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Appendix J

Risk Management Assessment Report

Risk Management Assessment Report

Tully BESS QLD

Attexo Group Pty Ltd
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Risk Management Assessment Report

Tully BESS QLD

Attexo Group Pty Ltd

Prepared by

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

Quality Management

Rev	Date	Remarks	Prepared By	Reviewed By
A	25th February 2026	Draft issued for comment	Ezra Bagaskara	Renton Parker
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Executive Summary

Background

Attexo Group Pty Ltd (Attexo) is assisting RWE Tully Battery Pty Ltd (RWE) with the development application for the Tully Battery Energy Storage System (BESS) located within the Cassowary Coast Regional Council. As part of the planning services, subspecialist reports will be required to meet the performance outcomes outlined in the published State Code 27: Battery storage facility development of the State Development Assessment Provisions. This document presents the RMAR, which aligns with the risk management guidelines established in AS ISO 31000:2018 (Ref. [1]).

Attexo on behalf of RWE has commissioned Riskcon Engineering Pty Ltd (Riskcon) to prepare the required documentation for the Project. This document represents the RMAR for the Tully BESS

Conclusions

A RMAR was prepared for the proposed Tully BESS. A hazard identification table was developed 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 a potential for offsite impacts. Postulated scenarios were discussed qualitatively and any scenarios that would not impact offsite were eliminated from further assessment. The likelihood and consequences of these events were qualitatively discussed to determine the risk.

Incidents carried forward for quantitative analysis were modelled in integral consequence modelling software EFFECTS in detail to estimate the impact distances. Impact distances were developed into scenario contours and overlaid onto the site layout diagram to determine if an offsite impact would occur. The impact distances of the incidents analysed using EFFECTS were shown to not affect adjacent equipment and thus, would not cause incident propagation. Furthermore, there are no potential off-site impacts. The likelihood of these events was semi-quantitatively determined to be near negligible, meaning the risks (combining the limit consequence and low likelihood) of these events are acceptably low.

Based on the analysis conducted, it is concluded that there are no unacceptable risks at the site boundary, nor any risk of incident propagation. Thus, the risks are considered sufficiently managed by the inherent safety features of the BESS units and by existing safety precautions.

Recommendations

Based on the analysis, the following recommendations have been made:

- Evidence of UL 9540A testing shall be provided to the relevant authorities upon acquisition and submission for approval.
- All site personnel shall be inducted in site procedures and emergency response protocols relevant to their roles.
- All site personnel who require training must undergo formal training in the required procedures and emergency response protocols relevant to their role.
- Necessary personnel to provide first aid are to be trained in accordance with the QLD Code of Practice for first aid in workplaces 2021– high-risk workplaces (Ref. [1]).

- Site management to prepare and maintain operational procedures to minimise the number of hazardous incidents and accidents on site and to mitigate the consequences of incidents regarding the handling of dangerous goods and chemicals.
- A site Safety and Emergency Management Plan per the requirements of HIPAP No. 1 and State Code 27 shall be prepared and shall include measures to advise neighbouring premises in the event of an emergency with potential offsite impacts.
- Dangerous Goods (DG) documentation shall be prepared as required by the Work Health and Safety Regulation 2011 to demonstrate the risks associated with the storage and handling of DGs has been assessed and minimised.
- Any DGs stored at the site shall be stored and handled in accordance with the Work Health and Safety Regulation 2011 and any applicable storage and handling standards.

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Abbreviations

Abbreviation	Description
ADG	Australian Dangerous Goods Code
AFAC	Australasian Fire and Emergency Service Authorities Council Limited
APZ	Asset Protection Zones
AS	Australian Standard
BESS	Battery Energy Storage System
BMS	Battery Management System
CBD	Central Business District
CFD	Computational Fluid Dynamics
DA	Development Application
DGs	Dangerous Goods
DPHI	Department of Planning, Housing and Infrastructure
EMS	Environmental Management Strategy
HIPAP	Hazardous Industry Planning Advisory Paper
ISO	International Organization for Standardization
LEL	Lower Explosive Limit
NSW	New South Wales
MVPS	Medium Voltage Power Station
PCU	Power Conversion Unit
QLD	Queensland
QFD	Queensland Fire Department
RFS	Rural Fire Service
RMAR	Risk Management Assessment Report
SARA	State Assessment and Referral Agency
SEP	Surface Emissive Power

1.0 Introduction

1.1 Background

Attexo Group Pty Ltd (Attexo) is assisting RWE Tully Battery Pty Ltd (RWE) with the development application for the Tully Battery Energy Storage System (BESS) located within the Cassowary Coast Regional Council. As part of the planning services, subspecialist reports will be required to meet the performance outcomes outlined in the published State Code 27: Battery storage facility development of the State Development Assessment Provisions. This document presents the RMAR, which aligns with the risk management guidelines established in AS ISO 31000:2018 (Ref. [1]).

Attexo on behalf of RWE has commissioned Riskcon Engineering Pty Ltd (Riskcon) to prepare the required documentation for the Project. This document represents the RMAR for the Tully BESS

1.2 Objectives

According to AS ISO 31000:2018, the key objectives of this RMAR are to:

- Identify potential hazards to the BESS facility that would hinder regular operations or have potential off-site impacts.
- Analyse the consequences and likelihood of a hazardous event, thus assigning hazards a risk level.
- Evaluate the risks against relevant risk criteria to determine where additional action is required, until the risks are mitigated As Low As Reasonably Practicable (ALARP).

1.3 Scope of Services

The scope of work is to prepare a RMAR for the BESS Project to assist in evaluating possible dangerous goods and demonstrating the facility is safe to operate and compliant with the relevant codes, standards, and regulations.

2.0 Methodology

2.1 Risk Assessment Methodology

The risk assessment methodology described below is based on the Australian Standard AS31000-2018, “Risk Management-Principles and Guidelines”, as per the requirements of State Code 27. The risk assessment methodology broadly uses the principles of Identification, Analysis and Evaluation, as summarised in **Figure 2-1**.

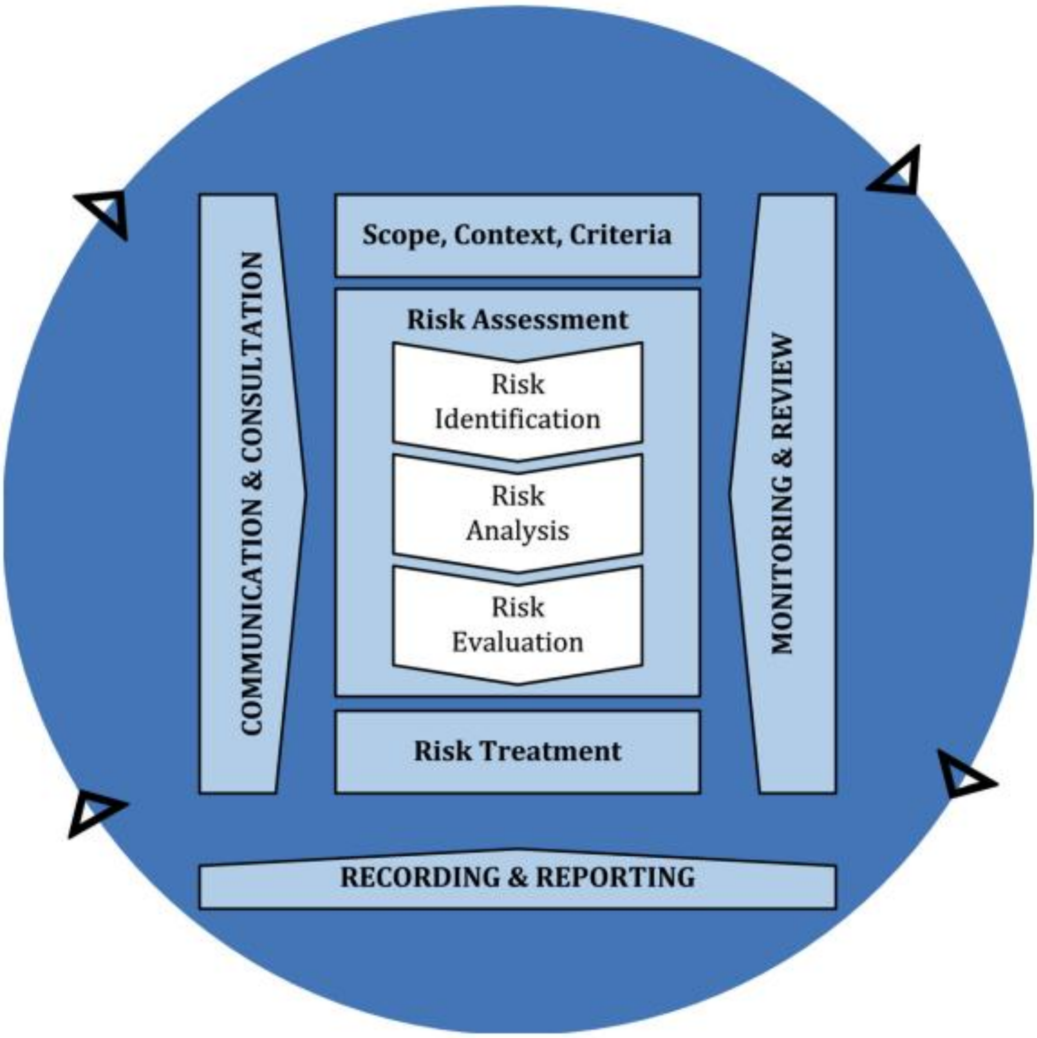


Figure 2-1: Risk Assessment Process (Source: AS ISO 31000:2018)

2.1.1 Hazard Identification Methodology

While AS ISO 31000:2018 refers to ‘Risk Identification’, it is more accurate to discuss hazard identification, with ‘hazard’ being defined as a source of potential harm or damage to health, property or the environment. ‘Risk’ is the description of the combined assessment of consequence and likelihood of a hazardous event and is more useful in the later stages of Analysis and Evaluation.

To properly assess risks, hazard identification is a crucial step. For this Project, hazards are identified based on previous projects, previous hazardous events that have occurred, and potential hazards arising from properties of the specific dangerous goods stored on-site.

2.1.2 Risk Analysis Methodology

Risk analysis is the process of assessing the consequences of hazardous events in conjunction with the likelihood of these events. The methodologies of risk analysis presented in AS31000 range from fully quantitative to fully qualitative. The Multi-Level Risk Assessment approach, published and adopted by NSW Department of Planning, Housing and Infrastructure (DPHI), is a useful screening tool to determine the type of risk assessment to use. As there is no QLD equivalent approach, therefore this is used. The levels of a Multi-Level Risk Assessment (Ref. [3]) are summarised in **Table 2-1**.

Table 2-1: Multi-Level Risk Assessment

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

A partially quantitative (Level 2) methodology is normally used for low- to medium-range risk analysis and early-phase analyses and uses the risk matrix approach. Based on the type of DGs to be used and handled at the proposed site, this level of assessment (Level 2) is considered suitable. 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.

The qualitative approach uses a series of tables to assess the consequence severity and likelihood of an identified hazard (to cause harm to people, property or the environment (see **Table 2-2** and **Table 2-3**) and uses a risk matrix to assess the risk level of the identified hazard (see **Figure 2-2**). The results indicate the level of risk associated with the hazard.

Table 2-2: Consequence Values Used in Risk Assessment

Consequence		Consequence Description			
Score	Descriptor	Operations/ Maintenance	Financial	Safety	Environment
1	Insignificant	Short duration down time – adequate redundancy, process unaffected	Less than $5k damage	First Aid Injury (FAI), no lost time	Localised spill contained in a bund or in the immediate spill area Fugitive emissions
2	Minor	Downtime – managed without affecting process (e.g. recycle within the plant)	$5k to $100k damage	Medical Treatment Injury, no lost time	Spill contained in site Short term emissions
3	Moderate	Major non-critical equipment failure	$100k to $1M damage	Lost Time Injury or illness (LTI)	Spill escapes to stormwater or groundwater system Some complaints received over environmental issue

Consequence		Consequence Description			
Score	Descriptor	Operations/ Maintenance	Financial	Safety	Environment
4	Major	Critical equipment failure Structural failure Failure to meet licence conditions	$1M to $10M damage	Permanent disability Single fatality	Major spill to the stormwater system Prosecution from air emissions Numerous neighbour complaints
5	Catastrophic	Extended downtime causing loss of asset Explosion/Major Fire	More than $10M damage	Multiple fatalities	Large media coverage of environmental incident Fines from DPE

Table 2-3: Likelihood Values Used in Risk Assessment

Likelihood Indicator		Likelihood Description
Score	Indicator	
A	Almost Certain	Has occurred many times, repeated occurrence
B	Likely	Occurs annually, has happened & will re-occur
C	Occasional	Has occurred once in the past, may occur some time
D	Unlikely	Has occurred in organisation at other sites, but not at this site, <10% chance of happening during the plant's life
E	Rare	Has not occurred at in the organisation but has occurred in the industry, has the potential to occur, <1% chance of happening but only in exceptional circumstances

	Consequence				
Likelihood	Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
A (almost certain)	S	S	H	H	H
B (likely)	M	S	S	H	H
C (moderate)	L	M	S	S	H
D (unlikely)	L	L	M	M	S
E (rare)	L	L	L	M	M

H	High Risk – Requires both hardware and procedures to mitigate
S	Significant Risk – Review hardware requirements and develop new procedures
M	Moderate Risk – Review existing procedures for adequacy, additional procedures where required
L	Low Risk – Managed mainly with existing procedures

Figure 2-2: Risk Matrix used in Risk Assessment

Where risks are identified to require quantitative consequence assessment, the hazardous event is modelled in EFFECTS by Gexcon and the consequence contours are assessed compared to the consequence criteria listed in Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 (see **Appendix B**). The potential for incident propagation is assessed from the consequence contours.

Where the hazardous event has consequence contours that impact the site boundary or have the potential for incident propagation, the frequency of such an event is quantitatively determined. Otherwise, the consequences are considered sufficiently controlled for qualitative frequency analysis.

2.1.3 Risk Evaluation Methodology

Risk evaluation is the process of comparing the risk level assigned to acceptable risk criteria. Where the risk is deemed to be unacceptable, risk mitigation strategies and safeguards are recommended, and the risk is re-analysed. This re-analysis and re-evaluation is repeated until the risk level is deemed acceptable and the risk is reduced ALARP.

For risks analysed **qualitatively**, the risk level assigned to the hazard shall be considered acceptable if it is of moderate (M) or low (L) risk.

For risks analysed **quantitatively**, the risk is compared to the risk criteria published in the Hazardous Industry Planning Advisory Paper (HIPAP) No. 4, published by NSW DPHI. The acceptable risk criteria published in the HIPAP relate to injury, fatality and property damage. The values presented in **Table 2-4** are the maximum acceptable levels of risk for the land-use, as fatality is considered the worst-case scenario.

Table 2-4: Individual Fatality Risk Criteria

Land Use	Suggested Criteria (risk per million per year)
Hospitals, schools, child-care facilities, old age housing	0.5
Residential, hotels motels and tourist resorts	1
Commercial developments including retail centres, offices and entertainment centres	5
Sporting complexes and active open spaces	10
Industrial	50

Where risks exceed the acceptable risk criterion for the land use, additional risk mitigation strategies and safeguards are recommended until the risk is reduced below the acceptable risk criterion.

2.2 Methodology Summary

The methodology used, as established in AS ISO 31000:2018, is summarised below.

- **Hazard Identification** – an integral part of any risk assessment is the identification of hazards. Without the hazard first being identified it will not be possible to assess the risk and, where required, apply risk reduction measures.

  It is necessary to obtain a reasonable understanding of the project under assessment and to use experienced people to assist in identifying the hazards. This can be done by individuals or in a workshop situation.

- **Risk Analysis** –the risk analysis can take the form of a semi-quantitative study, which is performed to address the potential hazards identified with the observed tasks. The study can be a workshop style or individual assessment. Identified hazards are systematically worked through identifying consequences, likelihoods and risks.

  Risks are recorded in tabular format as shown below:

No.	Hazard and Cause	Consequence	Safeguard	S*	L*	R*	Recommended Risk Reduction Measure	Residual Risk		
								S*	L*	R*

* S = Severity, L = Likelihood Value, R = Risk Level

- **Risk Evaluation and Reduction** – as shown in the table above, once the risk have been assessed the risk level is evaluated against acceptable risk criteria, and risk reduction measures are sought where required. These are then recorded and the risk reanalysed to estimate the residual risk. The residual risk indicates the effectiveness of the proposed risk reduction measures and whether further risk reduction is required to reach the ALARP level.

- **Reporting** – on completion of the study a report is developed listing the objectives, scope of work, methodology, results, conclusions and recommendations.

3.0 Site Description

3.1 Site Location

The proposed site for the Tully BESS is approximately 4 km (via Tully Gorge Road) to the south-west of the centre of Tully and approximately 145 km south of Cairns via the Bruce Highway. **Figure 3-1** shows the location of the proposed site in relative to Tully. **Figure 3-2** shows the conceptual BESS Layout with the existing substation. It is acknowledged that the designs are preliminary at this stage; however, any changes to the design are unlikely to be significant to the hazards present.

3.2 Adjacent Land Uses

The land for the proposed site is located in a regional / rural area surrounded by the following land used which are adjacent to the sites:

- North – Power link substation
- South – Cane farm
- East – Wet land
- West – Rural land used for cattle grazing and evaporation ponds

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 can be seen in **Figure 3-3**.

3.4 General Description

The Project includes a proposed BESS with a capacity up to 200 MW for a duration of 4 hours and associated infrastructure (e.g. transformer, OHTL, air insulated switchgear, access roads, laydown areas, foundations, hard stand, parking, switch rooms and storage). The BESS and associated infrastructure will comprise a total development footprint of approximately 9 ha within the 28.7 ha Project Site.

The Project has been designed to minimise impacts, in keeping with the sustainable nature of the development for supporting renewable energy projects and reducing greenhouse gas emissions. Accordingly, the existing environment; existing land use at the Site and the surrounding locality; proximity to existing electricity infrastructure; stormwater management; and noise impact have all been considered in the design development.

The primary components of the Project will consist of the following:

- Up to 188 battery units will cover a total area of approximately 2.5 ha. The foundations for the proposed battery units will likely be screw piles, piers or concrete pad formations. The BESS will be connected to the adjacent switch rooms via underground cables. Inverters may be incorporated as part of the battery units or there may be separate Power Conversion Units (PCU) that convert the DC energy from the battery units.

- Switching station will be located to the north of the battery unit and comprise a 132/33 kV high-voltage transformer, switchgear, an auxiliary transformer, two 33 kV switch rooms and potentially harmonic filters.
- Stormwater drainage systems will be constructed to allow for safe collection and diversion of rainwater at the BESS facility and will be established for both construction and operational phases.
- Access to the facility will be via the existing local road network with upgraded access proposed from Sandy Creek Road.
- Grid connection will be via an overhead transmission line running from the north of the BESS area to substation on the adjoining lot. The OHTL will be supported by five (5) single circuit 132 kV concrete poles approximately 27.5 m in height.
- The BESS area will be fenced for safety and security purposes.
- An Asset Protection Zone (APZ) will be established and maintained around the battery storage infrastructure to ensure protection from bushfire and to allow access to firefighting personnel in the event of fire.
- A perimeter access track around BESS units will be provided for operations, maintenance and emergency response.
- Earthworks, including batters and clearing required for access to undertake civil works.
- An acoustic wall of 6 m in height has been included with the design, this is located directly on the northern perimeter of the BESS units. The acoustic wall may not be required, subject to further design enhancements of the BESS units to reduce noise levels.
- The Project includes provision for lighting for when maintenance works are to be undertaken at night; these will be on 10 m high poles. Additionally, there would be security lighting that is controlled by sensor. All lighting would be designed and operated in accordance with AS 4282:2023 Control of the obtrusive effects of outdoor lighting.
- Two lightning arrestors will also be located within the development footprint; these will be up to 20 m in height.

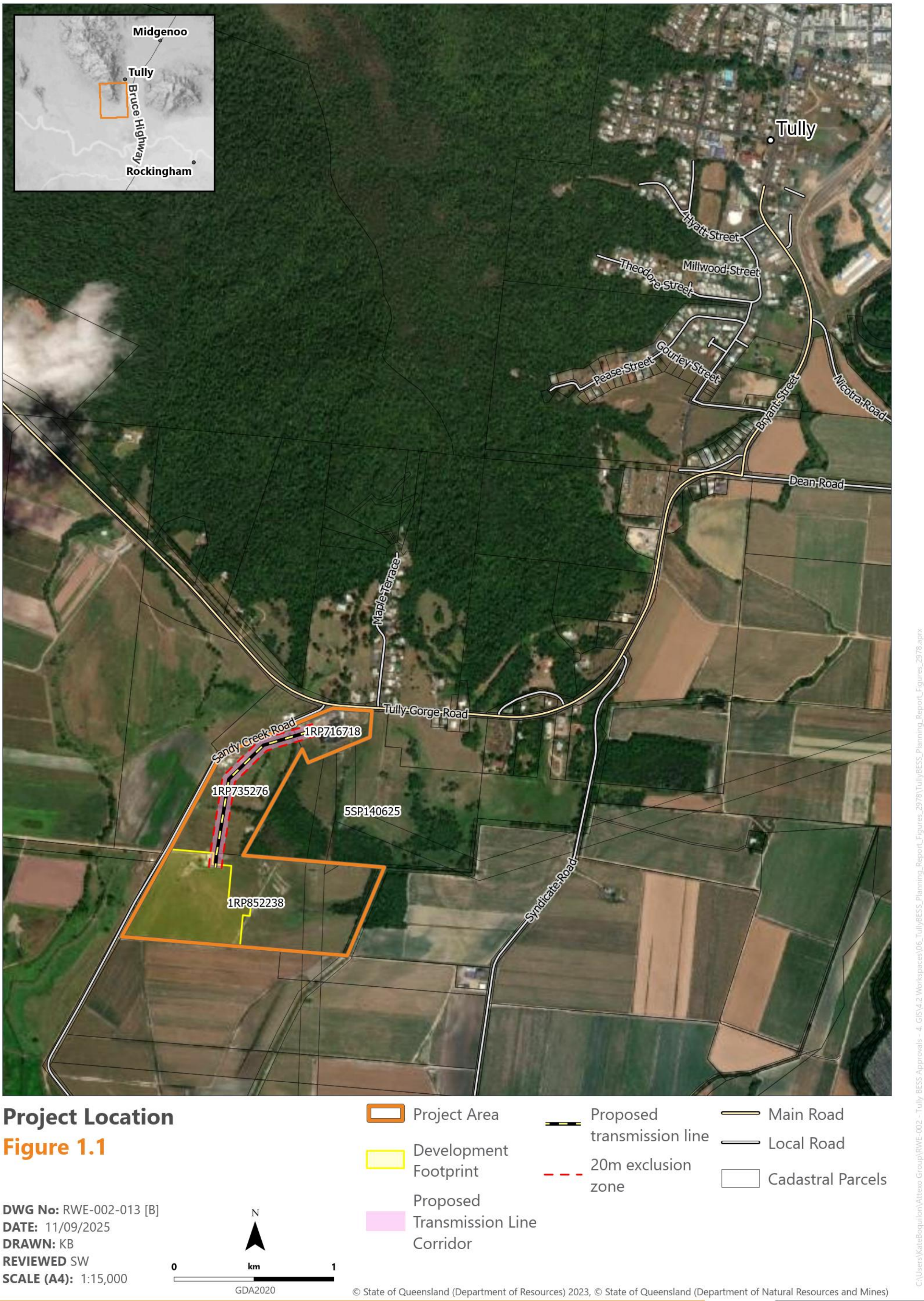


Figure 3-1: Site Location

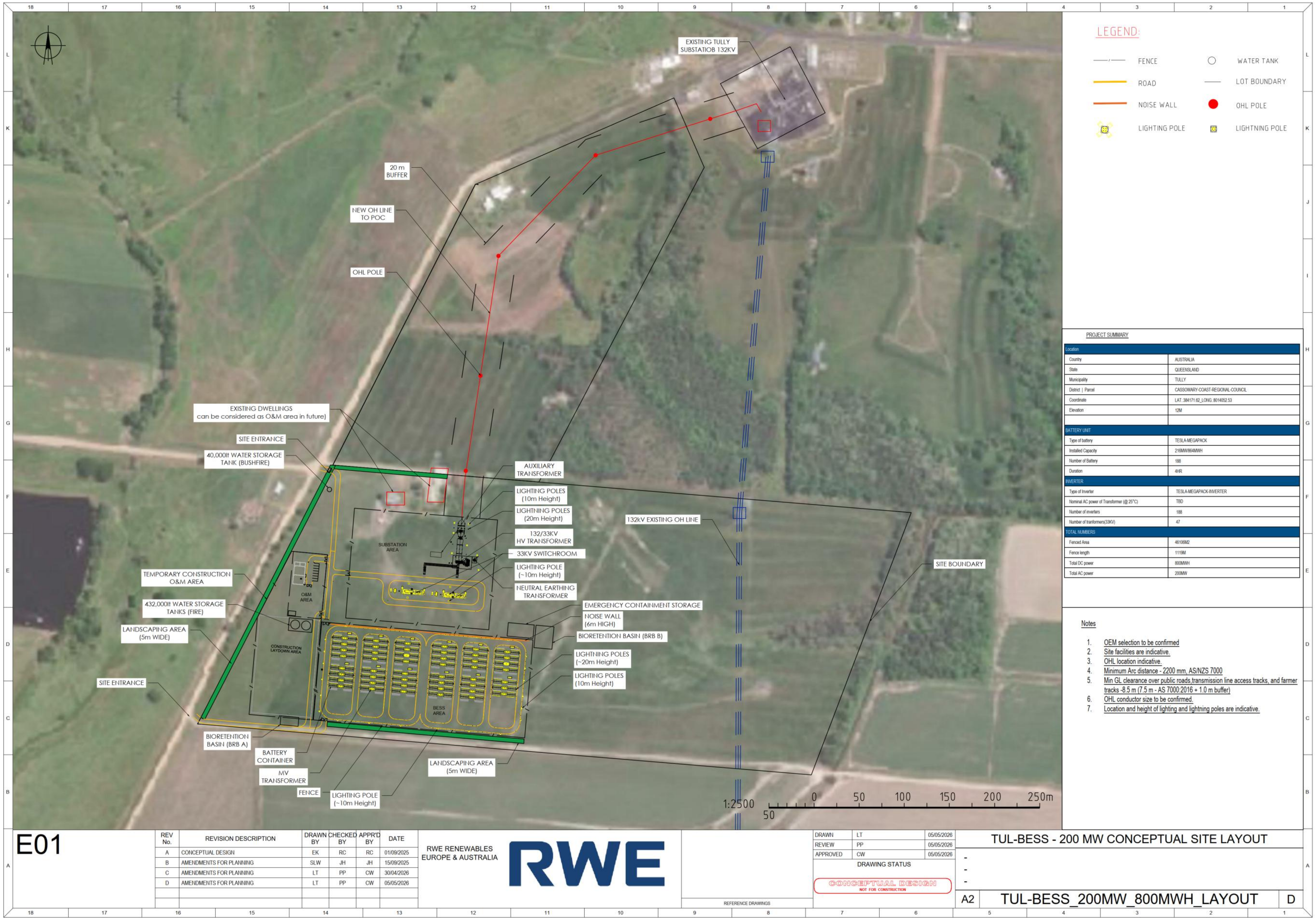


Figure 3-2: Conceptual BESS Layout

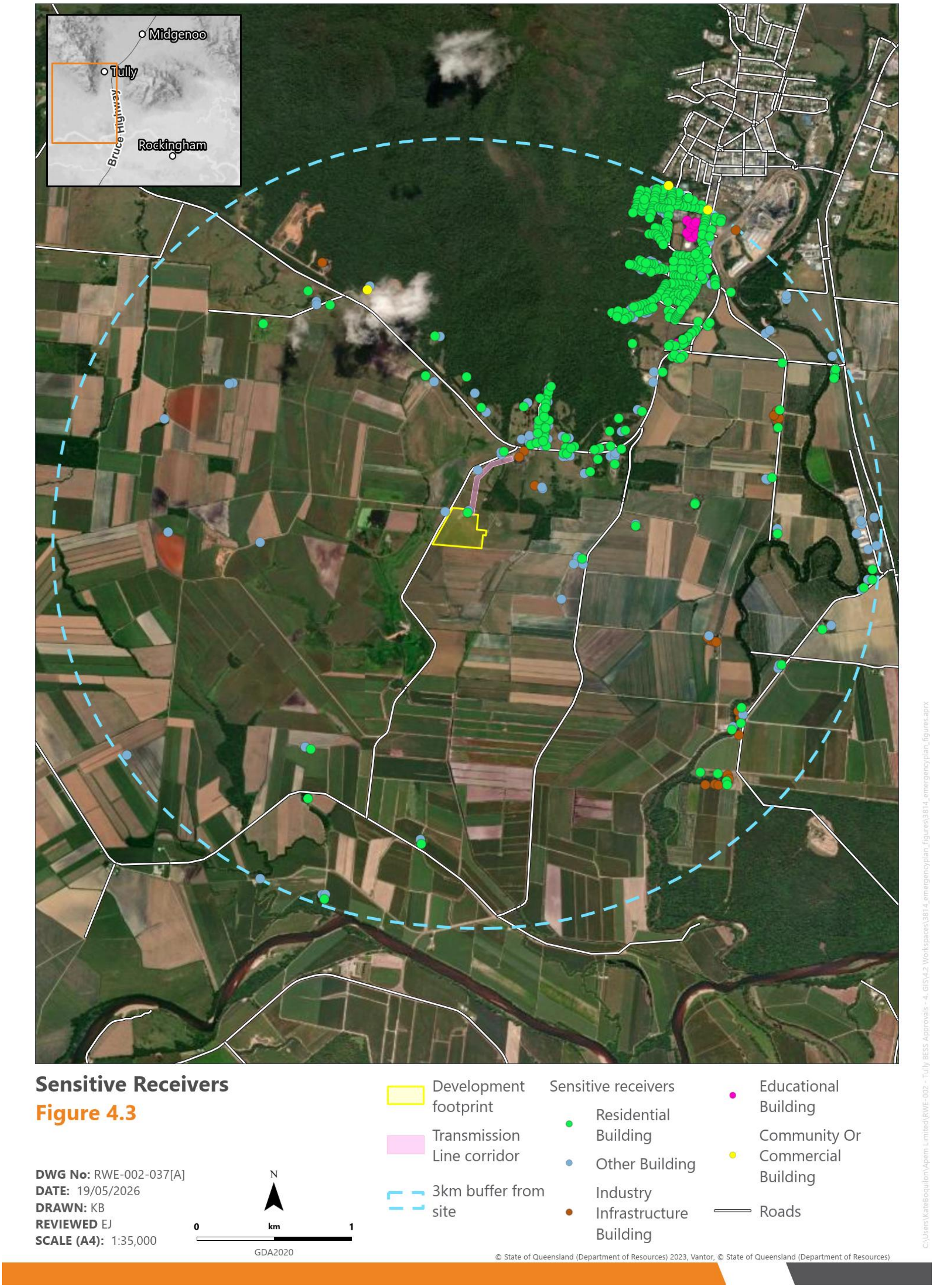


Figure 3-3: Sensitive Receptor Locations

3.5 Detailed Description

The purpose of the Project is to store excess dispatchable energy generated by the national grid, as part of Queensland's commitment to decarbonisation.

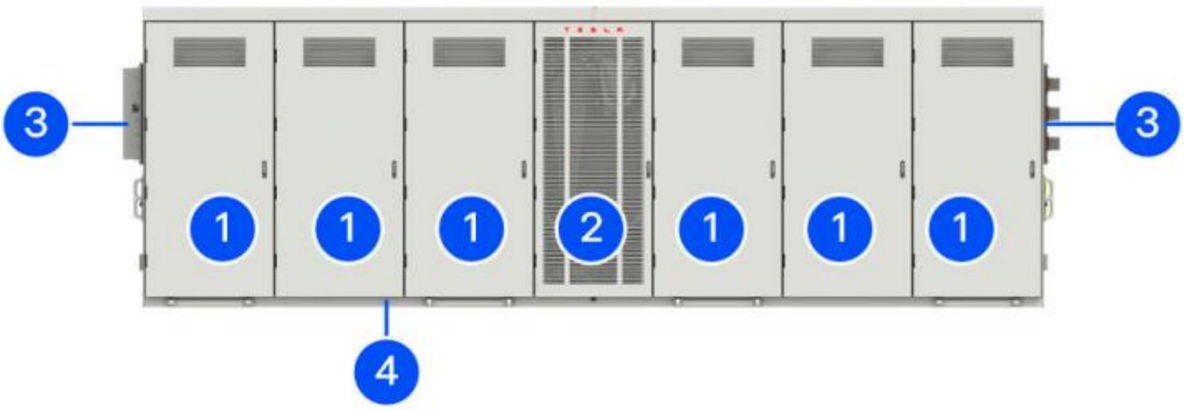
The Project will be able to store electricity with a capacity of approximately 200 MW / 800 MWh. The BESS units will store the electricity to be dispatched based on electricity demand fluctuations, providing the opportunity for greater supply dispatch flexibility when electricity demand is highest. This is enabled by the fast response times achievable through lithium-ion battery storage.

3.5.1 Battery Storage

The BESS units will be located within the designated BESS area. The BESS converts electrical energy into chemical energy and stores the energy internally. The BESS model is expected to be the Megapack 3 which is shown in **Figure 3-4**.

Figure 3-4: Tesla Megapack 3 Model

The Tesla Megapack 3 is a fully integrated battery energy storage unit capable of charging and discharging real power and injecting and absorbing reactive power. The overall dimension of each unit is 8,550 (W) mm x 2100 (D) mm x 2,785 (H) mm, which houses six Li-Ion (Lithium Iron Phosphate – LFP) battery module bays, a thermal bay and bus assemblies that connect to the Megablock's MV transformer. Each model is monitored by a Battery Management System (BMS). The BMS tracks cell voltages and temperatures, and ensures the stability of the batteries, preventing thermal runaway by isolating any cell that falls outside operating parameters. Temperature and humidity within the container are regulated by an internal cooling system that uses liquid to cool. An overview has been provided in **Figure 3-5**.



1. Battery module bays (Battery Modules on page 13)
2. Thermal bay (Thermal System on page 13)
3. Megapack bus connector to the MV transformer (MV Assembly on page 14)
4. IP66 enclosure (Megapack); IP2X enclosure (thermal bay)

Figure 3-5: Tesla Megapack 3 Overview

Battery modules are factory-installed into the Tesla Megapack 3 battery module bays and contain prismatic lithium-ion battery cells. A battery module in turn is the smallest field-replaceable battery unit. Each of the Tesla Megapack 3's six battery bays contain up to two battery modules. Each battery module includes an integrated inverter module for power conversion. Battery modules are connected in parallel to Megapack's internal AC bus, each with an AC power and communications output connection. An image of the battery module has been provided in **Figure 3-6**.

Figure 3-6: Battery Module in a Tesla Megapack 3

While the Tesla Megapack 3 has not undergone third party certification to attain UL9540A, the adjacent battery model (Tesla Megapack 2XL) has been certified in accordance with UL9540. As the battery chemistry is identical between the models, it is not expected that the UL9540A results would be materially different in all levels, from cell to unit level. Hence, it is concluded that the inherent fire mitigation in the design of the BESS is sufficient to operate without additional suppression methods in the event of a fire.

Note that the Tesla Megapack 3 is currently planned to be installed in the "Megablock" arrangement. This arrangement is essentially two or more Tesla Megapack 3s connected together by a single MV transformer in a single line. **Figure 3-7** has been provided to visualise this.

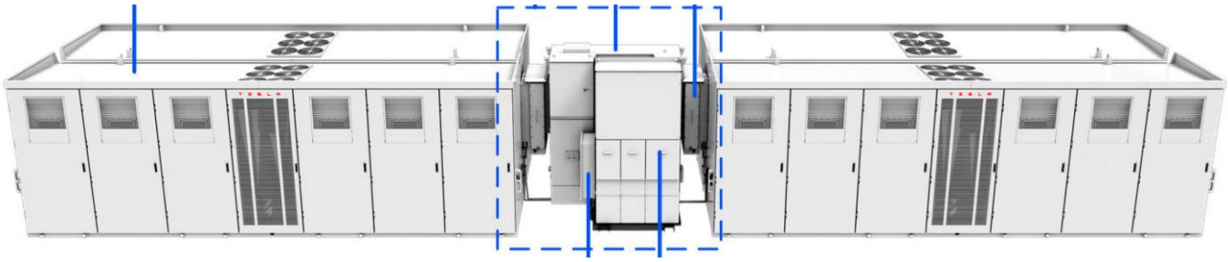


Figure 3-7: Megablock Arrangement

3.5.2 Protection Measures

While the Tesla Megapack 3 has not undergone third party certification to attain UL9540A, the adjacent battery model (Tesla Megapack 2XL) has been certified in accordance with UL9540. As the battery chemistry is identical between the models, it is not expected that the UL9540A results would be materially different in all levels, from cell to unit level. Furthermore, the fire-safety features of the Tesla Megapack 3 offer the same or higher level of protection in comparison to the Tesla Megapack 2XL. **Table 3-1** has been provided to showcase the key fire-safety features of the Tesla Megapack 3 in comparison the Tesla Megapack 2XL.

Table 3-1: Key Fire-Safety Features of the Tesla Megapack 3

Fire-Safety Feature	Description
BMS	Similar to the Tesla Megapack 2XL, the Tesla Megapack 3 features a complex BMS that continuously monitors cell temperatures, voltages, currents, insulation levels, and general system health. The BMS automatically responds to off-normal conditions and plays a central role in limiting or preventing escalation during early-stage anomalies. In addition to baseline monitoring functions, the Tesla Megapack 3, incorporates BMS-driven protective modes, such as: (1) Automatic Safe Discharge which lowers the battery's state of energy if potential thermal runaway indicators are detected, and (2) Thermal Limp Mode, which reduces module or unit-level power output when temperatures approach unsafe thresholds.
Thermal Management System (TMS)	Mirroring the philosophy used in the Tesla Megapack 2XL, the Tesla Megapack 3 uses a fully integrated active thermal management system that provides active cooling and heating to maintain safe operating temperatures across all internal components. An external HVAC or thermal system is therefore not required for the Tesla Megapack 3 to operate. The system consists of: (1) Thermal Bay and (2) Coolant manifolds.
Explosion Control System Sparkers	Like the Tesla Megapack 2XL, the Tesla Megapack 3 includes a Sparker System that proactively ignites low-concentration flammable gases before they reach hazardous levels. By combusting gases early, sparkers significantly reduce deflagration potential and work in tandem with the overpressure vents for a fully engineered explosion-mitigation strategy.
Explosion Control System Pressure-Sensitive Vents	As with the Tesla Megapack 2XL, the Tesla Megapack 3 incorporates overpressure vents in each battery bay that open automatically during a rapid internal-pressure rise. Once

Fire-Safety Feature	Description
	activated, these vents route gases and combustion products from the battery bay into the thermal bay and then out through the doors, preventing pressure buildup and preserving enclosure integrity.
Explosion Control System Automated Door Opening	Not found in the Tesla Megapack 2XL, the Tesla Megapack 3 further enhances deflagration mitigation by incorporating automated door opening when harmful interior conditions are detected. This provides additional pressure relief and supports more rapid ventilation, thereby shortening the duration and severity of a thermal event. Prior to door opening, an external warning the form of audible and visible notification will be given, alerting site personnel to the potential hazard.
Safety Controller	Not found in the Tesla Megapack 2XL, the Tesla Megapack 3 includes a dedicated Safety Controller located in the thermal bay, responsible for aggregative safety-related sensor data, executing alert logic, and initiating protective actions when required. The safety controller provides an external warning and communication system which consist of an audible alarm and flashing lights as well as Alarm communication to the Tesla System Controller. The safety controller hardware/firmware is evaluated under UL 1998 and UL 991, confirming robustness of safety-related controls and proper fail-safe behaviour.

NFPA 855 allows for the BESS units to be installed without fire suppression systems where fire, explosion and fault condition testing documents indicate the inherent BESS design is sufficient to limit thermal runaway events.

While the BESS layout in **Figure 3-2** is preliminary, its design contains safety features that are assumed to be incorporated into the final layout design. These include:

- Storage of infrastructure (BESS and MVPSs) no less than 9 m from site boundary
- A 3 m clearance of infrastructure (BESS and MVPSs) from site access roads and other infrastructure
- BESS access roads 6 m in width.
- Implementation of recommendations from the Bushfire Hazard Management Plan.

3.6 Quantities of Dangerous Goods

Prior to operations, combustible oils in transformers and lithium-ion batteries transported to or held/handled on-site are considered to be DGs under the Australian Dangerous Goods Code (ADGC). However, once the these are used in operations, it is not considered a DG under Division 1 Part 7.1 of the Work Health and Safety Regulation 2011 (Ref. [4]). Other DGs that are expected to be held onsite include oil in the transformers (often ester or mineral oils). The precise quantities of DGs are to be confirmed, however **Table 3-2** contains the expected quantities of DGs onsite for a project of this scale.

The threshold column in **Table 3-2** indicates placard threshold for combustible liquids, at which there are certain legal requirements to comply with Work Health and Safety Regulation 2011.

Table 3-2: Maximum Quantities of Dangerous Goods Stored & Preliminary Risk Screening

Area	Class	Description	Quantity	WHS 2011 Placard Threshold
BESS Units	9	Li-Batteries	2,847 T	n/a
Transformer oil	C1	Combustible Liquid	400 kL*	10,000 L

*TBC. Estimated quantity based on similar projects

4.0 Hazard Identification

4.1 Introduction

A hazard identification table has been developed and is presented at **Appendix A**. Those hazards identified to have a potential fire or explosion impact are assessed in the following sections of this document.

Where the hazards or hazardous events are qualitatively deemed to be of low enough consequence or likelihood, a qualitative risk analysis is conducted at the end of each subsection, and a risk level is assigned. Where the hazards required further analysis, they are carried forward for quantitative risk analysis.

4.2 Properties of Dangerous Goods

The type of DGs and quantities stored and used at the site has been described in **Table 3-2**. **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 60.5^{o}C. 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.

* According to the Australian Code for the Transport of Dangerous Goods by Road and Rail (Ref. [5]))

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.
- Li-ion battery fire and toxic gas dispersion.
- Electrical equipment failure and fire.
- Transformer, oil spill, ignition and bund fire.
- Transformer electrical surge protection failure and explosion
- Electromagnetic field impacts
- Natural hazards – Bushfires
- Natural hazards – Earthquakes
- Natural hazards – Flooding

- Natural hazards – Extreme heat
- Natural hazards – Cyclone/ Strong winds
- Natural hazards – Landslide
- Firewater application on Li-ion battery fire, contamination and environmental incident

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 lithium iron phosphate (LFP) batteries, the cathode is composed of LFP or $LiFePO_4$ and the anode is composed of graphite. During charging, lithium ions are released from the cathode, through the electrolyte and across the separator and are stored in the graphite. When discharge occurs, the electrons are released in the circuit and the lithium ions exit the anode and return to the cathode. This process is shown in **Figure 4-1**.

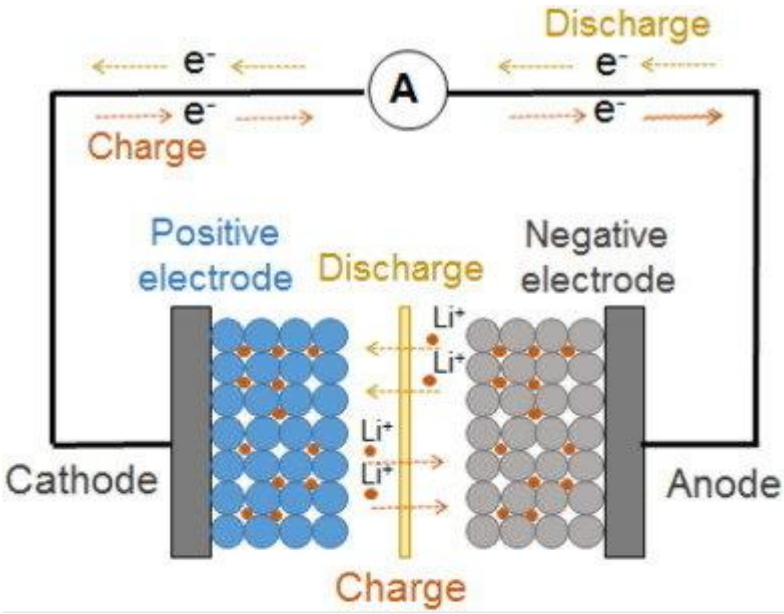


Figure 4-1: Cathode and Anode of a Battery (Source Research Gate)

The key hazard associated with Lithium-ion-BESS (Li-BESS) systems is thermal runaway which can be initiated in a cell by several events including (Ref. [6]) :

- Manufacturing defects
- Overcharging
- Overheating
- Mechanical abuse

During thermal runaway, cells can release a large quantity of both toxic and flammable gases creating a risk for explosion and toxicity to bystanders. Thermal runaway in a single cell within a BESS unit has potential to induce thermal runaway propagation which may eventually lead to larger-scale fire and/or explosion incidents (Ref. [7]).

The likelihood and consequence of thermal runaway in a BESS is dependent on several factors including the design, battery chemistry and installed systems. The battery product that has been proposed for this project is the Tesla Megapack 3 of which the battery chemistry is LiFePO4, or simply LFP. LFP cells are the current standard for large-scale BESS systems accounting for approximately 80% of the total battery storage market as of 2023. This is largely due to lower cost, higher cycle lives and safety considerations when compared to other chemistries such as nickel manganese cobalt (NMC)(Ref. [8]). Although NMC has a higher energy density, LFP batteries have begun to dominate the grid-scale energy market due to the following advantages when compared to NMC (Ref. [9]):

- Longer cycle life and less capacity reduction over time
- Higher thermal stability and less prone to overheating
- Better mechanical stability
- More stable electrochemically with fewer side reactions which accelerate degradation
- More resilient to state of charge (SOC) and depth of discharge (DOD) with less degradation from deep cycling

While the Tesla Megapack 3 has not yet attained its certification, the Tesla Megapack 2XL has. The two models share the same battery chemistry and arrangement on a system level; hence, the results of the tests are expected to be comparable as discussed in **Table 3-1**. The testing would have demonstrated in the event of thermal runaway initiated in a single cell; it is highly unlikely that propagation beyond the initiating module would occur even in absence of active control measures. Tesla has provided a letter of commitment to provide the test results once it is available, which has been provided in **Appendix C**.

During a thermal runaway triggered at the cell level, flaming outside of the unit does not typically occur. However, should a larger issue such as electrical faults or arcing in a number of cells occur, thermal runaway in multiple cells may occur with may cause the entire unit to catch fire and the spacing between units and fire suppression installed would be relied upon to prevent fire spread.

Therefore, it is important that adequate clearance between units (specifically in the Megablock arrangement as described in **Section 3.0**) have been provided. Tesla has provided recommended clearances in its datasheet. This can then be compared with other established minimum clearances provided by different standards/sheets, which has been assessed in **Table 4-2**.

Table 4-2: Separation Distance Requirement Review

Organisation	Standard / Sheet	Clause	Requirement	Current Design Compliance
Tesla	Megablock System Specification	8.5.1	2.5 m front-to-front (i.e., long side)	Y
Factory Mutual Insurance Company	FMDS 5-33	2.3.2.2	1.5 m on sides that contain access panels, doors or deflagration vents	Y

As observed in the BESS layout provided in **Figure 3-2**, the front-to-front clearance of one Megablock to another is a minimum of 3 m; hence, the requirements of FMDS 5-33 and the

Megablock System Specification are complied with. The arrangement of a Megablock can be seen in **Figure 3-7**

As would be seen in the UL9540A report, the LFP technology does not provide a source of ignition during thermal runaway. Should fire develop within one BESS container it would not transfer to nearby containers due to the fire safety design features and recommended separation. Notwithstanding, this incident has been carried forward for further analysis to identify whether fire protection equipment is impacted.

4.4.1 Risk Analysis

The consequences and likelihood of a flaming Li-ion battery fire are summarised in **Table 4-4.**

Table 4-3: Qualitative Risk Analysis of Li-Ion Battery Fire

Hazard	Cause	Consequence	Safeguard	Assessed Risk		
				S	L	R
Li-ion Battery Fire	Puncturing or internal damage Internal arcing	Injury/single fatality Damage to property <$1M	• Low likelihood of initiating event (stable battery chemistry) • Unmanned site during regular operations – low likelihood of people being present • No sensitive receivers within 650 m of site • Inherent design limits incident propagation (when UL 9540A compliant) • Sufficient spacing between units to limit propagation • Physical barriers (e.g., bollards, etc) to prevent vehicular collision	4	D	M

4.5 Li-ion Battery Fire and Toxic Gas Dispersion

If a BESS failure occurs resulting in a fire, toxic biproducts 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; and
- Fluorine gases.

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

4.5.1 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 of exposed persons. The Short Term Exposure Limit (STEL) is 30,000 ppm (3%) as established by SafeWork Australia; thus, levels above 50,000 ppm (5%) will induce a strong respiration effect, along with dizziness, confusion, headaches, and shortness of breath. Concentrations more than 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, 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. This incident has not been carried forward for further analysis.

4.5.2 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.**

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

Carbon monoxide may be generated if there is insufficient oxygen to sustain complete combustion during a BESS fire. 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. This incident has not been carried forward for further analysis.

4.5.3 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. [10]).

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. Several tests on different variables, such as battery chemistry, configuration and State of Charge (SOC), indicated most of the batteries did not produce observable POF_3 with the condition that a specific battery chemistry was at 0% SOC (Ref. [10]). Therefore, the main fluorine gas of concern in a Li-ion battery fire is HF.

HF gas is hydroscopic that readily dissolves into water vapour / humidity or moisture in airways, forming hydrofluoric acid. Although hydrofluoric acid is a weak acid, it is highly corrosive and may result in chemical burns. In addition, it has calcium scavenging properties. 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 negligible due to the highly stable and safe battery chemistries used. By ensuring the BESS units implemented are compliant with the UL9540A test criteria, the presence of toxic gases released in the unlikely event of thermal runaway will be negligible.

Furthermore, Franqueville *et al.* (Ref. [11]) completed a Computational Fluid Dynamics (CFD) study to determine the dispersion of toxic gases from Li-Ion batteries in various scenarios. In a worst case scenario, in which the wind reaches 32 km/h and the failed BESS is actively burning, the study showed that a safe distance from the burning Li-Ion battery would be maximum of 54 m. Therefore, a toxic gas dispersion impacting any sensitive receptors within a 600 m radius from the BESS facility is not deemed a credible scenario. Notwithstanding, this incident has been carried forward for further analysis.

4.5.4 Risk Analysis

The consequences and likelihood of toxic gas formation and dispersion from a Li-Ion battery are summarised in **Table 4-4.**

Table 4-4: Qualitative Risk Analysis of Li-Ion Battery Toxic Gas

Hazard	Cause	Consequence	Safeguard	Assessed Risk		
				S	L	R
Li-ion Battery and Toxic Gas Release	Li-Ion fire	Risk to worker health Air pollution	• Low likelihood of initiating event (stable battery chemistry)	3	E	L

			• Rapid dispersion of potentially toxic gases to below the threshold IDLH • Unmanned site during regular operations – low likelihood of people being present • No sensitive receivers within 100 m of site			

4.6 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 used within 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 impacts to firefighting equipment and incident propagation. Therefore, qualitative risk analysis is considered suitable for this hazardous event.

4.6.1 Risk Analysis

The consequences and likelihood of an electrical fire from electrical equipment failure are summarised in **Table 4-4.**

Table 4-5: Qualitative Risk Analysis of Electrical Fire

Hazard	Cause	Consequence	Safeguard	Assessed Risk		
				S	L	R
Electrical fire	Electrical equipment failure	Fire Damage to equipment <$1M Injury to worker (some lost time)	• Slow fire development • Arcing safeguards in equipment • Lightning protection • Switch-off procedure	3	E	L

4.7 Transformers, Oil Release, 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. To minimise the likelihood of such occurrence, transformers are fitted with a low oil pressure switch, oil temperature monitoring and switches, gas formation detectors and a pressure surge protection. These devices identify potential oil and pressure events within the transformer, isolating power and alarming operators.

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.

The transformer to be used on site will be insulated using natural ester based insulating oil. Natural esters have a flash point exceeds 300°C (Ref. [12]) and are classified as non-dangerous goods under the Australian Dangerous Goods Code (Ref. [5]). Therefore, ignition of the fluid is extremely difficult, and a fire occurring from a natural ester insulated transformer is not considered a credible scenario. Furthermore, transformers are ubiquitous units with a low potential for failure.

Notwithstanding this, due to the number of transformers on site, and the potential for natural ester oil to be substituted with more flammable transformer oil, this incident has been carried forward for quantitative risk analysis for conservatism.

4.8 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. [13]) 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 4.7**.

In order to protect against overheating and explosions, transformers have surge protection, which programs them to shut down upon detection of an energy spike. However, the surge protection can have a slight delay. In the event of a major lightning strike, significant oil deterioration or physical damage such as a fallen tree, the surge protection may be too slow to stop an electrical overload (Ref. [14]).

However, the transformers will be protected against lightning as per the requirements of AS 2067:2016 (Ref. [15]). Furthermore, the transformers will use natural esters as the insulating liquid instead of mineral oil. As previously discussed, natural esters have a flash point exceeding 300°C (Ref. [12]), and so are classified as non-dangerous goods under the Australian Dangerous Goods Code (Ref. [16]).

Therefore, there is the potential for an explosion to occur which may result in impacts to fire protection equipment; however, as noted, these units are ubiquitous and have a low potential for failure. Qualitative risk analysis is deemed sufficient for this event.

4.8.1 Risk Analysis

The consequences and likelihood of a transformer explosion from surge protection failure are summarised in **Table 4-4.**

Table 4-6: Qualitative Risk Analysis of Transformer Explosion

Hazard	Cause	Consequence	Safeguard	Assessed Risk		
				S	L	R
Transformer	Surge protection failure	Explosion Damage to property < $1M Fatality/fatalities Incident propagation	• Lightning protection • Use of natural esters for insulating oil (non-flammable) • Global use indicates relative safety	4	E	L

4.9 Electromagnetic Field Impacts

4.9.1 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 EMFs in the range of 30 to 300 Hz.

4.9.2 Existing Standards

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. [17]).

Table 4-7 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. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) advises that the strength of radiation decreases exponentially with distance from the source, and it will become indistinguishable from background radiation within 50 m of a high voltage power line and within 5 to 10 m of a substation. (Ref. [18]).

Table 4-7: 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

4.9.3 Exposure Discussion

A review of the site indicates the nearby residences adjacent to the area where the BESS will be developed are separated by over 650 m providing substantial distance for attenuation of EMFs. Based upon the typical levels which may be generated by transmission equipment the cumulative effect would not exceed the 2,000 mG limit for prolonged exposure.

As the potential for exposure to EMF exceeding the international guidelines is negligible, this incident can be qualitatively analysed.

4.9.4 Risk Analysis

The consequences and likelihood of damage from electromagnetic field impacts are summarised in **Table 4-8.**

Table 4-8: Qualitative Risk Analysis of EMF Impacts

Hazard	Cause	Consequence	Safeguard	Assessed Risk		
				S	L	R
EMF impacts	Electrical equipment and BESS	Minor health impacts from extended exposure	• Inherently lower levels than background radiation • Drop off within short distances • No sensitive receivers within 1,000 m of the site	1	C	L

4.10 Natural Hazard – Bushfires

There is the potential for an external fire event to impact the BESS Project such as a bushfire incident. The proposed BESS site is located outside of bushfire prone land with a Very High, High and Medium Potential Bushfire Intensity, as indicated in **Figure 4-2.** As such, the site shall maintain good groundskeeping procedures to prevent the accumulation of combustible loads; hence, in such an event any escalation would be expected to be a minor grass fire. Grass fires can move quickly; however, they tend to be short lived as the combustible load is exhausted. Subsequently, sustained radiant heat impacts at the site would not be expected and would be unlikely to result in sufficient heat to impact the BESS or other infrastructure such that incident propagation occurs.

A bushfire hazard assessment and associated bushfire management plan has been developed by Meridian Urban. It is expected that the design of the site will incorporate the recommendations and findings of the assessment to mitigate the risks of bushfire impact on the BESS. In the case of larger bushfires, emphasis will be placed on evacuating the site if required. A fire water supply will be provided in a 40 kL tank for the brigade to use as well.

The equipment on the site is also protected by the features described in the previous sections and are thus unlikely to be significantly damaged to minor bushfires. The pieces of equipment are also arranged to be sufficiently separated from one another, meaning there is empty space with no fuel between equipment pieces. This would decelerate the bushfire and reduce the impacts.

The potential for incident escalation as a result of bushfire impact to occur is considered low; hence, this incident is reasonably analysed qualitatively.

4.10.1 Risk Analysis

The consequences and likelihood of site damage from bushfire disasters are summarised in **Table 4-9.**

Table 4-9: Qualitative Risk Analysis of Bushfire Impacting BESS

Hazard	Cause	Consequence	Safeguard	Assessed Risk		
				S	L	R
Bushfire	Lightning strike Spontaneous combustion of organic matter due to exothermic reaction (decay) Arson Power line failures Discarded cigarettes Accidental ignition from activities such as parties, campfires, etc	Destruction or damage to electrical infrastructure Radiant heat flux causing thermal runaway Damage to property < $1M Fatality/fatalities Incident propagation	• Separated arrangement of equipment to limit propagation (remove fuel) • Housekeeping procedures to keep grass low • Inherent fire protection in BESS and high heat resistance of other equipment • Bushfire hazard assessment and management plan	4	D	M

4.11 Natural Hazards – Earthquakes

Queensland has the lowest forecast earthquake hazard of any Australian state or territory, as identified in the Queensland State Earthquake Risk Assessment, as can be seen in **Figure 4-3**. No earthquakes above magnitude 6.0 have been recorded in Queensland in the past 50 years, and no significant injury or loss of life from seismic events has been recorded in the region. Under the Geoscience Australia National Seismic Hazard Assessment (NSHA18), the subject site is classified in the second-lowest peak ground acceleration band ,0.005 to 0.01 g, at a 10% probability of exceedance in 50 years, and 0.02 to 0.04 g at a 2% probability of exceedance in 50 years. The potential for earthquake impact on the BESS site is highly unlikely, and is not projected to change with climate.

Nevertheless, a seismic event, even a relatively modest one, could cause structural damage to battery units, the substation, switch rooms, transformers and the overhead transmission line, and may limit site access. Safeguards focus on resilient foundation design, geotechnically certified retaining structures, reinforced access road embankments, and slope stabilisation measures consistent with a separate erosion and sediment control plan. As there is negligible risk to the BESS units, and thus leading to off-site impact, this incident has not been carried forward for further analysis.

4.11.1 Risk Analysis

The consequences and likelihood of site damage from an earthquake are summarised in **Table 4-10.**

Table 4-10: Qualitative Risk Analysis of Earthquake Impacting BESS

Hazard	Cause	Consequence	Safeguard	Assessed Risk		
				S	L	R
Earthquake	Sudden movement/slip along faults in the Earth	Structural damage to electrical infrastructure Plant downtime costing < $100k Medical treatment for affected personnel	• QLD has lowest forecast earthquake hazard in Australia • No earthquakes above Mw 6.0 recorded in QLD in past 50 years. • Resilient foundation design. • Geotechnical assessment and certified retaining structures. • Design in accordance with standards for seismic loading.	2	C	M

4.12 Natural Hazards – Flooding

The site is located within the Tully River Catchment, a catchment of approximately 1,475 km² with a well-documented history of significant flooding. Large flood events have been recorded in 1967, 1999, 2009, 2018, 2023, 2024 and 2025, with the largest on record occurring in March 2018 when Ex-Tropical Cyclone Nora caused the river to reach a height of 8.93 m. Portions of the site are mapped within the Flood Hazard Overlay under the Cassowary Coast Planning Scheme 2015, encompassing low, high and extreme hazard categories. Detailed flood modelling undertaken by Water Technology (modelled flood event provided in **Figure 4-4**) found that the BESS footprint is only marginally affected in the 1% AEP event, with minor flood fringe inundation along the southern boundary reaching maximum depths of 0.30 m in the southwest corner and 0.23 m in the southeast corner. Overland flows from the north and west do not pose a material flood risk, and flow velocities across the infrastructure areas remain below 0.5 m/s. Future rainfall projections indicate a slight decrease in extreme precipitation indices by 2050 and 2090, which somewhat moderates the flood risk outlook.

Key safeguards include designing infrastructure to a minimum 0.2% AEP plus climate change flood immunity, raised and elevated electrical components, waterproof housings, resilient foundation design, site-specific drainage infrastructure, and bioretention basins. Sufficient advance flood warning is generally available to allow the facility to be secured prior to inundation. As there is unlikely risk to the BESS units, and thus leading to off-site impact, this incident has not been carried forward for further analysis.

4.12.1 Risk Analysis

The consequences and likelihood of site damage from flooding are summarised in **Table 4-11.**

Table 4-11: Qualitative Risk Analysis of Flood Impacting BESS

Hazard	Cause	Consequence	Safeguard	Assessed Risk		
				S	L	R
Flood	Heavy rainfall Site located within Tully River Catchment Portions of site within Flood Hazard Overlay	Corrosion, equipment damage, electrical hazards and power disruption Inundation of low-lying components if not adequately elevated Damage to property < $1M Fatality/fatalities Incident propagation	• Infrastructure designed to minimum 0.2% AEP + climate change flood immunity. • Site drainage system designed for site-specific rainfall and flooding. • Raised/elevated platforms for critical infrastructure. • Bioretention basin for stormwater management.	4	D	M

4.13 Natural Hazards – Extreme Heat

There is potential for extreme heat events, such as heatwaves, to impact the electrical infrastructure on-site. The Cassowary Coast LGA has an average January maximum temperature of 31.5°C, with the historical extreme recorded at 42.6°C at Cardwell Marine Parade. Heatwave frequency has been observably increasing since 1958, and between 1986 and 2015 much of Queensland experienced an average of three heatwave events per year. Future projections under SSP3-7.0 are as follows: by 2050 heatwave frequency is projected to increase by a mean of 8.7 additional days per year, hot nights are projected to increase by 47.4 additional nights per year, and heatwave duration is projected to increase by 3.5 days on average. By 2090, these figures increase further to 35 additional heatwave days and over 100 additional hot nights per year. The consequences for BESS infrastructure are multi-faceted and serious. Elevated temperatures accelerate chemical degradation within battery cells, reduce lifespan and cause capacity fade, lower efficiency and power output, increase cooling system demand and operating costs, and increase the risk of thermal runaway, which can result in fire, explosion and the release of toxic gases. Combined UV and heat exposure also accelerates corrosion and component degradation.

The facility is designed to an ambient operating temperature of 50°C, with active cooling systems, battery monitoring systems, temperature sensors, controlled shutdown systems and UV-rated housing specified as key mitigations. Furthermore, it is expected that the BESS units undergo annual maintenance checks to ensure that container integrity has not degraded to such a point that it is compromised. If the BESS units do undergo thermal runaway due to extreme heat, it is expected that adequate separation distances between other infrastructure will prevent fire propagation. As there is unlikely risk to the BESS units, and thus leading to off-site impact, this incident has not been carried forward for further analysis.

4.13.1 Risk Analysis

The consequences and likelihood of site damage from extreme heat are summarised in **Table 4-12.**

Table 4-12: Qualitative Risk Analysis of Extreme Heat Impacting BESS

Hazard	Cause	Consequence	Safeguard	Assessed Risk		
				S	L	R
Extreme Heat	Climate change leading to increase of maximum weather temperature Increasing frequency of heat waves	Overwhelmed cooling system leading to thermal runaway Damage to property < $1M Fatality/fatalities Incident propagation	• Active cooling systems for BESS units • Temperature sensors and BMS • Controlled automated shutdown triggered on temperature limit exceedance • UV-rated housing • Regular maintenance programme	3	D	M

4.14 Natural Hazards – Cyclone / Strong Winds

The Cassowary Coast LGA is located within one of Australia's most cyclone-exposed regions, forming part of the Far North Queensland disaster district with a hazard probability value of 4 for tropical cyclone events between 2021 and 2040. The area has been directly impacted by a succession of significant cyclonic events, including Tropical Cyclone Winifred (Category 2, 1986), Severe Tropical Cyclone Larry (Category 4, 2006, crossing coast approximately 50 km north of Tully), and Severe Tropical Cyclone Yasi (Category 5, 2011, making landfall at Mission Beach approximately 20 km east of the site). During Yasi, the Tully Sugar Mill dataloggers recorded gusts of 285 km/h. Cyclone projections under RCP8.5 for 2050 indicate that a 1% AEP event corresponds to a Category 5 system with gust speeds of 80.19 m/s at the site. While the overall frequency of tropical cyclones is projected to decrease slightly through to 2060, the intensity of the most severe events is expected to remain significant. Separate to cyclone risk, the Cassowary Coast LGA experiences 3–4 lightning ground flashes per km² per year, and 129 severe storm events were recorded across the Far North Region between 1921 and 2021, carrying risks of large hail, damaging wind gusts, flash flooding and lightning strike.

The consequences of cyclonic and severe wind events for the BESS include structural failure of enclosures and infrastructure, water ingress, material fatigue, flying debris damage to sensitive components, transmission line failure, and the potential for thermal runaway from physical damage to battery modules. Safeguards include wind-rated structural engineering, IP66-rated battery enclosures, lightning protection and surge protection systems, weather monitoring, and shutdown and isolation procedures activated in advance of approaching severe events. As there is unlikely risk to the BESS units, and thus leading to off-site impact, this incident has not been carried forward for further analysis.

4.14.1 Risk Analysis

The consequences and likelihood of site damage from extreme heat are summarised in **Table 4-13.**

Table 4-13: Qualitative Risk Analysis of Cyclone / Strong Winds Impacting BESS

Hazard	Cause	Consequence	Safeguard	Assessed Risk		
				S	L	R
Cyclone / Strong Winds	Climate change affecting weather patterns, intensifying wind movement	Damage to property < $1M Fatality/fatalities Incident propagation	• Wind-rated structural engineering for infrastructure per AS/NZS 1170.2. • IP-66 rated battery enclosure and IP2X rated thermal bay. • Lightning protection systems. • Weather monitoring. • Securing and anchoring of all temporary equipment pre-event. • Workers not expected on-site during active cyclone conditions.	3	D	M

4.15 Natural Hazards – Landslide

Landslide mapping of the Cassowary Coast LGA, provided in **Figure 4-5**, indicates that the subject is not located within an identified landside hazard area; hence, there is negligible impact to the site. This incident has not been carried forward for further analysis.

4.15.1 Risk Analysis

The consequences and likelihood of site damage from landside are summarised in **Table 4-14.**

Table 4-14: Qualitative Risk Analysis of Cyclone / Strong Winds Impacting BESS

Hazard	Cause	Consequence	Safeguard	Assessed Risk		
				S	L	R
Landslide	Unstable slope foundation	Not located in an identified landslide hazard area – no risk.	• Site is not within an identified landslide hazard area.	1	E	L

4.16 Firewater Application on Li-ion Battery Fire, Contamination and Environmental Incident

A review of 35 documented large-scale BESS fire incidents (Ref. [19]) across the United States between 2012 and 2024 found that in all cases where post-incident environmental sampling was conducted, water and soil samples did not reveal hazardous contamination levels requiring remediation. This finding is particularly significant given that many of these incidents involved early-generation BESS units that predate modern safety codes, lacked integrated safety features, and in some cases involved NMC chemistry rather than the less hazardous LFP chemistry installed on this site. The fact that even these less well-protected, earlier-generation systems did not produce environmental contamination outcomes requiring remediation establishes a strong baseline for the lower risk presented by a modern LFP installation.

The 2021 Victorian Big Battery (VBB) fire at Geelong is one of the most well-documented large-scale LFP BESS fire events globally and is directly relevant to this site given that it involved the same Tesla Megapack product. The fire involved two Megapack units burning for approximately six hours (Ref. [20]) before being extinguished. Despite the duration and scale of the event, environmental contamination from firewater runoff was not identified as a significant outcome, in part because the attending fire brigade adopted a containment-focused response rather than applying large volumes of suppression water to the burning units.

It is also relevant that the broader body of BESS incident data shows a trend of decreasing incident frequency as system design, safety integration, and operational practices have matured. Nearly half of the 35 US incidents reviewed occurred within the first six months of operation, highlighting commissioning as the highest-risk phase. As this site progresses beyond commissioning into steady-state operation, the statistical likelihood of a fire event, and therefore the likelihood of any firewater runoff being generated, diminishes further.

The potential for incident escalation as a result of an environmental incident resulting from contaminated firewater to occur is considered low; hence, this incident is reasonably analysed qualitatively.

4.16.1 Risk Analysis

The consequences and likelihood of environmental incident from contaminated firewater are summarised in **Table 4-9.**

Table 4-15: Qualitative Risk Analysis of Environmental Incident from Contaminated Firewater

Hazard	Cause	Consequence	Safeguard	Assessed Risk		
				S	L	R
Contaminated Firewater	Firewater application on flaming BESS	Adverse impact on nearby ecosystems if metal contaminants reach water sources. Potential litigation from nearby residential communities.	• Low likelihood of initiating event (stable battery chemistry). • Unmanned site during regular operations – low likelihood of people being present. • No sensitive receivers within 650 m of site.	3	E	L

			• Inherent design limits incident propagation (when UL 9540A compliant). • Sufficient spacing between units to limit propagation. • Response plan for a BESS fire does not involve applying firewater to the flaming unit.			

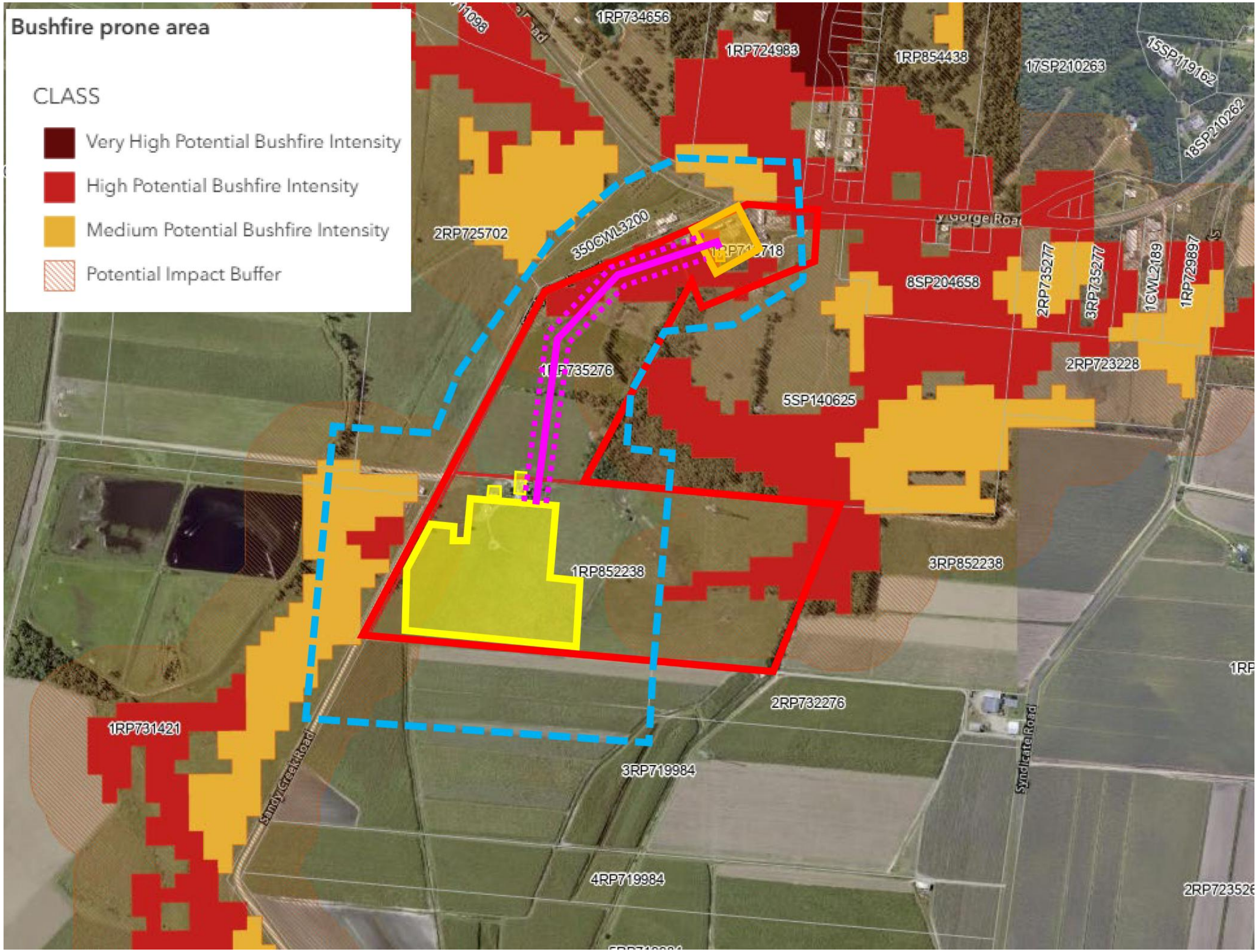


Figure 4-2: Bushfire Prone Land

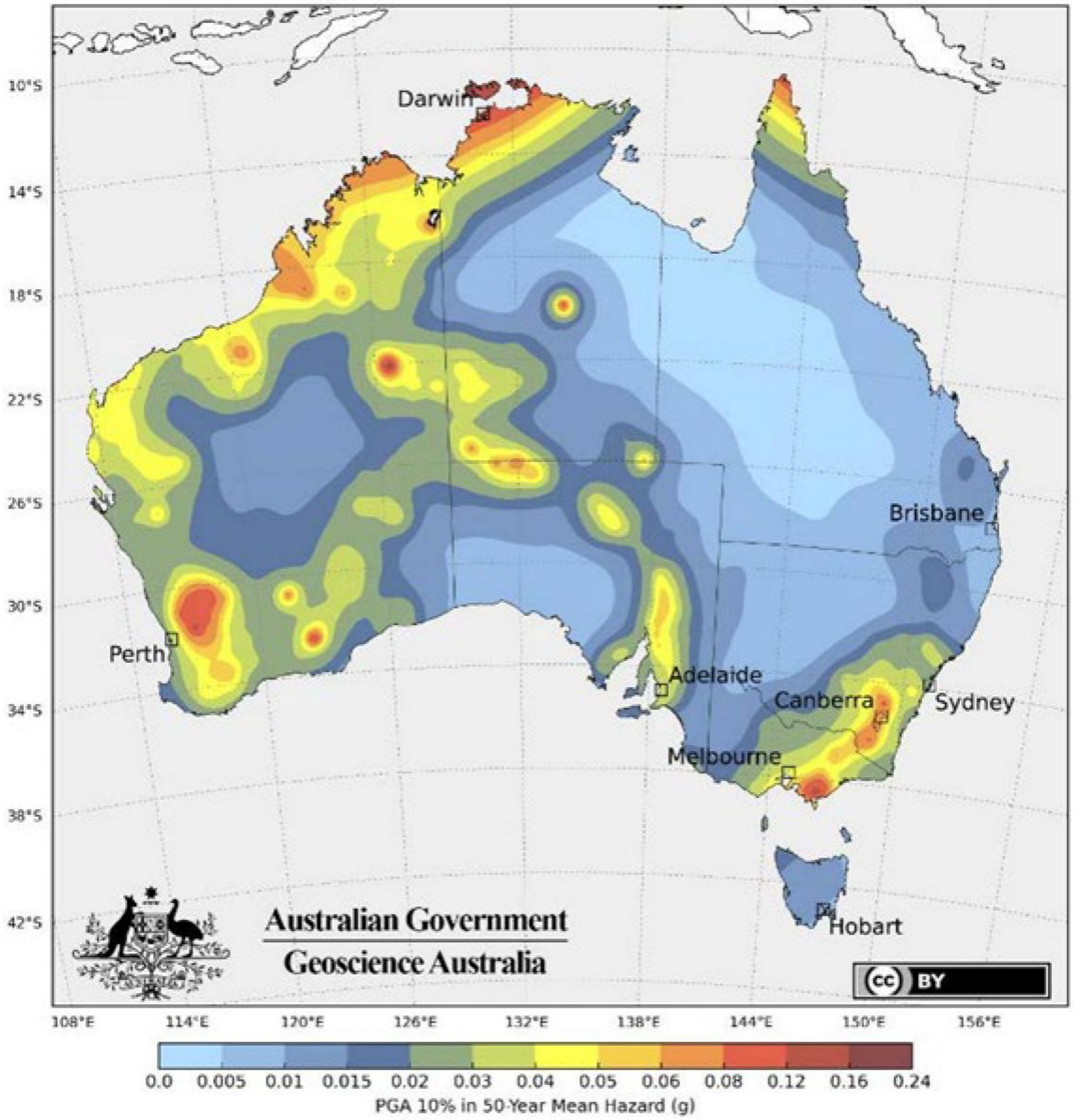


Figure 4-3: National Seismic Hazard Assessment Hazard Map

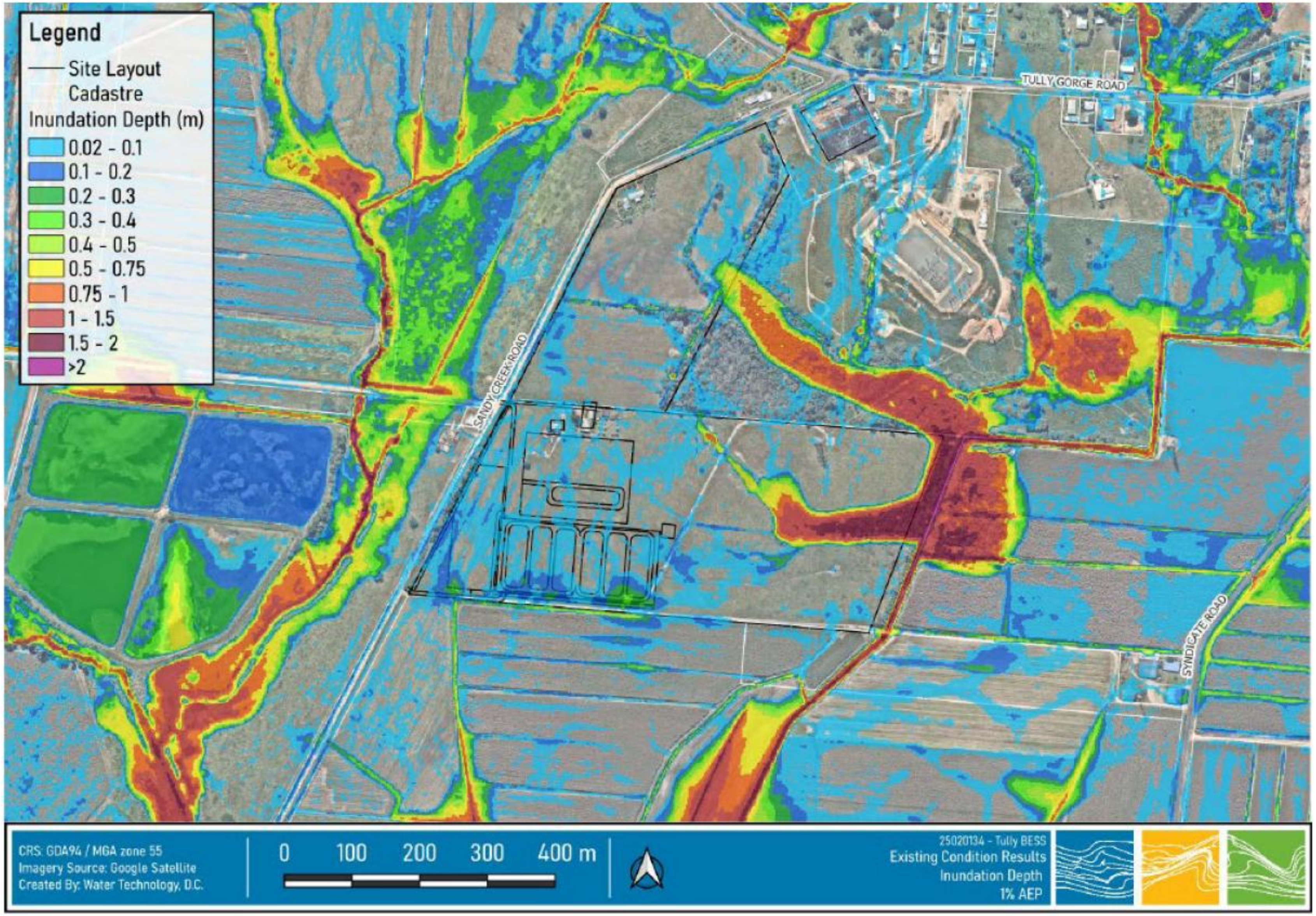


Figure 4-4: 1% AEP Modelled Flood Event

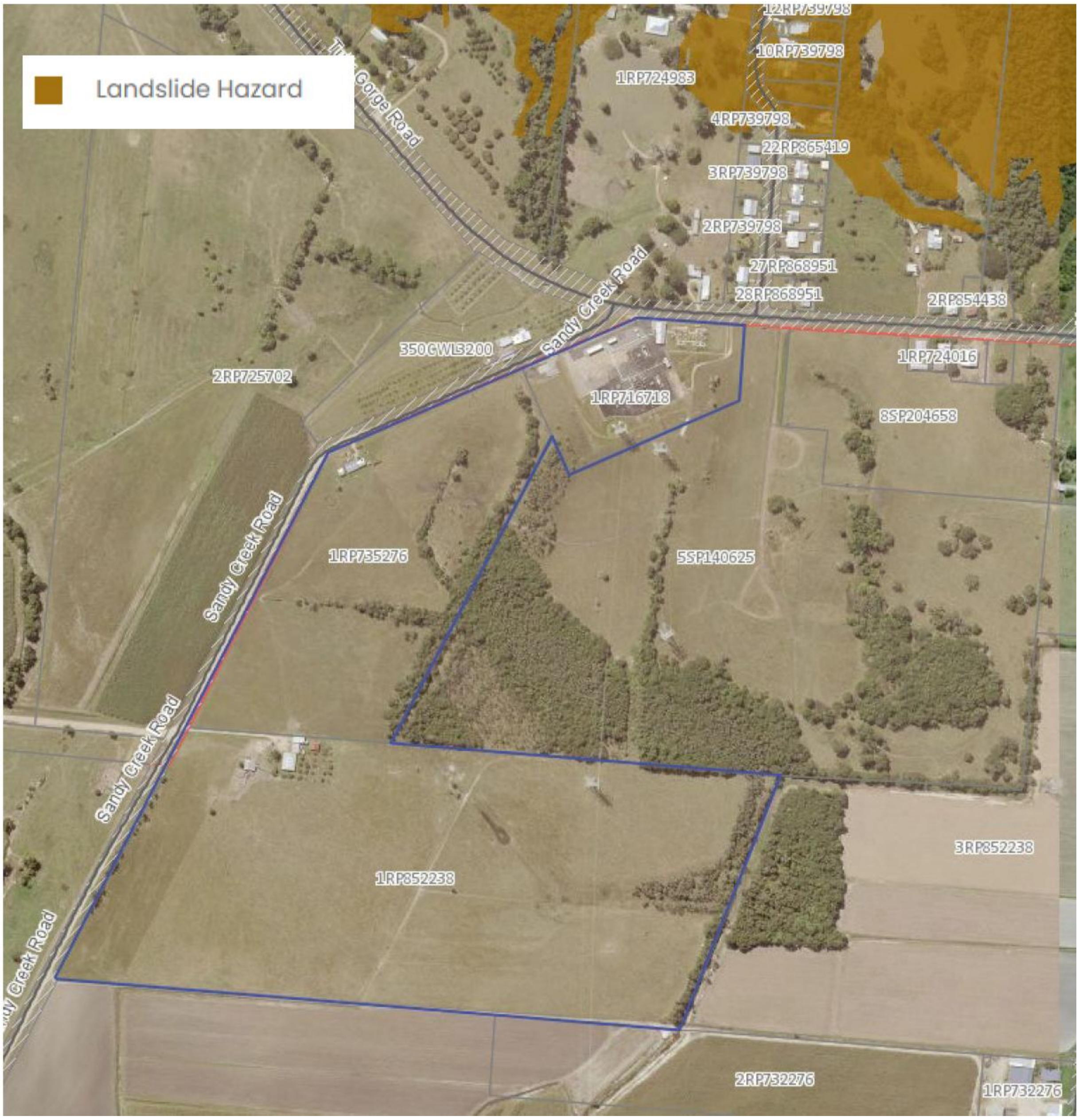


Figure 4-5: Landslide Hazard Overlay Mapping in the Cassowary Coast Planning Scheme

5.0 Consequence Analysis

5.1 Incidents Carried Forward for Consequence Analysis

The following incidents were identified to have the potential to impact fire protection systems or to complicate firefighting interventions:

- Li-ion battery fault, thermal runaway and fire.
- HV transformer, oil spill, ignition and bund fire.
- MV transformers, oil release, ignition and bund fire.
- Li-ion battery fire and toxic gas dispersion.

Each incident has been assessed in the following sections, with acknowledgement of the two potential sites where applicable. A detailed analysis of each scenario is outlined in **Appendix B**, along with the criteria used to assess each incident.

5.2 Li-Ion Battery Fault, Thermal Runaway and Fire

5.2.1 Radiant Heat Modelling

Currently, there are little established data to ascertain the radiant heat emitted from a BESS lithium fire. However, a Large Fire Scale Test (LFST) has been conducted on a BESS for a past project with similar capacity noting that the exact details of the are under a non-disclosure agreement. The results from the test indicated that fire propagation is minimal and only the unit that was initiated to undergo thermal runaway had caught on fire. It was observed that the adjacent unit suffered only cosmetic damage; however, it remained operational throughout the duration of fire from the initiating unit. The flame characteristics from the unit observed are as follows:

- A maximum flame temperature of 675.3°C was recorded.
- Peak flame extended 1.8 m vertically and 1.2 m horizontally.
- Maximum heat flux is 48.72 kW/m^2 at a distance of 1.2 m.
- No adjacent units have initiated thermal runaway due to the fire event in the initiating unit; hence, a full BESS container fire is not considered to be credible.

Based on the data provided, the radiant heat contour impacts can be determined by using the known maximum heat flux at the measured distance and the view factor methodology provided in **Appendix B**. The maximum view factor can be derived using the provided which yielded a Fmax of 0.5. **Equation A-1** can then output a SEP value of 95.6 kW/m^2 which will be used as the basis to calculate the distances of radiant heat impacts. This has been summarised in **Table 5-1** below.

Table 5-1: Radiant Heat Impact from a BESS Unit Fire

Heat Radiation (kW/m^2)	Distance (m)
48.72	1.2
35	1.3
23	2.0
12.6	2.8
4.7	4.2

3.0	5.9

The 23 kW/m^2 contour has been used to assess the potential for propagation of the incident. The results in indicates the 23 kW/m^2 contour may impact its own MV transformer. The consequence analysis of the MV transformer has been provided in **Figure 5-2**. The separation distance between neighbouring Megablocks is 3.0 m; hence, incident propagation is not expected to occur. Furthermore, the fire safety features inherent to the BESS units and MV Transformers are not considered in the modelling of the pool fires and make the risk of incident propagation negligible. If the layout in **Figure 3-2** is emulated in the final design, there will be no off-site impact from the 4.7 kW/m^2 contour.

5.2.2 FM Global Datasheet 5-33 Compliance

There is potential that a Li-Ion battery may fault resulting in thermal decomposition and fire which may spread throughout the whole fire unit if not isolated / protected. As of this report's writing, a Large Scale Fire Test (LSFT) has not been finalised for the Tesla Megapack 3. While past UL9540A test results will conclude on whether fire propagation, based on different levels, would occur during thermal runaway, it does not induce a sustained fire condition (i.e., flammable gas emitted by thermal runaway reactions and ignited). A recommendation has been made to address this:

- A LSFT in compliance with the U9540A 6th Edition shall be conducted for the Tesla Megapack 3 and provided to the Consenting Authority once available.

Tesla has provided a letter of commitment to provide the test results once it is available, which has been provided in **Appendix C**.

Notwithstanding the above, it is important to identify whether the design, excluding the inherent fire safety systems and BMS of the Tesla Megapack 3, has adequately provided measures against the risks of fire. FM Global Datasheet 5-33 (Ref. [19]) has been consulted to review the design against its relevant requirements. The datasheet contains loss prevention measures that are applicable to BESS that exceed 20 kWh. FM Global describes its recommendations based on live fire testing data that it conducts in its facility; however, the information is proprietary and thus cannot be shared. Nevertheless, a clause-by-clause assessment of the design has been conducted and can be found in **Table 5-2** against the datasheet's relevant provisions. It is expected that adequate compliance with FM Global Datasheet 5-33 will result in the mitigation of fire and explosion risks so far as is reasonably practicable. However, if the design is not prescriptively complied with, the level of protection is assessed whether it meets the intent.

As observed in the table, the design complies with level of protection required by FM Global Datasheet 5-33.

Table 5-2: Clause-by-Clause Assessment of FM Global Datasheet 5-33

No.	Loss Prevention Requirement	Compliance Assessment
2.3.1.1	Locate BESS in an enclosure outside an away from critical buildings or equipment in accordance with 2.3.2	Yes - BESS units are located wholly outdoors and in special designated enclosures away from critical buildings or equipment.
2.3.2.1	Select or construct LIB-ESS enclosures/containers using only non-combustible materials.	Yes – BESS enclosures/containers are made of non-combustible materials.
2.3.2.2	For containerized LIB-ESS comprised of LFP cells, provide aisle separation of at least 1.5 m on sides that contain	Yes – Each Tesla Megablock is separated by at least 3.0 m front-to-front. Additionally, a Tesla Megapack 3 in a Megablock is

No.	Loss Prevention Requirement	Compliance Assessment
	access panels, doors or deflagration vents.	separated by at least 1.5 m on sides that contain access panels, doors or deflagration vents.
2.3.2.4	Provide separation between solid walls having no openings based on installation-level testing that demonstrates thermal runaway cannot propagate between containers. Where a fire test report is not available or the test did not result in a fire in the unit of origin, provide separation as indicated in Section 2.3.2.2.	Yes – The separation distances are compliant per Section 2.3.2.2.
2.3.2.4.1	If any penetrations are present, the separation should be extended, or the penetrations should be protected or equipped with FM Approved fire-safe wall penetrations.	Yes – The separation is in excess of the recommendation in Section 2.3.2.2. Additionally, any penetrations would be protected by the inherent systems in each BESS unit.
2.3.2.4.2	Where explosion vents or other penetrations are provided, ensure they are arranged and directed away from surrounding equipment and buildings.	Yes – The explosion vents or other penetrations are arranged and directed away from buildings and/or other BESS/electrical equipment.
2.3.2.5	Provide a minimum space separation between LIB-ESS enclosures and adjacent buildings or critical site utilities or equipment in accordance with Data Sheet 1-20 using hazard category 3 for the exposing building occupancy.	Yes – The separation distance between the nearest BESS enclosure to the adjacent building or critical site utilities is 50 m, which is more than adequate in terms of separation distance.

5.2.3 Past Battery Incidents

It is important to validate the discussion and findings in both **Sections 5.2.1** and **0**. Tesla has provided several case studies on past incidents involving BESS thermal runaway. This subsection contains a review of these incidents, involving the cause, key takeaways and observations, which are provided in **Table 5-3**.

Table 5-3: Review of Past Battery Incidents

Location	Date (DD/MM/YYYY)	Model	Cause	Emergency Response	MP3 Safety Implementations
Geelong, Victoria Australia	30/07/2021	MP1	• Coolant leak within the liquid cooling system of MP-1. • Leak of conductive liquid on electrical system led to arcing in the power electronics of the Megapack's battery modules. • This resulted in heating of lithium-ion cells that led to thermal runaway. • Contributory causes include the lack of a SCADA system, lack of telemetry, fault monitoring and electrical active safety devices.	• The MP1 was shut off manually prior to the fire incident. Once smoke was observed by site personnel, they electrically isolated all MP1s and called the brigade. • The brigade set up a perimeter and started applying cooling water to the nearby exposures. • Fire propagated from one container to another via plastic vents on the roof (combustible). • The MP1s was allowed to burn out, and water was not applied to it.	• Improved inspection of the thermal system. • Reduced telemetry setup from twenty-four hours to one hour, along with avoiding using the keylock switch during commissioning or operation unless the unit is being actively serviced. • Updated firmware, to include alerts for the thermal system, keeping all active safety systems active, and monitoring of the pyrotechnic disconnect. • Replaced the plastic roof vents with thermally insulated steel vent shields. • Refinement of the ERP to avoid using water on an MP fire, but only on nearby exposures, to allow the MP to burn out.
Elkhorn, California USA	20/09/2022	MP1	• Rainwater intrusion into the units due to result of displaced umbrella valves on the roof which were displaced during the installation of new vent shields.	• The initiating MP1 fire detection alarms, and the site operator called 911 shortly thereafter. • Firefighters set up two hose streams on exposures.	• Introduction of an Automatic Safe Discharge (ASD) feature. • Updated alarms and approval processes, including battery isolation failure alerts, server-side alarms now being elevated to Tesla operators.

Location	Date (DD/MM/YYYY)	Model	Cause	Emergency Response	MP3 Safety Implementations
			• Water ingress ultimately led to electrical shorts which initiated thermal runaway of the battery cells. • Sustained flame condition was observed.	• No fire propagation between containers was observed. • The MP1 was allowed to burn out, and water was not applied to it.	• Playbook guidance for isolation-failure alerts. • Prioritisation of thermal-alarm transmission to eliminate the delay of alerting the fire brigade. • Refinement of the ERP regarding roles, responsibilities and training. • Update on the water-application guidance: cooling water is not to be applied to nearby MPs.
Bouldercombe, Queensland Australia	26/09/2023	MP2	• A fault occurred on the AC side of the specific MP2 which led to arcing. • This resulted in heating of lithium-ion cells that led to thermal runaway.	• The initiating MP2 caused a trip in the RMU, isolating it from the rest of the site. • The brigade set up two hose streams on exposures. • No fire propagation between containers was observed. • The MP2 was allowed to burn out, and water was not applied to it.	• Review of inverter module and AC bus quality assurance and inspection, and replacement of parts. • Updates to firmware to better detect a thermal event. • Improved commissioning and service self-testing.

5.2.4 The Victorian Big Battery Fire

As outlined in **Table 5-3**, an incident involving propagation between two BESS containers occurred in Geelong VIC on 30 July 2021 which has been named as the Victorian Big Battery (VBB) fire. The VBB is a 300 MW / 450 MWh BESS facility which is fitted with 212 Tesla Megapacks. The Megapacks was designed to safely operate in close proximity to adjacent units, in which they are arranged as close as 15 cm apart in one ‘block’. This design was validated through UL9540A testing.

However, a fire occurred due to a coolant leak resulted in several LPF cells undergoing thermal runaway. The specific chain of events occurred are as follows:

1. Flames exiting MP-1’s roof were pushed sideways by strong winds directly onto the MP-2 roof.
2. This flame impingement ignited the combustible plastic overpressure vents on the MP-2 roof.
3. The burning vents created an open pathway for flames and hot gases to enter the MP-2 battery bays.
4. Battery cells exposed to temperatures above 139ºC entered thermal runaway and caught fire.

Telemetry data from MP-2 was critical in ruling out alternative causes. At the time when fire was observed within the roof of the MP-2, internal cell temperatures had only risen by 1ºC over two hours which strongly suggests that either radiant and/or conductive heat transfer across the 15 cm gap between the containers was not the cause. The fire propagated through direct flame impingement/exposure on the roof, not through the gap between containers. UL9540A testing permits a maximum wind speed of only 19.3 km/h which is lower than the wind conditions present during the VBB fire. The higher winds created flame behaviour that could not be observed during the UL9540A testing.

Ultimately, it was identified that the vulnerability lied in the plastic overpressure vents which are combustible. These have been replaced with steel vents in the MP3.

5.3 HV Transformer, Oil Release, Ignition and Bund Fire

There is potential that arcing may occur within the 33/132 kV transformer in the substation which may lead to generation of gases and pressure above the structural integrity of the oil reservoir. This may rupture leaking oil into the bund. As a result of the arcing and rupture, the oil may ignite leading to a bund fire within the dimensions of the bund.

A detailed analysis has been conducted in **Appendix B** and the radiant heat impact distances estimated for this scenario are shown in **Table 5-4.** The radiant heat contours associated with a fire occurring within a transformer bund are shown in **Figure 5-1**.

Table 5-4: Radiant Heat from a Transformer Fire

Heat Radiation (kW/m^2)	Distance (m)
35	18
23	19
12.6	23
4.7	30
3.0	35

The 4.7 kW/m² contour has been used to assess the potential for propagation of the incident. **Figure 5-1** shows that the 4.7 kW/m² heat radiation contour from a transformer fire will not impact the site boundary, nor additional infrastructure. Furthermore, the modelling has been completed without consideration for additional fire protection features that may be implemented, such as fire walls. Thus, the impact of a transformer bund fire will be negligible.

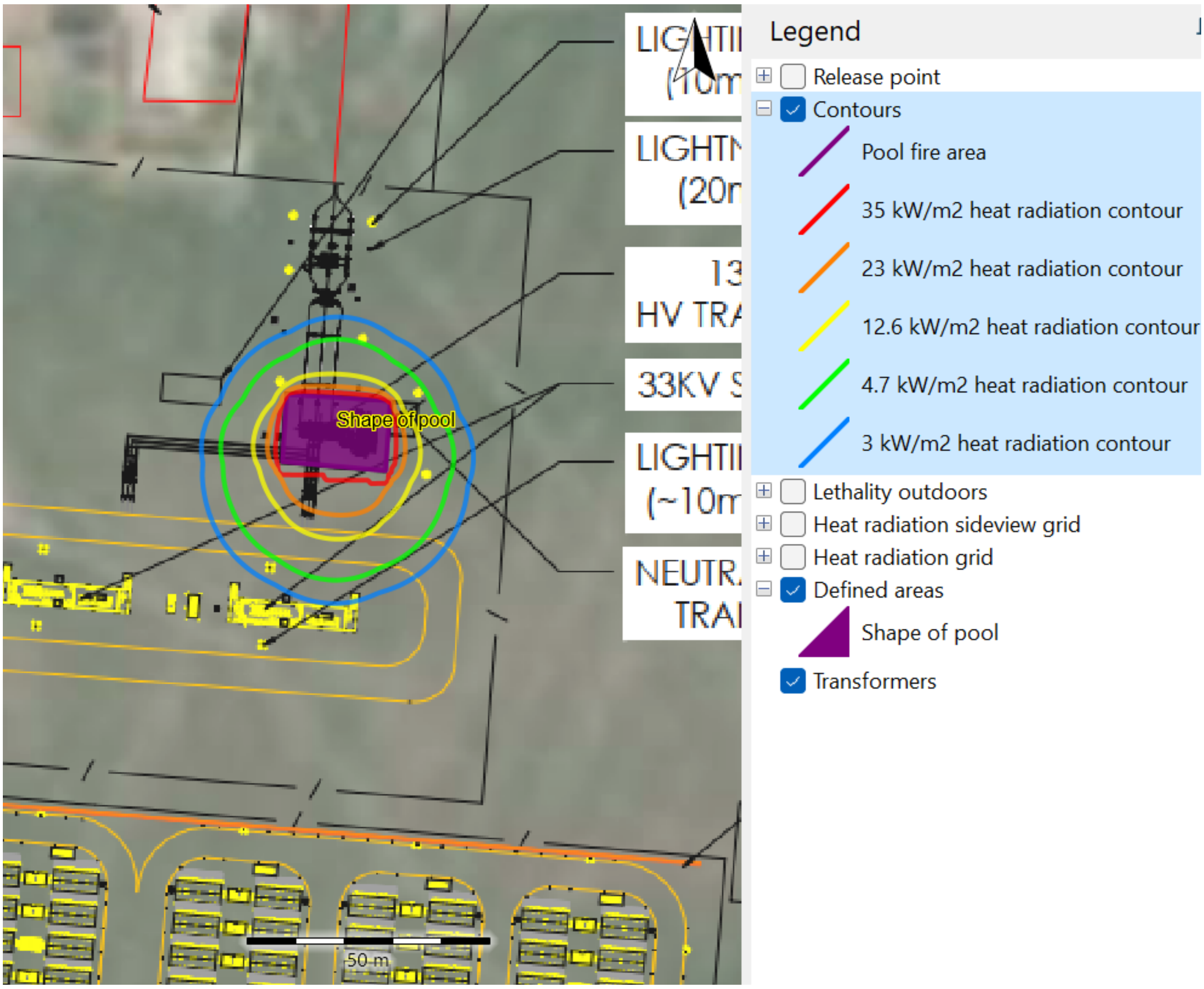


Figure 5-1: Transformer Fire Radiant Heat Contours

5.4 MV Transformers, Oil Release, Ignition and Bund Fire

There is potential that arcing may occur within the MV transformers which may lead to generation of gases and pressure above the structural integrity of the oil reservoir which may rupture leaking oil into the bund. As a result of the arcing and rupture, the oil may ignite leading to a bund fire within the dimensions of the bund.

A conservative detailed analysis has been conducted in **Appendix B** and the radiant heat impact distances estimated for this scenario are shown in **Table 5-5.** The radiant heat contours associated with a fire occurring within the MV Transformers are shown in **Figure 5-2**.

Table 5-5: Radiant Heat from a MV Transformer Fire

Heat Radiation (kW/m²)	Distance (m)
35	4.5

23	4.8
12.6	5.8
4.7	8.5
3.0	9

The 23 kW/m^2 contour has been used to assess the potential for propagation of the incident. The results in **Table 5-5** indicates the 23 kW/m^2 contour may impact adjacent infrastructure (other MV Transformer or adjacent BESS units) as they are within 5 m of the incident MV Transformers. However, the fire safety features inherent to the BESS units and MV Transformers are not considered in the modelling of the pool fires and make the risk of incident propagation negligible. Furthermore, **Figure 5-2** shows that the 4.7 kW/m^2 contours are shown not to impact the site boundary.

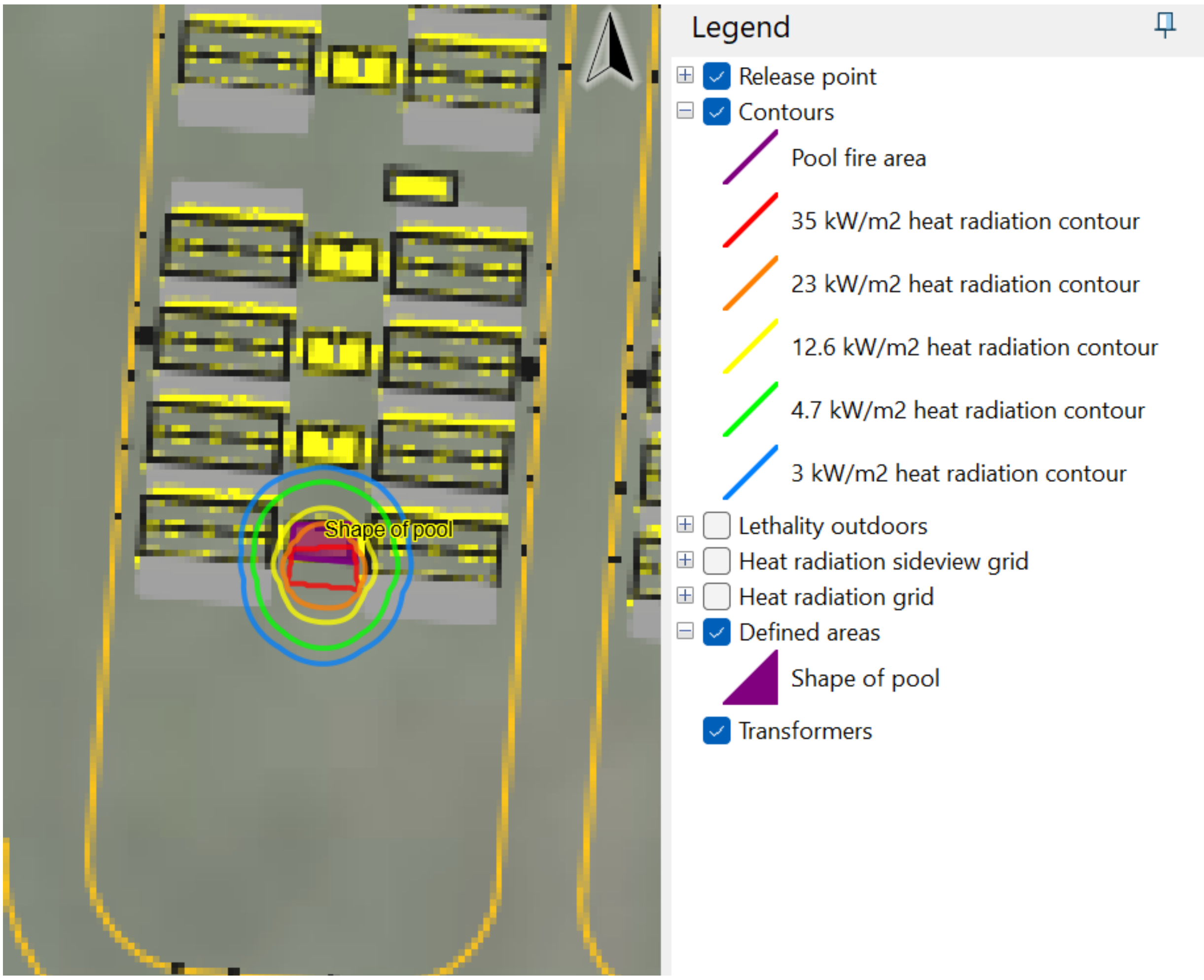


Figure 5-2: MV Transformer Fire Radiant Heat Contours

5.5 Li-ion Battery Fire and Toxic Gas Dispersion

As discussed in **Section 4.4,** there is potential for a battery fire that will lead to the emission of several toxic gases. A detailed analysis has been conducted in **Appendix B** using GEXCON EFFECTS modelling software. The anticipated distances to the defined AEGL toxicity thresholds, assessed at a representative breathing height, are presented in **Table 5-6**

Table 5-6: HF AEGL 5 Minute Exposure Contours to 1.5 m Receiver (Breathing Height)

AEGL Level	Impact Distances (m)
AEGL 2 (Injury)	14
AEGL 3 (Life threatening health effects)	11

Figure 5-3 illustrates the HF plume geometry resulting from the worst-case BESS fire scenario, while **Figure 5-4** presents the spatial extent of AEGL-2 and AEGL-3 exposure zones at a received height of 1.5 m. These figures demonstrate the potential exposure of personnel during evacuation or movement to shelter, as well as the proximity of the toxic plume to external receptors.

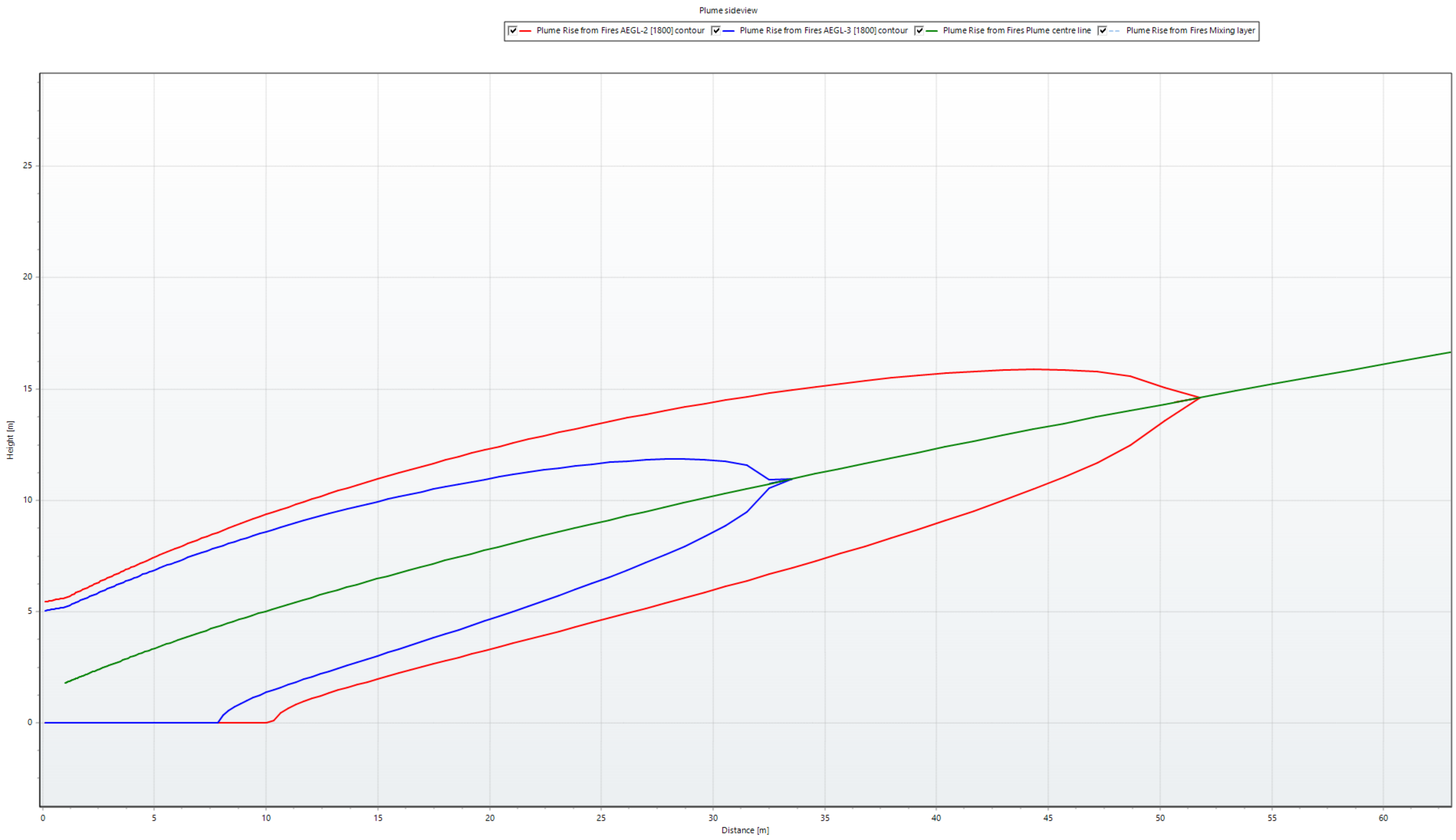


Figure 5-3: HF AEGL 5 Minute Exposure Plume Sideview

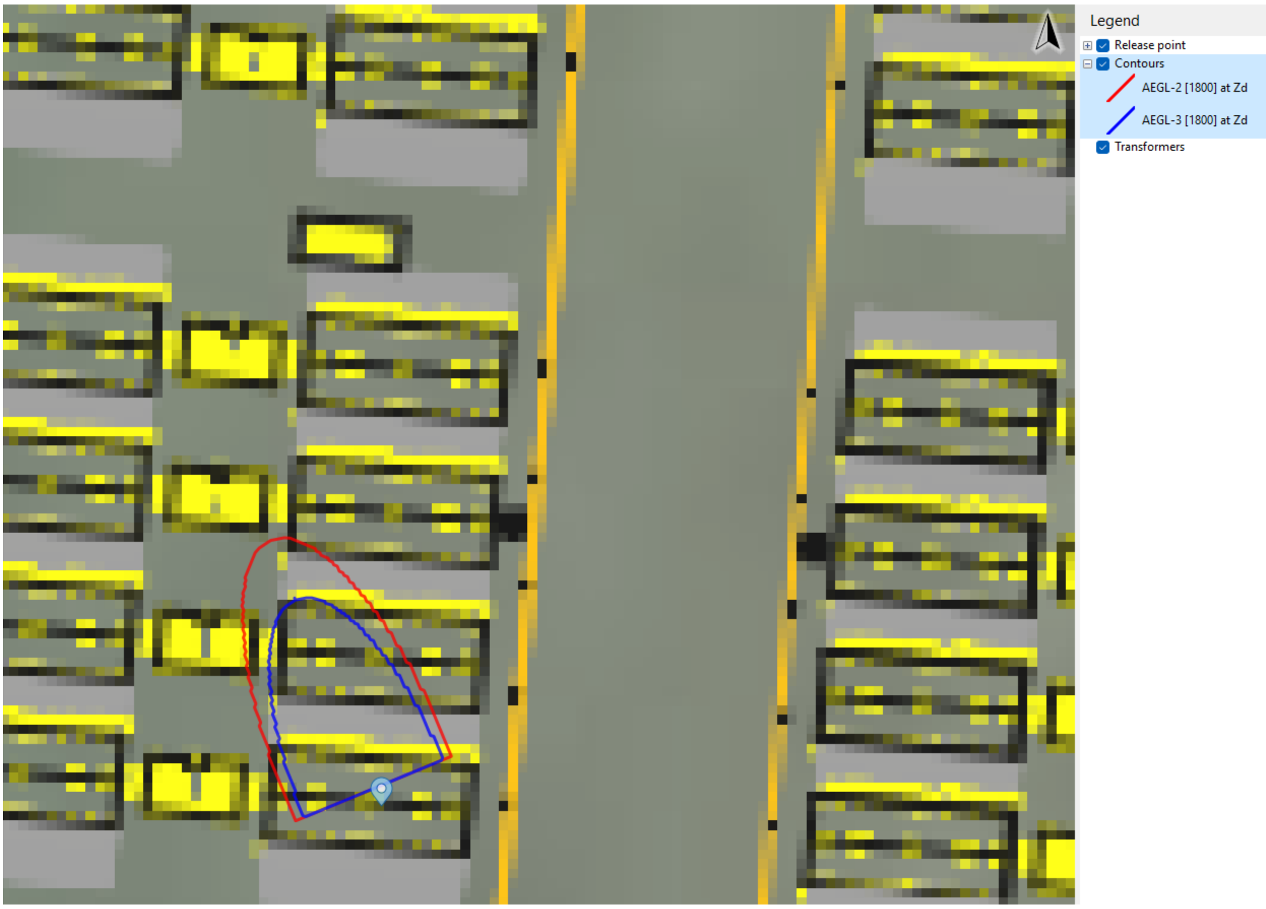


Figure 5-4: HF AEGL 5 Minute Exposure Contours Proximity to Offsite Receptors.

The modelled AEGL contours for a 5-minute exposure duration indicate that toxic impacts associated with the worst-case BESS fire scenario are highly localised and limited in extent, with AEGL-2 and AEGL-3 thresholds confined to within 14 m and 11 m of the source, respectively. These distances demonstrate that personnel are able to evacuate the immediate vicinity or reach a place of safety without significant exposure likely to result in long-term health effects, particularly given the short duration of exposure associated with movement to shelter or evacuation.

It is noted that BESS fires are characterised by high heat release rates, resulting in strong plume buoyancy and vertical entrainment. For the purposes of this assessment, the convective heat release has been conservatively modelled using parameters representative of cellulosic materials, which are significantly cooler than a BESS fire. This approach reduces plume buoyancy and results in increased predicted ground-level concentrations, thereby providing a conservative estimate of toxic exposure. This assumption also implicitly addresses both early-stage fire conditions (where heat release may be lower) and later-stage scenarios, ensuring that potential impacts are not underestimated.

The plume modelling indicates that, as the release travels downwind, it rises in elevation due to buoyancy and entrainment, resulting in reduced concentrations at typical human breathing height (approximately 1.5 m). Consequently, AEGL threshold exceedances are not predicted to extend to off-site receptors at ground level. As the plume continues to travel, it cools and disperses, with concentrations decreasing below AEGL thresholds prior to reaching sensitive receptors.

Based on prevailing meteorological conditions, winds at the site are predominantly from the either south or north/northeast based on the day, and emergency response arrangements have been developed accordingly. The following recommendation has been made:

- A windsock shall be installed at the facility in a location visible from all operational areas.

The windsock will enable personnel and emergency responders (including QFD) to readily determine wind direction and select an appropriate assembly point or command location.

As noted, the AEGL-2 contour does not impact the site boundary; hence, off-site impact will not occur from a BESS toxic smoke scenario.

5.6 Likelihood Analysis

For the purposes of estimating the likelihood of a transformer fire, it is considered similar to a transformer. The initiating event for a transformer fire is a major oil spill from the transformer casing. This would be classified as a catastrophic failure as all oil contained within the transformer would be released. Failure rate data from the CCPS indicates that the frequency of a catastrophic transformer failure is in the range of 0.125 to 9.26 failures per 10^6 hours (Ref. [20]).

It is noted that this data base was compiled in 1989 and as such is somewhat outdated. It would be expected that more modern equipment would be more reliable due to advances in materials, better understanding of oil management in transformers, better monitoring systems and process safety requirements. Therefore, the lower range of expected failures has been selected for this assessment to reflect the increased safety present in the transformer systems at the site. Hence, the failure frequency would be 0.125 per 10^6 hours, or 1.10×10^{-3} p.a.

However, a transformer fire also requires an ignition source. An assessment of power transformer reliability conducted by Tenbohlen *et al* which analysed 112 major transformer failures throughout Europe indicates that most major failures do not result in any external effects (Ref. [21]). The Tenbohlen *et al* study indicates that only 6.3% of major transformer failures result in a fire (Ref. [21]). This results in the likelihood of a transformer fire being $1.10 \times 10^{-3} \times 0.063 = 6.9 \times 10^{-5}$ p.a. Assuming the site operates for 20 years and there are 47 transformers, this is a 6.5% chance of a transformer fire throughout the entire lifespan of the Project. This is considered a very conservative estimation for this analysis as it is assumed non-flammable natural esters will be used as transformer oils, lowering the likelihood of ignition. Nevertheless, this value is assumed for conservatism.

Given that the site is typically unmanned and would only be attended for maintenance and inspections, the risk to humans is further limited. In a worst-case scenario, the site would be attended for maintenance for an hour every week (which may apply in the early stages of the site's occupation). This would result in a human being on-site, and potentially within the consequence contours previously established, for 4% of the year. This means there is a 0.13% chance of fatality if the person is impacted by the 4.7 kW/m^2. However, it is unlikely that the transformer would suddenly burst into a flaming fire, and is more likely to build into the fires slowly modelled in **Sections 5.3** and **5.4**, giving the person ample time to move away from the impact areas. Thus, the likelihood of fatality can be significantly reduced qualitatively to be considered near negligible.

The consequences of the transformer fires have already been shown not to propagate incidents, meaning the incident would limit property damage. Furthermore, the impacts of a short-lived fire on the environment (such as via smoke) disperse quickly, leaving negligible lasting environmental impacts.

6.0 Risk Evaluation

The results of the risk analyses conducted throughout **Sections 4.0** and **5.0** are compared to the acceptable risk criteria. **Appendix A** contains the results of the qualitative risk analyses, which shows that all hazards have a risk of medium (M) or lower, which is the acceptable qualitative risk threshold.

For the quantitatively analysed risks, the consequence contours determined from EFFECTS are shown not to cause incident propagation, nor to impact the site boundary. The likelihood of such events causing damage to humans, property or the environment is semi-quantitatively shown to be negligible. Thus, the risks associated with transformers are considered acceptable.

Thus, the initial risks presented by the BESS and the equipment of the site are considered sufficiently mitigated for normal operations.

7.0 Conclusion and Recommendations

7.1 Conclusions

A RMAR was prepared for the proposed Tully BESS. A hazard identification table was developed 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 a potential for offsite impacts. Postulated scenarios were discussed qualitatively and any scenarios that would not impact offsite were eliminated from further assessment. The likelihood and consequences of these events were qualitatively discussed to determine the risk.

Incidents carried forward for quantitative analysis were modelled in integral consequence modelling software EFFECTS in detail to estimate the impact distances. Impact distances were developed into scenario contours and overlaid onto the site layout diagram to determine if an offsite impact would occur. The impact distances of the incidents analysed using EFFECTS were shown to not affect adjacent equipment and thus, would not cause incident propagation. Furthermore, there are no potential off-site impacts. The likelihood of these events was semi-quantitatively determined to be near negligible, meaning the risks (combining the limit consequence and low likelihood) of these events are acceptably low.

Based on the analysis conducted, it is concluded that there are no unacceptable risks at the site boundary, nor any risk of incident propagation. Thus, the risks are considered sufficiently managed by the inherent safety features of the BESS units and by existing safety precautions.

7.2 Recommendations

Based on the analysis, the following recommendations have been made:

- A Large Scale Fire Test (LSFT) in compliance with the UL9540A 6th Edition shall be conducted for the Tesla Megapack 3 and provided to the Consenting Authority once available.
- A windsock shall be installed at the facility in a location visible from all operational areas
- All site personnel shall be inducted in site procedures and emergency response protocols relevant to their roles.
- All site personnel who require training must undergo formal training in the required procedures and emergency response protocols relevant to their role.
- Necessary personnel to provide first aid are to be trained in accordance with the QLD Code of Practice for first aid in workplaces 2021– high-risk workplaces (Ref. [2]).
- Site management to prepare and maintain operational procedures to minimise the number of hazardous incidents and accidents on site and to mitigate the consequences of incidents regarding the handling of dangerous goods and chemicals.
- Dangerous Goods (DG) documentation shall be prepared as required by the Work Health and Safety Regulation 2011 QLD to demonstrate the risks associated with the storage and handling of DGs has been assessed and minimised.
- Any DGs stored at the site shall be stored and handled in accordance with the Work Health and Safety Regulation 2011 QLD and any applicable storage and handling standards.

8.0 References

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Appendix A

Risk Assessment Table

A1. Risk Identification and Assessment Table

ID	Area/Operation	Cause	Consequence	Existing Safeguards	Risk		
					S	L	R
1	Battery Storage	• Battery fault / failure • Failure of Li-ion battery protection systems	• Thermal runaway resulting in fire or explosion • Incident propagation through battery cells • Damage to property <$1M	• Batteries are tested by manufacturer prior to sale / installation • Overcharging and electrical circuit protection • Battery monitoring systems • Batteries composed of subcomponents reducing risk of substantial component failure (such as liquid cooling system) • Batteries are not located in areas where damage could easily occur (i.e. within the fenced property) • Electrical systems designed per AS/NZS 3000:2018 (Ref. [22]) • Ventilation • Explosion venting • Heat detection • No sensitive receptor within 100 m • Separation distances are complaint with listed specifications • BESS model will be tested in accordance with UL9540A	3	D	M
2			• Toxic smoke dispersion • Injury to worker • Short-term environmental damage		3	E	L
3	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 is separated from other sources of fire	3	E	L

ID	Area/Operation	Cause	Consequence	Existing Safeguards	Risk		
					S	L	R
4	HV Transformer and MV Transformers	• Arcing within transformer, vaporisation of fluid and rupture of fluid reservoir	• Transformer fluid release spill, ignition and fire	• Natural ester used as dielectric fluid – Natural esters have a high flash point (>300°C) such that ignition is very unlikely to occur. • Transformers are bunded • Electrical protection for transformer faults • Control of ignition sources – no smoking / open flames around the transformers	Carried forward for quantitative analysis		
5	HV Transformer	• Power surge to transformers (e.g. from lightning, fault, etc.)	• 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	4	D	M
6	MV transformers	• Power surge to transformers (e.g. fault)	• Major failure of surge protection in transformer, vapourisation of mineral oil, ignition and explosion	• Transformers are in containers which protect from lightning and cables are underground. • Control of ignition sources – no smoking / open flames around the transformers	4	D	M
7	Electrical equipment	• Constant release of electromagnetic field	• Minor health impacts from extended exposure	• Inherently lower levels than background radiation • Drop off within short distances	1	C	L

ID	Area/Operation	Cause	Consequence	Existing Safeguards	Risk		
					S	L	R
				• No sensitive receivers within 1 km of the site			
8	Bushfire	• Lightning strike • Maliciously lit fire	• Destruction or damage to electrical infrastructure. • Radiant heat flux causing thermal runaway. • Damage to property < $1M • Fatality/fatalities • Incident propagation	• Separated arrangement of equipment to limit propagation (remove fuel) • Housekeeping procedures to keep grass low • Inherent fire protection in BESS and high heat resistance of other equipment • Bushfire hazard assessment and management plan	4	D	M
9	Earthquake	• Sudden movement/slip along faults in the Earth	• Structural damage to electrical infrastructure. • Plant downtime costing < $100k • Medical treatment for affected personnel	• QLD has lowest forecast earthquake hazard in Australia • No earthquakes above Mw 6.0 recorded in QLD in past 50 years. • Resilient foundation design. • Geotechnical assessment and certified retaining structures. • Design in accordance with standards for seismic loading.	2	C	M
10	Flood	• Heavy rainfall • Site located within Tully River Catchment • Portions of site within Flood Hazard Overlay	• Corrosion, equipment damage, electrical hazards and power disruption. • Inundation of low-lying components if not adequately elevated.	• Infrastructure designed to minimum 0.2% AEP + climate change flood immunity. • Site drainage system designed for site-specific rainfall and flooding. • Raised/elevated platforms for critical infrastructure.	4	D	M

ID	Area/Operation	Cause	Consequence	Existing Safeguards	Risk		
					S	L	R
			• Damage to property < $1M • Fatality/fatalities • Incident propagation	• Bioretention basin for stormwater management.			
11	Extreme Heat	• Climate change leading to increase of maximum weather temperature • Increasing frequency of heat waves	• Overwhelmed cooling system leading to thermal runaway. • Damage to property < $1M • Fatality/fatalities • Incident propagation	• Active cooling systems for BESS units. • Temperature sensors and BMS. • Controlled automated shutdown triggered on temperature limit exceedance. • UV-rated housing. • Regular maintenance programme.	3	D	M
12	Cyclone / Strong Winds	• Climate change affecting weather patterns, intensifying wind movement	• Structural damage to electrical infrastructure. • Flying debris damage to electrical infrastructure. • Damage to property < $1M • Fatality/fatalities • Incident propagation	• Wind-rated structural engineering for infrastructure per AS/NZS 1170.2. • IP-66 rated battery enclosure and IP2X rated thermal bay. • Lightning protection systems. • Weather monitoring. • Securing and anchoring of all temporary equipment pre-event. • Workers not expected on-site during active cyclone conditions.	3	D	M
13	Landslide	• Unstable slope foundation	• Not located in an identified landslide hazard area – no risk.	• Site is not within an identified landslide hazard area.	1	E	L
14	Contaminated firewater	• Application of water on BESS Fire	• Potential for adverse impact on nearby ecosystems if metal	• Batteries are tested by manufacturer prior to sale / installation.	3	E	L

ID	Area/Operation	Cause	Consequence	Existing Safeguards	Risk		
					S	L	R
			contaminants reach water sources • Potential litigation from nearby residential communities	• Overcharging and electrical circuit protection. • Battery monitoring systems. • Batteries composed of subcomponents reducing risk of substantial component failure (such as liquid cooling system). • Batteries are not located in areas where damage could easily occur (i.e. within the fenced property). • Electrical systems designed per AS/NZS 3000:2018 (Ref. [22]). • Ventilation. • Explosion venting. • Heat detection. • No sensitive receptor within 100 m. • Separation distances are complaint with listed specifications. • BESS model will be tested in accordance with UL9540A.			

Appendix B

Consequence Analysis

B1. Incidents Assessed in Detailed Consequence Analysis

- Li-ion battery fault, thermal runaway and fire.
- HV transformer, oil spill, ignition and bund fire.
- MV transformers, oil release, ignition and bund fire.
- Li-ion battery fire and toxic gas dispersion.

Each incident has been assessed in the sections below.

B2. Radiant Heat Physical Impacts

Appendix Table B-1 provides noteworthy heat radiation values and the corresponding physical effects of an observer exposed to these values (Ref. [23]).

Appendix Table B-1: Heat Radiation and Associated Physical Impacts

Heat Radiation (kW/m^2)	Impact
35	• Cellulosic material will pilot ignite within one minute's exposure • Significant chance of a fatality for people exposed instantaneously
23	• Likely fatality for extended exposure and chance of a fatality for instantaneous exposure • Spontaneous ignition of wood after long exposure • Unprotected steel will reach thermal stress temperatures which can cause failure • Pressure vessel needs to be relieved or failure would occur
12.6	• Significant chance of a fatality for extended exposure. High chance of injury • Causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure • Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure
4.7	• Will cause pain in 15-20 seconds and injury after 30 seconds exposure (at least second degree burns will occur)
3.0	• FRNSW criterion for accessibility of hydrants and other fire protection systems. Assumed as the criterion for QFD

B3. Gexcon - Effects

The modelling was prepared using Effects where appropriate, which is proprietary software owned by Gexcon which has been developed based upon the TNO Coloured books and updated based upon CFD modelling tests and physical verification experiments. The software can model a range of incidents including pool fires, flash fires, explosions, jet fires, toxic dispersions, warehouse smoke plumes, etc.

B4. View Factor Radiant Heat Model

The modelling for the BESS units was carried out using a manual view factor calculation method outlined below.

B4.1 Radiant Heat Flux

The heat flux (Q) for the view factor model is given by **Equation 8-1**.

$$Q = \tau E F$$ **Equation 8-1**

Where;

- Q = heat flux (kW/m^2) at the target
- F = geometric view factor
- τ = transmissivity
- E = SEP (kW/m^2)

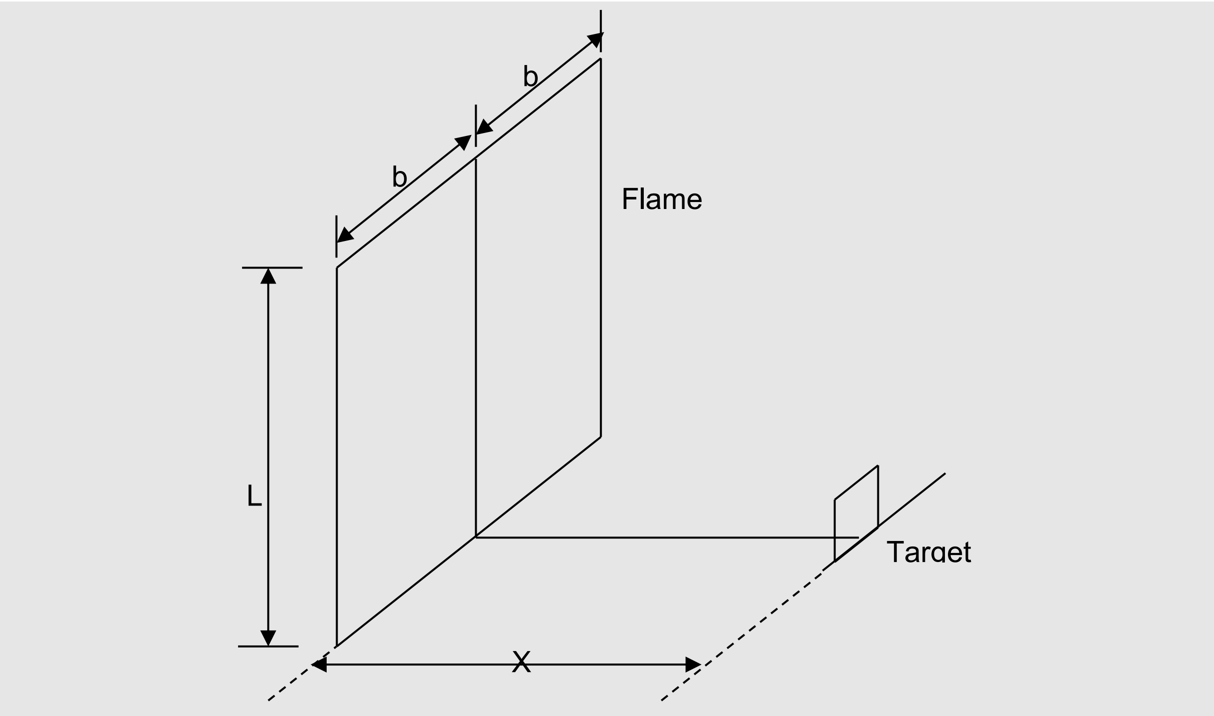
Each of the required inputs is determined in the sections following.

B4.2 View Factor

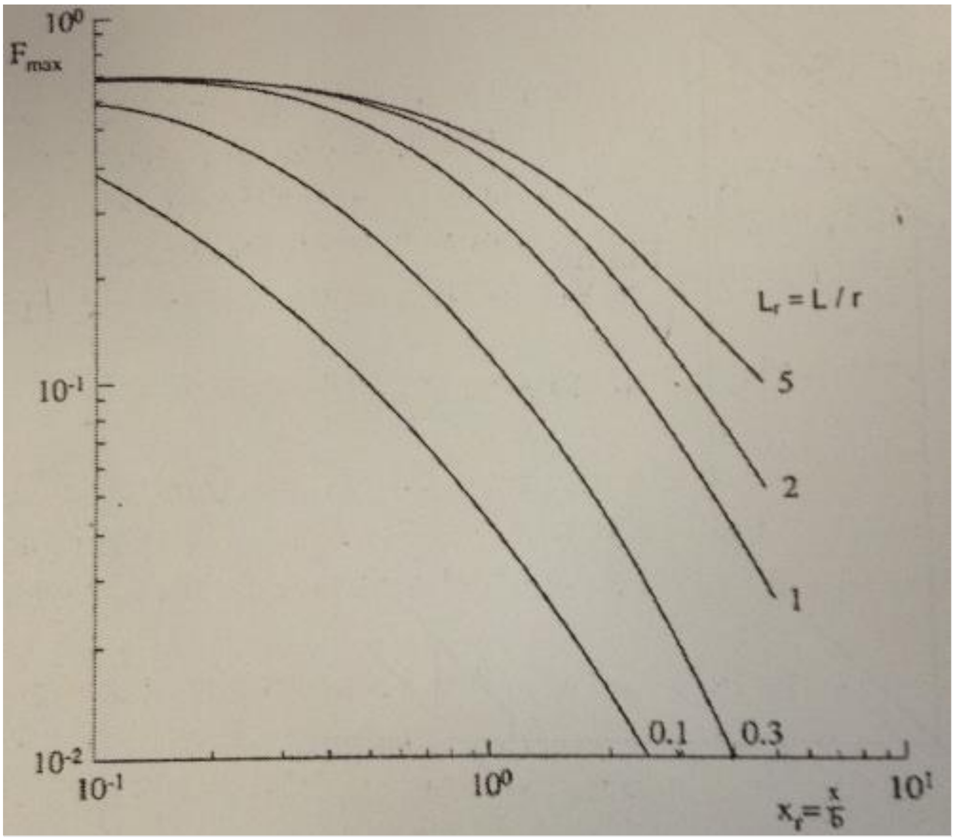
The view factor for a flat surface fire is estimated using the scenario shown in **Appendix Figure B-1** where the flame is the vertical surface of height L and length 2b with receiver located centrally and at a distance of X. Two dimensionless parameters are calculated, and the view factor read from **Appendix Figure B-2**. The dimensionless parameters are shown in **Equation 8-2** and **Equation 8-3**.

$$L_r = \frac{L}{b}$$ **Equation 8-2**

$$X_r = \frac{x}{b}$$ **Equation 8-3**



Appendix Figure B-1: Vertical Flame Geometry View Factor Geometry



Appendix Figure B-2: Vertical Flame Maximum View Factor (Ref. [24])

B4.3 Transmissivity

The transmissivity is estimated using **Equation 8-4**.

$$\tau = 1.006 - 0.01171(\log_{10} X(H_2O) - 0.02368(\log_{10} X(H_2O))^2 - 0.03188(\log_{10} X(CO_2) + 0.001164(\log_{10} X(CO_2))^2 \quad \textbf{Equation 8-4}$$

Where:

- $X(H_2O) = (R_H \times L \times S_{mm} \times 2.88651 \times 10^2)/T$
- $X(CO_2) = L \times 273/T$

And;

- R_H = percentage relative humidity
- L = distance to target (m)
- S_{mm} = saturated water vapour pressure in mm mercury at temperature (at 200°C S_{mm} = 11549)
- T = temperature (473 K assumed air is heated to 200°C)

B5. Li-Ion Battery Fault, Thermal Runaway and Fire

The flame characteristics from the unit observed are as follows:

- A maximum temperature of 675.3°C was recorded.
- Peak flame extended 1.8 m vertically and 1.2 m horizontally.
- Maximum heat flux is 48.72 kW/m^2 at a distance of 1.2 m.

- No adjacent units have initiated thermal runaway due to the fire event in the initiating unit; hence, a full BESS unit is not considered to be credible.

Based on the data provided, the radiant heat contour impacts can be determined by using the known maximum heat flux at the measured distance and the view factor methodology. The maximum view factor can be derived using the graph in **Appendix Figure B-2** and the variables discerned from the LSFT results, which yielded a Fmax of 0.5. **Equation A-1** can then output a SEP value of 95.6 kW/m^2 which will be used as the basis to calculate the distances of radiant heat impacts. This has been summarised in the table below. Note that the assessment does not consider the effect of safeguards that are available in the BESS, such as the aerosol fire extinguishing device and primary firefighting equipment.

Appendix Table B-2: BESS Fire Radiant Heat Distances

Heat Radiation (kW/m^2)	Distance (m)
48.72	1.2
35	1.3
23	2.0
12.6	2.8
4.7	4.2
3.0	5.9

B6. HV Transformer, Oil Release, Ignition and Bund Fire

Transformers contain oil to provide cooling and insulation. If arcing occurs within the transformer, the oil will rapidly heat generating gases above their auto ignition point. The pressure of the gases may rupture the reservoir allowing oxygen to enter resulting in the gases auto igniting. The oil is released from the reservoir and is ignited by the burning gases.

The transformer is assumed to be bunded and so in the event of a spill and ignition, the pool fire will have dimensions of the bund. The inputs for the model are provided in **Appendix Table B-3**.

Appendix Table B-3: HV Transformer Fire Modelling Inputs

Input	Value	Justification
Chemical name	Linoleic acid	Transformer oil to be used is a natural ester, which is typically a combustible liquid of some formulation which have high flash points. For the purposes of providing a conservative analysis, linoleic acid has been selected. This material has a flash point of approximately 200^{o}C. Natural ester oils typically have flash points exceeding 330^{o}C, thus this material selection is considered to be conservative.
Type of pool fire calculation	Rew & Hulbert	The model has been developed for modelling fires based on the radiant heat emitted from the radiant surface. The model uses the clear and sooty portions of the flame to estimate the radiant heat at the target. The terminology (i.e. pool fire) is because these models were originally developed from liquid pool fires. However, the model actually works by looking at the flame surface to estimate the radiant heat that is emitted from that surface. The flame surface is present irrespective of the material burning (i.e. a solid or liquid pool will have a flame that will have a clear and sooty portion). Based on the above discussion, it is considered that the Rew & Hulbert model is appropriate for modelling the fire.

Input	Value	Justification
Type of pool fire source	Instantaneous	Conservative as it assumes full fire immediately
Soot definition	Calculated	Calculated
Total mass released	n/a	Spill is limited to bund dimensions and not by spill mass
Temperature of pool	30°C	Conditions expected to be observed regularly. Also, negligible impact on results.
Type of pool	Polygon	Modelled based on transformer bund area.
Max pool surface area	n/a	Spill is limited to bund dimensions and not by spill mass
Height of confined pool above ground level	0 m	Modelled at ground level
Include shielding to bottom side of flame	No	No shielding provided in modelling.
Height of shielding	n/a	n/a
Wind speed	6 m/s	High wind speed modelled for worst-case scenario.
Wind direction	North	Worst-case direction, pushing flames towards BESS units.
Ambient temperature	30°C	Conditions expected to be observed regularly. Also, negligible impact on results.
Ambient pressure	1.0151 bar	Atmospheric pressure
Ambient relative humidity	40%	Typical humidity in the area
CO2 concentration	0.0004	CO2 concentration in atmosphere

The results of the analysis are shown in **Appendix Table B-4.**

Appendix Table B-4: Heat Radiation Impacts from a Transformer Bund Fire

Heat Radiation (kW/m^2)	Distance (m)
35	18
23	19
12.6	23
4.7	30
3.0	35

B7. MV Transformers, Oil Release, Ignition and Fire

The MV transformers contain oil to provide cooling and insulation. If arcing occurs within the transformer, the oil will rapidly heat generating gases above their auto ignition point. The pressure of the gases may rupture the reservoir allowing oxygen to enter resulting in the gases auto igniting. The oil is released from the reservoir and is ignited by the burning gases.

It has been assumed that the transformer has bund dimensions of the MV transformers; hence, if a spill from the transformer was to occur it would fill the base of the bund resulting in a pool fire with the dimensions of the bund. The inputs for the model are provided in **Appendix Table B-5**.

Appendix Table B-5: MV Transformer Fire Modelling Inputs

Input	Value	Justification
Chemical name	Linoleic acid	Transformer oil to be used is a natural ester, which is typically a combustible liquid of some formulation which have high flash points. For the purposes of providing a conservative analysis, linoleic acid has been selected. This material has a flash point of approximately 200°C. Natural ester oils typically have flash points exceeding 330°C, thus this material selection is considered to be conservative.
Type of pool fire calculation	Rew & Hulbert	The model has been developed for modelling fires based on the radiant heat emitted from the radiant surface. The model uses the clear and sooty portions of the flame to estimate the radiant heat at the target. The terminology (i.e. pool fire) is because these models were originally developed from liquid pool fires. However, the model actually works by looking at the flame surface to estimate the radiant heat that is emitted from that surface. The flame surface is present irrespective of the material burning (i.e. a solid or liquid pool will have a flame that will have a clear and sooty portion). Based on the above discussion, it is considered that the Rew & Hulbert model is appropriate for modelling the fire.
Type of pool fire source	Instantaneous	Conservative as it assumes full fire immediately
Soot definition	Calculated	Calculated
Total mass released	2,500 kg	Estimate mass of oil in the MV transformer
Temperature of pool	25°C	Conditions expected to be observed regularly. Also, negligible impact on results.
Type of pool	Polygon	Modelled based on transformer bund area.
Max pool surface area	n/a	Dimension of MV enclosure
Height of confined pool above ground level	0 m	Modelled at ground level
Include shielding to bottom side of flame	No	No shielding provided in modelling.
Height of shielding	n/a	n/a
Wind speed	6 m/s	High wind speed modelled for worst-case scenario.
Wind direction	North	Worst-case direction, pushing flames towards boundary.
Ambient temperature	30°C	Conditions expected to be observed regularly. Also, negligible impact on results.

Input	Value	Justification
Ambient pressure	1.0151 bar	Atmospheric pressure
Ambient relative humidity	40%	Typical humidity in the area
CO2 concentration	0.0004	CO2 concentration in atmosphere

The results of the analysis are shown in **Appendix Table B-6**.

Appendix Table B-6: Heat Radiation Impacts from a MV Transformer Fire

Heat Radiation (kW/m^2)	Distance (m)
35	4.5
23	4.8
12.6	5.8
4.7	8.5
3.0	9

B8. Li-ion Battery Fire and Toxic Gas Dispersion

The toxic gas source term associated with a BESS thermal runaway event has been developed using a modelling approach consistent with the Gexcon EFFECTS "Li-ion Battery Storage Thermal Runaway" model. This model simulates the decomposition of battery materials during thermal runaway and estimates the generation rates and total mass of key toxic species over the duration of the event. The model accounts for both partial thermal runaway (limited to a single module) and full BESS involvement, where thermal propagation occurs across multiple modules or the entire unit. Inputs to the model include battery capacity, assumed chemistry, and release duration, which together define the rate of gas generation and temporal release profile. A conservative approach has been undertaken assessing a full BESS involvement. Hydrogen fluoride is typically adopted as the controlling toxic species due to its high toxicity and conservative representation of potential impacts. The resulting time-dependent mass release forms the basis for subsequent dispersion modelling.

B9. Plume Rise from Fire Model

It is necessary to assess the associated impacts of the smoke plume downwind of the facility, as it may have far reaching impacts on the wider community. When assessing the downwind impacts of the fire plume, the main contributors to the dispersion are:

- The fire size (diameter) and energy released as convective heat
- The atmospheric conditions such as wind speed, relative humidity, atmospheric stability and ambient temperature.

These parameters interact to determine the buoyancy of the smoke plume (vertical rise) which is controlled by the convective energy within the smoke plume in addition to the atmospheric conditions. The atmospheric conditions will vary from stable conditions (generally night time) to unstable conditions (high insolation from solar radiation), which results in substantial vertical mixing which aids in the dispersion. Contributing to this is the impact of wind speed which will limit the vertical rise of a plume but may exacerbate the downwind impact distance.

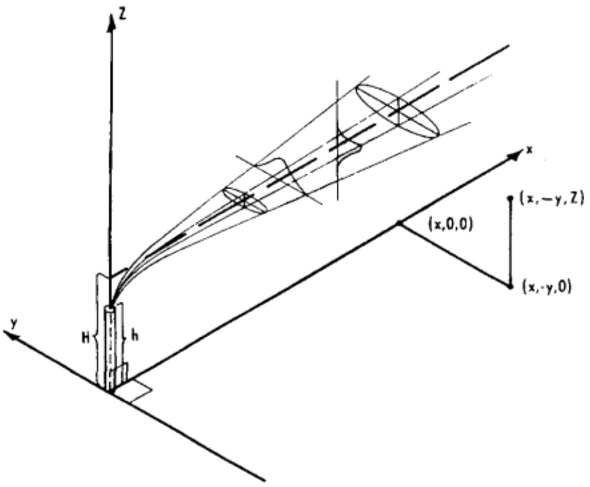
The atmospheric conditions are classified as Pasquill Guifford's Stability categories which are summarised in **Appendix Table B-6** (Ref. [25]).

Appendix Table B-7: Pasquill Guifford's Stability Categories

Surface wind speed at 10 m height (m/s)	Insolation			Night	
	Strong	Moderate	Slight	Thinly overcast or ≥50% cloud	<50% cloud.
<2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

Generally, the most onerous conditions are F conditions which result in stable air masses and typically have inversion characteristics. Inversion characteristics occur when a warm air mass sits above a cold air mass. Typically, hot air will rise due to lower density than the bulk air; however, in an inversion, a warm air mass sits above the cooler denser air; hence, as the warm air rises through the cold mass it hits a 'wall' of warmer air preventing vertical mixing above this point. In a fire scenario, the hot smoke plume will cool as it rises; however, if it encounters an inversion, it will begin to run along this boundary layer preventing vertical mixing and allowing the smoke plume to spread laterally for substantial distances.

A smoke plume is buoyant, and will disperse laterally and vertically as it rises essentially following a Gaussian dispersion as shown in **Appendix Figure B-3** Ref. [25]).



Appendix Figure B-3: Co-ordinate System for Gas Dispersion

Effects has been used to model a smoke plume arising from a BESS fire. The model has been developed based on a Gaussian dispersion model accounting for modifications to the plume drag coefficients required to model a plume dispersion from a warehouse fire. D5 conditions have been used to model the plume dispersion.

B10. Toxic Effect Threshold

The toxic effect thresholds for HF are defined by the US EPA's Acute Emergency Guideline Levels (AEGLs) drawing on human exposure data from the AEGL documentation. The three harm levels were mapped to the AEGL tiers as follows:

- Fatality / life-threatening effects were linked to the AEGL-3 concentration

- Serious injury was linked to the AEGL-2 concentration

Appendix Table B-8: AEGL Health Levels, Effects and Concentration for Hydrogen Fluoride

AEGL Level	Health effects	HF concentration (ppm
AEGL-2	Injury threshold	24
AEGL-3	Life-threatening health effects threshold	44

B11. Wind Climate

Wind data recorded at Cairns Aerodrome (Bureau of Meteorology Site 031011, May 1941 to July 2019) shows a difference in wind directions between morning and afternoon. In the morning, winds are almost exclusively southerly, moderate in strength (typically 10–30 km/h), and calm conditions are relatively common at around 9% of observations. By the afternoon, the wind shifts markedly to the north and northeast as a sea breeze develops, becoming stronger with speeds more frequently exceeding 30 km/h, while calm conditions drop to just 2% of observations.

Given that 3 pm represents the period of maximum solar heating in subtropical Tully, the prevailing stability class conditions are physically incompatible with the stable, near-calm nocturnal state. Accordingly, a D5 atmospheric stability class has been adopted to represent a most probable daytime dispersion scenario, characterised by neutral stability and moderate wind speeds.

The use of D5 conditions therefore provides a robust and representative assessment, capturing realistic prevailing conditions for the site while also considering a conservative worst-case credible scenario for dense gas dispersion to inform emergency response planning.

B12. BESS Fire Source Model

The BESS configuration proposed for the Tully site incorporates sufficient separation distances between adjacent units to prevent thermal runaway propagation. On this basis, the consequence assessment has conservatively considered a single BESS unit in a fully involved fire scenario. The scenarios were modelled using the following key inputs:

Appendix Table B-9: BESS Fire Source Model Parameters

Parameter	Value	Justification
Battery Chemistry	LFP	Battery chemistry used.
Energy Capacity Based On	Battery System	Conservatively assessing a BESS unit fire.
Energy Capacity	5 MWh	The energy capacity of each BESS unit.
Duration of release	43,200 Seconds	Full BESS reaches thermal runaway over 12 hours. Such estimation is in line with the duration of full BESS fires, which can last for days. A 12-hour assessment provides conservative results, yielding a greater HF release per unit time.

The generated HF was determined to be 0.02585 kg/s from a fully involved BESS fire burning over a 12-hour period.

B13. BESS Plume Rise

Toxic exposure duration has been determined based on a defined approach that considers the application of appropriate exposure limits relative to the scenario. The duration of exposure may be influenced by several factors, including the time required for personnel to seek shelter or evacuate, the time taken for the toxic plume to reach a given location, and the duration of the release itself.

In the event of a BESS fire at the facility, it is assumed that personnel exposed to a potential toxic release would initiate emergency response actions, including seeking shelter or evacuating to a designated safe area upwind from the incident. Based on the site layout and access to shelter locations, it is conservatively estimated that personnel would require approximately 5 minutes to reach a suitable refuge or move to a non-affected area.

Accordingly, the assessment adopts a 5-minute exposure duration to represent the period during which personnel may be exposed to the toxic plume while relocating. The following inputs and calculations have been developed to quantify the potential exposure to personnel during this period and to determine the corresponding AEGL-based impact thresholds for emergency response planning.

To further the sensitivity of the analysis the heat release rate has been reduced to cellulosic levels, accounting for variance in the heat due to the size of the fire, which in turn increases AEGL impact distances at receiver height; this conservative assumption has been adopted as the basis for the consequence assessment.

Appendix Table B-10: Plume Rise from BESS Fire Source Model

Parameter	Value	Justification
Chemical Name	Hydrogen Fluoride	Most Toxic gas released from BESS fire.
Mass flow rate of the source	0.02585 kg/s	Mass flow rate of BESS fire over 12 hours.
Height of release (Z-coordinate)	1.25 m	Release from the centre of the BESS.
Pasquill stability class	D	D5 is the probable stability class and F2 is the sensitive stability class determined from the wind rose provided by the Cairns weather station.
Wind speed at 10 m height	5 m/s	
Predefined wind direction	S/SSE	Prevailing wind seen in Cairns weather station windrose (9 am and 3 pm)
Ambient temperature	20 deg C	Ambient temperature.
Roughness length description	High Crops scattered large objects	The BESS facility is surrounded by rural farmland and a substation.
Reporting/ receiver height (Zd)	1.5 m	Breathing height.

Appendix C

Tesla – Letter of Commitment

Appendix C

TESLA

Attachment A Megapack Compliance and Testing Overview

Megapack 3 Fire Safety Documentation

Compliance Deliverables:
Megapack 3 UL 9540A Cell Testing
Megapack 3 UL 9540A Module Testing
Megapack 3 UL 9540A Unit Testing
Megapack 3 Large-Scale Fire Testing
Megapack 3 Fire Protection Engineering Report
Megapack 3 UL Compliance Package

Megapack 3 UL 9540A Cell Testing

- It is expected (like MP2XL) that the MP3 UL9540A cell-level test applicable to this project will fail UL9540A cell testing and UL 9540A module testing being required as cell thermal runaway (TR) will occur with flammable vent gases in the cell test.

Megapack 3 UL 9540A Module Testing

- It is expected (like MP2XL) that the MP3 UL9540A module level test applicable to this project will fail due to the flammable gases measured in the UL 9540A cell level test and Unit level testing will be required.

Megapack 3 UL 9540A Unit Testing

- It is expected (like MP2XL) that MP3 UL9540A Unit-level test applicable to this project will pass.

Megapack 3 Large-Scale Fire Testing

- While Tesla considers UL9540A unit level testing a robust demonstration of safety features, Tesla will conduct an additional Large Scale Fire Test demonstrating safety during a fully developed fire condition. The methodology Tesla will use is in line with the UL9540A 6th edition methodology which was published on the 13th of March 2026.
- The 6th edition is the first edition of UL9540A to provide a LSFT methodology and using the UL9540A 6th edition methodology is aligned with direction of industry. Tesla's LSFT for MP3 will have neighboring units present during the test with the evaluation criteria being no thermal runaway or cell venting in the neighboring units.

- This is an enhancement on the testing conducted for MP2XL which had a bespoke destructive fire test with a FLIR camera captured the temperature contour of the external surface of the initiating MP2XL, but no target units were installed nearby due to the absence of an appropriate LSFT methodology for MP2XL at the time of testing.

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Attachment B Megapack 3 and Megapack 2XL Key Fire-Safety Features

Summary

- Tesla has a long-standing commitment to robust fire-safety practices across its energy storage portfolio. Building on this established foundation, it is anticipated that Megapack 3 will uphold the same rigorous expectations for safety performance and is actively progressing toward obtaining UL 9540 certification.
- The following provides a high-level overview of the fire-safety measures incorporated into the previous Megapack model (MP2XL), as well as a summary of the anticipated fire-safety features for Megapack 3

Summary of Key Fire-Safety Features in Megapack 2 XL (MP2XL)

- Battery Management System (BMS)
  The MP2XL features an integrated Battery Management System that continuously monitors cell, module, and cabinet conditions including temperature, voltage, current, and state of charge. The BMS autonomously responds to off-normal conditions by activating cooling, isolating an affected module, or disconnecting it entirely. These automatic protections can prevent a localized failure from escalating and help limit thermal propagation within the cabinet.

- Thermal Management System (TMS)
  The MP2XL employs a dual thermal management strategy combining a closed-loop liquid cooling system with an integrated air-cooling thermal roof to maintain safe battery operating temperatures. The system circulates a water glycol coolant through the battery modules and power electronics, using pumps, heaters, and a compressor to autonomously regulate internal temperatures across varying environmental conditions. Above the battery bays, the MP2XL includes an IP20 rated thermal roof containing radiators and fans. Cool ambient air enters through front grates, passes over the radiators to absorb heat, and is then exhausted upward. This air cooling layer removes heat from the coolant loop. This helps prevent cell over-temperature and reduces the likelihood of thermal runaway events.

- Explosion Control System
  The MP2XL includes an explosion control system to mitigate the risk of uncontrolled deflagration. The system includes pressure-sensitive vents (overpressure vents) and sparkers installed throughout the battery module bay.

- Sparkers: MP2XL incorporates sparkers strategically placed throughout the battery module bays. These devices intentionally ignite flammable gases early before the gases can accumulate to a concentration that may cause deflagration. This engineered early ignition strategy has been validated in largescale testing across Megapack generations and effectively minimizes explosion risk inside the enclosure.
- Pressure Sensitive Vents: The system also includes passive overpressure vents installed on the roof of the sealed IP66 battery bay. These vents open automatically only when internal pressure increases, safely releasing gases upward into the thermal roof. This design prevents cabinet doors from opening during a thermal event, avoids projectile hazards, and maintains enclosure integrity while directing gases away from personnel and adjacent equipment.

Summary of Key Fire-Safety Features in Megapack 3 (MP3)

- Battery Management System (BMS)
  Similar to MP2XL, MP3 features a complex Battery Management System that continuously monitors cell temperatures, voltages, currents, insulation levels, and general system health. The BMS automatically responds to off-normal conditions and plays a central role in limiting or preventing escalation during early-stage anomalies. In addition to baseline monitoring functions, MP3 incorporates BMS-driven protective modes such as:
  - Automatic Safe Discharge, which lowers the battery's state of energy if potential thermal-runaway indicators are detected.
  - Thermal Limp Mode, which reduces module or unit-level power output when temperatures approach unsafe thresholds.

  These controls act as preventative safety barriers that limit fault escalation before it develops into a thermal event.

- Thermal Management System (TMS)
  Mirroring the philosophy used in MP2XL, Megapack 3 uses a fully integrated active thermal management system that provides active cooling and heating to maintain safe operating temperatures across all internal components. An external HVAC or thermal system is therefore not required for Megapack 3 to operate. The system consists of:
  - Thermal bay (accessible by Service Providers only), located in the middle part of Megapack 3, containing fans, radiators, pumps, compressors, thermal power electronics. The thermal

bay also provides an upward ventilation path for air, helping to direct heat away from critical components.
    - Coolant manifolds

- <u>Explosion Control System</u>
    - Sparkers: Like MP2XL, the MP3 includes a Sparker System that proactively ignites low-concentration flammable gases before they reach hazardous levels. By combusting gases early, sparkers significantly reduce deflagration potential and work in tandem with the overpressure vents for a fully engineered explosion-mitigation strategy.
    - Pressure-Sensitive Vents: As with MP2XL, MP3 incorporates overpressure vents in each battery bay that open automatically during a rapid internal-pressure rise. Once activated, these vents route gases and combustion products from the battery bay into the thermal bay and then out through the doors, preventing pressure buildup and preserving enclosure integrity.
    - Automated Door Opening: MP3 further enhances deflagration mitigation by incorporating automated door opening when harmful interior conditions are detected. This provides additional pressure relief and supports more rapid ventilation, thereby shortening the duration and severity of a thermal event. Prior to door opening, an external warning in the form of audible and visible notification will be given, alerting site personnel to the potential hazard.

- <u>Safety Controller</u>

  MP3 includes a dedicated Safety Controller located in the thermal bay, responsible for aggregating safety-related sensor data, executing alert logic, and initiating protective actions when required. The safety controller provides an external warning and communication system which consists of an audible alarm and flashing lights as well as Alarm communication to the Tesla System Controller. The safety controller hardware/firmware is evaluated under UL 1998 and UL 991 (1998 - Software in Programmable Components: for the firmware on the board. 991 - Tests for Safety-Related Controls Employing Solid-State Devices), confirming robustness of safety-related controls and proper fail-safe behavior.

Attachment C Firefighting Response

[MP Emergency Response Guide] outlines the information relevant to emergency responders and Authority Having Jurisdiction (AHJs) regarding safety surrounding MPs. During storage or operation, signs of an emergency include but are not limited to:

- Suspicious odor observed near the MP
- Smoke or fire emanating from the MP
- Severe physical impact on the MP

In case of an emergency, isolate, deny entry and perform the following steps:

1. If possible, and if trained and properly equipped, shut off the unit/system
2. Evacuate the area.
3. If not already present, notify appropriately trained first responders, the local fire department, and any appointed subject matter expert (SME) if available.
4. Contact Tesla for guidance

The following further advice is provided regarding firefighting measures:

- Firefighters should wear SCBAs and structural firefighting gear.
- Do not approach the unit and attempt to open any doors which are not already opened
- If a fire develops, allow the affected unit to consume itself as it is designed to do. Applying water to the burning unit will have minimal effect and will only slow down its eventual combustion.
- At the discretion of first responders, use a fog pattern to cool nearby exposures.
- It may take 24-48 hours for the unit to cool down so continue to remain at a safe distance.

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Attachment D Megapack (MP) Case Studies

There are no recorded MP2XL or MP3 fires at the time of writing this memo. This section will focus on known fires of other MP products and their learning outcomes.

VBB

The VBB fire occurred on 30 July 2021 during the commissioning phase of the Neoen site, near Geelong, Victoria, Australia. The fire involved two MP1s with the following key components, extracted from the [Blum Report]:

- The initiating MP1 was shut off manually prior to the fire incident. Once smoke was observed by site personal, they electrically isolated all MP1s and called the Country Fire Authority (CFA).
- The CFA set up a perimeter and started applying cooling water to the nearby exposures. Despite this, the fire spread to the nearest MP1 via the plastic vents on the roofs.
- The CFA allowed both MP1s to burn out and did not apply water directly on them.
- Six hours after the start of the fire event, visible fire had subdued, and the CFA monitored the site for three days before deeming it under control.
- The most likely root cause of the fire was a cooling-system leak within the initiating MP1 that caused arcing in the power electronics of a battery module. This resulted in heating of the battery module's Li-ion cells and resulted in TR.
- Contributory to the root cause was the lack of Supervisory Control and Data Acquisition (SCADA), lack of telemetry, fault monitoring and electrical active safety devices. The power supply to the pyrotechnic disconnect was also most likely disabled by the leaking coolant, which would have otherwise interrupted the fault current passing through the battery module prior to it escalating to a fire event.

The following mitigation measures were incorporated into the MP2 and MP2XL and will be incorporated for MP3 based on learnings from the VBB fire, as well as updated Emergency Response Plan (ERP) and commissioning processes:

- Improved inspection of the thermal system.
- Reduced telemetry setup from twenty-four hours to one hour, along with avoiding using the keylock switch during commissioning or operation unless the unit is being actively serviced.

- Updated firmware, to include alerts for the thermal system, keeping all active safety systems active, and monitoring of the pyrotechnic disconnect.
- Replaced the plastic roof vents with thermally insulated steel vent shields.
- Refinement of the ERP to avoid using water on an MP fire, but only on nearby exposures, to allow the MP to burn out

Elkhorn

the Elkhorn fire occurred on 20 September 2022 in Monterey County, California, United States of America. The fire involved a single MP1 with the following key components, extracted from the [Grant Report]:

- The initiating MP1 initiated fire detection alarms, and the site operator called 911 (similar to 000 in Australia) shortly thereafter.
- The North County Fire Protection District (NCFPD) set up two hose streams on exposures.
- The NCFPD allowed the MP1 to burn out and did not apply water directly on it.
- Initial water application for 3.7 hours, with a follow-up water application for 2.2 hours, mostly using two hose streams for the duration.
- Six hours after the start of the fire event, visible fire had subdued, and the NCFPD lifted the road closures and shelter in-place advisory approximately 18 hours after the initial fire detection.
- The root cause of the fire was water ingress. That allowed electrical shorts to initiate TR. A displaced umbrella valve was the cause. It was incorrectly installed with the new steel vent shields from the VBB learning outcomes.

The following mitigation measures were incorporated into the MP2, and MP2XL and will be incorporated for MP3 based on learnings from the Elkhorn fire, as well as updated ERPs and commissioning processes:

- Introduction of an Automatic Safe Discharge (ASD) feature.
- Updated alarms and approval processes, including battery isolation failure alerts, server-side alarms now being elevated to Tesla operators.
- Playbook guidance for isolation-failure alerts.
- Prioritization of thermal-alarm transmission to eliminate the delay of alerting the fire brigade.
- Refinement of the ERP, known as the Emergency Response Guideline, regarding roles, responsibilities and training.

- Update on the water-application guidance: cooling water is not to be applied to nearby MPs

Bouldercombe

The Bouldercombe fire occurred on 26 September 2023 near Rockhampton, Queensland, Australia. The fire involved a single MP2 with the following key components, extracted from the [Bouldercombe Findings]:

- The site had completed compliance testing, demonstrated stable operation, and was awaiting final approval.
- The initiating MP2 caused a trip in the RMU, isolating it from the rest of the site.
- QFB set up two hose streams on exposures. Around this same time, CCTV images show signs of fire and arcing from the initiating MP2. Tesla received a call from the customer representative approximately an hour after this, alerting Tesla to the fire.
- QFB allowed the MP2 to burn out and did not apply water for the duration of the incident, including no water used to cool nearby exposures. • Approximately forty-eight hours after the start of the fire event, visible fire had subdued, and QFB returned to the site the following day.
- The most likely root cause of the fire was an arcing event in the CIB, which is the AC area of the MP2, and therefore not caused by a Li-ion cell or a battery module.

Based on learnings from the Bouldercombe fire the following mitigation measures were incorporated into the MP2 and MP2XL and will be incorporated for MP3, as well as updated ERPs and commissioning processes:

- Review of inverter module and AC bus QA and inspection, and replacement of parts.
- Updates to firmware to better detect a thermal event.
- Improved commissioning and service self-testing.

In conclusion, the Elkhorn and Bouldercombe case studies, which involved smaller firebreaks, are not directly applicable to MP2XL or MP3 units, however, they still illustrate that the radiant heat flux and the target-unit cell temperatures are not expected to result in fire spread between units.