APPENDIX 15

Preliminary Hazard Analysis

Riskcon engineering

Preliminary Hazard Analysis

Wattle Creek Battery Energy Storage System Project – SSD-63345458

Spark Renewables Pty Ltd
Document No. RCE-24004_Umwelt_PHA_Final_11Mar25_Rev(3)
Date 11/03/2025

Preliminary Hazard Analysis

Wattle Creek Battery Energy Storage System Project – SSD-63345458

Spark Renewables Pty Ltd

Prepared by

Riskcon Engineering Pty Ltd
37 Pogson Drive
Cherrybrook NSW 2126
www.riskcon-eng.com
ABN 74 626 753 820

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Quality Management

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Executive Summary

Background

Spark Renewables propose to develop the Wattle Creek Battery Energy Storage System (BESS) Project (the Project) to provide a reliable and affordable source of energy for the people of NSW and contribute to reducing greenhouse gas (GHG) emissions associated with energy generation and to enhance national energy security. The Project Area is located on Arthursleigh Farm (Lot 3 of DP 1120270), approximately 80 kilometres (km) west of Wollongong and 15 km northwest of Marulan.

The Project includes a BESS with 350 MW capacity (AC or DC coupled), and project-related infrastructure.

The Secretary's Environmental Assessment Requirements (SEARs) require the risks associated with the Project to be assessed in the form of a Preliminary Hazard Analysis (PHA) and Dangerous Goods preliminary risk screening.

The Project is State Significant Development (SSD), requiring development consent under Part 4, Division 4.7 of the *Environmental Planning and Assessment Act 1979*.

Conclusions

A hazard identification table was developed for the Project to identify potential hazards that may be present at the site as a result of operations or storage of materials. Based on the identified hazards, scenarios were postulated that may result in an incident with the potential for offsite impacts. Postulated scenarios were discussed qualitatively and any scenarios that would not impact offsite were eliminated from further assessment. Scenarios not eliminated were then carried forward for consequence analysis.

A review of all possible incidents associated with the Project indicates that there were no observed offsite impacts; therefore, based on the analysis conducted, it is concluded that the risks at the site boundary are not considered to exceed the acceptable risk criteria; hence, the project would only be classified as potentially hazardous and would be permitted within the current land zoning for the site.

Recommendations

The following recommendations have been made as a result of the assessment:

- BESS must be tested in accordance with UL9540A.
- Testing to demonstrate clearances required to prevent propagation of fires between separated units.
- BESS to be installed in accordance with manufacturer and UL9540A report recommended clearances based on testing.
- BESS to be installed with fire protection systems specified by the manufacturer and UL9540A report.
- Before construction, detailed design to validate the system can be installed in the project area whilst meeting the recommended clearances.
- UL testing information shall be made available to the certifying authority. It is noted that a confidentiality agreement may be required.

- The vent covers of the BESS shall be constructed of non-combustible material.
- The vents shall not be located above battery packs within the BESS container.

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Abbreviations

Abbreviation	Description
AC	Alternating Current
ADG	Australian Dangerous Goods Code
AS	Australian Standard
BESS	Battery Energy Storage System
DC	Direct Current
DGs	Dangerous Goods
EIS	Environmental Impact Statement
ELF	Extra Low Frequency
EMF	Electric and Magnetic Field
ERPG	Emergency Response Planning Guideline
FCAS	Frequency Control Ancillary Services
FHA	Final Hazard Analysis
HF	Hydrogen Fluoride
HIPAP	Hazardous Industry Planning Advisory Paper
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IDLH	Immediately Dangerous to Life and Health
LFP	LiFePO4 (Lithium Iron Phosphate)
MVPS	Medium Voltage Power Station
NMC	Nickel-Manganese-Cobalt
PHA	Preliminary Hazard Analysis
Pmpy	Per million per year
PV	Photovoltaic
REZ	Renewable Energy Zone
SEARs	Secretary’s Environmental Assessment Requirements
SEP	Surface Emissive Power
SEPP	State Environmental Planning Policy
SOC	State of Charge
SSDA	State Significant Development Application
STEL	Short Term Exposure Limit
VBB	Victorian Big Battery

1.0 Introduction

1.1 Background

Spark Renewables propose to develop the Wattle Creek Battery Energy Storage System (BESS) Project (the Project) to provide a reliable and affordable source of energy for the people of NSW and contribute to reducing greenhouse gas (GHG) emissions associated with energy generation and to enhance national energy security. The Project Area is located on Arthursleigh Farm (Lot 3 of DP 1120270), approximately 80 kilometres (km) west of Wollongong and 15 km northwest of Marulan.

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The Project is State Significant Development (SSD), requiring development consent under Part 4, Division 4.7 of the *Environmental Planning and Assessment Act 1979*.

1.2 Objectives

The key objectives of this PHA are to:

- Determine whether SEPP-RH applies to the Project based on the quantity of DGs being stored; and
- Complete the PHA according to the Hazardous Industry Planning Advisory Paper (HIPAP) No. 6 – Hazard Analysis (Ref. [1]);
- Assess the PHA results using the criteria in HIPAP No. 4 – Risk Criteria for Land Use Planning (Ref. [2]); and
- Demonstrate compliance of the site with the relevant codes, standards and regulations (i.e. Planning and Environment Regulation, WHS Regulation, 2017 Ref. [3]).

This PHA has been prepared in accordance with the Secretary's Environmental Assessment Requirements (SSD-63345458, dated 22 December 2023) as listed below.

Requirement	**Report Section**
Project SEARs (SSD-63345458)	
• A preliminary risk screening completed in accordance with the State Environmental Planning Policy (Resilience and Hazards) and applying SEPP 33 (DoP, 2011)	**3.6**
• A preliminary hazard analysis (PHA) prepared in accordance with Hazardous Industry Planning Advisory Paper No.6 – Guideline for Hazard Analysis (DoP, 2011) and Multi-Level Risk Assessment (DoP, 2011). The PHA must consider all recent standards and codes and verify separation distances to on-site and off-site receptors to prevent fire propagation and compliance with Hazardous Industry Advisory Paper No.4, 'Risk Criteria for Land Use Safety Planning (DoP, 2011)	**4.0**
• An assessment of potential hazards and risks including but not limited to assessment of bushfire risk against the RFS *Planning for Bushfire Protection* 2019 electromagnetic fields or the proposed grid connection infrastructure against the *International Commission on Non-Ionizing Radiation Protection (ICNIRP)*	**4.12** (Bushfire report prepared separately, Ref. [4]) **4.13** (EMF report prepared separately, Ref. [5])

1.3 Scope of Services

The scope of work is to complete a preliminary risk screening and PHA study for the Project to address the SEARs.

2.0 Methodology

2.1 Multi-Level Risk Assessment

The Multi-Level Risk Assessment approach (Ref. [6]) published by the NSW Department of Planning, Industry and Environment, has been used as the basis for the study to determine the level of risk assessment required. The approach considered the development in context of its location, the quantity and type (i.e. hazardous nature) of Dangerous Goods (DGs) stored and used, and the project's technical and safety management control. The Multi-Level Risk Assessment Guidelines are intended to assist industry, consultants and the consent authorities to carry out and evaluate risk assessments at an appropriate level for the project being studied.

There are three levels of risk assessment set out in Multi-Level Risk Assessment which may be appropriate for a PHA, as detailed in **Table 2-1**.

Table 2-1: Level of Assessment PHA

Level	Type of Analysis	Appropriate If:
1	Qualitative	No major off-site consequences and societal risk is negligible
2	Partially Quantitative	Off-site consequences but with low frequency of occurrence
3	Quantitative	Where 1 and 2 are exceeded

The Multi-Level Risk Assessment approach is schematically presented in **Figure 2-1**.

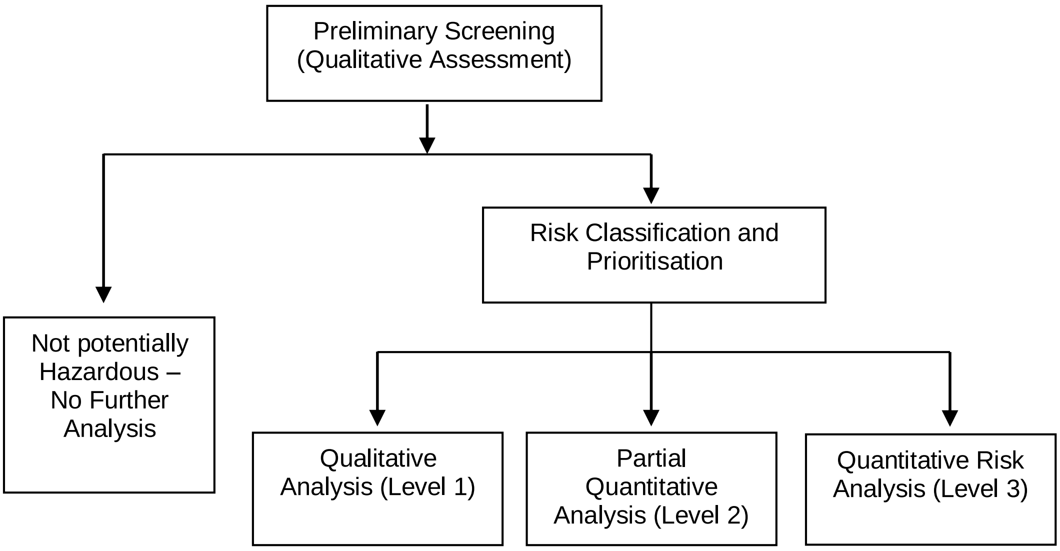

Figure 2-1: The Multi-Level Risk Assessment Approach

Based on the type of DGs to be used and handled associated with the project, a **Level 2 Assessment** was selected. This approach provides a qualitative assessment of those DGs of lesser quantities and hazard, and a quantitative approach for the more hazardous materials to be used on-site. This approach is commensurate with the methodologies recommended in "Applying SEPP 33's" Multi Level Risk Assessment approach (DPIE, 2011).

2.2 Risk Assessment Study Approach

The methodology used for the PHA is as follows:

Hazard Analysis – A detailed hazard identification was conducted for the proposed facilities and operation. Where an incident was identified to have a potential off-site impact, it was included in the recorded hazard identification word diagram (**Appendix A**). The hazard identification word diagram lists incident type, causes, consequences and safeguards. This was performed using the word diagram format recommended in HIPAP No. 6 (Ref. [1]).

Each postulated hazardous incident was assessed qualitatively in light of proposed safeguards (technical and management controls). Where a potential offsite impact was identified, the incident was carried into the main report for further analysis. Where the qualitative review in the main report determined that the safeguards were adequate to control the hazard, or that the consequence would obviously have no offsite impact, no further analysis was performed. **Section 3.1** of this report provides details of values used to assist in selecting incidents required to be carried forward for further analysis.

Consequence Analysis – For those incidents qualitatively identified in the hazard analysis to have a potential offsite impact, a detailed consequence analysis was conducted. The analysis modelled the various postulated hazardous incidents and determined impact distances from the incident source. The results were compared to the consequence criteria listed in HIPAP No. 4 (Ref. [2]). The criteria selected for screening incidents is discussed in **Section 3.1**.

Where an incident was identified to result in an offsite impact, it was carried forward for frequency analysis. Where an incident was identified to not have an offsite impact, and a simple solution was evident (i.e. move the proposed equipment further away from the boundary), the solution was recommended, and no further analysis was performed.

Frequency Analysis – In the event a simple solution for managing consequence impacts was not evident, each incident identified to have potential offsite impact was subjected to a frequency analysis. The analysis considered the initiating event and probability of failure of the safeguards (both hardware and software). The results of the frequency analysis were then carried forward to the risk assessment and reduction stage for combination with the consequence analysis results.

Risk Assessment and Reduction – Where incidents were identified to impact offsite and where a consequence and frequency analysis was conducted, the consequence and frequency analysis for each incident were combined to determine the risk and then compared to the risk criteria published in HIPAP No. 4 (Ref. [2]). Where the criteria were exceeded, a review of the major risk contributors was performed, and the risks reassessed incorporating the recommended risk reduction measures. Recommendations were then made regarding risk reduction measures.

Reporting – On completion of the study, a draft report was developed for review and comment. A final report was then developed, incorporating the comments received for submission to the regulatory authority.

3.0 Site Description

3.1 Site Location

The Project Area is located approximately 80 kilometres west of Wollongong and 15 km northwest of Marulan within the Upper Lachlan Shire Council Local Government Area (LGA) and abuts the Wingecarribee Shire LGA to the east, and Goulburn Mulwaree Shire Council LGA to the south.

Figure 3-1 shows the regional location of the Project Area. The conceptual Project layout has been provided in **Figure 3-2**.

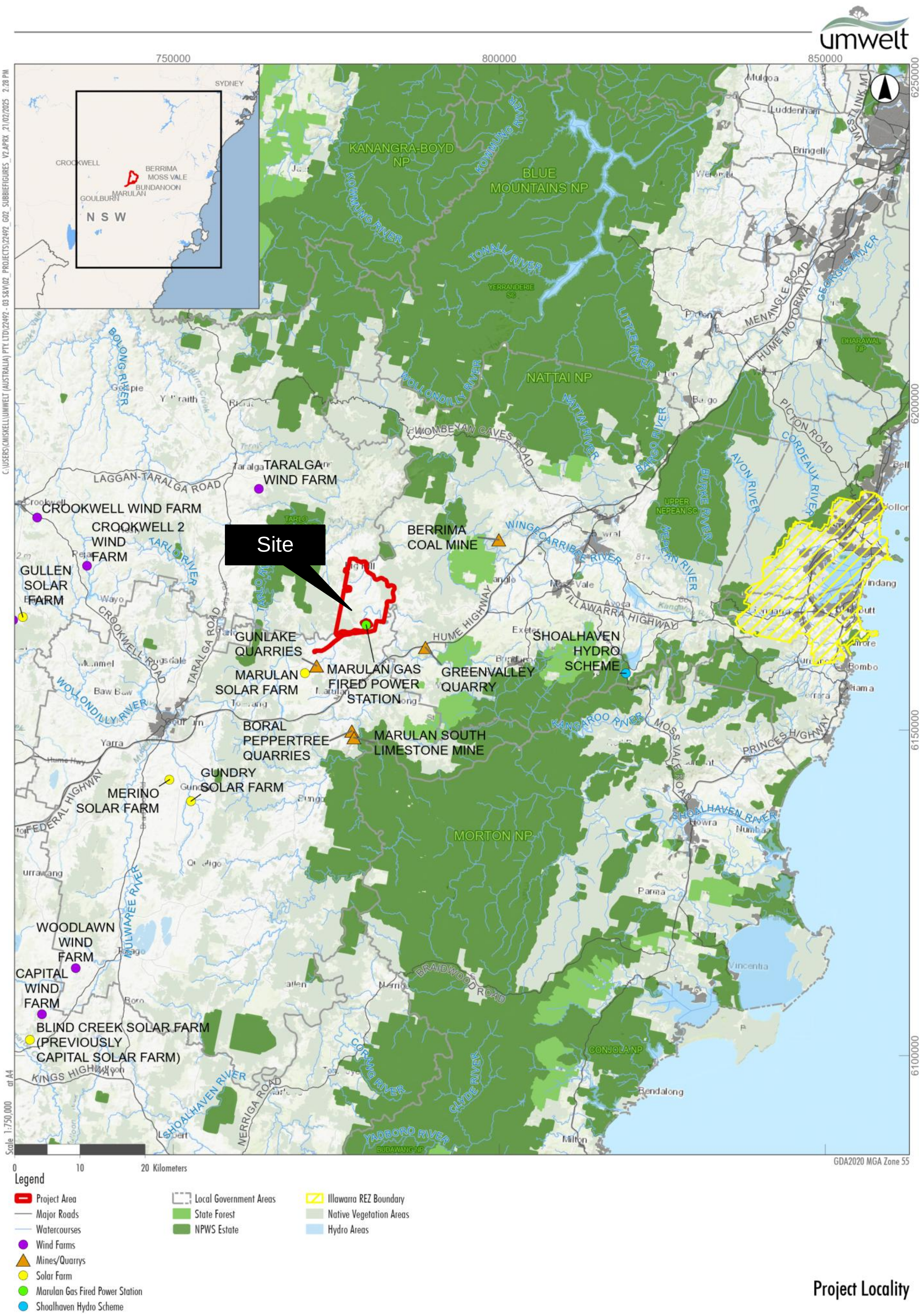

Figure 3-1: Site Location

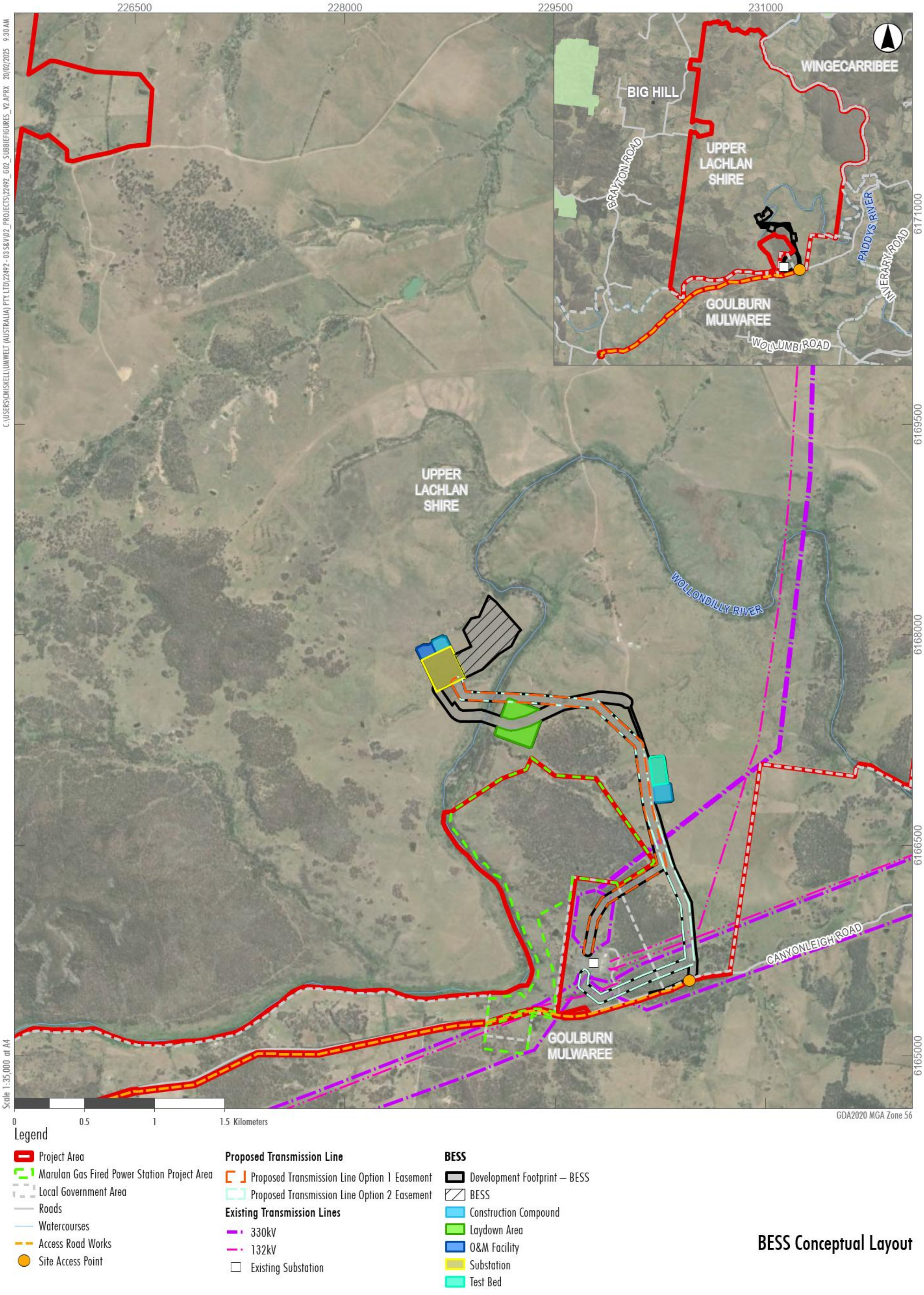

Figure 3-2: Conceptual Project Layout

3.2 Adjacent Land uses

The Project Area is located in a rural area surrounded by the following land uses, which are adjacent to the site:

- North - Rural residential
- South - Rural residential
- East - Rural residential
- West - Rural farmland

3.3 Sensitive Receptors

Sensitive receptors refer to locations or areas that are vulnerable or responsive to changes in the surrounding environment which can include ecological, cultural, residential and agriculture bodies. A survey revealed that some residences are located within proximity of the Project area that can be considered sensitive. The locations of nearby residential receptor, both involved and non-involved with the Project, can be seen in **Figure 3-3**. The distance between the BESS infrastructure and the nearest sensitive receptors have been summarised in **Table 3-1**.

Table 3-1: Distance Between BESS and Nearest Sensitive Receptor

Category	Sensitive Receptor	Separation Distance (m)
Involved	USyD FSAE Testing Grounds	750
Non-involved	House	2,000

Figure 3-3: Location of Nearest Sensitive Receptor

3.4 General Description

The Project comprises the installation, operation, maintenance and decommissioning of a large-scale BESS, supported by associated infrastructure. The Project will have a capacity of up to approximately 350 MW (AC or DC coupled) and will have provision for up to four (4) hours of storage (1400 MWh), with the aim of providing both storage as well as firming capacity to the NEM and assisting in grid stability by providing frequency control ancillary services. The design of the BESS will allow for the storage and exportation of renewable energy within the network so that it can be used during times of peak demand.

3.5 Detailed Description

The conceptual project layout represents a disturbance area of approximately 75 ha, including associated ancillary infrastructure (i.e. substations, the operations and maintenance facility, test bed and both transmission line corridors for optionality). The indicative project components are outlined in **Table 3-2**.

Two transmission line options are being investigated, to allow for optionality during the assessment process and greater flexibility in the connection design. Only one transmission option will be constructed.

Table 3-2: Indicative Project Components and Approximate Dimensions/Capacity

Project component/infrastructure	Approximate dimensions	Quantity
BESS Modules		
Maximum height	3 m	-
Minimum height	1.5 m	
Containers	Approximately 3.85 MWh per container (subject to final BESS provider selection)	656
Ancillary Infrastructure		
Collector (on-site) substation	6 ha	1
High voltage Transformers	300 megavolt amperes (MVA) high voltage transformers within substation (subject to detailed design)	3
Inverters and medium voltage transformers	4200 kVA inverters, with one medium voltage per transformer (subject to final inverter selection)	248
Overhead transmission lines (high to low voltage)	Internal overhead cables i.e. high voltage transmission lines from the BESS to the grid connection point.	n/a
Underground cables (medium to low voltage)	2 km	n/a
Internal access tracks	Approximately 7 km of internal roads that connect to the broader internal Wattle Creek Energy Hub road network	n/a
Primary site access point(s)	Canyonleigh Road and Arthursleigh Road, however subject to further intersection design during the EIS.	2
Operations and maintenance facility	100 m x 80 m	1
Temporary Construction Facilities		
Construction compound, including: • construction laydown areas for equipment and supplies, • stockpile and material storage areas • concrete batching plants, as required • construction compounds, site office, etc.	~ 2 ha	1

3.6 Quantities of Dangerous Goods & SEPP-RH Screening

The classes and quantities of DGs provided in **Table 3-3** are indicative only and subject to detailed design. These numbers were adapted from another BESS project with a similar scale (350 MW/1400 MWh) and are considered an appropriate assumption for the assessment of the Project.

Additionally, the SEPP threshold of the individual classes have been provided for the purposes of the SEARs.

Table 3-3: Maximum Quantities of Dangerous Goods Stored & Preliminary Risk Screening

Area	Class	Description	Quantity	SEPP Threshold
BESS	9	Lithium Batteries	5,125 T	N/A
PCU Transformer	C2	Transformer oils	150,000 L	N/A
Substation Transformer	C2	Transformer oils	20,000 L	N/A
Control room generator	C1	Diesel	100,000 L	N/A

*Approximately 2,111 L per transformer.

4.0 Hazard Identification

4.1 Introduction

A hazard identification table has been developed and is presented at **Appendix A**. This table has been developed following the recommended approach in Hazardous Industry Planning Advisory Paper No. 6, Hazard Analysis Guidelines (Ref. [1]). The Hazard Identification Table provides a summary of the potential hazards, consequences and safeguards at the site. The table has been used to identify the hazards for further assessment in this section of the study. Each hazard is identified in detail and no hazards have been eliminated from assessment by qualitative risk assessment prior to detailed hazard assessment in this section of the study.

In order to determine acceptable impact criteria for incidents that would not be considered for further analysis, due to limited impact offsite, the following approach has been applied:

- *Fire Impacts* - It is noted in Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 (Ref. [2]) that a criterion is provided for the maximum permissible heat radiation at the site boundary (4.7 kW/m^2) above which the risk of injury may occur and therefore the risk must be assessed. Hence, to assist in screening those incidents that do not pose a significant risk, for this study, incidents that result in a heat radiation less that at 4.7 kW/m^2, at the site boundary, are screened from further assessment.

  Those incidents exceeding 4.7 kW/m^2 at the site boundary are carried forward for further assessment (i.e. frequency and risk). This is a conservative approach, as HIPAP No. 4 (Ref. [2]) indicates that values of heat radiation of 4.7 kW/m^2 should not exceed 50 chances per million per year at sensitive land uses (e.g. residential). It is noted that the closest residential area is more than 0.5 km from the BESS infrastructure, hence, by selecting 4.7 kW/m^2 as the consequence impact criteria the assessment is considered conservative.

- *Explosion* - It is noted in HIPAP No. 4 (Ref. [2]) that a criterion is provided for the maximum permissible explosion over pressure at the site boundary (7 kPa) above which the risk of injury may occur and therefore the risk must be assessed. Hence, to assist in screening those incidents that do not pose a significant risk, for this study, incidents that result in an explosion overpressure less than 7 kPa, at the site boundary, are screened from further assessment. Those incidents exceeding 7 kPa, at the site boundary, are carried forward for further assessment (i.e. frequency and risk). Similarly, to the heat radiation impact discussed above, this is conservative as the 7 kPa value listed in HIPAP No. 4 relates to residential areas, which are more than 0.5 km away from the BESS infrastructure.

- *Toxicity* – Toxic by-products of combustion may be generated by a BESS fire; hence, toxicity has been assessed.
- *Property Damage and Accident Propagation* - It is noted in HIPAP No. 4 (Ref. [2]) that a criterion is provided for the maximum permissible heat radiation/explosion overpressure at the site boundary (23 kW/m^2/14 kPa) above which the risk of property damage and accident propagation to neighbouring sites must be assessed. Hence, to assist in screening those incidents that do not pose a significant risk to incident propagation, for this study, incidents that result in a heat radiation heat radiation less than 23 kW/m^2 and explosion over pressure less than 14 kPa, at the site boundary, are screened from further assessment. Those incidents exceeding 23 kW/m^2 at the site boundary are carried forward for further assessment with respect to incident propagation (i.e. frequency and risk).
- *Societal Risk* – HIPAP No. 4 (Ref. [2]) discusses the application of societal risk to populations surrounding the Project. It is noted that HIPAP No. 4 indicates that where a development proposal involves a significant intensification of population, in the vicinity of such a project, the change in societal risk needs to be taken into account. In the case of the project, there is currently no significant intensification of population around the Project Area; hence, societal risk has not been considered in this assessment.

4.2 Properties of Dangerous Goods

The type of DGs and quantities stored and used at the site has been described in **Section 3**. **Table 4-1** provides a description of the DGs to be stored and handled at the site, including the Class and the hazardous material properties of the DG Class.

Table 4-1: Properties* of the Dangerous Goods and Materials Stored at the Site

Class	Hazardous Properties
9 – Miscellaneous DGs	Class 9 substances and articles (miscellaneous dangerous substances and articles) are substances and articles which, during transport present a danger not covered by other classes. Releases to the environment may cause damage to sensitive receptors within the environment. It is noted that the Class 9s stored within this project are lithium-ion batteries which may undergo thermal runaway (i.e. escalating reaction resulting in heat which ultimately leads to failure of the battery and a fire).
Combustible Liquids	Combustible liquids are typically long chain hydrocarbons with flash points exceeding 60.5ºC. Combustible liquids are difficult to ignite as the temperature of the liquid must be heated to above the flash point such that vapours are generated which can then ignite. This process requires either sustained heating or a high-energy ignition source.

* The Australian Code for the Transport of Dangerous Goods by Road and Rail (Ref. [7])

4.3 Hazard Identification

Based on the hazard identification table presented in **Appendix A**, the following hazardous scenarios have been developed:

- Li-ion battery fault, thermal runaway and fire.
- Victorian Big Battery fire review.
- Li-ion battery fire and toxic gas dispersion.
- Electrical equipment failure and fire.

- Transformer internal arcing, oil spill, ignition and bund fire.
- Transformer electrical surge protection failure and explosion
- Bushfire and Incident Propagation
- Electromagnetic Field Impacts

Each identified scenario is discussed in further detail in the following sections.

4.4 Li-Ion Battery Fault, Thermal Runaway and Fire

Lithium ion (Li-ion) batteries are composed of a metallic anode and cathode which allows for electrons released from the anode to travel to the cathode where positively charged ions in the solute migrate to the cathode and are reduced. The flow of electrons provides the source of energy which is discharged from a battery and used for work. In a Li-ion battery, the lithium metal composites (a composite of lithium with other metals such as cobalt, manganese, nickel, or any combination of these metals) oxidises (loses an electron) becoming a positively charged ion in solution which migrates through the battery separator to the cathode. At the same time, the lost electron travels through the circuit to the cathode. The lithium ions in solution then recombine with the electron at the cathode forming lithium metal within the cathodic metal composite. This process is shown in **Figure 4-1**.

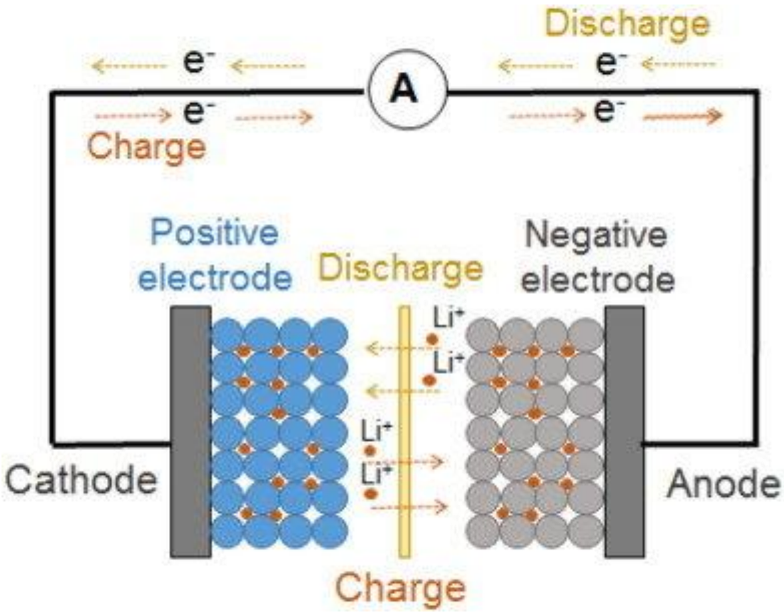

Figure 4-1: Cathode and Anode of a Battery (Source Research Gate)

Initial lithium batteries were designed around lithium metal (i.e. no composite structure) due to the high energy density yielded by the metal. However, when overcharging a battery, lithium ions can begin to plate on the anode in the form of lithium dendrites. Eventually, the dendrites pierce the separator within the battery resulting in a short of the battery which could result in heat, fire, or explosion of the battery. The technology evolved to move away from lithium metal to lithium ions (held within composite materials) which reduced the incidence of lithium dendrites forming resulting in an overall safer battery.

Despite the improvement in battery technology, there are several degradation mechanisms that are still present within the battery which can result in thermal runaway. These include:

- Chemical reduction of the electrolyte at the anode

- Thermal decomposition of the electrolyte
- Chemical reduction of the electrolyte at the cathode
- Thermal decomposition by the cathode and the anode
- Internal short circuit by charge effects

These effects arise primarily as a result of high discharge, overcharging, or water ingress into the battery which results in a host of by-products being formed within the battery during charge and discharge cycles.

As a result, Li-ion batteries are equipped with several safety features to prevent the batteries from charging or discharging at voltages which result in battery degradation, leading to shorting of the battery and thermal runaway. Safety features generally include:

- Shut-down separator (for overheating)
- Tear-away tab (for internal pressure relief)
- Vent (pressure relief in case of severe outgassing)
- Thermal interrupt (overcurrent/overcharging/environmental exposure)

These features are designed to prevent overcharging or excessive discharge, pressurisation arising from heat generated at the anode or from battery contamination. Protection techniques for Li-ion batteries are standard; hence, the potential for thermal runaway to occur in normal operation is very low with the only exceptions being due to manufacturing faults or battery damage (i.e. battery cell is ruptured as this can short circuit the battery resulting in thermal runaway).

In terms of physical damage, the batteries are contained within in modules which are located within a fenced area; therefore, there is a low potential for damage to occur to the batteries which may initiate an incident.

A review of the batteries proposed to be used as part of this project indicates the battery chemistry is Lithium-Ion phosphate (LiFePO4, or simply LFP) which are considered to be one of the safest battery chemistries within the industry. When exposed to external heat the thermal rise of typical lithium-ion battery chemistries is 200-400 ^{o}C/min resulting thermal run away and fire which can then propagate to adjacent batteries escalating the incident to a full container fire. For LFP batteries, the thermal rise of the batteries at peak is 1.5^{o}C/min which results in a gradual temperature rise and does not result in fire and thus incident propagation to other batteries. The thermal rise of various battery chemistries is provided in **Figure 4-2** with a zoomed in temperature rise for LFP provided in the top right of **Figure 4-2**. The stability of the batteries is due to the cathode which does not release oxygen therefore preventing violent redox reactions resulting in rapid temperature rise as the oxygen oxides the electrolyte.

Additional testing for shock and damage to batteries (i.e. nail puncture test) has been shown that LFP batteries when punctured through membranes which typically results in a shorting of the battery and fire does not result in ignition of the battery demonstrating that the battery chemistry is protected against shock damage.

In the event that LFP chemistries do ignite by artificial means, the combustion by products release carbon dioxide which reduces the oxygen concentration within a confined space reducing the combustion rate. Finally, the containers are fitted with a fire suppression system which will activate to suppress and control a fire preventing escalation to other battery units.

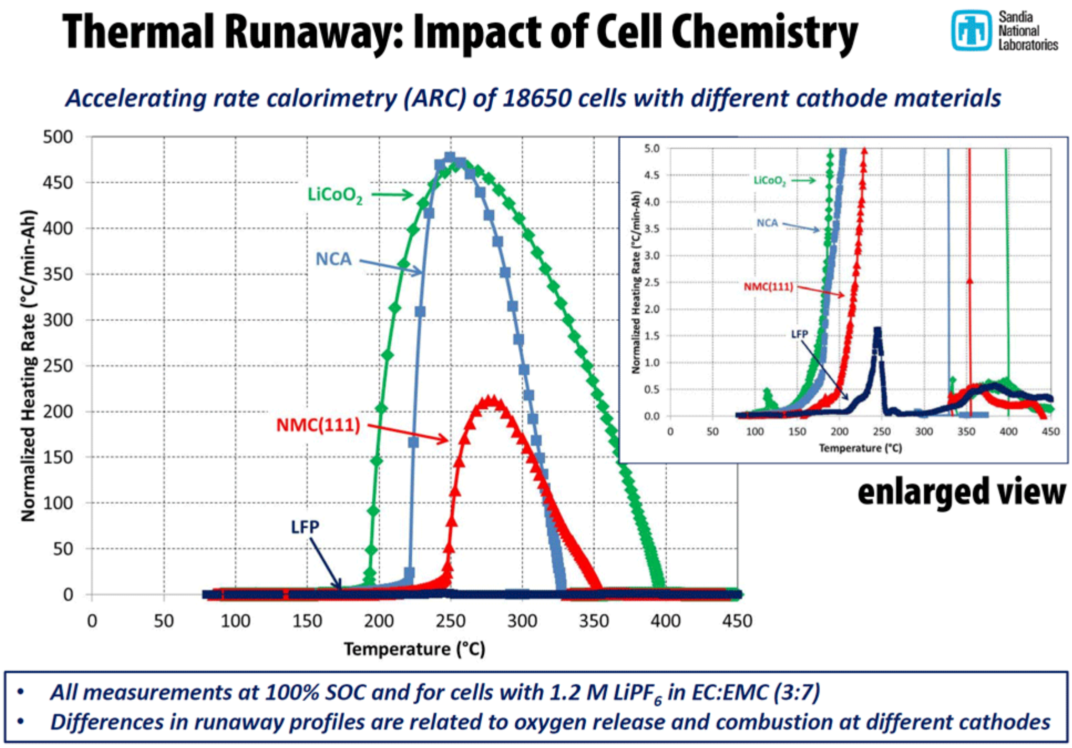

Figure 4-2: Temperature Rise of Lithium-Ion Battery Chemistries (Ref. [8]).

The preliminary battery product considered for the purposes of a preliminary hazard analysis for the project is a BESS with LFP technology. A UL9540A report has been completed for this product but is unable to be shared due to privacy reasons.

Similarly, based on data shown from UL9540A reports for similar systems, the results demonstrate that when thermal runaway is triggered in one cell in a BESS container, the heat generated would neither be transferred to all cells within one battery module, nor from the test module to adjacent ones. This is attributed to the nature of LFP technology as well as the sheer mass of the battery module (heavier objects have higher thermal capacity).

Although the LFP technology does not cause fire, there can be circumstances where battery modules catch fire due to leaking coolant or electric faults. In those cases, fire will be constrained by the stainless-steel enclosure. Similar systems show that generally the container wall remains intact after sustaining heating in a furnace to over 900°C.

Furthermore, each container should also have multiple built-in fire protection devices that work collaboratively, including smoke and thermal sensors, combustible gas detector, pressure relief system, and aerosol E-Stop buttons. Therefore, a container will automatically detect an internal fire in the first instance.

Different systems deploy different battery fire mitigation strategies depending on the solution, but in any case, the project will implement the manufacturer's recommended fire protection systems. The assessed and final selected system will hold relevant UL and IEC certifications (i.e. UL9540, UL9540A, UL1741, UL1973, UN38.3; CE; EMC; NFPA 70; IEEE C37.32; IEC:62933, 62619, 60204, ASTM4169).

In conclusion, the LFP technology is unlikely to cause fire during thermal runaway provided the protection systems are in place and operating. Should fire be developed within one BESS container it would not transfer to nearby containers due to the fire safety design features; therefore, further analysis is not required.

Notwithstanding, based on advice from NSW Department of Planning, Housing and Infrastructure (DPHI), the following recommendations have been made:

- BESS must be tested in accordance with UL9540A.
- Testing to demonstrate clearances required to prevent propagation of fires between separated units.
- BESS to be installed in accordance with manufacturer and UL9540A report recommended clearances based on testing.
- BESS to be installed with fire protection systems specified by the manufacturer and UL9540A report.
- Before construction, detailed design to validate the system can be installed in the project area whilst meeting the recommended clearances.
- UL testing information shall be made available to the certifying authority. It is noted that a confidentiality agreement may be required.

4.5 Victorian Big Battery Fire Review

Notwithstanding the findings of **Section 4.4**, it is necessary to review recent large scale BESS fires to determine whether similar incidents could occur with the Project.

The Project has been designed with consideration of the separation distance considering fire safety, and operation and maintenance. The fire safety assessment is essentially around heat transfer which has been discussed in detail in **Section 4.4**.

The Victorian Big Battery (VBB) also has a back-to-back layout. According to the independent investigation report on its fire incidence, the back-to-back layout was not the cause. The main reason for fire propagation was strong wind blowing flames from one Megapack into the unprotected vent atop of an adjacent Megapack which resulted in the ignition of the plastic fan which was able to impact the battery modules directly beneath the fan.

Lessons learnt from the VBB incident results in fire safety precautions on the design of the Project. The vent atop the containers shall be made of metal instead of plastic and covered by a metallic mesh shield. Furthermore, the placement of the fans shall be such that batteries or flammable materials shall not be located directly beneath ventilation openings. To ensure the above are captured the following recommendations have been made:

- The vent covers of the BESS shall be constructed of non-combustible material.
- The vents shall not be located above battery packs within the BESS container.

Based upon the designs incorporated with the container based upon the VBB fire, the available area assessment and the separation distance assessment, it is considered that the propagation between two units is considered unlikely; hence, this incident has not been carried forward for further analysis.

4.6 Available Space for BESS Allocation Review

DPHI has indicated in the past that an assessment should be undertaken to show whether the allocated space for the BESS is sufficient to accommodate all the units that are planned to be installed. As a UL9540A report has not been commenced as of this report's writing, the separation distances for the BESS are taken from similar previously approved projects and is applied to this instance. Note that this is indicative only and is a conservative estimate. This will be revised during the detailed design phase once results from the UL9540A report have been disclosed. An example of this configuration has been provided in **Figure 4-3**.

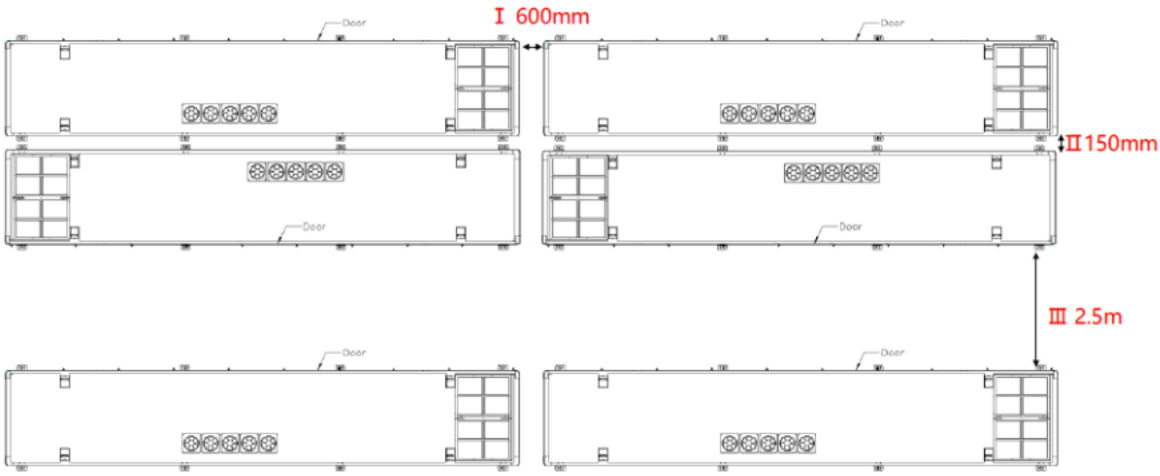

Figure 4-3: BESS Layout Guide

As the separation distance between modules is 2.5 m, it is assumed that the area footprint for a single BESS including the clearances (with a dimension of 7.50 m x 3.13 m x 2.51 m), is 59 m^2. This value can then be divided by the available space to show the maximum number of BESS that can be installed (rounded down). These are summarised in **Table 4-2**.

Table 4-2: Potential BESS Allocation Areas

Available area (m^2)	Maximum no. of BESS
134,000	2,270

Spark Renewables has indicated that up to 656 BESS units is currently being considered; hence, the assessment has indicated that there is enough available space for the allocation of BESS units in each of the potential locations.

4.7 Li-ion Battery Fire and Toxic Gas Dispersion

If a BESS failure occurs resulting in a fire, toxic by-products of combustion may form. A literature review was conducted on lithium-ion battery fires to identify the toxic gases which may be generated in the event of a fire. The review identified the following gases or classes of gases can form:

- Carbon dioxide.
- Carbon monoxide.
- Fluorine gases.

Each of these have been discussed in further detail in the following subsections.

4.7.1 Carbon Dioxide

Carbon dioxide is a colourless, odourless, dense gas which is naturally forming and is present in the atmosphere at concentrations around 415 ppm (0.0415%). At low concentrations carbon dioxide is physiologically impotent and at low concentrations does not appear to have any toxicological effects. However, as the concentration grows it increases the respiration rate with short term Exposure Limit (STEL) occurring at 30,000 ppm (3%), above 50,000 ppm (5%) a strong respiration effect is observed along with dizziness, confusion, headaches, and shortness of breath. Concentrations in excess of 100,000 ppm (10%) may result in coma or death.

Carbon dioxide is a by-product of combustion where hydrocarbon or carbon-based materials are involved. A typical combustion reaction producing carbon from a hydrocarbon has been provided in **Equation 4-1**. This reaction proceeds when there is an excess of oxygen to the fuel being consumed and is known as complete combustion as it is the most efficient reaction pathway.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3Co_2(g) + 4H_2O(g) \qquad \textbf{Equation 4-1}$$

The lithium-ion batteries are predominantly composed of metal structures. However, during a fire event ancillary equipment and materials within the batteries will be involved in the fire including wiring, plastics, anodes, etc. which will liberate carbon dioxide. However, a review of the toxicological impacts indicates high concentrations would be required to result in injury or fatality. Based upon a review of the sensitive areas, and the similar BESS fires (i.e. Victoria BESS fire), it is not considered that the formation of carbon dioxide in a fire would be sufficient to result in downwind impacts sufficient to cause injury or fatality. In other words, there would be insufficient production of carbon dioxide to generate a plume of sufficient concentration to displace the required oxygen for a significant downwind consequence to occur. Therefore, this incident does not require further analysis.

4.7.2 Carbon Monoxide

Carbon monoxide is an odourless, colourless gas which is slightly denser than air and occurs naturally in the atmosphere at concentrations around 80 ppb. Carbon monoxide is a toxic gas as it irreversibly binds with haemoglobin which prevents these molecules from carrying out the function of oxygen / carbon dioxide exchange. The loss of 50% of the haemoglobin may result in seizures, coma or death which can occur at concentration exposures of approximately 600 ppm (0.06%).

Carbon monoxide is by-product of combustion if there is insufficient oxygen to enable complete combustion. The reaction pathway for the formation of carbon monoxide is provided in **Equation 4-2**.

$$2C_3H_8(g) + 7O_2(g) \rightarrow 6CO(g) + 8H_2O(g) \qquad \textbf{Equation 4-2}$$

As noted, in **Section 4.7.1** there is the potential for a fire to occur with the BESS units which could form carbon monoxide if there is insufficient oxygen to sustain complete combustion. However, it is noted that the combustible load within the BESS which could result in the formation of carbon monoxide is relatively low compared to the available oxygen in the surrounding atmosphere. Therefore, it is considered that the formation of carbon monoxide at levels which would result in a substantial downwind impact are not considered credible and subsequent analysis of, this incident is not required.

4.7.3 Fluoride Gases

The electrolyte used in Li-ion batteries typically is lithium hexafluorophosphate ($LiPF_6$) or other li-salts containing fluorine. In the event of a thermal runaway, the electrolyte will expand and be vented from the battery. In the event of a fire, the vented gas and other components such as the polyvinylidene fluoride binders may form gases such as hydrogen fluoride (HF), phosphorous pentafluoride (PF_5) and phosphoryl fluoride (POF_3) (Ref. [9]).

The decomposition of $LiPF_6$ can be promoted by the presence of water / humidity according to reactions **Equation 4-3** to **Equation 4-5**.

$LiPF_6 \rightarrow LiF + PF_5$	**Equation 4-3**
$PF_5 + H_2O \rightarrow POF_3 + 2HF$	**Equation 4-4**
$LiPF_6 + H_2O \rightarrow LiF + POF_3 + 2HF$	**Equation 4-5**

Of the fluorine gases formed, PF_5 is a short-lived gas while POF_3 is a reactive intermediate. Thermal destruction of a several battery chemistry, configurations and State of Charge (SOC) indicated the vast majority of these did not produce observable POF_3 with the only observance occurring in a specific battery chemistry at 0% SOC (Ref. [9]). Therefore, the main fluorine gas of concern in a Li-ion battery fire is HF.

HF gas is hydroscopic readily dissolving into water vapour / humidity or moisture in airways forming hydrofluoric acid. Hydrofluoric acid is a weak acid although is highly corrosive and may result in chemical burns. In addition, it is calcium scavenging. Hence, it will readily bind with calcium in cells and tissues disrupting the nerve signalling. The immediately dangerous to life or Health (IDLH) for HF is 30 ppm and the 10-minute lethal concentration is 170 ppm.

For a toxic gas dispersion, a battery container fire is necessary as the initiating event. As discussed in **Section 4.4** the potential for a fire to occur is considered unlikely provided the protection systems are installed and operating due to the highly stable and safe battery chemistries used. As the potential for the initiating event is considered unlikely, this incident has not been carried forward for further analysis.

4.8 Electrical Equipment Failure and Fire

Electrical equipment is located within the switch room which may fail resulting in overheating, arcing, etc. which could initiate a fire. In the event of a fire, it may begin to propagate to adjacent combustible materials (i.e. wiring). It is noted that electrical equipment fires typically start by smouldering before flame ignition occurs resulting in a slow fire development.

The type of equipment proposed as part of the Project is ubiquitous throughout the world and across industry segments and is therefore not a unique fire scenario. Based upon fire development within switch rooms the fire would be considered to be relatively slow in growth and would be unlikely to result in substantial impacts in terms of offsite impact or incident propagation. Therefore, this incident does not require further analysis.

4.9 Marulan Gas Fired Power Plant and Incident Propagation

It has been indicated that a power plant that borders the southern Project Area will be built in the future (near the Marulan Substation). There are concerns regarding the potential for incident propagation from the BESS, given its proximity to the Project. However, it must be noted that the separation distance between the approved power plant site and the allocated BESS area is 1 km, which is substantial. As discussed in the previous sections, it is not expected that a BESS fire will impact the proposed power plant due to the inherent stable chemistry of LFP batteries, the safety systems installed in each BESS and the compliance with UL9540A; hence, this incident has not been carried forward for further analysis.

4.10 Transformer Internal Arcing, Oil Spill, Ignition and Bund Fire

Transformers contain oil which is used to insulate the transformers during operation. If arcing occurs within the transformer (e.g. due to a low oil level), the high energy passing through the coolant vaporises the oil into light hydrocarbons (methane, ethane, acetylene, etc.) resulting in rapid pressurisation within the reservoir.

Notwithstanding the protection systems, if the pressure rise exceeds the structural integrity of the reservoir, and the installed pressure relief devices, the reservoir can rupture allowing the release of oil into the bund. The rupture also allows oxygen to enter the reservoir. The temperature of the gases is above the auto ignition point, but this does not occur until oxygen is present. When oxygen enters the reservoir, the gases auto ignite which generates sufficient heat to ignite the oil in the bund.

Notwithstanding this, transformers are ubiquitous units with a low potential for failure and the separation distance to the site boundary and other adjacent units would be unlikely to result in incident propagation and offsite impacts. Therefore, this incident has not been carried forward for further analysis.

4.11 Transformer Electrical Surge Protection Failure and Explosion

Transformers generate large amounts of heat as a result of the high electrical currents that pass through them; hence, oil is used as an insulating material within the transformers to protect the mechanical components. However, if the transformer gets an extreme surge of energy, such as that which could occur due to a lightning strike, and the electrical surge protection measures fail, the mineral oil may start to decompose and vapourise, resulting in gas bubbles of hydrogen and methane (Ref. [10]) as temperatures above the autoignition of the gases.

The formation of gases will increase the pressure within the transformer which can result in the transformer structure rupturing which allows the ingress of oxygen. As the oxygen enters, the concentration of flammable gases falls within the explosive limits which are above their autoignition temperatures which ignite resulting in increased formation of hot gaseous products resulting in an explosion. The explosion may generate significant overpressure, sparks and fire and would result in a whole transformer fire, as discussed in **Section 4.9**.

In order to protect against overheating and explosions, transformers generally have surge protection devices which shunt electrical surges safely to ground. However, these surge detection and protection devices are not universally installed nor do they protect against all events such as in the case of a major lightning strike or significant oil deterioration, leakage of water into the transformer, and physical damage such as a fallen tree (Ref. [11]). Therefore, there is the potential for an explosion to occur which may result in offsite impacts; however, as previously noted, these units are ubiquitous and have a low potential for failure. Therefore, this incident has not been carried forward for further analysis.

4.12 Bushfire and Incident Propagation

4.12.1 Introduction

Bushfires are uncontrolled fires that occur in natural vegetation, typically in forests, grasslands, or scrublands. The ecological phenomenon is a particular concern in rural Australia as much of the region is fire-prone due to factors such as, but not limited to, dry climate, vegetation, and seasonal conditions. As provided in **Figure 4-4**, the Project is adjacent to dense vegetation that has been categorised as bushfire prone land; hence, certain measures must be taken to ensure that the risk do not result in damage, consequent loss in the BESS units, and potential propagation of fire.

4.12.2 Discussion

To that end, Umwelt has conducted a separate bushfire assessment (Ref. [4]) for the Project that has been prepared in accordance with RFS *Planning for Bush Fire Protection 2019* (PBP, Ref. [12]). Several measures have been identified to adequately mitigate the risks associated with bushfires and incident propagation, which are as follows:

- Compliance with the aims and objectives of the PBP 2019.
- The development of an Emergency Response Plan in consultation with RFS and NSW Fire and Rescue.
- The implementation of Asset Protection Zones (APZs) with a minimum 10 m clearance for all the proposed infrastructure.
- Appropriate bushfire management and mitigation measures.

Due to the measures identified above, it is considered that the bushfire risk would be appropriately managed; hence, this incident has not been carried forward for further analysis. Additionally, appropriate measures would be implemented to prevent fire associated with the operation of the proposed infrastructure and resulting spread of fire outside of the Project Area, as outlined in **Section 5.2**.

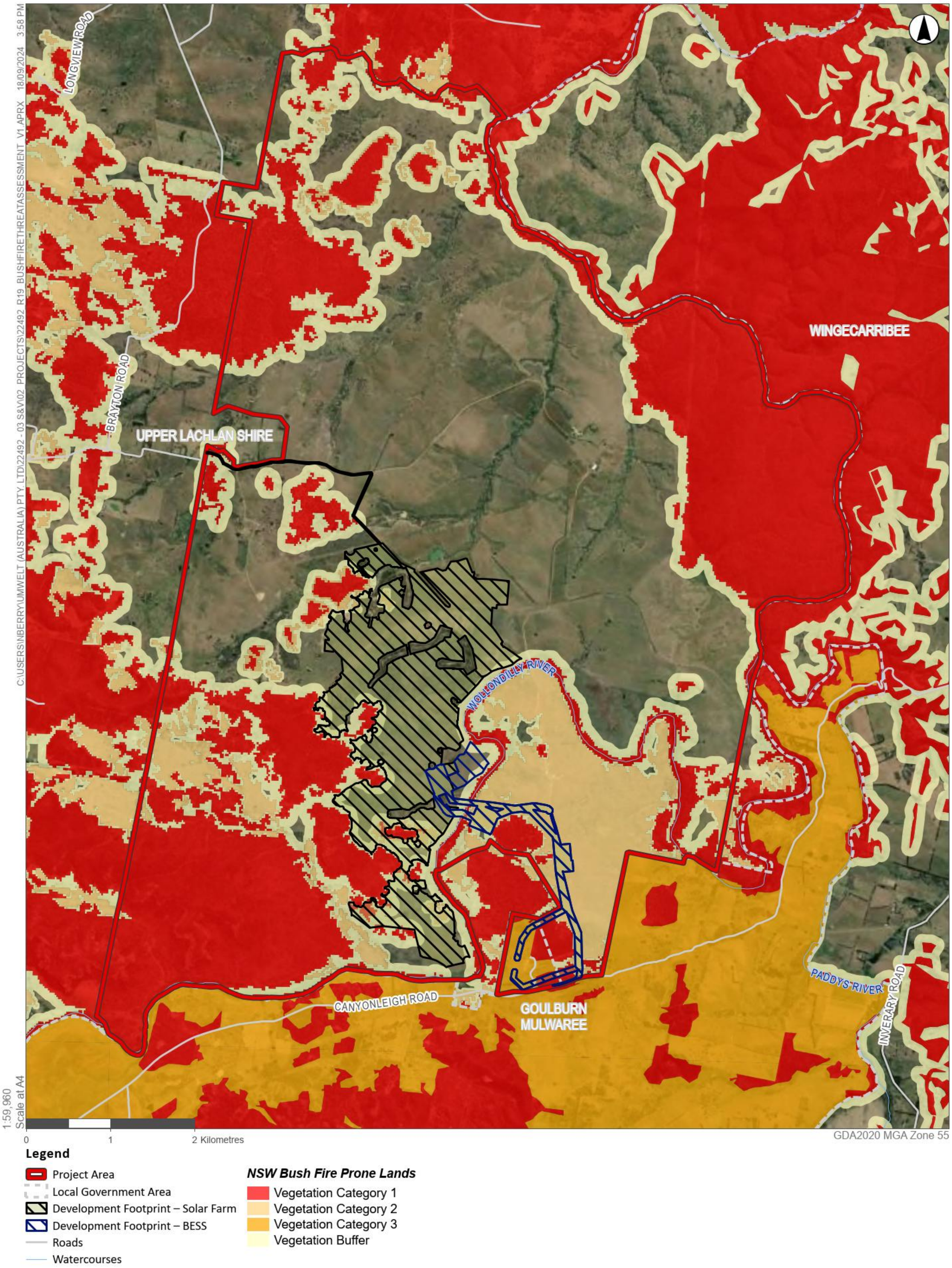

Figure 4-4: Bush Fire Prone Lands

4.13 Electromagnetic Field Impacts

4.13.1 Introduction

Electric and Magnetic Fields (EMFs) are associated with a wide range of sources and occur both naturally as well as man-made. Naturally occurring EMFs, occurring during lightning storms, are generated from Earth's magnetic field. Man-made EMFs are present wherever there is electricity; hence, EMFs are present in almost all built environments where electricity is used.

Extremely low frequency (ELF) electric and magnetic fields (EMF) occupy the lower part of the electromagnetic spectrum in the frequency range 0-3,000 Hz which is the current will change direction 0-3,000 times a second. ELF EMF result from electrically charged particles. Artificial sources are the dominant sources of ELF EMF and are usually associated with the generation, distribution and use of electricity at the frequency of 50 Hz in Australia. The electric field is produced by the voltage whereas the magnetic field is produced by the current.

BESS create EMFs from operational electrical equipment, such as transmission lines, transformers and the electrical components found within BESS units, inverters, etc. This equipment has the potential to produced ELF EMF's in the range of 30 to 300 Hz.

4.13.2 Exposure Discussion

There are currently no existing standards in Australia for governing the exposure limits to ELF EMFs; however, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has provided some guidelines around exposure limits for prolonged exposure which limits the exposure to 2,000 milligauss (mG) for members of the public in a 24 hour period (Ref. [13]).

Table 4-3 provides typical magnetic field measurements and ranges associated with EMF sources. It is noted that electric fields around devices are generally close to 0 due to the shielding provided around the equipment. In addition, EMF levels drop away quickly with distance; hence, while a value may be measurable at the source, within a short distance the EMF is undetectable.

Table 4-3: EMF Sources and Magnetic Field Strength

Source	Typical Measurement (mG)	Measurement Range (mG)
Television	1	0.2 – 2
Refrigerator	2	2 – 5
Kettle	3	2 – 10
Personal computer	5	2 – 20
Electric blanket	20	5 – 30
Hair dryer	25	10 – 70
Distribution powerline (under the line)	10	2 – 20
Transmission power line (under the line)	20	10 – 200
Edge of easement	10	2 – 50

An Electromagnetic Field desktop study (Ref. [5]) was conducted by Middleton Group Engineering Pty Ltd for the Project to estimate/calculate the EMF emitted by the conductors and then assess their potential impact on human health. Results obtained from a proprietary modelling software indicated that there are no unsafe electric and magnetic fields that the general public will be exposed to where the 33 kV underground cable circuits are buried at a depth of 800 mm minimum, and the lowest conductor sag of 330 kV overhead line is at least 8 m above ground level.

As the potential for exposure to EMF exceeding the international guidelines is negligible, this incident has not been carried forward for further analysis.

5.0 Conclusion and Recommendations

5.1 Conclusions

A hazard identification table was developed for the Project to identify potential hazards that may be present at the site as a result of operations or storage of materials. Based on the identified hazards, scenarios were postulated that may result in an incident with the potential for offsite impacts. Postulated scenarios were discussed qualitatively and any scenarios that would not impact offsite were eliminated from further assessment. Scenarios not eliminated were then carried forward for consequence analysis.

A review of all possible incidents associated with the Project indicates that there were no observed offsite impacts; therefore, based on the analysis conducted, it is concluded that the risks at the site boundary are not considered to exceed the acceptable risk criteria; hence, the project would only be classified as potentially hazardous and would be permitted within the current land zoning for the site.

5.2 Recommendations

The following recommendations have been made as a result of the assessment:

- BESS must be tested in accordance with UL9540A.
- Testing to demonstrate clearances required to prevent propagation of fires between separated units.
- BESS to be installed in accordance with manufacturer and UL9540A report recommended clearances based on testing.
- BESS to be installed with fire protection systems specified by the manufacturer and UL9540A report.
- Before construction, detailed design to validate the system can be installed in the project area whilst meeting the recommended clearances.
- UL testing information shall be made available to the certifying authority. It is noted that a confidentiality agreement may be required.
- The vent covers of the BESS shall be constructed of non-combustible material.
- The vents shall not be located above battery packs within the BESS container.

6.0 References

[1] Department of Planning, Industry and Environment, “Hazardous Industry Planning Advisory Paper No. 6 - Guidelines for Hazard Analysis,” Department of Planning, Industry and Environment, Sydney, 2011.

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[3] SafeWork NSW, “Work Health and Safety Regulation,” SafeWork NSW, Lisarow, 2017.

[4] Umwelt, Wattle Creek Energy Hub - Bushfire Threat Assessment, Sydney: Umwelt, 2024.

[5] Middleton Group, “Wattle Creek Energy Hub - EMF / Human Health Assessment”.

[6] Department of Planning, Industry and Environment, Multi-Level Risk Assessment, Sydney: Department of Planning, Industry and Environment, 2011.

[7] National Transport Commission (NTC), “Australian Code for the Transport of Dangerous Goods by Road & Rail, 7th Edition,” 2011.

[8] Power Tech Systems, “Safety of Lithium-Ion batteries,” Power Tech Systems, 2022. [Online]. Available: https://www.powertechsystems.eu/home/tech-corner/safety-of-lithium-ion-batteries/. [Accessed 13 April 2022].

[9] F. Larson, P. Andersson, P. Blomqvist and B.-E. Mellander, “Toxic fluoride gas emissions from lithium ion battery fires,” Nature: Scientific Reports, 2017.

[10] J. Demos, “What Causes Transformer Explosions and Burns?,” Durabarrier USA Fire Barrier Experts, 26 July 2021. [Online]. Available: https://firebarrierexperts.com/what-causes-transformer-explosions-and-burns. [Accessed 2 February 2022].

[11] P. Hoole, S. Rufus, N. Hashim, M. Saad, S. Abdullah, A. Othman, K. Piralaharan, A. CV and S. Hoole, “Power Transformer Fire and Explosion: Causes and Control,” *International Journal of Control Theory and Applications,* vol. 10, no. 16, pp. 211-219, 2017.

[12] NSW Rural Fire Service, “Planning for Bush Fire Protection,” NSW Government, Sydney, 2019.

[13] International Commission on Non-Ionizing Radiation Protection, “ICNIRP Guideline for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1-100 Hz),” International Commission on Non-Ionizing Radiation Protection, 2010.

[14] Standards Australia, “AS/NZS 3000:2007 - Wiring Rules,” Standards Australia, Sydney, 2007.

Appendix A

Hazard Identification Table

Appendix A

A1. Hazard Identification Table

Area/Operation	Hazard Cause	Hazard Consequence	Safeguards
Battery Storage	• Failure of Li-ion battery protection systems	• Thermal runaway resulting in fire or explosion • Incident propagation through battery cells • Toxic smoke dispersion	• Batteries are tested by manufacturer prior to sale / installation • Overcharging and electrical circuit protection • Battery monitoring systems • Batteries composed of subcomponents (i.e. BBU, cells) reducing risk of substantial component failure • Batteries are not located in areas where damage could easily occur (i.e. within the fenced property) • Electrical systems designed per AS/NZS 3000:2007 (Ref. [14]) • UL9540A testing • Manned facility • Water supply (>20,000 L) is provided for emergency activities in consultation with NSW RFS.
Switch rooms, communications, etc.	• Arcing, overheating, sparking, etc. of electrical systems	• Ignition of processors and other combustible material within servers and subsequent fire	• Fires tend to smoulder rather than burn • Isolated location • Switch room separation from other sources of fire
Substation	• Arcing within transformer, vaporisation of oil and rupture of oil reservoir	• Transformer oil spill into bund and bund fire	• Bunded • Isolated location
	• Power surge to transformers (e.g. from lightning)	• Major failure of surge protection in transformer, vapourisation of mineral oil, ignition and explosion	• Transformers have surge protection system to shut down upon detection of extreme energy input • Lightning protection to prevent lightning strikes impacting transformers • Control of ignition sources – no smoking / open flames around the transformers

Area/Operation	Hazard Cause	Hazard Consequence	Safeguards
EMF	• Electric and magnetic equipment	• Generation of ELF EMF and injury / nuisance to surrounding area	• Large separation distances allow for attenuation of EMFs • Cumulative impacts from equipment below acceptable thresholds. • Low occupancy density within vicinity of the development