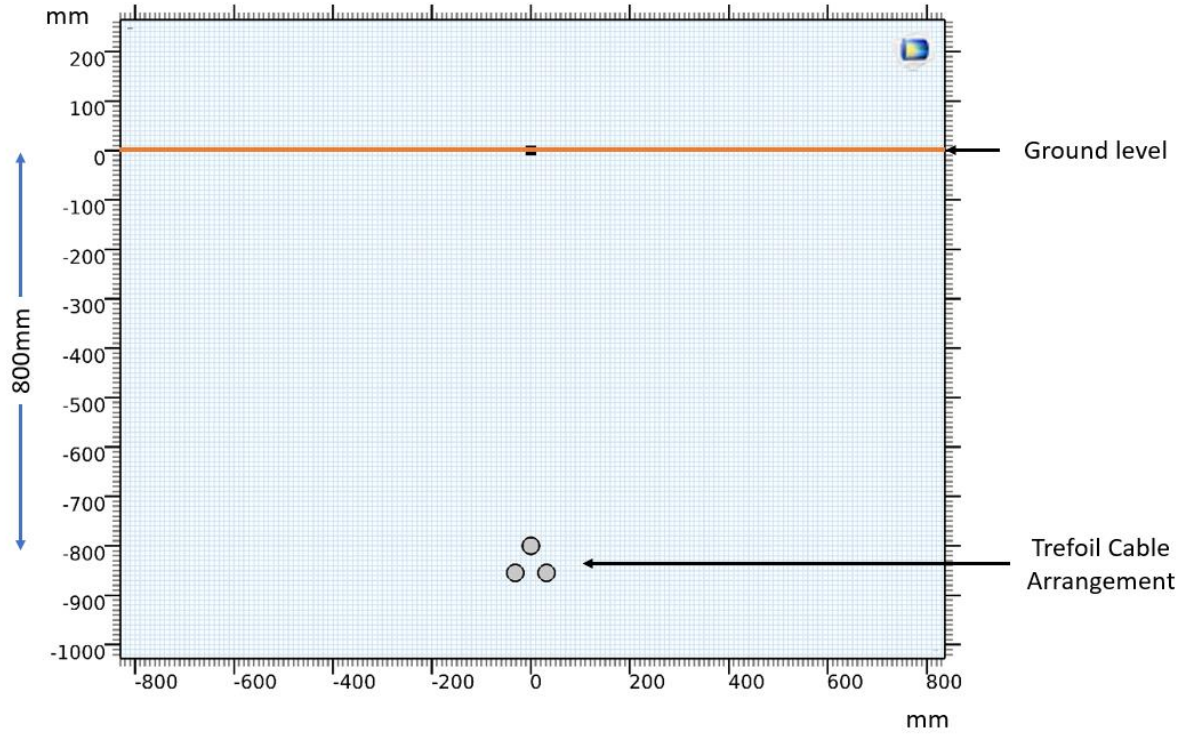


Figure 1 Underground cable arrangement and burial depth

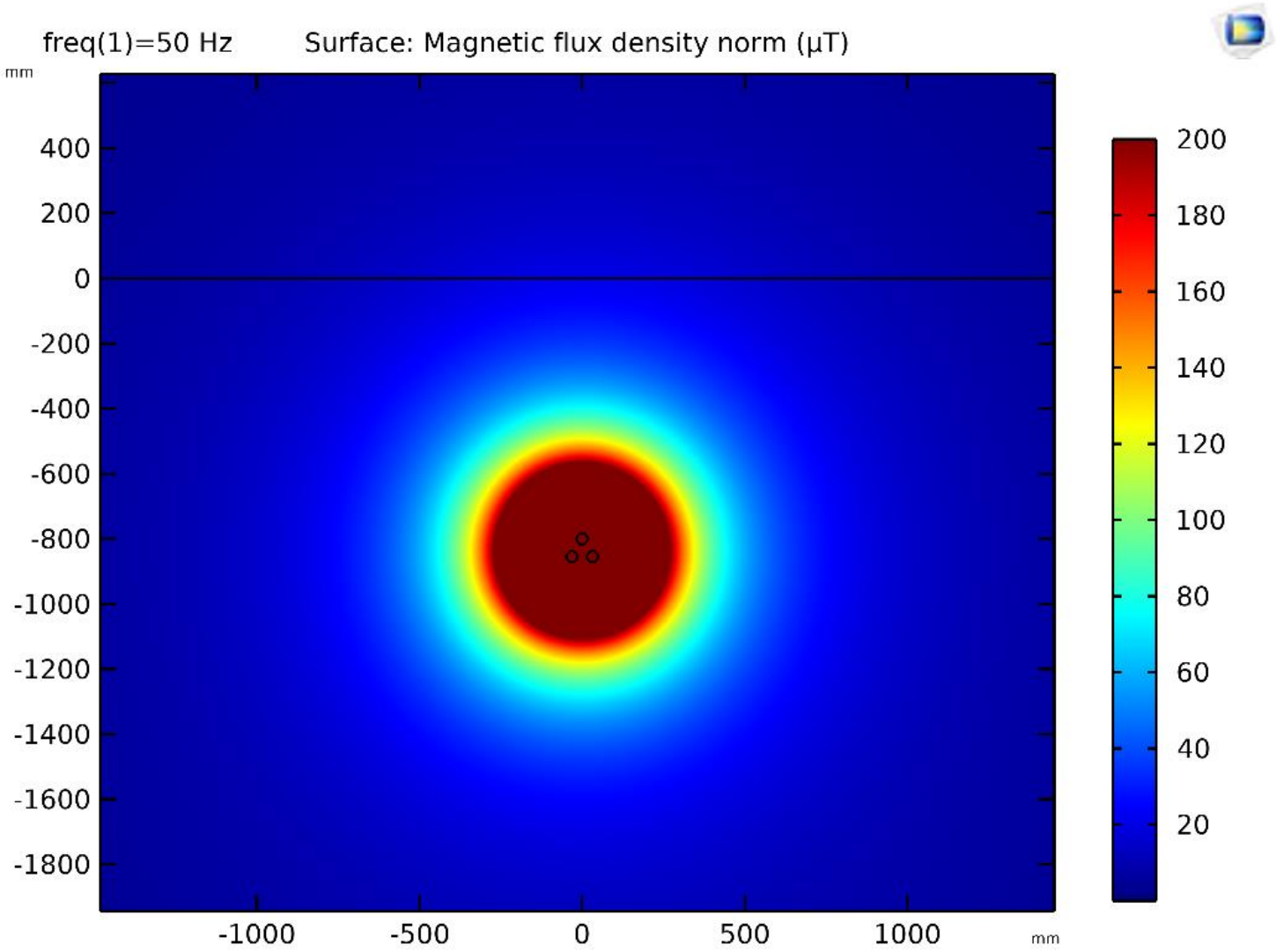


Figure 2 Magnetic field (µT) distribution around the cable at 800 mm below ground level under worst-case conditions

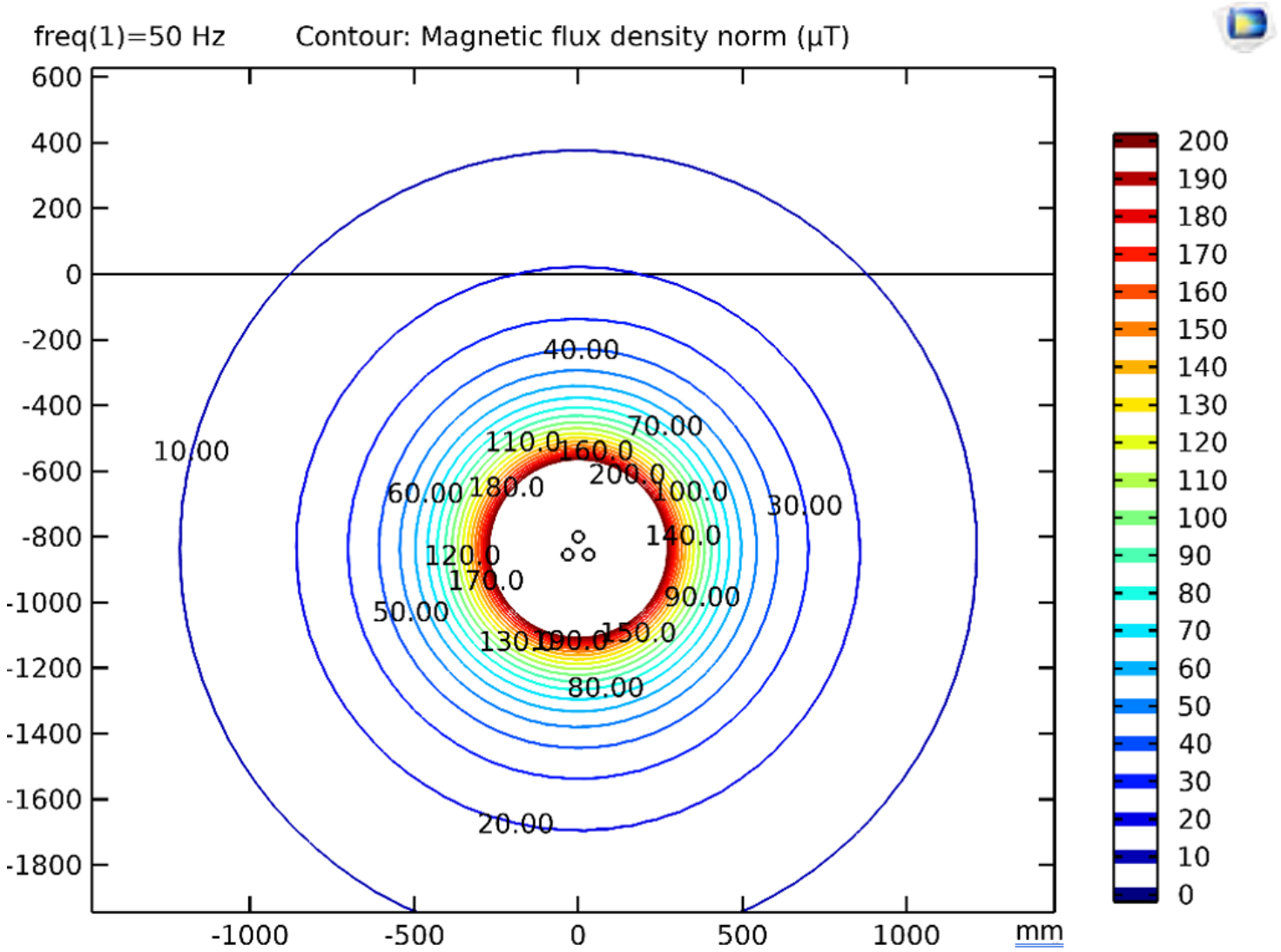


Figure 3 Magnetic field (μT) contours around the cable at 800 mm below ground level under worst-case conditions

4.3 Summary of modelled EMF and expected health impacts

The maximum magnetic field strength modelled for the medium-voltage underground cabling proposed for the Project is summarised and compared to the limits recommended by the ICNIRP and WHO for general public exposure in Table 8. This maximum value is observed at ground level immediately above the underground cable. Since magnetic field strength decreases as the distance from the source increases, the field strength at all other locations is expected to be less than the maximum value given in Table 8, which is already well within the recommended exposure limits.

Table 8 Summary of magnetic field strengths evaluated for the Project

Source and measurement location	Maximum magnetic field [1] [μT]
Underground cable, measured at ground level	20
ICNIRP 2010 reference level for general public exposure [7]	200
WHO recommendation for general public exposure [4]	100

1. Due to attenuation effects, the electric field strength at ground level for underground cables is expected to be negligible and has not been considered in this assessment.

The closest two dwellings to the Project infrastructure are located approximately 55 m and 70 m away respectively from the underground cabling network. Since magnetic field strengths decrease with increasing distance from the source, the EMF produced by the proposed cabling within the wind farm site will be well below the relevant exposure limits at these dwellings and is expected to be indistinguishable from background levels. All other dwellings are located more than 1000 m from the underground cabling, at which distance the EMF from the Project will be negligible.

As discussed above, the magnetic field strengths due to the medium-voltage 33 kV cabling at all locations in and around the wind farm site at ground level are expected to be well within the limits recommended by the ICNIRP. However, DNV notes that there is a potential for cumulative EMF impacts at ground level at locations where the underground cabling network passes below the proposed 220/330 kV overhead transmission lines. The risk of cumulative impacts can be mitigated in the detailed design of the electrical infrastructure for the Project by designing the underground cabling and transmission lines such that the cumulative EMF strengths are within acceptable levels.

As discussed in Section 4.1, it is expected that other electrical equipment associated with the Project, including the substation, step-up facility, and high-voltage transmission lines, will be designed and installed in accordance with the relevant guidelines for EMF exposure. Although substations have the potential to produce large magnetic fields, all identified dwellings are located more than 1700 m from the proposed substations. At this distance, attenuation of the magnetic fields will be sufficient to ensure that the field strengths are below the relevant exposure limits. It is also expected that the substations will be fenced off with sufficient clearances from the electrical equipment to the fencing to ensure that EMF levels at the boundary are within the recommended limits. The EMF produced by the Project is therefore expected to be within the recommended exposure limits at all publicly accessible locations in and around the wind farm site.

Based on this assessment, and given that conservative assumptions were used in the simulations, the risks to human health from EMF associated with the Project are considered low and there is no need to carry out further prudent avoidance.

5 CONCLUSIONS

Broadcast towers and transmission paths around the Project were investigated to determine if EMI would be experienced as a result of the development and operation of the Project. The Project will involve the installation of 148 wind turbine generators. DNV has considered a turbine geometry that will be conservative for turbine configurations with dimensions satisfying all of the following criteria: a rotor diameter of 180 m or less and an upper tip height of 250 m or less.

The results of this assessment are summarised in Table 9.

The Project is likely to cause interference to several point-to-point links passing over the wind farm site through diffraction of the signals. DNV recommends consulting with the operators of the links to confirm the potential for impact and identify any mitigation options. This may result in the relocation of turbines to be outside of agreed clearance zones around the affected links.

Turbines at the Project may interfere with point-to-area style services such as mobile phone signals and terrestrial television broadcasting, particularly in areas with poor or marginal signal coverage. Dwellings in the vicinity of the Project may experience interference to DTV broadcast signals from the Central Western Slopes and Coolah towers, although the coverage maps suggest that many of the dwellings located in the potential interference zones may not currently be receiving signals from these towers. However, there is some potential for interference to signals from the Central Western Slopes tower to be experienced outside the identified zones, if dwellings in those areas receive a reflected signal from the turbines that is stronger than the direct signal. Mobile phone services may be susceptible to interference in areas that are currently receiving a weak signal, but the overall likelihood of interference is low and previous advice received from the network operators has generally indicated that they do not expect wind farm developments to interfere with their services. If interference to these services is experienced, a range of options are available to rectify difficulties.

Impacts to satellite television and internet signals that may be received at dwellings in the vicinity of the Project are considered unlikely. The proposed turbines are not expected to interfere with any satellite television or internet services intended for Australian audiences. Interference is possible for signals from satellites that do not provide services designed for Australian audiences, however these are unlikely to be used by nearby residents.

While the Project may cause interference to point-to-multipoint links and meteorological radar, further information from the operators of those services is required to determine the likely impacts. Potential impacts on other services considered in this assessment, including wireless internet services, broadcast radio, citizens band radio, and trigonometrical stations, are considered minor.

DNV notes that the Project is located in the Central-West Orana REZ, which is likely to become an area of high wind farm development activity, with the approved Liverpool Range Wind Farm located nearby. Based on the relative locations of the wind farms, there is some potential for increased interference to mobile phone and FM radio signals in areas where there may be multiple wind turbines between the user and the transmission tower. Cumulative impacts to other services are considered unlikely or, in the case of point-to-multipoint links and meteorological radar, can be assessed through consultation with the relevant operators.

There is potential for the proposed overhead transmission lines to cause interference to fixed point-to-point and point-to-multipoint links crossing the transmission line route through diffraction, reflection, or scattering of signals. Interference to NBN fixed wireless internet signals may also

occur if the transmission lines intersect the line of sight from an NBN tower to a nearby dwelling. DNV recommends that this assessment be reviewed once the likely heights for the transmission line are known, and that the potential for interference be further assessed through consultation with the relevant operators. Interference caused by electromagnetic noise produced by the proposed transmission lines is not expected to be an issue for the Project.

The potential human health impacts of EMF associated with the Project were also evaluated. Based on this analysis, the risks to human health from EMF are considered low. Simulation of the EMF produced by the proposed medium-voltage underground cabling network at the Project has shown that the EMF at ground level will be within the exposure limits recommended for the protection of the general public. EMF from other equipment at the Project is also expected to be compliant with the relevant guidelines. The EMF levels produced by the Project are therefore expected to be within the recommended exposure limits at all publicly accessible locations in and around the wind farm site, and indistinguishable from background levels at nearby dwellings.

Table 9 Summary of EMI assessment results for the proposed Project

Licence or service type	Assessment findings	Expected impact			Stakeholder feedback (to date)	Potential mitigation options
		Wind farm in isolation	With neighbouring wind farms	Transmission lines		
Radio-communication towers	No towers within 2 km of proposed turbine locations or 1 km of proposed transmission line route	No impact	No cumulative impact	No impact	Consultation not considered necessary	None required
Fixed point-to-point links	42 links over 11 link paths crossing wind farm site, operated by Essential Energy, NBN Co, NSW Telco Authority, NSW Police Force, NSW RFS, Telstra, Warrumbungle Shire Council 27 links over 5 link paths crossing transmission line route, operated by Essential Energy, NBN Co, NSW Telco Authority, and Telstra Diffraction effects: 3 turbines in exclusion zones established by DNV for links operated by NBN Co, NSW Police Force, and Warrumbungle Shire Council; transmission lines may impact links operated by Essential Energy and NBN Co Reflection/scattering effects: turbines are sufficiently far from towers to avoid impacts; transmission lines may impact links operated by Essential Energy and NBN Co Near-field effects: turbines and transmission lines are sufficiently far from towers to avoid impacts	Likely to cause interference to links operated by NBN Co, NSW Police Force, and Warrumbungle Shire Council through diffraction of signals	No cumulative impact	Potential for interference to links operated by Essential Energy and NBN Co through diffraction, reflection, or scattering of signals	Consultation recommended but not undertaken	Reroute affected links, install additional towers, replace affected links with alternative technologies, relocate turbines to be outside clearance zones
Fixed point-to-multipoint links	64 assignments within 75 km of wind farm site One base station within 20 km of wind farm site, operated by Ulan Coal Mines Ltd	Potential for interference if link paths cross the wind farm site near turbines	Potential for cumulative impact if link paths cross both wind farms	Potential for interference if link paths cross the transmission line route	Consultation recommended but not undertaken	If required – reroute affected links, install additional towers, replace affected links with alternative technologies

Table 9 Summary of EMI assessment results for the proposed Project (continued)

Licence or service type	Assessment findings	Expected impact			Stakeholder feedback (to date)	Potential mitigation options
		Wind farm in isolation	With neighbouring wind farms	Transmission lines		
Other licence types	Point-to-area style communications: see findings for emergency services, mobile phones, radio broadcasting, and television broadcasting Aeronautical and radiodetermination: to be considered as part of an aviation impact assessment	-	-	-	-	-
Emergency services	Point-to-point links: 3 NSW Telco Authority links, 1 NSW Police Force link, and 2 NSW RFS links crossing wind farm site (see above); no links crossing transmission line route Mobile telephony systems: unlikely to be affected	Likely to cause interference to point-to-point link operated by NSW Police Force Unlikely to cause interference to mobile telephony systems	No cumulative impact to point-to-point links Very low potential for cumulative impact to mobile telephony systems	No impact to point-to-point links Unlikely to cause interference to mobile telephony systems	Consultation recommended but not undertaken	Point-to-point links: as above Mobile telephony systems: if required – increase signal strength from affected tower or alternative towers, install signal repeater, install additional tower
Meteorological radar	Nearest radar: "Namoi", 106 km from Project	Potential for interference if turbines at the Project can be detected by radars	Potential for cumulative impact if turbines at both wind farms can be detected by radars	Unlikely to cause interference	Consultation recommended but not undertaken	To be determined through consultation with the BoM
Trigonometrical stations	26 stations within 20 km of wind farm site Electronic equipment: unlikely to be affected Sight lines to other stations: may be blocked by turbines	Unlikely to cause interference	Very low potential for cumulative impact	Unlikely to cause interference	Consultation recommended but not undertaken	None required

Table 9 Summary of EMI assessment results for the proposed Project (continued)

Licence or service type	Assessment findings	Expected impact			Stakeholder feedback (to date)	Potential mitigation options
		Wind farm in isolation	With neighbouring wind farms	Transmission lines		
Citizen's band radio	Unlikely to be affected	Unlikely to cause interference	Very low potential for cumulative impact	Unlikely to cause interference	Consultation not considered necessary	None required
Mobile phones	Optus and Telstra networks: unlikely to be affected in areas with good coverage, may experience interference from turbines in areas with marginal coverage away from populated areas around Coolah and Dunedoo Vodafone network: unlikely to be used by nearby residents due to existing poor coverage	Low likelihood of interference	Low potential for cumulative impact	Unlikely to cause interference	Consultation recommended but not undertaken	If required – increase signal strength from affected tower or alternative towers, install additional tower
Wireless internet	Likely service providers: Optus, Telstra, NBN Co NBN: available as a fixed wireless and satellite service in areas surrounding the Project	Low likelihood of interference to mobile internet services Unlikely to cause interference to NBN services	Low potential for cumulative impact to mobile internet services No cumulative impact to NBN services	Unlikely to cause interference to mobile internet services Potential for interference to NBN services if transmission lines intersect line of sight from tower to dwelling	Consultation recommended but not undertaken	Mobile phone networks: as for mobile phones NBN: none required

Table 9 Summary of EMI assessment results for the proposed Project (continued)

Licence or service type	Assessment findings	Expected impact			Stakeholder feedback (to date)	Potential mitigation options
		Wind farm in isolation	With neighbouring wind farms	Transmission lines		
Satellite television and internet	Services intended for Australian audiences: unlikely to be affected Services intended for international audiences: signals from 16 satellites intercepted by turbines at 40 dwellings	Unlikely to cause interference to services intended for Australian audiences Low likelihood of interference to services intended for international audiences	No cumulative impact	Unlikely to cause interference	Consultation with operators not considered necessary Current usage of potentially affected services could be confirmed by engaging with residents of identified dwellings	If required – redirect satellite dish to alternative satellite, install larger or higher-quality satellite dish, change location or height of satellite dish
Radio broadcasting	AM and FM signals: may experience interference in close proximity to turbines Digital radio signals: Project is outside the intended service area	Low likelihood of interference to AM and FM signals	Low potential for cumulative impact	Unlikely to cause interference	Consultation not considered necessary	AM and FM signals: if required – install higher-quality antenna at affected location Digital radio signals: none required

Table 9 Summary of EMI assessment results for the proposed Project (continued)

Licence or service type	Assessment findings	Expected impact			Stakeholder feedback (to date)	Potential mitigation options
		Wind farm in isolation	With neighbouring wind farms	Transmission lines		
Television broadcasting	Digital signals: may experience interference in areas with poor or marginal reception					If required – re-align antenna at affected dwelling to existing tower, re-direct antenna to alternative tower, install more directional or higher gain antenna, change location of antenna, install cable or satellite television, install relay transmitter
	Central Western Slopes tower: 'variable' to 'poor' or non-existent coverage across the Project site, with small areas of 'good' coverage to the north and southwest 52 dwellings (22 associated dwellings) in potential interference zone for turbines	Low likelihood of interference at identified dwellings, as dwellings may not currently be receiving signals Potential for interference outside identified zone if dwellings receive a reflected signal that is stronger than the direct signal	Low potential for cumulative impact	Unlikely to cause interference	Consultation recommended but not undertaken	
	Coolah tower: 'variable' to 'good' coverage to the northeast of the Project site, 'poor' or non-existent coverage elsewhere 32 dwellings (11 associated dwellings) in potential interference zone for turbines	Low likelihood of interference at identified dwellings, as dwellings may not currently be receiving signals	Low potential for cumulative impact	Unlikely to cause interference	Consultation recommended but not undertaken	

6 REFERENCES

[1] Department of Planning, Industry and Environment, "Planning Secretary's Environmental Assessment Requirements," application number SSD-10461, NSW Government, 9 June 2020.

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APPENDIX A – TELEVISION INTERFERENCE CAUSED BY REFLECTION OR SCATTERING OF SIGNALS

A.1 Susceptibility of DTV signals to reflection or scattering

The United Kingdom telecommunications regulator Ofcom [38] states the following with regard to interference to DTV reception:

> *"Digital television signals are much better at coping with signal reflections, and digital television pictures do not suffer from ghosting. However a digital receiver that has to deal with reflections needs a somewhat higher signal level than one that has to deal with the direct path only. This can mean that viewers in areas where digital signals are fairly weak can experience interruptions to their reception should new reflections appear… reflections may still affect digital television reception in some areas, although the extent of the problem should be far less than for analogue television."*

DNV has drawn two conclusions from this report:

- Firstly, that DTV is very robust and does not suffer from ghosting. In most cases DTV signals are not susceptible to interference from wind farm developments.
- Secondly, that areas of weak DTV signal can experience interruptions to their reception should new reflections appear, such as those from nearby wind turbines.

For television broadcast signals, which are omni-directional or point-to-area signals, interference from wind turbines is dependent on many factors including:

- the proximity of turbines to the television broadcast tower
- the proximity of turbines to receivers (dwellings)
- the location of turbines in relation to dwellings and television broadcast towers
- the rotor blade material, rotor speed, and rotor blade direction (always into the wind)
- the properties of the receiving antenna (e.g., type, directionality, and height)
- the location of the television receiver in relation to terrain and other obstacles
- the frequency and power of the television broadcast signal.

A.2 Forward and back scatter of DTV signals

Wind turbines can cause interference to DTV signals by introducing reflections that may be received by the antenna at a dwelling, in addition to the signal received directly from the transmitter, which causes multipath errors. A wind turbine has the potential to scatter electromagnetic waves carrying DTV signals both forward and back.

Forward scatter can occur when the transmitter, one or more turbines, and receiver are almost aligned as shown in Figure A.1. The forward scatter region in this case is characterised by a shadow zone of reduced signal strength behind the turbine, where direct and scattered signals can be received, with the blade rotation introducing a rapid variation in the scattered signal [46]. Both of these effects can potentially degrade the DTV signal quality.

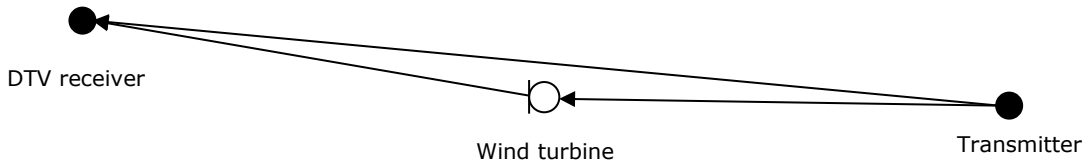

Figure A.1 Forward scatter signal path for DTV signals

Back scatter from wind turbines occurs when DTV signals are reflected from turbine towers and blades onto a receiver as shown in Figure A.2. The reflected signals are attenuated, time-delayed and phase-shifted (due to a longer path from transmitter to receiver) compared to the original signal. The reflected signals are also time-varying due to the rotation of the blades and vary with wind direction. The resultant signal at the receiver includes the original signal (transmitter to receiver) and a series of time-varying multipath signals (transmitter-turbine-receiver).

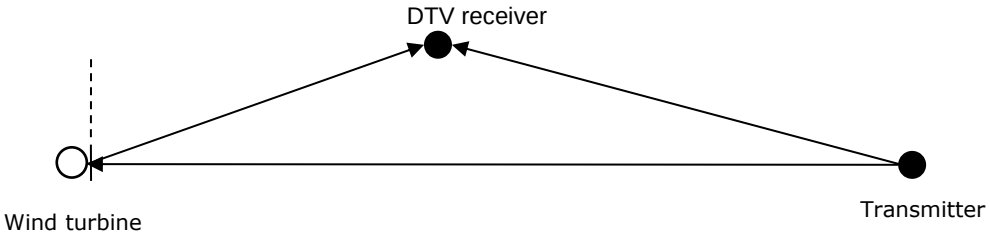

Figure A.2 Back scatter signal path for DTV signals

Interference to DTV signals from wind turbines can potentially occur in both the forward and backward scatter region. The effect of a turbine on a DTV signal can be different depending on the scattering region where the receiver is located [46].

According to Ofcom [38], the forward scatter region does not typically extend further than 5 km for the worst combination of factors [10, 61]. Interference may extend beyond 5 km if the dwellings are screened from the broadcast transmitter, but do have line-of-sight to the turbines [38]. The shape of this region, assuming a relatively high gain, directional antenna, can be represented by a circular segment with an azimuthal range of approximately ±15° to ±20°, corresponding to the beam width of the antenna. If a lower gain or omni-directional antenna is being used, this region is likely to be larger.

Back scattered signals arrive at the dwelling delayed relative to the source signal from the broadcast transmitter. The back scatter region generally does not extend further than 500 m [10, 38], assuming a high gain, directional antenna that has a relatively high front-to-back ratio (meaning the signal received by the front of the antenna is much higher than that received from the back). If an antenna with a lower front-to-back ratio, or an omni-directional antenna is used, this region is likely be larger.

The combination of the forward and back scatter regions, as shown in Figure A.3, resembles a keyhole.

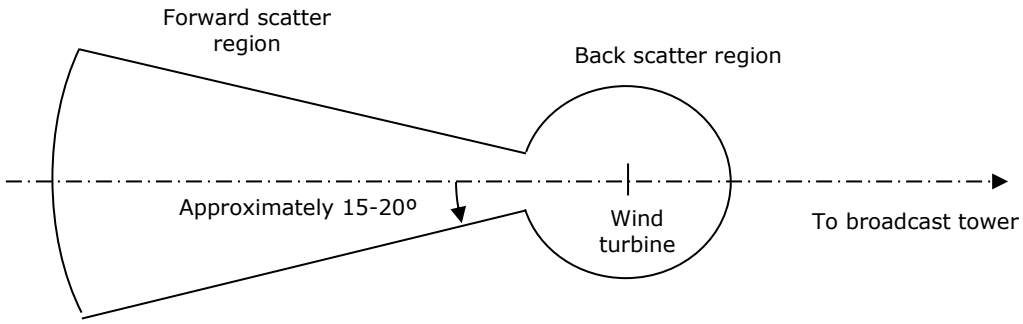

Figure A.3 Potential television interference zones around a wind turbine

Television interference mechanisms rely on many factors (as previously mentioned) and are complex to calculate. Previous experience has shown that even after great effort has been put into performing such calculations, they tend to have limited accuracy, and would require field validation after the wind farm is operational.

In Australia, DTV signals are transmitted using the DVB-T (Digital Video Broadcasting – Terrestrial) standard. The International Telecommunication Union (ITU) Recommendation BT.1893 [62] states the following in regards to the forward scatter region for DVB-T signals:

> *"In most of the situations where the impact of a wind farm to DVB-T reception quality was analyzed, the threshold C/N [carrier-to-noise] ratios obtained were similar to those expected in environments with the absence of wind farms. More precisely, in the forward scattering region of the wind turbines, where the transmit antenna, one or more turbines and the receive antenna are lined-up (±60° behind the wind turbine), the DVB-T reception quality may not be affected though further work of analysis is needed in order to confirm this point, especially in the vicinity of 0°."*

In other words, wind turbines are not generally expected to affect DVB-T DTV signals in the forward scatter region. However, the ITU [47] also highlight that in the case where there is significant blockage of the direct signal, but clear line-of-sight to one or more turbines, interference to the reception of the DTV signal is possible. Results of studies reported by the ITU also suggest that interference may be more likely in areas where the existing DTV signal is already weak or degraded [47].

With regards to back scattering, the ITU states:

> *"In the case of the backscattering region, in those situations where the scattered signals from wind turbines are significant in amplitude and variability, the threshold C/N ratio necessary for quasi error free (QEF) condition is higher."*

In other words, the C/N ratio needs to be higher in the presence of significant back scatter to achieve the same QEF condition as is the case without the presence of turbines, which effectively means that interference is more likely to occur as coverage quality decreases.

A.3 Theoretical models for wind turbine scattering estimation

Various theoretical scatter models to predict scatter of terrestrial television signals have been proposed, some dating back to the late 1970s. A review of these models, as well as a comparison against empirical data has been reported in [63]. This comparison with empirical data found:

> *"…none of the analyzed methods seems to be accurate enough to provide realistic estimations of the signal scattered by the wind turbines. In conclusion, a more complete scattering model is needed in order to provide more practical estimations of the scattered signals and evaluate their potential impact on the broadcasting services."*

Notably, the scattering model proposed by the ITU to specifically address DTV signals [62], was found to be the most inaccurate, and does not provide signal estimations in the forward scattering zone of the blades. Additionally, DNV notes that it only applies to a single wind turbine rather than a wind farm as a whole.

As an alternative to signal scattering models, it is common practice to identify those dwellings or areas that are most likely to experience potential television interference based on likely forward and back scatter regions. As introduced above and shown in Figure A.3, this is often referred to as the 'keyhole' approach and is an established technique for predicting where terrestrial television interference is most likely, based on a number of assumptions regarding receiving antenna characteristics. The approach involves combining multiple keyhole shaped areas that are placed over each turbine location [38]. The combination of these areas forms a region where there is an increased likelihood of interference to television signals occurring.

LIST OF TABLES

Table 10 Proposed turbine layout for the Project

Turbine ID	Easting[1] [m]	Northing[1] [m]	Base elevation [m]	Turbine ID	Easting[1] [m]	Northing[1] [m]	Base elevation [m]
GR2	759945	6458231	608	GR50	755293	6462992	601
GR3	760266	6458556	612	GR51	756547	6462872	597
GR4	760586	6458892	613	GR52	756615	6463253	595
GR5	760344	6459439	599	GR53	760536	6461038	600
GR6	760398	6460058	614	LV3	750412	6451622	581
GR7	760673	6460477	624	LV4	749149	6450439	566
GR8	760633	6461525	615	LV5	748725	6450996	571
GR9	760499	6462087	618	LV6	749248	6451226	591
GR10	760558	6462570	623	LV7	749742	6451474	609
GR11	760662	6463034	636	LV8	749804	6452595	602
GR12	760732	6463508	635	LV9	743856	6450600	559
GR13	758437	6459580	621	LV10	744180	6451053	591
GR14	758774	6460044	624	LV11	744638	6451295	582
GR15	758710	6460549	629	LV12	745107	6451517	602
GR16	758512	6461086	624	LV13	745622	6451740	597
GR17	758101	6461651	661	LV14	746241	6452426	596
GR18	758391	6462049	682	LV15	746104	6453164	611
GR19	758581	6462465	692	LV16	746352	6453548	591
GR20	758621	6462950	695	LV17	746047	6454129	573
GR21	759036	6463235	674	LV18	745567	6452957	613
GR22	758869	6463772	648	LV19	745296	6453565	614
GR23	757523	6459696	642	LV20	744079	6453841	608
GR24	757475	6460156	640	LV21	744650	6454153	619
GR25	757355	6460644	669	LV22	745061	6454503	574
GR26	757170	6461573	678	LV23	746110	6451978	582
GR27	757371	6461983	675	MH3	749309	6466081	644
GR28	756638	6458841	622	MH4	750188	6467171	696
GR29	756257	6459394	632	MH5	749563	6466459	666
GR30	756755	6459622	643	MH6	749886	6466813	679
GR31	756560	6460197	647	MH7	750476	6467535	705
GR32	756394	6461193	631	MH8	750972	6467764	694
GR33	756157	6462107	616	MH9	751253	6468129	694
GR34	756641	6462425	613	MH10	751503	6468528	716
GR35	755093	6459082	619	MH11	751805	6468888	734
GR36	755296	6459451	623	MH12	752150	6469641	739
GR37	755281	6460071	643	MH13	752361	6470112	764
GR38	755577	6460432	643	MH14	747817	6466696	655
GR40	753534	6457741	622	MH15	747065	6467377	684
GR41	753568	6458120	625	MH16	747930	6467308	683
GR42	753647	6458773	630	MH17	748267	6467737	689
GR43	754027	6459160	626	MH18	748696	6468095	668
GR44	754337	6459537	624	MH19	748877	6468597	662
GR45	754591	6459954	638	MH20	749286	6468978	654
GR46	754527	6460557	614	MH21	747907	6469080	647
GR47	754417	6461744	605	MH22	749923	6469162	683
GR48	754828	6462099	611	MH23	750526	6469694	712
GR49	755070	6462556	613	MH24	751232	6469727	755

Table 10 Proposed turbine layout for the Project (continued)

Turbine ID	Easting[1] [m]	Northing[1] [m]	Base elevation [m]	Turbine ID	Easting[1] [m]	Northing[1] [m]	Base elevation [m]
MH25	751472	6470235	770	MH53	747056	6473145	717
MH26	750575	6470261	730	MH54	747268	6474010	722
MH27	751772	6470722	741	MH55	744418	6471707	700
MH28	751977	6471223	716	MH56	744717	6472070	728
MH29	752310	6471721	675	MH57	744782	6472677	734
MH30	751130	6472104	721	MH58	744861	6473222	739
MH31	751344	6472529	725	MH59	745928	6473658	720
MH32	751417	6472992	731	MH60	745096	6473850	730
MH33	751276	6473501	736	MH61	745040	6474391	719
MH34	751106	6474245	747	MH62	745050	6475075	704
MH35	751406	6474745	724	MH63	745247	6475480	683
MH36	751670	6475201	757	MH64	742133	6469994	734
MH37	751352	6475973	733	MH65	742318	6470441	718
MH38	750845	6475561	721	MH66	742473	6470869	670
MH39	750100	6475562	728	MH67	742563	6471441	714
MH41	749651	6471621	653	MH68	742902	6471897	720
MH42	749585	6472139	689	MH69	743645	6472240	703
MH43	749773	6472586	721	MH70	743672	6473040	722
MH44	750116	6472964	727	MH71	744028	6473891	717
MH45	750306	6473745	739	MH72	744137	6474343	714
MH46	747638	6471921	682	MH73	743784	6474855	719
MH47	747721	6472509	708	MH74	742159	6472559	681
MH48	748002	6472991	748	MH75	742831	6472638	736
MH49	748343	6473897	708	MH76	741504	6473173	692
MH50	745938	6471610	720	MH77	742548	6473400	689
MH51	746165	6472193	725	MH78	743053	6474076	706
MH52	746506	6472632	728	MH79	742832	6474786	699

1. Coordinate system: MGA zone 55, GDA94 datum.

Table 11 Dwellings in the vicinity of the proposed Project

Dwelling ID	Easting[1] [m]	Northing[1] [m]	Status[2]	Distance to nearest turbine [km]
1	734981	6472339	Non-associated	6.6
2	746379	6447381	Non-associated	4.1
3	745948	6447823	Non-associated	3.5
4	*753101*	*6463829*	*Associated*	*2.3*
5	755421	6457013	Non-associated	2.0
6	*759530*	*6455684*	*Associated*	*2.6*
7	763075	6455305	Non-associated	4.3
8	762963	6455246	Non-associated	4.2
9	763231	6454831	Non-associated	4.7
10	762967	6454937	Non-associated	4.5
11	762705	6455055	Non-associated	4.2
12	762740	6455416	Non-associated	4.0
13	733861	6466920	Non-associated	8.8
15	737201	6473051	Non-associated	4.3
16	737755	6472222	Non-associated	3.9
18	739308	6473409	Non-associated	2.2
20	741069	6454918	Non-associated	3.2
21	739967	6453723	Non-associated	4.1
22	760936	6451008	Non-associated	7.3
23	760118	6451273	Non-associated	7.0
24	748070	6479973	Non-associated	4.9
25	754355	6471244	Non-associated	2.1
29	760666	6451936	Non-associated	6.3
30	761089	6451033	Non-associated	7.3
31	761005	6451269	Non-associated	7.0
32	761212	6451295	Non-associated	7.1
33	761353	6451238	Non-associated	7.1
34	761369	6451171	Non-associated	7.2
35	761091	6451144	Non-associated	7.2
36	759216	6450514	Non-associated	7.8
38	754911	6444800	Non-associated	8.1
68	755181	6479834	Non-associated	5.4
69	752848	6479567	Non-associated	3.9
70	747413	6480066	Non-associated	5.1
71	746673	6480703	Non-associated	5.4
72	745452	6478966	Non-associated	3.5
74	741694	6480854	Non-associated	6.2
75	746815	6478831	Non-associated	3.7
76	746931	6477150	Non-associated	2.4
77	746881	6477383	Non-associated	2.5
78	747641	6477534	Non-associated	3.2
79	749213	6477458	Non-associated	2.1
80	754732	6476204	Non-associated	3.2
81	754873	6474160	Non-associated	3.4
82	754207	6473728	Non-associated	2.8
83	754619	6473446	Non-associated	2.9
84	754429	6471484	Non-associated	2.1
85	754408	6471140	Non-associated	2.2
86	753987	6468626	Non-associated	2.1
87	754582	6468371	Non-associated	2.7
88	753927	6468282	Non-associated	2.2

Table 11 Dwellings in the vicinity of the proposed Project (continued)

Dwelling ID	Easting[1] [m]	Northing[1] [m]	Status[2]	Distance to nearest turbine [km]
89	*753395*	*6464620*	*Associated*	*2.5*
90	750756	6463565	Non-associated	2.9
91	750140	6463442	Non-associated	2.8
92	762208	6450512	Non-associated	8.0
105	758540	6477457	Non-associated	7.2
127	739381	6473472	Non-associated	2.1
128	738171	6472152	Non-associated	3.5
129	739609	6466013	Non-associated	4.7
130	739390	6465864	Non-associated	5.0
131	740065	6464783	Non-associated	5.6
138	756950	6472421	Non-associated	4.7
139	757437	6474378	Non-associated	5.8
140	757213	6474589	Non-associated	5.6
141	758349	6474301	Non-associated	6.6
144	756386	6474747	Non-associated	4.7
145	734200	6467113	Non-associated	8.4
151	741898	6454216	Non-associated	2.2
152	740135	6454155	Non-associated	4.0
153	740573	6454499	Non-associated	3.6
154	740638	6454539	Non-associated	3.5
155	740355	6454536	Non-associated	3.8
156	740334	6454453	Non-associated	3.8
157	740317	6454360	Non-associated	3.8
158	740395	6454644	Non-associated	3.8
159	740389	6454766	Non-associated	3.8
160	740403	6454831	Non-associated	3.8
161	740353	6454875	Non-associated	3.9
162	740241	6454785	Non-associated	4.0
163	740230	6454831	Non-associated	4.0
164	740306	6454902	Non-associated	3.9
165	740380	6455007	Non-associated	3.9
166	740430	6454977	Non-associated	3.8
167	740355	6455087	Non-associated	3.9
168	740468	6455066	Non-associated	3.8
169	740333	6455144	Non-associated	4.0
170	740373	6455137	Non-associated	3.9
171	740470	6455116	Non-associated	3.8
172	740530	6455051	Non-associated	3.7
173	740685	6455020	Non-associated	3.6
174	740629	6455086	Non-associated	3.7
175	740576	6454869	Non-associated	3.6
176	740629	6454877	Non-associated	3.6
177	741088	6455103	Non-associated	3.2
178	740954	6455696	Non-associated	3.6
179	743895	6457724	Non-associated	3.4
180	744543	6457051	Non-associated	2.6
181	744651	6456900	Non-associated	2.4
182	744756	6456823	Non-associated	2.3
183	747538	6459062	Non-associated	5.2
184	748332	6458762	Non-associated	5.2
185	749295	6459958	Non-associated	4.5

Table 11 Dwellings in the vicinity of the proposed Project (continued)

Dwelling ID	Easting[1] [m]	Northing[1] [m]	Status[2]	Distance to nearest turbine [km]
186	746835	6445854	Non-associated	5.1
187	749160	6447972	Non-associated	2.5
188	751199	6448076	Non-associated	3.1
189	752739	6451129	Non-associated	2.4
190	752432	6451039	Non-associated	2.1
191	743060	6445665	Non-associated	5.0
192	740205	6448046	Non-associated	4.5
193	740088	6448500	Non-associated	4.3
196	738726	6451703	Non-associated	5.2
197	738933	6453171	Non-associated	5.2
199	754235	6473500	Non-associated	2.6
200	740806	6456985	Non-associated	4.5
202	744281	6461510	Non-associated	6.3
203	739797	6453784	Non-associated	4.3
210	759263	6473500	Non-associated	7.2
232	763251	6451497	Non-associated	7.5
234	737882	6471631	Non-associated	3.9
236	757447	6450586	Non-associated	7.1
239	739288	6474136	Non-associated	2.4
240	738762	6472196	Non-associated	2.9
241	737562	6471660	Non-associated	4.2
242	737405	6471598	Non-associated	4.4
243	737618	6470862	Non-associated	4.5
245	735754	6476885	Non-associated	6.8
246	*748131*	*6455397*	*Associated*	*2.4*
250	*749022*	*6473369*	*Associated*	*0.9*
251	*753164*	*6466539*	*Associated*	*2.5*
252	*754389*	*6470802*	*Associated*	*2.1*
253	*754611*	*6470634*	*Associated*	*2.3*
254	*754133*	*6470786*	*Associated*	*1.9*
255	*743766*	*6479281*	*Associated*	*4.1*
256	*755133*	*6457788*	*Associated*	*1.3*
257	*758006*	*6458421*	*Associated*	*1.2*
258	*758930*	*6458666*	*Associated*	*1.0*
275	*743837*	*6479160*	*Associated*	*3.9*
276	*755240*	*6466546*	*Associated*	*3.6*
277	757382	6466462	Non-associated	3.1
278	757286	6465235	Non-associated	2.1
279	*755442*	*6466588*	*Associated*	*3.5*
280	*752452*	*6465757*	*Associated*	*2.5*
281	*752089*	*6466194*	*Associated*	*1.9*
282	750905	6464541	Non-associated	2.2
283	765440	6458396	Non-associated	4.9
284	*764484*	*6459565*	*Associated*	*3.9*
285	764991	6461410	Non-associated	4.4
286	765365	6462457	Non-associated	4.7
287	765097	6464096	Non-associated	4.4
288	765042	6464250	Non-associated	4.4
289	765293	6464515	Non-associated	4.7
291	759318	6473603	Non-associated	7.3
292	759236	6472605	Non-associated	7.0

Table 11 Dwellings in the vicinity of the proposed Project (continued)

Dwelling ID	Easting[1] [m]	Northing[1] [m]	Status[2]	Distance to nearest turbine [km]
293	759597	6472971	Non-associated	7.4
297	*749296*	*6473388*	*Associated*	*0.9*
298	743639	6467415	Non-associated	3.0
303	*744499*	*6452361*	*Associated*	*1.0*
304	*747967*	*6452124*	*Associated*	*1.4*
305	*750133*	*6449337*	*Associated*	*1.5*
306	*749757*	*6449493*	*Associated*	*1.1*
307	751248	6461300	Non-associated	3.2
309	*740935*	*6471801*	*Associated*	*1.4*
310	*749622*	*6449493*	*Associated*	*1.1*
311	746187	6461138	Non-associated	5.8
312	744539	6460932	Non-associated	6.4
313	741908	6456885	Non-associated	3.7
314	747145	6464575	Non-associated	2.2
315	744846	6483257	Non-associated	7.8
317	740866	6483819	Non-associated	9.2
318	754976	6474025	Non-associated	3.5
319	741289	6459255	Non-associated	6.1
323	740366	6456873	Non-associated	4.8
324	741826	6454136	Non-associated	2.3
329	*753159*	*6462751*	*Associated*	*1.6*
330	738207	6465715	Non-associated	5.8
333	756633	6446418	Non-associated	8.1
352	760042	6453499	Non-associated	4.7
354	740542	6462804	Non-associated	7.4
357	753294	6449796	Non-associated	3.4
358	737277	6464798	Non-associated	7.1
363	754001	6454871	Non-associated	2.9
364	*749004*	*6457109*	*Associated*	*4.2*
497	758214	6457020	Non-associated	2.1
498	747808	6479925	Non-associated	4.9
499	736139	6474946	Non-associated	5.7
501	749272	6461488	Non-associated	4.6
503	750093	6477937	Non-associated	2.3
504	741818	6463483	Non-associated	6.5
505	754664	6472168	Non-associated	2.4
506	754653	6473923	Non-associated	3.2

1. Coordinate system: MGA zone 55, GDA94 datum.
2. Associated dwellings are indicated by *underlined italic text*.

Table 12 Details of point-to-point links crossing the proposed wind farm site

Link no.	Licence number	Assignment ID	Frequency [Hz]	Licence owner
1	1426036/1	807214	404900000	Essential Energy Attn: Ray Northcott PO Box 5730 PORT MACQUARIE BC NSW 2444
		807215	404900000	
		807212	414350000	
		807213	414350000	
2	10444171/2	3854517	11095000000	NBN Co Limited Level 11 100 Arthur Street NORTH SYDNEY NSW 2060
		3854518	11095000000	
		3854515	11585000000	
		3854516	11585000000	
3	10444172/2	3854521	11055000000	
		3854522	11055000000	
		3854519	11545000000	
		3854520	11545000000	
4	10444173/2	3854525	11175000000	
		3854526	11175000000	
		3854523	11665000000	
		3854524	11665000000	
5	10444178/1	3766356	6460000000	
		3766357	6460000000	
		3766354	6800000000	
		3766355	6800000000	
6	10444179/1	3766360	6460000000	
		3766361	6460000000	
		3766358	6800000000	
		3766359	6800000000	
7	10444180/1	3766364	6540000000	
		3766365	6540000000	
		3766362	6880000000	
		3766363	6880000000	
8	10444181/1	3766368	6620000000	
		3766369	6620000000	
		3766366	6960000000	
		3766367	6960000000	
9	10444182/1	3766372	6660000000	
		3766373	6660000000	
		3766370	7000000000	
		3766371	7000000000	
10	10444183/1	3766376	6700000000	
		3766377	6700000000	
		3766374	7040000000	
		3766375	7040000000	

Table 12 Details of point-to-point links crossing the proposed wind farm site (continued)

Link no.	Licence number	Assignment ID	Frequency [Hz]	Licence owner
11	10444184/1	3766380	6740000000	NBN Co Limited Level 11 100 Arthur Street NORTH SYDNEY NSW 2060
		3766381	6740000000	
		3766378	7080000000	
		3766379	7080000000	
12	10444185/1	3766384	7747700000	
		3766385	7747700000	
		3766382	8059020000	
		3766383	8059020000	
13	10444186/1	3766388	7747700000	
		3766389	7747700000	
		3766386	8059020000	
		3766387	8059020000	
14	10444187/1	3766392	7866300000	
		3766393	7866300000	
		3766390	8177620000	
		3766391	8177620000	
15	10444188/1	3766396	7866300000	
		3766397	7866300000	
		3766394	8177620000	
		3766395	8177620000	
16	11192657/1	7576581	6640000000	
		7576582	6640000000	
		7576579	6980000000	
		7576580	6980000000	
17	11192658/1	7576585	6640000000	
		7576586	6640000000	
		7576583	6980000000	
		7576584	6980000000	
18	11192659/1	7576589	6720000000	
		7576590	6720000000	
		7576587	7060000000	
		7576588	7060000000	
19	11192660/1	7576593	6720000000	
		7576594	6720000000	
		7576591	7060000000	
		7576592	7060000000	
20	11194184/1	7596633	6640000000	
		7596634	6640000000	
		7596631	6980000000	
		7596632	6980000000	

Table 12 Details of point-to-point links crossing the proposed wind farm site (continued)

Link no.	Licence number	Assignment ID	Frequency [Hz]	Licence owner
21	11194185/1	7596637	6640000000	NBN Co Limited Level 11 100 Arthur Street NORTH SYDNEY NSW 2060
		7596638	6640000000	
		7596635	6980000000	
		7596636	6980000000	
22	11194186/1	7596641	6720000000	
		7596642	6720000000	
		7596639	7060000000	
		7596640	7060000000	
23	11194187/1	7596645	6720000000	
		7596646	6720000000	
		7596643	7060000000	
		7596644	7060000000	
24	11194317/1	7602089	10915000000	
		7602090	10915000000	
		7602087	11405000000	
		7602088	11405000000	
25	11194318/1	7602093	10915000000	
		7602094	10915000000	
		7602091	11405000000	
		7602092	11405000000	
26	11194319/1	7602097	10995000000	
		7602098	10995000000	
		7602095	11485000000	
		7602096	11485000000	
27	11194320/1	7602101	10995000000	
		7602102	10995000000	
		7602099	11485000000	
		7602100	11485000000	
28	11197151/1	7645268	6560000000	
		7645269	6560000000	
		7645266	6900000000	
		7645267	6900000000	
29	11197152/1	7645272	6560000000	
		7645273	6560000000	
		7645270	6900000000	
		7645271	6900000000	
30	11197153/1	7645276	6480000000	
		7645277	6480000000	
		7645274	6820000000	
		7645275	6820000000	

Table 12 Details of point-to-point links crossing the proposed wind farm site (continued)

Link no.	Licence number	Assignment ID	Frequency [Hz]	Licence owner
31	11197154/1	7645280	6480000000	NBN Co Limited Level 11 100 Arthur Street NORTH SYDNEY NSW 2060
		7645281	6480000000	
		7645278	6820000000	
		7645279	6820000000	
32	1964651/2	3765946	6540000000	
		3765947	6540000000	
		3765944	6880000000	
		3765945	6880000000	
33	1966042/3	3854513	11135000000	
		3854514	11135000000	
		3854511	11625000000	
		3854512	11625000000	
34	10677945/1	5227354	7435000000	New South Wales Government Telecommunications Authority Telco Authority (GRN) Locked Bag 2 HAYMARKET NSW 1240
		5227355	7435000000	
		5227352	7596000000	
		5227353	7596000000	
35	10677946/1	5227358	7484000000	
		5227359	7484000000	
		5227356	7645000000	
		5227357	7645000000	
36	10677947/1	5227362	7442000000	
		5227363	7442000000	
		5227360	7603000000	
		5227361	7603000000	
37	10433297/1	3666149	805100000	NSW Police Force Radio Engineering Services Level 4 151-241 Goulburn St Sydney Police Centre, SURRY HILLS NSW 2010
		3666150	805100000	
		3666147	850100000	
		3666148	850100000	
38	1204074/1	765795	451125000	NSW Rural Fire Service Locked Mail Bag 17 GRANVILLE NSW 2142
		765796	451125000	
		765793	460625000	
		765794	460625000	
39	1969342/1	967623	7557500000	
		967624	7557500000	
		967621	7718500000	
		967622	7718500000	
40	9992729/2	1574481	7807000000	Telstra Corporation Limited Radio Engineering Attn Nik Patel Radio, Transport Engineering (Attn Nik Patel) Locked Bag 3501 BRISBANE QLD 4001
		1574482	7807000000	
		1574479	8118320000	
		1574480	8118320000	
41	17860/1	1286117	404375000	Warrumbungle Shire Council PO Box 191 COONABARABRAN NSW 2357
		1286118	404375000	
		1286115	413825000	
		1286116	413825000	
42	1987155/1	1004716	404375000	
		1004717	404375000	
		1004714	413825000	
		1004715	413825000	

Table 13 Details of point-to-multipoint licences within 75 km of the proposed Project

Assignment ID	Site ID	Licence no.	Latitude [GDA94]	Longitude [GDA94]	Distance to Project [km]	Licence owner
2389905	10003449	10179497/1	-31.8293	150.3479	56	Bureau of Meteorology GPO Box 1289 MELBOURNE VIC 3001
2389902	10003449	10179497/1	-31.8293	150.3479	56	
2389913	10003446	10179499/1	-32.4710	150.1059	59	
2389910	10003446	10179499/1	-32.4710	150.1059	59	
2765176	11308	1184808/3	-32.4137	150.1171	55	Endeavour Energy PO Box 6366 BLACKTOWN DC NSW 2148
2765177	11308	1184808/3	-32.4137	150.1171	55	
3980998	9007130	10487011/1	-31.8182	149.2035	31	Essential Energy Attn: Ray Northcott PO Box 5730 PORT MACQUARIE BC NSW 2444
3981001	9007130	10487011/1	-31.8182	149.2035	31	
900122	151198	1928254/1	-32.4434	149.5620	42	
900119	151198	1928254/1	-32.4434	149.5620	42	
3981002	11018	10487012/1	-31.3463	149.0262	71	
3981005	11018	10487012/1	-31.3463	149.0262	71	
887433	201640	1920150/1	-31.5060	150.0179	48	Liverpool Plains Shire Council PO Box 152 QUIRINDI NSW 2343
887436	201640	1920150/1	-31.5060	150.0179	48	
783107	250425	1251762/1	-32.3889	149.5127	37	Magesta Pty Ltd 77 Pentecost Ave PYMBLE NSW 2073
783110	250425	1251762/1	-32.3889	149.5127	37	
782641	250313	1251376/1	-32.3673	149.5422	34	Mid-Western Regional Council PO Box 156 MUDGEE NSW 2850
946291	250313	1958588/1	-32.3673	149.5422	34	
946294	250313	1958588/1	-32.3673	149.5422	34	
782644	250313	1251376/1	-32.3673	149.5422	34	
937230	11344	1952737/1	-32.6171	149.5538	61	
937233	11344	1952737/1	-32.6171	149.5538	61	
782636	11344	1251366/1	-32.6171	149.5538	61	
782633	11344	1251366/1	-32.6171	149.5538	61	
2573298	6210	56027/3	-32.1215	150.3122	53	The Trustee for Blue Op Partner Trust & Others Ausgrid Operator Partnership GPO Box 4009 SYDNEY NSW 2001
2573299	6210	56027/3	-32.1215	150.3122	53	

Table 13 Details of point-to-multipoint licences within 75 km of the proposed Project (continued)

Assignment ID	Site ID	Licence no.	Latitude [GDA94]	Longitude [GDA94]	Distance to Project [km]	Licence owner
4322577	9025971	1231285/2	-32.1811	149.7218	13	Ulan Coal Mines Ltd Private Mail Bag 3006 ULAN NSW 2850
4322574	9025971	1231285/2	-32.1811	149.7218	13	
773025	11336	1220626/1	-32.2409	149.7682	21	
773022	11336	1220626/1	-32.2409	149.7682	21	
707649	205563	93240/1	-32.2704	149.6177	22	
707652	205563	93240/1	-32.2704	149.6177	22	
707641	11316	93216/1	-32.2666	149.7401	23	
707640	11316	93216/1	-32.2666	149.7401	23	
778686	204658	1231283/1	-32.2648	149.7536	23	
778689	204658	1231283/1	-32.2648	149.7536	23	
707648	204658	93233/1	-32.2648	149.7536	23	
707647	204658	93233/1	-32.2648	149.7536	23	
991161	9021960	1980866/1	-32.1492	150.3614	58	Upper Hunter Shire Council PO Box 208 SCONE NSW 2337
991158	9021960	1980866/1	-32.1492	150.3614	58	
872722	9009346	1910128/1	-31.8202	149.1300	38	Warrumbungle Shire Council PO Box 191 COONABARABRAN NSW 2357
872719	9009346	1910128/1	-31.8202	149.1300	38	
8634705	6761	11438934/1	-31.2859	149.2611	8634705	
8634706	6761	11438934/1	-31.2859	149.2611	8634706	
2853042	6761	10283232/1	-31.2859	149.2611	2853042	
2853039	6761	10283232/1	-31.2859	149.2611	2853039	
6264308	6761	10890933/1	-31.2859	149.2611	6264308	
6264307	6761	10890933/1	-31.2859	149.2611	6264307	
8634701	6778	11438933/1	-31.2730	149.0684	75	
8634702	6778	11438933/1	-31.2730	149.0684	75	
2853046	6778	10283233/1	-31.2730	149.0684	75	
2853043	6778	10283233/1	-31.2730	149.0684	75	
6264304	6778	10890932/1	-31.2730	149.0684	75	
6264303	6778	10890932/1	-31.2730	149.0684	75	
2825716	250307	10275990/1	-32.4255	149.1036	60	WATER NSW Attn: P Dudley PO Box 398 Parramatta NSW 2124
2825713	250307	10275990/1	-32.4255	149.1036	60	
2863327	250307	1220692/2	-32.4255	149.1036	60	
2863328	250307	1220692/2	-32.4255	149.1036	60	
2825701	11344	10275987/1	-32.6171	149.5538	61	
2825704	11344	10275987/1	-32.6171	149.5538	61	
2863332	11344	1220693/2	-32.6171	149.5538	61	
2863331	11344	1220693/2	-32.6171	149.5538	61	
4560157	461568	10579504/1	-32.3417	149.8781	36	Wilpinjong Coal Locked Bag 2005 MUDGEE NSW 2850
4560160	461568	10579504/1	-32.3417	149.8781	36	

Table 14 Details of other licences identified within 75 km of the proposed Project

Licence category	Licence type	Number of assignment IDs
1800 MHz Band	Spectrum	82
2 GHz Band	Spectrum	60
2.3 GHz Band	Spectrum	1970
2.5 GHz Band	Spectrum	16
3.4 GHz Band	Spectrum	92
700 MHz Band	Spectrum	314
800 MHz Band	Spectrum	211
Aeronautical Assigned System	Aeronautical	4
Amateur Repeater	Amateur	8
Ambulatory System	Land Mobile	18
AWL - FSS Only	Spectrum	100
CBRS Repeater	Land Mobile	6
Commercial Radio	Broadcasting	5
Commercial Television	Broadcasting	14
Community Broadcasting	Broadcasting	4
Land Mobile System - > 30MHz	Land Mobile	584
Land Mobile System 0-30MHz	Land Mobile	4
Narrowcasting Service (Fixed Tax)	Broadcasting	1
Narrowcasting Service (LPON)	Broadcasting	28
National Broadcasting	Broadcasting	18
Paging System - Exterior	Land Mobile	25
PMTS Class B	PTS	72
PMTS Class B (935-960 MHz)	PTS 900 MHz	49
Radiodetermination	Radiodetermination	3
Retransmission	Broadcasting	10

Table 15 Emergency services with radiocommunication assets in the vicinity of the proposed Project

Emergency service	Contact details	Distance from closest site to wind farm site [km]
Ambulance Service of NSW	Ambulance Service of NSW Service Manager Telecommunications Matt Wheat Locked Bag 105 ROZELLE NSW 2039	48
New South Wales Government Telecommunications Authority	New South Wales Government Telecommunications Authority Telco Authority (Essential Energy) Level 18, McKell Building 2-24 Rawson Place SYDNEY NSW 2000	Within wind farm site
NSW Police Force	NSW Police Force Radio Engineering Services Level 4 151-241 Goulburn St Sydney Police Centre, SURRY HILLS NSW 2010	7
NSW Rural Fire Service	NSW Rural Fire Service Locked Mail Bag 17 GRANVILLE NSW 2142	7
NSW Volunteer Rescue Association Inc	NSW Volunteer Rescue Association Inc Secretary PO Box 6151 DURAL DC NSW 2158	4
St John Ambulance Australia (N.S.W.)	St John Ambulance Australia (N.S.W.) St John Ambulance Australia Nsw 9 Deane Street BURWOOD NSW 2134	63
St. John Ambulance Australia Incorporated	St. John Ambulance Australia Incorporated Technical Services 170 Forster Road MOUNT WAVERLEY VIC 3149	63

Table 16 BoM radar sites in the vicinity of the proposed Project

BoM radar site	Radar type	Latitude[1]	Longitude[1]	Distance to Project [km]
Namoi	Doppler	150.192	-31.024	102
Newcastle	Doppler	152.025	-32.730	227
Sydney	Doppler	151.209	-33.701	230
Moree	Standard weather watch	149.850	-29.500	255
Kurnell	Doppler	151.226	-34.015	260
Wollongong	Doppler	150.875	-34.263	268
Brewarrina	Doppler	146.814	-29.971	332
Wagga Wagga	Standard weather watch	147.467	-35.167	396
Grafton	Standard weather watch	152.951	-29.622	398
Canberra	Doppler	149.512	-35.661	399

1. Coordinate system: Lat/Lon GDA94 datum.

Table 17 Trigonometrical stations in the vicinity of the proposed Project

Station name	Datum	Latitude[1]	Longitude[1]	Distance to Project [km]
8831-1000 TP	AGD66, AGD84, GDA94	-32.214	149.690	16
Abundance	AGD66	-31.620	149.590	19
Bark	AGD66	-32.155	149.409	19
Bobadeen	AGD66, AGD84, GDA94	-32.125	149.746	9
Booyamurna	AGD66, GDA94	-31.818	149.814	12
Bullaroy	AGD66	-31.736	149.497	9
Bullinda	AGD66	-31.890	149.450	7
Cockabutta	AGD66, AGD84, GDA94	-32.131	149.645	7
Collier	AGD66, AGD84, GDA94	-31.942	149.736	Within wind farm site
Coolah	AGD66, AGD84, GDA94	-31.877	149.656	Within wind farm site
Dunedoo	AGD66	-32.022	149.395	17
Hook	AGD66, AGD84, GDA94	-32.047	149.550	3
Martindale	AGD66	-31.928	149.348	17
Mooren	AGD66	-31.714	149.384	20
Mumbedah	AGD66, AGD84, GDA94	-31.856	149.573	Within wind farm site
Narangarie	AGD66, AGD84, GDA94	-31.968	149.554	6
PM78730	GDA94	-32.167	149.762	14
PM85632	GDA94	-32.129	149.662	6
PM85633	GDA94	-32.046	149.765	2
PM85634	GDA94	-32.172	149.579	12
PM85635	GDA94	-32.112	149.843	12
Queensborough	AGD66, GDA94	-31.776	149.727	7
SS71911	GDA94	-32.181	149.857	20
Talla	AGD66, AGD84, GDA94	-32.204	149.491	18
Terraban	AGD66, AGD84, GDA94	-32.022	149.647	Within wind farm site
Turill	AGD66, AGD84, GDA94	-31.996	149.889	12
Ulan	AGD66, AGD84, GDA94	-32.215	149.706	16
Wargundy	AGD66	-32.056	149.435	14
Weetaliba	AGD66	-31.680	149.562	12

1. Coordinate system: Lat/Lon GDA94 datum.

Table 18 Dwellings with increased potential to experience EMI to DTV from television broadcast towers

Dwelling ID	Easting[1] [m]	Northing[1] [m]	Located in potential interference zone[2]	
			Central Western Slopes	Coolah
2	746379	6447381	X	X
3	745948	6447823	X	X
4	*753101*	*6463829*	*X*	
5	755421	6457013	X	X
6	*759530*	*6455684*	*X*	*X*
7	763075	6455305	X	
8	762963	6455246	X	
9	763231	6454831	X	
10	762967	6454937	X	
11	762705	6455055	X	
12	762740	6455416	X	
16	737755	6472222		X
18	739308	6473409		X
25	754355	6471244	X	
81	754873	6474160	X	
82	754207	6473728	X	
83	754619	6473446	X	
84	754429	6471484	X	
85	754408	6471140	X	
86	753987	6468626	X	
87	754582	6468371	X	
88	753927	6468282	X	
89	*753395*	*6464620*	*X*	
90	750756	6463565	X	
91	750140	6463442	X	X
127	739381	6473472		X
128	738171	6472152		X
187	749160	6447972		X
188	751199	6448076	X	
191	743060	6445665		X
199	754235	6473500	X	
234	737882	6471631		X
239	739288	6474136		X
240	738762	6472196		X
241	737562	6471660		X
242	737405	6471598		X
243	737618	6470862		X
250	*749022*	*6473369*	*X*	*X*
251	*753164*	*6466539*	*X*	
252	*754389*	*6470802*	*X*	
253	*754611*	*6470634*	*X*	
254	*754133*	*6470786*	*X*	
256	*755133*	*6457788*	*X*	*X*
257	*758006*	*6458421*	*X*	*X*
258	*758930*	*6458666*	*X*	*X*
276	*755240*	*6466546*	*X*	
279	*755442*	*6466588*	*X*	
280	*752452*	*6465757*	*X*	
281	*752089*	*6466194*	*X*	
282	750905	6464541	X	X

Table 18 Dwellings with increased potential to experience EMI to DTV from television broadcast towers (continued)

Dwelling ID	Easting[1] [m]	Northing[1] [m]	Located in potential interference zone[2]	
			Central Western Slopes	Coolah
284	*764484*	*6459565*	*X*	
285	764991	6461410	X	
297	*749296*	*6473388*	*X*	*X*
298	743639	6467415	X	
303	*744499*	*6452361*	*X*	*X*
304	*747967*	*6452124*	*X*	
305	*750133*	*6449337*	*X*	*X*
306	*749757*	*6449493*	*X*	*X*
309	*740935*	*6471801*		*X*
310	*749622*	*6449493*	*X*	*X*
314	747145	6464575		X
318	754976	6474025	X	
352	760042	6453499		X
357	753294	6449796	X	
363	754001	6454871		X
497	758214	6457020	X	X
505	754664	6472168	X	
506	754653	6473923	X	

1. Coordinate system: MGA zone 55, GDA94 datum.
2. Associated dwellings are indicated by *underlined italic text*.

Table 19 Details of point-to-point links crossing the proposed transmission line routes

Link no.	Licence number	Assignment ID	Frequency [Hz]	Licence owner
1	1426036/1	807212	414350000	Essential Energy Attn: Ray Northcott PO Box 5730 PORT MACQUARIE BC NSW 2444
		807213	414350000	
		807214	404900000	
		807215	404900000	
2	10444178/1	3766354	6800000000	NBN Co Limited Level 13 100 Arthur Street NORTH SYDNEY NSW 2060
		3766355	6800000000	
		3766356	6460000000	
		3766357	6460000000	
3	10444179/1	3766358	6800000000	
		3766359	6800000000	
		3766360	6460000000	
		3766361	6460000000	
4	10444180/1	3766362	6880000000	
		3766363	6880000000	
		3766364	6540000000	
		3766365	6540000000	
5	10444181/1	3766366	6960000000	
		3766367	6960000000	
		3766368	6620000000	
		3766369	6620000000	
6	10444182/1	3766370	7000000000	
		3766371	7000000000	
		3766372	6660000000	
		3766373	6660000000	
7	10444183/1	3766374	7040000000	
		3766375	7040000000	
		3766376	6700000000	
		3766377	6700000000	
8	10444184/1	3766378	7080000000	
		3766379	7080000000	
		3766380	6740000000	
		3766381	6740000000	
9	10444185/1	3766382	8059020000	
		3766383	8059020000	
		3766384	7747700000	
		3766385	7747700000	
10	10444186/1	3766386	8059020000	
		3766387	8059020000	
		3766388	7747700000	
		3766389	7747700000	

Table 19 Details of point-to-point links crossing the proposed transmission line routes (continued)

Link no.	Licence number	Assignment ID	Frequency [Hz]	Licence owner
11	10444187/1	3766390	8177620000	NBN Co Limited Level 13 100 Arthur Street NORTH SYDNEY NSW 2060
		3766391	8177620000	
		3766392	7866300000	
		3766393	7866300000	
12	10444188/1	3766394	8177620000	
		3766395	8177620000	
		3766396	7866300000	
		3766397	7866300000	
13	11192657/1	7576579	6980000000	
		7576580	6980000000	
		7576581	6640000000	
		7576582	6640000000	
14	11192658/1	7576583	6980000000	
		7576584	6980000000	
		7576585	6640000000	
		7576586	6640000000	
15	11192659/1	7576587	7060000000	
		7576588	7060000000	
		7576589	6720000000	
		7576590	6720000000	
16	11192660/1	7576591	7060000000	
		7576592	7060000000	
		7576593	6720000000	
		7576594	6720000000	
17	11194184/1	7596631	6980000000	
		7596632	6980000000	
		7596633	6640000000	
		7596634	6640000000	
18	11194185/1	7596635	6980000000	
		7596636	6980000000	
		7596637	6640000000	
		7596638	6640000000	
19	11194186/1	7596639	7060000000	
		7596640	7060000000	
		7596641	6720000000	
		7596642	6720000000	
20	11194187/1	7596643	7060000000	
		7596644	7060000000	
		7596645	6720000000	
		7596646	6720000000	

Table 19 Details of point-to-point links crossing the proposed transmission line routes (continued)

Link no.	Licence number	Assignment ID	Frequency [Hz]	Licence owner
21	11197151/1	7645266	6900000000	NBN Co Limited Level 13 100 Arthur Street NORTH SYDNEY NSW 2060
		7645267	6900000000	
		7645268	6560000000	
		7645269	6560000000	
22	11197152/1	7645270	6900000000	
		7645271	6900000000	
		7645272	6560000000	
		7645273	6560000000	
23	11197153/1	7645274	6820000000	
		7645275	6820000000	
		7645276	6480000000	
		7645277	6480000000	
24	11197154/1	7645278	6820000000	
		7645279	6820000000	
		7645280	6480000000	
		7645281	6480000000	
25	1964651/2	3765944	6880000000	
		3765945	6880000000	
		3765946	6540000000	
		3765947	6540000000	
26	10677946/1	5227356	7645000000	New South Wales Government Telecommunications Authority Telco Authority (GRN) Locked Bag 2 HAYMARKET NSW 1240
		5227357	7645000000	
		5227358	7484000000	
		5227359	7484000000	
27	11363994/1	8423101	11645000000	Telstra Corporation Limited Radio, Transport Engineering (Attn Nik Patel) Locked Bag 3501 BRISBANE QLD 4001
		8423102	11645000000	
		8423103	11155000000	
		8423104	11155000000	

LIST OF FIGURES

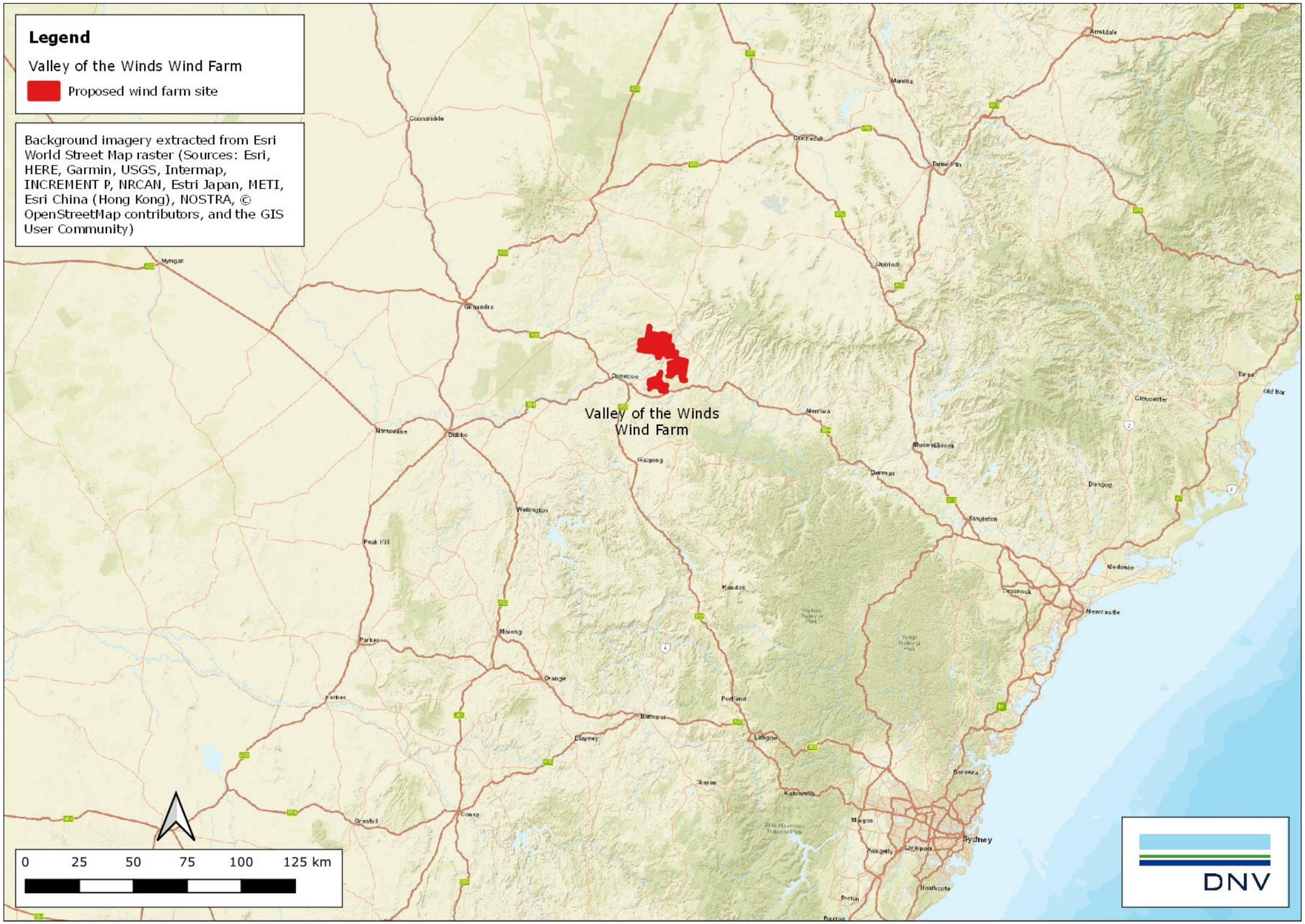

Figure 4 Location of the proposed Project

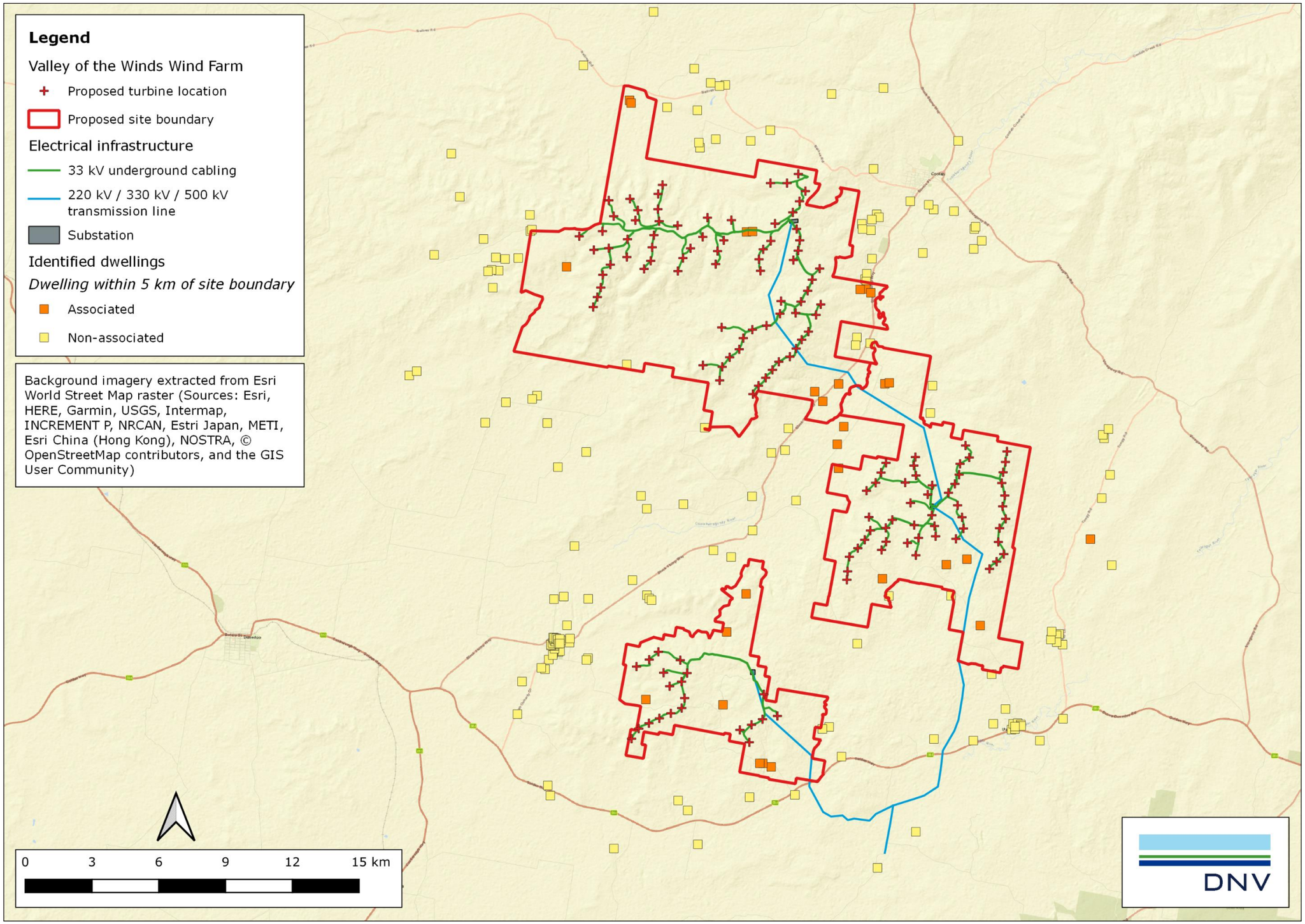

Figure 5 Map of the proposed Project, showing wind farm site, turbine locations, electrical infrastructure, and locations of nearby dwellings

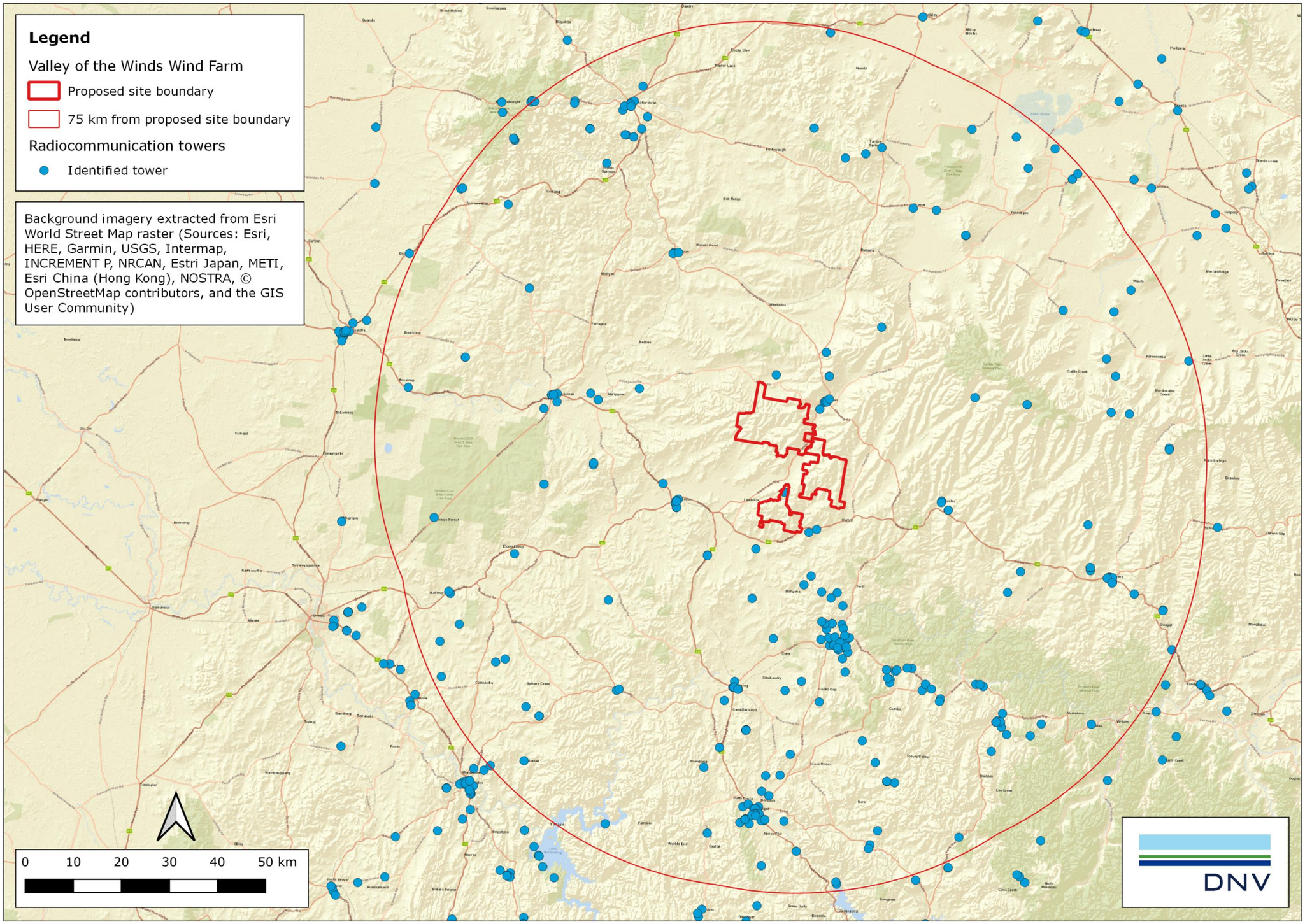

Figure 6 Location of the proposed Project and identified nearby radiocommunication sites

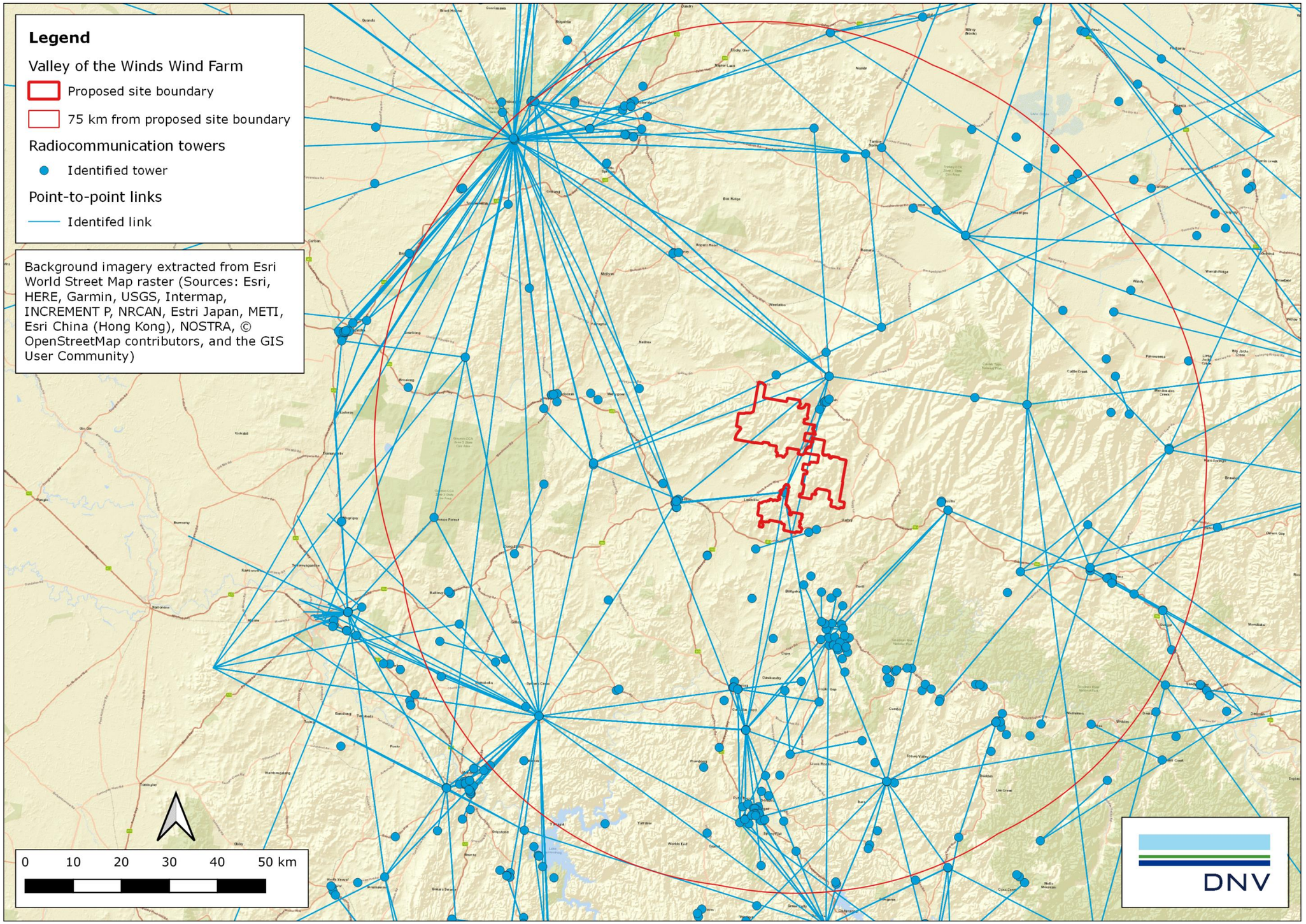

Figure 7 Identified transmission vectors for fixed licences of point-to-point type in the vicinity of the proposed Project

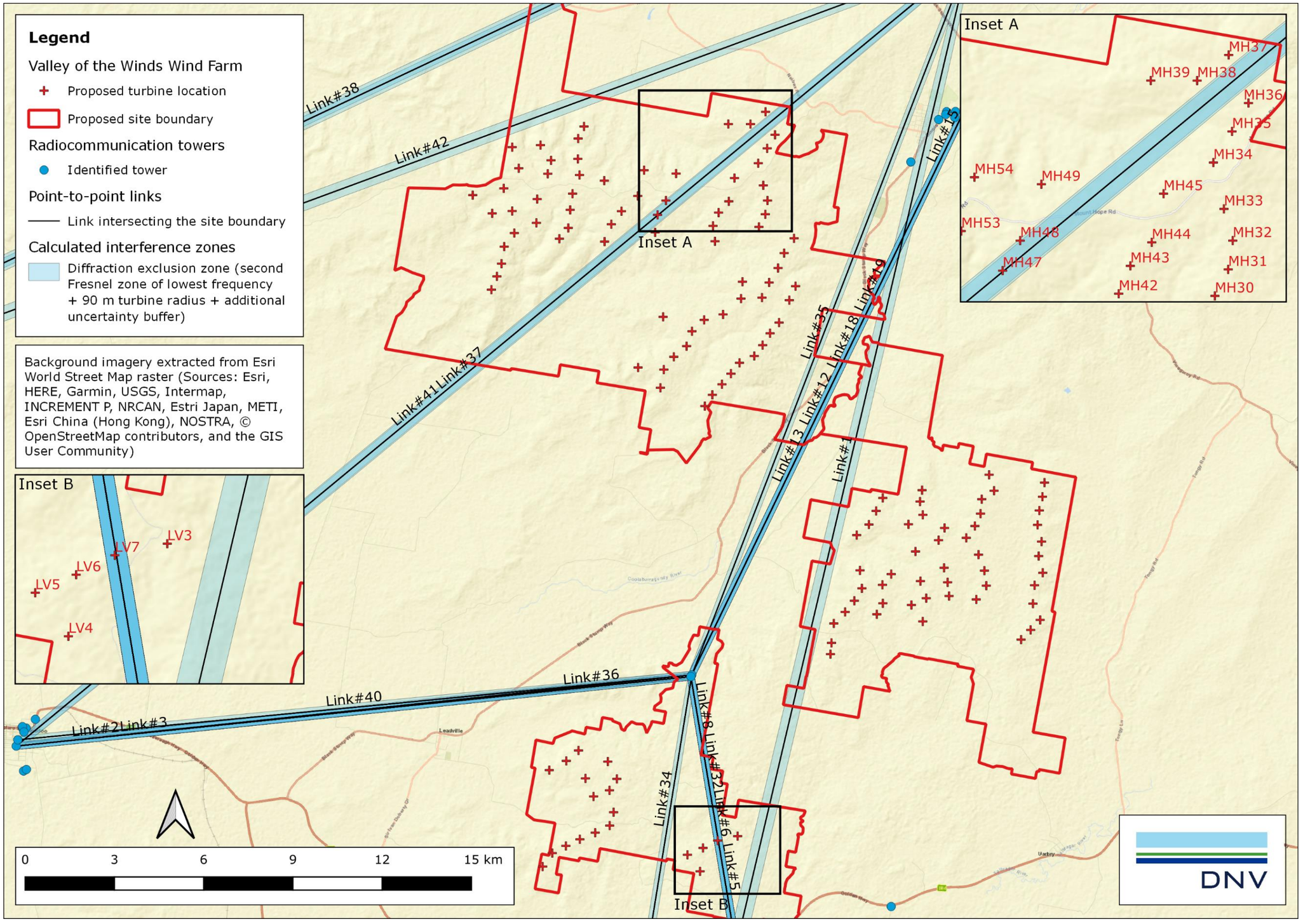

Figure 8 Identified point-to-point radiocommunication vectors crossing the proposed Project and calculated interference zones

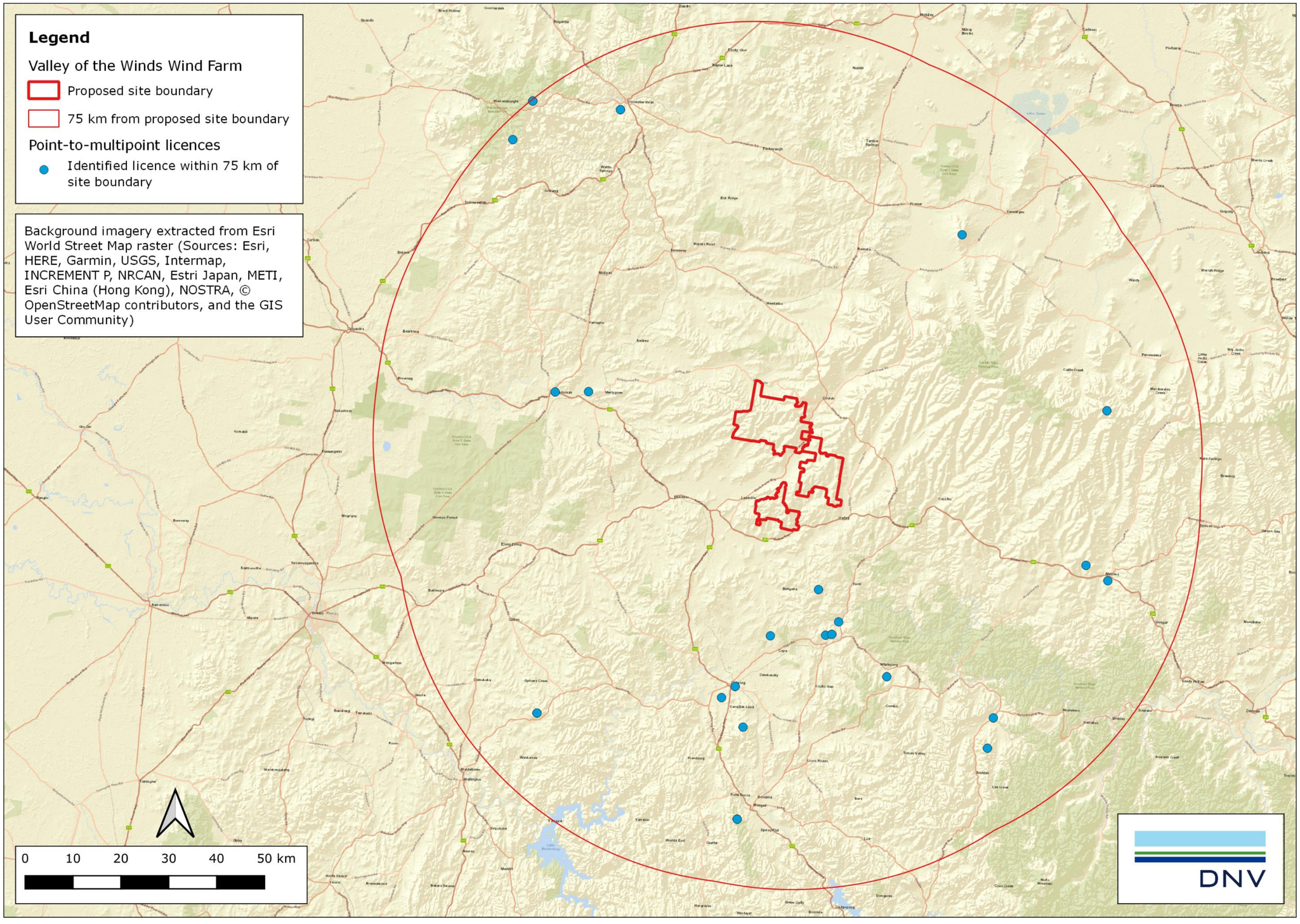

Figure 9 Location of point-to-multipoint licences in the vicinity of the proposed Project

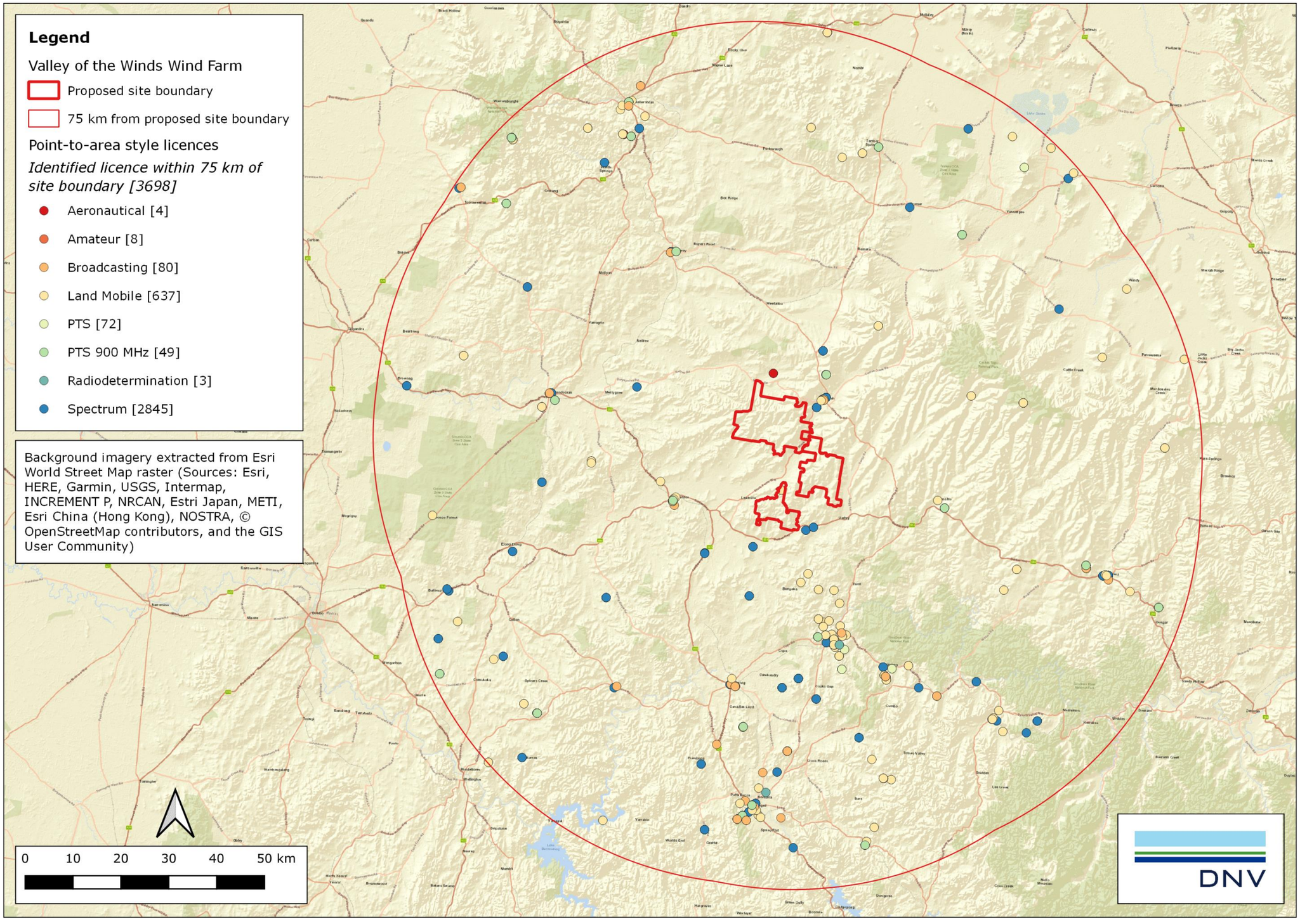

Figure 10 Location of general point-to-area style licences within 75km of the proposed Project

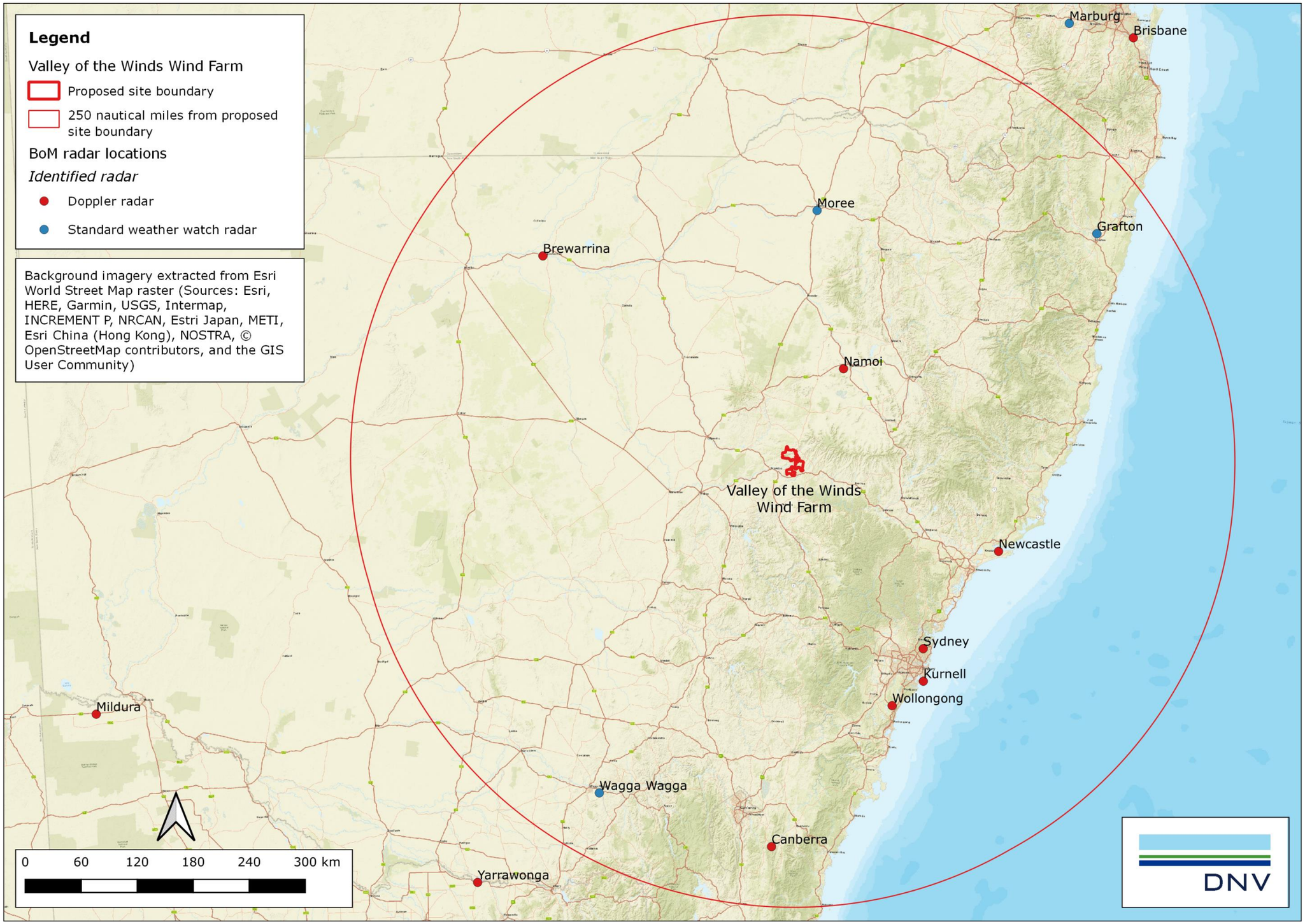

Figure 11 Location of meteorological radar sites within 250 nautical miles of the proposed Project

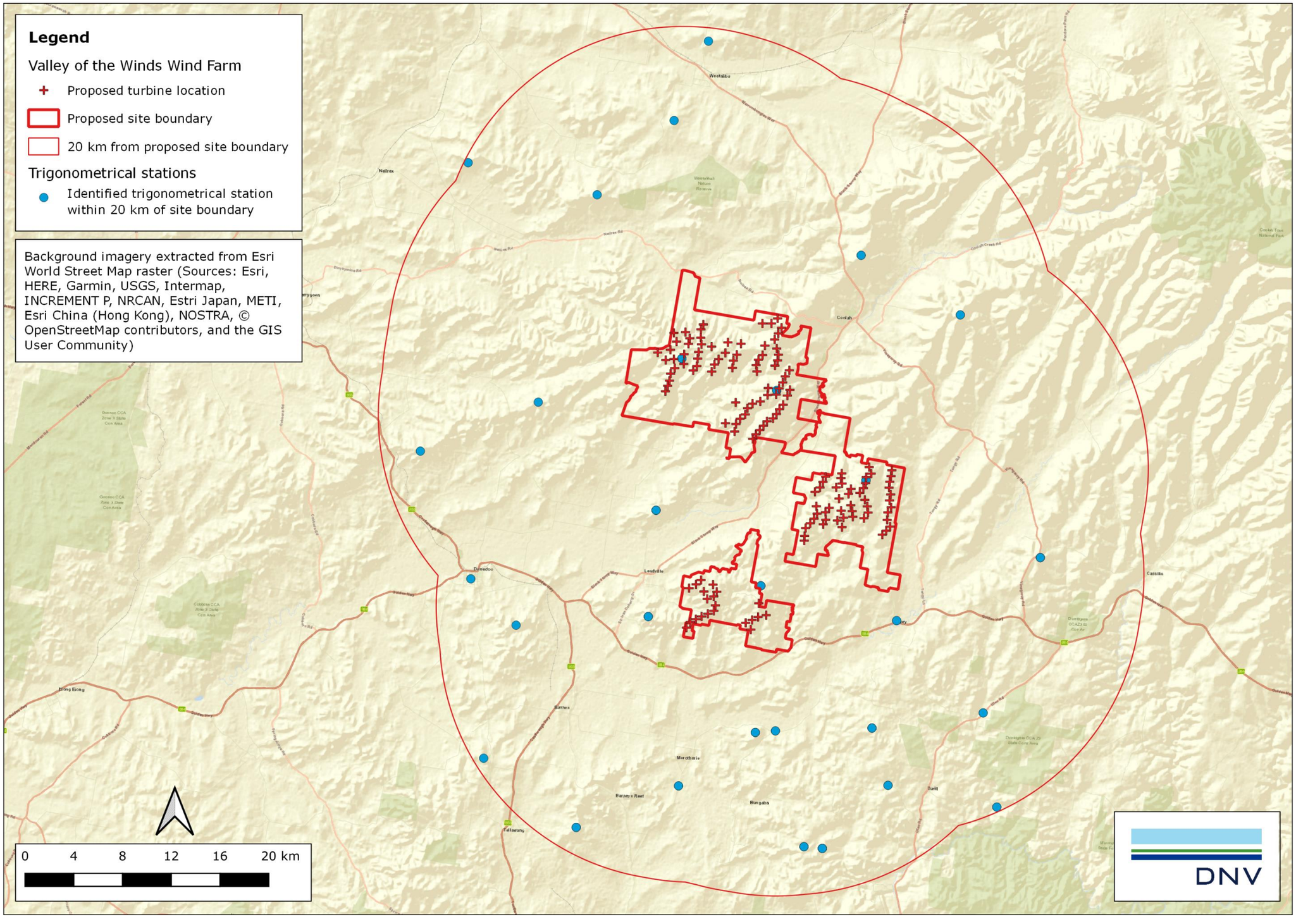

Figure 12 Location of trigonometrical stations within 20 km of the proposed Project

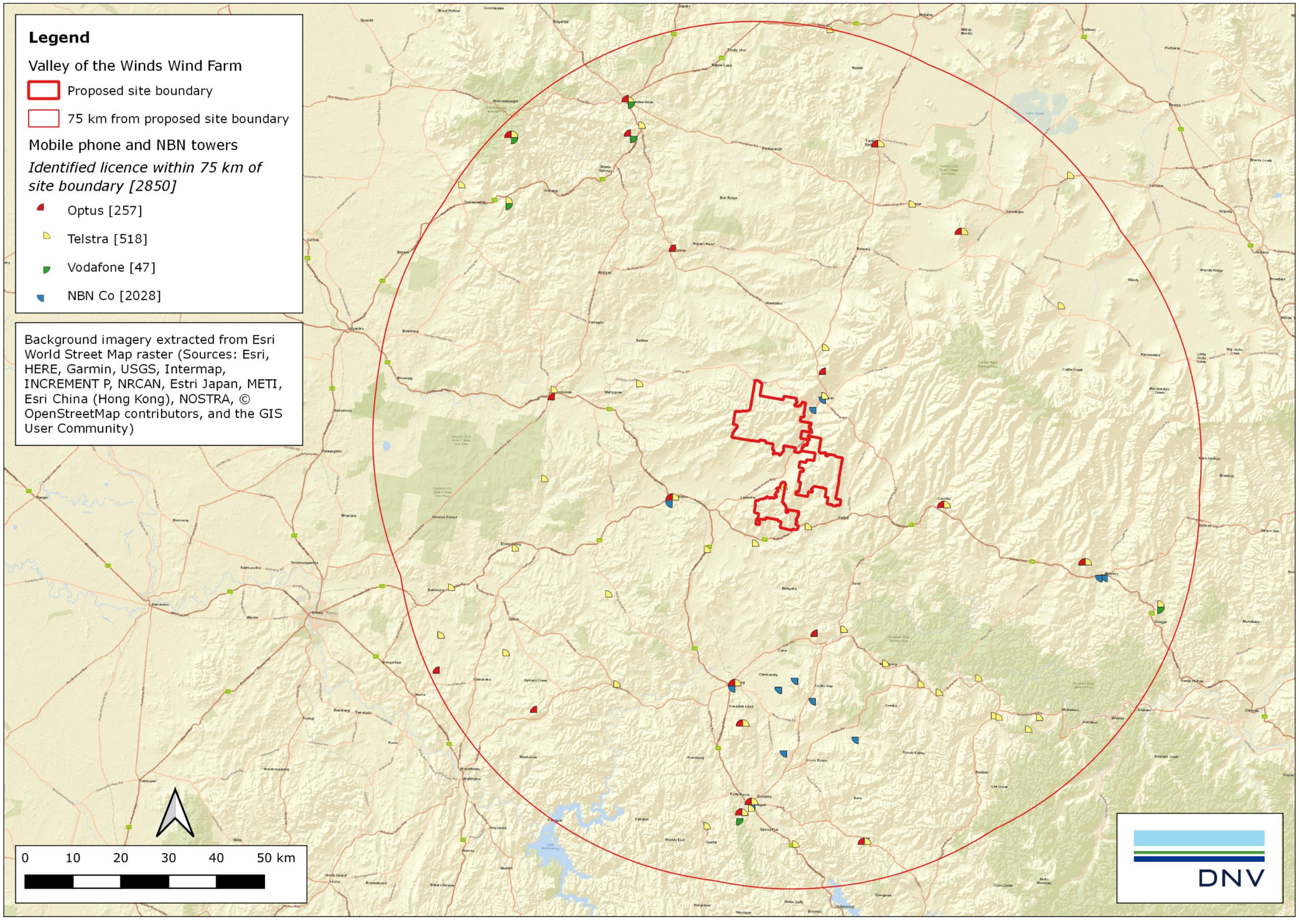

Figure 13 Location of mobile phone and NBN towers within 75 km of the proposed Project

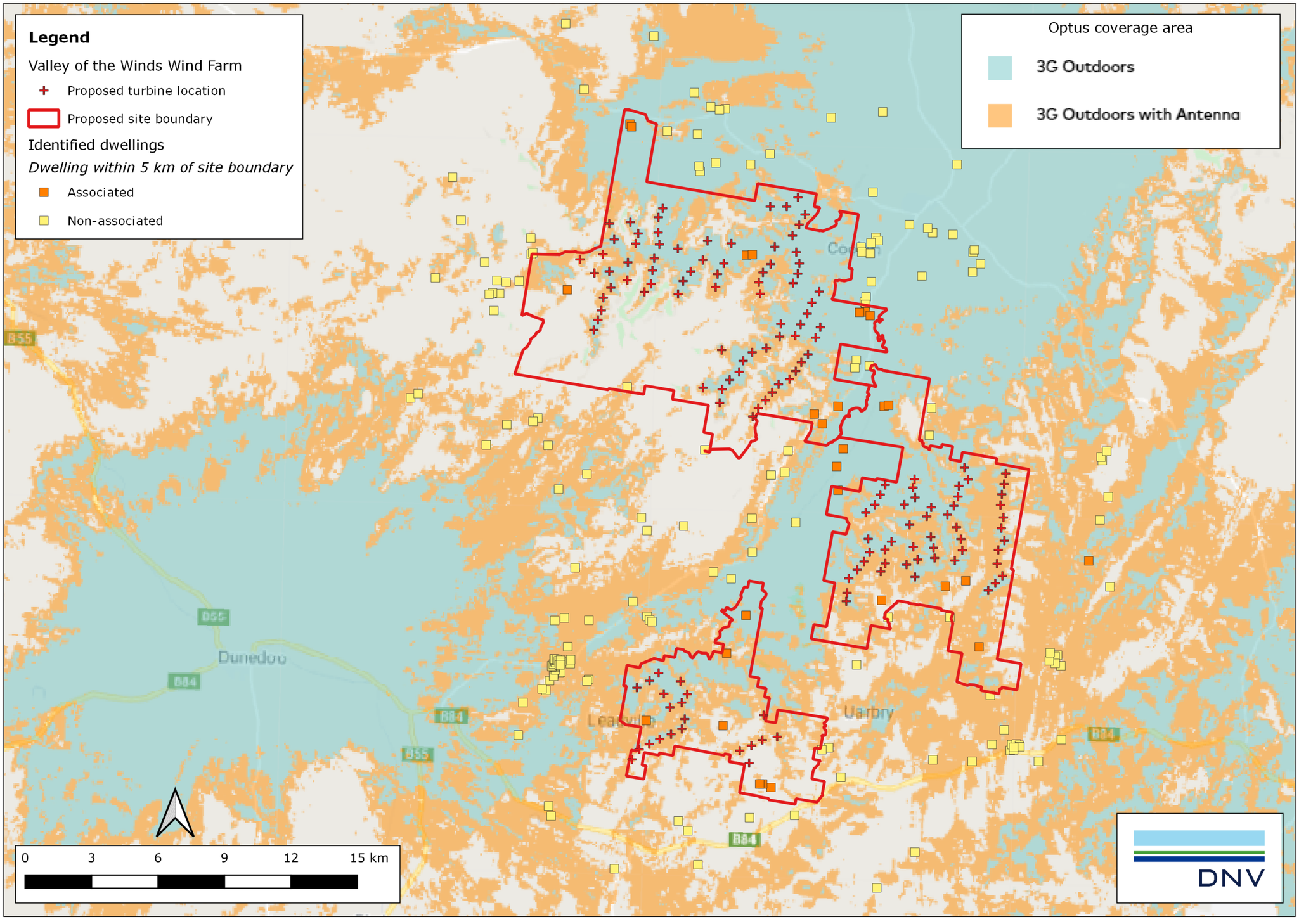

Figure 14 Optus Mobile 3G network coverage for the proposed Project

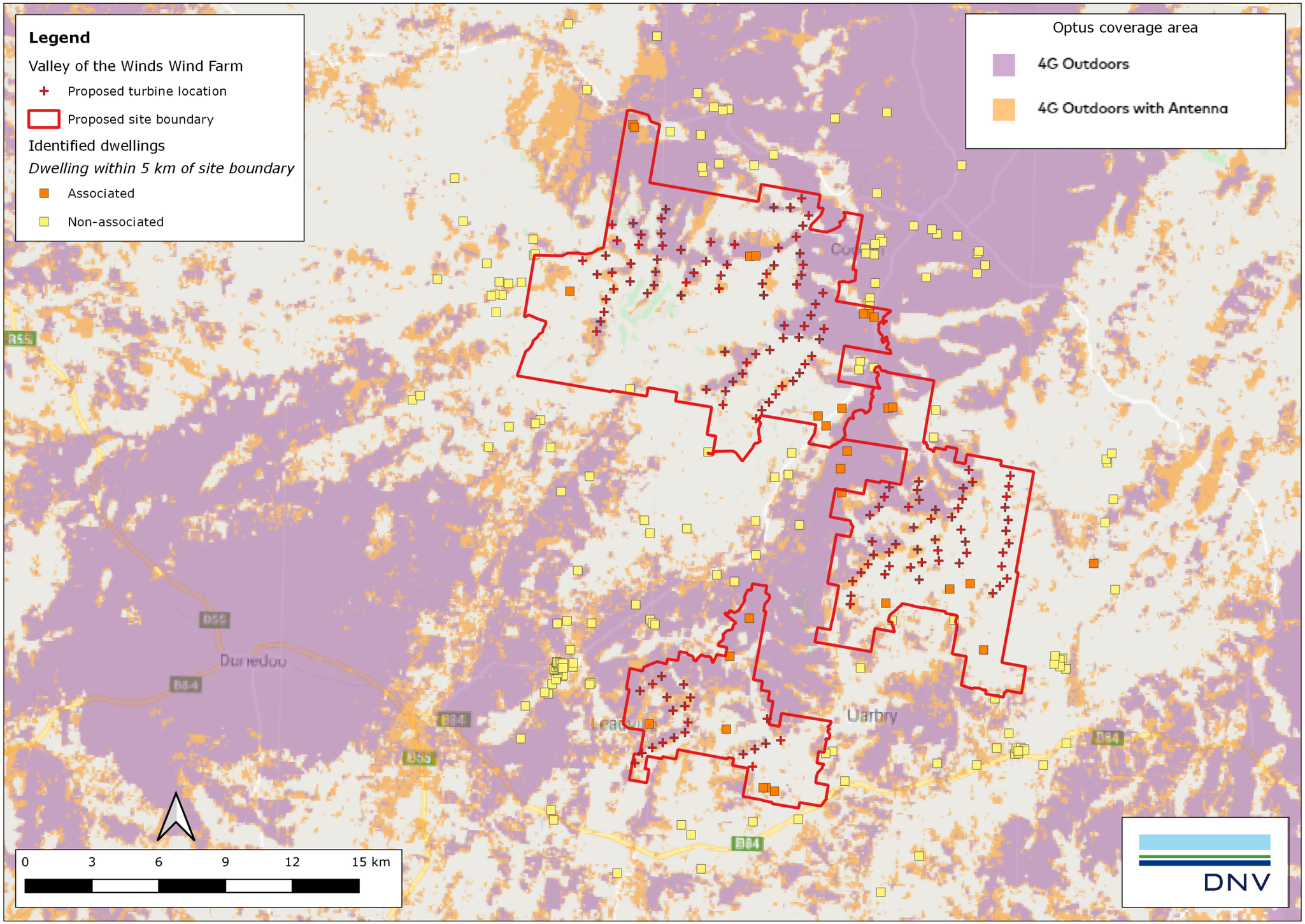

Figure 15 Optus Mobile 4G network coverage for the proposed Project

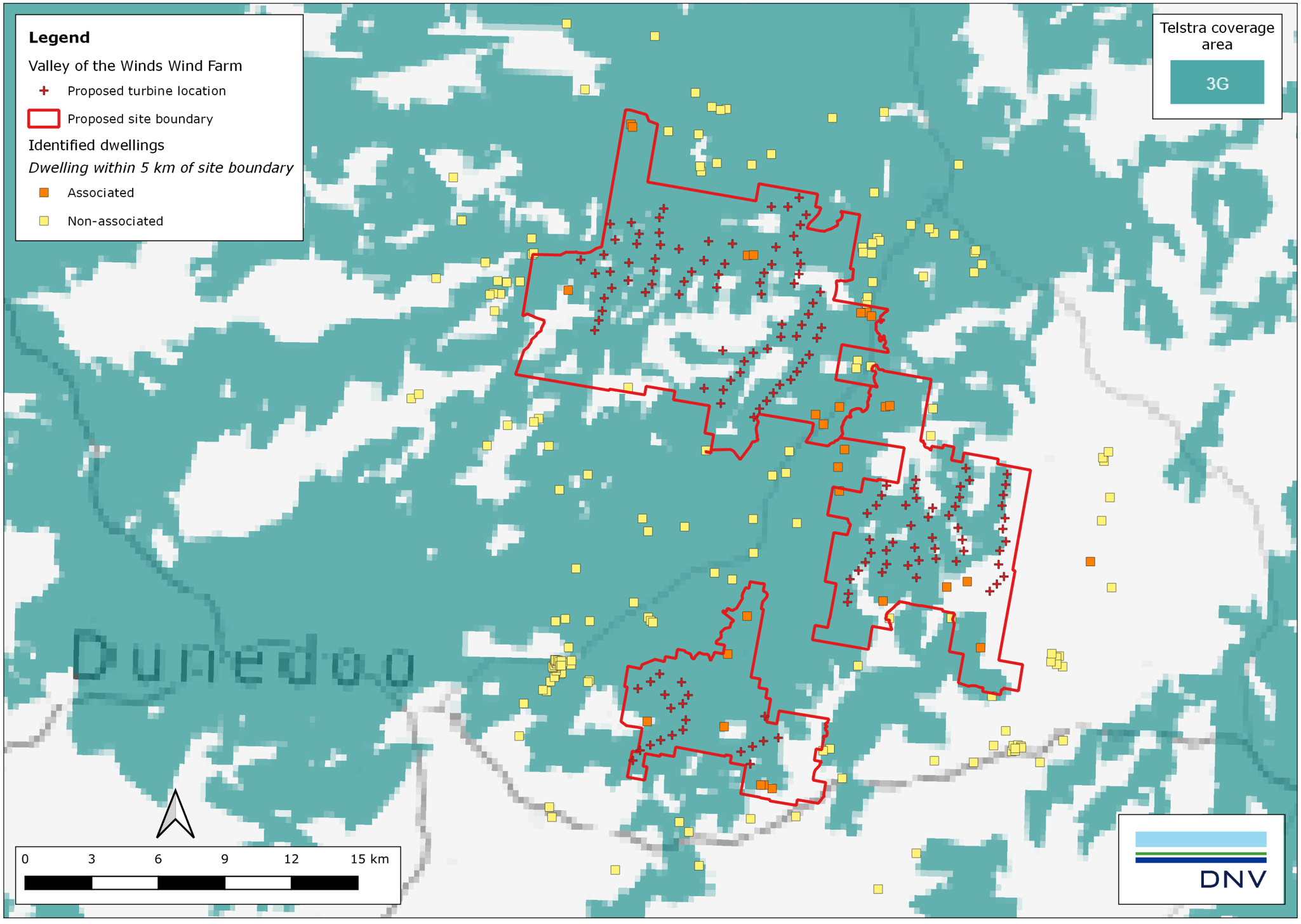

Figure 16 Telstra 3G network coverage for the proposed Project

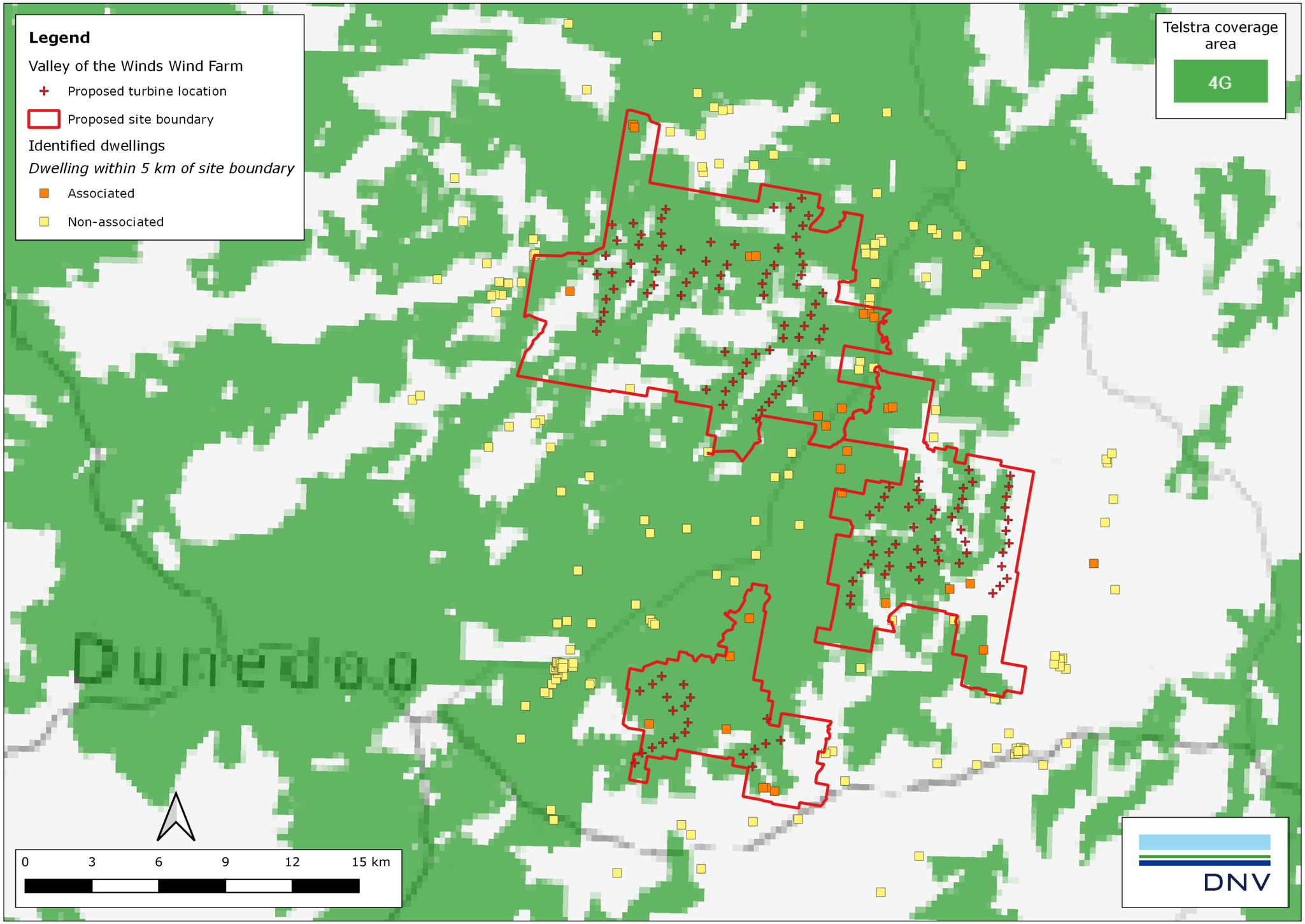

Figure 17 Telstra 4G network coverage for the proposed Project

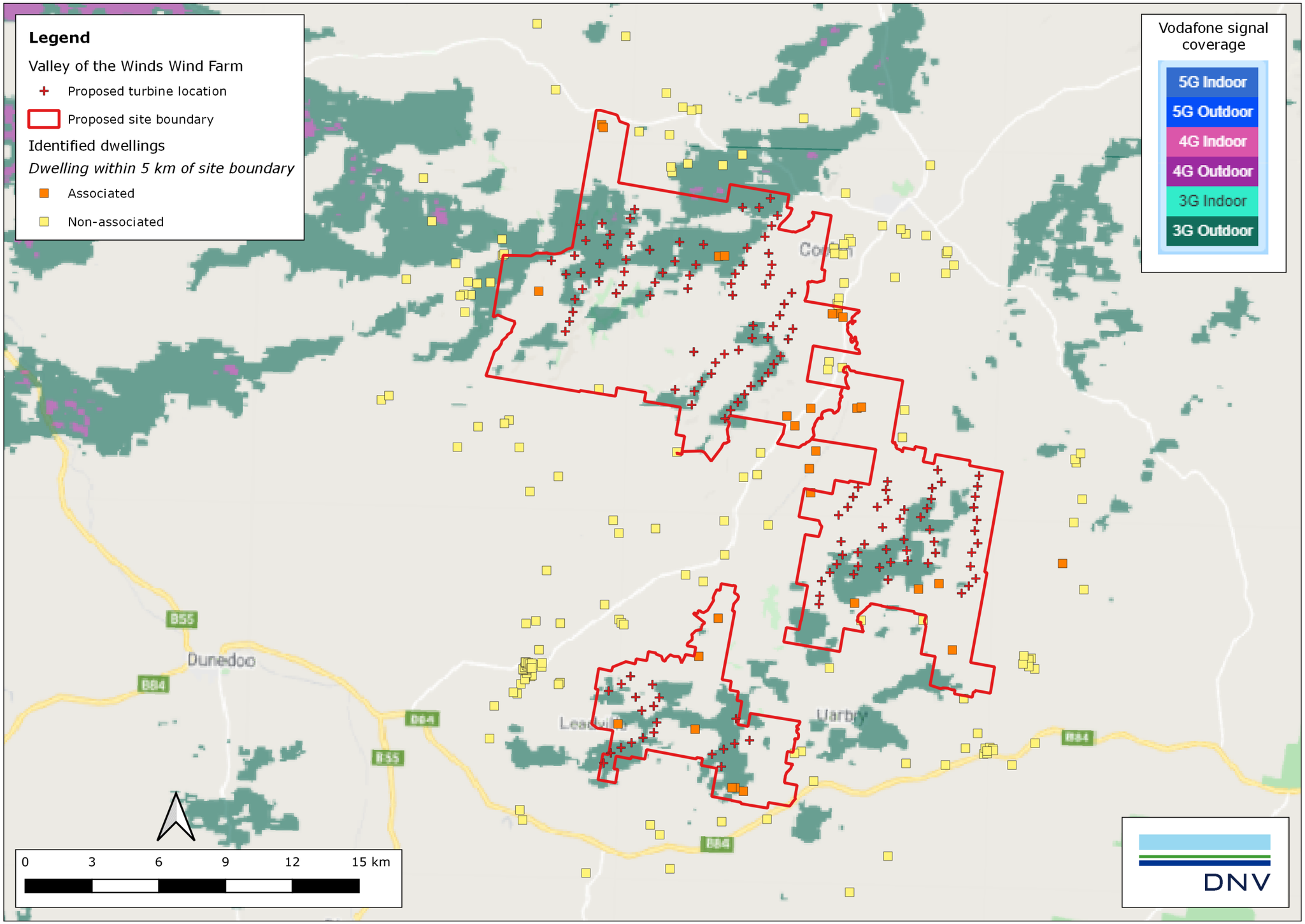

Figure 18 Vodafone network coverage (Apple iPhone X handset) for the proposed Project

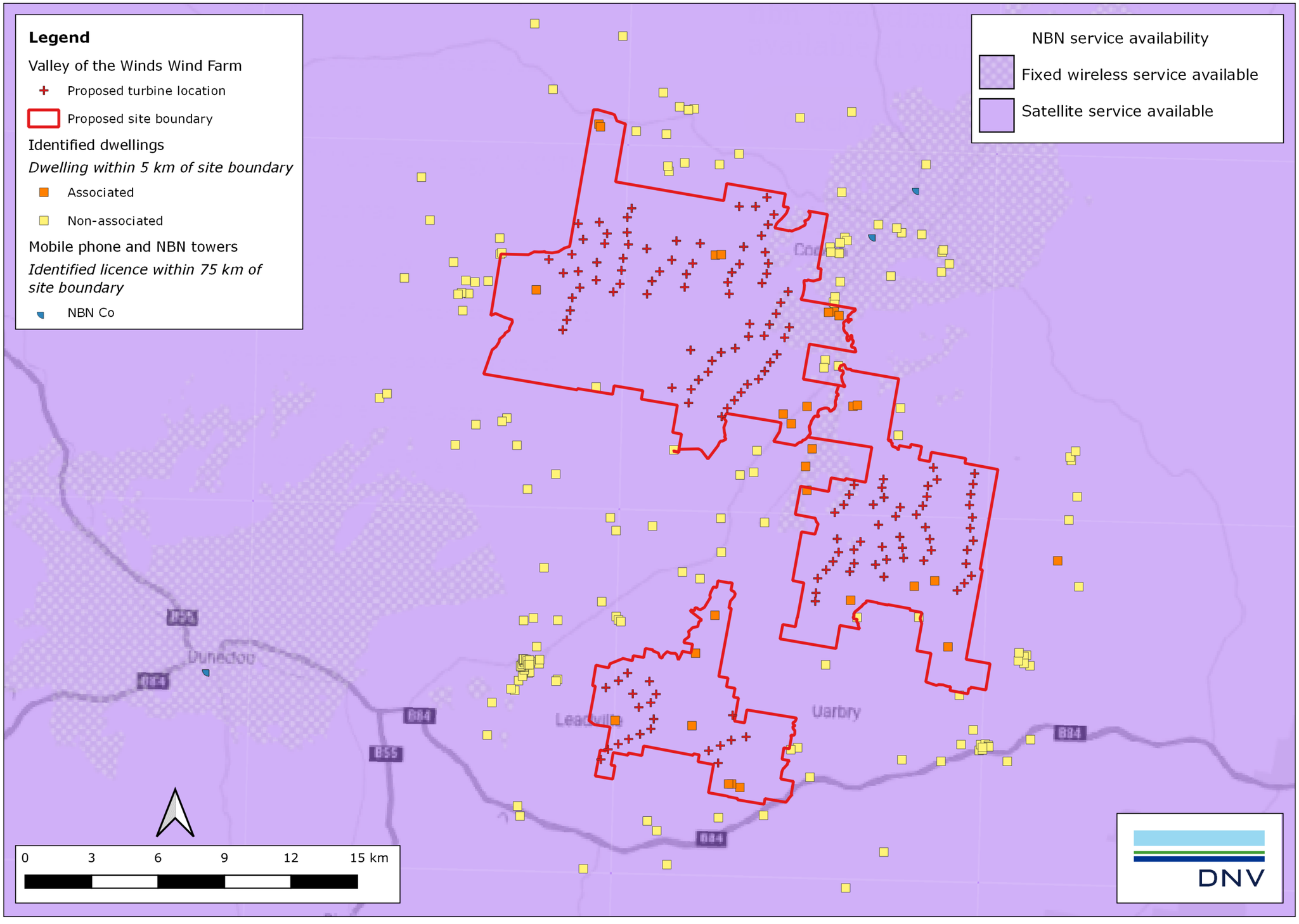

Figure 19 NBN internet coverage in the vicinity of the proposed Project

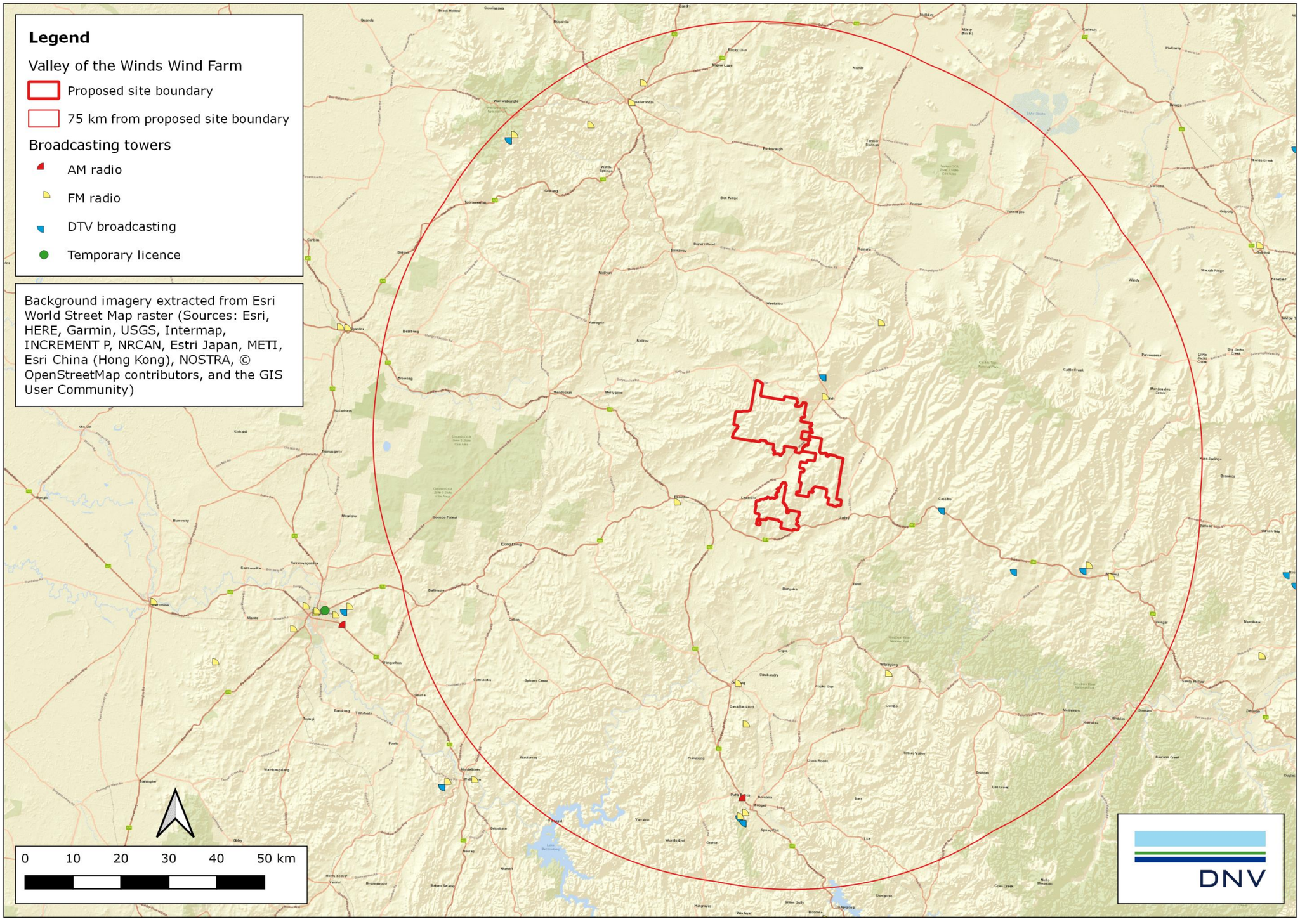

Figure 20 Location of broadcast transmitters in the vicinity of the proposed Project

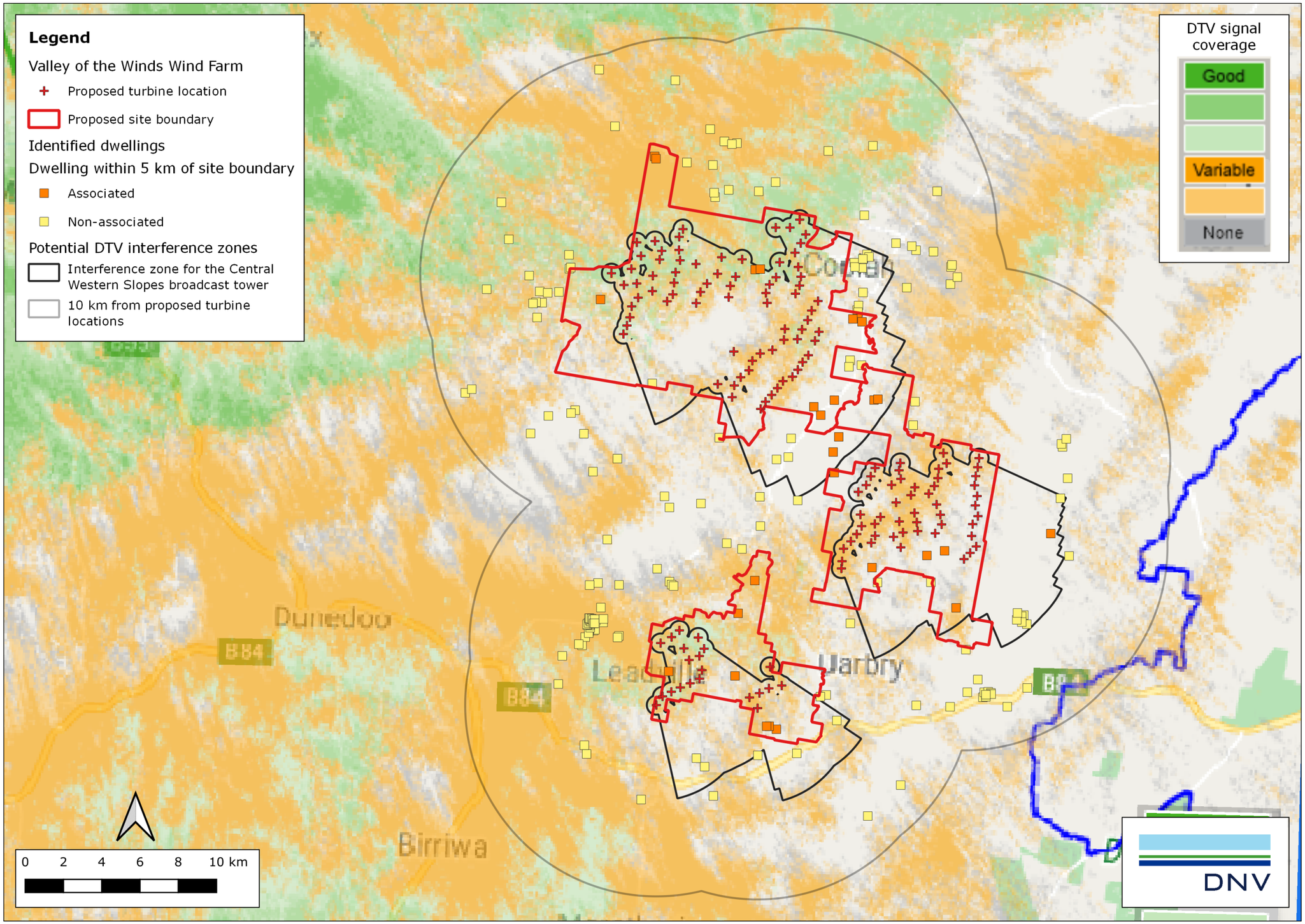

Figure 21 Potential television EMI zones for the Central Western Slopes broadcast tower from the proposed Project

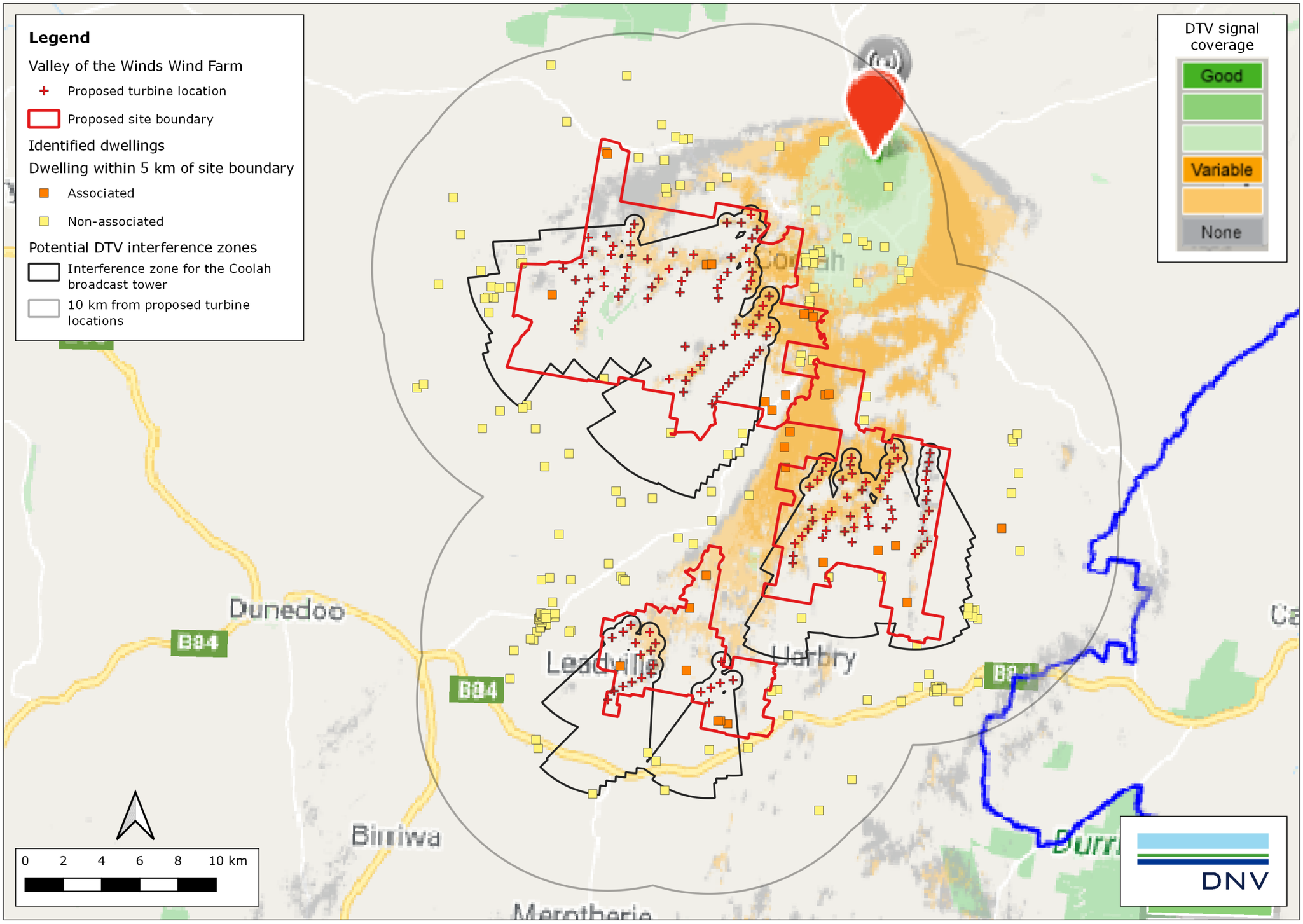

Figure 22 Potential television EMI zones for the Coolah broadcast tower from the proposed Project

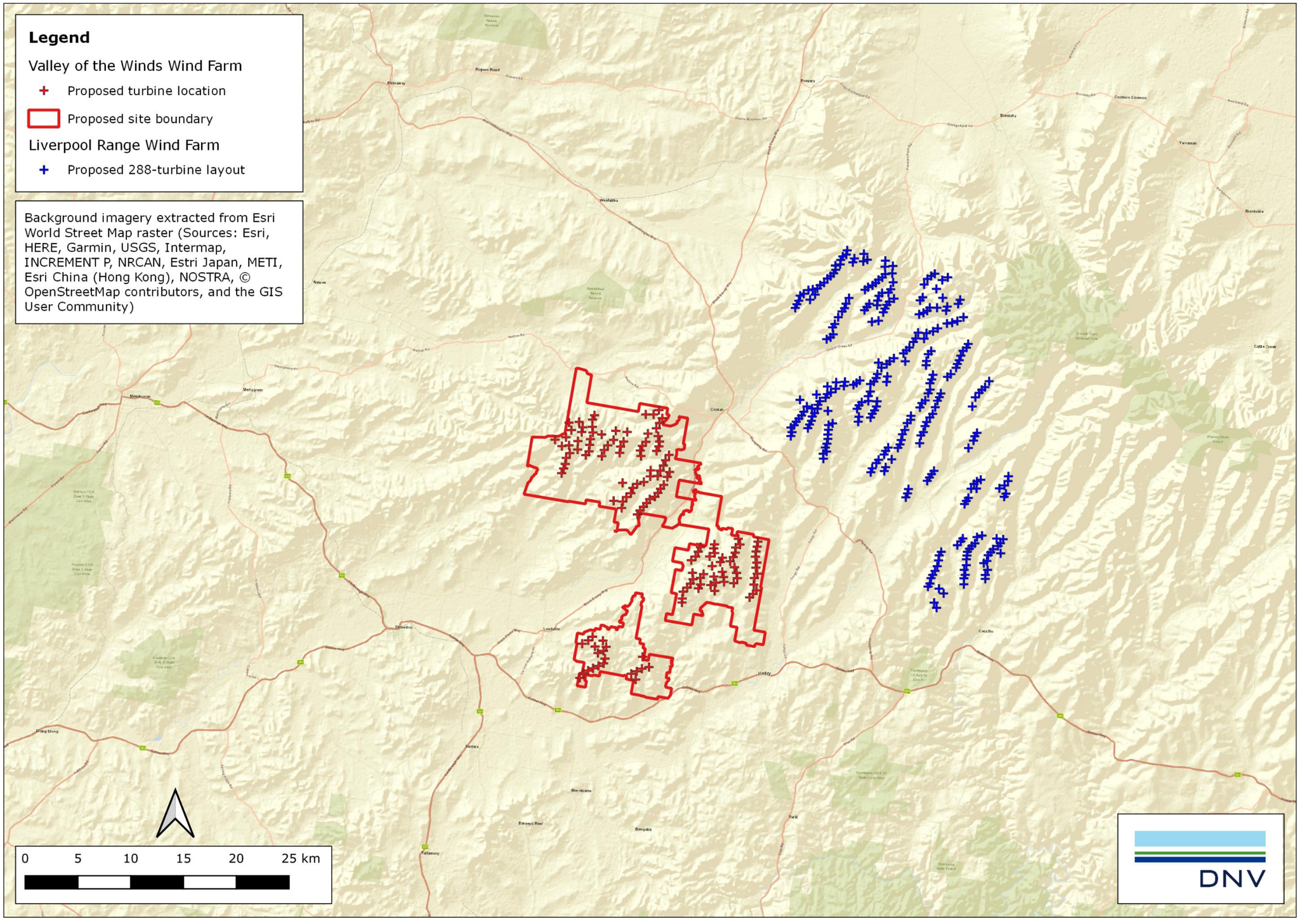

Figure 23 Map of the proposed Project, showing neighbouring wind farm developments

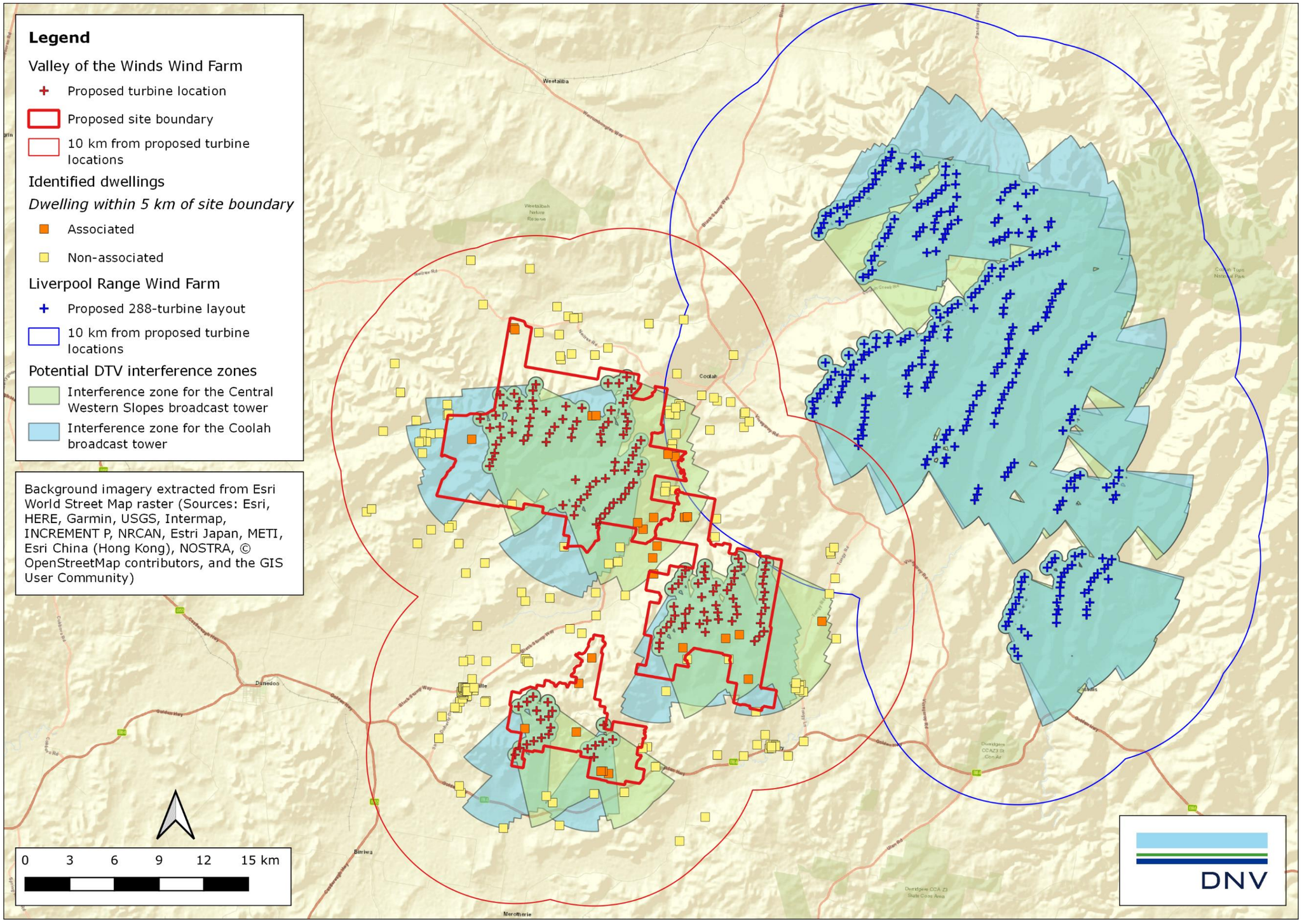

Figure 24 Potential cumulative EMI impacts to television signals from the Central Western Slopes and Coolah broadcast towers

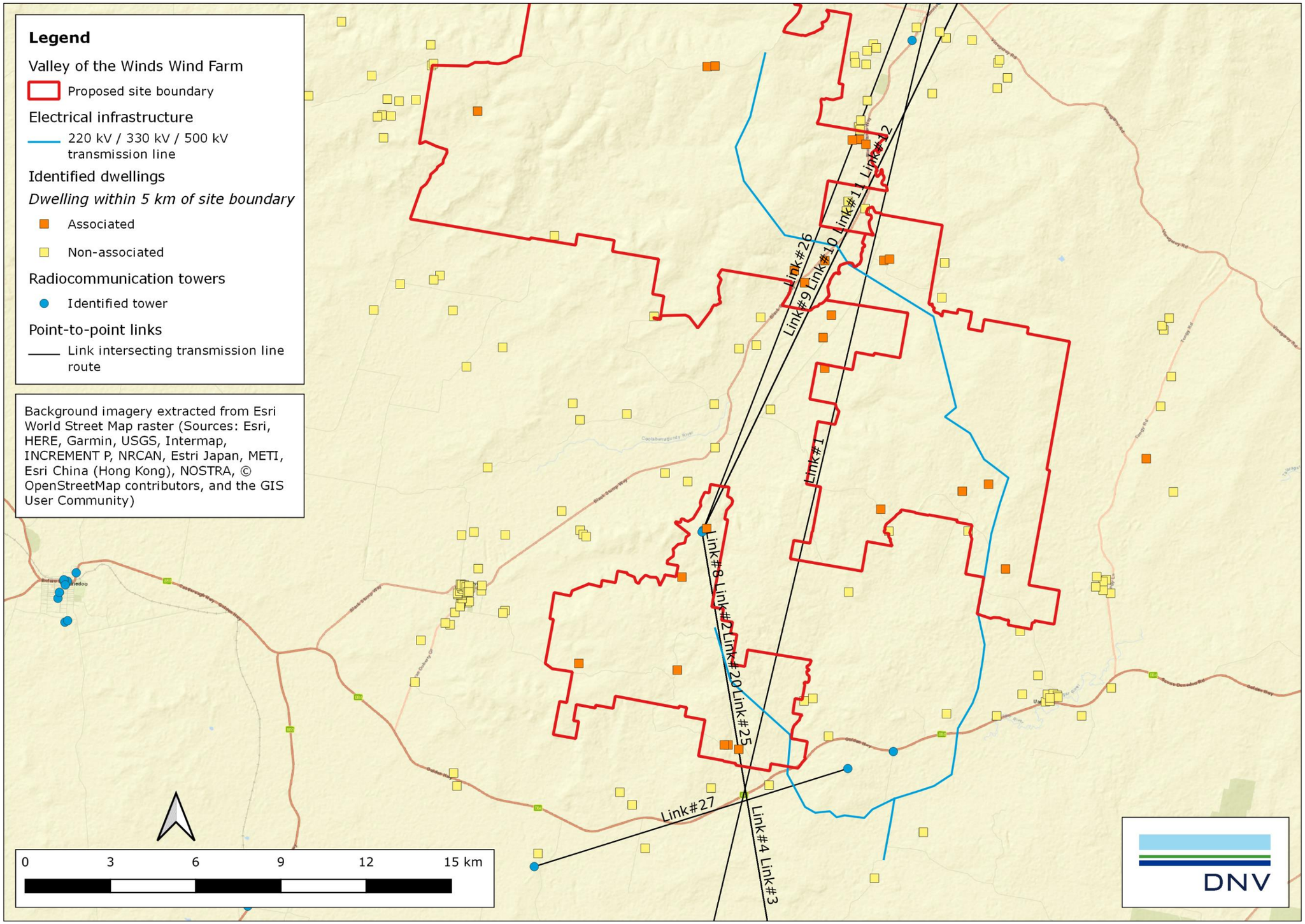

Figure 25 Map of the proposed Project and transmission lines, showing locations of nearby dwellings and identified point-to-point radiocommunication vectors crossing the transmission line routes

About DNV

DNV is the independent expert in risk management and assurance, operating in more than 100 countries. Through its broad experience and deep expertise DNV advances safety and sustainable performance, sets industry benchmarks, and inspires and invents solutions.

Whether assessing a new ship design, optimizing the performance of a wind farm, analysing sensor data from a gas pipeline or certifying a food company's supply chain, DNV enables its customers and their stakeholders to make critical decisions with confidence.

Driven by its purpose, to safeguard life, property, and the environment, DNV helps tackle the challenges and global transformations facing its customers and the world today and is a trusted voice for many of the world's most successful and forward-thinking companies.