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Neale House
Santos NSW (Eastern) Pty Ltd
Brisbane Qld 4000

Dear Neale,

Leewood Central Gas Processing Facility and Medium Pressure Trunkline Quantitative Risk Assessment

1. Background

1.1 Department of Planning and Environment Request

On 21 May 2019 Santos received the following request from the NSW Department of Planning and Environment in relation to the Hazards and Risk Assessment for the Narrabri Gas Project (NGP) Environmental Impact Statement (EIS).

1. A full quantitative risk assessment (QRA) is required for the Leewood facility, inclusive of the trunkline from Bibblewindi to Leewood, to demonstrate compliance with all of the Department's risk criteria for land use safety planning as per *Hazardous Industry Planning Advisory Paper No 4 – HIPAP 4* (NSW Department of Planning 2011a).
2. The QRA required for the Leewood facility (refer to item no. 10) must include the relevant hazards and risks associated with all equipment and activities (e.g. pig launch and recovery) at this facility.

1.2 Risk Modelling of NGP Facilities

A QRA has been undertaken applying advanced risk modelling techniques using DNV-GL SAFETI software. Figures 1-1, 1-2, 1-6 and 1-7 of the Hazard and Risk Assessment (GHD 2016), submitted as Appendix S of the NGP EIS, provide the context for the risk modelling undertaken.

The Bibblewindi to Leewood medium pressure (MP) Trunkline would be used to transfer the gas from Bibblewindi to the Leewood Central Gas Processing Facility (CGPF). It was modelled as an 864 mm diameter pipeline, approximately 16 km long, carrying gas at 177,000 kg/hr at a pressure of 2,000 kPag. The MP Trunkline terminates at the pig launcher and receiver area in the pipeline corridor just to the west of the Leewood CGPF.

Figure 1-7 in GHD (2016) provides a layout for the Leewood CGPF. It shows the:

- CGPF
- flare
- main processing stages for the untreated gas imported at the MP Trunkline that include
 - compression
 - carbon dioxide (CO₂) removal using amine membranes
 - dehydration using Triethylene Glycol (TEG)
- sales gas export infrastructure.

The gas entering the Leewood CGPF at 2,000 kPag is compressed to 6,500 kPag prior to CO₂ removal, then further compressed to 15,000 kPag for dehydration and sales gas production. Once treated, the gas is exported from the Leewood CGPF to the high pressure (HP) export pipeline. There is an isolation valve at the outlet of the Leewood CGPF which serves as the boundary between the Leewood CGPF and the HP export pipeline, and therefore, the demarcation point for the assessment reported herein.

A power generation facility is also proposed for the Leewood site, which will consist of ten gas turbines for power generation. The power generation facility is powered by gas from the MP Trunkline at the inlet end of the Leewood CGPF.

1.3 Scope of QRA

The scope for the QRA was to analyse hydrocarbon loss of containment (LOC) events. Process related LOC events were analysed to determine the offsite risk to the surrounding people, property and biophysical environment as required under *Hazardous Industry Planning Advisory Paper No 6 – Hazard Identification HIPAP 6* (NSW Department of Planning 2011b).

The risk contours prepared in the QRA are for:

- The Leewood CGPF
- The MP Trunkline from Bibblewindi to Leewood.

The offtake station and downstream HP export pipeline are not part of the NGP and are outside the scope of this QRA.

2. Methodology

The NGP is at an early stage of concept design, and technical and engineering documentation of a nature suitable for a full QRA is not yet available. This QRA is therefore a preliminary study of the risk contours around the Leewood CGPF and MP Trunkline.

The methodology adopted for the QRA followed the HIPAP 6 Guidelines (NSW Department of Planning 2011b) and involved the following steps:

1. Define the process within the QRA scope boundary and prepare a list of all potential leak and release points (the “parts count”)¹
2. Establish the process conditions within the QRA scope boundary
3. Establish the meteorological conditions
4. Determine leak and release frequencies from recognised industry databases and publications
5. Determine LOC event outcomes (jet fires, flash fires, pool fires, fireballs and explosions)
6. Undertake risk modelling using SAFETI² software
7. Plot individual fatality risk contours, injury contours and transects on scaled drawings
8. Compare individual risks and societal risks to HIPAP 4 criteria.

The assumptions made during the development of the QRA have been conservative to ensure that risks are not understated. Therefore, further refinement of the modelling may show reduction in offsite risk.

¹The parts count for Leewood CGPF has been based on an industry standard design for a plant of this nature. Conservative assumptions have been made in the estimation of piping sizes and lengths, numbers and sizing of vessels, and equipment items to ensure the risk results are an overestimate.

² DNV GL Software for Assessing Fire Explosion and Toxic Incidents, Version 6.7.

3. Results

3.1 Risk Contours

3.1.1 Individual Fatality Risk

Based on the risk modelling undertaken using the SAFETI software for the QRA, Figure 1 shows the individual fatality risk contours for the Leewood CGPF. The contours are based on HIPAP 4 criteria for individual fatality risk.

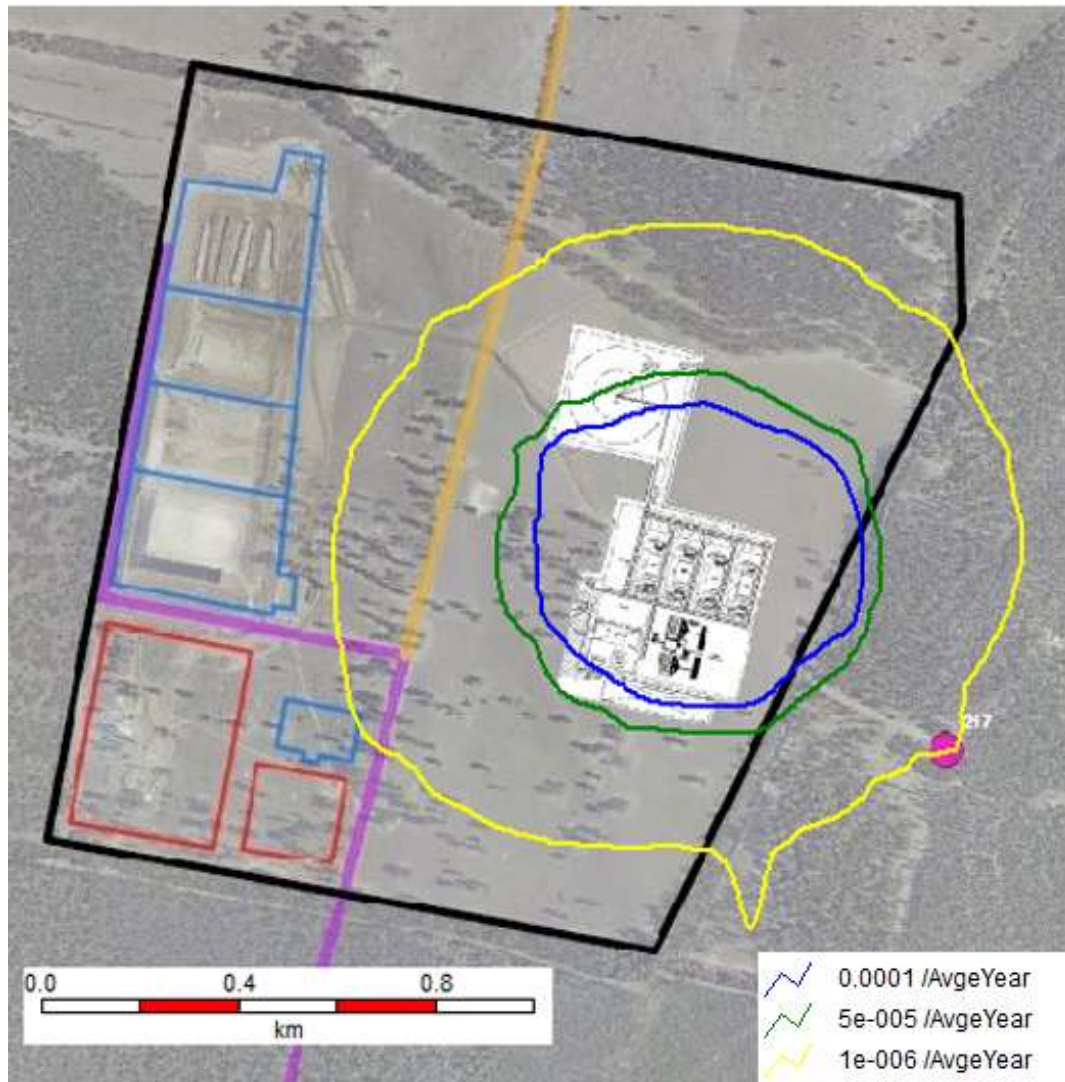


Figure 1 Individual Fatality Risk Contours for NGP Leewood CGPF as shown in NGP EIS (Base Case)

Figure 1 shows that the 1×10^{-6} p.a. (yellow) contour passes through the nearest occupied dwelling located 350 m away (sensitive receiver 217). The individual fatality risk at sensitive receiver 217 is 1.14×10^{-6} p.a.

The 1×10^{-4} p.a. (blue) and 5×10^{-5} p.a. (green) contours also extend offsite around the Leewood CGPF, but do not cross any sensitive receivers.

Upon review of these initial risk modelling results that were undertaken consistent with the location of the Leewood CGPF in the NGP EIS, a risk mitigation strategy was identified whereby the Leewood CGPF and all associated infrastructure was moved 75 m to the west. The revised risk contours for this singular mitigation strategy are shown in Figure 2.

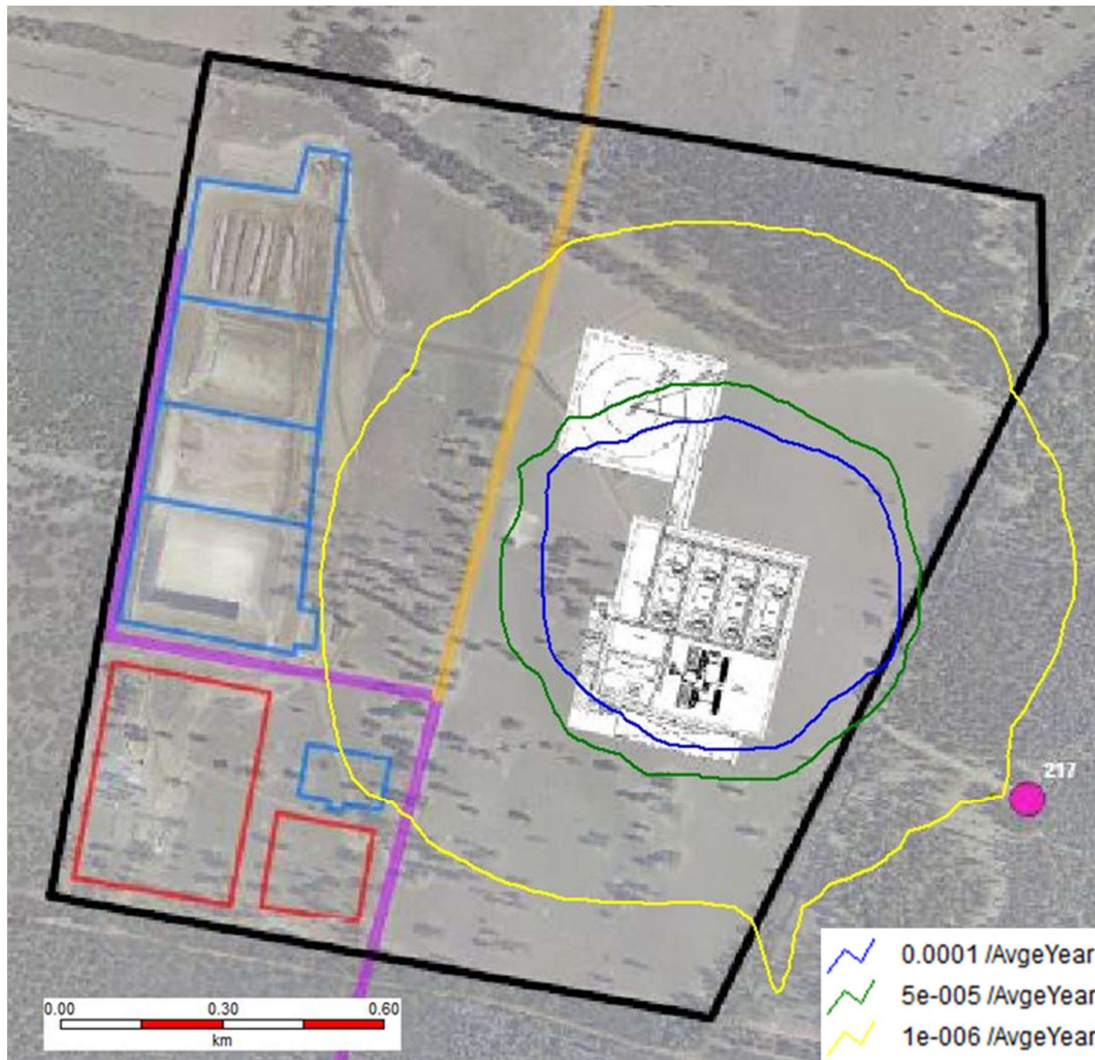


Figure 2 Individual Fatality Risk Contours for Leewood CGPF, mitigation applied

Figure 2 shows that sensitive receiver 217 is now located outside of the 1×10^{-6} p.a. (yellow) contour. The individual fatality risk at sensitive receiver location 217 is 4.7×10^{-7} p.a. The 1×10^{-4} p.a. (blue) and 5×10^{-5} p.a. (green) contours also extend offsite around the Leewood CGPF but do not cross any sensitive receivers.

Figure 3 shows the individual fatality risk contours for the MP Trunkline located as per the NGP EIS.

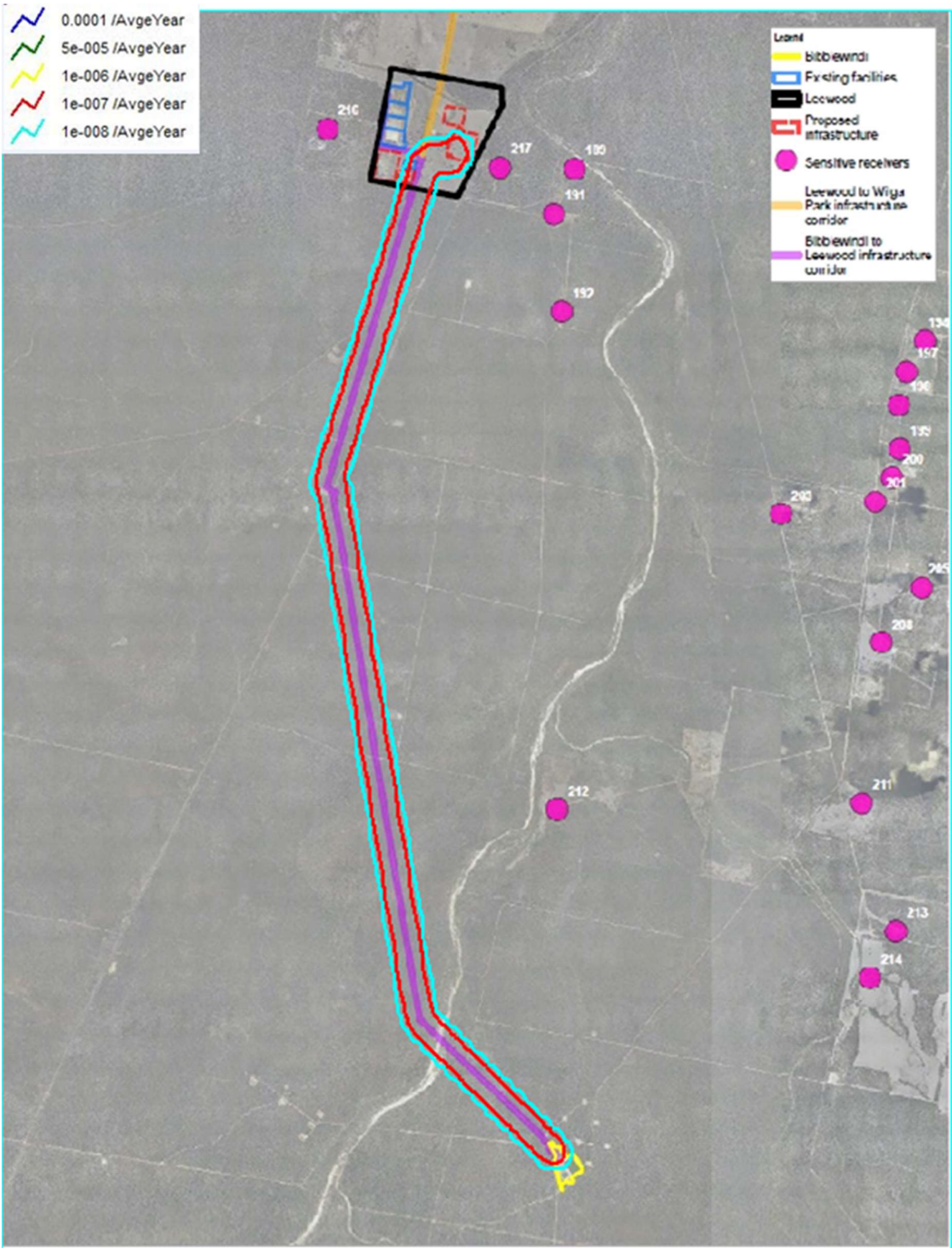


Figure 3 Individual Fatality Risk Contours for MP Trunkline

Figure 3 shows that the MP Trunkline individual fatality risk contours do not cross any sensitive receiver.

The 1×10^{-7} p.a. (red) 1×10^{-8} p.a. (light blue) individual fatality risk contours for the MP Trunkline are tightly located around the trunkline and do not cross the closest sensitive receiver (212), located approximately 1.5 km to the east, or on any other dwelling or industrial site.

3.1.2 Injury Risk

Based on the risk modelling undertaken using the SAFETI software for the QRA, Figure 4 shows the injury risk contour for the Leewood CGPF. The injury risk contour is based on HIPAP 4 criteria (4.7 kW/m² incident heat flux radiation being exceeded at a frequency of 5×10^{-5} p.a.).

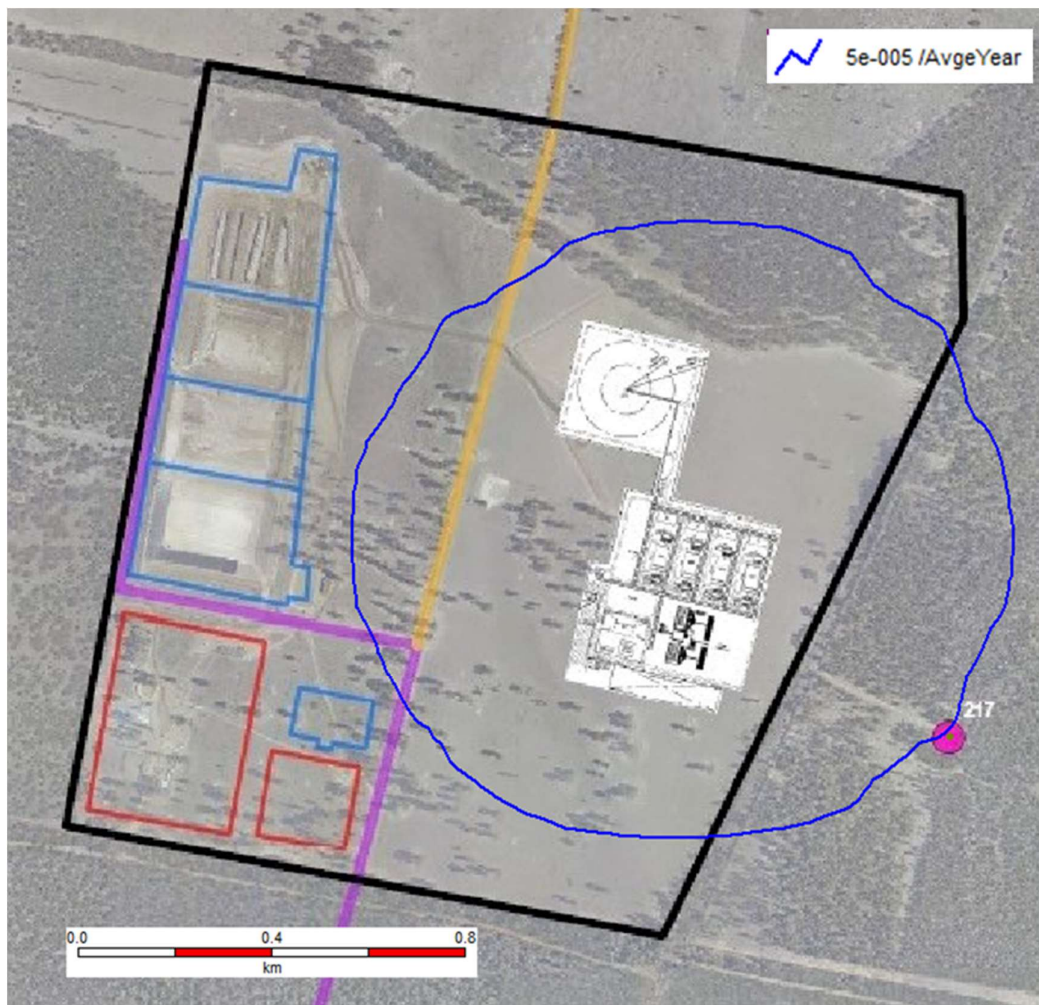


Figure 4 Injury Risk Contour for NGP Leewood CGPF as shown in NGP EIS (Base Case)

Figure 4 shows that the plot shows the 5×10^{-5} p.a. (blue) injury risk contour passes through sensitive receiver 217.

Figure 5 shows the injury risk contour for the Leewood CGPF with the mitigation strategy of moving the Leewood CGPF 75 m west applied.



Figure 5 Injury Risk Contour for Leewood CGPF, mitigation applied

Figure 5 shows that sensitive receiver 217 is located outside of the 5×10^{-5} p.a. (blue) injury risk contour with mitigation applied.

There are no injury risk contours for the MP Trunkline because the QRA results show that the injury risk does not reach 5×10^{-5} p.a.

3.2 Societal Risk

Figure 3 of HIPAP 4 provides indicative criteria for societal risk to address concerns arising when there is a risk of multiple fatalities occurring in one event. A Fatality–Number (FN) curve (obtained by plotting the frequency at which such events might kill N or more people, against N) provides a useful means of comparing the impact profiles of man-made accidents with the equivalent profiles for natural disasters with which society has to live. The FN curve for societal risk for the NGP (incorporating the Leewood CGPF and the MP Trunkline), has been plotted in Figure 6.

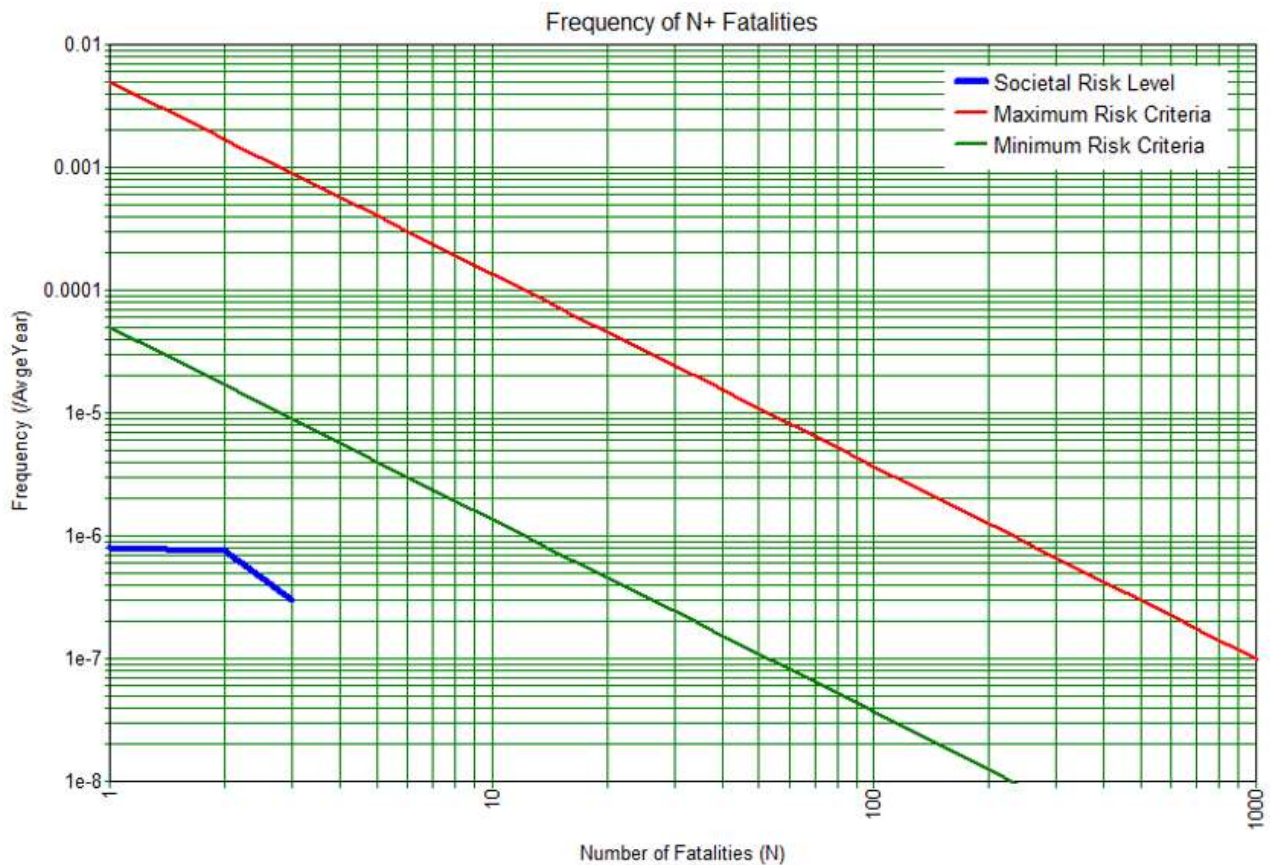


Figure 6 FN curve for societal risk for NGP

Figure 6 shows that the societal risk of multiple fatality events (blue line) falls below the minimum risk criteria shown in HIPAP 4. Therefore, provided other individual criteria are met, societal risk is not considered significant.

3.3 Compliance with HIPAP 4

3.3.1 Individual Fatality and Injury Risk

Based on the findings of the QRA, Table 1 lists the compliance of the NGP with the HIPAP 4 individual fatality risk criteria for the following two cases:

- Leewood CGPF and MP Trunkline located as per NGP EIS (Base Case)
- Risk mitigation applied whereby the Leewood CGPF and all associated infrastructure is moved 75 m to the west (Mitigated Case).

Table 1 Individual Fatality Risk Criteria

Exposure Type	Risk Criteria	QRA results demonstrate compliance with HIPAP 4?
Hospitals, schools, child-care facilities and old age housing developments	Half in a million per year (5×10^{-7} per year)	Yes
Residential developments and places of continuous occupancy (hotels/resorts)	One in a million per year (1×10^{-6} per year)	No (Base Case) Yes (when mitigated)
Commercial developments, including offices, retail centres, warehouses with showrooms, restaurants and entertainment centres	Five in a million per year (5×10^{-6} per year)	Yes
Sporting complexes and active open space areas	Ten in a million per year (1×10^{-5} per year)	Yes
Industrial sites	Fifty in a million per year (5×10^{-5} per year)	Yes (Note 1)

Note 1: The nearest offsite industrial facility is the HP export pipeline. Since this is a conjoined facility, it is not regarded as an external industrial facility for the purposes of assessing HIPAP 4 compliance.

Based on the findings of the QRA, Table 2 lists the NGP compliance against the HIPAP 4 injury risk criteria.

Table 2 Injury Risk Criteria

Exposure Type	Risk Criteria	QRA results demonstrate compliance with HIPAP 4?
Incident heat flux radiation at residential and sensitive use areas	Should not exceed 4.7 kW/m^2 at a frequency of more than 50 chances in a million per year.	No (Base Case) Yes (when mitigated)

3.3.2 Societal Risk

As discussed in Section 3.2 the societal risk for the NGP falls below the minimum risk criteria shown in HIPAP 4, and provided other individual criteria are met, societal risk is not considered significant.

4. Conclusions and Recommendations

A QRA has been undertaken for the Leewood CGPF, inclusive of the MP Trunkline from Bibblewindi to Leewood. The QRA has included the relevant hazards and risks associated with equipment and activities at the facility.

As the NGP is at an early stage of concept design, and technical and engineering documentation of a nature suitable for a full QRA is not yet available, this QRA was limited to being a preliminary study of the risk contours around the Leewood CGPF and MP Trunkline.

The QRA results obtained from the modelling undertaken using the SAFETI software have shown:

1. The Leewood CGPF located as per the NGP EIS is not compliant with HIPAP 4 criteria for individual fatality risk.
2. The Leewood CGPF is compliant with HIPAP 4 criteria for individual fatality risk, when the risk is mitigated by moving the CGPF 75 m to the west of its position shown in the EIS.
3. The MP Trunkline located as per the NGP EIS is compliant with HIPAP 4 criteria for individual fatality risk.
4. The Leewood CGPF located as per the NGP EIS is not compliant with HIPAP 4 criteria for injury risk.
5. The Leewood CGPF is compliant with HIPAP 4 criteria for injury risk, when the risk is mitigated by moving the Leewood CGPF 75 m to the west of its position shown in the EIS.
6. The societal risk for the NGP (incorporating the Leewood CGPF and the MP Trunkline) falls below the minimum risk criteria shown in HIPAP 4. Therefore, provided other individual criteria are met, societal risk is not considered significant.

Due to the preliminary nature of the QRA, these results are considered to be conservative, and the risk will likely be reduced upon further design and layout development.

As there is a potential interaction of LOC events between the HP export pipeline and Leewood CGPF, the following recommendations are made:

- Consideration should be given during detailed design to this potential interaction extending beyond the facility boundaries and the layout should be optimised with the intention to minimise such interactions.
- A combined emergency response plan for both facilities should be prepared.

Kind regards,



Russell Mills

Executive Advisor
GHD Advisory

5. References

- GHD (2016). Hazard and Risk Assessment. *Narrabri Gas Project Environmental Impact Statement*, Appendix S.
- NSW Department of Planning (2011a). *Hazardous Industry Planning Advisory Paper No 4, Risk Criteria for Land Use Safety Planning (HIPAP 4)*.
- NSW Department of Planning (2011b). *Hazardous Industry Planning Advisory Paper No 6, Hazard Identification (HIPAP 6)*.