18 HAZARD AND RISK

This chapter outlines QGC's general approach to hazard, risk and emergency management that will apply across the whole of the Project, and the proposed LNG Component in particular. Specific hazard and risk assessments and emergency management plans for the Gas Field Component and Pipeline Component of the Project are described in *Volume 3, Chapter 17* and *Volume 4, Chapter 16* respectively.

This chapter describes:

a) hazard and risk issues (including hazard identification and risk assessment) associated with the construction, commissioning and operation of the LNG Facility, within the broader LNG Component, and associated LNG and LPG shipping

b) cumulative risk issues arising from changes to the existing environment associated with other relevant existing or proposed industrial facilities in the vicinity of the LNG Facility

c) the status and process of emergency management planning for the Project as appropriate to the current stage of LNG Facility design.

The aim of assessing hazards and risks is to ensure ecological health, public amenity and safety are maintained during the construction, operation and decommissioning of the LNG Component and associated infrastructure and that any potential hazards or risks to ecological health, public amenity and safety are identified and avoided or managed effectively.

As part of front-end engineering and design (FEED), QGC is considering options for infrastructure type, configuration and location of the LNG Component works to reduce any unnecessary hazards or risks from construction, operation and subsequent decommissioning.

The hazard and risk assessment described in this chapter is based on the Environmental Impact Statement (EIS) Reference Case described in *Volume 2, Chapter 2.*

18.1 DESCRIPTION OF PROJECT ENVIRONMENTAL OBJECTIVES

The Project environmental objective for road, rail, air and public transport is: to protect ecological health, public amenity and safety of those on site or in proximity to the site from hazardous events.

18.2 CONTEXT

18.2.1 LNG Facility

The proposed LNG liquefaction facility (LNG Facility) and export terminal is similar to many active LNG liquefaction and export terminals around the world. The safety record of these facilities over the past 45 years has been excellent, due in part to the design codes followed by the designers, constructors and operators of these facilities.

18.2.2 Storage Tanks

A description of the LNG storage tank design is provided in *Volume 2, Chapter 9*. In 35 years, modern LNG tanks, using 9 per cent nickel steel, have never suffered a crack failure.[1] The design of the LNG Facility's LNG tanks will comply with API 620,[2] ACI 318-08,[3] NFPA 59A,[4] AS-3961[5] and other applicable regulatory and permitting requirements of the Queensland and Federal Governments as well as internal BG Group standards.

QGC proposes to construct full containment tanks with a 9 per cent nickel steel inner container and an outer container with pre-stressed, reinforced concrete walls and concrete roof. Tanks will also be protected by safeguards such as alarms, back-up safety measures, emergency shutdown (ESD) systems and separation distances between tanks as described in *Volume 2, Chapter 9*.

Tanks will include overpressure protection relief. The flaring philosophy and overpressure protection will comply with *API 520*,[6] *API 521*[7] and *API 2000*.[8]

18.2.3 LNG Shipping

In the past 42 years, LNG ships have made more than 47,000 voyages covering more than 185 million kilometres without a major accident[9] and with no collisions, fires, explosions or hull failures resulting in a loss of containment in ports or at sea. Only eight marine incidents worldwide have resulted in accidental LNG spillage. None of the spills resulted from a failure or breach of a containment system, there were no fires and only minor structural damage resulted. No explosions or fatalities from a cargo spill have ever occurred aboard an LNG carrier.

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1 Centre for Liquefied Natural Gas, 2009: http://www.lngfacts.org/about-lng/Facility-Safety.asp

2 American Petroleum Institute Standard 620: *Design and Construction of Large, Welded, Low-Pressure Storage Tanks, Tenth Edition*

3 American Concrete Institute; *Building Code Requirements for Structural Concrete and Commentary*

4 US National Fire Protection Association: *NFPA 59A: Standard for the Production, Storage and Handling of Liquefied Natural Gas*

5 Standard Australia, AS 3961-2005: *The storage and handling of liquefied natural gas*

6 API RP 520: *Sizing, Selection and Installation of Pressure-Relieving Devices in Refineries: Part I – Sizing and Selection*

7 American Petroleum Institute ANSI/API Std 521/ISO 23251 *Pressure-relieving and Depressuring Systems, Fifth Edition (Includes 2008 Addendum*)

8 American Petroleum Institute API Std 2000 *Venting Atmospheric and Low-Pressure Storage Tanks: Nonrefrigerated and Refrigerated*

9 Centre for Liquefied Natural Gas 2009: http://www.lngfacts.org/about-lng/carrier-safety.asp

Details of the proposed LNG shipping activities associated with the Project are included in *Volume 5, Chapter 15*. Quantification of risks associated with LNG shipping for the Project is provided in *Sections 18.4.3, 18.4.4* and *18.4.5* . Potential impacts on marine biota arising from incidents and accidents associated with LNG shipping are discussed in *Volume 5, Chapter 8*.

18.3 LEGISLATION, STANDARD AND CODES OF PRACTICE

QGC has established a system to identify legislation, standards and codes of practice pertaining to Health, Safety, Security and the Environment (HSSE) and to monitor changes to legislation. A list of Queensland and Federal Acts and Regulations, codes of practice and standards that may apply to the Project is provided in *Annex E*. QGC will comply with all applicable legal and statutory requirements, codes and standards during the design, construction, commissioning and operation of the facility. In order to ensure that legislation, codes and standards are applied correctly and in the appropriate parts of its business, QGC has undertaken reviews and gap analyses of its internal systems and procedures and revised these as needed to comply.

18.3.1 Dangerous Goods

The Dangerous Goods Safety Management (DGSM) Act 2001 and the *DGSM Regulation 2001* are administered by Workplace Health and Safety Queensland (previously through the Chemical Hazards and Emergency Management Services (CHEM Services) under the Department of Emergency Services). The Hazardous Industries and Chemical Branch (HICB) is the agency of Workplace Health and Safety Queensland responsible for coordination, ongoing training and industry support.

Following substantial completion of detailed design, QGC will notify the HICB that the proposed LNG Facility is a large dangerous goods location and a potential major hazard facility (MHF). MHF classification depends on the types and quantities of dangerous goods to be stored and/or used at the liquefaction plant and other factors such as proximity to other industrial activities in the area. QGC expects the LNG Facility will be declared a major hazard facility for the life of the Project in accordance with HICB guidelines.

All hazardous materials used on site will be managed in accordance with the relevant regulatory requirements and standards, including Australian Standards such as:

- AS/NZS 4452:1997 (a): The Storage and Handling of Toxic Substances
- AS 1940:2004 The Storage and Handling of Flammable and Combustible Liquids
- AS 3780:1994 The Storage and Handling of Corrosive Substances.

Material safety data sheets (MSDS) for all relevant chemicals will be required on site before delivery is accepted. MSDS will be kept with the goods, provided to the users of dangerous goods and kept with the HSSE managers. Spill prevention measures will be implemented and spill response strategies developed.

18.3.2 QGC Standards, Guidelines and Approach

QGC, as a member of BG Group, will incorporate BG Group's HSSE philosophy into all aspects of the Project, including hazard and risk. This HSSE philosophy provides direction for the development and implementation of sound principles for the protection of the environment and the health and safety of Project stakeholders and the community.

BG Group maintains a Value Assurance Framework (VAF) consisting of a range of standards addressing process safety, the environment, security, occupational health and safety and other general management requirements of the business, including ventures such as the QCLNG Project.

These standards are in place to ensure best practice operations by the company's employees, contractors and contract employees regardless of which country or jurisdiction they work in and ensures a consistent approach to HSSE management.

In Australia and Queensland, where national standards such as AS/NZS 4801 and detailed state guidance exist, BG Group standards operate in addition to these minimum requirements.

The Project has reviewed all applicable Australian Standards and Queensland requirements and supplemented the BG Group standards with this information to ensure its operators, contractors and suppliers at any location comply with Australian statutory requirements and internal company policy. A summary of applicable BG Group standards relating to health and safety is provided in *Table 5.18.1*.

Table 5.18.1 Key BG Group Standards Applicable to Health and Safety

BG Group Standard	Standard objective/intent
HSSE Deliverables Standard	Assists in implementing HSSE policies on projects by ensuring HSSE is integrated into, and effectively managed throughout, the life-cycle stages of a project (inception, business case, feasibility assessment, concept selection, FEED, Engineering, Procurement and Construction (EPC), operate/maintain)
Risk Management Standard	Ensures that appropriate HSSE risk assessments are conducted for all BG Group projects, assets and activities that have the potential to pose any health, safety, security or environmental risk to BG Group or stakeholders throughout the project life-cycle
Safety Case Standard	Specifies safe operation of major hazard facilities.[10] Requires a systematic review of major accident hazards and adequacy of risk control measures throughout the facility's life-cycle. Demonstrates that suitable and sufficient measures are in place to prevent a major accident and to reduce the effects of a major accident, should one occur

10 Operational facilities which have the potential of a major accident due to storage, handling or processing of hazardous or toxic materials or other activities are classed as major hazard facilities.

BG Group Standard	Standard objective/intent
Behaviour-Based Safety Standard	Removes barriers to continual improvement by engaging personnel at all levels in addressing human factors of safety
Driving Standard	Commitment to eliminating road traffic accidents involving employees and contractors
Personal Protective Equipment Standard	Specifies appropriate and suitable selection of personal protective equipment (PPE) for employees, contractors and visitors against the identified hazards of the job to be undertaken
Crisis Management Standard	Ensures robust crisis management systems are in place to cover all aspects of crisis management including incident management and contingency planning
HSSE Communication Standard	Ensures development and implementation of formal and robust system of consultation and communication with employees, contractors and stakeholders and that these engagement processes are monitored and measured for effectiveness to promote positive HSSE performance
Contractor Management Standard	Ensures that contractor and contract employees comply with all BG Group HSSE processes, policies, standards, procedures and other contract conditions during the conduct of their work
HSSE Documentation Management Standard	Ensures all BG Group assets maintain the required HSSE processes that will ensure effective and ongoing HSSE documentation management and be consistent with the HSSE management system requirements
HSSE Training and Competency Standard	Ensures that BG Group's approach and methodology provides for requisite skills and knowledge, training and assessment of competency within its operators and ensures employees and contractors are able to carry out their work safely and skilfully
Performance Improvement Planning Standard	Provides minimum requirements for the production of HSSE performance improvement plans to ensure suitable plans are in place to achieve BG Group's HSSE objectives, comply with applicable laws and regulations and maintain awareness of changes to HSSE legislation
HSSE Performance Monitoring and Reporting Standard	Mandates that performance is measured and monitored and results reported to management so risks can be managed, absolute performance can be improved and deteriorating trends can be identified and rectified
Incident Reporting and Analysis Standard	Mandates that all incidents associated with business related activities or property involving near misses, hazards and occupational illnesses are reported, categorised, investigated and analysed, and actions taken to minimise impact, prevent recurrence and improve effectiveness of the HSSE management system

BG Group Standard	Standard objective/intent
Incident Investigation Standard	Ensures effective and methodical investigations are conducted for all incidents associated with business activities that did, or could, result in harm to people and/or loss or damage to the environment or an asset. The standard seeks to identify the facts and root causes associated with the incident and to develop and implement controls and corrective actions to prevent recurrence
Quantitative Risk Assessment	Outlines BG Group's requirements for conducting quantitative risk assessments that contribute to the safety case for specific operations and situations (see Safety Case Standard) for major hazard facilities
Health Management Standard	Ensures that all health hazards arising for the business are identified, assessed and managed in order to reduce the risk of people developing work related illnesses
Health Surveillance Standard	Seeks to conduct health surveillance to identify health effects arising from work activities, including evidence of direct damage to health and secondary effects in employees, contractors and sub-contractors
Security Standard	Ensures that security risks to personnel, physical assets and information are managed in a structured and systematic manner

18.4 HAZARD IDENTIFICATION AND RISK ASSESSMENT

A preliminary hazard identification exercise has been undertaken addressing the nature of hazards that might occur during construction and operation of the LNG Facility. This has been expanded in a Quantitative Risk Assessment (QRA) performed for the LNG Facility, as well as a detailed risk assessment associated with marine activities covering:

- LNG/LPG carriers transiting the Port of Gladstone
- a marine berth QRA for the loading/unloading of LNG/LPG carriers
- LNG/LPG carriers transiting the Great Barrier Reef Marine Park (GBRMP).

Details of these risk assessments and key findings are provided below.

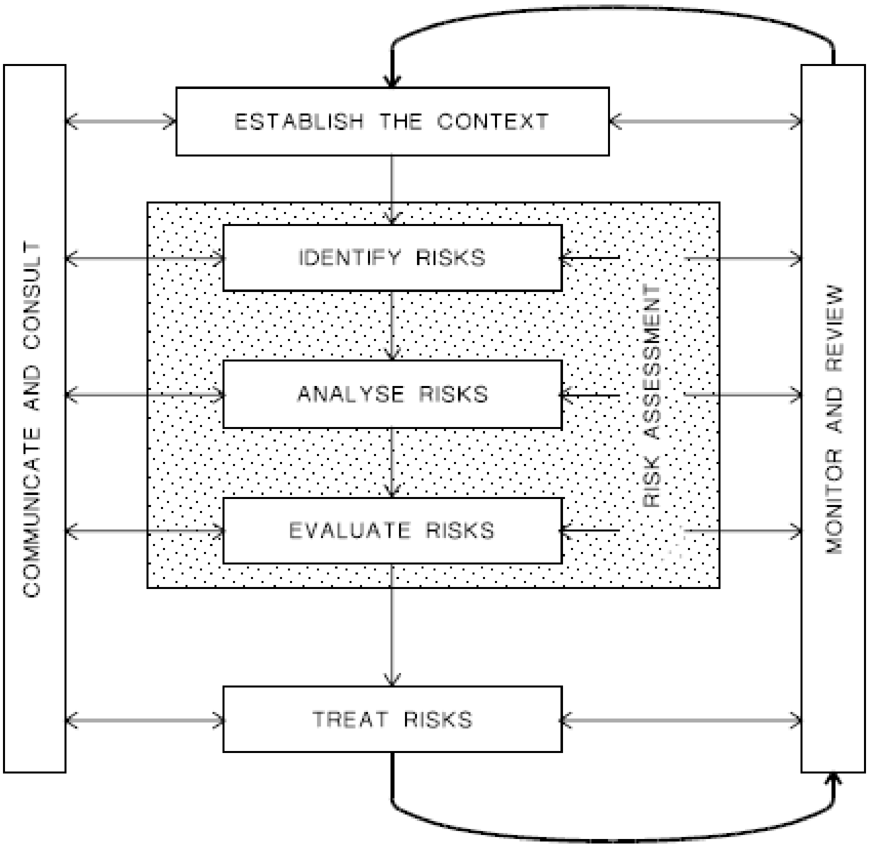
18.4.1 Preliminary Hazard Identification

Hazard identification for LNG Facility operations was undertaken in detail as part of the LNG Facility QRA described in *Section 18.4.2,* with hazard identification for shipping described in *Sections 18.4.3*, *18.4.4* and *18.4.5*. A detailed hazard identification for construction activities will be undertaken during the detailed design process, but a draft hazard identification process (HAZID) Word Diagram for construction activities has been prepared by the EPC contractor, and is provided in *Annex F* as an indicative overview of the nature and extent of construction hazards anticipated at this stage of the Project as well as potential management and mitigation measures.

18.4.2 LNG Facility QRA

A QRA has been performed for the LNG Facility by Quest Consultants Inc, of Oklahoma, USA.[11] Quest has extensive experience and expertise in risk assessment and with LNG projects worldwide. The methodology of this analysis was consistent with the requirements of *Australian/New Zealand Standard for Risk Management* (AS/NZS 4360:2004), which provides the following graphical summary of the process used for the LNG Facility QRA:

Figure 5.18.1 Summary of AS/NZS 4360:2004 Risk Management Process



The shaded area represents the risk assessment process, which can be either qualitative or quantitative. The Quest risk assessment was quantitative, and used risk criteria established originally by the New South Wales Department of Planning and adopted by Queensland to assess the suitability of the development.

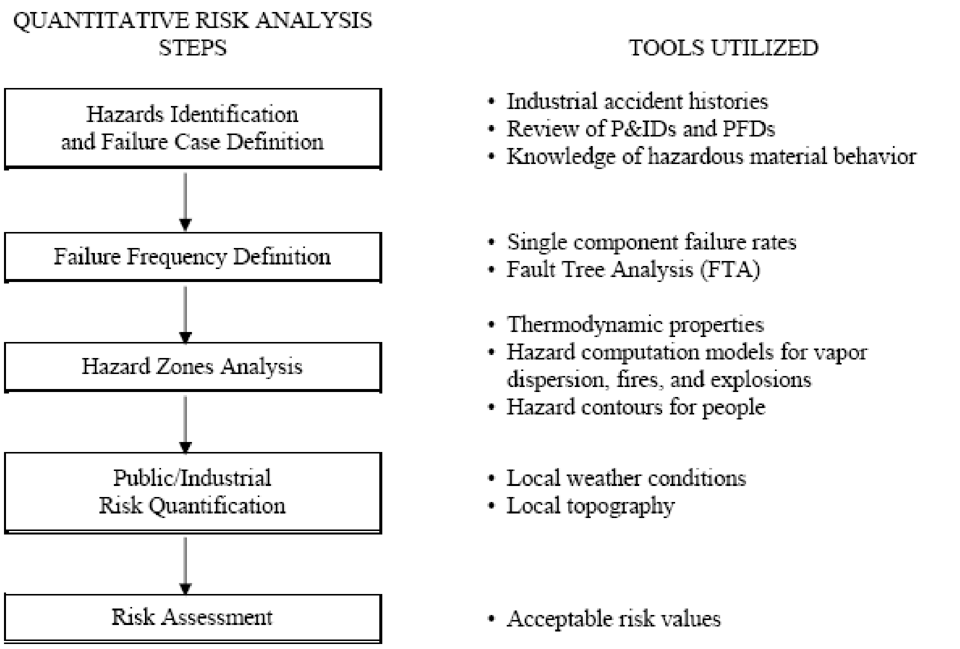
The QRA was based on the LNG Facility design data current at the time this EIS was prepared. However, given that detailed design is ongoing, the QRA is considered preliminary. It will be refined before the LNG Facility is constructed to ensure all appropriate risk reduction measures are incorporated into the design. A summary of the QRA methodology (including representative incident scenarios) and key findings is provided below. The full QRA contains

11 Quest Consultants Inc 2009. *Preliminary Quantitative Risk Analysis for the BG Queensland Curtis LNG Liquefaction Facility*

proprietary process data and has not been appended to this EIS.

The QRA process was broken down into a series of key tasks, as outlined in *Figure 5.18.2.*

Figure 5.18.2 QRA Risk Assessment Steps and Tools – Overview of Risk Analysis Methodology



18.4.2.1 Representative Incident Scenarios

A set of representative incident scenarios was determined, based on the current design of the LNG Facility and other public information related to the QCLNG export terminal along with knowledge of similar LNG facilities, applicable codes and standards, and good engineering practice. These scenarios include a range of the hazardous events that have some potential to occur in each area of the facility. In general, these events can be divided into the following categories:

1. small releases (leaks), characterised by a ¼ inch (6.35 mm) diameter hole
2. moderate releases (punctures), characterised by a 1 inch (25.4 mm) diameter hole
3. large releases (ruptures), characterised by a hole with a diameter equal to the pipe diameter or, for vessels and certain process equipment, a hole with a diameter equal to the diameter of the largest attached pipe
4. catastrophic failure of a vessel, characterised by a rapid release of its contents.

Potential releases of flammable or toxic gas, liquefied flammable or toxic gas, or flammable or toxic liquid were considered for each area or unit within the export terminal. For small, moderate, and large releases, each scenario was evaluated with consideration of the ESD systems included in the preliminary design. In the case where an ESD system is available, the normal flow of material is assumed to continue for no more than a set period of time (e.g. two minutes). In all scenarios, the release was allowed to continue until the available system mass was depleted.

18.4.2.2 Consequence Analysis

Each selected release scenario was evaluated to determine the extent and location of flammable or toxic vapour clouds; radiation from torch fires, pool fires, or a BLEVE fireball (Boiling Liquid, Expanding Vapour Explosion) (as applicable); and the extent of overpressures following a vapour cloud explosion.

Extent and location of flammable or toxic vapour clouds included an assessment of release of the inlet-air chilling (IAC) refrigerant, which for the purposes of the QRA was assumed to be propane. Detailed assessment of the IAC refrigerant is ongoing and subject to change during the detailed design process.

Release, dilution, and dispersion of gases and aerosols was modelled to determine potential exposure. The modelling package (CANARY by Quest®) contains a set of models that calculate release conditions, initial dilution of the vapour (dependent upon the release characteristics) and the subsequent dispersion of the vapour introduced into the atmosphere. The models contain algorithms that account for thermodynamics, mixture behaviour, transient release rates, gas cloud density relative to air, initial velocity of the released gas, and heat transfer effects from the surrounding atmosphere and the substrate. The release and dispersion models contained in the QuestFOCUS package (the predecessor to CANARY by Quest®) were reviewed in a United States Environmental Protection Agency (EPA) sponsored study[12] and an American Petroleum Institute (API) study.[13] In both studies the QuestFOCUS software was evaluated on technical merit (appropriateness of models for specific applications) and on model predictions for specific releases. One conclusion drawn by both studies was that the dispersion software tended to over predict the extent of the gas cloud travel, thus resulting in too large a cloud when compared to the test data (i.e. a conservative approach).

CANARY also contains models for pool fire and torch fire radiation. These models account for impoundment configuration, material composition, target height relative to the flame, target distance from the flame, atmospheric attenuation (including humidity), wind speed and atmospheric temperature. Both are based on information in the public domain (published literature) and have been validated with experimental data.

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12 TRC, 1991. *Evaluation of Dense Gas Simulation Models*. Prepared for the U.S. Environmental Protection Agency by TRC Environmental Consultants Inc, East Hartford, Connecticut 06108, EPA Contract No. 68-02-4399, May, 1991.

13 S.R. Hanna, D. G. Strimaitis and J. C. Chang, 1991. *Hazard Response Modelling Uncertainty (A Quantitative Method)*, Volume II, Evaluation of Commonly Used Hazardous Gas Dispersion Models. Study cosponsored by the Air Force Engineering and Services Center, Tyndall Air Force Base, Florida, and the American Petroleum Institute; performed by Sigma Research Corporation, Westford, Massachusetts, September, 1991.

18.4.2.3 Release Event Trees

For any single release from a vessel or piping system, several hazards may occur, depending on such factors as availability of ignition sources and the reactivity of the material (for overpressure potential). The chance that any single event will result from a release of material depends on these factors, as well as the extent of the release. For this work, the release was divided into three categories:

1. small releases (leaks), characterised by a ¼ inch (6.35-mm) diameter hole
2. moderate releases (punctures), characterised by a 1 inch (25.4-mm) diameter hole
3. large releases (ruptures), characterised by a hole with a diameter equal to the pipe diameter or, for vessels and certain process equipment, a hole with a diameter equal to the diameter of the largest attached pipe.

A typical release event tree is provided in *Figure 5.18.3*.

Figure 5.18.3 Example Release Event Tree for an LNG Release

	Hole Size	Ignition	Outcome
Release from Piping Containing LNG	Rupture	Immediate	Torch Fire/Pool Fire
		Delayed	Flash Fire/Torch Fire/Pool Fire/Vapor Cloud Explosion
		None	Dissipation
	Puncture	Immediate	Torch Fire/Pool Fire
		Delayed	Flash Fire/Torch Fire/Pool Fire/Vapor Cloud Explosion
		None	Dissipation
	Leak	Immediate	Torch Fire/Pool Fire
		Delayed	Flash Fire/Torch Fire/Pool Fire/Vapor Cloud Explosion
		None	Dissipation

18.4.2.4 Consequence Analysis

For each release identified, a number of consequence analysis calculations were performed. As an example, consider a release of LNG from the piping leaving a liquefaction unit and being sent to storage. This scenario has several potential outcomes, with the following hazards considered:

a. *Flash Fire Hazards Following Release from the LNG Line leaving a Liquefaction Unit*: The extent of the potential flash fire hazards is determined by the process conditions, hole size, wind speed, atmospheric stability, etc. For this analysis, the following parameters were held constant during the evaluation:

- relative humidity

- ambient air temperature
- surface temperature.

A release from the LNG line leaving a liquefaction unit is defined to be from one of three hole sizes: leak, puncture, or rupture. A range of possible wind speed/atmospheric stability combinations exist. A release from the LNG line has the potential to produce a vapour/aerosol cloud (momentum-dominated jet) and a pool of LNG on the ground (heavy gas cloud). Thus, for each hole size evaluated, a range of dispersion calculations to the lower flammable limit (LFL) must be made (two types of clouds multiplied by a range of weather conditions).

b. *Torch Fire and Pool Fire Radiation Hazards Following Release from the LNG Line Leaving a Liquefaction Unit:* The extent of the potential torch fire and pool fire hazards following a release from the LNG line leaving a liquefaction unit is determined by many of the same parameters that define the release rate for flash fire dispersion analysis. For torch fire and pool fire calculations, atmospheric stability is not an important parameter; thus, for each hole size, fewer thermal radiation calculations need to be made (one for each wind speed for immediate ignition and delayed ignition torch fires, and the same number for pool fires).

Vapour Cloud Explosion Overpressure Hazards

The extent of a potential explosion overpressure hazard zone is initially influenced by the same parameters as the flash fire hazard zones. Once a flammable cloud develops, it then requires an ignition source and some degree of confinement or congestion in order to develop significant overpressure. Areas within the LNG terminal that provide this congestion or confinement are referred to as potential explosion sites (PESs). A list of the PESs is provided in *Table 5.18.2* (note that the first seven entries in *Table* 5.18.2 are located in a liquefaction train, so occur once in each of the three trains.)

Table 5.18.2 Vapour Cloud Explosion Accident Scenarios

Scenario Number	Potential Explosion Site	Volume [m^3]
1	Refrigeration Structure	3205
2	Dehydration Process Area	3120
3	Acid Gas Removal Process Area	1510
4	Amine Regeneration Area	2745
5	Refrigeration Compressor Shelter: below the compressor deck	5835
6	Refrigeration Compressor Shelter: above the compressor deck	1935
7	Pipe Rack Area	3295
8	Power Generation Area	2220
9	Refrigerant Storage Area	4560
10	Inlet Air Refrigeration System	685

Hazards Associated with a Catastrophic Failure of the LNG Storage Tank

If an event were to occur that resulted in the failure of the inner tank and outer concrete shell of the full containment LNG storage tank (e.g., an earthquake of sufficient magnitude to cause a peak ground acceleration that would fail the tank), the potential for developing a large flammable vapour cloud would be solely dependent on the released material not being ignited immediately. It should be noted that the outer concrete tank will be designed to allow for worst-case design earthquakes and will have inherent resilience to earthquakes above those levels. The worst-case failure scenario is cracking or spalling of the tank. The flammable extent of an un-ignited cloud following a catastrophic release from one tank can extend approximately 4.5 km under worst-case conditions. In order for a flammable vapour cloud to extend as far as predicted, it cannot ignite before it reaches its maximum size. Once ignited, the hazard is due to a short-lived flash fire followed by heat radiation from a pool fire. It is difficult to imagine a catastrophic failure of a full containment LNG tank that would not result in immediate ignition of the released material. Furthermore, even if ignition did not occur immediately, the likelihood of the flammable cloud growing to its maximum extent would be extremely low since the cloud would encounter numerous ignition sources within the LNG Facility.

Hazards Associated with BLEVE Fireballs

A BLEVE is by definition a catastrophic failure of a pressure vessel that contains a superheated liquid. A fire-induced BLEVE has the potential to cause several types of hazards: vessel fragments propelled at high velocity, an overpressure wave (blast wave) near the initial location of the vessel and radiant heat from the resultant fireball.

The largest, most prominent BLEVE hazard is the fireball. The prediction of shrapnel hazards is imprecise, and site-specific. In general, only six to eight fragments of the shell are produced in a BLEVE. The impacts of the initial overpressure wave are typically limited to the area immediately surrounding the failed vessel. The QRA therefore included the radiant impacts of BLEVE fireballs only, assuming an ignition source at the time of vessel failure (i.e. a fire-induced failure).

Summary of Consequence Analysis Results

A total of 88 different flammable release scenarios and 13 IAC refrigerant release scenarios were analysed, covering all areas of the plant from the incoming gas feed line to LNG export, including import, storage, handling of spiking gas and the turbine inlet-air chilling system. The full risk analysis considered three different hole sizes for each case, with calculations for 19 combinations of wind speed and atmospheric stability, and 64 wind directions for each release.

18.4.2.5 *Accident Frequency*

The likelihood of a particular accident occurring within a specific time period can be expressed in different ways. One is to state the statistical probability that the accident will occur in a one-year period. This annual probability of occurrence can be derived from failure frequency databases of similar accidents that have occurred with similar systems or components in the past.

Due to the scarcity of accident frequency databases, it is not always possible to derive an exact probability of occurrence for a particular accident. Also, variations from one system to another (e.g. differences in design, construction, operation, maintenance or mitigation measures) can alter the probability of occurrence for a specific system. Therefore, variations in accident probabilities are usually not significant unless the variation approaches one order of magnitude.

As part of the QRA, accident frequency rates were derived for the following failure scenarios:

- piping failures
- gas transmission pipeline failure
- gasket failures (leak or rupture)
- valve failures (external leakage or rupture)
- pressure vessel failures
- heat exchanger failures
- pump failures (for rotating seals)
- compressor failures
- cargo transfer arm failures
- check valve failures
- insulated or refrigerated storage tank failures
- heat-induced BLEVE resulting from fire external to a pressure vessel.

Effects of non-continuous use of components such as tanks, pipelines and heat exchangers was also considered, and the annual probability of failure based on the number of hours a component would be used during the year.

Potential ESD system failure was also assumed. The ESD system might be activated automatically in response to hazard detectors (such as combustible-gas detectors or fire detectors), process alarms (such as pressure loss in a pipe) or an operator pushing an ESD button. Such systems typically have little effect on the failure rate of plant equipment since they normally operate only in response to a release, but they can affect the duration of the release, thereby affecting its consequences.

Hazardous Events Following Fluid Releases

A release of hazardous fluid to the atmosphere may create one or more hazardous conditions, depending on events after the release. For a flammable fluid, the possibilities are:

a. no ignition. If a flammable vapour cloud forms but never ignites, there is no hazard
b. immediate ignition. If ignition occurs near the beginning of the release, the hazard may be thermal radiation from a torch fire (pressurised release) or pool fire (non-pressurised release).
c. delayed ignition.

If there is a delay between the start of the release and ignition, a flammable vapour cloud will form. After ignition, there will be a vapour cloud fire (flash fire), possibly followed by a pool fire or torch fire. If the flammable vapour cloud is contained, or partially contained, within a confined or congested space, the vapour cloud deflagrates after ignition, producing local overpressure.

Each of these possibilities has some probability of occurring after a release. Consequences of the hazardous events that may occur after a release of hazardous fluid are also proportional to the extent of the release. Therefore, when calculating accident probability, it is necessary to estimate the distribution of releases by size.

The estimates used for hole size and ignition probability are best illustrated by event trees, with a release of fluid as the initial event. A typical event tree is provided in *Figure 5.18.4.* It begins with the release of gas from a compressor (such as the refrigeration compressors in the liquefaction trains). Moving from left to right, the tree first branches into three leak sizes, each being defined by the diameter (d) of the hole through which the fluid is being released. Each of these three branches divides into three branches based on ignition timing and probability. At the far right of the event tree are the nine outcomes that have some probability of occurring if the initiating release occurs. To arrive at the probability of a specific outcome, the overall failure rate is modified by the probability at each applicable branching of the event tree. The estimated annual probability of occurrence of each possible outcome, per metre of pipe, is listed on the event tree.

Similar event trees were constructed for all releases of flammable fluids from a range of pipe sizes, and for releases from pressure vessels and process equipment. The outcome probabilities from the event trees are combined with consequence outcomes in the risk mapping analysis.

Figure 5.18.4 Event Tree for a Release of Gas from a Compressor

	Hole Size	Ignition		Conditional Probability	Event Frequency per metre of pipe per year	Outcome
Release of gas from a compressor 6.35 x 10^{-2} failures/compressor/yr	Rupture 0.008	Immediate	0.27	0.0022	1.3176 x 10^{-4}	Torch/Pool Fire
		Delayed	0.03	0.0002	1.5240 x 10^{-5}	Flash/Torch/Pool Fire Vapor Cloud Explosion
		None	0.7	0.0056	3.5560 x 10^{-4}	Dissipation
	Puncture 0.050	Immediate	0.026	0.0013	8.2550 x 10^{-5}	Torch/Pool Fire
		Delayed	0.003	0.0002	9.5250 x 10^{-6}	Flash/Torch/Pool Fire Vapor Cloud Explosion
		None	0.971	0.0486	3.0829 x 10^{-3}	Dissipation
	Leak 0.942	Immediate	0.009	0.0085	5.3835 x 10^{-4}	Torch/Pool Fire
		Delayed	0.001	0.0009	5.9817 x 10^{-5}	Flash/Torch/Pool Fire Vapor Cloud Explosion
		None	0.99	0.9326	5.9219 x 10^{-2}	Dissipation

18.4.2.6 *Risk Quantification*

The risk posed by hazardous materials is often expressed as the product of the probability of occurrence of a hazardous event and the consequences of that event. In order to quantify the risk associated with hazardous fluids, it is necessary to quantify the probabilities of accidents that would release the fluids into the environment, and the consequences of such releases. The release frequencies and potential consequences must then be combined using a methodology that accounts for the influence of weather conditions and other pertinent factors.

A summary of risk quantification outcomes for the LNG Facility is provided below. Results are presented graphically as risk contours, where each risk contour is the locus of points where there exists a specific probability of being exposed to a fatal hazard, over a one-year period. The level of risk illustrated by a particular risk contour is the risk of lethal exposure to any of the acute hazards associated with many possible releases. Because the risk contours are based on annual data, the risk level for a given contour is the risk to an individual who remains at a specific location for 24 hours per day, 365 days per year. Risk contours define the summation of all hazard zones for all accident scenarios combined with all respective probabilities.

Where applicable, impact levels used were based on *Hazardous Industry Planning Advisory Paper No. 10 – Land Use Safety Planning* (2007) (HIPAP10). This guidance document is published by the New South Wales Department of Planning, and is a combination of two earlier guidance documents referred to as HIPAP4 and HIPAP6. The risk acceptability criteria set forth in the HIPAP documents have been adopted for use by Queensland[14].

Toxic Exposure Impacts

The proposed export terminal does not process, produce, store, import or export any acutely toxic materials. Thus, there are no potential toxic impacts associated with releases from the LNG terminal.

Heat Radiation Impacts

A composite vulnerability zone for radiant impact was prepared, with impacts assessed as defined by HIPAP (Table 5.18.3). A number of release scenarios, such as the loading lines, involve many potential release points. These cases create vulnerability corridors, which are combined with the vulnerability zones to produce the composite vulnerability zone for the entire facility. The vulnerability zones are produced by the largest credible rupture events identified in the LNG terminal.

Composite vulnerability zones at or above the radiant flux level of 4.7 kW/m2 (see *Table 5.18.3*) are fully contained within the boundary to the south, east and north, extending only beyond the site boundary into marine areas.

14 DES (2002), Queensland Department of Emergency Services, Chemical Hazards and Emergency Management Services unit. http://www.emergency.qld.gov.au/chem/publications/pdf/Interim_Risk_Objectives_for_MHFs.pdf

Table 5.18.3 HIPAP Defined Radiant Impact Levels

Radiant Flux Level (kW/m^2)	Defined Impact per HIPAP10
1.2	Received from the sun at noon in summer.
4.7	Will cause pain in 15-20 seconds and injury after 30 seconds exposure (at least second-degree burns will result). *This flux level not to be exceeded at adjacent residential areas more than 50 x 10^{-6} per year.*
12.6	Significant chance of fatality for extended exposure. High chance of injury. After long exposure, the temperature of wood rises to a point where it can be readily ignited by a naked flame. Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure.
23.0	Likely fatality for extended exposure and chance for fatality for instantaneous exposure. Spontaneous ignition of wood after long exposure. Unprotected steel will reach thermal stress temperatures which can cause failures. Pressure vessel needs to be relieved or failure will occur. *This flux level not to be exceeded at adjacent industrial areas more than 50 x 10^{-6} per year.*

Explosion Overpressure Impacts

Vulnerability zones, as defined by the HIPAP10 overpressure endpoints, were calculated as composite vulnerability zones for all nine PESs (potential explosion sites) selected for this study. All calculated overpressure levels as defined by HIPAP (see *Table* 5.18.4) for the LNG Facility fall within the onshore boundary.

Table 5.18.4 HIPAP Defined Overpressure Impact Levels

Overpressure Level (kPa)	Defined Impact per HIPAP10
3.5	90% 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. *This overpressure level not to be exceeded at adjacent residential areas.* *more than 50 x 10^{-6} per year.*
14	House uninhabitable and badly cracked. *This overpressure level not to be exceeded at adjacent industrial areas.* *more than 50 x 10^{-6} per year.*
21	Reinforced structures distort.

Overpressure Level (kPa)	Defined Impact per HIPAP10
	Storage tanks fail. 20% chance of fatality to a person in a building.
35	House uninhabitable. Wagons and plant items overturned. Threshold of eardrum damage. 50% change 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

Fatality and Injury Risks

The risk an individual is potentially exposed to by events that originate in the LNG Facility can be represented numerically. This measure represents the probability of an individual being exposed to a fatal hazard during a year-long period.

Table 5.18.5 Risk Level Terminology and Numerical Values

Numerical Value	Shorthand Notation	Chance Per Year of Fatality
1.0×10^{-3}/year	10^{-3}	One chance in 1,000 of being killed per year
1.0×10^{-4}/year	10^{-4}	One chance in 10,000 of being killed per year
1.0×10^{-5}/year	10^{-5}	One chance in 100,000 of being killed per year
1.0×10^{-6}/year	10^{-6}	One chance in 1,000,000 of being killed per year
1.0×10^{-7}/year	10^{-7}	One chance in 10,000,000 of being killed per year
1.0×10^{-8}/year	10^{-8}	One chance in 100,000,000 of being killed per year

HIPAP10 uses the following definitions of acceptable and unacceptable risk limits for new industrial installations located near residential developments:

- Risk levels lower than 1.0×10^{-6} per year are defined as acceptable for residential areas.
- Risk levels greater than 1.0×10^{-6} per year are defined as unacceptable for residential areas.

The HIPAP10 guidelines also define risk acceptability as a function of both the numerical risk value and the population at risk. Different acceptability criteria are defined based upon the composition of the potentially exposed population, and are summarised in *Table 5.18.6* below.

Table 5.18.6 HIPAP Suggested Individual Fatality Risk Criteria

Land Use	Suggested Criteria (risk in a million per year)
Hospitals schools, child-care facilities, old-age housing	0.5 (expressed as 0.5 x 10^{-6}/yr)
Residential, hotels, motels, tourist resorts	1.0 (expressed as 1.0 x 10^{-6}/yr)
Commercial developments including retail centres, offices and entertainment centres	5.0 (expressed as 5.0 x 10^{-6}/yr)
Sporting complexes and active open space	10 (expressed as 10.0 x 10^{-6}/yr)
Industrial	50.0 (expressed as 50.0 x 10^{-6}/yr)

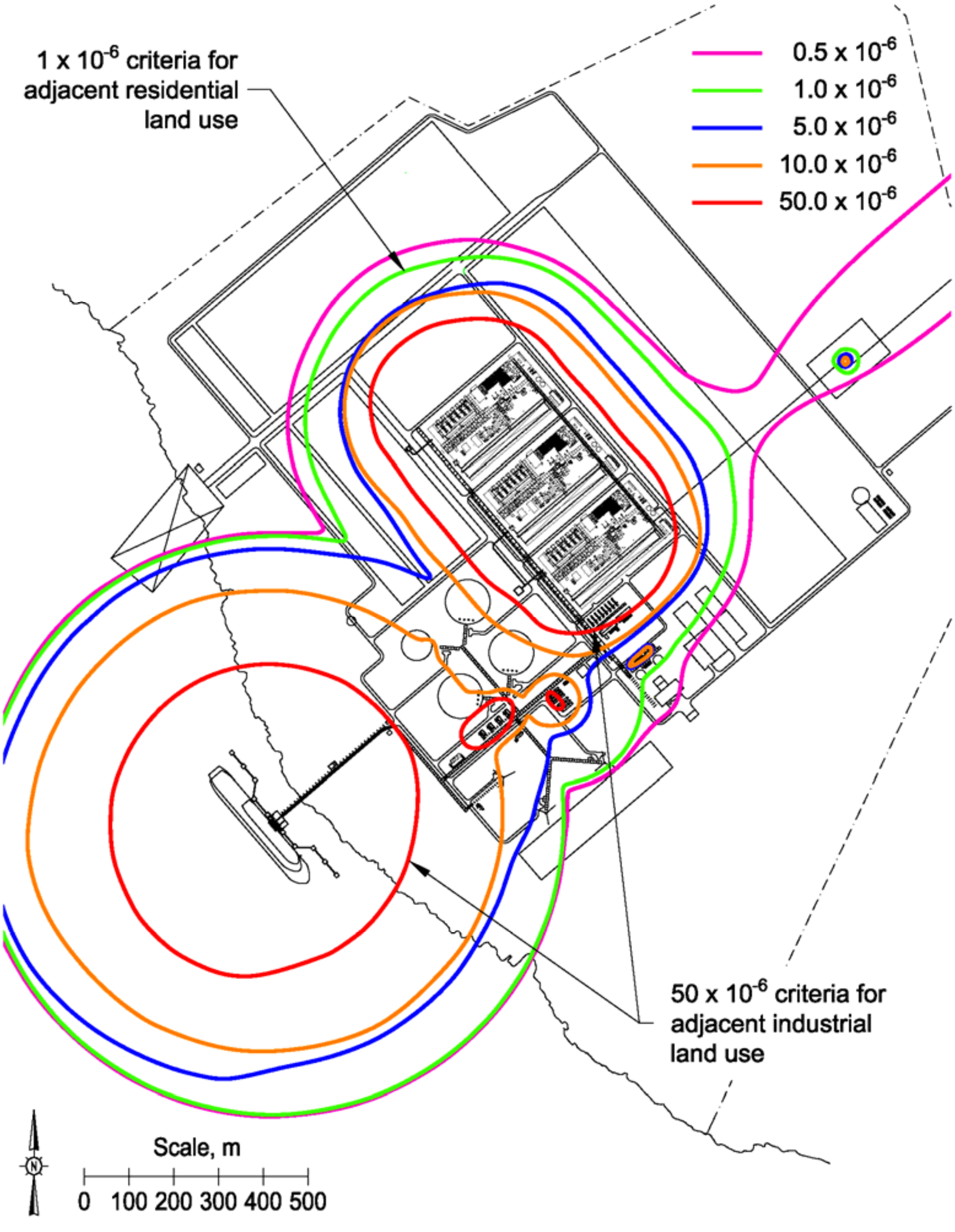
Figure 5.18.5 presents the risk contours (to the levels defined in the HIPAP guidelines) for the LNG Facility. Each contour illustrates the annual risk to persons in the area of the terminal as a function of their location, based on fatal exposure to any of the hazards associated with all releases originating within the liquefaction units, the associated natural gas inlet pipeline, product and refrigerant storage, the product export lines leading to the marine loading dock, and the LNG ship loading operations. For example, the contour labelled 10^{-6} in *Table 5.18.5* represents one chance in one million per year of being exposed to a fatal hazard from any of the possible releases of flammable or toxic material from the terminal. Because the risk contours are based on annual data, this level of risk depends on an individual being in the location where the 10^{-6} contour is shown 24 hours per day, 365 days per year.

From *Figure 5.18.5* it can be seen that:

1. Except for areas along the incoming gas pipeline, none of the risk contours extend into onshore areas beyond the facility property line.
2. In the areas along the pipeline affected by the 0.5 x 10^{-6} risk level, there are no public developments.
3. Except for areas offshore (surrounding the marine loading/unloading area), risk levels higher than 0.5 x 10^{-6} are contained within the facility property lines.
4. There is no potential impact to future neighbouring industrial sites because the 50 x 10^{-6} risk contour does not extend beyond any LNG Facility property line that can be built upon.

In summary, all the HIPAP risk criteria are satisfied by the layout and design of the LNG Facility. This is due to the low level of risk associated with terminals of this scale and design as well as the location of the terminal in an uninhabited area away from any residential development.

Figure 5.18.5 Risk Contours for the LNG Facility – HIPAP Risk Levels (Fatality Risk Per Year)



18.4.2.7 LNG Facility QRA Key Findings and Conclusions

The hazards and risks associated with the proposed LNG Facility are similar to those of other LNG export facilities worldwide. The design and location of the terminal result in public risk levels that are clearly acceptable by the HIPAP guidelines. In addition, when the vulnerability zones for the largest credible events associated with the LNG export terminal are overlaid on the proposed plot plan, the radiant and overpressure levels necessary to cause damage according to HIPAP10 guidelines have minimal impact on offsite areas.

Cumulative Risk

Currently there are no existing neighbouring industrial facilities on Curtis Island. However, QGC is aware of proposals by others to develop comparable industrial facilities, including LNG plants, on Curtis Island adjacent to the QCLNG Project's proposed LNG Facility. To date, no risk assessments of these other proposed facilities are available.

Regardless, examination of the risk contours presented in *Figure 5.18.5* shows that the criterion for industrial land use (50 x 10^{-6} pa) is contained within the site boundary (except along the coastal side of the site where contours extend into offshore (marine) areas), as is the more conservative criteria for hospitals, schools, child-care facilities and old-age housing (0.5 x 10^{-6} pa). This suggests no or minimal impact to the risk contours of other facilities from the QCLNG Project's proposed LNG Facility, assuming other facilities also meet the applicable risk criteria.

18.4.3 Shipping Risk Assessment – Berthing and Ship Loading

In addition to the LNG Facility QRA described above (which includes product lines to the LNG jetty and ship loading operations), Lloyd's Register[15] has performed a marine QRA assessing the LNG/LPG carrier berthing/unberthing and cargo transfer operations. This QRA includes hazard identification, consequence analysis, frequency and likelihood analysis, and risk analysis and assessment.

A summary of the Lloyd's *LNG Carrier Loading and LPG Unloading Safety QRA* methodology (including representative incident scenarios) and key findings is provided below. The full QRA contains proprietary data and has not been appended to this EIS.

The systems and operations assessed in the *LNG Carrier Loading and LPG Unloading Safety QRA* included:

- final berthing manoeuvres and initial un-berthing manoeuvres of the LNG/LPG carrier.
- the ship-to-shore interface (including the LNG/LPG liquid transfer arms and LNG vapour return lines). The first on-shore isolation valve marks the boundary of the study
- all LNG/LPG pipe work on the jetty
- all equipment on the LNG/LPG carrier that will contain LNG/LPG while the carrier is at the berth (e.g. cargo tanks, pipe work on deck, equipment in the cargo machinery room)
- for LNG/LPG carriers with Moss spherical design or GTT membrane design (see *Volume 5, Chapter 15*), the cargo tanks are included within the study boundary
- LNG loading and LPG off-loading operations that occur while the

15 Lloyd's Register, 2009. *LNG Carrier Loading & LPG Carrier Unloading Safety: Quantitative Risk Assessment of LNG/LPG Carriers at Berth at Gladstone Port* . unpublished report for BG LNG Services, Report # HOU/MCS/Q09-002 Rev. 2, March 2009

LNG/LPG carrier is at the berth

The scope of the QRA was defined by the following:

- only incidents involving a potential release of LNG and LPG were included
- accidents associated with a release of LNG and LPG from on-shore terminal facilities on the terminal side of the first on-shore isolation valve were excluded (risks associated with the LNG Facility on-shore were addressed through the LNG Facility QRA described in *Section 18.4.2*)
- consideration of direct fatality and injury risk for individuals on the jetty, LNG/LPG carrier and/or the shore (within or outside the port boundaries), including QGC personnel and non-QGC personnel within the port boundaries (including on the LNG/LPG carrier) and members of the public outside the port boundaries
- an assessment of the risk of property damage (e.g. on-shore facilities or the LNG/LPG carrier at the berth) is excluded from the scope of the QRA
- movement of the LNG/LPG carrier through the port to and from the berth is excluded from the scope of this QRA but has been addressed separately (see *Section 18.4.4*). Final berthing and initial un-berthing manoeuvres of the LNG/LPG carrier are included in the QRA, as there is a potential risk of allision with the jetty
- other vessels are never berthed at the same berth as the LNG/LPG carrier. Therefore, vessel-to-vessel incidents involving multiple berthed LNG/LPG carriers or non-LNG/LPG vessels (e.g. cross-connection of transfer arms, fire propagation between adjacent vessels, mooring failures leading to vessel-to-vessel impacts etc.) are excluded from the QRA
- incidents from intentional threats are excluded from the QRA. The likelihood of an intentional threat is very difficult to quantify
- emergency departures of the LNG/LPG carrier from the port and resulting sloshing of LNG/LPG in the cargo tanks are excluded from the QRA

18.4.3.1 Representative Incident Scenarios /Hazard Identification

A structured HAZID was undertaken to determine the representative major accident events (MAEs) for LNG/LPG carriers at the berth. A range of incident failure nodes was identified as summarised in *Table 5.18.7*.

Table 5.18.7 Incident Failure Nodes Identified in Ship Loading HAZID

Node	Description
1	Jetty and LNG/LPG carrier interface (includes interactions during transfer and berthing and un-berthing)
2	Pipe work on jetty (includes vapour and liquid pipes, valves, etc. from the first on-shore isolation valve to the PERCs on the transfer arm/s)
3	Transfer arm (includes vapour and liquid pipes, valves and hoses and PERCs to the connection point of the LNG/LPG carrier)
4	LNG/LPG equipment on board (includes all equipment on board that may result in an LNG/LPG release if it fails)

A range of potential incidents resulting in LNG/LPG release were assessed, including:

- release of LNG/LPG from a Transfer Arm (by overextension or failure of the arm due to carrier movement; incorrect connection, mechanical failure etc.)
- a release of LNG or LPG (liquid or vapour) from the jetty pipe work due to overpressurisation, mechanical failure, flange/fitting failures, valve gland leaks, external impact (e.g. vehicular traffic on jetty road)
- incidents on board, including overpressurations due to sloshing, overfilling during cargo loading, build-up of boil-off gas and material failure
- marine incidents causing LNG/LPG releases. Two types of marine incidents were identified which have the potential to cause an LNG/LPG release from the cargo tanks:
    - a vessel impact with the LNG/LPG carrier while it is at the berth
    - LNG/LPG carrier allision with the jetty during berthing or unberthing.

Both of these marine incidents are unlikely to result in a loss of containment from the cargo tanks due to the double hull design of the LNG/LPG carrier. Prior studies indicate that breaching of the cargo tanks does not occur until impact velocities exceed approximately 6 to 7 knots for large vessels (30,000+ dead-weight tons). For small vessels such as pleasure craft, the kinetic energy is insufficient to penetrate the inner hull of a double hull vessel such as an LNG/LPG carrier.

Low speed allision with the jetty (e.g. due to mooring failure or tidal conditions) is not a credible cause of a release of LNG/LPG from the cargo tanks. Normally the LNG/LPG carrier approaches the berth at 0.2 to 0.3 knots, much less than the 6 to 7 knots required to cause penetration of the cargo tanks. Therefore, a significant loss of control would be required before a sufficiently high speed allision could occur during final berthing or unberthing manoeuvres.

On the basis of these and other potential incidents, the following MAE scenarios were identified:

Table 5.18.8 MAEs Identified in Ship Loading HAZID

MAE	Description
1	Release of LNG/LPG (liquid) from transfer arm failure
2	Release of LNG/LPG (liquid) from jetty pipe work leakage
3	Release of LNG (vapour) from a transfer arm failure or leakage
4	Release of LNG/LPG (liquid) from vessel hull leakage
5	Release of LNG/LPG (liquid) from a transfer pipe leakage or rupture on jetty
6	Release of LNG (vapour) from vapour jetty pipe leakage or rupture
7	Release of LNG/LPG (liquid) from equipment and piping on deck from leakage or rupture
8	Release of LNG/LPG (vapour) from equipment and piping on deck from leakage or rupture
9	Release of LNG/LPG (vapour) from equipment and pipe work in enclosed areas

18.4.3.2 *Consequence Analysis*

The consequences and likelihood of representative LNG/LPG releases were estimated for each MAE with due consideration of the installed safety systems.

For the MAEs described, a range of potential hazards arise, including:

Exposure to Cryogenic Liquid

LNG and LPG are liquid at atmospheric pressure below -162 ºC and -42 ºC respectively. At these temperatures, LNG and LPG form clear, colourless liquids with a density about half that of water. Due to their low temperature, LNG and LPG can cause severe cryogenic burns to exposed skin.

For the QRA, the potential for fatality was considered wherever direct exposure to a liquid release might occur.

Rapid Phase Transition

There may be a rapid change of phase (from liquid to vapour), when low temperature LNG or LPG (liquid) is released onto warmer water. The corresponding increase in volume (a 600-fold and 300-fold increase for LNG and LPG respectively) can lead to rapid phase transition (RPT) explosion and potentially hazardous overpressure.

No flame is associated with an RPT and the overpressure is localised. Damaging overpressures only occur very close to the source and vapour ignition has never been observed. The effects of RPT explosions were not included in the QRA.

Asphyxiation

The main constituents of LNG (methane) and LPG (propane for the purposes of the QCLNG Project) are classified as simple asphyxiants with low toxicity to humans. For the QRA, the potential for fatality was only considered for persons located within a large pool of unignited liquid LNG.

Jet Fire

Combustion of LNG/LPG vapour released from an orifice (e.g. hole in a pipe) may create a jet fire. For LNG/LPG carriers, where the LNG/LPG is stored at relatively low pressure, this type of fire is unlikely to occur except during cargo transfer operations, when pumping increases the pressure. The potential for fatality due to exposure to heat radiation from a jet fire was included in the QRA.

Pool Fire

If ignited, LNG/LPG liquid released from an orifice (e.g. hole in a pipe) onto the ground or onto water may result in a pool fire. The potential for fatality due to exposure to heat radiation from a pool fire was included in the QRA.

Flash Fire

Methane is flammable between concentrations of approximately 5.3 per cent (Lower Flammability Limit [LFL]) and 14 per cent (Upper Flammability Limit [UFL]) by volume when mixed with air. For fuels such as LNG and LPG, combustion of an unconfined gas cloud will usually progress at low velocities and will not generate a significant overpressure. Ignition of the gas cloud will cause the vapour to burn back to the spill source. This is a flash fire and only has the potential to injure individuals within the ignited gas cloud. The potential for fatality due to direct exposure to a flash fire was included in the QRA.

Vapour Cloud Explosion

The potential for fatality due to exposure to overpressure from a LNG (methane) or LPG (propane) vapour cloud explosion was not included in the QRA due to the lack of confinement that could cause an explosion.

18.4.3.3 Frequency Analysis

The likelihood of each representative LNG/LPG release scenario was estimated using:

- generic historical frequency data modified to reflect the operations and controls at the port facility
- parts count data, including pipe lengths and the number of transfer arms for a typical LNG/LPG carrier. The number of cargo transfer operations (although not strictly a parts count) is also relevant as this was used to determine annual likelihood where the base failure rate data is reported per operation.

The likelihood of each potentially hazardous outcome (i.e. jet fire, pool fire, etc.) was then estimated using event tree analysis and representative ignition probabilities.

18.4.3.4 Ship loading QRA Key Findings and Conclusions

Based on a review of hazards, consequence and frequency of the following outcomes, the risks associated with the berth loading and unloading meet the injury risk criterion of 50 in a million at residential areas. The risks also meet the fatality risk criteria of 0.5 in a million at sensitive land uses, one in a million at residential areas, 10 in a million at commercial areas and 50 in a million at (potential) neighbouring industrial facilities.

The group risk of accidents during the transfer operations affect predominately the personnel on the ship and jetty who are controlling and monitoring the transfer. The risk to people located in the LNG plant and the support tug are much lower. The risks fall within the As Low As Reasonably Practicable (ALARP) region.

In summary, the location proposed for the LNG/LPG berth meets the risk criteria because it is sufficiently distant from other land users and the controls on the risks are sufficiently strong.

18.4.4 Shipping Risk Assessment – Transit of Port of Gladstone

In addition to the QRAs described above, Lloyd's Register[16] has assessed the hazards and risks associated with an LNG tanker transiting the Port of Gladstone to and from the proposed berths on Curtis Island.

A summary of the Lloyd's *Gladstone Port LNG Ship Transit Risk Assessment* methodology (including representative incident scenarios) and key findings is provided below.

An assessment of potential impacts on marine biota arising from some of the incident scenarios described below is provided in *Volume 5, Chapter 8*.

18.4.4.1 Ship movements and Incidents in Port of Gladstone

The forecast number of total vessel visits to Gladstone between 2008 and 2012 is 1450 per year (Port of Gladstone, 2009) with an average size of 67,000 tonnes. Using a frequency of 1.84 x 10^{-3} per vessel visit gives a predicted likelihood incident occurrence of two to three per year for all ships.

There have been four significant incidents in Gladstone since 2002:

1. Grounding of La Pampa in 2002
2. Collision between Global Peace and Tom Tough in 2006
3. Grounding of Endeavour River in 2007
4. Grounding of Grain Harvester in 2007.

18.4.4.2 Representative Incident Scenarios /Hazard Identification

A systematic HAZID exercise of different failures of equipment, people and processes for port transit and berthing was conducted. The methodology was comparable to the concepts behind the UK's Control of Major Accident Hazards (COMAH). The intention was to rigorously examine all credible scenarios and accidental events that might arise during the operation of the Project. The scenarios identified in *Table 5.18.9* were assessed for nine principle nodes:

1. anchorage (including approaching anchorage and anchoring in position)
2. pilot boarding and disembarkation
3. south Channel (inbound and outbound)
4. Gatcombe (inbound and outbound)
5. Auckland Channel and Clinton Bypass Channel (inbound and outbound)[17]
6. swinging vessel
7. berthing vessel

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16 R. Hutchison, 2008. *Gladstone Port LNG Ship Transit Risk Assessment.* Unpublished report by Lloyd's Register for NG LNG Services Ltd, Report No. NAO0800507-01 Revision 3, ,

17 Following assessment of the Auckland channel node, remaining channels and the swing basin were not considered to have any additional scenarios to those already considered.

8. unberthing vessel – normal operation
9. unberthing vessel – emergency operation.

Table 5.18.9 Scenarios Assessed for Port Transit and Berthing

Shipping hazard scenarios	
Steering	Propulsion
Pilot errors	Large vessel nearby
Small vessel nearby	Channel depth – sedimentation
Channel width	Channel bends
Pipelines and cables	Shoals
Anchorage and mooring	Tidal levels
Currents	Waves
Winds	Poor visibility
Electrical failure	Berthing aid failure
Tugs	Natural hazards – cyclone
Impact to fixed structure	Intentional acts
Human factors	Future development in the port
Pilot transfer	Bunkering/stores
Fire on berth	

Based on these scenarios, 18 incident scenarios were identified that had a significant or very significant risk. The main incidents raised were associated with the potential for equipment failure or human error to result in the LNG/LPG ship grounding or striking one of the ships berthed along the route through the Port of Gladstone.

18.4.4.3 Frequency Analysis

The likelihood of each of these scenarios was examined in more detail due to the potential consequences of occurence. Estimation of the likelihood of such scenarios is difficult to undertake with certainty. Nevertheless, the historical record of such incidents, both in Gladstone and internationally, can be used to develop likelihood estimates.

The frequency of an incident in a wide river/narrow estuary port like Gladstone is 1.84×10^{-3} per vessel[18]. This incident frequency is based on information supplied by ports in Great Britain and covers 75 per cent of the total commercial traffic in Great Britain. The type of incidents covered in the study was defined as: “any untoward event within the jurisdiction of the port authority that caused (or might well have caused) either injury to people or non-trivial damage to the fabric of the port or the ship, or non-trivial pollution”.

18 AEA Technology 1996, *Marine Incidents in Ports and Harbours in Great Britain 1988-1992*, Report prepared for Health and Safety Executive, March 1996.

This includes grounding, allision (with a fixed structure such as a berth), collision (with another vessel under way) and striking (another vessel that is not under way, e.g. anchored or berthed).

Although the incident rate given by the UK data is low, it may overestimate the likelihood of incidents involving LNG carriers. LNG carriers are generally better maintained and operated than other shipping, including passenger ships. According to the Canadian Gas Association[19], gas carriers have the lowest detention rate (as a percentage of inspections) of all ship types. A lower detention rate indicates the vessel's navigational systems, maintenance and crew training are more likely to be in line with class, governmental and other compliance requirements. In 2004 the gas carrier detention rate was 1.95 per cent, compared with 3.9 per cent for passenger ships/ferries and 5.84 per cent for all ship types.

If the ratio of incident rates for LNG carriers to the incident rates for all ships is assumed to be proportional to the ratio of gas carrier to all ship detentions (1.95 per cent divided by 5.84 per cent), the frequency of an incident in Gladstone can be seen to be one-third of the incident rate for all ships.

The Port of Gladstone is characterised as a wide estuary. The frequency of incidents for different port types is shown in

Table 5.18.10.

Table 5.18.10 Incident Frequencies for Different Types of Ports

Port type	Collision per encounter	Grounding per km	Striking per passing	Impact per visit
Open sea port	5.0 x 10-4	6.5 x 10-5	4.0 x 10-6	2.2 x 10-3
Wide estuary	**4.0 x 10-5**	**8.0 x 10-6**	**4.0 x 10-6**	**2.2 x 10-3**
Wide river	1.2 x 10-4	1.6 x 10-5	9.0 x 10-6	2.1 x 10-3
Narrow river	5.0 x 10-4	6.5 x 10-5	4.2 x 10-5	6.5 x 10-3

Taking into consideration the following features of the Port of Gladstone, the incident frequencies were estimated as incidents per LNG carrier visit. The features relevant to the estimation of LNG carrier incident frequencies are:

1. a 12km entry/exit return journey from Fairway Buoy to the Swing Basin. In the Port of Gladstone, the LNG carrier is constrained within channels. If the ship loses directional control, it is most likely to ground on the side of the channel before it collides with another ship or strikes a berth or other fixed object. Therefore, it is appropriate to assume that the impacts that occur during inward and outward journeys are only grounding incidents. The clay-based substrate on the bottom of the Port of Gladstone further reduces the likelihood of any containment loss in the event of grounding.
2. smaller ships using the shallower Golding channel at the same time as LNG vessels use the deeper channel. This affects the potential for

19 Canadian Gas Association, Liquefied Natural Gas, Fall 2005, http://www.cga.ca/publications/documents/CGAUnderstandingLNGfall2005update.pdf

collision between these ships but the separation of the channels is assumed to reduce the likelihood of collision.

3. the potential for striking is based on the distance from the shipping channels and the locations where ships could be anchored or berthed. It is assumed that only one ship at anchor or berth will be close to the LNG carriers every 10 visits.
4. the incident rates for LNG carriers are only one-third of those for all ships, based on detention rates.

The port transit incident frequency estimates are provided in *Table 5.18.11.*

Table 5.18.11 Estimate of Incident Frequencies for the Port of Gladstone

Collision per visit	Grounding per visit	Striking per visit	Impact per visit
2.7×10^{-5}	2.1×10^{-4}	1.3×10^{-7}	5.6×10^{-4}

Given this, the likelihood of grounding during a LNG carrier visit is estimated to be 2.1×10^{-4} per visit to the port. This estimate is considered to be an upper bound of the actual grounding likelihood due to the following factors:

1. The historical groundings of all ships has been close to this rate in the Port of Gladstone and LNG carriers have a much lower incident frequency than all ships.
2. Port procedures and management systems have improved over the period that the historical data was collected.
3. Ship instrumentation including radar and other position-locating devices have improved significantly over the period that the historical data was collected.

In addition, the history of LNG shipping shows that releases of LNG are extremely rare and have only occurred during cargo loading. No releases of LNG have occurred during transit through ports.[20,21] One LNG carrier, the El Paso Paul Kayser, grounded at full speed on rocky seabed, extensively damaging its outer hull. However, due to its double-hull construction, there was no loss of containment.

The small rate for shipping incidents such as grounding or striking a fixed object is still significantly higher than the likelihood of a release of LNG from such an incident. The great majority of incidents will involve damage to the hull or equipment of the carrier but the interior tanks will not be affected.

It is conservatively assumed that 1 per cent of all incidents would result in a loss of containment of LNG. Thus, the likelihood of an incident resulting in a release of LNG is less than 2.1×10^{-6} per carrier visit.

20 http://www.coltoncompany.com/shipbldg/worldsbldg/gas/lngcaccidents.htm11/17/2006 12:53:50 PM

21 Testimony of J. Mark Robinson, Director Office of Energy Projects, before the Transportation and Infrastructure Subcommittee on Coast Guard and Maritime Transportation, U.S. House of Representatives Hearing on Safety and Security of Liquefied Natural Gas, May 7, 2007, p. 24ff.

18.4.4.4 *Bunker Fuel Oil Spill*

It is possible that some older carriers without double hull protection of the fuel bunker may operate in the early stages of the Project. Given the small number of possible voyages over the first five years of terminal operation, the likelihood of a bunker spill is almost the same as a cargo tank breach.

Therefore, the likelihood of an incident resulting in a release of bunker fuel is lower than 2.1×10^{-6} per LNG vessel visit. Potential consequences of a bunker spill on marine biota are discussed in *Volume 5, Chapter 8*.

18.4.4.5 *Key Findings and Conclusions*

The overall conclusion of the ship transit risk assessment includes the following:

- The overall set-up at the Port of Gladstone is extremely safe, with navigation features, support systems and redundancy all contributing towards a low risk of an incident during transit.
- There are a number of hazards with potential for a major incident should there be a lack of sufficient control in managing the transit of a LNG carrier to the berth. Key hazards include the passage through the Outer Channel, transit past other facilities at Auckland Point and other berths, and interaction between the LNG carrier and support vessels during transit.
- The route through the port meets industry criteria for channel draught, angles of turn and turning basin even for large beam LNG carriers. It should be noted that the largest vessels on this route through the port are not LNG carriers.
- A high level comparison with industry criteria determined that the channel width was less than recommended. However it is accepted that specific modelling of transit through the port can provide acceptable specific requirements for channel width. A reduced channel width is acceptable given a scenario specific risk assessment and implementation of appropriate mitigation measures. Such an assessment and demonstration of acceptability is being undertaken as part of the shipping simulation studies being undertaken, and is also being addressed through potential channel expansion as outlined in *Volume 6*.
- The quantitative assessment of all incidents (such as a collision, grounding, allision, capsizing, sinking or exposure to specific hazardous conditions) occurring during the transit shows that the likelihood is extremely low – less than 2.1×10^{-4} per carrier visit. The likelihood of an incident resulting in a release of LNG or bunker fuel spill is even lower – less than 2.1×10^{-6} per carrier visit.

18.4.5 Shipping Risk Assessment – Transit of GBRMP

Lloyd's Register[22] has assessed the hazards and risks associated with a LNG

22 Lloyd's Register, 2009. *Transit Risk Study for LNG and LPG Ships Passing Through Water In and Near the Great Barrier Reef*. Unpublished report by Lloyd's Register for BG LNG Services Ltd, Report No. HOU/MCS/Q09-001 Rev. 2, March 6, 2009

carrier transiting to and from Gladstone to the Coral Sea and Torres Strait.

A summary of the Lloyd's *Transit Risk Study for LNG and LPG Ships Passing Through Water In and Near the Great Barrier Reef* methodology (including representative incident scenarios) and key findings is provided below.

An assessment of potential impacts on marine biota arising from some of the incident scenarios described below is provided in *Volume 5, Chapter 8*.

A review of the shipping route, environmental conditions and shipping activities in and around the waters of the GBRMP and Torres Strait was carried out and is summarised in *Volume 5, Chapter 15*.

18.4.5.1 Shipping Incidents

Recent studies on ship transit identified a number of incidents, mainly collision and groundings. These incidents have also been reported in incident databases of the Australian Transportation Safety Board (ASTB) covering a period from 1982 to December 2008 (Marine Transport Safety Investigation, 2008). *Table 5.18.12* provides a summary of incidents for the GBRMP, Torres Strait and outer route/coral sea areas for the period from 1985 to 2008.

Table 5.18.12 Summary of Incidents in the GBRMP and Torres Strait

Type of Incident	Area		
	GBRMP	**Torres Strait**	**Outer route/ Coral Sea**
Collision	16	-	-
Grounding	12	9	1
Other	-	2*	2**
Total Incidents	28	10	4
*1 equipment failure, 1 founder			
**1 cargo shift, 1 man overboard			

Based on these statistics, the frequencies of collision and grounding incidents for all vessels have been estimated at $9.88x10^{-5}$ per ship year and $1.35x10^{-4}$ per ship year, respectively. It is noted that the majority of incidents occurring in the GBRMP take place in the inner route.[23]

Based on the history of shipping movements and incidents, the transit study focused mainly on the incidents that could result in the accidental release of LNG/LPG cargo, bunker fuel and ballast water into the GBRMP environment and the impact such releases will have on the environment.

18.4.5.2 Representative Incident Scenarios /Hazard Identification

A systematic hazard identification exercise (HAZID) of different failures of

23 *Ibid*.

equipment, people and processes for the ship transit was conducted. The methodology used is comparable to the concepts behind COMAH (UK's Control of Major Accident Hazards).

The purpose of the HAZID was to apply a rigorous format of examination to all credible scenarios and accidental events that might arise during the operation of the Project. A range of scenarios (including presence of whales/whale strike, and terrorist activities) were assessed for three key sectors of the route:

1. Fairway buoy to outer route via Capricorn Channel or Curtis Channel
2. Torres Strait
3. outer route.

Nine incident scenarios were identified that had a significant or very significant risk. The main incidents raised were associated with the potential for equipment failure or human error to result in the LNG/LPG ship grounding or collision with other passing ships, including large ships and fishing/recreational vessels. The impacts of these incidents included releases of bunker fuel to the environment, introduction of foreign organisms into waterways from lost ballast water, physical reef damage and in each case the consequential impacts on the culture of Torres Strait islanders and tourism.

18.4.5.3 Frequency Analysis

A summary of the frequency analysis for a range of consequences is provided below. Discussion of potential impacts on marine biota is provided in *Volume 5, Chapter 8*.

Collisions and Groundings

Based on an analysis of the frequency of LNG/LPG shipping collisions and groundings worldwide and in the GBRMP relative to the total number of LNG ship movements over the same period, frequency estimates for proposed LNG/LPG shipping in GBRMP have been made (see *Table 5.18.13)*

Table 5.18.13 Frequency Estimates for Proposed LNG/LPG Shipping

Incident	Estimated Frequencies for Proposed LNG/LPG Ship Transit
	LNG/LPG Ships (per ship year)
Collision	1.98×10^{-5}
Grounding	2.70×10^{-5}

The likelihood of a grounding or collision resulting in a cargo release depends on the susceptibility of the cargo tank location to rupture, which in turn depends on whether the construction is single or double hull. A single hull is more prone to rupture than a double hull during grounding or collision.

Likelihood of LPG/LNG release per collision or grounding effect was estimated as summarised.in *Table 5.18.14*.

Table 5.18.14 Likelihood of LNG/LPG Release per Collision/Grounding Incident

Incident	Estimated Likelihood of LNG/LPG Release (per collision/grounding incident)	
	Single Hull	Double Hull
Major Release (75 m^3 in 30 mins)	0.1	1.5×10^{-4}
Minor Release (20 m^3 in 30 mins)	0.2	6.0×10^{-3}

Using these likelihood values, the frequencies of potential major and minor cargo releases due to collision and grounding events were estimated as the products of the rupture likelihoods and the incident (collision or grounding) frequencies and are shown in *Table 5.18.15*.

Table 5.18.15 Frequency of Potential Release of LNG/LPG Due to Collision and Grounding Incidents

Incident	Estimated Frequencies for Release of LNG/LPG (per ship year)	
	Single Hull	Double Hull
Major Release due to Collision	1.98×10^{-6}	2.97×10^{-9}
Minor Release due to Collision	3.96×10^{-6}	1.19×10^{-7}
Major Release due to Grounding	2.70×10^{-6}	4.05×10^{-9}
Minor Release due to Grounding	5.40×10^{-6}	1.62×10^{-7}

The frequency of release of LNG/LPG cargo due to collision or grounding is estimated to be up to 5.40×10^{-6} per ship year for single hull vessels and less than 1.62×10^{-7} per ship year for double hull vessels. It is noted that the frequencies for release of cargo from double hull LNG/LPG carriers are at least one order of magnitude lower, showing the benefit of double hull construction.

18.4.5.4 Bunker Fuel Oil Release

All BG Group ships have double-hull protection around the forward and aft bunker fuel tanks. However, on some LNG carriers around 30 years old, the engine room bunker fuel tanks are not within the double hull. These older BG Group vessels will no longer be carrying BG Group cargo by the time QCLNG Project's proposed LNG terminal starts operations. Given the present age of these vessels, they are expected to disappear from the world fleet entirely during the first five years of the terminal's operations. However, in the event that a cargo is sold freight on board and the buyer uses one of these older vessels or an LPG carrier without double-hull protection of the bunker fuel tanks, an assessment of bunker fuel release has been undertaken.

Given the small number of possible voyages over the first five years of terminal operation using the older LNG carriers, the likelihood of a bunker spill is almost the same as a cargo tank breach. The likelihood of a collision or grounding incident resulting in a release of bunker fuel is approximately 5.40×10^{-6} per ship year for single hull LNG/LPG vessels and approximately 1.62×10^{-7} per ship year for double hull LNG/LPG vessels.

18.4.5.5 Ballast Water Release

Frequent visits of vessels from international ports increases the potential for introduction of undesirable exotic species and sediments into the ecosystem from ballast water, and vessels employed in QCLNG Project operations will comply with Australian Quarantine Inspection Service (AQIS)[24] mandatory ballast water management requirements for vessels engaged in international shipping.

Unplanned introduction of ballast water from a LNG carrier and or LPG carrier can result from penetration of the ballast tank due to grounding or collision. The likelihood of a collision or grounding incident resulting in a release of ballast water into the environment is estimated to be lower than 5.40×10^{-6} per ship year.

18.4.5.6 Whale Strike

The Queensland Department of Environment and Resource Management (DERM) (formerly the Environmental Protection Agency (EPA)), maintains a marine wildlife stranding and mortality database that summarises the temporal and spatial distribution of injured, moribund and dead marine wildlife in Queensland. From this database, accidents and death involving whales and ships have been examined based on the frequency per year.

From the table it is seen that the level of ship strikes causing whale fatalities in Queensland is very low, the frequency of occurrence being approximately 3.16×10^{-4} per year.

18.4.5.7 Summary

The transit risk analysis and assessment has indicated that:

- The overall outer route to be used is extremely safe, with navigational features, support systems, rules, guidelines, control measures and redundancy all contributing towards a low risk of an incident during transit.
- There are a number of hazards with potential for a major accident should there be a lack of sufficient control in managing the transit. Key hazards are centred on collision and grounding. Accidents could potentially result in release of cargo, bunker fuel or ballast water, which could cause severe environmental damage and or impacts to the island communities and to tourism.

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24 Department of Agriculture, Fisheries and Forestry (2008) Australian Ballast Water Management Requirements. Version 4 – March, 2008. www.aqis.gov.au

- The quantitative assessment of the main accident incidents – grounding, collision, whale/ship strike – occurring during transit show that the likelihood of any of these events is extremely low. Given the occurrence of a collision or grounding incident, the likelihood of cargo, bunker fuel or ballast water release is estimated as 5.4 $x10^{-6}$ per ship visit for single hull vessels and 1.6 $x10^{-7}$ per ship visit for double hull vessels.
- The frequency of ship strikes with whales in the GBRMP and Torres Strait is very low – an estimated $3.16x10^{-4}$ per year.
- Even though the likelihood of release of bunker fuel for single hull ships is low, the use of double hull protection reduces the likelihood further by an order of magnitude.

18.5 BUSHFIRE HAZARD ASSESSMENT

A bushfire hazard assessment has been undertaken to assess the potential hazard of bushfire to the LNG Facility and to summarise management and mitigation measures.

This assessment includes the provision of management measures to be implemented as part of the proposed development and has been prepared in accordance with *Appendix 3* of *State Planning Policy Guideline 1/03* (Queensland Department of Local Government and Planning 2003).[25]

18.5.1 Context

18.5.1.1 Climate

Climatic conditions applicable to the LNG Facility are described in *Volume 5, Chapter 2*.

18.5.1.2 Bushfire Regimes

Subtle variations in the timing of bushfire season occur across Queensland. In south-east and central Queensland, bushfires typically occur during dry spring conditions (Australian Institute of Criminology [AIC] 2008)[26]. Fire regimes also vary in terms of size and frequency. The tropical savannas of northern Queensland are characterised by frequent large burns, with little impact to native flora and fauna. In contrast, rainforests along the east coast of Queensland are sensitive to fire and a bushfire in these regions may have disastrous consequences for biodiversity. Between these areas lie *Acacia* scrublands and woodlands of southern central Queensland and eucalypt open forests on the coastal plains and ranges, where bushfires are less frequent

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25 Queensland Department of Local Government and Planning (2003) Mitigating the Adverse Impacts of Flood, Bushfire and Landslide. Queensland Government Department of Local Government and Planning, and Queensland Government Department of Emergency Services, Queensland Australia.

26 Australian Institute of Criminology (AIC) 2008 Australian Institute of Criminology (2008) Understanding Bushfire: Trends in Deliberate Vegetation Fires in Australia by Colleen Bryant. Available online: http://www.aic.gov.au/publications/tbp/tbp027/

than in the savannas (AIC 2008).

18.5.1.3 *Fire Services*

Three major agencies provide fire services in Queensland. They are the Queensland Fire and Rescue Service (QFRS), Forestry Plantations Queensland (FPQ) and the Queensland Parks and Wildlife Service (QPWS).

The Queensland Rural Fire Service (QRFS) is a distinct body within the QFRS that provides fire services in 93 per cent of the state. The QRFS's jurisdiction is principally within regional, rural and remote areas, where the population density is comparatively low. There are about 1,550 rural fire brigades, with approximately 41,000 volunteers, and a warden network of 2,445. Although its jurisdiction lies outside that covered by land management agencies, the QFRS (including the QRFS) will attend fires in those areas and vice versa (AIC 2008).

FPQ is responsible for hazard-reduction and fire-response capability for the forests under its management.

The QPWS falls under the umbrella of the DERM and provides fire management for an estate of nearly 12 million hectares. These lands are primarily protected areas such as national parks state forests under joint management with commercial forest agencies. QPWS fire management includes involvement in planned burning for ecological and hazard reduction purposes and wildfire response.

18.5.1.4 *Bushfire History*

Queensland sustains greater losses from cyclones and floods than from bushfires. However, several bushfires have resulted in loss of life and property and large areas have been burned without extensive loss of life or property.

In data analysed by the AIC (2008), less than 2 per cent of vegetation fires in Queensland occurred in state forests, national parks, and conservation and forest reserves. Most documented vegetation fires occurred near major urban centres, about half in the Brisbane region.

18.5.2 *Legislative Context*

18.5.2.1 *State Planning Policy 1/03*

The State Planning Policy (SPP) *Mitigating the Adverse Impacts of Flood, Bushfire and Landslide*[27] is a statutory instrument under the provisions of the *Integrated Planning Act 1997* (IPA) (Qld). The SPP was developed to facilitate consideration of the adverse impacts of flood, bushfire and landslide on people, property, economic activity and the environment during development

27 Queensland Government (2003) State Planning Policy and Guideline (2003) *Mitigating the Adverse Impacts of Flood, Bushfire and Landslide*. Queensland Government Department of Local Government and Planning and Queensland Government Department of Emergency Services.

planning.

A natural hazard management area (bushfire) is described in Annex 3 of the SPP as follows:

- *(i)* an area identified by a local government in its planning scheme consistent with the conclusions of a bushfire hazard assessment prepared in accordance with Appendix 3 of the SPP Guideline or other methodology approved by the Queensland Fire and Rescue Service (QFRS); or
- *(ii)* where such a study has not been undertaken, an area identified by a local government in its planning scheme, reflecting the medium and high hazard area of the bushfire risk analysis maps produced by QFRS, suitably modified following a visual assessment of the accuracy of the maps; or
- *(iii)* where an area has not been identified by a local government, the medium and high hazard areas on the bushfire risk analysis maps produced by QFRS.

Natural hazard management areas (bushfire) trigger development outcomes and development assessment requirements specified in Outcome 1 of the SPP, and are also required to enable the development of the planning strategies and detailed measures required by Outcomes 5 and 6 of the SPP.

18.5.2.2 The Building Code of Australia

Development of buildings on bushfire-prone land should comply with bushfire construction requirements under *Australian Standard 3959-2009 Construction of Buildings in Bushfire-prone Areas* (AS 3959-2009),[28] which provides construction requirements for buildings within, or proposed within, bushfire-prone lands. LNG Plants are not considered specifically within the AS 3959:2009 standard. However, this standard has been considered for hazard assessment purposes. Consideration of the code will also provide for flexibility in micro-siting components of the facility within the study area.

18.5.2.3 Nature Conservation Act and Environment Protection and Biodiversity Conservation Act

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*) and the Queensland *Nature Conservation Act 1992* (*NC Act*) provide for the protection of Commonwealth- and State-listed threatened and rare flora and fauna species and endangered ecological communities. All fire mitigation activities (e.g. creation and maintenance of setbacks) must address the environmental consequences of the activity on these species within the area, or with the potential to occur in the area.

Project impacts on terrestrial flora/fauna at the LNG Facility site have been assessed in Volume 5, Chapter 7.

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28 Standards Australia (2009) Australian Standard 3959-2009 Construction of Buildings in Bushfire-prone Areas

18.5.3 Bushfire Hazard Assessment

18.5.3.1 Methodology

This Bushfire Hazard Assessment has been developed through literature review and site inspection and in consultation with Gladstone Regional Council and the Gladstone Rural Fire Brigade.

Existing bushfire hazards were identified for the study area and surrounds using existing maps, information on bushfire behaviour and the distribution and structure of vegetation types present within and adjacent to the study area. Results obtained during ecological investigations of the study area were used to provide detailed information on vegetation type, slope, aspect and proximity to hazards.

The methodology for assessing bushfire hazard was adopted from the Bushfire Hazard Assessment Methodology contained within Appendix 3 of the SPP, which uses three factors to assess bushfire hazard: vegetation community type, land slope and topographical aspect. A score is given to each factor for the assessable area and the total score reflects the severity of bushfire hazard.

18.5.3.2 Identification of Existing Bushfire Hazards

Bushfire-Prone Land Mapping

The Gladstone Fire and Rescue Service has mapped the study area and surrounds as a medium-risk area for bushfire,[29] with some scattered areas of low risk, primarily on and adjacent to the tidal areas.

Site Assessment

Vegetation Communities

The vegetation communities identified within and surrounding the study area include Blue Gum open woodland, Ironbark woodland, Yellow-scented Gum and Narrow Leaf Ironbark open forest, mixed forest, saltpan vegetation and mangrove forest[30]. Refer *Volume 5, Chapter 7* for detail.

Different types of vegetation determine the rate at which dry fuel accumulates, which contributes to variations in fire behaviour. The vegetation communities and REs in the study area have been categorised three ways:

1. paperbark heath and swamps, eucalypt forest with dry-shrub ladder fuels
2. grassy eucalypt and Acacia forest
3. mangrove forest.

The SPP describes typical fire behaviour for the different vegetation types and a corresponding bushfire hazard score. The hazard scores range from zero to

29 Queensland Fire and Rescue Service (2008) *Bushfire Risk Analysis for Gladstone Regional Council*

30 Unidel (2009) QCLNG Curtis Island Component Flora Report. Prepared for ERM on behalf of QGC

10, with zero being the lowest. The fire behavior and hazard scores for the vegetation in the study area and surrounds are summarised in *Table 5.18.16.* The location of each type is shown in *Figure 5.18.7*.

Table 5.18.16 Hazard Scores for Vegetation Type within the Study Area

Vegetation Community	Fire Behaviour	Hazard Score
Paperbark heath and swamps, eucalypt forest with dry-shrub understorey	Depends on fuel accumulation, but can be severe, with flame lengths up to 20 m. Spot fires are frequent across fire breaks in this vegetation type, with radiant heat and direct flame for 15 minutes.	8
Grassy eucalypt and *Acacia* forest	Tend to be severe in intensity with flame lengths to 20 m, but with less attack from embers.	6
Mangrove forest	Virtually fireproof and have been assigned a hazard score of zero. Where the vegetation community is assessed as having a vegetation community hazard score of zero, no other factors require consideration and the area's overall bushfire hazard should be rated as "low" severity.	0

Slope

The SPP states that fires burn more quickly and with greater intensity up slope, generally doubling in speed and intensity for every 10 degrees of slope. The hazard scores for slope range from one to five, with one being the lowest.

The study area and surrounds are predominantly flat plains with gradients of zero to five per cent and small undulating hills with gradients of five to 10 per cent. There are some areas with slopes of 10 to 20 per cent, 20 to 30 per cent and greater than 30 per cent. However, these areas are restricted in distribution and are associated with the larger hills in the south and east of the surrounding area.

The hazard scores for each of the slope categories used in the SPP are shown in *Table 5.18.17.* The slopes of the study area and surrounding areas are mapped in *Figure 5.18.8.*

A slope of zero per cent has been given to the entire development footprint, as this area will be levelled.

Table 5.18.17 SPP Hazard Scores for Slope Category

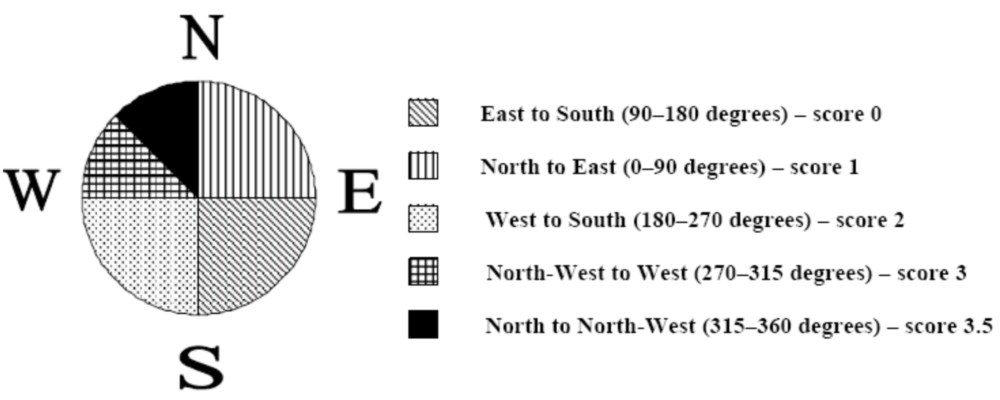
Slope	Hazard Score
Gorges and mountains (>30%)	5
Steep Hills (>20% to 30%)	4
Rolling Hills (>10% to 20%)	3
Undulating (>5% to 10%)	2
Plain (0% to 5%)	1

Aspect

Aspect affects bushfire risk by affecting vegetation exposure to direct sunlight and correlates closely with exposure to low-humidity winds that can increase bushfire intensity. Aspect has only a minor influence on flatter land and the SPP does not consider aspect significant on land with a slope of less than 5 per cent. The SPP rates hazards on a scale of zero to 3.5, with zero being the lowest.

The study area and surrounds have an undulating topography, so various aspects are present. The SPP hazard scores for each aspect category are shown in *Figure 5.18.6*. Aspect within the study area and surrounds is mapped in *Figure 5.18.9.*

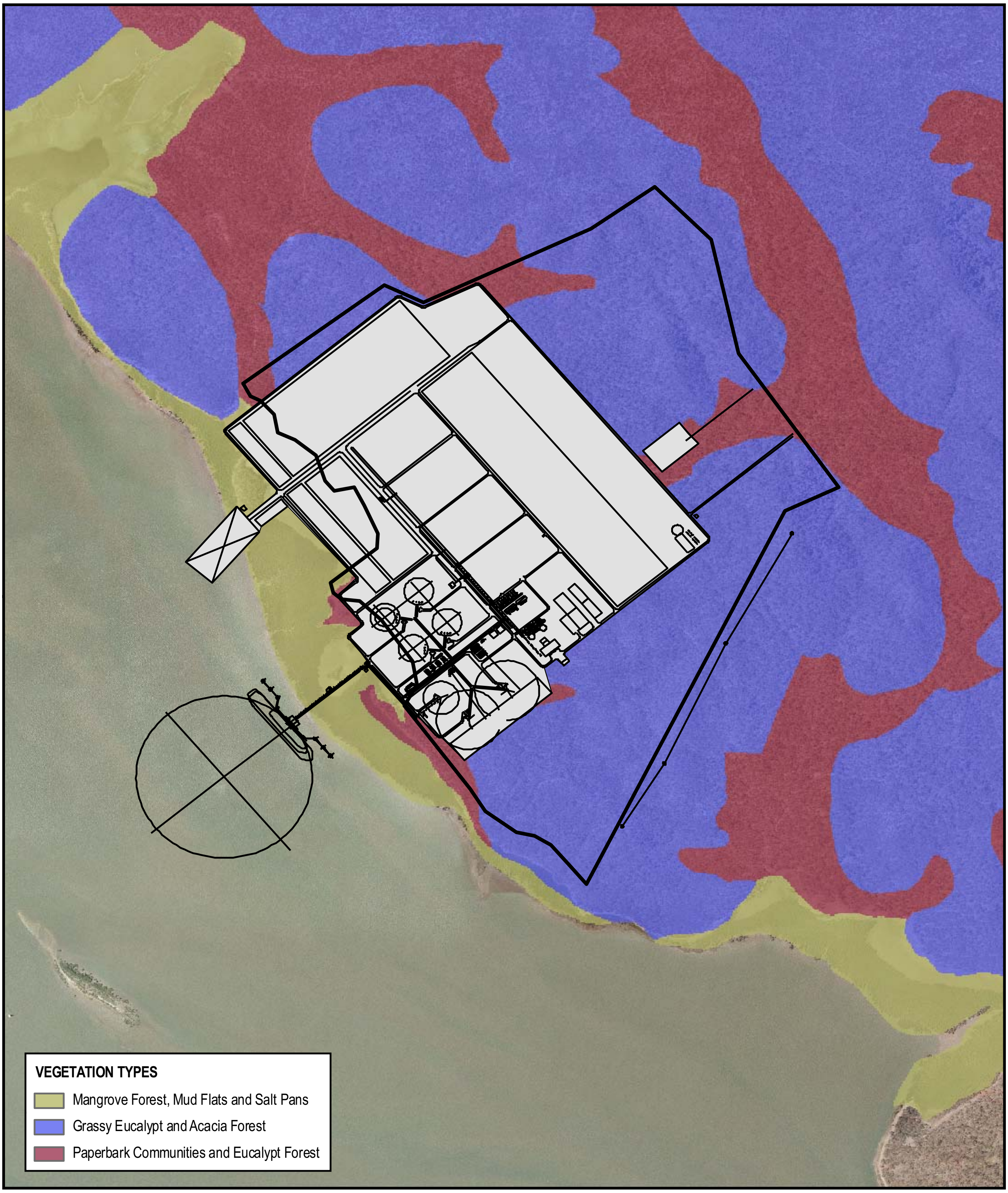
Figure 5.18.6 SPP Hazard Scores for Aspect Category



Total Hazard Score

The total hazard score for the study area is calculated with this SPP formula: Total hazard score = vegetation community hazard score + slope hazard score + aspect hazard score.

- The total hazard scores and corresponding bushfire hazard severity classification for the study area and surrounds were calculated using the Geographic Information System (GIS) layers of each component. The resultant hazard assessment for the study area and surrounds is shown in Figure 5.18.10*.* The figure shows all areas classified as low, medium or high hazard.



Legend

- QCLNG Site Boundary
- Indicative Footprint Plant Layout

Source Note:
Aerial Photo - Department of Infrastructure and Planning for QCLNG Project

Projection: UTM MGA Zone 56 Datum: GDA 94

0 125 250 500 m

N

QUEENSLAND CURTIS LNG
A BG Group business

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Project	Queensland Curtis LNG Project		
Client	QGC - A BG Group business		
Drawn	JF/JB	Volume 5	Figure 5.18.7
Approved	RB	File No:	0086165b_EIS_BF_GIS006_F5.18.7
Date	26.05.09	Revision	2

Title **Vegetation Types within the Study Area**

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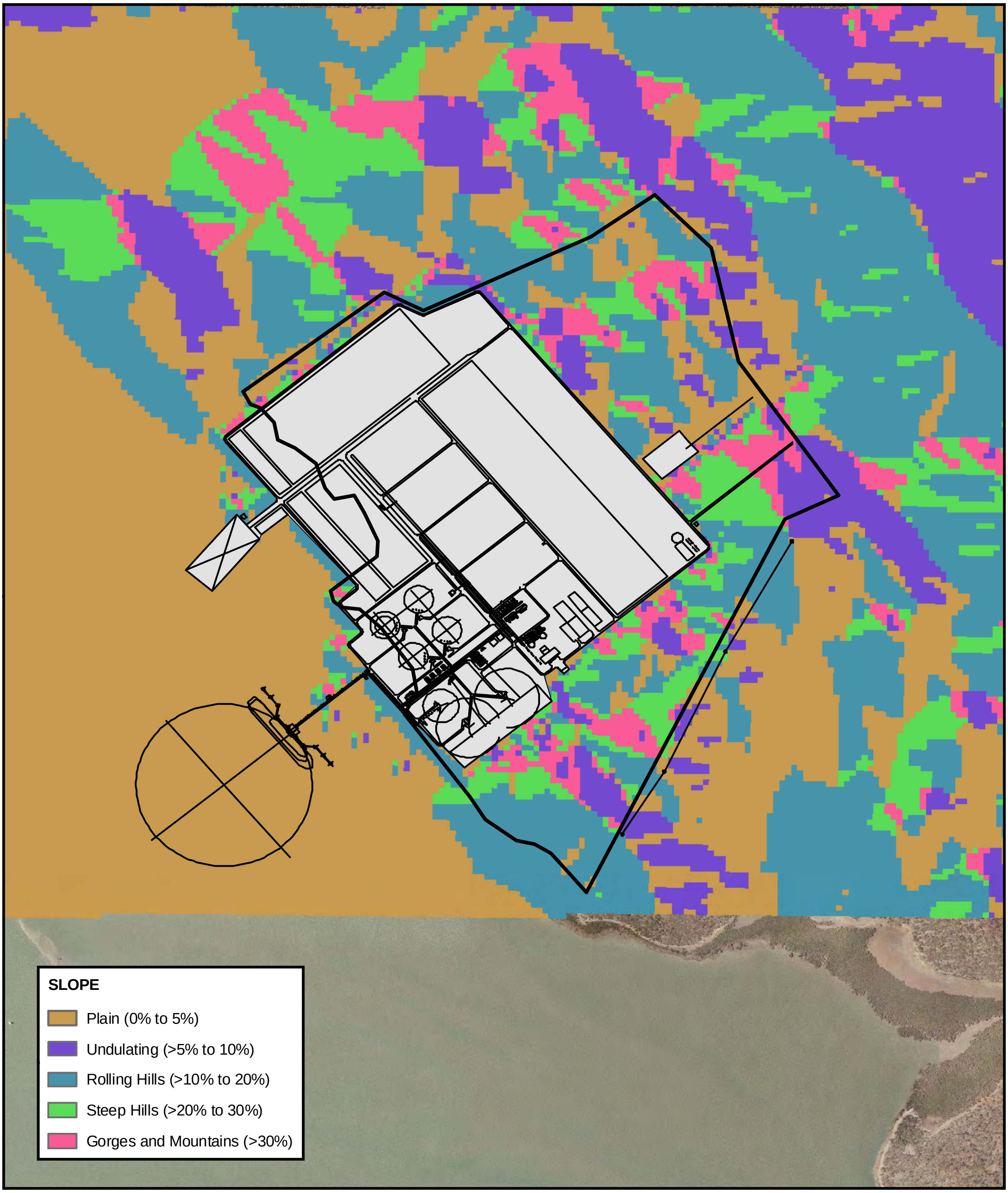

Legend

QCLNG Site Boundary

Indicative Footprint Plant Layout

Source Note:
Aerial Photo - Department of Infrastructure and Planning for QCLNG Project

Projection: UTM MGA Zone 56 Datum: GDA 94

0 125 250 500 m

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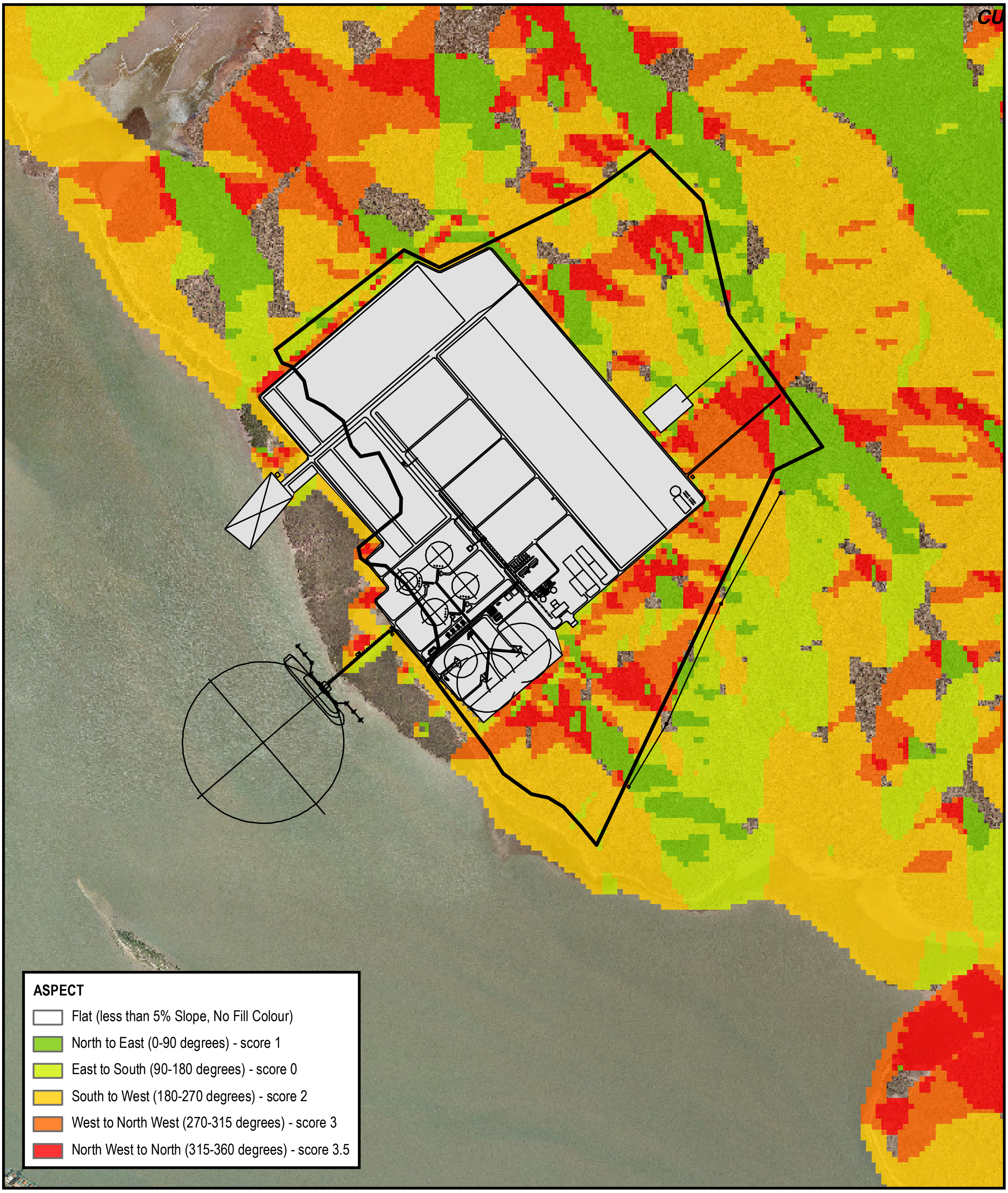
QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project		Title: Slope Across the Study Area
	Client: QGC - A BG Group business		
ERM Environmental Resources Management Australia Pty Ltd	Drawn: JF/JB	**Volume 5** **Figure 5.18.8**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved: RB	File No: 0086165b_EIS_BF_GIS005_F5.18.8	
	Date: 26.05.09	Revision: 2	



Legend

QCLNG Site Boundary

Indicative Footprint Plant Layout

Source Note:

Aerial Photo - Department of Infrastructure and Planning for QCLNG Project

Projection: UTM MGA Zone 56 Datum: GDA 94

0 200 400 800 m

N

QUEENSLAND CURTIS LNG A BG Group business

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Project	Queensland Curtis LNG Project		
Client	QGC - A BG Group business		
Drawn	JF/JB	Volume 5	Figure 5.18.9
Approved	RB	File No:	0086165b_EIS_BF_GIS001_F5.18.9
Date	26.05.09	Revision	2

Title **Aspect Categories Across the Study Area**

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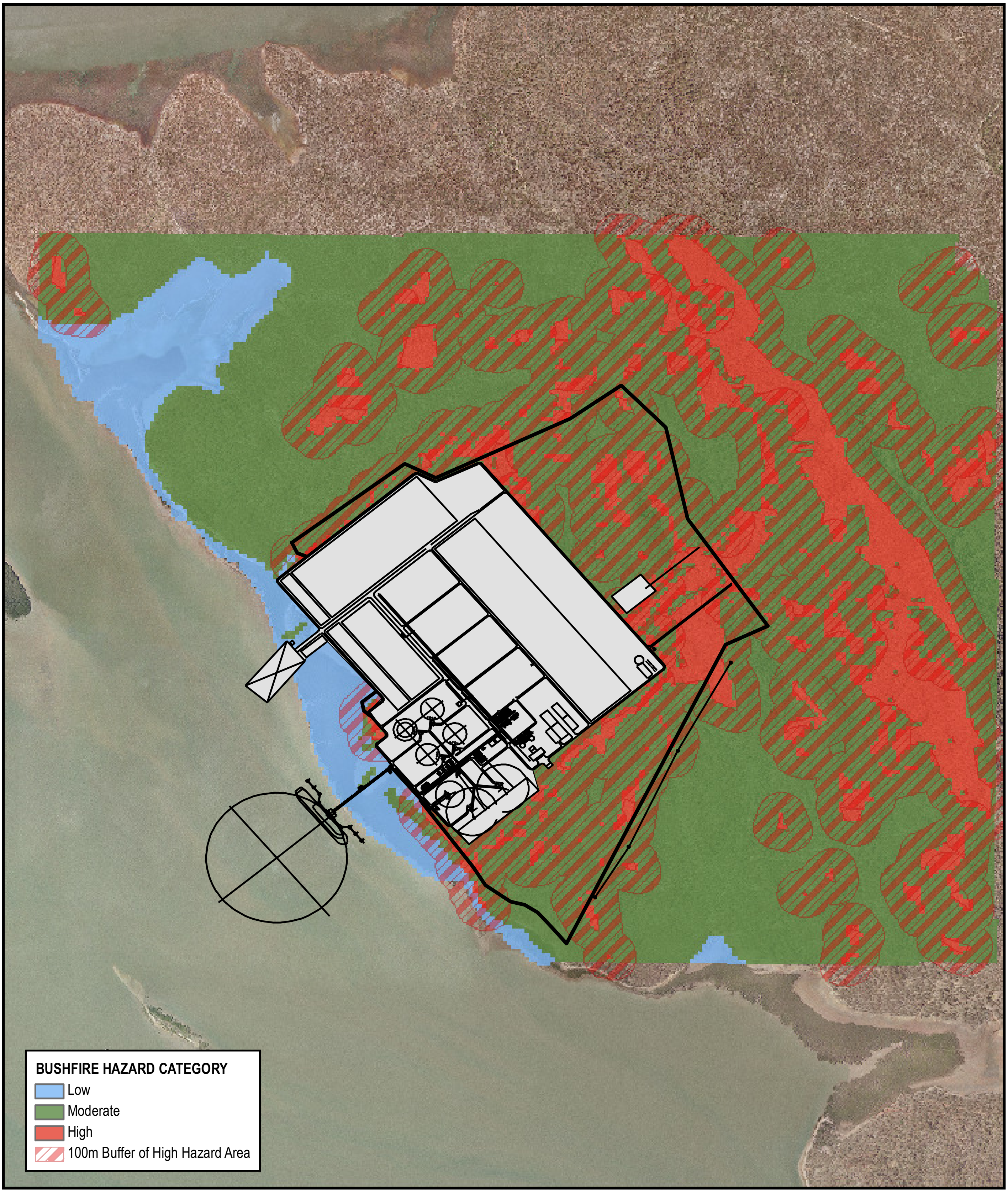

Legend

QCLNG Site Boundary

Indicative Footprint Plant Layout

Source Note:
Aerial Photo - Department of Infrastructure and Planning for QCLNG Project

Projection: UTM MGA Zone 56
Datum: GDA 94

0 200 400 800 m

N

QUEENSLAND CURTIS LNG
A BG Group business

ERM
Environmental Resources Management Australia Pty Ltd

Project	Queensland Curtis LNG Project		
Client	QGC - A BG Group business		
Title	Bushfire Hazard at the Study Area		
Drawn	JF/JB	Volume 5	Figure 5.18.10
Approved	RB	File No: 0086165b_EIS_BF_GIS004_F5.18.10	
Date	19.05.09	Revision 1	

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18.5.3.3 *Safety Buffer*

A safety buffer of land around high and medium bushfire hazard areas should be included within a natural hazard management area. The safety buffer is required because bushfires can affect unvegetated land in close proximity, particularly due to winds fanning flames, smoke, embers and radiant heat.

In accordance with the SPP:

- any land within 100 m of an area identified as having a high bushfire hazard classification should be included in the high bushfire hazard area
- any land within 50 m of an area identified as having a medium bushfire hazard classification should be included in the medium bushfire hazard area
- safety buffer areas on the boundary between high and medium bushfire hazard areas should be included in the high bushfire hazard area.
- Safety buffers around medium and high hazard areas are included in Figure 5.18.10*.*
- As all vegetation within the LNG plant footprint will be cleared or managed as a fuel reduction zone (although not all vegetation within the Facility site boundary), the majority of the study area would be considered a low hazard area. However, there are areas around the fringes that are included as high hazard and medium hazard due to the safety buffer.
- Two key considerations in building in high or medium hazard areas are:
- avoiding higher risk situations, particularly locations with a combination of slope and certain aspects
- maximising the setbacks from hazardous vegetation.

As the plant site will be graded and located downslope of all hazards, the effective slope is 0 per cent and therefore the plant site is situated in the best position with regard to fire damage potential. However, the study area would still be at risk from vegetation upslope (e.g. falling, burning logs), and parts of the study area would be classified as high-risk areas because they lie within 100 m of high hazard areas that will not be cleared or modified (see Figure 5.18.10*)*.

Setbacks and buffers will be applied around the LNG plant footprint and infrastructure, not around the LNG Facility site boundary as a whole.

18.5.3.4 *Setbacks from Hazardous Vegetation*

The SPP recommends that on lots greater than 2500 square metres, buildings should be situated so the following minimum setbacks from hazardous vegetation can be achieved:

- the greater of 10 metres or 1.5 times the predominant mature canopy tree height
- 10 metres from any retained vegetation strips or small areas of vegetation.

For the study area, infrastructure and personnel buildings will be set back from the surrounding vegetation by a minimum of 37.5 metres (vegetation height is calculated at an average of 25 metres). Within this setback area, fuel will be managed to reduce the potential for bushfire affecting the development (see *Management of Fuel within Setback)*

18.5.4 Bushfire Management Measures

Management measures to mitigate bushfire risk to acceptable and/or regulatory limits and guidelines are outlined below.

18.5.4.1 Siting of Development

Buildings situated upslope of bushfire hazards are in the most dangerous location, as fire has the potential to accelerate when travelling upslope. The most appropriate siting of development is on a flat site at the base of a gentle slope, where the development is located downslope of the bushfire hazard.

The development is proposed to be cleared and leveled. It will be located downslope of (or level with) all bushfire hazards in surrounding areas, thus reducing the risk of bushfire attack.

18.5.4.2 Setback

Development on bushfire-prone land will normally require the implementation of a setback distance, referred to as an asset protection zone (APZ). An APZ is meant to protect human life, property and highly valued assets. It is a buffer zone between a bushfire hazard and buildings that is managed progressively to minimise fuel loads and reduce potential radiant heat, flame contact, and ember and smoke attack.

The setback for the development is a minimum of 37.5 m. Within this zone, fuel will be managed to further reduce the threat of bushfire.

Management of Fuel within Setback

The primary purpose of fuel management is to ensure that a break occurs between the bushfire hazard and any combustible structures within the development. This area should be designed to:

- maximise the separation distance between high intensity fire and any structure, thereby reducing radiation and direct flame contact
- provide an area where embers can fall with minimal opportunity to create further fire outbreaks
- provide fire fighters safe access by reducing the heat level from the main fire
- provide a safe retreat for fire fighters
- provide a clear control line from which to begin back-burning or hazard reduction operations.

A fuel reduction zone will be located adjacent to the hazard. Here fuel loads are reduced through thinning of vegetation, mechanical clearing, hazard reduction burning (not recommended for the study area) or location of suitable developments such as playing fields or car parks as recommended by the Institute of Public Works Engineering Australia (IPWEA).[31]

Fuel loads within this zone will be kept to a level where the fire intensity expected will not affect the development. In the absence of any policy to the contrary, IPWEA advises that eight tonnes per hectare of total fuel is commonly used.

A fuel-free zone will be located adjacent to the development and should include a perimeter road for fire-fighting access. The perimeter road will lie between the fuel reduction zone and the plant infrastructure within the recommended setback. The road reserve will be at least 20 m wide, with a 6 m access track and passing bays about every 200 m. Areas where the highest intensity fires are likely (i.e. high hazard areas, see Figure 5.18.10) will have the widest fire breaks.

18.5.5 Building Construction Requirements

Australian Standard 3959-2009 specifies requirements for the design and construction of buildings in bushfire-prone areas in order to improve their performance when subjected to burning debris, radiant heat or flame contact generated from a bushfire. The standard uses its own factors in determining construction requirements.

Site-specific factors used in the calculation of construction requirements include:

- Fire Danger Index, which is the chance of a fire starting, its rate of spread, its intensity and the difficulty of its suppression according to various combinations of air temperature, relative humidity, wind speed and long- and short-term drought effects
- the distance from the development to the vegetation hazard
- the slope under the vegetation
- the predominant type of vegetation.

For the purpose of this assessment, the predominant vegetation type was classified as woodland (Vegetation Group B Woodlands). The study area will be leveled before the plant is constructed, therefore the surrounding vegetation will be upslope (or flat). In keeping with the SPP, the development will provide a setback of 37.5 m from hazards.

Using these factors, the Bushfire Attack Level (BAL) for the majority of the study area was calculated to be 12.5, a low level of bushfire risk. The main risk is from ember attack and construction elements expected to be exposed to a heat flux not greater than 12.5 kW/m^2.

Recommended construction levels for a BAL of 12.5 are provided in *Australian*

31 Institute of Public Works Engineering Australia (IPWEA) 2008. Mackay City Council Engineering Design guidelines D10 Bushfire Protection

Standard 3959-2009, Section 3: Construction General and Section 5: Construction for Bushfire Attack Level 12.5.

For the study area, relevant structures will include the construction camp, first-aid and office buildings, guardhouse and control room, administration building and any other buildings where personnel will reside.

18.5.5.1 Fire-Fighting Infrastructure

Fire Water Supply and Management

General discussion of water supply and management is provided in *Volume 2 Chapter 9*. The plant layout will maximise the use of passive protection in the form of equipment spacing and drainage of possible liquid spillages away from critical equipment to containment sumps. However, active measures such as fire and gas detection, a firewater system and overpressure protection will also be included in the detailed design.

The fire protection and safety systems include:

- fire water – underground distribution loop and aboveground system
- fire and gas detection systems – response to release of combustible, hazardous and/or low temperature gases and fires
- fire proofing (subject to fire studies to be conducted during detailed engineering)
- fire water tank
- fire water pumps.

Emergency Response

Emergency response plans are detailed in *Section 18.6* of this chapter.

Emergency Infrastructure

A fire, safety and first-aid facility will be located near the control building and will allow occupation by emergency personnel during incidents. The following systems will be provided (subject to finalisation of detail LNG Facility design):

- plant radio
- marine radio
- aeronautical radio
- PA control
- pager control
- national/international/hot-line/short-dial telephone
- closed-circuit television monitoring
- local area network computer connection points
- meteo display.

The fire station will contain the fire-fighting and safety equipment needed to deal with incidents in the Facility. Offices will be included for permanent fire/safety and security staff, as well as a small workshop and fire-training ground. A small open compound for storage of road signs and other items will be adjacent to the building. Hose washing and drying facilities and foam storage tanks will be provided. Covered shelter will be provided for two fire-fighting trucks and trailers. The building will mainly consist of a steel-framed structure on a reinforced concrete foundation. The outside walls will be built from double sheeted insulated steel sandwich cladding or a reinforced concrete frame with block-work infill.

18.5.5.2 Maintenance

At regular intervals, particularly prior to bushfire danger periods, several maintenance tasks will be performed to protect buildings and assets from bushfire attack, including:

- clearing the setback of fuel
- inspecting all fire trails
- checking all fire-fighting equipment such as water tanks and pumps to ensure that they are in good working condition.

18.5.5.3 Climate Change and Impact on the Management of Bushfires

The Project's life is expected to be approximately 20 years per LNG train. It is unlikely that significant changes to vegetation would occur such that the bushfire hazard would increase and the recommended setbacks would require expansion.

18.5.6 Summary of Key Findings

Key findings of the bushfire hazard assessment include:

- establishing a minimum APZ between bushfire hazards and buildings of 37.5 metres
- ensuring relevant structures meet BAL 12.5 *AS 3959-2009*
- establishing hazard barriers (which may be appropriate buffer zones) around buildings that house personnel
- providing sufficient water access and storage for a worst-case scenario
- constructing the main access roadway to standards for fire management
- regularly maintaining the road and APZ, particularly before bushfire danger periods.

18.6 EMERGENCY MANAGEMENT

This section provides preliminary detail (as appropriate to the Project design stage, and to be refined further through the FEED process), of

- proposed safety/contingency systems for the LNG Facility and shipping operations

- a description of the emergency planning procedure and outlines of proposed emergency management procedures
- fire management and fire control systems and plans.

18.6.1 Safety/Contingency Systems

18.6.1.1 LNG Facility

LNG Facility design incorporates a range of safety/contingency systems, including:

- a site security system
- fire prevention/protection
- leak detection/minimisation
- ESD systems.

Security

Details of the proposed LNG Facility security system are provided in *Volume 2, Chapter 9*. In summary, while detailed security risk assessment will be undertaken for the site during the FEED process and levels of security discussed and agreed with federal and state authorities, at this stage the planned security philosophy incorporates these baseline elements:

- perimeter fencing
- access gates with guardhouses
- restricted vehicular access
- restricted personnel access with use of a personnel electronic identity card system to control access for both terminal employees and visitors to the process and jetty areas
- a security control area within the main control room equipped with closed-circuit television monitoring and access to the electronic identity/swipe card system
- a perimeter intruder-detection system will be installed to cover the plant and jetty compound.

Fire Prevention/protection

A range of fire prevention and protection measures will be incorporated into the LNG Facility detailed design, including:[32]

- Passive fire protection, based on prior experience and a fire hazard analysis to be undertaken during FEED. Fire-proofing-zone (FPZ) drawings will be developed to identify where exposure from excessive heat flux exists and fire-proofing must be used.
- Pool fire and BLEVE prevention. Pool fires can occur when a flammable

32 BG Design Basis: Engineering, 2008. *QCLNG Project Design Basis*

liquid collects in low points or bunded areas, followed by ignition. Pressurised vessels exposed to fire conditions can undergo a catastrophic failure known as BLEVE. Avoidance of pool fires and BLEVE is therefore an important aspect of good safety design. Detailed design will address this through:

- identifying potential hazards
- siting of pressure vessels
- controlling ignition sources through area classification
- fire and gas detection
- limiting pool size with collection and impoundment structures
- active fire protection (i.e., water monitors) or passive fire protection of pressure vessels, to be determined through FEED.

- Fire and gas detection systems will be installed. These are described in *Volume 2, Chapter 9* and will include:[33]
  - plant fire detection in LNG plant areas and the storage and jetty areas via multi-spectrum infrared flame detection
  - gas detection capability
  - spill detection. Cold temperature detectors will be located within trenches and sumps designed for cryogenic liquid spill collection. They will also be located in the drainage path between major cryogenic liquid process inventories, such as the cold boxes, and the collection trench. Cold temperature spill detectors will alarm only on activation, requiring investigation from the operators to determine cause and appropriate action.
- Fire water systems: Design of the fire water systems is preliminary and will be confirmed during FEED Phase 2 once plant and equipment layout is better defined. The system will be designed and constructed in compliance with *NFPA 59A*[34] and *AS 2419*[35] and other applicable Australian standards. In general, as described in *Volume 2, Chapter 9*, this will include:
  - underground fire water distribution loop and above-ground system
  - fire- and gas-detection systems responding to the release of combustible, hazardous and/or low temperature gases and fires
  - fire-proofing of major structural steel and insulated vessels in the liquefaction section that normally contain flammable or combustible hydrocarbon. Detailed engineering will address the extent of fireproofing required.
  - Fire water tank and diesel and electric pumps. ˜ Their preliminary locations and those power generation utilities are shown in *Figure 5.18.11*.

33 Bechtel Oil, Gas and Chemicals Inc 2008. *Queensland Curtis LNG Project: Fire and Gas Detection Philosophy*)

34 US National Fire Protection Association: *NFPA 59A: Standard for the Production, Storage and Handling of Liquefied Natural Gas*

35 Australian Standard AS 2419.1-2005 *Fire Hydrant Installations – System Design, Installation and Commissioning*

- fire prevention and protection for ship loading. The LNG jetty will be equipped with:[36]
  - gas and smoke detection systems
  - dry-powder portable extinguishers
  - water monitors
  - international shore fire connection
  - foam generation equipment
  - a water curtain on critical equipment only.
- LNG tank relief valve vent fire suppression: Automatic fixed dry chemical extinguishing systems will be provided at the relief valve vents to extinguish any fire resulting from a relief valve vent fire.
- gas turbine fire protection: Gas turbine enclosures, such as for power generation or refrigerant compression, will have gas, fire detection and fire suppression devices wired to a local panel.
- gaseous extinguishing systems: Gaseous extinguishing systems will be activated by fire and smoke detectors located in the buildings.

Bushfire management is discussed in *Section 18.4*.

Leak Detection and Minimisation

Leak detection and minimisation for the LNG Facility is described under Fire and Gas Detection Systems above.

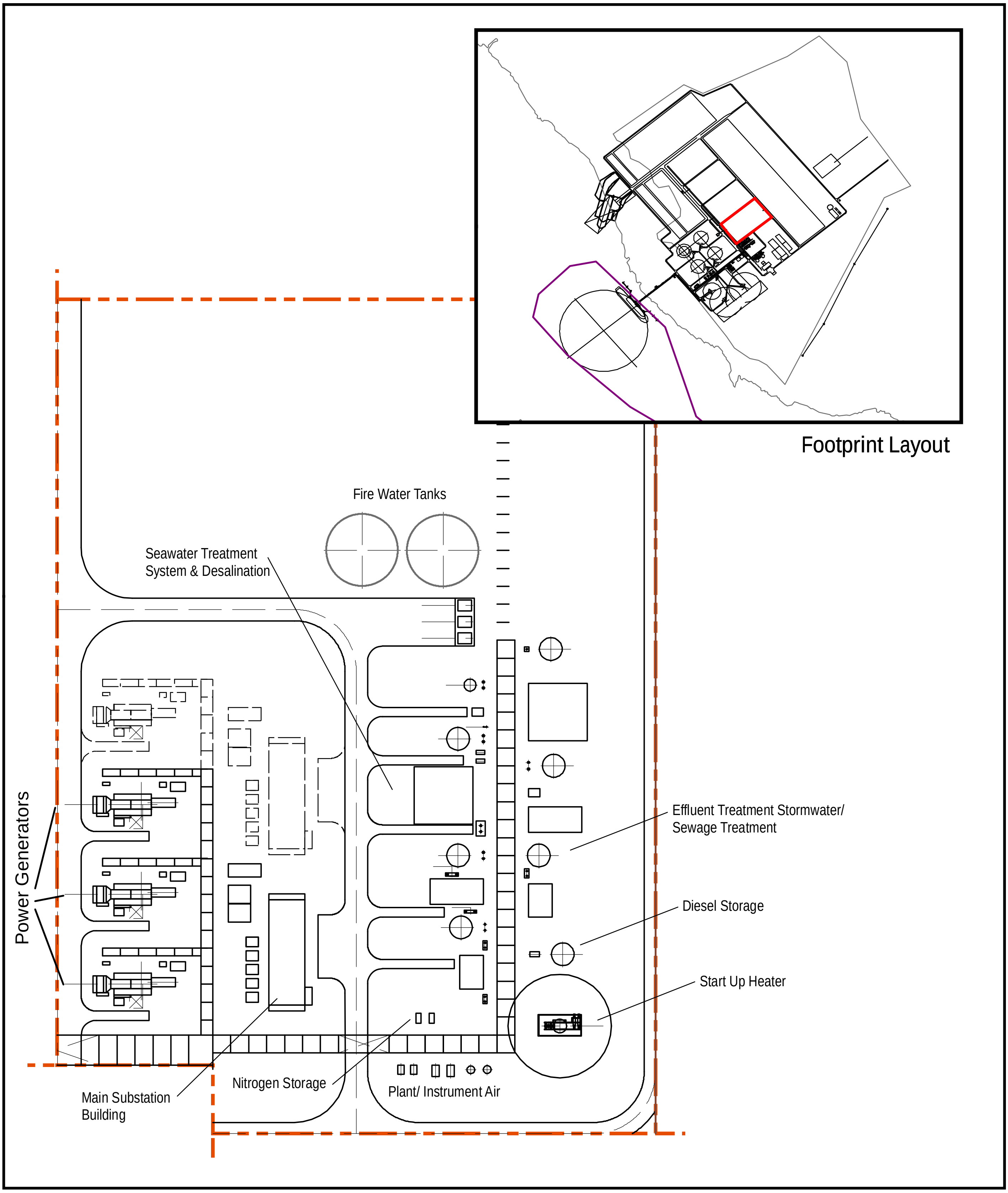
Spill containment will be undertaken through a combination of:

- Containment integrity: All process piping will be welded where possible, with an emphasis on minimum flanged connections. Screwed piping shall not be used in any service, including water, air or other utility services.
- Secondary containment: For storage areas, 110 per cent secondary containment will be provided for flammable, combustible or toxic materials, as required by Australian Standards including but not limited to *AS-3961*[37] and *AS-1940*.[38]
- Drainage and collection: Flammable liquid hydrocarbons process and storage areas will have drainage systems designed to remove a spill as quickly as possible so heat flux damage to equipment is minimised if ignition occurs.

36 Lloyd's Register 2009. *LNG Carrier Loading and LPG Carrier Unloading Safety: Quantitative Risk Assessment of LNG/LPG Carriers at Berth at Gladstone Port*.

37 Standards Australia AS 3961-2005. *The Storage and Handling of Liquefied Natural Gas*

38 Standard Australia AS 1940-2004. *The Storage and Handling of Flammable and Combustible Liquids*



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QUEENSLAND CURTIS LNG
A BG Group business

ERM
Environmental Resources Management Australia Pty Ltd

Project	Queensland Curtis LNG Project		
Client	QGC - A BG Group business		
Drawn	JB	**Volume 5**	**Figure 5.18.11**
Approved	DS	File No: 0086165b_EIS_HR_GIS001_F5.18.11	
Date	26.05.09	Revision 1	

Title
Location of Power Generation Utility and Fire Water Tanks

Disclaimer:
Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only.
ERM does not warrant the accuracy of any such Maps and Figures.

ESD Systems

LNG Facility

Details of the ESD system and isolation philosophy will be developed during detailed engineering design. In general, the overall control and shutdown systems will consist of the following:

- distributed control system
- process shutdown system
- ESD system.

All interlocks within the safety integrity system will be assessed to determine the safety integrity level required to adequately control risk. The safety integrity system will comply with AS/IEC 61508/61511.[39]

Emergency isolation valves will be located at process boundary limits or as dictated by inventory isolation requirements. The location of the valves will be finalised after fire and risk assessment studies.

Ship loading

LNG vessels will be covered by emergency Isolation and ESD systems while loading. Port regulations require a warm and cold test of the ESD system before loading/off-loading. The ship and jetty ESD systems are linked when the ship is berthed.

The transfer arms at the LNG Facility are equipped with powered emergency release couplings. These are set to close in 15 seconds (10 second delay, five seconds to close) to prevent surge pressure generation.

18.6.2 Emergency Planning and Emergency Response

18.6.2.1 Emergency Planning Procedure

The Emergency Planning procedure that will be adopted for the QCLNG Project falls within the structure of the BG Group Crisis Management Standard. The Standard will establish emergency management teams; systems and procedures at the BG Group level, at a coordinating asset level (i.e. the QCLNG Project) and at the specific site level; and links between these levels.

The BG Group management incident and emergency response hierarchy that will apply to the Project is provided in *Figure 5.18.12*.

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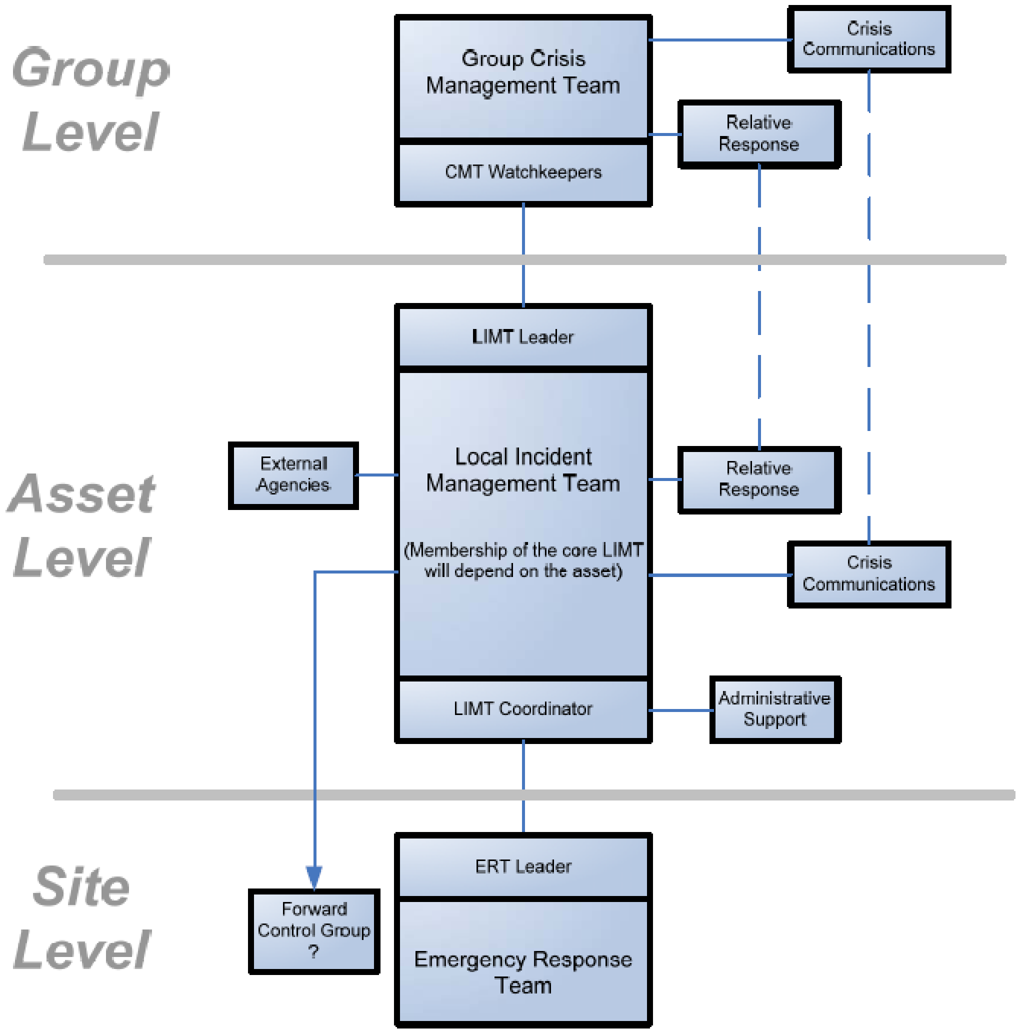
39 International Electrotechnical Commission IEC 61508. *Functional Safety of Electrical/electronic/programmable Electronic Safety-related Systems* and IEC 61511 *Functional Safety – Safety Instrumented Systems for the Process Industry Sector*

Figure 5.18.12 BG Group Incident and Emergency Response Hierarchy



BG Group's Standard for Crisis Management requires that a local incident management plan be prepared for each asset. Such plans will be prepared for each asset component of the Project. The plan will include information on:

- the organisation for incident management of the asset
- the process for identifying incidents
- the procedure for notifying incidents
- the procedure for escalation, if necessary
- the procedure for activation of the incident management organisation
- tools for the management of an incident
- roles and responsibilities of incident management teams.

18.6.2.2 Emergency Response Plans

In the event of an incident, the primary response will usually occur at site level. In many instances, the incident will be adequately addressed at this level by prevailing emergency response plans (ERPs) that will be prepared in advance of construction, commissioning and operational phases as they develop over the life of the Project. However, in order to prevent an incident from escalating, a local incident management team (LIMT) may be activated so it can bring its greater resources to bear. This may involve command and control and/or support with resources, expertise or logistics. In major incidents, further escalation to a group level crisis management team can occur.

ERPs are prepared at site level and include descriptions of:

- expectations of individuals at the site responding to an emergency
- roles and responsibilities for emergency response leaders
- the human and material resources available for response to an emergency
- the process for identification, notification and escalation of incidents
- the linkages to the higher asset and group level incident management systems.

In accordance with the BG Group Standard, the crisis management team/local incident management team arrangement will be tested at least annually to determine the effectiveness of the links between the BG Group and the QCLNG Project.

Reviews of the incident and emergency management procedures will be conducted after desktop exercises, simulated incidents and incidents and will determine:

- the effectiveness and appropriateness of plans
- the extent to which personnel are capable of implementing plans
- any gaps in planning and implementation and any proposed steps for improvement.
- Emergency response plans and procedures when fully developed will comply with the Guideline for Major Hazard Facilities: Publication D – Emergency Plans and Procedures.[40]

18.6.2.3 *Developmental Emergency Response Plans*

The Engineering, Procurement and Construction (EPC) contractor will develop emergency response plans covering the construction phase before work begins on site.

Before hydrocarbons are introduced into the LNG process, detailed emergency response plans will be prepared addressing commissioning and operations as part of the LNG Facility's HSSE management plan. The plan will be prepared in consultation with the HICB (Hazardous Industries and Chemical Branch Workplace Health and Safety Queensland) and emergency response providers following the Queensland Department of Employment and Industrial Relations *Guideline for Major Hazard Facilities*. The HSSE management plan will incorporate:

- a systematic risk assessment

40 Queensland Government Chemical Hazard and Emergency Management Unit, 2002. *Guidelines for Major Hazard Facilities*. MHF-04-OGL_1, Issued May 2002

- emergency plans and procedures
- a safety management system
- a program of induction, information, education, supervision and training for all persons at the LNG Facility
- information to, and opportunities for, consultation with the neighbouring community
- a safety report.

Consultation with HICB and emergency response providers is ongoing. An overview of consultation to date is described in *Section 18.6.2.4.*

A helicopter landing facility will be available during construction and operations as part of the emergency response and evacuation procedure.

18.6.2.4 Consultation in Development of Emergency Response Plans

Shipping Emergency Response and Security

Consultation has commenced with the Port of Gladstone Harbour Master and security officer, and with the Commonwealth Department of Infrastructure, Transport, Regional Development and Local Government with regard to shipping security. Further consultation with Queensland Police and ongoing consultation with the Harbour Master regarding fire fighting and emergency response is anticipated.

Construction Emergency Response

The EPC contractor will develop construction emergency response plans before works begin on site. Preliminary discussion with QFRS has been undertaken and the EPC contractor will consult Queensland Police, the Queensland Department of Community Safety and the Queensland Ambulance Service when preparing the construction emergency response plan.

Commissioning and Operations Emergency Response

To date emergency response providers and security agencies have not been consulted regarding commissioning and operations. Development of emergency response plans for commissioning and operations will be undertaken in consultation with the Port of Gladstone Harbour Master, Commonwealth Department of Infrastructure, Transport, Regional Development and Local Government, Queensland Police, QFRS, Queensland Department of Community Safety and Queensland Ambulance Service.

18.6.3 Emergency Plans

A risk assessment will be conducted to identify the highest risks posed to workers and the public during construction.

The following topics will be covered by site-specific plans or procedures or by standard QGC or EPC contractor procedures for construction and/or operations, as appropriate:

- medical emergency response (heart-attack, stroke or similar)
- major accident (construction related) with injury response
- confined space rescue
- high-angle rescue
- excavation rescue
- structural rescue
- medical treatment and response after a major accident
- fire
- environmental response to major spill or chemical release
- weather or seismic event
- tropical cyclone
- transient thunderstorm/lightning
- earthquake
- flooding/tidal influence
- civil disobedience
- labour strike
- external protests
- marine transportation emergency
- capsized/crippled vessel with passengers
- capsized/crippled vessel with lost load
- oil spill to the marine environment.

18.6.3.1 Construction Fire Response

Operations fire systems are described in *Section 18.6.1*. Detailed fire response for construction works will be developed before construction activities begin, but typical fire management systems on similar construction sites include:

- training and educating workforce regarding specific fire hazards and risks, drills and practice
- supply and use of fire extinguishers. Hand-held extinguishers are provided for general use and trolley mounted extinguishers for larger fire risk areas and fuel storage.
- water truck with pump to meet limited fire-fighting needs
- no smoking policy
- hot work permit policy
- temporary building specification, materials and spacing which meet Queensland Fire Code/Building Code requirements for temporary

structures
- flammable materials storage and use
- volunteer fire response team
- training of the response team
- drill and practice for first responders
- coordination with local fire brigade with jurisdiction.

Typical fire management systems for temporary camp accommodations include:

- smoking and cooking policies to reduce fire risk in accommodation units
- building specifications, materials and spacing which meet Queensland Fire Code/Building Code requirements for temporary living accommodation
- installation and maintenance of a smoke detection and fire alarm system for living quarters, common areas and cafeteria/mess assembly areas
- 24 hour security/front desk attendance for emergency dispatch
- supply and use of fire extinguishers. Hand-held extinguishers are provided for general use and trolley mounted extinguishers for larger fire risk areas and fuel storage
- carbon dioxide fire-suppression systems for cooking areas
- water truck with pump to meet limited fire-fighting needs
- training and education of workforce regarding specific fire hazards and risks, drills and practice
- volunteer fire response team
- training of the response team
- drill and practice for first responders
- coordination with local fire brigade with jurisdiction.

18.6.3.2 Medical Response – Construction

Two types of medical issues are typically associated with a construction project with onsite camp accommodation:

- emergency response for construction incidents
- provision of acute medical care for camp residents.

A risk assessment will be conducted to determine the medical personnel and emergency care facilities required. The assessment will include response times for medical evacuation by air and by sea.

For construction emergency planning purposes for a remote location which is not conducive to fast-response city services, onsite medical facilities usually have to be able to provide advanced life support for multiple trauma victims, typically three with serious injuries and five or six with moderate injuries.

Paramedics, nurses, ambulance drivers and attendants are typically staffed to provide necessary emergency care. The need for a physician to be on-site full-time cannot be deduced at this time.

Arrangements with public health authorities or an air ambulance service will be made to transport critically injured patients to an appropriate hospital emergency care department. The modes and methods of transportation have not been evaluated at this time.

A clinic will be provided at the camp to provide acute, walk-in care for minor illnesses, injury treatment, examination and screening. The clinic will be staffed by paramedics or nurses for full 24-hour coverage in the event of a domestic medical emergency such as heart attack, seizure or accidental injury. The provision of a part-time clinic physician will be determined as part of the overall medical risk assessment. Follow-up, referral and routine medical and dental care will probably be outsourced to health providers in Gladstone.

18.6.3.3 Medical Response – Operations

Senior first-aid facilities will be available on site during operations, including personnel trained to senior first-aid level. Medivac capability will be provided in accordance with the emergency response plan that is yet to be developed.

18.7 CONCLUSION

The LNG Facility is similar to many active LNG liquefaction and export terminals around the world. The historical safety record of these facilities over the past 45 years has been excellent. No member of the public has been fatally injured as a result of a spill, fire or explosion at any of these facilities. In 35 years, modern LNG storage tanks using 9 per cent nickel steel (as proposed for the QCLNG Project) have never suffered a crack failure and LNG ships have covered more than 185 million kilometres without a major incident.

The hazards and risks associated with the construction, operation and decommissioning of the QCLNG Project's LNG Facility and associated LNG and LPG shipping were assessed using a QRA approach. Bushfire hazards were also assessed.

LNG Facility

The design and location of the LNG Facility results in acceptable public risk levels in terms of HIPAP guidelines. In addition, when vulnerability zones for the largest credible events associated with the LNG Facility are overlaid on the proposed plot plan, the radiant and overpressure levels necessary to cause damage according to HIPAP10 guidelines have minimal impact on offsite areas.

Ship Loading/Unloading at the LNG Facility Jetty

The risks associated with the berth loading and unloading meet the injury risk criterion of 50 in a million at residential areas. The risks also meet the fatality risk criteria of 0.5 in a million at sensitive land uses, one in a million at residential areas, 10 in million at commercial areas and 50 in a million at potential neighbouring industrial facilities.

The group risk of accidents during transfer operations affect predominantly the personnel on the ship and jetty who are controlling and monitoring the transfer. The risk to people located in the LNG Facility and the support tug are much lower. The risks are in the ALARP region.

In summary, the location proposed for the LNG/LPG berth meets the risk criteria because it is sufficiently distant from other land users and the controls on the risks are sufficiently strong.

Shipping Transit in Port of Gladstone

Overall, the Port of Gladstone is extremely safe, with navigation features, support systems and redundancy contributing towards a low risk of an incident during transit.

Absent appropriate controls, key hazards for the transit of LNG carriers to the berth include the passage through the outer channel, transit past other facilities at Auckland Point and other berths, and interaction between the LNG carriers and support vessels during transit.

The route through the port meets industry criteria for channel draught, angles of turn and turning basin even for large-beam LNG carriers. A high level comparison with industry criteria determined that the channel width was less than recommended. However, channel width remains acceptable following a scenario-specific risk assessment and implementation of appropriate mitigation measures. Such an assessment and demonstration of acceptability is being undertaken as part of the ongoing shipping simulation studies and is also being addressed through potential channel expansion as outlined in *Volume 6*.

Quantitative assessment of all potential incidents (including collision, grounding, allision, capsizing, sinking or exposure to specific hazardous conditions) during transit shows that the likelihood of an incident is extremely low – less than 2.1 x 10^{-4} per LNG carrier visit. The likelihood of an incident resulting in a release of LNG or bunker fuel spill is even lower – less than 2.1 x 10^{-6} per LNG carrier visit.

Shipping Transit through GBRMP

The overall outer route to be used is extremely safe, with navigational features, support systems, rules, guidelines, control measures and redundancy contributing towards a low risk of an incident during transit.

Absent the appropriate controls during LNG carrier transit, there are a number of hazards with the potential to cause a major accident. Key hazards include collision and grounding. Accidents might result in the release of cargo, bunker fuel or ballast water which could cause environmental damage and affect island communities and tourism.

Quantitative assessment of the primary potential incidents (grounding, collision, whale/ship strike) occurring during transit showed that the likelihood of any of these events is extremely low. In a collision or grounding incident, the likelihood of cargo, bunker fuel or ballast water release is estimated as 5.4 x10^{-6} per ship visit for single hull vessels and 1.6 x10^{-7} per ship visit for double hull vessels.

The number of ship strikes with whales in the GBRMP and Torres Strait is very low – approximately $3.16x10^{-4}$ per year.

Even though the likelihood of release of bunker fuel for single hull ships is low, the use of double hull protection reduces the likelihood further by an order of magnitude.

Bushfire Hazard

The bushfire hazard assessment determined a minimum APZ between bushfire hazard and buildings of 37.5 m. Recommendations for reducing bushfire risks have been provided to mitigate the risk of bushfire at the LNG Component.

Due to thorough risk assessment, emergency management plans and the use of detailed security systems, the risk of a major incident causing material or serious environmental harm or an incident causing community concern is considered negligible. A summary of the impacts outlined in this chapter is provided in *Table 5.18.18*.

Table 5.18.18 Summary of Hazard and Risk Chapter

Impact assessment criteria	Assessment outcome
Impact assessment	Negligible
Impact type	Direct
Impact duration	Long term
Impact extent	Local
Impact likelihood	High

Overall assessment of impact significance: negligible.