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Integrating Innovation without Compromising Safety - Battery Energy Storage System Consequence Modelling Case Study for a Defence Base

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Lithium-Ion Battery Energy Storage System Consequence Modelling Case Study for a Defence Base

- Overview of BESS Technology for Defence Applications
- Description of Hazards
- Outline of Case Study
- Presentation of Findings

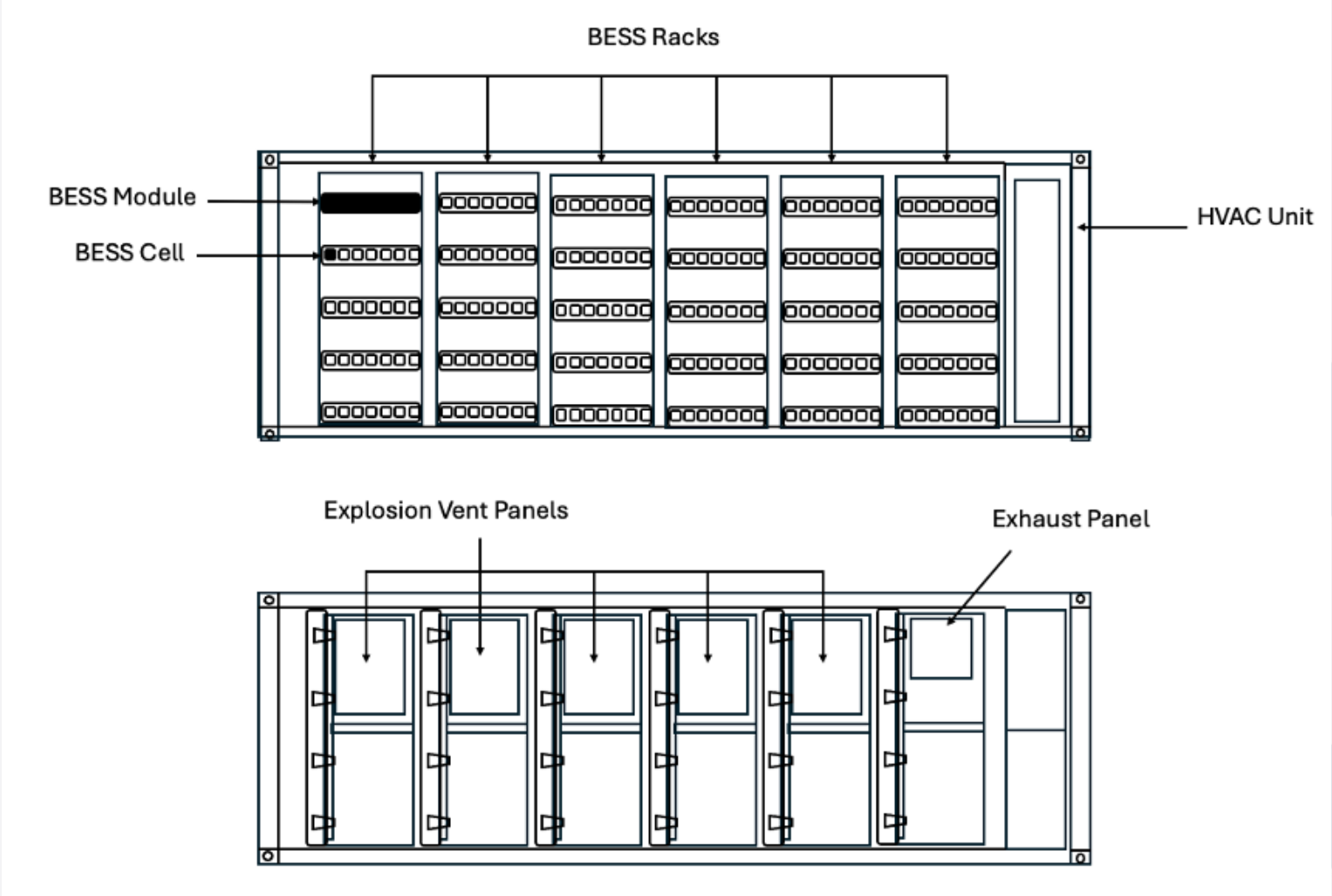
Overview of BESS Technology on Defence Bases

- Lithium-Ion Battery Energy Storage System (BESS) technology is an emerging option for Defence Bases in Australia, allowing for energy storage and reuse in order to maintain operational capability and personnel safety.
- BESS technology provides multiple benefits such as:
  - Increased backup power reliability; and
  - Reduced dependence on hydrocarbon fuels and the associated fuel supply chains to power backup generators.
- Scale of BESS systems range from small systems supporting on-site generation during peak demand periods, to larger grid-scale systems.

Description of Hazards

- Lithium-ion battery electrolyte is a flammable organic solvent.
- Heating of battery cells above the design temperature can result in an exothermic, self-sustaining chemical reaction (“thermal runaway”), which causes further rapid increases in battery temperature.
- Thermal runaway results in off-gassing of the cell, which can result in several hazardous events including:
  - Dispersion of toxic components in the off-gas (including carbon monoxide, hydrogen cyanide and hydrofluoric acid).
  - Ignition of flammable components in the off-gas (including hydrogen, methane and other hydrocarbons).
  - Ignition may result in several flammable impacts including battery fires, flash fires and vapor cloud explosions.

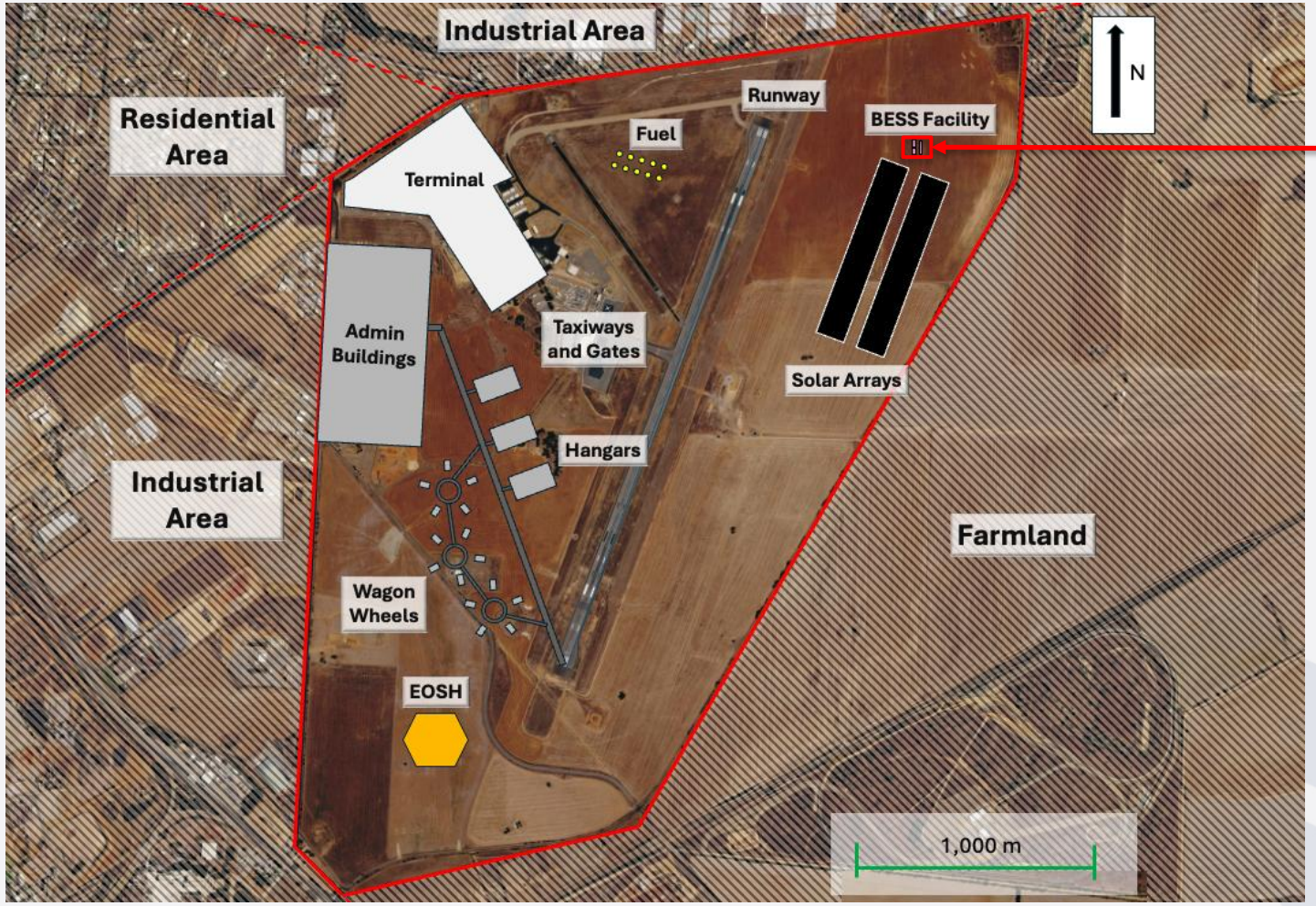
BESS Container Arrangement

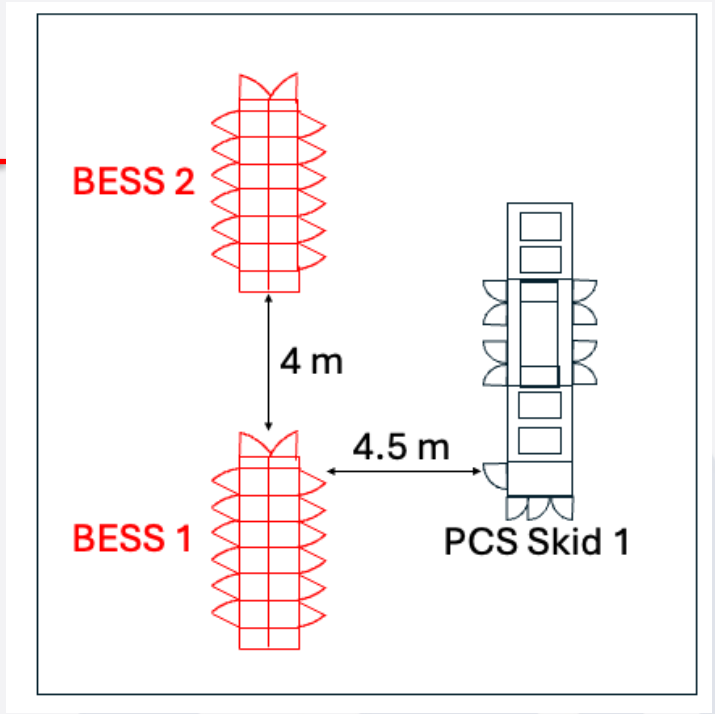


Outline of Case Study

- The BESS facility considered in this case study comprises a Lithium Iron Phosphate (LFP) storage system with a power output of 5 MWhr at 35 kV at the Point of Connect (PoC) supplying a defence base with fuel storage and explosive ordnance stored on-site.
- The BESS provides energy storage and reuse capabilities to serve as a backup power source in the event that power supply to critical systems is interrupted.

Site Layout





BESS Facility

Outline of Case Study Risk Assessment Methodology

- Step 1 – Hazard Identification & Screening.
- Step 2 – Scenario Development.
- Step 3 – Initial Consequence Analysis.
- Step 4 – Evaluation against Acceptance Criteria.
- Step 5 – Detailed Analysis.

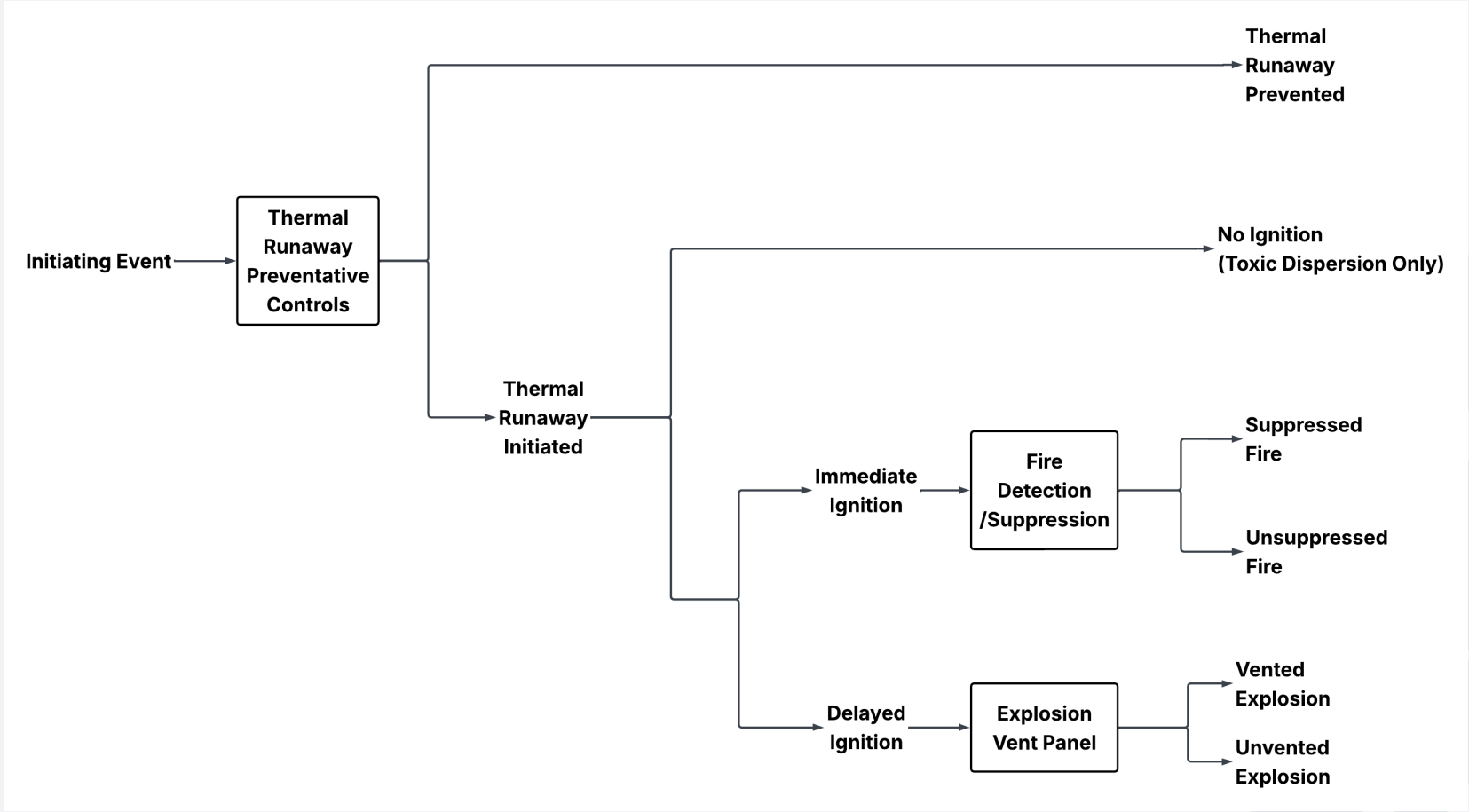
Threshold Criteria

Severity level	Severity level description	Explosion over-pressure	Thermal radiation intensity (kW/m²)	Concentration
1	Tolerable	3.5 kPa	2.1	< AEGL 1
2	Intolerable, unless a risk-based approach is utilised which shows that Individual Fatality Frequency or operational disruptions $<10^{-4}$ yr^{-1}	7 kPa 14 kPa 21 kPa	4.7 12.6	AEGL 1 AEGL 2
3	Not tolerable	35 kPa 70 kPa	23	AEGL 3

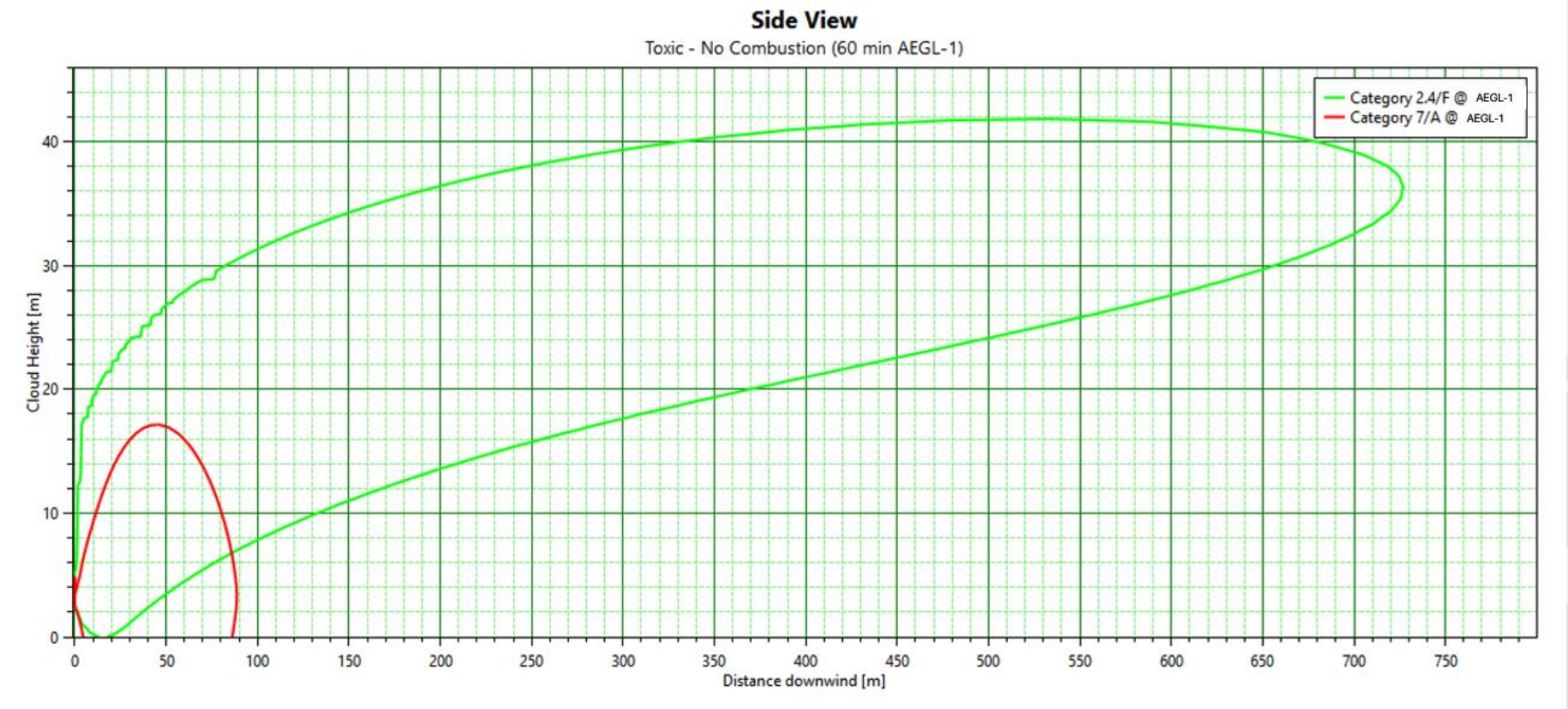
Consequence Modelling Approach

- Modelling Tools and Standards used:
  - DNV PHAST™ v8.22 software used to model toxic dispersion and fire scenarios.
  - EN 14994:2007 used to calculate vented explosion effects.

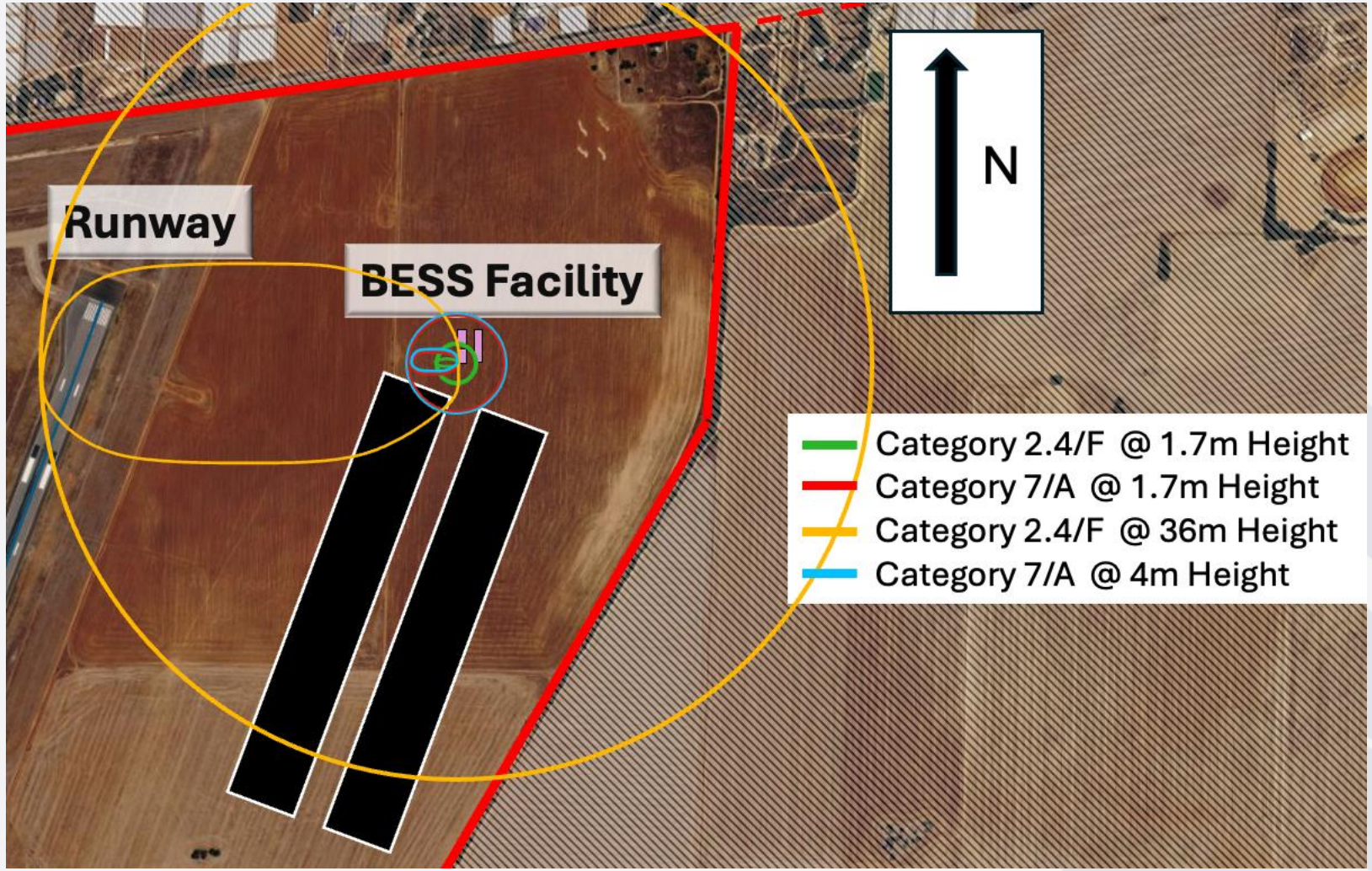
Event Tree Approach



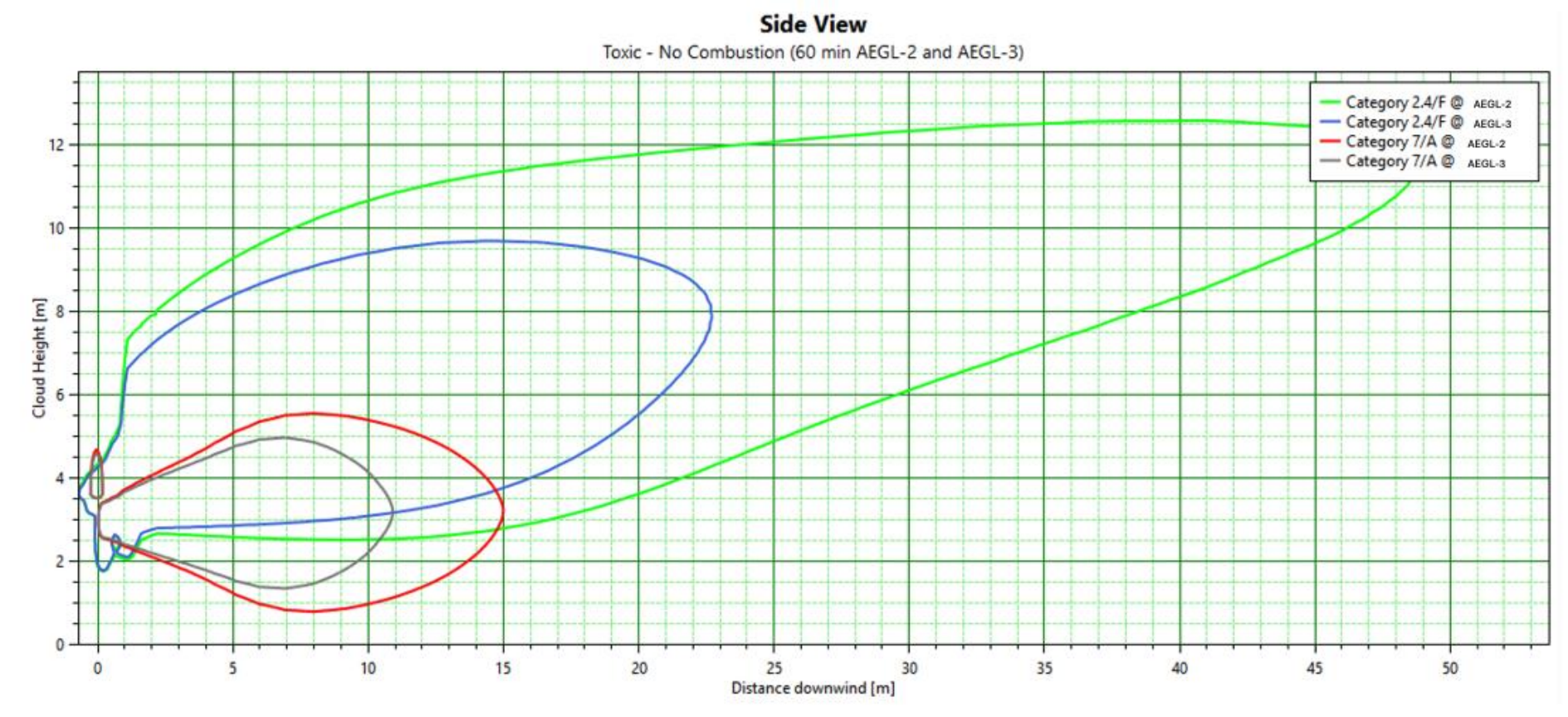
Toxic Impact, No Ignition, Single Container, AEGL-1 (60 minute) Side Profile



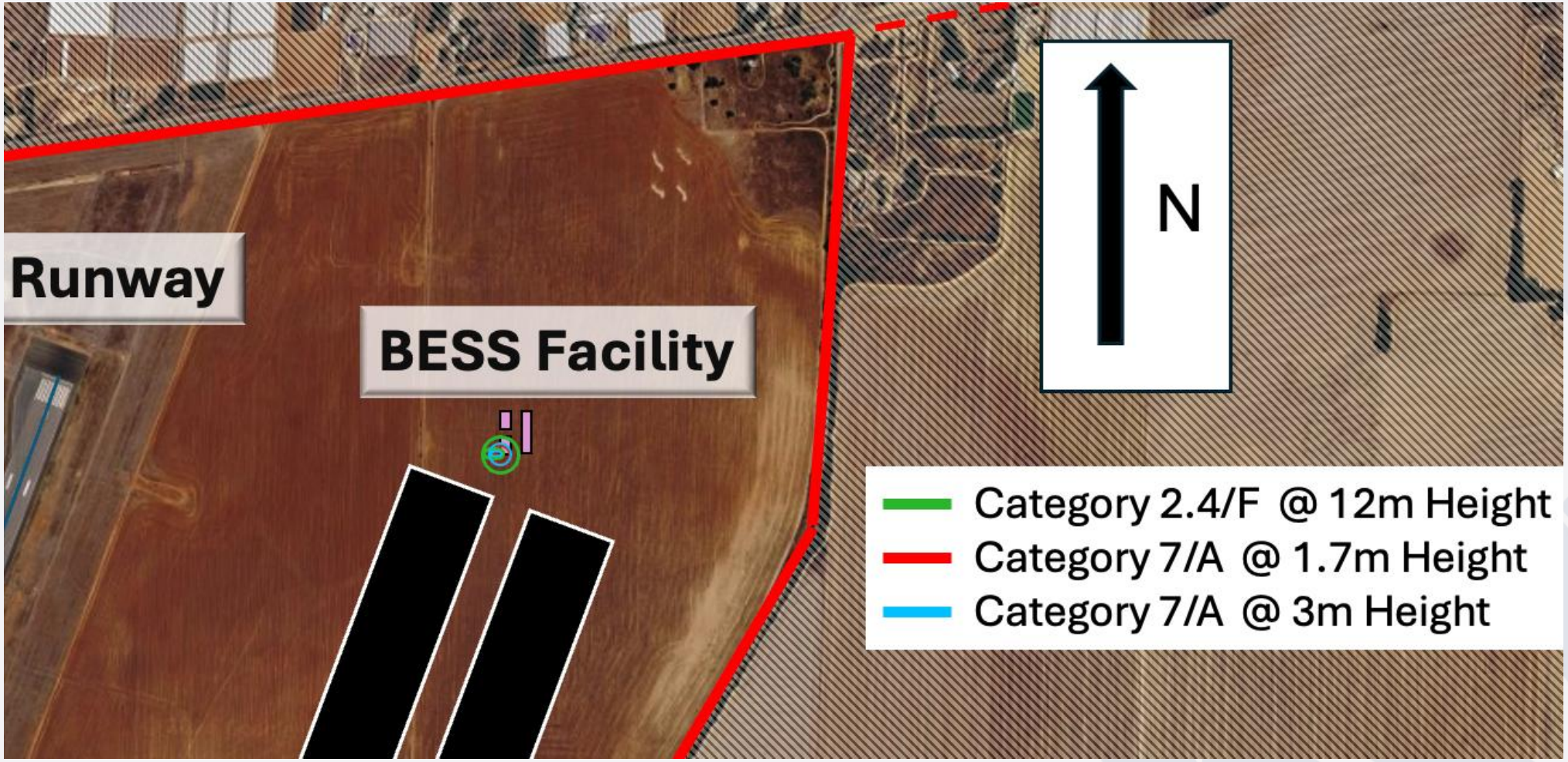
Toxic Impact, No Ignition, Single Container, AEGL-1 (60 minute) Overhead Profile



Toxic Impact, No Ignition, Single Container, AEGL-2 and AEGL-3 (60 minute) Side Profile



Toxic Impact, No Ignition, Single Container, AEGL-2 (60 minute) Overhead Profile



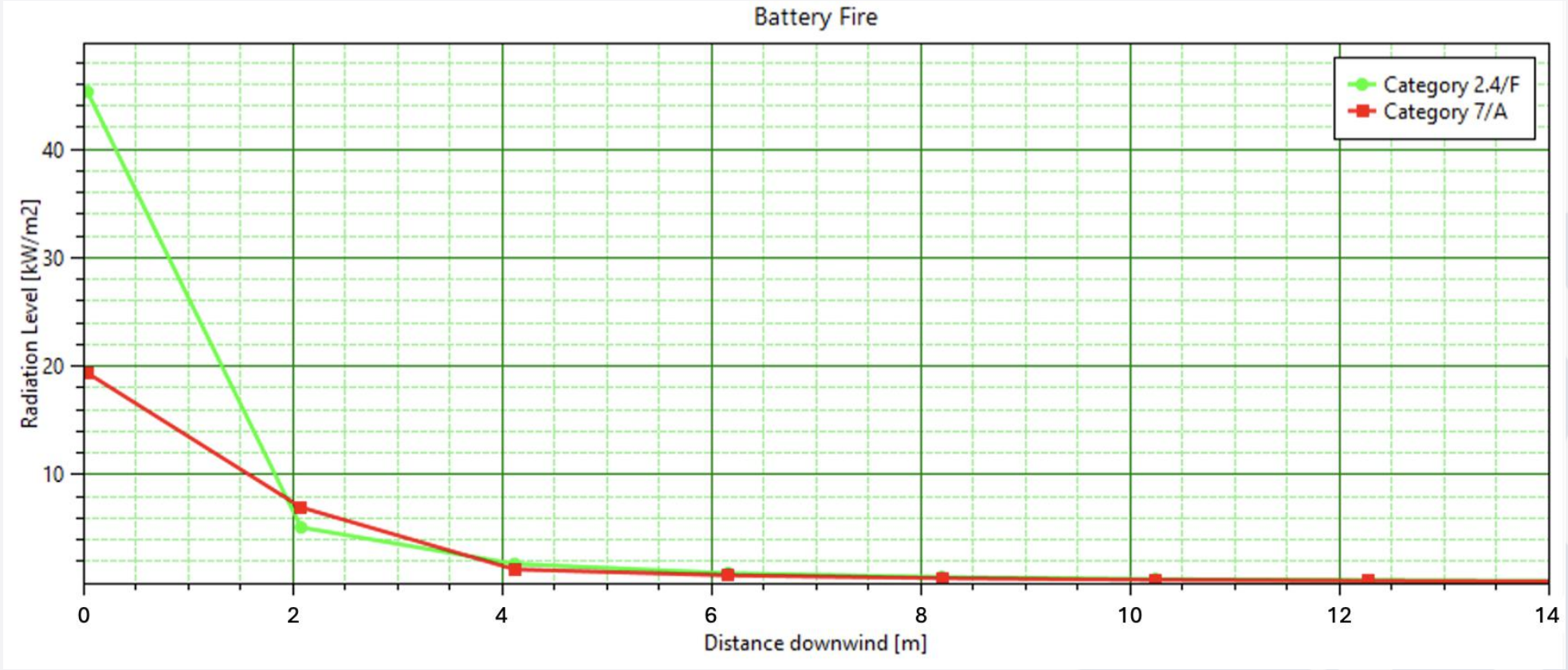
Controls for Toxic Impact

- The consequence modelling results indicates that while the distance to hazardous concentrations at ground level is limited, the toxic cloud contours overlap the run-way at greater heights, which may impact Defence Base operations.

Toxic Scenario	Weather	Distance at personnel height of 1.7 m (m)	Max. cloud distance (m)	Height at max. cloud distance (m)
AEGL-1 (60 min)	2.4/F	35	727	36
	7/A	85	88	4
AEGL-2 (60 min)	2.4/F	Not reached	25	12
	7/A	13	15	3

- The following controls are recommended for consideration:
  - Establish multiple muster points for a range of weather conditions.
  - Monitor wind direction to determine evacuation path.
  - Install fixed point gas detectors to detect off-gassing.
  - Self-Contained Breathing Apparatus (SCBA) to be used for fire fighting.

Thermal Radiation Results

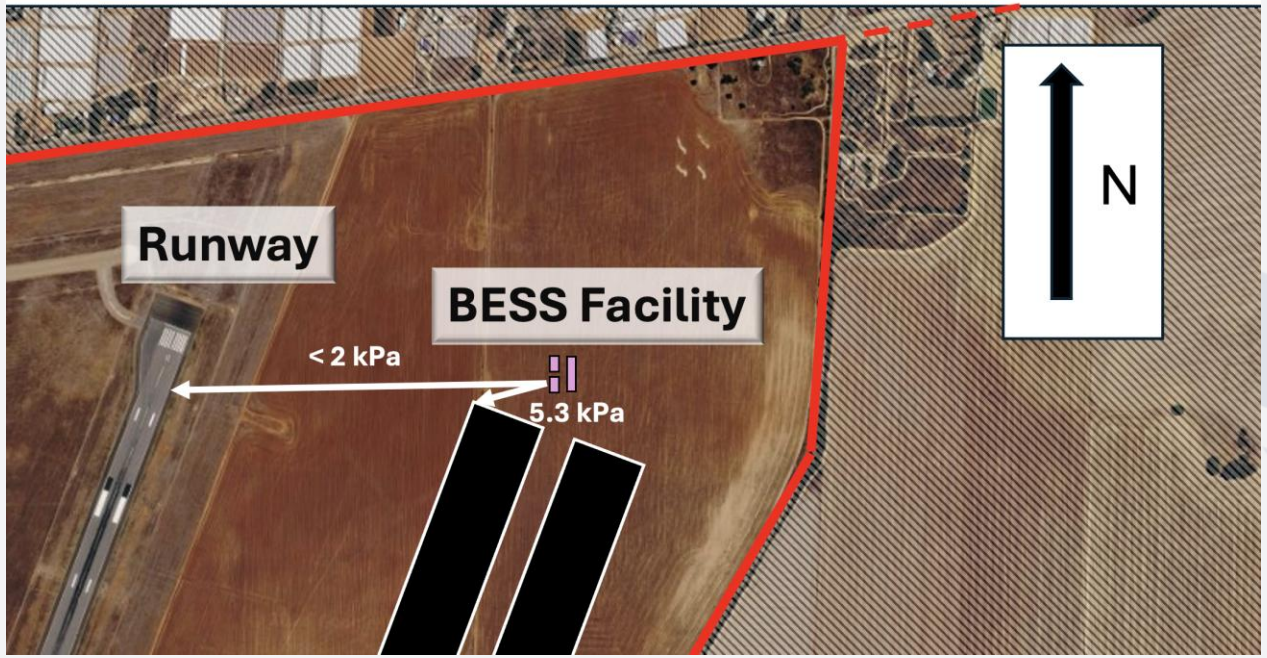


Controls for Thermal Radiation Impact

- Thermal runaway events may escalate or have thermal impacts on other auxiliary equipment and structures.
- Based on the results of this analysis, it is considered that escalation of a BESS fire to other defence base assets is not credible at the distance of the container from these assets.
- The following controls are recommended for consideration:
  - Increase distance between the BESS containers.
  - Implement appropriate fire control measures, including the use of fixed gas, smoke and flame detectors.

Explosion Overpressure Results

Angle (°)	Explosion overpressure severity levels					
	2 kPa	7 kPa	15 kPa	20 kPa	35 kPa	70 kPa
0	320.3	50.1	16.2	10.6	4.6	1.7
10	305.8	47.8	15.5	10.1	4.4	1.6



Explosion Overpressure Results

Consequence event	Frequency (probability of occurrence per annum)
Off-gassing without ignition	2.00×10^{-4}
Off-gassing with ignition	5.00×10^{-5}
Multiple module fire	3.00×10^{-5}
Vented explosion	4.00×10^{-4}
Unvented explosion	4.00×10^{-6}

Firefighting Strategy

- A controlled burn-out of the battery facility or enclosure(s) will be the most appropriate action in many cases.
- Water is considered the preferred agent for suppressing LFP battery fires due to its superior cooling capacity and ease of transport to the seat of the fire.
- Self-contained breathing apparatus to be used in the vicinity of fire control operations and air quality monitoring should be done.
- Pumps should be sized appropriately to achieve the required fire mitigation strategy.

Conclusion

- The case study presented in this paper provides an example of how the DNV Phast software package and other calculation methods can be used to model the effects of battery thermal runaway events including toxic dispersion, fires and explosions.
- This has been demonstrated in the context of a BESS facility located on a Defence Base, in proximity to the runway, occupied buildings, explosive ordnance and fuel storage.
- This type of analysis is important for ensuring the appropriate implementation of preventative measures, site layout planning and emergency response planning when considering the implementation of BESS systems at defence bases.

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