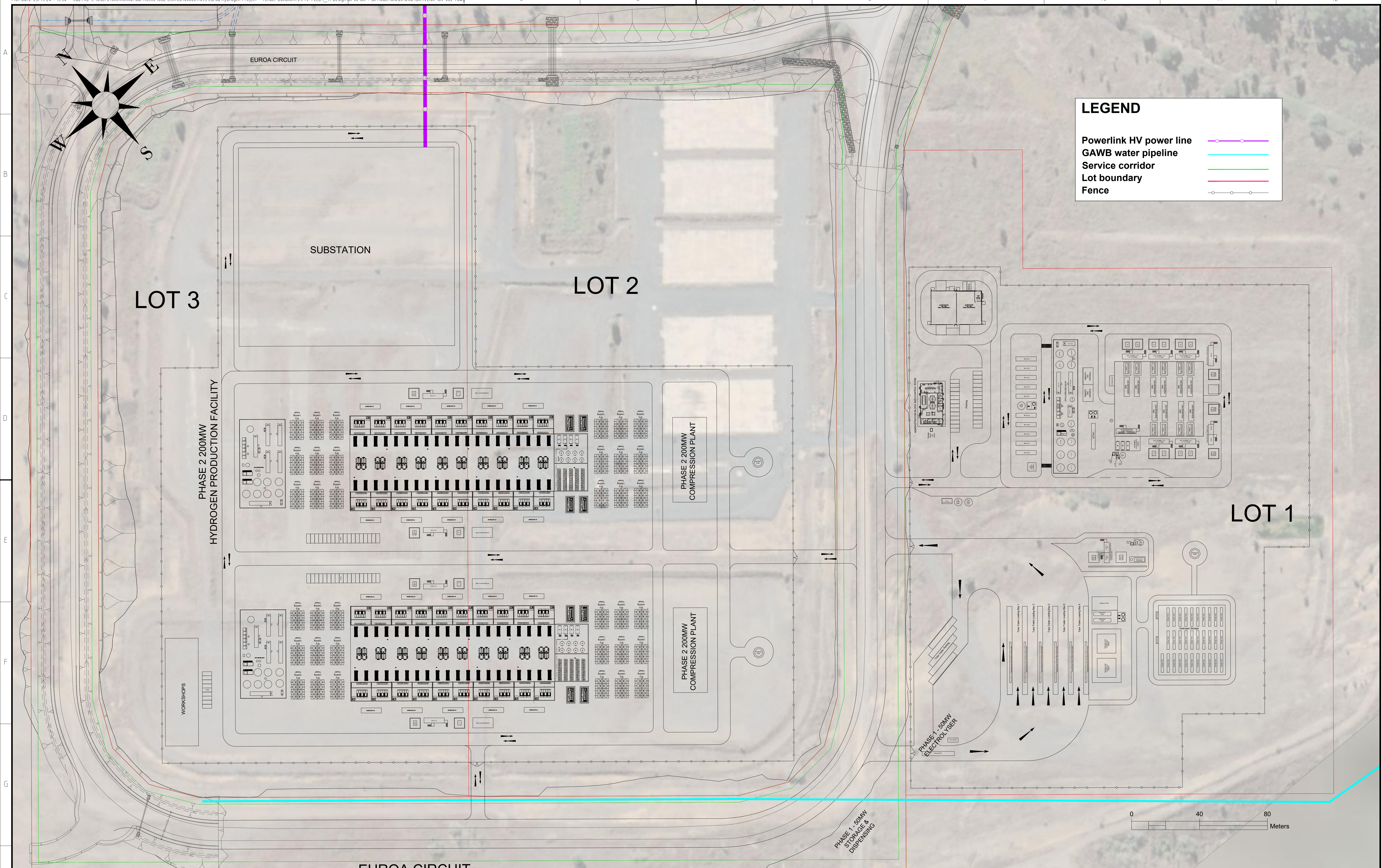


Appendix E Electricity Transmission Connection Plan

Appendix F Phase 2 400MW Layout Plan



Appendix G Response to State Code 1

State code 1: Development in a state-controlled road environment

State Development Assessment Provisions guideline - State Code 1: Development in a state-controlled road environment. This guideline provides direction on how to address State Code 1.

Table 1.1 Development in general

Performance outcomes	Acceptable outcomes	Response
Buildings, structures, infrastructure, services and utilities		
PO1 The location of the development does not create a safety hazard for users of the state-controlled road .	AO1.1 Development is not located in a state-controlled road . AND AO1.2 Development can be maintained without requiring access to a state-controlled road .	Complies with AO1.1 and AO1.2 Site is not located in state-controlled road (SCR) or seeks to require direct access from a SCR.
PO2 The design and construction of the development does not adversely impact the structural integrity or physical condition of the state-controlled road or road transport infrastructure .	No acceptable outcome is prescribed.	Achieves PO2. The proposed development is not located near a state-controlled road to create and any adverse impacts to the structural integrity or physical condition of the SCR or road transport infrastructure (RTI)
PO3 The location of the development does not obstruct road transport infrastructure or adversely impact the operating performance of the state-controlled road .	No acceptable outcome is prescribed.	Achieves PO3. The subject site is not located near any RTI to obstruct it, or near a SCR to create and impacts to the operating performance.
PO4 The location, placement, design and operation of advertising devices, visible from the state-controlled road , do not create a	No acceptable outcome is prescribed.	N/A The proposed development does not seek include any advertising devices.

Performance outcomes	Acceptable outcomes	Response
safety hazard for users of the state-controlled road .		
PO5 The design and construction of buildings and structures does not create a safety hazard by distracting users of the state-controlled road .	AO5.1 Facades of buildings and structures fronting the state-controlled road are made of non-reflective materials. AND AO5.2 Facades of buildings and structures do not direct or reflect point light sources into the face of oncoming traffic on the state-controlled road. AND AO5.3 External lighting of buildings and structures is not directed into the face of oncoming traffic on the state-controlled road. AND AO5.4 External lighting of buildings and structures does not involve flashing or laser lights.	N/A The proposed development does not propose any buildings or structures near the SCR
PO6 Road, pedestrian and bikeway bridges over a state-controlled road are designed and constructed to prevent projectiles from being thrown onto the state-controlled road .	AO6.1 Road, pedestrian and bikeway bridges over the state-controlled road include throw protection screens in accordance with section 4.11 of the Design Criteria for Bridges and Other Structures Manual, Department of Transport and Main Roads, 2020.	N/A The proposed development does not propose any bridges.
Landscaping		
PO7 The location of landscaping does not create a safety hazard for users of the state-controlled road .	AO7.1 Landscaping is not located in a state-controlled road. AND	N/A The proposed development does not propose any landscaping in an SCR.

Performance outcomes	Acceptable outcomes	Response
	AO7.2 Landscaping can be maintained without requiring access to a state-controlled road. AND AO7.3 Landscaping does not block or obscure the sight lines for vehicular access to a state-controlled road.	
Stormwater and overland flow		
PO8 Stormwater run-off or overland flow from the development site does not create or exacerbate a safety hazard for users of the state-controlled road .	No acceptable outcome is prescribed.	Achieves PO8 As detailed in the Planning Report, the proposed development will manage stormwater to have no adverse impacts to neighbouring properties. The flows from the site enter into Euroa Circuit culverts and into lot 7, then flow into existing drainage lines, which flow to Larcom Creek and do not impact any flows in or near the SCR.
PO9 Stormwater run-off or overland flow from the development site does not result in a material worsening of the operating performance of the state-controlled road or road transport infrastructure .	No acceptable outcome is prescribed.	Achieves PO9 As detailed in the Planning Report, the proposed development will manage stormwater to have no adverse impacts to neighbouring properties. The flows from the site enter into Euroa Circuit culverts and into lot 7, then flow into existing drainage lines, which flow to Larcom Creek and do not impact any flows in or near the SCR.
PO10 Stormwater run-off or overland flow from the development site does not adversely impact the structural integrity or physical condition of the state-controlled road or road transport infrastructure .	No acceptable outcome is prescribed.	Achieves P10 As detailed in the Planning Report, the proposed development will manage stormwater to have no adverse impacts to neighbouring properties. The flows from the site enter into Euroa Circuit culverts and into lot 7, then flow into existing drainage lines, which flow to Larcom Creek and do not impact any flows in or near the SCR.
PO11 Development ensures that stormwater is lawfully discharged.	AO11.1 Development does not create any new points of discharge to a state-controlled road .	Complies with A11.1, A11.2 and A11.3 Discharge of stormwater mainly flows from Lot 1(primary premises) flows into Lot 7, which the

Performance outcomes	Acceptable outcomes	Response
	AND AO11.2 Development does not concentrate flows to a state-controlled road. AND AO11.3 Stormwater run-off is discharged to a lawful point of discharge. AND AO11.4 Development does not worsen the condition of an existing lawful point of discharge to the state-controlled road.	applicant has provided evidence from the owner of Lot 7 to accept these flows. Flows from Lot 2 and 3 discharge to the Euroa Circuit (Local Road) No discharge to the SCR.
Flooding		
PO12 Development does not result in a material worsening of flooding impacts within a state-controlled road.	AO12.1 For all flood events up to 1% annual exceedance probability, development results in negligible impacts (within +/- 10mm) to existing flood levels within a state-controlled road. AND AO12.2 For all flood events up to 1% annual exceedance probability, development results in negligible impacts (up to a 10% increase) to existing peak velocities within a state-controlled road. AND AO12.3 For all flood events up to 1% annual exceedance probability, development results	Complies with AO12.1, AO12.2 and AO12.3 The subject site is not located within a flood area or the prescribed level, thus won't impact the flooding levels in the area. All flows from the site flow into Larcom Creek which is downstream of the SCR, this won't impact the any flood areas in the SCR.

Performance outcomes	Acceptable outcomes	Response
	in negligible impacts (up to a 10% increase) to existing time of submergence of a state-controlled road .	
Drainage Infrastructure		
PO13 Drainage infrastructure does not create a safety hazard for users in the state-controlled road .	AO13.1 Drainage infrastructure is wholly contained within the development site, except at the lawful point of discharge . AND AO13.2 Drainage infrastructure can be maintained without requiring access to a state-controlled road .	Complies with AO13.1 and AO13.2 The lawful point of discharge is Euroa Circuit and Lot 7 and does not require access through the SCR.
PO14 Drainage infrastructure associated with, or within, a state-controlled road is constructed, and designed to ensure the structural integrity and physical condition of existing drainage infrastructure and the surrounding drainage network.	No acceptable outcome is prescribed.	N/A No drainage infrastructure is proposed in or near the SCR.

Table 1.2 Vehicular access, road layout and local roads

Performance outcomes	Acceptable outcomes	Response
Vehicular access to a state-controlled road or within 100 metres of a state-controlled road intersection		
		Not Applicable The proposed development does not propose access to an SCR or is within 100m of an intersection with an SCR.
Public passenger transport and active transport		
		Not Applicable The subject site is not located near or seek to utilise or rely on near any public passenger transport infrastructure, public passenger services and active transport infrastructure .

Table 1.3 Network impacts

Performance outcomes	Acceptable outcomes	Response
PO25 Development does not compromise the safety of users of the state-controlled road network.	No acceptable outcome is prescribed.	Achieves PO25 The Traffic Impact Assessment report demonstrates the development does not compromise the safety of users of the SCR
PO26 Development ensures no net worsening of the operating performance of the state-controlled road network.	No acceptable outcome is prescribed.	Achieves PO26 The Traffic Impact Assessment report demonstrates the development ensures no net worsening of the operating performance of the SCR network.
PO27 Traffic movements are not directed onto a state-controlled road where they can be accommodated on the local road network.	No acceptable outcome is prescribed.	Achieves PO27 Traffic can only utilise the SCR (Gladstone-Mount Larcom Road) to access the wider road network. This access is via the local road network being Euroa Circuit and Aldoga Road.
PO28 Development involving haulage exceeding 10,000 tonnes per year does not adversely impact the pavement of a state-controlled road .	No acceptable outcome is prescribed.	Not Applicable. The project proposes to haul a maximum of 6500 tonnes per year of H2 when in operation, thus does not exceed 10,000 tonnes per year.
PO29 Development does not impede delivery of planned upgrades of state-controlled roads .	No acceptable outcome is prescribed.	Refer to Traffic Impact Assessment for response to this item
PO30 Development does not impede delivery of corridor improvements located entirely within the state-controlled road corridor .	No acceptable outcome is prescribed.	Refer to Traffic Impact Assessment for response to this item

Table 1.4 Filling, excavation, building foundations and retaining structures

Performance outcomes	Acceptable outcomes	Response
		Not Applicable The proposed development does not propose and any works or structures in or near the SCR.

Table 1.5 Environmental emissions

State Development Assessment Provisions v3.2

State code 1: Development in a state-controlled road environment

Statutory note: Where a **state-controlled road** is co-located in the same transport corridor as a railway, the development should instead comply with Environmental emissions in State code 2: Development in a railway environment.

Performance outcomes	Acceptable outcomes	Response
		Not Applicable. The proposed development is not located near a SCR and is not use requiring mitigating environmental emissions from the SCR.

Table 1.6: Development in a future state-controlled road environment

Performance outcomes	Acceptable outcomes	Response
		Not Applicable The site is not in or near any future SCR

Appendix H Traffic Impact Assessment

EUROA HYDROGEN PROJECT

Euroa Circuit, Aldoga, QLD 4694

Traffic Impact Assessment

For Vena Energy Services (Australia) Pty Ltd



ENGINEERS
MANAGERS
SCIENTISTS

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ENGINEER – TRAFFIC & TRANSPORT

1 Introduction

Lambert & Rehbein (SEQ) Pty Ltd has been commissioned by Vena Energy Services (Australia) Pty Ltd to prepare a Traffic Impact Assessment (TIA) for a proposed hydrogen facility located at Euroa Circuit, Aldoga QLD 4694. The development site extends over three (3) lots formally described as Lot 1, 2 and 3 on SP245955 with a total site area of approximately 26.0ha.

The proposed development involves a hydrogen production facility which seeks to produce compressed hydrogen gas that will be distributed domestically using purpose-built road tube trailers. The proposed site layout, prepared by Vena Energy is included in **Appendix A**.

This report has been prepared to assess the potential impact that the proposed development could have on the external road network surrounding the site, and is set out as follows:

Section 2 discusses the existing land use and traffic arrangements in the vicinity of the proposed development site.

Section 3 provides details of the proposed development, including an assessment of the site layout, access, car parking and servicing arrangements.

Section 4 displays the calculations and assumptions used to establish the forecast generation of the proposed development traffic.

Section 5 summarises the key outcomes of the traffic investigations.

Lambert & Rehbein has derived the data in this report primarily from the data provided by the Client, and a desktop site investigation.

This report has been prepared on behalf of and for the exclusive use of the Client, and is subject to and issued in connection with the provisions of the agreement between Lambert & Rehbein and the Client. Lambert & Rehbein accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report by any third party.

2 Context of the Development Site

This section of the report describes the context of the proposed development and includes a description of the existing road network, adjacent land uses, and existing active and public transport facilities servicing the site.

2.1 Development Site

The proposed development is located at Euroa Circuit, Aldoga QLD 4694. The development site extends over three (3) lots formally described as Lot 1, 2 and 3 on SP245955 with a total site area of approximately 26.0ha.

The development site is currently located within the Gladstone State Development Area (GSDA) which is the primary land use planning framework for the area. The subject site is situated within the 'High Impact Industry Precinct'. The site is generally surrounded by land use zoning of similar nature with the 'Materials Transportation and Services Corridor Precinct' located to the east and the 'Medium Impact Industry Precinct' located southeast of the subject site.

The development site in context of the surrounding land use zoning precincts is shown in **Figure 2-1**.

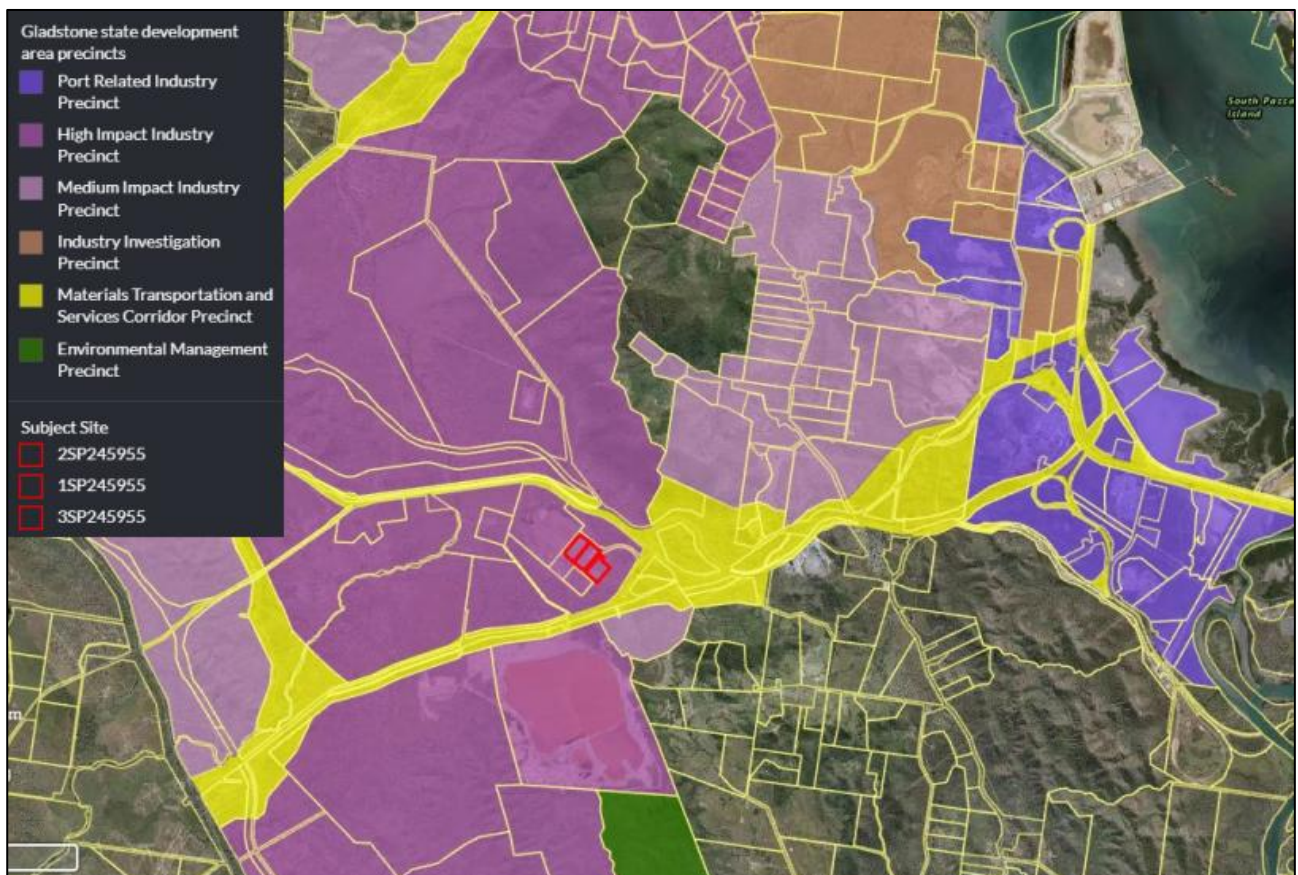


Figure 2-1 GSDA Development Scheme Precincts Map

2.2 Adjacent Road Network

Investigation of the land use, road condition, intersection characteristics, public transport facilities, pedestrian access, and cyclist provisions surrounding the proposed development site have been undertaken in preparation of this traffic assessment. This was completed to collect information about the road network operation, safety characteristics, public transport network and specific network / land-use factors potentially of influence on the proposed development.

2.2.1 Euroa Circuit

The proposed development site gains access to the broader state-controlled road (SCR) via Euroa Circuit. The general form of Euroa Circuit at the site frontage is shown in **Figure 2-2** and was observed to have the following characteristics:

- Two-way, two lane undivided road;
- Pavement width of approximately 18m including 6m wide gravel shoulders on both sides of the road;
- No kerb and channel provided;
- No parking provisions available;
- No dedicated cycle lanes or footpaths provided on either side of the road; and
- Posted speed limit of 60km/hr.

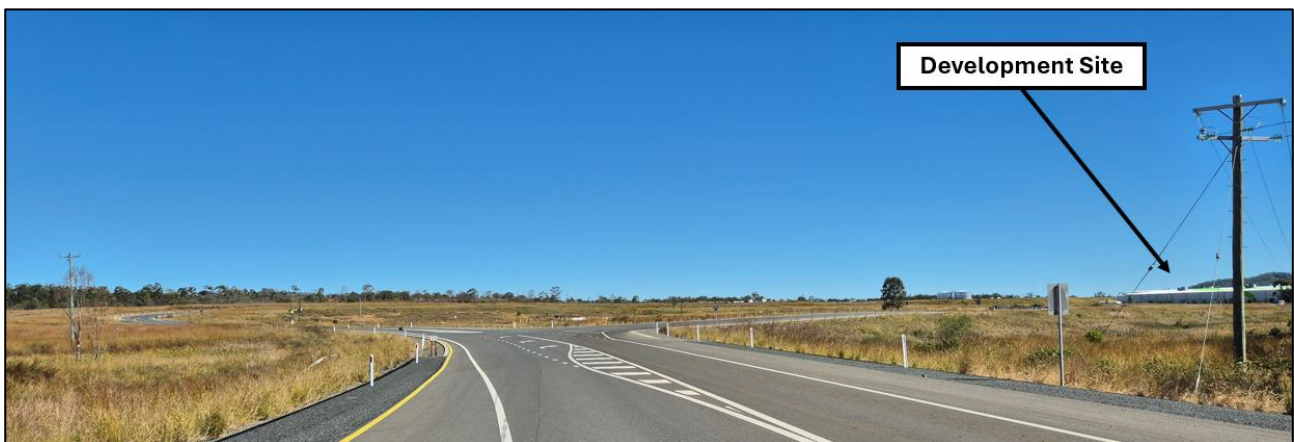


Figure 2-2 Euroa Circuit- Facing Southwest (Site Visit, June 2025)

2.2.2 Aldoga Road

Aldoga Road is a Council controlled road (Gladstone Regional Council (GRC) and intersects with Euroa Circuit in the form of a priority-controlled intersection. The general form of Aldoga Road is shown in **Figure 2-3** and was found to have the following characteristics at the site frontage:

- Two lane, two-way road;
- Pavement width of approximately 12m;
- No kerb and channel provided on either side of the road;
- No parking provisions available;
- No dedicated cycle lanes or footpaths provided; and
- Posted speed limit of 60km/hr.

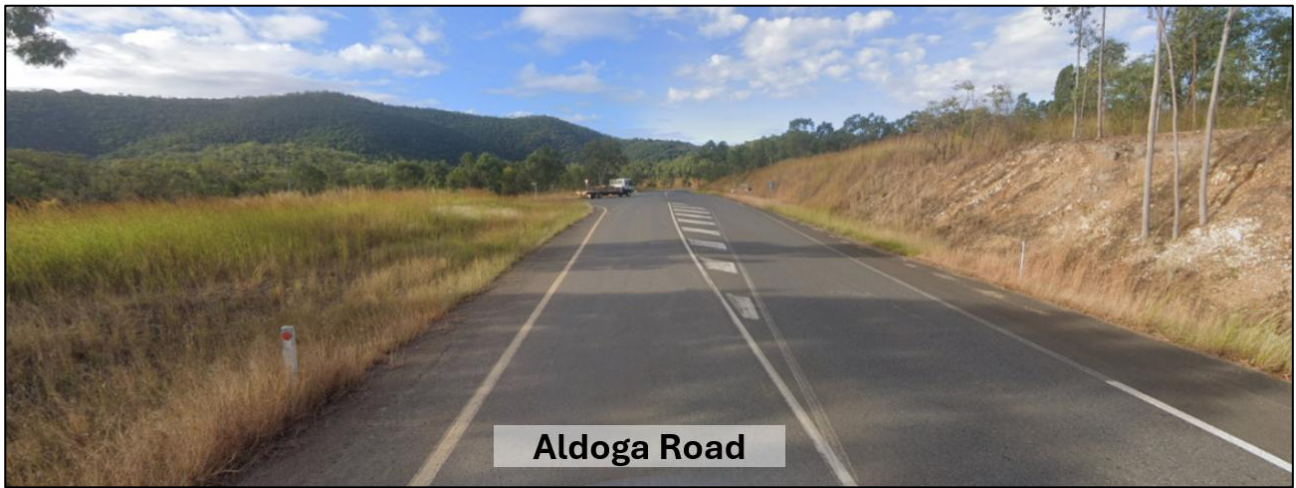


Figure 2-3 Aldoga Road- Facing North (Google, May 2025)

2.2.3 Gladstone-Mt Larcom Road

Gladstone-Mt Larcom Road is a SCR providing connectivity between Gladstone (East) to Mount Larcom and the Bruce Highway (west) and is a gazetted 26m B-Double Route. The general form of Gladstone-Mt Larcom Road is shown in **Figure 2-4** and was found to have the following characteristics at the site frontage:

- Two lane, two-way road;
- Pavement width of approximately 8m;
- No kerb and channel provided on either side of the road;
- No parking provisions available;
- No dedicated cycle lanes or footpaths provided; and
- Posted speed limit of 100km/hr.



Figure 2-4 Gladstone-Mount Larcom Road- Facing Southeast (Google, May 2025)

2.3 Future Infrastructure Upgrades

The following resources were reviewed to determine if there are any future transport infrastructure upgrades within close proximity of the development site:

- GRC's Local Government Infrastructure Plan (LGIP);
- Queensland Transport and Roads Investment Program (QTRIP); and
- Queensland Government's Development Assessment Mapping System (DAMS).

A review of these resources found no future transport infrastructure upgrades within close proximity (500m) of the development site.

3 Details of the Proposed Development

3.1 Proposed Development

The proposed development involves an integrated hydrogen production facility including onsite storage and distribution domestically via purpose-built road tube trailers. The proposed site layout, prepared by Vena Energy is included in **Appendix A**.

The proposed facility is expected to operate across 24 hours a day and 7 days a week. The proposed tube trailer filling station will comprise of four (4) filling stations which can fit two (2) truck and trailer combinations in each bay simultaneously although the preference is for only one (1) bay to be filled at a time. The site is expected to service up to 17.3 trucks per day with each truck having a capacity of 1 tonne, as per detailed provided by the client. It has been estimated that it may take up to 5.45 hours for semitrailers to enter and leave the site to allow for setting up and filling.

3.2 Access Arrangements

The proposed hydrogen facility will gain access to the external road network via separate access locations on Euroa Circuit as highlighted in **Figure 3-1**. These have been strategically designed to enhance operational efficiency and safety of the overall site.

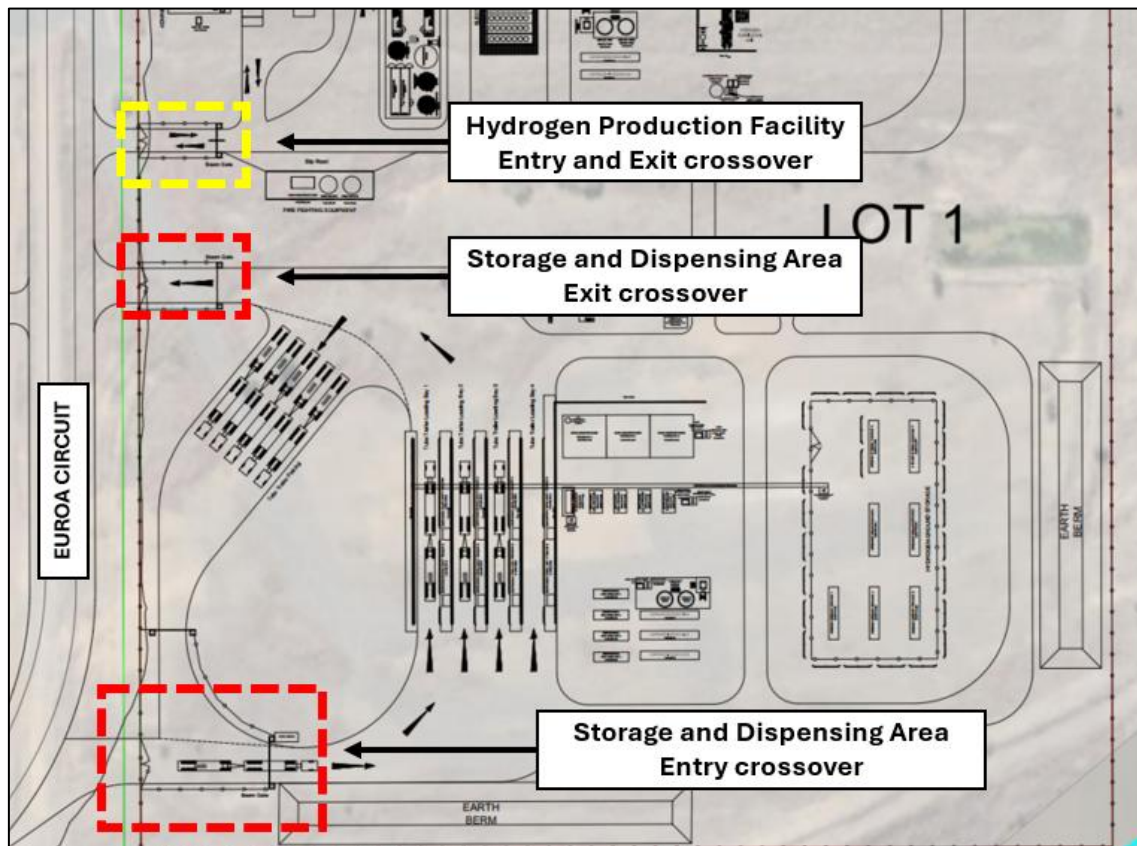


Figure 3-1 Access Arrangements

The site layout has been designed to segregate heavy vehicle movements comprising of truck and trailers from light vehicle traffic used by staff and occasional maintenance contractors.

The storage and dispensing area features separate truck entry and exit crossovers (highlighted red in **Figure 3-1**) to enable safe movements of trucks through the site.

North of the truck exit crossover, a single entry/exit crossover on Euroa Circuit (highlighted yellow in **Figure 3-1**) will serve the hydrogen production area, facilitating truck movements for the disposal of wastewater and light vehicle movements such as staff vehicles and maintenance vehicles.

Within the site, the internal road network is designed as a loop configuration, ensuring all vehicles can enter and exit in a forward gear. The accesses will be designed to meet heavy duty crossover requirements during the detailed design phase, as per GRC's planning scheme and AS2890.1.

3.3 Car Parking

The proposed development seeks to provide a total of 30 onsite car parking spaces which we believe will be sufficient to cater for employees, contractors and visitors to the site. The main parking module comprising of 27 spaces, will be conveniently located near the front entry of the site adjacent to the administration building. This layout minimises interaction between light and heavy vehicles movements further into the site. The remaining three (3) parking spaces will be located at the rear of the workshop. In addition, separate angled parking bays for heavy vehicle trailers will be provided. Dedicated heavy vehicle loading bays will also be provided on site which are located east of the trailer parking bays.

The proposed carpark layout has also been designed generally in accordance with GRC's requirements and AS2890.1. We note that the loading and trailer parking bays will be designed to accommodate longer heavy vehicles in the event that operators are able to obtain relevant access permits to the site.

3.4 Servicing Arrangements

The proposed development will be serviced by as-of-right prime mover and semitrailer combinations up to 20m in length which will enter and exit the site via Euroa Circuit. However, as outlined in **Section 3.3**, all heavy vehicle loading and trailer parking bays have been designed to accommodate longer heavy vehicles with additional trailers. We note that access to the site for longer heavy vehicles will be subject to specific permits from relevant authorities (DTMR, GRC and the National Heavy Vehicle Regulator). These vehicles include A-doubles, which are longer heavy vehicles up to 36.5m in length that have two (2) semitrailers.

All vehicles will approach the site from the northwest via Gladstone- Mt Larcom Road, turning right into Aldoga Road and then right again onto Euroa Circuit to access the facility.

A swept path assessment demonstrating circulation and manoeuvrability of semitrailer combinations within the site is provided in **Appendix B**.

4 Traffic Impact Assessment

This section of the report provides details of the potential impact that the development generated traffic volumes could have on the operation of the surrounding road network.

4.1 Background Traffic

Vehicle Movement survey data was collected on Thursday the 17th of July 2025 at the following intersections:

- Euroa Circuit intersection;
- Aldoga Road / Euroa Circuit intersection; and
- Gladstone-Mount Larcom Road / Aldoga Road intersection.

The intersection count data was collected and presented in 15-minute peak periods to capture peak periods. The intersection peak hours for the main Gladstone-Mount Larcom Road intersection were adopted for the analysis as follows:

- AM Peak: 8:30AM to 9:30AM; and
- PM Peak: 2:45PM to 3:45PM.

A summary of the traffic survey data is displayed in **Figure C1**, attached in **Appendix C**.

For the purposes of assessment, the opening year for the proposed development has been assumed to be 2027. To assess the future background traffic, a linear growth rate of 1% has been applied to all movements at all three intersections.

The predicted background traffic in the opening year (2027) has been presented in **Figure C2**, attached in **Appendix C**.

4.2 Construction Traffic

Construction traffic is envisaged to comprise of a peak workforce of 50-80 workers (possibly for a period of 3-5 months). This traffic will largely comprise of private vehicles from a local workforce travelling to and from the Gladstone Region.

Therefore, we have adopted a worst-case scenario of 80 workers assuming 40 peak hour trips in and 40 peak hour trips out for the purposes of analysis.

Occasionally, it is expected that heavy vehicles will be utilised to transport various components into the site and deliver materials or machinery such as cranes and excavators however this has been excluded from the analysis. Some components of the facility will be shipped from overseas and will be transported by road from the Gladstone general cargo berth to the development site. Based on a review of recent traffic impact assessments undertaken for similar development along Euroa Circuit, it was found that the existing local road network will be able to adequately cater for the proposed oversized vehicles during this phase, noting specific permits from authorities may be required for these movements.

4.3 Operational Traffic

Operational traffic will consist largely of daily trucks/trailer movements required to distribute hydrogen gas from the hydrogen storage and dispensing area. The following parameters have been used to estimate traffic:

- Approx. 17 tonnes of H₂ will be produced per day;
- Each prime mover and semitrailer combination (1 tube trailer) has a 1 tonne capacity;
- Fuelling period per tube trailer is 5.45 hours;
- 4 x fuelling bays; and
- Up to 8 trucks filled in each bay per day.

Based on these parameters, it is calculated that in a 24-hour period, approximately 17 tube trailers/trucks will need to be filled to distribute the full daily hydrogen output.

There is provision for 30 parking spaces, and it is estimated that a maximum of 20 staff will be onsite during peak periods. Assuming the peak hour will coincide with the shift change over, it is estimated that 20 vehicles will arrive at shift change while another 20 will depart at change over.

Given it takes 5.45 hours to load up a single truck, an average of 4 trucks will enter the site on a single day. We have assumed a maximum of 4 HV's enter and then exit the site during the peak hour.

As a worst-case scenario, it is anticipated that the site will generate a maximum of 40 light vehicle trips in addition to eight (8) heavy vehicle trips during the AM and PM peak hours respectively.

Other traffic generated by the development which have not been accounted for within our analysis include:

- Light vehicle movements for 4-6 permanent staff on site at any one time;
- Private contractor vehicle movements associated with onsite maintenance; and
- Truck movements for disposal of wastewater; likely 2-4 trips per month.

4.3.1 Trip Distribution

For the additional traffic splits generated by the proposed development, the following assumptions have been made regarding the state-controlled Gladstone-Mount Larcom / Aldoga Road intersection:

- For traffic leaving the site:
 - 10% turning west onto Gladstone-Mt Larcom Road; and
 - 90% turning east onto Gladstone-Mt Larcom Road.
- For traffic entering the site:
 - 90% approaching from the east along Gladstone-Mt Larcom Road; and
 - 10% approaching from the west along Gladstone-Mt Larcom Road.

4.4 SIDRA Intersection Assessment

SIDRA Intersection software has been used to assess the performance of the Gladstone Mt Larcom Road-Aldoga Road intersection. Due to the uncommon configuration of the priority-controlled intersection, a SIDRA network has been created to best represent and model the operation of the intersection. The network consists of two (2) intersections that have been combined to form the network as illustrated in **Figure 4-1**.

For the purposes of the report, these intersections are referred to and reported to separately as the following:

- Gladstone Mt Larcom Road – Aldoga Road (North);
- Gladstone Mt Larcom Road -Aldoga Road (South);

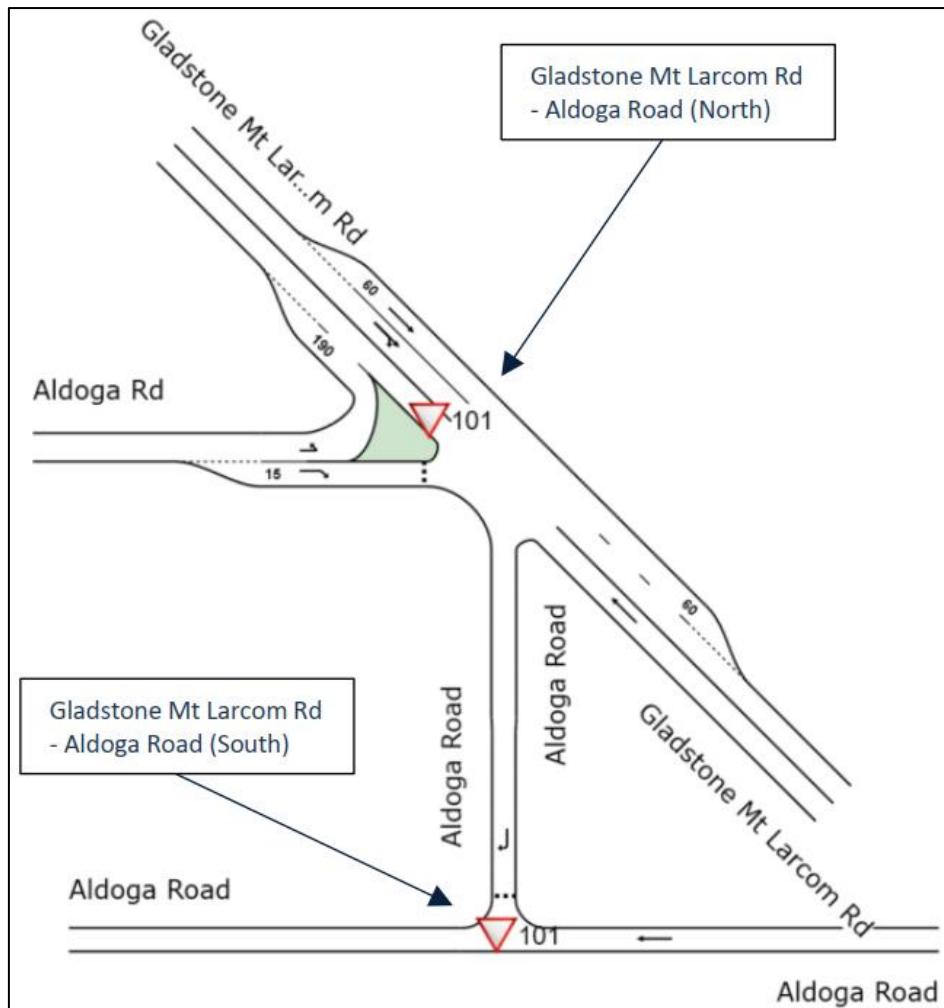


Figure 4-1 Gladstone Mt Larcom Road / Aldoga Road intersection SIDRA Network configuration

4.4.1 SIDRA Model Assumptions

The following parameters have been applied to the SIDRA models:

- A Saturation Flow of 1,950 through car units per hour;
- A Peak Flow Period of 30 minutes, with a conservative Peak Flow Factor of 95%;
- Intersection geometry based on measurements of aerial imagery; and
- Gap acceptance parameters based on default SIDRA values.

4.4.2 Analysis Scenarios

Based on DTMR's *Guide to Traffic Impact Assessment (GTIA)*, Table 6.5 outlines that access intersections should be assessed for the year of opening, and for a 10-year design horizon. As such, the following assessment scenarios have been considered:

- 2025 Background Traffic;
- 2027 Background Traffic;
- 2025 Background + **Construction** Traffic; and
- 2027 Background + **Operational** Traffic;

4.4.3 Intersection Analysis Results

The results of the SIDRA assessment are provided in **Table 4-1** with detailed SIDRA outputs attached in **Appendix D**.

Table 4-1 SIDRA Outputs- Gladstone Mt Larcom Road / Aldoga Road Intersection 2025 Background

Scenario	Approach	AM Peak				PM Peak			
		DoS	Avg Delay (s)	LoS	95% Back of Queue (m)	DoS	Avg Delay (s)	LoS	95% Back of Queue (m)
2025 Background Traffic	Gladstone Mt Larcom Road / Aldoga Road Intersection (North)								
	SE: Gladstone Mt Larcom Rd	0.08	0	NA	0	0.084	0	NA	0
	NW: Gladstone Mt Larcom Rd	0.068	0.2	NA	0.3	0.071	0.1	NA	0.1
	W: Aldoga Road	0.066	8.6	A	2.2	0.039	8.3	A	1.2
	Gladstone Mt Larcom Road / Aldoga Road Intersection (South)								
	E: Aldoga Road	0.008	0	A	0	0.007	0	A	0
	N: Aldoga Road	0.003	6.6	A	0.1	0.001	7	A	0

Table 4-2 SIDRA Outputs- Gladstone Mt Larcom Road / Aldoga Road Intersection 2027 Background

Scenario	Approach	AM Peak				PM Peak			
		DoS	Avg Delay (s)	LoS	95% Back of Queue (m)	DoS	Avg Delay (s)	LoS	95% Back of Queue (m)
2027 Background Traffic	Gladstone Mt Larcom Road / Aldoga Road Intersection (North)								
	SE: Gladstone Mt Larcom Rd	0.082	0	NA	0	0.086	0	NA	0
	NW: Gladstone Mt Larcom Rd	0.071	0.3	NA	0.4	0.074	0.2	NA	0.2
	W: Aldoga Road	0.069	8.8	A	2.4	0.043	8.6	A	1.3
	Gladstone Mt Larcom Road / Aldoga Road Intersection (South)								
	E: Aldoga Road	0.009	0	NA	0	0.008	0	NA	0
	N: Aldoga Road	0.004	6.7	A	0.1	0.002	7.1	A	0.1

Table 4-3 SIDRA Outputs- Gladstone Mt Larcom Road / Aldoga Road Intersection 2025 BG + Construction Traffic

Scenario	Approach	AM Peak				PM Peak			
		DoS	Avg Delay (s)	LoS	95% Back of Queue (m)	DoS	Avg Delay (s)	LoS	95% Back of Queue (m)
2025 Background + Construction Traffic	Gladstone Mt Larcom Road / Aldoga Road Intersection (North)								
	SE: Gladstone Mt Larcom Rd	0.073	0	NA	0	0.079	0	NA	0
	NW: Gladstone Mt Larcom Rd	0.064	0.3	NA	0.4	0.067	0.3	NA	0.3
	W: Aldoga Road	0.103	7	A	2.9	0.088	7.2	A	2.4
	Gladstone Mt Larcom Road / Aldoga Road Intersection (South)								
	E: Aldoga Road	0.027	0	NA	0	0.025	0	NA	0
	N: Aldoga Road	0.006	6	A	0.1	0.004	6.1	A	0.1

Table 4-4 SIDRA Outputs- Gladstone Mt Larcom Road / Aldoga Road Intersection 2027 BG + Operational Traffic

Scenario	Approach	AM Peak				PM Peak			
		DoS	Avg Delay (s)	LoS	95% Back of Queue (m)	DoS	Avg Delay (s)	LoS	95% Back of Queue (m)
2027 Background + Operational Traffic	Gladstone Mt Larcom Road / Aldoga Road Intersection (North)								
	SE: Gladstone Mt Larcom Rd	0.076	0	NA	0	0.083	0	NA	0
	NW: Gladstone Mt Larcom Rd	0.065	0.3	NA	0.3	0.068	0.2	NA	0.2
	W: Aldoga Road	0.064	7.9	A	2	0.064	7.4	A	1.8
	Gladstone Mt Larcom Road / Aldoga Road Intersection (South)								
	E: Aldoga Road	0.018	0	NA	0	0.016	0	NA	0
	N: Aldoga Road	0.005	6	A	0.1	0.003	6.1	A	0.1

As illustrated in **Table 4-3** and **Table 4-4**, in all design scenarios, the Gladstone Mt-Larcom Road / Aldoga Road intersection will theoretically operate well below the practical capacity ($DoS \leq 0.80$) for a priority-controlled intersection in both peak periods, with very minor increases in delay and queue lengths as a result of the construction and operational traffic.

5 Summary

Lambert & Rehbein (SEQ) Pty Ltd has been commissioned by Vena Energy Services (Australia) Pty Ltd to prepare a Traffic Impact Assessment (TIA) for a proposed hydrogen facility located at Euroa Circuit, Aldoga QLD 4694. The development site extends over three (3) lots formally described as Lot 1, 2 and 3 on SP245955 with a total site area of approximately 26.0ha.

The proposed development involves a hydrogen production facility which seeks to produce compressed hydrogen gas that will be distributed domestically using purpose-built road tube trailers. The proposed site layout, prepared by Vena Energy is included in **Appendix A**.

The proposed facility is expected to operate across 24 hours a day and 7 days a week. The proposed tube trailer filling station will comprise of four (4) filling stations which can fit two (2) truck and trailer combinations in each bay simultaneously although the preference is for only one (1) bay to be filled at a time. The site is expected to service up to 17.3 trucks per day with each truck having a capacity of 1 tonne. It has been estimated that it may take up to 5.45 hours for semitrailers to enter and leave the site to allow for setting up and filling.

The site layout has been designed to segregate heavy vehicle movements comprising of truck and trailers from light vehicle traffic used by staff and occasional maintenance contractors. The storage and dispensing area features separate truck entry and exit crossovers to enable safe movements of trucks through the site.

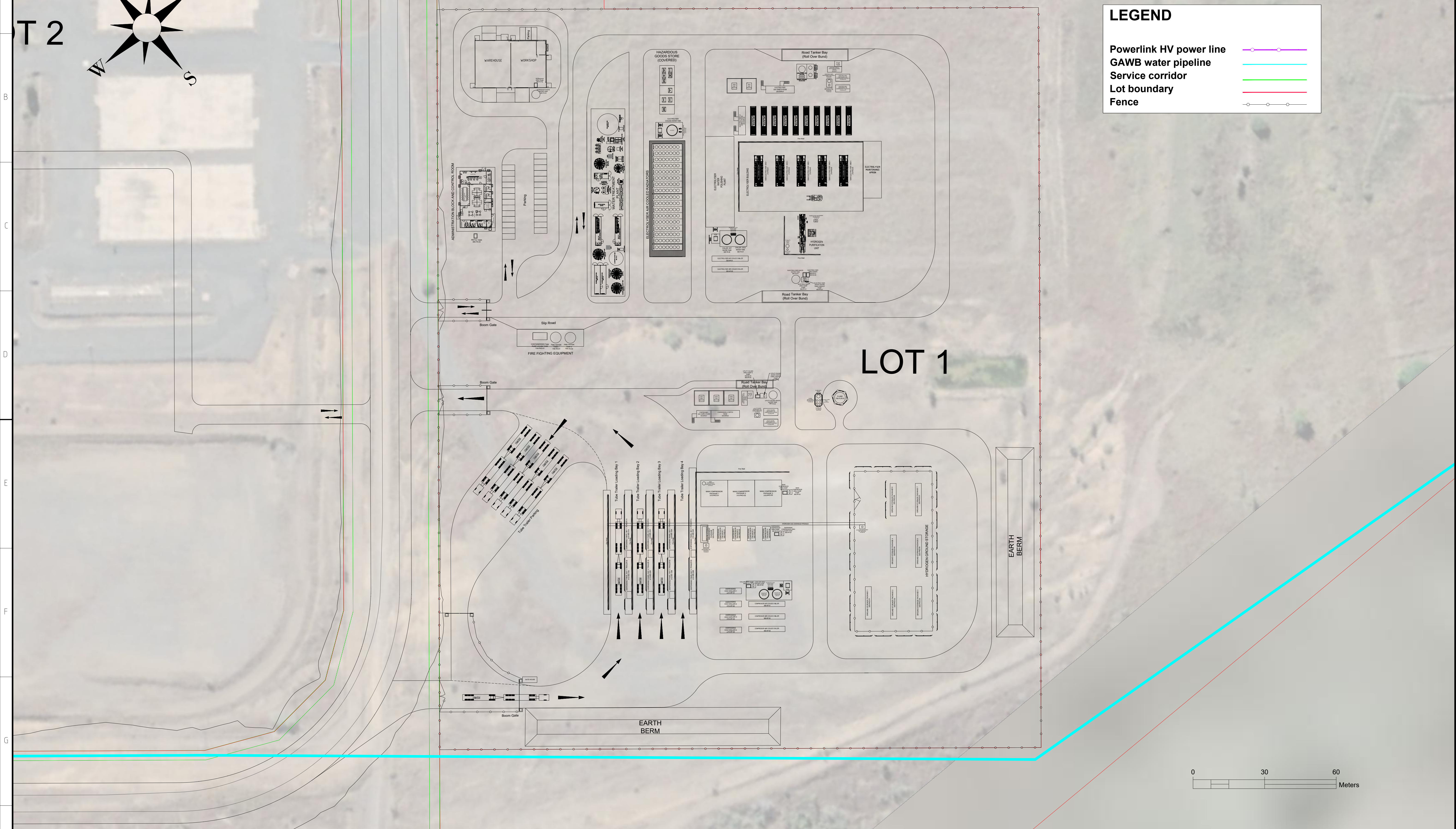
North of the truck exit crossover, a single entry/exit crossover on Euroa Circuit will serve the hydrogen production area, facilitating truck movements for the disposal of wastewater and light vehicle movements such as staff vehicles and maintenance vehicles. Within the site, the internal road network is designed as a loop configuration, ensuring all vehicles can enter and exit in a forward gear.

Construction traffic is envisaged to comprise of a peak workforce of 50-80 workers (possibly for a period of 3-5 months). This traffic will largely comprise of private vehicles from a local workforce travelling from in and around the Gladstone Region. Therefore, we have adopted a worst-case scenario of 80 workers assuming 40 peak hour trips in and 40 peak hour trips out for the purposes of analysis.

There is provision for 30 parking spaces, and it is estimated that a maximum of 20 staff will be onsite during peak periods. Assuming the peak hour will coincide with the shift change over, it is estimated that 20 vehicles will arrive at shift change while another 20 will depart at change over. Given it takes 5.45 hours to load up a single truck, an average of 4 trucks will enter the site on a single day. We have assumed a maximum of 4 HV's enter and then exit the site during the peak hour. As a worst-case scenario, it is anticipated that the site will generate a maximum of 40 light vehicle trips in addition to eight (8) heavy vehicle trips during the AM and PM peak hours respectively.

The SIDRA intersection analysis concluded that in all design scenarios, the Gladstone Mt-Larcom Road / Alodga Road intersection will theoretically operate well below the practical capacity ($DoS \leq 0.80$) for a priority-controlled intersection in both peak periods, with very minor increases in delay and queue lengths as a result of the construction and operational traffic.

Appendix A – Site Layout



LEGEND

Powerlink HV power line

GAWB water pipeline

Service corridor

Lot boundary

Fence

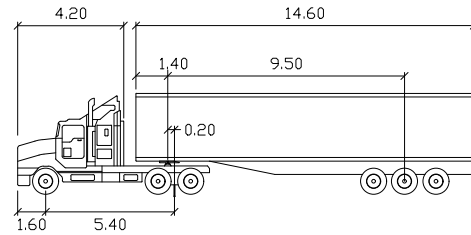
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[illegible]

DOCUMENT STATUS UNLESS THIS DOCUMENT BEARS A RED STAMP IT IS UNCONTROLLED AND MAY NOT BE THE LATEST ISSUE THEREFORE VERIFY STATUS BEFORE USE

	DESIGNED	BW	VENA ENERGY HYDROGEN PROJECT HYDROGEN PRODUCTION PLANT STAGE 1: FEED STUDY 50MW ELECTROLYZER HYDROGEN PLANT GENERAL ARRANGEMENT			
	CHECKED	IM				
	DRAWN	BW				
	CHECKED	SHB				
	APPROVED	SHB				
A1	NTS		CLIENT	UGL DRAWING No.	SHEET	REV
			VENA ENERGY	17695-SITF-GA-1002-01	01	1

Appendix B – Swept Path Assessment



AV

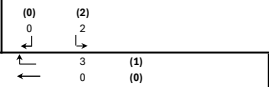
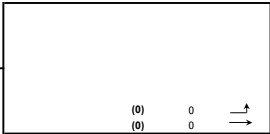
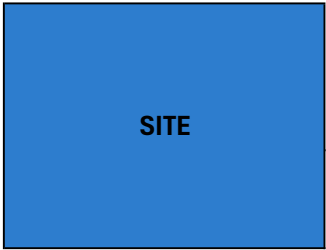
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Tractor Width	4.20			
Trailer Width		14.60		
Tractor Track	1.60		5.40	
Trailer Track				9.50

NOTE:
SCALE IS BASED ON SUPPLIED SITE LAYOUT PDF – REFER TO THE SCALE BAR SHOWN FOR REFERENCE

CONCEPT ONLY
14 October 2025

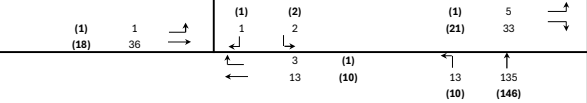
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									Scale: AS SHOWN	A1
	File Ref: SEE BELOW								Sheet Size	
	Drawn: MDB	Checked: MB							Approved: MB	Rev.

Appendix C – Traffic Movement Diagrams



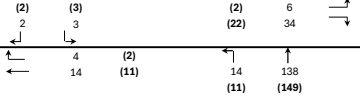
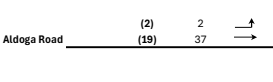
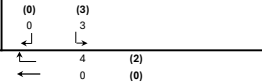
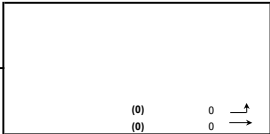
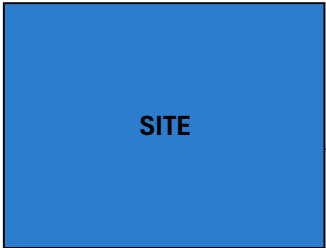
Euroa Court

Aldoga Road



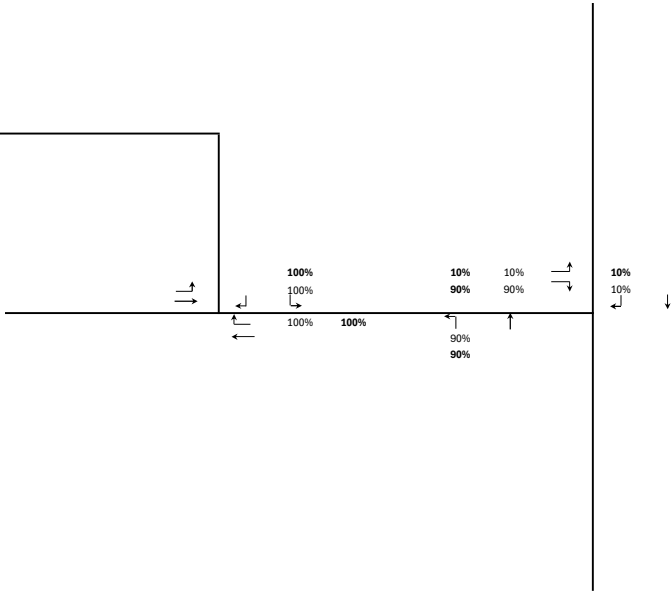
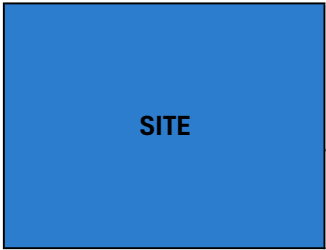
Gladstone Mount Larcom Road

Project Number:	B25169	Title: Background Traffic - All Vehicles 2025	Figure Number: C 1	
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Address:	Euroa Circuit, Aldoga			
Client:	Vena Energy Services (Australia) Pty Ltd			
Prepared: LM Approved: Rev. Date:				

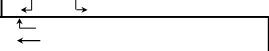
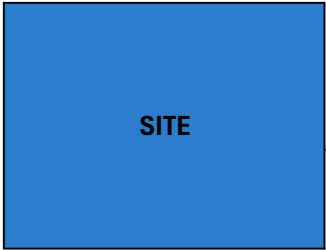


GROWTH
1%

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Client:	Vena Energy Services (Australia) Pty Ltd					
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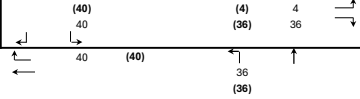


	825189	Trip Distribution				
	Proposed Development					
	Euroa Circuit, Aldoga					
	Vena Energy Services (Australia) Pty Ltd					
Prepared:	LM	Approved:		Rev:	31/07/2025	
				Date:		
						C 3



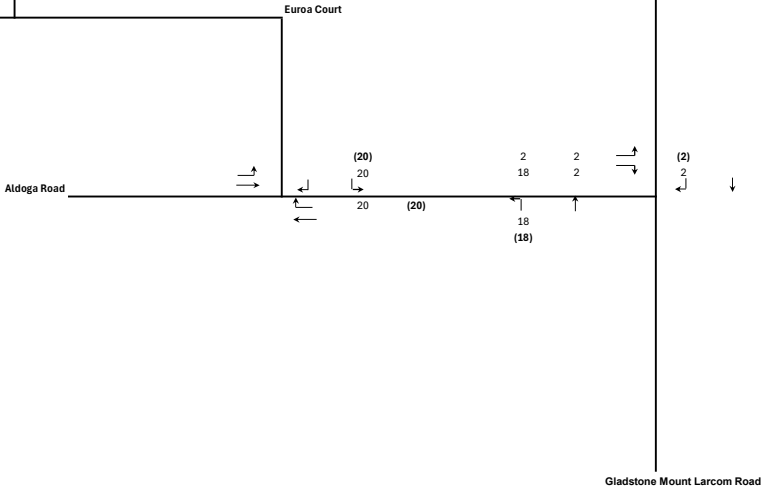
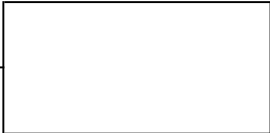
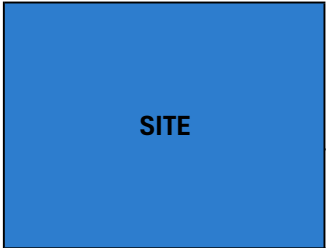
Euroa Court

Aldoga Road

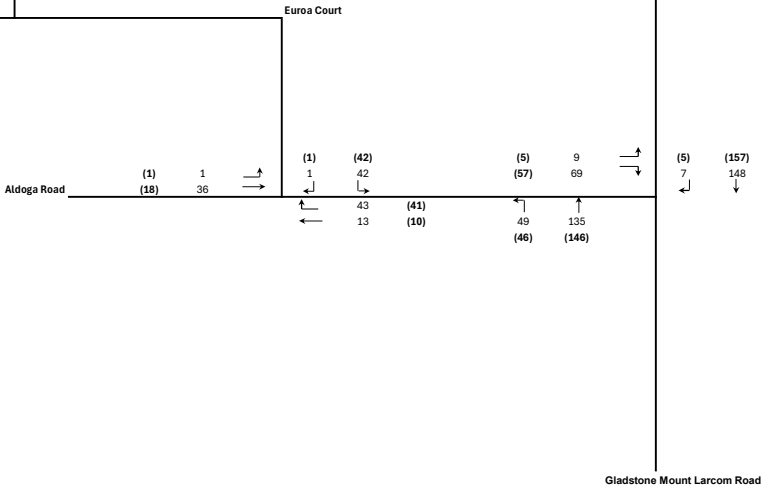
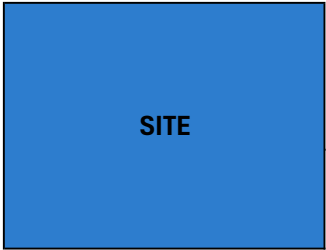


Gladstone Mount Larcom Road

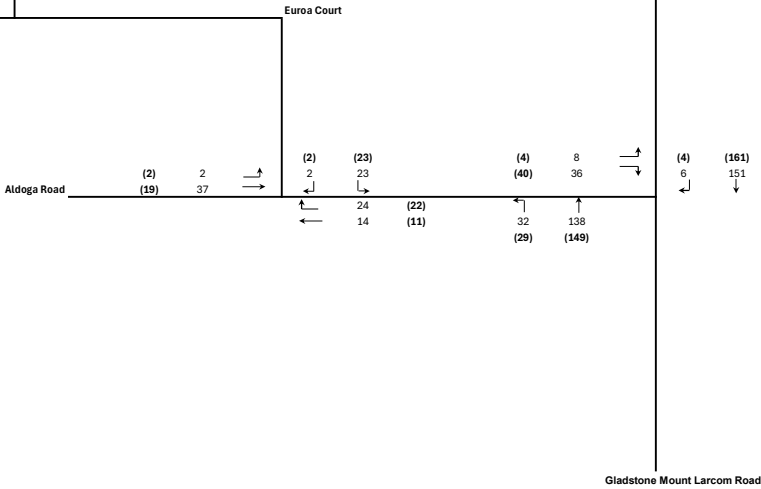
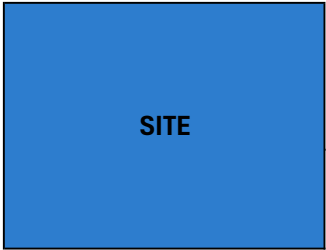
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Client:	Vena Energy Services (Australia) Pty Ltd							
			Prepared:	LM	Approved:	Rev:	Date:	



Project Number:	B25169	Title: Operational Traffic- Trips			A 31/07/2025		Figure Number:	
Project Name:	Proposed Development						C 5	
Address:	Euroa Circuit, Aldoga							
Client:	Vena Energy Services (Australia) Pty Ltd							
Prepared: LM		Approved:	Rev:		Date:			



Project Number:	B25169	Title: Background + Construction Traffic 2025			A 31/07/2025		Figure Number:	
Project Name:	Proposed Development						C 6	
Address:	Euroa Circuit, Aldoga							
Client:	Vena Energy Services (Australia) Pty Ltd							
			Prepared:	LM	Approved:	Rev:	Date:	



Project Number:	B25169	Title: Background + Operational Traffic 2027					Figure Number:	
Project Name:	Proposed Development						C 7	
Address:	Euroa Circuit, Aldoga		A 31/07/2025					
Client:	Vena Energy Services (Australia) Pty Ltd		Prepared: LM	Approved:	Rev:	Date:		

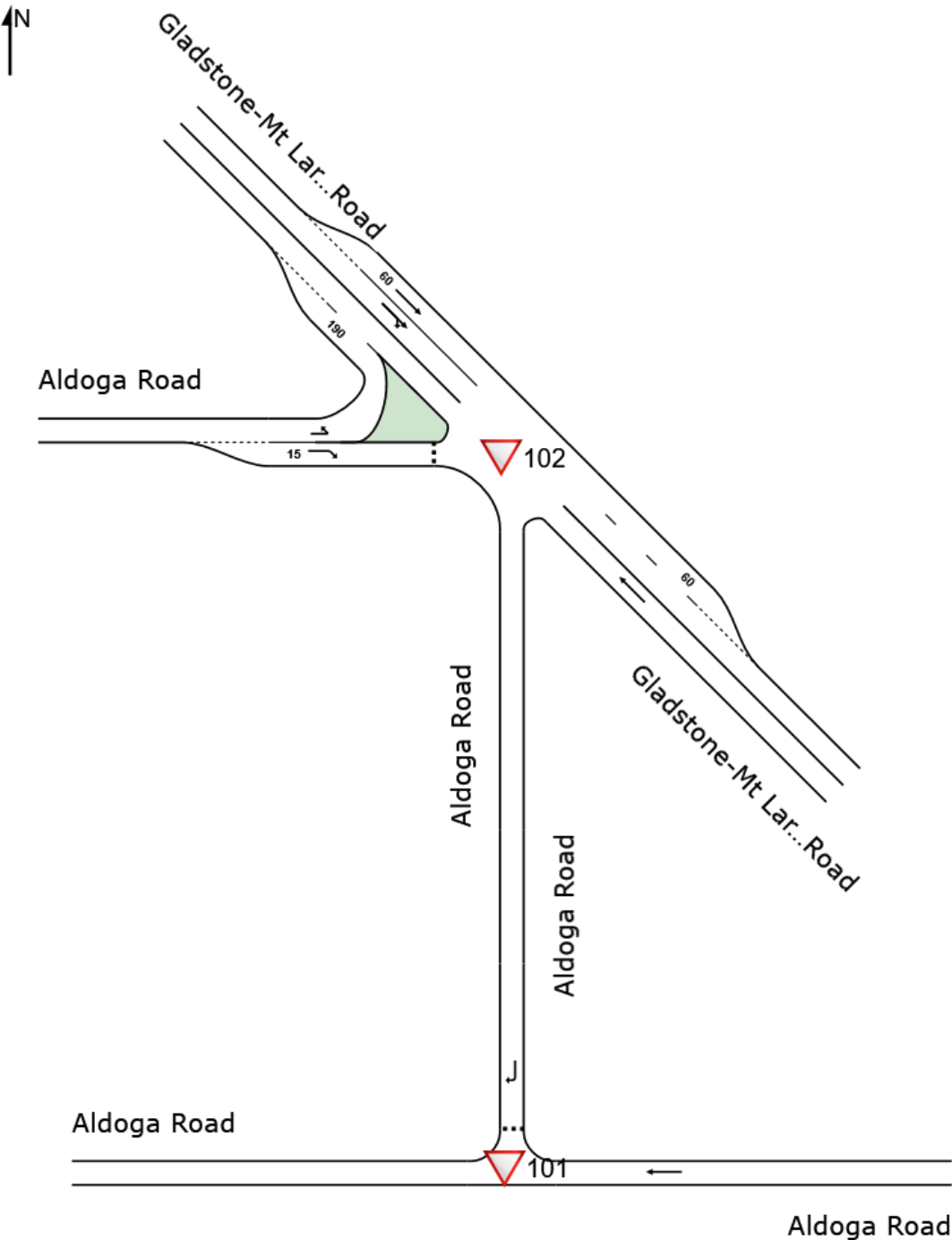
Appendix D – SIDRA Results

NETWORK LAYOUT

■ Network: N101 [Gladstone-Mt Larcom Road-Aldoga Road
2025 BG AM Peak (Network Folder: 2025 BG)]

New Network
Network Category: (None)

Layout pictures are schematic functional drawings reflecting input data. They are not design drawings.



SITES IN NETWORK		
Site ID	CCG ID	Site Name
▽102	NA	Gladstone-Mt Larcom Road-Aldoga Road (North) 2025 BG AM Peak
▽101	NA	Gladstone-Mt Larcom Road-Aldoga Road (South) 2025 BG AM Peak

MOVEMENT SUMMARY

▼ Site: 101 [Gladstone-Mt Larcom Road-Aldoga Road (South)
2025 BG AM Peak (Site Folder: 2025 BG)]

Output produced by SIDRA INTERSECTION Version: 9.1.6.228

■ Network: N101 [Gladstone-Mt Larcom Road-Aldoga Road
2025 BG AM Peak (Network Folder: 2025 BG)]

New Site
Site Category: (None)
Give-Way (Two-Way)

Vehicle Movement Performance															
Mov ID	Turn	Mov Class	Demand Flows		Arrival Flows		Deg. Satn	Aver. Delay	Level of Service	95% Back Of Queue		Prop. Que	Eff. Stop Rate	Aver. No. of Cycles	Aver. Speed
			[Total HV]	%	[Total HV]	%				[Veh. veh	Dist] m				
			veh/h		veh/h		v/c	sec							km/h
East: Aldoga Road															
5	T1	All MCs	14	30.8	14	30.8	0.008	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	60.0
Approach			14	30.8	14	30.8	0.008	0.0	NA	0.0	0.0	0.00	0.00	0.00	60.0
North: Aldoga Road															
9	R2	All MCs	3	66.7	3	66.7	0.003	6.6	LOS A	0.0	0.1	0.06	0.60	0.06	49.2
Approach			3	66.7	3	66.7	0.003	6.6	LOS A	0.0	0.1	0.06	0.60	0.06	49.2
All Vehicles			17	37.5	17	37.5	0.008	1.2	NA	0.0	0.1	0.01	0.11	0.01	57.6

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Network Data dialog (Override Site Data tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA (TWSC): Level of Service is not defined for major road approaches or the intersection as a whole for Two-Way Sign Control (HCM LOS rule).

Two-Way Sign Control Capacity Model: SIDRA Standard.

Delay Model: SIDRA Standard (Control Delay: Geometric Delay is included).

Queue Model: SIDRA queue estimation methods are used for Back of Queue and Queue at Start of Gap.

Gap-Acceptance Capacity Formula: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

MOVEMENT SUMMARY

▼ Site: 102 [Gladstone-Mt Larcom Road-Aldoga Road (North)
2025 BG AM Peak (Site Folder: 2025 BG)]

Output produced by SIDRA INTERSECTION Version: 9.1.6.228

■ Network: N101 [Gladstone-Mt Larcom Road-Aldoga Road
2025 BG AM Peak (Network Folder: 2025 BG)]

New Site
Site Category: (None)
Give-Way (Two-Way)

Vehicle Movement Performance															
Mov ID	Turn	Mov Class	Demand Flows		Arrival Flows		Deg. Satn	Aver. Delay	Level of Service	95% Back Of Queue		Prop. Que	Eff. Stop Rate	Aver. No. of Cycles	Aver. Speed
			[Total HV]	[Total HV]	[Total HV]	[Total HV]	v/c	sec		[Veh. veh	Dist]				km/h
			veh/h	%	veh/h	%					m				
SouthEast: Gladstone-Mt Larcom Road															
22	T1	All MCs	142	14.1	142	14.1	0.080	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	60.0
Approach			142	14.1	142	14.1	0.080	0.0	NA	0.0	0.0	0.00	0.00	0.00	60.0
NorthWest: Gladstone-Mt Larcom Road															
28	T1	All MCs	156	15.5	156	15.5	0.068	0.1	LOS A	0.0	0.3	0.02	0.02	0.02	59.9
29a	R1	All MCs	3	66.7	3	66.7	0.068	5.7	LOS A	0.0	0.3	0.02	0.02	0.02	59.7
Approach			159	16.6	159	16.6	0.068	0.2	NA	0.0	0.3	0.02	0.02	0.02	59.9
West: Aldoga Road															
10b	L3	All MCs	5	40.0	5	40.0	0.004	7.6	LOS A	0.0	0.0	0.00	0.55	0.00	51.4
12a	R1	All MCs	35	36.4	35	36.4	0.066	8.8	LOS A	0.2	2.2	0.48	0.66	0.48	49.8
Approach			40	36.8	40	36.8	0.066	8.6	LOS A	0.2	2.2	0.42	0.65	0.42	50.0
All Vehicles			341	17.9	341	17.9	0.080	1.1	NA	0.2	2.2	0.06	0.08	0.06	58.5

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Network Data dialog (Override Site Data tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA (TWSC): Level of Service is not defined for major road approaches or the intersection as a whole for Two-Way Sign Control (HCM LOS rule).

Two-Way Sign Control Capacity Model: SIDRA Standard.

Delay Model: SIDRA Standard (Control Delay: Geometric Delay is included).

Queue Model: SIDRA queue estimation methods are used for Back of Queue and Queue at Start of Gap.

Gap-Acceptance Capacity Formula: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

MOVEMENT SUMMARY

▼ Site: 102 [Gladstone-Mt Larcom Road-Aldoga Road (North)
2027 BG AM Peak (Site Folder: 2027 BG)]

Output produced by SIDRA INTERSECTION Version: 9.1.6.228

■ Network: N101 [Gladstone-Mt Larcom Road-Aldoga Road
2027 BG AM Peak (Network Folder: 2027 BG)]

New Site
Site Category: (None)
Give-Way (Two-Way)

Vehicle Movement Performance															
Mov ID	Turn	Mov Class	Demand Flows		Arrival Flows		Deg. Satn	Aver. Delay	Level of Service	95% Back Of Queue		Prop. Que	Eff. Stop Rate	Aver. No. of Cycles	Aver. Speed
			[Total HV]	%	[Total HV]	%				[Veh. veh	Dist] m				
			veh/h	%	veh/h	%	v/c	sec							km/h
SouthEast: Gladstone-Mt Larcom Road															
22	T1	All MCs	145	14.5	145	14.5	0.082	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	60.0
Approach			145	14.5	145	14.5	0.082	0.0	NA	0.0	0.0	0.00	0.00	0.00	60.0
NorthWest: Gladstone-Mt Larcom Road															
28	T1	All MCs	159	15.9	159	15.9	0.071	0.1	LOS A	0.0	0.4	0.02	0.02	0.02	59.9
29a	R1	All MCs	4	75.0	4	75.0	0.071	6.1	LOS A	0.0	0.4	0.03	0.03	0.03	59.6
Approach			163	17.4	163	17.4	0.071	0.3	NA	0.0	0.4	0.02	0.03	0.02	59.9
West: Aldoga Road															
10b	L3	All MCs	6	50.0	6	50.0	0.005	7.7	LOS A	0.0	0.0	0.00	0.54	0.00	51.1
12a	R1	All MCs	36	38.2	36	38.2	0.069	9.0	LOS A	0.3	2.4	0.49	0.67	0.49	49.6
Approach			42	40.0	42	40.0	0.069	8.8	LOS A	0.3	2.4	0.42	0.65	0.42	49.8
All Vehicles			351	18.9	351	18.9	0.082	1.2	NA	0.3	2.4	0.06	0.09	0.06	58.5

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Network Data dialog (Override Site Data tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA (TWSC): Level of Service is not defined for major road approaches or the intersection as a whole for Two-Way Sign Control (HCM LOS rule).

Two-Way Sign Control Capacity Model: SIDRA Standard.

Delay Model: SIDRA Standard (Control Delay: Geometric Delay is included).

Queue Model: SIDRA queue estimation methods are used for Back of Queue and Queue at Start of Gap.

Gap-Acceptance Capacity Formula: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

MOVEMENT SUMMARY

▼ Site: 101 [Gladstone-Mt Larcom Road-Aldoga Road (South)
2027 BG AM Peak (Site Folder: 2027 BG)]

Output produced by SIDRA INTERSECTION Version: 9.1.6.228

■ Network: N101 [Gladstone-Mt Larcom Road-Aldoga Road
2027 BG AM Peak (Network Folder: 2027 BG)]

New Site
Site Category: (None)
Give-Way (Two-Way)

Vehicle Movement Performance															
Mov ID	Turn	Mov Class	Demand Flows		Arrival Flows		Deg. Satn	Aver. Delay	Level of Service	95% Back Of Queue		Prop. Que	Eff. Stop Rate	Aver. No. of Cycles	Aver. Speed
			[Total HV]	%	[Total HV]	%				[Veh. veh	Dist] m				
			veh/h		veh/h		v/c	sec							km/h
East: Aldoga Road															
5	T1	All MCs	15	35.7	15	35.7	0.009	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	60.0
Approach			15	35.7	15	35.7	0.009	0.0	NA	0.0	0.0	0.00	0.00	0.00	60.0
North: Aldoga Road															
9	R2	All MCs	4	75.0	4	75.0	0.004	6.7	LOS A	0.0	0.1	0.07	0.60	0.07	48.9
Approach			4	75.0	4	75.0	0.004	6.7	LOS A	0.0	0.1	0.07	0.60	0.07	48.9
All Vehicles			19	44.4	19	44.4	0.009	1.5	NA	0.0	0.1	0.01	0.13	0.01	57.1

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Network Data dialog (Override Site Data tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA (TWSC): Level of Service is not defined for major road approaches or the intersection as a whole for Two-Way Sign Control (HCM LOS rule).

Two-Way Sign Control Capacity Model: SIDRA Standard.

Delay Model: SIDRA Standard (Control Delay: Geometric Delay is included).

Queue Model: SIDRA queue estimation methods are used for Back of Queue and Queue at Start of Gap.

Gap-Acceptance Capacity Formula: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

MOVEMENT SUMMARY

▼ Site: 102 [Gladstone-Mt Larcom Road-Aldoga Road (North)
2027 BG PM Peak (Site Folder: 2027 BG)]

Output produced by SIDRA INTERSECTION Version: 9.1.6.228

■ Network: N101 [Gladstone-Mt Larcom Road-Aldoga Road
2027 BG PM Peak (Network Folder: 2027 BG)]

New Site
Site Category: (None)
Give-Way (Two-Way)

Vehicle Movement Performance															
Mov ID	Turn	Mov Class	Demand Flows		Arrival Flows		Deg. Satn	Aver. Delay	Level of Service	95% Back Of Queue		Prop. Que	Eff. Stop Rate	Aver. No. of Cycles	Aver. Speed
			[Total HV]	[Total HV]	[Veh. veh	Dist]									
			veh/h	%	veh/h	%	v/c	sec			m				km/h
SouthEast: Gladstone-Mt Larcom Road															
22	T1	All MCs	157	10.1	157	10.1	0.086	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	60.0
Approach			157	10.1	157	10.1	0.086	0.0	NA	0.0	0.0	0.00	0.00	0.00	60.0
NorthWest: Gladstone-Mt Larcom Road															
28	T1	All MCs	169	17.4	169	17.4	0.074	0.1	LOS A	0.0	0.2	0.01	0.01	0.01	59.9
29a	R1	All MCs	2	100.0	2	100.0	0.074	6.1	LOS A	0.0	0.2	0.02	0.01	0.02	59.6
Approach			172	18.4	172	18.4	0.074	0.2	NA	0.0	0.2	0.01	0.01	0.01	59.9
West: Aldoga Road															
10b	L3	All MCs	2	100.0	2	100.0	0.002	8.4	LOS A	0.0	0.0	0.00	0.51	0.00	48.9
12a	R1	All MCs	23	27.3	23	27.3	0.043	8.6	LOS A	0.2	1.3	0.48	0.65	0.48	50.2
Approach			25	33.3	25	33.3	0.043	8.6	LOS A	0.2	1.3	0.44	0.64	0.44	50.1
All Vehicles			354	15.8	354	15.8	0.086	0.7	NA	0.2	1.3	0.04	0.05	0.04	59.1

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Network Data dialog (Override Site Data tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA (TWSC): Level of Service is not defined for major road approaches or the intersection as a whole for Two-Way Sign Control (HCM LOS rule).

Two-Way Sign Control Capacity Model: SIDRA Standard.

Delay Model: SIDRA Standard (Control Delay: Geometric Delay is included).

Queue Model: SIDRA queue estimation methods are used for Back of Queue and Queue at Start of Gap.

Gap-Acceptance Capacity Formula: SIDRA Standard (Akcelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

MOVEMENT SUMMARY

▼ Site: 101 [Gladstone-Mt Larcom Road-Aldoga Road (South)
2027 BG PM Peak (Site Folder: 2027 BG)]

Output produced by SIDRA INTERSECTION Version: 9.1.6.228

■ Network: N101 [Gladstone-Mt Larcom Road-Aldoga Road
2027 BG PM Peak (Network Folder: 2027 BG)]

New Site
Site Category: (None)
Give-Way (Two-Way)

Vehicle Movement Performance															
Mov ID	Turn	Mov Class	Demand Flows		Arrival Flows		Deg. Satn	Aver. Delay	Level of Service	95% Back Of Queue		Prop. Que	Eff. Stop Rate	Aver. No. of Cycles	Aver. Speed
			[Total HV]	%	[Total HV]	%				[Veh. veh	Dist]				
			veh/h	%	veh/h	%	v/c	sec							km/h
East: Aldoga Road															
5	T1	All MCs	12 54.5		12 54.5		0.008	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	60.0
Approach			12 54.5		12 54.5		0.008	0.0	NA	0.0	0.0	0.00	0.00	0.00	60.0
North: Aldoga Road															
9	R2	All MCs	2 100.0		2 100.0		0.002	7.1	LOS A	0.0	0.1	0.06	0.59	0.06	47.1
Approach			2 100.0		2 100.0		0.002	7.1	LOS A	0.0	0.1	0.06	0.59	0.06	47.1
All Vehicles			14 61.5		14 61.5		0.008	1.1	NA	0.0	0.1	0.01	0.09	0.01	57.6

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Network Data dialog (Override Site Data tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA (TWSC): Level of Service is not defined for major road approaches or the intersection as a whole for Two-Way Sign Control (HCM LOS rule).

Two-Way Sign Control Capacity Model: SIDRA Standard.

Delay Model: SIDRA Standard (Control Delay: Geometric Delay is included).

Queue Model: SIDRA queue estimation methods are used for Back of Queue and Queue at Start of Gap.

Gap-Acceptance Capacity Formula: SIDRA Standard (Akcelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

MOVEMENT SUMMARY

▼ Site: 102 [Gladstone-Mt Larcom Road-Aldoga Road (North)
2025 BG + Cons AM Peak (Site Folder: 2025 BG + Construction)]
Output produced by SIDRA INTERSECTION Version: 9.1.6.228

■ Network: N101 [Gladstone-Mt Larcom Road-Aldoga Road
2025 BG + Construct AM Peak
(Network Folder: 2025 BG + Construction)]

New Site
Site Category: (None)
Give-Way (Two-Way)

Vehicle Movement Performance															
Mov ID	Turn	Mov Class	Demand Flows		Arrival Flows		Deg. Satn	Aver. Delay	Level of Service	95% Back Of Queue		Prop. Que	Eff. Stop Rate	Aver. No. of Cycles	Aver. Speed
			[Total HV]		[Total HV]					[Veh. veh	Dist]				
			veh/h	%	veh/h	%	v/c	sec			m				km/h
SouthEast: Gladstone-Mt Larcom Road															
22	T1	All MCs	142	0.7	142	0.7	0.073	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	60.0
Approach			142	0.7	142	0.7	0.073	0.0	NA	0.0	0.0	0.00	0.00	0.00	60.0
NorthWest: Gladstone-Mt Larcom Road															
28	T1	All MCs	156	0.7	156	0.7	0.064	0.1	LOS A	0.1	0.4	0.03	0.03	0.03	59.7
29a	R1	All MCs	7	14.3	7	14.3	0.064	5.1	LOS A	0.1	0.4	0.04	0.05	0.04	59.2
Approach			163	1.3	163	1.3	0.064	0.3	NA	0.1	0.4	0.03	0.03	0.03	59.7
West: Aldoga Road															
10b	L3	All MCs	9	11.1	9	11.1	0.006	7.2	LOS A	0.0	0.0	0.00	0.57	0.00	52.3
12a	R1	All MCs	73	1.4	73	1.4	0.103	7.0	LOS A	0.4	2.9	0.45	0.64	0.45	52.0
Approach			82	2.6	82	2.6	0.103	7.0	LOS A	0.4	2.9	0.39	0.63	0.39	52.1
All Vehicles			387	1.4	387	1.4	0.103	1.6	NA	0.4	2.9	0.10	0.15	0.10	58.0

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Network Data dialog (Override Site Data tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA (TWSC): Level of Service is not defined for major road approaches or the intersection as a whole for Two-Way Sign Control (HCM LOS rule).

Two-Way Sign Control Capacity Model: SIDRA Standard.

Delay Model: SIDRA Standard (Control Delay: Geometric Delay is included).

Queue Model: SIDRA queue estimation methods are used for Back of Queue and Queue at Start of Gap.

Gap-Acceptance Capacity Formula: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

MOVEMENT SUMMARY

▼ Site: 101 [Gladstone-Mt Larcom Road-Aldoga Road (South)
2025 BG + Cons AM Peak (Site Folder: 2025 BG +
Construction)]

Output produced by SIDRA INTERSECTION Version: 9.1.6.228

■ Network: N101 [Gladstone-Mt Larcom Road-Aldoga Road
2025 BG + Construct AM Peak
(Network Folder: 2025 BG +
Construction)]

New Site
Site Category: (None)
Give-Way (Two-Way)

Vehicle Movement Performance															
Mov ID	Turn	Mov Class	Demand Flows		Arrival Flows		Deg. Satn	Aver. Delay	Level of Service	95% Back Of Queue		Prop. Que	Eff. Stop Rate	Aver. No. of Cycles	Aver. Speed
			[Total HV]	%	[Total HV]	%				[Veh. veh	Dist] m				
			veh/h	%	veh/h	%	v/c	sec							km/h
East: Aldoga Road															
5	T1	All MCs	52	2.0	52	2.0	0.027	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	60.0
Approach			52	2.0	52	2.0	0.027	0.0	NA	0.0	0.0	0.00	0.00	0.00	60.0
North: Aldoga Road															
9	R2	All MCs	7	14.3	7	14.3	0.006	6.0	LOS A	0.0	0.1	0.11	0.59	0.11	51.4
Approach			7	14.3	7	14.3	0.006	6.0	LOS A	0.0	0.1	0.11	0.59	0.11	51.4
All Vehicles			59	3.6	59	3.6	0.027	0.8	NA	0.0	0.1	0.01	0.07	0.01	58.8

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Network Data dialog (Override Site Data tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA (TWSC): Level of Service is not defined for major road approaches or the intersection as a whole for Two-Way Sign Control (HCM LOS rule).

Two-Way Sign Control Capacity Model: SIDRA Standard.

Delay Model: SIDRA Standard (Control Delay: Geometric Delay is included).

Queue Model: SIDRA queue estimation methods are used for Back of Queue and Queue at Start of Gap.

Gap-Acceptance Capacity Formula: SIDRA Standard (Akcelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

MOVEMENT SUMMARY

▼ Site: 102 [Gladstone-Mt Larcom Road-Aldoga Road (North)
2025 BG + Cons PM Peak (Site Folder: 2025 BG + Construction)]
Output produced by SIDRA INTERSECTION Version: 9.1.6.228

■ Network: N101 [Gladstone-Mt Larcom Road-Aldoga Road
2025 BG + Construct PM Peak
(Network Folder: 2025 BG + Construction)]

New Site
Site Category: (None)
Give-Way (Two-Way)

Vehicle Movement Performance															
Mov ID	Turn	Mov Class	Demand Flows		Arrival Flows		Deg. Satn	Aver. Delay	Level of Service	95% Back Of Queue		Prop. Que	Eff. Stop Rate	Aver. No. of Cycles	Aver. Speed
			[Total HV]		[Total HV]					[Veh. veh	Dist]				
			veh/h	%	veh/h	%	v/c	sec			m				km/h
SouthEast: Gladstone-Mt Larcom Road															
22	T1	All MCs	154	0.7	154	0.7	0.079	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	60.0
Approach			154	0.7	154	0.7	0.079	0.0	NA	0.0	0.0	0.00	0.00	0.00	60.0
NorthWest: Gladstone-Mt Larcom Road															
28	T1	All MCs	165	0.6	165	0.6	0.067	0.1	LOS A	0.0	0.3	0.02	0.02	0.02	59.8
29a	R1	All MCs	5	20.0	5	20.0	0.067	5.1	LOS A	0.0	0.3	0.03	0.03	0.03	59.4
Approach			171	1.2	171	1.2	0.067	0.3	NA	0.0	0.3	0.02	0.02	0.02	59.8
West: Aldoga Road															
10b	L3	All MCs	5	20.0	5	20.0	0.004	7.3	LOS A	0.0	0.0	0.00	0.56	0.00	52.0
12a	R1	All MCs	60	1.8	60	1.8	0.088	7.2	LOS A	0.3	2.4	0.45	0.64	0.45	51.9
Approach			65	3.2	65	3.2	0.088	7.2	LOS A	0.3	2.4	0.42	0.64	0.42	51.9
All Vehicles			389	1.4	389	1.4	0.088	1.3	NA	0.3	2.4	0.08	0.12	0.08	58.4

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Network Data dialog (Override Site Data tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA (TWSC): Level of Service is not defined for major road approaches or the intersection as a whole for Two-Way Sign Control (HCM LOS rule).

Two-Way Sign Control Capacity Model: SIDRA Standard.

Delay Model: SIDRA Standard (Control Delay: Geometric Delay is included).

Queue Model: SIDRA queue estimation methods are used for Back of Queue and Queue at Start of Gap.

Gap-Acceptance Capacity Formula: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

MOVEMENT SUMMARY

▼ Site: 101 [Gladstone-Mt Larcom Road-Aldoga Road (South)
2025 BG + Cons PM Peak (Site Folder: 2025 BG + Construction)]
Output produced by SIDRA INTERSECTION Version: 9.1.6.228

■ Network: N101 [Gladstone-Mt Larcom Road-Aldoga Road
2025 BG + Construct PM Peak
(Network Folder: 2025 BG + Construction)]

New Site
Site Category: (None)
Give-Way (Two-Way)

Vehicle Movement Performance															
Mov ID	Turn	Mov Class	Demand Flows		Arrival Flows		Deg. Satn	Aver. Delay	Level of Service	95% Back Of Queue		Prop. Que	Eff. Stop Rate	Aver. No. of Cycles	Aver. Speed
			[Total HV]	%	[Total HV]	%				[Veh. veh	Dist] m				
			veh/h	%	veh/h	%	v/c	sec							km/h
East: Aldoga Road															
5	T1	All MCs	48	2.2	48	2.2	0.025	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	60.0
Approach			48	2.2	48	2.2	0.025	0.0	NA	0.0	0.0	0.00	0.00	0.00	60.0
North: Aldoga Road															
9	R2	All MCs	5	20.0	5	20.0	0.004	6.1	LOS A	0.0	0.1	0.11	0.59	0.11	51.1
Approach			5	20.0	5	20.0	0.004	6.1	LOS A	0.0	0.1	0.11	0.59	0.11	51.1
All Vehicles			54	3.9	54	3.9	0.025	0.6	NA	0.0	0.1	0.01	0.06	0.01	59.0

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Network Data dialog (Override Site Data tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA (TWSC): Level of Service is not defined for major road approaches or the intersection as a whole for Two-Way Sign Control (HCM LOS rule).

Two-Way Sign Control Capacity Model: SIDRA Standard.

Delay Model: SIDRA Standard (Control Delay: Geometric Delay is included).

Queue Model: SIDRA queue estimation methods are used for Back of Queue and Queue at Start of Gap.

Gap-Acceptance Capacity Formula: SIDRA Standard (Akcelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

MOVEMENT SUMMARY

▼ Site: 102 [Gladstone-Mt Larcom Road-Aldoga Road (North)
2027 BG + Operational AM Peak (Site Folder: 2027 BG +
Operational)]

Output produced by SIDRA INTERSECTION Version: 9.1.6.228

■ Network: N101 [Gladstone-Mt Larcom Road-Aldoga Road
2027 BG + Operational AM Peak
(Network Folder: 2027 BG +
Operational)]

New Site
Site Category: (None)
Give-Way (Two-Way)

Vehicle Movement Performance															
Mov ID	Turn	Mov Class	Demand Flows		Arrival Flows		Deg. Satn	Aver. Delay	Level of Service	95% Back Of Queue		Prop. Que	Eff. Stop Rate	Aver. No. of Cycles	Aver. Speed
			[Total HV]		[Total HV]					[Veh. veh	Dist]				
			veh/h	%	veh/h	%	v/c	sec			m				km/h
SouthEast: Gladstone-Mt Larcom Road															
22	T1	All MCs	145	3.6	145	3.6	0.076	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	60.0
Approach			145	3.6	145	3.6	0.076	0.0	NA	0.0	0.0	0.00	0.00	0.00	60.0
NorthWest: Gladstone-Mt Larcom Road															
28	T1	All MCs	159	2.0	159	2.0	0.065	0.1	LOS A	0.0	0.3	0.03	0.03	0.03	59.7
29a	R1	All MCs	6	16.7	6	16.7	0.065	5.1	LOS A	0.0	0.3	0.04	0.04	0.04	59.3
Approach			165	2.5	165	2.5	0.065	0.3	NA	0.0	0.3	0.03	0.03	0.03	59.7
West: Aldoga Road															
10b	L3	All MCs	8	25.0	8	25.0	0.006	7.4	LOS A	0.0	0.0	0.00	0.56	0.00	51.8
12a	R1	All MCs	38	22.2	38	22.2	0.064	8.0	LOS A	0.2	2.0	0.46	0.64	0.46	50.8
Approach			46	22.7	46	22.7	0.064	7.9	LOS A	0.2	2.0	0.38	0.63	0.38	51.0
All Vehicles			357	5.6	357	5.6	0.076	1.2	NA	0.2	2.0	0.06	0.09	0.06	58.5

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Network Data dialog (Override Site Data tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA (TWSC): Level of Service is not defined for major road approaches or the intersection as a whole for Two-Way Sign Control (HCM LOS rule).

Two-Way Sign Control Capacity Model: SIDRA Standard.

Delay Model: SIDRA Standard (Control Delay: Geometric Delay is included).

Queue Model: SIDRA queue estimation methods are used for Back of Queue and Queue at Start of Gap.

Gap-Acceptance Capacity Formula: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

MOVEMENT SUMMARY

▼ Site: 101 [Gladstone-Mt Larcom Road-Aldoga Road (South)
2027 BG + Operational AM Peak (Site Folder: 2027 BG +
Operational)]

Output produced by SIDRA INTERSECTION Version: 9.1.6.228

■ Network: N101 [Gladstone-Mt Larcom Road-Aldoga Road
2027 BG + Operational AM Peak
(Network Folder: 2027 BG +
Operational)]

New Site
Site Category: (None)
Give-Way (Two-Way)

Vehicle Movement Performance															
Mov ID	Turn	Mov Class	Demand Flows		Arrival Flows		Deg. Satn	Aver. Delay	Level of Service	95% Back Of Queue		Prop. Que	Eff. Stop Rate	Aver. No. of Cycles	Aver. Speed
			[Total HV]	%	[Total HV]	%				[Veh. veh	Dist] m				
			veh/h	%	veh/h	%	v/c	sec							km/h
East: Aldoga Road															
5	T1	All MCs	34	6.3	34	6.3	0.018	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	60.0
Approach			34	6.3	34	6.3	0.018	0.0	NA	0.0	0.0	0.00	0.00	0.00	60.0
North: Aldoga Road															
9	R2	All MCs	6	16.7	6	16.7	0.005	6.0	LOS A	0.0	0.1	0.09	0.60	0.09	51.3
Approach			6	16.7	6	16.7	0.005	6.0	LOS A	0.0	0.1	0.09	0.60	0.09	51.3
All Vehicles			40	7.9	40	7.9	0.018	1.0	NA	0.0	0.1	0.01	0.09	0.01	58.4

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Network Data dialog (Override Site Data tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA (TWSC): Level of Service is not defined for major road approaches or the intersection as a whole for Two-Way Sign Control (HCM LOS rule).

Two-Way Sign Control Capacity Model: SIDRA Standard.

Delay Model: SIDRA Standard (Control Delay: Geometric Delay is included).

Queue Model: SIDRA queue estimation methods are used for Back of Queue and Queue at Start of Gap.

Gap-Acceptance Capacity Formula: SIDRA Standard (Akcelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

MOVEMENT SUMMARY

▼ Site: 102 [Gladstone-Mt Larcom Road-Aldoga Road (North)
2027 BG + Operational PM Peak (Site Folder: 2027 BG +
Operational)]

Output produced by SIDRA INTERSECTION Version: 9.1.6.228

■ Network: N101 [Gladstone-Mt Larcom Road-Aldoga Road
2027 BG + Operational PM Peak
(Network Folder: 2027 BG +
Operational)]

New Site
Site Category: (None)
Give-Way (Two-Way)

Vehicle Movement Performance															
Mov ID	Turn	Mov Class	Demand Flows		Arrival Flows		Deg. Satn	Aver. Delay	Level of Service	95% Back Of Queue		Prop. Que	Eff. Stop Rate	Aver. No. of Cycles	Aver. Speed
			[Total HV]	[Total HV]	[Veh. veh	Dist]									
			veh/h	%	veh/h	%	v/c	sec			m				km/h
SouthEast: Gladstone-Mt Larcom Road															
22	T1	All MCs	157	4.0	157	4.0	0.083	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	60.0
Approach			157	4.0	157	4.0	0.083	0.0	NA	0.0	0.0	0.00	0.00	0.00	60.0
NorthWest: Gladstone-Mt Larcom Road															
28	T1	All MCs	169	1.2	169	1.2	0.068	0.1	LOS A	0.0	0.2	0.02	0.02	0.02	59.8
29a	R1	All MCs	4	25.0	4	25.0	0.068	5.2	LOS A	0.0	0.2	0.03	0.02	0.03	59.6
Approach			174	1.8	174	1.8	0.068	0.2	NA	0.0	0.2	0.02	0.02	0.02	59.8
West: Aldoga Road															
10b	L3	All MCs	4	25.0	4	25.0	0.003	7.4	LOS A	0.0	0.0	0.00	0.56	0.00	51.8
12a	R1	All MCs	42	5.0	42	5.0	0.064	7.4	LOS A	0.2	1.8	0.46	0.64	0.46	51.7
Approach			46	6.8	46	6.8	0.064	7.4	LOS A	0.2	1.8	0.42	0.63	0.42	51.7
All Vehicles			377	3.4	377	3.4	0.083	1.0	NA	0.2	1.8	0.06	0.09	0.06	58.7

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Network Data dialog (Override Site Data tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA (TWSC): Level of Service is not defined for major road approaches or the intersection as a whole for Two-Way Sign Control (HCM LOS rule).

Two-Way Sign Control Capacity Model: SIDRA Standard.

Delay Model: SIDRA Standard (Control Delay: Geometric Delay is included).

Queue Model: SIDRA queue estimation methods are used for Back of Queue and Queue at Start of Gap.

Gap-Acceptance Capacity Formula: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

MOVEMENT SUMMARY

▼ Site: 101 [Gladstone-Mt Larcom Road-Aldoga Road (South)
2027 BG + Operational PM Peak (Site Folder: 2027 BG +
Operational)]

Output produced by SIDRA INTERSECTION Version: 9.1.6.228

■ Network: N101 [Gladstone-Mt Larcom Road-Aldoga Road
2027 BG + Operational PM Peak
(Network Folder: 2027 BG +
Operational)]

New Site
Site Category: (None)
Give-Way (Two-Way)

Vehicle Movement Performance															
Mov ID	Turn	Mov Class	Demand Flows		Arrival Flows		Deg. Satn	Aver. Delay	Level of Service	95% Back Of Queue		Prop. Que	Eff. Stop Rate	Aver. No. of Cycles	Aver. Speed
			[Total HV]	%	[Total HV]	%				[Veh. veh	Dist] m				
			veh/h		veh/h		v/c	sec							km/h
East: Aldoga Road															
5	T1	All MCs	31	6.9	31	6.9	0.016	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	60.0
Approach			31	6.9	31	6.9	0.016	0.0	NA	0.0	0.0	0.00	0.00	0.00	60.0
North: Aldoga Road															
9	R2	All MCs	4	25.0	4	25.0	0.003	6.1	LOS A	0.0	0.1	0.08	0.60	0.08	51.0
Approach			4	25.0	4	25.0	0.003	6.1	LOS A	0.0	0.1	0.08	0.60	0.08	51.0
All Vehicles			35	9.1	35	9.1	0.016	0.7	NA	0.0	0.1	0.01	0.07	0.01	58.7

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Network Data dialog (Override Site Data tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA (TWSC): Level of Service is not defined for major road approaches or the intersection as a whole for Two-Way Sign Control (HCM LOS rule).

Two-Way Sign Control Capacity Model: SIDRA Standard.

Delay Model: SIDRA Standard (Control Delay: Geometric Delay is included).

Queue Model: SIDRA queue estimation methods are used for Back of Queue and Queue at Start of Gap.

Gap-Acceptance Capacity Formula: SIDRA Standard (Akcelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

EUROA HYDROGEN PROJECT

Euroa Circuit, Aldoga, QLD 4694

Pavement Impact Assessment

For Vena Energy Services (Australia) Pty Ltd



ENGINEERS
MANAGERS
SCIENTISTS

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Revision	Date	Description	Author	Verifier	Approver
Draft	21/08/2025	Draft	II	MB	
RevA	14/10/2025	Final	II	MB	KC

Authorised by:



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SENIOR TRAFFIC ENGINEER



K.M. CHUA BE(Civil), RPEQ (#31618), CPEng, NER

ENGINEER – TRAFFIC & TRANSPORT

1 Introduction

Lambert & Rehbein (SEQ) Pty Ltd has been commissioned by Vena Energy Services (Australia) Pty Ltd to prepare a Pavement Impact Assessment (PIA) for a proposed hydrogen facility located at Euroa Circuit, Aldoga QLD 4694. The development site extends over three (3) lots formally described as Lot 1, 2 and 3 on SP245955 with a total site area of approximately 26.0ha.

The proposed development involves a hydrogen production facility which seeks to produce compressed hydrogen gas that will be distributed domestically using purpose-built road tube trailers. The proposed site layout, prepared by Vena Energy is included in **Appendix A**.

This report has been prepared to assess the potential impact that the proposed development could have on the external road network surrounding the site, and is set out as follows:

Section 2 discusses the existing land use and traffic arrangements in the vicinity of the proposed development site.

Section 3 provides details of the proposed development, including an assessment of the site layout, access, car parking and servicing arrangements.

Section 4 details the pavement impact assessment methodology.

Section 5 details the pavement impact assessment calculations.

Section 6 summarises the key outcomes of the traffic investigations.

Lambert & Rehbein has derived the data in this report primarily from the data provided by the Client, and a desktop site investigation.

This report has been prepared on behalf of and for the exclusive use of the Client, and is subject to and issued in connection with the provisions of the agreement between Lambert & Rehbein and the Client. Lambert & Rehbein accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report by any third party.

2 Context of the Development Site

This section of the report describes the context of the proposed development and includes a description of the existing road network and adjacent land uses.

2.1 Development Site

The proposed development is located at Euroa Circuit, Aldoga QLD 4694. The development site extends over three (3) lots formally described as Lot 1, 2 and 3 on SP245955 with a total site area of approximately 26.0ha.

The development site is currently located within the Gladstone State Development Area (GSDA) which is the primary land use planning framework for the area. The subject site is situated within the 'High Impact Industry Precinct'. The site is generally surrounded by land use zoning of similar nature with the 'Materials Transportation and Services Corridor Precinct' located to the east and the 'Medium Impact Industry Precinct' located southeast of the subject site.

The development site in context of the surrounding land use zoning precincts is shown in **Figure 2-1**.

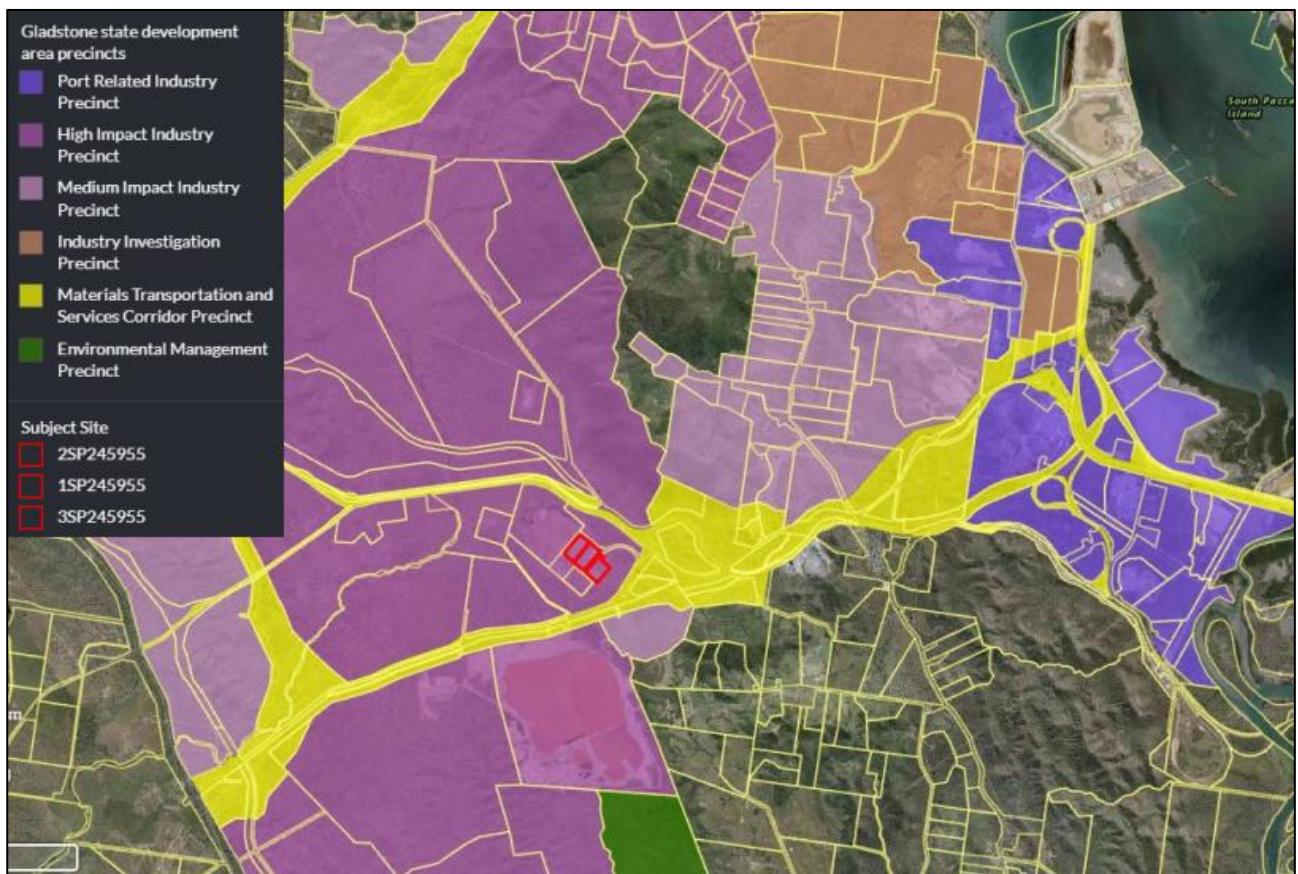


Figure 2-1 GSDA Development Scheme Precincts Map

2.2 Adjacent Road Network

Investigation of the land use, road condition, intersection characteristics, public transport facilities, pedestrian access, and cyclist provisions surrounding the proposed development site have been undertaken in preparation of this traffic assessment. This was completed to collect information about the road network operation, safety characteristics, public transport network and specific network / land-use factors potentially of influence on the proposed development.

2.2.1 Euroa Circuit

The proposed development site gains access to the broader state-controlled road (SCR) via Euroa Circuit. The general form of Euroa Circuit at the site frontage is shown in **Figure 2-2** and was observed to have the following characteristics:

- Two-way, two lane undivided road;
- Pavement width of approximately 18m including 6m wide gravel shoulders on both sides of the road;
- No kerb and channel provided;
- No parking provisions available;
- No dedicated cycle lanes or footpaths provided on either side of the road; and
- Posted speed limit of 60km/hr.

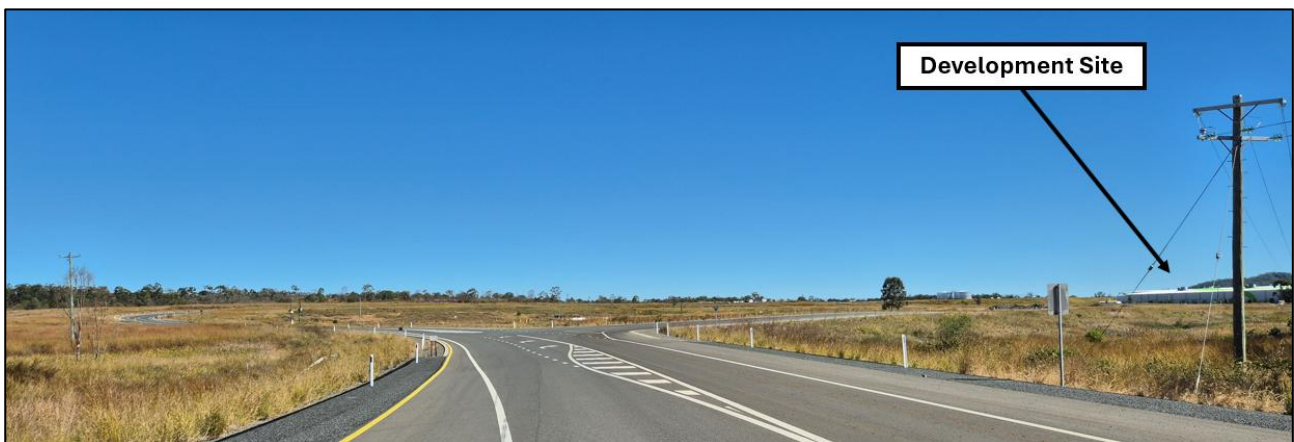


Figure 2-2 Euroa Circuit- Facing Southwest (Site Visit, June 2025)

2.2.2 Aldoga Road

Aldoga Road is a Council controlled road (Gladstone Regional Council (GRC) and intersects with Euroa Circuit in the form of a priority-controlled intersection. The general form of Aldoga Road is shown in **Figure 2-3** and was found to have the following characteristics at the site frontage:

- Two lane, two-way road;
- Pavement width of approximately 12m;
- No kerb and channel provided on either side of the road;
- No parking provisions available;
- No dedicated cycle lanes or footpaths provided; and
- Posted speed limit of 60km/hr.

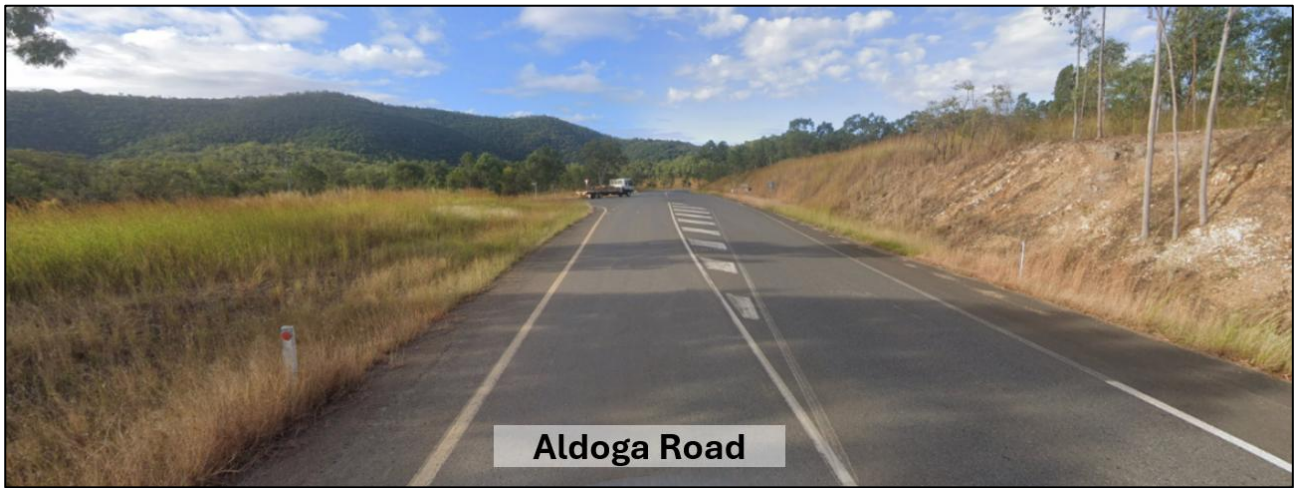


Figure 2-3 Aldoga Road- Facing North (Google, May 2025)

2.2.3 Gladstone-Mt Larcom Road

Gladstone-Mt Larcom Road is a SCR providing connectivity between Gladstone (East) to Mount Larcom and the Bruce Highway (west) and is a gazetted 26m B-Double Route. The general form of Gladstone-Mt Larcom Road is shown in **Figure 2-4** and was found to have the following characteristics at the site frontage:

- Two lane, two-way road;
- Pavement width of approximately 8m;
- No kerb and channel provided on either side of the road;
- No parking provisions available;
- No dedicated cycle lanes or footpaths provided; and
- Posted speed limit of 100km/hr.



Figure 2-4 Gladstone-Mount Larcom Road- Facing Southeast (Google, May 2025)

2.3 Future Infrastructure Upgrades

The following resources were reviewed to determine if there are any future transport infrastructure upgrades within close proximity of the development site:

- GRC's Local Government Infrastructure Plan (LGIP);
- Queensland Transport and Roads Investment Program (QTRIP); and
- Queensland Government's Development Assessment Mapping System (DAMS).

A review of these resources found no future transport infrastructure upgrades within close proximity (500m) of the development site.

3 Details of the Proposed Development

3.1 Proposed Development

The proposed development involves an integrated hydrogen production facility including onsite storage and distribution domestically via purpose-built road tube trailers. The proposed site layout, prepared by Vena Energy is included in **Appendix A**.

The proposed facility is expected to operate across 24 hours a day and 7 days a week, 52 weeks a year. The proposed tube trailer filling facility will include four (4) bays, each capable of accommodating two (2) truck and trailer combinations simultaneously. However, the operational preference is to fill only one (1) bay at a time. The site is expected to service up to 17.3 trucks per day with each truck having a capacity of 1 tonne. It has been estimated that it may take up to 5.45 hours for semitrailers to enter and leave the site to allow for setting up and filling.

3.2 Proposed Haulage Profile

The proposed hydrogen production facility is projected to produce approximately 6,552 (1 tonne x 18 trucks x 7 days x 52 weeks) tonnes of hydrogen gas per year. Haulage activities will involve loading product at the quarry and transporting it to the following destinations, as seen in **Figure 3-1**:

- East via Gladstone – Mount Larcom Road to Gladstone Port;
- Northwest via Gladstone – Mount Larcom Road to Gladstone Port and Bruce Highway to North of Mount Larcom; and
- South via Gladstone – Mount Larcom Road to Bruce Highway to Brisbane.



Figure 3-1 DTMR Gazetted Road Network (Qld Globe, 2025)

3.3 Proposed Haulage Routes

Three (3) primary haulage routes, both assessed as part of this pavement impact assessment, are proposed for the development:

- Route 1 (East): Gladstone – Mount Larcom Road to Gladstone Port;
- Route 2 (North-West): Gladstone – Mount Larcom Road to Bruce Highway to North of Mount Larcom; and
- Route 3 (South): Gladstone – Mount Larcom Road to Bruce Highway to Brisbane.

We note that each route is gazetted as a 25/26m B-Double haulage route, so the hauling of product via 19m AVs is acceptable.

Return trips to the quarry will occur via the same routes, with trucks operating empty (unladen) on the inbound journey.

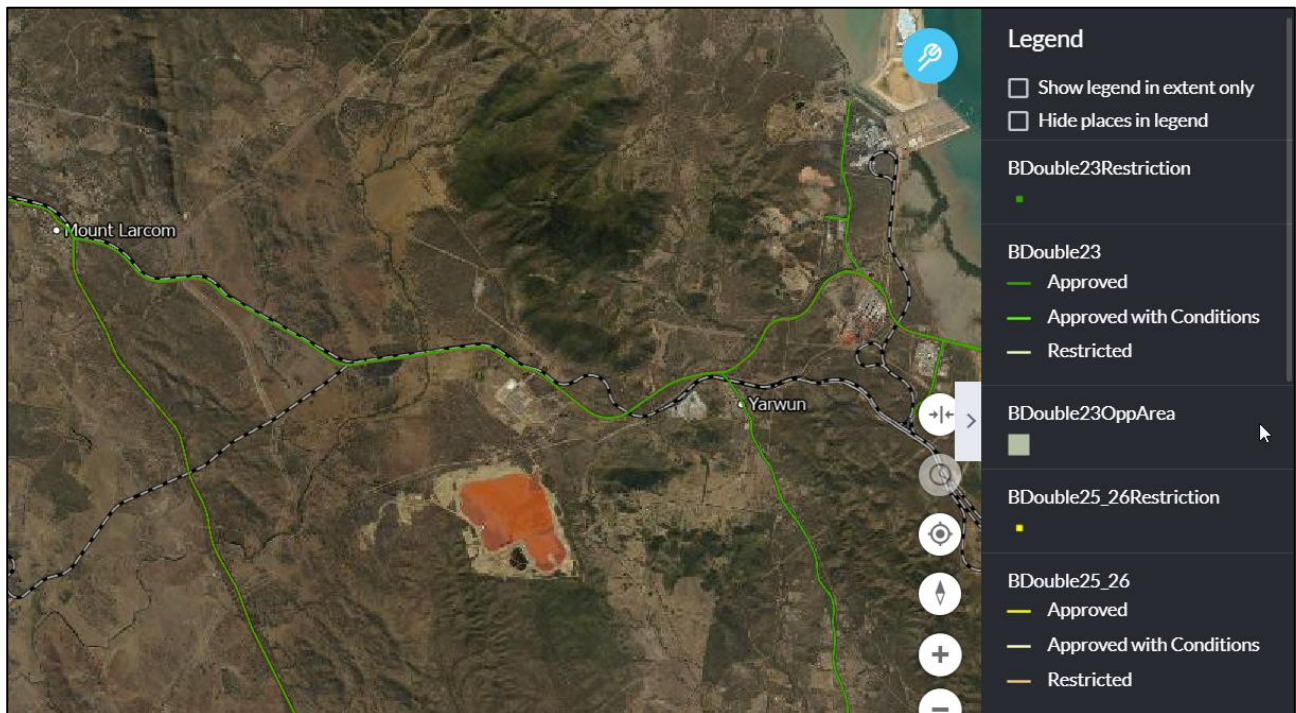


Figure 3-2 25/26m B-Double Gazetted Road Network (Qld Globe, 2025)

3.4 Design Vehicle

The designated haulage vehicle for the development is a standard Six-Axle Articulate Vehicle (AV). Specifications for this vehicle, as outlined by the Austroads, are provided in **Figure 3-3**.

The design vehicle's axle configuration comprises:

- One (1) Single Axle with Single Tyres (SAST) group;
- One (1) Tandem Axle with Dual tyres (TADT) group; and
- One (1) Triaxle with Dual Tyres (TRDT) group.

Class	Typical description	Dominant vehicle in each class
Long (11.5m to 19.0m)		
9	Six axle articulated (semi-trailer)	

Figure 3-3 Design Vehicle - 19m Articulated Vehicle (AV)

It is understood that the payload for each laden trip will be limited to 1 tonne. The payload of 1 tonne has been distributed across the vehicle's axles based on the maximum payload distribution, as documented below in **Table 3-1**.

Table 3-1 Design Vehicle Axle Group

Design Vehicle	19m Articulated Vehicle		
Axle Group	Steer	1st Group	2nd Group
Layout	O	OO	OOO
Configuration	SAST	TADT	TRDT
GML (t)	6	16.5	20
Unloaded (t)	4.5	5	6.5
Max Payload (t)	1.5	11.5	13.5
Avg Payload Distribution	6%	43%	51%
Payload (1t)	0.1	0.4	0.5

Based on the assumed payload of 1 tonne vehicle and assumed payload distribution, as documented in **Table 3-1**, the standard number of ESAs per vehicle is 0.51 unladen and 0.55 laden. These calculations are presented in **Table 3-2** and **Table 3-3**.

Table 3-2 Design Vehicle Unladen SARS4 Calculation

Vehicle Type – AV 19m		Standard Loads	
Axle Group	No.		
SAST	1	53	kN
TADT	1	135	kN
TRDT	1	181	kN
Load Magnitude			
SAST	4.5	tonnes max	
TADT	5.0	tonnes max	
TRDT	6.5	tonnes max	
ESA Calculation			
Max Payload	0	Tonnes (unladen)	
SAST	0.48	ESA's	
TADT	0.02	ESA's	
TRDT	0.02	ESA's	
SARS 4 ESAs	0.51	ESA's	

Table 3-3 Design Vehicle Laden SARS4 Calculation

Vehicle Type – AV 19m		Standard Loads	
Axle Group	No.		
SAST	1	53	kN
TADT	1	135	kN
TRDT	1	181	kN
Load Magnitude			
SAST	4.6	tonnes max	
TADT	5.4	tonnes max	
TRDT	7.0	tonnes max	
ESA Calculation			
Max Payload	1.00	Tonnes	
SAST	0.51	ESA's	
TADT	0.02	ESA's	
TRDT	0.02	ESA's	
SARS 4 ESAs	0.55	ESAs'	

3.5 Traffic Generation

The development is expected to generate approximately 18 vehicles one-way trips per day, seven days a week for 52 weeks of the year. Based on this frequency, the haulage of 1.0 tonne payload and return unladen trips will equate to 13,104 AADT (6,552 AADT laden, 6,552 AADT unladen) initially on Gladstone – Mount Larcom Road which is a SCR.

Based on the assumed distribution across the three (3) haulage routes, as outlined in **Table 3-4**, the site will generate the following trips per year.

Table 3-4 Traffic Distribution Based on Haulage Routes

Direction	%	Trips per Year
West - Gladstone – Mount Larcom Road (CH20.0 - CH32.14)	75%	9,828
East - Gladstone – Mount Larcom Road (CH20.0 - CH12.29)	25%	3,276
North – Bruce Highway (45.288-85.308)	50%	6,552
South – Bruce Highway (45.288-11.445)	25%	3,276

Table 3-5 Haulage Route Laden / Unladen

Direction	A	G
West - Gladstone – Mount Larcom Road (CH20.0 - CH32.14)	Unladen	Laden
East - Gladstone – Mount Larcom Road (CH20.0 - CH12.29)	Laden	Unladen
North – Bruce Highway (45.288-85.308)	Unladen	Laden
South – Bruce Highway (45.288-11.445)	Laden	Unladen



Figure 3-4 State Controlled Road Chainage

4 PIA Methodology

Pavement Impact Assessment (PIA) is an assessment required by the Department of Transport and Main Roads (DTMR) *Guide to Traffic Impact Assessment* (GTIA) guidelines to allocate the costs of road maintenance and rehabilitation arising from heavy commercial vehicle traffic.

For State-controlled roads, DTMR maintains records of historical maintenance and rehabilitation costs. These costs are spread across the expected service life of a road, which is expressed in Standard Axle Repetitions (SAR), which is a measure of the cumulative load a pavement can withstand before requiring maintenance or rehabilitation. The service life is determined through fatigue calculations and depends on factors such as pavement composition and design speed.

By combining design life with rehabilitation costs, a Pavement Marginal Cost (cost per SAR per kilometre) is derived. Heavy vehicle haulage contributes disproportionately to pavement wear, shortening pavement life. Where a haulage route increases the existing SAR load on a road by more than 5%, it is deemed to have a 'significant impact' and compensation to the road owner is required.

Compensation is calculated by multiplying the additional annual SAR load from the nominated activity by the Pavement Marginal Cost. In resource haulage operations, this cost is often converted into a unit rate per tonne of material (\$/t), enabling charges to reflect actual production and haulage volumes.

This section of the report provides details of the potential impact that the development generated traffic volumes could have on the operation of the surrounding road network.

4.1 Pavement Damage Assessment

The pavement damage formula applied in this assessment, as outlined in the DTMR's GTIA (Practice Note, December 2018) is shown in **Figure 4-1**.

$$SAR_{m_{ij}} = \left(\frac{L_{ij}}{SL_i} \right)^m$$

where

$SAR_{m_{ij}}$	=	number of Standard Axle Repetitions (or passages of the Standard Axle) which causes the same amount of damage as a single passage of axle group type i with load L_{ij} , where the load damage exponent is m
SL_i	=	Standard Load for axle group type i (from Table 2.3 – Base Load per SAR4), which causes the same damage as a Standard Axle
L_{ij}	=	j th load magnitude on the axle group type i
m	=	load damage exponent for the damage type (from Table 2.1)

Figure 4-1 SAR4 Calculation

Under the GTIA, a PIA is required for any road section where the SAR's generated by a development or activity exceed 5% of the background traffic SAR's.

4.2 Background ESA Factor

Table 4-1 outlines the two (2) Traffic Analysis and Reporting System (TARS) data collection sites that have been considered in selection of the background ESA factors for each road comprised within the study's impact assessment area.

Table 4-1 Road ESA vs Chainage

ROAD_SECTION_ID	ROAD NAME	ESA/HV	CH	
			TdistStart	TdistEnd
10E	BRUCE HIGHWAY (BENARABY - ROCKHAMPTON)	2.9	11.445	45.288
			45.288	45.42
			45.42	46.017
181	GLADSTONE - MOUNT LARCOM ROAD	3.2	9.325	12.29
			12.29	32.14

5 Marginal SAR Assessment

The following section outlines the calculations completed to calculate:

- Background SAR4;
- Development SAR;
- 5% assessment to determine if further analysis is required.

5.1 Gladstone - Mount Larcom Road (Background ESA)

Gladstone – Mount Larcom Road background SARs are calculated in **Table 5-1** for the assessment corridor (CH 9.325 - CH 32.14).

Table 5-1 2027 Bruce Highway (Benaraby – Rockhampton) SAR4 Calculations

Direction	Road Name	Direction	Tdist Start	Tdist End	2024 AADT	PERCENT_HV	ESA/veh	2024 SAR p.a	2027 AADT	2027 SAR p.a
East	GLADSTONE - MOUNT LARCOM ROAD (181)	A	9.325	12.29	3,230	20.76	3.2	783,728	3,286	796,828
	GLADSTONE - MOUNT LARCOM ROAD (181)	G	9.325	12.29	3,207	19.17	3.2	718,320	3,195	715,480
West	GLADSTONE - MOUNT LARCOM ROAD (181)	A	12.29	32.14	2,106	18.17	3.2	447,344	2,663	565,075
	GLADSTONE - MOUNT LARCOM ROAD (181)	G	12.29	32.14	2,307	17.31	3.2	466,032	3,064	619,514

5.2 Bruce Highway (Benaraby - Rockhampton) (Background ESA)

Bruce Highway (Benaraby – Rockhampton) background SARs are calculated in **Table 5-2** for the assessment corridor (CH11.45 - CH 85.31).

Table 5-2 2027 Bruce Highway (Benaraby – Rockhampton) SAR4 Calculations

Direction	Road Name	Direction	TdistStart	TdistEnd	2024 AADT	PERCENT HV	ESA/veh	2024 SAR p.a	2027 AADT	2027 SAR p.a
South	BRUCE HIGHWAY (BENARABY - ROCKHAMPTON)	A	11.45	45.29	2,531	28.7	2.9	768,471	2,763	782,228
		G	11.45	45.29	2,494	26.8	2.9	706,020	2,798	848,967
North		A	45.29	45.42	2,531	28.7	2.9	768,471	2,763	782,228
		G	45.29	45.42	3,146	27.3	2.9	909,252	2,798	848,967
		A	45.42	46.02	3,112	31.2	2.9	1,028,86	3,299	953,284
		G	45.42	46.02	3,146	27.3	2.9	909,252	3,281	1,084,24
		A	46.02	85.31	3,112	31.2	2.9	1,028,86	3,299	953,284
		G	46.02	85.31	3,918	24.6	2.9	1,020,39	3,281	1,084,24

5.3 Development (ESA)

Table 5-3 demonstrates the calculated development traffic road link impacts, during 2027, theoretically, do not exceed the >5% road link SAR4 threshold for Gladstone – Mount Larcom Road or the Bruce Highway.

Table 5-3 Development Traffic Impact Assessment

Direction	Trips	Trips per Year	ESA per Veh		ESAs		Impact > 5%	
			A	G	A	G	A	G
West - Gladstone – Mount Larcom Road (CH20.0 - CH32.14)	75%	9828	0.51	0.55	5,012	5,405	NO	NO
East - Gladstone – Mount Larcom Road (CH20.0 - CH12.29)	25%	3276	0.55	0.51	1,802	1,671	NO	NO
North – Bruce Highway (45.288-85.308)	50%	6552	0.51	0.55	3,342	3,604	NO	NO
South – Bruce Highway (45.288-11.445)	25%	3276	0.55	0.51	1,802	1,671	NO	NO

As such, based on the above analysis and results, no road links have been identified where development volumes will have significant impacts (i.e. >5%). Therefore, further assessment is not required. PIA calculations have been included in **Appendix B**.

6 Summary

Lambert & Rehbein (SEQ) Pty Ltd has been commissioned by Vena Energy Services (Australia) Pty Ltd to prepare a Pavement Impact Assessment (PIA) for a proposed hydrogen facility located at Euroa Circuit, Aldoga QLD 4694. The development site extends over three (3) lots formally described as Lot 1, 2 and 3 on SP245955 with a total site area of approximately 26.0ha.

The proposed development involves a hydrogen production facility which seeks to produce compressed hydrogen gas that will be distributed domestically using purpose-built road tube trailers. The proposed site layout, prepared by Vena Energy is included in **Appendix A**.

The proposed hydrogen production facility is projected to produce approximately 6,552 (1 tonne x 18 trucks x 7 days x 52 weeks) tonnes of hydrogen gas per year.

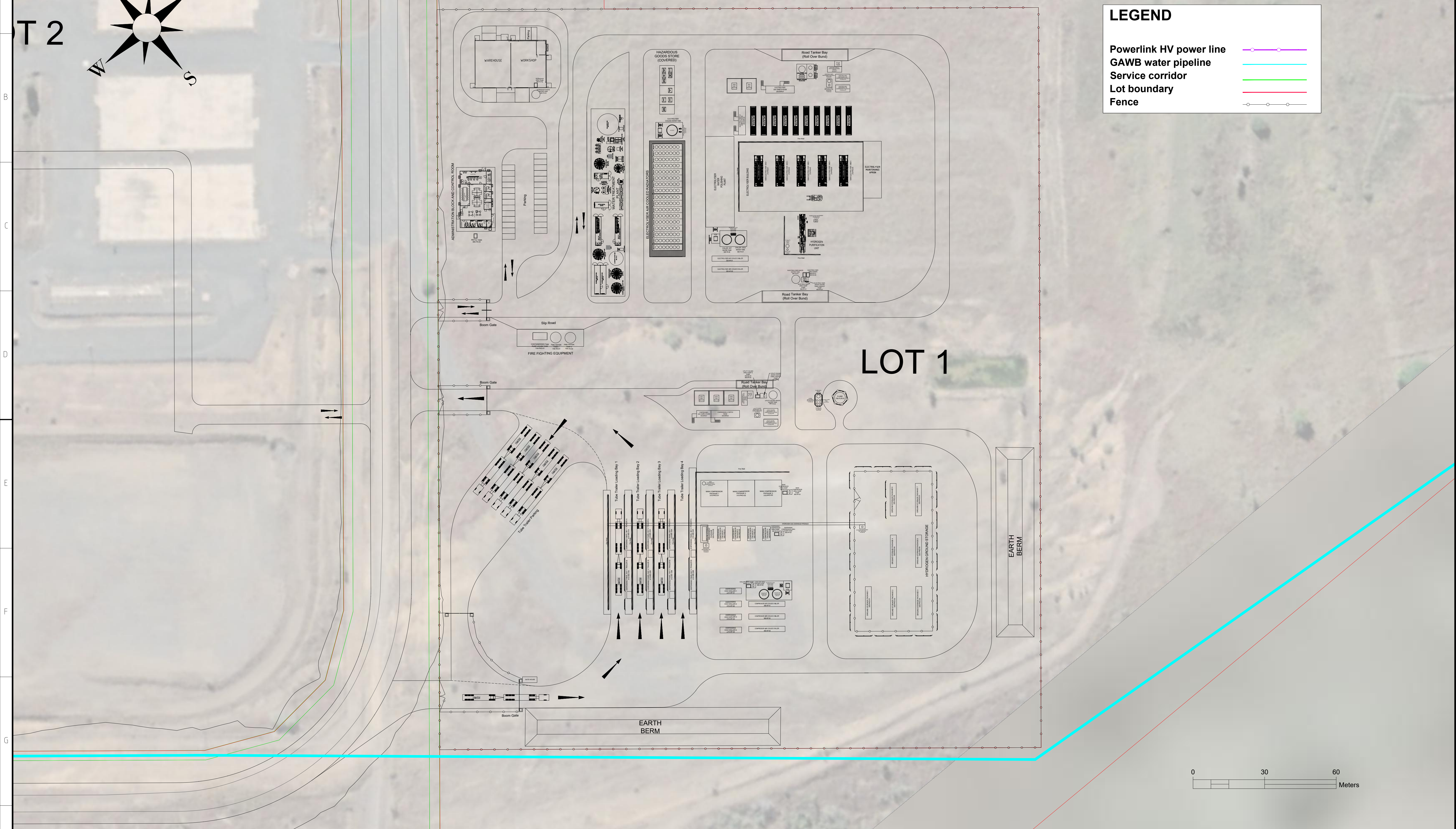
Three (3) primary haulage routes, both assessed as part of this pavement impact assessment, are proposed for the development:

- Route 1 (East): Gladstone – Mount Larcom Road to Gladstone Port;
- Route 2 (North-West): Gladstone – Mount Larcom Road to Bruce Highway to North of Mount Larcom; and
- Route 3 (South): Gladstone – Mount Larcom Road to Bruce Highway to Brisbane.

Based on this frequency, the haulage of 1.0 tonne payload and return unladen trips will equate to 13,104 AADT (6,552 AADT laden, 6,552 AADT unladen) initially on Gladstone – Mount Larcom Road which is a SCR.

Based on the analysis in **Section 5**, no road links have been identified where development volumes will have significant impacts (i.e. >5%). Therefore, further assessment is not required.

Appendix A – Site Layout

[illegible][illegible]

DOCUMENT STATUS: UNLESS THIS DOCUMENT BEARS
RED STAMP IT IS UNCONTROLLED AND MAY NOT BE THE
LATEST ISSUE. THEREFORE, VERIFY STATUS BEFORE USE.

DESIGNED	BW	VENA ENERGY HYDROGEN PROJECT			
CHECKED	IM	HYDROGEN PRODUCTION PLANT			
DRAWN	BW	STAGE 1: FEED STUDY 50MW ELECTROLYZER			
CHECKED	SHB	HYDROGEN PLANT GENERAL ARRANGEMENT			
APPROVED	SHB				
A1	NTS	CLIENT VENA ENERGY	UGL DRAWING No. 17695-SITE-GA-1002-01	SHEET 01	REV I

Appendix A – PIA Calculations

19m AV



Determined GML service.nhvr.gov.au

Axle Config	Unloaded	Allowable Load (t) for GML roads (per axle group)
SAST	4.5	6.0
TADT	5	16.5
TRDT	6.5	20.0

Finding total Payload

Design Vehicle	19m AV						
Axle Group	Steer	1st Group	2nd Group				
Layout	O OO OOO						
Config	SAST	TADT	TRDT	CHECK			
GML (t)	6.0	16.5	20.0	ε 42.5			
Unloaded (t)	4.5	5.0	6.5	ℓ 16.0			
Max Payload (t)	1.5	11.5	13.5	£ 26.5			
Payload Dist	6%	43%	51%	ε			
Payload (1t)	0.1	0.4	0.5	1.0			
Total	1.0						

Loaded (Product Haul)

Traffic Multipliers			
Vehicle Type			
AV 19m		Standard Loads	
SAST	1	53 kN	
	1	135 kN	
TRDT	1	181 kN	
Load Magnitude			
SAST	4.6 tonnes max		
TADT	5.4 tonnes max		
TRDT	7.0 tonnes max		
ESA Calculation			
SAST	0.51	ESA's	
TADT	0.02	ESA's	
TRDT	0.02	ESA's	
Combined	0.55	ESA's	
Payload	1.0 tonnes		
SARS 4 ESAs	0.55 ESAs		
	SAR5	SAR7	SAR12
SAST	0.43	0.30	0.13
TADT	0.01	0.00	0.00
TRDT	0.01	0.00	0.00
Combined	0.444261718	0.306196321	0.129566076

Unloaded

Traffic Multipliers			
Vehicle Type			
AV 19m		Standard Loads	
SAST	1	53 kN	
	1	135 kN	
TRDT	1	181 kN	
SAST	4.5 tonnes max		
TADT	5.0 tonnes max		
TRDT	6.5 tonnes max		
Calculate ESA			
SAST ESA's	0.48	ESA's	
TADT ESA's	0.02	ESA's	
TRDT ESA's	0.02	ESA's	
Combined	0.51	ESA's	
Payload	0.0 tonnes		
SARS 4 (ESAs)	0.51 ESAs		
	SAR5	SAR7	SAR12
SAST	0.40	0.28	0.11
TADT	0.01	0.00	0.00
TRDT	0.01	0.00	0.00
Combined	0.412651076	0.27963405	0.111507138

tonnage

1 t

$$SARm_{ij} = \left(\frac{L_{ij}}{SL_i}\right)^m$$

where

- SARm_{ij}

=

number of Standard Axle Repetitions (or passages of the Standard Axle) which causes the same amount of damage as a single passage of axle group type i with load L_{ij}, where the load damage exponent is m
- SL_i

=

Standard Load for axle group type i (from Table 2.3 – Base Load per SAR4), which causes the same damage as a Standard Axle
- L_{ij}

=

jth load magnitude on the axle group type i
- m

=

load damage exponent for the damage type (from Table 2.1)

2.1.2 ESA vs. SAR

Under GARID, ESA is defined as:

"A measure defining the cumulative damaging effect to the pavement of the design traffic. It is expressed in terms of the equivalent number of 80kN axles passing over the pavement up to the design horizon."

The formula to calculate ESAs is outlined in Figure 1.

$$ESA_{ij} = (L_{ij}/SL_i)^4$$

axle load (L_{ij})
standard load (SL_i)

Figure 1: ESA formula
(Source: TMR Technical Note 167: A new Approach to Asphalt Pavement Design, 2017)

Note: refer to Heavy vehicle (Mass, Dimension and Loading) National Regulation (Part 2) for detailed Legal Loading.

2.1.7 SAR by Austroads heavy vehicle classification

The SAR for a specific heavy vehicle is simply the sum of the SAR for each relevant axle group type. Table 3 provides a summary of loaded and unloaded SAR for the dominant vehicle in each Austroads class. Detailed calculations by axle group type are provided in Appendix A. Note, the loaded SAR values in Table 3 are based on the full payload for each vehicle classification. If the payload was reduced (i.e. trucks not at 100% of their legal capacity), the SAR value would also reduce.

Table 3: SAR calculation by Austroads heavy vehicle classification

Austroads vehicle class	3	4	5	6	7	8	9	10	11	12
Legal Loading (t)	15.0	22.5	27.5	24.0	31.5	39.0	42.5	62.5	79.0	115.5
Base Load per SAR4	13.6	19.2	23.0	21.8	27.4	33.0	37.7	56.2	70.0	102.3
Unloaded Axle Group Load (t)	8.5	9.5	12.5	12.5	13.5	14.5	16.0	22.5	27.5	39.0
Unloaded SAR4	0.54	0.50	0.46	0.60	0.56	0.52	0.51	0.53	0.55	0.58
Unloaded SAR5	0.43	0.41	0.37	0.46	0.44	0.41	0.41	0.42	0.43	0.44
Unloaded SAR12	0.11	0.11	0.09	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Loaded Axle Group Load (t)	15.0	22.5	27.5	24.0	31.5	39.0	42.5	62.5	79.0	115.5
Loaded SAR4	2.98	3.57	4.09	4.43	5.02	5.61	4.93	6.30	8.34	11.75
Loaded SAR5	3.29	4.14	4.89	4.88	5.73	6.58	5.61	7.09	9.53	13.45
Loaded SAR12	6.60	12.08	17.07	9.65	15.13	20.61	14.63	17.17	25.71	36.79
Payload (t)	6.5	13.0	15.0	11.5	18.0	24.5	26.5	40.0	51.5	76.5

Truck	Common 6 Axle Semi Trailer	
Class		9
Number of Vehicles		18
Size Length		19m
Unladen weight Metric Tonne		15.5
Laden Weight Metric Tonne		43.5
Number Of Axles		6
Maximum Tonnage Product		28
Average Tonnage Product		27
Daily Frequency per truck ave		1
Days per week		7
Route	Country South East Qld	
Weeks per year		52
	Common 6 Axle Semi Trailer Class (9)	Total Trips
Daily Trips	18	18
Weekly Trips	126	126
Yearly Trips	6552	6552

Daily Development SAR4s

Austroads vehicle class	Loaded		Unloaded			
	Daily Demand	SAR4_PER_VEH	SAR4_PER_DAY	Daily Demand	SAR4_PER_VEH	Loaded SAR4_PER_DAY
Common 6 Axle Semi Trailer Class (9)	18	0.55	9.920275699	18	0.51	9.254479628
Total	18	0.551126428	9.920275699	18	0.514137757	9.254479628

Yearly Development SAR4s

Austroads vehicle class	Loaded		Unloaded			
	Annual Demand	SAR4_PER_VEH	SAR5_PER_YEAR	Annual Demand	SAR4_PER_VEH	SAR4_PER_YEAR
Common 6 Axle Semi Trailer Class (9)	6552	0.551126428	3610.980355	6552	0.514137757	3368.630584
		Total (Both Ways)	3,610.98		Total (Both Ways)	3,368.63

Trigger Assessment

Direction	Trip%	Trips per Year	ESA per Veh		ESAs		Impact >5%	
			A	G	A	G	A	G
West - Gladstone – Mount Larcom Road (CH20.0 - CH32.14)	75%	9,828	0.51	0.55	5,012	5,405	NO	NO
East - Gladstone – Mount Larcom Road (CH20.0 - CH12.29)	25%	3,276	0.55	0.51	1,802	1,671	NO	NO
North – Bruce Highway (45.288-85.308)	50%	6,552	0.51	0.55	3,342	3,604	NO	NO
South – Bruche Highway (45.288-11.445)	25%	3,276	0.55	0.51	1,802	1,671	NO	NO

SAR by Austroads HV class

Class	Typical description	Dominant vehicle in each class
Medium (5.5m to 14.5m)		
3	Two axle truck	
4	Three axle truck	
5	Four axle truck	
Long (11.5m to 19.0m)		
6	Three axle articulated	
7	Four axle articulated	
8	Five axle articulated	
9	Six axle articulated (semi-trailer)	
Medium combination (17.5m to 36.5m)		
10	8 Double	
11	Double road train	
Large combination (over 33.0m)		
12	Triple road train	

Austroads vehicle class	9
Legal Loading (t)	42.5
Base Load per SAR4	37.7
Unloaded Axle Group Load (t)	16
Unloaded SAR4	0.51
Unloaded SAR5	0.41
Unloaded SAR12	0.11
Loaded Axle Group Load (t)	42.5
Loaded SAR4	4.93
Loaded SAR5	5.61
Loaded SAR12	14.63
Payload (t)	26.5

Notes
Disclaimers

Table 5 (Existing)

Annual average daily traffic data for sealed segments of the selected road sections

RoadName	ROAD_SECTION_ID	SUPERSET_CWAY	Direction	TdistStart	TdistEnd	SURFACE_TYPE_LABEL	AADT	AADT_YEAR	GROWTH_PC_5YR	AADT_NONHV	PERCENT_NONHV	AADT_HV	PERCENT_HV	ExistingSAR	
BRUCE HIGHWAY (BENARABY - RO 10E	1		A	0	11.445	SEALED	2807	2024	1.81	2047	72.92	760	27.08	2204	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		G	0	11.445	SEALED	2910	2024	2.62	2122	72.92	788	27.08	2285.2	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		A	11.445	45.288	SEALED	2494	2024	3.59	1827	73.25	667	26.75	1934.3	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		G	11.445	45.288	SEALED	2531	2024	3.51	1805	71.33	726	28.67	2105.4	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		A	45.288	45.42	SEALED	2494	2024	3.59	1827	73.25	667	26.75	1934.3	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		G	45.288	45.42	SEALED	2531	2024	3.51	1805	71.33	726	28.67	2105.4	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		A	45.42	46.017	SEALED	3146	2024	1.62	2287	72.7	859	27.3	2491.1	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		G	45.42	46.017	SEALED	3112	2024	1.81	2140	68.78	972	31.22	2818.8	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		A	46.017	85.308	SEALED	3146	2024	1.62	2287	72.7	859	27.3	2491.1	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		G	46.017	85.308	SEALED	3112	2024	1.81	2140	68.78	972	31.22	2818.8	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		A	85.308	87.08	SEALED	3918	2024	3	2954	75.39	964	24.61	2795.6	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		G	85.308	87.08	SEALED	3858	2024	3.02	3034	78.63	824	21.37	2389.6	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		A	87.08	108.938	SEALED	3676	2024	0.91	2949	80.22	727	19.78	2108.3	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		G	87.08	108.938	SEALED	3728	2024	1.73	2696	72.33	1032	27.67	2992.8	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		A	108.938	114.088	SEALED	2635	2024	-1.58	1739	66.01	896	33.99	2598.4	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		G	108.938	114.088	SEALED	2861	2024	-0.21	2076	72.56	785	27.44	2276.5	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		A	114.088	114.388	SEALED	2635	2024	-1.58	1739	66.01	896	33.99	2598.4	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		G	114.088	114.388	SEALED	2861	2024	-0.21	2076	72.56	785	27.44	2276.5	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		A	114.388	116.961	SEALED	5514	2024	1.89	4731	85.8	783	14.2	2270.7	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		G	114.388	116.961	SEALED	6009	2024	1.85	5222	86.9	787	13.1	2282.3	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		A	116.961	119.785	SEALED	10493	2024	4.9	8827	84.12	1666	15.88	4831.4	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		G	116.961	119.785	SEALED	11223	2024	4.29	9812	87.43	1411	12.57	4091.9	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		A	119.785	121.051	SEALED	10652	2024	5.25	9098	85.41	1554	14.59	4506.6	2.9
BRUCE HIGHWAY (BENARABY - RO 10E	1		G	119.785	121.051	SEALED	11267	2024	3.14	9611	85.3	1656	14.7	4802.4	2.9
GLADSTONE - MOUNT LARCOM RO 181	1		A	0	0.175	SEALED	5948	2024	12.29	5436	91.4	512	8.6	1638.4	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		G	0	0.175	SEALED	5650	2024	8.7	5150	91.15	500	8.85	1600	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		A	0.175	0.675	SEALED	6043	2024	12.27	5008	82.87	1035	17.13	3312	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		G	0.175	0.675	SEALED	5316	2024	8.02	4539	85.39	777	14.61	2486.4	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		A	0.675	1.4	SEALED	3574	2024	2.96	2955	82.68	619	17.32	1980.8	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		G	0.675	1.4	SEALED	3900	2024	1.58	3363	86.23	537	13.77	1718.4	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		A	1.4	2.277	SEALED	3657	2024	4.79	3206	87.67	451	12.33	1443.2	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		G	1.4	2.277	SEALED	3737	2024	5.28	3173	84.91	564	15.09	1804.8	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		A	2.277	3.2	SEALED	3657	2024	4.79	3206	87.67	451	12.33	1443.2	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		G	2.277	3.2	SEALED	3737	2024	5.28	3173	84.91	564	15.09	1804.8	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		A	3.2	3.26	SEALED	3657	2024	4.79	3206	87.67	451	12.33	1443.2	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		G	3.2	3.26	SEALED	3737	2024	5.28	3173	84.91	564	15.09	1804.8	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		A	3.26	3.37	SEALED	5144	2024	3.4	4127	80.22	1017	19.78	3254.4	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		G	3.26	3.37	SEALED	4186	2024	-2.57	3520	84.08	666	15.92	2131.2	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		A	3.37	3.756	SEALED	5144	2024	3.4	4127	80.22	1017	19.78	3254.4	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		G	3.37	3.756	SEALED	4186	2024	-2.57	3520	84.08	666	15.92	2131.2	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		A	3.756	3.892	SEALED	5144	2024	3.4	4127	80.22	1017	19.78	3254.4	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		G	3.756	3.892	SEALED	4186	2024	-2.57	3520	84.08	666	15.92	2131.2	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		A	3.892	4.625	SEALED	5144	2024	3.4	4127	80.22	1017	19.78	3254.4	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		G	3.892	4.625	SEALED	4186	2024	-2.57	3520	84.08	666	15.92	2131.2	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		A	4.625	7.063	SEALED	3230	2024	0.58	2559	79.24	671	20.76	2147.2	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		G	4.625	7.063	SEALED	3207	2024	-0.12	2592	80.83	615	19.17	1968	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		A	7.063	9.325	SEALED	3230	2024	0.58	2559	79.24	671	20.76	2147.2	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		G	7.063	9.325	SEALED	3207	2024	-0.12	2592	80.83	615	19.17	1968	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		A	9.325	12.29	SEALED	3230	2024	0.58	2559	79.24	671	20.76	2147.2	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		G	9.325	12.29	SEALED	3207	2024	-0.12	2592	80.83	615	19.17	1968	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		A	12.29	32.14	SEALED	2106	2024	8.81	1723	81.83	383	18.17	1225.6	3.2
GLADSTONE - MOUNT LARCOM RO 181	1		G	12.29	32.14	SEALED	2307	2024	10.94	1908	82.69	399	17.31	1276.8	3.2

RoadName	Direction	TdistStart	TdistEnd	2024 AADT	PERCENT	ESA/veh	2024 SAR	2027 AADT	2027 SAR
GLADSTONE - MOUNT LARCOM RO A	A	9.325	12.29	3,230	20.76	3.2	2,147	3,286	796,828
	G	9.325	12.29	3,207	19.17	3.2	1,968	3,195	715,480
	A	12.29	32.14	2,106	18.17	3.2	1,226	2,663	565,075
	G	12.29	32.14	2,307	17.31	3.2	1,277	3,064	619,514



Table 5 (DESIGN YEAR)																				
Annual average daily traffic data for sealed segments of the selected road sections																				
RoadName	ROAD_SECTION_ID	SUPERSET_CWAY	Direction	TdistStart	TdistEnd	SURFACE_TYPE_LABEL	AADT	AADT_YEAR	GROWTH_PC_5YR	AADT_NONHV	PERCENT_NONHV	AADT_HV	AADT_HV (5%)	PERCENT_HV	Design Year SAR per day	Design SAR per year	5% Trigger	SITE AV SAR	% Increase	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	A	0	11.445	SEALED	2,959	2,027	2	2,158	73	801	40	27	2,324	848,294	42,415	6,980	0.82%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	G	0	11.445	SEALED	3,139	2,027	3	2,289	73	850	42	27	2,465	899,690	44,985	6,980	0.78%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	A	11.445	45.288	SEALED	2,763	2,027	4	2,024	73	739	37	27	2,143	782,228	39,111	6,980	0.89%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	G	11.445	45.288	SEALED	2,798	2,027	4	1,995	71	802	40	29	2,326	848,967	42,448	6,980	0.82%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	A	45.288	45.42	SEALED	2,763	2,027	4	2,024	73	739	37	27	2,143	782,228	39,111	6,980	0.89%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	G	45.288	45.42	SEALED	2,798	2,027	4	1,995	71	802	40	29	2,326	848,967	42,448	6,980	0.82%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	A	45.42	46.017	SEALED	3,299	2,027	2	2,398	73	901	45	27	2,612	953,284	47,664	6,980	0.73%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	G	45.42	46.017	SEALED	3,281	2,027	2	2,257	69	1,024	51	31	2,971	1,084,245	54,212	6,980	0.64%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	A	46.017	85.308	SEALED	3,299	2,027	2	2,398	73	901	45	27	2,612	953,284	47,664	6,980	0.73%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	G	46.017	85.308	SEALED	3,281	2,027	2	2,257	69	1,024	51	31	2,971	1,084,245	54,212	6,980	0.64%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	A	85.308	87.08	SEALED	4,271	2,027	3	3,220	75	1,051	53	25	3,048	1,112,483	55,624	6,980	0.63%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	G	85.308	87.08	SEALED	4,208	2,027	3	3,308	79	899	45	21	2,608	951,750	47,588	6,980	0.73%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	A	87.08	108.938	SEALED	3,776	2,027	1	3,029	80	747	37	20	2,166	790,660	39,533	6,980	0.88%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	G	87.08	108.938	SEALED	3,921	2,027	2	2,836	72	1,085	54	28	3,147	1,148,551	57,428	6,980	0.61%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	A	108.938	114.088	SEALED	2,510	2,027	-	1,657	66	853	43	34	2,474	903,095	45,155	6,980	0.77%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	G	108.938	114.088	SEALED	2,843	2,027	-	0	2,063	73	780	39	27	2,262	825,749	41,287	6,980	0.85%
BRUCE HIGHWAY (BENARABY - RO)	10E	1	A	114.088	114.388	SEALED	2,510	2,027	-	1,657	66	853	43	34	2,474	903,095	45,155	6,980	0.77%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	G	114.088	114.388	SEALED	2,843	2,027	-	0	2,063	73	780	39	27	2,262	825,749	41,287	6,980	0.85%
BRUCE HIGHWAY (BENARABY - RO)	10E	1	A	114.388	116.961	SEALED	5,827	2,027	2	4,999	86	827	41	14	2,399	875,785	43,789	6,980	0.80%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	G	114.388	116.961	SEALED	6,342	2,027	2	5,512	87	831	42	13	2,410	879,473	43,974	6,980	0.79%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	A	116.961	119.785	SEALED	12,035	2,027	5	10,124	84	1,911	96	16	5,543	2,023,040	101,152	6,980	0.35%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	G	116.961	119.785	SEALED	12,667	2,027	4	11,075	87	1,592	80	13	4,618	1,685,441	84,272	6,980	0.41%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	A	119.785	121.051	SEALED	12,330	2,027	5	10,531	85	1,799	90	15	5,217	1,904,138	95,207	6,980	0.37%	
BRUCE HIGHWAY (BENARABY - RO)	10E	1	G	119.785	121.051	SEALED	12,328	2,027	3	10,516	85	1,812	91	15	5,256	1,918,285	95,914	6,980	0.36%	
GLADSTONE - MOUNT LARCOM RO	181	1	A	0	0.175	SEALED	8141.03	2027	12.29	7441	91.4	700	35	8.6	2,240	817,750	40,887	6,980	0.85%	
GLADSTONE - MOUNT LARCOM RO	181	1	G	0	0.175	SEALED	7124.65	2027	8.7	6494	91.15	631	32	8.85	2,018	736,461	36,823	6,980	0.95%	
GLADSTONE - MOUNT LARCOM RO	181	1	A	0.175	0.675	SEALED	8267.43	2027	12.27	6851	82.87	1416	71	17.13	4,532	1,654,134	82,707	6,980	0.42%	
GLADSTONE - MOUNT LARCOM RO	181	1	G	0.175	0.675	SEALED	6595.03	2027	8.02	5631	85.39	964	48	14.61	3,083	1,125,408	56,270	6,980	0.62%	
GLADSTONE - MOUNT LARCOM RO	181	1	A	0.675	1.4	SEALED	3891.37	2027	2.96	3217	82.68	674	34	17.32	2,157	787,215	39,361	6,980	0.89%	
GLADSTONE - MOUNT LARCOM RO	181	1	G	0.675	1.4	SEALED	4084.86	2027	1.58	3522	86.23	562	28	13.77	1,800	656,983	32,849	6,980	1.06%	
GLADSTONE - MOUNT LARCOM RO	181	1	A	1.4	2.277	SEALED	4182.51	2027	4.79	3667	87.67	516	26	12.33	1,650	602,342	30,117	6,980	1.16%	
GLADSTONE - MOUNT LARCOM RO	181	1	G	1.4	2.277	SEALED	4328.94	2027	5.28	3676	84.91	653	33	15.09	2,090	762,981	38,149	6,980	0.91%	
GLADSTONE - MOUNT LARCOM RO	181	1	A	2.277	3.2	SEALED	4182.51	2027	4.79	3667	87.67	516	26	12.33	1,650	602,342	30,117	6,980	1.16%	
GLADSTONE - MOUNT LARCOM RO	181	1	G	2.277	3.2	SEALED	4328.94	2027	5.28	3676	84.91	653	33	15.09	2,090	762,981	38,149	6,980	0.91%	
GLADSTONE - MOUNT LARCOM RO	181	1	A	3.2	3.26	SEALED	4182.51	2027	4.79	3667	87.67	516	26	12.33	1,650	602,342	30,117	6,980	1.16%	
GLADSTONE - MOUNT LARCOM RO	181	1	G	3.2	3.26	SEALED	4328.94	2027	5.28	3676	84.91	653	33	15.09	2,090	762,981	38,149	6,980	0.91%	
GLADSTONE - MOUNT LARCOM RO	181	1	A	3.26	3.37	SEALED	5668.69	2027	3.4	4547	80.22	1121	56	19.78	3,588	1,309,639	65,482	6,980	0.53%	
GLADSTONE - MOUNT LARCOM RO	181	1	G	3.26	3.37	SEALED	3863.26	2027	-2.57	3248	84.08	615	31	15.92	1,968	718,356	35,918	6,980	0.97%	
GLADSTONE - MOUNT LARCOM RO	181	1	A	3.37	3.756	SEALED	5668.69	2027	3.4	4547	80.22	1121	56	19.78	3,588	1,309,639	65,482	6,980	0.53%	
GLADSTONE - MOUNT LARCOM RO	181	1	G	3.37	3.756	SEALED	3863.26	2027	-2.57	3248	84.08	615	31	15.92	1,968	718,356	35,918	6,980	0.97%	
GLADSTONE - MOUNT LARCOM RO	181	1	A	3.756	3.892	SEALED	5668.69	2027	3.4	4547	80.22	1121	56	19.78	3,588	1,309,639	65,482	6,980	0.53%	
GLADSTONE - MOUNT LARCOM RO	181	1	G	3.756	3.892	SEALED	3863.26	2027	-2.57	3248	84.08	615	31	15.92	1,968	718,356	35,918	6,980	0.97%	
GLADSTONE - MOUNT LARCOM RO	181	1	A	3.892	4.625	SEALED	5668.69	2027	3.4	4547	80.22	1121	56	19.78	3,588	1,309,639	65,482	6,980	0.53%	
GLADSTONE - MOUNT LARCOM RO	181	1	G	3.892	4.625	SEALED	3863.26	2027	-2.57	3248	84.08	615	31	15.92	1,968	718,356	35,918	6,980	0.97%	
GLADSTONE - MOUNT LARCOM RO	181	1	A	4.625	7.063	SEALED	3286.2	2027	0.58	2604	79.24	682	34	20.76	2,183	796,828	39,841	6,980	0.88%	
GLADSTONE - MOUNT LARCOM RO	181	1	G	4.625	7.063	SEALED	3195.45	2027	-0.12	2583	80.83	613	31	19.17	1,960	715,480	35,774	6,980	0.98%	
GLADSTONE - MOUNT LARCOM RO	181	1	A	7.063	9.325	SEALED	3286.2	2027	0.58	2604	79.24	682	34	20.76	2,183	796,828	39,841	6,980	0.88%	
GLADSTONE - MOUNT LARCOM RO	181	1	G	7.063	9.325	SEALED	3195.45	2027	-0.12	2583	80.83	613	31	19.17	1,960	715,480	35,774	6,980	0.98%	
GLADSTONE - MOUNT LARCOM RO	181	1	A	9.325	12.29	SEALED	3286.2	2027	0.58	2604	79.24	682	34	20.76	2,183	796,828	39,841	6,980	0.88%	
GLADSTONE - MOUNT LARCOM RO	181	1	G	9.325	12.29	SEALED	3195.45	2027	-0.12	2583	80.83	613	31	19.17	1,960	715,480	35,774	6,980	0.98%	
GLADSTONE - MOUNT LARCOM RO	181	1	A	12.29	32.14	SEALED	2662.62	2027	8.81	2179	81.83	484	24	18.17	1,548	565,075	28,254	6,980	1.24%	
GLADSTONE - MOUNT LARCOM RO	181	1	G	12.29	32.14	SEALED	3064.16	2027	10.94	2534	82.69	530	27	17.31	1,697	619,514	30,976	6,980	1.13%	

Appendix I Response to State Code 21/Supporting information

State code 21: Hazardous chemical facilities

Planning guideline – State code 21: Hazardous chemical facilities provides direction on how to address this code.

Table 21.1: Material change of use

Performance outcomes	Response
Off-site impacts—vulnerable land use or land zoned for a vulnerable land use	
PO1 The hazardous chemical facility does not create a dangerous dose to human health .	Complies with PO1 The Euroa H2 Domestic Development project (situated in the Gladstone State Development Area - SDA) High Impact Precinct shall not create a dangerous dose to human health at vulnerable (PO1), sensitive (PO2) or commercial (PO3) land uses. The QRA (Euroa H2 Domestic Project QRA Rev 0_20_05_2025) demonstrates through consequence modelling coupled with established statistical risk-based methods that: - The QRA specifically prepared in accordance with the requirements of section 4 of the Planning Guide State Code 21. - Uses validated modelling approach using hydrogen-industry specific failure rates. - Includes failure rates from full bore (100% of total flow area) to small (0.01% of total flow area) failures. - Accidental high impact releases are coupled with their likelihood of failure using a parts-count method derived from the actual system bill-of-materials and hydrogen inventory. - Modelling undertaken using EFFECTS and RISKCURVES packages by Gexcon. - Includes the impact of fire walls and conservative assumptions for weather conditions. - Section 6.1.1 for the QRA shows that extents of dangerous doses to human health (12.6kW/m2 and 4.7kPa) from foreseeable major incidents do not extend into any vulnerable (PO1), sensitive (PO2) or commercial (PO3) land use. - The nearest vulnerable (PO1), sensitive (PO2) and commercial (PO3) land uses are located far enough away such that harmful events in the

	project boundary will not create dangerous doses to health or built environment. - Escalation studies, verification of plant item separation distances, as well as detailed assessment of onsite site risk (including of worker exposure through shift patterns) shall be undertaken during Detailed Design.
Off-site impacts—sensitive land use or land zoned for a sensitive land use	
PO2 The hazardous chemical facility does not create a dangerous dose to human health .	Complies with PO2 The Euroa H2 Domestic Development project (situated in the Gladstone State Development Area - SDA) High Impact Precinct shall not create a dangerous dose to human health at vulnerable (PO1), sensitive (PO2) or commercial (PO3) land uses. The QRA (Euroa H2 Domestic Project QRA Rev 0_20_05_2025) demonstrates through consequence modelling coupled with established statistical risk-based methods that: - The QRA specifically prepared in accordance with the requirements of section 4 of the Planning Guide State Code 21. - Uses validated modelling approach using hydrogen-industry specific failure rates. - Includes failure rates from full bore (100% of total flow area) to small (0.01% of total flow area) failures. - Accidental high impact releases are coupled with their likelihood of failure using a parts-count method derived from the actual system bill-of-materials and hydrogen inventory. - Modelling undertaken using EFFECTS and RISKCURVES packages by Gexcon. - Includes the impact of fire walls and conservative assumptions for weather conditions. - Section 6.1.1 for the QRA shows that extents of dangerous doses to human health (12.6kW/m² and 4.7kPa) from foreseeable major incidents do not extend into any vulnerable (PO1), sensitive (PO2) or commercial (PO3) land use. - The nearest vulnerable (PO1), sensitive (PO2) and commercial (PO3) land uses are located far enough away such that harmful events in the project boundary will not create dangerous doses to health or built environment. - Escalation studies, verification of plant item separation distances, as well as detailed assessment of onsite site risk (including of worker

	exposure through shift patterns) shall be undertaken during Detailed Design.
Off-site impacts—commercial or community activity land use or land zoned for a commercial or community activity land use	
PO3 The hazardous chemical facility does not create a dangerous dose to human health .	Complies with PO3 The Euroa H2 Domestic Development project (situated in the Gladstone State Development Area - SDA) High Impact Precinct shall not create a dangerous dose to human health at vulnerable (PO1), sensitive (PO2) or commercial (PO3) land uses. The QRA (Euroa H2 Domestic Project QRA Rev 0_20_05_2025) demonstrates through consequence modelling coupled with established statistical risk-based methods that: - The QRA specifically prepared in accordance with the requirements of section 4 of the Planning Guide State Code 21. - Uses validated modelling approach using hydrogen-industry specific failure rates. - Includes failure rates from full bore (100% of total flow area) to small (0.01% of total flow area) failures. - Accidental high impact releases are coupled with their likelihood of failure using a parts-count method derived from the actual system bill-of-materials and hydrogen inventory. - Modelling undertaken using EFFECTS and RISKCURVES packages by Gexcon. - Includes the impact of fire walls and conservative assumptions for weather conditions. - Section 6.1.1 for the QRA shows that extents of dangerous doses to human health (12.6kW/m² and 4.7kPa) from foreseeable major incidents do not extend into any vulnerable (PO1), sensitive (PO2) or commercial (PO3) land use. - The nearest vulnerable (PO1), sensitive (PO2) and commercial (PO3) land uses are located far enough away such that harmful events in the project boundary will not create dangerous doses to health or built environment. - Escalation studies, verification of plant item separation distances, as well as detailed assessment of onsite site risk (including of worker exposure through shift patterns) shall be undertaken during Detailed Design.
Off-site impacts—open space land use or land zoned for an open space land use	

PO4 The hazardous chemical facility, does not create: a. a dangerous dose to human health; or b. where (a) cannot be achieved, an individual fatality risk level of 10×10^{-6}/year and the societal risk criteria in figure 21.1.	Complies with PO4 The Euroa H2 Domestic Development project (situated in the Gladstone State Development Area - SDA) High Impact Precinct shall not create a dangerous dose to human health at open space land use (PO4). The QRA (Euroa H2 Domestic Project QRA Rev 0_20_05_2025) demonstrates through consequence modelling coupled with established statistical risk-based methods: - The QRA specifically prepared in accordance with the requirements of section 4 of the Planning Guide State Code 21. - Uses validated modelling approach using hydrogen-industry specific failure rates. - Includes failure rates from full bore (100% of total flow area) to small (0.01% of total flow area) failures. - Accidental high impact releases are coupled with their likelihood of failure using a parts-count method derived from the actual system bill-of-materials and hydrogen inventory. - Modelling undertaken using EFFECTS and RISKCURVES packages by Gexcon. - Includes the impact of fire walls and conservative assumptions for weather conditions. - Section 6.1.1 for the QRA shows that extents of dangerous doses to human health (12.6kW/m² and 4.7kPa) from foreseeable major incidents do not extend into any open space land use or land zoned for open space activity. - The QRA shows there is no dangerous dose from foreseeable major incidents at the Project Site which would extend into any open space land use or land zoned for open space activity. Since dangerous dose can be eliminated for this PO, societal risk is not applicable. - Escalation studies, verification of plant item separation distances, as well as detailed assessment of onsite site risk (including of worker exposure through shift patterns) shall be undertaken during Detailed Design
Off-site impacts—industrial land use or land zoned for an industrial land use	
PO5 The hazardous chemical facility, does not create either of the following: a. a dangerous dose to the built environment; and b. an individual fatality risk level of 50×10^{-6}/year.	Complies with PO5 The Euroa H2 Domestic Development project (situated in the Gladstone State Development Area - SDA) High Impact Precinct shall not create a dangerous dose to human health at industrial land use (PO5).

	- The individual fatality risk criteria are met since 50e-6 fatalities per year does not extend into any offsite industrial land use or land zoned for industrial activity. See QRA section 6.1.1. - However, when considering the worst-case scenarios of 1) compression inlet, hydrogen dispensers and tube trailer loading in the South-West side of the site boundary and 2) Storage management package to hydrogen interunit pipework and hydrogen storage impacting the South-Easter side of the site boundary; the contours of harmful dosages slightly exceed the site boundaries. - The QRA report Recommendation 1 is that an earth berm be implemented and verified for performance using CFD. - This earth berms already feature the FEED design in the South-East and South-West sides as recommended in the QRA and can be seen in the GA drawing 17695-SITE-GA-1001-01_L General Arrangement as well as fire system GAs which can be found in 17695-FIRE-RPT-1001. Their performance shall be validated against the QRA and PO5 during Detailed Design.
Storage and handling areas	
PO6 Storage and handling areas for fire risk hazardous chemicals are provided with a 24-hour monitored fire detection system that has the ability to detect a fire in its early stages and notify an emergency responder at all times.	Complies with PO6 The fire protection system shall be designed according to AS1670 and normative standards. The FEED stage design features a Fire and Explosion Risk Assessment (17695-FIRE-RPT-1001). This deliverable identifies key fire risks and safeguards for the facility. It features complimentary layers of technologies such a hydrogen, flame, thermal and smoke detection to mitigate fire hazards from hydrogen, as well as other flammable substances. - The current design also features safety systems such as ESTOP and ESD as detailed in 17695-CONT-SPS-1001_C Control Logic Narrative and 17695-PROC-RPT-B-HAZOP Report, as well as normative drawings. - The fire detection and alarm system shall be designed to operate 24/7/365 and will automatically notify emergency responders (Queensland Fire Department - QFD) automatically in case of any fire detected on the site premises. The detailed implementation design to be designed during Detailed Design. - The system will also feature appropriately rated SIL and redundant fire and gas detection and alarm system. It will be connected to UPS in case of power loss to the facility.

	- More generally Fire and Explosion Risk Assessment package (17695-FIRE-RPT-1001) showcases the Fire Services Functional Specification (17965-FIRE-SPC-1001). This document highlights how the FEED stage design complies with AS1670, NCC and local authority requirements, with IEC060331-25 complaint fibre optic cabling. The system shall feature heat/smoke detectors, flame detectors and point-type thermal detectors for various areas of the plant as shown in Fire System GAs 17695-FIRE-GA-1001 and related. - The alarm system design also features manual activation call points through several areas and combined with horns and visual warnings. - The monitoring system also features data gathering panels complete with fire detection & indicating equipment with networked cabling to the main facility control room; along with occupancy warning panels to facilitate evacuation. - This document also shows how hydrogen detection systems will be used in process critical areas such as the tube trailer filling and electrolyser areas. - The design of the fire system will be reviewed with QFD during the Detailed Design phase and their feedback shall be incorporated in the design. Their comments will form a key aspect of verification of the requirements of the design against required standards such as AS1670 and others as outlined in the Fire Services Functional Specification (17965-FIRE-SPC-1001). Furthermore, the system will also be verified for compliance and performance via an independent third party RPEQ system certifier.
PO7 Storage and handling areas for packages of liquid or solid fire risk hazardous chemicals are provided with a spill containment system with a working volume capable of containing a minimum of 100 percent of all packages (prescribed hazardous chemicals and/or non-hazardous chemicals) within the area plus the output of any fixed firefighting system provided for the area over a minimum of 90 minutes.	Conforms with PO7 The facility will store some limited quantities of flammable substances which are liquids in their storage state such as LPG for flaring, diesel fuel, transformer oil, lubricants, glycols for heat exchange and trace substances such as paints, paint thinners and strippers and others. - 17695-PROC-RPT-1004 B-HAZOP Report, and applicable drawings such as 17695-WAS-PFD-1001-01 (and related) as well as 17695-WAS-PID-1001-01 (and related) already identify key areas where bunding is required such as in Nodes 1, 5, 7, 11, 16, 19 and Overview. - These substances which could pose a fire risk shall be segregated from the main hydrogen process and design according to the requirements of AS1940 requirements. This can be further seen with the levels of monitoring and alarm found in Fire and Explosion Risk Assessment

	package (17695-FIRE-RPT-1001) along with the Fire Services Functional Specification (17965-FIRE-SPC-1001). - Given the limited volume of these substances on site, bunding and containment capacity calculations shall be undertaken and verified during Detailed Design ensuring full compliance to volumetric requirements, including 90mins of firewater as mandated by PO7 - 17695-PROC-RPT-1003_D Process Safety Specification will also be updated outline the key requirements for handling these substances and reinforce the design intent and operational requirements of spill containment systems. It will also show the intent of managing spillage of these substances during plant commissioning and operation. See response for PO9 for further details. - Fire and Explosion Risk Assessment package (17695-FIRE-RPT-1001) along with the Fire Services Functional Specification (17965-FIRE-SPC-1001) and related GAs show the locations of fire safety devices including fire water tanks, hose reels, firewater piping and similar.
PO8 Storage and handling areas for liquid or solid fire risk hazardous chemicals in tanks are provided with a spill containment system with a working volume capable of containing a minimum of: 110 percent of the largest tank within a spill compound or 25 percent of the aggregate where multiple tanks are located within a spill compound, whichever is the greater; and - the output of any fixed firefighting system provided for any bulk tank within a spill compound over a minimum of 90 minutes.	Conforms with PO8 Only applicable if large volumes of flammable liquids in tanks (vs packages like IBCs. Response depends on the largest liquid tank size or 25% of the aggregate - whichever is largest. - This project does not foresee large quantities of chemical stored in tanks. However, should this change, for and flammable substances stored in tanks, spill containment systems shall be designed such that 110% of the largest tank or 25% of the aggregate tank volume plus 90min of firewater. - Containment system designs such as bunded area and their capacity calculations will be conducted during detailed design phase and shall be compliant to AS1940. - 17695-PROC-RPT-1004_B-HAZOP Report, and applicable drawings such as 17695-WAS-PFD-1001-01 (and related) as well as 17695-WAS-PID-1001-01 (and related) already identify key areas where bunding is required such as in Nodes 1, 5, 7, 11, 16, 19 and Overview. - These substances which could pose a fire risk shall be segregated from the main hydrogen process and design according to the requirements of AS1940 requirements. This can be further seen with the levels of monitoring and alarm found in Fire and Explosion Risk Assessment package (17695-FIRE-RPT-1001) along with the Fire Services Functional Specification (17965-FIRE-SPC-1001).

	- Given the limited volumes of these substances on site, bunding and containment capacity calculations shall be undertaken and verified during Detailed Design ensuring full compliance to volumetric requirements, including 90mins of firewater as mandated by PO7/PO8 - 17695-PROC-RPT-1003_D Process Safety Specification will also be updated outline the key requirements for handling these substances and reinforce the design intent and operational requirements of spill containment systems. It will also show the intent of managing spillage of these substances during plant commissioning and operation. See response for PO9 for further details. - Fire and Explosion Risk Assessment package (17695-FIRE-RPT-1001) along with the Fire Services Functional Specification (17965-FIRE-SPC-1001) and related GAs show the locations of fire safety devices including fire water tanks, hose reels, firewater piping and similar.
PO9 Storage and handling areas for prescribed hazardous chemicals that, if in contact with each other, may react to produce a fire, explosion or other harmful reaction, or a flammable, toxic or corrosive vapour are designed to prevent contact between the prescribed hazardous chemicals.	Conforms with PO9 The project design philosophy prevents unintentional contact between reactive chemicals from a design, operational and risk assessment perspective. The principal reactive chemical hazard is the accidental contact between hydrogen and oxygen/air which as per the QRA (Euroa H2 Domestic Project QRA Rev 0_20_05_2025) can lead to considerable harm to people and equipment. - The plant items where this is most likely to occur have several layers of hazard detection to monitor for this such can be seen in several drawings comprising the Fire and Explosion Risk Assessment package (17695-FIRE-RPT-1001) and associated GAs. As mentioned previously, these drawings show the FEED-stage design for the fire monitoring system, with the Fire Services Functional Spec (17695-FIRE-SPC-1001) provides high levels of detail regarding the placement of devices to effectively mitigate fire hazards and considering detection and firefighting devices performance. - The design of the plant has significant segregation and isolation systems. Moreover, these segregable units form the basis of hydrogen inventory used in the QRA calculations (see section 2.3). - The plant layout also considers physical separation between plant items as shown in the NFPA2 drawing pack (17695-SITE-GA-1003-01_E NFPA 2 Group 1 Safety Spacing) - The Purging Procedure, which will be generated in Detailed Design, will showcase the specific steps the operator will use to isolate the system and subsystems, and purge any air using inert nitrogen gas

	- The detailed design will also include LOPA for SIL verification studies, SIS Design, finalised interlocks and detailed instrument specifications. It will also include documents such as: Updated Fire Safety studies, updated QRA for onsite risk and based on staffing and exposure for onsite risk during Detailed design, Operating Procedures, Emergency Response Procedures, Cause & Effects Matrix, Training and Competence Matrices, Commissioning Procedures, Detailed Drainage and Containment designs, Chemical Handling Procedures and finalised P&IDs will all be verified against the project risks and requirements of PO9.
PO10 Development is designed and sited to mitigate impacts on storage and handling areas from natural hazard including, but not limited to: - flood; - bushfire; - erosion; - storm tide inundation; - landslide; - earthquake; wind action.	Conforms with PO10 The Facility itself has a low exposure to natural hazards as determined with Economic Development Queensland and the project design will implement mitigating measures against all identified natural hazards including flooding, bushfire, seismic events, and wind loading as applicable during detailed design. Several FEED stage risk reviews have identified these such as the CHAIR and HAZOP. - As already identified in the HAZOP Overview Node items 33, 68, 67 and 70, Wind Loading and Earthquake actions have been taken into consideration in terms of structural design, which will be completed during Detailed Design and verified against AS/NZS1170.2 (Wind actions) and AS1170.4 (Earthquake actions). This will include generation of other deliverables such as: natural hazard reports, structural design specifications, drainage system design and specification and other mitigating measures as applicable. - Also, the CHAIR study (17695-PROC-RPT-1005) highlights in several areas such as Overview Node 3, 4, and 9 where high winds could cause damages. This report showcases several recommendations for this which will be included as part of the detailed design package. These include Flood, Geotech, Site Contaminants and Traffic Studies which will all be completed during detailed design - The detailed design will also highlight specific mitigating measures against Wind actions as stated. This will also include what flooding mitigations are included in drainage system design, which ties-in with PO6, PO7/PO8 and PO9.
All development	
PO11 Development is designed and sited to mitigate the risks from hazard scenarios occurring at existing hazardous chemical facilities .	Conforms with PO11

	The Project is in the Aldoga Precinct which is currently occupied by Stage 1 of FFI's GEM Facility. The Project has considered the siting of the currently operational and future stages of the GEM Facility. This will be inclusive of considering safety buffers and the implementation of controls to limit the impact of any incident which may affect local development. As other projects are developed in the surrounding precinct, there will be communication between developers to share details, including the offsite risks results from the QRA. The project shall also provide details on the frequency of hazardous substances such hydrogen tube trailer or flammable liquid patterns such that adjacent projects can include any relevant risks into their operations and vice versa. Assessment of external facility risks, communication protocols, and any required additional protective measures will be finalized during detailed design and into pre-commissioning. The emergency response plan will address coordination with neighbouring facilities and external emergency services.
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QUANTITATIVE RISK ASSESSMENT FOR THE EUROA HYDROGEN DOMESTIC PROJECT - GLADSTONE HYDROGEN PRODUCTION FACILITY

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Quantitative Risk Assessment for the Euroa Hydrogen Domestic Project - Gladstone Hydrogen Production Facility

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EXECUTIVE SUMMARY

Introduction

Vena Energy Australia (VENA) are proposing the Euroa H₂ Domestic Project at a designated site in Aldoga in the Gladstone region.

The Euroa H₂ Domestic Project is an integrated hydrogen electrolysis, hydrogen compression, storage and domestic distribution facility located approximately 18 kilometres west of the Gladstone CBD.

The project seeks to create an integrated hydrogen production and supply chain solution that will cater to the domestic and international markets.

UGL has commissioned Planager Pty Ltd (Planager) to prepare a Quantitative Risk Assessment (QRA) including determining the risk profile associated with the Euroa H₂ Domestic Project, as related to hazards and risks associated with hydrogen.

This QRA is prepared at the FEED-stage of the Euroa H₂ Domestic Project.

Overview of the risk assessment methodology

Hazards and risks are assessed in compliance with international methodology for such studies, including as specified in the ISO 31000:2009 - *Risk management - Principles and guidelines*. The study is conducted using a combined qualitative and quantitative approach to consequences and risks using internationally recognised consequence and risk modelling software tools and likelihood databases developed for the type of facility being assessed.

In this study software models Effects® and Riskcurves® (by Gexcon, previously developed by Dutch Government TNO) are used, and the methodology employed follow that in TNO's *Yellow* and *Purple* Books which are internationally recognised for such studies.

Hydrogen incident categorisation, failure rates and probabilities are based on the Hydrogen Risk Assessment Models (HyRAM) database.

Scope and aim

The aim of the FEED-stage QRA is to identify and assess the risk associated with high-consequence, low-probability events, so called *Major Incidents* (MIs), and ensure that these are in line with current criteria for land use planning in use in Queensland.

The study focuses on the acute effects of fires and explosions that could result in injury and fatality in case of a loss of containment or major event at the proposed facility.

The purpose of the FEED-stage QRA is to demonstrate that the proposed Euroa H₂ Domestic Project development is designed and sited, so far as reasonably practicable, to ensure:

- Human health and safety, and the built environment are protected from off-site risks resulting from physical or chemical hazards.

The FEED-stage QRA can be used to support internal and external stakeholder consultation, including with QLD Governmental Agencies as required.

Results and conclusions

This FEED stage QRA has found that the levels of hazards and risks from the Euroa H₂ Domestic Project can be managed within general Performance Outcomes defined in SDAP21, provided suitable fire and overpressure protection is implemented at the southwestern and southeastern boundaries of the site.

The individual fatality risk footprint of $50 \times 10^{-6}/\text{yr}$, associated with the Euroa H₂ Domestic Project, is fully contained within the site boundary.

The safety, efficiency and stability of the Euroa H₂ Domestic Project can be achieved through the use of high-level safety systems including automatic detection and protective measures and a regular preventative maintenance program.

The performance outcome of the project development against PO1 to PO5 is summarised in the table below, with detailed findings from consequence and risk assessments provided in the body of the report.

Table E1: Euroa H₂ Domestic Project Performance Outcomes PO1 to PO5 compliance

Land use	Performance outcomes		Euroa H ₂ Domestic Project compliance
	Dangerous dose	Risk assessment	
Vulnerable land use or land zoned for a vulnerable land use (childcare centre; community care centre; educational establishment; health care service; hospital; retirement facility)	<u>PO1, PO2 and PO3:</u>	Not applicable	The dangerous dose from foreseeable major incidents at the Euroa H ₂ Domestic Project development does not extend into any vulnerable, sensitive of commercial land use or land zoned for vulnerable, sensitive of commercial activity.
Sensitive land use or land zoned for a sensitive land use (community residence; dual occupancy; dwelling house; educational establishment; multiple dwelling; relocatable home park; residential care facility; rooming accommodation; short-term accommodation; tourist park)	The hazardous chemical facility does not create a dangerous dose to human health <u>with dangerous dose defined as follows:</u>		
Commercial or community activity land use or land zoned for a commercial or community activity land use (shopping centre; shop; office; major sport, recreation and entertainment facility; market; showroom; tourist attraction; entertainment facility; place of worship; community use; theatre)	For exposure to heat and/or overpressure from a fire or explosion: 4.7 kW/m ² and/or 7 kPa.		

Land use	Performance outcomes		Euroa H ₂ Domestic Project compliance
	Dangerous dose	Risk assessment	
Open space land use or land zoned for an open space land use (Outdoor sport and recreation; park; environment facility; rural industry)	<u>PO4:</u> The hazardous chemical facility does not create a dangerous dose to human health <u>with dangerous dose defined as follows:</u> For exposure to heat and/or overpressure from a fire or explosion: 4.7 kW/m² and/or 7 kPa	Where the dangerous dose cannot be eliminated, the individual fatality risk criteria of 10 x 10 ⁻⁶ /year and the societal risk criteria in Figure 21.1 of SDAP21	The dangerous dose from foreseeable major incidents at the Euroa H ₂ Domestic Project development does not extend into any open space land use or land zoned for open space activity.
Industrial land use or land zoned for an industrial land use (an extractive industry; a high impact industry; a low impact industry; a marine industry; a medium impact industry; a research and technology industry; a service industry; a special industry; a warehouse)	<u>PO5:</u> The hazardous chemical facility does not create a dangerous dose to the built environment <u>with dangerous dose defined as follows:</u> Exposure to heat and/or overpressure from a fire or explosion: 12.6 kW/m² and/or 14 kPa	The hazardous chemical facility does not create an individual fatality risk level of 50 x 10 ⁻⁶ /year	The dangerous dose from foreseeable major incidents at the Euroa H₂ Domestic Project development does not extend into any industrial land use or land zoned for industrial activity, with the exception of a worst-case release at the: • Compression inlet, dispensers and tube trailer loading impacting the southwestern boundary of the site • Storage Management Package to hydrogen storage interunit pipework and hydrogen storage impacting the southeastern boundary of the site. This will be addressed with the implementation of earth berms at the southwestern and southeastern boundary of the site (see recommendation 1). The individual fatality risk level of 50 x 10⁻⁶/year for the Euroa H₂ Domestic Project development does not extend into any off-site industrial land use or land zoned for industrial activity.

The individual fatality risk contour, associated with the Euroa H₂ Domestic Project development, is presented in Figure E1 below. The 50×10^{-6} per year fatality risk contour is contained within the project site, demonstrating compliance with Performance outcome PO5.

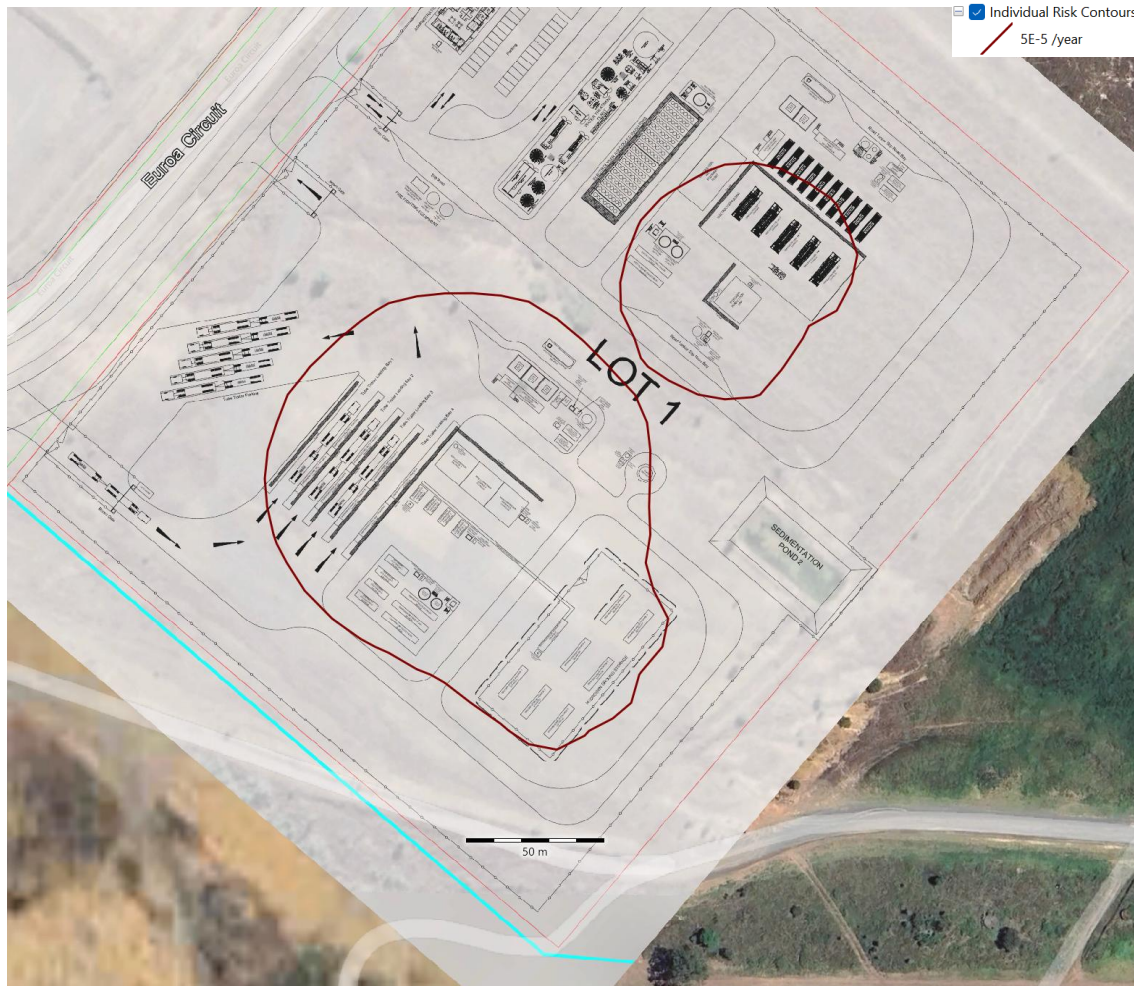


Figure E1: Individual risk contour for PO5, of 50×10^{-6} per year, for Euroa H₂ Domestic Project

Recommendations

It is recommended that the following safety considerations be included into the design process:

Recommendation 1: Review the requirements for fire and overpressure protection (e.g. implementation of earth berm) at the southwestern boundary and southeastern boundary of the site. Should an earth berm be installed, ensure a sizing review is completed during detailed design (consider use of CFD modelling when determining the design criteria).

Recommendation 2: Review the design of the safety instrumented systems during the detailed design phase using a Layer Of Protection Analysis (LOPA) methodology to ensure the required

SIL rating is achieved (inc. meeting the SIL requirements e.g. probability of failure on demand of the safety instrumented function).

Recommendation 3: This quantitative risk assessment has been developed using the design assumptions for risk reduction at the FEED stage. Key assumptions include:

- Automatic closure of isolation valves on process upset detection within system (e.g. due to a rupture or major leak causing a major loss of pressure)
- Automatic closure of isolation valves on gas (LEL) detection, gas leak detection and/or fire detection
- Double dissimilar non-return valves are provided in the process to prevent backflow of hydrogen in the event of isolation failure (provided as a minimum at the main compression, dispensing compression and hydrogen storage)
- Automatic blowdown valves are provided to relieve the gas inventory between isolatable sections to the flare header.

Other key assumptions are detailed in Appendix 1.

The quantitative risk assessment should be reviewed and risk reduction measures verified as part of the detailed design

GLOSSARY

BOM	Bureau Of Meteorology
CBD	Central Business District
CFD	Computational Fluid Dynamics
DA	Development Application
DCS	Distributed Control System
ESD	Emergency Shut-Down
FEED	Front End Engineering Design
F0.5	Pasquil stability condition “F” (stable wind weather) with 0.5 metres per second wind
HAZOP	Hazard and Operability Study
HMI	Human Machine Interfaces
HyRAM	Hydrogen Risk Assessment Models
LFL	Lower Flammability Limit
LOC	Loss Of Containment
LOPA	Layers Of Protection Analysis
MI	Major Incident
PFD	Probability of Failure on Demand
PO	Performance Outcome
QRA	Quantitative Risk Assessment
SDAP	State Development Assessment Provision
SFAIRP	So Far As Is Reasonably Practicable
SIL	Safety Integrity Level
TNO	Netherlands Organisation for Applied Scientific Research
UFL	Upper Flammability Limit
UPS	Uninterrupted Power Supply
VCE	Vapour Cloud Explosion
WHS	Work Health and Safety

REPORT

1 INTRODUCTION

1.1 BACKGROUND

Vena Energy Australia (VENA) are proposing the Euroa H₂ Domestic Project at a designated site in Aldoga in the Gladstone region.

The Euroa H₂ Domestic Project is an integrated hydrogen electrolysis, hydrogen compression, storage and domestic distribution facility located approximately 18 kilometres west of the Gladstone CBD.

The project seeks to create an integrated hydrogen production and supply chain solution that will cater to the domestic and international markets.

UGL has commissioned Planager Pty Ltd (Planager) to prepare a Quantitative Risk Assessment (QRA) including determining the risk profile associated with the Euroa H₂ Domestic Project, as related to hazards and risks associated with hydrogen.

This QRA is prepared at the FEED-stage of the Euroa H₂ Domestic Project.

1.2 SCOPE AND AIM OF THE STUDY

This QRA is carried out at the FEED-stage of the facility.

The aim of the FEED-stage QRA is to identify and assess the risk associated with high-consequence, low-probability events, so called *Major Incidents* (MIs), and ensure that these are in line with current criteria for land use planning in use in Queensland.

The study focuses on the acute effects of fires and explosions that could result in injury and fatality in case of a loss or major event at the proposed facility (usually associated with a loss of containment (LOC) event).

The scope includes all plant and equipment where hydrogen is generated and produced, handled and stored, as these will have major hazard implications to the site.

1.3 PURPOSE STATEMENT

The purpose of the FEED-stage QRA is to demonstrate that the proposed Euroa H₂ Domestic Project development is designed and sited, so far as reasonably practicable, to ensure:

- Human health and safety, and the built environment are protected from on-site risks resulting from physical or chemical hazards;

The above statement consists of point one of the *Purpose statement* in State Code 21^{Ref 2} (SDAP21) for hazardous chemical facilities¹. Offsite hazard scenarios at existing hazardous chemical facilities and natural hazards are outside of the scope of this QRA.

1.4 METHODOLOGY AND REPORT STRUCTURE

The methodology for the risk assessments is well established in Australia. The Hazard Analysis has been carried as per the ISO 31000:2009 - *Risk management - Principles and Guidelines*^{Ref 1}.

It aligns with the methodology for Hazard Analysis in SDAP21 including as described in the guidance Planning guideline for *State code 21: Hazardous chemical facilities*^{Ref 2}.

An overview of the ISO 31000 methodology is depicted in Figure 1-1 and described below.

¹ From SDAP21: A hazardous chemical facility (HCF) means the use of premises for a facility at which a prescribed hazardous chemical is present or likely to be present in a quantity that exceeds 10 per cent of the chemical's threshold quantity under schedule 15 of the Work Health and Safety Regulation 2011. For hydrogen (UN number 1049) the threshold is 50 tonnes and 10% of the threshold is 5 tonnes.

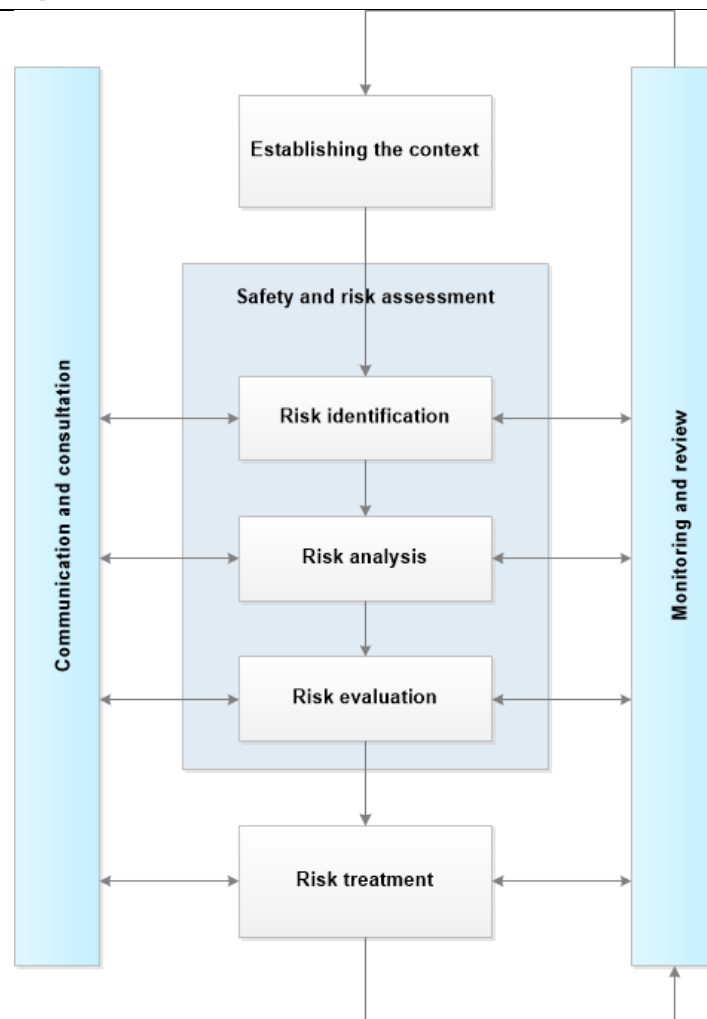


Figure 1-1: General risk management framework

The study is conducted using a combined qualitative and quantitative approach to consequences and risks using internationally recognised consequence and risk modelling software tools and likelihood databases developed for the type of facility being assessed, as follows:

- The *Context* for the study is described in Sections 1.4 to 1.7 and Section 2.
- The *Risk identification* is described in Section 3. The process for this Project involved desktop assessment carried out by Planager, considering available information against known loss of containment, fire and explosion incidents that have occurred generally in industry and as available in databases. Further hazard identification studies would need to be undertaken as part of the design process, including evaluation of layouts to minimise risk of confinement or congestion of hydrogen gas and incident propagation and detailed Hazard and Operability (HAZOP) studies.
- *Risk analysis* conducted for this assessment is a combination of qualitative and quantitative assessment. In accordance with SDAP21^{Ref 2} the risk analysis consists of (1) an assessment of the off-site *dangerous dose to human safety and the built environment* (Section 4) and (2) an analysis of the risk levels to human safety (Section 5).

The software tool developed by the Dutch Government TNO (the Netherlands Organisation for Applied Scientific Research) and commercialised by Gexcon®, entitled Effects® are used for all assessment of the dangerous doses. The software tool allows for calculations of dispersion, jet and pool fire, vapour cloud explosions and flash fires associated with releases of hazardous material to atmosphere. It is developed based on the TNO “Yellow Book”^{Ref 3}.

To characterise the range of leaks that may occur from the different equipment items typically presented within this type of facility, a set of representative hole sizes are defined and used in the consequence calculations, as defined in the database documented in the Hydrogen Risk Assessment Models (HyRAM^{Ref 4}) database.

Following assessment of incident consequence, events may need to be carried forward for frequency analysis and risk assessment as per the methodology for Hazard Analysis in SDAP21. The software tool entitled Riskcurves® (TNO / Gexcon®) was used to calculate risk levels in this study.

- *Risk evaluation* consists of evaluating the performance of the Euroa H₂ Domestic Project against the performance outcomes (PO1 to PO5) in SDAP21^{Ref 2}. The risk evaluation for this study is presented in Section 6.
- *Monitoring and review*: This is the first quantitative risk assessment conducted for the Euroa H₂ Domestic Project and is based on FEED-stage design information. As the Project design progresses, the assessment should be reviewed to ensure the performance outcomes are adhered to. Further, risk to people onsite and offsite would need to be critically evaluated and demonstrated to adhere to So Far As Reasonably Practicable (SFARP) principles.
- *Communication and consultation*: Stakeholder engagement is required as part of the Euroa H₂ Domestic Project development.

1.5 RISK AND CRITERIA

1.5.1 Performance outcomes for off-site impact at neighbouring land use

The performance outcomes (POs) associated with siting of potentially hazardous facilities in relation to surrounding land use are summarised in the table below, as sourced from SDAP21^{Ref 2}.

Table 1: Performance outcomes for off-site outcomes at neighbouring land use (SDAP21)

Land use	Performance outcomes	
	Consequence screening	Maximum fatality risk level
Vulnerable land use or land zoned for a vulnerable land use (childcare centre; community care centre; educational establishment; health care service; hospital; retirement facility)	<u>PO1, PO2 and PO3:</u> The hazardous chemical facility does not create a	

Land use	Performance outcomes	
	Consequence screening	Maximum fatality risk level
Sensitive land use or land zoned for a sensitive land use (community residence; dual occupancy; dwelling house; educational establishment; multiple dwelling; relocatable home park; residential care facility; rooming accommodation; short-term accommodation; tourist park)	dangerous dose to human health <u>with dangerous dose defined as follows:</u> For exposure to heat and/or overpressure from a fire or explosion: 4.7 kW/m ² and/or 7 kPa.	
Commercial or community activity land use or land zoned for a commercial or community activity land use (shopping centre; shop; office; major sport, recreation and entertainment facility; market; showroom; tourist attraction; entertainment facility; place of worship; community use; theatre)		
Open space land use or land zoned for an open space land use (outdoor sport and recreation; park; environment facility; rural industry)	<u>PO4:</u> The hazardous chemical facility does not create a dangerous dose to human health <u>with dangerous dose defined as follows:</u> For exposure to heat and/or overpressure from a fire or explosion: 4.7 kW/m ² and/or 7 kPa	OR, if not achievable An individual fatality risk level of 10 × 10 ⁻⁶ /year AND Societal risk from figure 21.1 in SDAP21
Industrial land use or land zoned for an industrial land use (an extractive industry; a high impact industry; a low impact industry; a marine industry; a medium impact industry; a research and technology industry; a service industry; a special industry; a warehouse)	<u>PO5:</u> The hazardous chemical facility does not create a dangerous dose to the built environment <u>with dangerous dose defined as follows:</u> Exposure to heat and/or overpressure from a fire or explosion: 12.6 kW/m ² and/or 14 kPa	AND An individual fatality risk level of 50 × 10 ⁻⁶ /year

1.6 SAFETY MANAGEMENT

Quantitative risk assessments can only be a valid tool for assisting in the overall assessment of a site if the facility being examined is or will be subject to appropriate management control of hazards.

Without such control, the assumptions inherent to quantitative techniques become invalid in two general areas. First, the identification of hazards is based on experience in similar installations and on engineering judgement - without proper management control of safety issues, the range and impact of potential hazards becomes unpredictable. Second, the frequency at which incidents of any type may occur cannot be adequately estimated using historical data.

Safety management systems allow the risk from potentially hazardous installations to be minimised by a combination of hard controls and soft controls. It is essential to ensure that the reliability of the systems and procedures used to assure the safe operation of the facility are of the highest standards.

This study assumes that an effective Safety Management System will be implemented at the Euroa H₂ Domestic Project site.

1.7 MAJOR ASSUMPTIONS

The FEED-stage QRA is conducted with a number of major assumptions as listed below. These assumptions consist of essential safety requirements which are not individually listed:

- Plant will be under competent management and the control room will be staffed 24/7.
- Plant will be operated and maintained in accordance with good practice by experienced, competent, and qualified workers.
- Plant will be inspected and maintained in good working order:
 - all items will be included in a maintenance system with specific routines and frequencies nominated.
 - plant and equipment, including critical control functions such as control loops, will be tested regularly and maintained in good working order.
 - faulty controls will be replaced.
- Plant will be operated at or below design rates and process conditions.
- Changes to plant will be investigated using robust Management of Change process.

These tasks will be integrated within the Safety Management System.

2 DESCRIPTION OF THE PROJECT

2.1 DESCRIPTION OF PLANT AND OPERATION AT FEED

The Project location, as known at the FEED-stage, is shown in Figure 2-1. A FEED-stage block flow diagram with major process components shown is shown in Figure 2-2.

The project's main infrastructure systems are:

- *Hydrogen Production System:* Hydrogen production system, including an electrolysis plant.
- The hydrogen production system includes 50 MW hydrogen gas electrolysis facility including water purification, de-oxidation, dehydration, and hydrogen gas compression, storage and dispensing components.
- *Hydrogen Storage and Compression:* The hydrogen gas will be compressed and stored on site to allow continuous supply of hydrogen gas to tube trailers with intermittent operation of the electrolyzers.
- *Hydrogen Distribution:* Four (4) hydrogen tube trailer loading bays are provided to facilitate distribution of compressed gas into tube trailers.

The proposed site is located approximately 18km west of the Gladstone CBD in the Aldoga locality within the Gladstone region.

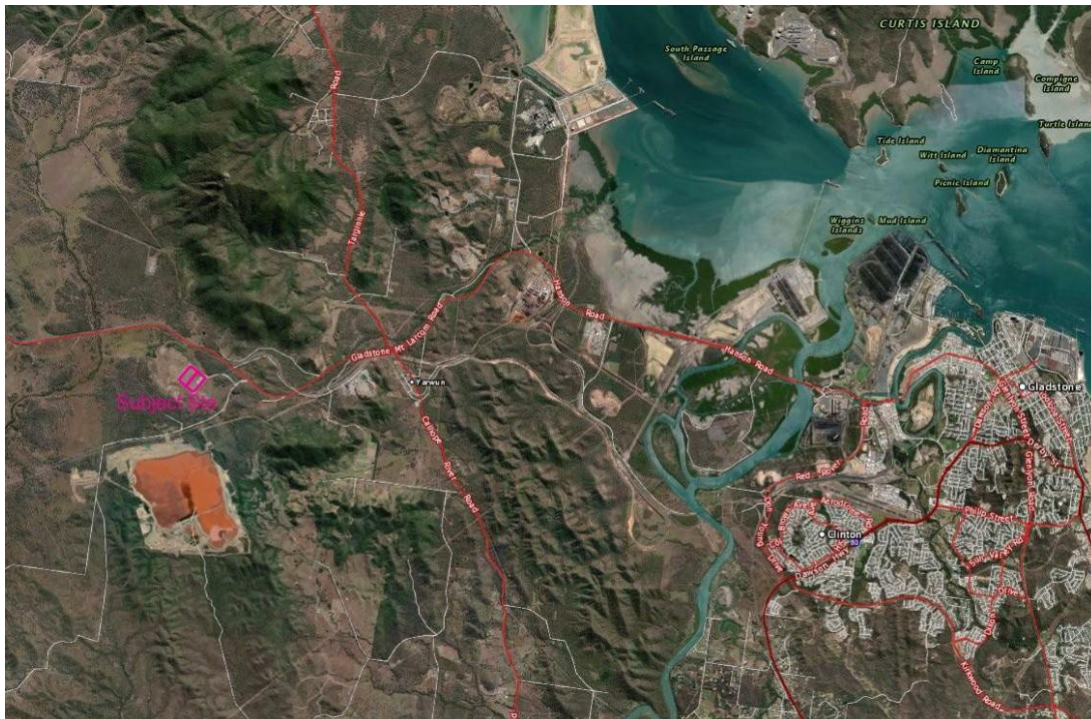
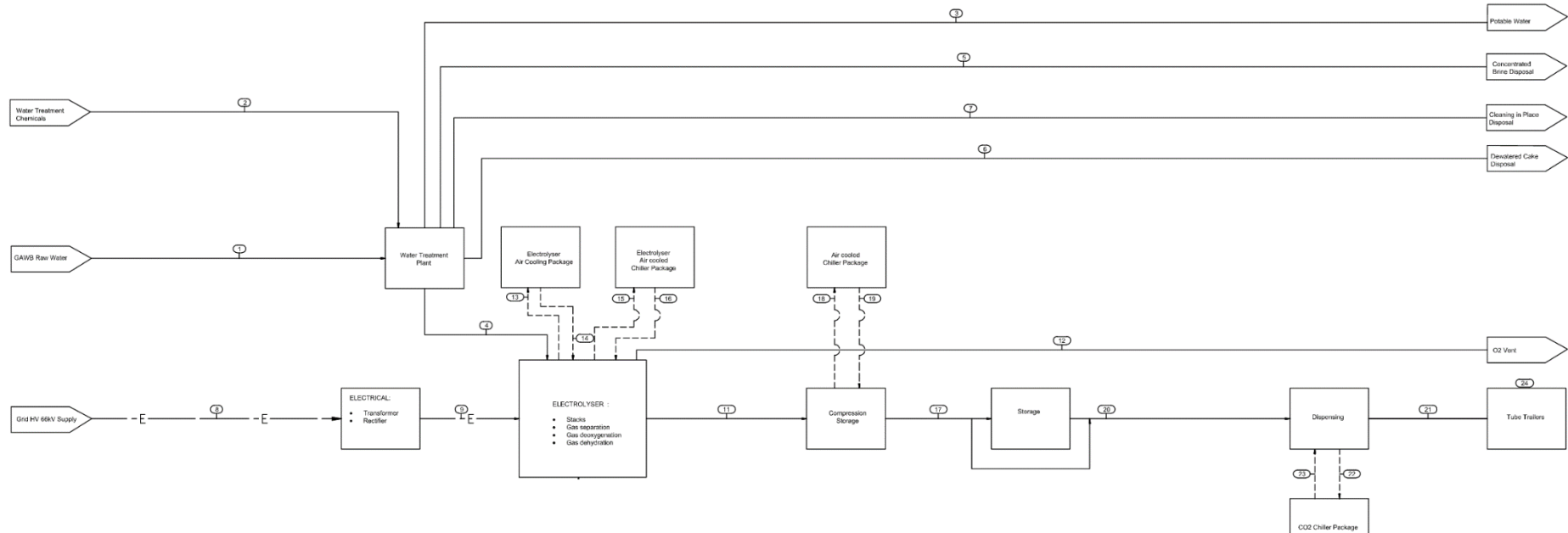


Figure 2-1: Site Location

Figure 2-2: FEED block flow diagram



2.2 LAND USE

The proposed location is within an area which has been zoned for industrial use. As this stage there are some non-developed areas adjacent to the site but none are zoned as per the definition of open space in SDAP21.

2.3 SIGNIFICANT DESIGN ASSUMPTIONS AND PARAMETERS

All data used in the present QRA is for a plant operating 100% of the time and with all pipes, vessels and tanks pressurised and full to capacity 100% of the time, with the exception of intermittent operations which have been considered at 100% of their design capacity.

Major design assumptions and parameters for the hydrogen plant and equipment for the Euroa H₂ Domestic Project are detailed in Table 2 and Table 3, with the isolatable areas shown in Figure 2-3.

Table 2: Major design assumptions

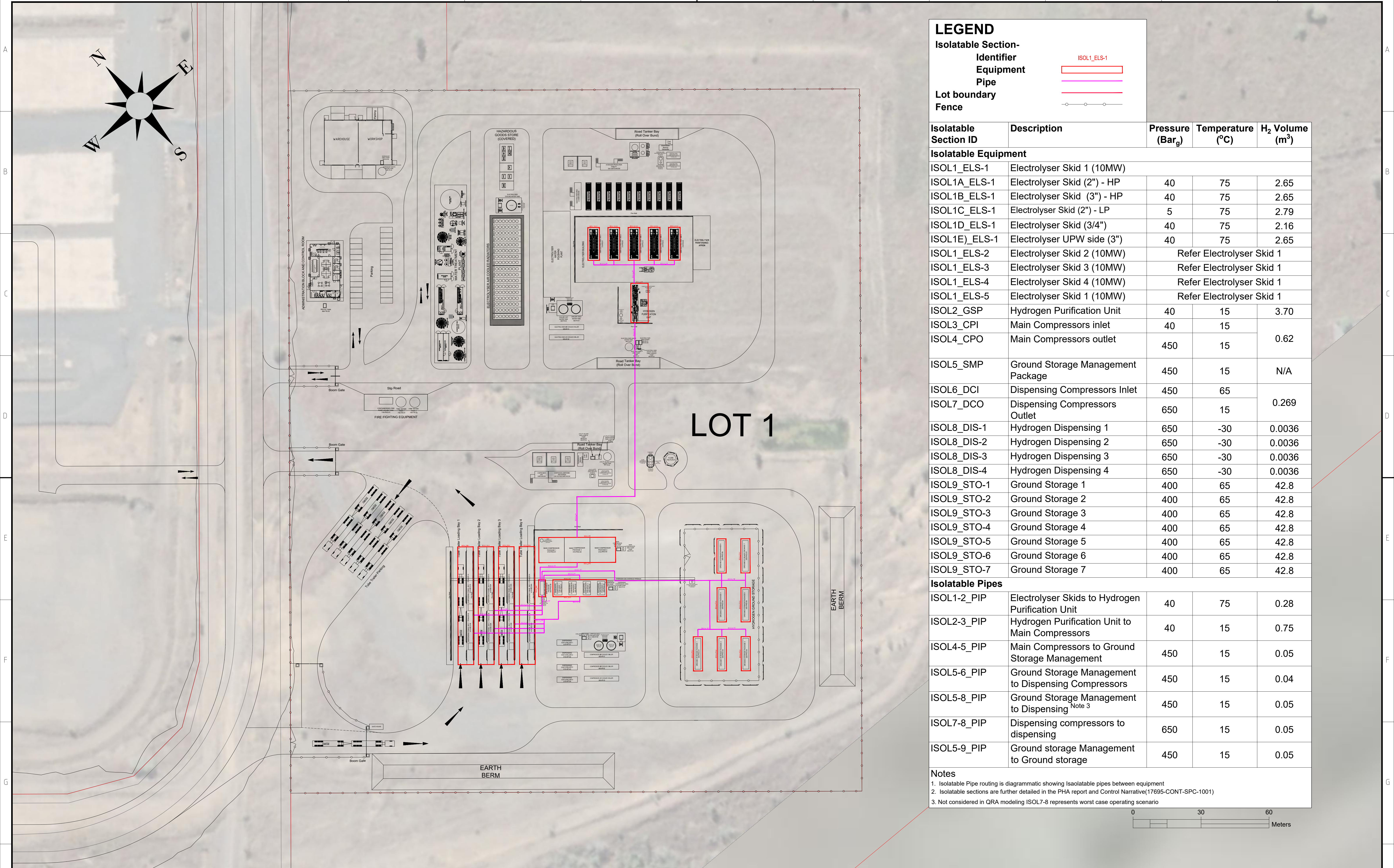
Item	Detail
Materials assessed in the QRA	Hydrogen – major hazard potential
Other hazards	Electricity (including transmission line and connection point infrastructure) WHS type hazards (work at heights, confined space, pressure equipment, moving machinery, rotating machinery etc.). These hazards are outside of the scope of this QRA
Pipe, vessels and storage material	Preliminary details in FEED design
Isolation System(s)	Full remote control of automatic isolation valves from control room and via key trips (to be defined in detailed design)
Control Measures	Hydrogen awareness programs, Standard Operating Procedures and competency training. Site patrols / tours, signage, maintenance inspections and preventative maintenance programs, in line with manufacture recommendations. These systems will be implemented on the site.

Table 3: Major design parameters (per individual unit)

Isolatable section code	Isolatable section, title and colour coding (refer to PRELIMINARY HAZARD ASSESSMENT ISOLATABLE SECTIONS)	Outside Diameter (mm)	Pressure (bar g)	Temp (°C)	Length of pipe (m)	Approx. volume of isolatable section (m ³)	Pipe location (Above / Under ground)
ISOL1A_ELS	Electrolyser Skid (2" pipe) – High Pressure side	50.8	40	75	39.5	2.65	AG
ISOL1B_ELS	Electrolyser Skid (3" pipe) – High Pressure side	76.2	40	75	39.5	2.65	AG

Isolatable section code	Isolatable section, title and colour coding (refer to PRELIMINARY HAZARD ASSESSMENT ISOLATABLE SECTIONS)	Outside Diameter (mm)	Pressure (bar g)	Temp (°C)	Length of pipe (m)	Approx. volume of isolatable section (m ³)	Pipe location (Above / Under ground)
ISOL1C_ELS	Electrolyser Skid (2" pipe) – Low Pressure side	50.8	5	75	25	2.79	AG
ISOL1D_ELS	Electrolyser Skid (3/4" pipe)	19.05	40	75	21	2.65	AG
ISOL1E_ELS	Electrolyser Ultrapure Water side (3" pipe)	76.2	40	75	55	2.65	AG
ISOL1-2_PIP	Electrolyser to purification interunit pipework	76.2	40	75	62	0.28	UG
ISOL2_GSP	Gas Purifier	76.2	40	15	150	4.00	AG
ISOL2-3_PIP	Purification to compression interunit pipework	76.2	40	15	165	0.75	UG
ISOL3_CPI	Compression inlet	76.2	40	15	18	0.31	AG
ISOL4_CPO	Compression outlet	25.4	450	15	5	0.31	AG
ISOL4-5_PIP	Compression to storage management interunit pipework	25.4	450	15	90	0.05	AG
ISOL5_SMP	Storage management Package	25.4	450	15	20	0.01	AG
ISOL5-6_PIP	Storage management to dispensing compression interunit pipework	25.4	450	15	78	0.04	AG
ISOL6_DCI	Dispensing compression inlet	25.4	450	15	7	0.15	AG
ISOL7_DCO	Dispensing compression outlet	25.4	650	15	8	0.15	AG
ISOL7-8_PIP	Dispensing compression to dispensing bay interunit pipework	25.4	650	15	105	0.05	AG
ISOL8_DIS	Dispensers	25.4	650	-30	7.2	0.004	AG
ISOL5-9_PIP	Storage management to storage pipework	25.4	450	15	91	0.05	AG
ISOL9_STO	Storage	25.4	400	25	20	42.8	AG
ISOL10_TUB	Tube trailer inc. loading hose	25.4	517	-30	10	19.4	AG

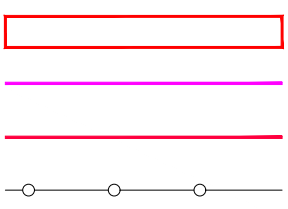
Figure 2-3: PRELIMINARY HAZARD ASSESSMENT ISOLATABLE SECTIONS, 17695-SITE-GA-1005-01



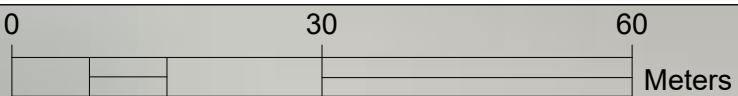
LEGEND

Isolatable Section-
Identifier
Equipment
Pipe
Lot boundary
Fence

ISOL1_ELS-1



Isolatable Section ID	Description	Pressure (Bar _g)	Temperature (°C)	H ₂ Volume (m ³)
Isolatable Equipment				
ISOL1_ELS-1	Electrolyser Skid 1 (10MW)			
ISOL1A_ELS-1	Electrolyser Skid (2") - HP	40	75	2.65
ISOL1B_ELS-1	Electrolyser Skid (3") - HP	40	75	2.65
ISOL1C_ELS-1	Electrolyser Skid (2") - LP	5	75	2.79
ISOL1D_ELS-1	Electrolyser Skid (3/4")	40	75	2.16
ISOL1E)_ELS-1	Electrolyser UPW side (3")	40	75	2.65
ISOL1_ELS-2	Electrolyser Skid 2 (10MW)	Refer Electrolyser Skid 1		
ISOL1_ELS-3	Electrolyser Skid 3 (10MW)	Refer Electrolyser Skid 1		
ISOL1_ELS-4	Electrolyser Skid 4 (10MW)	Refer Electrolyser Skid 1		
ISOL1_ELS-5	Electrolyser Skid 1 (10MW)	Refer Electrolyser Skid 1		
ISOL2_GSP	Hydrogen Purification Unit	40	15	3.70
ISOL3_CPI	Main Compressors inlet	40	15	0.62
ISOL4_CPO	Main Compressors outlet	450	15	
ISOL5_SMP	Ground Storage Management Package	450	15	N/A
ISOL6_DCI	Dispensing Compressors Inlet	450	65	0.269
ISOL7_DCO	Dispensing Compressors Outlet	650	15	
ISOL8_DIS-1	Hydrogen Dispensing 1	650	-30	0.0036
ISOL8_DIS-2	Hydrogen Dispensing 2	650	-30	0.0036
ISOL8_DIS-3	Hydrogen Dispensing 3	650	-30	0.0036
ISOL8_DIS-4	Hydrogen Dispensing 4	650	-30	0.0036
ISOL9_STO-1	Ground Storage 1	400	65	42.8
ISOL9_STO-2	Ground Storage 2	400	65	42.8
ISOL9_STO-3	Ground Storage 3	400	65	42.8
ISOL9_STO-4	Ground Storage 4	400	65	42.8
ISOL9_STO-5	Ground Storage 5	400	65	42.8
ISOL9_STO-6	Ground Storage 6	400	65	42.8
ISOL9_STO-7	Ground Storage 7	400	65	42.8
Isolatable Pipes				
ISOL1-2_PIP	Electrolyser Skids to Hydrogen Purification Unit	40	75	0.28
ISOL2-3_PIP	Hydrogen Purification Unit to Main Compressors	40	15	0.75
ISOL4-5_PIP	Main Compressors to Ground Storage Management	450	15	0.05
ISOL5-6_PIP	Ground Storage Management to Dispensing Compressors	450	15	0.04
ISOL5-8_PIP	Ground Storage Management to Dispensing ^{Note 3}	450	15	0.05
ISOL7-8_PIP	Dispensing compressors to dispensing	650	15	0.05
ISOL5-9_PIP	Ground storage Management to Ground storage	450	15	0.05
Notes				
1. Isolatable Pipe routing is diagrammatic showing Isolatable pipes between equipment				
2. Isolatable sections are further detailed in the PHA report and Control Narrative(17695-CONT-SPC-1001)				
3. Not considered in QRA modeling ISOL7-8 represents worst case operating scenario				



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		C REVISED		BW	IM	BW	IM	SHB	05/05/2025
		B REVISED		BW	IM	BW	IM	SHB	30/04/2025
		A ISSUED FOR REVIEW		BW	IM	BW	SHB		04/04/25
REV		AMENDMENT DETAILS		DESIGN	CHK'D	DRAWN	CHK'D	APP'D	DATE

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DESIGNED	BW	VENA ENERGY HYDROGEN PROJECT	
CHECKED	IM	HYDROGEN PRODUCTION PLANT	
DRAWN	BW	STAGE 1: FEED STUDY 50MW ELECTROLYZER	
CHECKED	SHB	PRELIMINARY HAZARD ASSESSMENT	
APPROVED	SHB	ISOLATABLE SECTIONS	
A1	NTS	CLIENT VENA ENERGY	UGL DRAWING No 17695-SITE-GA-1005-01
			SHEET 01
			REV D

CONFIRM SCALE

100mm ON A1 ORIGINAL

2.4 OPERATING PARAMETERS

2.4.1 Operating hours

The Euroa H₂ Domestic Project site would operate continuously with on-site personnel 24 hour per day 365 days per year.

2.4.2 Operational Workforce

The site operation would be managed by a Site Manager and would consist of multiple teams which would include Plant shift operators, Maintenance staff, Engineering staff and Administrative Support staff. Plant shift operations would typically be led by the Operations Team leader who would be responsible for site operations in the absence of the Site Manager.

Staffing levels and shift team composition would be determined based on benchmarking and good operating practice.

2.5 FACILITY SAFEGUARDING SYSTEMS

2.5.1 Plant control

A Central Control Room would be used to control and monitor the facility via various Human Machine Interfaces (HMI). It would be continuously staffed by trained and competent operators (24/7).

A Distributed Control System (DCS) would be installed on site to manage the control systems of plant and processes. The DCS would control process alarms and shut-down, fire and gas detection and alarms, and Emergency Shutdown functions. Critical control functions would operate independently of each other and the Central Control Room.

Critical control functions would operate on battery backup so that, in the event of a total power failure, operators are enabled to shut down the plant in a completely controlled and safe manner. After a set duration, the plant would fail automatically in a safe manner if the main power supply is not restored.

2.5.2 Power supply

Mains power to the facility would be supplied to the site, e.g. via a Substation. IA stand-by generator is be installed to provide backup power for the emergency systems; and an Uninterrupted Power Supply (UPS) will provide backup power to critical control functions, the Control Room, egress lighting, and security.

2.5.3 Venting and flaring operations

It is assumed that hydrogen gas venting would be included in the Euroa H₂ Domestic Project, with hydrogen gas vented to the flare header. Hydrogen venting is expected to be undertaken under the following circumstances:

- Compressor unit blowdown (via blowdown valves on individual compressor units)
- During plant start-ups and shut-down, and plant commissioning
- Emergency blowdown following emergency shut-down (ESD) at each isolatable section
- Plant and vessel overpressure relief

2.5.4 Fire prevention and protection

Fire detection, gas (LEL) detection, and gas leak detection systems

Fire detection, gas (LEL) detection and gas leak detection systems would be installed, capable of providing indication of the existence of fire or flammable gas, and the means to initiate appropriate executive actions. Gas leak detection would be installed on all above ground hydrogen piping.

A process upset detection from pressure transmitters (e.g. due to a rupture or major leak causing a major loss of pressure) would also be installed.

The detection system(s) would receive signals from detection equipment located around the facility providing alarms to the operators via the control room HMI.

Automatic shutdowns of electrical equipment (motors and valves) within a zoned area would be included, as defined during the detailed design phase.

Fire protection systems

Fighting a fire involving hydrogen involves first and foremost isolation of the source (usually by closing valves on either side of the leak). Isolation is achieved at each isolatable section through the following:

- Automatic closure of isolation valves on process upset detection within system (e.g. due to a rupture or major leak causing a major loss of pressure)
- Automatic closure of isolation valves on gas (LEL) detection, gas leak detection or fire detection
- Double dissimilar non-return valves are provided in the process to prevent backflow of hydrogen in the event of isolation failure (provided as a minimum at the main compression, dispensing compression and hydrogen storage)

In addition, automatic blowdown valves are provided to relieve the gas inventory between the isolatable section to the flare header.

Fire walls are provided at the electrolyser building, hydrogen purification unit, main compression area and in between each tube trailer loading bay.

The main purpose of a firewater system in the event of a fire is to cool adjacent structures and plant to prevent propagation of the event to other parts of the facility.

The need for cooling or fire water would be assessed during the detailed design phase.

2.5.5 Emergency management

An Emergency Response Plan would be prepared for the Project in collaboration with emergency services. The Emergency Response Plan and procedures would include measures to evacuate the workforce and, if required, adjacent industrial facilities. The Emergency Response Plan would include a communication strategy which would address the need to communicate with other parties, e.g. neighbouring facilities in the vicinity of the site in the event of an emergency.

The appropriate government agencies would be consulted to provide input to the Emergency Response Plan.

2.5.6 Security management

A Security Plan would be developed for the site. The Security Plan would include responses to actual security events and threats.

The plan would be prepared in consultation with the appropriate government agencies.

3 HAZARD IDENTIFICATION AND FAILURE MODES

3.1 HAZARDOUS MATERIALS

3.1.1 Inventories

Refer to Section 2.3 Table 3 for the inventory of hydrogen in each isolatable section.

3.1.2 Properties of hydrogen

A summary of physical properties and hazards associated with hydrogen produced, and handled in the Project are listed in Table 4 below.

Table 4: Summary of physical properties and materials hazards (hydrogen)

Topic	Description
Appearance	Hydrogen gas is colourless, odourless, and non-toxic gas which is highly buoyant and much lighter than air.
Physical properties	With molecular weight 2 g/mol hydrogen is the lightest element at ambient temperatures, with a relative density at STP of approx. 0.089 compared to 1.225 of air. Upon release the gas tends to quickly rise into the atmosphere provided the gas is not released into an obstructed or contained environment. This property is taken into account as part of the project design to minimise risks associated with hydrogen, where all plant and equipment where hydrogen is stored or transported at significant volumes and pressures would be located outdoors, allowing for safe dispersion of the gas in an accidental release. If a pressure vessel or pipeline of hydrogen starts leaking, hydrogen gas would be pushed out by the high operating pressures resulting in significant release rates.
Hazard	Hydrogen is a low flash-point fuel, and flammability and explosion risk are usually the major concern. Compared to methane (a major constituent of natural gas), which is a well-known and used gas in Australia (as it is often used as fuel for households), hydrogen has a 15-20 times lower minimum ignition energy than methane. The lower and upper flammability limits of hydrogen are 4% and 75% in air (by volume) at a temperature of 25°C, which is 6-7 times wider flammable range than methane, and up to 6-7 times higher burning velocity than methane with associated higher explosion pressures. The flame temperature of hydrogen jet-fires are reported to be higher than for methane. Hydrogen flames are invisible in daylight, which may represent an additional hazard to people. Hydrogen flames are, on the other hand, generally reported to be directed upwards due to the high buoyancy of the gas and to give significantly less radiation than natural gas flames, thus if direct flame exposure

Topic	Description
	is prevented, the hazards from flame radiation should be less compared to natural gas. A sudden release from a rupture of a pressurised storage vessel may give rise to a fire ball or rapid flash fire. Hydrogen may cause embrittlement in equipment used for its storage and transport, due to its small size which allows hydrogen molecules to permeate through materials to a greater extent compared with other gases. Hydrogen may combine with carbon in carbon-steel to form methane pockets, potentially weakening the materials – this is prevented through material selection. The high pressure associated with the pressurised hydrogen can cause pressure hazards, typically to on-site personnel during maintenance activities.

3.2 DETAILED CONSIDERATION OF ALL HAZARDS

Several variables must be addressed in developing an assessment of a release and its general dispersion, including potential for ignition sources. The factors determine the possible outcomes of an uncontrolled release, whether it:

- Disperses without any flammable effect
- Burns as a jet or flash fire or as a fireball or explodes as a vapour cloud explosion.

The hazards identified with potential to cause loss of containment associated with hydrogen can be broadly categorised as:

- Internal and process related hazards
- External hazards, including natural hazards and intentional acts (outside of the scope of this QRA).

Heat radiation and explosion overpressures associated with an ignited releases from a plant or equipment have the potential to escalate to other plant and facilities.

Flame impingement, heat radiation or explosion overpressure exceeding safe design limits (defined as 23kW/m² and 14 kPa(g) in several NSW planning documents²) impacting on vessels or pipes can result in failure with consequences more serious than those of the initiating event. Such potential would be considered in plant layouts and pressure relief considerations during the detailed design process of the Project and is not included in the scope of this QRA.

² NSW Department of Planning Hazardous Industry Planning Advisory Paper Number 4, HIPAP6, 2011

4 DANGEROUS DOSE TO HUMAN HEALTH AND THE BUILT ENVIRONMENT

The SDAP21^{Ref 2} requires assessment of the *dangerous dose to human health* and to the *built environment* (refer to Section 1.5) as part of the demonstration of compliance with Performance outcome criteria PO1 to PO5.

To this effect, worst case scenarios have been evaluated, assuming that built-in safety provisions fail and consequently, maximum release rates occur.

The probability that the incidents will develop to this magnitude is not taken into account in the analysis of this part of the assessment (refer to Section 5).

4.1 INTRODUCTION AND THEORIES

Consequence analysis includes evaluation of the gas outflow rates and dispersion, thermal radiation and explosion overpressures in case of ignition, and the effects of radiation and overpressure on people and property.

The software modelling software tool Effects[®] (by TNO, commercialised by Gexcon[®]) is used to model release behaviour for compressed gas and liquids from tanks, vessels and pipelines. Effects[®] incorporates the consequence models described in the *Yellow Book*^{Ref 3}. The tool is used to model release conditions and outflow rates, gas dispersion, heat radiation and explosion overpressures.

Effects[®] and the Yellow Book models have world-wide recognition as consequence assessment tools and have been used for several decades for decision support for infrastructure design and licencing, including for hydrogen infrastructure. The version of Effects[®] used in this study (v.12.4) has been updated for use in hydrogen assessment.

4.1.1 Hole sizes and release rate

An appropriate release rate equation is selected based on the release situation and initial state of the material. Riskcurves[®] and Effects[®] software products model release behaviour for compressed gas or liquid from vessels, pipelines, or total vessel rupture. Input data includes the type of release, location of release with respect to vessel geometry, pipe lengths and initial conditions of the fluid before release.

Representative hole sizes are set for each release case, in line with the methodology in the HyRAM^{Ref 4} for hydrogen plant and equipment (refer to Appendix 1 assumption no. 5).

The release rate is assumed to remain constant until isolation can be achieved – this is a conservative approach as in reality there would be pressure reduction and hence a reduction in leak rate.

4.1.2 Duration

The duration of a leak would depend on the hardware systems available to isolate the source of the leak, the nature of the leak itself and the training, procedures, and management practices at the facility.

While in some cases it may be argued that a leak can easily be isolated within one minute, the same leak under different circumstances may take 10 minutes to isolate.

Under worst case conditions, for example where there are large quantities of materials between two isolating valves, the release may last even longer. In such cases, the release pressure and hence the release rate would decrease with time. The approach used in this study for the identified failure scenarios is to assume the release continues until the inventory has been released, or when steady-state dispersion has been established.

4.1.3 Dispersion of gas

The processes of release and subsequent distribution of a gas is strongly dependent on its thermodynamic state during storage. Pressurized hydrogen gas forms a free jet or would be flash-released if there was a failure of the storage vessel or pipeline.

In either case, parameters of concern are the expansion of a gas or vapor cloud, the height that it could attain, the time until it becomes sufficiently diluted below the flammability limits, and the total quantity of gas in the cloud.

The atmospheric dispersion model is used to model dispersion behaviour of gas and vapours. The software tool can predict when the dispersed gas becomes neutral through incorporation of air and switches model automatically.

Dispersion is affected by the atmospheric conditions at the time of the release, including surface roughness, wind speed and weather stability, with the local wind weather conditions used in the modelling³.

The worst case steady-state distance to a given concentration is used to describe the distance to hazardous endpoints (see Table 5 and Table 6).

³ Meteorological data from Aldoga (Gladstone Region), located approximately 2km north-west of the site was used (refer to Appendix 1, assumption no. 2)

4.1.4 Heat radiation calculation

- **Jet fire:** High-pressure gas release generates a high momentum jet or spray with a high discharge velocity. The jet results in a high degree of mixing of the gas with air and can burn with very high intensity and emit large amounts of heat to the surrounding environment. Jet fires generally continue to burn for as long as the supply of flammable material is sustained and can therefore last for a long time.

Heat radiation effects are calculated based on flame surface emissive power which is dependent on the quantity of material, its heat of combustion, flame dimensions and the fraction of heat radiated.

The view factor method is used to determine heat radiation, taking into account the distance from the flame to the target, the flame dimensions and the orientation angle between the flame and the target.

The flame dimensions for each wind weather category are calculated in Effects® and Riskcurves® and incorporated into the risk assessment together with their respective probability of occurrence.

The Chamberlain® model is used for jet fire modelling. This model shows acceptable correlations with hydrogen fires. Jet fires are conservatively assessed as 100% horizontal and 0% vertical (unless obstructed by a firewall, in which case the jet flame is assumed to be directed vertically).

- **Flash fire:** If a flammable gas is mixed with air before it is ignited, large amounts of combustible material can be burned in a short time resulting in a flash fire or a vapour cloud explosion. The combustion would mainly take place where the substance is present in a flammable concentration (i.e. at concentrations above the LFL), but due to the temperature rise during combustion, the air in the flame would expand and may push the unburned flammable cloud outwards to approximately double size if ignition occurs in the centre of the flammable cloud (Ref 5). For edge ignition, this effect is significantly lower since the expansion only partially enters the flammable cloud.

If the flammable cloud is in an area with a high equipment density, or, as in the case of highly reactive hydrogen gas, combustion reactions in the flammable cloud would accelerate and thus also the pressure build-up, transitioning into a deflagration.

The consequences of a deflagration would typically be represented by larger distances to end point values than those for a pure flash fire. Hence, in this QRA, flash fires have been ignored and instead assessed as deflagrations, as discussed in Section 4.1.5. This is in line with current recommendations for hazard and risk assessments involving hydrogen^{Ref 5, 6}.

As per standard methodology in hazard and risk assessment, the risk of injury or fatality is calculated without taking into account any chance of escape from the incident.

The end point values relevant to SDAP21^{Ref 2} for heat radiation is presented in bold in Table 5.

Table 5: End point values and effects of heat radiation

Radiant Heat Level (kW/m ²)	<i>Dangerous dose as per SDAP21</i>	Effect (results of exposure depends on exposure duration)
1.2	Not included	Received from the sun at noon in summer
2.1	Not included	Minimum to cause pain after 1 minute
4.7	To human safety	Will cause pain in 15-20 seconds and injury after 30 seconds' exposure
12.6	To the built environment	Significant chance of fatality for extended exposure. High chance of injury
23	Not included	Likely fatality for extended exposure and chance of fatality for instantaneous (short) 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
35	Not included	Significant chance of fatality for people exposed instantaneously

4.1.5 Vapour cloud explosion calculations

A vapour cloud explosion is primarily defined by the environment in which the gas disperses. The explosive mass in the flammable gas cloud is taken as the maximum mass between the LFL⁴ and UFL⁵ concentration for that section of the cloud that overlaps a congested area, also for relatively low congested areas.

The peak side-on overpressure resulting from an explosion is estimated using the Multi Energy method option in the Effects® and Riskcurves® software.

In line with current recommendations for hydrogen risk assessment modelling^{Ref 6}, each ignited hydrogen release, additionally to the resulting fire scenario, is taken as resulting in deflagration overpressure. The Effects® Multi Energy (ME) model curve number 5 is used as representative of the environment for a hydrogen cloud in a low or medium congestion, involving 100% of the gas within the flammable range.

There is evidence that congested hydrogen clouds can detonate^{Ref 6} and, while this is contrary to some opinions expressed in the literature, this possibility is included in the present QRA.

For cases where hydrogen gas is released into a high congested area and then ignites, ME model curve number 10 is used to model the hydrogen detonation. If dimensions of equipment in the congested area are unknown, it is conservatively assumed that 100% of the cloud is involved in the explosion. If dimensions of the congested area is known, the fraction of cloud involved in explosion is determined and ME model adjusted accordingly. In this study, congested areas

⁴ Lower Flammable Limit

⁵ Upper Flammable Limit

where detonation may occur have been identified for the electrolyser building and the hydrogen storage areas, and volume blockage ratios (VBRs) have been determined for these areas (see Appendix 1, assumption no. 11).

As per the methodology in SDAP21^{Ref 2}, the risk of injury or fatality is calculated without taking into account any chance of escape from the incident.

The end point values relevant to SDAP21^{Ref 2} for explosion overpressure are presented in bold in Table 6.

Table 6: End point values and effects of explosion overpressure

Explosion overpressure (kPa(g))	Dangerous dose as per SDAP21	Effect
7	To human safety	Damage to internal partitions & joinery. 10% probability of injury, no fatality
14	To the built environment	Houses uninhabitable and badly cracked. Potential for propagation at industrial facilities
21	Not included	Reinforced structures distort, storage tanks fail. 20% chance of fatality to person in building
35	Not included	Houses uninhabitable, rail wagons & plant items overturned. Threshold of eardrum damage, 50% chance of fatality for a person in a building, 15% in the open
70	Not included	Complete demolition of houses. Threshold of lung damage, 100% chance of fatality for a person in a building or in the open

4.1.6 Effect of shelter or escape

Inclusion of the effect of available shelter or escape from a major incident is ignored for individual risk calculations, in line with international convention for quantitative hazard and risk assessment (including as per SDAP21^{Ref 2}) for assessments that may affect the public.

4.2 RESULTS OF THE CONSEQUENCE ANALYSIS

The assessment of the dangerous dose to human health and the built environment is required to demonstrate compliance with performance outcomes PO1 to PO5 (refer to the SDAP21^{Ref 2} risk criteria in Section 1.5).

The detailed results of the assessment of the dangerous dose associated with the Euroa H₂ Domestic Project are presented in Sections 4.2.1 to 4.2.17. The consequence analysis assesses a worst-case scenario (isolation fails with wind directed to the closest site boundary) as discussed in the detailed results below. A summary is provided in Table 7.

Within the confines of the information available for the Euroa H₂ Domestic Project at the FEED stage, the QRA has demonstrated the following:

- *Compliance with performance outcomes PO1 to PO3* in SDAP21 has been demonstrated, with the dangerous dose to human health not exceeding the threshold at off-site commercial, sensitive or vulnerable land use or land zone. No further analysis to demonstrate compliance with PO1 to PO3 is required
- *Compliance with performance outcome PO4* in SDAP21 has been demonstrated, with the dangerous dose to human health not exceeding the threshold at any known off-site open space land use or land zone. No further analysis to demonstrate compliance with PO3 is required
- *Compliance with performance outcomes PO5* in SDAP21 for dangerous dose to the built environment has not been demonstrated, as the dangerous dose exceeds the threshold at an off-site industrial land use or land zone (discussed further in sections below).

To demonstrate full compliance with PO5, an assessment of the individual fatality risk against the SDAP21 risk criteria is still required (as reported in Section 5).

Table 7: Summary results of the consequence assessment against performance criteria in PO1 to PO5 (subject to assumptions in Section 4.2.1 to 4.2.6)

Plant, equipment pipeline	Type of off-site impact	Dangerous dose enters adjacent land used or zoned for (YES/NO)					Needs further analysis (YES / NO)	Representative scenarios to carry forward for likelihood and risk analysis
		Vulnerable use	Sensitive use	Commercial, community use	Open space use	Industrial use		
Electrolyser Skid	Human health	NO	NO	NO	NO	NO	NO	-
	Built environment	NO	NO	NO	NO	NO	YES	Individual fatality risk assessment is required
Electrolyser to Purification Interunit Pipework	Human health	NO	NO	NO	NO	NO	NO	-
	Built environment	NO	NO	NO	NO	NO	YES	Individual fatality risk assessment is required
Hydrogen Gas Purifier	Human health	NO	NO	NO	NO	NO	NO	-
	Built environment	NO	NO	NO	NO	NO	YES	Individual fatality risk assessment is required
Purification to Compression Interunit Pipework	Human health	NO	NO	NO	NO	NO	NO	-
	Built environment	NO	NO	NO	NO	NO	YES	Individual fatality risk assessment is required
Compression Inlet	Human health	NO	NO	NO	NO	NO	NO	-
	Built environment	NO	NO	NO	NO	YES	YES	Individual fatality risk assessment is required
Compression Outlet	Human health	NO	NO	NO	NO	NO	NO	-

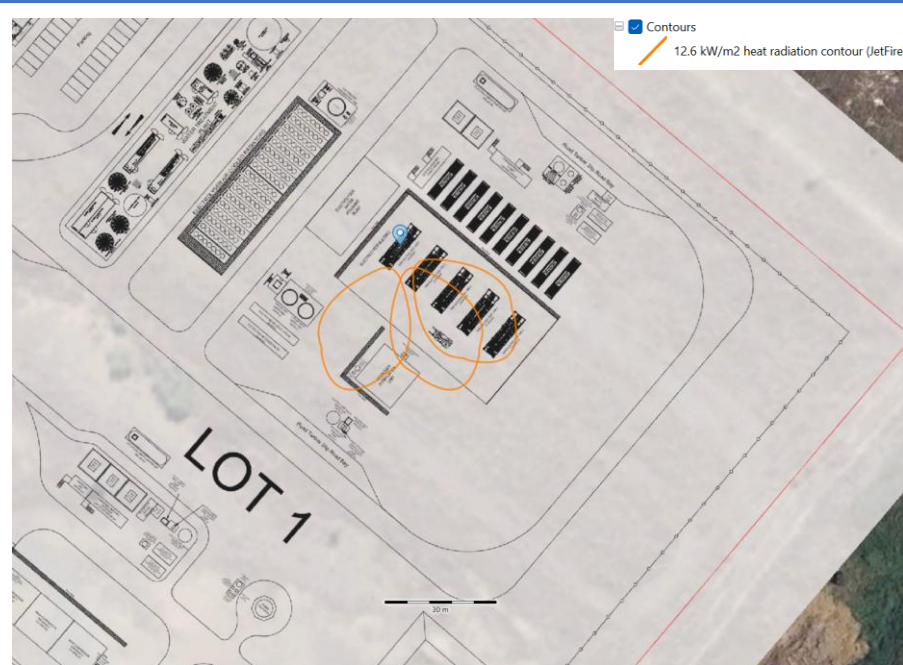
Plant, equipment pipeline	Type of off- site impact	Dangerous dose enters adjacent land used or zoned for (YES/NO)					Needs further analysis (YES / NO)	Representative scenarios to carry forward for likelihood and risk analysis
		Vulnerable use	Sensitive use	Commercial, community use	Open space use	Industrial use		
	Built environment	NO	NO	NO	NO	NO	YES	Individual fatality risk assessment is required
Compression to storage management interunit pipework	Human health	NO	NO	NO	NO	NO	NO	-
	Built environment	NO	NO	NO	NO	NO	YES	Individual fatality risk assessment is required
Storage Management Package	Human health	NO	NO	NO	NO	NO	NO	-
	Built environment	NO	NO	NO	NO	NO	YES	Individual fatality risk assessment is required
Storage Management Package to Dispensing Compression Interunit Pipework	Human health	NO	NO	NO	NO	NO	NO	-
	Built environment	NO	NO	NO	NO	NO	YES	Individual fatality risk assessment is required
Dispensing Compression Inlet	Human health	NO	NO	NO	NO	NO	NO	-
	Built environment	NO	NO	NO	NO	NO	YES	Individual fatality risk assessment is required
Dispensing Compression Outlet	Human health	NO	NO	NO	NO	NO	NO	-
	Built environment	NO	NO	NO	NO	NO	YES	Individual fatality risk assessment is required

Plant, equipment pipeline	Type of off- site impact	Dangerous dose enters adjacent land used or zoned for (YES/NO)					Needs further analysis (YES / NO)	Representative scenarios to carry forward for likelihood and risk analysis
		Vulnerable use	Sensitive use	Commercial, community use	Open space use	Industrial use		
Dispensing compression to dispensing bay interunit pipework	Human health	NO	NO	NO	NO	NO	NO	-
	Built environment	NO	NO	NO	NO	NO	YES	Individual fatality risk assessment is required
Dispensers	Human health	NO	NO	NO	NO	NO	NO	-
	Built environment	NO	NO	NO	NO	YES	YES	Individual fatality risk assessment is required
Storage Management Package to Hydrogen Storage Interunit Pipework	Human health	NO	NO	NO	NO	NO	NO	-
	Built environment	NO	NO	NO	NO	YES	YES	Individual fatality risk assessment is required
Hydrogen Storage	Human health	NO	NO	NO	NO	NO	NO	-
	Built environment	NO	NO	NO	NO	YES	YES	Individual fatality risk assessment is required
Tube trailer inc. loading hose	Human health	NO	NO	NO	NO	NO	NO	-
	Built environment	NO	NO	NO	NO	YES	YES	Individual fatality risk assessment is required

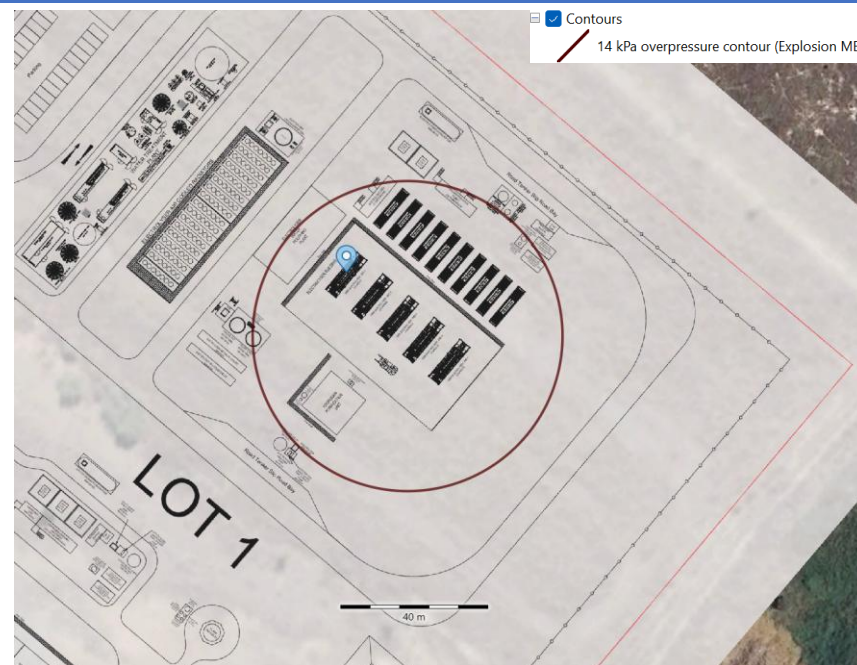
4.2.1 Release from the electrolyser skid

Figure 4-1 ISOL1A_ELS - 12.6 kW/m² Heat Radiation Contour (Jet Fire) & 14 kPa Overpressure Contour (Explosion)

ISOL1A_ELS - Electrolyser Skid (2") – HP



ISOL1A_ELS as representative consequence for the electrolyser skid scenarios. Fire wall at electrolyser building assumed to be designed such that it is 100% effective at deflecting and/or absorbing heat radiation. Heat radiation contours are therefore shown for directions away from the fire wall. Heat radiation contour stays within the Site Boundary.

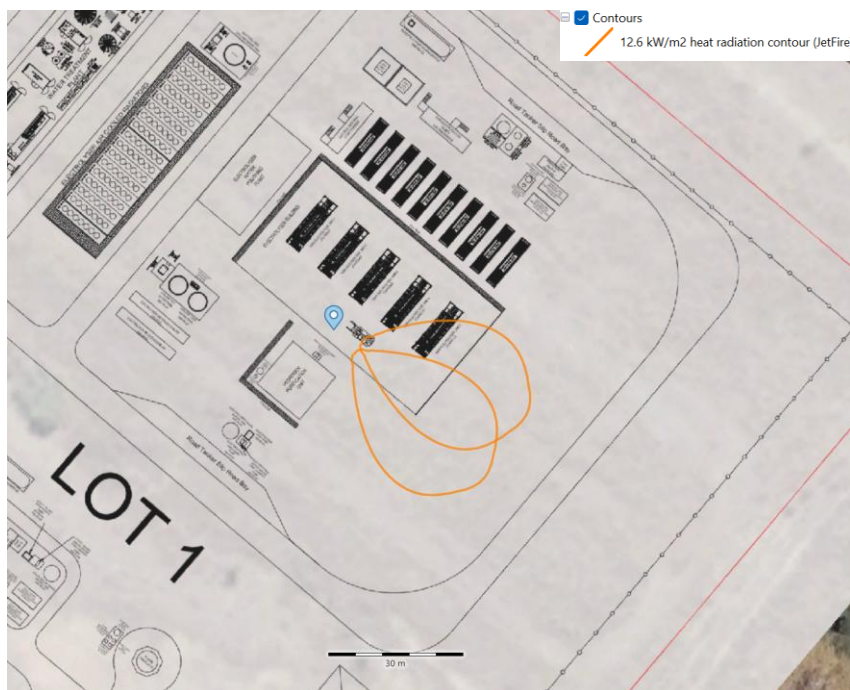


ISOL1A_ELS as worst-case scenario output for VCE from the electrolyser skid with largest hydrogen mass in the congested area. Potential for gas accumulation at hydrogen storage packages. Detonation assessed as TNO MEM blast strength 10 and 86% of cloud involved in explosion as per VBR dimensions at electrolyser building (refer to Appendix 1, assumption no. 11). Overpressure contour stays within the Site Boundary.

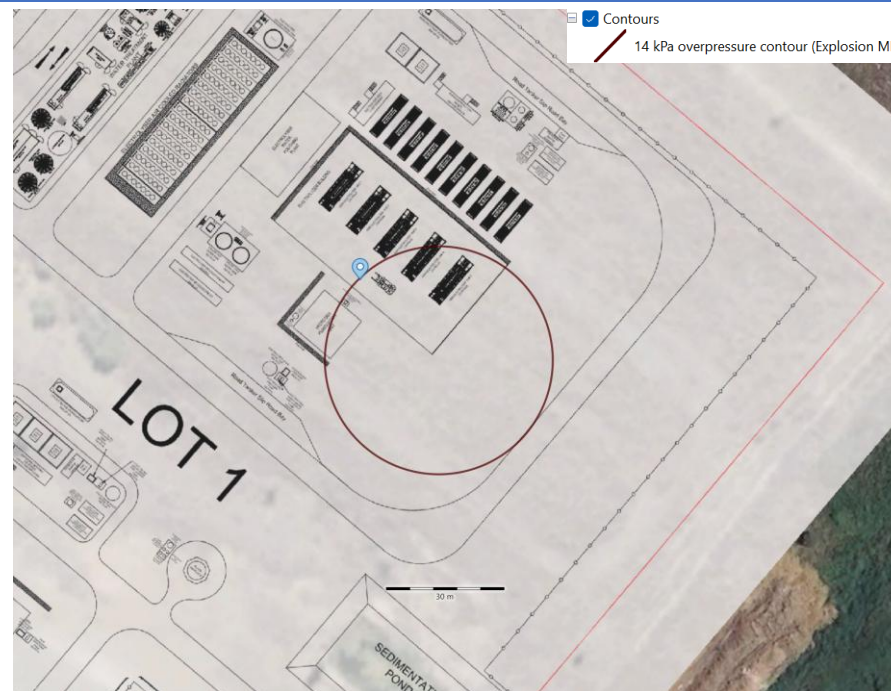
4.2.2 Release electrolyser to purification interunit pipework

Figure 4-2 ISOL1-2_PIP - 12.6 kW/m² Heat Radiation Contour (Jet Fire) & 14 kPa Overpressure Contour (Explosion)

ISOL1-2_PIP - Electrolyser to purification interunit pipework



Fire wall at the electrolyser building is assumed to be designed such that it is 100% effective at deflecting and/or absorbing heat radiation. Heat radiation contours are therefore shown for directions away from the fire wall. Heat radiation contour stays within the Site Boundary.

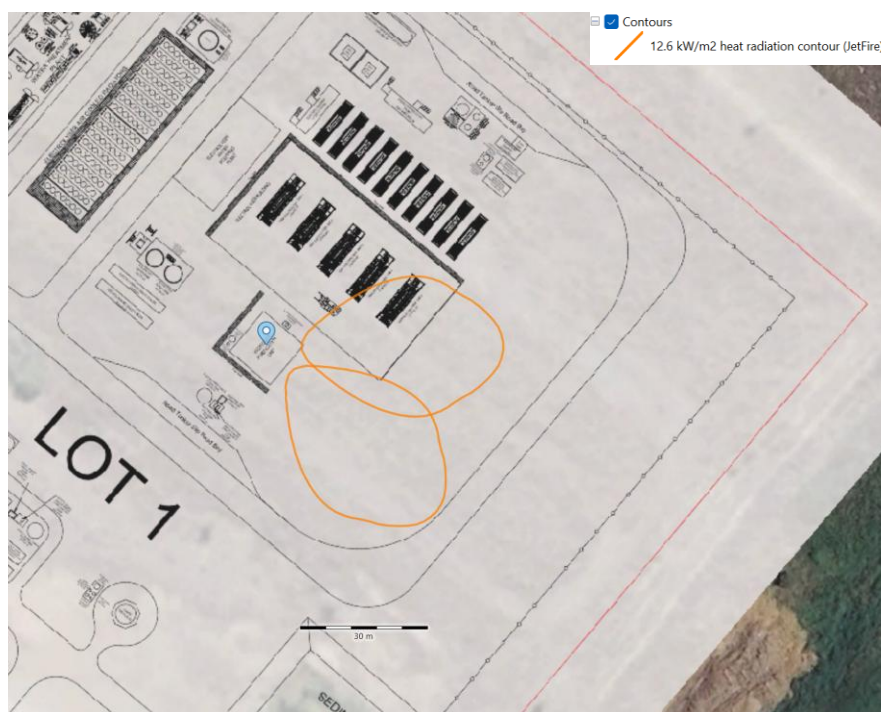


Low congested gas accumulation and deflagration (TNO MEM blast strength 5). Overpressure contour stays within the Site Boundary.

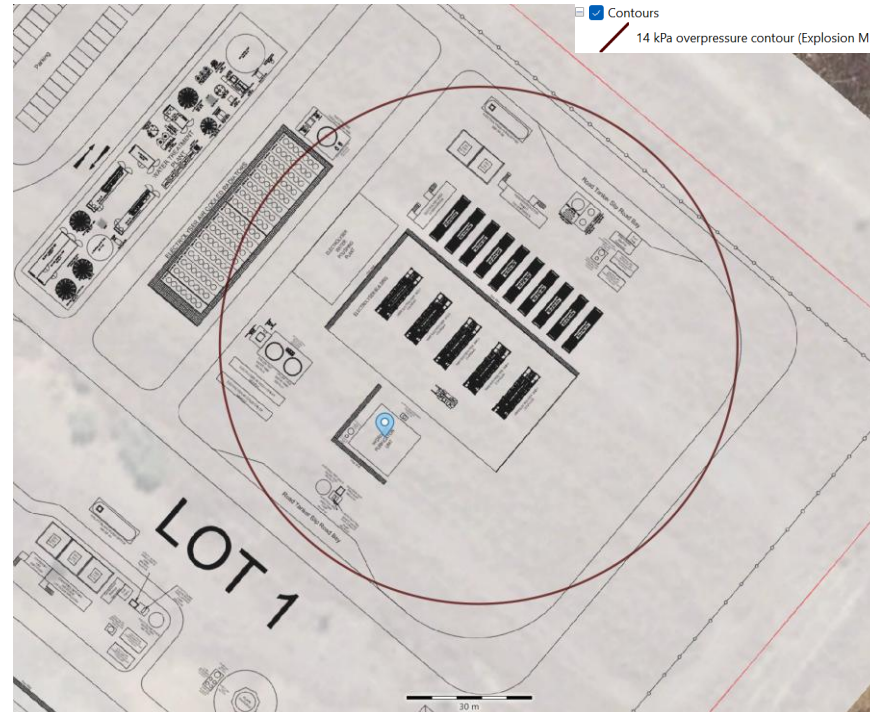
4.2.3 Release from hydrogen gas purifier

Figure 4-3 ISOL2_GSP - 12.6 kW/m² Heat Radiation Contour (Jet Fire) & 14 kPa Overpressure Contour (Explosion)

ISOL2_GSP - Hydrogen gas purifier



Fire wall at the hydrogen purification unit assumed to be designed such that it is 100% effective at deflecting and/or absorbing heat radiation. Heat radiation contours are therefore shown for directions away from the fire wall. Heat radiation contour stays within Site Boundary.

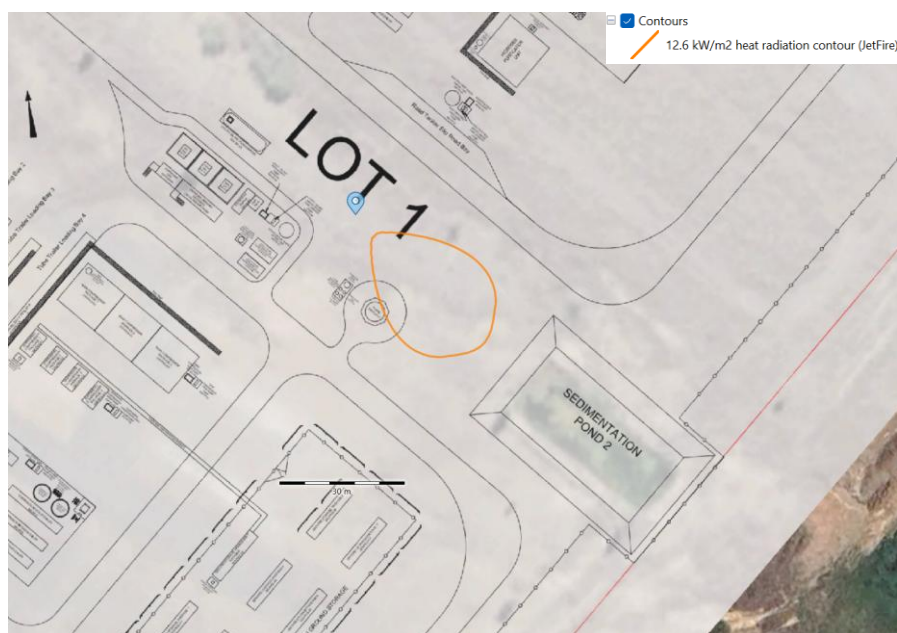


Potential for accumulation of vapour cloud into congested area at the electrolyzers. Conservatively assessed as worst-case overpressure scenario (TNO MEM blast strength 10 and 100% of cloud involved in explosion) as dimensions of hydrogen purification equipment unknown. Overpressure contour stays within Site Boundary.

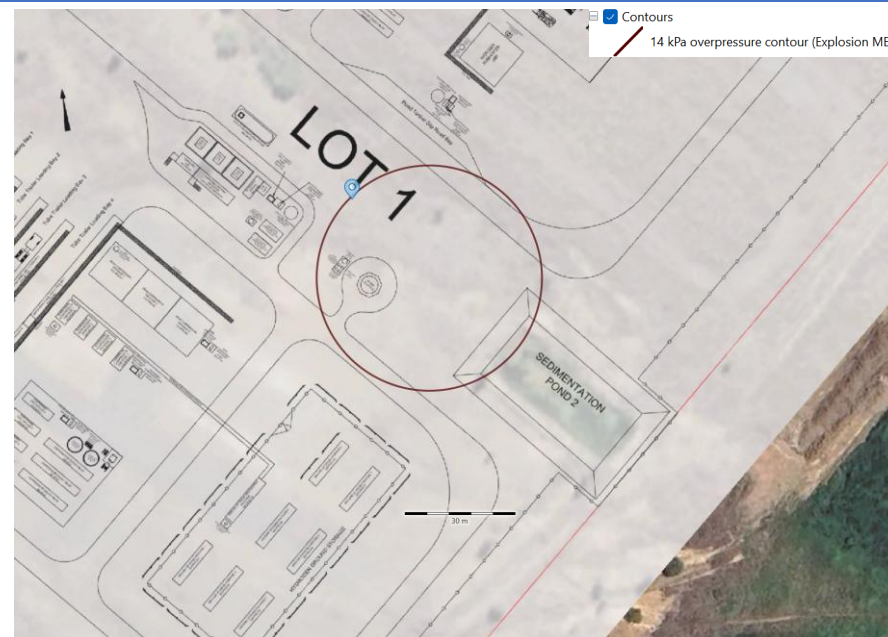
4.2.4 Release from purification to compression interunit pipework

Figure 4-4 ISOL2-3_PIP - 12.6 kW/m² Heat Radiation Contour (Jet Fire) & 14 kPa Overpressure Contour (Explosion)

ISOL2-3_PIP - Purification to compression interunit pipework



Heat radiation contour shown towards Site Boundary only. Heat radiation contour stays within the Site Boundary

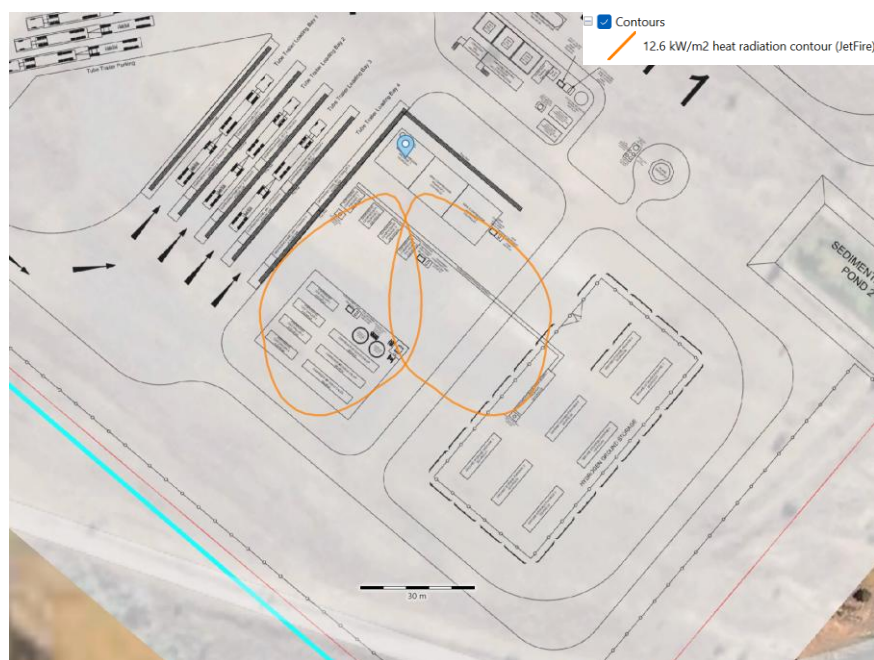


Low congested gas accumulation and deflagration (TNO MEM blast strength 5). Overpressure contour stays within the Site Boundary.

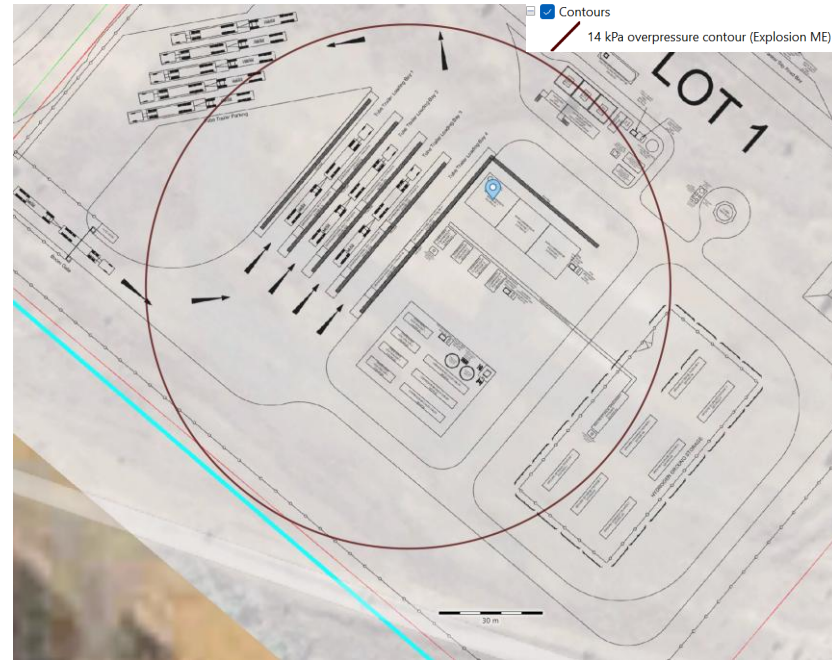
4.2.5 Release from compression inlet

Figure 4-5 ISOL3_CPI - 12.6 kW/m² Heat Radiation Contour (Jet Fire) & 14 kPa Overpressure Contour (Explosion)

ISOL3_CPI - Main compression inlet



Fire wall at the main compression area assumed to be designed such that it is 100% effective at deflecting and/or absorbing heat radiation. Heat radiation contours are therefore shown to be directed away from the fire wall. Heat radiation contour stays within the Site Boundary.

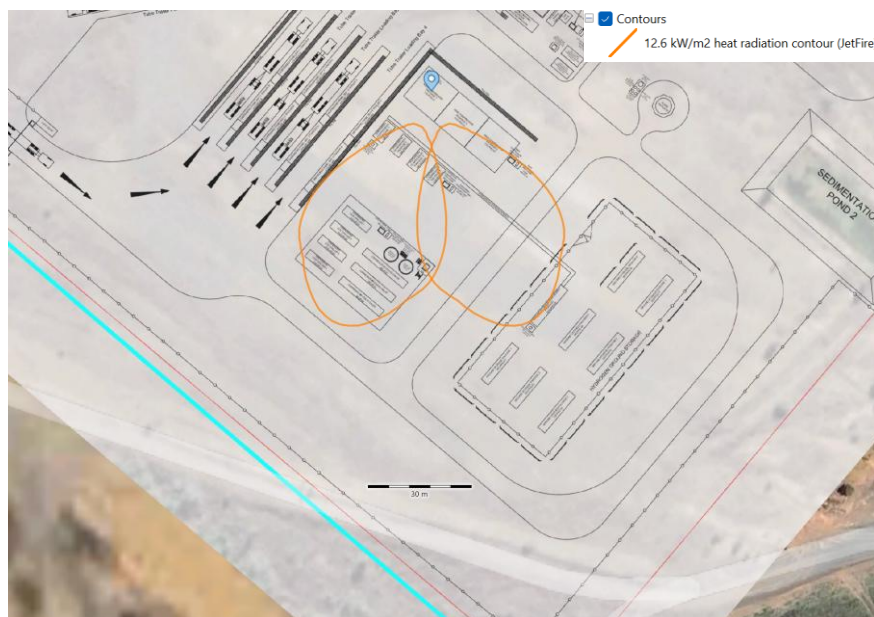


Potential for congested gas accumulation and confined vapour cloud explosion at various locations around the compression area. Conservatively assessed as worst-case overpressure scenario (TNO MEM blast strength 10 and 100% of cloud involved in explosion) as dimensions of equipment at each area unknown. Overpressure contour exceeds southwestern boundary (when modelled towards the closest Site Boundary).

4.2.6 Release from compression outlet

Figure 4-6 ISOL4_CPO - 12.6 kW/m² Heat Radiation Contour (Jet Fire) & 14 kPa Overpressure Contour (Explosion)

ISOL4_CPO - Main compression outlet



Fire wall at the main compression area is assumed to be designed such that it is 100% effective at deflecting and/or absorbing heat radiation. Heat radiation contours are therefore shown for directions away from the fire wall. Heat radiation contour stays within the Site Boundary.

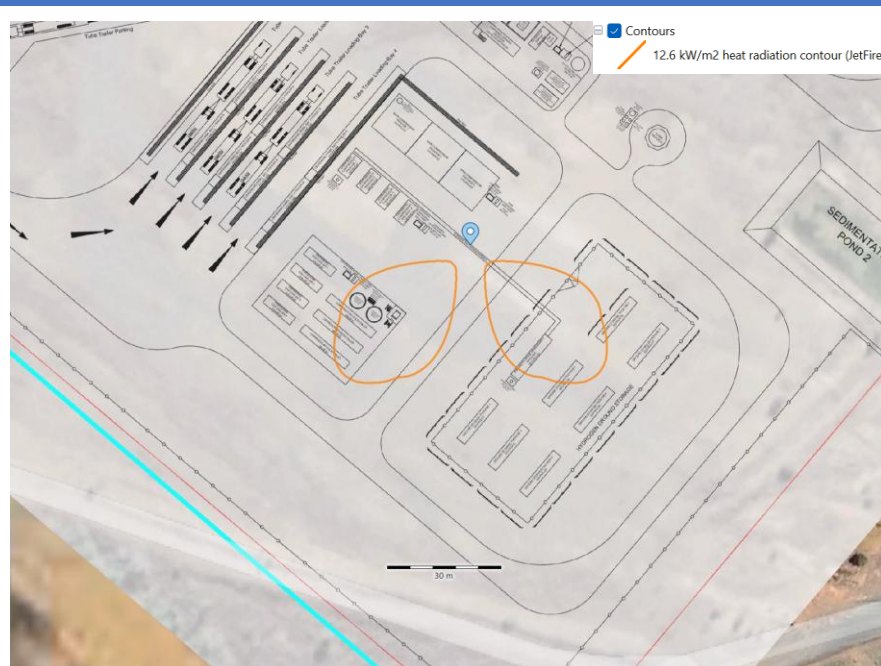


Potential for congested gas accumulation and confined vapour cloud explosion at various locations around the compression area. Conservatively assessed as worst-case overpressure scenario (TNO MEM blast strength 10 and 100% of cloud involved in explosion) as dimensions of equipment at each area is currently unknown. Overpressure contour stays within the Site Boundary (when modelled towards the closest Site Boundary).

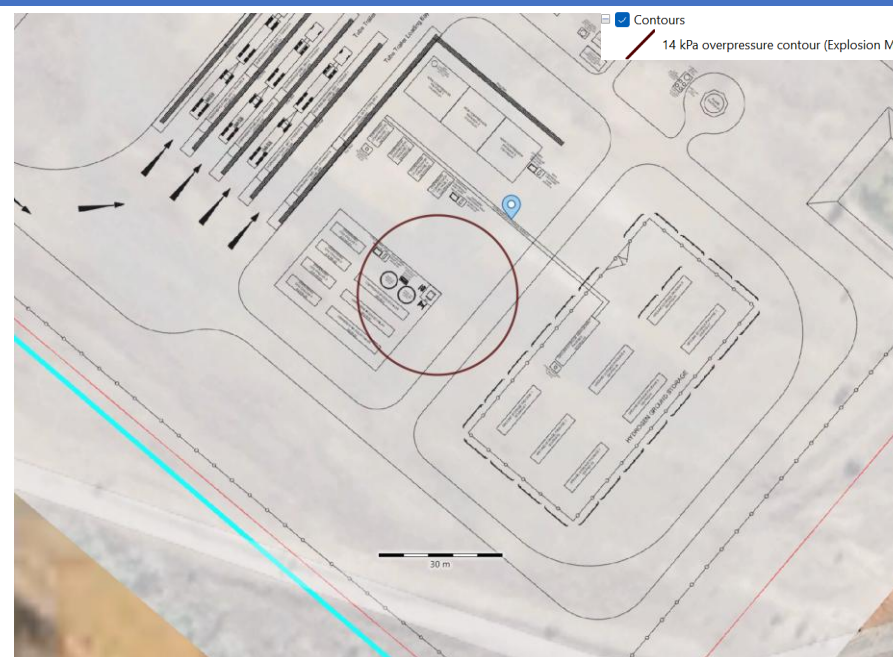
4.2.7 Release from compression to storage management package interunit pipework

Figure 4-7 ISOL4-5_PIP - 12.6 kW/m² Heat Radiation Contour (Jet Fire) & 14 kPa Overpressure Contour (Explosion)

ISOL4-5_PIP - Compression to storage management package interunit pipework



Heat radiation contours shown as directed towards the Site Boundary. Heat radiation contour stays within the Site Boundary.

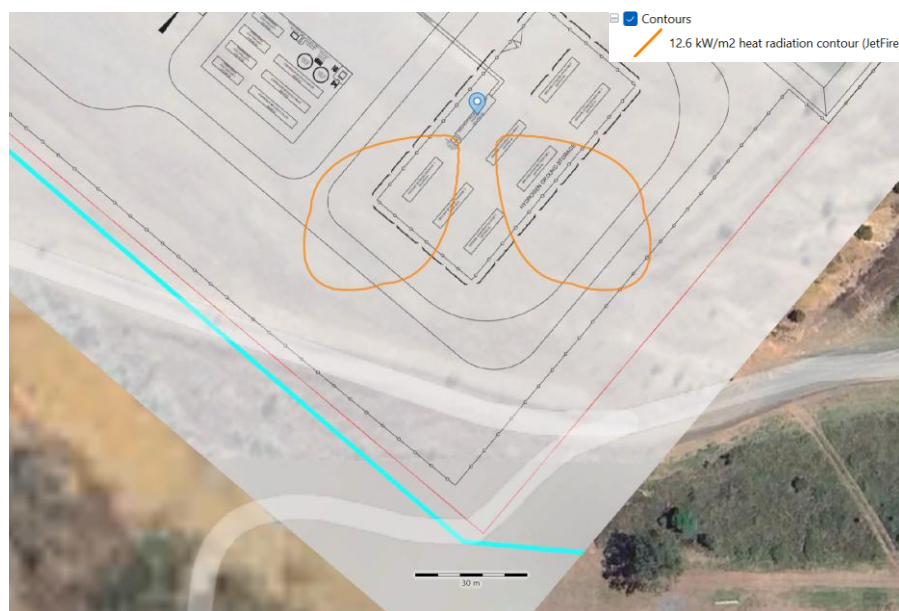


Low congested gas accumulation and deflagration (TNO MEM blast strength 5). Overpressure contour stays within the Site Boundary.

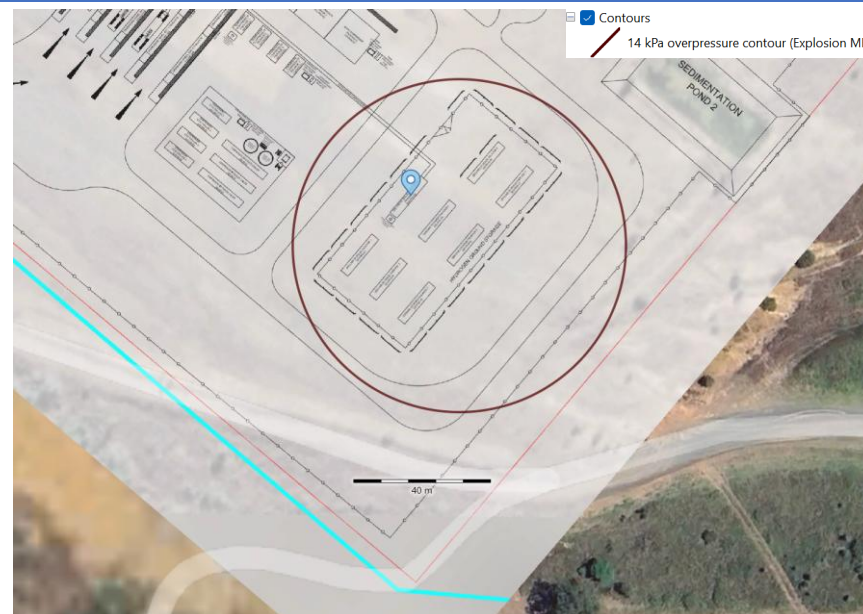
4.2.8 Release from storage management package

Figure 4-8 ISOL5_SMP - 12.6 kW/m² Heat Radiation Contour (Jet Fire) & 14 kPa Overpressure Contour (Explosion)

ISOL5_SMP - Storage management Package



Heat radiation contour shown to be directed towards the Site Boundary. Heat radiation contour stays within the Site Boundary.

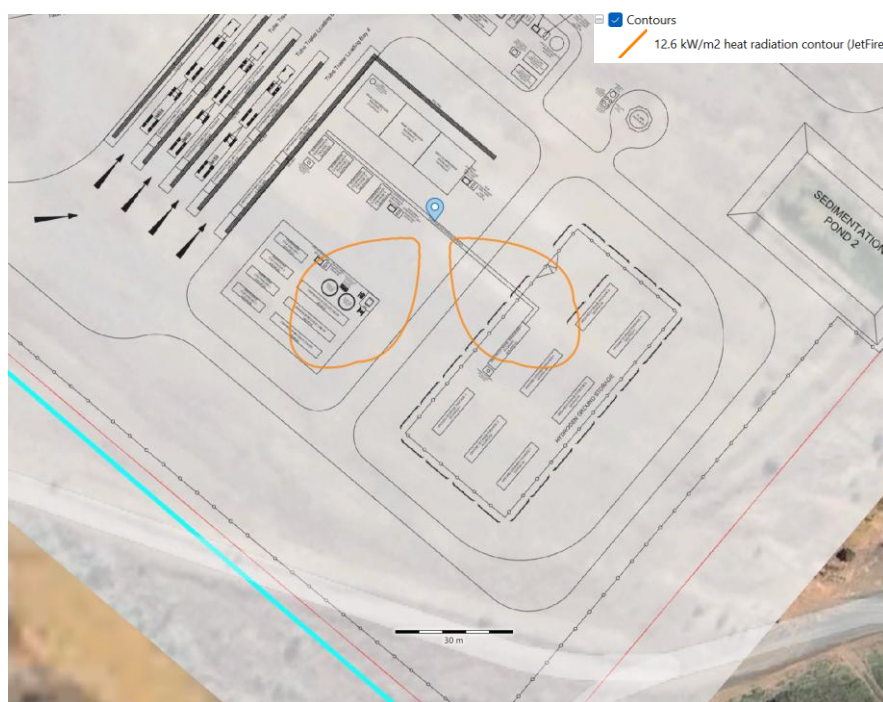


Potential for gas accumulation at hydrogen storage packages. Assessed as TNO MEM blast strength 10 with 76% of cloud involved in explosion as per VBR dimensions at hydrogen storage package area (refer to Appendix 1, assumption no. 11). Overpressure contour stays within the Site Boundary (when modelled towards the closest Site Boundary).

4.2.9 Release from storage management to dispensing compression interunit pipework

Figure 4-9 ISOL5-6_PIP - 12.6 kW/m² Heat Radiation Contour (Jet Fire) & 14 kPa Overpressure Contour (Explosion)

ISOL5-6_PIP - Storage management to dispensing compression interunit pipework



Heat radiation contours shown towards the Site Boundary. Heat radiation contour stays within the Site Boundary.

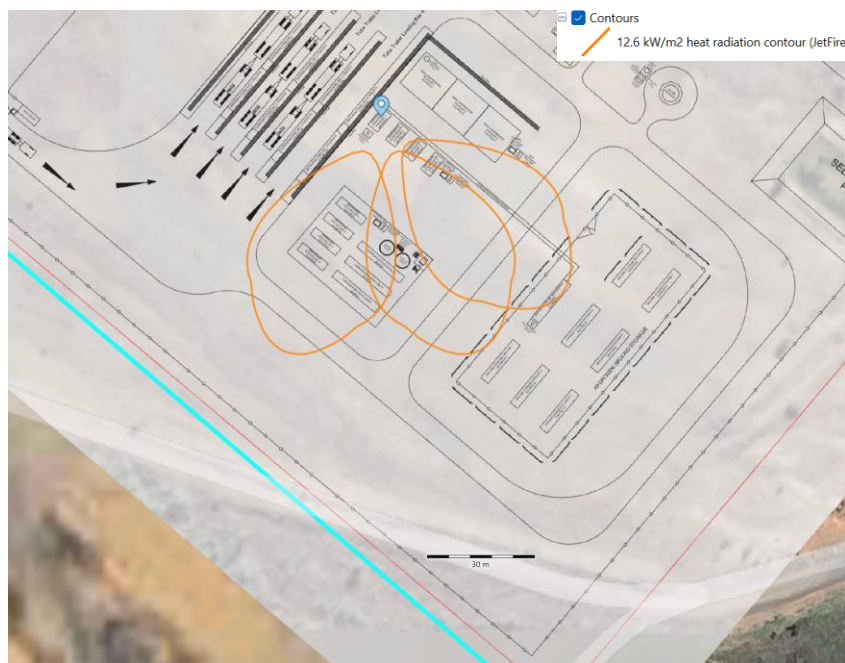


Low congested gas accumulation and deflagration (TNO MEM blast strength 5). Overpressure contour stays within the Site Boundary.

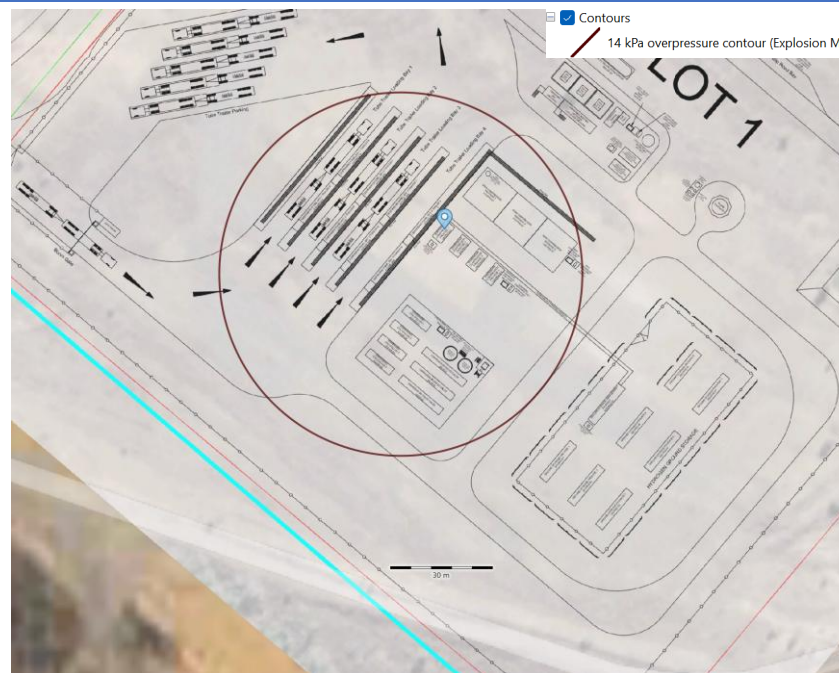
4.2.10 Release from dispensing compression inlet

Figure 4-10 ISOL6_DCI - 12.6 kW/m² Heat Radiation Contour (Jet Fire) & 14 kPa Overpressure Contour (Explosion)

ISOL6_DCI - Dispensing compression inlet



Fire wall at dispensing compression area is assumed to be designed such that it is 100% effective at deflecting and/or absorbing heat radiation. Heat radiation contours are therefore shown for directions away from the fire wall. Heat radiation contour stays within the Site Boundary.

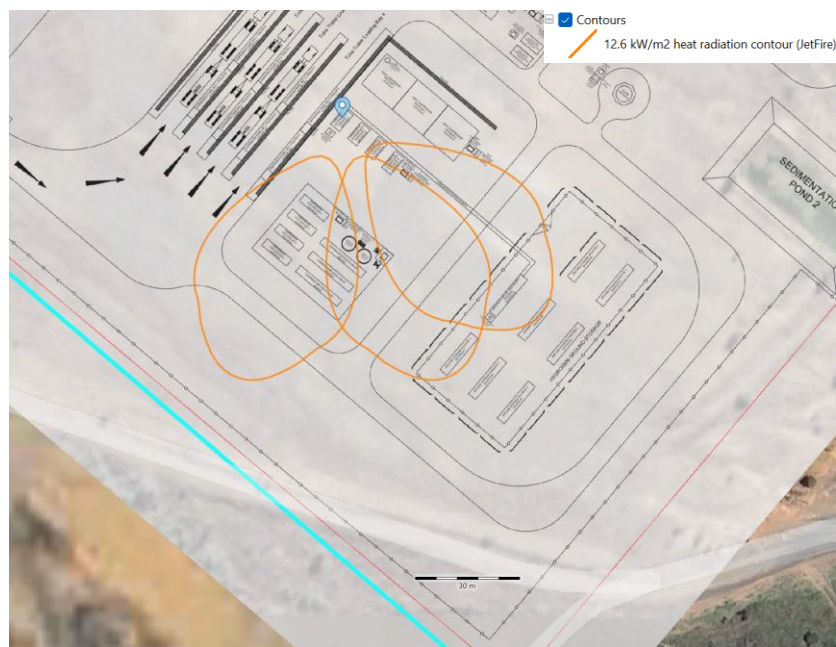


Potential for congested gas accumulation and confined vapour cloud explosion at various locations around the dispensing compression area. Conservatively assessed as worst-case overpressure scenario (TNO MEM blast strength 10 and 100% of cloud involved in explosion) as dimensions of equipment at each area are as yet unknown. Overpressure contour stays within Site Boundary (when modelled towards the closest Site Boundary).

4.2.11 Release from dispensing compression outlet

Figure 4-11 ISOL7_DCO - 12.6 kW/m² Heat Radiation Contour (Jet Fire) & 14 kPa Overpressure Contour (Explosion)

ISOL7_DCO - Dispensing compression outlet



Fire wall at the dispensing compression area is assumed to be designed such that it is 100% effective at deflecting and/or absorbing heat radiation. Heat radiation contours are therefore shown for directions away from the fire wall. Heat radiation contour stays within Site Boundary.

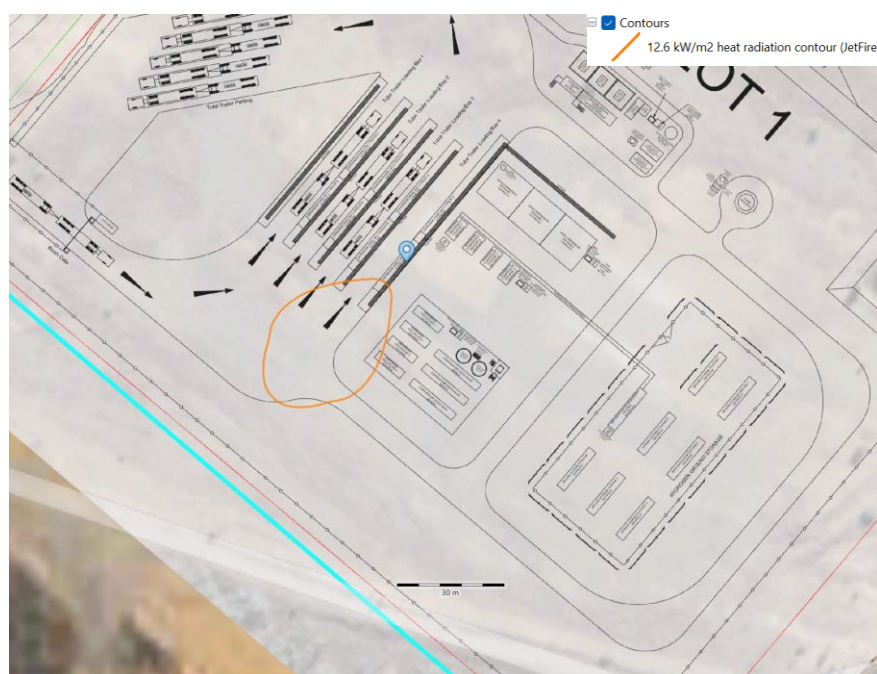


Potential for congested gas accumulation and confined vapour cloud explosion at various locations around the dispensing compression area. Conservatively assessed as worst-case overpressure scenario (TNO MEM blast strength 10 and 100% of cloud involved in explosion) as dimensions of equipment at each area are as yet unknown. Overpressure contour stays within the Site Boundary (when modelled towards the closest Site Boundary).

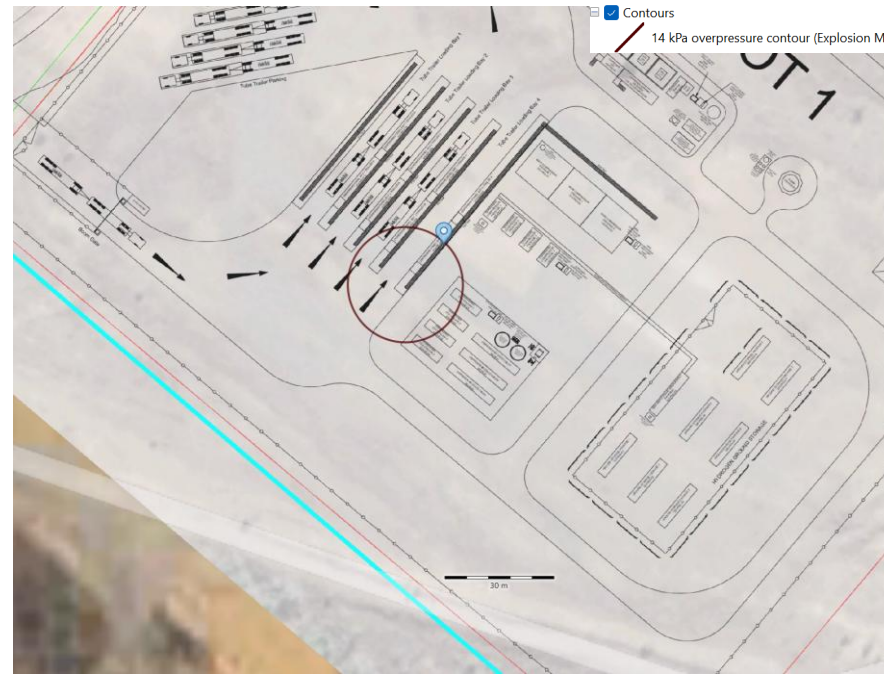
4.2.12 Release from compression to dispensing bay interunit pipework

Figure 4-12 ISOL7-8_PIP - 12.6 kW/m² Heat Radiation Contour (Jet Fire) & 14 kPa Overpressure Contour (Explosion)

ISOL7-8_PIP - Dispensing compression to dispensing bay interunit pipework



Fire wall at dispensing bay area is assumed to be designed such that it is 100% effective at deflecting and/or absorbing heat radiation. Heat radiation contours are therefore shown away from the fire wall and towards the closest Site Boundary. Heat radiation contour stays within the Site Boundary.



Low congested gas accumulation and deflagration (TNO MEM blast strength 5). Overpressure contour stays within the Site Boundary.

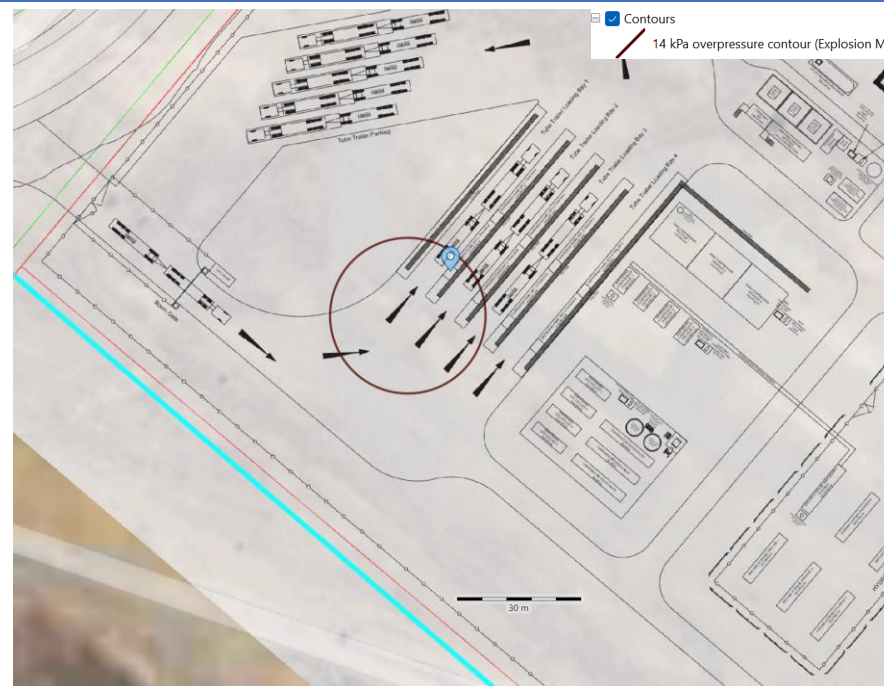
4.2.13 Release from dispensers

Figure 4-13 ISOL8_DIS - 12.6 kW/m² Heat Radiation Contour (Jet Fire) & 14 kPa Overpressure Contour (Explosion)

ISOL8_DIS - Dispensers



Fire wall at the dispensers is assumed to be designed such that it is 100% effective at deflecting and/or absorbing heat radiation. Heat radiation contour is therefore shown away from fire wall and towards closest Site Boundary. Heat radiation contour exceeds the southwestern boundary.



Low congested gas accumulation and deflagration (TNO MEM blast strength 5). Overpressure contour stays within the Site Boundary.

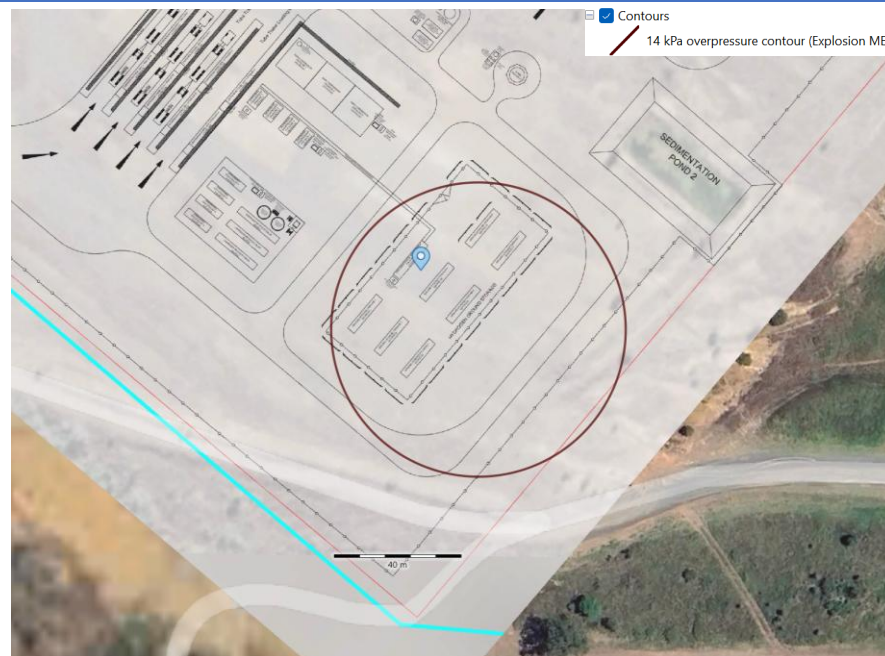
4.2.14 Release from storage management to storage pipework

Figure 4-14 ISOL5-9_PIP - 12.6 kW/m² Heat Radiation Contour (Jet Fire) & 14 kPa Overpressure Contour (Explosion)

ISOL5-9_PIP - Storage management to hydrogen storage interunit pipework



Heat radiation contour shown as directed towards the Site Boundary. Heat radiation contour stays within the Site Boundary.

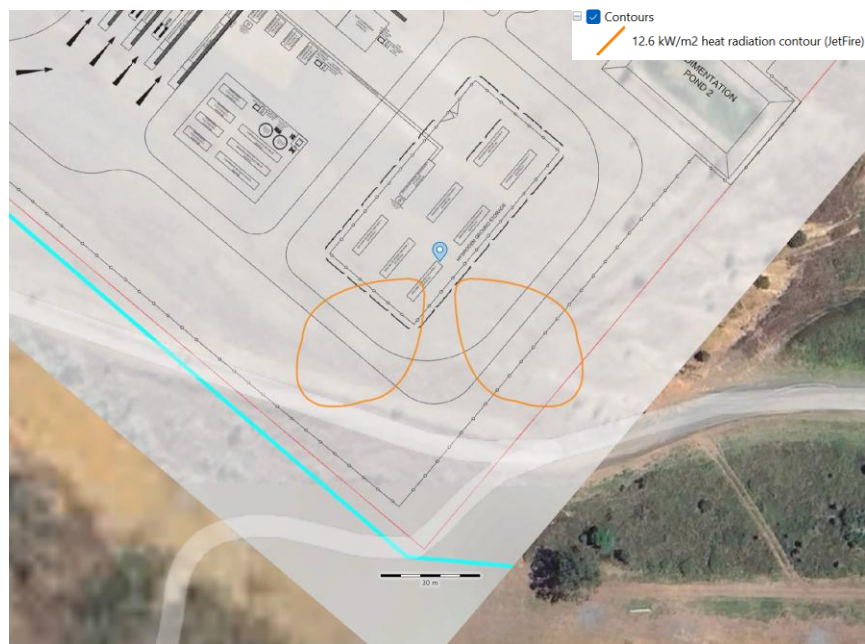


Potential for gas accumulation at the hydrogen storage packages. Assessed as TNO MEM blast strength 10 and 76% of cloud involved in explosion as per VBR dimensions at hydrogen storage package area (refer to Appendix 1, assumption no. 11). Overpressure contour exceeds the southeastern boundary (when modelled towards the closest Site Boundary).

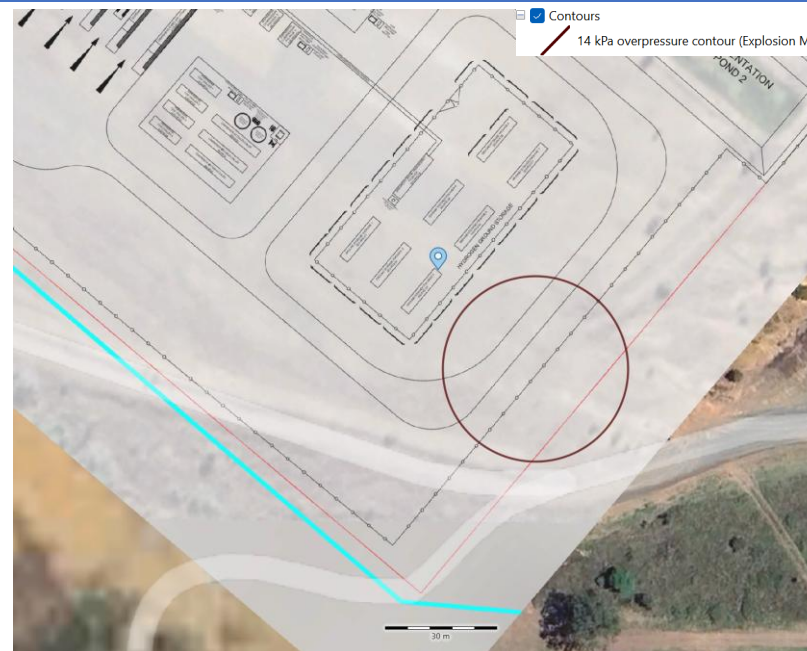
4.2.15 Release from hydrogen storage

Figure 4-15 ISOL9_STO - 12.6 kW/m² Heat Radiation Contour (Jet Fire) & 14 kPa Overpressure Contour (Explosion)

ISOL9_STO - Hydrogen Storage



Heat radiation contours shown towards Site Boundary. Heat radiation contour exceeds the southeastern boundary.

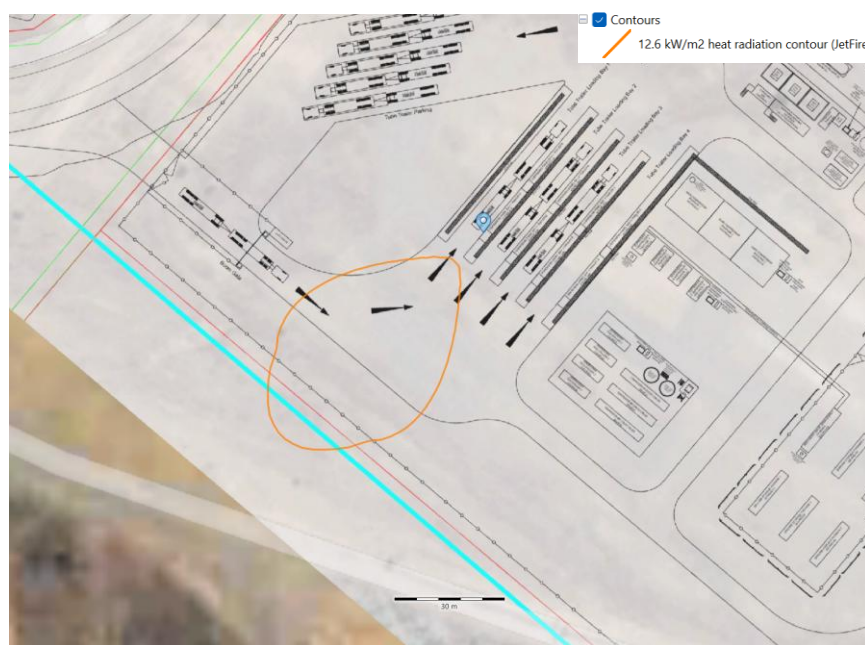


Low congested gas accumulation and deflagration (TNO MEM blast strength 5). Overpressure contour exceeds southeastern boundary (when modelled towards the closest Site Boundary).

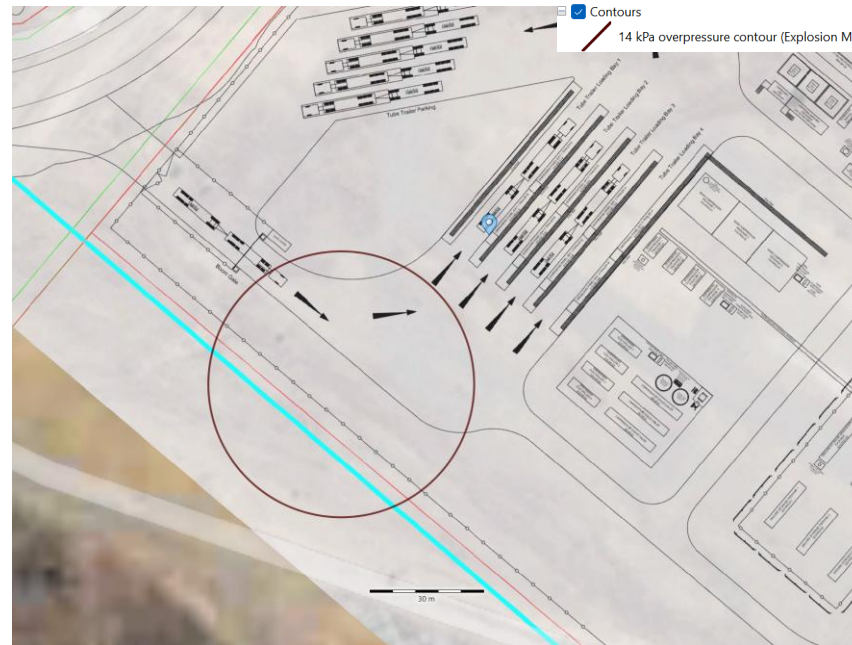
4.2.16 Release from tube trailer inc. loading hose

Figure 4-16 ISOL10_TUB - 12.6 kW/m² Heat Radiation Contour (Jet Fire) & 14 kPa Overpressure Contour (Explosion)

ISOL10_TUB - Hydrogen tube trailer inc. loading hose



Fire wall at the tube trailer and loading hose is assumed to be designed such that it is 100% effective at deflecting and/or absorbing heat radiation. Heat radiation contour is therefore shown away from fire wall and directed towards the closest Site Boundary only. Heat radiation contour exceeds the southwestern boundary.



Low congested gas accumulation and deflagration (TNO MEM blast strength 5). Overpressure contour exceeds the southwestern boundary (when modelled as directed towards the closest Site Boundary).

4.2.17 Consequence results summary

The results of the consequence assessment is provided in Appendix 2. The worst-case results of the Effects® modelling are detailed in Table 8. The dimensions are shown as measured downwind from the centre of the flammable cloud or the source of the jet fire.

Very stable Pasquill Stability Class (**F** with wind speeds of 0.5 metres/second) has been selected to represent the worst-case meteorological conditions. In each release case, the pre-defined wind direction is selected to direct the release to the closest Site Boundary.

The representative scenarios involve a full bore rupture release of pressurised hydrogen. The release is modelled as a loss of containment with isolation valves failing to close, resulting in release rates proportional to the pressure and the hole size.

Table 8: Distance to Dangerous Dose to the built environment for representative scenarios

Release scenario	Dangerous dose to built environment	Distance to dangerous dose, measured radially from the centre of flammable cloud or the source of the jet fire (m)	
		F0.5 with wind directed towards the closest Site Boundary	
		Worst case fire	Worst case deflagration /detonation
Electrolyser skid	Radiant heat: 12.6kW/m ² Overpressure: 14kPa	41	65 (detonation)
Electrolyser to purification interunit pipework	Radiant heat: 12.6kW/m ² Overpressure: 14kPa	46	57 (deflagration)
Hydrogen gas purifier	Radiant heat: 12.6kW/m ² Overpressure: 14kPa	55	92 (detonation)
Purification to compression interunit pipework	Radiant heat: 12.6kW/m ² Overpressure: 14kPa	43	60 (deflagration)
Compression inlet	Radiant heat: 12.6kW/m ² Overpressure: 14kPa	72	111 (detonation)
Compression outlet	Radiant heat: 12.6kW/m ² Overpressure: 14kPa	72	70 (detonation)
Compression to storage management package interunit pipework	Radiant heat: 12.6kW/m ² Overpressure: 14kPa	47	45 (deflagration)
Storage management package	Radiant heat: 12.6kW/m ² Overpressure: 14kPa	61	68 (detonation)

Release scenario	Dangerous dose to built environment	Distance to dangerous dose, measured radially from the centre of flammable cloud or the source of the jet fire (m)	
		F0.5 with wind directed towards the closest Site Boundary	
		Worst case fire	Worst case deflagration /detonation
Storage management to dispensing compression interunit pipework	Radiant heat: 12.6kW/m ² Overpressure: 14kPa	49	44 (deflagration)
Dispensing compression inlet	Radiant heat: 12.6kW/m ² Overpressure: 14kPa	70	71 (detonation)
Dispensing compression outlet	Radiant heat: 12.6kW/m ² Overpressure: 14kPa	80	63 (detonation)
Dispensing compression to dispensing bay interunit pipework	Radiant heat: 12.6kW/m ² Overpressure: 14kPa	53	31 (deflagration)
Dispensers	Radiant heat: 12.6kW/m ² Overpressure: 14kPa	87	33 (deflagration)
Storage management to hydrogen storage interunit pipework	Radiant heat: 12.6kW/m ² Overpressure: 14kPa	47	71 (detonation)
Hydrogen storage	Radiant heat: 12.6kW/m ² Overpressure: 14kPa	57	62 (deflagration)
Tube trailer inc. loading hose	Radiant heat: 12.6kW/m ² Overpressure: 14kPa	77	89 (deflagration)

Analysis of consequence distances shows that the dangerous dose to the built environment from worst-case a fire, deflagration or detonation associated with a loss of containment of hydrogen remains on site with the exception of the following two (2) worst-case release scenarios at the:

- Compression inlet, dispensers and tube trailer loading impacting the southwestern boundary of the site
- Storage Management Package to Hydrogen Storage Interunit Pipework and hydrogen storage impacting the southeastern boundary of the site

Recommendation: Review the requirements for fire and overpressure protection (e.g. implementation of earth berm) at the southwestern boundary and southeastern boundary of the site. Should an earth berm be installed, ensure a sizing review is completed during detailed design (consider use of CFD modelling when determining the design criteria).

The risk assessment is included in Section 5.

5 RISK ANALYSIS

5.1 INTRODUCTION AND THEORIES

5.1.1 Failure Rates

The standard leak frequencies in the HyRAM database^{Ref 4} has been used for all plant and equipment handling hydrogen. The HyRAM database is currently regarded as the most relevant and up-to-date source of incident statistics for hydrogen plant and equipment.

The following methods are used in the likelihood assessment:

- The parts count of major equipment, piping/fittings is derived using a count of the number of components for each identified failure case within an isolatable inventory. This is completed by taking the component count based on piping and instrument diagrams available at the FEED-stage and multiplying by the release frequencies as defined in Table 9 below. A 20% contingency margin is then added to the calculated release frequencies to allow for changes during the design process.
- All vessels, process equipment and piping are assumed to be fully welded with the exception of high-pressure piping (operating at above 400barg) which consist of tubing with a cone and thread connection at every 6m length of piping
- Process piping lengths are conservative engineering best-estimates at the FEED-design stage, as provided by UGL or the vendor.

Table 9: Equipment failures and associated frequencies – hydrogen (HyRAM, Sandia)^{Ref 4}

Component	unit	Very Small	Minor	Medium	Major	Rupture
Compressor	Per compressor-year	1.00E-01	1.90E-02	6.40E-03	2.00E-04	3.00E-05
Vessel	Per vessel-year	1.80E-06	1.50E-06	9.60E-07	5.40E-07	2.80E-07
Filter	Per filter-year	2.20E-02	1.20E-02	1.10E-02	6.10E-03	6.10E-03
Flange	Per flange-year	6.10E-02	4.20E-03	2.00E-03	3.50E-05	1.20E-05
Hose	Per hose-year	6.20E-04	2.40E-04	2.00E-04	1.80E-04	1.00E-04
Joint	Per joint-year	3.60E-05	6.90E-06	9.10E-06	9.10E-06	8.00E-06
Pipe	Per m of piping-year	1.00E-05	4.70E-06	2.10E-06	9.40E-07	8.10E-07

Component	unit	Very Small	Minor	Medium	Major	Rupture
Valve	Per valve-year	3.00E-03	6.40E-04	1.00E-04	3.00E-05	1.20E-05
Instrument	Per instrument-year	8.00E-04	2.80E-04	1.70E-04	1.80E-04	1.10E-04

5.1.2 Likelihood and risk reduction factors

The risk reduction factors applied in the likelihood assessment are presented in Table 10 below.

Table 10: Risk reduction factors

Mitigation measure	Reduction factor	Used in the QRA
Automated plant trip and shutdown via automatic closure of isolation valves on process upset detection within system (e.g. due to a rupture or major leak causing a major loss of pressure)	0.05	Safety system assumed as minimum Safety Integrity Level 1 (SIL1) with a probability of failure on demand (PFD) of 0.05. Assumed to activate for rupture and major leak scenarios only, and not to activate for very small, minor and medium size release scenarios.
Automated plant trip and shutdown via automatic closure of isolation valves on gas leak detection or fire detection	0.05	Safety system assumed as minimum SIL1 with PFD of 0.05. Includes pressure blowdown (where relevant) upon activation.
Automated plant trip and shutdown via automatic closure of isolation valves on gas (LEL) detection.	0.05	Safety system assumed as minimum SIL1 with PFD of 0.05. Applied to delayed ignition scenarios only in the QRA for the applicable isolatable sections.
Automatic opening of blowdown valves upon emergency shutdown to relieve the gas inventory between the isolatable section to the flare header	-	A total time from initiation of blowdown valve opening to full valve opening is taken as 220 milliseconds ⁶ and set as the maximum release duration when assessing the isolated cases for the QRA.

Recommendation: Review the design of the safety instrumented systems during the detailed design phase using a Layer Of Protection Analysis (LOPA) methodology to ensure the required SIL

⁶ A. Vesper, A. Friedrich, M. Kuznetsov, T. Jordan, N. Kotchourko, "Hydrogen Blowdown Release Experiments at Different Temperatures in the DISCHA-Facility", 9th International Conference on Hydrogen Safety (ICHS), Edinburgh, UK, 21–23 September 2021.

rating is achieved (inc. meeting the SIL requirements e.g. probability of failure on demand of the safety instrumented function).

The detection and protection measures integrated into the plant design are detailed in Table 11 below.

Table 11: Detection and protection measures

Isolatable section	Gas (LEL) detection (Y/N)	Gas leak detection (Y/N)	Flame detection (Y/N)	Process upset detection within system (Y/N)	Isolation on confirmed (Y/N)	Blowdown on confirmed detection (Y/N)
Electrolyser Skid	Y	Y	Y	Y	Y	Y
Electrolyser to purification interunit pipework	N	Y	Y	Y	Y	Y
Gas Purifier	N	Y	Y	Y	Y	Y
Purification to compression interunit pipework	N	Y	Y	Y	Y	Y
Compression inlet	N	Y	Y	Y	Y	Y
Compression outlet	N	Y	Y	Y	Y	Y
Compression to storage management interunit pipework	N	Y	Y	Y	Y	Y
Storage management Package	N	Y	Y	Y	Y	Y
Storage management to dispensing compression interunit pipework	N	Y	Y	Y	Y	Y
Dispensing compression inlet	N	Y	Y	Y	Y	Y
Dispensing compression outlet	N	Y	Y	Y	Y	Y
Dispensing compression to dispensing bay interunit pipework	N	Y	Y	Y	Y	Y
Dispensers	N	Y	Y	Y	Y	Y
Storage management to storage pipework	N	Y	Y	Y	Y	Y
Storage	Y	Y	Y	Y	Y	Y
Tube trailer inc. loading hose	Y	Y	Y	Y	Y	Y

5.1.3 Risk assessment

For individual risk of fatality calculations, the output gives risk or frequency values at each grid point within the area defined using the grid increment defined at the start of the run.

The results of the risk calculations are presented as follows:

- *Individual fatality risk*: the likelihood of fatality to notional individuals at locations around the site, as a result of the defined fire/explosion scenarios. This is shown as contours on a map of the area. The units for individual risk are probability (of fatality) per million per year. By convention it is assumed that people are located outdoors, are always present and take no evasive action if an incident occurs. The results are presented cumulatively for all fire/explosion.

Two release cases are analysed in *Riskcurves*® and provided as a cumulative risk:

- *Isolated release*, i.e. controls work as intended and shutoff valves close on detection of a loss of containment or fire event. In this case, the amount of hazardous gas released is equal to the inventory between two shutoff valves. If a blowdown valve is fitted then the hazardous gas inventory would be released until full opening of the blowdown valve, whereby the remaining inventory would be vented to the flare header and safely dispersed (see Appendix 1, assumption no. 17 for blowdown opening time).
- *Non-isolated release*, i.e. the controls fail and the shutoff valves do not close as required. In this case, the inventory may be larger and may involve other upstream and downstream plant units. The amount of hazardous gas that may be released is determined as that available between mechanical controls (e.g. double dissimilar non return valves), and the “steady-state” scenario is considered. A steady-state is achieved where the release rate or the amount of gas in the vapour cloud would not increase by nominating further inventory. Double dissimilar non-return valves are assumed to be available at the main compression, dispensing compression and hydrogen storage.

The risk calculations were conducted at the FEED-stage of the Project. Significant design changes may impact the QRA results and it is likely that the QRA will need to be updated as per of the detailed design to confirm the findings in this QRA.

Recommendation: This quantitative risk assessment has been developed using the design assumptions for risk reduction at the FEED stage. Key assumptions include:

- Automatic closure of isolation valves on process upset detection within system (e.g. due to a rupture or major leak causing a major loss of pressure)
- Automatic closure of isolation valves on gas (LEL) detection, gas leak detection and/or fire detection
- Double dissimilar non-return valves are provided in the process to prevent backflow of hydrogen in the event of isolation failure (provided as a minimum at the main compression, dispensing compression and hydrogen storage)
- Automatic blowdown valves are provided to relieve the gas inventory between isolatable sections to the flare header.

Other key assumptions are detailed in Appendix 1.

The quantitative risk assessment should be reviewed and risk reduction measures verified as part of the detailed design.

5.2 RESULTS

The results of the likelihood assessment is provided in Appendix 3.

The individual fatality risk contour, associated with the Euroa H₂ Domestic Project, is presented in Figure 5-1. This represents the total individual fatality risk calculated as the cumulative risk from all credible hazardous scenarios defined at the FEED stage of the project.

The 50×10^{-6} per year fatality risk contour is contained within the site.

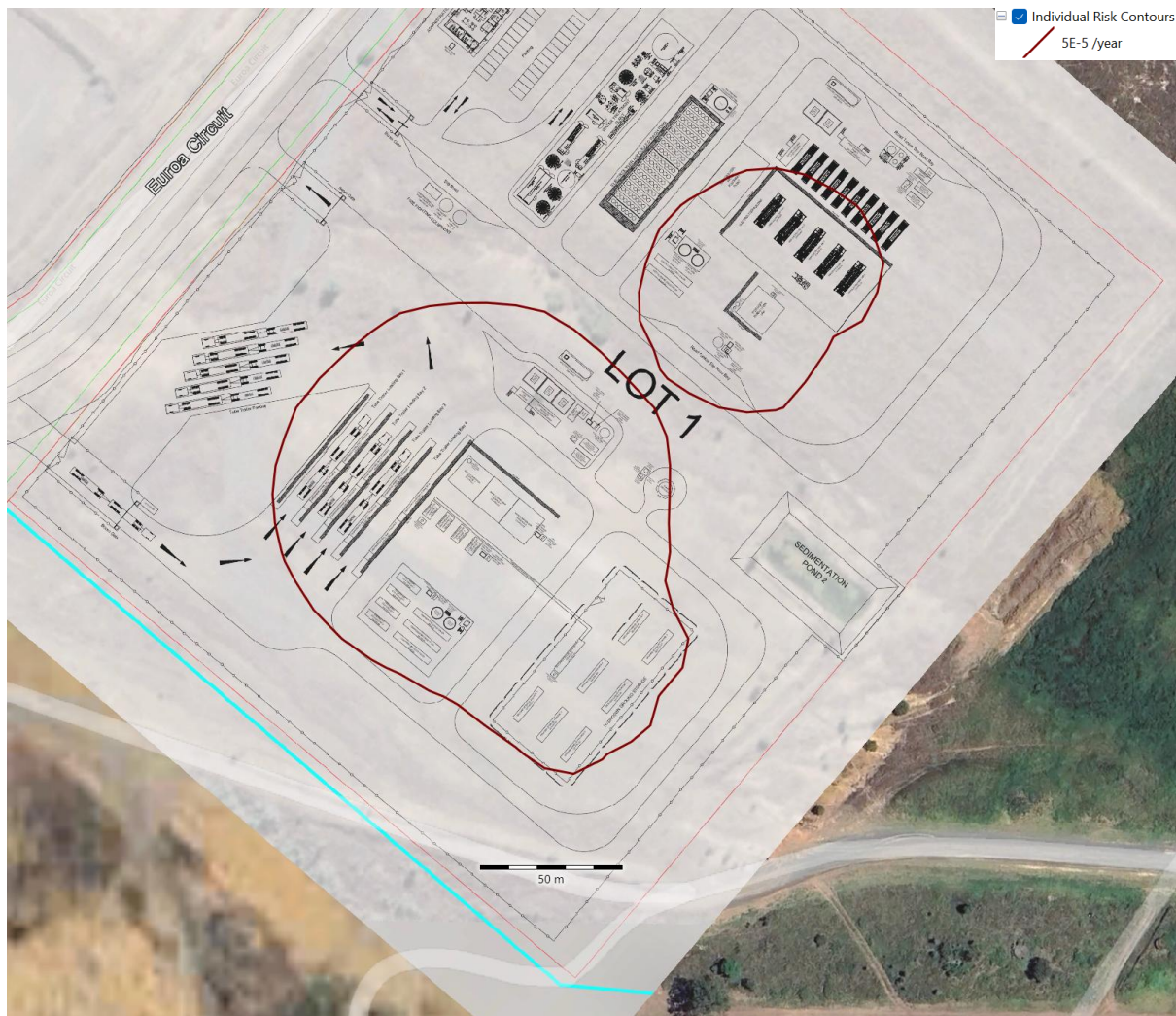


Figure 5-1: Individual risk contour for PO5, of 50×10^{-6} per year, for Euroa H₂ Domestic Project

6 MEETING PERFORMANCE OUTCOMES

Hazard identification, hazard analysis and risk analysis are the three primary tools for assessing the suitability of hazardous industry for a site.

The FEED stage QRA demonstrates that the risk from a facility can be designed to be tolerable when considering the surrounding land uses.

Table 12 details the results of the FEED stage QRA against the required performance outcomes as per SDAP2^{Ref2}. The results demonstrate that the hazards and risk associated with the Euroa H₂ Domestic Project development can be appropriately and adequately managed without undue risk to human health and to the built environment. Relevant Australian Standards, industry best practice and sound engineering principles are available to develop industrial hydrogen plants and would be used throughout the design process to reduce risk so far as reasonably practicable.

These principles are consistent with the duties under the Work Health and Safety Act 2011. Specifically, section 22 duty for a designer: *the person who designs plant and structures is to ensure, so far as is reasonably practicable, that the plant or structure is designed without risks to health and safety of persons.*

The assessment completed at the FEED stage has identified foreseeable hazard scenarios associated with the development. Where applicable, consequences from the worst case credible hazardous scenarios have been quantitatively modelled ignoring risk reduction measures that would be included throughout the design process. As such, the assessment represents the worst-case situation for the development.

6.1.1 Performance outcomes for off-site impact at neighbouring land use

The performance outcome of the Euroa H₂ Domestic Project development against PO1 to PO5 is summarised below.

Table 12: Euroa H₂ Domestic Project Performance Outcomes PO1 to PO5 compliance

Off-site impact at neighbouring land use	Performance outcomes		Euroa H ₂ Domestic Project compliance
	Dangerous dose	Risk assessment	
Vulnerable land use or land zoned for a vulnerable land use (childcare centre; community care centre; educational establishment; health care service; hospital; retirement facility)	<u>PO1, PO2 and PO3:</u> The hazardous chemical facility does not create a dangerous dose to human health <u>with dangerous dose defined as follows:</u> For exposure to heat and/or overpressure from a fire or explosion: 4.7 kW/m² and/or 7 kPa.	Not applicable	The dangerous dose from foreseeable major incidents at the Euroa H ₂ Domestic Project development does not extend into any vulnerable, sensitive of commercial land use or land zoned for vulnerable, sensitive of commercial activity.
Sensitive land use or land zoned for a sensitive land use (community residence; dual occupancy; dwelling house; educational establishment; multiple dwelling; relocatable home park; residential care facility; rooming accommodation; short-term accommodation; tourist park)			
Commercial or community activity land use or land zoned for a commercial or community activity land use (shopping centre; shop; office; major sport, recreation and entertainment facility; market; showroom; tourist attraction; entertainment facility; place of worship; community use; theatre)			

Off-site impact at neighbouring land use	Performance outcomes		Euroa H ₂ Domestic Project compliance
	Dangerous dose	Risk assessment	
Open space land use or land zoned for an open space land use (Outdoor sport and recreation; Park; environment facility; rural industry)	<u>PO4:</u> The hazardous chemical facility, does not create a dangerous dose to human health <u>with dangerous dose defined as follows:</u> For exposure to heat and/or overpressure from a fire or explosion: 4.7 kW/m² and/or 7 kPa	Where the dangerous dose cannot be eliminated, an individual fatality risk level of 10×10^{-6} /year and the societal risk criteria in figure 21.1 of SDAP21	The dangerous dose from foreseeable major incidents at the Euroa H ₂ Domestic Project development does not extend into any open space land use or land zoned for open space activity.
Industrial land use or land zoned for an industrial land use (an extractive industry; a high impact industry; a low impact industry; a marine industry; a medium impact industry; a research and technology industry; a service industry; a special industry; a warehouse.)	<u>PO5:</u> The hazardous chemical facility, does not create a dangerous dose to the built environment <u>with dangerous dose defined as follows:</u> Exposure to heat and/or overpressure from a fire or explosion: 12.5 kW/m² and/or 14 kPa	The hazardous chemical facility, does not create an individual fatality risk level of 50×10^{-6} /year	The dangerous dose from foreseeable major incidents at the Euroa H₂ Domestic Project development does not extend into any industrial land use or land zoned for industrial activity, with the exception of a worst-case release at the: • Compression inlet, dispensers and tube trailer loading impacting the southwestern boundary of the site • Storage Management Package to hydrogen storage interunit pipework and hydrogen storage impacting the southeastern boundary of the site This will be addressed with the implementation of earth berms at the southwestern and southeastern boundary of the site (see recommendation 1). The individual fatality risk level of 50×10^{-6}/year for the Euroa H₂ Domestic Project development does not extend into any off-site industrial land use or land zoned for industrial activity.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 OVERALL CONCLUSION

The main hazards associated with the Euroa H₂ Domestic Project are associated with the production, storage and handling of flammable hydrogen gas and this forms the focus of the present study.

Hazards may arise in fixed plant, storage vessels and pipelines. The predominant mode in which a hazardous incident may occur is associated with a loss of containment (leak), where the release would generally only have the potential to cause injury or damage if it were ignited, resulting in a fire or an explosion.

The extent of the incident is determined by the size of the release and/or the rate at which the hazardous material is released.

The safety, efficiency and stability of Project would be achieved through the use of high level safety systems, automated detection and protection systems, and regular preventative maintenance programs.

This FEED stage QRA has found that the levels of hazards and risks from the Euroa H₂ Domestic Project can be managed within general Performance Outcomes defined in SDAP21, provided suitable fire and overpressure protection is implemented at the southwestern and southeastern boundaries of the site.

The potential incidents are understood and the design of the facilities would emphasise minimising the probability of an incident happening and mitigating an incident if it did occur.

7.2 RECOMMENDATIONS

It is recommended that the following safety considerations be included into the design process:

Recommendation 1: Review the requirements for fire and overpressure protection (e.g. implementation of earth berm) at the southwestern boundary and southeastern boundary of the site. Should an earth berm be installed, ensure a sizing review is completed during detailed design (consider use of CFD modelling when determining the design criteria).

Recommendation 2: Review the design of the safety instrumented systems during the detailed design phase using a Layer Of Protection Analysis (LOPA) methodology to ensure the required SIL rating is achieved (inc. meeting the SIL requirements e.g. probability of failure on demand of the safety instrumented function).

Recommendation 3: This quantitative risk assessment has been developed using the design assumptions for risk reduction at the FEED stage. Key assumptions include:

- Automatic closure of isolation valves on process upset detection within system (e.g. due to a rupture or major leak causing a major loss of pressure)
- Automatic closure of isolation valves on gas (LEL) detection, gas leak detection and/or fire detection
- Double dissimilar non-return valves are provided in the process to prevent backflow of hydrogen in the event of isolation failure (provided as a minimum at the main compression, dispensing compression and hydrogen storage)
- Automatic blowdown valves are provided to relieve the gas inventory between isolatable sections to the flare header.

Other key assumptions are detailed in Appendix 1.

The quantitative risk assessment should be reviewed and risk reduction measures verified as part of the detailed design.

8 REFERENCES

- 1 ISO31000-2009 Risk management – Principles and guidelines, International Standards Organisation, 2009
- 2 State of Queensland, the Department of State Development, Infrastructure and Planning, State Development Assessment Provisions Version 3.2, State Code 21: Hazardous Chemical Facilities, 3 February 2025
- 3 Uijt de Haag P.A.M. (Dr), Ale B.J.M. (Dr), Publication Series on Dangerous Substances (PGS 3), “Yellow Book”, Methods for the Calculation of the Physical Effects of the Escape of Dangerous Material, CPR 14E, Parts 1& 2, Committee for the Prevention of Disasters, Ministerie van VROM Ministerie van Verkeer en Waterstaat (TNO), 2005
- 4 Ehrhart B. D. et al., HyRAM (Hydrogen Risk Assessment Models), Sandia National Laboratory, Version 4.1. April 2022
- 5 Risan A, Pappas J, Dalheim J, *Guidelines for quantitative risk analysis of facilities handling hazardous substances*, Report for The Norwegian Directorate for Civil Protection (DSB), Vysus Norway AS, 19 November 2021
- 6 *Application of Phast and Safeti to Hydrogen Consequences and Risks*, DNV, February 2022

Appendix 1

Assumptions register

Quantitative Risk Assessment for the Euroa Hydrogen Domestic Project - Gladstone Hydrogen Production

Appendix 1: Assumptions register

This FEED QRA is based on a number of key technical assumptions, which are summarised in the QRA report for the Euroa H₂ Domestic Project. These assumptions relate to the source release and gas dispersion, failure rates, ignition probabilities etc., as well as to modelling assumptions (e.g. release orientations, shielding, effects, etc.).

The key assumptions adopted for the quantitative consequence and risk assessment are provided below.

The assumptions are, as far as possible, supported by:

- Actual operating experience and experimental data in the literature, taking into account the reliability of the sources, and, in particular the size of the item population and the time period of the data collection, and comparing actual operating experience with historical data;
- Advice by QRA modelling software developers (TNO / Gexcon; DNV)
- Similar assumptions made by experts in the field and a general consensus among risk analysts; and
- As a last resort, if no other data is available, engineering judgement of the analyst.

The main objectives are to minimise uncertainty in the risk estimate as far as is possible, and to ensure that the assumptions result in a *conservative best estimate* of hazards risk.

The table below lists the assumption title included in this register by their general subject (or topic).

List of assumptions by topic

General topic	Assumption No.	Assumption title
Design Parameters	0	Major design parameters
Hazard identification	1	Hazard mechanism
Locational data	2	Ambient conditions (wind speed, stability conditions, wind directions)
	3	Surface roughness length
Consequence modelling	4	Release modelling
	5	Representative hole sizes
	6	Height of release
	7	Direction of release / obstruction
	8	Dispersion

General topic	Assumption No.	Assumption title
	9	Heat radiation modelling
	10	Explosion overpressure modelling
	11	Determining fraction of cloud involved in explosion
Likelihood Analysis	12	Failure rate data
	13	Sources of ignition and flammable outcome
	14	Probability of ignition
	15	Reduction factor

Design Parameters

Assumption No. 0 Major Design Parameters

Subject: Major Design Parameters

Assumption:

- The major design parameter assumptions for the QRA are included in the table below.

Table A1.0: Major design parameter assumptions

Isolatable section code	Isolatable section, title and colour coding	
ISOL1A_ELS	Electrolyser Skid (2" pipe) – High Pressure side	1. Electrolyser skid contains two isolatable sections (Plug document P107828-BEDP-PC-PID-001): - SDVS101 (from WTP) to SDVS-302,303 – consequence assessed separately for HP side (2", 3", ¾") and UPW side (3") - SDVS-303 to SDVS306, 307, 308 – consequence assessed for LP side (2")
ISOL1B_ELS	Electrolyser Skid (3" pipe) – High Pressure side	
ISOL1C_ELS	Electrolyser Skid (2" pipe) – Low Pressure side	
ISOL1D_ELS	Electrolyser Skid (3/4" pipe)	
ISOL1E_ELS	Electrolyser Ultrapure Water side (3" pipe)	2. Plug assumption of pipework length per electrolyser system: - HP 2" header = 30m per electrolyser system (15m per header x 2) - HP 2" out of HP cathode to SDV = 7m per electrolyser system - HP 3" = 2.5m per electrolyser system - HP ¾" = 21m per electrolyser system (2.1m per stack x 10 stacks) - LP 2" = 25m per electrolyser system - UPW 3" = 55m per electrolyser system 3. ISOL1E_ELS conservatively modelled as containing full volume of hydrogen (design of system will be predominantly liquid filled)
ISOL1-2_PIP	Electrolyser to purification interunit pipework	1. UGL assumption of interunit pipework length: Electrolysers to purification = 62m 2. Underground pipework 3. Assumed pipeline isolatable from electrolyser outlet to isolation at hydrogen purification inlet
ISOL2_GSP	Gas Purifier	1. UGL assumption of pipework length of 150m within hydrogen purification unit

		2. Assumed gas purifier isolatable from inlet and outlet of hydrogen purification unit
ISOL2-3_PIP	Purification to compression interunit pipework	1. UGL assumption of interunit pipework length: • Purification to main compression = 165m 2. Underground pipework 3. Assumed pipeline isolatable from isolation at purification outlet to isolation at main compression inlet
ISOL3_CPI	Compression inlet	1. Compressor supplier assumption of pipework length of 18m per compressor (stage 1 & 2 suction/discharge, stage 3 suction) 2. Assumed main compressor isolatable from inlet and outlet of compressor package 3. Only two compressors operating at one time
ISOL4_CPO	Compression outlet	1. Compressor supplier assumption of pipework length of 5m per compressor (stage 3 discharge) 2. Assumed main compressor isolatable from inlet and outlet of compressor package 3. Only two compressors operating at one time
ISOL4-5_PIP	Compression to storage management interunit pipework	1. UGL assumption of interunit pipework length: • Main compression to storage management package = 90m 2. Above ground pipework 3. Assumed pipeline isolatable from isolation at main compression outlet to isolation at storage management package inlet
ISOL5_SMP	Storage management Package	1. UGL assumption of pipework length of 20m at storage management package 2. Assumed pipeline isolatable from inlet and outlet of storage management package
ISOL5-6_PIP	Storage management to dispensing compression interunit pipework	1. UGL assumption of interunit pipework length: • Storage management package to dispensing compression = 78m 2. Above ground pipework 3. Assumed pipeline isolatable from isolation at storage management package to isolation at dispensing compression inlet
ISOL6_DCI	Dispensing compression inlet	1. Compressor supplier assumption of pipework length of 7m per dispensing compression 2. Assumed dispensing compressor isolatable from inlet and outlet of dispensing compressor package

		3. Conservatively assumed four dispensing compressors operating at one time (design of system will have 3 out of 4 operating).
ISOL7_DCO	Dispensing compression outlet	1. Compressor supplier assumption of pipework length of 8m per dispensing compression 2. Assumed dispensing compressor isolatable from inlet and outlet of dispensing compressor package 3. Conservatively assumed four dispensing compressors operating at one time (design of system will have 3 out of 4 operating).
ISOL7-8_PIP	Dispensing compression to dispensing bay interunit pipework	1. UGL assumption of interunit pipework length: • Dispensing compression to dispensing bay = 105m 2. Above ground pipework 3. Assumed pipeline isolatable from isolation at dispensing compression outlet to isolation at dispensing inlet
ISOL8_DIS	Dispensers	1. UGL assumption of pipework length of 7.2m per dispenser 2. Assumed dispenser isolatable from shutdown valves located on the dispenser pipework
ISOL5-9_PIP	Storage management to storage pipework	1. UGL assumption of interunit pipework length: • Storage management to storage pipework = 91m 2. Above ground pipework 3. Assumed pipeline isolatable from isolation at storage management package outlet to isolation at each hydrogen storage package
ISOL9_STO	Storage	1. UGL assumption of pipework length of 20m for all interconnecting pipework for hydrogen storage package (x7) 2. Assumed each hydrogen storage package is isolatable
ISOL10_TUB	Tube trailer inc. loading hose	1. Pipework from dispensers to the tube trailer loading hoses and loading hoses assumed to be 10m (from available vendor drawings).

Hazard identification

Assumption No. 1 Hazard mechanism

Subject: Hazard identification and mechanism

Assumption:

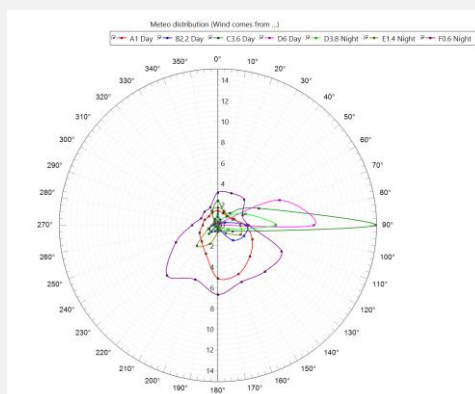
- Hydrogen gas behavior upon release to the atmosphere is taken from Effects® modelling showing dense vapour cloud at the point of release
- As a high reactivity material, the risk of hydrogen exploding or burning is high compared with the standard petroleum gases and liquids (e.g. propane, butane) [TNO, Purple Book]
- Ignition of hydrogen gas at the point of release is possible, in which case the gas would burn as a jet (or torch) flame.
- There is evidence that hydrogen clouds can generate significant overpressures and may even detonate (DNV, 2022) and, while this is contrary to some opinions expressed in the literature, this possibility is included in the present QRA.
- In line with current recommendations for hydrogen risk assessment modelling (several, including DNV 2022), each hydrogen release is taken as resulting in some overpressure, with the Multi-Energy Model (MEM), developed by TNO curve number 5 used as representative of the environment for a hydrogen cloud in a low or medium congestion area. Where there is potential for congested gas accumulation and confined vapour cloud explosion at the area of release (based on LFL contour), an overpressure detonation scenario is modelled using MEM blast strength 10 (see assumption no. 10).
- Hazards associated with of non-ignited compressed gas:
 - Asphyxiation hazard is low compared with flammability hazard for a release of hydrogen. Oxygen deficiency is not believed to constitute a major issue because the flammability limits and fire concerns (for hydrogen) will most likely be the dominant effects. With standard confined space entry procedures and appropriate security arrangements, the risk associated with asphyxiation from hydrogen is not included as a credible safety risk.
 - Locally, the pressure of compressed hydrogen gas may be hazardous in case of an uncontrolled release. This is a hazard for example to maintenance personnel. However, it is not included as a precursor to a credible safety risk associated with the Project within the scope of this study. Pressure hazards, while important to people working at the site, do not have implications beyond the immediate location of the release.
 - Therefore, the risk associated with non-ignited compressed hydrogen gas does not form part of the scope of the present risk assessment.

Assumption No. 2: Ambient conditions (wind speed, stability conditions, wind directions)

Subject: Locational Data

Assumptions:

- Behavior of the gas a distance away from a release, once momentum ceases to dominate release behavior, is dependent on ambient conditions such as wind speed and weather stability
- Dispersion of gas clouds and impacts of thermal radiation is governed by prevalent weather conditions including, wind speed and direction (horizontal mixing) as well as stability of the atmosphere (vertical mixing). The latter is the extent that wind turbulence, responsible for the dispersion, is either suppressed or assisted. On cold windless nights, cold air is trapped close to the surface of the earth and any gas release would not be easily dispersed. In comparison, on a hot summer's day there is increased turbulence of the air due to heating of the earth's surface, this aids the dispersion of gases.
- The meteorological data available in the public domain for Aldoga (Gladstone Region) 2021 hourly meteorological data (located approximately 2km north-west of the site) has been used for the study.
- Atmospheric conditions are summarised in the following Pasquil-Gifford classes:
 - A – Turbulent
 - B – Moderately unstable
 - C – Slightly unstable
 - D – Neutral
 - E – Slightly stable
 - F – Moderately stable
- Pasquil stability categories (A to F) used to define the stability of the atmosphere are used as input into Riskcurves®. The wind rose for Aldoga (Gladstone Region) is provided below:



- A full set of wind spreads and weather conditions can be entered into Riskcurves® to calculate the risk profile. To provide the reader with an overview of the results from the assessment, seven representative wind weather conditions have been defined to represent typical day time and typical night time wind weather conditions:

- Pasquil stability category A at windspeed of 1 m/s (A1), B at windspeed of 2.2 m/s (B2.2), C at windspeed of 3.6 m/s (C3.6), D at windspeed of 6 m/s (D6) is set to represent typical day-time conditions and
 - Pasquil stability category D with windspeed of 3.8 m/s (D3.8), E at windspeed of 1.4 m/s (E1.4), F at windspeed of 0.6m/s (F0.6) is set to represent typical night time conditions.
- Relative humidity is set at 60%
 - The mean atmospheric pressure: Use default in Effects® of 1.013bar
 - Average CO₂ in atmosphere: This QRA uses the default in Effects® of 0.03%
 - Average ambient temperature (day/night) is set at 25°C.

Assumption No. 3: Surface roughness length

Subject: Locational data

Assumptions:

- The roughness factor used for all scenarios is described as follows:
 - *High crops, scattered large obstacles*

Justification of assumptions:

- Ground roughness effects the turbulent flow properties of wind, hence dispersion of a released material. Terrain effects are taken into account to some degree in dispersion modelling by use of a surface roughness length.
- Effects® requires the user to select a surface roughness length that is representative of the types of terrain and obstacles near the proposed site.
- It is possible to define different surface roughness lengths for different locations (land and water) for different scenarios. It is not possible to define different roughness lengths within a single Effect®-model.
- The roughness length for different surface types, as listed in the Effects® user manual, is shown below in the table below.

Table A1.1: Surface roughness length

Description	Roughness Length (m)
Open water, at least 5 km	0.0002
Mud flats, snow, no vegetation, no obstacles	0.005
Open flat terrain, grass, few isolated objects	0.03
Low crops; occasional large obstacles, $x/h > 20$	0.1
High crops, scattered large obstacles, $15 < x/h < 20$	0.25
Parkland, bushes, numerous obstacles, $x/h < 15$	0.5
Regular large obstacle coverage (suburb, forest)	1
City centre with high- and low-rise buildings	3

Assumption No. 4: Release Modelling

Subject: Consequence Analysis

Assumptions:

- Effects® is used to model release behaviour for gases released from plant and equipment.
- Effects® is used to model release conditions and outflow rates, gas dispersion, and heat radiation and explosion overpressures from an ignited release
- Riskcurves® is used to combine the consequences and the likelihoods to develop the risk profile for the Project
- Input data includes the type of release, location of release with respect to initial conditions of the fluid (i.e. before release) and atmospheric conditions (i.e. once the release has occurred)
- The release rate is assumed to remain constant until isolation can be achieved and the “representative” release rate, as suggested by Effects® is used
- Escape by people e.g. due to hazard warning, is ignored as per the convention for risk assessments
- Riskcurves® and Effects® are internationally recognised as suitable models for release behaviour of a range of material in a range of conditions.
- Release rate is dependent on pressure, and releases directly from pipeline and vessels are modelled at the operating pressure.
- Assuming the release rate as remaining constant until isolation can be achieved is a simplified approach as Riskcurves® cannot include more than one release rate for the same scenario. It is a conservative approach as in reality there would be pressure reduction and hence reduction in leak rate, but justifiable as exposure to the initial heat or overpressure is likely to cause the representative injury or damage.

Reference(s):

- Yellow Book (TNO), Guidelines for Quantitative Risk Assessment, Committee for the Prevention of Disasters, CPR 18E, First Edition, The Hague, 3rd Ed, 2nd print, 2005

Assumption No. 5: Representative hole sizes

Subject: Consequence Analysis

Assumption:

- Representative hole sizes were assumed for each release case in line with the methodology in the HyRAM for hydrogen plant and equipment. The following hole sizes are included in the QRA:
 - Small – Leak area is 0.01 % of total flow area
 - Minor – Leak area is 0.1% of total flow area
 - Medium – Leak area is 1% of total flow area
 - Major – Leak area is 10% of total flow area
 - Rupture – Leak area is 100% of total flow area.
- HyRAM database is used for hydrogen release cases

References:

- HyRAM V2.0 User Guide, Sandia National Laboratories operated for the United States Department of Energy by National Technology and Engineering Solutions of Sandia, LLC
- HyRAM computer tool v4.1, 28 April 2022

Assumption No. 6: Height of release

Subject: Consequence Analysis

Assumptions:

- All releases from underground interunit pipework are modelled at a release height of 0 m above ground level.
- All releases from aboveground interunit pipework are modelled at a release height of 1.5 m above ground level.
- All releases from aboveground equipment are modelled at a release height of 2.5 m above ground level, with the exception of the dispensers, tube trailer inc. loading hose and hydrogen storage modelled at a release height of 1.5 m above ground level

Assumption No. 7: Direction of release / obstruction

Subject: Consequence Analysis

Assumptions:

- The direction of release is dependent on the failure mode and representative hole size.
- For the worst-case consequence modelling, the direction of release has been selected to direct the release to the closest site boundary.
- All hole sizes are modelled as follows:
 - Jet fire non obstructed: Horizontal release
 - Jet fire obstructed: Horizontal release (normally should be assumed as vertical which gives lower heat radiation distances)
 - Jet fire obstructed: where fire walls are present at direction of release, fire walls are assumed to be designed such that it is 100% effective at deflecting and/or absorbing heat radiation, in which case the jet flame is assumed to be directed vertically.
 - Dispersion and/or vapour cloud explosion: downward release

Assumption No. 8: Dispersion

Subject: Consequence Analysis

Assumption:

- Effects® software is used to model flammable hydrogen gas dispersion
- Hydrogen is modelled as a neutral dispersion with Effects® predicting when the flammable gas cloud becomes lighter than air.
- Release rates for gas dispersion models are taken from gas release rates calculated by Effects®.
- Benchmarking hydrogen gas dispersion using the Effects® model against other commercially available software models e.g. Phast® by DNV indicates Effects® dispersion provides conservative results
- The developers of Effects® (Gexcon / TNO) are updating the models for better representation of hydrogen effects – as such models are not commercially available to-date, the modelling conducted in this QRA uses a series of conservative assumptions throughout. Full 3D environment around the facility, requiring a 3D CFD based modelling approach, such as FLACS, may be useful during detailed design of this facility.
- The height of the target is set at 1.5 metres, which is standard for QRAs.

Assumption No. 9: Heat radiation modelling

Subject: Consequence Analysis

Assumption:

- Heat radiation effects are dependent on the quantity of flammable or combustible product released, its heat of combustion, flame dimensions and the fraction of heat radiated.
- Heat radiation is determined as a sum of the net energy released as a result of the combustion reaction. It is assumed to occur outdoors, hence, with an infinite supply of oxygen.
- Jet fires are modelled using the standard “Chamberlain approach” in Effects® which has been benchmarked against other commercially available models and found to provide acceptable if somewhat conservative results
- The heat flux at a particular distance from a fire is calculated using the view factor method.
- Jet flame dimensions and burning rates vary depending on the wind weather conditions.
- The effect or impact of heat radiation on people is shown in the table below.

Table A1.2: Effects of heat radiation

Radiant Heat Level (kW/m ²)	Physical Effect (effect depends on exposure duration)
1.2	Received from the sun at noon in summer
2.1	Minimum to cause pain after 1 minute
4.7	Will cause pain in 15-20 seconds and injury after 30 seconds' exposure
12.6	Significant chance of fatality for extended exposure. High chance of injury
23	Likely fatality for extended exposure and chance of fatality for instantaneous (short) exposure
35	Significant chance of fatality for people exposed instantaneously

Assumption No. 10: Explosion overpressure modelling

Subject: Consequence Analysis

Assumption:

- An explosion is primarily defined by the environment in which the gas disperses.
- Partial confinement is a major cause of blast in gas cloud deflagrations for VCEs from obstructed releases of from high pressure equipment.
- The peak side-on overpressure resulting from an explosion is estimated using the Multi Energy method option in the Effects® software assuming 100% of the cloud between LEL and UEL participating in the explosion [TNO, Purple Book and modelling software developers' recommendation]. MEM curve 5 is used for all hydrogen releases where worst-case release (towards closest site boundary) is not in a congested area.
- Where there is potential for congested gas accumulation and confined vapour cloud explosion at the area of release (based on LFL contour), an overpressure detonation scenario is modelled using MEM blast strength 10. If dimensions of equipment in the congested area are unknown, it is conservatively assumed that 100% of the cloud is involved in the explosion. Volume blockage ratios have been determined for the electrolyser building and hydrogen storage areas for this study (see assumption 11).
- Only overpressure effects are included as being the representative hazard from vapour cloud explosions. Projectiles and whole-body displacement are not included.
- The effect or impact of explosion overpressure is shown in Table A1-7 below.

Table A1.3: Effects of explosion overpressure

Explosive overpressure(kPa)	Physical Effect (effect depends on exposure duration)
3.5	90% glass breakage. No fatality, very low probability of injury
7	Damage to internal partitions & joinery. 10% probability of injury, no fatality
14	Houses uninhabitable and badly cracked
21	Reinforced structures distort, storage tanks fail. 20% chance of fatality to person in building
35	Houses uninhabitable, rail wagons & plant items overturned. Threshold of eardrum damage, 50% chance of fatality for a person in a building, 15% in the open
70	Complete demolition of houses. Threshold of lung damage, 100% chance of fatality for a person in a building or in the open

Assumption No. 11: Determining fraction of cloud involved in explosion

Subject: Consequence Analysis

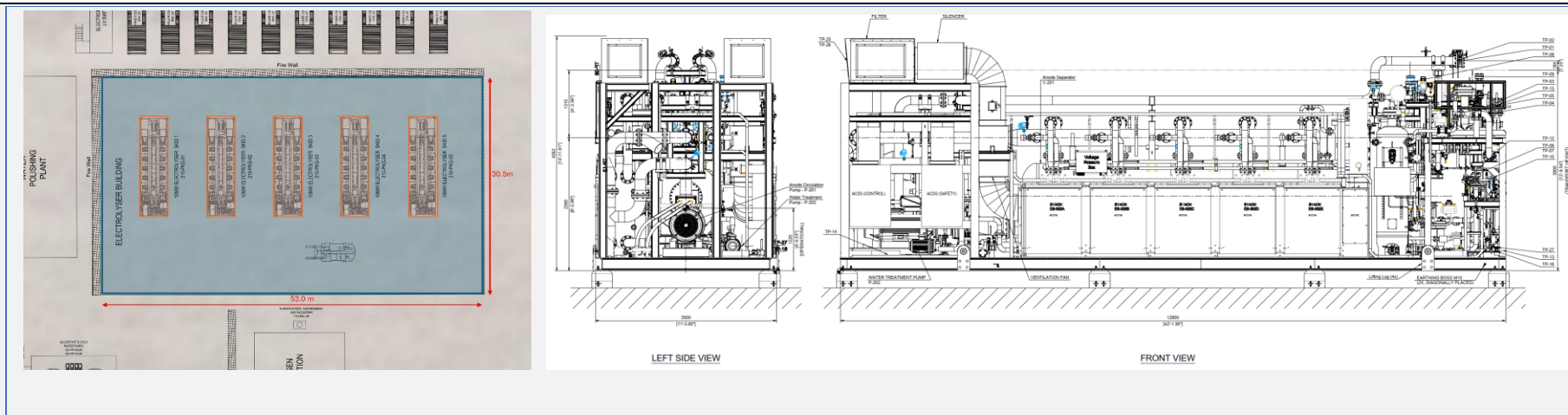
Assumption:

- The vapour cloud explosion consequence is determined by the volume of vapour space where the hydrogen can accumulate, at a concentration higher than the LFL. Gas accumulation and fraction of cloud involved in explosion at the electrolyser building and hydrogen storage areas have been determined in the tables below.

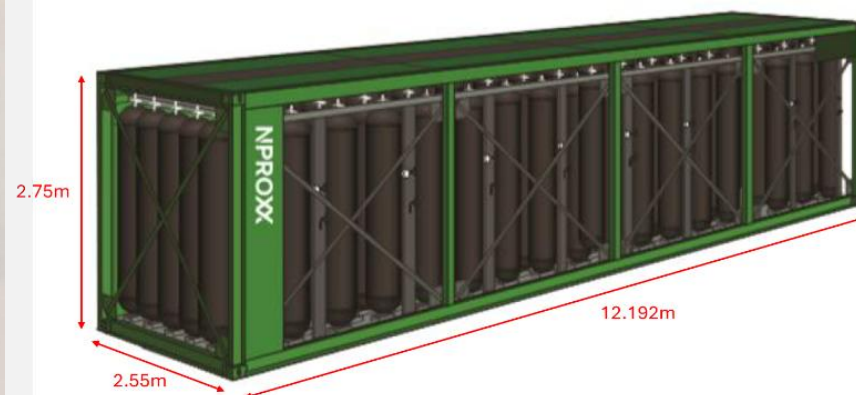
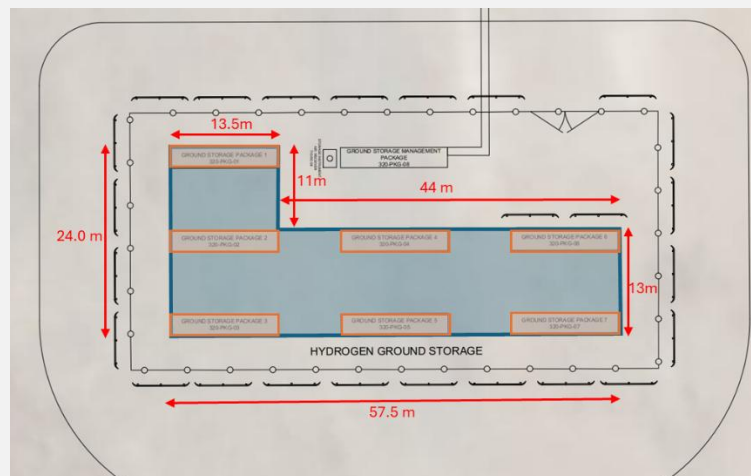
Area	Overall congested area dimension ^{Note 3}				Electrolyser skid ^{Note 4}				Volume blockage ratio (VBR)	TNO MEM blast strength
	L (m)	W (m)	H (m)	V (m ³)	L (m)	W (m)	H (m)	V (m ³)		
Electrolyser Building	53.0	30.5	4.56	7,374	12.85	3.5	4.562	1026 ^{Note1}	13.91%	10

Note:

- Total volume of 5 x 10MW electrolyser skids
- 'Electrolyser Skid (2") – HP' used as representative volume (worst-case scenario output for VCE from electrolyser skid with largest hydrogen mass in the congested area)
- Electrolyser building dimensions as per UGL drawing 17695-SITE-GA-1002-01 Hydrogen Plant General Arrangement
- Electrolyser skid dimensions as per Plug document P107828-BEDP-PP-GAS-001



Area	Overall congested area dimension				Hydrogen storage package				Volume blockage ratio (VBR)	TNO MEM blast strength
	L (m)	W (m)	H (m)	V (m ³)	L (m)	W (m)	H (m)	V (m ³)		
Hydrogen Ground Storage	Note1	Note1	2.75	2464	12.19	2.55	2.75	599 Note2	24.29%	10
Notes: 1. Congested area dimensions as per UGL drawing 17695-SITE-GA-1002-01 Hydrogen Plant General Arrangement 2. Total volume of 7 x hydrogen storage packages 3. Hydrogen package dimensions as per NPPROXX Factsheet										



Likelihood Analysis

Assumption No. 12: Failure rate data

Subject: Likelihood Analysis

Assumption:

- The parts count of major equipment, piping/fittings used is derived using a count of the number of components for each identified failure case within an isolatable inventory. This is completed by taking the component count from piping and instrument diagrams available at the FEED-stage (versions available at the time of the assessment) and multiplying by the release frequencies as defined in the body of the report.
- All vessels, process equipment and piping are assumed to be fully welded
- Process piping lengths are estimated as provided by UGL or the vendor
- For tube trailer unloading, the frequency of hose coupling error and truck driveaway whilst still connected is shown in the table below. This frequency data assumes the following:
 - Multi safety system facility as excess flow valve at hose connection and breakaway coupling are included in current design (UK HSE, 2017):
 - Multi safety system: Two pullaway prevention systems, and also an effective pullaway mitigation system and inspection and pressure/leak tests to prevent transfer system leaks and burst
 - The safety systems applicable to the facility are pullaway prevention (e.g. wheel chocks, interlock brakes, interlock barriers), pullaway mitigation that stops the flow in the event of a pullaway (e.g. short airline, but only if it will separate and activate a shut off valve before the transfer system fails, movement detectors), and hose failure protection (pressure leak test, hose inspection)
 - No additional credit is given for duplicate non-redundant safety systems

Table A1.4: Hose failure frequency for multi safety system facility (UK HSE, 2017)

Component	unit	Very Small	Minor	Medium	Major	Rupture
Hose coupling error and drive away whilst still connected	Per connection	0.00E+00	6.00E-06	4.00E-07	0.00E+00	2.00E-07

Assumption No. 14: Sources of ignition and flammable outcome

Subject: Likelihood Analysis

Assumption:

- Hydrogen is considered a *high reactivity* gas (e.g. TNO Purple Book).
- The term immediate ignition is used to represent ignition due to a nearby source that occurs before an appreciable vapour cloud is produced [UK HSE RR 1034].
- Immediate ignition is incident generated, e.g. in the case where a pipe is broken on impact, by the frictional sparks that may be generated and acting as an ignition source, thus resulting in immediate ignition. Immediate ignition may also be generated through friction of the outflowing material. It is assumed that immediate ignition occurs within 30 s of a release [UK HSE RR 1034].
- Immediate ignition of a jet of flammable gas from a hole in a pipe or vessel will result in a jet fire.
- If immediate ignition does not occur, the released flammable cloud may continue to travel downwind until it encounters a sufficient source of ignition. This type of ignition is referred to as *delayed remote ignition*. Delayed remote ignition can occur if there are insufficient ignition sources close to the release point.
- An immediate and a delayed ignition probability are defined for each minor and major release case
- The Probability of ignition is provided in Assumption No. 15.

Assumption No. 15: Probability of ignition

Subject: Likelihood analysis

Assumption:

- Ignition probabilities used in the QRA for hydrogen release cases is obtained from Table 5-6 of a report by Sandia National Laboratories, and has been summarised in the table below. The ignition probabilities are a function of the hydrogen release rate. The Sandia report refers to 'Tchouvelev values' and a 'HYSAFE' program model as follows:
 - 'HYSAFE' program model⁷: Immediate ignition probabilities range from 0.0001 to 0.9, and delayed ignition probabilities range from 0.004 to 0.5. The HYSAFE probabilities are for self-ignition only, and hence are not recommended by the Sandia report.
 - Tchouvelev ignition model⁸: were adapted for hydrogen from values suggested in Cox, Lee, & Ang. The Sandia report states it has been determined that Tchouvelev value were reasonable and should be used in the base line risk analysis
- It should be noted the maximum immediate and delayed ignition probability, based on Tchouvelev Model is capped at 0.23 and 0.12 for immediate and delayed ignition for release rate > 6.25 kg/s. In order to reflect higher ignition probability for larger release, ignition model in TNO Purple Book (Uijt de Haag and Ale, 2005, Table 4.5 and Table 4.A.1), is combined with Tchouvelev model, to cover a wide range of release rate, i.e. > 6.25 kg/s

Table A1.5: Hydrogen Ignition Probability

Combined model of Tchouvelev and TNO Purple Book			HYSAFE Model (reference only)	
Hydrogen Release Rate (kg/s)	Immediate Ignition Probability	Delayed Ignition Probability	Hydrogen Release Rate (kg/s)	Immediate Ignition Probability
<0.125	0.008	0.004	0.01 – 0.1	0.001
0.125 – 6.25	0.053	0.027	0.01 – 1	0.001 + 0,001 when P>100 bar
6.25 -10	0.23	0.12	1 – 10	0.01 + 0.01 when P>100 bar
10-100	0.5	0.35 ¹	>10	0.1 + 0.01 or 0.02
>100	0.7	0.21 ¹	N/A	N/A

Note 1: Based on TNO Purple book, delayed ignition probability of flammable cloud within heavy industry site is 0.7, if not immediately ignited before the full growth of cloud

⁷ L.K. Rodsaetre and K. Ottestad Holmefjord, "An Ignition Probability Model for Hydrogen Risk Analysis," HYSAFE Deliverable No. 71, January 6, 2007.

⁸ Canadian Hydrogen Safety Program, "Quantitative Risk Comparison of Hydrogen and CNG Refueling Options," Presentation, IEA Task 19 Meeting, 2006.

Assumption No. 17: Reduction factors

Subject: Likelihood analysis

Assumption:

- The protection factor included in the QRA are presented in the table below.

Table A1.6: Reduction factors

Mitigation measure	Reduction factor	Used in the QRA
Automated plant trip and shutdown via automatic closure of isolation valves on process upset detection within system (e.g. due to a rupture or major leak causing a major loss of pressure)	0.05	Safety system assumed as minimum SIL1 with PFD of 0.05. Assumed to activate for rupture and major leak scenarios only (not activated for very small, minor and medium size release scenarios).
Automated plant trip and shutdown via automatic closure of isolation valves on gas or fire detection	0.05	Safety system assumed as minimum SIL1 with PFD of 0.05. Includes blowdown (where relevant) upon activation.
Automatic opening of blowdown valves upon emergency shutdown to relieve the gas inventory between the isolatable section to the flare header	-	A total time from trigger to full blowdown valve opening is taken as 220 milliseconds and set as the maximum release duration when assessing isolated cases for the QRA.

- For isolated scenarios, blowdown valve opening times have been obtained from available literature on hydrogen blowdown release experiments⁹. The experiment states “A reaction time of approx. 40 ms elapses before the ball in the pneumatic valve starts to rotate, and to open the full cross section of the valve further approx. 180 ms are needed”. A total time from trigger to full blowdown valve opening is taken as 220 milliseconds and set as the maximum release duration when assessing isolated scenarios for the QRA.

⁹ A. Vesper, A. Friedrich, M. Kuznetsov, T. Jordan, N. Kotchourko, "Hydrogen Blowdown Release Experiments at Different Temperatures in the DISCHA-Facility", 9th International Conference on Hydrogen Safety (ICHs), Edinburgh, UK, 21–23 September 2021.

Appendix 2

Consequence analysis results

Quantitative Risk Assessment for the Euroa Hydrogen Domestic Project - Gladstone Hydrogen Production

Appendix 2: Consequence analysis results for isolation fail scenarios (worst case)

Consequence analysis results for isolation fail scenarios (worst case):

Isolatable section	Section Code	Release Category Code	Connection size (mm)	Release size (mm)	Material	Mass inventory of isolatable section (kg)	Operating Temp. (°C)	Operating Pressure (barg)	Release rate (kg/s)	Distance to heat radiation level (m)		Distance to overpressure level (m)		Flammable dispersion - distance to LFL (m)
										4.7kW/m ²	12.6 kW/m ²	7 kPa	14 kPa	
Electrolyser Skid (2" pipe) – Low Pressure side	ISOL1A_ELS	XL	50.8	50.8	H ₂	51.922	75	40	1.982	47	41	96	65	48
Electrolyser to purification interunit pipework	ISOL1-2_PIP	XL	76.2	76.2	H ₂	51.922	75	40	4.534	56	46	85	57	68
Gas Purifier	ISOL2_GSP	XL	76.2	76.2	H ₂	62.610	15	40	3.597	63	55	137	92	64
Purification to compression interunit pipework	ISOL2-3_PIP	XL	76.2	76.2	H ₂	62.610	15	40	3.459	52	43	90	60	61
Compression inlet	ISOL3_CPI	XL	76.2	76.2	H ₂	62.610	15	40	6.773	82	72	167	111	85
Compression outlet	ISOL4_CPO	XL	25.4	25.4	H ₂	17.830	15	450	7.400	82	72	109	70	84
Compression to storage management interunit pipework	ISOL4-5_PIP	XL	25.4	25.4	H ₂	17.830	15	450	2.731	54	47	64	45	63
Storage management Package	ISOL5_SMP	XL	25.4	25.4	H ₂	17.830	15	450	5.109	70	61	104	68	77
Storage management to dispensing compression interunit pipework	ISOL5-6_PIP	XL	25.4	25.4	H ₂	17.830	15	450	2.917	56	49	64	44	65
Dispensing compression inlet	ISOL6_DCI	XL	25.4	25.4	H ₂	17.830	15	450	6.920	80	70	111	71	82
Dispensing compression outlet	ISOL7_DCO	XL	25.4	25.4	H ₂	8.751	15	650	9.320	91	80	100	63	81
Dispensing compression to dispensing bay interunit pipework	ISOL7-8_PIP	XL	25.4	25.4	H ₂	8.751	15	650	3.516	60	53	47	31	65
Dispensers	ISOL8_DIS	XL	25.4	25.4	H ₂	10.242	-30	650	10.370	99	87	52	33	89
Storage management to storage pipework	ISOL5-9_PIP	XL	25.4	25.4	H ₂	17.830	15	450	2.718	54	47	105	71	63
Storage	ISOL9_STO	XL	25.4	25.4	H ₂	7022.200	25	400	4.427	65	57	87	62	77
Tube trailer inc. loading hose	ISOL10_TUB	XL	25.4	25.4	H ₂	4520.900	-30	517	7.852	88	77	124	89	111

Appendix 3

Likelihood assessment

Quantitative Risk Assessment for the Euroa Hydrogen Domestic Project - Gladstone Hydrogen Production

Appendix 3: Likelihood assessment

Likelihood assessment for isolated scenarios:

Section code	Release Category	Connection size (mm)	Release size (mm)	Material	Release rate (kg/s)	Release Frequency (/year)	ISOL base frequency with risk reduction (does not include ignition probabilities)	ISOL VCE at tube trailer loading bay frequency (/year)	ISOL VCE at H2 storage frequency (/year)	ISOL VCE at main compressors frequency (/year)	ISOL VCE at dispensing compressors frequency (/year)	ISOL VCE at purification unit frequency (/year)	ISOL VCE at electrolyzers frequency (/year)
ISOL1A_ELS	XS	50.8	0.51	H ₂	0.000	2.08E+00	2.08E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1A_ELS	S	50.8	1.6	H ₂	0.004	1.48E-01	1.48E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1A_ELS	M	50.8	5.1	H ₂	0.034	6.97E-02	6.97E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1A_ELS	L	50.8	16.1	H ₂	0.373	2.66E-03	2.53E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.98E-04
ISOL1A_ELS	XL	50.8	50.8	H ₂	2.190	7.90E-04	7.50E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.15E-05	1.18E-04
ISOL1B_ELS	XS	76.2	0.76	H ₂	0.001	3.66E-01	3.66E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1B_ELS	S	76.2	2.4	H ₂	0.008	2.54E-02	2.54E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1B_ELS	M	76.2	7.6	H ₂	0.076	1.22E-02	1.22E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.93E-03
ISOL1B_ELS	L	76.2	24.1	H ₂	0.839	3.45E-04	3.28E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.56E-05	5.16E-05
ISOL1B_ELS	XL	76.2	76.2	H ₂	5.671	7.44E-05	7.07E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.68E-06	1.11E-05
ISOL1C_ELS	XS	50.8	0.51	H ₂	0.000	1.57E+00	1.57E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1C_ELS	S	50.8	1.6	H ₂	0.001	1.13E-01	1.13E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1C_ELS	M	50.8	5.1	H ₂	0.005	5.28E-02	5.28E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1C_ELS	L	50.8	16.1	H ₂	0.055	2.25E-03	2.14E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.38E-04
ISOL1C_ELS	XL	50.8	50.8	H ₂	0.370	6.92E-04	6.57E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.04E-04
ISOL1D_ELS	XS	19.1	0.19	H ₂	0.000	2.52E-06	2.52E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1D_ELS	S	19.1	0.6	H ₂	0.001	1.18E-06	1.18E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1D_ELS	M	19.1	1.9	H ₂	0.005	5.29E-07	5.29E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1D_ELS	L	19.1	6	H ₂	0.052	2.37E-05	2.25E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1D_ELS	XL	19.1	19.1	H ₂	0.251	2.04E-05	1.94E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.15E-05
ISOL1E_ELS	XS	76.2	0.76	H ₂	0.001	2.94E-02	2.94E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1E_ELS	S	76.2	2.4	H ₂	0.008	2.05E-03	2.05E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Section code	Release Category	Connection size (mm)	Release size (mm)	Material	Release rate (kg/s)	Release Frequency (/year)	ISOL base frequency with risk reduction (does not include ignition probabilities)	ISOL VCE at tube trailer loading bay frequency (/year)	ISOL VCE at H2 storage frequency (/year)	ISOL VCE at main compressors frequency (/year)	ISOL VCE at dispensing compressors frequency (/year)	ISOL VCE at purification unit frequency (/year)	ISOL VCE at electrolyzers frequency (/year)
ISOL1E_ELS	M	76.2	7.6	H ₂	0.076	9.85E-04	9.85E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.86E-04
ISOL1E_ELS	L	76.2	24.1	H ₂	0.837	3.13E-05	2.98E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.23E-06	1.77E-05
ISOL1E_ELS	XL	76.2	76.2	H ₂	5.160	6.59E-06	6.26E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.80E-07	3.72E-06
ISOL1-2_PIP	XS	76.2	0.76	H ₂	0.001	1.54E-01	1.47E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1-2_PIP	S	76.2	2.4	H ₂	0.008	1.20E-02	1.14E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1-2_PIP	M	76.2	7.6	H ₂	0.084	5.20E-03	4.94E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1-2_PIP	L	76.2	24.1	H ₂	0.821	2.26E-04	2.04E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1-2_PIP	XL	76.2	76.2	H ₂	4.651	1.18E-04	1.06E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL2_GSP	XS	50.8	0.51	H ₂	0.001	1.93E+01	1.84E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL2_GSP	S	50.8	1.6	H ₂	0.009	1.39E+00	1.32E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL2_GSP	M	50.8	5.1	H ₂	0.092	6.53E-01	6.21E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL2_GSP	L	50.8	16.1	H ₂	0.909	2.63E-02	2.37E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-02
ISOL2_GSP	XL	50.8	50.8	H ₂	3.976	1.35E-02	1.22E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.69E-03
ISOL2-3_PIP	XS	76.2	0.76	H ₂	0.001	1.56E-01	1.48E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL2-3_PIP	S	76.2	2.4	H ₂	0.009	1.25E-02	1.19E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL2-3_PIP	M	76.2	7.6	H ₂	0.092	5.46E-03	5.18E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL2-3_PIP	L	76.2	24.1	H ₂	0.902	3.42E-04	3.09E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL2-3_PIP	XL	76.2	76.2	H ₂	3.737	2.18E-04	1.97E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL3_CPI	XS	76.2	0.76	H ₂	0.001	5.95E+00	5.65E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL3_CPI	S	76.2	2.4	H ₂	0.009	4.83E-01	4.59E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL3_CPI	M	76.2	7.6	H ₂	0.092	2.29E-01	2.18E-01	0.00E+00	0.00E+00	8.72E-02	0.00E+00	0.00E+00	0.00E+00
ISOL3_CPI	L	76.2	24.1	H ₂	0.911	1.84E-02	1.66E-02	0.00E+00	0.00E+00	6.65E-03	4.83E-03	0.00E+00	0.00E+00
ISOL3_CPI	XL	76.2	76.2	H ₂	6.917	8.76E-03	7.90E-03	0.00E+00	0.00E+00	3.17E-03	2.30E-03	0.00E+00	0.00E+00
ISOL4_CPO	XS	25.4	0.25	H ₂	0.001	1.63E+00	1.54E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL4_CPO	S	25.4	0.8	H ₂	0.010	1.60E-01	1.52E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL4_CPO	M	25.4	2.5	H ₂	0.099	6.62E-02	6.29E-02	0.00E+00	0.00E+00	2.52E-02	0.00E+00	0.00E+00	0.00E+00

Section code	Release Category	Connection size (mm)	Release size (mm)	Material	Release rate (kg/s)	Release Frequency (/year)	ISOL base frequency with risk reduction (does not include ignition probabilities)	ISOL VCE at tube trailer loading bay frequency (/year)	ISOL VCE at H2 storage frequency (/year)	ISOL VCE at main compressors frequency (/year)	ISOL VCE at dispensing compressors frequency (/year)	ISOL VCE at purification unit frequency (/year)	ISOL VCE at electrolyzers frequency (/year)
ISOL4_CPO	L	25.4	8	H ₂	1.007	2.67E-03	2.41E-03	0.00E+00	0.00E+00	9.66E-04	7.01E-04	0.00E+00	0.00E+00
ISOL4_CPO	XL	25.4	25.4	H ₂	8.110	4.25E-04	3.83E-04	0.00E+00	4.51E-05	1.54E-04	1.12E-04	0.00E+00	0.00E+00
ISOL4-5_PIP	XS	25.4	0.25	H ₂	0.001	3.38E-01	3.21E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL4-5_PIP	S	25.4	0.8	H ₂	0.010	3.00E-02	2.85E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL4-5_PIP	M	25.4	2.5	H ₂	0.099	1.14E-02	1.09E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL4-5_PIP	L	25.4	8	H ₂	0.955	8.65E-04	7.81E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL4-5_PIP	XL	25.4	25.4	H ₂	2.934	4.62E-04	4.17E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5_SMP	XS	25.4	0.25	H ₂	0.001	2.17E+00	2.07E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5_SMP	S	25.4	0.8	H ₂	0.010	1.58E-01	1.50E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5_SMP	M	25.4	2.5	H ₂	0.098	7.22E-02	6.86E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5_SMP	L	25.4	8	H ₂	0.952	2.27E-03	2.05E-03	0.00E+00	1.19E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5_SMP	XL	25.4	25.4	H ₂	5.117	6.39E-04	5.76E-04	0.00E+00	3.35E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5-6_PIP	XS	25.4	0.25	H ₂	0.001	1.16E+00	1.10E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5-6_PIP	S	25.4	0.8	H ₂	0.010	8.88E-02	8.44E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5-6_PIP	M	25.4	2.5	H ₂	0.099	3.87E-02	3.68E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5-6_PIP	L	25.4	8	H ₂	0.959	1.70E-03	1.53E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5-6_PIP	XL	25.4	25.4	H ₂	3.112	6.47E-04	5.84E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL6_DCI	XS	25.4	0.25	H ₂	0.001	1.15E+00	1.10E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL6_DCI	S	25.4	0.8	H ₂	0.010	9.58E-02	9.10E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL6_DCI	M	25.4	2.5	H ₂	0.099	4.24E-02	4.03E-02	0.00E+00	0.00E+00	0.00E+00	7.39E-03	0.00E+00	0.00E+00
ISOL6_DCI	L	25.4	8	H ₂	1.003	1.44E-03	1.30E-03	0.00E+00	0.00E+00	6.69E-04	2.38E-04	0.00E+00	0.00E+00
ISOL6_DCI	XL	25.4	25.4	H ₂	7.484	2.73E-04	2.47E-04	0.00E+00	0.00E+00	1.27E-04	4.53E-05	0.00E+00	0.00E+00
ISOL7_DCO	XS	25.4	0.25	H ₂	0.001	1.38E+00	1.31E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL7_DCO	S	25.4	0.8	H ₂	0.014	1.12E-01	1.07E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL7_DCO	M	25.4	2.5	H ₂	0.136	5.11E-02	4.85E-02	0.00E+00	0.00E+00	0.00E+00	8.91E-03	0.00E+00	0.00E+00
ISOL7_DCO	L	25.4	8	H ₂	1.383	2.48E-03	2.24E-03	0.00E+00	0.00E+00	1.15E-03	4.10E-04	0.00E+00	0.00E+00

Section code	Release Category	Connection size (mm)	Release size (mm)	Material	Release rate (kg/s)	Release Frequency (/year)	ISOL base frequency with risk reduction (does not include ignition probabilities)	ISOL VCE at tube trailer loading bay frequency (/year)	ISOL VCE at H2 storage frequency (/year)	ISOL VCE at main compressors frequency (/year)	ISOL VCE at dispensing compressors frequency (/year)	ISOL VCE at purification unit frequency (/year)	ISOL VCE at electrolyzers frequency (/year)
ISOL7_DCO	XL	25.4	25.4	H ₂	10.077	3.10E-04	2.79E-04	0.00E+00	0.00E+00	1.44E-04	5.13E-05	0.00E+00	0.00E+00
ISOL7-8_PIP	XS	25.4	0.25	H ₂	0.001	4.95E-01	4.70E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL7-8_PIP	S	25.4	0.8	H ₂	0.014	4.25E-02	4.04E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL7-8_PIP	M	25.4	2.5	H ₂	0.136	1.67E-02	1.58E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL7-8_PIP	L	25.4	8	H ₂	1.313	1.11E-03	9.99E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL7-8_PIP	XL	25.4	25.4	H ₂	3.800	5.77E-04	5.21E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL8_DIS	XS	25.4	0.25	H ₂	0.001	4.51E-01	4.29E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL8_DIS	S	25.4	0.8	H ₂	0.015	3.32E-02	3.15E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL8_DIS	M	25.4	2.5	H ₂	0.145	1.54E-02	1.47E-02	4.57E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL8_DIS	L	25.4	8	H ₂	1.380	7.64E-04	6.90E-04	2.15E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL8_DIS	XL	25.4	25.4	H ₂	10.370	1.37E-04	1.23E-04	3.85E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5-9_PIP	XS	25.4	0.25	H ₂	0.001	2.33E+00	2.22E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5-9_PIP	S	25.4	0.8	H ₂	0.010	1.70E-01	1.62E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5-9_PIP	M	25.4	2.5	H ₂	0.099	7.73E-02	7.34E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5-9_PIP	L	25.4	8	H ₂	0.955	2.44E-03	2.21E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5-9_PIP	XL	25.4	25.4	H ₂	2.921	9.24E-04	8.34E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL9_STO	XS	25.4	0.25	H ₂	0.001	1.20E+00	1.14E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL9_STO	S	25.4	0.8	H ₂	0.009	8.81E-02	8.37E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL9_STO	M	25.4	2.5	H ₂	0.087	4.13E-02	3.92E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL9_STO	L	25.4	8	H ₂	0.887	2.18E-03	1.97E-03	0.00E+00	1.97E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL9_STO	XL	25.4	25.4	H ₂	5.039	3.73E-04	3.37E-04	0.00E+00	3.37E-04	8.74E-05	8.74E-05	0.00E+00	0.00E+00
ISOL10_TUB	XS	25.4	0.25	H ₂	0.001	3.45E-01	3.28E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL10_TUB	S	25.4	0.8	H ₂	0.012	2.49E-02	2.36E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL10_TUB	M	25.4	2.5	H ₂	0.121	1.18E-02	1.12E-02	3.48E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL10_TUB	L	25.4	8	H ₂	1.233	5.69E-04	5.14E-04	1.60E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL10_TUB	XL	25.4	25.4	H ₂	8.700	1.74E-04	1.57E-04	4.91E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Likelihood assessment for non-isolated (isolation fail) scenarios:

Section code	Release Category	Connection size (mm)	Release size (mm)	Material	Release rate (kg/s)	Release Frequency (/year)	NON-ISOL base frequency with risk reduction failed (/year) (does not include ignition probabilities)	NON-ISOL VCE at tube trailer loading bay frequency (/year)	NON-ISOL VCE at H2 storage frequency (/year)	NON-ISOL VCE at main compressors frequency (/year)	NON-ISOL VCE at dispensing compressors frequency (/year)	NON-ISOL VCE at purification unit frequency (/year)	NON-ISOL VCE at electrolyzers frequency (/year)
ISOL1A_ELS	XS	50.8	0.51	H ₂	0.000	2.08E+00	2.08E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1A_ELS	S	50.8	1.6	H ₂	0.004	1.48E-01	1.48E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1A_ELS	M	50.8	5.1	H ₂	0.035	6.97E-02	6.97E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1A_ELS	L	50.8	16.1	H ₂	0.336	2.66E-03	1.33E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.10E-05
ISOL1A_ELS	XL	50.8	50.8	H ₂	1.982	7.90E-04	3.95E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.29E-06	6.23E-06
ISOL1B_ELS	XS	76.2	0.76	H ₂	0.001	3.66E-01	3.66E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1B_ELS	S	76.2	2.4	H ₂	0.008	2.54E-02	2.54E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1B_ELS	M	76.2	7.6	H ₂	0.076	1.22E-02	1.22E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.93E-03
ISOL1B_ELS	L	76.2	24.1	H ₂	0.756	3.45E-04	1.72E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.87E-06	2.72E-06
ISOL1B_ELS	XL	76.2	76.2	H ₂	5.184	7.44E-05	3.72E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.04E-07	5.87E-07
ISOL1C_ELS	XS	50.8	0.51	H ₂	0.000	1.57E+00	1.57E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1C_ELS	S	50.8	1.6	H ₂	0.001	1.13E-01	1.13E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1C_ELS	M	50.8	5.1	H ₂	0.005	5.28E-02	5.28E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1C_ELS	L	50.8	16.1	H ₂	0.051	2.25E-03	1.13E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.78E-05
ISOL1C_ELS	XL	50.8	50.8	H ₂	0.341	6.92E-04	3.46E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.45E-06
ISOL1D_ELS	XS	19.1	0.19	H ₂	0.000	2.52E-06	2.52E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1D_ELS	S	19.1	0.6	H ₂	0.001	1.18E-06	1.18E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1D_ELS	M	19.1	1.9	H ₂	0.005	5.29E-07	5.29E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1D_ELS	L	19.1	6	H ₂	0.047	2.37E-05	1.18E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1D_ELS	XL	19.1	19.1	H ₂	0.226	2.04E-05	1.02E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.07E-07
ISOL1E_ELS	XS	76.2	0.76	H ₂	0.001	2.94E-02	2.94E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1E_ELS	S	76.2	2.4	H ₂	0.008	2.05E-03	2.05E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1E_ELS	M	76.2	7.6	H ₂	0.076	9.85E-04	9.85E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.86E-04
ISOL1E_ELS	L	76.2	24.1	H ₂	0.755	3.13E-05	1.57E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.70E-07	9.31E-07

Section code	Release Category	Connection size (mm)	Release size (mm)	Material	Release rate (kg/s)	Release Frequency (/year)	NON-ISOL base frequency with risk reduction failed (/year) (does not include ignition probabilities)	NON-ISOL VCE at tube trailer loading bay frequency (/year)	NON-ISOL VCE at H2 storage frequency (/year)	NON-ISOL VCE at main compressors frequency (/year)	NON-ISOL VCE at dispensing compressors frequency (/year)	NON-ISOL VCE at purification unit frequency (/year)	NON-ISOL VCE at electrolyzers frequency (/year)
ISOL1E_ELS	XL	76.2	76.2	H ₂	4.709	6.59E-06	3.29E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.58E-08	1.96E-07
ISOL1-2_PIP	XS	76.2	0.76	H ₂	0.001	1.54E-01	7.72E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1-2_PIP	S	76.2	2.4	H ₂	0.008	1.20E-02	5.98E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1-2_PIP	M	76.2	7.6	H ₂	0.076	5.20E-03	2.60E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1-2_PIP	L	76.2	24.1	H ₂	0.754	2.26E-04	2.20E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL1-2_PIP	XL	76.2	76.2	H ₂	4.534	1.18E-04	1.15E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL2_GSP	XS	50.8	0.51	H ₂	0.001	1.93E+01	9.66E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL2_GSP	S	50.8	1.6	H ₂	0.009	1.39E+00	6.94E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL2_GSP	M	50.8	5.1	H ₂	0.084	6.53E-01	3.27E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL2_GSP	L	50.8	16.1	H ₂	0.819	2.63E-02	2.56E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.19E-03
ISOL2_GSP	XL	50.8	50.8	H ₂	3.597	1.35E-02	1.32E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.15E-04
ISOL2-3_PIP	XS	76.2	0.76	H ₂	0.001	1.56E-01	7.78E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL2-3_PIP	S	76.2	2.4	H ₂	0.009	1.25E-02	6.27E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL2-3_PIP	M	76.2	7.6	H ₂	0.084	5.46E-03	2.73E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL2-3_PIP	L	76.2	24.1	H ₂	0.817	3.42E-04	3.34E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL2-3_PIP	XL	76.2	76.2	H ₂	3.459	2.18E-04	2.13E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL3_CPI	XS	76.2	0.76	H ₂	0.001	5.95E+00	2.98E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL3_CPI	S	76.2	2.4	H ₂	0.009	4.83E-01	2.42E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL3_CPI	M	76.2	7.6	H ₂	0.084	2.29E-01	1.15E-02	0.00E+00	0.00E+00	4.59E-03	0.00E+00	0.00E+00	0.00E+00
ISOL3_CPI	L	76.2	24.1	H ₂	0.834	1.84E-02	1.79E-03	0.00E+00	0.00E+00	7.18E-04	5.22E-04	0.00E+00	0.00E+00
ISOL3_CPI	XL	76.2	76.2	H ₂	6.773	8.76E-03	8.54E-04	0.00E+00	1.01E-04	3.42E-04	2.48E-04	0.00E+00	0.00E+00
ISOL4_CPO	XS	25.4	0.25	H ₂	0.001	1.63E+00	8.13E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL4_CPO	S	25.4	0.8	H ₂	0.010	1.60E-01	7.98E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL4_CPO	M	25.4	2.5	H ₂	0.089	6.62E-02	3.31E-03	0.00E+00	0.00E+00	1.33E-03	0.00E+00	0.00E+00	0.00E+00
ISOL4_CPO	L	25.4	8	H ₂	0.907	2.67E-03	2.60E-04	0.00E+00	0.00E+00	1.04E-04	7.58E-05	0.00E+00	0.00E+00

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ISOL4_CPO	XL	25.4	25.4	H ₂	7.400	4.25E-04	4.14E-05	0.00E+00	4.88E-06	1.66E-05	1.21E-05	0.00E+00	0.00E+00
ISOL4-5_PIP	XS	25.4	0.25	H ₂	0.001	3.38E-01	1.69E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL4-5_PIP	S	25.4	0.8	H ₂	0.010	3.00E-02	1.50E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL4-5_PIP	M	25.4	2.5	H ₂	0.089	1.14E-02	5.72E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL4-5_PIP	L	25.4	8	H ₂	0.869	8.65E-04	8.44E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL4-5_PIP	XL	25.4	25.4	H ₂	2.731	4.62E-04	4.50E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5_SMP	XS	25.4	0.25	H ₂	0.001	2.17E+00	1.09E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5_SMP	S	25.4	0.8	H ₂	0.010	1.58E-01	7.89E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5_SMP	M	25.4	2.5	H ₂	0.089	7.22E-02	3.61E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5_SMP	L	25.4	8	H ₂	0.900	2.27E-03	2.22E-04	0.00E+00	1.29E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5_SMP	XL	25.4	25.4	H ₂	5.109	6.39E-04	6.23E-05	0.00E+00	3.62E-05	7.44E-06	8.71E-06	0.00E+00	0.00E+00
ISOL5-6_PIP	XS	25.4	0.25	H ₂	0.001	1.16E+00	5.79E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5-6_PIP	S	25.4	0.8	H ₂	0.010	8.88E-02	4.44E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5-6_PIP	M	25.4	2.5	H ₂	0.089	3.87E-02	1.93E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5-6_PIP	L	25.4	8	H ₂	0.874	1.70E-03	1.66E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5-6_PIP	XL	25.4	25.4	H ₂	2.917	6.47E-04	6.31E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL6_DCI	XS	25.4	0.25	H ₂	0.001	1.15E+00	5.77E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL6_DCI	S	25.4	0.8	H ₂	0.010	9.58E-02	4.79E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL6_DCI	M	25.4	2.5	H ₂	0.089	4.24E-02	2.12E-03	0.00E+00	0.00E+00	0.00E+00	3.89E-04	0.00E+00	0.00E+00
ISOL6_DCI	L	25.4	8	H ₂	0.906	1.44E-03	1.40E-04	0.00E+00	0.00E+00	7.23E-05	2.57E-05	0.00E+00	0.00E+00
ISOL6_DCI	XL	25.4	25.4	H ₂	6.920	2.73E-04	2.66E-05	0.00E+00	4.20E-06	1.38E-05	4.89E-06	0.00E+00	0.00E+00
ISOL7_DCO	XS	25.4	0.25	H ₂	0.001	1.38E+00	6.88E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL7_DCO	S	25.4	0.8	H ₂	0.013	1.12E-01	5.61E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL7_DCO	M	25.4	2.5	H ₂	0.122	5.11E-02	2.55E-03	0.00E+00	0.00E+00	0.00E+00	4.69E-04	0.00E+00	0.00E+00
ISOL7_DCO	L	25.4	8	H ₂	1.251	2.48E-03	2.42E-04	0.00E+00	0.00E+00	1.25E-04	4.43E-05	0.00E+00	0.00E+00

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ISOL7_DCO	XL	25.4	25.4	H ₂	9.320	3.10E-04	3.02E-05	0.00E+00	4.76E-06	1.56E-05	5.54E-06	0.00E+00	0.00E+00
ISOL7-8_PIP	XS	25.4	0.25	H ₂	0.001	4.95E-01	2.48E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL7-8_PIP	S	25.4	0.8	H ₂	0.013	4.25E-02	2.13E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL7-8_PIP	M	25.4	2.5	H ₂	0.122	1.67E-02	8.33E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL7-8_PIP	L	25.4	8	H ₂	1.194	1.11E-03	1.08E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL7-8_PIP	XL	25.4	25.4	H ₂	3.516	5.77E-04	5.63E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL8_DIS	XS	25.4	0.25	H ₂	0.001	4.51E-01	2.26E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL8_DIS	S	25.4	0.8	H ₂	0.014	3.32E-02	1.66E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL8_DIS	M	25.4	2.5	H ₂	0.133	1.54E-02	7.71E-04	2.41E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL8_DIS	L	25.4	8	H ₂	1.356	7.64E-04	7.45E-05	2.32E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL8_DIS	XL	25.4	25.4	H ₂	10.370	1.37E-04	1.33E-05	4.15E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5-9_PIP	XS	25.4	0.25	H ₂	0.001	2.33E+00	1.17E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5-9_PIP	S	25.4	0.8	H ₂	0.010	1.70E-01	8.52E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5-9_PIP	M	25.4	2.5	H ₂	0.089	7.73E-02	3.86E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5-9_PIP	L	25.4	8	H ₂	0.869	2.44E-03	2.38E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL5-9_PIP	XL	25.4	25.4	H ₂	2.718	9.24E-04	9.01E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL9_STO	XS	25.4	0.25	H ₂	0.001	1.20E+00	6.00E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL9_STO	S	25.4	0.8	H ₂	0.009	8.81E-02	4.40E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL9_STO	M	25.4	2.5	H ₂	0.087	4.13E-02	2.07E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL9_STO	L	25.4	8	H ₂	0.873	2.18E-03	2.12E-04	0.00E+00	2.12E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL9_STO	XL	25.4	25.4	H ₂	4.710	3.73E-04	3.64E-05	0.00E+00	3.64E-05	9.44E-06	9.44E-06	0.00E+00	0.00E+00
ISOL10_TUB	XS	25.4	0.25	H ₂	0.001	3.45E-01	1.73E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL10_TUB	S	25.4	0.8	H ₂	0.012	2.49E-02	1.24E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL10_TUB	M	25.4	2.5	H ₂	0.121	1.18E-02	5.88E-04	1.83E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ISOL10_TUB	L	25.4	8	H ₂	1.193	5.69E-04	5.55E-05	1.73E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

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ISOL10_TUB	XL	25.4	25.4	H ₂	7.852	1.74E-04	1.70E-05	5.31E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

SCOPE OF WORKS & GENERAL SPECIFICATION

GENERAL CONDITIONS

UNLESS OTHERWISE NOTED, ALL WORKMANSHIP AND MATERIALS SHALL BE IN ACCORDANCE WITH THE BUILDING REGULATIONS AND THE NCC.
THE FIRE CONTRACTOR IS TO UNDERTAKE THE FULL DESIGN OF THE FIRE HYDRANT, FIRE HOSE REEL, PORTABLE FIRE EXTINGUISHERS, FIRE DETECTION AND ALARM SYSTEMS.
CO-ORDINATE THE LOCATION OF ALL ITEMS WITH OTHER TRADES, INCLUDING BUT NOT LIMITED TO STRUCTURAL ELEMENTS, ELECTRICAL, MECHANICAL, CIVIL AND HYDRAULIC SERVICES LAYOUTS.

CODES, RULES, PERMITS, AND FEES

ALL MATERIALS SUPPLIED, AND ALL WORKS UNDERTAKEN, SHALL COMPLY WITH CODES, RULES, AND REGULATIONS OF ALL STATUTORY AUTHORITIES INCLUDING, BUT NOT NECESSARILY LIMITED TO:

- NATIONAL CONSTRUCTION CODE (NCC), 2022
- AS 1670.1 - FIRE DETECTION, WARNING, CONTROL AND INTERCOM SYSTEMS – SYSTEM DESIGN, INSTALLATION AND COMMISSIONING – FIRE
- AS 1670.4 - FIRE DETECTION, WARNING, CONTROL AND INTERCOM SYSTEMS – EMERGENCY WARNING AND INTERCOM SYSTEMS
- AS 1603 - AUTOMATIC FIRE DETECTION AND ALARM SYSTEMS
- AS 2444 - PORTABLE FIRE EXTINGUISHERS AND FIRE BLANKETS
- AS 2419.1 - FIRE HYDRANT INSTALLATIONS – SYSTEM DESIGN, INSTALLATION AND COMMISSIONING
- AS 2441 - INSTALLATION OF FIRE HOSE REELS
- AS 2304 - WATER STORAGE TANKS FOR FIRE PROTECTION SYSTEMS
- AS 2941 - FIXED FIRE PROTECTION INSTALLATIONS – PUMPSET SYSTEMS
- AS 1074 - STEEL TUBES AND TUBULARS FOR ORDINARY SERVICE
- AS 1345 - IDENTIFICATION OF THE CONTENTS OF PIPES, CONDUITS AND DUCTS
- AS 3000 - WIRING RULES
- AS 3500 - PLUMBING AND DRAINAGE
- AS 1940 - STORAGE OF FLAMMABLE AND COMBUSTIBLE LIQUIDS
- AS 1851 - ROUTINE SERVICE OF FIRE PROTECTION SYSTEMS AND EQUIPMENT

THE CONTRACTOR SHALL MAKE ALL APPLICATIONS AND PAY ALL FEES REQUIRED TO COMPLY WITH THE RELEVANT AUTHORITY REQUIREMENTS. ALL NEW FIRE PROTECTION SERVICES EQUIPMENT PROVIDED SHALL BE LISTED IN THE ACTIVE FIRE REGISTER OF FIRE PROTECTION EQUIPMENT.

INSPECTION

1. THESE DRAWINGS ARE TO BE TAKEN AS INDICATIVE OF THE INTENDED SYSTEM DESIGN, AND DO NOT PURPORT TO SHOW ALL PIPEWORK, CHANGES OF DIRECTION, DETECTORS, SPEAKERS, OR DEVICES TO PROVIDE A COMPLETE SYSTEM AND/OR COVERAGE. IT IS THE RESPONSIBILITY OF THE CONTRACTOR TO CONDUCT THEIR OWN DESIGN REVIEW BEFORE SUBMISSION OF THEIR TENDER. MAKE ALL ALLOWANCES FOR A CONFORMING AND FUNCTIONALLY ACCEPTED INSTALLATION AND DESIGN. DESIGN AND INSTALLATION SHALL TAKE INTO ACCOUNT THE FUNCTIONAL NEEDS OF THE INSTALLED ADJACENT EQUIPMENT AND ITS INTENDED USE BY THE CLIENT.

SCOPE OF WORK

1. THESE DRAWINGS INDICATE THE DESIGN INTENT. THE DRAWINGS DO NOT PURPORT TO SHOW MINOR OFFSETS AND TRANSITIONS REQUIRED FOR COORDINATION WITH STRUCTURE AND OTHER SERVICES. MAKE ALLOWANCE FOR THESE OFFSETS AND TRANSITIONS.
2. THE SCOPE OF WORKS OF THE FIRE PROTECTION CONTRACTOR INCLUDES THE DETAILED DESIGN, SUPPLY, DELIVERY & / OR SHIPPING TO SITE, INSTALLATION, COMMISSIONING, AND SETTING TO WORK OF THE FOLLOWING SYSTEMS, EQUIPMENT, AND MATERIALS.

WORKS TO BE INCLUDED

- THE FOLLOWING WORK IS TO BE CARRIED OUT BY THE CONTRACTOR:
- THE FIRE PROTECTION SERVICES CONTRACTOR SHALL BE RESPONSIBLE FOR CO-ORDINATION WITH ALL OTHER SERVICES AND SHALL FURNISH ALL NECESSARY INFORMATION AS REQUIRED TO THE CONSTRUCTION MANAGER AND OTHER CONTRACTORS SO THAT THE WORKS CAN BE CARRIED OUT WITHOUT UNDUE DELAY TO THE CONSTRUCTION PROGRAM.
 - ANY EXISTING OR OTHER SERVICES AND CONDITIONS DAMAGED DURING CONSTRUCTION OF THE SITE WORKS SHALL BE MADE GOOD AT THE CONTRACTOR'S EXPENSE. THE SITE, ON COMPLETION IS TO BE LEFT IN A NEAT AND TIDY CONDITION.
 - PROTECTION OF FLOOR COVERINGS DURING THE WORK.
 - FORMING AND MAKING GOOD ALL OPENINGS IN WALLS AND CEILINGS.
 - TRENCHING AND BACKFILLING.
 - SEAL ALL PENETRATIONS THROUGH FIRE RATED CONSTRUCTION, ACOUSTIC AND SMOKE BAFFLES WITH AN APPROVED FIRE, ACOUSTIC AND SMOKE SEALANT RESPECTIVELY.
 - PAINTING AND IDENTIFICATION
 - ALL OTHER WORKS REQUIRED FOR THE EXECUTION OF THE WORKS.

THE ABOVE MAY NOT BE ALL INCLUSIVE. THE CONTRACTOR IS TO MAKE ALLOWANCE FOR ALL WORKS AND EQUIPMENT REQUIRED TO COMPLETE THE WORKS TO THE APPLICABLE STANDARDS, SCOPING, AND CERTIFICATION NECESSARY FOR HANDOVER.

SITE WIDE

- WORKS TO BE INCLUDED
- FIRE WATER STORAGE TANKS TO ACCOMMODATE SITE FIRE HYDRANT AND HOSE REEL SYSTEM C/W BASE
 - CONTAINERISED DUTY STANDBY ELECTRIC/DIESEL FIRE HYDRANT PUMPSET COMPLETELY ASSEMBLED AND FACTORY TESTED PRIOR TO DELIVERY TO SITE.
 - SITE WIDE RETICULATION OF THE FIRE HYDRANT SYSTEM C/W INGROUND AND ABOVE GROUND PIPEWORK AS NECESSARY, INCLUDING A SITE WIDE RING MAIN PROVIDING OPEN YARD PROTECTION TO ALL POTENTIAL EXTERNAL STORAGE AND PROCESSING AREAS.
 - DUAL HEADED FIRE HYDRANTS C/W 65mm QRT CONNECTIONS
 - INGROUND SLUICE ISOLATION VALVES COMPLETE WITH BOX AND COVER PLATE FOR ACCESS VIA SPINDLE, VALVES TO BE NUMBERED.
 - BOLLARD PROTECTION AND ANTI VANDAL COVERS TO FIRE HYDRANT LOCATIONS.
 - FIRE BRIGADE SUCTION AND BOOSTER ARRANGEMENT C/W BASE AND CABINET
 - DATA GATHERING PANELS (OR SUB-FIPS) TO BUILDINGS WITH NETWORKED INGROUND CABLING TO THE MAIN FIRE DETECTION CONTROL & INDICATING EQUIPMENT (FDCIE) PANEL (ALSO REFERRED TO AS FIRE INDICATOR PANEL). THE FIP IS LOCATED IN THE HYDROGEN PRODUCTION FACILITY CONTROL ROOM. HYDROGEN PRODUCTION FACILITY IS LOCATED IN THE ELECTROLYSER HALL.
 - OCCUPANT WARNING PANELS AS REQUIRED TO FACILITATE EVACUATION ALARMS TO BUILDINGS AS INDICATED

ELECTROLYSER HALL

- WORKS TO BE INCLUDED
- FIRE HYDRANT COVERAGE FROM EXTERNAL FIRE HYDRANTS
 - FIRE HOSE REEL COVERAGE FROM INTERNAL FIRE HOSE REELS
 - FIRE ALARM SYSTEM CONSISTING OF FLAME DETECTION, POINT TYPE THERMAL DETECTION, MANUAL CALL POINTS, VISUAL WARNING DEVICES, AND HORN SPEAKERS
 - PORTABLE FIRE EXTINGUISHERS

WORKSHOP & WAREHOUSE BUILDINGS

- WORKS TO BE INCLUDED
- FIRE HYDRANT COVERAGE FROM EXTERNAL FIRE HYDRANTS
 - FIRE HOSE REEL COVERAGE FROM INTERNAL FIRE HOSE REELS
 - FIRE ALARM SYSTEM CONSISTING OF FLAME DETECTION, POINT TYPE SMOKE DETECTION, MANUAL CALL POINTS, VISUAL WARNING DEVICES, AND CEILING MOUNTED & HORN SPEAKERS
 - PORTABLE FIRE EXTINGUISHERS

CONTROL ROOM & AMMENITIES, H2 PRODUCTION FACILITY SWITCHROOM ELECTRICAL ROOMS (HV, LV, MV, RECTIFIER)

- WORKS TO BE INCLUDED
- FIRE ALARM SYSTEM CONSISTING OF FLAME DETECTION, POINT TYPE SMOKE DETECTION, MANUAL CALL POINTS, VISUAL WARNING DEVICES, AND CEILING MOUNTED & HORN SPEAKERS
 - PORTABLE FIRE EXTINGUISHERS

OUTDOOR SYSTEMS (TRANSFORMERS, H2 GAS CLEANING, WATER TREATMENT, COOLING, COMPRESSION, H2 STORAGE, TUBE TRAILERS LOADING BAYS)

- WORKS TO BE INCLUDED
- FIRE HYDRANT COVERAGE FROM EXTERNAL FIRE HYDRANTS
 - PORTABLE FIRE EXTINGUISHERS
 - FIRE ALARM SYSTEM CONSISTING OF FLAME DETECTION AND POINT TYPE THERMAL DETECTION (AS REQUIRED FOR HYDROGEN DETECTION)

DETECTION SYSTEM

THE SCOPE OF WORK SHALL COMPRISE THE SUPPLY OF ALL LABOUR AND MATERIALS NECESSARY FOR THE COMPLETE SUPPLY, INSTALLATION, TESTING AND COMMISSIONING OF THE FOLLOWING SERVICES IN ACCORDANCE WITH THE SPECIFICATION, AND THE ACCOMPANYING DRAWINGS.

1. THE INSTALLATION OF THE FIRE DETECTION AND BUILDING OCCUPANT WARNING SYSTEM IS TO COMPLY WITH AS1670, NCC AND LOCAL AUTHORITY REQUIREMENTS.
2. PROVIDE AND INSTALL ONE OFF FDCIE C/W LABEL AT THE GROUND FLOOR WITH LABEL "FIRE DETECTING AND CONTROL EQUIPMENT (FDCIE)" IN THE EVENT OF FIRE CALL 000 AT THE FRONT OF THE CUPBOARD.
3. BUILDING OCCUPANCY WARNING SYSTEM INTEGRATED INTO THE FIP.
4. PROVIDE HEAT/SMOKE DETECTORS AS REQUIRED.
5. PROVIDE SPEAKERS AND CONNECT TO THE FIP. ALLOW FOR ADDITIONAL SPEAKERS AS DETERMINED BY ON-SITE MEASUREMENTS TO ACHIEVE THE REQUIRED SOUND LEVEL AS PER BY CODE.
6. PROVIDE SPEAKER AND CONNECT TO THE FDCIE. IN THE EVENT OF A FIRE, WARNING SIGNALS SHALL SOUND THROUGH THE BUILDING TO ALERT OCCUPANTS. ADJUST SPEAKER EXACT LOCATION ON SITE AS REQUIRED. REFER TO FIRE ENGINEERING REPORT FOR DETAIL, PROGRAMING AND INSTALLATION.
7. PROVIDE COMPLIANCE CERTIFICATION ON COMPLETION OF THE INSTALLATION. PROVIDE 3 HARD COPIES AND ONE ELECTRONIC COPY OF AS-INSTALLED DRAWINGS AND O&M MANUALS.
8. ALARM SIGNALING EQUIPMENT (ASE) IS REQUIRED TO BE INSTALLED.
9. ENGAGEMENT OF AN INDEPENDENT SYSTEM CERTIFIER FOR EACH OF THE SYSTEMS INSTALLED OR MODIFIED AS PART OF THE WORKS. THE INDEPENDENT FIRE SERVICES CERTIFIERS SHALL BE ACCREDITED BY THE FIRE PROTECTION ASSOCIATION AUSTRALIA AND SHALL BE NOMINATED BY THE PRINCIPAL/CLIENT.
10. PROVIDE GFA (GENERAL FIRE ALARM) CONTACTS FOR THE MECHANICAL SWITCHBOARD WHERE REQUIRED
11. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE FINAL CO-ORDINATED SPEAKER AND VISUAL WARNING DEVICE (VWD) SET-OUT WITHIN AREAS TO COMPLY WITH THE RELEVANT CODES AND SOUND PRESSURE LEVELS AND VISUAL EFFECTIVENESS.
12. ALLOW FOR ALL WORKS/PANELS REQUIRED AT THE MAIN FDCIE AND SUB-FIP PANELS.
13. ANY PENETRATION SHALL BE SEALED FOR WATERPROOF AND FIRE RATED RESISTANCE.
14. FIBRE OPTIC CABLES SHALL CONFORM TO IEC 60331-25 WITH A MINIMUM OF 12 MIN FLAME APPLICATION TIME.
15. MAIN AND SUB FIPS SHALL ACCEPT ALARM SIGNAL INPUTS FROM THE FOLLOWING HYDROGEN GAS, LEAK, AND FLAME DETECTION INSTRUMENTS AS SHOWN ON THE RELATED DRAWINGS.
 - HYDROGEN GAS LEAKAGE DETECTION, DRAWING 17695-FIRE-GA-1002-03
 - HYDROGEN FLAME DETECTION, DRAWING 17695-FIRE-GA-1002-02
 - HYDROGEN GAS DETECTION, DRAWING 17695-FIRE-GA-1002-01

FIRE HYDRANT

- PROVIDE FOR 2 OFF WATER STORAGE TANKS FOR THE SITE FIRE HYDRANT SYSTEM TO ALLOW FOR 50% REDUNDANCY DURING DRAIN DOWN FOR CLEANING &/OR MAINTENANCE.
- TANK CAPACITY SHALL ALLOW FOR NOT LESS THAN 3 OFF FIRE HYDRANTS TO OPERATE AT A DUTY OF 10 L/s EACH FOR A PERIOD OF 4 HOURS. TANK CAPACITY CAN NOT BE REDUCED AS IT IS UNCERTAIN A RELIABLE AUTOMATIC INFILL CAN BE PROVIDED FROM THE RAW WATER MAIN.
- TANK SHALL BE OF GALVANISED STEEL CONSTRUCTION AND BE COMPLETE WITH GALVANISED SHEET METAL ROOFING AND ANTI-VERMIN PROTECTION. MANHOLE ACCESS IN THE ROOF AND AT THE SIDE AT LOW LEVEL. EXTERNAL GALVANISED LADDER TO AS1567, TANK LEVEL INDICATOR, TANK SIGNAGE TO AS2419.1, INLET, OUTLET WITH ANTI-VORTEX PLATE, OVERFLOW CONNECTION, SCOUR OUTLET, AND TEST RETURN CONNECTION.
- PROVIDE A CONTAINERISED DUTY / STANDBY ELECTRIC / DIESEL FIRE HYDRANT PUMP WITHIN AN ENCLOSURE COMPLYING WITH AS2941 AND BE COMPLETE WITH JACKING PUMP AND ALL CONTROLS.
- THE FIRE PUMP IS TO BE SIZED TO MEET THE FIRE HYDRANT AND HOSE REEL SYSTEM DUTY FLOWS WHILE THE 3 MOST REMOTE HYDRANTS ARE OPERATING AT NOT LESS THAN 700kPa.
- INGROUND PIPING RETICULATION TO BE IN HDPE (PE100 RCD PIPE RECOMMENDED FOR SYSTEM LONGEVITY) NOMINALLY 180mm AND 125mm AND SHALL BE COORDINATED WITH OTHER TRADES AND STRUCTURES. HDPE PIPING SHALL BE BLACK WITH RED STRIP. HDPE PIPE FITTINGS MAY BE ALL BLACK.
- EXTERNAL HYDRANTS SHALL BE DUAL OUTLET C/W QRT CONNECTIONS, CAPS, ANTI-VANDAL COVERS AND FINAL LOCATIONS SHALL BE COORDINATED WITH OTHER SERVICES AND EQUIPMENT SO AS NOT TO OBSTRUCT ACCESS AND MAINTENANCE.
- HYDRANTS ARE TO BE PROTECTED BY BOLLARDS APPROPRIATELY LOCATED.
- INGROUND ISOLATION VALVES ARE TO BE PROVIDED AND LOCATED TO THE REQUIREMENTS OF AS2419.1, AND SHALL BE INSTALLED WITH PIPEWORK TO PROTECT THE SPINDLE FROM INGRESS OF DIRT AND A NUMBERED ACCESS COVER FOR IDENTIFICATION.
- ANY ABOVE GROUND ISOLATION VALVES SHALL BE OF THE MONITORED CLASS A TYPE AND CONNECTED BACK TO THE MPDIE PANEL.
- ABOVE GROUND PIPEWORK SHALL BE OF GALVANISED STEEL TO AS1074. PROVIDE LOCATION IDENTIFICATION SIGNAGE WITHIN A CLEARLY VISIBLE LOCATION.
- ALL UNDER GROUND STEEL PIPEWORK, STEEL PIPE FITTINGS AND VALVES SHALL BE DENSE WRAPPED AS PER AS2419.1 TO 200mm ABOVE GRADE.
- ALL HYDRANT RISERS SHALL BE GALVANISED STEEL PIPE TO MINIMUM 0.5m PAST FIRST ELBOW BELOW GRADE.
- ALL HYDRANT RISERS SHALL HAVE CAST CONCRETE THRUST BLOCK ON FIRST BELOW GRADE ELBOW, MINIMUM 0.9m CUBE WITH SL81 MESH REINFORCEMENT, MINIMUM 50mm COVER.
- A FIRE BRIGADE BOOSTER CABINET, C/W PLINTH, AND HOUSING A DUAL BOOSTER AND TANK SUCTION CONNECTION AND REMOTE PUMP START AND RUN CONTROLS IS TO BE PROVIDED. THE LOCAL FIRE BRIGADE IS TO BE CONSULTED TO DETERMINE WHETHER A SINGLE LARGE BORE CONNECTION TYPE AND SIZE, 2 OFF SMALL BORE (65mm) TANK SUCTION CONNECTIONS OR BOTH ARE OPERATIONALLY REQUIRED.
- INCLUSION IS TO BE MADE FOR EXTERNAL SIGNAGE, BLOCK PLANS, AND TEST AND WORKING PRESSURE SIGNAGE.
- YARD WITHIN FENCED PLANT AREAS WILL BE KEPT CLEAR OF VEGETATION AND COMBUSTIBLE MATERIALS UNLESS OTHERWISE SPECIFICALLY NOMINATED.

FIRE HOSE REELS

1. ALLOW FOR FIRE HOSE REELS TO BE PROVIDED TO ELECTROLYSER HALL, WORKSHOP AND IF REQUIRED BASED ON HAZARDS, TO PROTECT STORAGE AREAS FOR FLAMMABLE AND COMBUSTIBLE LIQUIDS IN ACCORDANCE WITH AS 1940.
2. FIRE HOSE REELS SHALL BE 36m X 19m DIA, INSTALLED WITHIN A PROPRIETARY CABINET AND IN ACCORDANCE WITH AS2441, AND SHALL INCLUDE FOR LOCATION SIGNAGE WITHIN A CLEARLY VISIBLE LOCATION. POSITION THE FIRE HOSE REELS WITH CONSIDERATION GIVEN TO ACCESS AND OTHER SERVICES.
3. ALLOW TO PROVIDE SUITABLE TAIL END FOAM CREATION FACILITIES IF REQUIRED BY AS 1940.

PORTABLE FIRE EXTINGUISHERS

1. ALL PLANTROOMS AND WORKSHOPS ARE TO BE PROVIDED WITH 4.5kg ABE DRY POWDER PORTABLE FIRE EXTINGUISHERS LOCATED ADJACENT TO ENTRY, WITHIN 5m. TRAVEL DISTANCE FROM EXTINGUISHER TO THE HAZARD TO BE NO MORE THAN 15m.
2. DIESEL TANKS AND PUMPS AND GENERATOR ROOMS ARE TO BE PROVIDED WITH 9.1L FOAM PORTABLE FIRE EXTINGUISHERS LOCATED ADJACENT TO AND EXTERNAL TO ENTRY, WITHIN 5m. TRAVEL DISTANCE FROM EXTINGUISHER TO THE HAZARD TO BE NO MORE THAN 15m.
3. ELECTRICAL AND MECHANICAL SWITCHBOARDS ARE TO BE PROVIDED WITH 5kg CARBON DIOXIDE PORTABLE FIRE EXTINGUISHERS LOCATED BETWEEN 2m AND 15m FROM THE BOARD.
4. ELECTRICAL SWITCHROOMS ARE TO BE PROVIDED WITH 5kg CARBON DIOXIDE PORTABLE FIRE EXTINGUISHERS LOCATED ADJACENT TO ENTRY, WITHIN 5m. TRAVEL DISTANCE FROM EXTINGUISHER TO THE HAZARD TO BE NO MORE THAN 15m.
5. STORAGE AREAS FOR FLAMMABLE AND COMBUSTIBLE LIQUIDS ARE TO HAVE EXTINGUISHERS PROVIDED IN ACCORDANCE WITH AS 1940 DEPENDANT ON LIQUIDS STORED AND QUANTITIES.
6. ANY OTHER BUILDING AREAS ARE TO BE PROVIDED WITH ABE DRY POWDER EXTINGUISHERS WITH A TRAVEL DISTANCE OF NOT MORE THAN 15m FROM ANY POINT ON THE FLOOR TO AN EXTINGUISHER IN LINE WITH PRIMARY EXTINGUISHER PROTECTION.
7. ALL PORTABLE FIRE EXTINGUISHERS ARE TO BE WALL MOUNTED, INSTALLED IN ACCORDANCE WITH AS 2444 AND WITH ALL STATUTORY SIGNAGE.

TESTING & CERTIFICATION

1. SUBMIT A COMMISSIONING TEST REPORT AS NOMINATED IN APPENDIX F OF AS1670.1, AND AS1851.
2. SUPPLY ALL SKILLED LABOUR AND ASSISTANCE FOR TESTING, OPERATION AND ADJUSTING THE SYSTEMS AND EQUIPMENT, AND FOR FULLY INSTRUCTING THE PRINCIPAL OR HIS REPRESENTATIVE IN THE OPERATION OF THE SYSTEM AND EQUIPMENT. ALL TESTS SHALL BE MADE IN THE PRESENCE OF THE PRINCIPAL AND APPROPRIATE CERTIFIER. GIVE NOT LESS THAN SEVEN DAYS' NOTICE IN WRITING TO THESE PARTIES BEFORE MAKING ANY TESTS.
3. TESTING OF THE DETECTION AND ALARM SYSTEMS SHALL BE IN ACCORDANCE WITH AS1670.1 & AS1670.4. TEST THE CONNECTION OF THE DETECTION SYSTEM TO THE BUILDING FDCIE PANEL. VERIFICATION OF ALL INTERFACES TO ENSURE CORRECT FIRE MODE OPERATION IN ACCORDANCE WITH BASE BUILDING REQUIREMENTS.
4. TESTING OF THE EMERGENCY WARNING AND INTERCOM SYSTEM TO BE INCLUDED FOR ALL INTERFACING AND FOR CORRECT SOUND PRESSURE LEVELS.
5. ENSURE THAT ALL TESTING IS IN ACCORDANCE WITH AS1851.
6. PROVIDE INDEPENDENT CERTIFICATION FOR ALL SYSTEMS INSTALLED, INCLUDING: FIRE DETECTION & ALARM SYSTEMS, FIRE HYDRANT & HOSE REEL SYSTEM.
7. PROVIDE INSTALLER'S LETTERS OF COMPLIANCE FOR ALL WORKS CARRIED OUT, INCLUDING BUT NOT LIMITED TO: FIRE SPRINKLERS, FIRE DETECTION, PORTABLE FIRE EXTINGUISHERS, AND SEALING OF PENETRATIONS.

EVACUATION DIAGRAMS

1. PREPARE, SUPPLY, AND INSTALL NEW EVACUATION DIAGRAMS FOR EACH OF THE DETAILED BUILDINGS. DIAGRAMS ARE TO BE LAMINATED, FRAMED AND MOUNTED TO THE WALL. ALL DIAGRAMS ARE TO BE AS PER THE REQUIREMENTS OF AS3745, AND AS A MINIMUM SHALL REFLECT THE SAME DETAIL AS CURRENTLY DISPLAYED ON THE CURRENT DIAGRAMS.
2. DIAGRAMS SHALL BE SUBMITTED FOR APPROVAL, PRIOR TO INSTALLATION.

SHOP DRAWINGS

1. SHOP DRAWINGS ARE TO BE SUBMITTED FOR APPROVAL PRIOR TO COMMENCING INSTALLATION.
 2. SHOP DRAWINGS AND SAMPLES SHALL INCLUDE BUT SHALL NOT NECESSARILY BE LIMITED TO THE FOLLOWING:
 - PDF's OF ALL EQUIPMENT TECHNICAL DATA
 - DETECTION AND ALARM SYSTEM LAYOUTS AND SCHEMATICS
 - PUMPS AND TANK
 - SITE WIDE FIRE HYDRANT SYSTEM INCLUDING HOSE COVERAGE PLANS AND SCHEMATICS
 - FIRE HOSE REEL SYSTEMS INCLUDING HOSE COVERAGE PLANS
 - FIRE EXTINGUISHERS
 - BUILDER'S WORK REQUIRED
- VERIFICATION OF HYDRAULIC CALCULATIONS AS PER HYENA CALCULATIONS OR SIMILAR ARE REQUIRED PRIOR TO ORDERING OF PUMPS AND TANK.

AS BUILT DRAWINGS

PROVIDE AS BUILT DOCUMENTATION IN ACCORDANCE WITH THE CONTRACT. AS BUILT DOCUMENTATION TO INCLUDE ALL HYDRANTS, HOSE REELS, DETECTORS, SPEAKERS, AND FIELD DEVICES IN THE AFFECTED AREAS WITHIN 30 DAYS OF PRACTICAL COMPLETION. THE DRAWINGS SHALL ACCURATELY SHOW THE FULL EXTENT OF THE HYDRANT, DETECTION & ALARM SYSTEMS, ON PLANS SUFFICIENT TO FULLY DESCRIBE THE WORK UNDERTAKEN. DRY FIRE AS INSTALLED DRAWINGS ARE TO BE PROVIDED FOR THE FDCIE PANEL.

PRACTICAL COMPLETION

1. PRACTICAL COMPLETION OF THE PROJECT WILL NOT BE GRANTED UNTIL THE FOLLOWING HAVE BEEN PROVIDED AND APPROVED:
 - INDEPENDENT THIRD PARTY CERTIFICATION OF THE FIRE ALARM (DETECTION AND EMERGENCY WARNING), FIRE HYDRANT & FIRE HOSE REEL, AND PUMPS & TANK SYSTEMS (DEFECT FREE)
 - INSTALLERS STATEMENT OF COMPLIANCE FOR ALL WORKS UNDERTAKEN I.E. FIRE HYDRANT, FIRE HOSE REEL, PUMPS & TANK, FIRE DETECTION, EMERGENCY WARNING, PORTABLE FIRE EXTINGUISHERS, AND PENETRATIONS. LETTER/S TO SPECIFY COMPLYING AUSTRALIAN STANDARDS, AND BE DATED AND SIGNED.
 - COMMISSIONING AND TESTING DOCUMENTS AS PER AS1670 AND AS1851
 - OPERATION & MAINTENANCE MANUALS
 - SYSTEM BLOCK PLANS (HYDRANT AND DRY FIRE) HAVE BEEN SUBMITTED AND APPROVED
 - AS-INSTALLED DRAWINGS HAVE BEEN SUBMITTED AND APPROVED
 - EVACUATION DIAGRAMS HAVE BEEN SUBMITTED AND APPROVED
 - ALSO REFER TO THE CONTRACT CONDITIONS
 - DEFECTS LIABILITY
2. ALL FIRE PROTECTION SERVICES INSTALLATION WORKS SHALL BE CARRIED OUT TO A HIGH QUALITY OF WORKMANSHIP AND INSTALLATION PRACTICE AND SHALL BE GUARANTEED AGAINST DEFECTS FOR A PERIOD OF 12 MONTHS FROM THE DATE OF ISSUE OF THE CERTIFICATE OF PRACTICAL COMPLETION.
3. DURING THIS PERIOD REPLACE ALL DEFECTIVE EQUIPMENT, FIXTURES, AND MATERIALS AT NO ADDITIONAL COST.
4. INCLUDE FOR AS1851 TESTING AND PREVENTATIVE MAINTENANCE DURING WARRANTY PERIOD

OPERATION AND MAINTENANCE MANUALS

OPERATION AND MAINTENANCE MANUALS ARE TO BE PROVIDED IN ACCORDANCE WITH THE CONTRACT. ENSURE THAT COPIES OF ALL TEST REPORTS, CERTIFICATION CERTIFICATES, AND AS INSTALLED DOCUMENTATION ARE INCLUDED IN THE MANUALS. MANUALS ARE TO BE PRESENTED IN INDEXED FORMAT, THREE (3) COPIES EACH AS FOLLOWS:

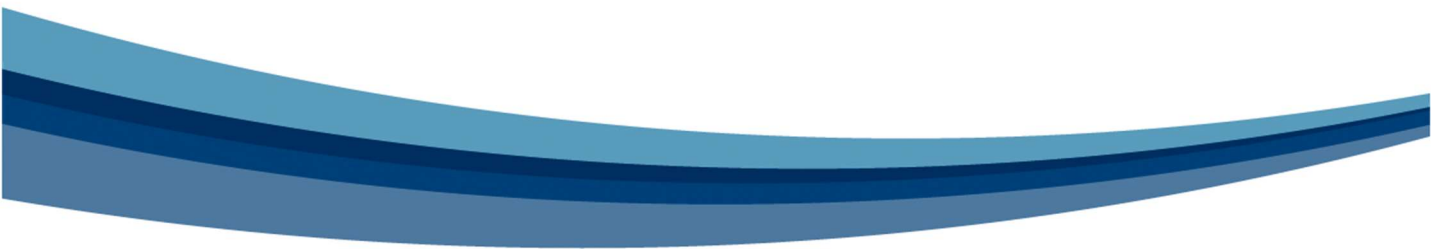
- HARD COPY, 3 RING BINDERS
- ELECTRONIC COPY

SYSTEM BLOCK PLANS

PROVIDE SYSTEM BLOCK PLANS MOUNT AT THE FDCIE PANEL.

- PROVIDE FOR SIDE WIDE FIRE HYDRANT BLOCK PLANS AT THE FIRE BRIGADE BOOSTER CABINET AND AT THE FDCIE PANEL.
- BLOCK PLANS ARE TO BE LAMINATED AND FRAMED AND BE FADE RESISTANT.

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											DRAWN	KPB	STAGE 1: FEED STUDY 50MW ELECTROLYZER						
											CHECKED	SHB	FIRE SERVICES FUNCTIONAL SPECIFICATION						
											APPROVED	SHB							
B	ISSUED FOR MILESTONE 3							KPB	IM	KPB	SHB	SHB	01/05/25	A3	N.T.S.	Client VENA ENERGY	UGL DRAWING No. 17695-FIRE-SPC-1001	SHEET 01	REV B
A	ISSUED FOR REVIEW							KPB	IM	KPB	SHB	SHB	04/04/25						
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VENA EUROA HYDROGEN PROJECT

Process Safety Specification

50MW Hydrogen Production Facility

UGL Project TC-17695

CLIENT: VENA ENERGY AUSTRALIA

Document: 17695-PROC-RPT-1003

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1 Purpose

The Vena Euroa Hydrogen Project involves the construction of a 50MW hydrogen production plant, hydrogen storage and tube trailer filling facilities.

Process safety is the management of the integrity of operating systems by applying inherently safer design principles, engineering and disciplined operating practices. It deals with the prevention and mitigation of incidents that have the potential for a loss of control of a hazardous material or energy. Such loss of control may lead to severe consequences with fire, explosion, and may ultimately result in loss of life, serious injury, extensive property damage, environmental impact and lost production with associated financial and reputational impacts.

The purpose of this specification is to detail the process safety considerations for the design of the facility.

2 Definitions

2.1 Definitions

- AS – Australian Standard
- BPCS – Basic Plant control system
- CEB – Chemically enhanced backwash
- CHAIR – Construction Hazard Assessment Implementation Review
- CHAZOP – Control Hazard and operability study
- CIP – Clean In place
- Company – UGL
- ESD – Emergency Shutdown
- FEED – Front End Engineering & Design
- FMEA – Failure Mode and Effects Analysis
- HAZOP – Hazard and operability study
- ISD – Inherently Safer Design
- LOPA – Layers of Protection Analysis
- MSDS – Material Safety Data Sheets
- PCBU – Person Conducting a Business or Undertaking
- PCM – Power Conversion Module
- PLC – Programmable Logic Controller
- QRA – Quantative Risk Assessment
- SI – International System of Units
- SIS – Safety Instrumented System
- SIL – Safety Integrity Level
- SIF – Safety Instrumented Function
- UGL – UGL Engineering Pty Ltd
- VENA – Vena Energy Australia

3 Scope

The scope of this specification is to outline the process to identify the risks and determine the approach to process safety relating to the hydrogen production facility. Process safety will be integrated into the design process through both the FEED and detailed design processes.

Whilst the process hazards associated with the production, storage and handling of hydrogen are predominantly associated with explosion and fire risks with hydrogen gas, other risks will also be considered during the design process including:

- Storage and handling of compressed gasses
- Storage and handling of asphyxiant gasses (nitrogen and hydrogen)
- Dangerous goods handling such as water treatment plant chemicals
- Electrical safety and earthing
- Lightning
- Traffic management

4 General

4.1 WHS ACT 2011

The guiding principle of the Queensland WHS Act 2011 is that all people are given the highest level of health and safety protection from hazards arising from work, so far as is reasonably practicable.

Section 22 of the WHS Act requires that designers must ensure, so far as is reasonably practicable that the plant is designed to be without risks to the health and safety of persons:

- a) who, at a workplace, use the plant, substance or structure for a purpose for which it was designed; or
- b) who handle the substance at a workplace; or
- c) who store the plant or substance at a workplace; or
- d) who construct the structure at a workplace; or
- e) who carry out any reasonably foreseeable activity at a workplace in relation to:
 - i) the manufacture, assembly or use of the plant for a purpose for which it was designed, or the proper storage, decommissioning, dismantling or disposal of the plant; or
 - ii) the manufacture or use of the substance for a purpose for which it was designed or the proper handling, storage or disposal of the substance; or
 - iii) the manufacture, assembly or use of the structure for a purpose for which it was designed or the proper demolition or disposal of the structure; or
 - iv) Inspection, operation, cleaning, maintenance or repair of plant.
- f) who are at or in the vicinity of a workplace and who are exposed to the plant, substance or structure at the workplace or whose health or safety may be affected by a use or activity referred to in paragraph (a), (b), (c), (d) or (e).

The term 'reasonably practicable' means what could reasonably be done at a particular time to ensure health and safety measures were in place. In determining what is reasonably practicable, there is a requirement to weigh up all relevant matters including:

- the likelihood of a hazard or risk occurring (i.e. the probability of a person being exposed to harm)
- the degree of harm that might result if the hazard or risk occurred (i.e. the potential seriousness of injury or harm)
- what the person concerned knows, or ought to reasonably know, about:
 - the hazard or risk and
 - ways of eliminating or minimising it
- the availability of suitable ways to eliminate or minimise the hazard or risk
- the cost of eliminating or minimising the hazard or risk.

Ordinarily, cost will not be the key factor in determining what it is reasonable for a duty holder to do unless it can be shown to be 'grossly disproportionate' to the risk. If the risk is particularly severe, a PCBU (Person Conducting a Business or Undertaking) will need to demonstrate that costly safety measures are not reasonably practicable due to their expense and that other less costly measures could also effectively minimise the risk.

4.2 Storage And Handling of Chemicals

Chemicals used and stored on site are included in Table 4-1. The storage of chemicals will be within bounded areas in accordance with relevant Australian standards.

Table 4-1- Chemicals

Chemical	Use	Area	Comment
Nitrogen Liquid	Maintenance and safety purging, continuous purging and nitrogen blanketing	Bulk nitrogen storage	Refer Typical Safety Data Sheet included in Appendix A2 for further details
Sodium Hydroxide Solution	Water Treatment chemical (pH adjustment- Clean In place (CIP) Chemically enhanced backwash (CEB) and Water,	Water treatment Plant	Refer Typical Safety Data Sheet included in Appendix A2 for further details
Citric Acid Solution	Water Treatment chemical (CIP)	Water treatment Plant	Refer Typical Safety Data Sheet included in Appendix A2 for further details
Sodium Hypochlorite Solution	Water Treatment chemical (Disinfection)	Water treatment Plant	Refer Typical Safety Data Sheet included in Appendix A2 for further details
Coagulant solution	Water Treatment chemical (Coagulation)	Water treatment Plant	Refer Typical Safety Data Sheet included in Appendix A2 for further details
Biocide	Water Treatment chemical (CIP)	Water treatment Plant	Refer Typical Safety Data Sheet included in Appendix A2 for further details
Anti-scalant	Water Treatment chemical (CIP)	Water treatment Plant	Refer Typical Safety Data Sheet included in Appendix A2 for further details
Polymer	Water Treatment chemical (Coagulation)	Water treatment Plant	Refer Typical Safety Data Sheet included in Appendix A2 for further details
Corrosion Inhibitor	Cooling/Chilling chemical	Cooling/Chilling circuits	Refer Typical Safety Data Sheet included in Appendix A2 for further details
Chemicals for water polishing	PLUG TO ADVISE		

4.3 Pressurised Gasses

Pressurised gasses stored on site are detailed in Table 4-2. Vessels for the storage of pressurised gasses will be designed in accordance with AS1210.

Venting and relief systems are further detailed in the Process Venting and Relief Philosophy (17695-PROC-RPT-1002)

Table 4-2- Pressurised Gasses

Chemical	Use	Area	Comment
Hydrogen	Product	Electrolysis, compression, storage and dispensing	Refer Typical Safety Data Sheet included in Appendix A2 for further details
Oxygen	Byproduct from hydrogen production	Electrolysis	Refer Typical Safety Data Sheet included in Appendix A2 for further details
Nitrogen	Maintenance and safety purging, continuous purging and nitrogen blanketing	Nitrogen storage Electrolysis, compression, storage and dispensing	Refer Typical Safety Data Sheet included in Appendix A2 for further details
Carbon Dioxide	Chilling gas	Dispensing chillers	Refer Typical Safety Data Sheet included in Appendix A2 for further details
Compressed Air	Instrument air	All	Refer Typical Safety Data Sheet included in Appendix A2 for further details

Particular risks associated with the storage and handling of hydrogen is further detailed in section 4.4.

4.4 Hydrogen Properties

Hydrogen has unique physical and chemical properties that make it an attractive option for energy storage, transport, and use. However, hydrogen also poses fire/explosion risks due to its high flammability. Hydrogen is a colourless, odourless, and tasteless gas that is highly flammable in air and can ignite at concentrations as low as 4%. It has the lowest density of all gases and is fourteen times lighter than air. Hydrogen occurs in nature in the form of diatomic molecules (H_2) and can be obtained from various sources such as natural gas, water, and biomass.

Hydrogen can form a flammable mixture with air, which can cause explosions if ignition occurs. Hydrogen reacts with oxygen to form water, which is a reaction that releases a significant amount of energy.

Hydrogen is a very light gas that diffuses rapidly in air and can easily spread over large distances. This behaviour is quite positive in terms of the risk effect since the dispersion of hydrogen in air is very effective and hydrogen can rapidly reduce its concentration. However, this poses a risk of explosion since hydrogen concentrations may reach the flammable range very close to the source point in the first moment of the gas release. Whilst not toxic, hydrogen is an asphyxiant.

In addition, hydrogen flames are transparent and difficult to detect, therefore, it is more difficult to identify and mitigate hydrogen flames, at least in the early stages. Moreover, due to its low molecular weight, hydrogen molecules can easily penetrate materials such as metals and plastics, thus activating cracking or embrittlement phenomena which cause accidental H_2 release. This can pose a risk if not assessed during material of construction choices and if hydrogen leaks occur from vessels as it can rapidly spread and accumulate in enclosed spaces.

Other hydrogen gas properties are:

- Low ignition energy;
- High reactivity due to its chemical and physical properties;
- Wide flammability limits: 4%–75% in air

- Deflagration-to-detonation transition: the transition can easily occur and is often observed in the case of a large-scale system;
- High burning velocity: the laminar burning velocity is significantly higher than that of many other fuels.
- Hydrogen is colorless, odorless, and tasteless
- High reactivity with materials (embrittlement): significant investments are needed on material investigation.
- Low gas density and diffusivity: in the case of release, it can stratify in the upper part of confined spaces.

4.5 Design Standards

All relevant Australian Standards, codes, regulations and by-laws will be applied to engineering design activities. All project standards are treated as controlled documents and latest current issues will be utilised. The Project will be based on Australian codes and standards, where an Australian code or standard does not exist, International Standards will apply.

Order of precedence:

- Australian Standards and Codes.
- American Standards and Codes; and
- British Standards and Codes.
- Other international codes and standards.

A list of applicable standards is included in APPENDIX 1- Design Standards

5 Process Design Safety

5.1 Hazard And Risk Identification

During the feed and detailed design phases a number of tools will be utilised to identify Hazards and assess risks associated with the process. The tools to be utilised are detailed in Table 5-1.

Table 5-1- Investigations, Studies and Workshops

Investigation	Description	FEED Study	Detailed Design
HAZOP (Hazard and Operability Study)	Structured technique performed by a multidisciplinary team to prompt a detailed analysis of process design to identify potential deviations from intended design and function	✓	✓
CHAZOP (Control Hazard and operability study)	Control Hazard and Operability Study is a procedure for carrying out the safety and reliability analysis of existing or planned control and computer systems.		✓
CHAIR. (Construction Hazard Assessment Implementation Review)	Construction Hazard Assessment Implication Review is a tool to assist designers, constructors, clients and other key stakeholders to come together to reduce construction, maintenance, repair and demolition safety risks associated with design.	✓	✓
FMEA (Failure Mode and Effects Analysis)	Takes a selected part of a system, usually a piece of hardware, and examines every failure mode of every item and every element within it; consequences for each failure mode are determined to evaluate the adequacy of the response to the failure		✓

Investigation	Description	FEED Study	Detailed Design
LOPA (Layers of Protection Analysis)	Analytical procedure that draws on fault and event tree analysis to examine the independent protection layers in a plant and the actions should a specific unwanted event occur		✓
SIL Assessment (Safety Integrity Level Assessment)	Relative level of risk reduction provided by a safety instrumented function (SIF) expressed as the probability that the safety instrumented system (SIS) will perform its safety function		✓
Fire and Explosion Risk Assessment	Fire & Explosion Risk Assessment (FERA) is a structured and systematic process to identify and assess risks from fire and explosion hazards. The results of this assessment are used to ensure safe facility layouts, specify passive and active fire protection requirements, and provide input for Escape and Evacuation Risk Assessment (EERA), Emergency Systems Survival Assessment (ESSA), Building Risk Assessment (BRA) and Quantitative Risk Assessment (QRA) studies.	✓	✓
Hazardous Area Classification study	The Hazardous Area Classification Study involves the assessment of the areas of the plant where an explosive atmosphere may exist. Hazardous zones are 3 dimensional spaces where an explosive atmosphere exists and are classified in accordance with AS/NZS IEC 60079.10.1:2022 Explosive atmospheres and the electrical equipment permitted within the zoned area are identified. The hazardous area zones and flammable material properties are used to define the appropriate equipment for use with the hazardous zones.	✓	✓
QRA Quantitative Risk Analysis	Quantitative assessment of risks associated with fire and explosions to classify activities and inventories; to estimate consequences to people and to property from accidental releases of potentially hazardous material and energy; and to assess the risk to people and to neighbouring (on and off site) plant and facilities to allow decisions around buffer distances and layout of plant and equipment to be made. The purpose of the Consequence and Risk Assessment is to simulate over pressure and radiation contours that demonstrate that major incident hazards and risks associated with the project have been identified and can be managed appropriately	✓	✓
Safety Separation Distance application	Safety separation distances are safe distances between equipment to prevent a fire or explosion in one piece of equipment propagating to another potential resulting in cascading failures. Separation distances are defined by: • NFPA 2 (Hydrogen Technologies Code) • Quantitative Risk Assessment (QRA) • Other standards including AS2067 (Substations and high voltage installations exceeding 1kV a.c) • Hazardous Area Classification	✓	✓

Investigation	Description	FEED Study	Detailed Design
	The definition of safety separation distances allows the plant layout to be developed and any additional fire and explosion controls required to be developed (e.g. fire walls)		

5.2 Control Of Risk

Control of risks to prevent and mitigate hazardous incidents is the overall objective of hazard identification, risk assessment and safety-related management. The priority for control actions is:

- Elimination through design
- Prevention
- Evaluation and assurance
- Mitigation.

Prevention and mitigation are achieved through passive, active and administrative barriers applied within a systematic approach to the process safety and OHS management.

5.2.1 Elimination through Design

Inherently Safer Design (ISD) is based on the premise that it is better to remove the hazard or reduce the magnitude of the hazard than to control it with equipment and procedures. While there are several ways of categorising ISD strategies, including:

- Minimisation
- Substitution
- Moderation
- Simplification

it is usually not possible to target all hazards in a plant equally. For example, to allow for a reduced inventory of a hazardous chemical, the design may require processing at a higher temperature and pressure; in this case the higher temperature and pressure is accepted to reduce the risk of a hazardous inventory. Another scenario is that there may be two possible solvents for a process – one flammable with low toxicity, the other with low flammability but high acute toxicity. The hazard and ISD strategy selected will often represent a compromise based on intensive risk assessment that considers the life cycle of the plant and the technology available at the time.

5.2.1.1 Minimisation

Reducing the hazardous energy by reducing the size of the equipment inventory (intensification of the process) is inherently safer as the consequences of a loss of containment will be correspondingly reduced. Use of smaller units also enables implementation of other design safety features such as stronger containment. Process conditions in smaller containers are more uniform so there will be better process control and improved safety. As smaller equipment is cheaper to build there are also financial benefits.

5.2.1.2 Substitution

Substitution of a less-hazardous chemical or process reduces the overall hazards but must usually be considered at the design stage. Examples of such substitutions are the use of an aqueous solution as a solvent in a purification process rather than a flammable solvent such as toluene or methanol, and cleaning with detergent and water rather than a solvent. Substitution for safety reasons is often linked with strategies to reduce environmental impact of chemicals and chemical processing.

5.2.1.3 Moderation

Sometimes referred to as attenuation, changing a material or process to moderate a hazard can reduce the consequences of a loss of control. Moderation involves using processes requiring less-hazardous operating conditions, i.e. reaction conditions closer to ambient temperature and atmospheric pressure. This may be achieved by:

- Dilution with a less-hazardous material, reducing the impact of a loss of containment and, in some cases, increasing the stability of the chemical.
- Refrigeration (e.g. storing liquefied natural gas under refrigeration at atmospheric pressure thus reducing the need for pressure containment).
- Changing physical characteristics (e.g. handling and transporting a chemical in crystalline form rather than as a fine or combustible dust).
- Use of a catalyst to allow a lower operating temperature.

5.2.1.4 Simplification

For a complex process or plant that is usually more difficult to operate and less tolerant of errors, at the design stage the emphasis should be on the simplest design possible to eliminate a hazard or minimise the need for complex control and safeguard systems. Some general principles are:

- Use of stronger (higher pressure rated) equipment to reduce the need for complex pressure relief systems, instrumentation and interlocks.
- Elimination of seldom-used piping.
- Processes tolerant to variations in operating parameters and feedstock changes.
- Making incorrect operation impossible (e.g. use of selective couplings to prevent inadvertent cross-connection of utilities such as nitrogen and breathing air systems).
- Good human factor design to ensure equipment operates the way people expect it to operate and provides feedback to confirm proper operation (Mannan, 2012).

5.2.2 Layers of protection

A single safety measure alone can eliminate risk, where the level of risk cannot be reduced to an acceptable level by a safety measure additional protective layers of safety measures may be required such that if one protection layer fails, successive layers can take the process to a safe state. As the number of protection layers and their reliability increases, the safety of overall process increases. A typical example of the safety protection systems is shown in Table 5-2.

Table 5-2 Layers of protection

Layer of protection	Protection measure	Examples	Safeguards
Layer 1	Process design	Design to standards, inherently safer design	
Layer 2	Basic controls	Process controls, process alarms (yellow), operator supervision	
	Critical alarms	Process alarms (red), operator intervention Safety Instrument System	Preventive safeguards
Layer 3	Automatic actions	Shutdown, emergency shutdown (ESD) Safety Instrument System	
Layer 4	Physical protection	Relief valves, rupture discs, fire and gas system	Mitigative safeguards
		Firewalls, dikes, berms, bunds (local containment)	

Layer of Protection Analysis (LOPA) is a method whereby all known process hazards and all known layers of protection are closely scrutinized. Each non-SIS safety measure is assigned its own hazard risk reduction factor. For each process hazard where the LOPA study concludes that existing non-SIS protection cannot reduce risk to an acceptable or tolerable level, a Safety Instrumented System i.e., SIS is required. Not all process hazards will require the use of a SIS.

During the FEED phase a Layers of Protection analysis (LOPA) will not be undertaken for the whole of plant system, however safety critical systems have been identified and additional layers of protection have been applied. A full LOPA will need to be undertaken for the integrated system during the detailed design phase.

The first layer of protection is the safety of the design itself. The FEED design has been developed in accordance with the processes outlined in this specification and considers:

- Hazards identified during the pre-feed HAZOP.
- Risks identified during the design process.
- HAZOP
- CHAIR

The second layer of protection is the Control System. The plant is equipped with a PLC based BPCS (Basic Plant control system) with various parameter measurement instruments and control elements such as control valves to ensure the steady state operation of the system and to manage process upsets.

The third layer of protection is the Automated Safety System. The plant has an independent Safety Instrumented System (SIS). If there is any process upset which cannot be controlled by the BPCS or is caused by failure / errors in the BPCS, then the system is taken to the safe state. The SIS consists of parameter measurement instruments independent of the control instruments. Once the trip(s) on the safety instrument is triggered, the system is taken to a safe state by tripping the PCM (Power Conversion Module) to stop further production of hydrogen and then depressurized with the help of a network of blowdown valves. Critical instruments, equipment and controllers are SIL (Safety Integrity Level) rated and are hard-wired to and from the SIS to increase their reliability and ultimately improving the reliability of the system.

It is expected the process area that contains the systems is equipped with hydrogen gas detectors and/or flame detection to warn operators and shut down the system in case of a hazardous situation due to a hydrogen leak or fire.

An H₂ in O₂ analyzer is also provided to continuously monitor the hydrogen content on the anode side of the electrolyser stack to ensure that there is no membrane failure or large hydrogen carry-over.

The fourth layer of protection is the Mechanical Safety Devices. The plant is equipped with pressure safety valves and rupture discs to ensure that the system is depressurized to safe pressure levels in case the other layers of protection fail. The pressure safety valves are designed to relieve the pressure safely which might be the result of various cases as follows:

- Fire Case
- Blocked Outlet
- Liquid Overfilling
- Gas Blowby
- Membrane rupture
- Control valve / actuated valve failure
- Reverse flow due to check valve / actuated valve failure, etc.

5.2.3 Safety Instrument System (SIS)

The safety instrumented system (SIS) is an engineered set of hardware and software controls which provides a protection layer preventing unsafe operations or dangerous conditions from occurring.

The safety instrumented system consists of instruments, controllers and controls which meet a defined safety integrity level (SIL) requirement.

The safety integrity level is used to define the reliability of a specific safety instrumented function (SIF) which is implemented by a safety instrumented system.

5.2.4 Safety Integrity Level (SIL)

Each hazard that requires the use of the safety instrument system must be assigned a target safety integrity level. A formal SIL study is not proposed for the FEED stage of the project and will occur during the detailed design phase.

SIL means Safety Integrity Level that comes from standard IEC 61511 – Safety Instrumented System for the process industry sector, to quantify safety performance requirements for hazardous operations.

There are four SIL Levels (SIL1 – SIL4). A higher SIL level means a greater process hazard and a higher level of risk reduction required from the SIS.

Each SIF serves as a layer of protection to bring the effective hazard frequency below the acceptable hazard frequency. To do this, each SIF must have a minimum risk reduction factor. The difference between the acceptable hazard frequency and the frequency of hazard determined after applying non-SIS protection layers should be the minimum risk reduction factor or target SIL level of the SIF.

A1 APPENDIX 1- Design Standards

The following table contains a list of standards which may be utilized in hydrogen plant design. Additional or alternative standards will likely be required and considered.

Source	Number	Year	Description
AS	1020	2023	The control of undesirable static electricity
AS	1170.0	2002	Structural design actions - General principles
AS	1170.1	2002	Structural design actions - Permanent, imposed and other actions
AS	1170.2	2021	Structural design actions - Wind actions
AS	1170.4	2007	Structural Design Actions Part 4: Earthquake Actions in Australia
AS	1171	1998	Non-destructive testing – Magnetic particle testing of ferromagnetic products, components and structures
AS	1200	2015	Pressure equipment
AS	1210	2010	Pressure Vessels
AS	1554	-	Structural steel welding - Set
AS	1657	2018	Fixed platforms, walkways, stairways and ladders — Design, construction and installation
AS	1796	2022	Welder Certification
AS	2030.1	2009	Gas Cylinders, Part 1 - General Requirements
AS	2030.4	1985	The verification, filling, inspection, testing and maintenance of cylinders for storage and transport of compressed gases, Part 4: Welded cylinders - Insulated
AS	2030.5	2009	Gas cylinders, Part 5: Filling, inspection and testing of refillable cylinders
AS	2177	2006	Non-destructive testing – Radiography of welded butt joints in metal – Methods of test
AS	2337.1	2004	Gas cylinder test stations, Part 1: General requirements, inspection and tests - Gas cylinders
AS	2337.3	2020	Gas cylinder test stations, Part 3: Transportable gas cylinders - Periodic inspection and testing of composite cylinders (ISO 11623:2015, MOD)
AS	2885.0	2018	Pipelines - Gas and liquid petroleum - Part 0: General requirements
AS	3000	2018	Electrical installations (known as the Australian/New Zealand Wiring Rules)
AS	3452.2	2023	Non-destructive testing – penetrant testing – testing of penetrant materials
AS	3788	2024	Pressure equipment - In-service inspection
AS	3892	2001	Pressure Equipment – Installation
AS	3920	2015	Pressure equipment - Conformity assessment
AS	3992	2020	Pressure Equipment – Welding and Brazing Qualification
AS	4037	1999	Pressure Equipment – Examination and Testing
AS	4041	2006	Pressure Piping
AS	4332	2004	The storage and handling of gases in cylinders
AS	4343	2014	Pressure Equipment - Hazard Levels
AS	4458	1997	Pressure Equipment – Manufacture
AS	4481	1997	Pressure Equipment - Inspection Bodies and Personnel
AS	4484	2016	Gas Cylinders for industrial, scientific, medical and refrigerant use - Labelling and colour coding
AS	4564	2020	General-purpose natural gas

Source	Number	Year	Description
SA	TS 5359	2022	The storage and handling of hydrogen
AS	14687	2020	Hydrogen fuel quality - Product Specification
AS	SA TR 15916	2021	Basic considerations for the safety of hydrogen systems
AS	16110.1	2020	Hydrogen generators using fuel processing technologies
AS	16111	2020	Transportable gas storage devices - Hydrogen absorbed in reversible metal hydride
AS	19880.1	2023	Gaseous hydrogen - Fueling stations, Part 1: General requirements (ISO 19880-1:2020, MOD)
AS	19880-3	2020	Gaseous hydrogen - Fueling stations Part 3 Valves
AS	ISO 19880-5	2021	Gaseous hydrogen - Fueling stations Part 5 Dispensing hoses and assemblies
AS	ISO 19880-8	2021	Gaseous hydrogen - Fueling stations Part 8 Fuel quality control
AS	ISO 19881	2020	Gaseous hydrogen - Land Vehicle fuel containers
SA	TS 19883	2020	Safety of pressure swing adsorption systems for hydrogen separation and purification
AS	22734	2020	Hydrogen generators using water electrolysis - Industrial, commercial, and residential applications
AS	26142	2020	Hydrogen detection apparatus - Stationary applications
AS	60079.0	2019	Explosive atmospheres – Equipment – General requirements
AS	60079.10.1	2022	Explosive atmospheres, Part 10.1: Classification of areas - Explosive gas atmospheres
AS	60079.14	2022	Explosive atmospheres Design selection, erection and initial inspection
AS	60079.29.1	2017	Explosive atmospheres - Gas detectors - Performance requirements of detectors for flammable gases
AS	60079.29.2	2016	Explosive atmospheres - Gas detectors - Selection, installation, use and maintenance of detectors for flammable gases and oxygen
AS	60529	2004	Degrees Of Protection Provided by Enclosures (IP Code)
AS	TR 61508.0	2006	Functional safety of electrical/electronic/programmable electronic safety-related systems - Functional safety and AS 61508
AS	61508.1	2011	Functional safety of electrical/electronic/programmable electronic safety-related systems - General requirements
AS	61508.2	2011	Functional safety of electrical/electronic/programmable electronic safety-related systems - Requirements for electrical/electronic/programmable electronic safety-related systems
AS	61508.3	2011	Functional safety of electrical/electronic/programmable electronic safety-related systems - Software requirements
AS	61508.4	2011	Functional safety of electrical/electronic/programmable electronic safety-related systems - Definition and abbreviations
AS	61508.5	2011	Functional safety of electrical/electronic/programmable electronic safety-related systems - Examples of methods for the determination of safety integrity levels
AS	61508.6	2011	Functional safety of electrical/electronic/programmable electronic safety-related systems - Guidelines on the application of AS 61508.2 and AS 61508.3
AS	61508.7	2011	Functional safety of electrical/electronic/programmable electronic safety-related systems - Overview of techniques and measures
AS	61511.1	2018	Functional safety - Safety instrumented systems for the process industry sector, Part 1: Framework, definitions, system, hardware and application programming requirements

Source	Number	Year	Description
AS	61511.2	2018	Functional safety—Safety instrumented systems for the process industry sector Part 2: Guidelines for the application of AS IEC 61511.1
AS	61511.3	2018	Functional safety—Safety instrumented systems for the process industry sector Part 3: Guidance for the determination of the required safety integrity levels
AS	62282.2.100	2022	Fuel cell technologies Part 2.100: Fuel cell modules - Safety
AS	62282.3.100	2021	Fuel cell technologies Part 3.100: Stationary fuel cell power systems - Safety
AS	62282.3.300	2021	Fuel cell technologies Part 3.100: Stationary fuel cell power systems - Installation
AS	80079.20.1	2019	Explosive atmospheres, Part 20.1: Material characteristics for gas and vapour classification - Test methods and data
AS	HB225	2023	Guideline for blending hydrogen into pipelines and gas distribution networks
CSA	HGV 4.8	2012	Hydrogen gas vehicle fueling station compressor guidelines
ASME	B1.20.1	2013	Pipe Threads, General Purpose (Inch)
ASME	B16.11	2021	Forged Fittings, Socket-Welding & Threaded
ASME	B16.20	2023	Metallic Gaskets for Pipe Flanges Ring-Joint, Spiral-Wound, and Jacketed
ASME	B16.47	-	Large Diameter Steel Flanges Series B
ASME	B16.5	2020	ASME Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard
ASME	B16.9	2018	Factory –Made Wrought Butt-welding Fittings
ASME	B31.3	2022	Process Piping
ASME	B31.12	2023	Hydrogen Piping and Pipelines
ASME	B36.10	2022	Welded and Seamless Wrought Steel Pipe
ASME	B36.19	2022	Stainless Steel Piping
ASME	BPVC Sections II, V, VIII, IX	-	ASME Boiler and Pressure Vessel Code Section II – Material Specifications Section V – Non-Destructive Examination Section VIII – Rules for Construction of Pressure Vessels Section IX – Welding, Brazing and Fusing Qualifications
ASME	STP-PT-006	2007	Design Guidelines for Hydrogen Piping and Pipelines
API	14C	2017	Analysis, design, installation and testing of basic surface safety system for offshore production platforms
API	14E	1991	Recommended Practice for Design and Installation of Offshore Products Platform Piping Systems
API	520	2020	Sizing, Selection, and Installation of Pressure Relieving Device
API	521	2020	Pressure-relieving and Depressuring Systems
API	537	2017	Flare Details for General Refinery and Petrochemical Service
API	614	2022	Lubrication, Shaft-sealing and Oil-control Systems and Auxiliaries, Sixth Edition
API	617	2022	Axial and Centrifugal Compressors and Expander-compressors
API	618	2007	Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services
API	619	2010	Rotary-Type Positive-Displacement Compressors for Petroleum, Petrochemical, and Natural Gas Industries
API	682	2014	Pumps-Shaft Sealing Systems for Centrifugal and Rotary Pumps
API	692	2018	Dry Gas Sealing Systems for Axial, Centrifugal, and Rotary Screw Compressors and Expanders
CGA	G-5	2017	Compressed Gas Association - Hydrogen, 8th Edition
CGA	G-5.3	2017	Compressed Gas Association - Commodity Specification for Hydrogen, 7th edition

Source	Number	Year	Description
CGA	G-5.4	2019	Compressed Gas Association - Standard for Hydrogen Piping Systems at Consumer Locations, 6th edition
CGA	G-5.5	2021	Compressed Gas Association - Hydrogen Vent Systems, 4th edition
CGA	G-5.6	2005	Compressed Gas Association - Hydrogen Pipeline Systems, 1st edition
CGA	G-5.7	2014	Compressed Gas Association - Carbon Monoxide and Syngas Pipeline Systems, 2nd edition
CGA	G-5.8	2007	Compressed Gas Association - High Pressure Hydrogen Pipeline Systems at Consumer locations, 1st edition
CGA	P-8.10	2021	Compressed Gas Association - Industrial Gas Pipeline Integrity Management, 1st edition
CGA	H-3	2019	Standard for Cryogenic Hydrogen Storage
CGA	H-4	2020	Terminology Associated with Hydrogen Fuel Technologies
CGA	H-5	2020	Standard for Bulk Hydrogen Supply Systems (an American National Standard)
CGA	H-7	2024	Standard Procedures for Hydrogen Supply Systems
CGA	H-11	2020	Safe Startup and Shutdown Practices for Steam Reformers
CGA	H-13	2023	Hydrogen Pressure Swing Adsorber (PSA) Mechanical Integrity Requirements
CGA	H-17	2023	Guideline for Small Scale Hydrogen Production
CGA	PS-46	2024	CGA Position Statement on Roofs Over Hydrogen Storage Systems
IOGP	S-722	2020	JIP33, Supplementary Specification to API 537
IOGP	S-722Q	2020	JIP33, Quality Requirements for Flare Package
EIGA	DOC 15	2021	Gaseous Hydrogen Installations
EIGA	DOC 63	2014	Prevention of Tow-Away Incidents
EIGA	DOC 75	2021	METHODOLOGY FOR DETERMINATION OF SAFETY AND SEPARATION DISTANCES
EIGA	DOC 100	2020	HYDROGEN CYLINDERS AND TRANSPORT VESSELS
EIGA	DOC 121	2014	Hydrogen Pipeline Systems
EIGA	DOC 122	2018	Environmental Impacts of Hydrogen Plants
EIGA	DOC 134	2021	POTENTIALLY EXPLOSIVE ATMOSPHERES EU DIRECTIVE 1999/92/EC
EIGA	DOC 187	2014	GUIDELINE FOR THE LOCATION OF OCCUPIED BUILDINGS IN INDUSTRIAL GAS PLANTS
EIGA	DOC 211	2017	Hydrogen Vent Systems for Customer Applications
EIGA	DOC 244	2023	RECIPROCATING CRYOGENIC PUMPS AND PUMP INSTALLATIONS FOR HYDROGEN AND LIQUEFIED NATURAL GAS
EIGA	DOC 250	2024	STANDARD PROCEDURES FOR HYDROGEN SUPPLY SYSTEMS
EIGA	DOC 251	2024	OVERVIEW OF HYDROGEN PRODUCTION METHODS
AIAA	G095A	2017	Guide to Safety to Hydrogen and Hydrogen Systems
ISO	7866	2012	Gas cylinders - Refillable seamless aluminum alloy gas cylinders - Design, construction and testing
ISO	9223	2012	Corrosion of metals and alloys - Corrosivity of atmospheres - Classification, determination and estimation
ISO	9809-01	2019	Gas cylinders - Design, construction and testing of refillable seamless steel gas cylinders and tubes - Part 1: Quenched and tempered steel cylinders and tubes with tensile strength less than 1 100 Mpa
ISO	9809-02	2019	Gas cylinders - Design, construction and testing of refillable seamless steel gas cylinders and tubes - Part 2: Quenched and tempered steel cylinders and tubes with tensile strength greater than or equal to 1 100 Mpa

Source	Number	Year	Description
ISO	9809-03	2019	Gas cylinders - Design, construction and testing of refillable seamless steel gas cylinders and tubes - Part 3: Normalized steel cylinders and tubes
ISO	9809-04	2021	Gas cylinders - Design, construction and testing of refillable seamless steel gas cylinders and tubes - Part 4: Stainless steel cylinders with an Rm value of less than 1 100 Mpa
ISO	11114-4	2017	Transportable gas cylinders - Compatibility of cylinder and valve materials with gas contents - Part 4: Test methods for selecting steels resistant to hydrogen embrittlement
ISO	11119.1	2020	Gas cylinders - Design, construction and testing of refillable composite gas cylinders and tubes - Part 1: Hoop wrapped fiber reinforced composite gas cylinders and tubes up to 450
ISO	11119.2	2020	Gas cylinders - Design, construction and testing of refillable composite gas cylinders and tubes - Part 2: Fully wrapped fiber reinforced composite gas cylinders and tubes up to 450 l with load-sharing metal liners
ISO	11119.3	2020	Gas cylinders - Design, construction and testing of refillable composite gas cylinders and tubes - Part 3: Fully wrapped fiber reinforced composite gas cylinders and tubes up to 450 l with non-load-sharing metallic or non-metallic liners or without liners
ISO	11119.4	2020	Gas cylinders - Refillable composite gas cylinders - Design, construction and testing - Part 4: Fully wrapped fiber reinforced composite gas cylinders up to 150 l with load-sharing welded metallic liners
ISO	11515	2022	Gas cylinders - Refillable composite reinforced tubes of water capacity between 450 l and 3000 l - Design, construction and testing
ISO	12944-1	2017	Paints and varnishes - Corrosion protection of steel structures by protective paint systems - Part 1: General introduction
ISO	15649	2001	Petroleum and natural gas industries - Piping
ISO	17268	2020	Gaseous hydrogen land vehicle refueling connection devices
ISO	19880-1	2020	Gaseous hydrogen - Fueling stations - Part 1: General Requirements
ISO	19884	2018	Draft Document - Gaseous hydrogen - Cylinders and tubes for stationary storage
ISO	22734	2019	Hydrogen generators using water electrolysis. Industrial, commercial, and residential applications
ISO	26142	2010	Hydrogen detection apparatus. Stationary applications
NFPA	2	2023	Hydrogen Technologies Code
NFPA	55	2023	Compressed Gases and Cryogenic Fluids Code
NFPA	56	2023	Standard for Fire and Explosion Prevention During Cleaning and Purging of Flammable Gas Piping Systems
NFPA	67	2019	Guide on Explosion Protection for Gaseous Mixtures in Pipe Systems
WRC	107/537	-	Local Stresses in Spherical and Cylindrical Shells due to External Loadings
WRC	297	-	Local Stresses in Spherical and Cylindrical Shells due to External Loadings on Nozzles – Supplement to WRC Bulletin No. 107
EN	10204	2004	Metallic Products – Types of Inspection Certificates
BSI	PD 5500	2021	UK National Specification for unfired pressure vessels
EU	2014/68/EU	2016	The Pressure Equipment Directive (PED)(2014/68/EU) applies to the design, manufacture and conformity assessment of stationary pressure equipment with a maximum allowable pressure greater than 0,5 bar.
FM	7-91	2024	Property Loss Prevention Data Sheets - Hydrogen
UL	2075	2013	Gas and Vapor Detectors and Sensors

A2 APPENDIX 2- Typical Safety Data Sheets