31 January 2022

Shaunte Farrington
Gladstone Regional Council
PO Box 29
Gladstone QLD 4680

Dear Shaunte,

DA/25/2021 – Further Advice Response

We write in response to Council's letter dated 22 December regarding hazard and risk considerations associated with the proposed Hydrogen Park Gladstone Project.

Australian Gas Networks (AGN) acknowledges that the additional submissions made to Council (dated 3 December and 10 December 2021) have raised queries in relation to the adequacy of the Quantitative Risk Assessment (Thornton Tomasetti, 8 October 2021) previously provided to Council in our response to submissions dated 8 November 2021. It is recognised that the information presented in the QRA is of a highly technical nature and that Council is unlikely to have the internal technical expertise to be able to determine whether the issues raised in the additional submissions are in fact valid.

AGN recognises the community interest in this issue and the need to ensure that the public has confidence in the veracity of the assessment and ability of the site to be developed and operated safely. AGN is committed to ensuring that Council has been provided with the information needed to be able to complete its assessment of the development application and has therefore engaged Advisian to undertake an independent peer review of the original QRA and to respond specifically on the matters raised in the additional submissions (see attached Review of QRA Study ref: 411012-00430).

The Advisian report confirms the robustness of the approach and methodology adopted in the QRA and makes several recommendations all of which have been addressed either in the updated QRA by Thornton Tomasetti (dated 28 January 2022) or otherwise in the attached technical memo prepared by AGN parent company Australian Gas Infrastructure Group (dated 31 January 2022).

In accordance with section 32 of the Development Assessment Rules (DA Rules), please be advised that with the submission of this material we withdraw the stop notice previously provided. We now look forward to Council's timely determination of the application.

Should you wish to discuss this matter further, please contact the undersigned.

Yours sincerely,

Jim Fjeldsoe

Partner and Principal Consultant

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Thornton Tomasetti

Gladstone Hydrogen Park Quantitative Risk Assessment

Thornton Tomasetti AE21016-R01 Rev 1

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28th January 2022

Executive Summary

The Australia Gas Infrastructure Group (AGIG) is developing Hydrogen Park Gladstone (HyP Gladstone) which will deliver a whole of gas network decarbonisation project, blending natural gas with up to 10% hydrogen to more than 770 homes and businesses throughout Gladstone's existing gas network.

HyP Gladstone is not classified as a Hazardous Chemical Facility under Queensland State code 21, as the hydrogen inventory is 0.02% of the threshold quantity for hydrogen (50 kg) (i.e. at least 10% is required to be classified as a HCF), the code has been applied to illustrate comparison with acceptable risk criteria. In order to support this assessment a Quantitative Risk Assessment (QRA) has been performed to assess the risk associated with releases at the site.

The assessment has determined that the most onerous consequences associated with natural gas and hydrogen gas releases at HyP Gladstone can extend up to:

- 47.5 m flame for the most onerous hydrogen jet fire but the duration of this scenario is less than 1 second;
- 42.7 m flame for a release of natural gas from the inlet to the gate station (above ground), an vent which could last almost one hour; and
- 74.1 m downwind for the LFL cloud and 97.8 m downwind for the 0.5 LFL cloud from a large (100 mm) release from hydrogen storage, though the effect duration is less than 1 second.

Assessment against dangerous dose to health criteria indicates that the 4.7 kW/m^2 heat flux and 7 kPa overpressures could extend beyond the site boundary but at extremely low frequencies.

The risk assessment has determined that the risk of fatality at the site boundary is less than 1E-06 per year and meets the tolerable individual risk at the boundary of the nearest residential areas within proximity of the site.

A number of potential risk reduction considerations are made and these are summarised in Section 6.

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Appendices

Appendix A: Isolatable Inventory P&ID Mark Ups
Appendix B: Assumption Sheets

Revision History

Revision	Prepared By:	Reviewed By:	Approved By:
A For Client Review and Comment 22/09/2021	J Tarleton Principal Consultant	A Nelson Principal Consultant	
0 Issued for use 08/10/2021	J Tarleton Principal Consultant	A Nelson Principal Consultant	A Nelson Principal Consultant RPEQ Registration No. 25810
1 Issued for use 28/01/2022	J Tarleton Principal Consultant	A Nelson Principal Consultant	A Nelson Principal Consultant RPEQ Registration No. 25810

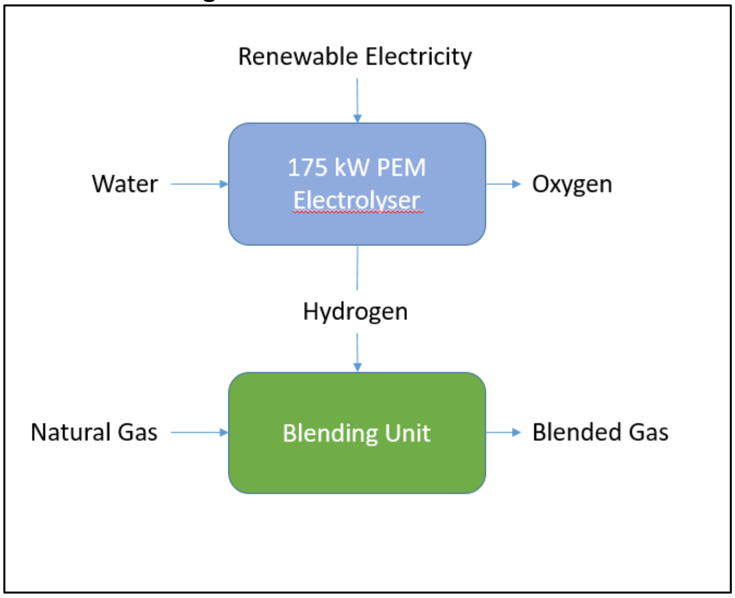
1.0 Introduction

1.1 Background

The Australia Gas Infrastructure Group (AGIG) is developing Hydrogen Park Gladstone (HyP Gladstone) which will deliver a whole of gas network decarbonisation project, blending natural gas with up to 10% hydrogen to more than 770 homes and businesses throughout Gladstone's existing gas network.

At HyP Gladstone, AGIG plan to produce renewable hydrogen using a 175 kW electrolyser with water and renewable electricity as illustrated in Figure 1-1. The proposed hydrogen storage volume is 10 kg.

Figure 1-1 Process Schematic



Detailed design is underway and Development Approvals are being sought with the plan to commence work at the site in Q2, 2022 and commence delivery of blended gas in Q3, 2022.

The Quantitative Risk Assessment (QRA) presents a risk assessment for offsite populations based on operating parameters, hazardous inventories and environmental conditions at the site.

1.2 Objectives and Scope

The QRA for HyP Gladstone models hazardous inventories which present a credible risk to offsite populations as follows:

- Gladstone City Gate Station which receives the Jemena Queensland Gas Pipeline (QGP) feed gas and exports blended gas to the Gladstone domestic network; and
- Hydrogen Storage Vessel, Injection & Blending facilities.

The QRA has been developed to determine the risk to populations in the surrounding area.

1.2.1 Exclusions

The following hazards are excluded from the QRA model:

- Visiting vehicle collisions with equipment on site;
- External hazards such as extreme weather, flooding, land slippage or third party interference; and
- The effects of wild life impacting the site and safety systems, e.g. mud daubers blocking vents, spiders spinning webs across flame detector sensors, etc.
- The site is shielded from the road by an earth bund so the risk of impact from passing vehicles is not considered to present a credible impact hazard.
- Long term structural integrity issues are not considered. Technical assessments have been conducted and these concluded that 10% blended gas will not have an adverse impact on the materials used in the downstream network following the introduction of natural gas blended with hydrogen [1].

1.3 Report Structure

This report is structured as follows:

- Section 2.0 presents a description of the site layout and features of the facility design;
- Section 3.0 presents the QRA approach;
- Section 4.0 presents the consequence modelling results;
- Section 5.0 presents the risk results;
- Section 6.0 presents a list of references; and

Appendix A presents the Process and Instrumentation Drawings (P&ID) markups supporting the release frequency assessment.

1.4 Acronyms and Abbreviations

AGIG	Australian Gas Infrastructure Group
HCF	Hazardous Chemical Facility
HH	High-High
HyP	Hydrogen Park
IOGP	International Association of Oil and Gas Producers
IR	Individual Risk
PS	Process Section
LFL	Lower Flammability Limit
LSIR	Location Specific Individual Risk
MAOP	Maximum Allowable Operating Pressure
P&IDs	Piping and Instrumentation Drawings
PEM	Proton Exchange Membrane
PSV	Process Safety Valve
QGP	Queensland Gas Pipeline
QRA	Quantitative Risk Assessment
RRP	Risk Ranking Point

2.0 Site Description

2.1 Location and Topography

The HyP Gladstone facility will be located on an approximately 1,100 m^2 fenced site, of 37 m x 30 m, on Derby Street, South Gladstone. The surrounding area is cleared and compacted, except for an earth bund located between the site and Derby Street.

The natural terrain of the proposed site means the facility is not visually prominent from the street or surrounding residential areas and the existing earth bund and landscaping along Derby Street provide visual screening. The site is also visually screened from residential areas to the east, north and west by a combination of existing natural terrain and vegetation.

The Derby Street site is sufficiently large that the property provides additional buffers from adjoining residential areas as illustrated in Figure 2-1.

2.2 Site Features

The proposed HyP Gladstone development comprises four key components as illustrated in Figure 2-2 and Figure 2-3:

1. Gladstone City Gate, which takes natural gas from the transmission pipeline network (located adjacent to the site in the Derby St road reserve) and reduces its pressure for use in the distribution network which supplies homes and businesses in Gladstone. This area is within a compound, fenced on all sides and is approx. 25 m from the adjoining Derby St road reserve;

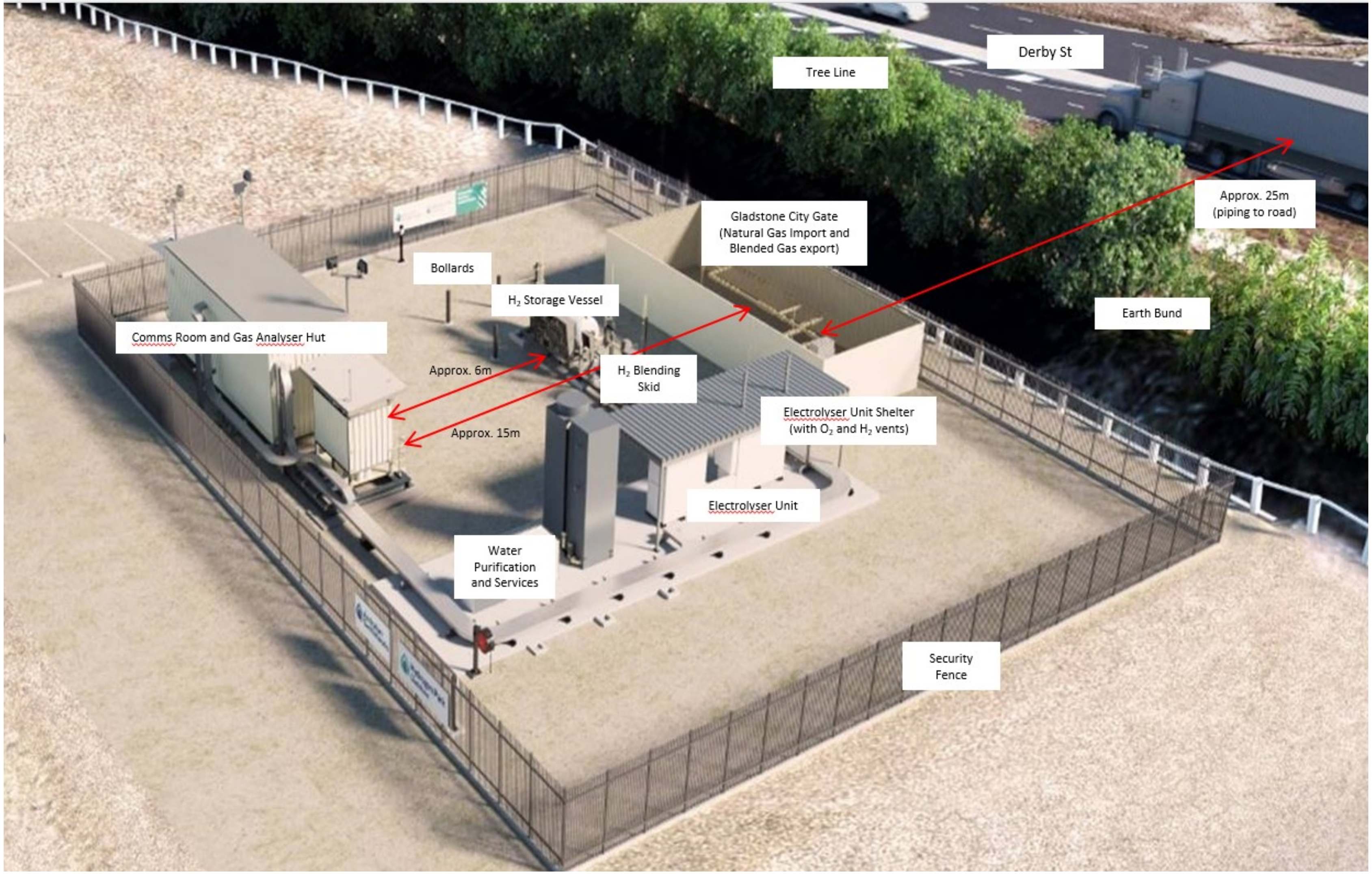
2. Hydrogen generator, water purification and other utilities. The Hydrogen generator is a Nel Proton Exchange Membrane (PEM) C Series Hydrogen Generator Unit (electrolyser) which is an enclosed unit equipped with ventilation. It is protected by a shelter which has openings for the hydrogen and oxygen vents from the electrolyser unit;

3. Hydrogen storage and blending. Up to 10 kg of hydrogen is proposed to be stored in a 4m^3 storage vessel for regulation of hydrogen to be blended into the distribution network; and

4. Shelter and Control Room which regulates the utility systems, water supply, power supply, and control systems which supports Park operations, and Gas Analyser Hut. The Control Room is approximately 6 m away from the Hydrogen Storage Vessel and the Blending unit, and approximately 12 m from the Gladstone City Gate.

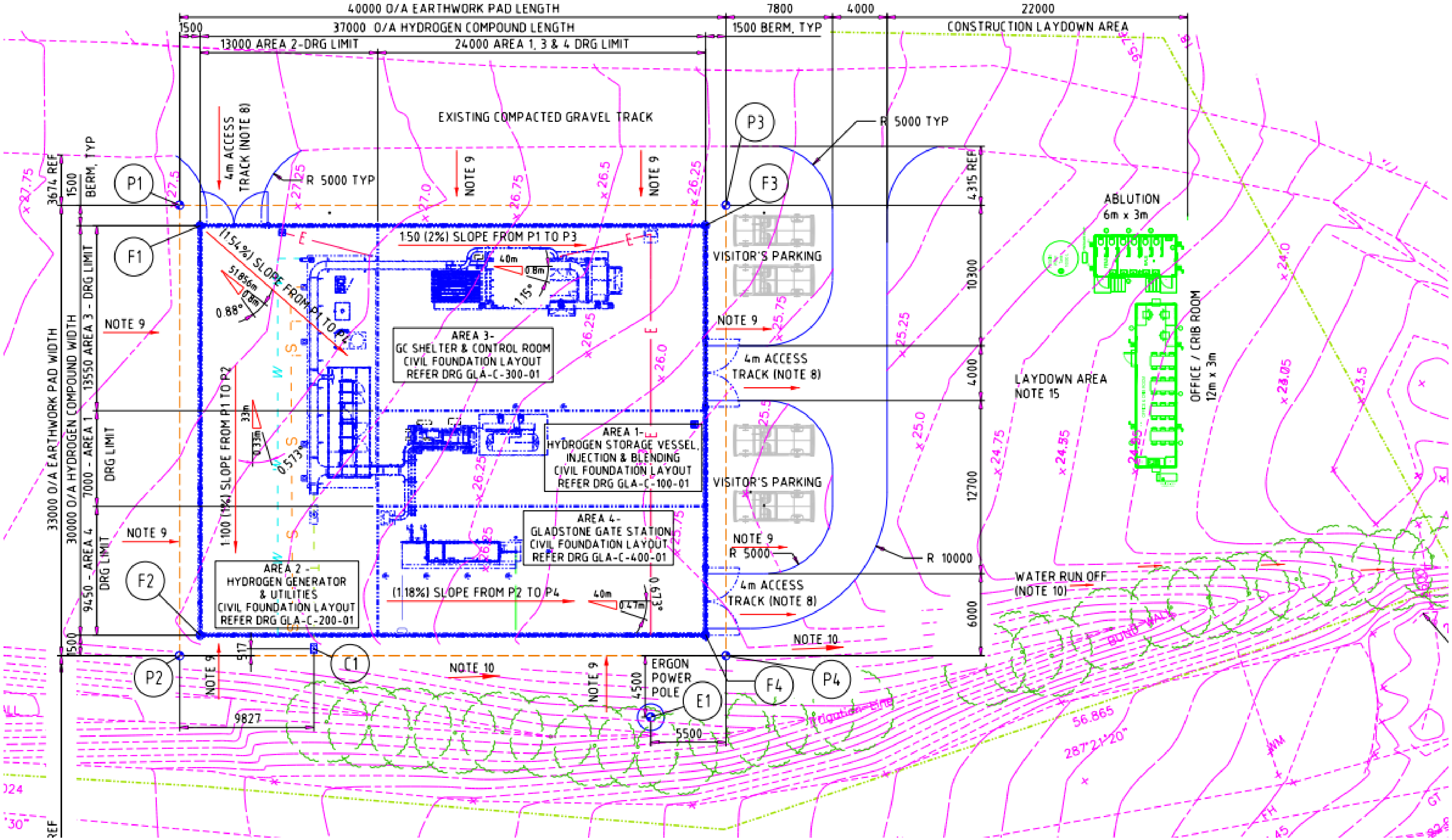
Figure 2-1 HyP Gladstone Location

Figure 2-2 Annotated Artist's Impression of HyP Gladstone[1]



[1] Note that the fence illustrated around the Gladstone City Gate will not be installed.

Figure 2-3 HyP Gladstone Layout [2]



2.3 Process Sections

Natural gas feed to the Gladstone City Gate is from the QGP which is predominantly methane. The natural gas feed enters the site underground and rises to above grade within the Gladstone City Gate compound. The incoming pipeline's diameter is 50 mm and its Maximum Allowable Operating Pressure (MAOP) is 5100 kPag at 30 °C. The feed gas composition is presented in Table 2-1.

Table 2-1 QGP Gas Composition [3]

Composition[2]	**Molar Amount**
Nitrogen	0.0150
CO_2	0.0062
Methane	0.9689
Ethane	0.0076
Propane	0.0013
Butane (i and n)	0.0006
Pentane (i and n)	0.0002
C6+	0.0002

The blended hydrogen gas mix accommodates 10% hydrogen in the gas feed and is exported from the Gladstone City Gate compound at 215 kPag and 30 °C via an 80 mm diameter underground pipeline.

Hydrogen is produced using the PEM electrolyser [4] illustrated in Figure 2-4. Releases from the electrolyser have not been modelled as the maximum onboard inventory is 0.016 kg (7 scf) and the enclosure is ventilated.

The hydrogen inventories modelled are the electrolyser output to the blending skid and the hydrogen storage vessel.

Figure 2-4 Nel Proton PEM C Series Hydrogen Generator Unit

[2] Noted that Benzene, Xylene, Toluene are present in trace quantities but do not present a flammable or offsite hazard.

3.0 QRA Approach

HyP Gladstone is not classified as a Hazardous Chemical Facility (HCF) under Queensland State code 21, as the hydrogen inventory is 0.02% of the threshold quantity for hydrogen (i.e. at least 10% is required to be classified as a HCF), the code has been applied to illustrate comparison with acceptable risk criteria. In order to support this assessment a Quantitative Risk Assessment has been performed to assess the risk associated with releases at the site.

The modelling tool used to perform the HyP Gladstone QRA is DNV SAFETI v8.4 [5].

In order to determine the consequences associated with releases from hazardous inventories at HyP Gladstone, the following steps have been applied:

1. Define the hazard (pressure, temperature, volume);
2. Determine the consequences (hazard range);
3. Calculate the frequency of a release (based on parts count);
4. Determine ignition probabilities;
5. Generate risk results; and
6. Compare risk against defined criteria.

3.1 QRA / Consequence Modelling Assumptions

The QRA model has been prepared using inputs agreed with AGIG, including:

- Representative weather conditions as described in Assumption Sheet 3 of Appendix B – atmospheric stability, wind speed, temperature, and humidity;
    - Ambient temperature is taken as 30°C;
    - Relative humidity is taken as 65%;
    - Pasquill Stability Class of D has been selected for daytime and F for nighttime. Daytime wind speed of 8 m/s is assumed and night time wind speed of 4 m/s.
- Process segments and associated composition and operating conditions;
    - Two hydrocarbon gas inventories have been identified, feed gas and blended distribution gas. MAOP for the gas lines as determined from the P&IDs has been used for consequence modelling; and
    - Two hydrogen inventories have been identified; generated hydrogen to the blending and storage skid and the hydrogen storage vessel to the blending skid and injection to blended gas distribution. 'High – High' (HH) pressure trips and Process Safety Valve (PSV) set points have been used to determine the maximum pressures from these equipment items.
- Release frequencies have been determined using applicable datasets for hydrocarbon facilities [6] and typical hydrogen facilities [7].

- Ignition probability determined using the Energy Institute approach [8] for hydrocarbon inventories and NFPA 2 [9] for typical hydrogen facilities; and
- Thermal radiation levels of interest (4.7 kW/m^2, 12.6 kW/m^2 and 35 kW/m^2) and overpressures of interest (3.5 kPa, 7 kPa, 14 kPa, 21 kPa, and 55 kPa).

3.1.1 Hazard Definition

Hazard definition involved determining the location of release sources for the hazardous inventories and defining the key properties of hazards that present a flammable risk, i.e., pressure, temperature, composition, volumes of Process Sections (PSs).

For HyP Gladstone, four hazardous PSs with the potential to present a risk offsite were identified as marked up in Appendix A:

- PS1: Pipeline upstream (feed gas);
- PS2: Hydrogen feed from electrolyser;
- PS3: Hydrogen storage; and
- PS4: Blended gas feed to Gladstone Distribution Network.

Pressure, temperature and volume inputs used in the QRA model are presented in Table 3-1.

Table 3-1 Inventory Properties

PS	Description	Volume (m^3) [3]	Pressure (KPag)	Temperature (°C)
PS1	Feed Gas	-	5200	30
PS2	Hydrogen feed from electrolyser	0.04	3550	57
PS3	Hydrogen storage	4	3450	30
PS4	Blended gas feed to Gladstone	-	320	30

The hydrogen inventory within the electrolyser was not included due to the small volume and the control measures in place to limit the size of any release.

3.2 Consequence Modelling

Consequence modelling has been performed within the QRA model to determine the hazard range associated with the defined release scenarios. The model uses the PHAST software module within the DNV SAFETI QRA tool [5].

PHAST is an industry standard software tool and is baselined and validated against test data.

[3] The pipeline and distribution network (PS1, PS4) inventory has been modelled as a very large volume to maintain a steady state release.

3.3 Frequency Assessment

The marked-up P&IDs and parts count summaries are presented in Appendix A.

Release frequencies for the natural gas feed and blended gas to distribution are based on IOGP process release frequency data [6]. The release frequencies for a pressure vessel were also based on this dataset.

Release frequencies for hydrogen containing inventories were generated using HyRAM v3.1.0 [7].

Catastrophic failure of the hydrogen storage vessel is based on UK HSE data for land use planning [10].

3.4 Ignition Modelling

Ignition probabilities for hydrogen containing inventories were generated using NFPA 2 [9].

Ignition probabilities for hydrocarbon inventories were determined using the Energy Institute approach [8].

3.5 Congested Areas

In general, the site is flat and clear of significant obstructions and congested areas. It is recognised that the trees forming the tree line at the boundary with Derby Street offers the potential for a flammable gas cloud to form in a congested area and as such an obstructed area has been modelled along the treeline to a height of approximately 10 m. The congested area assumes high obstacle density, no significant confinement and a low ignition energy and conservative selection of a blast curve of 5 based on Pitlabo et al [11].

3.6 Risk Ranking Points

Risk Ranking Points (RRPs) are monitor points which support reporting and interpretation of risk results. These have been set at the locations shown in Figure 3-1.

Figure 3-1 HyP Gladstone RRPs

RRP No.	Description	RRP No.	Description
1	Hydrogen Storage Vessel	4	Security Fenceline SW
2	Hydrogen Electrolyser	5	Security Fenceline SE
3	Gladstone Gate Station		

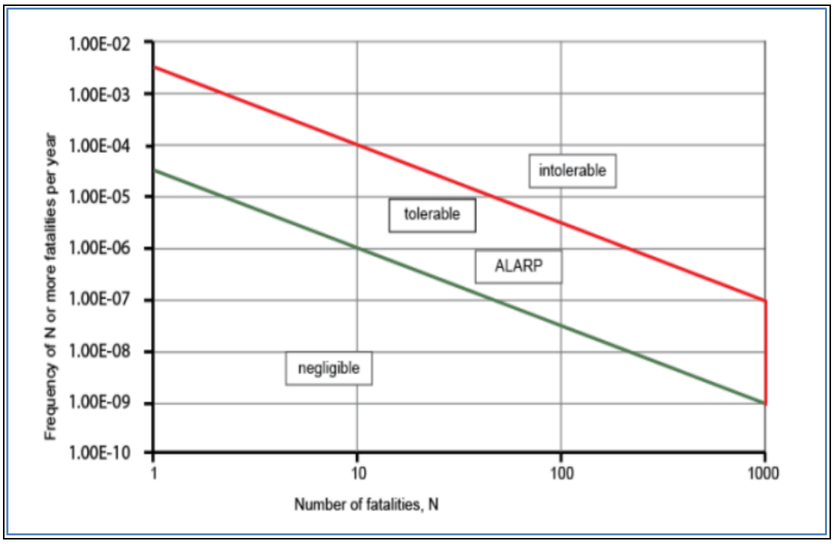
3.7 Risk Criteria

The land use around the site is a combination of community facilities, open space and residential which is classed as sensitive. Queensland State code 21 sets out acceptable outcomes for sensitive land use [12].

Any off-site impact from a hazard scenario shall not exceed, at the boundary of any sensitive land use or zone:

1. *a dangerous dose to human health; or*
2. *if the above criteria cannot be achieved:*
    a. *an individual fatality risk level of 1 x 10^{-6} /year; or*
    b. *the societal risk criteria in Figure 3-2.*

Figure 3-2 Societal Risk Criteria



Per Queensland State code 21 [12], the risk assessment should demonstrate that any offsite impact shall not exceed at the boundary of the sensitive land use or zone:

- Dangerous dose to human health, i.e. an effect that equals or exceeds 4.7 kW/m^2 for heat radiation or 7 kPa for explosion overpressure; or
- Individual fatality risk of 1E-06 per year. Individual fatality risk is the Location Specific Individual Risk (LSIR) at a location should a person be present for 24 hours a day, 365 days a year; or
- Assessment of societal risk using a graph showing the frequency vs number of fatalities from events which could occur at the site (FN curve), taking account of populations at locations within range of the hazardous outcomes.

4.0 Results

4.1 Release Frequencies and Ignition Probabilities

Release frequencies by inventory and hole size are presented in Table 4-1.

Table 4-1 Release Frequency Summary

PS	Description	Maximum Diameter (mm)	Release Size (mm)	Release Frequency (per year)
PS1	Feed Gas	50	2	4.56E-03
			7	1.82E-03
			22	7.37E-04
			50 (Full bore)	2.10E-04
PS2	Hydrogen feed from electrolyser	20 [4]	2	1.78E-01
			22	1.52E-04
PS3	Hydrogen storage	100 [5]	2	1.08E+00
			22	5.36E-03
			100	4.90E-05
PS4	Blended gas feed to Gladstone	80	2	1.75E-03
			7	7.46E-04
			22	3.38E-04
			80 (Full bore)	8.48E-05

The frequency of catastrophic failure of the hydrogen storage vessel, resulting in loss of all contents instantaneously has been taken as 2E-06 per year [10].

Ignition probabilities used in the model are presented in Table 4-2.

Table 4-2 Ignition Probability

PS	Hole Size (mm)	Immediate Ignition Probability	Delayed Ignition Probability
PS1	2	0.00E+00	7.00E-04
	7	5.00E-04	1.17E-03
	22	4.38E-03	1.02E-02
	50	1.46E-02	3.41E-02
PS2	2	8.00E-03	4.00E-03
	22	5.30E-02	2.57E-02

[4] Piping is ¾" Swagelock SS tubing which gives maximum hole size. 22 mm is selected as the representative hole size.
[5] 100 mm is the maximum flange size for the vessel.

PS	Hole Size (mm)	Immediate Ignition Probability	Delayed Ignition Probability
PS3	2	8.00E-03	4.00E-03
	22	5.30E-02	2.57E-02
	100	2.30E-01	1.20E-01
PS4	2	0.00E+00	0.00E+00
	7	0.00E+00	7.00E-04
	22	4.38E-04	1.02E-03
	80	4.04E-04	9.24E-03

4.2 Hazard Ranges

The potential consequences of an ignited gas release are:

- Jet fire (immediate ignition);
- Flash fire (delayed ignition); and
- Explosion (delayed ignition).

The hazard range for these consequences are presented in the following subsections.

4.2.1 Jet Fire

Table 4-3 presents the jet fire hazard and effect range associated with releases from the inventories at HyP Gladstone.

Table 4-3 Jet Fire Consequences

Process Section	Hole size (mm)	Flame length (m)	Event Duration (s)	Distance downwind (m) to:		
				4.7 kW/m²	12.6 kW/m²	35 kW/m²
PS1 QGP Feed Gas	2	2.3	3600	n/a	n/a	n/a
	7	7.0	3600	6.8	n/a	n/a
	22	20.0	3600	27.2	23.3	19.7
	50	42.7	3356	64.3	54.2	46.3
PS2 Hydrogen from Electrolyser to Storage	2	1.4	19	n/a	n/a	n/a
	22	12.1	0.2	15.3	13.5	11.8
PS3 Hydrogen Storage	2	1.4	1886	n/a	n/a	n/a
	22	12.3	16	15.6	13.7	12.0
	100	47.5	0.8	72.2	61.1	53.1
PS4 Blended Gas to Town Supply	2	0.7	3600	n/a	n/a	n/a
	7	2.2	3600	n/a	n/a	n/a
	22	6.1	3600	6.0	n/a	n/a
	80	20.4	3600	27.3	23.7	20.3

The most onerous consequences are not of a size which can reach the boundaries with nearby residences.

4.2.2 Flash Fire

Table 4-4 presents the maximum gas cloud sizes calculated for 50% of the Lower Flammability Limit (LFL) and for LFL.

Table 4-4 LFL Cloud Sizes

PS	Hole size (mm)	Distance to 0.5LFL (m)	Distance to LFL (m)
PS1 QGP Feed Gas	2	1.8	1.0
	7	5.5	3.2
	22	17.3	9.3
	50	66.4	24.5
PS2 Hydrogen from Electrolyser to Storage	2	3.0	1.9
	22	13.3	6.9
PS3 Hydrogen Storage	2	3.0	2.0
	22	56.5	28.9
	100	97.8	74.1[6]
	Catastrophic	33.8	14.4
PS4 Blended Gas to Town Supply	2	0.6	0
	7	1.7	1.0
	22	4.8	2.9
	80	25.9	10.1

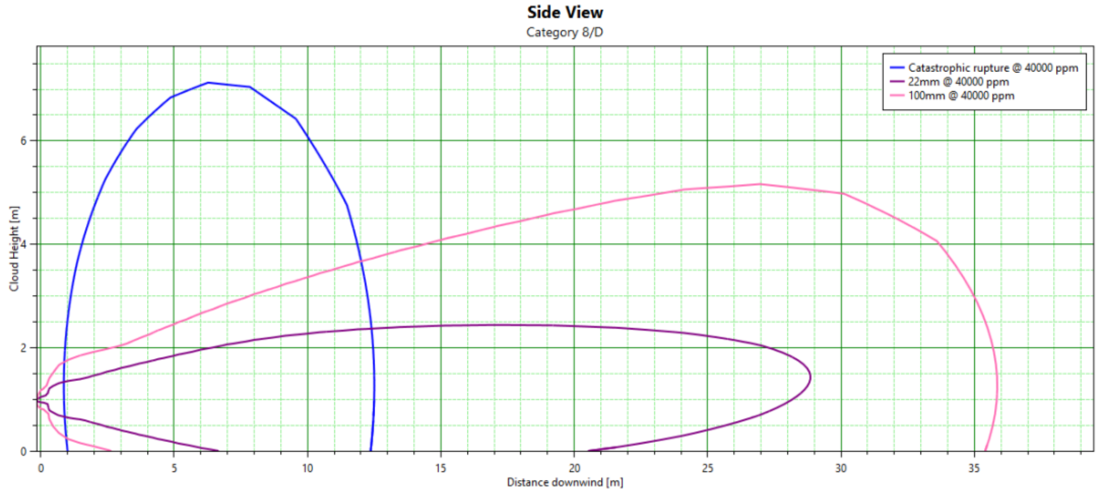
From Table 4-4 it can be seen that the distance to LFL is greatest for releases from the Hydrogen storage vessel extending to 74.1 m downwind for a 100 mm release and 28.9 m for a 22 mm release. Although the 100 mm release could extend 74.1 m downwind, this happens in a very short period of time (less than 1 second) before the cloud disperses to below LFL.

If the plume reaches the tree line and the road, ignition could result generating a noticeable overpressure. Figure 4-1 presents the ideal, free field plume shape as the modelling software is not able to account for obstacles presented to the plume. Hence the predicted hazard range is conservative.

The most onerous consequences are not of a size which can reach the boundaries with nearby residences.

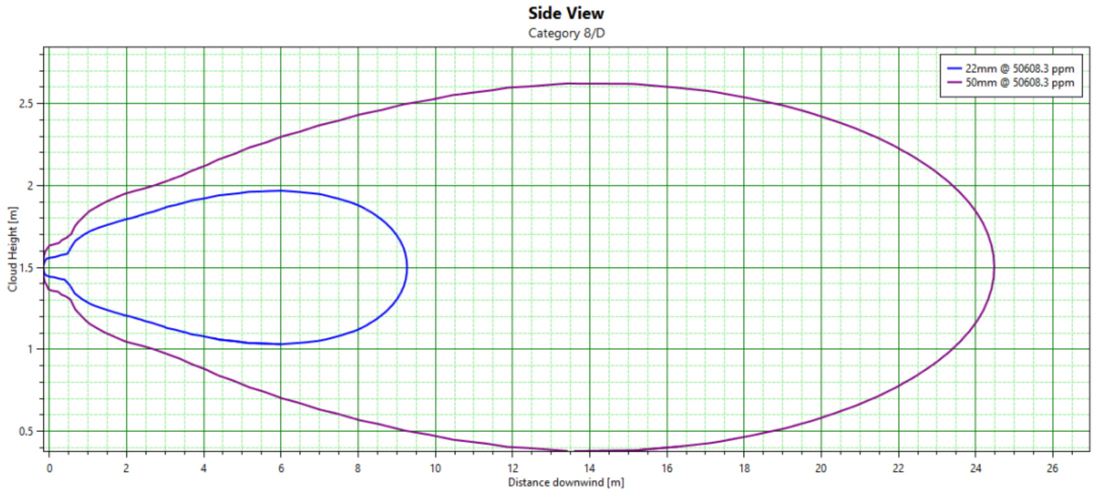
[6] The release is of short duration and reaches 75 m downwind in less than 3 seconds before the cloud disperses fully.

Figure 4-1 PS3 Hydrogen Storage Release Side View of LFL Plume for 22 mm, 100 mm and Catastrophic releases



From Table 4-4 it can be seen that the distance to LFL from feed gas supplies is 26 m for a 50 mm release and 10 m for a 22 mm release. Figure 4-2 gives an indication of the plume shape downwind of the release source.

Figure 4-2 PS1 QGP Feed Gas Release Side View of LFL Plume for 22 mm and 50 mm releases



4.2.3 Explosions

Due to the limited congestion and locations where flammable inventories can accumulate in and around HyP Gladstone, explosion modelling does not generate any appreciable overpressures for releases from inventories released at the site for most areas.

Modelling the effects of congestion within the treeline indicates that overpressures of up to 14 kPa could be experienced from releases within this congested area and overpressures of 7 kPa could be experienced beyond the site boundary, but not as far as the road. Modelling shows overpressures of 21 kPa and above are not reached. The potential overpressure diameters that could result from ignition of a gas cloud at the treeline are presented in Table 4-5.

Table 4-5 Explosion Overpressures

Process Section Source	Hole size (mm)	Maximum Diameter (m) at overpressure (kPa):				
		3.5	**7**	**14**	**21**	**35**
PS1 QGP Feed Gas	50	73.3	36.5	18.1	-	-
PS2 Hydrogen from Electrolyser to Storage	2	-	-	-	-	-
	22	-	-	-	-	-
PS3 Hydrogen Storage	22	50.3	25.2	12.5	-	-
	100	133.7	66.5	33.0	-	-
	Catastrophic	123.4	61.4	30.4		
PS4 Blended Gas to Town Supply	80	32.8	16.3	8.1	-	-

The most onerous consequences are not of a size which can reach the boundaries to nearby residences.

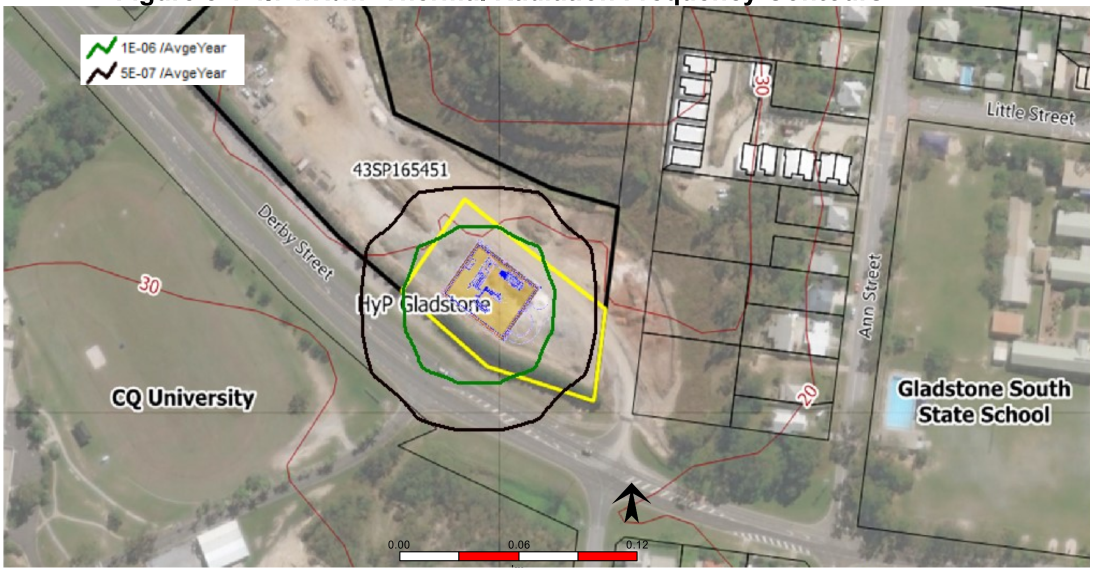
5.0 Risk Results

5.1 Dose Dangerous to Health

Dose dangerous to health are measured in terms of thermal radiation effects of 4.7 kW/m^2 and overpressures of 7 kPa at the site boundary.

It can be seen from Figure 5-1 that the 4.7 kW/m^2 radiation effects can be experienced beyond the site boundary at a frequency of 1E-06 per year and can extend across the footpath running alongside the site.

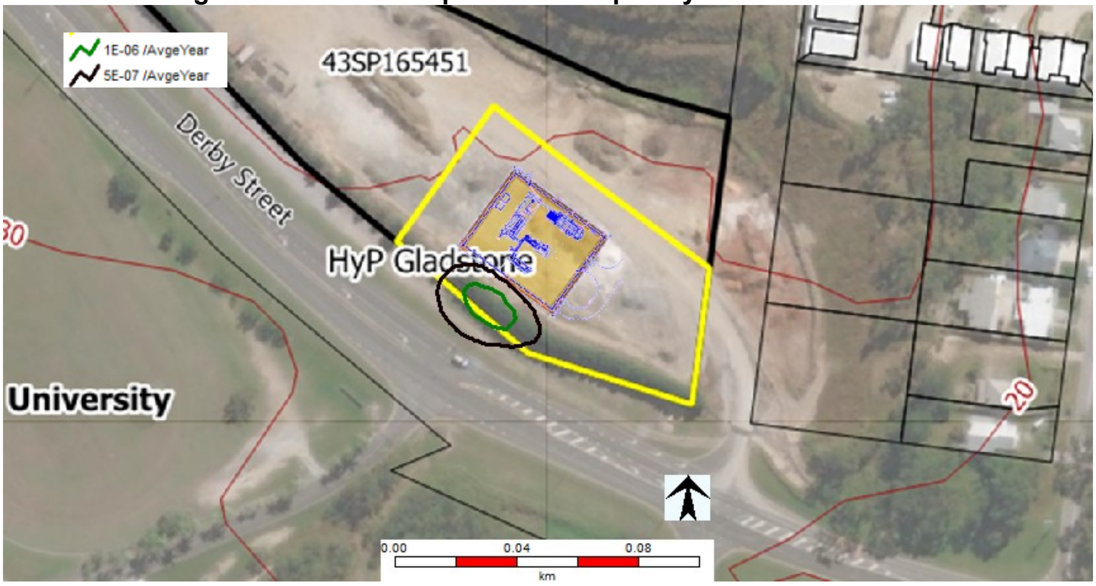
Figure 5-1 4.7 kW/m^2 Thermal Radiation Frequency Contours



As described in Appendix B, exposure to the 4.7 kW/m^2 thermal radiation for a period of 30 seconds can result in injury. This threshold is selected to capture the potential for serious harm to non-ambulant individuals (the elderly, sick or injured parties). However, this modelling does not account for the ignition of the tree line, in which case higher thermal radiation levels would be experienced in this area, albeit the frequency of the event remains very low.

Figure 5-2 shows that the 7 kPa overpressure will also be experienced beyond the site boundary at a frequency of approximately 1E-06 per year. It can be seen that at the frequency of interest this overpressure is not experienced at the footpath.

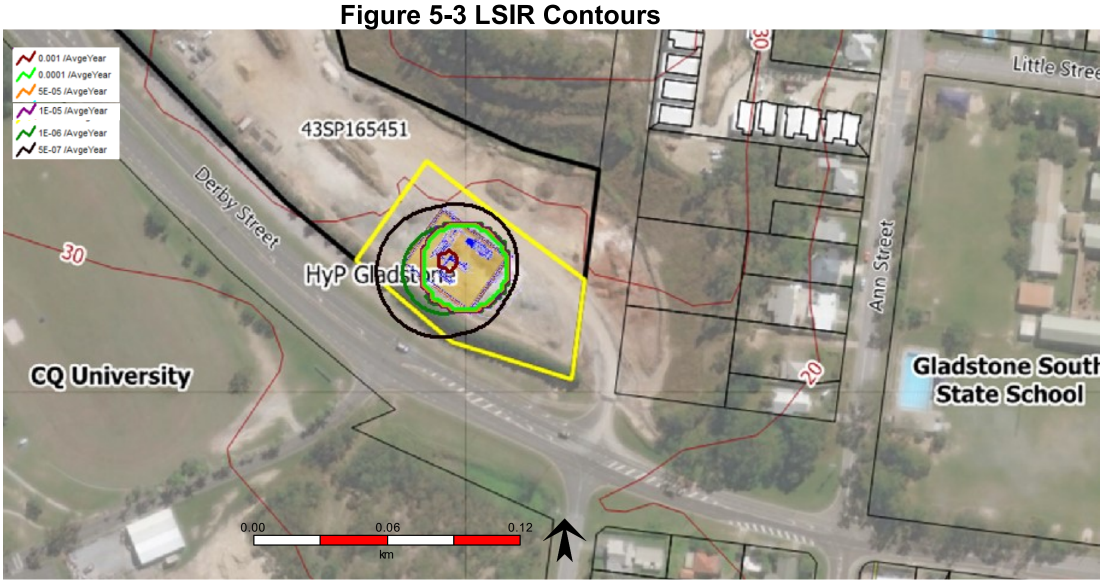
Figure 5-2 7 kPa Overpressure Frequency Contours



5.2 Individual Risk of Fatality

Figure 5-3 shows the LSIR contours associated fatalities arising from the release of flammable from inventories at HyP Gladstone and it can be seen that the risk of fatality at the site boundary is less than 1E-06 per year.

Figure 5-3 LSIR Contours



5.3 Individual Risk at Key Locations

Risk Ranking Points (RRPs) were captured as identified in Figure 3-1. The risk to personnel in outdoor locations at these RRPs is presented in Table 5-1. It should be noted that these points are within the site boundary.

Table 5-1 LSIR at RRPs

RRP	Fatality Risk in Outdoor Locations
1. Hydrogen Electrolyser	2.97E-04
2. Hydrogen Storage Vessel	5.29E-04
3. Gladstone Gate Station	2.99E-04
4. Security Fenceline SW	8.00E-07
5. Security Fenceline SE	1.11E-06

6.0 Discussion

6.1 Risk Results

The Dose Dangerous to Health (for thermal radiation and overpressures) is exceeded at the site boundary but the frequency of this exceedance is extremely low.

The hazard range indicates that flammable events are not experienced at the nearest residential and educational establishment boundaries and the risk contours illustrate that the risk of fatality is lower than 5E-07 per year at these boundaries.

Review of the LSIR contours shows that the Individual Risk of fatality for a person present at the site boundary 24 hours a day, 365 days a year is less than 1E-06 per year and as such meets the tolerability criteria.

Given the hazard range does not extend from the site to the boundary of populated locations (school, university, residences) and the risk of fatality at the site boundary is less than 1E-06 per year, a societal risk assessment is not considered to be required.

In terms of risk to an exposed individual transiting the path adjacent to the site making trips to nearby residences or the school, an exposure time of up to 1 hour a day, 5 days a week and 45 weeks a year means the risk to an exposed individual is around 3E-08 per year. Supplementary information presented in Appendix B places this low risk level into context.

It should also be noted that the risk contours do not account for site topography or the effects of obstacles on or around the site and as such these results are a conservative assessment at the risk of fatality or harm from scenarios which arise from releases at the facility.

6.2 Hazard Effects Summary

There is the potential for flammable scenarios from larger releases to extend offsite but these scenarios are extremely low frequency events. The hazards are discussed below.

6.2.1 Jet Fires

The largest release from the QGP feed gas pipeline could result in a jet fire of 42.7 m, however the presence of the earth bund is likely to reduce the hazard range in practice.

The largest release from the hydrogen storage vessel could result in a fire of 47.5 m and this could reach the control building or extend outside the security fence. The control building on site could be impinged by hydrogen jet fires from an ignited release from the hydrogen storage vessel or associated equipment but the duration of such events is short (< 1 minute).

Hydrogen fires are not readily visible in daylight but a pressurised release will be audible and there will be flame detection on site.

For the hydrogen storage vessel releases from adjacent equipment fed by the storage vessel inventory could result in self-impingement in the event of an ignited release. However, as the fire heats the vessel, the vessel and associated inventory would depressurise, thus reducing the potential for the vessel to rupture. The potential for the vessel to rupture under such conditions has not been assessed, rather it is judged as not credible given that fire detection will trigger emergency shut down and safe venting of the storage inventory.

The other hydrogen inventory modelled is hydrogen generated from the electrolyser which is small and, once isolated, is unable to sustain a jet fire for very long (less than 20 seconds).

6.2.2 Flash fire

Flash fire effects from hydrogen releases are transient due to a relatively small inventory and the release disperses using its natural buoyancy. If the release is directed towards the road the high momentum jet will impinge on the earth bund and lose horizontal momentum. For other directions, the release will remain within the site boundary and personnel on the site may be exposed to a flash fire if the event is ignited.

6.2.3 Explosions

In general, the flat relatively open area means there is little or no potential for gas build up to support the generation of high overpressures. However, the treeline presents an opportunity for gas buildup in a congested area and conservative assessment has indicated that overpressures of up to 14 kPa could be reached on site and 7 kPa could be experienced beyond the site boundary. It is noted that this event is also of extremely low frequency.

6.3 Site Layout and Design Considerations

There are a number of features in the site design which are not explicitly captured within the QRA model due to the limitations of the modelling approach but which act to support management of low risk levels:

- The electrolyser shelter roof is raked and three sides are open; these features promote upward dispersion of an accidental release of hydrogen in this area;
- The earth bund which separates the facility from the neighbouring road provides a barrier to jet fires and gas cloud migration; and
- Vehicle bollards around the storage area prevent the potential for accidental vehicle impact with hydrogen containing equipment;

There are a number of features which could help to further manage risk on site:

- Given the nature of hydrogen flames, flame detection placement should be verified to ensure an adequate field of view and coverage of the risk areas;
- Placement of manual ESD buttons for fast shutdown and isolation of hazardous inventories need to be strategically placed (e.g. control room, diagonally opposite access gates) to ensure they can be accessed in an emergency; and
- Management of vegetation along the treeline is needed to limit congestion which could result in overpressures higher than those predicted for a typically open area.

7.0 References

[1] AGIG, Gladstone: Blended Gas Risk Assessment Report, 430-RP-R-0012.

[2] AGIG, HyP Gladstone, Hydrogen Generation and Blending Facility, Bulk Earthworks and Overall Civil Foundation Plot Plan, GLA-C-001-01, Rev A.

[3] Email Jeff Kong to Joanne Tarleton, dated 13/09/2021: Pressure Temperature Inputs.

[4] Nel Hydrogen, Proton PEM C Series Hydrogen Generation Systems Specification Sheet, 2019

[5] DNV, Safeti v8.4.

[6] IOGP, Risk Assessment Data Directory – Process Release Frequencies, 434-01, September 2019.

[7] Sandia National Laboratories, HyRAM 3.1, Rev 3.1.

[8] Energy Institute, Guidance on Assigning Ignition Probabilities in Onshore and Offshore Risk Assessments, 2nd Ed, May 2019.

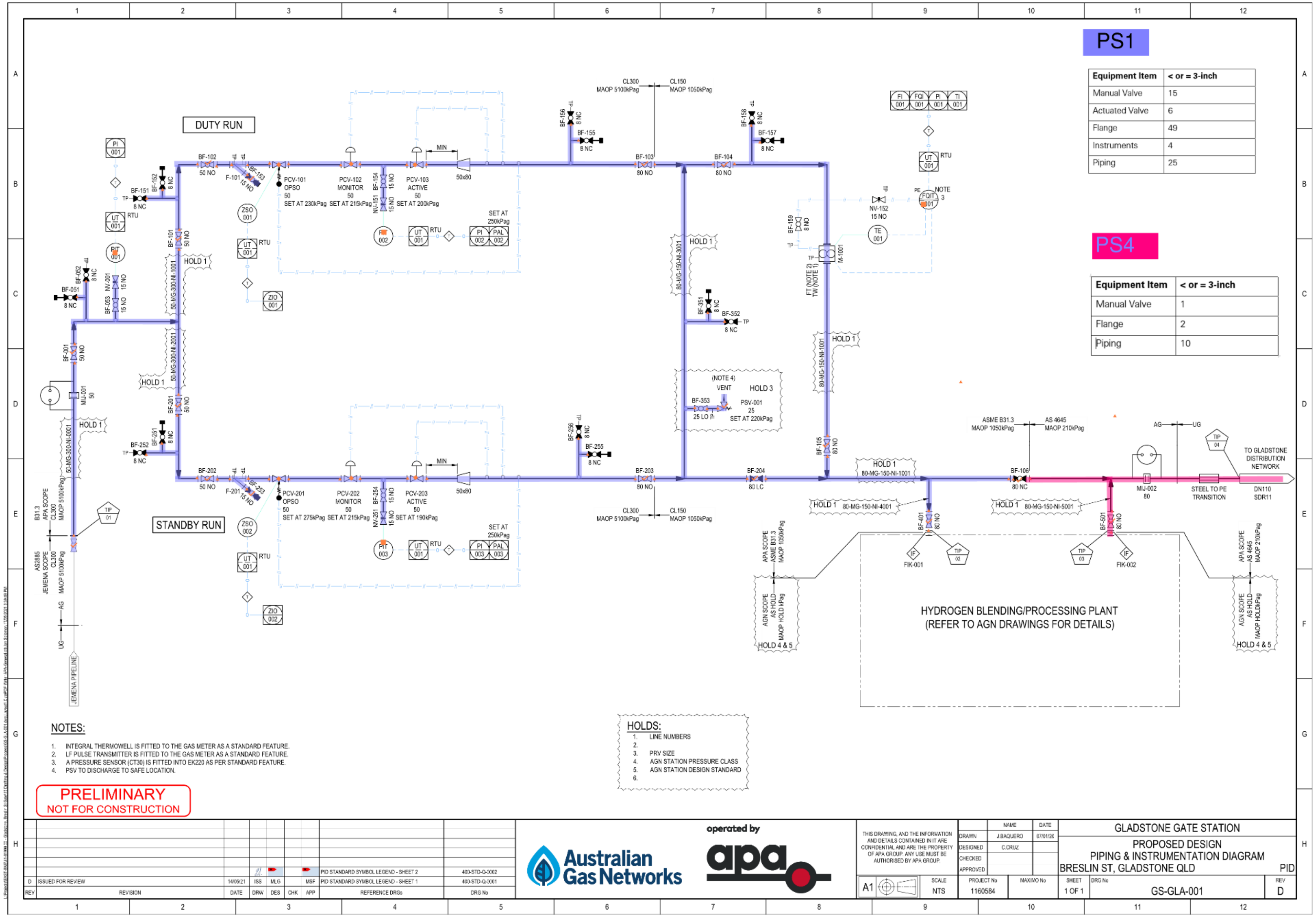
[9] National Fire Protection Association, NFPA 2 Hydrogen Technical Code.

[10] UK HSE, Land Use Planning: Failure frequencies for major failures of high pressure storage vessels at COMAH sites: A comparison of data used by HSE and the Netherlands, C Nussey, 2006.

[11] Alderman, J., Pitlabo, R. and Thomas J.K., "Facilitating Consistent Siting Hazard Distance Predictions Using the TNO Multi- Energy Model", Journal of Loss Prevention in the Process Industries, July 2014.

[12] Queensland Government, Planning guideline State code 21: Hazardous chemical facilities, 2017

Appendix A: Isolatable Inventory P&ID Mark Ups


PS1
Equipment Item | < or = 3-inch
Manual Valve | 15
Actuated Valve | 6
Flange | 49
Instruments | 4
Piping | 25
PS4
Equipment Item | < or = 3-inch
Manual Valve | 1
Flange | 2
Piping | 10
DUTY RUN
STANDBY RUN
PCV-101 OPSO 50 SET AT 230kPag
PCV-102 MONITOR 50 SET AT 215kPag
PCV-103 ACTIVE 50 SET AT 200kPag
PCV-201 OPSO 50 SET AT 275kPag
PCV-202 MONITOR 50 SET AT 215kPag
PCV-203 ACTIVE 50 SET AT 190kPag
CL300 MAOP 5100kPag
CL150 MAOP 1050kPag
PSV-001 25 SET AT 220kPag
HYDROGEN BLENDING/PROCESSING PLANT
(REFER TO AGN DRAWINGS FOR DETAILS)
TO GLADSTONE DISTRIBUTION NETWORK
STEEL TO PE TRANSITION
DN110 SDR11
JEMENA PIPELINE
NOTES:
1. INTEGRAL THERMOWELL IS FITTED TO THE GAS METER AS A STANDARD FEATURE.
2. LF PULSE TRANSMITTER IS FITTED TO THE GAS METER AS A STANDARD FEATURE.
3. A PRESSURE SENSOR (CT30) IS FITTED INTO EK220 AS PER STANDARD FEATURE.
4. PSV TO DISCHARGE TO SAFE LOCATION.
HOLDS:
1. LINE NUMBERS
2.
3. PRV SIZE
4. AGN STATION PRESSURE CLASS
5. AGN STATION DESIGN STANDARD
6.
PRELIMINARY
NOT FOR CONSTRUCTION
D ISSUED FOR REVIEW 14/05/21 ISS MLG MSF
PID STANDARD SYMBOL LEGEND - SHEET 2 400-STD-Q-0002
PID STANDARD SYMBOL LEGEND - SHEET 1 400-STD-Q-0001
REV REVISION DATE DRW DES CHK APP REFERENCE DRGs DRG No
Australian Gas Networks
operated by apa
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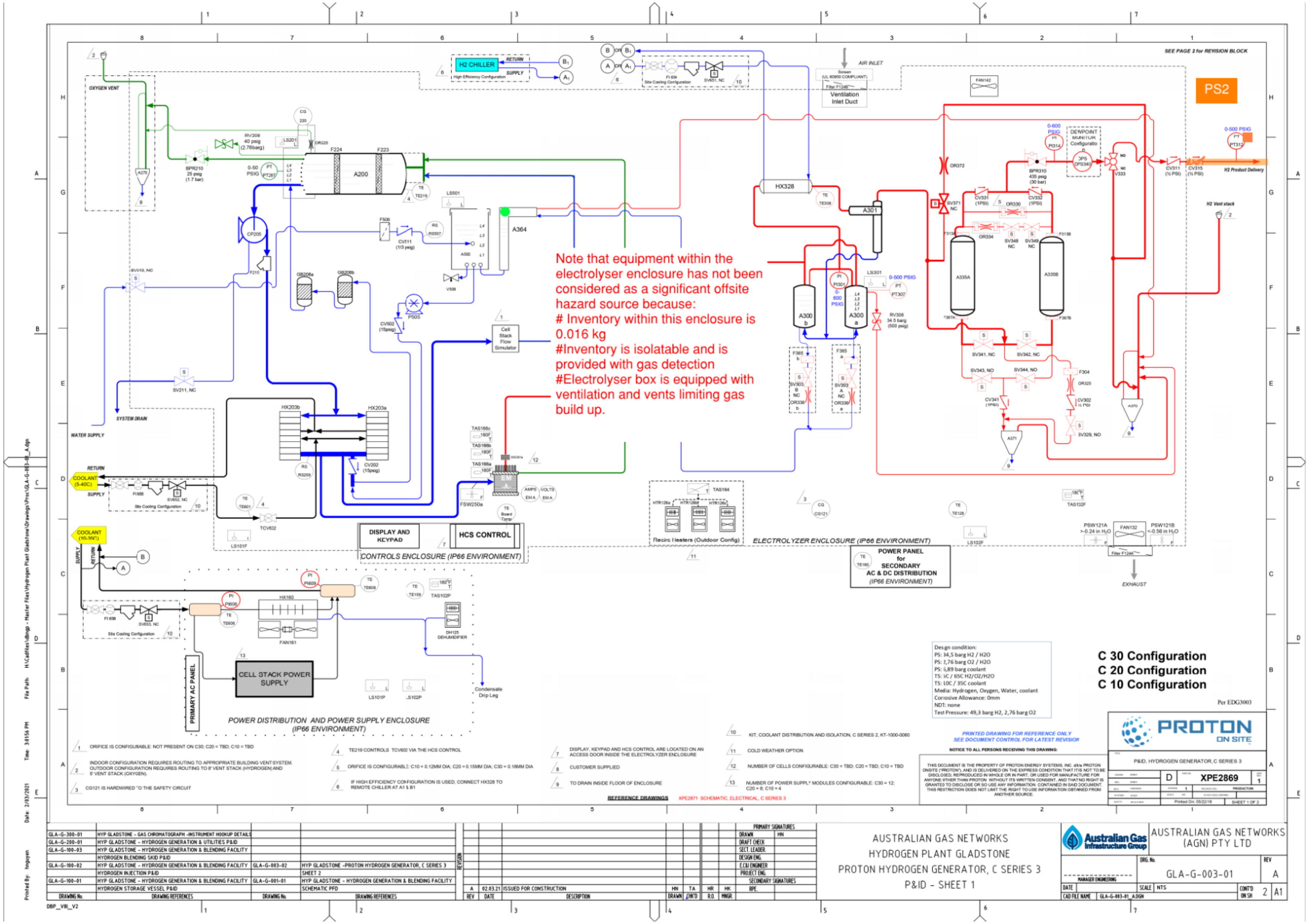
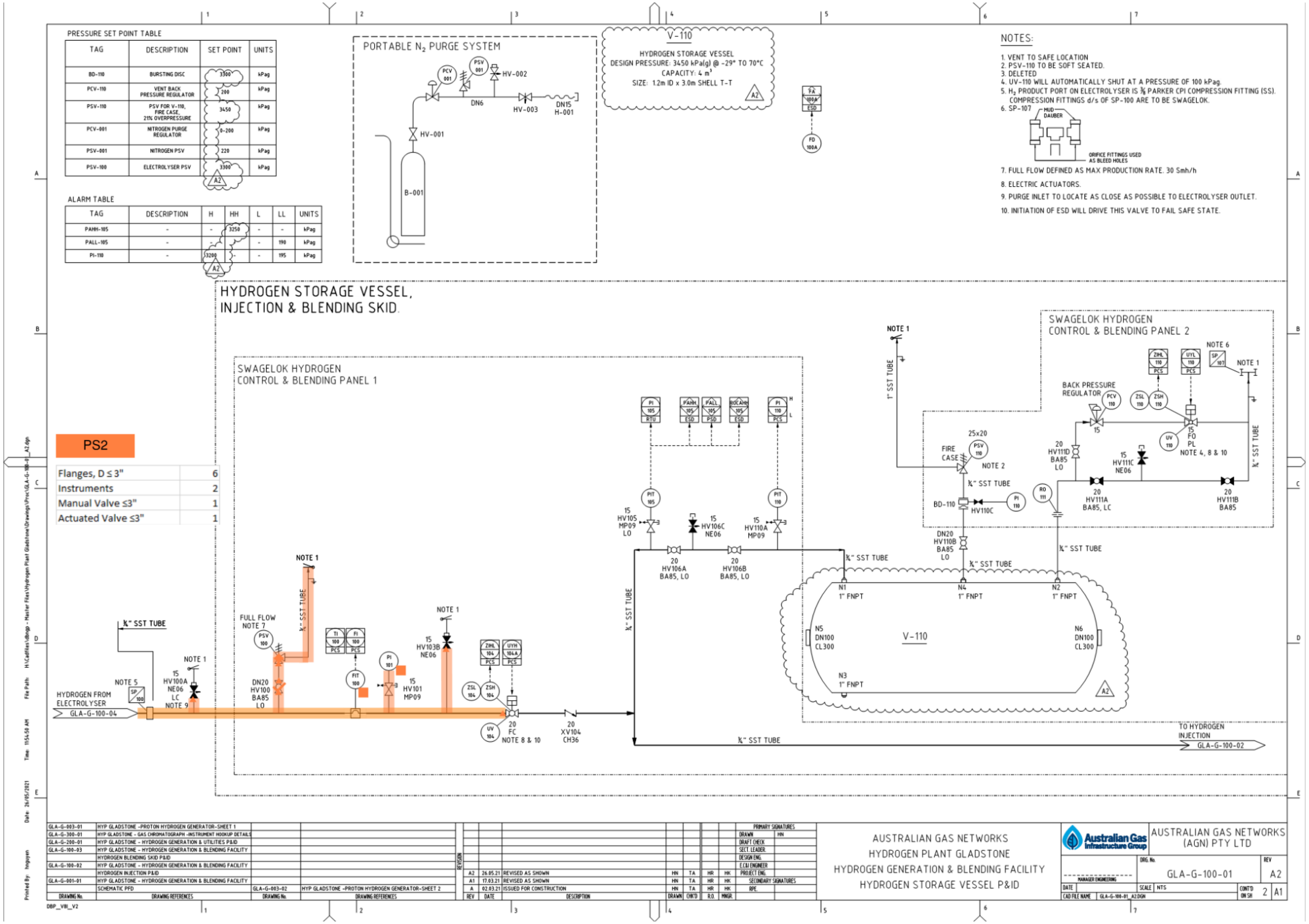
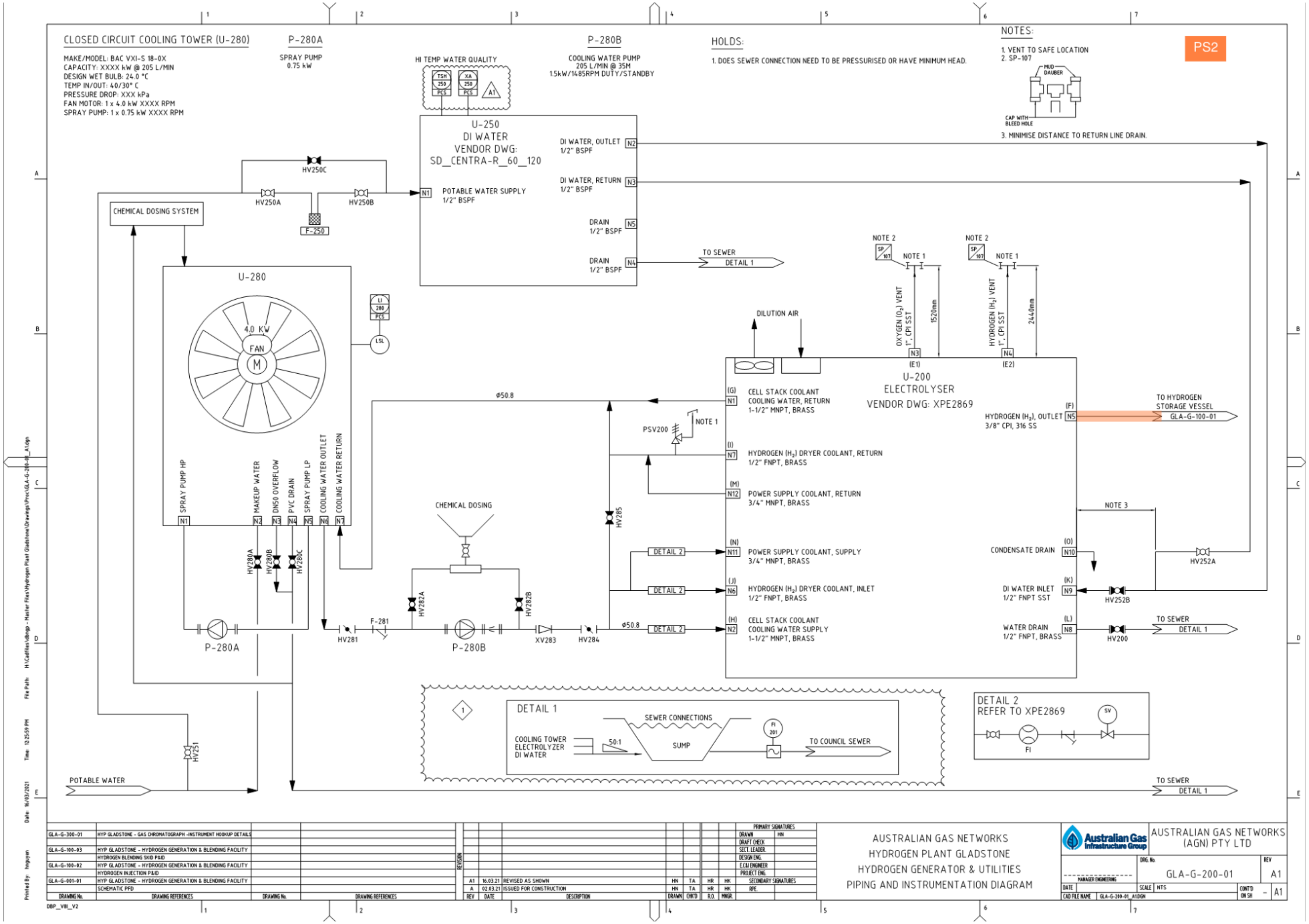
DRAWN J.BAQUERO 07/01/20
DESIGNED C.CRUZ
CHECKED
APPROVED
GLADSTONE GATE STATION
PROPOSED DESIGN
PIPING & INSTRUMENTATION DIAGRAM
BRESLIN ST, GLADSTONE QLD
PID
A1 SCALE NTS
PROJECT No 1160584
SHEET 1 OF 1
DRG No GS-GLA-001
REV D

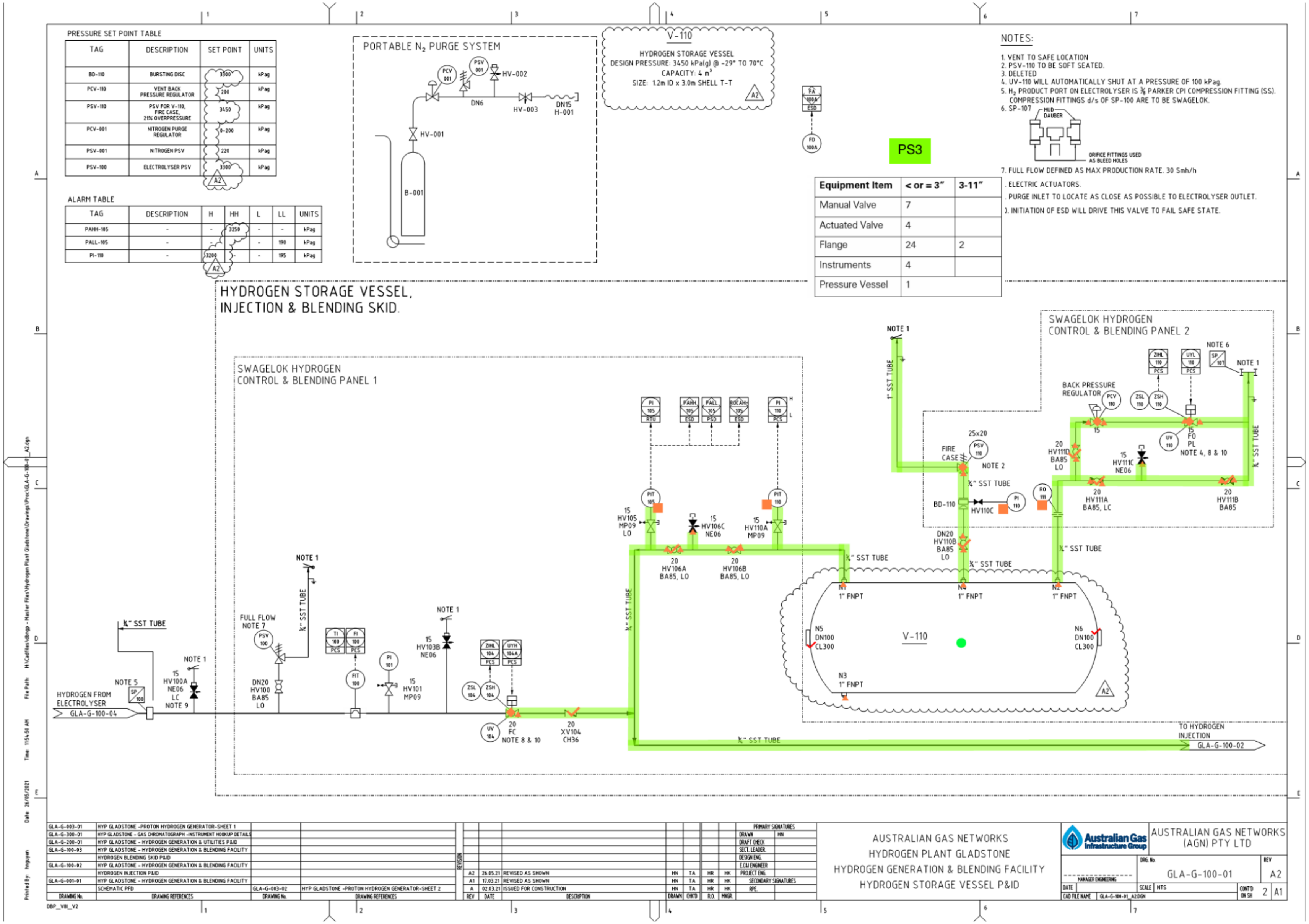


Note that equipment within the electrolyser enclosure has not been considered as a significant offsite hazard source because:
Inventory within this enclosure is 0.016 kg
#Inventory is isolatable and is provided with gas detection
#Electrolyser box is equipped with ventilation and vents limiting gas build up.
PS2
H2 CHILLER
HX328
A301
A300
A200
A364
HX203b
HX203a
DISPLAY AND KEYPAD
HCS CONTROL
CONTROLS ENCLOSURE (IP66 ENVIRONMENT)
ELECTROLYZER ENCLOSURE (IP66 ENVIRONMENT)
POWER PANEL for SECONDARY AC & DC DISTRIBUTION (IP66 ENVIRONMENT)
CELL STACK POWER SUPPLY
PRIMARY AC PANEL
POWER DISTRIBUTION AND POWER SUPPLY ENCLOSURE (IP66 ENVIRONMENT)
COOLANT (5-40C)
WATER SUPPLY
SYSTEM DRAIN
OXYGEN VENT
H2 Product Delivery
H2 Vent stack
EXHAUST
C 30 Configuration
C 20 Configuration
C 10 Configuration
PROTON ON SITE
XPE2869
AUSTRALIAN GAS NETWORKS
HYDROGEN PLANT GLADSTONE
PROTON HYDROGEN GENERATOR, C SERIES 3
P&ID - SHEET 1
AUSTRALIAN GAS NETWORKS (AGN) PTY LTD
GLA-G-003-01

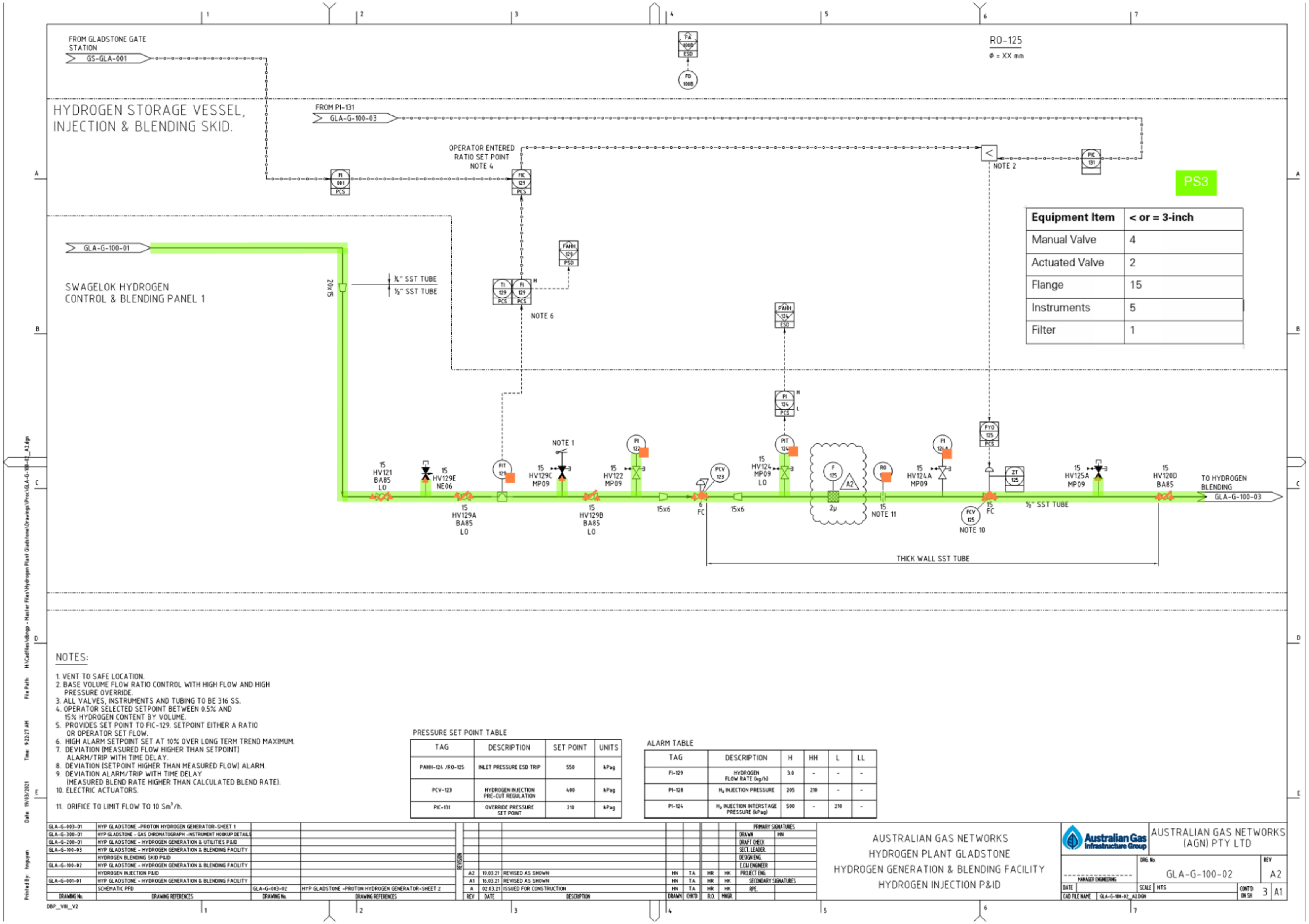


PS2	
Flanges, D ≤ 3"	6
Instruments	2
Manual Valve ≤3"	1
Actuated Valve ≤3"	1


CLOSED CIRCUIT COOLING TOWER (U-280)
P-280A
P-280B
HOLDS:
NOTES:
1. VENT TO SAFE LOCATION
2. SP-107
3. MINIMISE DISTANCE TO RETURN LINE DRAIN.
PS2
1. DOES SEWER CONNECTION NEED TO BE PRESSURISED OR HAVE MINIMUM HEAD.
U-250
DI WATER
VENDOR DWG: SD_CENTRA-R_60_120
U-280
U-200
ELECTROLYSER
VENDOR DWG: XPE2869
CHEMICAL DOSING SYSTEM
CHEMICAL DOSING
POTABLE WATER
TO HYDROGEN STORAGE VESSEL
GLA-G-100-01
TO SEWER
DETAIL 1
DETAIL 2
REFER TO XPE2869
AUSTRALIAN GAS NETWORKS
HYDROGEN PLANT GLADSTONE
HYDROGEN GENERATOR & UTILITIES
PIPING AND INSTRUMENTATION DIAGRAM
AUSTRALIAN GAS NETWORKS (AGN) PTY LTD
GLA-G-200-01
A1



Equipment Item	< or = 3"	3-11"
Manual Valve	7	
Actuated Valve	4	
Flange	24	2
Instruments	4	
Pressure Vessel	1	



Equipment Item	< or = 3-inch
Manual Valve	4
Actuated Valve	2
Flange	15
Instruments	5
Filter	1

NOTES:

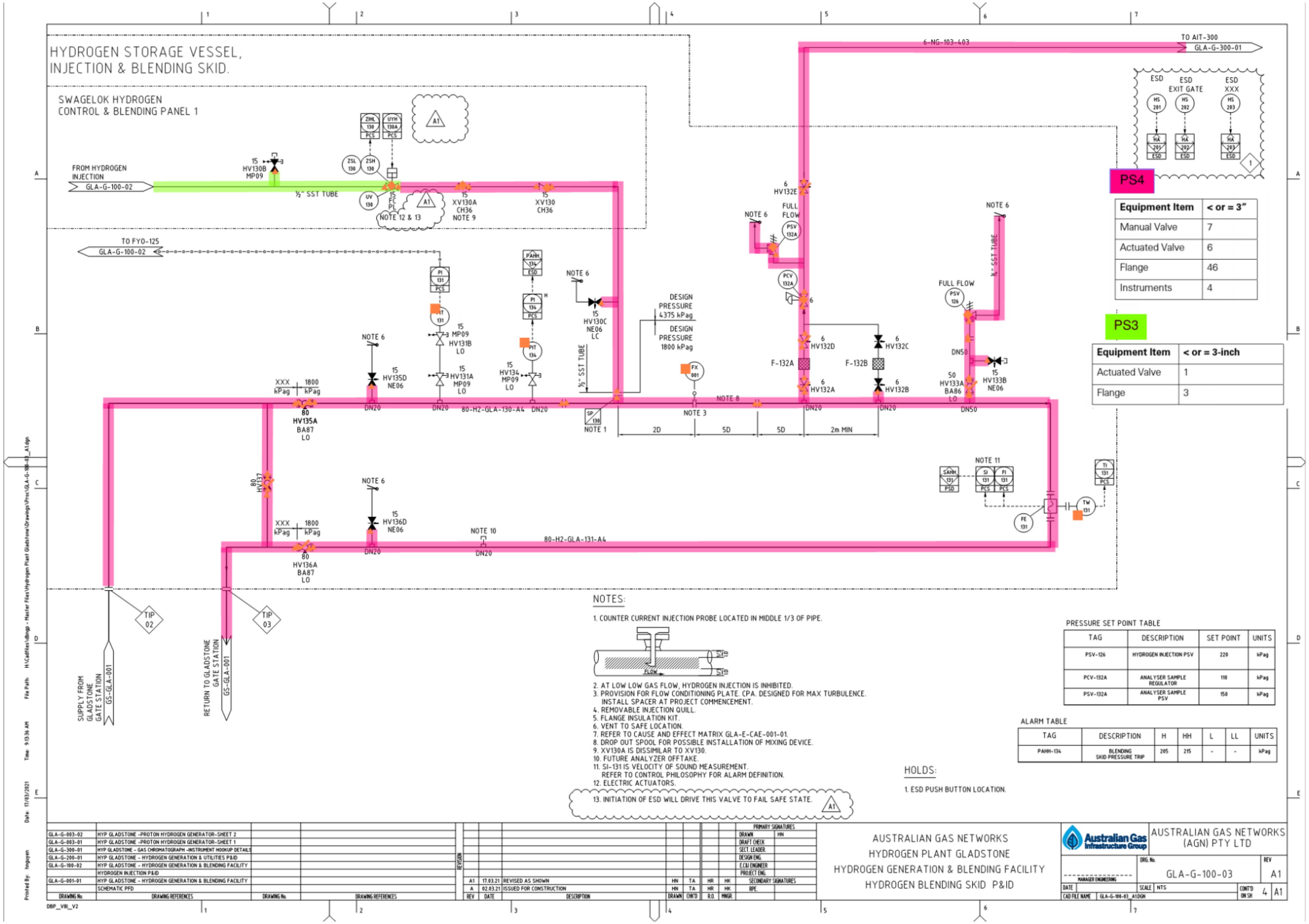
1. VENT TO SAFE LOCATION.
2. BASE VOLUME FLOW RATIO CONTROL WITH HIGH FLOW AND HIGH PRESSURE OVERRIDE.
3. ALL VALVES, INSTRUMENTS AND TUBING TO BE 316 SS.
4. OPERATOR SELECTED SETPOINT BETWEEN 0.5% AND 15% HYDROGEN CONTENT BY VOLUME.
5. PROVIDES SET POINT TO FIC-129. SETPOINT EITHER A RATIO OR OPERATOR SET FLOW.
6. HIGH ALARM SETPOINT SET AT 10% OVER LONG TERM TREND MAXIMUM.
7. DEVIATION (MEASURED FLOW HIGHER THAN SETPOINT) ALARM/TRIP WITH TIME DELAY.
8. DEVIATION (SETPOINT HIGHER THAN MEASURED FLOW) ALARM.
9. DEVIATION ALARM/TRIP WITH TIME DELAY (MEASURED BLEND RATE HIGHER THAN CALCULATED BLEND RATE).
10. ELECTRIC ACTUATORS.
11. ORIFICE TO LIMIT FLOW TO 10 Sm^3/h.

PRESSURE SET POINT TABLE

TAG	DESCRIPTION	SET POINT	UNITS
PAHH-124 /RO-125	INLET PRESSURE ESD TRIP	550	kPag
PCV-123	HYDROGEN INJECTION PRE-CUT REGULATION	400	kPag
PIC-131	OVERRIDE PRESSURE SET POINT	210	kPag

ALARM TABLE

TAG	DESCRIPTION	H	HH	L	LL
FI-129	HYDROGEN FLOW RATE (kg/h)	3.0	-	-	-
PI-128	H_2 INJECTION PRESSURE	205	210	-	-
PI-124	H_2 INJECTION INTERSTAGE PRESSURE (kPag)	500	-	210	-


HYDROGEN STORAGE VESSEL,
INJECTION & BLENDING SKID.
SWAGELOK HYDROGEN
CONTROL & BLENDING PANEL 1
FROM HYDROGEN INJECTION
GLA-G-100-02
½" SST TUBE
TO FYO-125
GLA-G-100-02
6-NG-103-403
TO AIT-300
GLA-G-300-01
PS4
Equipment Item | < or = 3"
Manual Valve | 7
Actuated Valve | 6
Flange | 46
Instruments | 4
PS3
Equipment Item | < or = 3-inch
Actuated Valve | 1
Flange | 3
80-H2-GLA-130-A4
80-H2-GLA-131-A4
DESIGN PRESSURE 4375 kPag
DESIGN PRESSURE 1800 kPag
SUPPLY FROM GLADSTONE GATE STATION
GS-GLA-001
RETURN TO GLADSTONE GATE STATION
GS-GLA-001
NOTES:
1. COUNTER CURRENT INJECTION PROBE LOCATED IN MIDDLE 1/3 OF PIPE.
2. AT LOW LOW GAS FLOW, HYDROGEN INJECTION IS INHIBITED.
3. PROVISION FOR FLOW CONDITIONING PLATE. CPA. DESIGNED FOR MAX TURBULENCE. INSTALL SPACER AT PROJECT COMMENCEMENT.
4. REMOVABLE INJECTION QUILL.
5. FLANGE INSULATION KIT.
6. VENT TO SAFE LOCATION.
7. REFER TO CAUSE AND EFFECT MATRIX GLA-E-CAE-001-01.
8. DROP OUT SPOOL FOR POSSIBLE INSTALLATION OF MIXING DEVICE.
9. XV130A IS DISSIMILAR TO XV130.
10. FUTURE ANALYZER OFFTAKE.
11. SI-131 IS VELOCITY OF SOUND MEASUREMENT. REFER TO CONTROL PHILOSOPHY FOR ALARM DEFINITION.
12. ELECTRIC ACTUATORS.
13. INITIATION OF ESD WILL DRIVE THIS VALVE TO FAIL SAFE STATE.
HOLDS:
1. ESD PUSH BUTTON LOCATION.
PRESSURE SET POINT TABLE
TAG | DESCRIPTION | SET POINT | UNITS
PSV-126 | HYDROGEN INJECTION PSV | 220 | kPag
PCV-132A | ANALYSER SAMPLE REGULATOR | 110 | kPag
PSV-132A | ANALYSER SAMPLE PSV | 150 | kPag
ALARM TABLE
TAG | DESCRIPTION | H | HH | L | LL | UNITS
PAHH-134 | BLENDING SKID PRESSURE TRIP | 205 | 215 | - | - | kPag
AUSTRALIAN GAS NETWORKS
HYDROGEN PLANT GLADSTONE
HYDROGEN GENERATION & BLENDING FACILITY
HYDROGEN BLENDING SKID P&ID
AUSTRALIAN GAS NETWORKS (AGN) PTY LTD
GLA-G-100-03
A1

Appendix B: Assumption Sheets

Assumption Sheet 1: Summary of Flammable Hazard Scenarios

The hydrocarbons located at HyP Gladstone are flammable natural gas and hydrogen. These are flammable hazardous inventories and a fire or explosion could result if a release occurs and is ignited. Depending on a number of factors, the consequence could extend outside the facility boundary.

Per State code 21, vapour releases could give rise to jet fires, flash fires and explosions:

- **Jet fires:** a jet fire occurs when a flammable liquid or gas, under pressure, is released and the high velocity vapour is ignited, resulting in the formation of a long stable flame. Jet flames can be very intense and can impose high heat loads on nearby plant and equipment leading to escalation of the incident.

- **Flash fires:** a flash fire occurs when a cloud of flammable gas mixed with air is ignited. The flame spreads at a subsonic speed (deflagration) typically giving rise to negligible overpressures. Though very brief, a flash fire can cause serious to fatal injuries to anyone inside the burning cloud. Its effects are confined almost entirely to the area within the burning cloud. Flash fire plumes are affected by wind direction and can drift for some distance from the point of release prior to ignition. Once ignited if the source of the vapour is still present, the fire can back burn to the source starting pool fires or jet fires; and

- **Explosion:** if a gas cloud is sufficiently large, and there is confinement created by structures, it is also possible that the flame front may accelerate to a sufficiently high velocity for a Vapour Cloud Explosion (VCE) to occur. Escalation of the incident can occur through ignition of materials or structures within the cloud leading to follow-on incidents. Explosions occur through the release of exothermic chemical energy converted into mechanical energy creating a pressure wave at the blast front, typically known as overpressure. Blast overpressure can affect people and structures, and trigger knock-on events at locations other than the source of the explosion. Factors strongly influencing the magnitude of an overpressure are:

  - degree of confinement;
  - the size of the cloud;
  - degree of turbulence;
  - the combustion properties of the gas; and
  - the location of the ignition source relative to the cloud.

Modelling Exclusions - Projectiles

The damage or harm associated with projectiles from a VCE or catastrophic failure of the pressure vessel have not been modelled in the QRA. The modelling of such a failure does not readily fit within a QRA modelling framework since the specific mechanism by which the failure occurs influences the formation of fragments, the launch trajectories and ultimately the hazard ranges.

From a VCE perspective, the open environment and low source overpressures result in limited forces being initially imparted into the fragments and the low drag loads further limit the forces acting on fragments in the initial stages of an explosion.

With respect to catastrophic failure of the vessel due to overpressurisation, hazard ranges attributed to projectiles could be significantly larger than thermal effects / overpressures. Other quantitative risk assessment techniques such as LOPA should be used to ensure the likelihood of vessel failure is adequately mitigated given the potential for offsite effects in the event of catastrophic failure.

Modelling Exclusions – Explosions within the Electrolyser

Examination of the electrolyser's data sheet (for the C30 unit) indicates the 0.016 kg of onboard hydrogen equates to 7 SCF or 0.198 m^3 at standard conditions. At 30% by volume, a stoichiometric cloud would be 0.66 m^3. The volume of the electrolyser enclosure is 5.88 m^3 (2.52 m x 1.16 m x 2.01 m) and equipment in the enclosure takes up around 20 % of the volume, hence the stoichiometric cloud occupies 14 % of the enclosure's volume. The potential for overpressure to be generated is dependent on the role of confinement and congestion on the flame speed in the event the cloud is ignited, and these two factors are addressed qualitatively below given the limitations of the models built into PHAST:

- To understand if the confinement produces appreciable overpressure, consideration is given to a constant pressure expansion of the combustion process. For hydrogen, the volume ratio (i.e. the ratio of post combustion to pre-combustion volume) for a constant pressure expansion is 6.89. This results in an expanded cloud of 4.5 m^3 which is less than the free volume of the enclosure. Furthermore, venting of the enclosure ensures there is the means by which the combustion gases can vent in a slow deflagration and therefore limit the potential for overpressures to develop.
- The interaction of the combustion of the cloud with equipment (congestion) within the enclosure can cause flame acceleration which itself generates overpressure, with hydrogen flame fronts having a propensity to accelerate. As highlighted above the enclosure is not highly congested and its characteristic dimensions are small, thus the potential for flame acceleration is limited, as is the resultant overpressure.

Given the above considerations, and the lightweight nature of the enclosure, significant overpressures are not considered credible for such limited inventory.

Assumption Sheet 2: Flammable Hazard Scenarios Effects

The effects of flammable hazard scenarios are thermal radiation from fires and overpressures arising from explosions. The effects associated with different levels of thermal radiation are presented in Table B-1 and the effects of overpressure levels are presented in Table B-2.

Table B-1 Effects of Thermal Radiation

Heat radiation (kW/m^2)	Effect
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 (at least second degree burns will occur)
12.6	Significant chance of fatality for extended exposure. High chance of injury Causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure
23	Likely fatality for extended exposure and chance of fatality for instantaneous exposure Spontaneous ignition of wood after long exposure Unprotected steel will reach thermal stress temperatures which can cause failure Pressure vessel needs to be relieved or failure would occur
35	Cellulosic material will pilot ignite within one minute’s exposure Significant chance of fatality for people exposed instantaneously

Table B-2 Effects of Overpressure

Overpressure (kPa)	Effect
3.5	% glass breakage No fatality and very low probability of injury
7	Damage to internal partitions and joinery but can be repaired Probability of injury is 10%. No fatality
14	House uninhabitable and badly cracked
21	Reinforced structures distort Storage tanks fail 20% chance of fatality to a person in a building
35	House uninhabitable Wagons and plants items overturned Threshold of eardrum damage 50% chance of fatality for a person in a building and 15% chance of fatality for a person in the open
70	Threshold of lung damage 100% chance of fatality for a person in a building or in the open Complete demolition of houses

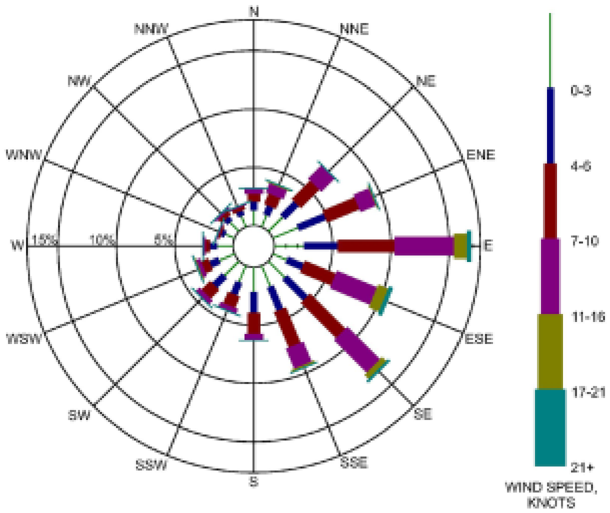
Assumption Sheet 3: Weather Conditions and Wind Rose

Weather conditions used in the model are representative of conditions at the site. These are based on recordings taken at Gladstone Radar Station and include:

- 27 °C which is the average annual temperature. This was rounded up to 30°C to align with the representative ambient temperature used for the natural gas inventory.
- 65% humidity (averaging the 67% at 9 am and 59% at 3 pm); and
- Wind speeds of 8 m/s for daytime conditions and 4 m/s for nighttime conditions.

The windrose used for the model is taken from the Gladstone Radar Station and is presented in Figure B-1.

Figure B-1 Annual Wind Rose



Assumption Sheet 4: Risk of Fatality

When assessing the risk of fatality or serious harm associated with undertaking an activity or being exposed to a hazard introduced as a result of a change to land use or new facilities, it is helpful to compare against the risk associated with undertaking day to day activities. The risk on a MHF is limited to personnel on the site or in close proximity and is assessed in the manner described in this study.

Some hazards are carried by large numbers of people, for example, being killed by lightning or in a road accident or by some other violent cause and as such the risk of fatality is given as the number per 100,000 people, but others are only relevant to people undertaking the risk, for example, air or rail travel, and the risk is determined per kilometre travelled.

Estimating the risk for events tends to be based on direct or historical experience and the assessment is based on the same trend. Sometimes, in the absence of data, estimates are based on expert judgements considering a variety of factors such as the known rate of failure of engineering components.

All are subject to significant margins of error and some statistics will be overstated because of caution and pessimism built into the estimates where others may be understated because, for many hazards, they compare only the chance of immediate death, ignoring that the hazards also carry with them a risk of injury or ill health or of delayed death.

Potential fatality risks presented in Reducing Risks, Protecting People [1] include:

- Annual risk of death by lightning is 1 in 18,700,000 (5.34E-08);
- Annual risk of death in a traffic accident is 1 in 16,800 (5.95E-05); and
- Annual risk of death by injury or poisoning is 1 in 3,137 (3.19E-04).

Other data sources specific to Australia estimate the risk of death by lightning (from 1910–1989) to be 0.08 per 100 000 population (8E-07) [2] and the annual fatality rate for death in a traffic accident in Queensland is 5.4 per 100,000 people (5.4E-05) [3].

References

[1] HSE Books, Reducing risks, Protecting People HSE’s decision-making process, 2001.
[2] Coates, L., Blong, R. & Siciliano, F. Lightning fatalities in Australia, 1824–1991. Nat Hazards 8, 217–233 (1993). https://doi.org/10.1007/BF00690909
[3] Road trauma Australia 2020 statistical summary (bitre.gov.au)

Hydrogen Park Gladstone

Review of QRA Study

Australian Gas Infrastructure Group

28 January 2022

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PROJECT 411012-00430 - 00-SR-REP-0001: Hydrogen Park Gladstone - Review of QRA Study

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Executive Summary

Advisian have carried out a peer review of the quantitative risk assessment (QRA) study, conducted by others, for the proposed Gladstone hydrogen park. The scope of the review has been framed by a series of questions received by Australian Gas Infrastructure Group (AGIG) from Gladstone Regional Council to support the proposed project approval process.

The hydrogen park is to be located on approximately 1,100 m^2 fenced site on Derby Street, South Gladstone and includes a natural gas pipeline pressure reduction station, with a hydrogen generator, storage and blending to achieve a gas mixture of up to 10% hydrogen in natural gas. This mixture then passes into the gas distribution system.

Land use adjacent to site can be described as a mix of public infrastructure and residential land use.

The review by Advisian concluded that:

- The QRA methodology is appropriate for the proposed development and site location.
- The software used (DNV SAFETI) is a widely used QRA tool. Queensland State Code 21 recognises the QRA modelling tool, using its previous name PHAST RISK.
- The QRA assumptions are appropriate, noting that clarification is required to ensure consistency across the report with regard to weather parameters and maximum pressure values for the hydrogen storage vessel. The QRA report authors need to confirm that QRA results do not materially change when the correct value has been confirmed.
- Typical hazards that are expected to be addressed in a QRA for an above-ground pipeline facility have been addressed, noting the purpose of the QRA is to assess risk to offsite populations. Whilst there may be other effects from the equipment failure on the site (e.g. projectiles), these are not generally included in the QRAs conducted for land planning purposes. These effects are not expected to impact the calculated risk measures and/or alter the conclusions reached. Rupture of hydrogen storage vessel is a low probability event but should be considered.
- The risk to the public as calculated in the QRA report complies with the Queensland land planning criteria for the adjacent land use. The risk contour for sensitive (residential) land use does not reach residential land. The worst case jet fire radiation and explosion overpressure consequence do not reach residential land. There is an even greater separation distance to the school. The worst case flammable cloud is from hydrogen storage and extends 73.5 m downwind, which has a potential to reach residential land use areas. The QRA report notes that the cloud disperses in less than 1 second so this event presents a very low risk to adjacent populations.
- The fatality risk to a typically exposed individual that will be transiting past the site on the way to the school or nearby housing was found to be low ($<10^{-7}$ per annum), comparable to the risk of being struck by lightning.
- The QRA calculated the location specific individual risk and the risk to a typically exposed individual. Due to these metrics showing low risk and the fact that the estimated jet fire and over-pressure effect distances do not reach populated areas, there is no need to calculate the societal risk, that is, the risk that shows the likelihood of suffering multiple fatality events of various magnitudes.

Acronyms and abbreviations

Acronym/abbreviation	Definition
AGIG	Australian Gas Infrastructure Group
ALARP	As Low as Reasonably Practicable
BLEVE	boiling liquid expanding vapour explosion
BoM	Bureau of Meteorology
FN	Societal Risk - cumulative frequency of events versus number of fatalities
HAZOP	Hazard and Operability
HCF	Hazardous Chemical Facility
HIPAP	Hazardous Industry Planning Advisory Paper
HSE	(UK) Health and Safety Executive
HyP	Hydrogen Park
LOPA	Layers of Protection Analysis
LSIR	Location Specific Individual Risk
MAOP	Maximum Allowable Operating Pressure
P&ID	Piping and Instrumentation Diagram
PSV	Pressure Safety (relief) Valve
QRA	Quantitative Risk Assessment
SDAP	State Development Assessment Provisions

1 Introduction

The hydrogen park Gladstone is proposed to decarbonise the gas network, blending natural gas with up to 10% hydrogen. Renewable energy will be used to power an electrolyser to generate the hydrogen for blending into the natural gas distribution network.

The proposed facility is shown in Figure 1-1.

Figure 1-1: Proposed Hydrogen Park Gladstone

Advisian have been requested to carry out a peer review of the QRA study (Ref. 12) conducted for the Gladstone hydrogen park by MMI Thornton Tomasetti.

The QRA Report (Ref. 12) assesses the risk "for offsite populations based on operating parameters, hazardous inventories and environmental conditions at the site".

The QRA study review presented in this document is structured to answer a number of questions provided by AGIG that reflect a request for further information made by Gladstone Regional Council as the assessment manager for the development application currently under assessment for the project. These include:

- Is the approach and methodology adopted appropriate in the context of the proposed development and site location?
- Is the modelling package used widely accepted in the industry for the completion of assessments of this nature?
- Has the modelling been based on appropriate assumptions that reflect the potential risks associated with the operation of the facility?
- Have all credible hazardous events been considered and assessed?
- Comment on the results of the assessment in terms of the risk presented to the public in the event of an incident at the site. Are the risk levels calculated acceptable when compared against any established criteria – e.g. what does 1 in a million per year (or 0.5 in a million per year) mean and how far does this risk level extend to beyond the site boundary.
- How do the risks presented compare to those associated with other commonly acceptable societal risks (i.e.: driving or flying) or other common facilities such as service stations?
- Comment on "what is societal risk" and based on the assessment presented, is the conclusion that a societal risk calculation is not required based on established criteria (i.e. no results on FN curve) an appropriate conclusion.

The scope of review by Advisian is limited to the review of the QRA report prepared by others. A QRA study is just one of the various studies that are conducted during facility design to identify, assess and manage risk from pipeline facilities.

2 QRA Review

2.1 Context of Proposed Development and Site Location

Question 1: Is the approach and methodology adopted appropriate in the context of the proposed development and site location?

The proposed development is located on approximately 1100 m^2 fenced site on Derby Street, South Gladstone. Adjacent land can be described as a mix of public infrastructure and residential land use. A quantitative risk assessment is an appropriate response to consider risk both to onsite workforce and to offsite populations.

The use of the QRA is consistent with the requirements of the State Development Assessment Provisions (Ref. 26) for Hazardous chemical facilities (HCF). Whilst the proposed development does not qualify as a HCF as it carries much lower inventories of dangerous chemicals than the threshold quantities specified in Schedule 15 of the Queensland Work Health and Safety Regulation 2011 (Ref. 32), the approach used to assess the risk is the same as would generally be used for HCF.

2.2 QRA Modelling Package

Question 2: Is the modelling package used widely accepted in the industry for the completion of assessments of this nature.

The modelling tool used is DNV SAFETI (QRA Section 3.0, Ref. 12). DNV SAFETI is widely used both in Australia and internationally as a QRA modelling tool. Advisian has acknowledged DNV SAFETI as an industry accepted modelling tool and utilises this tool to undertake QRA.

DNV SAFETI was also known previously as PHAST RISK and is the same package that is mentioned in Section 4.5.5.3 of State Code 21 (Ref. 25) as one of the QRA tools that can be used.

2.3 Assumptions

Question 3: Has the modelling been based on appropriate assumptions that reflect the potential risks associated with the operation of the facility.

The assumptions listed in the QRA (Section 3.1 and Appendix B) are reviewed.

2.3.1 Weather conditions

Weather assumptions are documented in QRA Report Appendix B Assumption Sheet 3. The selection of Bureau of Meteorology (BoM) records for Gladstone is valid. The temperature and humidity assumption is verified on the BoM web site on 13 January 2022.

There is an inconsistency in wind speed selection between the QRA Section 3.1 and QRA Appendix B Assumption Sheet 3 as noted in Table 2-1. It is recommended that the wind speed inconsistency be resolved.

Table 2-1: Wind Speeds in the QRA Report

QRA Report	Day Time	Night Time
Section 3.1	5 m/s (18 km/hr)	3 m/s (11 km/hr)

QRA Report	Day Time	Night Time
Appendix B, Assumption Sheet 3	8 m/s (29 km/hr)	5 m/s (18 km/hr)

The selection of these wind speeds is not specified in QRA Figure B-1, which is an annual wind rose. The BoM charts of 9 a.m. and 3 p.m. mean wind speed shown in Figure 2-1 were downloaded from the BoM site and indicate that the lower wind speeds stated in QRA Section 3.1 would better reflect local conditions. Higher wind speed will have little impact on jet fires, however for cloud dispersion and flash fires, higher wind speed reduces the size of the consequence and risk. The QRA impact is expected to be minimal.

The Pasquill stability selection class (QRA Section 3.1) is appropriate:

- Day time: 5D, 5 m/s wind speed, day time neutral conditions
- Night time: 3F, 3 m/s wind speed, night time moderately stable conditions.

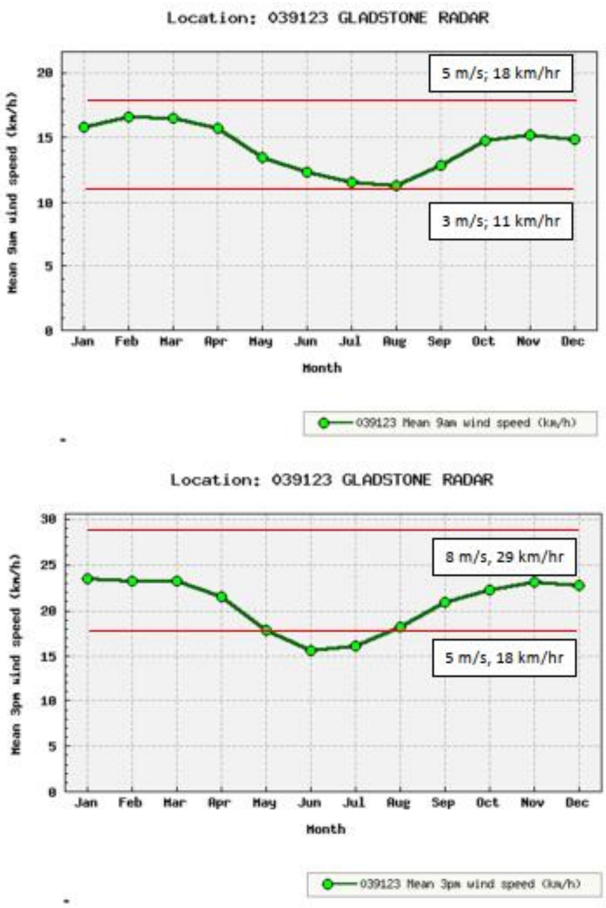

Figure 2-1: Bureau of Meteorology mean wind speed

2.3.2 Isolatable Inventories

Process segments, composition and operating conditions are indicated in QRA Section 3.1, with marked up piping and instrumentation diagrams (P&IDs) in Appendix A for:

- Hydrocarbon gas
  - PS1 Feed gas
  - PS4 Blended distribution gas
- Hydrogen
  - PS2 Generated hydrogen to blending and storage
  - PS3 Hydrogen storage vessel

The division into these systems is valid.

2.3.3 Maximum Pressure

Maximum pressures are a key input into the consequence calculation, which is done within DNV SAFETI. It is stated that the maximum allowable operating pressure (MAOP) for hydrocarbon inventories is determined from the values shown on the Gate Station P&ID (Ref. 21). For hydrogen it is stated that the maximum pressure is determined from high pressure trip settings and pressure safety valve (PSV) set pressures, which are shown on the hydrogen storage vessel P&ID (Ref. 15). This is an acceptable approach.

Inventory properties are listed in QRA Table 3-1. The pressures for system PS1, PS2 and PS4 are accepted as valid. The hydrogen storage pressure of 32 kPag (refer Table 2-2) appears inconsistent with the hydrogen storage P&ID GLA-G-100-01 Rev A2 (refer Figure 2-2) which states the design pressure is 3,450 kPag. It is recommended that the correct pressure value for system PS3 in the QRA model be confirmed.

Consideration of QRA Report Table 4-3 shows the same consequence for PS2 and PS3 for the same hole size releases (2mm and 22mm). This may support the conclusion that the QRA model utilises the correct higher pressure for PS3 inventory and the pressure in the QRA Table 3-1 is incorrect (a typo).

Table 2-2: Inventory Properties, QRA Report Table 3-1

PS	Description	Volume (m^3) 3	Pressure (KPa)	Temperature (°C)
PS1	Feed Gas	-	5200	30
PS2	Hydrogen feed from electrolyser	0.04	3550	57
PS3	Hydrogen storage	4	32	30
PS4	Blended gas feed to Gladstone	-	320	30

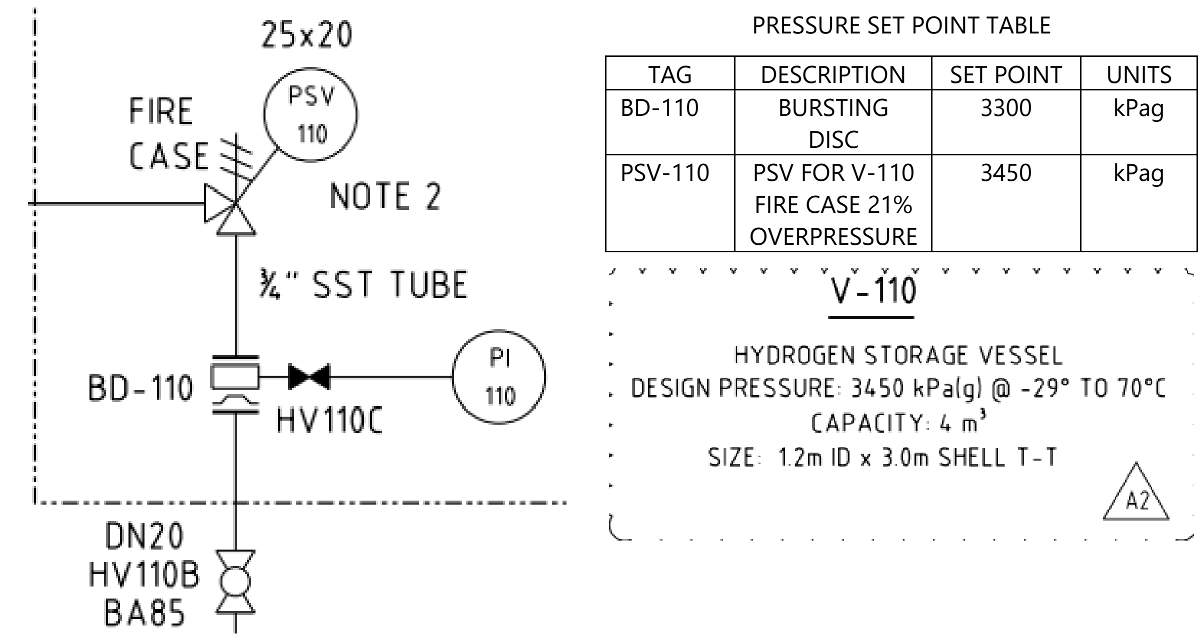

Figure 2-2: Details from the Hydrogen Storage P&ID GLA-G-100-01

2.3.4 Composition

Gas composition is listed in QRA Table 2-1. Hydrogen composition is presumed to be pure hydrogen, although not explicitly stated.

2.3.5 Parts Count

Parts count is shown on P&IDs provided in the QRA Appendix A. This is a key input into leak frequency. Spot checks conducted by Advisian indicate that the parts count presented in Appendix A appears as expected, but this review did not verify the parts count in the model.

2.3.6 Release Frequencies

Release frequencies use valid data sources:

- Hydrocarbon facilities: IOGP Process Release Frequencies 434-01 (QRA Ref. 6); and
- Hydrogen facilities: Sandia National Laboratories HyRam (QRA Ref. 7)

The frequency distribution is provided in QRA Table 4-1 and appears valid.

2.3.7 Ignition Probability

Ignition probability is sourced from:

- Hydrocarbon facilities : Energy Institute (QRA Ref. 8); and
- Hydrogen facilities: NFPA 2 Hydrogen Technical Code (QRA Ref. 9)

The ignition probability is provided in QRA Table 4-2. This table has been reproduced in Table 2-3.

Ignition probability:

- Increases with the discharge mass flow and therefore, is higher for larger hole sizes and for a given hole size, for higher pressures.
- Will be expected to be higher for hydrogen reflecting the lower ignition energy and wide flammable range.

This review accepts the assumptions used in the QRA for hydrocarbon ignition probabilities.

No conclusion is reached for the ignition probability of hydrogen. The values shown in QRA Table 4-2 (Refer Table 2-3) for PS2 and PS3 inventories are three orders different at 2 mm but identical at 22 mm. Evaluation is more difficult due to the inconsistency in PS3 pressure noted in Section 2.3.3.

It is recommended that the hydrogen ignition probabilities for system PS3 be confirmed at the correct system pressure.

Table 2-3: Immediate Ignition Probability for QRA Table 4-2

	Hydrocarbon		Hydrogen	
Hole Size (mm)↓	**PS1**	**PS4**	**PS2**	**PS3**
Pressure (kPag)	5,200	320	3,550	32 or 3,450
2	0.00E+00	0.00E+00	8.00E-03	0.00E+00
7	5.00E-04	0.00E-00		
22	4.38E-03	4.38E-04	5.30E-02	5.30E-02
Large (50/80/100)	1.46E-02	9.24E-04		2.30E-01

2.3.8 Consequence Impacts

Consequence levels of interest and the impacts are listed in QRA Section 3.1 and QRA Appendix B Assumption Sheet 2.

Although no reference is provided in the QRA Report, the values are sourced from an accepted industry source, the NSW Planning, Hazardous Industry Planning Advisory Paper No. 4, Risk Criteria for Land Use Safety Planning (HIPAP 4) (Ref. 29).

2.3.9 Event Tree

There is no discussion of event trees and it is assumed that the default SAFETI event tree is used, which is normal practice.

2.4 Credible Hazards

Question 4: Have all credible hazardous events been considered and assessed?

2.4.1 Facility Design Issues

The adequacy of overpressure protection is addressed in studies such as Hazard and Operability (HAZOP) and Layers of Protection Analysis (LOPA). Therefore, the omission of this topic from the QRA Report scope is considered normal practice.

A comment is made on the use of a bursting disk in series with a PSV, noting this is outside of the QRA review scope. Bursting disks may be advantageous for hydrogen service to eliminate the seat leakage that occurs with conventional PSV. The use of bursting disks in series (upstream) of conventional PSV is specifically addressed in pressure vessel standards. P&ID GLA-G-100-01 (detail shown in Figure 2-2) has a bursting disk BD-110 with a set pressure of 3,300 kPag located upstream of PSV-110 with a higher set pressure of 3,450 kPag. It is recommended that AGIG confirm the hydrogen storage vessel HAZOP addresses that the BD-110/ PSV-110 arrangement is compliant with standards and that an adequate relief path is available for all overpressure scenarios.

Similar to the comment for overpressure protection, the design of ignition prevention controls such as earthing and lightning protection is not considered normal practice for inclusion in a QRA Report.

2.4.2 Fire and Explosion Hazards

The QRA report addresses fire and overpressure hazards. QRA models determine this by calculating the risk based on the frequency, size distribution and consequences of leaks to equipment and piping. The consequences assessed in this QRA report are jet fires, flash fires and explosion overpressure.

As discussed in Section 2.1, there are exclusions from the QRA such as vehicle collision on-site and from adjacent roads. These are not directly related to land use planning issues and the exclusion is appropriate.

The QRA Report Section 2.3, excludes the hydrogen electrolyser from the model because the maximum inventory is 0.016 kg (consequence) and the enclosure is ventilated (safeguard). It is accepted that the overpressure consequence is anticipated to be small. The report could also have reported the distances to overpressure consequence levels and then concluded that given the size of the consequence, the scenario is not included in the model. This would also then avoid any challenge of the effectiveness or integrity of the ventilation system for the wide hydrogen flammable range.

The ISO technical standard for fuelling stations (Ref. 27) presents some guidance on risk assessment. Consequences are identified in the standard Figure 3 as jet fire and deflagration/ detonation (explosions). The consequences of releases considered in the QRA Report are consistent with this guidance.

The QRA Model (QRA Section 3.6) includes a site specific detail for congestion due to the trees on the Derby Street boundary.

The centre of the explosion, as presented in QRA Report Figure 5-2, is the vegetation between the facility and Derby Street. Having this location as the origin of the congestion and mixing leading to an explosion is credible, as was reported for the investigation into the 2005 Buncefield UK fuel storage facility explosion (Ref. 33).

It is noted that releases between 2 mm and 100 mm from the hydrogen storage tank were modelled in the QRA, the 100 mm release size selected based on the largest nozzle size of 100 mm. The catastrophic vessel rupture was not included in the analysis. It is not an unreasonable approach. Pressure vessel design and inspection regimes are focused on avoiding catastrophic cold rupture so it is not uncommon to assume that leak will occur before rupture. In regard to vessel rupture due to impingement by an ignited release, this scenario was discussed in the QRA report and considered to be not credible due to controls in place.

Rupture of the hydrogen storage vessel is a credible, albeit very low probability, event. Due to concerns raised by the Gladstone Council (Ref. 6), it will be prudent to consider vessel rupture (with associated overpressures from both ignited and unignited releases) in the QRA study.

2.4.3 Projectile Impact from Hydrogen Storage Vessel

Projectile impact is not a normal inclusion in a QRA report.

Models exist that can estimate the potential range of the projectiles created by vessel rupture but these require numerous assumptions. However, even if the range (i.e. consequence distance) from the projectiles is estimated to be larger than consequences from the ignited release, it does not mean that the risk from this effect is higher. A projectile can fly in any direction and the probability of impacting any particular location within the predicted consequence range is essentially a geometric probability expressed as Area of the projectile / Total Area within Consequence Range[1]. When converted to the Location Specific Individual Risk (LSIR) calculated in a typical land planning QRA, this will result in a negligible contribution to the risk from fires and explosions along the calculated risk contours.

It is noted that both the natural gas and hydrogen storage are compressed gases. The process pressure (QRA Report Table 3-1) is 5,200 kPag for feed gas and 3,550 kPag for hydrogen. For comparison, industrial nitrogen cylinders are supplied at 25,000 kPag.

It is noted that a boiling liquid expanding vapour explosion (BLEVE) cannot occur at the site facility because there is no pressurised liquid storage. The results of BLEVE in liquified petroleum gas (LPG) storage facilities have contributed to historic fatality incidents. No pressurised liquid is present at the site.

2.4.4 Escalation Events from Vessel Rupture

Hydrogen vessel rupture may create over-pressures that can lead to failure of above-ground piping. Releases from these inventories are already accounted for in the QRA (by modelling PS1, PS2 and PS4 inventories with generic release rates that account for all release causes). The potential for escalation and design measures required to mitigate it is typically addressed in other studies, e.g. Fire and Explosion Risk Assessment.

Hydrogen storage vessel rupture is not considered to result in damage to the buried pipeline. The energy from either vessel burst and the above-ground explosion of the released inventory is not expected to generate damaging ground acceleration or loads sufficient to damage the buried pipeline[2].

2.4.5 Credible Hazard Conclusions

It is concluded that the QRA addresses typical material hazards expected in a QRA for the above-ground facility that is carried out for land-planning purposes. Other assessments and review tools (e.g. HAZOP/LOPA and Fire and Explosion Assessment) are used as part of the project process to ensure a design is safe to construct, commission, operate and maintain the facility.

It is recommended to include the scenario of the hydrogen storage vessel rupture in the QRA.

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[1] For example, if one assumes that a 1m^2 projectile can land anywhere inside the 1100 m^2 site, then the chance of landing at any particular 1m^2 spot is 1 in 1100, that is <0.0001. Note, this is not the probability of having projectiles as vessel rupture has to occur to create projectiles in the first place. Hence, the probability of a projectile impacting a particular area is several orders of magnitude lower than the failure probability.

[2] Blasting experiments indicate that buried pressurised pipelines can safely tolerate peak ground vibration of 0.3 m/s (Ref. 35).

2.5 Public Risk

Question 5: Comment on the results of the assessment in terms of the risk presented to the public in the event of an incident at the site. Are the risk levels calculated acceptable when compared against any established criteria – e.g. what does 1 in a million per year (or 0.5 in a million per year) mean and how far does this risk level extend to beyond the site boundary.

The QRA report indicates in:

- Section 3.0 that the proposed development is not classified as a HCF under Queensland State code 21 (Ref. 25)
- Section 3.8 that the State code 21 risk criteria are adopted.

This review accepts that the State code 21 is a relevant basis for selecting risk criteria, even if this facility is not classified as a HCF.

Individual risk acceptance criteria are provided in SDAP (Ref. 26) Table 21.2.1. The *individual fatality risk level* criteria reflect different land use as described in SDAP and shall not exceed:

- 0.5x10-6/year at the boundary of vulnerable land use
- 1x10-6/year at the boundary of sensitive land use
- 5x10-6/year at the boundary of commercial or community activity land use
- 10x10-6/year at the boundary of open space land use
- 50x10-6/year at the boundary of any industrial land use

For the Gladstone site (refer to Figure 2-3), the applicable land uses are:

- Sensitive land use, which includes residential houses and multiple dwelling
- Vulnerable land use, which includes educational establishments (taking the more stringent criteria as SDAP sensitive land use (Ref. 26, page 21-6) also includes educational establishments).

Hence, the design and site selection of the Hydrogen Park facility needs to ensure that the 0.5x10-6/year risk contour does not reach the school and the 1x10-6/year risk contour does not reach the residential areas.

Risk contours calculated in the QRA study are shown in Figure 2-4 (copy of QRA Figure 5-3). It is estimated that:

- there is approximately 60 m separation from the 1x10-6/year risk contour (indicated in dark green colour in Figure 2-4) to the closest residential land use
- there is approximately 175 m from the 0.5x10-6/year risk contour (indicated in black colour in Figure 2-4 to the closest school boundary.

Therefore, the risk contribution from the site, calculated in the QRA, is considered tolerable risk using the SDAP criteria.

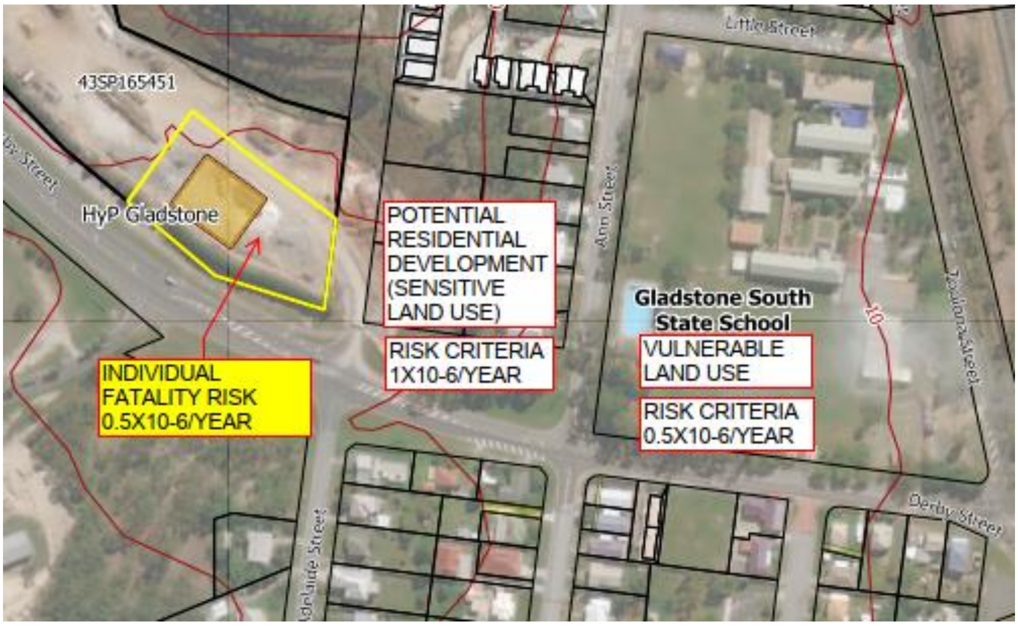

Figure 2-3: Facility Location

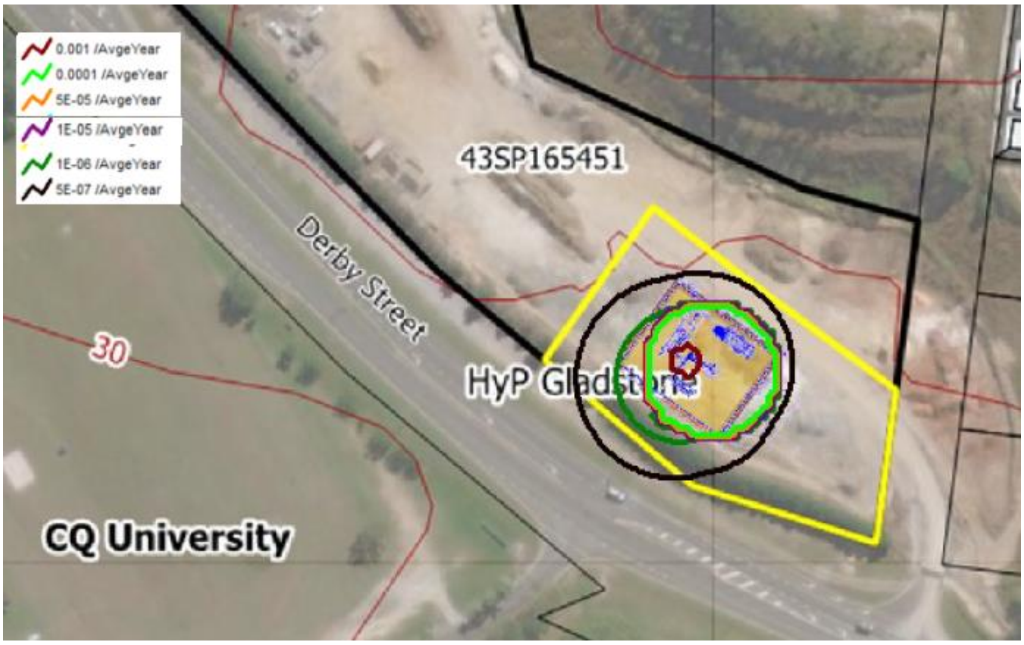

Figure 2-4: LSIR Contours from QRA Report Figure 5-3

2.6 Public Risk Tolerability

Question 6: How do the risks presented compare to those associated with other commonly acceptable societal risks (i.e.: driving or flying) or other common facilities such as service stations.

2.6.1 Available Tolerability Data

Public risk tolerability is considered dependent on whether the activity is voluntary or not. Driving and flying are generally considered voluntary and risk tolerability is higher than occupational risk.

The QRA report Appendix B Assumption Sheet 4 presents risks from the UK Health and Safety Executive (HSE):

- 5.3x10-8/year death by lightning
- 6.0x10-5/year death in a traffic accident
- 3.2x10-4/year death from injury or poisoning.

The NSW HIPAP 4 (Ref. 29) presents a broad range of risks as shown in Table 2-4 for comparison with the tolerable risk levels adopted in the land planning instruments (recognising that it is 1989 data).

Service stations were originally located well before land planning criteria were developed but it would be expected that a new facility would be assessed with similar risk tolerability as applied to the site.

Table 2-4: Risk to Individuals from NSW HIPAP 4

HIPAP 4: Risk Criteria for Land Use Safety Planning | January 2011

Table 5: Risks to Individuals in NSW[1]

	Chances of Fatality per million person years
Voluntary Risks (average to those who take the risk)	
Smoking (20 cigarettes/day)	
• all effects	5000
• all cancers	2000
• lung cancers	1000
Drinking alcohol (average for all drinkers)	
• all effects	380
• alcoholism and alcoholic cirrhosis	115
Swimming	50
Playing rugby football	30
Owning firearms	30
Transportation Risks (average to travellers)	
Travelling by motor vehicle	145
Travelling by train	30
Travelling by aeroplane	
• Accidents	10
Risks Averaged over the Whole Population	
Cancers from all causes	
• Total	1800
• Lung	380
Air pollution from burning coal to generate electricity	0.07-300
Being at home	
• accidents in the home	110
Accidental falls	60
Pedestrians being struck by motor vehicles	35
Homicide	20
Accidental poisoning	
• total	18
• venomous animals and plants	0.1
Fires and accidental burns	10
Electrocution (non-industrial)	3
Falling objects	3
Therapeutic use of drugs	2
Cataclysmic storms and storm floods	0.2
Lightning strikes	0. 1
Meteorite Strikes	0.001

2.6.2 Gladstone QRA Assessment

The risk contours calculated in the QRA study and discussed in Section 2.5 of this report are a different risk measure to those listed in Table 2-4, as they assume that an individual spends the entire year at a location of interest.

The QRA report Section 6.1 calculated how the risk contours shown in Figure 2-4 (QRA report Figure 5-3) translate into risk to an individual that may be transiting past the site on the way to school or housing.

- Exposure time is 1 hour per day, 5 days per week, 45 weeks per annum walking past the site.

The risk to this exposed individual is estimated at 3x10-8/year (i.e. lower than the likelihood of death by lightning).

2.7 Societal Risk

> *Question 7: Comment on "what is societal risk" and based on the assessment presented, is the conclusion that a societal risk calculation is not required based on established criteria (i.e. no results on FN curve) an appropriate conclusion.*

2.7.1 What is societal risk?

A description of societal risk is presented in NSW HIPAP 4 (Ref. 29).

"Risk criteria need to take account of both the physical magnitude of a given risk and community concerns over risks that are imposed rather than voluntarily accepted. Risk criteria are set with the understanding that no aspect of living can be risk free but that any imposed risk should be very small in the context of the generally accepted background risk.

Two aspects of risk need to be considered:

- individual risk, which considers the acceptability of a particular level of risk to an exposed individual; and
- societal risk, which takes into account society's aversion to accidents which can result in multiple fatalities."

In the context of this review, both, the individual risk and societal risk reflect the risk to public. They are simply two different measures reflecting different aspects of major hazards risk. The societal risk measure calculates the likelihood of certain number of fatalities caused by a hazardous event or a hazardous facility. This risk measure is generally presented as F-N curves that show cumulative frequency (F) of events that can cause fatalities versus number of fatalities (N).

2.7.2 Applicability of Societal Risk to the Gladstone QRA

The QRA Report Section 6.1 states "given the hazard range does not extend from the site to the boundary of populated locations (school, university, residences) and the risk of fatality at the site boundary is less than 1x10-6/year, a societal risk assessment is not considered to be required".

For societal risk, consideration has to be given to what scenarios would result in multiple fatalities of offsite populations. Consequence distances presented in QRA Report are used for this review (Table 4-3 Jet Fire Consequences (4.7 kW/m^2), Table 4-4 LFL Cloud Sizes (flash fires indicated by LFL), Table 4-5

Explosion Overpressures (7 kPa), Figure 5-1 Thermal Radiation Frequency and Figure 5-2 Overpressure Frequency).

Approximate separation distances from the site equipment (source) are:

- 100 m to the closest sensitive (residential) land use.
  - No jet fires, flash fires or overpressure consequences distances reach the sensitive (residential) land use.
- 200 m to the closest vulnerable (school) land use.
  - No jet fires, flash fires or overpressure consequences distances reach the vulnerable (school) land use.

As the populated areas lay outside the consequence distances calculated in the QRA, the societal (that is, multiple fatality) risk to these areas does not need to be considered.

Incidents at this facility can impact Derby Street:

- QRA Figure 5-1 indicates a 1x10-6/year frequency of radiation impact, ignoring the small 1x10-7/year overpressure impact.

The risk to an exposed individual is previously estimated at 3x10-8/year. (QRA Section 6.1, this report Section 2.6.2).

A number of additional assumptions would have to be made for the exposure time and number of people present in the 100 m of affected road. It is concluded that any societal risk is not credible or would be in the negligible region and further mitigation is not required.

The QRA report conclusion that societal risk is not required for populated locations is correct.

3 Conclusions and Recommendations

3.1 Conclusions

The Hydrogen Park Gladstone QRA Report (Ref. 12) has been reviewed.

1. The approach and methodology is appropriate for the proposed development and site location.
2. The QRA model tool is widely used by industry, including Advisian. It is also mentioned in the State Code 21 (under its previous name PHAST RISK).
3. The assumptions are generally appropriate. The assumptions rely on typical QRA sources and references and are structured for input into the QRA model. Two recommendations are made to (a) remove the inconsistency in wind speed between the report body and appendices and (b) to clarify the hydrogen storage pressure. The hydrogen storage pressure inconsistency is significant and impacts the risk through the consequence calculations and ignition probabilities.
4. Credible material hazards have been addressed for a risk assessment prepared for land use planning and the impact on offsite populations. Releases from hydrogen storage vessel were included but not the catastrophic vessel rupture scenario.
5. Risk tolerability criteria are adopted from the Queensland State Development Assessment Provisions and are typical of what is applied in other jurisdictions. The dangerous dose (consequences), as defined in the assessment provisions, extends past the site boundary and risk assessment is required. The individual risk fatality level of 1x10-6/year at the facility boundary is the risk tolerability for sensitive (residential) land use. The 0.5x10-6/year risk contour extends onto Derby Street and is the risk tolerability for vulnerable (e.g. school) land use.
6. Societal risk is discussed in this review. The QRA report conclusion, that societal risk calculation is not required for populated locations is correct. Assessment of any societal risk closer than the built infrastructure will require a number of assumptions to be made about public exposure at that location. With the calculated low risk at the facility boundary, it can be anticipated the societal risk is either not credible or would be in the negligible region.

3.2 Recommendations

Recommendations made during the review are listed in Table 3-1.

Table 3-1: Recommendations

Recommendation	Review Reference
1. Clarify the inconsistency in wind speed selection between the QRA Section 3.1 and QRA Appendix B Assumption Sheet 3.	2.3.1 Weather conditions
2. Clarify that the pressure for PS3 hydrogen storage used for consequence assessment is the design pressure of 3,450 kPag (P&ID GLA-G-100-01) and not 32 kPa (QRA Table 3-1).	2.3.3 Maximum Pressure
3. It is recommended that AGIG confirm the hydrogen storage vessel HAZOP addresses that the BD-110/ PSV-110 arrangement provides an adequate relief path for all overpressure scenarios. *NOTE: This recommendation is not related to the QRA. It is an observation by Advisian reviewers made on the review of the P&IDs provided as part of the QRA.*	2.3.3 Maximum Pressure
4. It is recommended that the hydrogen ignition probabilities for system PS3 be confirmed after confirmation of the correct system pressure.	2.3.7 Ignition Probability
5. The P&IDs show that vents with flapper type caps are used throughout the facility. It is recommended to review that these vent types are appropriate as there have been incidents where the use of these vents resulted in ignition. *NOTE: This recommendation is not related to the QRA. It is an observation by Advisian reviewers made on the review of the P&IDs provided as part of the QRA.*	Appendix A of the QRA report
6. Consider calculating the overpressure level from the electrolyser enclosure explosion to support the QRA conclusion that the small inventory is not expected to generate significant over-pressures.	2.4.2 Fire and Explosion Hazards
7. It is recommended to specifically address the explosion overpressure consequences for the hydrogen storage rupture scenario. It is recognised that the low likelihood of this scenario may not impact the QRA outcome.	2.4.2 Fire and Explosion Hazards

4 About Advisian SRM

Advisian (which is part of Worley Group) is an independent consulting company which provides engineering consulting services for a range of industries, including the pipeline industry. The Advisian Safety and Risk Management (SRM) group in Perth has provided safety and risk management advice to pipeline operators, regulators and developers for over 20 years.

In 2002, the SRM group was contracted to prepare a report for the Western Australian Department of Mineral & Petroleum Resources. The report, *Safely Meeting Current and Future Gas Transmission Needs*, Worley Doc. No. 450-01583-rpt-001, rev 0, May 2002, set out the framework for managing risk from high pressure transmission pipelines in this state and specifically addressed the issue of land planning near the pipelines. The report is referenced in Planning Bulletin 87 (Ref. 30).

Further work undertaken by the group for the Gas Pipeline Working Group (GPWG), which represented the WA gas pipeline safety regulator, established the setback distances from the buried pipelines and above-ground facilities that ensure risks to developments that lie outside of these set back distances are tolerable. This work was later used as a basis for Planning Bulletin 87 (Ref. 30).

The SRM group in Perth have been involved in all major pipeline projects in WA and facilitated many Safety Management Studies in accordance with AS2885 for both pipeline operators and other stakeholders (e.g. land developers or land users). SRM group have carried out numerous QRA studies estimating risk from pipelines and above-ground facilities and the risk reduction that can be achieved by various mitigation measures.

Through its collaboration with Advantica (formerly a research arm of British gas and now part of DNV), the SRM group had access to the latest research on the pipeline safety management.

Advisian
Worley Group

5 References

Documents provided by AGIG	File Name
1. 4000 L Hydrogen Vessel – General Arrangement	4000-Hyd Vessel
2. Site aerial image	1621474408-drone.02_v003
3. HyP Gladstone Site Location Figure 1-1	AGI_001-001[A] Site Plan
4. HyP Gladstone Site Location Figure 1-1 (modified site boundary)	AGI_001-001[B] Site Plan
5. Nel C series Hydrogen Generation Systems , Proton PEM	C-Series-Spec-Sheet-Rev-G
6. Letter from Gladstone Regional Council, 22 December 2021	DA.25.2021 – Further Advice Notice
7. Site 3D graphics layout	GLA-AMM-001_02.06.21
8. Bulk Earthworks & Overall Civil Foundation Plot Plan	GLA-C-001-01_A
9. Area 1 – Hydrogen Storage Vessel, Injection & Blending, Civil Foundation Layout	GLA-C-100-01_A
10. Area 2 – Hydrogen Generator & Utilities, Civil Foundations Layout	GLA-C-200-01_A
11. Area 3 – GC Shelter & Control Room, Civil Foundations Layout	GLA-C-300-01_A
12. Gladstone Hydrogen Park, Quantitative Risk Assessment, AE21016-R01, Rev 0, Thornton Tomasetti.	Gladstone Hydrogen Park QRA Report Rev 0
13. Proton Hydrogen Generator, C Series 3, Sheet 1, P&ID	GLA-G-003-01_A
14. Hydrogen Generation & Blending Facility, Combined Utilities & Service Plan	GLA-G-005-01_4
15. Hydrogen Generation & Blending Facility, Hydrogen Storage Vessel, P&ID	GLA-G-100-01_A2
16. Hydrogen Generation & Blending Facility, Hydrogen Injection P&ID	GLA-G-100-02_A2
17. Hydrogen Generation & Blending Facility, Hydrogen Blending Skid P&ID	GLA-G-100-03_A1
18. [Superseded by GLA-G-200-01]	GLA-G-100-04_1
19. Hydrogen Generator & Utilities, P&ID	GLA-G-200-01_A1
20. Hydrogen Generation & Blending Facility, Overall Site General Arrangement Plot Plan	GLA-M-010-01_2
21. Gladstone Gate Station, Proposed Design, P&ID	GS-GLA-001_D
22. Gladstone Gate Station, Proposed Design, General Arrangement	GS-GLA-002 [A]
23. Letter to Gladstone Regional Council, 3 December 2021	Post Additional Submissions
24. Presentation graphic, Pre-lodgement meeting minutes	Proposed Development

Advisian
Worley Group

Additional Reference Documents for this Review	Doc ID
25. Planning guideline, State code 21: Hazardous chemical facilities. Office of Industrial Relations, Workplace Health and Safety Queensland	State Code 21
26. State Development Assessment Provisions, Queensland Department of State Development, Manufacturing, Infrastructure and Planning, Version 2.6, 7 Feb 2020.	SDAP
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28. Information Sheet, Storage and handling of hydrogen, Western Australia, Department of Mines, Industry Regulation and Safety	-
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31. Reducing Risks: Protecting People – HSE's decision making process, UK Health and Safety Executive, 2001	RR: PP
32. Queensland Work Health and Safety Regulation 2011	-
33. Buncefield Explosion Mechanism Phase 1, Volume 1, UK Health and Safety Executive, Research Report 718t	RR718
34. Advantica (now part of DNV), An Overview of The PIPESAFE Risk Assessment Package for Natural Gas Transmission Pipelines, R8224, 2005	PIPESAFE Explained
35. D.E. Siskind, Vibration from Blasting, The International Society of Explosives Engineers, 2000	-

AGIG HyP Gladstone Project – Summary of Asset Management Approach and Response to Further Submissions

Controlled Copy Register

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Amendment Record

Version	Date	Amended by	Description of Change
0	18/1/2022	TR	Updates
1	22/1/2022	JK, HK, NO, OS, JF, MB, CdL	Final review

Approved by

Name	Title	Signature	Date
Tawake Rakai	Executive General Manager		28/1/2022

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1. Introduction

1.1. Purpose

The paper has been prepared by Australian Gas Infrastructure Group (AGIG) to provide additional information to Gladstone Regional Council in support of the development application currently being assessed for the Hydrogen Park Gladstone Project (HyP Gladstone), a small (175kW) hydrogen electrolyser and associated injection equipment within the proposed Australian Gas Networks' (AGN) Gladstone City Gate Station. In particular, the paper addresses the following:

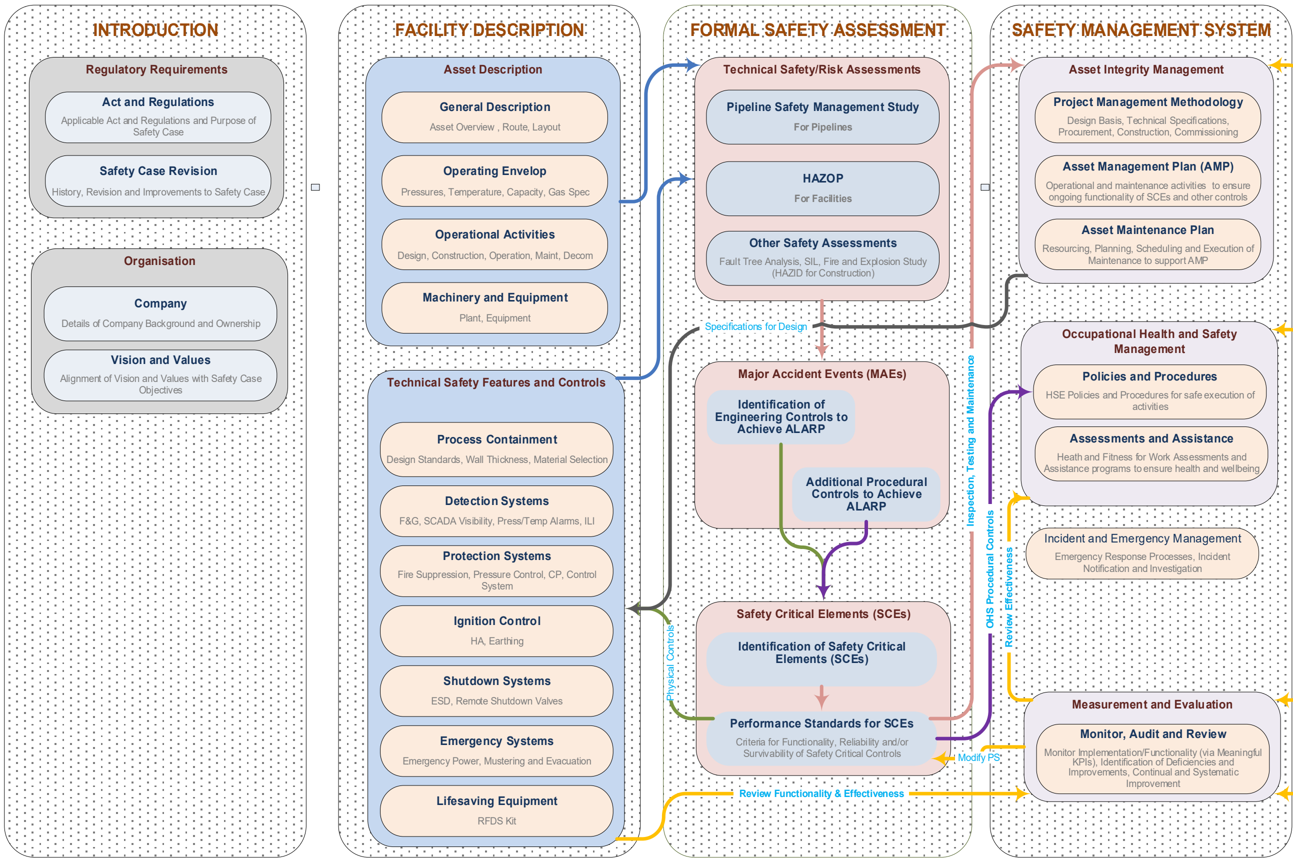
- a summary of the engineering processes implemented to ensure the safe development and transitioning of the proposed facility to operation; and
- a response to a number of specific items that have been raised by members of the community.

1.2. AGIG Asset Management Strategy

AGIG adopts the following approach, consistent with Australian Standards, in the development of gas assets from concept to design, through to construction, commissioning, and commercial operations.

AGIG adopts the safety case approach for all of its assets. Fundamental to this approach is the conduct of formal safety assessment on the assets to ensure hazards and risks are systematically identified and managed to As Far As Reasonably Practicable (AFARP), with the safety management system ensuring ongoing performance of the control of these risks. This ensures a high level of process safety in operation and hence protection of the public as well as occupational health and safety of site personnel.

This process and safe systems of works as applied to this development are summarised in the following diagram:



Asset Description

The key details of the project are described in a design basis that has been developed to capture all salient characteristics of the plant, both social, environment and operations. The asset description defines the asset that is being introduced for operation.

The design of the HyP Gladstone plant was delivered by AGIG and its experienced engineering contractors and consultants to all required standards, including the following specific activities:

- All mechanical, instrument, earthing and civil design conforms to all the relevant standards, signed off by suitable qualified engineers as register professional engineers Queensland (RPEQ).
- Noise studies have been performed and equipment changed to low noise options to reduce the potential for impacts to surrounding sensitive receptors.
- During fabrication of the hydrogen storage vessel, appropriate quality control processes were implemented, and a third party inspector appointed to verify all work in the fabrication workshop. This included material certification, approved welders and welding procedures, confirming post weld heat treatment etc.
- Hazardous area design was completed to limits applicable to hydrogen gas which implies, that if a hydrogen gas leak does occur, all equipment is suitably rated and will not act as an ignition source.
- All certification for pressurised equipment, piping and valves are in place. The verification of these conformance certificates will be a prerequisite prior to commissioning. Verification process is completed by an independent party as part of overall preparation in readiness for operation.
- Proper commissioning work instructions are in place to govern a structured commissioning phase when this occurs.

- Pressure test certificates for all pressure retaining equipment are available and will be a prerequisite prior to start-up.
- Stepped gas leak test will be conducted with nitrogen, before gas is introduced into the system.
- Shutdown and Fire and Gas detection systems have been designed and will be installed, to the required standards, which will safely shutdown plant if any unacceptable process conditions occur. These systems have sufficient dual redundancy in place and in event that these safety systems fail, the plant will shut down safely.

These engineering processes are adopted on all of our pressure components to ensure they conform and if breaches do occur the back up pressure relieving systems are in place to protect and eliminate over pressure. If in an extremely low likelihood event, failure does occur in a hypothetical sense, the manufacturing and inspection process adopted ensures that these vessels will fail safely i.e: ductile failure versus brittle failure.

Formal Safety Assessment

The plant was developed and designed with P&IDs created in accordance with relevant Australian Standards and Codes, and its interconnection to the AGN designed Gladstone City Gate Station.

The following processes were undertaken for this plant:

- Design review to identify key safety hazards taking into consideration the location and layout of the facility based on safety and operational risks.
- Consequence modelling of key potential release locations to determine releases from credible scenarios.
- Hazard and Operability study (HAZOP) to assess safety risks and operational matters based on deviations from the design intent and adequacy of safeguards and controls in place.
- Layer of Protection Analysis (LOPA) study to determine the Safety Integrity Level Classification of Safety Instrumented Functions to ensure the residual risks of the Plant are reduced and AFARP. The LOPA workshop was conducted in consultation with the electrolyser manufacture and ensured the US designed plant will operate under Australian Standards and conditions.
- Although the size (0.02% of the Hazardous Chemical Facility threshold) and hence hazards posed by the electrolyser and storage vessel combined did not require the conduct of a Quantitative Risk Assessment (QRA) under Queensland planning regulations, AGIG commissioned a reputable organisation that is deemed an expert in this area to carry out a QRA. Following strong community interest and to demonstrate compliance with land use planning criteria, an independent expert has also been commissioned to conduct a peer review of that study to demonstrate the extremely low risk that the plant poses to the public and AGIG's operations personnel.

Safety Management System

The plant's safety management system consists of two parts:

- The Asset Integrity Management component consisting of the processes and procedures required to ensures the asset is constructed to relevant standards under the AGIG Project Management methodology and the Asset Management Plan and Asset Maintenance Plans, inclusive of operations and maintenance directives that will determine how this plant is operated and maintained for ongoing safe operation thus ensuring safety of the public.

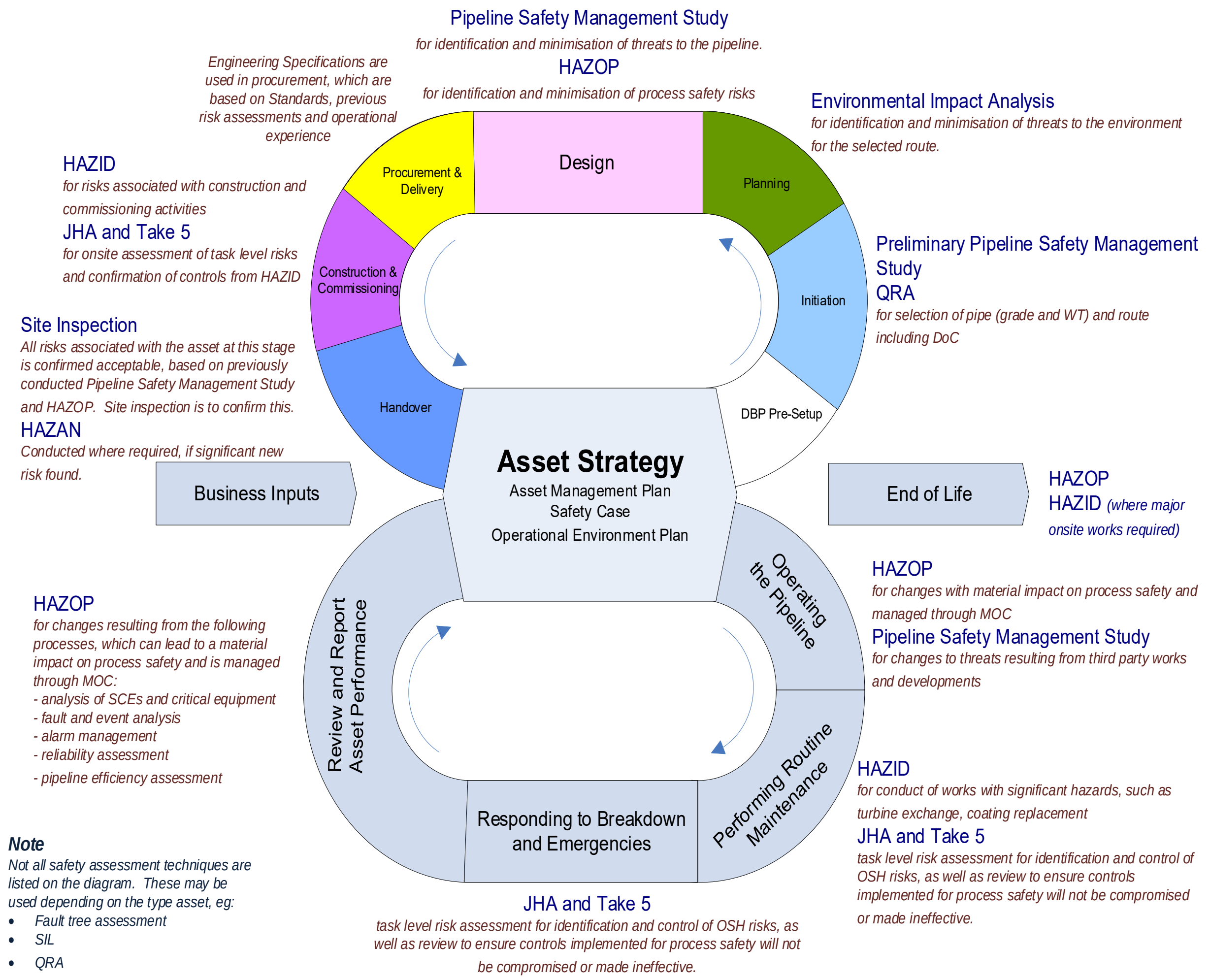
- The Occupational Health and Safety component that manages the safety of personnel and visitors to site and the human factor processes that have to be adhered to and managed when the site is manned, noting that this will normally be an unmanned site.

The plant will be monitored remotely 24/7 from AGIG's control room in Perth with routine maintenance campaigns and other necessary site attendance completed by appropriately qualified local contractors.

The above summarises the structural process that AGIG has adopted in the development, design, construction, commissioning and operation of its assets under its guidelines and in accordance with the relevant Australian Standards.

2. Asset Management Plan

The Asset Management Plan concept developed by AGIG is summarised in the following structure as adopted in the development of the HyP Gladstone project. The diagram below shows the processes used and the risk assessment scope required in each segment to drive and increase the safety of assets AGIG develops taking into account location and hazards that are present in these locations. The top segment depicts the process used when building new assets and the bottom segment captures the critical business processes required to safely operate the asset until end of life. Where Pipeline is referenced – it also applies to Facilities such as HyP Gladstone.



The Initiation of the project, Planning, Design, Procurement, Construction, Commissioning and the transition to operations all have components that are risk assessed with design and procedural actions developed to ensure that the level of risks encountred are acceptable.

The risk assessment and management process then transitions to the operation of the plant. The facility's operation, maintenance works and review of asset performance will continually inform and refine the approach to the operation and maintenance of the facility.

The HyP Gladstone project is being delivered by AGIG using the same processes that have been applied to the safe delivery and operation of all its gas transmission and mid-stream assets across Australia, including the existing Hydrogen Park South Australia project in Adelaide. As a matter of interest, ATCO currently operates a very similar electrolyser that has been in service for a few years at its Jandakot Facility adjacent to the Glen Iris residential development in Perth, Western Australia.

3. Responses to submissions

On 22 December 2021 GRC provided AGIG with a copy of two additional submissions that had been made to Council by members of the community dated 3 December and 10 December 2021 respectively. These submissions raise additional queries in relation to the hazard and risks associated with the proposed facility including commentary on the response to submissions that was lodged with Council by the applicant on 8 November 2021.

This section summarises AGIG's responses to the queries presented to the Council where of an engineering, design and/or hazard and risk nature. These responses should be read in conjunction with the following documents separately provided to Council:

- Hydrogen Park Gladstone, Review of QRA, prepared by Advisian, dated 28 January 2022; and
- Gladstone Hydrogen Park Quantitative Risk Assessment (Updated to address Advisian review), prepared by Thornton Tomasetti, dated 28 January 2022.

Vessel overpressure leading to catastrophic failure is a credible event. This should have been assessed by a different risk assessment method like Layer of Protection Analysis (LOPA) or similar where it has been demonstrated that this risk is managed to similar levels as shown in the QRA (e.g. less than 1x10^{-5} fatalities per year). There is no evidence that this or other safety management requirements have been satisfied.

In addressing this issue of 'vessel over-pressure leading to catastrophic failure is a credible event' the following is a summary of how risks of these nature are addressed within the AGIG risk management processes.

AGIG has in place formal safety assessment philosophy that is embedded into its systems for managing safety risks for all phases of a facility. The process applies from the initiation through to the end-of-life stage of the assets and comprises of safety studies conducted systematically to identify hazards that could lead to hazardous evens and assessment of risks to ensure the adequacy of controls implemented.

In line with this philosophy, the safety assessments conducted for the HyP Gladstone project include:

- Design review to identify key safety hazards taking into consideration the location and layout of the facility based on safety and operational risks;
- Consequence modelling of key potential release locations to determine releases from credible scenarios;
- Hazard and Operability study (HAZOP) to assess safety risks and operational matters based on deviations from the design intent and adequacy of safeguards and controls in place;
- Layer of Protection Analysis (LOPA) study to determine the Safety Integrity Level Classification of Safety Instrumented Functions to ensure As Far As Reasonably Practicable (AFARP) the residual risks of the Plant are reduced;

- Quantitative Risk Assessment (QRA) was conducted due to a strong community interest and to demonstrate compliance with land use planning criteria, although the project is 0.02% of the Hazardous Chemical Facility threshold in terms of hydrogen inventory.

As per AGIG's safety management principles, all the controls from the safety studies will be implemented and embedded into asset and safety management plans for the operational phase to ensure ongoing functionality of the safeguards.

The safeguards implemented to prevent an explosion of the storage vessel (as well as other hazardous events), have all been assessed through HAZOP and LOPA to ensure the risks are acceptable and AFARP. These safeguards include pressure relief devices, blowdown, trips and flame detection system for the facility yard, which will activate the emergency shutdown system and blowdown of the storage vessel upon detection. The implementation of these controls will further significantly reduce the risk of storage vessel failure.

After considering the engineering controls implemented (design, manufacture, test and validation), the probability of ignition and the storage conditions at ambient temperatures, AGIG is of the view that with these controls, the likelihood of a catastrophic pressure vessel failure is negligible and well below acceptable industry criteria.

Regardless of the extremely low (negligible) likelihood of a catastrophic pressure vessel failure, the updated QRA prepared by Thornton Tomasetti now includes consideration of the consequences of a flash fire and explosion associated with such an event. Importantly, the QRA outputs show that the consequence ranges for such an event are less than that associated with other scenarios and therefore do not alter the findings of the QRA as previously presented.

Projectile risk is not mentioned. Explosion modelling should provide an indicative projectile risk contour which is a different issue to the jet fire/thermal radiation/overpressure contours. This is important as projectile contours are typically much larger than the jet fire/thermal radiation/overpressure contours.

As described above and reinforced below, the engineering design and manufacture (including the inspection and testing regime) of the vessel, results in a negligible likelihood of catastrophic vessel failure by rupture and associated generation of projectiles.

In addition, the design, manufacture and testing regime ensures that materials used in the manufacture of the vessels confirm that material plastic deformation propagates in a ductile mode.

No controls have been demonstrated for the mitigation of lightning strike, including earthing systems, to prevent equipment and control system damage.

This facility has been designed adopting AGIG's earthing philosophy with the earthing system incorporated to protect the plant from lightening strike, static electricity and the site being supplied with power from the grid system. Equipment and control systems have adequate surge control devices to protect them from damage and earthing resistance will be tested and commissioned to meet designed levels that will assure protection. Earthing resistance to remote earth will be tested and monitored throughout the facilities operation.

The summary in the QRA is misleading - it says that the most onerous jet fire of 46.9m will last for less than 1 second (hydrogen) which is correct, however it doesn't mention the next most onerous jet fire of 42.7m lasts for almost 60 minutes (natural gas).

The QRA consultant identified that the second most onerous jet fire would be from the combustion of natural gas at the City Gate. AGIG understands the QRA consultant identified this as the next most onerous given it will be visible to the naked eye until it is isolated within an assumed timeframe of 60 mins. It should be noted that there are Gate Stations of this design and operation that are located across Australia and Queensland delivering natural gas to domestic consumers. These facilities are well designed and operated under Australian Standards that have been developed and improved, heavily regulated and are very safe and reliable facilities.

No evidence has been provided on measures to prevent rupture of pressure equipment. Proponent continues to quote chemical energy equivalents of the inventory of stored hydrogen (4 x 8.5 kg LPG bottles). This is irrelevant to the initial hazard of pressure equipment rupture. Sandia National Laboratories (U.S.) Hydrogen Risk Assessment Models 3.1 suggests evaluating an equivalent mass of recognised explosive, which in this case amounts to 330 kg of TNT. Elastic stored energy in the proposed H2 storage vessel is 50 times the elastic stored energy in 4 x 8.5 kg LPG bottles. This elastic stored energy will be released explosively in the event of vessel rupture. Rupture of a pressure vessel is a catastrophic event and could have an initial blast pressure of about 3300 kPa at the source. According to Australian Standard 4343 – 2005 Pressure equipment—Hazard levels, the hydrogen storage vessel should be rated as a level B hazard. In the event of a vessel rupture, large metal debris will be projected for hundreds of metres and loss of life is highly likely,

The storage vessel and associated pressure equipment installed at this site is designed, inspected and tested to relevant Australian Standards, as per AGIG's engineering specifications and management plans, including AS1210, AS4343 and AS3780. In addition to the design to ensure mechanical integrity of the pressure equipment, process controls have also been implemented to prevent vessel failure from uncontrolled over pressure, including:

- Installation of pressure relief valves;
- Blowdown system linked to emergency shutdown which will be activated during emergencies including fire events (detected via yard flame detectors);
- Electrolyser trip on high pressure.

These are standard controls to eliminate the risk of overpressure and overpressure failures.

As such, it is considered that the risk of a vessel rupture is negligible. In the hypothetical event of a rupture, vessel's materials are designed to propagate a ductile failure and as such the potential for multiple fragments from the rupture is not expected, especially at the relatively low operating pressure of 3MPa.

In addition, unlike storage of liquefied flammable gases, there is no potential for the proposed hydrogen storage vessel to undergo a BLEVE (Boiling Liquid Expanding Vapour Explosion).

Risk is the product of probability of occurrence of an event and the consequences of that event. The proponent has chosen to express risk in terms of potential lives lost per year. There has been no quantitative risk assessment (QRA) in relation to rupture of pressure equipment. Such ruptures are high consequence events. High consequence, low probability events, while being mathematically low risk, are difficult to treat. Many industries are prepared to spend large amounts to completely avoid such hazards.

AGIG acknowledges that catastrophic failure of pressurised vessels have the potential for significant consequences. However, as described above, a catastrophic vessel failure/rupture with projectiles is not considered to be a credible risk.

The storage vessel that is being proposed for the site is small in volume and will only store a limited inventory of hydrogen with energy content equivalent to a G size LPG bottle typically seen at residential properties that are not connected to a gas distribution system to fuel appliances such as hot water systems and cooking appliances.

The hydrogen storage vessel has been designed and will be operated and maintained to all relevant Australian Standards as explained above. In addition, the vessel which will be an approved registered pressure vessel in Australia, will undergo a thorough inspection and independent validation process to confirm compliance with AGIG specifications, Standards and Codes prior to installation on site.

The above coupled with controls implemented in the design (e.g: flame detection, process and emergency shutdown, pressure relief and automatic blowdown) will enable prevention of a catastrophic failure of the hydrogen storage vessel. The design and safeguards for the vessel at this location exceed accepted industry practice.

4. AGIG concluding summary

This paper has set out a summary of the engineering processes AGIG has adopted in the development of the HyP Gladstone project and provided further information addressing additional public submissions that have been received by GRC in relation to the project.

When read in conjunction with the QRA Review prepared by Advisian and updated QRA prepared by Thornton Tomasetti it can be concluded that the HyP Gladstone project can be developed safely and without any unacceptable risk to the public.

AGIG is committed to thoroughly implementing the recommendations and findings of all assessments that have been completed in order to deliver a project that can operate safely in the proposed location.