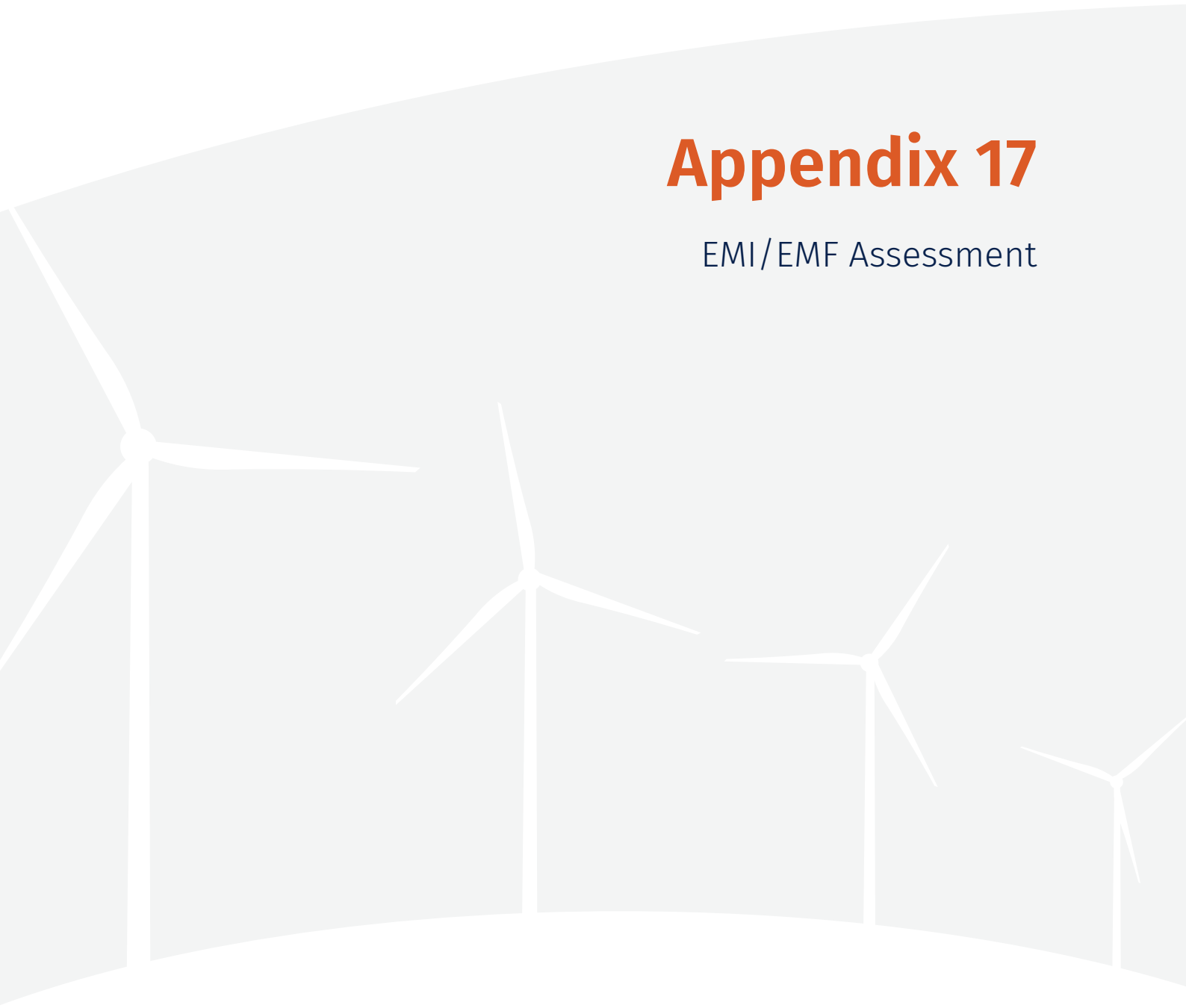
Appendix 17

EMI/EMF Assessment



THUNDERBOLT ENERGY HUB – STAGE 1

EMI and EMF Health Impact Assessment

Umwelt (Australia) Pty Limited

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Objective: Thunderbolt Energy Hub – Stage 1 EMI and EMF Health Impact Assessment

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EXECUTIVE SUMMARY

DNV has been commissioned by Umwelt (Australia) Pty Limited ("Umwelt") on behalf of Neoen Australia Pty Ltd ("Neoen" or "the Proponent") to independently assess potential electromagnetic interference (EMI) impacts and electromagnetic field (EMF) health impacts associated with the development and operation of the Thunderbolt Energy Hub – Stage 1 ("the Project") in the Kentucky Area 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) for the Thunderbolt Energy Hub Wind Farm [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 32 wind turbine generators (WTGs) with a rotor diameter of 190 m and tip height of 260 m has been considered. These dimensions represent the maximum overall tip height and rotor diameter under consideration for the Project, and are expected to correspond to the most significant potential EMI impacts for the WTG options currently being considered for the Project. The results presented here will therefore be conservative for WTG configurations with dimensions satisfying all of the following criteria: a rotor diameter of 190 m or less and an upper tip height of 260 m or less. For WTGs with a smaller rotor diameter, the potential EMI impacts of the Project are expected to be less than those presented here, provided that the overall upper tip height is no more than 260 m.

Fifty-eight dwellings have been identified within 5 km of the Project. Of these dwellings, 6 are host landholder dwellings, 11 are associated landholder dwellings, and 41 are non-associated dwellings.

Outcomes of the assessment

Potential EMI impacts

The results of the EMI assessment are summarised in the table on the following page. EMI-related impacts are generally expected to be minimal for the Project. Where the potential for interference exists, the overall likelihood is typically low and impacts are likely to be manageable through mitigation once the Project is operational.

The proposed WTGs 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 within approximately 5-10 km of the Project Area that are currently receiving weak signals from the Armidale or Upper Namoi television broadcast towers may experience interference to those services. Impacts are more likely for signals from the Upper Namoi tower, as many of the dwellings in the potential interference zone for the Armidale tower may not be using that service due to an existing lack of coverage. However, it is also possible that some dwellings in the potential interference zone for the Upper Namoi tower may be able to receive an alternative signal from the Armidale tower, which could be used to mitigate any interference that may occur. Mobile phone services may be more susceptible to interference in areas that are currently receiving a weak signal

to the north and west of the Project Area. However, previous advice received from mobile phone network operators has generally indicated that they do not expect wind farm developments to interfere with their services.

Impacts to satellite television and internet signals that may be received at dwellings in the vicinity of the Project Area are considered unlikely. The proposed WTGs 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.

Interference to fixed point-to-point links passing over the Project Area, which are used by various organisations for line-of-sight data, voice, and video transmissions, is considered unlikely as there are no WTGs located within the calculated exclusion zones for those links. Nevertheless, DNV has contacted the operators of these links to confirm the required clearances and the finding that impacts to their services is unlikely, and (if the potential for interference exists) to identify suitable options to avoid any disruptions. A response has been received from Optus, who have indicated that they do not expect the Project to cause material impacts to their fixed point-to-point links.

DNV has also contacted or is attempting to contact the operators of point-to-multipoint links, emergency services, wireless internet services, and meteorological radar in the vicinity of the Project Area to identify any potential for the Project to cause interference to these services and suitable options to avoid potential disruptions. Based on the available information, the likelihood of impact to these services is generally expected to be low and measures are expected to be available to mitigate impacts should unexpected impacts occur.

Potential EMI impacts on other services considered in this assessment, including radio broadcasting, trigonometrical stations, and CB radio, are considered to be minor.

DNV notes that the Project is located in an area of high wind farm development activity, with several other proposed wind farms nearby. The potential cumulative impacts of the Project in conjunction with the nearby wind farms have not been considered in detail in this assessment. However, 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 impacts.

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 cabling network and overhead line has shown that the EMF at the range of heights above ground level that humans are most likely to occupy (from 0 m above ground level to 2 m above 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 Project Area, and indistinguishable from background levels at nearby dwellings.

Summary of EMI assessment results for the Project

Licence or service type	Assessment findings	Expected impact	Stakeholder consultation	Mitigation
Radiocommunication towers	No towers within 2 km of proposed WTG locations	None	Consultation not considered necessary	None required
Fixed point-to-point links	21 links over 9 link paths crossing Project Area, operated by: Digital Distribution Australia Pty Limited (Digital Distribution) New South Wales Government Telecommunications Authority (NSW Telco Authority) NSW Electricity Networks Operations Pty Limited (TransGrid) Optus Mobile Pty Limited (Optus) Vodafone Australia Pty Limited (Vodafone) Diffraction effects: no WTGs in exclusion zones established by DNV Reflection/scattering and near-field effects: WTGs are considered sufficiently far from towers to avoid impacts	Unlikely to cause interference	DNV has contacted the relevant operators to confirm required clearances and that impacts are unlikely, and to identify suitable options to avoid any potential disruptions No concerns raised by Optus No other responses have been received to date	Mitigation is unlikely to be required; if there are material impacts, the Proponent will apply appropriate mitigation in consultation with the relevant operator
Fixed point-to-multipoint links	64 assignments within 75 km of Project Area No base stations within 20 km of Project Area	Potential for interference if link paths cross the Project Area near WTGs, but considered unlikely given distances and likely nature of services	DNV has contacted or is attempting to contact the relevant operators to identify the link paths, confirm the likelihood of impacts, and identify suitable options to avoid any potential disruptions No responses have been received to date	Mitigation is unlikely to be required; if there are material impacts, the Proponent will apply appropriate mitigation in consultation with the relevant operator
Other licence types	Point-to-area style communications: see findings for emergency services, mobile phones, radio broadcasting, and television broadcasting	-	-	

Summary of EMI assessment results for the Project (continued)

Licence or service type	Assessment findings	Expected impact	Stakeholder consultation	Mitigation
Emergency services	Point-to-point links: 3 NSW Telco Authority links crossing Project Area, unlikely to be affected (see "Fixed point-to-point links") Mobile radio systems: unlikely to be affected	Unlikely to cause interference	DNV has contacted or is attempting to contact the relevant operators to confirm that impacts are unlikely and identify suitable options to avoid any potential disruptions No responses have been received to date	Mitigation is unlikely to be required; if there are material impacts, the Proponent will apply appropriate mitigation in consultation with the relevant operator
Meteorological radar	Nearest radar: "Namoi", 105 km from Project Area	Potential for interference if proposed WTGs can be detected by radars	DNV has contacted the Bureau of Meteorology to evaluate likelihood of WTGs being detected by radars and identify suitable options to avoid any potential disruptions No response has been received to date	To be determined through consultation with the Bureau of Meteorology
Trigonometrical stations	Trigonometrical stations: unlikely to be affected	Unlikely to cause interference	DNV has contacted the relevant operators to confirm that impacts are unlikely and identify suitable options to avoid any potential disruptions No responses have been received to date	None required
Citizen's band radio	Unlikely to be affected	Unlikely to cause interference	Consultation not considered necessary	None required
Mobile phones	Unlikely to be affected in areas with good coverage, may experience interference in areas with marginal coverage	Low likelihood of interference	DNV has contacted the relevant operators to confirm that impacts are unlikely and identify suitable options to avoid potential disruptions No responses have been received to date	Mitigation is unlikely to be required; if there are material impacts, the Proponent will apply appropriate mitigation in consultation with the relevant operator once the Project is operational

Summary of EMI assessment results for the Project (continued)

Licence or service type	Assessment findings	Expected impact	Stakeholder consultation	Mitigation
Wireless internet	Likely service providers: Pivotel Mobile, TPG Internet, mobile phone networks, NBN Co NBN: available as a satellite service only	No impact expected for NBN services Low likelihood of interference to other services	DNV has contacted or is attempting to contact the relevant operators to confirm that impacts are unlikely and identify suitable options to avoid any potential disruptions No concerns raised by NBN Co No other responses have been received to date	Mobile broadband services: Mitigation is unlikely to be required; if there are material impacts, the Proponent will apply appropriate mitigation in consultation with the relevant operator once the Project is operational NBN: None required
Satellite television and internet	Services intended for Australian audiences: unlikely to be affected Services intended for international audiences: signals from 12 satellites intercepted at 12 dwellings (2 host landowner dwellings, 10 non-associated dwellings)	No impact expected for Australian services Low likelihood of interference to services intended for international audiences, as services are unlikely to be used by nearby residents	Consultation with operators not considered necessary Consultation with residents of identified dwellings to be undertaken prior to construction to determine whether potentially affected services are being used (and may therefore be subject to interference)	Mitigation is unlikely to be required; if there are material impacts, the Proponent will apply appropriate mitigation in consultation with the relevant landowner once the Project is operational
Radio broadcasting	AM and FM signals: may experience interference in close proximity to WTGs (within several tens of metres) Digital radio signals: Project Area is outside the intended service area	Low likelihood of interference to AM and FM signals, as receivers are unlikely to be located sufficiently close to WTGs	Consultation not considered necessary	AM and FM signals: Mitigation is unlikely to be required; if there are material impacts, the Proponent will apply appropriate mitigation in consultation with the relevant landowner once the Project is operational Digital radio signals: None required

Summary of EMI assessment results for the Project (continued)

Licence or service type	Assessment findings	Expected impact	Stakeholder consultation	Mitigation
	May experience interference in areas with poor or marginal reception			
Television broadcasting	*Armidale tower: 'poor' to 'variable' coverage across Project Area and in south and west, 'variable' to 'good' coverage in north and east* 11 dwellings (1 host landowner dwelling, 8 associated dwellings, 2 non-associated dwellings) in potential interference zone	Low likelihood of interference at identified dwellings, as dwellings may not currently be receiving signals	DNV has contacted BAI Communications to confirm likely impacts and identify suitable options to avoid any potential impacts No response has been received to date	The Proponent will undertake pre-construction measurements of signal strength at selected dwellings within 3 km of the Project Area to enable any interference after construction to be investigated
	Upper Namoi tower: 'variable' coverage across Project Area and surrounding area 17 dwellings (5 host landowner dwellings, 12 non-associated dwellings) in potential interference zone	Likely to cause interference at some identified dwellings, as dwellings may currently be receiving a weak signal	DNV has contacted BAI Communications to confirm likely impacts and identify suitable options to avoid any potential impacts No response has been received to date	If there are material impacts, the Proponent will apply appropriate mitigation in consultation with the relevant operator or landowner once the Project is operational

1 INTRODUCTION

Umwelt (Australia) Pty Limited ("Umwelt") on behalf of Neoen Australia Pty Ltd ("Neoen" or "the Proponent") has commissioned DNV to independently assess the potential electromagnetic interference (EMI) related impacts associated with the proposed Thunderbolt Energy Hub – Stage 1 ("the Project") in the Kentucky Area of New South Wales (NSW). The results of this work are reported here.

In accordance with the Secretary's Environmental Assessment Requirements (SEARs) for the Project [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], this assessment investigates the potential 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 DESCRIPTION OF THE PROJECT AREA AND PROJECT

2.1 The Project and Project Area

The proposed Thunderbolt Energy Hub is located in the Kentucky Area of NSW, approximately 47 km northeast of Tamworth and adjacent to the New England Highway. The Thunderbolt Energy Hub consists of two stages and includes wind and solar electricity generation. The Thunderbolt Energy Hub – Stage 1 ("the Project") consists of a wind farm and is the subject of this assessment. The Project Area is approximately 5,918 hectares (ha) and is located to the north of the New England Highway. The Thunderbolt Energy Hub – Stage 2 is proposed to consist of a wind farm and solar farm to the south of the New England Highway and will be subject to separate development approval processes.

The Project will include approximately 32 wind turbine generators (WTGs) with a maximum tip height of approximately 260 m and a capacity of approximately 192 megawatts (MW). The Project also includes the construction and operation of associated infrastructure including operation and maintenance buildings, roads, civil works and electrical infrastructure (including one new substation and switching station) required to connect to the existing electricity transmission network.

Each WTG will have a generating capacity of approximately 5-8 MW and each WTG site will consist of a foundation and tower, nacelle, rotor hub and blades. To achieve visual consistency through the landscape, the WTGs will feature uniform colour, design, height and rotor diameter, a matt-white finish and non-reflective material to reduce visibility, and no unnecessary signage or lighting.

2.2 Project details used in this assessment

2.2.1 Proposed conceptual layout

A conceptual layout including 32 WTGs was provided by the Proponent. A map of the Project Area with the proposed WTG layout is shown in Figure 9, and the coordinates of the proposed WTG locations are presented in Table 1.

Table 1 Proposed WTG layout for the Project

WTG ID	Easting[1] [m]	Northing[1] [m]	Elevation [m]	WTG ID	Easting[1] [m]	Northing[1] [m]	Elevation [m]
T1	335661	6594107	937	T17	336574	6597065	998
T2	341225	6597378	1084	T18	336850	6595039	1039
T3	340719	6596988	1103	T19	337401	6595420	1055
T4	340162	6596552	1082	T20	335739	6595504	984
T5	339556	6596100	1041	T21	335940	6594542	963
T6	338931	6595599	1035	T22	337676	6598098	1010
T7	338473	6595240	1022	T23	336942	6599833	1077
T8	338834	6594805	1006	T24	335883	6599958	1090
T9	338365	6594397	992	T25	335768	6600449	1055
T10	337854	6593964	973	T26	333549	6597099	967
T11	337532	6593412	993	T27	333137	6597539	954
T12	340014	6597494	1074	T28	333131	6598418	1005
T13	339635	6597942	1064	T29	338740	6597656	1036
T14	337718	6595842	1023	T30	339527	6597038	1057
T15	337867	6597269	994	T31	338989	6596546	1017
T16	336629	6596361	980	T32	335555	6596610	952

1. Coordinate system: MGA zone 56, GDA94 datum.

2.2.2 Dwelling locations

The locations of dwellings in the vicinity of the Project Area have been provided by the Proponent. For the purposes of this assessment, DNV has considered all identified dwellings within 5 km of the Project Area. There are 58 dwellings located within 5 km of the Project Area, of which 6 are host landholder dwellings, 11 are associated landholder dwellings, and 41 are non-associated dwellings. The coordinates of these dwellings are presented in Table 2, and the dwellings and Project Area considered in this assessment are shown in Figure 9.

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 except where indicated otherwise by the Proponent as noted in Table 2.

Table 2 Dwellings in the vicinity of the Project Area

Dwelling ID	Easting[1] [m]	Northing[1] [m]	Status[2]	Distance to nearest WTG [km]
3	345978	6596744	Non-Associated Landholder	4.8
4	*343635*	*6596914*	*Host Landholder*	*2.5*
5	344710	6595921	Non-Associated Landholder	3.8
6	344299	6595615	Non-Associated Landholder	3.5
7	347994	6594786	Non-Associated Landholder	7.2
8	347347	6593760	Non-Associated Landholder	7.1
9	346955	6592728	Non-Associated Landholder	7.4
10	340629	6592135	Non-Associated Landholder	3.2
12	339274	6590819	Non-Associated Landholder	3.1
15	339916	6588381	Non-Associated Landholder	5.6
17	*334195*	*6599732*	*Host Landholder*	*1.7*
18	339149	6600709	Non-Associated Landholder	2.4

Table 2 Dwellings in the vicinity of the Project Area (continued)

Dwelling ID	Easting[1] [m]	Northing[1] [m]	Status[2]	Distance to nearest WTG [km]
19	339010	6590368	Non-Associated Landholder	3.4
20	342417	6592461	Non-Associated Landholder	4.3
26	341941	6593172	Non-Associated Landholder	3.5
27	341318	6593565	Non-Associated Landholder	2.8
28	341090	6593361	Non-Associated Landholder	2.7
29	339724	6592770	Non-Associated Landholder	2.1
41	342111	6594228	Non-Associated Landholder	3.0
42	330861	6590610	Non-Associated Landholder	5.9
55	332742	6600385	Non-Associated Landholder	2.0
64	339373	6588304	Non-Associated Landholder	5.4
93	348653	6593325	Non-Associated Landholder	8.5
177	333328	6589464	Non-Associated Landholder	5.2
214	349414	6599099	Non-Associated Landholder	8.4
215	349291	6598605	Non-Associated Landholder	8.2
216	347923	6597066	Non-Associated Landholder	6.7
217	346955	6597433	Non-Associated Landholder	5.7
218[3]	348169	6595592	Non-Associated Landholder	7.2
219	341469	6599624	Non-Associated Landholder	2.3
220	341858	6600032	Non-Associated Landholder	2.7
221	338474	6602191	Non-Associated Landholder	2.8
222	342872	6599122	Non-Associated Landholder	2.4
223	343614	6600525	Non-Associated Landholder	4.0
224	343624	6600743	Non-Associated Landholder	4.1
225	343664	6601724	Non-Associated Landholder	5.0
226	335911	6602846	Non-Associated Landholder	2.4
227	332822	6603678	Non-Associated Landholder	4.4
229	330378	6602290	Non-Associated Landholder	4.8
230	*330667*	*6590549*	*Associated Landholder*	*6.1*
260	333842	6591136	Non-Associated Landholder	3.5
270	*334904*	*6598857*	*Associated Landholder*	*1.5*
275	*332282*	*6594903*	*Associated Landholder*	*2.5*
277	*332736*	*6595809*	*Associated Landholder*	*1.5*
278[4]	*333672*	*6591649*	*Associated Landholder*	*3.2*
279	*332359*	*6594847*	*Associated Landholder*	*2.5*
286	*330187*	*6601650*	*Associated Landholder*	*4.4*
287	330971	6589986	Non-Associated Landholder	6.2
298	*343989*	*6596780*	*Host Landholder*	*2.8*
299	*344220*	*6596330*	*Host Landholder*	*3.2*
300[3]	*340929*	*6594484*	*Host Landholder*	*2.1*
302[3]	*338378*	*6595428*	*Host Landholder*	*0.2*
305	*330163*	*6601956*	*Associated Landholder*	*4.6*
306	*332872*	*6594144*	*Associated Landholder*	*2.8*
307	*331563*	*6593389*	*Associated Landholder*	*4.2*
308	339242	6599999	Non-Associated Landholder	2.1
309	339123	6600480	Non-Associated Landholder	2.3
310[3]	*333797*	*6595810*	*Associated Landholder*	*1.3*

1. Coordinate system: MGA zone 56, GDA94 datum.
2. Host landholder and associated landowner dwellings are indicated by *underlined italic text*.
3. Vacant dwelling.
4. Derelict dwelling.

3 REGULATORY REQUIREMENTS

3.1 EMI impacts

The SEARs for the Project [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.

3.2 EMF health impacts

The SEARs for the Thunderbolt Energy Hub Wind Farm [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 WTGs 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].

4 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 32 WTGs, as outlined in Table 1.

For the purpose of the EMI assessment, a hypothetical WTG with a rotor diameter of 190 m and a tip height of 260 m has been considered. These dimensions represent the maximum tip height and rotor diameter under consideration for the Project, and are expected to correspond to the most significant potential EMI impacts for the WTG options currently being considered for the Project. The results generated based on this WTG configuration will therefore be conservative for all WTG configurations with dimensions that remain inside the WTG envelope by satisfying all of the following criteria:

- a rotor diameter of 190 m or less
- an upper tip height of 260 m or less.

For WTGs with a smaller rotor diameter than 190 m and increased hub height, the potential EMI-related impacts of the Project are expected to be less than those presented here, provided that the overall upper tip height is no more than 260 m.

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 Project Area, and then assess the radiocommunication licences attached to these towers.

Since the signal frequencies used for fixed radiocommunication links (which are typically in the order of 30 MHz to 30 GHz) may travel up to several hundred kilometres, the use of a larger search area reduces the likelihood that radiocommunication links crossing the Project Area are inadvertently excluded from the assessment. Although lower frequency signals can travel even greater distances, these services are generally designed to operate in the presence of physical obstructions and are not expected to be susceptible to interference from WTGs. Based on DNV's experience, a 75 km search radius is considered sufficient to capture any radiocommunication links and services passing over the Project Area that have the potential to experience interference as a result of the Project.

To conduct the EMI assessment, information regarding radiocommunications licences in the vicinity of the Project Area was obtained from a downloaded copy of the Australian Communication and Media Authority (ACMA) Register of Radiocommunications Licences (RRL) database dated 31 August 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 WTG 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. The distances between the proposed WTGs and each relevant service type are discussed in the following sections. DNV has consulted more broadly with any organisation 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 operators that have been contacted and all responses received to date are summarised in Appendix A.

The radiocommunication licences and services with potential to experience EMI-related impacts from the Project are considered in the following sections. 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 Area and the expected potential for interference. Details of any feedback obtained from the service operators and potential mitigation options are also included where appropriate.

DNV notes that the Project Area is located in an area of high wind farm development activity, with several other proposed wind farms nearby. These developments include the adjacent Thunderbolt Energy Hub – Stage 2 wind farm and the proposed Tara Springs and Bendemeer Wind Farms. Limited detail is available about the Tara Springs and Bendemeer Wind Farms as these proposed developments have not yet entered into the formal NSW approval process (no Scoping Report has been submitted). The details of the Thunderbolt Energy Hub – Stage 2 are also subject to confirmation. DNV understands that the EMI impact assessment for the Thunderbolt Energy Hub – Stage 2 will include an assessment of the potential cumulative impacts in conjunction with Stage 1.

The closest wind farm development currently engaged in the NSW approval process is the Winterbourne Wind Farm, located approximately 30 km southeast of the Project Area, at which distance cumulative EMI impacts on point-to-area style radiocommunications (such as mobile phone signals, radio broadcasting, and terrestrial television broadcasting) are unlikely to be significant. However, there may be potential for cumulative impacts to fixed point-to-point or fixed point-to-multipoint radiocommunication links (discussed in Sections 4.2 and 4.3) if those links pass over both the Winterbourne Wind Farm site and the Project Area.

While the potential cumulative EMI-related impacts of the Project in conjunction with the nearby wind farms have not been considered in detail in this assessment, cumulative impacts are generally not expected for services where impact from the Project itself is considered either unlikely or non-existent.

4.1 Radiocommunication towers

WTGs 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 WTG location be considered as a having the potential to be impacted by near-field effects. The potential for a WTG 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 WTG. 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 WTG is to be located within 2 km of a radiocommunication site.

4.1.1 Locations of radiocommunication towers and potential for interference

From the ACMA RRL database, there are 428 radiocommunication towers within a nominal 75 km of the Project Area. The locations of these radiocommunication towers relative to the Project are shown in Figure 10.

There are no radiocommunication towers located within 2 km of the proposed WTG locations. The nearest tower is located within the Project Area approximately 2.8 km southeast of the nearest proposed WTG location (WTG T2). Therefore, it is not expected that the proposed WTGs will cause interference to the signals from this tower through reflection or scattering of signals or near-field effects.

4.2 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.

WTGs 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.

4.2.1 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 11. 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 21 point-to-point links over nine link paths recorded in the ACMA RRL database that pass over the proposed Project Area, operated by Digital Distribution Australia Pty Limited (Digital Distribution), New South Wales Government Telecommunications Authority (NSW Telco Authority), NSW Electricity Networks Operations Pty Limited (TransGrid), Optus Mobile Pty Limited (Optus), and Vodafone Australia Pty Limited (Vodafone). The details of the links are provided in Table 3, and the link paths are shown in greater detail in Figure 12.

The potential interference mechanisms and interference zones established by DNV for these links are described in Sections 4.2.1.1, 4.2.1.2, and 4.2.1.3.

Table 3 Details of point-to-point links crossing the Project Area

Link no.	Licence number	Assignment ID	Frequency [Hz]	Licence owner
1	10424423/1	3614995	3810000000	Digital Distribution Australia Pty Limited PO Box 1966 Macquarie Centre NORTH RYDE NSW 2113
		3614996	3810000000	
		3614993	4130000000	
		3614994	4130000000	
2	10424424/1	3614999	3850000000	
		3615000	3850000000	
		3614997	4170000000	
		3614998	4170000000	
3	1511462/1	826701	3730000000	
		826702	3730000000	
		826699	4050000000	
		826700	4050000000	
4	1511463/1	826709	3770000000	
		826710	3770000000	
		826707	4090000000	
		826708	4090000000	
5	1511465/1	826717	3810000000	
		826718	3810000000	
		826715	4130000000	
		826716	4130000000	
6	1511468/1	826725	3850000000	
		826726	3850000000	
		826723	4170000000	
		826724	4170000000	
7	10434008/1	3670235	7449000000	New South Wales Government Telecommunications Authority Telco Authority (FRNSW) Level 18, McKell Building 2-24 Rawson Place SYDNEY NSW 2000
		3670236	7449000000	
		3670233	7610000000	
		3670234	7610000000	
8	10956327/1	6800072	7435000000	
		6800073	7435000000	
		6800070	7596000000	
		6800071	7596000000	
9	10971587/1	6886739	804012500	
		6886740	804012500	
		6886737	849012500	
		6886738	849012500	
10	21613/2	1367937	42710000	NSW Electricity Networks Operations Pty Limited 180 Thomas Street HAYMARKET NSW 2000
		1367938	42710000	
		1367936	44710000	
		1367939	44710000	

Table 3 Details of point-to-point links crossing the Project Area (continued)

Link no.	Licence number	Assignment ID	Frequency [Hz]	Licence owner
11	11164085/1	7462295	7807000000	Optus Mobile Pty Limited 4G TXN 1 Lyonpark Road MACQUARIE PARK NSW 2113
		7462296	7807000000	
		7462293	8118320000	
		7462294	8118320000	
12	1804717/1	857625	7792175000	
		857626	7792175000	
		857623	8103495000	
		857624	8103495000	
13	10207275/1	2465207	10815000000	Vodafone Australia Pty Limited PO BOX 1113 Att: Ahmed Dawood NORTH SYDNEY NSW 2060
		2465208	10815000000	
		2465205	11305000000	
		2465206	11305000000	
14	10276705/1	2830199	5974850000	
		2830200	5974850000	
		2830197	6226890000	
		2830198	6226890000	
15	10276706/1	2830203	5945200000	
		2830204	5945200000	
		2830201	6197240000	
		2830202	6197240000	
16	11227715/1	7818336	5960025000	
		7818337	5960025000	
		7818334	6212065000	
		7818335	6212065000	
17	11227716/1	7818340	5960025000	
		7818341	5960025000	
		7818338	6212065000	
		7818339	6212065000	
18	11227717/1	7818344	5960025000	
		7818345	5960025000	
		7818342	6212065000	
		7818343	6212065000	
19	11227718/1	7818348	6078625000	
		7818349	6078625000	
		7818346	6330665000	
		7818347	6330665000	
20	1948116/1	928585	6004500000	
		928586	6004500000	
		928583	6256540000	
		928584	6256540000	
21	1956035/1	942130	6034150000	
		942131	6034150000	
		942128	6286190000	
		942129	6286190000	

4.2.1.1 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, WTGs, 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 Project Area, DNV has established a diffraction exclusion zone based on the second Fresnel zone for that link as recommended in [9], which is the more conservative of the approaches commonly adopted in the literature. However, DNV notes that the operators of point-to-point links may impose different exclusion zones depending on the purpose of the link and the nature of the signals and equipment used. Consultation with the operators identified in Table 3 is currently being undertaken to confirm the required clearances, as summarised in Section 4.2.2.

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, which will give the largest radius of the second Fresnel zone for that link.

The potential diffraction exclusion zones in the horizontal plane are shown in Figure 12. Each exclusion zone includes the rotor radius for WTGs with a 190 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.

There are no WTGs located within the exclusion zones for any of the point-to-point links passing over the proposed Project Area. The nearest proposed WTG to any point-to-point link (WTG T25) is located 60 m outside the calculated diffraction exclusion zone, and all other WTGs are located more than 300 m from the point-to-point link exclusion zones. Therefore, it is not expected that the Project will cause interference to the point-to-point links through diffraction of the signals.

4.2.1.2 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 WTG will reflect or scatter electromagnetic waves is characterised by its radar cross section (RCS) [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 WTG at a specified location. By evaluating the C/I ratio for incremental changes in the distances between the transmitter, receiver, and WTG, and comparing this to the required C/I ratio, a potential interference zone can be defined.

DNV considers that the transmission towers for all the point-to-point links crossing the Project Area are sufficiently far from the proposed WTG locations to avoid reflection or scattering effects. Therefore, it is not expected that the Project will cause interference to the point-to-point links through reflection or scattering of the signals.

4.2.1.3 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 of all of the point-to-point links crossing the Project Area are sufficiently far from the proposed WTG 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.

4.2.2 Stakeholder consultation

DNV has contacted the operators of the point-to-point links crossing the Project Area, as identified in Table 3, to confirm the required clearances and the finding that the Project is unlikely to cause interference to their operations and services and, if the potential for interference exists, to identify suitable options to avoid disruptions to those services. The consultation status for each operator is summarised in Appendix A.

The response received from Optus indicates that they do not expect the Project to cause material impacts to their point-to-point links. No other responses have been received to date.

4.2.3 Mitigation

In the unlikely event that interference to point-to-point links is experienced as a result of the Project, DNV understands that the Proponent has committed to developing appropriate mitigation in consultation with the relevant service operators. If impacts are material and mitigation is required, it is expected that a range of options will be available to rectify any interference.

4.3 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.

4.3.1 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 Project Area. These licences are shown in Figure 13. The details of the licence holders as given in the ACMA database are provided in Table 4.

WTGs can cause interference to point-to-multipoint links through the same mechanisms as described for point-to-point links in Section 4.2.1. 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 currently being undertaken to determine whether there is any potential for interference, as summarised in Section 4.3.2.

Table 4 Details of point-to-multipoint licences within 75 km of the Project Area

Assignment ID	Site ID	Licence no.	Latitude [GDA94]	Longitude [GDA94]	Distance to Project Area [km]	Licence owner
808769	404075	1428027/1	-30.5443	151.6483	33	Armidale Regional Council[1] PO Box 75a ARMIDALE NSW 2350
808772	404075	1428027/1	-30.5443	151.6483	33	
4265909	250615	10535071/1	-30.5441	151.6517	34	
4265906	250615	10535071/1	-30.5441	151.6517	34	
780219	6632	1233502/1	-30.5149	151.6654	37	
780222	6632	1233502/1	-30.5149	151.6654	37	
1474432	6681	9968818/1	-30.3773	151.6011	45	
1474429	6681	9968818/1	-30.3773	151.6011	45	
808764	6647	1428026/1	-30.2904	151.7431	60	
808761	6647	1428026/1	-30.2904	151.7431	60	
6580303	6647	10924208/1	-30.2904	151.7431	60	
6580306	6647	10924208/1	-30.2904	151.7431	60	
4265902	250454	10535070/1	-30.2173	151.6831	64	
4265905	250454	10535070/1	-30.2173	151.6831	64	
2503563	250454	10099499/2	-30.2173	151.6831	64	
2503564	250454	10099499/2	-30.2173	151.6831	64	
1306022	405163	1145105/1	-31.1472	151.2306	40	Bureau of Meteorology GPO Box 1289 MELBOURNE VIC 3001
1306025	405163	1145105/1	-31.1472	151.2306	40	
836146	6481	1569197/1	-31.0755	150.9585	44	Essential Energy Attn: Ray Northcott PO Box 5730 PORT MACQUARIE BC NSW 2444
836143	6481	1569197/1	-31.0755	150.9585	44	

Table 4 Details of point-to-multipoint licences within 75 km of the Project Area (continued)

Assignment ID	Site ID	Licence no.	Latitude [GDA94]	Longitude [GDA94]	Distance to Project Area [km]	Licence owner
1749115	34767	10067310/1	-31.3266	151.6556	68	Goodcom Communications Pty Ltd[2] PO Box 190 WALCHA NSW 2354
1749180	34767	10067314/1	-31.3266	151.6556	68	
1749114	34767	10067310/1	-31.3266	151.6556	68	
1749177	34767	10067314/1	-31.3266	151.6556	68	
1178730	142447	1990912/1	-31.0400	151.0590	35	Tamworth Regional Council Water & Waste - Attn Tim Hurcum PO Box 555 TAMWORTH NSW 2340
1178733	142447	1990912/1	-31.0400	151.0590	35	
746323	6426	1145594/1	-31.1262	150.9390	49	
746327	6426	1145594/1	-31.1262	150.9390	49	
1178734	142450	1990913/1	-30.7460	150.7320	49	
1178737	142450	1990913/1	-30.7460	150.7320	49	
783653	250674	1252615/1	-30.7464	150.7320	49	
783650	250674	1252615/1	-30.7464	150.7320	49	
753414	6501	1182388/1	-31.1165	150.9096	50	
746310	6501	1145592/1	-31.1165	150.9096	50	
746307	6501	1145592/1	-31.1165	150.9096	50	
753396	6501	1182386/1	-31.1165	150.9096	50	
753393	6501	1182386/1	-31.1165	150.9096	50	
753408	6501	1182387/1	-31.1165	150.9096	50	
753405	6501	1182387/1	-31.1165	150.9096	50	
753409	6501	1182388/1	-31.1165	150.9096	50	
896358	9011774	1925006/1	-31.0823	150.8135	55	
896355	9011774	1925006/1	-31.0823	150.8135	55	
872297	48655	1909717/1	-31.3517	151.3738	62	
872294	48655	1909717/1	-31.3517	151.3738	62	
879706	138467	1914954/1	-30.3920	150.6078	72	
879703	138467	1914954/1	-30.3920	150.6078	72	
2375095	402425	10174592/1	-30.9887	151.5877	33	Walcha Council[1] (ATTN The General Manager) PO Box 2 WALCHA NSW 2354
2375092	402425	10174592/1	-30.9887	151.5877	33	
919286	41044	1941580/1	-30.9652	151.6309	34	
919283	41044	1941580/1	-30.9652	151.6309	34	
919294	9013090	1941581/1	-31.0522	151.5117	34	
919291	9013090	1941581/1	-31.0522	151.5117	34	
2807268	35571	1109814/2	-30.9462	151.1452	21	WATER NSW Attn: P Dudley PO Box 398 Parramatta NSW 2124
2807269	35571	1109814/2	-30.9462	151.1452	21	
2807264	6481	1109813/2	-31.0755	150.9585	44	
2807265	6481	1109813/2	-31.0755	150.9585	44	
2807220	204530	1224697/2	-30.5739	150.6911	56	
2807221	204530	1224697/2	-30.5739	150.6911	56	
2807273	34848	1109815/2	-30.7302	150.6486	57	
2807272	34848	1109815/2	-30.7302	150.6486	57	
2807261	52910	1109812/2	-31.3512	151.1534	63	
2807260	52910	1109812/2	-31.3512	151.1534	63	
3356459	250591	10380054/1	-30.8827	150.4929	74	
3356456	250591	10380054/1	-30.8827	150.4929	74	

1. Consultation with this operator is not considered necessary, as the Project Area is outside their defined service area.
2. Consultation with this operator is not considered necessary, due to the significant distance between the Project Area and their point-to-multipoint licences.

4.3.2 Stakeholder consultation

DNV has contacted or is attempting to contact the operators of potentially affected point-to-multipoint base stations, as identified in Table 4, to identify the associated link paths and hence determine the likelihood that the Project will cause interference to their services and, if the potential for interference exists, to identify suitable options to avoid disruptions to those services. The consultation status for each operator is summarised in Appendix A. No responses have been received to date.

4.3.3 Mitigation

In the event that interference to point-to-multipoint links is experienced as a result of the Project, DNV understands that the Proponent has committed to developing appropriate mitigation in consultation with the relevant service operators. If impacts are material and mitigation is required, it is expected that a range of options will be available to rectify any interference.

4.4 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.

4.4.1 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 Project Area. The locations of these licences and number of associated Assignment IDs for each licence type are shown in Figure 14 and Table 5.

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 WTGs 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 4.5 and 4.10 respectively, while the potential for interference to radio and television broadcasting services is considered in Sections 4.13 and 4.14.

A number of aeronautical licences, and radiodetermination licences which may be used for aircraft navigation, have been identified. DNV understands that potential impacts to aircraft navigation systems are addressed in the aviation impact study for the Project, and so these systems are not considered further in this assessment.

Table 5 Details of other licences identified within 75 km of the Project Area

Licence category	Licence type	Number of assignment IDs
1800 MHz Band	Spectrum	390
2 GHz Band	Spectrum	404
2.3 GHz Band	Spectrum	6631
2.5 GHz Band	Spectrum	158
3.4 GHz Band	Spectrum	12
700 MHz Band	Spectrum	498
800 MHz Band	Spectrum	482
Aeronautical Assigned System	Aeronautical	31
Amateur Repeater	Amateur	24
Ambulatory System	Land Mobile	56
AWL - FSS Only	Spectrum	88
CBRS Repeater	Land Mobile	18
Commercial Radio	Broadcasting	4
Commercial Television	Broadcasting	6
Community Broadcasting	Broadcasting	3
Earth Receive	Earth Receive	24
Fixed Earth	Earth	21
Fixed Receive	Fixed Receive	1
HF Domestic Service	Broadcasting	2
Land Mobile System - > 30MHz	Land Mobile	641
Land Mobile System 0-30MHz	Land Mobile	50
Narrowband Area Service station(s)	Broadcasting	3
Narrowcasting Service (Fixed Tax)	Broadcasting	4
Narrowcasting Service (LPON)	Broadcasting	20
National Broadcasting	Broadcasting	14
Paging System - Exterior	Land Mobile	31
Paging System - Interior	Land Mobile	3
PMTS Class B	PTS	216
PMTS Class B (935-960 MHz)	PTS 900 MHz	111
Radiodetermination	Radiodetermination	11
Retransmission	Broadcasting	10

4.5 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.

4.5.1 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 Area. The groups identified are listed in Table 6 along with their contact details. The nearest licence is associated with a tower located approximately 5 km from the Project Area.

The potential for the WTGs to interfere with emergency services point-to-point links crossing the Project Area is discussed in Section 4.2.

All other licences operated by emergency services in the vicinity of the Project Area are mobile telephony licences used for mobile radio and paging systems. As discussed in Section 4.4, mobile telephony systems are generally not affected by the presence of WTGs 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 WTGs be kept outside of clearance zones ranging from a distance of 200 m to 1,200 m from the tower for point-to-area style services [12].

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

Table 6 Emergency services with radiocommunication assets in the vicinity of the Project Area

Emergency service	Contact details	Distance from closest site to Project Area [km]
Ambulance Service of NSW	Ambulance Service of NSW Service Manager Telecommunications Matt Wheat Locked Bag 105 ROZELLE NSW 2039	16
Guyra Volunteer Rescue Association	Guyra Volunteer Rescue Association PO Box 146 GUYRA NSW 2365	44
Hunter Region SLSA Helicopter Rescue Service	Hunter Region SLSA Helicopter Rescue Service Attn: Facilities Manager PO Box 230 NEW LAMBTON NSW 2305	52
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	5
NSW Police Force	NSW Police Force Radio Engineering Services Level 4, 151-241 Goulburn St Sydney Police Centre SURRY HILLS NSW 2010	16
NSW Rural Fire Service	NSW Rural Fire Service Locked Mail Bag 17 GRANVILLE NSW 2142	5
NSW Volunteer Rescue Association Inc	NSW Volunteer Rescue Association Inc Secretary PO Box 6151 DURAL DC NSW 2158	33
St John Ambulance Australia (N.S.W.)	St John Ambulance Australia (N.S.W.) 9 Deane Street BURWOOD NSW 2134	37
St John Ambulance Australia Incorporated	St John Ambulance Australia Incorporated Technical Services 170 Forster Road MOUNT WAVERLEY VIC 3149	37
State Emergency Service (NSW)	State Emergency Service (NSW) New South Wales State Emergency Service PO Box 6126 WOLLONGONG NSW 2500	33

4.5.2 Stakeholder consultation

DNV has contacted the emergency services operators identified in Table 6 to confirm that the Project is unlikely to have any impact on their operations and services and, if the potential for interference exists, to identify suitable options to avoid disruptions to those services. The consultation status for each operator is summarised in Appendix A. No responses have been received to date.

4.5.3 Mitigation

Mitigation commitments and potential mitigation options for impacts to emergency services point-to-point links crossing the Project Area are discussed in Section 4.2.3.

As noted above, interference with mobile telephony services is considered unlikely. If localised interference to mobile radio or paging system signals is experienced during operation of the Project, this can potentially be rectified 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.

In the unlikely event that interference to mobile radio or paging systems is experienced over a larger area as a result of the Project, DNV understands that the Proponent has committed to developing appropriate mitigation in consultation with the relevant service operators. If impacts are material and mitigation is required, it is expected that a range of options will be available to rectify any interference.

4.6 Aircraft navigation systems and radar

DNV understands that potential impacts to aircraft navigation systems and radar are addressed in the aviation impact study for the Project.

4.7 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 3,000 m [16, 17], and approximately 100 km at a height of 1,000 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 WTGs should not be located within 5 km of a meteorological radar site, due to the high risk of 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 WTGs 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 WTGs 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 WTGs 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 WTGs 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 WTGs 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].

4.7.1 Locations of meteorological radars and potential for interference

DNV has identified that the BoM operates 10 weather radars within 250 nautical miles of the Project Area, with the closest radar, "Namoi", located approximately 105 km southwest of the Project Area. The locations of these radars are shown in Figure 15 and the details of each radar are given in Table 7.

The distance between the Project Area 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 WTGs are not within direct line of sight of the radar. Consultation with the BoM is currently being undertaken to determine whether there is any potential for interference from the proposed WTGs, as summarised in Section 4.7.2.

Table 7 BoM radar sites in the vicinity of the Project Area

BoM radar site	Radar type	Latitude[1]	Longitude[1]	Distance to Project Area [km]
Namoi (Blackjack Mountain)	Doppler	150.192	-31.024	106
Moree	Standard weather watch	149.850	-29.500	192
Grafton	Standard weather watch	152.951	-29.622	195
Newcastle	Doppler	152.025	-32.730	225
Sydney (Terrey Hills)	Doppler	151.209	-33.701	322
Sydney (Kurnell)	Doppler	151.226	-34.015	357
Brisbane (Marburg)	Standard weather watch	152.539	-27.608	364
Brisbane (Mt Stapylton)	Doppler	153.240	-27.718	380
Wollongong (Appin)	Doppler	150.875	-34.263	387
Brewarrina	Doppler	146.814	-29.971	435

1. Coordinate system: Lat/Lon GDA94 datum.

4.7.2 Stakeholder consultation

DNV has contacted the BoM, as recommended by the Draft National Guidelines, to determine the likelihood that the Project will interfere with their operations and services and, if the potential for interference exists, to identify suitable options to avoid disruptions to those services. The consultation status for the BoM is summarised in Appendix A. No response has been received to date.

4.7.3 Mitigation

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 likelihood of the wind farm causing reflection or scattering of radar signals, the WMO suggests it may be possible to reduce the potential impact through the relocation of individual WTGs prior to construction (through micro-siting). 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.

In the event that there is potential for the proposed WTGs to interfere with BoM radar operations, DNV understands that the Proponent will consult with the BoM to establish an understanding of how any impact to their services may be managed.

4.8 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 WTGs. 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 the AuScope GNSS network of around 100 CORS strategically distributed across the country. 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]. 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.

4.8.1 Locations of trigonometrical stations and potential for interference

According to Geoscience Australia [24], there are 14 trig points within 20 km of the Project Area. One trig point, “Standbye”, is located inside the Project Area approximately 2.7 km southeast of the nearest proposed WTG (WTG T2). The details of these trig points are provided in Table 8 and their locations are illustrated in Figure 16.

Table 8 Trigonometrical stations in the vicinity of the Project Area

Station name	Datum	Latitude[1]	Longitude[1]	Distance to Project Area [km]
Balala	AGD66, AGD84	151.319	-30.632	10
Bendemeer	AGD66, AGD84	151.142	-30.839	14
Goldsworth	AGD66, AGD84, GDA94	151.410	-30.586	16
Haning	AGD66, AGD84, GDA94	151.105	-30.825	17
Harnham	AGD66, AGD84, GDA94	151.485	-30.733	10
Harnham Hill	AGD66, AGD84, GDA94	151.485	-30.733	10
Kent	AGD66, AGD84	151.104	-30.670	16
Ohio Peak	AGD66, AGD84, GDA94	151.517	-30.887	20
Retreat	AGD66, AGD84	151.173	-30.649	11
Rimbanda	AGD66, AGD84	151.288	-30.815	3
Standbye	AGD66, AGD84, GDA94	151.363	-30.762	Within Project Area
Turkey Mtn	AGD66, AGD84	151.200	-30.748	5
Uralla	AGD66, AGD84, GDA94	151.529	-30.638	18
Walcha Road	AGD66, AGD84, GDA94	151.395	-30.945	19

1. Coordinate system: Lat/Lon GDA94 datum.

DNV has reviewed the primary geodetic network of Australia [25] and observed that the Project Area is located within the first-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 37 km northeast of the Project, at Armidale [24]. Due to the significant distance between the Project Area and the GNSS station, it is considered unlikely that the Project will cause interference to the GNSS network.

4.8.2 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 has contacted Geoscience Australia and NSW Spatial Services to advise them about the Project, confirm that the Project is unlikely to have any impact on their systems, and, if the potential for interference exists, to identify suitable options to avoid disruptions to their systems. The consultation status for each operator is summarised in Appendix A. No responses have been received to date.

4.9 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.

4.9.1 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 Project Area are likely to be intercepted by existing obstructions such as terrain and vegetation, and there is little evidence in the literature to suggest that WTGs pose a particular risk of interference to these systems. Therefore, the impact of the Project on CB radio services is expected to be minimal.

4.9.2 Mitigation

If localised interference to CB radio signals is experienced by users during operation of the Project, simple steps such as moving a short distance to a new or higher location until the signal strength improves may help to rectify 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.

It is not expected that the Proponent will be required to actively mitigate potential impacts to CB radio signals.

4.10 Mobile phones

Mobile phone networks typically operate at frequencies of either between 700 and 900 MHz, or between 1,800 MHz and 2,600 MHz, however some new services may operate at up to 3,500 MHz. At such frequencies, signals may be affected by physical obstructions such as buildings and WTGs.

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 WTGs 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 WTGs could cause some interference to the signal. However, there is little evidence in the literature of WTGs 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.

4.10.1 Availability of mobile phone services and potential for interference

DNV has reviewed the locations of mobile phone towers in the vicinity of the Project Area. The locations of these towers are shown in Figure 17. The nearest mobile phone tower is located within the Project Area, approximately 2.8 km southeast of the nearest proposed WTG location (WTG T2).

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

Figure 18 and Figure 19 show the Optus Mobile network coverage for the Project Area and surrounds [26]. Outdoor 3G coverage is available across most of the Project Area, and in areas to the south, east and northeast. However, an external antenna is required to receive 3G signals in many areas to the north and west of the Project Area and there are some regions where coverage is not available. Similarly, outdoor 4G coverage is available across much of the Project Area and in areas to the south, east, and northeast, but is marginal or not available in areas to the north and west of the Project Area.

Figure 20 and Figure 21 show the Telstra network coverage for the Project Area and surrounds [27]. Both 3G and 4G coverage are available across most of the Project Area, and in areas to the north, east, and south. However, there are large areas to the west and isolated regions in the north and south where coverage is not available.

Figure 22 shows the Vodafone network coverage for the Project Area and surrounds [28]. Outdoor 4G coverage is available across most of the Project Area, large areas to the east and south, and isolated areas in the west, with some areas in the eastern part of the Project Area and immediately to the southeast able to receive indoor 4G coverage. Outdoor 3G coverage is available across most of the remaining area in the vicinity of the Project Area, although there is no coverage available in the northwest.

In general, for areas with good coverage, interference to mobile phone signals is unlikely and previous advice received from the network operators has generally indicated that they do not expect wind farm developments to interfere with their services. 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 WTG intercepts the signal between a mobile phone and the tower. Based on the coverage maps discussed above, mobile phone signal coverage for all three network operators may be theoretically more likely to experience interference in areas that are currently receiving a weak signal to the north and west of the Project Area. In areas that are not currently receiving signals, due to existing coverage limitations, there will be no potential for interference.

4.10.2 Stakeholder consultation

DNV has contacted Optus, Telstra, and Vodafone to advise them about the Project, confirm that the Project is unlikely to have any impact on their services, and, if the potential for interference exists, to identify suitable options to avoid disruptions to those services. The consultation status for each operator is summarised in Appendix A. No responses regarding mobile phone services have been received to date.

4.10.3 Mitigation

As noted above, interference with mobile phone signals is generally considered unlikely. If localised interference is experienced by mobile phone users during operation of the Project, this can potentially be rectified by the user moving a short distance to a new or higher location to receive a clearer signal or using an external antenna to improve the signal reception (as is currently required in some locations surrounding the Project Area due to existing poor signal coverage).

In the unlikely event that interference to mobile phone signals is experienced over a larger area as a result of the Project, or in cases where it would not be possible or practical for the user to change their location, DNV understands that the Proponent has committed to developing appropriate mitigation in consultation with the relevant service operators. If there are material impacts and mitigation is required, it is expected that a range of options will be available to rectify any interference.

4.11 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).

4.11.1 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.

4.11.1.1 Availability of wireless broadband services and potential for interference

Internet service providers Pivotel Mobile and TPG Internet hold point-to-area style licences in the vicinity of the Project Area, with the nearest transmitters located 26 km and 21 km from the Project Area, respectively. As the locations of Pivotel Mobile and TPG internet customers are not known, it is not possible to determine whether there is the potential for interference to their services, however it is possible that transmitters at these distances may be servicing customers in the vicinity of the proposed Project Area.

Additionally, residents in the vicinity of the Project Area may use wireless broadband services provided by Optus, Telstra, and Vodafone. These wireless broadband services use the same networks as mobile phone services for those providers, and therefore the comments made in Section 4.10.1 are applicable here. Specifically, there is a low theoretical likelihood of interference in areas with marginal reception if a WTG intercepts the signal between a receiver and the tower.

4.11.1.2 Stakeholder consultation

DNV is attempting to contact Pivotel Mobile and TPG Internet to confirm their service area and hence determine the likelihood that the Project will cause interference with their operations and

services and, if the potential for interference exists, to identify suitable options to avoid disruptions to those services. As discussed in Section 4.10.2, DNV has also contacted Optus, Telstra, and Vodafone to confirm that the Project is unlikely to have any impact on their services. The consultation status for each operator is summarised in Appendix A. No responses regarding mobile internet services have been received to date.

4.11.1.3 Mitigation

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 4.10.3 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. In the unlikely event that interference is experienced over a larger area as a result of the Project, or in cases where it would not be possible or practical for the user to change their location, DNV understands that, if there are material impacts, the Proponent has committed to developing appropriate mitigation in consultation with the relevant service operators.

4.11.2 National Broadband Network

The national broadband network (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 WTGs [30].

For rural and remote users in areas that are not able to receive fixed line or fixed wireless services, NBN satellite internet signals are available from the NBN Sky Muster I and II satellites.

4.11.2.1 Availability of NBN services and potential for interference

The NBN website [31] indicates that the network is currently available as a satellite internet service only in the areas surrounding the Project Area. 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 Area in the near future. The potential for interference to satellite internet signals from the NBN Sky Muster I and II satellites is considered in Section 4.12.

4.11.2.2 Stakeholder consultation

DNV has contacted NBN Co to advise them about the Project, confirm that the Project is unlikely to have any impact on their services, and, if the potential for interference exists, to identify suitable options to avoid any disruptions to those services. The response received from NBN Co confirms that they do not expect the Project to cause any interference to their services.

4.12 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.

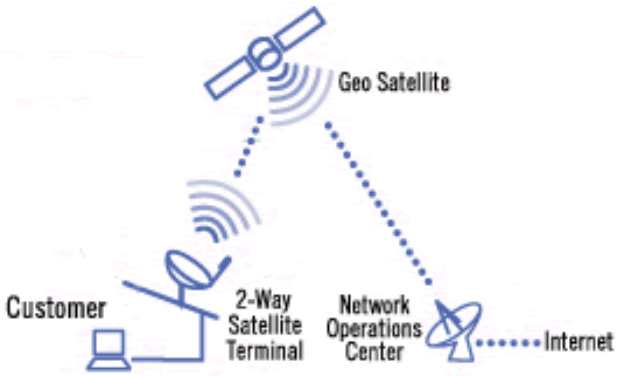

Figure 1 Two-way connection to the internet via satellite [34]

4.12.1 Locations of satellite vectors and potential for interference

Due to marginal coverage of some communication services, some residents in the vicinity of the Project Area 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 Area 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 9. Based on these results, the proposed WTGs may intercept signals from 12 satellites at 12 nearby dwellings, two of which are host landowner dwellings and 10 of which are non-associated dwellings.

Table 9 Satellite vectors with potential to be intercepted by the proposed Project

Intercepted satellite	Services provided [35]	Affected dwellings[1]
Eutelsat 70B	Programs intended for international audiences	*298*
Intelsat 22	Programs intended for international audiences	5, 7, 8, 9, 27, 217, 218[2], 220, *298*
G-Sat 7, G-Sat 11, G-Sat 14, G-Sat 18	Programs intended for international audiences	6, 27
ABS 2, ABS 2A	Programs intended for international audiences	27, *300*[2], 308
Apstar 7	Programs intended for international audiences	*300*[2], 308
Thaicom 6, Thaicom 8, Express 80	Programs intended for international audiences	*300*[2]

1. Host landowner dwellings are indicated by *underlined italic text*.
2. Vacant dwelling.

DNV understands that all the potentially affected satellites shown in Table 9 provide television signals intended for international audiences. Although these services are not typically intended for Australian audiences, they may be used by migrant communities in Australia. However, many of these satellites have a low angle of elevation above the horizon at the Project Area, 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 the proposed WTGs. If residents are not currently receiving signals from these satellites, 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 these services.

4.12.2 Stakeholder consultation

DNV understands that the Proponent is intending to consult with the residents of the dwellings identified in Table 9 prior to construction to determine if any are currently receiving signals from these satellites and, if so, to establish an understanding of how any impact to these services may be mitigated in the event that material interference is experienced during operation of the Project.

4.12.3 Mitigation

If nearby residents that are currently receiving satellite signals experience interference to those signals as a result of the Project, several mitigation options may be available. If an alternative source of the same programming is available, it may be possible for 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.

4.13 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 1,610 kHz, while FM radio operates in the very high frequency (VHF) band between 87.5 MHz and 108 MHz.

4.13.1 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 WTGs), 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 WTGs 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 (within several tens of metres) of a WTG [36].

4.13.1.1 Locations of AM transmitters and potential for interference

The locations of AM broadcast transmitters in the vicinity of the Project Area were determined from the ACMA Broadcast Transmitter Database [37], and are shown in Figure 23.

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

4.13.1.2 Mitigation

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

4.13.2 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 WTGs 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 WTG, where the signal-to-noise ratio is low [36, 39].

WTGs 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 WTG, 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 WTG. 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 WTGs are located within approximately 4 km of the transmission tower [40].

4.13.2.1 Locations of FM transmitters and potential for interference

The locations of FM broadcast transmitters in the vicinity of the Project Area were determined from the ACMA Broadcast Transmitter Database [37], and are shown in Figure 23.

The closest FM broadcast transmission tower is located approximately 33 km from the Project Area. Due to the considerable distance between the transmission tower and the Project Area, 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 Area to be affected by reflection or scattering of the radio signals from the WTGs.

4.13.2.2 Mitigation

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

4.13.3 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.

4.13.3.1 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 Area is outside the intended service area for digital radio broadcasts. Since it is therefore unlikely that residents in the vicinity of the Project Area are currently receiving digital radio signals, it is not expected that the Project will cause interference to digital radio services.

4.14 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 WTGs. 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 WTGs is discussed further in Section B.1 of Appendix B.

4.14.1 Availability of DTV broadcasting and potential for interference

The locations of DTV broadcast transmitters in the vicinity of the Project Area were determined from the ACMA Broadcast Transmitter Database [44], and are shown in Figure 23. The main DTV transmitter used by residents in the vicinity of the Project Area is likely to be the Armidale transmitter at Dumaresq, approximately 45 km northeast of the Project Area. However, according to the Australian Government mySwitch website [45], it is also possible that residents in the vicinity of the Project Area are able to receive DTV signals from the Upper Namoi transmitter, located approximately 116 km northwest of the Project Area. Coverage maps for these broadcast transmitters are reproduced in Figure 24 to Figure 25.

Figure 24 shows that DTV coverage from the Armidale tower is 'poor' to 'variable' across most of the Project Area and surrounding area to the south and west, with many areas apparently unable to receive signals from this tower. However, 'good' signal coverage from the Armidale tower is available in some areas to the north and east of the Project Area. DTV coverage from the Upper Namoi tower is generally 'variable' across the Project Area and surroundings, as shown in Figure 25, although there are some isolated areas of stronger signal coverage and some areas where no signal is available.

4.14.1.1 Interference caused by large scale effects

For broadcast signals, large scale interference can generally be avoided by placing the WTGs 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 Area is the Uralla relay transmitter, which is approximately 16 km away. Therefore, it is not expected that the Project will cause large scale interference to signals from this transmitter.

4.14.1.2 Interference caused by reflection or scattering

Although DTV signals are generally unlikely to be susceptible to interference from WTGs 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 WTG 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 Area, it is possible that some areas could be deemed to have marginal reception and interference could be encountered. In areas that are not currently receiving signals, due to existing coverage limitations, there will be no potential for interference.

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 scattered signals from a proposed WTG (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 B.3 of Appendix B.

The results of the analysis can be seen in Figure 24 and Figure 25. The dwellings most likely to be susceptible to interference include those within the possible interference zones, as summarised in Table 10.

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 B.2 of Appendix B. In particular, although DNV has considered the potential for interference to DTV signals at dwellings within 5 km of the proposed WTG 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 WTGs. Consultation with BAI Communications is currently being undertaken to confirm the potential for interference to DTV signals, as summarised in Section 4.14.2.

Table 10 Dwellings located within potential interference zones for DTV broadcast transmitters in the vicinity of the Project Area

DTV broadcast tower	Signal coverage in potential interference zone	Dwellings in potential interference zone
Armidale (Dumaresq)	Poor to variable, with many areas unlikely to be receiving signals	29[2], 260, *270*[2], *275*[2], *277*[2], *278*[3], *279*[2], *302*[2,4], *306*, *307*, *310*[4]
Upper Namoi (Mount Dowe)	Generally variable, with some isolated areas of stronger coverage and some areas with no signal	3[5], *4*[5], 5[5], 6[5], 10[2], 12[2], 20[2], 26[2], 27, 28, 29, 41, *298*[5], *299*[5], *300*[4], *302*[4], 308[5]

1. Host landholder and associated landholder dwellings are indicated by *underlined italic text.*
2. Signal coverage from the relevant broadcast tower may not be available at this dwelling, based on the coverage maps shown in Figure 24 and Figure 25.
3. Derelict dwelling.
4. Vacant dwelling.
5. Dwelling may be able to receive a stronger alternative signal from the Armidale broadcast tower.

Based on this assessment, one host landholder dwelling and one associated landholder dwelling located within the Project Area, along with seven associated landholder dwellings and two non-associated dwellings to the southwest of the Project Area, have increased potential to experience interference to DTV signals from the Armidale tower. However, the coverage map in Figure 24 suggests that many of these dwellings may not currently be able to receive a signal from this tower due to an existing lack of signal and therefore may not be affected in the event of interference as a result of the Project.

Five host landowner dwellings within the Project Area and twelve non-associated dwellings located immediately to the north, east, and southeast have increased potential to experience interference to DTV signals from the Upper Namoi tower, which has marginal coverage across most of the potentially affected areas. Again, DNV understands that that the Proponent has a negotiated agreement in place with host landholders to address impacts associated with the Project. The coverage maps in Figure 25 suggests that some of the identified non-associated dwellings may not currently be able to receive a signal from the Upper Namoi tower due to an existing lack of signal, but others may be receiving a weak signal that could therefore be subject to interference from proposed WTGs. However, based on the coverage maps, it is also possible that dwellings within the potential interference zone for the Upper Namoi tower to the north and northeast of the Project Area may be able to receive an alternative (and stronger) signal from the Armidale tower, as indicated in Table 10, which could be used to mitigate any interference as outlined in Section 4.14.3.

The method used here to assess the potential interference to television signals from the proposed WTGs 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 4.14.3.

4.14.2 Stakeholder consultation

DNV has contacted BAI Communications to advise them about the Project, allow them to undertake their own signal interference modelling if required and hence confirm the likely impacts of the Project on DTV signals in the surrounding area, and identify suitable options to avoid disruptions to those signals. The consultation status for BAI Communications is summarised in Appendix A. No response has been received to date.

4.14.3 Mitigation

DNV understands that the Proponent has committed to conducting pre-construction measurements of the average DTV reception strength at selected dwellings within approximately 3 km of the Project Area, to confirm the current availability of signals from the Armidale and Upper Namoi broadcast transmitters and to allow any complaints about interference after commissioning of the Project to be investigated.

In the event that television interference is found to be an issue during construction or operation of the Project, and is attributable to the Project, DNV understands that the Proponent has committed to developing appropriate mitigation in consultation with BAI Communications and any relevant landowner. If required, potential mitigation options may include:

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.

The suitability of these mitigation options may depend on the type of interference mechanism and the availability of alternative signals, as discussed further below, and can be further evaluated in consultation with BAI Communications and the relevant landowner if interference is experienced during operation of the Project.

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 tuning

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] also identified that the receiver height can 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].

5 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 strength of the electric field is proportional to the voltage of the EMF source, while the strength of the 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. The amount of energy transported by EMF is proportional to its frequency. ELF EMF contains very little energy. In comparison, microwave frequency EMF ranges from approximately 1 GHz to 30 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 evidence to conclusively link 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 WTGs themselves. At ground level, the EMF generated by transmission lines, underground cabling, overhead cabling, and WTGs is generally comparable to background 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 3.2 [6, 49, 50].

DNV has conducted an assessment to characterize the EMF in terms of the electric and magnetic field strengths in the vicinity of the Project Area, to address the SEARs requirement to identify potential hazards and risks to human health associated with EMF. A map of the Project Area with the proposed electrical infrastructure is shown in Figure 26.

For the purposes of this assessment, only the EMF produced by the medium voltage (33 kV) electrical infrastructure within the Project Area has been modelled. The design details for the 330/33 kV substation and 330 kV switching station 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 substation and switching station 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 substation and switching station 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 new section of high voltage (330 kV) transmission line within the Project Area is 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 substation, switching station, and high voltage transmission line are expected to be low or negligible at publicly accessible locations in and around the Project Area and are not considered further in this assessment.

Simulations were performed in the vicinity of the 33 kV underground electrical cables from the WTGs and the potential 33 kV overhead electrical lines within the Project Area. Only the magnetic field strength was considered for the underground cables as, due to 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]. For the overhead lines, both the electric field strength and magnetic field strength were considered. 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 EFC-400 [51] and the overhead line in the HIFREQ module of CDEGS (current distribution, electromagnetic interference, grounding and soil structure analysis) [52]. The magnetic field strength due to the cables and overhead lines depends on the current flowing through the cable and the distance from the cable or line to the point where the field is measured. The electric field strength due to the overhead lines depends on the voltage through the line and the distance to the point where the field is measured. The following assumptions were made:

- for the underground cables:
  - cable rating: 33 kV, 800 mm^2 cable (based on information provided by the Proponent)
  - cable layout: buried at a depth of 800 mm in trefoil formation (based on information provided by the Proponent)
  - one cable per phase (worst-case condition, assumed for the purposes of the assessment and discussed further in Section 5.1)
  - 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)
- for the overhead line:
  - line rating: 33 kV, phosphorous conductor (based on information provided by the Proponent)
  - line height: 8 m at the supporting towers with a maximum sag of 1 m (standard heights, assumed for the purposes of the assessment)
  - single conductor without a neutral conductor (worst-case condition for magnetic fields, assumed for the purposes of the assessment and discussed further in Section 5.2).

Table 11 shows the electric and magnetic field exposure limits recommended by the ICNIRP [7] and WHO [5] and considered in this assessment.

Table 11 Recommended electric and magnetic field exposure limits

Exposure	ICNIRP 2010 reference level [7]		WHO recommendation [5]
	General public	Occupational[1]	General public
Electric field	5 kV/m	10 kV/m	Not specified
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.

5.1 EMF due to underground cabling

The underground cabling was modelled as a single cable per phase under balanced phase loading conditions, and a maximum current of 1,000 A was 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. 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. For sections of cabling where there are two cables per phase, the interaction between the magnetic fields produced by each phase typically results in a cancellation effect that causes the overall magnetic field strength to be less than it would be for a single cable per phase configuration [6]. Therefore, the magnetic field strengths calculated here are expected to be conservative for all underground cabling configurations proposed for the Project.

Figure 2 shows the trefoil arrangement of the cable in EFC-400, Figure 3 shows the modelled magnetic field distribution around the cable, and Figure 4 shows the modelled magnetic field strength at ground level relative to the location of the cable. As may be expected, the maximum magnetic field strength at ground level due to the underground cabling is observed immediately above the cable. At this location, the magnetic field strength due to the underground cabling is approximately 22 μT which is well below the exposure limit specified in Table 11. 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 22 μT and therefore also below the relevant exposure limits.

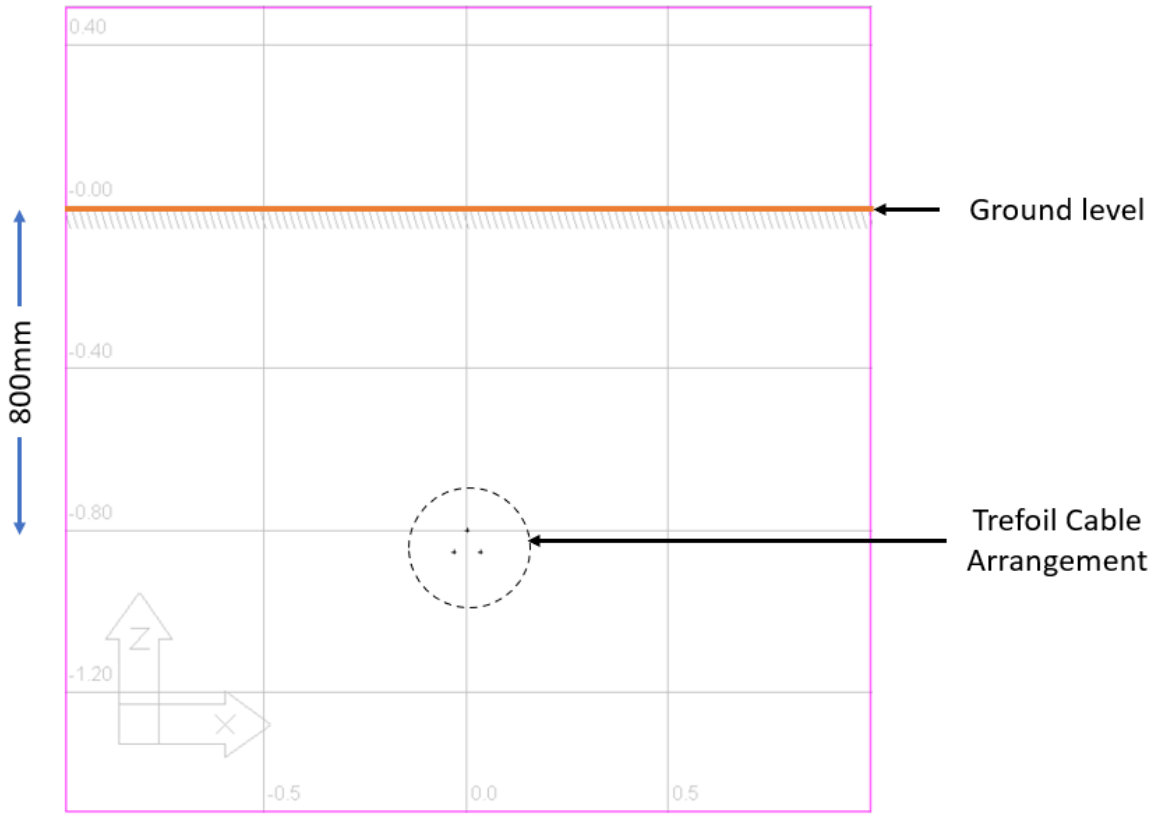

Figure 2 Underground cable arrangement and burial depth

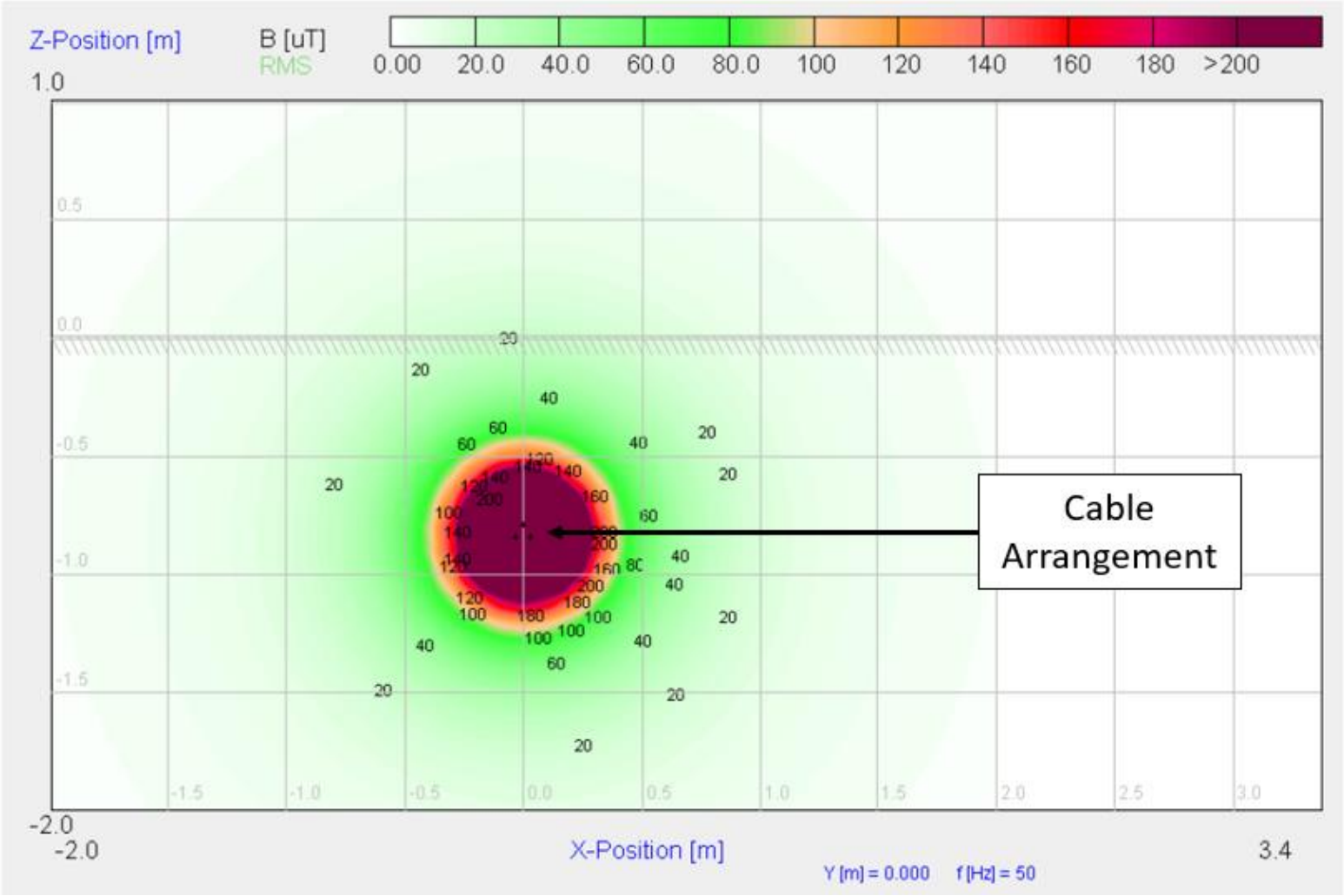

Figure 3 Magnetic field (μT) distribution around the cable at 800 mm below ground level under worst-case conditions

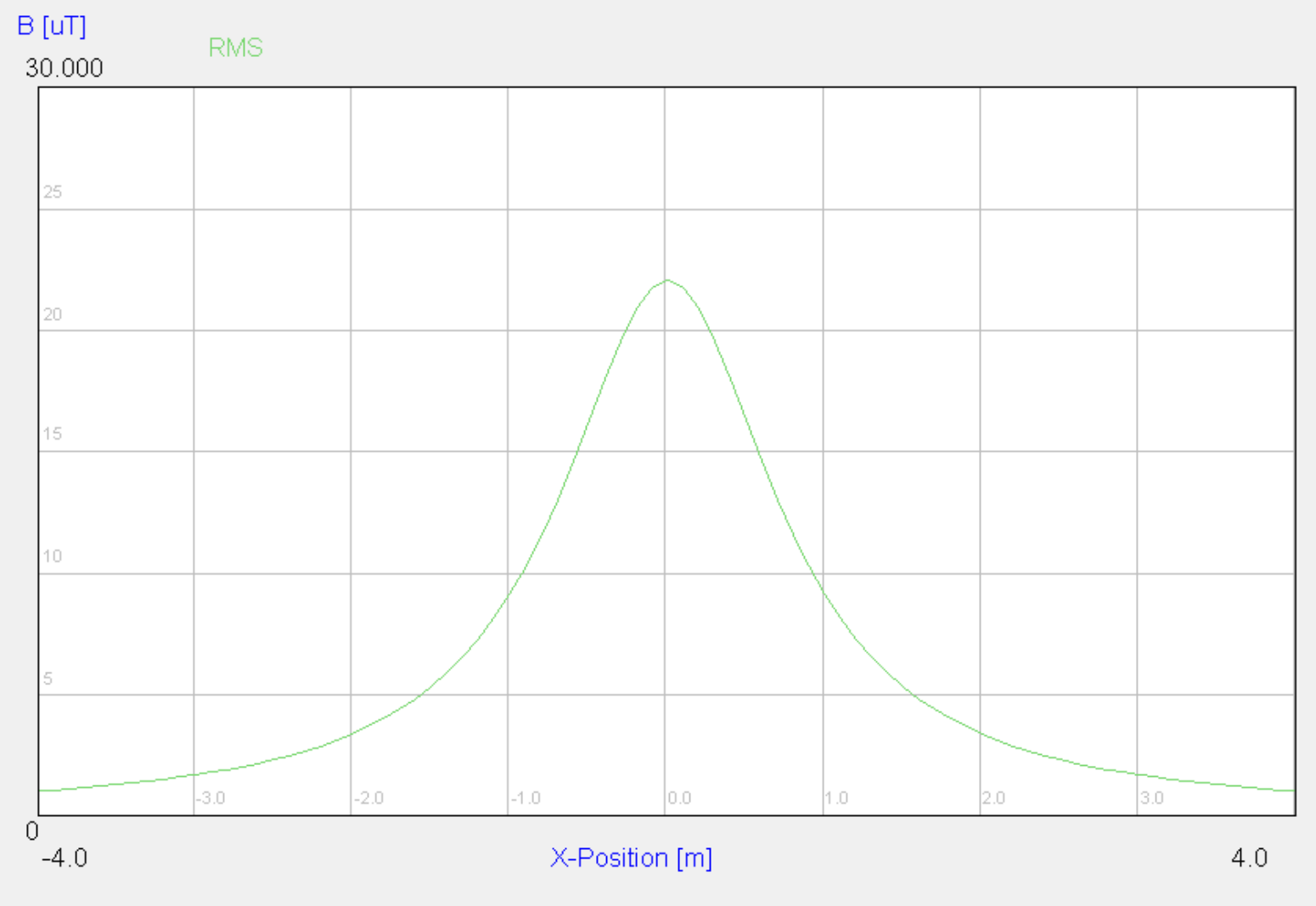

Figure 4 Magnetic field (μT) strength at ground level due to the underground cable under worst-case conditions, where x = 0.0 is the location immediately above the cable

5.2 EMF due to overhead lines

The overhead line was modelled as a 33 kV single conductor (single circuit) without a neutral conductor. A voltage of 33 kV was taken for the electric field calculations and a current of 1,000 A was taken for the magnetic field calculations.

These modelling parameters represent the worst-case conditions for the magnetic field and are expected to correspond to the largest magnetic field strength for the overhead lines. For double circuit and triple circuit overhead lines, the interaction between the magnetic fields produced by each circuit typically results in a cancellation effect that causes the overall magnetic field strength to be less than it would be for a single circuit configuration [6]. The magnetic field strength for a double or triple circuit line also decreases more rapidly as the distance from the line increases, compared to a single circuit line [6]. Additionally, the use of a neutral conductor (which is standard practice for overhead lines) acts to reduce the overall magnetic field strength produced by the line [6], and so the actual field strengths are expected to be lower than those predicted here in the absence of a neutral conductor. Therefore, the magnetic field strengths calculated here are expected to be conservative for all overhead line configurations proposed for the Project.

The electric field strengths at ground level below a double or triple circuit overhead line are typically of a similar magnitude to the electric field for a single circuit line, but may be slightly higher or lower depending on the line and phase arrangement [53, 54]. The potential for the electric fields to be greater in a double or triple circuit configuration can be mitigated in the detailed design of the electrical infrastructure for the Project by ensuring that the arrangements and heights of the lines are appropriate for the intended voltages and phases. Given that the potential health impacts of electric fields are of less concern than magnetic fields, and it is expected that the proposed double and triple circuit lines will be designed and installed in such a way that the electric fields are minimised, the assumption of a single circuit configuration is considered appropriate for the high-level assessment of electric field strengths presented here.

The electric and magnetic fields due to the overhead line were modelled at heights of 1.5 m and 2 m above ground level (AGL), to encompass the range of typical adult heights in Australia. Figure 5 and Figure 6 show the modelled electric field due to the overhead line (viewed from above) at heights of 1.5 m and 2 m above ground level, respectively. Figure 7 and Figure 8 show the modelled magnetic field due to the overhead line (viewed from above) at heights of 1.5 m and 2 m AGL, respectively.

As may be expected, the maximum electric and magnetic field strengths due to the overhead line are observed immediately below the line at a point half-way along its length. At this location, the line is at the minimum height of 7 m AGL based on the assumed line height of 8 m at the towers with a maximum sag of 1 m, and the field strengths are:

- 1.2 kV/m at 1.5 m AGL and 1.3 kV/m at 2 m AGL for the electric field
- 35 μT at 1.5 m AGL and 39 μT at 2 m AGL for the magnetic field

which are well below the exposure limits specified in Table 11. Since the electric and magnetic field strengths decrease as the distance from the line increases, the field strengths due to the overhead line at heights of 1.5 m AGL and 2 m AGL at all other locations will be less than the maximum values given above and therefore also below the relevant exposure limits.

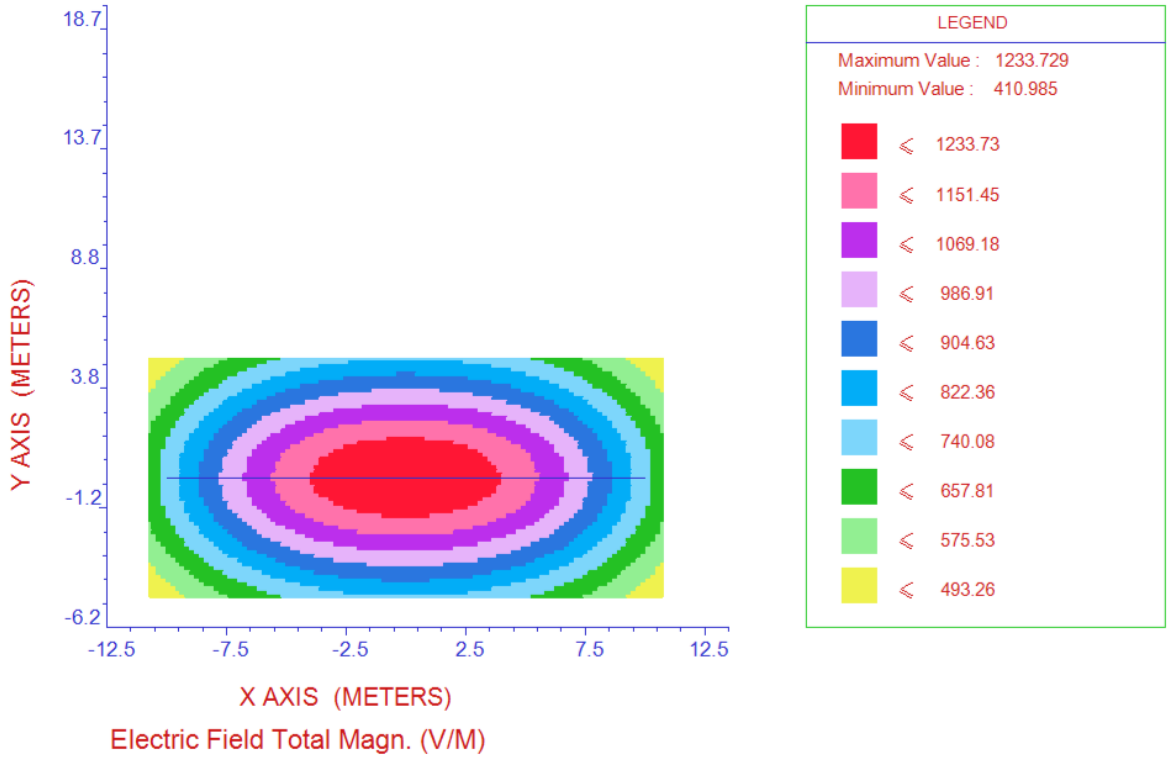

Figure 5 Electric field (V/m) distribution at 1.5 m AGL due the overhead line under worst case conditions

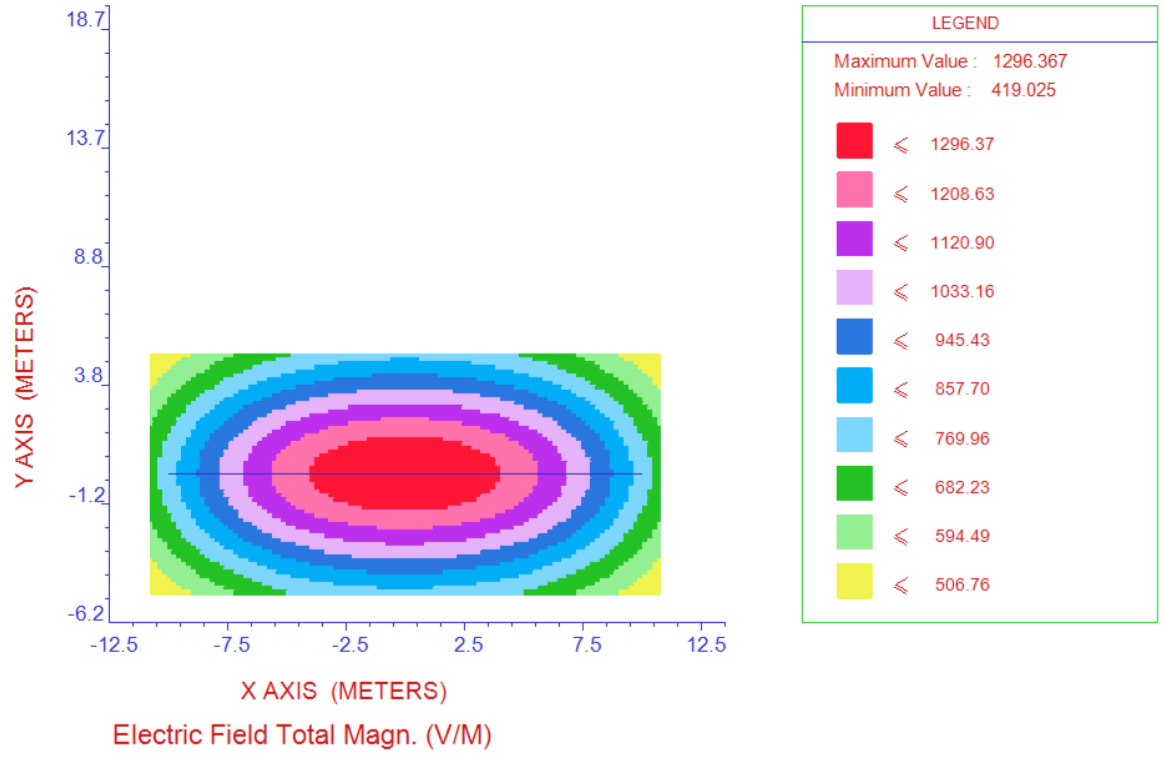

Figure 6 Electric field (V/m) distribution at 2 m AGL due the overhead line under worst-case conditions

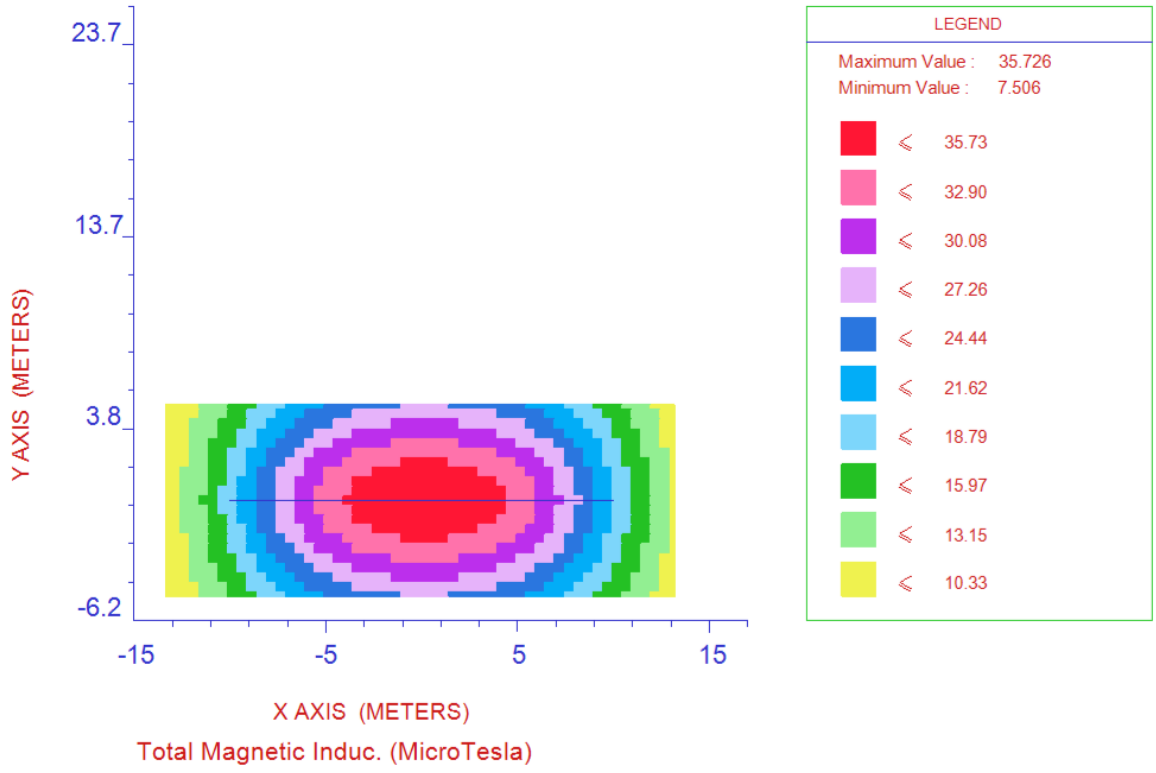

Figure 7 Magnetic field (μT) distribution at 1.5 m AGL due the overhead line under worst-case conditions

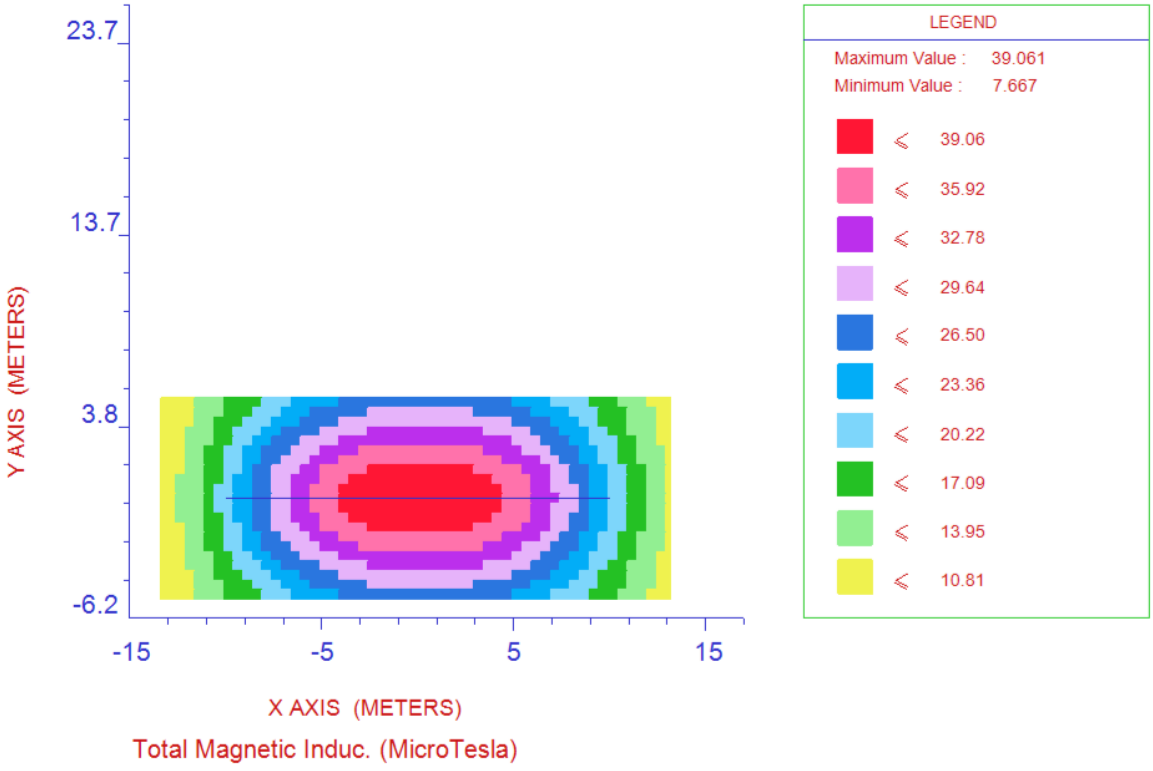

Figure 8 Magnetic field (μT) distribution at 2 m AGL due the overhead line under worst-case conditions

5.3 Summary of modelled EMF and expected health impacts

The maximum electric and magnetic field strengths modelled for the medium voltage underground cabling and overhead lines proposed for the Project are summarised and compared to the limits recommended by the ICNIRP and WHO for general public exposure in Table 12. These maximum values are observed immediately below the overhead line at a point half-way along its length, and at ground level immediately above the underground cable. Since electric and magnetic field strengths decrease as the distance from the source increases, the field strengths at all other locations are expected to be less than the maximum values given in Table 12. For the parameters and conservative assumptions considered in this assessment, the modelled EMF at the range of heights above ground level that humans are most likely to occupy is well within the recommended exposure limits and so the risks to human health from EMF associated with the Project are considered low.

Table 12 Summary of electric and magnetic field strengths evaluated for the Project

Source and measurement location	Maximum electric field [kV/m]	Maximum magnetic field [μT]
Overhead line, measured at 1.5 m AGL	1.2	35
Overhead line, measured at 2 m AGL	1.3	39
Underground cable, measured at ground level	Not evaluated[1]	22
ICNIRP 2010 reference level for general public exposure [7]	5	200
WHO recommendation for general public exposure [4]	Not specified	100

1. Due to attenuation effects, the electric field strength at ground level for underground cables is expected to be negligible.

The closest dwelling to the Project infrastructure is located approximately 180 m away from the underground cabling network and approximately 600 m away from the overhead lines. This dwelling (dwelling 302) is a host landholder dwelling and has been identifed by the Proponent as currently vacant. Since the electric and magnetic field strengths decrease with increasing distance from the source, the EMF produced by the proposed cabling and overhead lines within the Project Area will be significantly below the relevant exposure limits at this dwelling and is expected to be indistinguishable from background levels. All other dwellings are located more than 1,000 m from the underground cabling and 1,800 m from the overhead lines, at which distance the EMF from the Project will be negligible.

The electric and magnetic field strengths due to the medium voltage cabling and overhead lines at all locations in and around the Project Area at the range of heights that humans are most likely to occupy are expected to be well within the limits recommended by the ICNIRP, even with the conservative assumptions considered in this assessment. However, DNV notes that there is a potential for cumulative EMF impacts at ground level at the point where the underground cabling network passes below the existing 330 kV high voltage transmission line (between WTGs T7 and T8, as shown in Figure 26). The risk of cumulative impacts can be mitigated in the detailed design of the electrical infrastructure for the Project by designing the cabling and overhead lines such that the cumulative EMF strengths in the vicinity of any existing infrastructure are within acceptable levels.

As discussed above, it is also expected that other electrical equipment associated with the Project, including the substation, switching station, and new high voltage transmission lines within the Project Area, will be designed and installed in accordance with the relevant guidelines for EMF exposure. 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 Project Area. Based on this assessment, 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.

6 CONCLUSIONS

Broadcast towers and transmission paths around the Project Area were investigated to determine if EMI would be experienced as a result of the proposed 32 WTGs. DNV has considered a WTG geometry that will be conservative for WTG configurations with dimensions satisfying all of the following criteria: a rotor diameter of 190 m or less and an upper tip height of 260 m or less. For WTGs with a smaller rotor diameter, the potential EMI-related impacts of the Project are expected to be less than those presented here, provided that the upper tip height is no more than 260 m.

The results of this assessment are summarised in Table 13. EMI-related impacts are generally expected to be minimal for the Project. Where the potential for interference exists, the overall likelihood is typically low and impacts are likely to be manageable through mitigation once the Project is operational.

The proposed WTGs 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 within approximately 5-10 km of the Project Area that are currently receiving weak signals from the Armidale or Upper Namoi television broadcast towers may experience interference to those services. Impacts are more likely for signals from the Upper Namoi tower, as many of the dwellings in the potential interference zone for the Armidale tower may not be using that service due to an existing lack of coverage. However, it is also possible that some dwellings in the potential interference zone for the Upper Namoi tower may be able to receive an alternative signal from the Armidale tower, which could be used to mitigate any interference that may occur. Mobile phone services may be more susceptible to interference in areas that are currently receiving a weak signal to the north and west of the Project Area. However, previous advice received from mobile phone network operators has generally indicated that they do not expect wind farm developments to interfere with their services.

Impacts to satellite television and internet signals that may be received at dwellings in the vicinity of the Project Area are considered unlikely. The proposed WTGs 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.

Interference to fixed point-to-point links passing over the Project Area is considered unlikely as there are no WTGs located within the calculated exclusion zones for those links. Nevertheless, DNV has contacted the operators of these links to confirm the required clearances and the finding that impacts to their services is unlikely, and (if the potential for interference exists) to identify suitable options to avoid any disruptions. A response has been received from Optus, who have indicated that they do not expect the Project to cause material impacts to their fixed point-to-point links.

DNV has also contacted or is attempting to contact the operators of point-to-multipoint links, emergency services, wireless internet services, and meteorological radar in the vicinity of the Project Area to identify any potential for the Project to cause interference to these services and suitable options to avoid potential disruptions. Based on the available information, the likelihood of impact to these services is generally expected to be low and measures are expected to be available to mitigate impacts should unexpected impacts occur.

Potential EMI impacts on other services considered in this assessment, including radio broadcasting, trigonometrical stations, and CB radio, are considered to be minor.

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 underground cabling network and overhead lines at the Project has shown that the EMF at the range of heights above ground level that humans are most likely to occupy (from 0 m AGL to 2 m AGL) 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 Project Area, and indistinguishable from background levels at nearby dwellings.

DNV notes that the Project Area is located in an area of high wind farm development activity, with several other proposed wind farms nearby. The potential cumulative impacts of the Project in conjunction with the nearby wind farms have not been considered in detail in this assessment. However, 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 impacts.

Table 13 Summary of EMI assessment results for the Project

Licence or service type	Assessment findings	Expected impact	Stakeholder consultation	Mitigation
Radiocommunication towers	No towers within 2 km of proposed WTG locations Nearest tower: 2.8 km from WTGs	None	Consultation not considered necessary	None required
Fixed point-to-point links	21 links over 9 link paths crossing Project Area, operated by: Digital Distribution NSW Telco Authority TransGrid Optus Vodafone Diffraction effects: no WTGs in exclusion zones established by DNV Reflection/scattering and near-field effects: WTGs are considered sufficiently far from towers to avoid impacts	Unlikely to cause interference	DNV has contacted the relevant operators to confirm required clearances and that impacts are unlikely, and to identify suitable options to avoid any potential disruptions No concerns raised by Optus No other responses have been received to date	Mitigation is unlikely to be required; if there are material impacts, the Proponent will apply appropriate mitigation in consultation with the relevant operator
Fixed point-to-multipoint links	64 assignments within 75 km of Project Area No base stations within 20 km of Project Area	Potential for interference if link paths cross the Project Area near WTGs, but considered unlikely given distances and likely nature of services	DNV has contacted or is attempting to contact the relevant operators to identify the link paths, confirm the likelihood of impacts, and identify suitable options to avoid any potential disruptions No responses have been received to date	Mitigation is unlikely to be required; if there are material impacts, the Proponent will apply appropriate mitigation in consultation with the relevant operator
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	-	-	

Table 13 Summary of EMI assessment results for the Project (continued)

Licence or service type	Assessment findings	Expected impact	Stakeholder consultation	Mitigation
Emergency services	Point-to-point links: 3 NSW Telco Authority links crossing Project Area, unlikely to be affected (see "Fixed point-to-point links") Mobile telephony systems: unlikely to be affected	Unlikely to cause interference	DNV has contacted or is attempting to contact the relevant operators to confirm that impacts are unlikely and identify suitable options to avoid any potential disruptions No responses have been received to date	Mitigation is unlikely to be required; if there are material impacts, the Proponent will apply appropriate mitigation in consultation with the relevant operator
Meteorological radar	Nearest radar: "Namoi", 105 km from Project Area	Potential for interference if proposed WTGs can be detected by radars	DNV has contacted the Bureau of Meteorology to evaluate likelihood of WTGs being detected by radars and identify suitable options to avoid any potential disruptions No response has been received to date	To be determined through consultation with the Bureau of Meteorology
Trigonometrical stations	14 stations within 20 km of Project Area Electronic equipment: unlikely to be affected Sight lines to other stations: may be blocked by turbines	Unlikely to cause interference	DNV has contacted the relevant operators to confirm that impacts are unlikely and identify suitable options to avoid any potential disruptions No responses have been received to date	None required
Citizen's band radio	Unlikely to be affected	Unlikely to cause interference	Consultation not considered necessary	None required
Mobile phones	Fair to good coverage across Project Area and in the south, east, and northeast; marginal or no coverage in the north and west Unlikely to be affected in areas with good coverage, may experience interference in areas with marginal coverage	Low risk of interference	DNV has contacted the relevant operators to confirm that impacts are unlikely and identify suitable options to avoid potential disruptions No responses have been received to date	Mitigation is unlikely to be required; if there are material impacts, the Proponent will apply appropriate mitigation in consultation with the relevant operator once the Project is operational

Table 13 Summary of EMI assessment results for the Project (continued)

Licence or service type	Assessment findings	Expected impact	Stakeholder consultation	Mitigation
Wireless internet	Likely service providers: Pivotel Mobile, TPG Internet, mobile phone networks, NBN Co NBN: available as a satellite service only in areas surrounding the Project Area	Low likelihood of interference	DNV has contacted or is attempting to contact the relevant operators to confirm that impacts are unlikely and identify suitable options to avoid any potential disruptions No concerns raised by NBN Co No other responses have been received to date	Mobile broadband services: Mitigation is unlikely to be required; if there are material impacts, the Proponent will apply appropriate mitigation in consultation with the relevant operator once the Project is operational NBN: None required
Satellite television and internet	Services intended for Australian audiences: unlikely to be affected Services intended for international audiences: signals from 12 satellites intercepted at 12 dwellings (2 host landowner dwellings, 10 non-associated dwellings)	No impact expected for Australian services Low likelihood of interference to services intended for international audiences, as signals are unlikely to be used by nearby residents	Consultation with operators not considered necessary Consultation with residents of identified dwellings to be undertaken prior to construction to determine whether potentially affected services are being used (and may therefore be subject to interference)	Mitigation is unlikely to be required; if there are material impacts, the Proponent will apply appropriate mitigation in consultation with the relevant landowner once the Project is operational
Radio broadcasting	AM and FM signals: may experience interference in close proximity to WTGs (within several tens of metres) Digital radio signals: Project Area is outside the intended service area	Low likelihood of interference to AM and FM signals, as receivers are unlikely to be located sufficiently close to WTGs	Consultation not considered necessary	AM and FM signals: Mitigation is unlikely to be required; if there are material impacts, the Proponent will apply appropriate mitigation in consultation with the relevant landowner once the Project is operational Digital radio signals: None required

Table 13 Summary of EMI assessment results for the Project (continued)

Licence or service type	Assessment findings	Expected impact	Stakeholder consultation	Mitigation
Television broadcasting	Digital signals: may experience interference in areas with poor or marginal reception			
	Armidale tower: 'poor' to 'variable' coverage across Project Area and in south and west, 'variable' to 'good' coverage in north and east 11 dwellings (1 host landowner dwelling, 8 associated dwellings, 2 non-associated dwellings) in potential interference zone	Low likelihood of interference at identified dwellings, as dwellings may not currently be receiving signals	DNV has contacted BAI Communications to confirm likely impacts and identify suitable options to avoid any potential impacts No response has been received to date	The Proponent will undertake pre-construction measurements of signal strength at selected dwellings within 3 km of the Project Area to enable any interference after construction to be investigated
	Upper Namoi tower: 'variable' coverage across Project Area and surroundings 17 dwellings (5 host landowner dwellings, 12 non-associated dwellings) in potential interference zone	Likely to cause interference at some identified dwellings, as dwellings may currently be receiving a weak signal	DNV has contacted BAI Communications to confirm likely impacts and identify suitable options to avoid any potential impacts No response has been received to date	If there are material impacts, the Proponent will apply appropriate mitigation in consultation with the relevant operator or landowner once the Project is operational

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APPENDIX A – STAKEHOLDER CONSULTATION RECORDS

Table A.1 Summary of service operators contacted by DNV and responses received to date

	Licence/service type	Distance of closest site	Operator name and DNV reference	Consultation status and response received to date
1	Fixed point-to-point	8 km No turbines in point-to-point diffraction exclusion zones established by DNV	Digital Distribution Australia Pty Limited (Digital Distribution) 10296588-AUME-L-01	Consultation letter sent No response received to date
2	Fixed point-to-point Emergency service	5 km No turbines in point-to-point diffraction exclusion zones established by DNV	New South Wales Government Telecommunications Authority (NSW Telco Authority) 10296588-AUME-L-02	Consultation letter sent No response received to date
3	Fixed point-to-point	10 km No turbines in point-to-point diffraction exclusion zones established by DNV	NSW Electricity Networks Operations Pty Limited (TransGrid) 10296588-AUME-L-03	Consultation letter sent No response received to date
4	Fixed point-to-point PMTS/spectrum (mobile phone)	3 km from nearest turbine No turbines in point-to-point diffraction exclusion zones established by DNV	Optus Mobile Pty Limited (Optus) 10296588-AUME-L-04	Partial response received by email on 14 February 2022: *"There are no concerns from Optus in regard to nearby P2P microwave [links]."*
5	Fixed point-to-point PMTS/spectrum (mobile phone)	3 km from nearest turbine No turbines in point-to-point diffraction exclusion zones established by DNV	Vodafone Australia Pty Limited (Vodafone) 10296588-AUME-L-05	Consultation letter sent No response received to date
6	Fixed point-to-multipoint Meteorological radar	Point-to-multipoint: 40 km Meteorological radar: 105 km	Bureau of Meteorology (BoM) 10296588-AUME-L-06	Consultation letter sent No response received to date

Table A.1 Summary of service operators contacted by DNV and responses received to date (continued)

	Licence/service type	Distance of closest site	Operator name and DNV reference	Consultation status and response received to date
7	Fixed point-to-multipoint	44 km	Essential Energy 10296588-AUME-L-07	Consultation letter sent No response received to date
8	Fixed point-to-multipoint	35 km	Tamworth Regional Council 10296588-AUME-L-08	Attempting to make initial contact
9	Fixed point-to-multipoint	21 km	Water NSW 10296588-AUME-L-09	Consultation letter sent No response received to date
10	Emergency service	16 km	Ambulance Service of NSW (NSW Ambulance) 10296588-AUME-L-10	Attempting to make initial contact
11	Emergency service	44 km	Guyra Volunteer Rescue Association (Guyra VRA) 10296588-AUME-L-11	Attempting to make initial contact
12	Emergency service	52 km	Hunter Region SLSA Helicopter Rescue Service 10296588-AUME-L-12	Attempting to make initial contact
13	Emergency service	16 km	NSW Police Force 10296588-AUME-L-13	Consultation letter sent No response received to date
14	Emergency service	5 km	NSW Rural Fire Service 10296588-AUME-L-14	Consultation letter sent No response received to date
15	Emergency service	33 km	NSW Volunteer Rescue Association Inc (VRA Rescue NSW) 10296588-AUME-L-15	Consultation letter sent No response received to date

Table A.1 Summary of service operators contacted by DNV and responses received to date (continued)

	Licence/service type	Distance of closest site	Operator name and DNV reference	Consultation status and response received to date
16	Emergency service	37 km	St John Ambulance Australia 10296588-AUME-L-16	Attempting to make initial contact
17	Emergency service	33 km	State Emergency Service (NSW) (NSW State Emergency Service) 10296588-AUME-L-17	Attempting to make initial contact
18	Trigonometrical stations Global Navigational Satellite System (GNSS) stations	3 km from nearest turbine	Geoscience Australia 10296588-AUME-L-18	Consultation letter sent No response received to date
19	Trigonometrical stations Global Navigational Satellite System (GNSS) stations	3 km from nearest turbine	NSW Spatial Services 10296588-AUME-L-19	Consultation letter sent No response received to date
20	PMTS/spectrum (mobile phone)	3 km from nearest turbine	Telstra Corporation Limited (Telstra) 10296588-AUME-L-20	Consultation letter sent No response received to date
21	Wireless internet	27 km	Pivotel Mobile Pty Limited (Pivotel Mobile) 10296588-AUME-L-23	Attempting to make initial contact
22	Wireless internet	21 km	TPG Internet Pty Ltd (TPG Internet) 10296588-AUME-L-24	Attempting to make initial contact

Table A.1 Summary of service operators contacted by DNV and responses received to date (continued)

	Licence/service type	Distance of closest site	Operator name and DNV reference	Consultation status and response received to date
23	Wireless internet	15 km	NBN Co Limited (NBN Co) 10296588-AUME-L-21	Response received by email on 15 February 2022: *"I have reviewed the data provided based on the proposed wind farm location. The proposed wind farm boundary & tower locations do not pose any risk of introducing a physical obstruction to existing nbn wireless customer RF Path Profiles or to any boresight paths of existing nbn microwave links.* *A standard nbn response for wind farm applications regarding potential interference impact on the nbn Fixed Wireless network is as follows:* *Potential Impacts of the Proposed Thunderbolt Energy Hub Stage 1 Wind Farm on NBN Co Spectrum Communication Assets* *Referring to your letter dated 14th February 2022 regarding the application for the Thunderbolt Energy Hub Stage 1 Wind Farm.* *We confirm that NBN Co Spectrum Pty Ltd (nbn Spectrum) has a number of spectrum licences within 75 km of the proposed Thunderbolt Energy Hub Stage 1 Wind Farm.* *nbn have strict obligations to provide internet services to the community, and this area has been determined as a FW service area where the footprint of this service is now in place.* *nbn will be forced to consider its position as part of the planning should there be an interference issue.* *If the Application is amended before it is lodged we request that we are sent any amended Application so we can determine whether we have any objection to the amended Application.* *We note that, as you would be aware, under section 197 of the Radiocommunications Act 1992 (Cth) it is an offence to knowingly or recklessly do anything likely to interfere substantially with radiocommunications or otherwise substantially disrupt or disturb radiocommunications."*

Table A.1 Summary of service operators contacted by DNV and responses received to date (continued)

	Licence/service type	Distance of closest site	Operator name and DNV reference	Consultation status and response received to date
24	Television broadcasting	34 km	BAI Communications 10296588-AUME-L-22	Consultation letter sent No response received to date

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

B.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 WTGs.

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

- the proximity of WTGs to the television broadcast tower
- the proximity of WTGs to receivers (dwellings)
- the location of WTGs 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.

B.2 Forward and back scatter of DTV signals

WTGs 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 WTG has the potential to scatter electromagnetic waves carrying DTV signals both forward and back.

Forward scatter can occur when the transmitter, one or more WTGs, 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 WTG, 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.

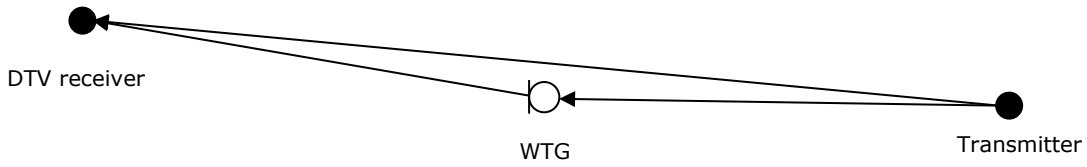

Figure B.1 Forward scatter signal path for DTV signals

Back scatter from WTGs occurs when DTV signals are reflected from WTG 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-WTG-receiver).

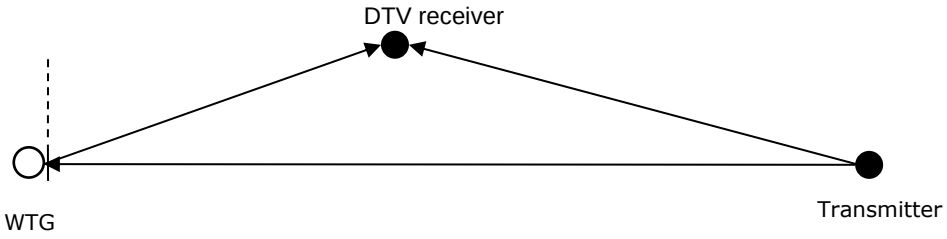

Figure B.2 Back scatter signal path for DTV signals

Interference to DTV signals from WTGs can potentially occur in both the forward and backward scatter region. The effect of a WTG 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, 55]. Interference may extend beyond 5 km if the dwellings are screened from the broadcast transmitter, but do have line-of-sight to the WTGs [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.

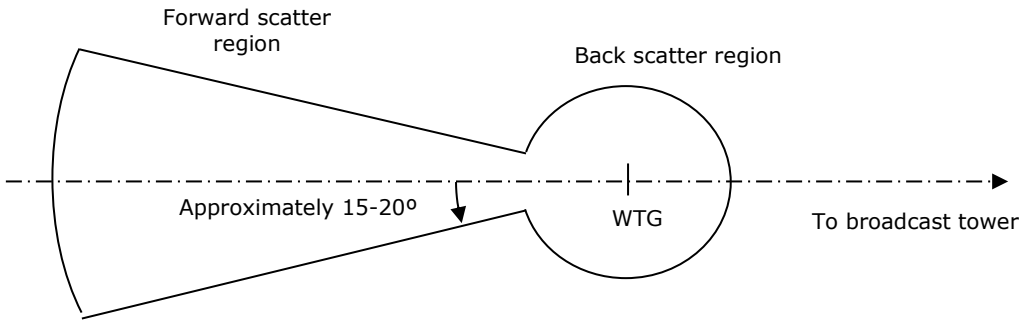

Figure B.3 Potential television interference zones around a WTG

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 [56] 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, WTGs 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 WTGs, 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 WTGs, which effectively means that interference is more likely to occur as coverage quality decreases.

B.3 Theoretical models for WTG 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 [57]. 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 [56], 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 WTG 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 WTG location [38]. The combination of these areas forms a region where there is an increased likelihood of interference to television signals occurring.

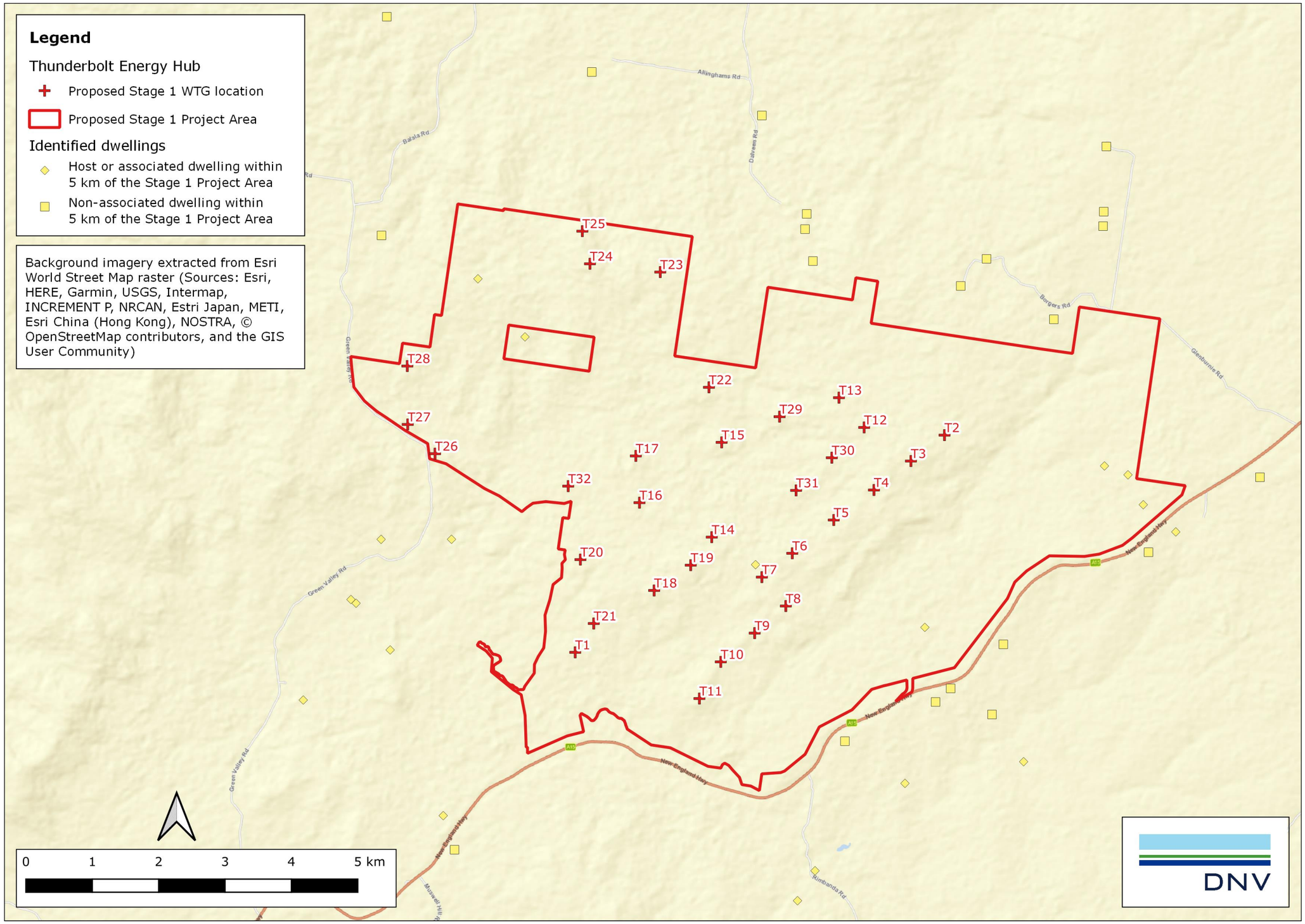

Figure 9 Map of the Project Area, proposed WTG locations, and locations of nearby dwellings

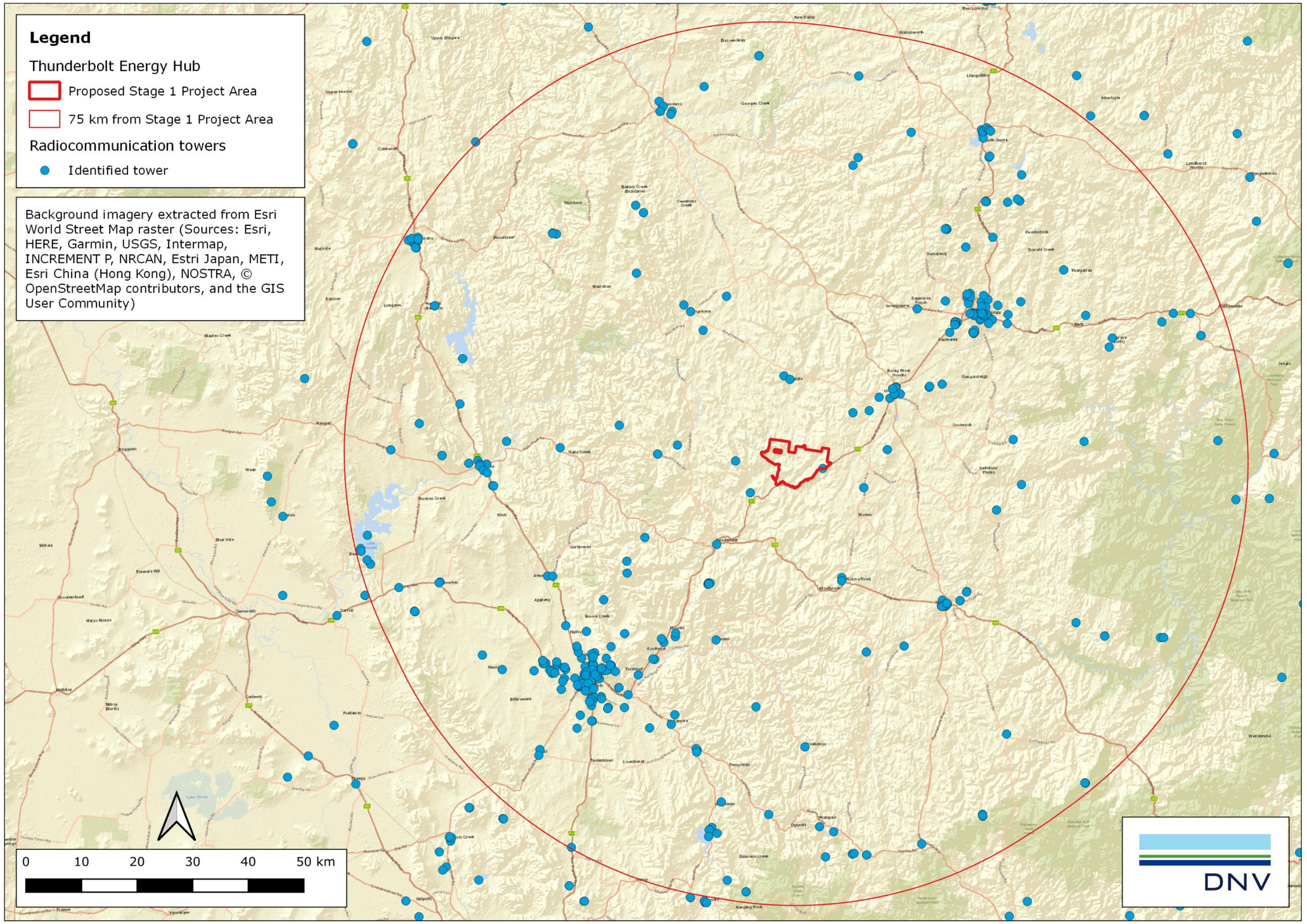

Figure 10 Location of the Project Area and identified nearby radiocommunication sites

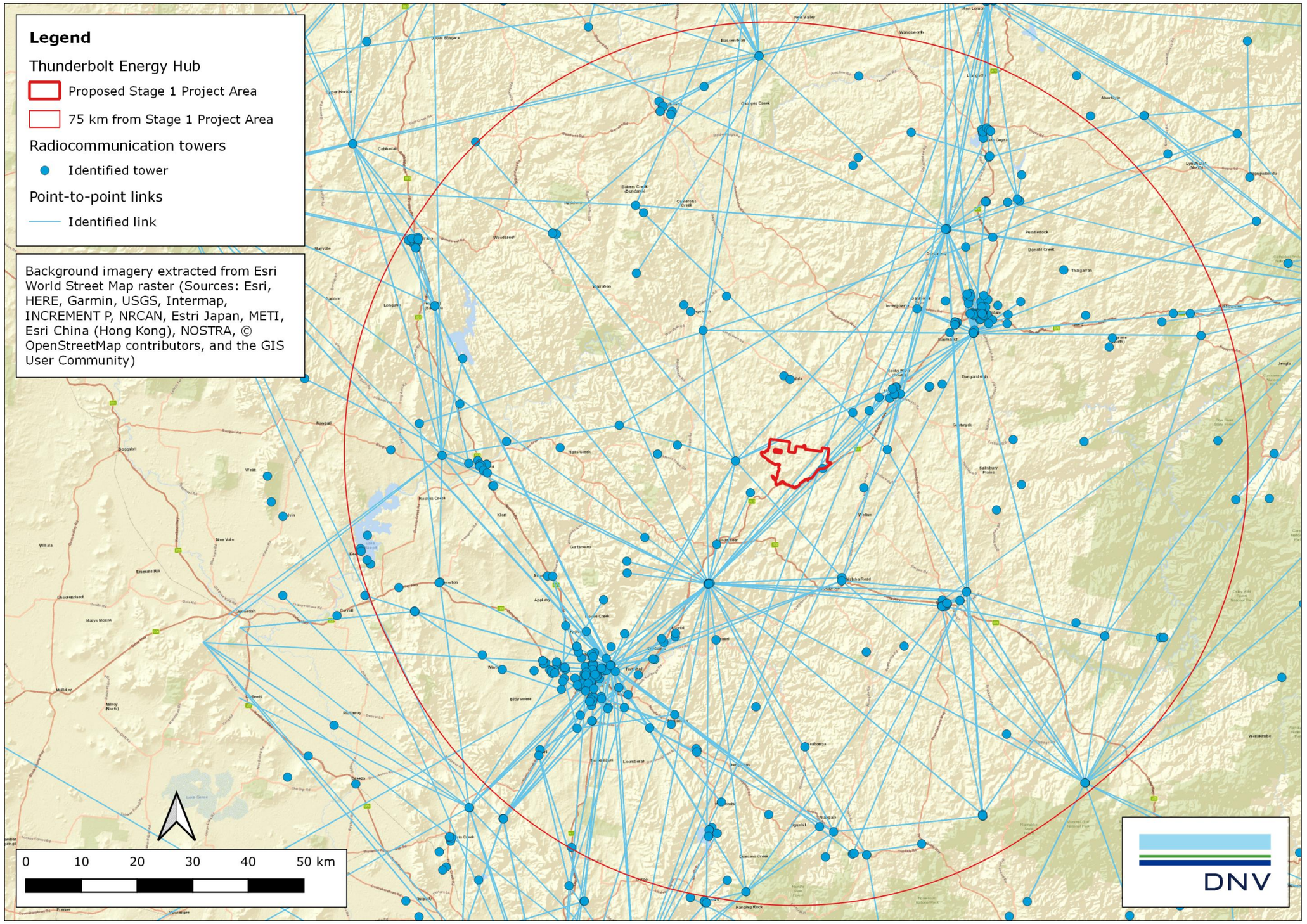

Figure 11 Identified transmission vectors for fixed point-to-point licences in the vicinity of the Project Area

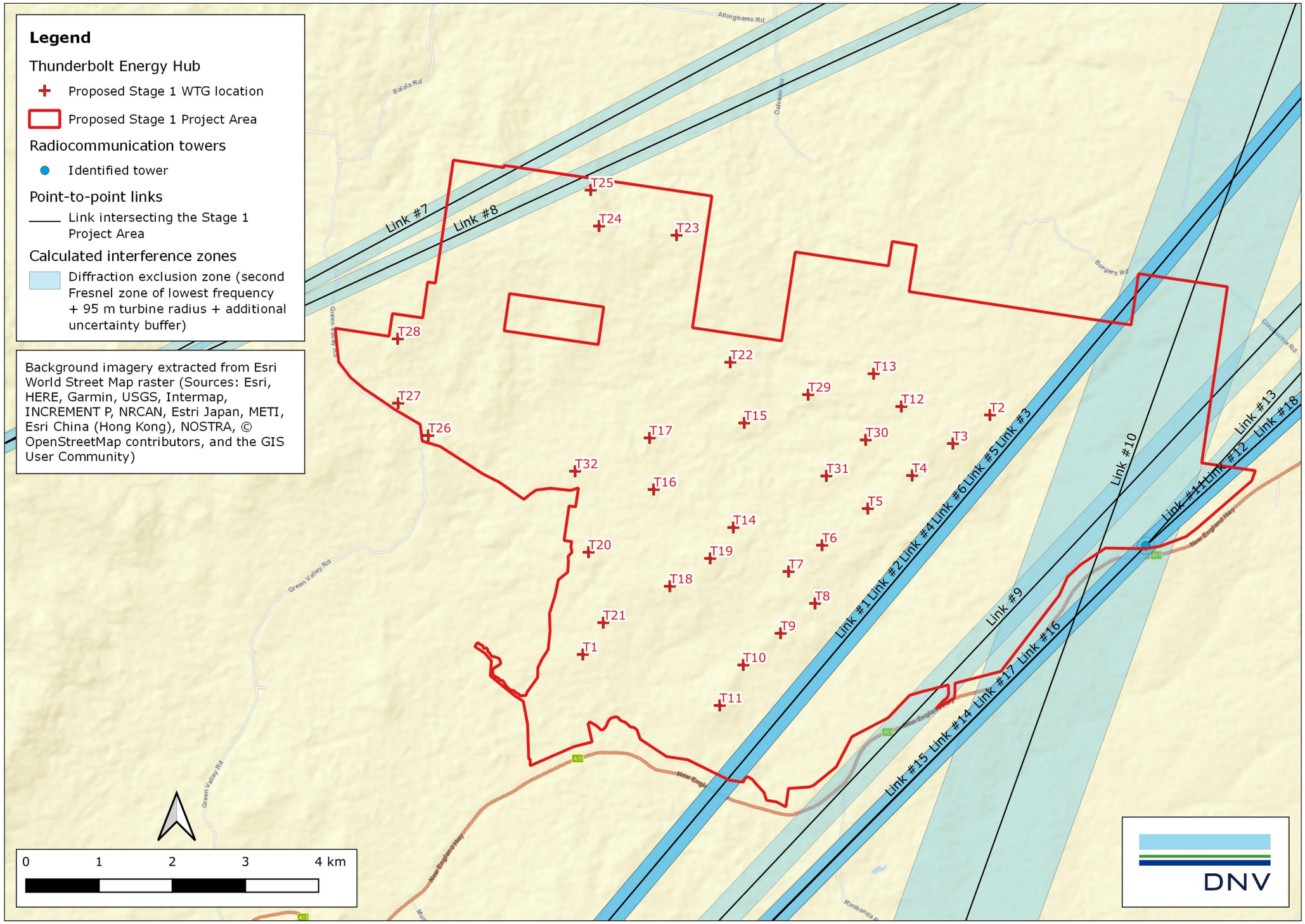

Figure 12 Identified point-to-point radiocommunication vectors crossing the Project Area and calculated interference zones

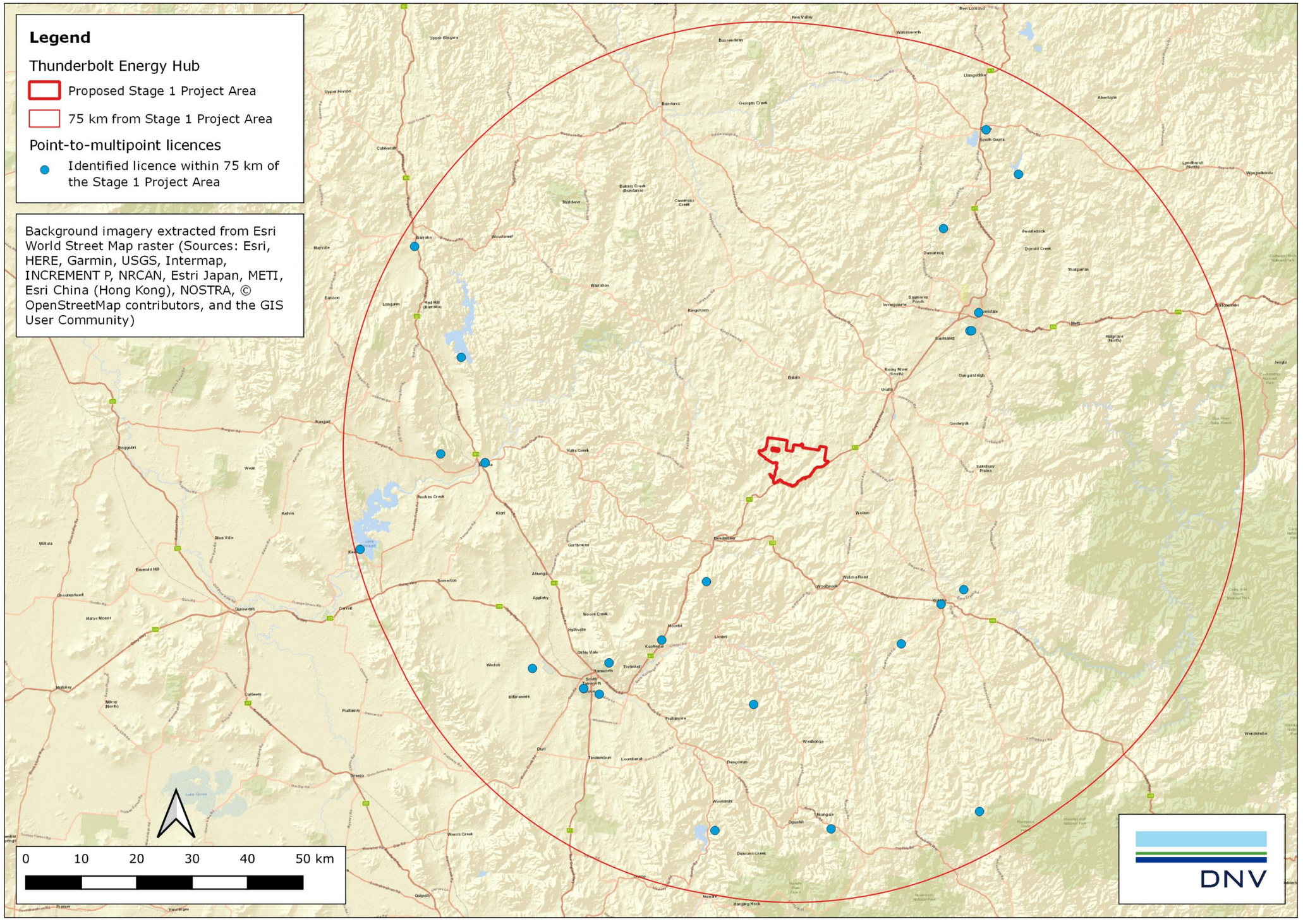

Figure 13 Location of point-to-multipoint licences in the vicinity of the Project Area

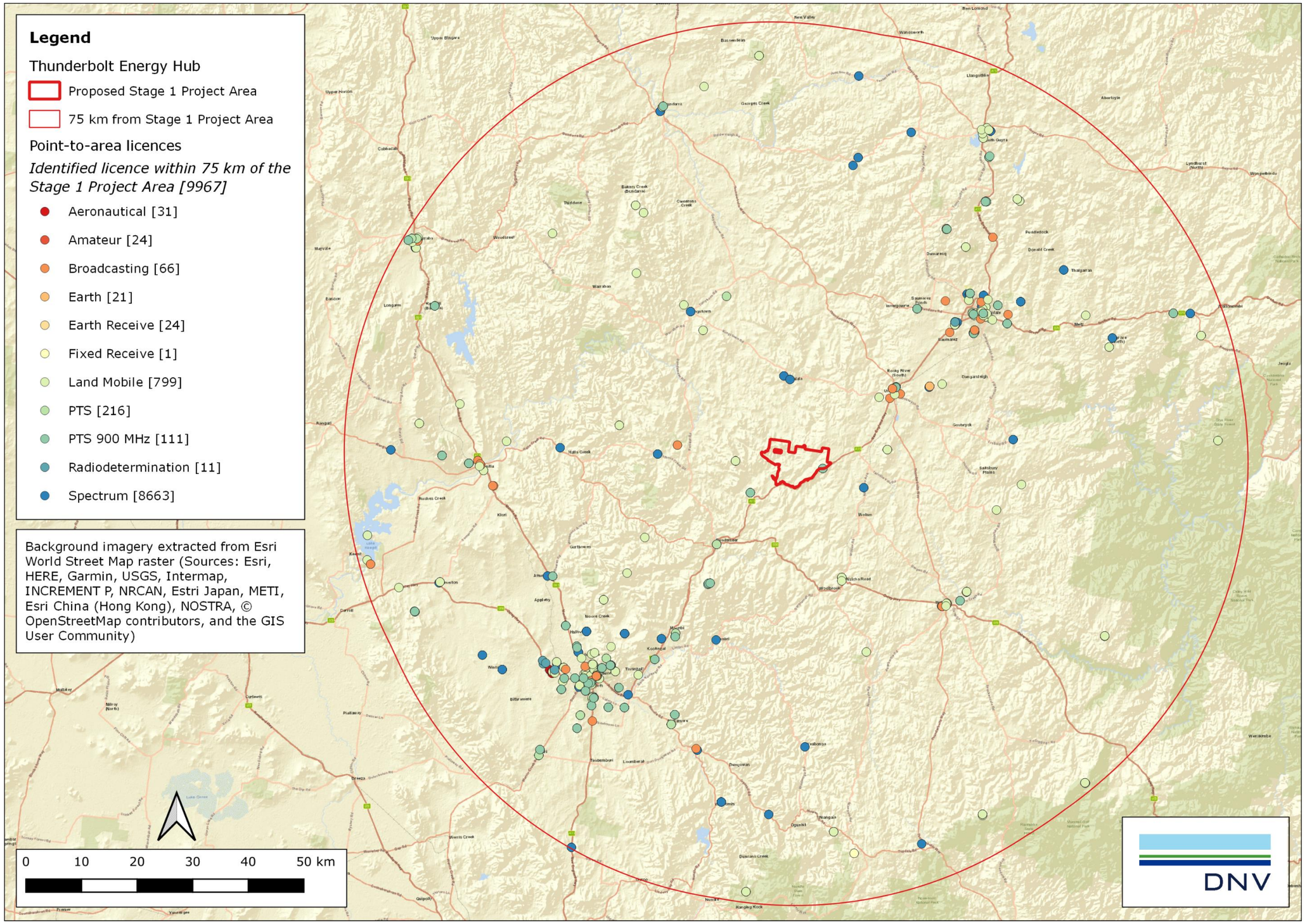

Figure 14 Location of general point-to-area style licences within 75km of the Project Area

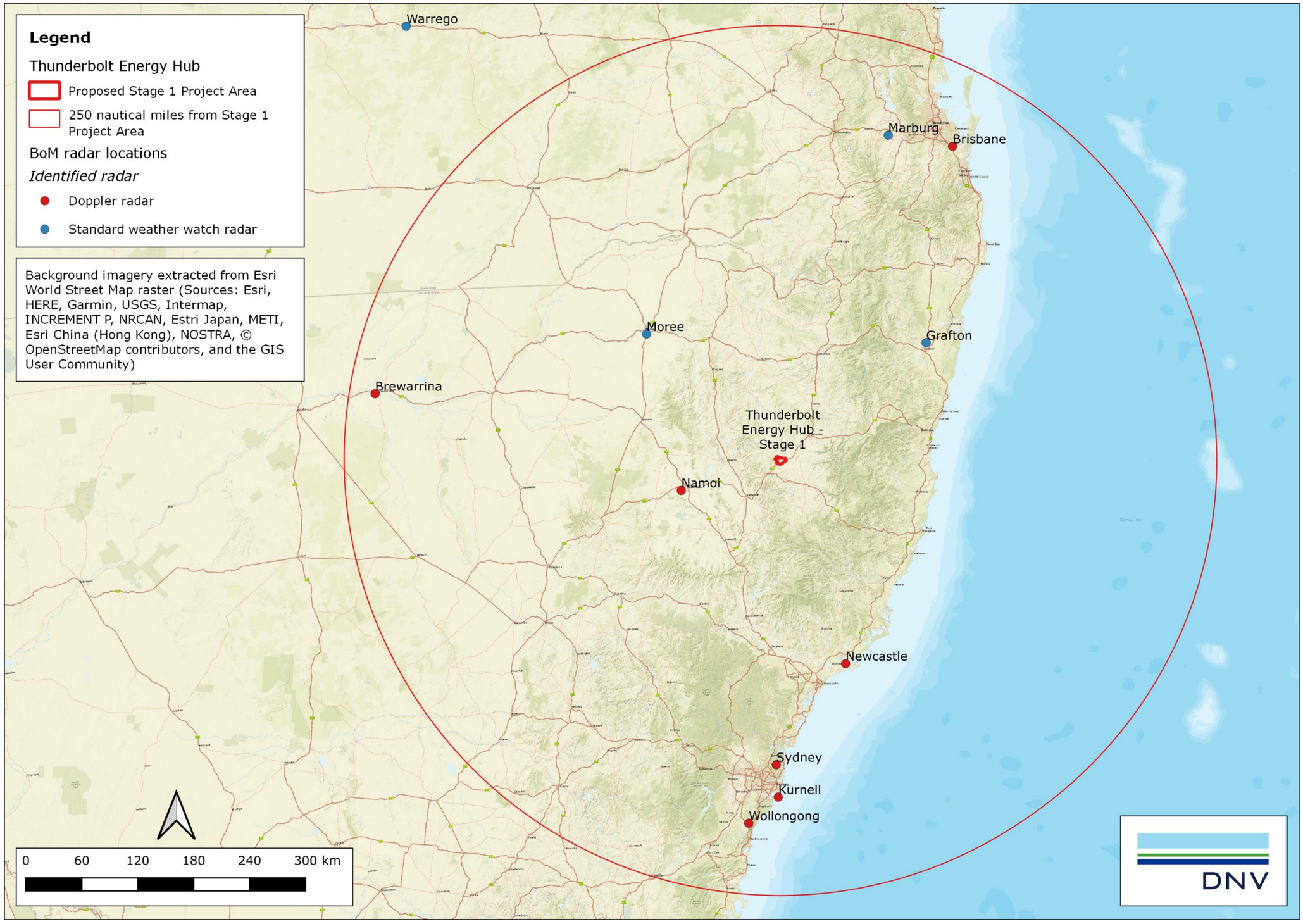

Figure 15 Location of meteorological radar sites within 250 nautical miles of the Project Area

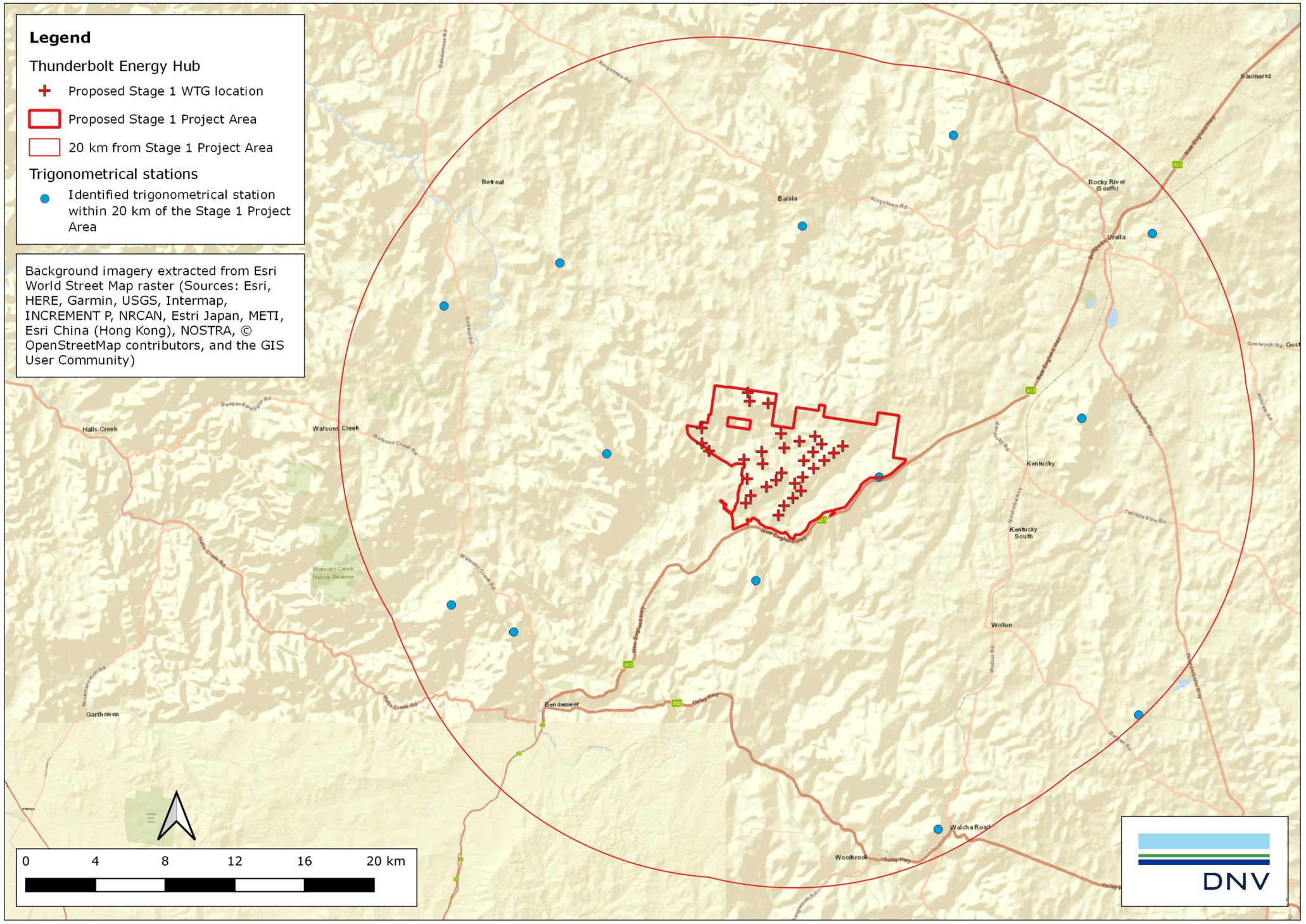

Figure 16 Location of trigonometrical stations within 20 km of the Project Area

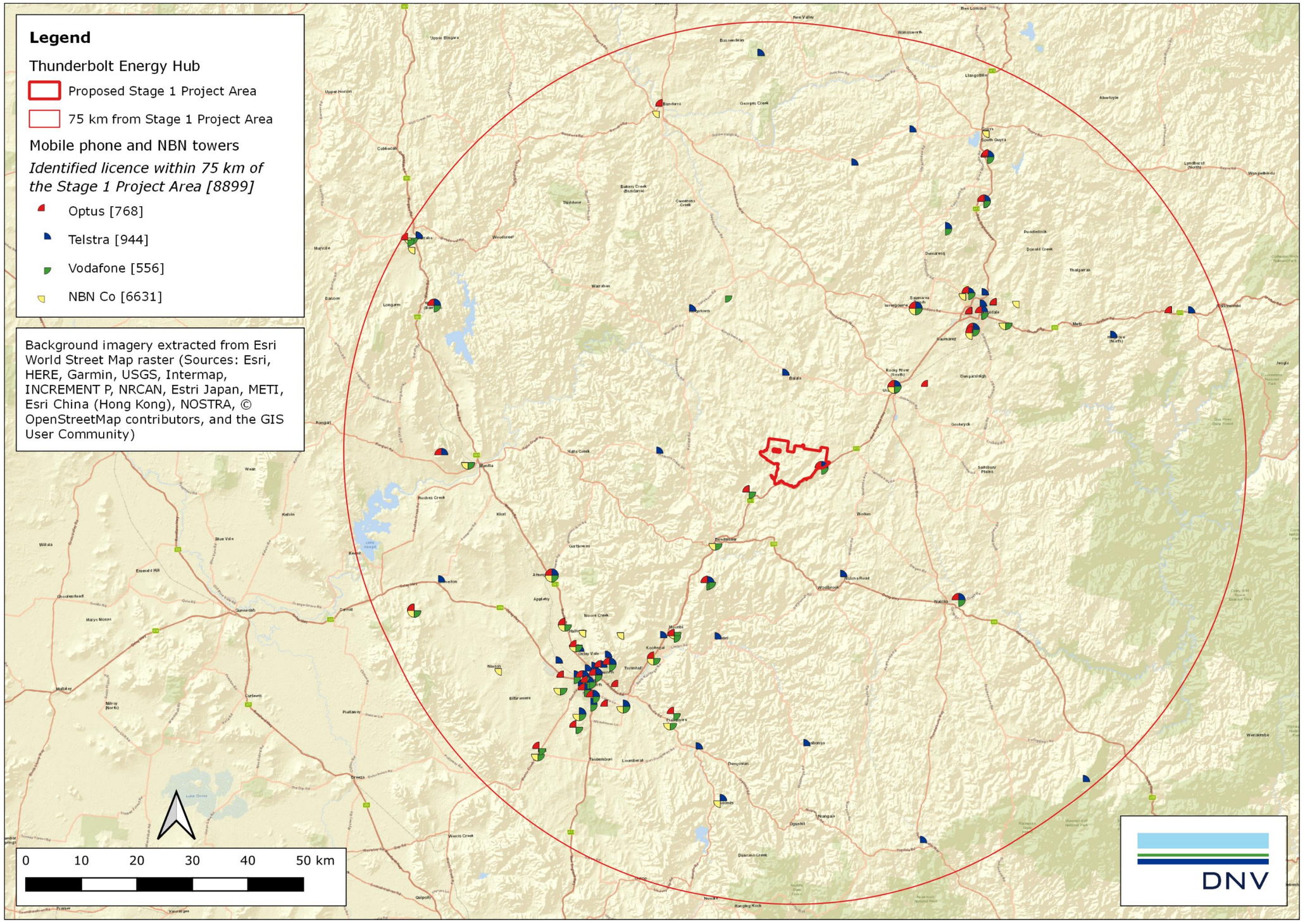

Figure 17 Location of mobile phone and NBN towers within 75 km of the Project Area

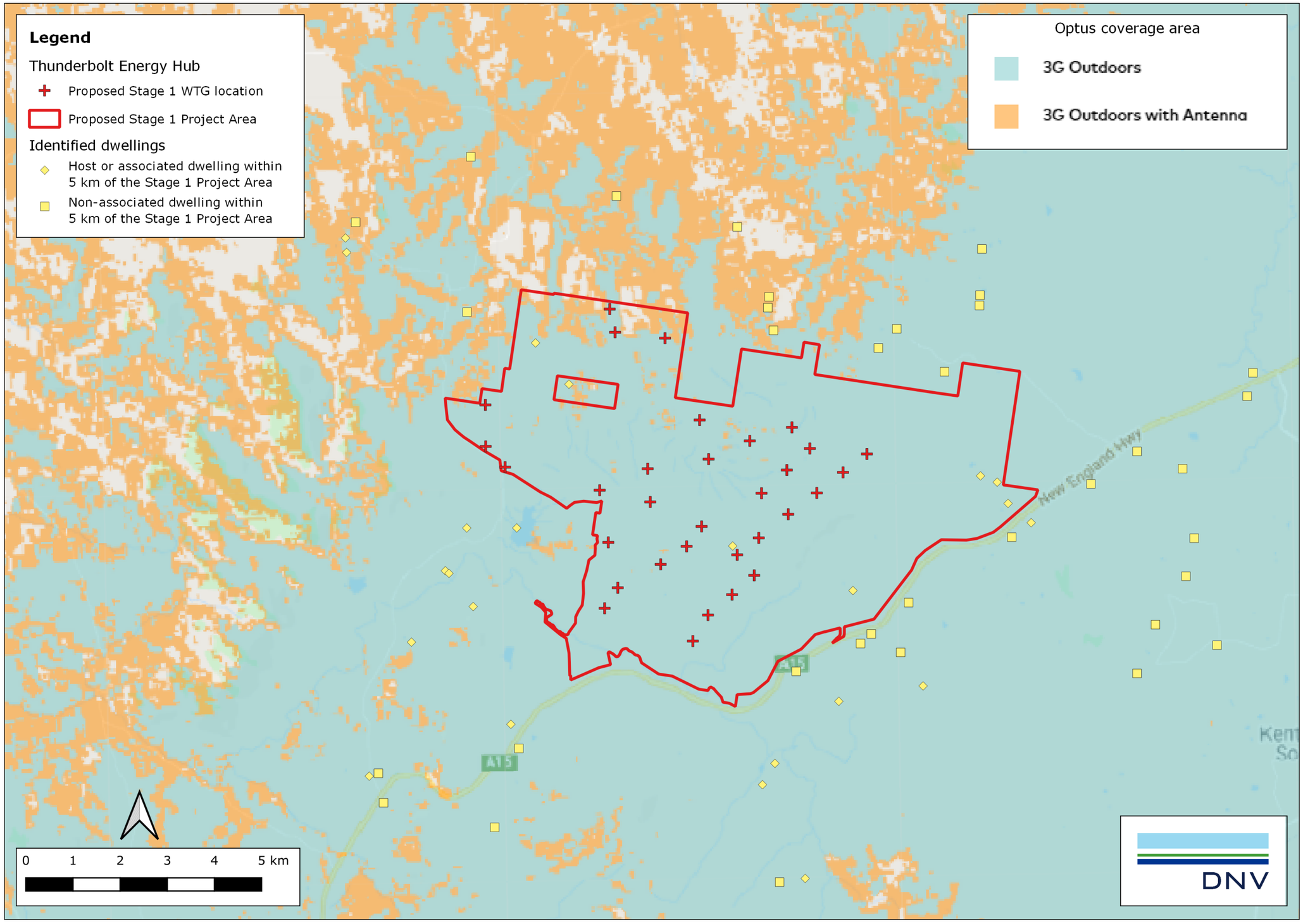

Figure 18 Optus Mobile 3G network coverage for the Project Area

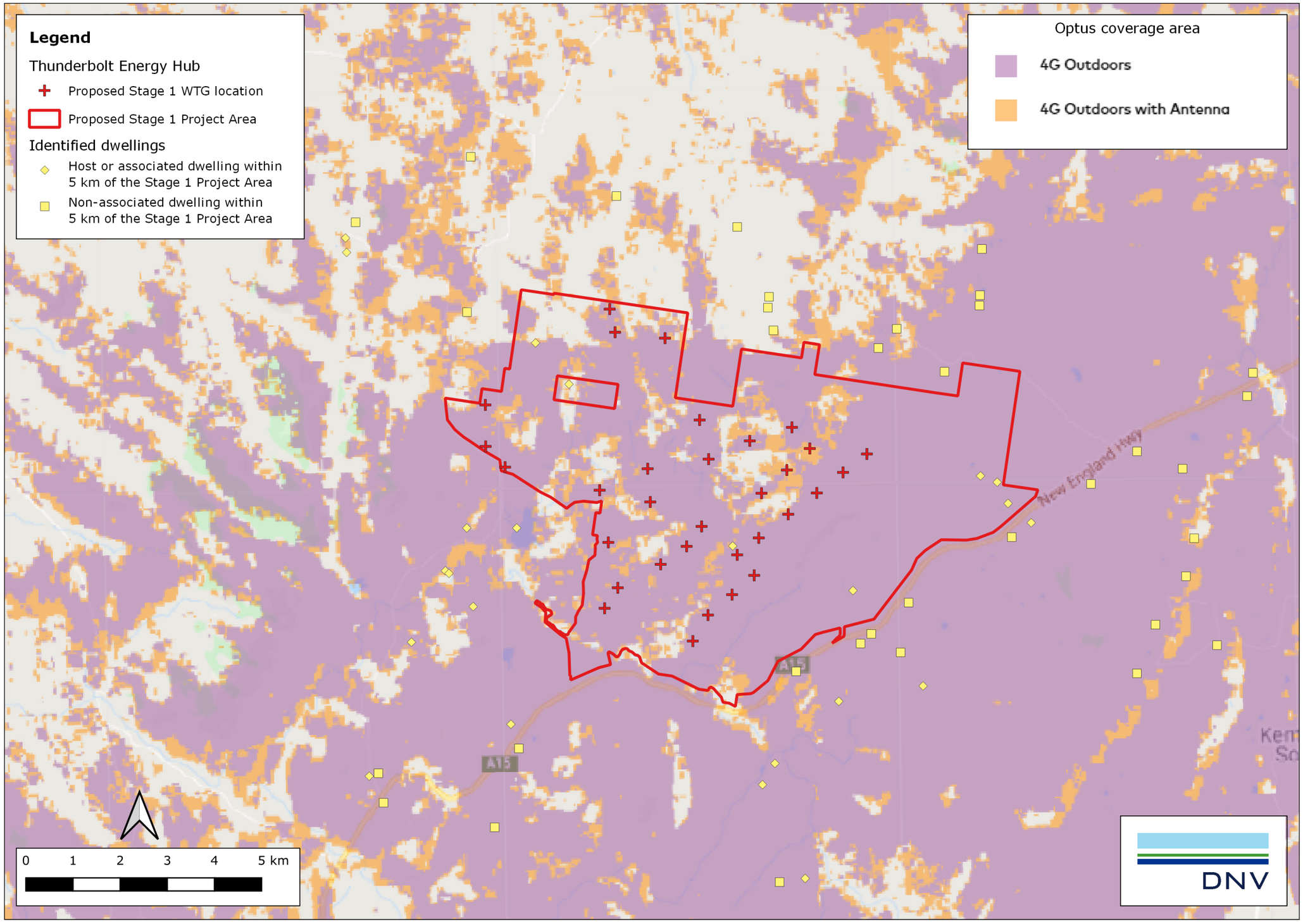

Figure 19 Optus Mobile 4G network coverage for the Project Area

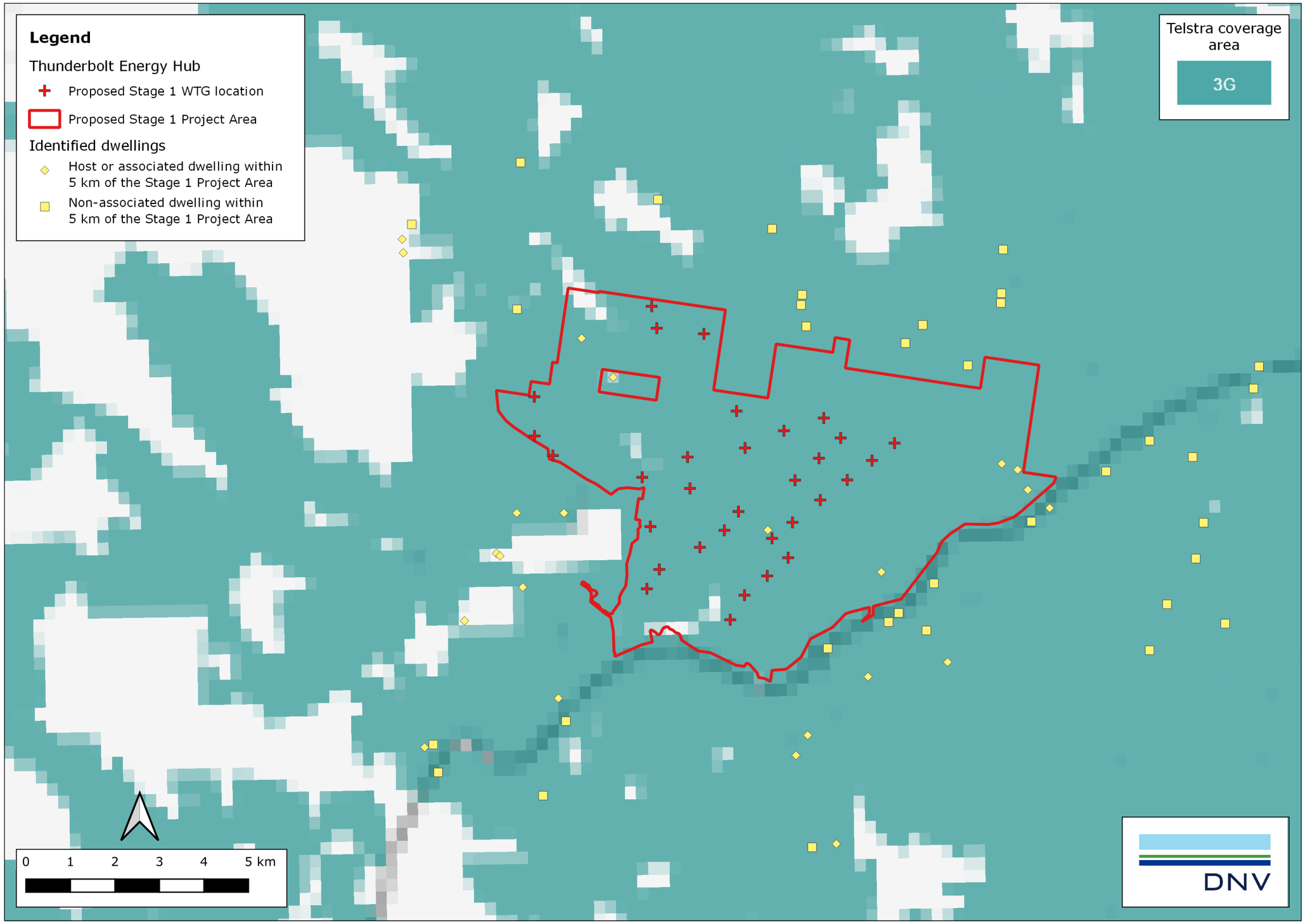

Figure 20 Telstra 3G network coverage for the Project Area

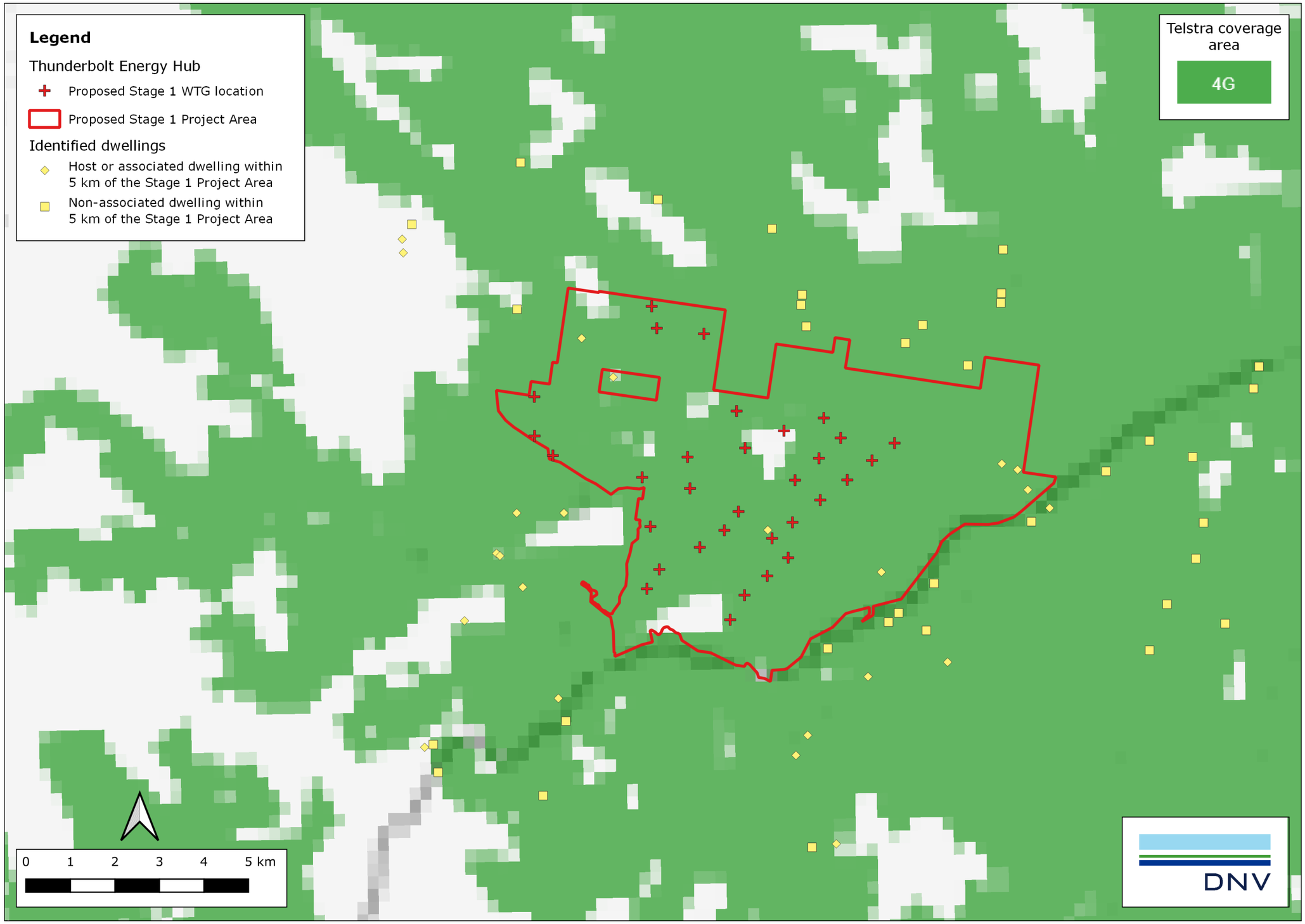

Figure 21 Telstra 4G network coverage for the Project Area

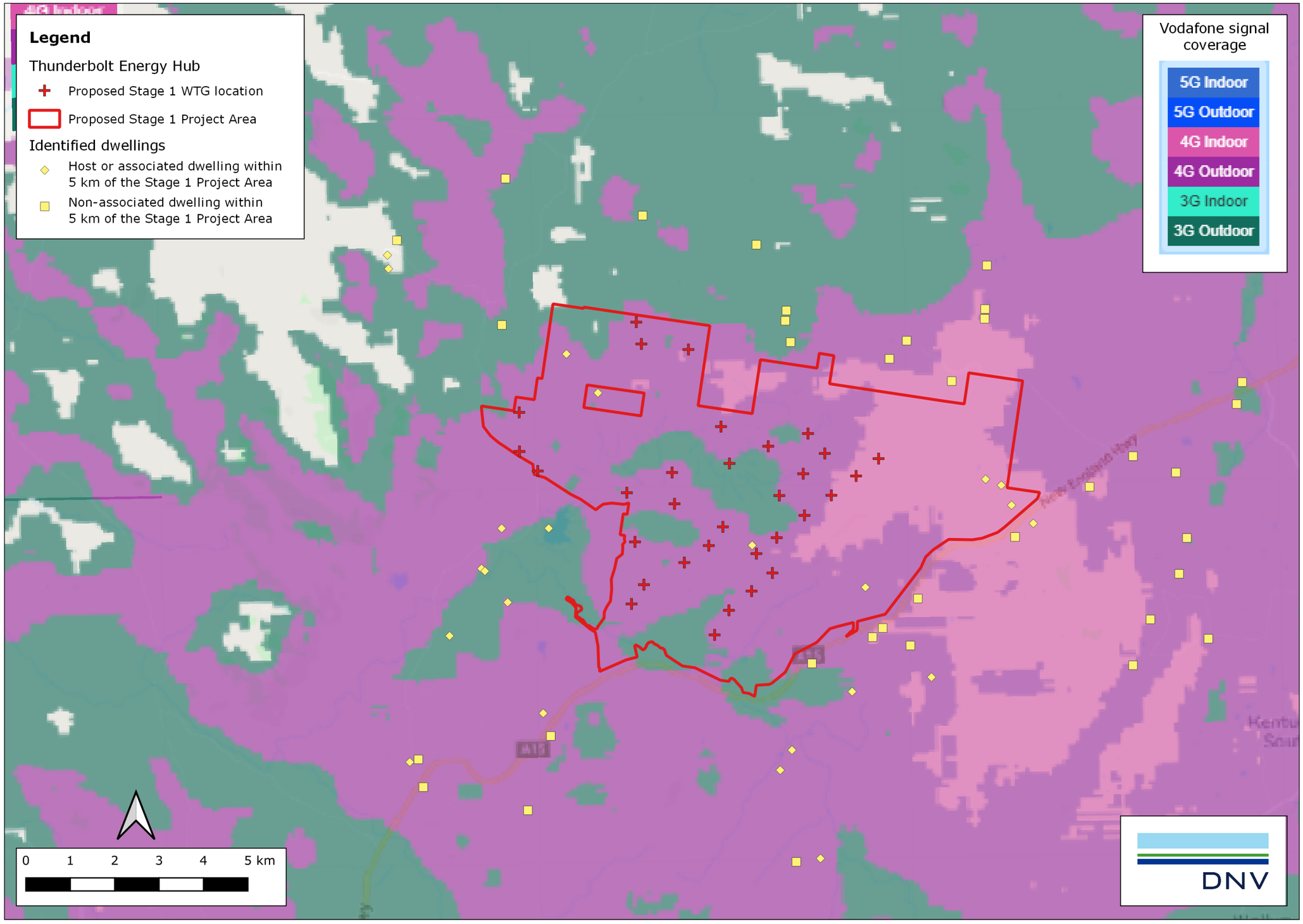

Figure 22 Vodafone network coverage (Apple iPhone 12 handset) for the Project Area

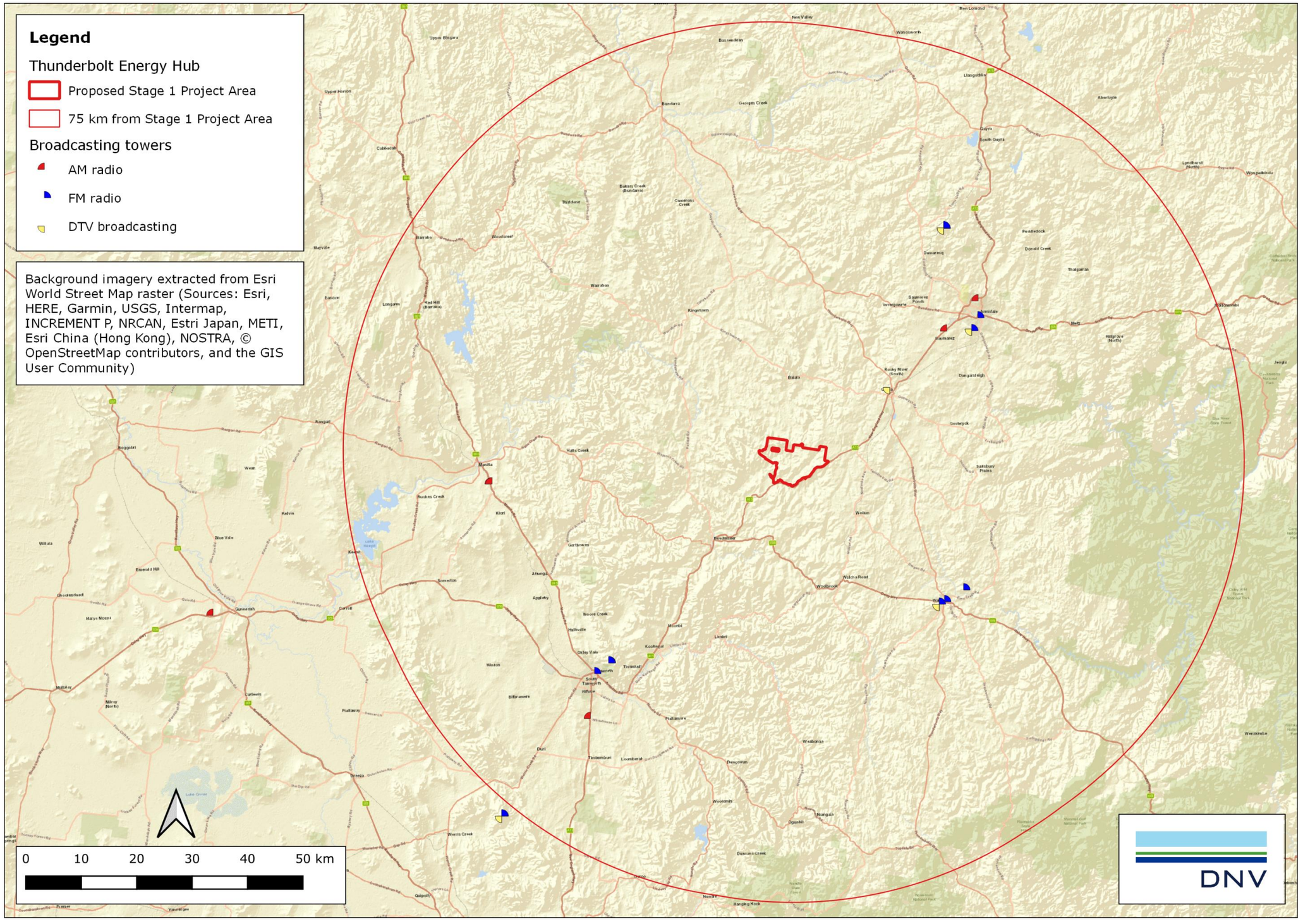

Figure 23 Location of broadcast transmitters in the vicinity of the Project Area

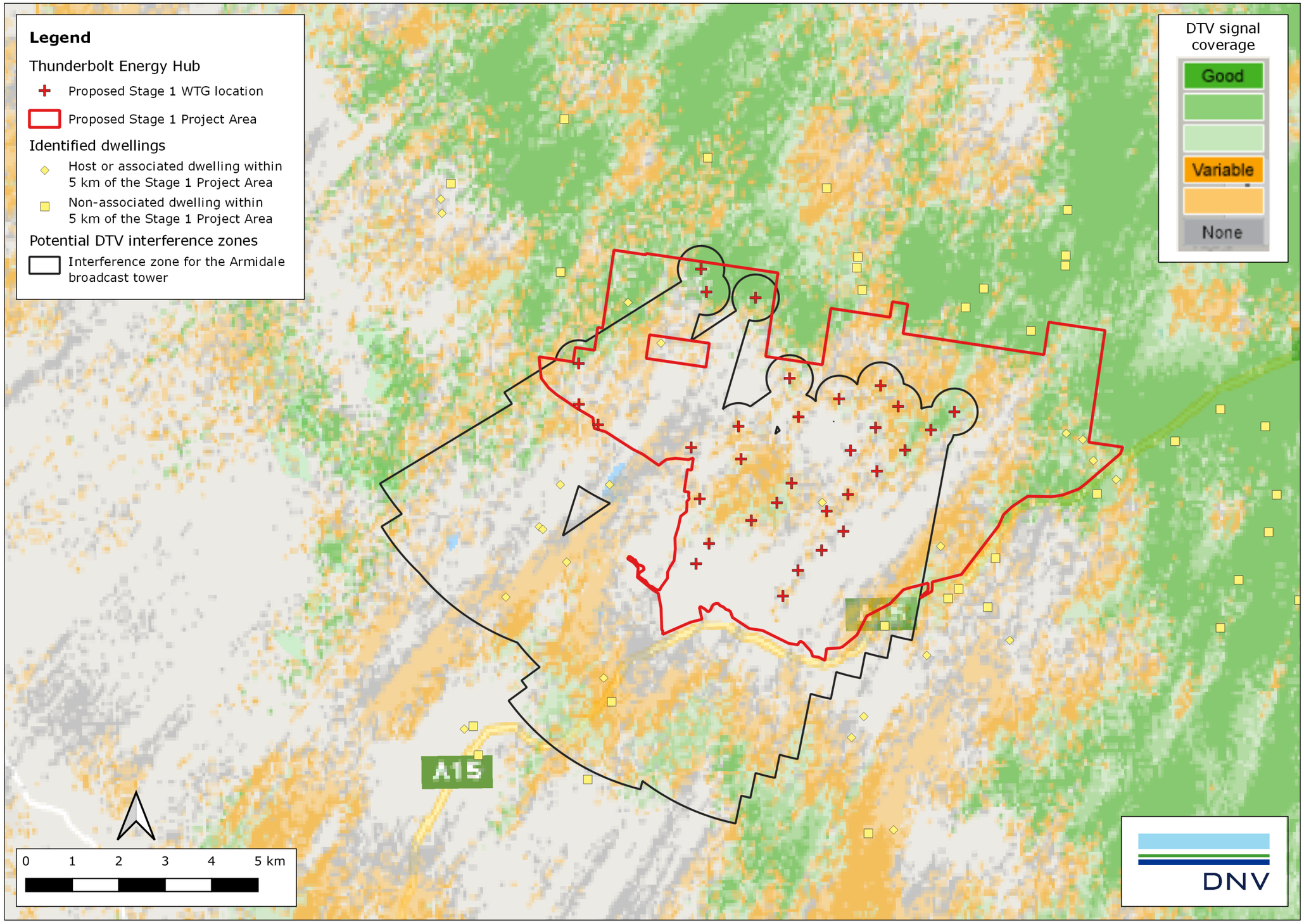

Figure 24 Potential television EMI zones for the Armidale broadcast tower from the proposed WTGs

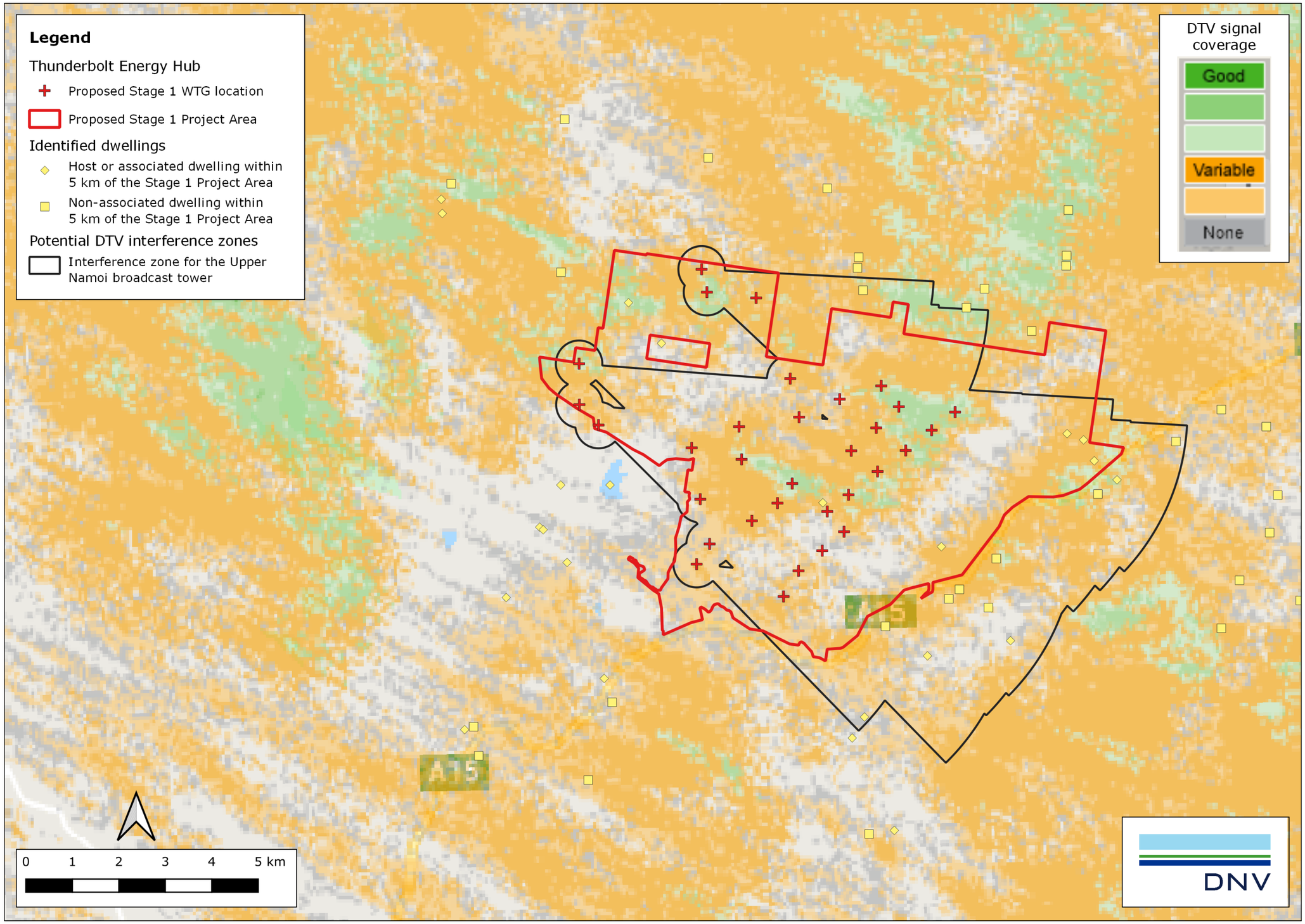

Figure 25 Potential television EMI zones for the Upper Namoi broadcast tower from the proposed WTGs

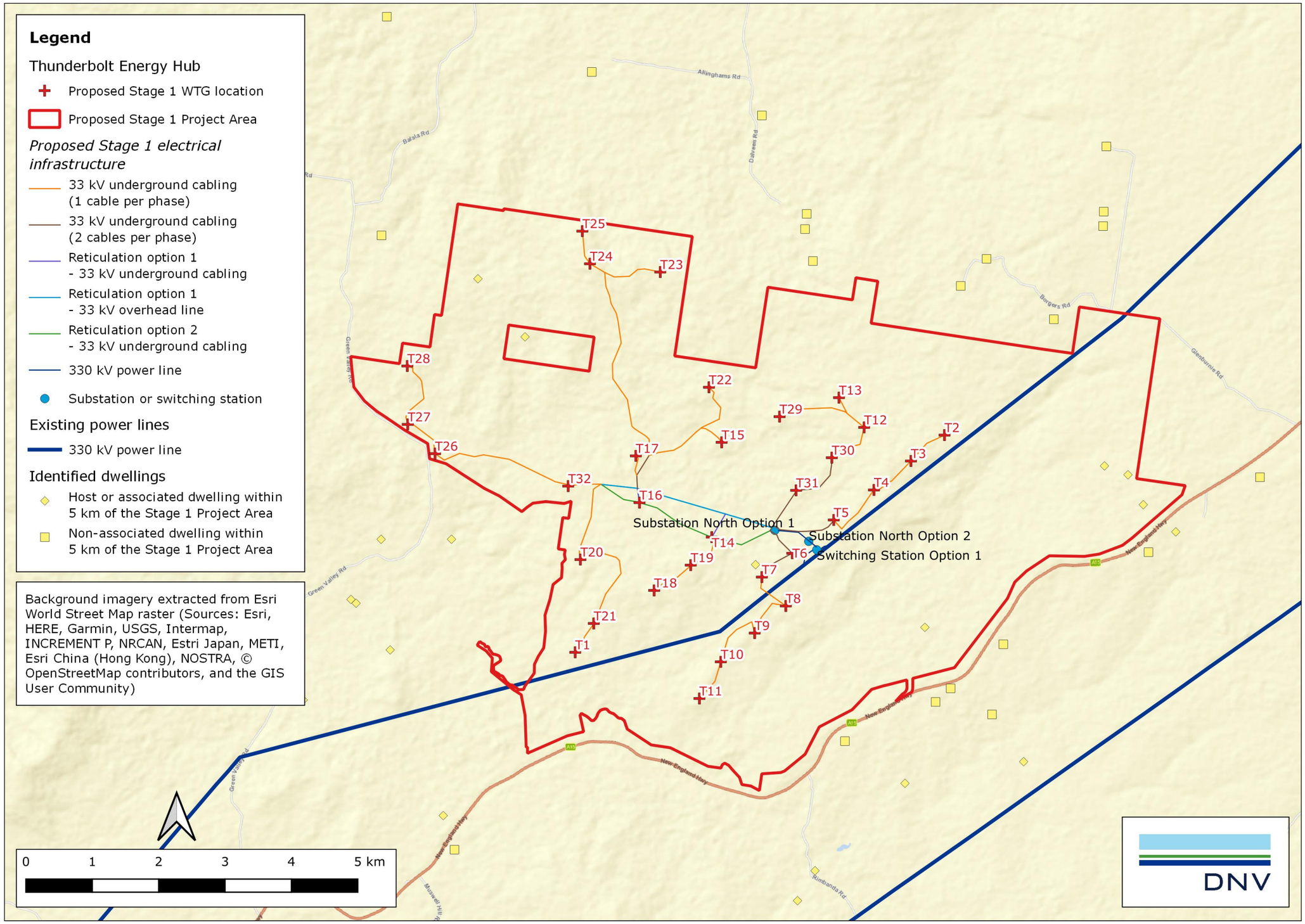

Figure 26 Map of the Project Area and proposed electrical infrastructure

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.