Section 2 Project Alternatives

The following section describes the conceptual, feasible, and prudent alternatives to the project. Each project component i.e. coal seam gas (CSG) fields, gas transmission pipeline and LNG facility is discussed separately. The consequences of not proceeding with the project are also discussed in this section.

2.1 Coal Seam Gas Field

2.1.1 Geographical Alternatives

Demand for natural gas in Queensland is met from conventional gas and CSG. Both are natural gas - but there are significant differences in the composition, the way the gas is extracted and the location of the reserves in Queensland. Conventional gas is drawn from fields covering the Surat, Cooper and Eromanga Basins in the south and south-west of Queensland. CSG and conventional gas are drawn from the Bowen and Surat Basins in central west Queensland. Queensland has over 10,680 petajoules (PJ) of proven and probable reserves of CSG (DME, October 2008) while eastern Australia has 16,120 PJ.

Although there are conventional gas reserves in the Surat and Bowen Basins, conventional gas is not an alternative source for this project. Due to the composition differences between CSG and conventional gas the LNG facility would require considerable pre-treatment equipment to accept the conventional gas.

Santos holds petroleum leases (PLs) and authorities to prospect (ATPs) across a large area of the Bowen and Surat Basins. The Bowen and Surat Basins were chosen by Santos for development of their CSG activities as these areas have been identified as having a certified proven and probable abundant CSG resource. Over the last seven years Santos has developed its CSG resources to service the domestic contracts. However the amount of gas available in the tenures that Santos has an interest in is sufficient to supply its existing contracts for the Australian domestic market demand and also feed the GLNG Project. Consequently there was no need for Santos to examine other basins to supply the project with gas.

When identifying and develop new gas resources, Santos implements a formalised site assessment process in accordance with its Environmental, Health and Safety Management System (EHSMS). This process considers a number of criteria including environmental and engineering constraints and landholder requirements before site selection decisions are made. Environmental considerations include planning to avoid undertaking development activities within endangered regional ecosystems (REs) and other environmentally and/or culturally sensitive areas. In addition, environmental controls are implemented during construction and operational phases to minimise impacts to watercourses, to locate infrastructure in naturally cleared or previously cleared areas as much as practicable, and to minimise areas of disturbance. This process is followed when all alternative field areas are considered for development.

2.1.2 Drilling Alternatives

Conventional drilling involves the development of vertical holes directly above the target resource. Most of the wells to be developed for the CSG fields will be vertically drilled in a conventional manner. However in environmentally sensitive areas, in areas of particular aesthetic significance, or in areas subject to conflicting land use, Santos will investigate the use of alternative drilling techniques designed to minimise the extent of disturbance to reduce the resultant environmental impact. Directional drilling techniques (both vertical and horizontal) can have a number of advantages over conventional wells in that it is possible to drill multiple wells from the one lease, to access resources that are laterally displaced from the lease area, and to access multiple formations from the one well. An example of this technology is shown in Figure 2.1.1.

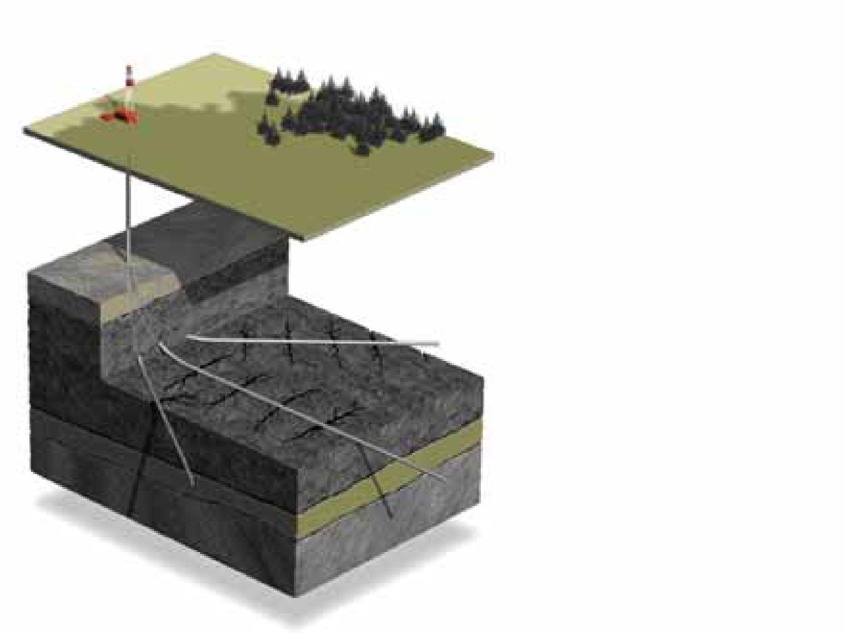

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Figure 2.1.1 Horizontal Drilling Concept

2.1.3 CSG Field Development Alternatives

There is a legislative requirement for Santos to actively explore for hydrocarbons in all of its tenements and to develop a resource if found. However the resources can be developed in a number of different ways. Santos is considering four different field development alternatives for its Fairview, Arcadia Valley and Roma CSG fields in order to optimise the appropriate development of each field. Field development may include a mix of any of these alternatives. These alternatives are listed below:

- Scenario A: Fairview and Roma - Development restricted to the two largest fields. Arcadia Valley not developed;
- Scenario B: Fairview, Roma and Arcadia Valley - Development of all three assets;
- Scenario C: Fairview and Roma - Scenario A with larger contribution from Roma; and
- Scenario D: Fairview, Roma, Arcadia Valley and Storage - Development of all three assets and utilising storage gas. Scenario D is a variation of scenario B, reflecting a higher contribution from Roma and Fairview, with Arcadia Valley remaining the same.

The locations of these CSG fields are shown in Figure 1.5.1.

All of the above alternatives provide adequate gas supply for at least Train 1 of the GLNG Project The work has highlighted the value of developing the three fields together as a common feedstock. Further work is required to optimise the gas resource in line with commercial and LNG requirements before the preferred alternative is identified.

Table 2.1.1 summarises the main characteristics of each of the four alternatives considered. Note that the table is based on a drilling timeframe from 2010 to 2034. Also, the well numbers are estimates and subject to change as more detailed exploration, planning and engineering are undertaken.

Table 2.1.1 Characteristics of Alternative Field Development Scenarios

Scenario	Peak Deliverable Capacity (MMscf/d	Number of Wells			Gas Production Rate (MMscf/d)[1]			Water Rate (kbbls/d)[2]		
		Fairview	Arcadia Valley	Roma	Fairview	Arcadia Valley	Roma	Fairview	Arcadia Valley	Roma
A	760	871	0	1,410	527	0	200	437	0	80
B	760	849	391	1,410	418	100	200	400	88	200
C	760	839	0	2,069	388	0	301	399	0	121
D	700	803	391	2,069	300	123	420	280	88	86

[1] million standard cubic feet per day
[2] thousand barrels per day

The peak deliverability capacities required to meet supply gas requirements of Train 1 of the LNG facility (one train) are listed in the table and are broken down by field. Peak deliverability capacities include a range of contingency factors for the LNG facility, field equipment and well availabilities. The adjusted total deliverable capacity (MDQ – maximum daily quantity) for Scenario D of 700 million standard cubic feet per day (MMscfd) (compared to the 760 MMscfd for scenarios A, B and C) is achieved through utilisation of storage gas volume built up over the ramp-up period prior to 2014.

Note that the listed well counts and production rates do not necessarily occur simultaneously. Total gas production rates are shown in terms of annual contract quantity which represents the average rate over each year.

A number of wells will be developed prior to the LNG facility start up and the remainder will be drilled during subsequent years as required to maintain production capacity. As the wells will be developed prior to the construction of the gas transmission pipeline, the gas produced will be stored and sold to the domestic market wherever possible.

The storage of produced CSG is presently being studied in South-West Queensland. Storage may be required to capture the gas produced from the neighbouring fields when it is unable to be sold into the local or LNG gas markets. The current studies are targeting underground gas storage in depleted conventional gas reservoirs and potentially depleted coal seams. In addition to the CSG appraisal and development activities, underground gas storage will require drilling, completing and connecting of storage wells as well as centralised compression and water treatment facilities. Santos presently operates conventional underground gas storage facilities at Ballera and Moomba.

The schedule of well development will be dictated by field performance and the drilling schedules will be designed to be responsive to early field results. The number of wells listed in Table 2.1.1 is expected to be at the upper end of the uncertainty range in actual well numbers required.

Peak water production will be determined by actual field dewatering performance and the balance of production between fields. Table 2.1.1 sets out estimated peak rates by field. Water handling facilities will be designed with the necessary flexibility to handle all water production.

2.1.4 CSG Field Facility Alternatives

During the design concept evaluation and selection process for the development of the CSG surface facilities Santos will adopt best industry standard practices under their Santos Quality Asset Development (SQAD) process to robustly consolidate the optimum overall design. This formal process evaluates a range of possible alternatives considering all key elements including:

- Safe facility design;

- Maintaining high environmental standards including water, emissions, noise, footprint, visual impact, community acceptance, rehabilitation considerations;
- Optimum performance over the economic life of the project, including inherent reliability, surveillance and asset maintenance;
- Flexibility to accommodate future field development; and
- Efficient construction and commissioning ensuring health, safety and environmental standards are maintained throughout the development.

The SQAD process ensures structured and thorough reviews of all potential alternatives consider the above elements to achieve the best overall project outcome.

Considering the key elements of the surface facilities development the above processes will be applied to:

- **Wellhead Lease Facilities -** reviewing current practices with consideration to minimising footprint and where practical increasing remote electronic monitoring to reduce traffic;
- **Flowlines and Gathering System** - reviewing alternative specifications and materials of construction to maximise system integrity thus reducing the potential for uncontrolled release. In addition, construction practices will be investigated to identify those conducive to rapid rehabilitation following installation and commissioning;
- **Nodal Compression Stations** - comparing a range of driver and compressor combinations to deliver compression packages with the appropriate balance with respect to efficiency, footprint, noise and aesthetic impact, remote monitoring capability and high inherent reliability to minimise operations traffic; and
- **Centralised Compression and Water Treatment Facilities** - identical to compression package optimisation as outlined for nodal compression stations combined with water treatment and gas processing facilities to centralise, as much as practical, and rationalise gas processing to again reduce overall footprint (by upsizing equipment at fewer locations) and reduce traffic impact throughout the region.

2.1.5 Market Alternatives

The CSG industry has developed rapidly in Queensland over the last decade, emerging as a flexible, clean and competitive source of energy in an expanding economy seeking lower carbon emission fuels. It can be used like the gas from conventional gas wells to power water heaters, stoves and space heaters for both domestic and business consumers. CSG can also be used as a direct source of energy for industry and as a fuel for electricity generation.

The current demand for CSG for domestic, industrial and power generation uses is being met by existing contracts. During 2006–07, Queensland's CSG production exceeded 85 PJ and by 2009-10 is expected to increase to more than 130 PJ (Department of Employment, Economic Development and Innovation, 2008. As of June 2008, Queensland had over 10,680 PJ of proven and probable (2P) reserves and eastern Australia had 16,120 PJ as at February 2009. These figures are set to increase given the increased exploration being undertaken.

2.2 Gas Transmission Pipeline

2.2.1 Route Alignment Options

Santos conducted Pre-FEED (Front End Engineering Design) studies as part of its gas transmission pipeline route selection process to select a preferred pipeline route alignment (refer to Appendix H for more details). The studies investigated route options between the CSG fields and the western edge of the Gladstone Transport Corridor within the Gladstone State Development Area (GSDA) and across Port Curtis to Curtis Island and the LNG facility site.

2.2.1.1 Route Selection Criteria

In order to select the optimal gas transmission pipeline route, an Infrastructure Corridor Assessment (INCA) methodology was used which combined multi-criteria assessment (MCA) approaches with desktop geographic information systems (GIS) analysis to optimise route selection against a range of criteria including those listed in the APIA Code of Environmental Practice (APIA, 2005).

Within the INCA framework, MCA techniques were used to identify, rank and weight the performance criteria that drive the INCA corridor modelling process. The adoption of MCA ensures that the route selection process took a balanced, transparent and traceable approach that considered environmental, socio-economic and engineering criteria while supporting a range of inputs from project stakeholders.

The criteria used in the route selection process are outlined in Table 2.2.1.

Table 2.2.1 Criteria for Route Selection Process

Issue	Criteria
Land Use	Minimise access through populated areas and rural houses.
	Parallel property boundaries adjacent to fence line where possible, rather than dissecting lots.
	Minimise crossing specialist agricultural blocks (i.e. irrigated areas, contoured land).
	Minimise number of landowners affected and avoid small rural lots.
Environmental	Avoid sites of known cultural heritage significance.
	Protection of landscape values.
	Avoiding ecosystems of conservation significance and essential habitats.
	Minimise impacts of vegetation clearing where avoidable.
	Cross watercourses at 90° to flow.
	Avoid crossing watercourses at bends, to prevent erosion of disturbed land.
	Minimise impacts on riparian vegetation, by crossing at disturbed areas.
	Avoid wetlands.
	Ensure environmental sustainability.
Co-Use of Easements	Road easements can be utilized, but not all easements will be able to cater for a 30 m ROW. Generally, road easements contain services which can threaten pipeline integrity.
	Pipeline easements can be used.
	Power line easements can be used; however, additional design costs apply.
	Railway easements are not ideal, unless significant space available.
	Cross roads, highways, railways and other services at 90° where practical and safe.
Safety	Relevant safety standards.
	Assessment of safety risks.
Commercial	Present market requirements.
	Construction and operating costs.
Engineering	Relevant construction and operation standards.
	Construction access requirements.
	Terrain and geotechnical constraints.
Physical Constraints	Avoid side slope (i.e. paralleling contours on a hill).
	It is preferential to run with slope (i.e. cross contours at 90°).
	Avoid escarpments – unless prepared to Horizontal Directional Drilling (HDD).
	Avoid unstable soils and erosion prone areas.

2.2.1.2 Route Options

As a result of the route selection process, the following three alternative gas transmission pipeline route options were considered:

- Option 1 Base route. Paralleling the existing Queensland Gas Pipeline (QGP) route from the northern end of the Arcadia Valley to Gladstone;
- Option 2 A more direct route to Gladstone, heading easterly from the Comet Ridge area in a large sweeping curve; and
- Option 3 Similar to Option 2 but in a more north-easterly direction.

All three options are illustrated in Figure 2.2.1 and are discussed in Table 2.2.2.

Table 2.2.2 Route Alignment Options

Option	Comment
Option 1	Option 1 considers an alignment that is generally adjacent to the existing QGP pipeline, running north of Injune and then east to the coast. The length of this route is approximately 435 km between the CSG fields and the LNG facility site on Curtis Island.
Option 2	Option 2 considered a direct corridor from the Fairview CSG field running north east to Gladstone. This alternative route is 380 km long and passes around the southern end of Expedition National Park and traverses across to the south of the Palm Tree and Robinson Creeks wetland system, 28 km north of Taroom. From here the most suitable route runs between Precipice National Park and the Anglo Coal (Theodore South) Mineral Development License area, although this presents a highly constrained solution in this area. The remainder of the route running north east to Gladstone is relatively unconstrained.
Option 3	Option 3 is similar to option 2; however this pipeline has a more northern-easterly alignment such that it proceeds to Dawson Valley. From the Dawson Valley it follows Option 1 to Curtis Island. The total length is approximately 390 km.

2.2.1.3 Preferred Route

Based on the selection criteria listed in Table 2.2.2, Option 1 was selected as the preferred route. A report on the pipeline route selection is given in Appendix H.

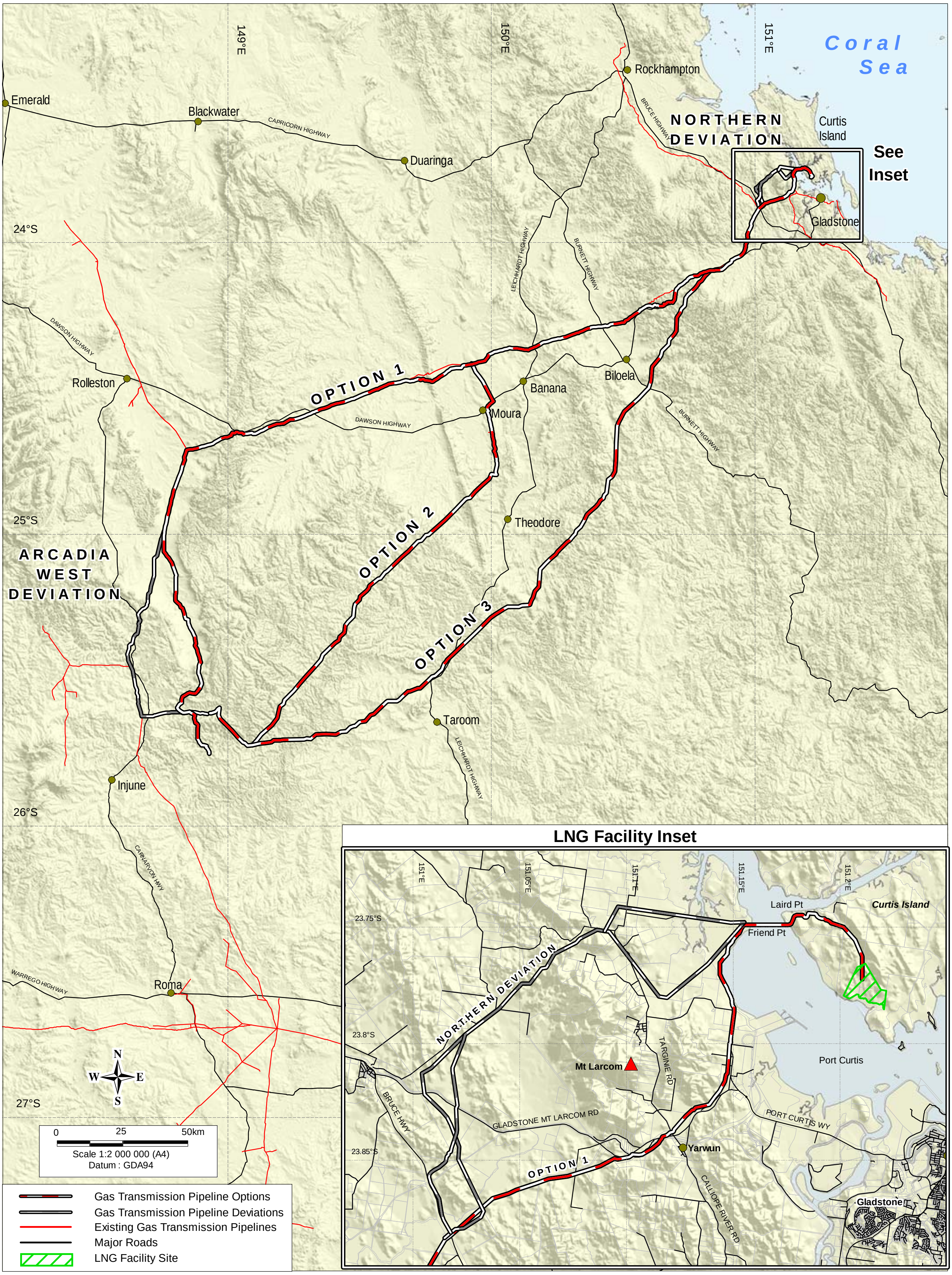
The proposed gas transmission pipeline will be located adjacent to the existing QGP for much of the 300 km of the corridor from south of Rolleston to Gladstone. This will reduce land disturbance and the impact on existing land uses and infrastructure. However there are sections along the corridor where due to landowner, land use or topographical constraints the proposed gas transmission pipeline will deviate from the QGP corridor.

Locating the gas transmission pipeline adjacent to powerlines or electrified rail lines is constrained by the risk of induced currents being generated in the steel pipeline which could accelerate the rate of corrosion and hence the risk to pipe integrity. For this reason co-location along power or rail easements can only be considered if there are adequate separation distances from the electrical facilities and no such opportunity is available for this option.

2.2.1.4 Alternative Deviations from Preferred Route

Following adoption of Option 1 as the preferred option, the alignment was further refined as a result of:

- Landholder consultation;
- Uncertainties associated with the GSDA;
- Reducing the number of highway crossings;
- Avoiding proposed major road re-alignments;
- Avoiding severely constrained areas in the higher range country; and
- Minimising impacts on biodiversity.



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Client	Project	Title
LNG	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**GAS TRANSMISSION PIPELINE ROUTE OPTIONS**
URS	Drawn: CA · Approved: JB · Date: 09-03-2009	Figure: **2.2.1** · Rev:B
	Job No: **4262 6220** · File No: 42626220-g-874.wor	A4

As a result, a number of alternative deviations from the preferred option have been identified. Baseline environmental studies have not been undertaken along these alternatives as they had not been identified at the time of the field investigations. However, desktop studies were undertaken and prior to construction commencing field verification will be undertaken. The alternatives identified are as follows:

- Arcadia Valley West; and
- Northern alternative within the GSDA.

A summary of the location and consequence of adopting the potential deviations are outlined in Table 2.2.3.

Table 2.2.3 Potential Alternative Deviations from Preferred Route

Alternative	Location	Consequence
Arcadia Valley West	On the western side of the Arcadia Valley and across the Carnarvon Range near the QGP corridor.	• Ecological constraints (including additional clearing within State Forest). • Topographic constraints. • Cultural heritage constraints. • Shorter pipeline length.
Northern Alternative within the GSDA.	To the north of Mt Larcom.	• Increase in pipeline length. • Avoids a narrow, constrained segment of the GSDA, known at the Yarwun Neck, especially when consideration is given to the cumulative impact of multiple proposed gas transmission pipelines and other infrastructure proposed to traverse this area. • Additional topographical constraints and potential for sideslope construction increasing width of right-of-way (ROW). • Interaction with GSDA future projects such as Aldoga Rail Yard and residue storage facilities.

The locations of the above potential route alternatives are shown on Figure 2.2.1.

Further route refinement studies will be undertaken during FEED to confirm whether either of the potential route deviations will be selected. The assessment will be based on the route selection criteria listed in Table 2.2.1.

Northern Alternative

Within the GSDA, the base case route for the gas transmission pipeline assessed in this EIS is parallel to Port Curtis Way and north of Yarwun where it passes though an area known as the “Yarwun Neck” before heading north along Fisherman’s Landing Road to Friend Point. The Yarwun neck route has been the basis for planning the project to date, but is not preferred by the Queensland Government due to the potential for congestion and cumulative impacts associated with numerous existing pipelines already in the area as well as the potential for more. There is also congestion caused by the presence of other linear infrastructure (i.e. road and rail) within the relatively narrow width of land available. In addition, the government has advised that its preference is for the gas transmission pipelines for all of the LNG facilities proposed for Curtis Island to be located in a common pipeline corridor across the GSDA. This corridor is assumed to be 120 m wide for planning purposes, sufficient for up to six pipelines.

To avoid the problems associated with the Yarwun Neck, the northern alternative is being considered. This route heads north along the eastern side of the Bruce Highway within the GSDA then north-east across the Gladstone-Mt Larcom Road and then turns in an easterly direction to the north of Mount Larcom to Friend Point (see Figure 2.2.1).

There a number of constraints in the area which need to be avoided including steep terrain, the proposed Aldoga railway yards and possible future residue disposal facilities.

As the route approaches Friend Point there are the following two alternatives:

- Follow the alignment of Targinie Rd to the south-east and then turn north-east to cross the mudflats to Friend Point; and
- Continue north-east and then head due east across the mangroves to Friend Point.

The first alternative via Targinie Road is preferred for the following reasons:

- It avoids potential future development areas; and
- It does not require a crossing of the significant mangrove system between the mainland and Kangaroo Island.

A desktop assessment of the existing environmental values along the northern alternative has been undertaken. The results of this assessment are given in Appendix AA.

As discussed above, the final selection of which alternative is selected will be undertaken during FEED.

As a final decision on the northern alternative has not yet been made, both it and the Option 1 route through the GSDA have been assessed in this EIS.

Energy Corridor

The State Government has announced a preference for an “Energy Corridor” for common user infrastructure between the GSDA area and the Callide Range. However, at this stage the route has not been finalised, and no desktop studies have been undertaken. GLNG will work closely with the government to ensure the preferred energy corridor is taken into consideration when finalising the gas transmission pipeline corridor.

2.2.2 Construction Technique Alternatives

2.2.2.1 Watercourse Crossings

Three alternative methods will be used for watercourse crossings by the gas transmission pipeline. These alternatives are as follows:

- **Open Trench.** The majority of watercourse crossings are expected to be constructed using standard open trenching construction. This technique is most suited to the dry or low flow conditions which will be preferred for the construction phase;
- **Open Trench with Flow Diversion.** Flow diversion is a modification to the standard open trench method employed where higher water volumes and flows are present (typically up to 1,000 litres per second). In this way the risk of erosion and interference with construction activities is reduced; and
- **Horizontal Directional Drilling (HDD).** HDD is generally used to cross major watercourses where standard open cut methods are not feasible or to avoid environmentally sensitive features. The feasibility of using HDD is limited by site conditions such as soil stability, slope, access, available workspace and the nature of subsurface strata.

As discussed above, it is anticipated that the majority of the watercourse crossings will be constructed using standard open trench methods. Where possible, construction activities will be scheduled for dry or low flow periods to enable open trench methods to be used. However, an evaluation of site conditions will be made at the time of construction and the need to use flow diversion methods will be assessed based on actual site conditions. It is proposed to use HDD methods for the two major river crossings (Dawson and Calliope Rivers) and possibly for the crossing of the Arcadia Valley escarpment to avoid the potential for significant environmental impact.

2.2.2.2 Port Curtis Crossing

It is proposed that the gas transmission pipeline will cross Port Curtis between Friend Point (on the mainland) and Laird Point (on Curtis Island). This is a distance of approximately 1.5 km. This route is to the north of the potential bridge alignment and is at the southern end of the Great Barrier Reef Coast Marine Park. The location north of the potential bridge alignment is preferred as a route south of the bridge would cause an increased risk of interference to port shipping and potential damage from ships' anchors.

The following four design options were considered for constructing the gas transmission pipeline across Port Curtis:

- Laying the pipeline directly on the sea floor;
- Placing the pipeline within a trench and backfilling;
- Suspending the pipeline from the potential road bridge; and
- HDD beneath the sea floor.

A summary of the issues associated with each of the four options is shown in Table 2.2.4.

Table 2.2.4 Summary of Issues for Design Options to Cross Port Curtis

Design Option	Summary of Issues
Laying the pipe on sea floor	• Potential loss of pipeline integrity due to damage from boat anchors and drifting ships. • Possible scouring - free span issue (pipeline integrity). • Potential erosion in the surrounding area. • Limited construction periods due to tide levels, large tidal flows and interference with boating activities. • Concerns regarding the shallow water depth and large tidal currents, exposing the pipeline and limiting boating movements through The Narrows.
Placing the pipe within a trench and backfilling with sand/rock	• A wide trench width will be required to enable installation, due to the sandy nature of the substrate. • Environmental disturbance of the seabed during construction. • Trench will need to be partially backfilled with rock to protect the pipeline. • Possible scouring due to tidal currents and disturbance during construction.
Suspending the pipe from the constructed bridge	• The bridge would not have available space to support up to six high pressure gas pipelines. • Bridge may not be constructed when the pipeline is required, or at all. • Minimal environmental impact.
HDD beneath the sea floor	• HDD of this length for a large diameter pipeline is at the outer limit of the technology. There would be a significant risk in attempting a HDD for this crossing, particularly as there are is limited space for the stringing of the pipe for pull-through for the length of crossing required. • Involves significant technical issues yet to be resolved due to the length of the crossing and the diameter of the pipeline. • Requires adequate space / land for construction equipment at both ends. • Reduced subtidal disturbance footprint.

The preferred design option for the pipeline crossing is to trench below the seabed and to backfill with sand and rock. This will avoid the risk from boat anchors if the pipe was not trenched and it also avoids the risk of delay if the bridge option was selected but the bridge was not constructed in time or not constructed at all. While both the trenched and HDD options will avoid the risk from pipeline damage due to boat anchors, there remain technical issues associated with the HDD option due to the length of the crossing and the diameter of the pipe. This crossing is considered to be at the extreme capability of the technology and carries technical risk. While the subtidal disturbance footprint of the preferred option is greater than that from the HDD option, detailed assessment of the proposed crossing location (Section 8.7) has shown that the resultant subtidal environmental impact will be limited to the following:

- Disturbance to the silt/mud substrate with some rubble near Friend Point and Laird Point and to the coarse sand substrate with some shell grit in the deeper water near the middle of the crossing;
- Loss of subtidal, soft bottom communities across The Narrows. No subtidal species or communities of conservation significance are located in this area;
- Introduction of a new habitat on the sand/rock backfill hard substrates and increase in habitat complexity. This would increase the available space for a number of species, such as sponges, gorgonians, soft corals, oysters and other species found on hard substrates within Port Curtis, and also provide habitat and food sources for mobile species (e.g. fish, crabs) which would use these new habitat for shelter and/or food; and
- Temporary increase in total suspended solids (TSS) concentrations in the vicinity of the pipeline crossing during construction to levels of the order of 12-14 mg/L which are comparable to the existing levels of variability in TSS present in the region. Further afield, both upstream and downstream of the pipeline, the additional TSS levels are predicted to nearly always be less than 5 mg/L, which will be effectively undetectable.

Construction of the pipeline crossing of Port Curtis will also result in disturbance to the intertidal areas at both Friend Point and Laird Point. However this disturbance will occur for both the open trench construction option and the HDD option.

The final design option for the pipeline crossing of Port Curtis will be made during FEED.

2.2.2.3 Road Crossings

Road crossing construction methods will be selected based on the road formation type. Crossing design and construction methods will vary according to road function, road design and the size and quantity of vehicles that use the road. The types of road crossing methods to be considered are summarised below, along with the relevant road types:

- **Open cut:** unformed and formed tracks, gravel roads and some bitumen roads;
- **Bored (cased or uncased):** some major highways and some bitumen roads; or
- **Directional drill (cased or uncased):** some major highways.

Section 7.11 provides details on the roads to be crossed by the gas transmission pipeline.

2.2.3 Infrastructure Alternatives

2.2.3.1 Access

Access for plant, equipment and personnel to the gas transmission pipeline right-of-way (ROW) will be via existing roads wherever possible. Along the proposed ROW there is a network of existing public roads and farm or forestry tracks which will reduce the amount of site disturbance otherwise required. Existing access roads and tracks will be used wherever practicable and all project-related movements will be restricted to approved access tracks and the ROW.

Where new access roads are required, options for their locations will be discussed with the relevant regulatory agencies and landowners prior to construction. They will be constructed as temporary roads and rehabilitated at the completion of the construction program in accordance with agency and landowner requirements.

Santos investigated the option of using the QGP ROW for access but this was not available, due to QGP expansion plans and operational constraints.

2.2.3.2 Pipe Delivery

Pipe will be shipped to Gladstone and unloaded at the Auckland Point wharves. Ships will arrive at a rate of approximately one per month with approximately 6,000 pipe lengths per shipment. From there it will be delivered to various laydown areas along the pipeline route. Both truck and rail are being considered as optional means of delivery of the pipe from Gladstone to the laydown areas.

Truck Delivery Option

For the truck delivery option, trucks will be used to transport the pipe from Auckland Point to one of six to ten laydown areas spaced roughly equidistant along the pipeline route. The laydown areas (approximately 5 ha) will consist of a hardstand area for pipe storage and associated facilities. Pipes will then be reloaded onto trucks for delivery to the pipeline construction areas.

Delivery will be at the rate of 65 - 70 truck loads per day (i.e. up to 140 truck movements per day). This will last for approximately six months. The primary delivery route will be along the Dawson Highway.

Rail Delivery Option

As an option to trucking, the use of rail has been considered. In this case the pipe will be loaded onto a train at Auckland Point and railed to one of three laydown areas along the gas transmission pipeline route. One laydown area will be at Moura and the other two at intermediate locations between Gladstone and Moura. A rail siding will be constructed at each laydown area and a hardstand and associated facilities developed for the unloading of pipe off the trains and loading it onto trucks for delivery to the pipeline construction areas. Beyond Moura the laydown arrangements will be the same as the trucking option (possibly four sites of 5 ha each).

Delivery will be at a rate of approximately one train per day for approximately six months (i.e. two train movements per day). Each train will consist of approximately 50 cars.

Santos is in discussion with Gladstone Ports Corporation regarding the use of Auckland Point wharves and with Queensland Rail regarding the use of rail and the construction of the rail sidings.

Comparison of Options

A summary comparison of the two options is given in Table 2.2.5.

Table 2.2.5 Summary of Pipe Transport Options

Aspect	Trucking Option	Rail Option
Road Traffic	• Up to 140 truck movements per day from Auckland Point through Gladstone and along the Dawson Highway to laydown areas. • Multiple truck deliveries from laydown areas to ROW.	• No trucks from Auckland Point through Gladstone to laydown areas. • Multiple truck deliveries from laydown areas to ROW. • No reduction in truck traffic west of Moura compared to the trucking option.
Road Safety	• Increased road safety risk due to additional truck traffic through Gladstone.	• No increase in road safety risk through Gladstone.
Noise	• Increased noise through Gladstone from up to 140 truck movements per day. • Increased noise at laydown areas.	• Lower noise increase through Gladstone but some noise from two train movements per day. • Increased noise at laydown areas.
Greenhouse Gases	• Greenhouse gases emitted by up to 140 truck movements/day.	• Less greenhouse gas emitted by two train movements per day.

Aspect	Trucking Option	Rail Option
Land Use	• Laydown areas required along pipeline route.	• One large laydown area at Moura and five smaller ones. Three laydown areas required for construction of rail spurs.
Environmental sustainability	• Less sustainable than rail option.	• More sustainable than trucking.

A detailed assessment of the traffic and noise impacts of each option is given in Sections 4 and 7.10 respectively.

A decision as to which option will be used will be made during FEED.

2.2.3.3 Accommodation

Due to the mainly rural nature of the region and the limited number of townships along the proposed gas transmission pipeline route, existing accommodation is not readily available. Hence dedicated workers' accommodation facilities will be required.

The workforce will be accommodated in a series of main and satellite accommodation facilities. There may be three main accommodation facilities located roughly equidistant along the pipeline. Facilities 1 and 2 will operate for half of the time and then facilities 2 and 3 will operate for the other half. There will be up to 500 workers accommodated in each of the two main accommodation facilities. In addition, two smaller satellite accommodation facilities could be located between the main facilities. They would operate one at a time and will accommodate up to 100 workers (note: the accommodation facilities will rarely be at full capacity, which allows workers to move between accommodation facilities as required during the project). The exact number of accommodation facilities will be determined during FEED in consultation with the construction contractor.

A number of options are available for the locations of the accommodation facilities but the exact locations will not be determined until the construction contractor has been appointed. The criteria used to identify the suitable accommodation facilities locations will include the following:

- Avoidance of areas of significant environmental value;
- Avoidance of areas subject to flooding;
- Avoidance of conflicting land uses;
- Minimise impacts on local communities;
- Flat area with minimal earthworks required;
- Landholder requirements;
- The availability of sufficient potable water;
- The ability to dispose of all workforce accommodation waste appropriately;
- Power supply (local vs. self generated);
- Provision of adequate road access;
- Proximity to the ROW; and
- Proximity to existing infrastructure.

Due to the mainly rural nature of the region and the limited number of townships along the proposed gas transmission pipeline route, existing accommodation is not readily available. If such facilities were available their use would result in significant daily commuting to the construction site and potential social disturbance issues in the local communities.

2.2.3.4 Water Supply

It has been proposed that due to the limited local water supplies, water demands for construction activities will be imported to the site from local municipal supplies located along the gas transmission pipeline. Local water sources have been considered, however due to the ephemeral nature of many of the watercourses within the region, it is assumed local sources such as rivers will not be used. The preferred water supply option will be further investigated once the locations of the accommodation facilities have been determined.

Local water sources have been suggested for the hydrostatic testing of the pipeline to be undertaken during the commissioning phase. However due to the ephemeral nature of many of the watercourses within the region, it is likely that local sources such as rivers will not be used. The most likely option is that the hydrotest water will be associated water from the CSG fields. It will be used to test short sections of the pipeline (5 – 50 km) at a time depending on differences in elevation. Upon completion of one section, the water will where possible be recycled and used for the next section. Otherwise the hydrotest water will be disposed of at appropriate locations in accordance with the relevant environmental authority conditions.

2.3 LNG Facility

2.3.1 Site Alternatives

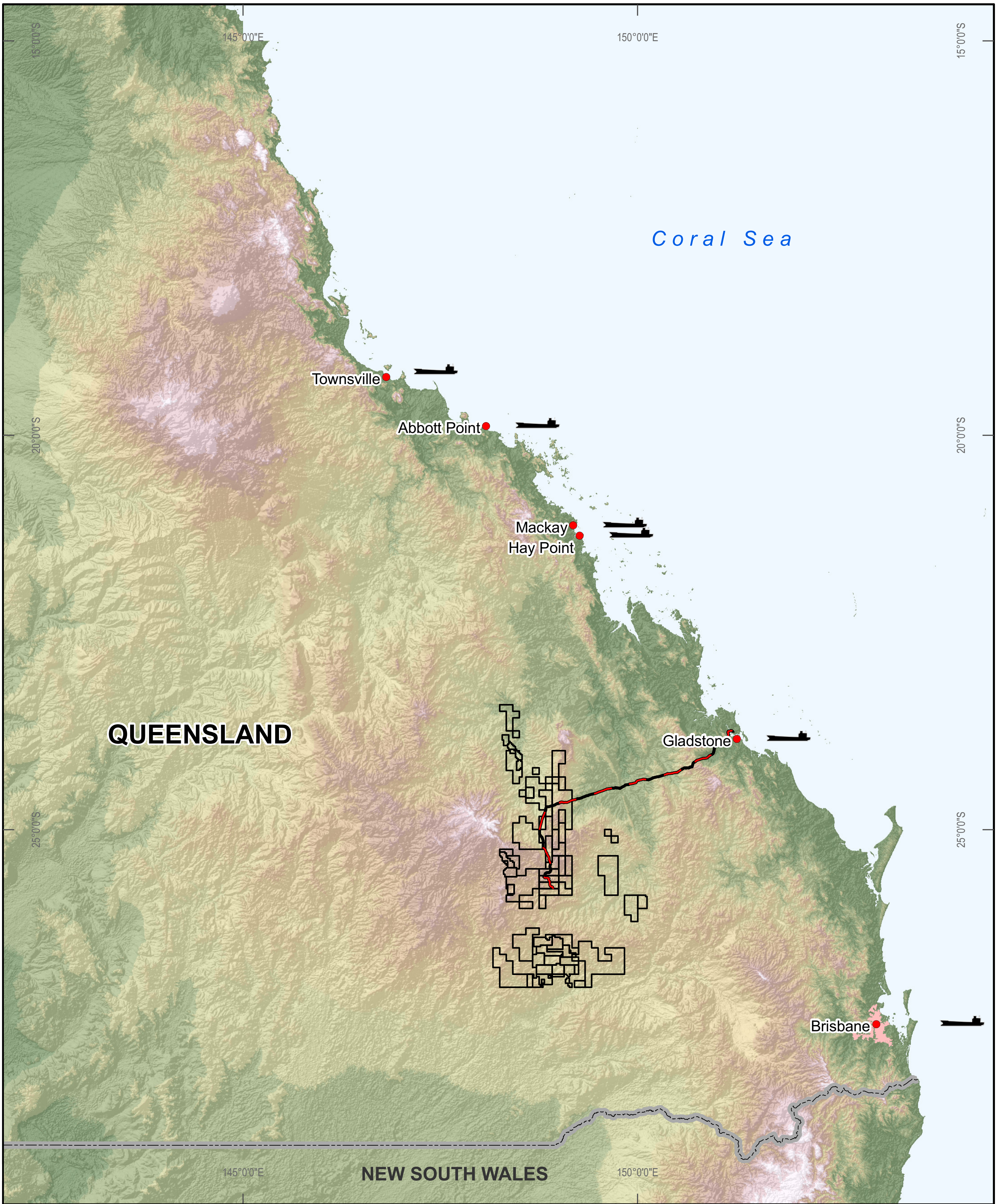
2.3.1.1 Alternative Locations within Queensland

Site selection evaluations for the GLNG Project were undertaken as part of Santos' feasibility study into the possible development of a land-based LNG and export facility on the Queensland coast. The evaluations considered social, environmental, economic and risk factors for each site.

During late 2005 and early 2006 Santos investigated a number of possible port locations between Townsville and Brisbane to site its LNG facility. Potential sites were selected based on a number of key criteria including:

- Proximity to CSG fields;
- Suitable land – including available unencumbered land with a minimum area of 200 ha, safe from flooding and storm surge, and capable of withstanding high foundation loads, suitable land ownership and proximity to utilities and road access;
- Sheltered and navigable water for the LNG export facility, within an economically viable dredging distance to deep water for LNG carriers;
- Available workforce - including proximity of nearby town(s) to house both construction and operations labour force;
- Controllable site safety and security, both landside and marine - including suitability in terms of proximity of LNG plant and ships to communities, other industries and planned wharves;
- Environmental impacts - including comparative advantages / disadvantages between the various sites and potential acceptance of an LNG export development in that location as well as land use and land tenure constraints; and
- Development cost - including the differential costs of land purchase, site preparation (including piling if required), road access, utilities supply, feed gas supply, LNG jetty and dredging.

The desired outcome of the site ranking process was to identify a site that was considered to be the least sensitive and to also provide Santos with an opportunity to contribute to the sustainability of the local and regional community. Six alternative ports were assessed and the results of the assessment including the assessment criteria are summarised in Table 2.3.1. The locations of the alternative port sites are shown on Figure 2.3.1.



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Alternate Shipping Ports
Gas Transmission Pipeline
CSG Fields
Port Localities
Qld-NSW border

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Client	Project	Title	
	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**ALTERNATIVE QUEENSLAND SITES FOR LNG FACILITY**	
Drawn: MG	Approved: JB	Date: 18-03-2009	Rev. B
Job No.: **4262 6220**	File No.: 42626220-g-1024.mxd	Figure: **2.3.1**	A4

Table 2.3.1 Assessment of Alternative Ports

Criteria	Townsville	Abbot Point	Mackay	Hay Point	Brisbane	Gladstone
Proximity to CSG field.	🔴	🔴	🔴	🔴	🔴	🟢
Suitable Land.	🔴	🟡	🔴	🟡	🔴	🟢
Navigable Waters.	🔴	🔴	🔴	🔴	🟡	🟢
Available Workforce.	🟡	🔴	🟡	🔴	🟢	🟢
Safety and Security.	🔴	🟡	🔴	🟡	🔴	🟡
Environmental Impacts.	🔴	🟡	🔴	🟡	🔴	🟡
Development Cost.	🔴	🔴	🔴	🔴	🔴	🟢

🔴 Unlikely to be suitable 🟡 Potentially suitable 🟢 Suitable

Table 2.3.2 summarises the basis for the assessment given in Table 2.3.1.

Gladstone was selected as the preferred site. The Port of Gladstone proved to be more feasible than the other ports assessed due to its available land, sheltered deep water, reduced dredging requirement, existing industrial infrastructure, availability of an experienced workforce, and proximity to the CSG fields. The environmental sustainability of the Gladstone site is favourable as it is the closest site to the CSG fields, it is located in an existing industrial port and it has manageable environmental impacts.

Furthermore the Queensland Government's strategic planning has identified Gladstone as a preferred location of LNG development. The Development Scheme for the Gladstone State Development Area (Coordinator General, 2008) has identified the Curtis Island Industry Precinct on Curtis Island as being suitable for the following purposes:

- *"To provide for the establishment of liquefied natural gas (LNG) facilities for processing operations (including liquefaction and storage) of national, state or regional significance that require access to export wharf facilities.*
- *To provide for establishment of infrastructure associated with LNG facilities including transport linkages to wharf facilities.*
- *To prevent the establishment of uses that may be incompatible with, adversely affect, or constrain existing or future LNG processing operations within the Curtis Island Industry Precinct."*

Table 2.3.2 Basis of Port Site Selection Assessment

Criteria	Townsville	Abbot Point	Mackay	Hay Point	Brisbane	Gladstone
Proximity to CSG fields – direct line	760 km	660 km	520 km	500 km	500 km	330 km
Suitable Land	Desktop evaluation did not identify a suitable area of land close to the port, although land there is potentially available.	Desktop evaluation identified potential suitable areas of land close to the port. Land ownership was not ascertained.	Desktop evaluation did not identify a suitable area of land close to the port.	Desktop evaluation identified potential suitable areas of land close to the port. Land ownership was not ascertained.	Desktop evaluation did not identify a suitable area of land close to the port.	Desktop evaluation identified potentially suitable areas of land close to the port, with some plots in the GSDA.
Sheltered and navigable waters	Breakwater harbour with relatively shallow channel access and limited space. Unlikely to be suitable.	Although the Abbot Point Coal Terminal handles large coal carriers, it is an offshore berth located in open water and not protected enough for loading LNG carriers through loading arms.	Breakwater harbour with relatively shallow channel access and limited space. Unlikely to be suitable.	Although existing port facilities handle large coal carriers, they are offshore berths located in open water and not protected enough for loading LNG carriers through loading arms.	Fisherman Islands area potentially suitable.	As an existing heavy industry port, handling coal carriers larger than LNG ships, The port deemed to be protected enough for loading LNG carriers through loading arms.
Available workforce	Based on a desktop evaluation, Townsville believed to have potential.	Nearest town is Bowen, some 25 km away, is too small.	Based on a desktop evaluation, Mackay believed to have potential.	Based on a desktop evaluation, Mackay, some 40 km away, believed to have potential.	Based on a desktop evaluation, Brisbane likely to supply workforce.	Based on a desktop evaluation, Gladstone likely to have experience workers.
Safety and security	Based on a desktop evaluation, unlikely to be suitable.	Based on a desktop evaluation, believed to be potentially suitable.	Based on a desktop evaluation, unlikely to be suitable.	Based on a desktop evaluation, believed to be potentially suitable.	Based on a desktop evaluation, unlikely to be suitable.	Based on a desktop evaluation, believed to be potentially suitable.
Environmental impacts	Based on a desktop evaluation, unacceptable.	Based on a desktop evaluation, potentially acceptable.	Based on a desktop evaluation, believed to be unacceptable.	Based on a desktop evaluation, potentially acceptable.	Based on a desktop evaluation, unacceptable.	Based on a desktop evaluation, potentially acceptable.
Development Cost	Long feed gas pipeline and high port development costs. High land costs.	Long feed gas pipeline and high port development costs.	Long feed gas pipeline and high port development costs.	Long feed gas pipeline and high port development costs.	Long feed gas pipeline, including through Brisbane suburbs. High land costs.	Lowest total development cost of all locations considered.

2.3.1.2 Alternative Sites within Gladstone

In late 2007 the Department of Infrastructure and Planning (DIP) assessed 13 sites in the Port of Gladstone region for their suitability to be developed for LNG projects. The DIP's two preferred sites were on Curtis Island; they were Hamilton Point West and North China Bay. Further information about the study is found on the DIP's website (http://www.dip.qld.gov.au/projects/energy/gas/gladstone-liquefied-natural-gas-site-study.html).

On the basis of this investigation, the DIP has since extended the GSDA to include an industry precinct on Curtis Island to accommodate LNG projects. The purpose of this precinct in providing for the establishment of LNG facilities is described above.

Within the area administered by the Gladstone Ports Corporation (GPC) the following alternative potential sites were investigated by Santos:

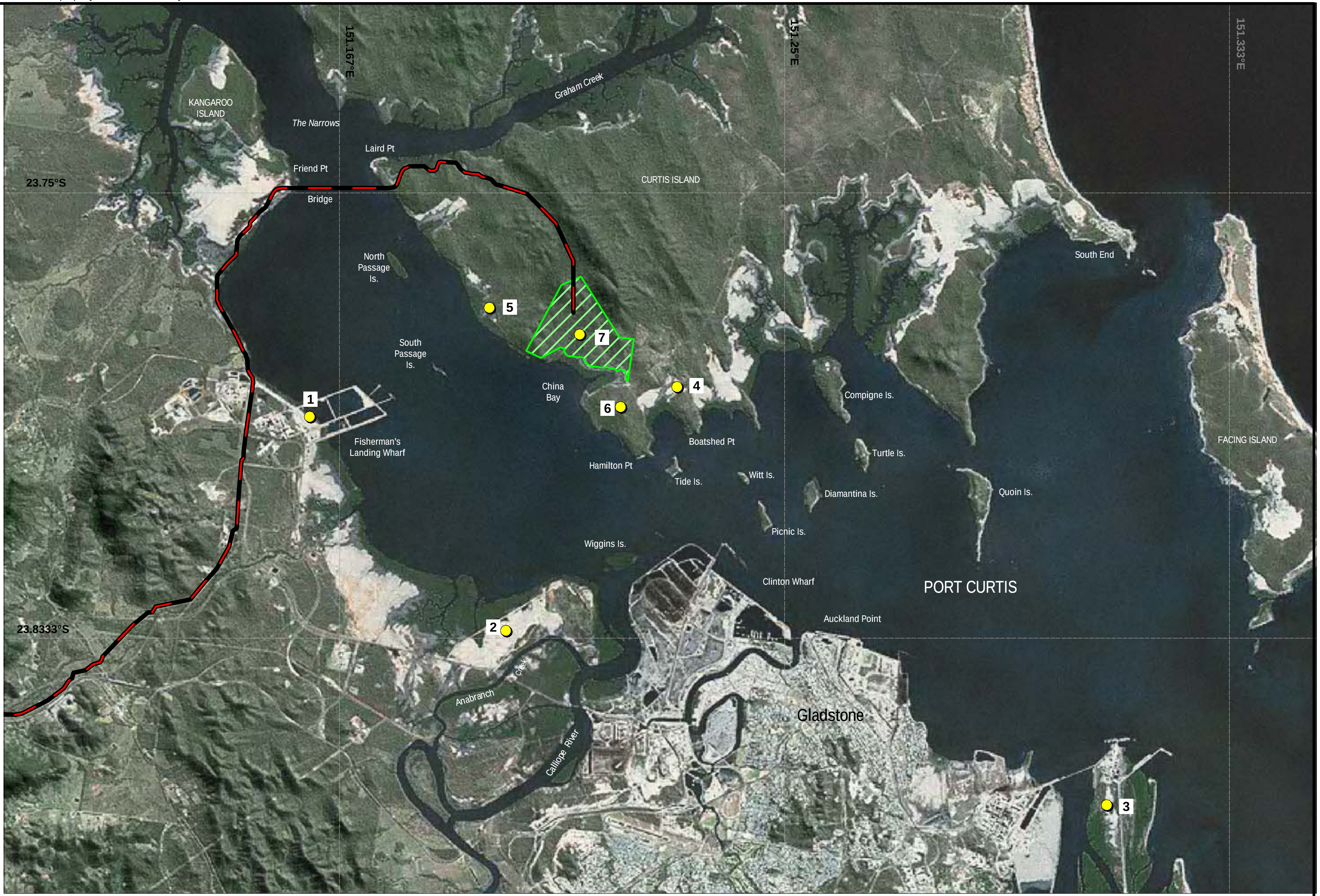
- GSDA west of Fisherman's Landing;
- Fisherman's Landing;
- Wiggins Island;
- South Trees Point;
- Port Alma;
- Boatshed Point, Curtis Island;
- North China Bay, Curtis Island;
- Hamilton Point, Curtis Island; and
- Hamilton Point West, Curtis Island.

The locations of these alternatives sites are shown on Figure 2.3.2. Port Alma which is 60 km to the north near the mouth of the Fitzroy River is not shown on Figure 2.3.2.

A desktop constraints analysis was conducted by Santos on each of the nominated Gladstone sites outlined above. The above sites were assessed against the following criteria:

- **Development cost** - including the differential costs of land purchase, site preparation (including piling if required), road access, utilities supply, feed gas supply, LNG jetty and dredging.
- **Suitable land** – including available area, terrain, geotechnical conditions, ownership, availability of utilities, and road access.
- **Shipping navigation** - including access to existing channels, extent of dredging required, and length of jetty required.
- **Safety and security** - including suitability in terms of relationship to housing, other industries, Gladstone CBD, as well as existing and planned wharves.
- **Environmental impacts** - including comparative advantages / disadvantages between the various sites.

The results of the analysis are summarised in Table 2.3.3.



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● 7 Alternative LNG Facility Location

Gas Transmission Pipeline

LNG Facility

1. Fisherman's Landing
2. Wiggins Island
3. South Trees Point
4. Boatshed Point
5. North China Bay
6. Hamilton Point
7. Hamilton Point West

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Client

URS

LNG

Project

GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Drawn: CA | Approved: JB | Date: 09-03-2009

Job No: 4262 6220 | File No: 42626220-g-875.wor

Title

ALTERNATIVE GLADSTONE SITES FOR LNG FACILITY

Figure: **2.3.2**

Rev:B

A4

Table 2.3.3 Assessment of Alternative Gladstone Sites

Criteria	Fisherman's Landing	Wiggins Island	South Trees Point	Port Alma	Boatshed Point	North China Bay	Hamilton Point	Hamilton Point West
Development Cost	🔴	🔴	🔴	🔴	🟡	🟡	🟢	🟢
Suitable Land	🔴	🔴	🔴	🟢	🟢	🟢	🟢	🟢
Shipping Navigation	🟡	🟢	🟢	🟡	🔴	🟢	🟢	🟢
Safety and Security	🔴	🔴	🔴	🟢	🟡	🟢	🟢	🟢
Environmental Impacts	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡

🔴 Unlikely to be suitable 🟡 Potentially suitable 🟢 Suitable

Table 2.3.4 summarises the basis for the assessment given in Table 2.3.3.

As can be seen from Table 2.3.3 Port Alma proved to be unsuitable. Since that assessment was undertaken, the GPC has dismissed Port Alma as being unsuitable for the LNG industry for a number of reasons including:

- Unsuitable foundations for heavy industrial loads;
- Land use restrictions due to an existing explosives licence; and
- Inadequate space in the harbour for the manoeuvring of LNG vessels.

Fisherman's Landing, Wiggins Island, South Trees Point and Boatshed Point did not meet the key safety, land availability and technical criteria. However the Curtis Island sites of Hamilton Point, Hamilton Point West and North China Bay were shown to be feasible from a technical, environmental and safety standpoint. Whilst Hamilton Point provided some advantages from reduced dredging effort, its function as a visual 'buffer' was also considered. No decision has yet been made by the Queensland Government to make the Hamilton Point site available for a gas liquefaction facility. Santos has an option to purchase Hamilton Point in the event it does become available. Santos understands that the North China Bay site has since been allocated to another LNG project. In these circumstances the proposed site is Hamilton Point West.

Table 2.3.4 Basis of Gladstone Site Selection Assessment

Criteria	Fisherman's Landing	Wiggins Island	South Trees Island	Port Alma	Boatshed Point, Curtis Island	North China Bay, Curtis Island	Hamilton Point, Curtis Island	Hamilton Point West, Curtis Island
Development Cost	Extensive dredging. Substantial piling required. Lower utility, feed gas pipeline, road access and jetty costs.	Substantial piling required. Lower utility, feed gas pipeline, road access and jetty costs. Minimal dredging required.	Substantial piling required. Lower utility, feed gas pipeline, road access and jetty costs. Least dredging required.	Extensive dredging. Substantial earth fill and foundation piling required. High utility, feed gas pipeline and road access costs. High construction costs (due to remote location).	High road/bridge, utility and feed gas pipeline costs. High construction costs (due to island location).	High road/bridge, utility and feed gas pipeline costs. High construction costs (due to island location).	High road/bridge, utility and feed gas pipeline costs. High construction costs (due to island location).	High road/bridge, utility and feed gas pipeline costs. High construction costs (due to island location).
Suitable Land	The area of land available was insufficient and constrained by other uses. Extensive piling would be required.	The area of land available was insufficient. Extensive earth fill and piling would be required.	This land is low lying and would require extensive earth fill and piling. The area of land available is insufficient. There is also a Native Title claim over land.	Desktop evaluation identified that extensive earth fill and foundation piling would be required. New access roads/bridges and utilities from adjacent to the Bruce Highway would be required.	Based on desktop evaluation, all of the sites considered on Curtis Island were deemed potentially acceptable.	Based on desktop evaluation, all of the sites considered on Curtis Island were deemed potentially acceptable.	Based on desktop evaluation, all of the sites considered on Curtis Island were deemed potentially acceptable.	Based on desktop evaluation, all of the sites considered on Curtis Island were deemed potentially acceptable.

Criteria	Fisherman's Landing	Wiggins Island	South Trees Island	Port Alma	Boatshed Point, Curtis Island	North China Bay, Curtis Island	Hamilton Point, Curtis Island	Hamilton Point West, Curtis Island
Shipping Navigation	This site was deemed to be potentially suitable, although Targinie Channel requires deepening and widening for LNG ships.	This site was deemed to be potentially suitable, if developed as extension of overall Wiggins Island Coal Terminal.	This site was deemed potentially suitable. Closest to Port entrance and potentially best location in terms of ship movements.	This site was deemed potentially unsuitable. The existing channel is navigable by small ships only. Dredging effort required for LNG vessels unknown. Silt load from Fitzroy River would necessitate substantial ongoing maintenance dredging.	This site was deemed unacceptable by MSQ staff, due to navigation risks associated with ship movements between Hamilton Point and Tide Island.	This site was deemed potentially suitable.	This site was deemed potentially suitable.	This site was deemed potentially suitable.
Safety and Security	This site was considered potentially unacceptable, due to close proximity of other industry.	This site was considered potentially unacceptable, due to close proximity of other industry.	This site was considered to be potentially unacceptable, due to close proximity of other industry.	This site was considered to be suitable.	This site was deemed potentially acceptable.	This site was considered to be suitable.	This site was considered to be suitable.	This site was considered to be suitable.
Environmental Impacts	Environmental management measures could be implemented to make the site potentially suitable.	Environmental management measures could be implemented to make the site potentially suitable.	Environmental management measures could be implemented to make the site potentially suitable.	Environmental management measures could be implemented to make the site potentially suitable.	Environmental management measures could be implemented to make the site potentially suitable.	Environmental management measures could be implemented to make the site potentially suitable.	Environmental management measures could be implemented to make the site potentially suitable.	Environmental management measures could be implemented to make the site potentially suitable.

2.3.2 Construction Options

The elements of the labour market which determine the potential availability of labour supply for the construction of the project include:

- Current characteristics of the local labour market;
- Local contractor capacity;
- Size of required labour force;
- Labour force participation;
- Construction sector participation; and
- Concurrent project activity.

Due to the current economic volatility across Australia, there is uncertainty on the impact on the construction labour market with respect to skilled manpower. Due to this volatility, the GLNG Project will need to be flexible with its construction planning. As the situation is uncertain regarding the project's ability to access enough skilled workers during construction using local labour, optional construction techniques that require less local labour are being considered.

One option being considered is conventional construction where all the basic construction materials will be barged to Curtis Island and assembled on-site. This method is known as stick-built. It will require all of the construction workers to be located on-site. It is estimated that the peak on-site construction workforce for this option would not exceed 3,000.

An optional construction technique being considered to reduce the impact on local infrastructure is the pre-assembling of major items of equipment off-site (either domestically or overseas) and then shipping them to site for installation. This would result in ocean-going barges delivering large pre-assembled modules directly to the site where they will be unloaded at the materials off-loading facility (MOF) and transported along the haul road by multi-wheeled heavy movers to the construction site. Figure 2.3.3 shows an example of a pre-assembled module unloading at an offloading facility at Gove in the Northern Territory and is typical of what might be expected for the GLNG Project.

Source: Outokumpu Technology Australasia Pty Ltd

Figure 2.3.3 Typical Pre-Assembled Module

Advantages of using pre-assembled modules include the following:

- Reduction in on-site construction employees to a peak of up to 2,000;
- Reduction in on-site accommodation services required for the additional construction workforce;
- Reduction in the demand for on-site infrastructure services including water, sewerage and power;
- Fewer barge trips across Port Curtis;
- Less on-site congestion during construction; and
- Reduction in construction wastes generated on-site and reduced disposal requirements.

At this stage it is uncertain as to which construction method (pre-assembled modules or stick-built) will be used. A decision will be made during FEED and will depend on a number of factors including an up-to-date estimate of locally available workers and the timing, availability and cost of pre-assembled modules.

Stick-built construction has been used as the base case in this EIS with respect to manpower numbers, material quantities and project schedule data. This is because the stick-built option would require greater manpower numbers and material quantities.

If modular construction is used, the construction manpower numbers and amount of equipment and materials requiring transport to Curtis Island would be reduced from those reported in this EIS as a significant portion of the materials (and labour hours) would be incorporated into the modules and delivered to Curtis Island in large pre-assembled units. Workforce and associated demographic and accommodation impacts would reduce by approximately one third.

As a final decision on the construction techniques to be used has not been made, both of the options have been assessed in this EIS.

2.3.3 Technology Alternatives

The purpose of an LNG facility is to liquefy natural gas to reduce its volume and thus facilitate its transport to markets (in the case of GLNG, overseas via ship).

The fundamental process used to liquefy natural gas is mechanical refrigeration, where gas is cooled and liquefied by heat exchange with a separate refrigerant. The refrigerant is expanded and compressed in a closed loop system to achieve the cold temperatures needed for liquefaction.

The basic principles for cooling and liquefying the gas using refrigerants involve matching as closely as possible the cooling/heating curves of the process gas and the refrigerant, as this results in a more efficient thermodynamic process requiring less power per unit of LNG produced. This applies to all liquefaction processes, however individual process licensors have implemented innovations to improve efficiency and optimise costs. The equipment used plays a major part in the overall efficiency, operability, reliability and cost of the plant. Key equipment items include the compressors used to circulate the refrigerants, the compressor drivers and the heat exchangers used to cool and liquefy the gas and exchange heat between refrigerants.

For GLNG, an additional requirement was the need to align the development concept and liquefaction process with coal seam gas deliverability characteristics. The LNG facility options therefore addressed the potential requirement to avoid total CSG well turndown by reducing LNG facility downtime.

The LNG industry is by nature conservative and for GLNG the decision was taken to avoid innovation and new technology where practicable, with only well proven processes and equipment to be considered.

2.3.3.1 Liquefaction Process Selection

A number of licensed LNG liquefaction processes have been developed over the last four decades based on the abovementioned refrigeration principle, and several are in use for base-load export developments, with varying degrees of operational experience.

The main differences between these LNG liquefaction processes are:

- Main cryogenic heat exchanger type (these have very large surface areas and a large number of passes, to enable close temperature approaches, and they are the heart of an LNG plant. Some processes use brazed aluminium plate fin heat exchangers, some use spiral wound heat exchangers);
- Compression string arrangement (most processes use a single 100 % compressor string, while one uses 2 x 50 % dual compressor strings); and
- Refrigerants (some processes use pure components while others use mixed refrigerants).

Of the available processes, Santos selected the two most used liquefaction processes for detailed evaluation in Pre-FEED - the ConocoPhillips (CoP) Optimised Cascade Process (OCP), and the Air Products Chemicals Incorporated (APCI) Propane Pre-cooled Mixed Refrigerant (C3MR) process. Both processes use similar gas pretreatment unit operations, LNG storage and LNG ship loading facilities, with the key differences being in the refrigeration technologies used to liquefy the purified gas. Each of these technology providers has proven designs in the 3-4 mtpa LNG range, and either process was deemed suitable for the GLNG Project.

The following issues are typical of those considered in selecting the technology for an LNG facility:

- Cooling media - for the main cooling medium, the choice is normally between air and water (the selection of gas turbine drivers and air cooling eliminated the need for a cooling water system which would have required seawater intake and discharge facilities);
- Compressor drivers - both gas turbine compressor drivers (the standard nowadays for LNG liquefaction plants) and electric motor drivers were evaluated;
- Acid gas removal – optimised process for the specific feed gas composition;
- Power supply – grid connection versus self-generated; and
- Water supply - town water supply versus onsite desalination.

A broad description of the two technologies evaluated is provided below:

Optimised Cascade Process (OCP)

The Phillips Petroleum Company first utilised this process at its Kenai (Alaska) LNG facility which started-up in 1969. This was the first LNG plant to ship LNG to Japan and it has achieved uninterrupted supply to its customers since.

Operating plants using OCP technology include facilities in Australia (Darwin), Alaska, Trinidad, Egypt and Equatorial Guinea. At year end 2008, the LNG production capacity from OCP plants was approximately 31 million tonnes per annum (mtpa).

This process uses three pure refrigerants – in cascaded propane, ethylene and methane circuits. Each refrigeration circuit uses two 50 % capacity gas turbine driven parallel compression strings (the two-in-one arrangement). The propane pre-cooling is carried out in core-in-kettle type exchangers, with the ethylene and methane refrigeration using brazed aluminium plate fin heat exchangers (PFHE) arranged in vertical cold boxes, with the process gas and refrigerant streams flowing through channels in the PFHEs in separate layers.

Propane Pre-Cooled Mixed Refrigerant Process (C3MR)

This process was first used for the Brunei LNG project in 1972 and accounts for a significant proportion of the world's LNG production capacity.

Operating plants using C3MR technology include facilities in Australia (Karratha), Brunei, Malaysia, Qatar, Algeria, Indonesia, Egypt, Nigeria, Libya, Abu Dhabi and Oman. At year-end 2008, the LNG production capacity from plants utilizing APCI technology was approximately 165 million tonnes per annum (Mtpa).

The process uses a two component refrigerant system: propane and a mixed refrigerant that is composed of nitrogen, methane, ethane and propane. The refrigeration circuit typically uses a single 100 % capacity gas turbine driven compressor string. The propane pre-cooling is carried out in kettle type heat exchangers, with refrigeration using a proprietary spiral wound heat exchanger (SWHE), consisting of two or three tube bundles arranged in a vertical shell, with the process gas and refrigerants entering the tubes at the bottom and flowing upward.

2.3.3.2 Process Selection

Selection of the LNG liquefaction process was based on technical, EHS and economic considerations.

Pre-FEED studies were carried out for both processes, utilising the extensive in-house LNG databases of the engineering contractors, the liquefaction licensors and main equipment vendors to develop designs to enable valid comparisons and optimum selections to be made. Sufficient process details were developed to define main equipment and operating parameters to evaluate options using relevant criteria. The technical considerations included process and equipment experience, reliability, availability, process efficiency, operations and maintenance, innovation and customisation, LNG production capacity, turndown capability and EHS impacts among others. The economic issues included capital cost, operating cost and life cycle costing. All of these aspects were evaluated to arrive at the optimum solution.

In terms of environmental impact, both processes have very similar footprints.

For the GLNG Project, the ConocoPhillips Optimised Cascade Process was selected.

2.3.4 Access Options

The following two options are being considered for the provision of access to the site on Curtis Island:

- A bridge and access road linking Curtis Island to the mainland; and
- A ferry/barge service.

The Queensland CG, as the lead agent for a working group comprising the Department of Infrastructure and Planning (DIP), Gladstone Ports Corporation Limited (GPC), Santos and the BG Group/Queensland Gas Company (QGC) joint venture, has engaged consultants to prepare a concept design of a potential access road and bridge to provide access between Friend Point on the mainland and Laird Point on Curtis Island (Connell Wagner, 2008).

The access road and bridge are not anticipated to be in place in time to support the construction of Train 1 and as such ferrying and barging infrastructure will need to be established for this purpose. Should the access road and bridge ultimately be built, it will be used for transportation of personnel and materials required for the operation of the LNG facility as well as for future stages of construction.

The final decision to build the road and bridge access to Curtis Island will depend on a number of factors including environmental impacts, relative health and safety impacts, and economic factors when compared with the barge/ferry option over the expected life of the LNG facility. If the bridge is not built, then the site will continue to be accessed by the use of ferries and barges.

Table 2.3.5 compares the bridge option to the “no bridge” option against a set of evaluation criteria. The table outlines the advantages and disadvantages of each.

Table 2.3.5 Bridge vs. "No Bridge" Options

Option	Evaluation Criteria	Advantages	Disadvantages
Bridge	• Environmental impact • Safety • Cost • Scheduling • Third party commitment • Security	• Reduce barge/ferry movements in Port Curtis • Easier access by road (no time tables) • Site more readily accessible for emergency vehicles	• Bridge construction may not fit with schedule for GLNG Project. • Bridge requires reliance on third parties • Potential negative community perspective of increased access to Curtis Island • Easier access has more security risk • Greater land and seabed disturbance • Large cost for construction of bridge
"No Bridge"	• Environmental impact • Safety • Cost • Scheduling • Third party commitment • Security	• No restriction to GLNG Project schedule • No reliance on third party for construction of the bridge • Security risk lower with reduced access to the Curtis Island • Lower cost • Reduced land and seabed disturbance	• Increased barge/ferry movements in Port Curtis • Increased traffic congestion at Auckland Point • Less convenient access based on ferry timetables • Helicopter or high speed boat needed for emergency access

As a final decision on the construction of the bridge and road access to Curtis Island has not been made, both of the access options to Curtis Island have been assessed in this EIS.

2.3.4.1 Bridge Option

Bridge Alignment

The location of the bridge crossing is influenced by a number of factors including:

- Potential future land uses on Curtis Island and the mainland, as well as the tidal area between the mainland and Kangaroo Island;
- Potential future infrastructure to be provided within the Curtis Island Infrastructure Corridor, as identified under the Gladstone Land Port Rail Road Infrastructure (GLPRRI) Study 2007;
- Possible future port development planned by the GPC off Friend Point and Laird Point;
- Environmental impacts, inclusive of the state marine park boundary; and
- Geotechnical conditions, if variances were to occur within the study area that would favour the location of the bridge based on better ground conditions.

As a result, the following alternative locations (Figure 2.3.4) were considered:

- Laird Point to Friend Point outside the state marine park; and
- Laird Point to Friend Point within the state marine park.

The preferred option is a compromise of the above two alternatives with the bridge being located partly inside (eastern half) and partly outside (western half) the state marine park. The preferred location was chosen based on the following:

- Clearance to potential future GPC port developments;
- Minimisation of land severance on Curtis Island to maximise the area available for future development on the western shoreline of Curtis Island;
- Reduce disturbance to seagrass areas;
- Straight horizontal alignment and simplified construction technique for the bridge structure; and
- Shorter overall bridge length and associated lower cost.

Bridge Design

The bridge design study included consideration of the following design alternatives:

- Flat bridge verses elevated;
- Opening bridge verses fixed;
- Two lane verses one lane;
- Public access versus restricted access; and
- Design features for reducing life cycle costs such as maintenance.

Taking into consideration the navigational and geotechnical findings and study inputs, the working group has settled on a preliminary bridge design which comprises a two lane, fixed elevated bridge structure as a basis for further assessment, including the EIS process. This structure would likely be a combination of in-situ concrete for the piles, pile caps and piers, and pre-cast construction for the main superstructure elements.

The final method of construction to be adopted will be determined in consultation with the construction contractor.

2.3.4.2 Barge/Ferry Option

It is proposed to use barges and ferries for access the site during the construction phase prior to construction of the bridge. It will be necessary to barge/ferry all plant, equipment and personnel to the LNG facility site for at least the construction of Train 1.

Given the prospect that the bridge may not be built, under the barge/ferry alternative, the barge/ferry service will continue into the operations phase of Train 1 and for the construction and operation of Trains 2 and 3.

As discussed in Section 2.3.2, two optional construction techniques of stick-built and pre-assembled modules are being considered. The stick-built option will require a larger number of barge trips to transport more but smaller items of equipment to Curtis Island where they will be assembled. With the pre-assembled module option, fewer barge trips will be necessary as larger but fewer items of equipment will be delivered to Curtis Island. A decision as to which construction technique will be used will be made during FEED.

Table 2.3.6 summarises the aspects considered in selecting the preferred ferry/barge terminal in Gladstone and the import ship/barge unloading site. For further information refer to Appendix J.

The locations of the alternative terminals considered are shown on Figure 2.3.5.

Based on the above considerations and on discussions with the Gladstone Ports Corporation, the preferred site for the ferry terminal is Auckland Point. However, pre-assembled module barges and heavy lift vessels will unload directly at the MOF on Curtis Island without using Auckland Point.

Scale 1:25 000 (A4)
Datum : GDA94

0 — 500 — 1000m

Potential Curtis Island Access Road

Great Barrier Reef Coast Marine Park Boundary

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Client: URS / LNG

Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT

Title: **ALTERNATIVE BRIDGE ALIGNMENTS**

Drawn: CA | Approved: JB | Date: 09-03-2009

Job No: **4262 6220** | File No: 42626220-g-948.wor

Figure: **2.3.4** | Rev: A | A4

Table 2.3.6 Barge/Ferry and Import Ship/Barge Alternatives

Alternative	Discussion
Ferry/Barge Terminal	
Auckland Point	• Preferred location for ferry/barge terminal based on discussions with GPC • Availability of space to develop necessary barge/ferry infrastructure including car parking, truck staging and trans-shipment laydown areas • Access to site using dedicated port access road • Access issues for workforce would need to be resolved with the relevant authorities • Slightly lower cycle time to Curtis Island as no speed restrictions compared with the Gladstone Marina and O'Connell Wharf
Gladstone Marina	• Existing infrastructure for barge and ferry movements • Sufficient vehicle/bus access • Insufficient parking space • Access to site on arterial road ways • Speed restrictions in the marina which would increase travel time compared to Auckland Point • Existing amenities. • Potential issue with increased ferry movements within a public marina
O'Connell Wharf	• Limited ferry manoeuvring space • Access to site on arterial road ways • 70 min ferry cycle time to Curtis Island • Limited vehicle parking • Dock height limited for passenger loading for some vessels • Dock infrastructure in poor condition
Fishermans Landing	• Limited suitable infrastructure • Access would be via rural roads • 50 min ferry cycle time to Curtis Island • Bus and vehicle access • Limited parking • Safety and security issues as site is currently being used for industry
Import Ship/Barge Unloading	
Fishermans Landing	• Current wharves not viable for construction materials import • Trucks will not pass through Gladstone • Potential bridge clearance issues • Road will need upgrading to high mass standards
Auckland Point	• Preferred location based on discussions with GPC • No unloading crane installed currently • Wharf load limit of 90 t • Able to handle larger ships than other alternative sites • Undercover warehouse facilities available • Laydown space available • Customs / AQIS facilities available • Proximity to existing rail access • Road access to arterial road network via dedicated port access road • Potential bridge clearance issues for larger items of equipment

2.3.5 Water Supply Alternatives

The following two alternatives have been considered for the supply of water to the LNG facility:

- Desalination; and
- Pipeline from mainland water supply.

For the desalination alternative, sea water will be extracted using pumps located at the product loading facility. Due to the biofouling nature of sea water, a sodium hypochlorite dosing system will be provided to suppress biological growth in the seawater pipework. Circular clarifiers will be used to remove any silt present and the settled sea water will be pumped to the desalination units. The desalination units will use reverse osmosis (RO) technology, with the required necessary pre-treatment. The brine reject from the membranes will be returned to sea as it is effectively concentrated seawater.

The pipeline alternative will require the construction of a pipeline from the mainland. This will supply water provided by the Gladstone Area Water Board. To cross Port Curtis, the pipeline is expected to be buried in a trench in a similar manner and location to that proposed for the gas transmission pipeline. If possible Santos will endeavour to use the same trench or adjacent trenches for both pipelines to minimise the extent of seabed disturbance. However that will depend on the timing of both construction activities and on the requirements of the Gladstone Area Water Board. Alternatively it could be carried by the bridge to Curtis Island should the bridge be built. However, the bridge is unlikely to be available in the timeframe required by the LNG facility. The water pipeline is likely to be approximately 200 mm diameter. Once on the island it will follow the same alignment as the gas transmission pipeline to the LNG facility.

Assessment of the impact of the discharge from the desalination plant to Port Curtis (Section 8.7) showed that there will be no detectable change in local water quality patterns due to this small discharge in the near field assessment. The far field assessment showed results were within natural variability levels in the region, which will be essentially undetectable. Consequently Santos is currently proposing to use desalination for the LNG facility. However, a final decision will be made during FEED.

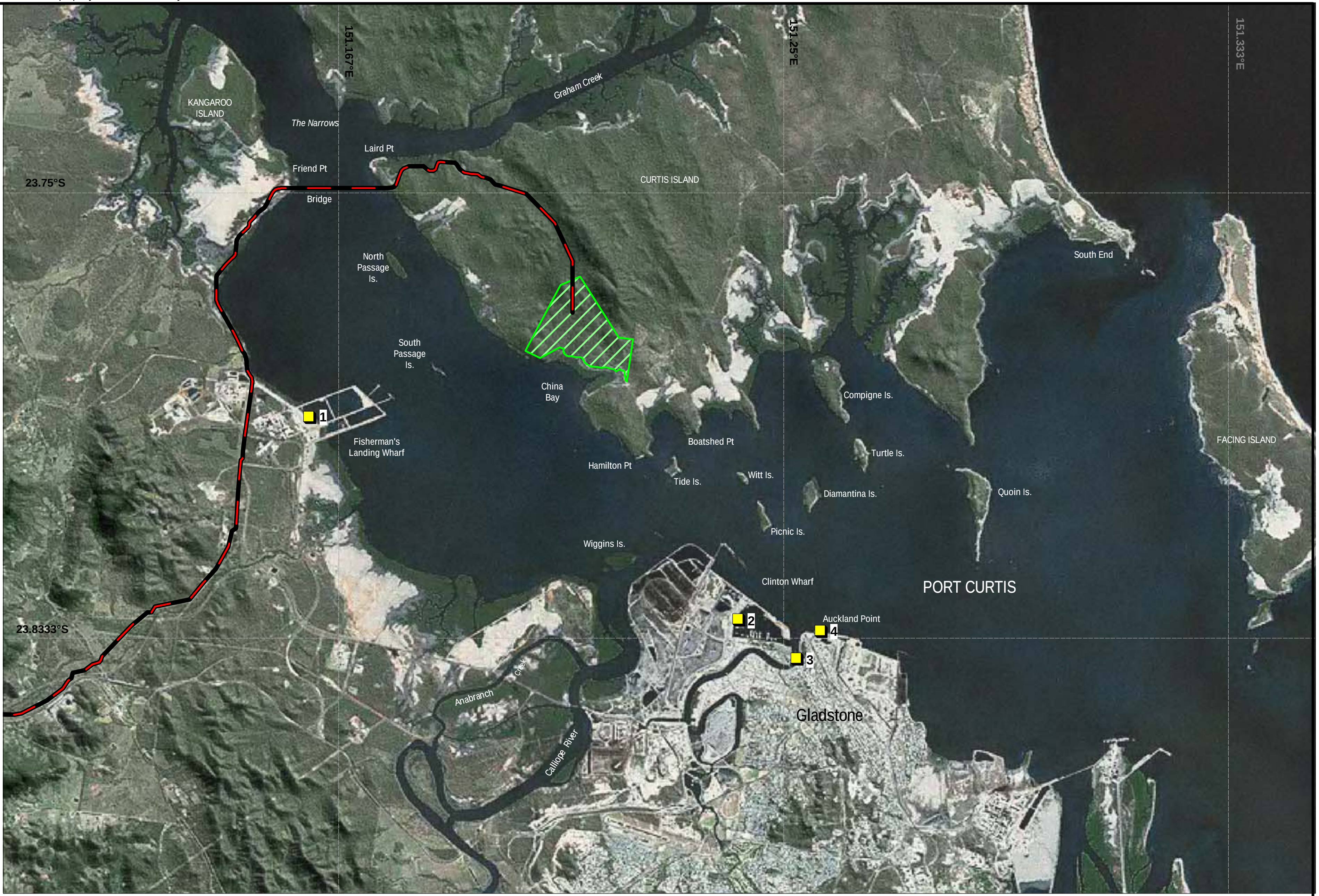
2.3.6 Power Supply Alternatives

Santos has evaluated both external power (from the national grid) and self-generated power from on site facilities.

Studies have shown that while power supplied from the national grid would be competitive in terms of system availability as well as capital and operating costs, there is a significant schedule risk associated with the external power supply option. Power from the grid has an expected implementation time of 5.5 to 6 years which is too late for project start-up. To avoid this risk, the LNG facility will self-generate electrical power at least for Train 1. However, power from the national grid will be considered for the subsequent trains.

Other considerations in support of self-generated power for Train 1 are:

- Current common user infrastructure plans for Curtis Island provide for only pole-mounted low voltage power supply across the bridge should it be built;
- There are concerns regarding existing harmonics problems with the power supply in the Gladstone area and the potential effect of additional large variable speed drives on this problem;
- It is not clear if acceptable terms could be reached regarding the reliability of the power supply to the LNG facility; and
- Self-generated power using gas fired generation units would have lower overall greenhouse gas emissions than if the power was drawn from the national grid which is primarily based on coal fired power.



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Scale 1:100 000 (A4)
Datum : GDA94

3	Alternative Ferry Terminal Sites
	Gas Transmission Pipeline
	LNG Facility

1. Fisherman's Landing
2. Gladstone Marina
3. O'Connell Wharf
4. Auckland Point

Client

Project
GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Title
ALTENRATIVE FERRY TERMINAL SITES

Drawn: CA | Approved: JB | Date: 09-03-2009

Job No: **4262 6220** | File No: 42626220-g-1027.wor

Figure: **2.3.5** | Rev:A | A4

2.3.7 Construction Workforce Accommodation Alternatives

A number of alternatives were considered for providing temporary accommodation for the LNG facility's construction workforce. The preferred option is for a Construction Accommodation Facility (CAF) and associated facilities on Curtis Island. The construction and operation of the CAF would ultimately be subject to the Coordinator General's approval of a principal material change of use (planning) application by Santos under the GSDA development scheme. The assessment of the application would involve a consideration as to whether the CAF and associated facilities fall within the definition of an ancillary use.

The alternatives considered included:

- CAF established within the Santos site on Curtis Island to accommodate the majority of construction workforce;
- CAF development (single or multiple CAFs) on the mainland to accommodate the majority of the construction workforce;
- Split between CAF on Curtis Island and CAF on mainland;
- Utilising existing housing on the mainland (through rental and/or purchase), hotels and developing additional accommodation as required; and
- Accommodating workforce on a former passenger liner within Port Curtis (Float-tel).

The implications associated with each of the above alternatives are summarised in Table 2.3.7. In particular, further research on Santos' preferred alternative has been undertaken, as detailed in the following table.

Table 2.3.7 Construction Workforce Accommodation Alternatives

Alternative	Implications
CAF on Curtis Island	• No lost time in daily commute (daily commute is walking distance) • Reduced transport and main road impacts • Reduced potential for worker interaction with Gladstone community • Reduced safety exposure associated with daily barging from mainland • Reduced pressure on existing accommodation facilities in Gladstone • Minimal disturbance to adjacent land uses contained on Santos site (confined to LNG facility site) verses mainland alternative • Single approval required for one accommodation facility • Increased disturbance footprint on Curtis Island
CAF on mainland	• Significant lost time in daily commute via ferry if/when the bridge is built – Approx. 3.5 hours daily travel time (mainland accommodation to Auckland Point to Curtis Island return) • Significant impact on transportation requirements – 240 bus movements per day (assuming 50 people per bus)[1] – 80 ferry movements per day (assuming 150 people per ferry)[1] • Increased potential for worker interaction with Gladstone community • Increased safety risks associated with daily ferry to/from Curtis Island • Potential disturbance to adjacent land uses • Multiple approvals likely • Reduced disturbance footprint on Curtis Island
CAF on Curtis Island and mainland	• Combination of all of the implications listed above

Alternative	Implications
Existing/new accommodation on mainland	• Significant lost time in daily commute via ferry if/when bridge is built • Increased potential for worker interaction with Gladstone community • Increased safety risks associated with daily ferry to/from Curtis Island • Increased pressure on existing Gladstone accommodation facilities and users • Multiple approvals likely for two or more accommodation sites • Reduced disturbance footprint on Curtis Island • Risk of distortion of local housing market
Float-tel	• Ferry trip still required to/from float-tel • Time lost in daily commute to site • Significant barge traffic required to service float-tel • Safety risk in the event of a cyclone • Reduced disturbance footprint on Curtis Island

Note: 1 At peak employment (up to potentially 3,000 persons), assuming all possible transport movements (including empty backloads 100 % of the time) it could be expected that as many as 80 ferry movements and 240 bus movements per day could potentially occur. .These numbers are considered worst case and differ from those quoted in Table 2.3.9 due to different assumptions being made.

Based on the above assessment, the preferred alternative selected is to develop a CAF on Curtis Island confined to the LNG facility site with the capacity to accommodate the entire construction workforce.

The proposed CAF will be completely self contained and will provide the housing, dining, logistics and recreational facilities for the construction workforce. The CAF will only be required for LNG facility construction activities. At the end of construction activities the CAF will no longer be required and will be demobilised.

During the operations phase, temporary short term accommodation will be provided on site for up to approximately 30 days on an as needs basis for major plant upgrades, maintenance and shut down programs (e.g. major turbine refurbishment is required approximately every three years) and statutory plant vessel inspections. In accordance with standard LNG industry practices, this work is conducted on a continuous 12 hour roster basis. At completion of these maintenance programs, these temporary facilities will be demobilised.

Also in the operations phase, in the event that adverse whether conditions temporarily prevent transfers from Curtis Island, limited emergency accommodation will be provided for a reduced operations workforce, located within the facility administration complex, and in the form of portable roll-out bedding.

The planning implications in relation to the Gladstone State Development (GSDA) development scheme of accommodating construction workers on Curtis Island are discussed in Section 8.11.5.11.

There are good town planning, environmental, transport, safety and security reasons to establish the CAF on Curtis Island as opposed to the other alternatives considered in this section. Any other approvals needed for the CAF will be obtained prior to the occupation and use of the accommodation facility. Santos will adopt the goals, standards and guidelines for environmental management under the GSDA development scheme. The environmental management strategies to be implemented for the LNG facility component of the project are outlined in Section 13.

Several factors were considered in the decision to locate the CAF on Curtis Island including logistics, workers safety, costs and the potential for negative social impacts.

The CAF on Curtis Island can offer workers increased benefits and opportunities while reducing certain hazards and risks associated with the other CAF alternative accommodation options. The advantages associated with having a majority construction workforce accommodated on Curtis Island include:

- Specific health and safety benefits of CAF style accommodation;

- Security considerations for the local community;
- Mitigation of social impacts to Gladstone communities;
- Economic benefits for the project; and
- Reduced environmental impacts.

Advantages of CAF Style Accommodation

Temporary CAFs have specific advantages over other forms alternate accommodation scenarios by providing a controlled environment for the workforce. The key advantages of a managed accommodation facility environment include:

- Controlled sleep environment – It has been shown that the best environment for a good sleep is one which is cool, dark and quiet. In a CAF it is possible to ensure that:
  - Bedrooms are completely dark for sleeping, using measures such as lined (thick) curtains, paper or foil on the windows;
  - Bedrooms are quiet for sleeping - Designing rooms to minimize noise transmission, selecting less intrusive room-sharing arrangements, and choosing the layout of rooms to minimize the impact from noisy areas such as dining rooms, transport areas and ablution blocks. CAF management can also minimize the level and hours of noise emanating from rooms and recreation areas, especially where alcohol consumption is occurring;
  - Bedrooms are cool for sleeping - Designing rooms which are not too hot or too cold for sleeping, through measures such as insulation, ventilation, and air conditioning; and
  - Beds and bedding materials are comfortable.
- Avoiding the pressures of home-based or self-catering accommodation - There are two main aspects which can impact on the ability to get good rest:
  - For many individuals, the impact of family and friends can reduce the quality and quantity of sleep. Many home-based employees face additional duties or social pressures compared to accommodation facility-based employees, which can cut into their sleep hours. Extensive survey data on employee sleep habits show that home-based employees average less than 7 hours sleep on the days that they work, accumulating sleep debt which they then recover on their days off; and
  - Time required for catering and domestic arrangements. Employees who live in self-catering accommodation report significantly less time for rest after shopping for provisions, cooking, cleaning, and laundry.

Employee alertness and health is not only affected by sleep, but also by individual health and lifestyle habits. Accommodation facility environments can support good health and lifestyle habits by providing and promoting:

- Recreation and exercise facilities;
- Responsible alcohol management;
- Controlling alcohol consumption which affects sleep quality and noise;
- Reducing the risk of uncontrolled alcohol consumption which can impact fitness for work;
- Healthy eating;
- Providing breakfast and healthy meal options;
- Avoiding spicy or heavy food before bedtime which affects sleep quality; and
- Locating the accommodation facility close to the worksite.

Accommodation facility supervision is an important factor in controlling undesirable behaviours, such as excessive alcohol consumption, which can affect the ability for residents to sustain good rest. The regular presence of work supervisors and managers in the accommodation facility has a strong influence.

Safety Considerations

- Fatigue Management Considerations

The construction workforce for the LNG facility will live in a CAF during their work cycles and commute daily to the worksite. After the completion of each work cycle workers may also commute long distances to their home base for breaks at the beginning and end of the work cycles. Employees will work this pattern for extended periods to complete the construction of the facility.

The location of the CAF will also influence employee opportunities to obtain proper rest and the risk of travel incidents.

  - Required Rest Time - After a 10 hour work shift, employees will have 14 hours to commute, eat, sleep, relax, exercise, communicate with family and friends and prepare for the next day's activities. This length of time increases opportunities for recuperative rest to sustain the proposed work patterns; and
  - Locating the CAF 3.5 hours return commute from the worksite will essentially reduce this non-work time to 10.5 hours, or less if transport time is extended due to barge or drive delays.

From a health and safety point of view, it is beneficial to have the CAF located close to the LNG facility site. This increases time off between work shifts.

Driving is one of the more significant safety risks associated with transport to remotely located CAFs. Micro-sleeps while driving sleep-deprived lead to increased road accidents. Transporting construction employees between the LNG facility site and CAF each day increases the risk of road accidents, which impacts both employees and the local community.

It is expected that a significant portion of the workforce may return to a home base outside the local area. Some of these individuals may be then driving longer distances after their work cycles. To improve their alertness during these drives, it is important for these individuals to be caught up on their rest (and not carrying additional sleep debt).

Construction work rosters commonly include single day breaks to ease the long work cycles. While this has not been finalized for the project, it is not unusual for employees to drive back to their home base in these short breaks and incur significant fatigue. There is more potential to control these practices with a local island based CAF.

Therefore the major benefits of locating the CAF on Curtis Island adjacent to the LNG facility include:

- Reduced fatigue and physical stress by;
  - Saving lost time spent travelling to and from the mainland each day (up to three and a half hours per day) for each non-transfer day;
  - Controlling worker's living environment (e.g. increasing sleep quality, patterns and duration); and
  - Providing good health and lifestyle habitats (including healthy eating choices, recreation and exercise facilities).
- Improving commuter safety by reducing the number of:
  - Harbour crossings (by up to 52 ferry movements per day – 13 return trips am/pm – on non-transfer days);
  - Sea/land transfers; and
  - Landward vehicle movements (e.g. approximately 80 bus movements to/from vehicle collection points each day).

Economic Benefits

General information relating to the costs and benefits of locating the CAF on Curtis Island are discussed in Section's 4, 8.14 and 8.15. However, due to the commercially sensitive nature of this information, information relating to costs is confidential and not released in the EIS.

Locating the CAF on Curtis Island will have significant economic benefits for the project as labour costs will be reduced by improving productivity through avoiding travel and providing a controlled accommodation environment, thereby reducing fatigue and physical stress.

The local community will still benefit from the CAF on Curtis Island as local purchasing of goods and services will remain in place and benefit the local economy directly.

In addition, having a CAF on Curtis Island will not adversely impact on other industrial developments within Gladstone.

Positive Environmental Impacts

- Less greenhouse gas emissions from transport sources;
- Less noise and traffic from marine and terrestrial transport; and
- Wastes centrally managed (therefore less impact on services).

Social Impacts

Large scale industrial projects in Gladstone have resulted in significant population increases during the construction phase with resulting impacts to local and regional communities. Gladstone has experienced a strong property market in recent years that has been characterized by high sales rates, demand for housing stock and a strong increase in median house prices and land prices. Accommodating the construction workforce on Curtis Island will reduce the risk of increasing demand for rental properties and property prices and minimise the disruption to the community. It is anticipated that locating the CAF on Curtis Island will have limited impact on Gladstone facilities and services as all imported workers will stay within the CAF site boundary.

In addition, locating the CAF on Curtis Island will significantly reduce traffic congestion associated with large numbers of workers commuting to nodal points and bus transfers.

Community Consultation in relation to CAFs

Three community information sessions were held with Curtis Island residents throughout the EIS preparation period in June, September and November 2008. Public sessions were also held with Gladstone community residents around the same time.

The largest audience for Curtis Island occurred at the September 2008 session where over 50 people were in attendance. At this session, a number of issues were raised by community members in relation to the possibility of a temporary construction accommodation facility being established on Curtis Island. The key concerns raised included:

- Will the workforce have access to South End?
- Will there be a road from the facility to South End?
- Will workers be able to use the public amenities at South End?
- Workers behaving badly due to excessive alcohol consumption and making a public nuisance;
- Number of construction workers;
- Large numbers of workers descending on South End; and
- Potential for an increase in violence and criminal activity.

GLNG Project team members responded to these issues by stating that if GLNG decided to seek approval for a construction accommodation facility on the Island, then the workforce would be tightly managed. The accommodation facility would be located within the fenced perimeter of the LNG facility and areas such as South End would be made a 'restricted area'. Workers 'on roster' would not be able to leave the facility to visit South End.

In follow up consultations with several community residents on the Island, it became clear that there was a divide of opinion in regard to the use of the Island. Many residents wanted their community left the way it is and did not want an influx of visitations; primarily to preserve the existing culture on the Island. However, other residents expressed an approval for more visitors, on the strict proviso that respect for locals and their property was maintained.

To address community concerns, Santos will actively monitor social issues through its local Community Engagement team presence in Gladstone, and continue to proactively communicate with Curtis Island residents in regard to their concerns. In terms of specifically addressing worker access to South End, Santos will liaise with the construction contractor to ensure appropriate behavioural provisions and locational restrictions are built into worker contracts. Breaches of these conditions will result in disciplinary action or dismissal.

Traffic Implications for Alternate CAFs

A further assessment of alternative accommodation scenarios for the stick-built option was undertaken based on the traffic implications of each. The alternatives assessed are as outlined in Table 2.3.8.

Table 2.3.8 Additional Construction Workforce Accommodation Alternatives

Alternative Number	Scenario
1	3,000 person accommodation facility on Curtis Island.
2	1,500 person accommodation on Curtis Island and a 1,500 person accommodation facility on the mainland (assumed to be at Calliope Historical Village).
3	3,000 person accommodation facility at Calliope Historical Village
4	1,500 person accommodation facility at Calliope Historical Village and 1,500 workers accommodation throughout Gladstone.

The assessment was based on the following assumptions:

- Buses are used to transfer workers from the mainland accommodation facilities to the ferry terminal (except for the workers living throughout Gladstone in Alternative 4 who would use private vehicles);
- All workers transferred from the mainland to Curtis Island by ferry;
- Non-local workers will work for a 10-day period followed by a 4-day rostered-off period;
- Local workers living in Gladstone will work a 5-day-on/2-day-off schedule;
- Two thirds of the workforce would be working at any one time and the remaining one third would be on leave;
- Workers living on the mainland would be transported to Curtis Island each day; and
- All ferry trips are back-loaded (i.e. all ferries delivering workers to the island will bring returning workers back).

Based on the above assumptions, the results of the travel assessment undertaken for each of the four alternatives listed in Table 2.3.8 are summarised in Table 2.3.9.

Table 2.3.9 Travel Implications of Accommodation Alternatives

Parameter (per 14-day work cycle)	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Bus Movements	68	353	639	639
Ferry Movements	21	124	196	196
Travel Time per Worker	2.8 hrs	2.8 hrs (Island accommodation) 31.4 hrs (Calliope accommodation)	31.4 hrs	28.1 hrs (Gladstone accommodation) 31.4 hrs (Calliope accommodation)
Total Travel Time (all workers)	8,655 hrs	52,734 hrs	96,813 hrs	91,679 hrs

The results in Table 2.3.9 show that Alternative 1 (all workers accommodated on Curtis Island) will result in significantly fewer bus and ferry trips and significantly reduced commuting time when averaged over the 14-day work cycle. This alternative will also result in significantly reduced traffic congestion in Gladstone and a lower increased risk to traffic safety. In addition, Alternative 1 will result in less disruption from the construction workers to the Gladstone community and less demand on existing accommodation facilities.

The overall assessment concluded that the provision of the construction workers accommodation facility on Curtis Island is the most sustainable accommodation solution for the project. On this basis it is the preferred alternative.

Further information on workforce accommodation aspects of the project are given in Section 8.14.

2.3.8 Dredge Alternatives

With reference to Section 2.3.1, the extent of dredging required to provide safe shipping access was a key issue in the selection of a suitable site for the LNG facility.

A capital dredging program will be required to provide shipping access to the LNG facility site. This access will include provision of a navigation approach channel, as well as berthing and manoeuvring areas. A total of some 8 million m^3 in situ is anticipated to be dredged.

For the site that was ultimately selected, Santos has been developing optimal dredge layouts for the approach channel and manoeuvring areas in close consultation with the GPC and the Regional Harbour Master. This ongoing process of consultation has included extensive testing of alternative layouts using navigation simulators with the intent of ensuring navigation safety is maximized and dredge volumes are minimised.

The alternative dredging equipment considered included:

- Trailing suction hopper dredge (TSHD);
- Cutter suction dredge (CSD); and
- Backhoe and barge.

The advantages and disadvantages of each are summarised in Table 2.3.10.

Table 2.3.10 Dredge Alternatives

Advantages	Disadvantages
Trailing Suction Hopper Dredge	
• Minimum effect on other shipping when operating adjacent to the Targinie Channel • Self-contained • Unlikely to be affected by local weather conditions • Not generally affected by sea state • Relatively inexpensive to mobilize • High production rate • Discharge area need not be close by	• Not able to work in very shallow water • Production not continuous • Fluidises soil • Sensitive to rubbish and debris • Not able to work in confined spaces
Cutter Suction Dredge	
• Continuous dredging and disposal • High production rate • Can dredge to create own depth	• Discharge by pipeline only • Fluidizes soil • Sensitive to rubbish and debris • May obstruct shipping traffic • Pipeline may obstruct shipping in Targinie Channel • May be expensive to mobilise
Backhoe and Barge	
• Simple construction and operation • Insensitive to rubbish and debris • Able to work in confined areas • Removes soil with minimal dilution	• More over-dredge required to achieve design depth • Low production rate • Needs hoppers to remove dredged material • Expensive to operate

The material, site conditions and proposed pumping distance may warrant one or a combination of the above dredging alternatives. A TSHD plant is most suitable for dredging silt, sand and very weak rock only, and requires at least 8 m depth of water to operate. The presence of the clayey material in the proposed dredging area would cause problems while attempting to pump over the required distances and pipe blockage would most likely be very onerous. Additionally, a large backhoe and barge would be time consuming.

Due to the characteristics of the material to be removed from the site and, in particular, the presence of small pockets of rock, the most technically suitable and cost effective dredging plant is a large or medium CSD. A small CSD would not be appropriate for the removal of hard rock as the vessels would have insufficient power and momentum or weight on the ladder to make significant progress. The cutter head of a small CSD would tend to ride over the rock areas rather than cut through them.

2.3.9 Dredged Material Management Alternatives

The estimated volume of material to be dredged is 8 million m^3. The capacity of the facility required for the disposal of the dredged material will need to be approximately 10 - 11 million m^3 to allow for 20 % bulking of the material following dredging.

As Australia is a signatory to the London Convention and 1996 Protocol to the London Convention, two basic principles need to be taken into account when relocating dredge material in the marine environment:

- The precautionary principle, by virtue of which preventative measures are to be taken when there are reasonable grounds for concern that substances or energy introduced into the marine environment may bring about hazard, harm, damage or interference, even when there is no conclusive evidence of a causal relationship between inputs and the effects; and
- The polluter pays principle, by virtue of which the costs of pollution prevention, control and reduction measures are to be borne by the polluter.

The Queensland Government and the GPC are presently reviewing the dredged material management plan for Port Curtis to plan for the long term dredging and dredged material disposal that may be required to provide safe and efficient access to existing and proposed port facilities in the harbour for the foreseeable future. The plan considers dredging and dredged material disposal required for industrial and port related projects currently proposed for Gladstone. As part of the plan, the GPC is considering a single dredged material disposal area which will be large enough to accommodate the combined dredged material from all of these projects in a manner which is consistent with GPC's long term port development objectives.

The GPC and the Queensland Government propose to undertake an environmental assessment of the overall plan and to obtain the necessary approvals before adopting and implementing the plan. If the plan is approved, the dredging and the associated dredged material placement for the GLNG Project will be undertaken in accordance with the plan provided the timing of the approval is consistent with the GLNG Project requirements.

If for some reason the GPC's strategic dredging and disposal project is delayed or does not proceed, a plan specific to the GLNG Project has been prepared to manage the project's dredge material. This plan is to develop a dredge material placement facility south of Laird Point on Curtis Island.

Santos recognises that the approved use of Laird Point as a dredged material placement facility site would require a further approval by the Queensland Coordinator General for a material change of use of the site to allow for dredged material placement. At the time of this EIS submission, Laird Point, while declared for LNG industry use, had not been formally acquired by a specific proponent for LNG industry use.

At this stage of GLNG Project the dredge material management plan being developed by the Queensland Government for Port Curtis is not sufficiently progressed to meet the timing requirements for the approval and construction of the GLNG Project. Consequently a project-specific dredge material placement facility is required to be assessed.

Santos has identified the following sites as potential dredge material placement facilities with the emphasis being placed on land-based placement and the containment of fine material:

- **Laird Point**. This site is located to the south of Laird Point on Curtis Island adjacent to the Great Barrier Reef Marine Coast Park boundary. Dredge material would be pumped to this location directly from the dredger. The pipeline between the dredge site and the dredge material disposal site would be in excess of 4 km and a pump booster station would be required. Storing dredge material at this location would involve the construction of a 20 m high bund wall across the bay to provide the required storage capacity. A series of lagoons and weirs will be constructed inside the placement facility to treat sea water from the dredge before it re-enters the marine environment;
- **Boatshed Point**. This site is located in the bay between Boatshed Point and Hamilton Point on Curtis Island. Dredge material would be pumped to this location directly from the dredger. The pipeline would be approximately 2 km long. A bund wall approximately 15 m high would be required across the bay to provide sufficient spoil capacity. This site is sufficiently large to construct a series of lagoons and weirs on the adjacent mudflats with seawater discharge into Port Curtis east of Boatshed Point;
- **Valley on Curtis Island**. This site is situated in a north-south trending valley to the north-east of the LNG facility site. Dredge material would be pumped 2 - 3 km to a dewatering facility between Boatshed Point and Hamilton Point. This would be for dewatering the dredge material, and once dewatered it would be trucked as a dry material to the valley via a temporary haul road. The material

would be contained within the valley walls with 30 m high rock-fill walls placed at either end of the valley. Runoff from the area would pass through a settling pond prior to discharge to Port Curtis at China Bay;

- **Fisherman's Landing**. This site is located in an existing reclamation area under the control of the GPC. It is 5 km from the dredge area. In consultation with the GPC, it has been established that there is no capacity for dredge material placement within either the existing reclamation or a proposed 153 ha extension of the current Fisherman's Landing facility; and
- **Offshore**. The GPC has an existing offshore dredge material disposal site which is situated in the Great Barrier Reef Marine Park (GBRMP). However it does not have the capacity required for the GLNG Project's dredging. Any proposal to develop a new offshore disposal site with sufficient capacity would most likely need to be within the GBRMP.

A summary of the alternatives and their implications are given in Table 2.3.11.

Table 2.3.11 Alternative Sites for Dredge Material Disposal

Alternative Site	Logistical Requirements	Advantages	Disadvantages
Laird Point	• 4 km pipeline from dredge site to bay • Booster pump required • 20 m high bund wall • Polishing pond placement	• Smaller footprint than Boatshed point due to wall heights • Reduced visual amenity impact due to distance and aspect from Gladstone and other popular viewing areas • Distance to seagrass is greater than for Boatshed Point • Possible site for future industry within GSDA Curtis Island industry precinct	• Increased distance from the dredging works
Boatshed Point	• Approx. 2 km pipeline from dredge site to disposal site • 15 m high bund wall • Polishing pond adjacent with discharge east of Boatshed Point	• Site of future port facilities in the GPC's strategic plan	• Increased visual amenity impact due to proximity and aspect in relation to Gladstone and other popular viewing areas • Closer to sea grass meadows than other sites • Larger footprint than Laird Point
Valley on Curtis Island	• 2 - 3 km pipeline from dredge site • Double handling required to dry material and then truck it to placement area • 30 m high bund walls required at either end of valley • Polishing pond adjacent with discharge to China Bay	• Minimal interruptions to shipping traffic	• Introduces marine water and sediments to a terrestrial environment • Risk of groundwater impact • Loss of terrestrial vegetation • Inconsistent with GSDA planning for provision of infrastructure corridor to service the proposed industry precinct on Curtis Island

Alternative Site	Logistical Requirements	Advantages	Disadvantages
Fisherman's Landing	• Inadequate capacity	• Consistent with GPC's strategic port plan	• Interference with shipping traffic • Increased distance from the dredging works • Capacity constraint • Timing is uncertain with respect to the GLNG Project schedule.
Offshore	• Significant distance from dredge site will require double handling onto barge for transport to disposal site • Inadequate capacity at the current licensed location	• No disturbance to coastal sites • No potential water quality effects in Port Curtis from material placement.	• Expansion of current offshore facility footprint or identification of a new off-shore facility required • Site likely to be located in GBRMP • As such, it would need to be subject to an extensive consultative process and environmental data collection program in accordance with the National Ocean Disposal Guidelines for Dredged Material and it will need to obtain approvals under the Sea Dumping Act and the GBRMP Act. • Approval time for a new offshore disposal site is lengthy (up to 5 years) and will incur significant delays to the dredging operation. • Water quality impacts and impacts to benthic fauna in GBRMP

The locations of the alternative sites (except the offshore site) are shown on Figure 2.3.6.

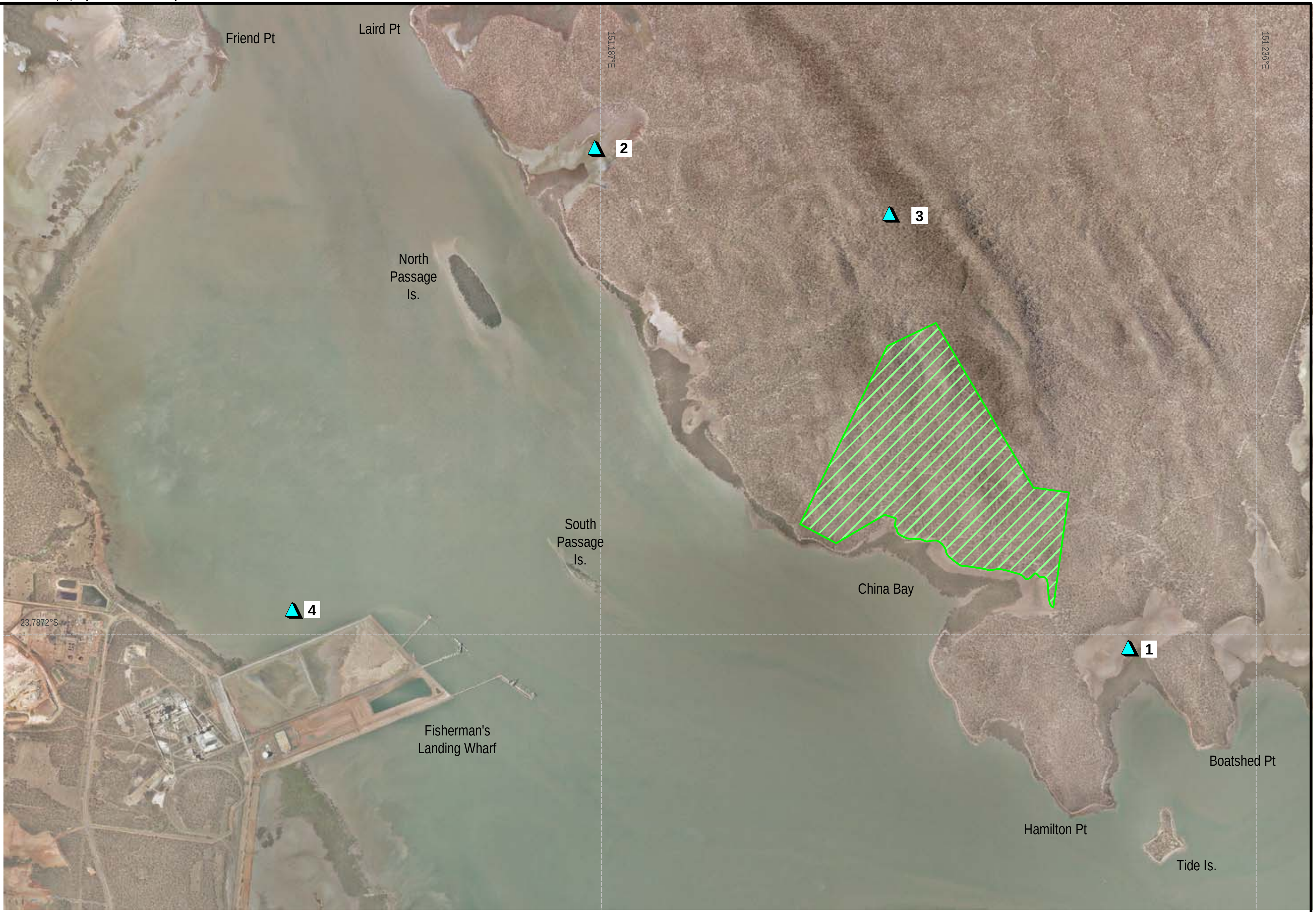
Offshore disposal has been dismissed due to the following reasons:

- The National Ocean Disposal Guidelines for Dredge Material require that all alternatives should be considered before offshore disposal is selected (i.e. it is an option of last resort);
- The impacts to water quality and benthic ecology in the Great Barrier Marine Park; and
- The timeframe to obtaining approvals may not be consistent with the GLNG Project schedule.

The Curtis Island Valley option has been dismissed for environmental and logistical reasons.

Fisherman's Landing was dismissed because of timing uncertainties and capacity constraints.

The GPC's strategic plan indicates future port developments at both Laird Point and Boatshed Point and reclamation of either of these sites using dredged material could be undertaken in such a way as to facilitate the development of future industrial uses. The impacts on visual amenity, footprint and potential for ecological impacts are considered less for the Laird Point option than that of Boatshed Point. Accordingly, Laird Point has been selected as the preferred location for the GLNG Project.



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2 Alternative Dredge Material Placement Sites

LNG Facility

1. Boatshed Point
2. Laird Point
3. Inland Valley
4. Fisherman's Landing

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Client

Project

GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Title

ALTERNATIVE DREDGE MATERIAL PLACEMENT SITES

Drawn: CA | Approved: JB | Date: 05-03-2009

Job No: **4262 6220** | File No: 42626220-g-876.wor

Figure: **2.3.6** | Rev: A | A4

Two alternative routes have been identified for pumping the dredged material from the dredge to the placement facility. One route is offshore parallel to the Curtis Island Coast and the other is onshore along the coastline. Further discussion of these alternatives is given in Section 3.10.2.

2.4 "No Project" Alternative

2.4.1 Loss of Economic Opportunities

There is worldwide growth in the demand for low carbon energy and LNG is a key component of meeting that demand. Should the GLNG Project not proceed, the opportunity for Queensland to benefit from that growth would reduce.

Not proceeding with the project would result in missed economic opportunities at a regional, state and national level. The majority of the capital cost of the project (if it proceeds) would be injected into the Australian economy. Up to approximately 5,000 construction jobs and approximately 1,000 operational jobs (mostly in Queensland) would not be created if the project was not to proceed. State and federal governments would miss out on billions of dollars in government revenue generated from tax and royalty payments paid by the upstream producers over the life of the project.

Other flow-on economic benefits that would be foregone include:

- Additional exports in excess of $6.3 billion per year (2008 prices) during the project's operation at full capacity;
- Increase in Queensland's gross state product of $5.3 billion;
- Accelerated exploration and reserves booking of the extensive coal seam gas resources; and
- The increased demand for goods and services that would stimulate business development and employment opportunities in the Roma and Gladstone economies.

2.4.2 Environmental and Social Impacts Avoided

Should the project not proceed many of its environmental and social impacts that are described in this EIS would be avoided. However not all impacts would be avoided for the following reasons:

- In the gas fields, Santos would continue with its current CSG development program to meet existing and future contracts. Impacts would still occur but the development would be at a much slower rate than it would be with the GLNG Project;
- It is likely that the gas transmission pipeline would not be built and hence the impacts associated with it would be avoided. However as the gas fields develop to meet existing and future contracts other pipelines may be required; and
- The impacts from the LNG facility would be avoided but as there are several other LNG projects proposed for Gladstone some of the cumulative impacts such as those from the development of Curtis Island, construction of the bridge access, and dredging of Port Curtis may still occur although their intensity may reduce without the GLNG Project.