Technical Assistance on Liquefied Natural Gas Options for Myanmar Phase 1: Analysis on Location 4 (Selection # 1216215)

Location 4 Gulf of Martaban (Revised)

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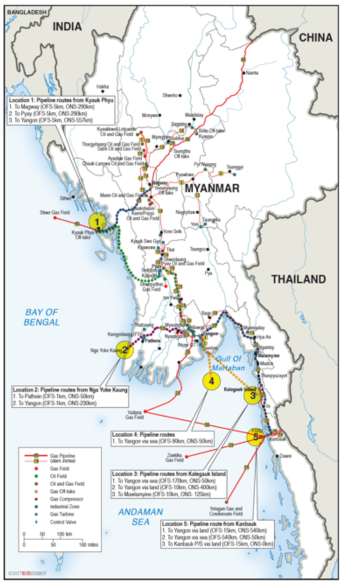
Abbreviations and acronyms

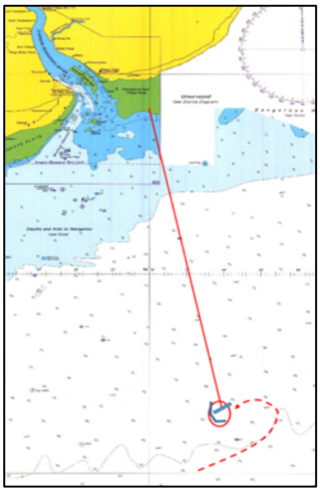
Abbreviation	Description
bbl	Barrels of oil
Bcm	Billion cubic metres
Btu	British thermal units
C&F	Cost and freight
cm	Cubic metres
FSU	Floating storage unit
FSRU	Floating storage and regasification unit
FY	Financial Year
GoM	Government of Myanmar
IOC	International Oil Company
IPP	Independent power producer
IRR	Internal rate of return
LNG	Liquefied Natural Gas
LNGC	Liquefied Natural Gas Carriers
mmbbl	Million barrels
mmbtu	Million British thermal units
mmcfd	Million cubic feet per day
MOGE	Ministry of Oil and Gas Enterprise
scf	Standard cubic feet
Tcf	Trillion cubic feet
ToR	Terms of Reference

Executive Summary



Section 1: Introduction – Following the delivery of a draft copy of the main report in November 2016 entitled 'Technical Assistance on Liquefied Natural Gas Options for Myanmar Phase 1: (Selection # 1216215)' the World Bank / IFC requested that two additional locations be assessed. This Report contains the results of the analysis on Location 4.[1]

Section 2: Site location – Location 4 is offshore in the Gulf of Martaban, 95 km south of the mouth of the Yangon River and is located in 17 m of water at 15°39'N, 096.36°E (15.65°N 096.60°E).



Section 3: Weather – The metocean study identifies potential sea states higher than 3.25m less than 0.01% of the time, which would be sufficient to break mooring lines requiring the FSRU/FSU to leave the berth producing a discontinuity of gas supply. One solution would be to use a breakwater, albeit at significant cost. Offshore winds can come from all sectors, with a mean hourly wind speed of 5.3 m/s over 20 years with a standard deviation of 2.4. However by using a berth alignment with the LNGC/FSRU positioned bow to the prevailing waves, modelled wind levels never exceed typical strengths in mooring loads. In terms of extreme weather, cyclones are rare (1 every 4 years), with May being the most likely month for a cyclone and April when the highest wind speeds are recorded. The jetty must be built sufficiently above the maximum wave height to avoid green water over topping. The maximum expected wave height from a non-cyclonic storm is 3.4m and 6.5-6.8m during a cyclone.

Section 4: Environmental, Social & Cultural Impact – In terms of LNGC transit no issues or impacts are expected. Whilst the FSRUs use seawater vaporisation with the water returned to the sea cooler and containing biocide, the berth is in deep water a long distance from land so water recirculation is not an issue. Whilst the biocide will damage ecology the extent will be limited and localised. A breakwater could change water flows in the bay and therefore cause scour and/or siltation. This would need to be modelled. Given the proposed location of the jetty there are no social, cultural or hazardous issues that might impact a local population. However, the isolated nature of the facility would make emergency response more difficult potentially increasing individual worker risk. A standby vessel capable of firefighting could substantially mitigate this risk. The subsea gas pipeline from the jetty to Yangon will require a small pipeline landfall compound with fiscal metering and pigging facilities.

Section 5: Geology – Earthquakes have been recorded in the vicinity of the Location 4 of magnitude 4 – 5, with a magnitude 7 earthquake recorded to the south of the Location 4 in 1967. Given that

[1] *Use of terminology – The Main Report examined three locations as potential LNG import locations referring to them as Location 1, 2 etc. However, within each generic location a number of different sites were considered which were referred to as Site 1A, Site 1B etc. Whilst this report uses the same basic terminology, identifying the general location as Location 4 and the specific site in this case as Site 4, it should be noted that since no other options were considered Location 4 and Site 4 are effectively one and the same.*

that the land directly to the north of Location 4 has a peak ground acceleration of about 0.4g, the marine facility should be designed to this standard although any additional costs to this will be limited to piling for mooring and berthing dolphins and a jetty platform which would not be particularly onerous.

Section 6: Navigation and marine issues – With a water depth of 17 m LNGCs would approach initially from the south west before turning about 2 nm northeast of the berth and approaching the jetty from the north east in the lea of the breakwater. Since all manoeuvres would be in water of 17m or more no dredging will be required. However, getting a pilot on board would be risky. One option would be for the LNGC to approach from the north east (under the guidance of the Captain alone) and move slowly towards the sheltered waters in the lea of the breakwater at which point the berthing pilot and tugs could be deployed. A breakwater of 335m intended to deflect the waves and reduce wave refraction combined with an island berth is suggested so that the FSRU is moored to the north side and the transferring LNG carrier to the south side. Both bows should be positioned to the south west. In terms of marine traffic no details of the number of movements or type of ship has been identified although given the location of the site near to the channel into Myanmar's main ports of Yangon and Thilawa further consultations with the Myanmar Port Authority are recommended. In addition, whilst Yangon appears to have at least one tug of sufficient size no details appear in international marine databases, implying this vessel is no longer under Class and in poor condition.

Section 7: Gas pipelines – The length of the subsea gas pipeline will depend on the landing point. The Project Team have chosen a mid-case solution opting for a offshore gas pipeline of 105km ($189million) and an onshore gas pipeline of 30km ($36million), which would ultimately tie into the existing gas transmission system. However, different lengths of offshore and onshore pipelines may be appropriate subject to local logistics. It is currently unclear if the local gas network will require additional reinforcement although the local gas network is generally in a poor state of repair.

Section 8: Infrastructure – There is no infrastructure at the proposed location therefore an island jetty will need to be created. Yangon, (former capital), is the closest city to the proposed jetty and has all the commercial services required for the project with only port services appearing to be restricted. In addition Yangon has good technical universities which may provide skills likely to be required for the FSRU, as well as public and private hospitals and an international airport.

Section 9: Results of analysis – As one would expect the traffic light analsyis highlighted the need for a breakwater due to the exposed location of Site 4 as well as the poor marine facilities and the potential geological risks. Based on the foregoing analysis it our suggestion that a breakwater is developed in conjunction with a jetty mounted FSRU. Therefore, based on this technological configuration Site 4 was analysed using SPT-Stage 3 (Discounted Expenditure Model), the conclusions of which are summarised in the following table.

Table 1 - Summary of the results of discounted expenditure selection

Site	Schedule (Months)	Capital Investment (US$ million)	Operating Expense (US$ million per annum)	Discounted Expenditure (DEX) (US$ million)
Site 4	48	312.8	81.1	649

Section 10.1: Conclusions – By combining the Site 4 finger jetty with a breakwater the exposed nature of the site can be mitigated. Whilst the potential marine support from Yangon might be limited the fact that Yangon is a commercial and technical centre is helpful. In addition the actual length of the offshore and onshore pipelines will depend on the landing point and local infrastructure connection.

Section10.2 Recommendation

- It will be important to engage with the MPA (Myamar Port Authority), the Myanmar Navy and other marine stakeholders to establish clarity over marine issues.
- A feasibility study should be undertaken to establish both the offshore subsea pipeline costs and onshore pipeline costs including as assessment of the condition of the local network.

1 Introduction

1.1 General

The high-level objectives of this project are to support the Government of Myanmar (GoM) in developing a gas sector development plan by focusing on the near-to-medium term options to meet the gas demand in Myanmar. Specifically the project focuses on import options of LNG, initially as a bridging fuel while new gas exploration gets underway in Myanmar, including assessment of potential technologies and locations for LNG receiving facilities in Myanmar. Given the aspirations of the GoM for deliveries of LNG in 2018 or 2019, this suggests prospects for development of floating regasification LNG terminals.

On November 8-11, 2016, the Draft Final Report for this Project was presented and discussed with GoM and industry stakeholders. As a result of these discussions, the original Terms of Reference for the consulting assignment have been expanded to include the analysis of two additional potential LNG sites, which shall be referred as Location 4 and Location 5 with the analysis of these additional locations prepared in the same manner and to the same level of detail as the analysis presented in the Draft Final Report for the original three locations.

Therefore, in keeping with the above objectives, this Report on Location 4 is submitted to the World Bank / IFC. In particular, this Report provides a specific analysis of Site 4 in order to assess its potential as possible location for LNG import facilities in Myanmar. (NB: This Report on Location 4 should be read in conjunction with the main project report in order to place these results in context. In addition the main project report contains detailed explanations of technology choices, the traffic light model and estimated costs of infrastructure used as part of the assessment process.)

1.2 Structure of this report

As highlighted above this document provides reports for all three tasks 1(a), (b), and (c) and is therefore structured as follows:

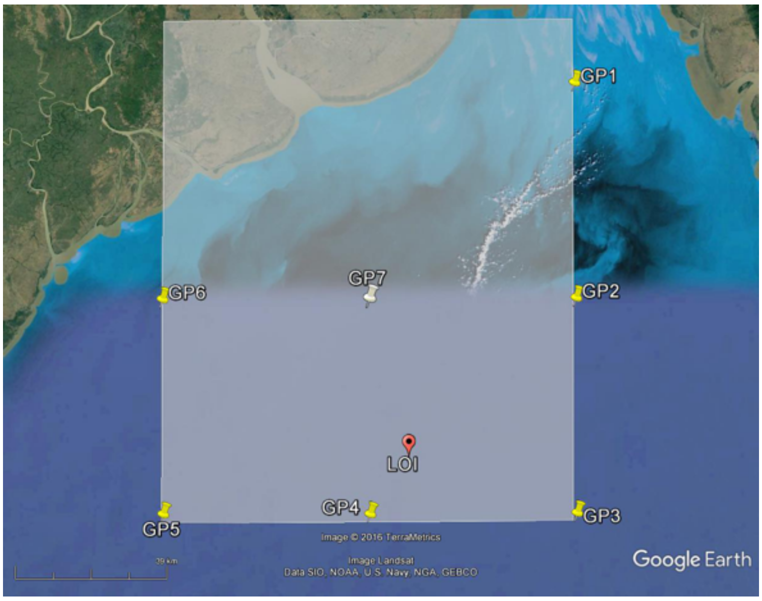
- Section 1 – Introduction.
- Section 2 – Location.
- Section 3 – Weather.
- Section 4 – Environmental, Social & Cultural Impact.
- Section 5 – Geology.
- Section 6 – Navigation.
- Section 7 – Access to gas pipelines.
- Section 8 – Infrastructure.
- Section 9 – Results of analysis.
- Section 10 – Conclusions and Recommendations.

2 Location 4: Gulf of Martaban

The location considered is offshore in the Gulf of Martaban, 95 km almost directly south of the mouth of the Yangon River. Location 4 is located in 17 m of water at 15°39’N, 096.36°E (15.65°N 096.60°E).

Figure 1 – Location 4 in relation to Myanmar

Figure 2 – Location 4 in relation to Yangon



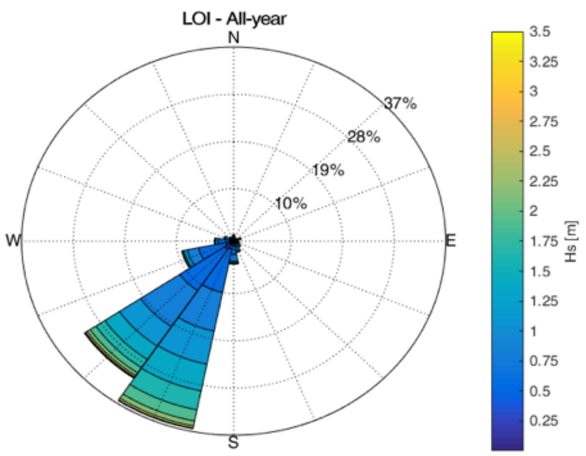
3 Weather

The purpose of this section is to examine the potential impact of weather on the proposed LNG import location. In particular the metocean analysis has examined the wave environment around the location of interest of the terminal and a proposed pilot transfer station. The assessment is based on offshore waves over a 20 year period which have been propagated to Location 4 by means of a numerical modelling exercise.

3.1 Waves

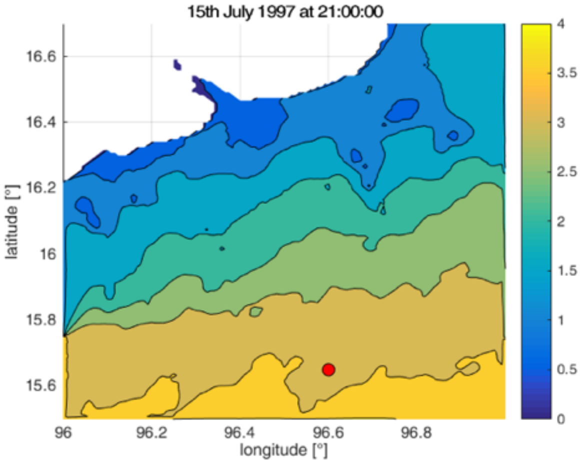
The offshore waves are almost wholly from the south western direction. At this site over a 20 year period the mean significant wave height (Hs) is 0.83m and a standard deviation of 0.46 as shown below.

Figure 3 – Waves Rose



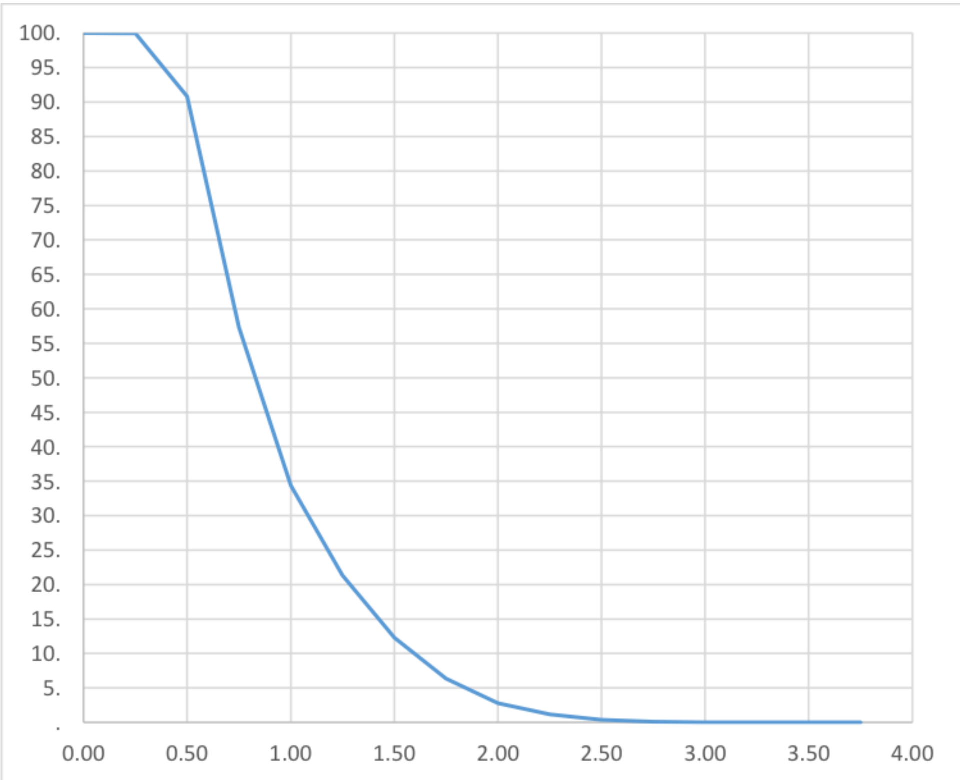
In the 20-year long period, the highest non-cyclonic significant wave height observed is 3.4m. Sea states higher than 3.25m are observed less than 0.01% of the time.

Figure 4 – Inshore Waves for non Cyclonic Storm



Waves of this magnitude would be sufficient to break mooring lines and would therefore require the FSRU or FSU to leave the berth during these storms producing a discontinuity of gas supply. A breakwater could be employed to prevent these waves from impacting on the FSRU, since the water depth is sufficiently shallow to allow a breakwater but at significant cost.

Figure 5 – Wave height exceedance curve

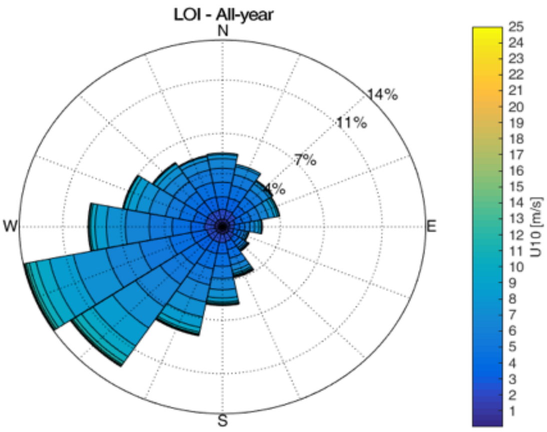


LNG carriers can berth and unload at a wave height of 1.5 m Hs for 87.7% of the year or 97.2% of the year at 2 m Hs. An exceedance level of 12.3% is high and will challenge commerciality. A 2.8% shortfall is very positive. The exact impact will depend on the annual distribution and duration of these non-availabilities. A breakwater if sufficiently large and properly oriented would significantly improve availability of the berth.

3.2 Wind

LNG carriers and FSRUs have high windage areas. The cargo is relatively light compared to water and therefore the flat side of the LNG carrier is out of the water and subject to wind loads. High winds can blow the vessel off the berth or onto the berth, preventing the LNG carrier escaping in an emergency. The metocean study examined offshore winds which can come from all sectors, with a mean hourly wind speed of 5.3 m/s (about 10 knots) over 20 years and standard deviation of 2.4, as shown in the following chart.

Figure 6 – Wind Rose

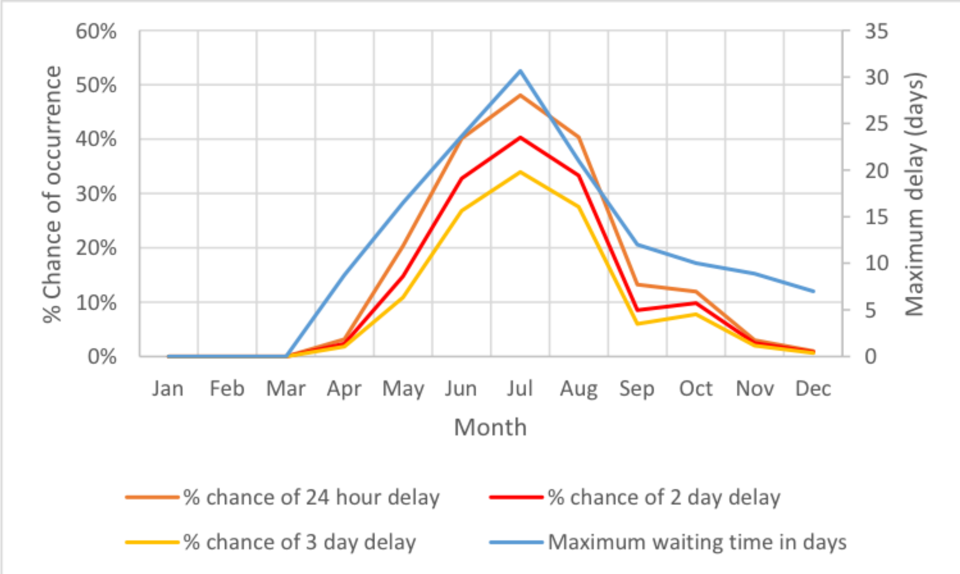


LNG industry body SIGTTO provides wind roses for various operating criteria on LNG carriers. Based on a berth alignment where the LNG carrier/FSRU is positioned bow to the prevailing waves, in this case north westerly, wind limits are exceeded only from a south westerly direction and only stop unloading for 0.55% of the year (2 days). The modelled wind levels never exceed typical strengths in mooring loads. Weathervaning at this location is not required.

3.3 Storm durations

Storms that produce wind or waves that exceed operating limits of either the berthing/unloading process, vaporisation/send out or mooring need to be considered for prevalence and duration. The storm duration is important in defining LNG storage volumes. The following graph shows the probability of different durations of weather that prevent a 24 hour window of waves less than 1.5 m Hs which are typically required to unload a LNG carrier.

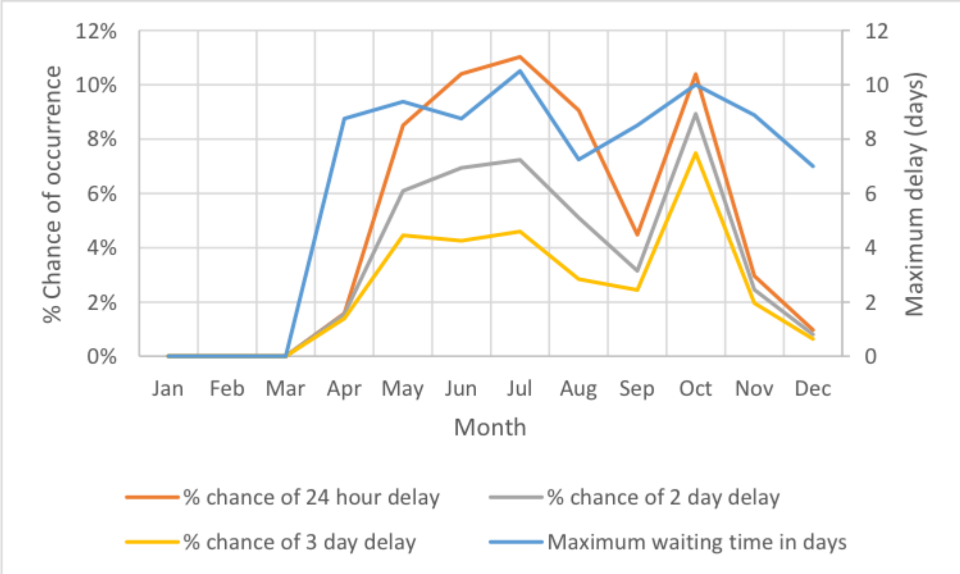
Figure 7 – Weather window durations and probabilities (1.5m Hs)



The above graph shows in blue and on the right hand axis the maximum recorded duration when a 24 hour unloading window is not possible. This is about 10 days apart from in June, July and August when it increases to 30 days. Building in 30 days of excess storage capacity would cover all historical events of the last 20 years but exceeds all industry norms and would result in the largest LNG carrier/FSRU ever built. More typically lower levels of storage are required. The red-orange lines and the left hand axis look at the probability of a 24 hour window not being available in any month, for 1, 2 or 3 days duration.

The probability of a 1 day delay is almost 50% in June, July and August and this does not reduce significantly if the delay increases to 3 days. The operability of Location 4 during this time is highly suspect. This period corresponds to the monsoon so hydroelectric power should be available at this time. Alternatively a breakwater could be used to reduce wave heights. If the berthing/unloading wave height can be increased to 2 m Hs considerable improvements in operability can be achieved, as show below.

Figure 8 – Weather window durations and probabilities (2m Hs)

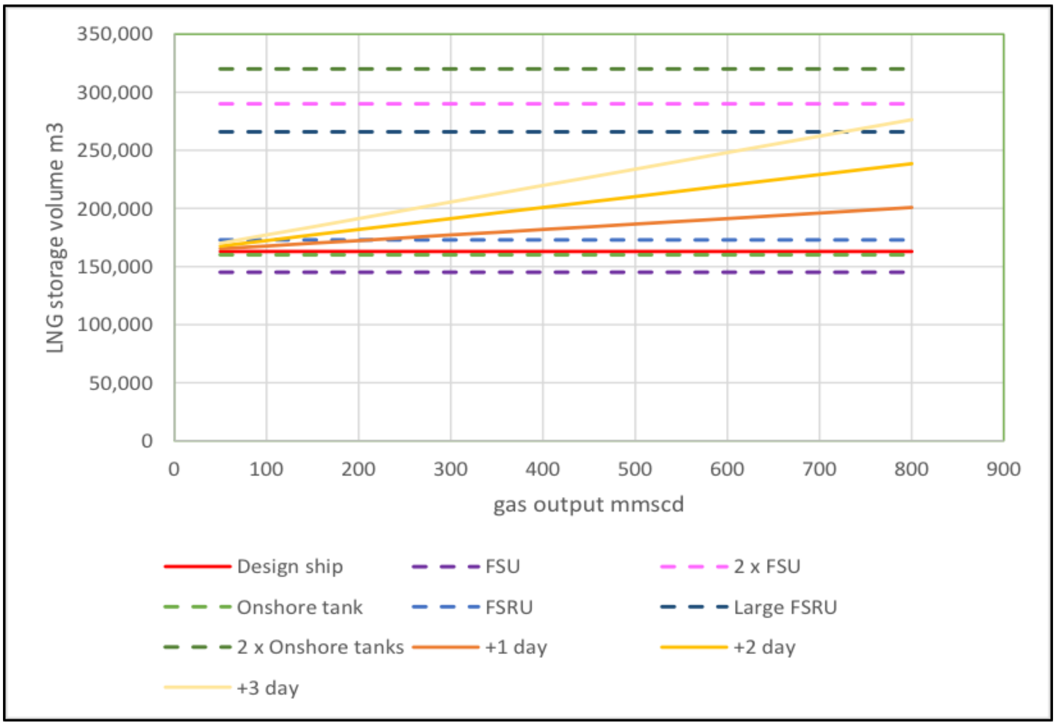


The maximum delay days historically reduces to 10 - 11 in June and July, with a second peak in October. Occurrence probability has also reduced to less than 12% in all cases with a significant difference between 1 day and 2 days.

The viability of 2 m Hs waves is uncertain. It has been achieved at the LNG liquefaction plant in Brunei. However, experience in Chile (wave height unknown) was quite negative with accelerated mooring rope failures occurring.

The following graph shows how large the LNG storage capability needs to be for the design ship (163,000m^3) and a variety of gas send out/LNG vaporisation rates for 1, 2 and 3 days additional storage.

Figure 9 – Vaporisation rate versus storage cover



Up to 3 days of storage reserve volume is possible but would require two FSUs. Maintaining two FSUs on the berth is possible but would require a large island jetty facility, Figure 10. With the FSRU, storage volumes of the same scale are possible but are not currently being built by the market except for deployment in Uruguay. The FSRU would therefore need to be a new build.

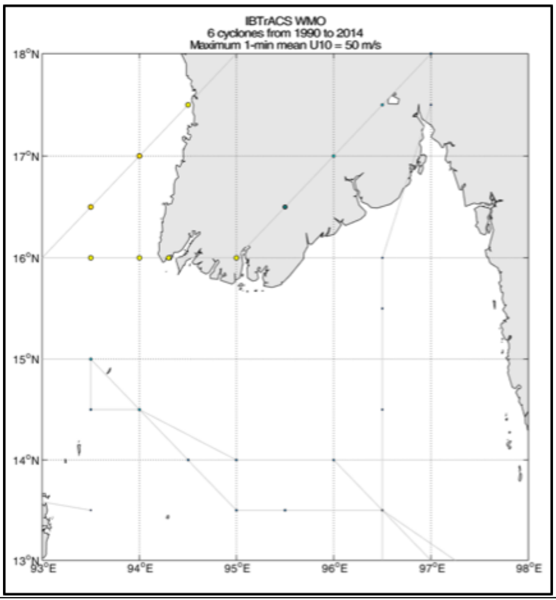
Alternatively a smaller design ship could be selected based on the contract negotiations with individual LNG suppliers.

Figure 10 – Island LNG Jetty in Brazil

3.4 Extreme Weather

Cyclones tend to track up the Andaman Island chain and do not frequently enter the Andaman Sea. However cyclones do occaisionally impact this area.

Figure 11 – Cyclone map



IBTrACS WMO data – Area 3 – Period: 1990-2014													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All-year
Number of events []	0	0	0	1	2	0	0	0	0	2	1	0	6
Maximum 1-min U10 [m/s]	0	0	0	49	44	0	0	0	0	22	17	0	49
Mean 1-min U10 [m/s]	0	0	0	38	28	0	0	0	0	18	17	0	25

Historical cyclone activity analysis records 6 cyclones in 24 years, 1 every 4 years. May is the most likely month for a cyclone and along with April is when the highest wind speeds are recorded.

Flooding is not appropriate. The jetty must be built sufficiently above the maximum wave height to avoid green water over topping. The maximum expected wave height from a non-cyclonic storm is 3.4m at the berth location. The maximum wave height during a cyclone could be 6.5-6.8m.

4 Environmental, Social & Cultural Impact

4.1 LNG carrier transit

The berth and approach are all through wide expanses of deep water so no issues/impacts expected. The extreme event would be a grounding but for this to occur the carrier would probably have completely failed to make its final turn or to have been a long way off course and therefore should already be aborting its transit. The sea bed is mud so would do little damage and the large tidal range should allow the carrier to float off, perhaps assisted by tugs, at high water.

4.2 LNG facility

4.2.1 Environmental

FSRUs use seawater to vaporise the LNG. This water is returned cooler and containing biocide into the local sea. The berth is in deep water a long distance from land so water recirculation is probably not an issue. The biocide required will damage the local ecology which would affect any local fishing. The distance of the site from shore would mean that only deeper water trawlers would be anticipated and the muddy seabed of the area would not expected to be particularly attractive to fishing vessels of this size. The extent of damage will also be highly localised.

A breakwater could change water flows in the bay and therefore cause scour and/or siltation. This would need to be modelled to provide an opinion.

4.2.2 Social & Cultural

The jetty is in deep water a significant distance from land. It is doubtful that the FSRU would be visible at this distance. No impact on the social and cultural heritage is expected.

4.2.3 Hazard

The facility is located a sufficient distance from land so no hazard scenarios would impact the local population

The isolated nature of the facility would make emergency response more difficult potentially increasing individual worker risk. A stand by vessel capable of firefighting could substantially mitigate this risk.

4.3 Pipeline

A new subsea gas pipeline directly across the Gulf of Martaban directly towards Yangon is required. A small pipeline landfall compound will be required near the beach landing. This would be able to meter the gas to fiscal standards and receive and launch pigs. A temporary vent may also be required.

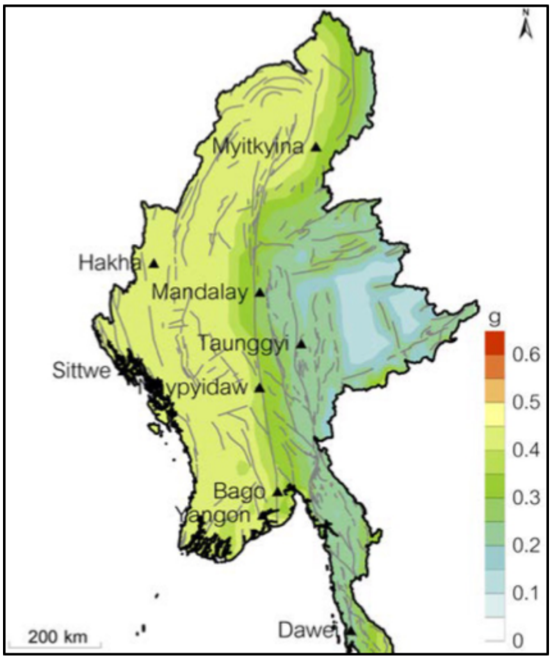
5 Geology

Earthquakes run along the Sagaing plate boundary which is close to Location 4. The Sagaing Fault is a major strike-slip structure that cuts through the centre of Myanmar broadly dividing the country into a western half including Locations 1 and 2 moving north with the Indian plate, and an eastern half including Location 3 attached to the Eurasian plate. The Indian plate continues to move north at about 35 mm per year putting a sideways pressure onto the Eurasian plate in Myanmar.

There have been recorded earthquakes in the vicinity of the site of Magnitude 4 – 5. A magnitude 7 earthquake took place on the fault to the south of the site in 1967.

The land directly to the north of Location 4 has a peak ground acceleration of about 0.4g, Figure 12. The marine facility should be designed to this standard. As the amount of civil works is limited to piling for mooring and berthing dolphins and a jetty platform this would not be particularly onerous.

Figure 12 – Peak ground accelerations for earthquakes in Myanmar



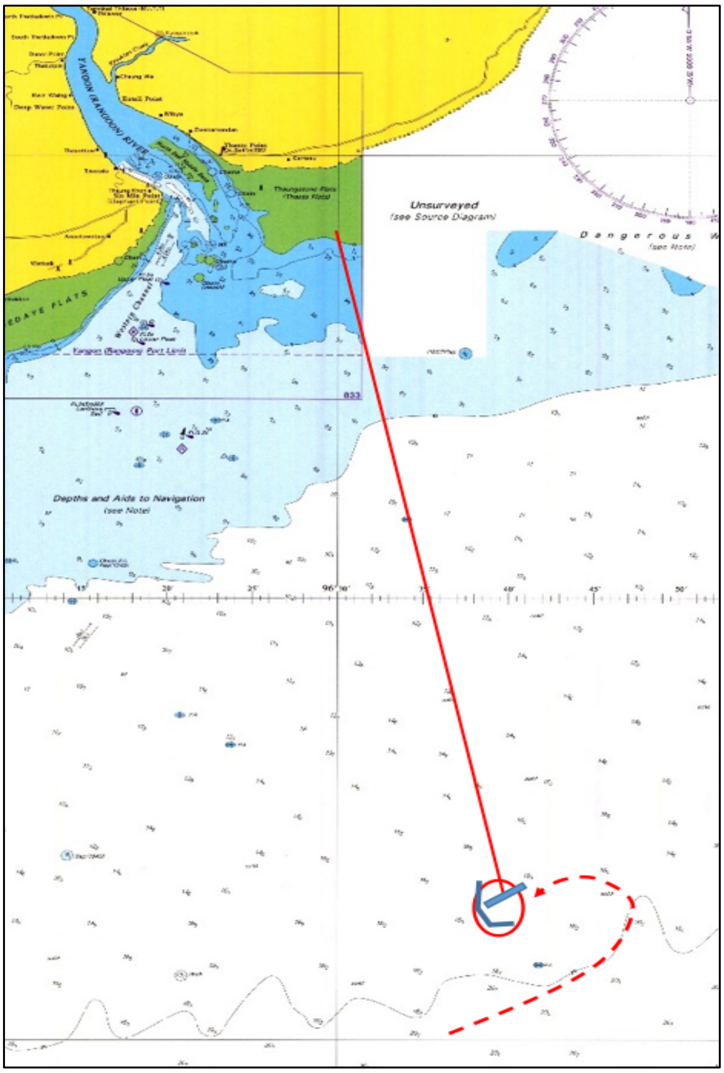
6 Navigation and marine issues

6.1 Navigation routes

UK Admiralty Chart No. 826, shows the area around the proposed berth. The water depth is 17 m and therefore appropriate for LNG carriers which would approach initially from the south west before turning about 2 nm northeast of the berth and approaching the jetty from the north east in the lea of the breakwater. All manoeuvres would be in water of sufficient depth so no dredging will be required.

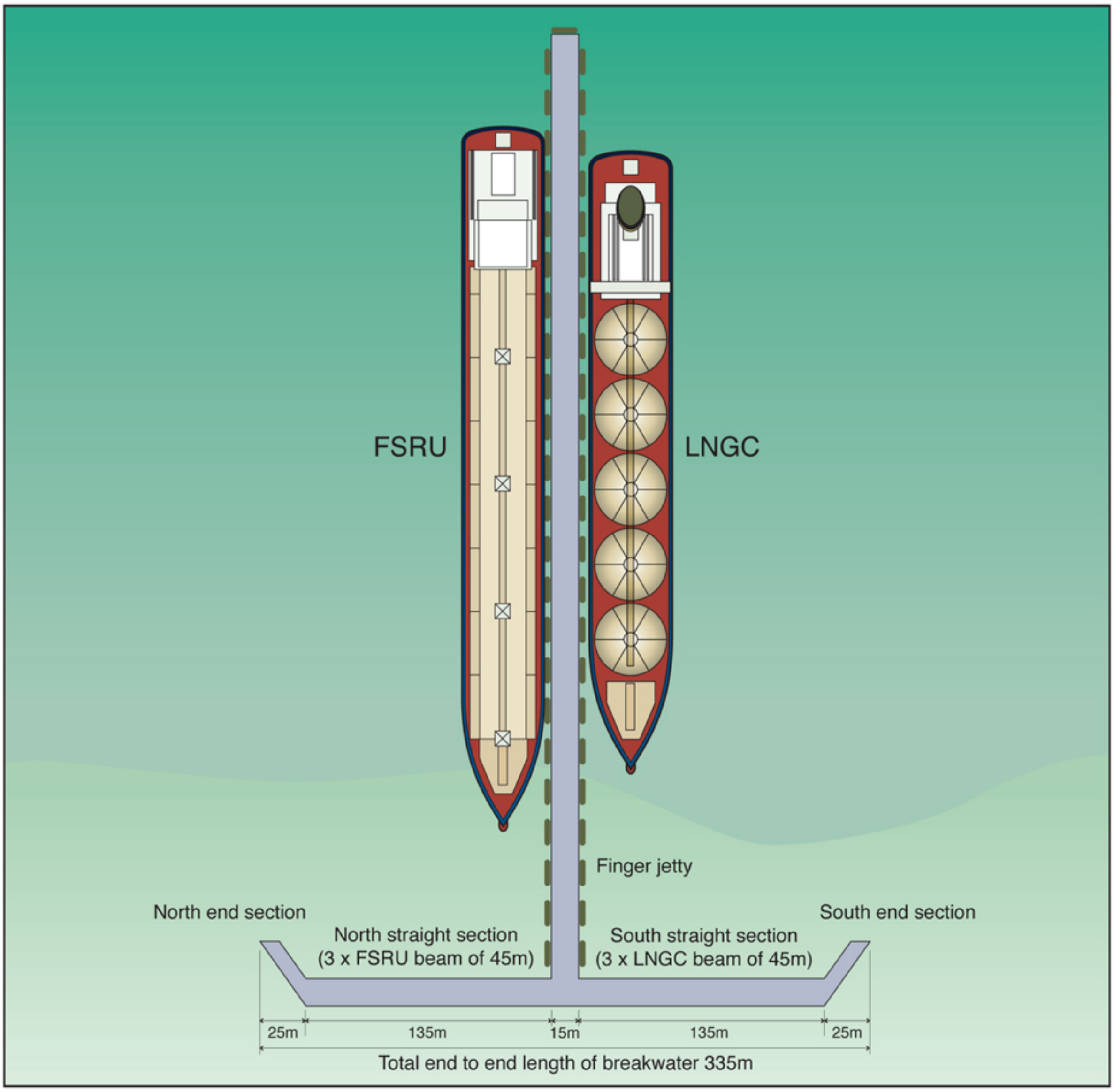
Getting a pilot on board in Hs > 1.75m to 2.00m is risky. But if the LNGC can approach from the north east (under the guidance of the Captain alone) and slowly creep in towards the sheltered waters in the lea of the breakwater, then the berthing pilot and tugs would then be called into undertake their role at the key time.

Figure 13 – Navigation route



A potential breakwater layout is shown in Figure 14. The end sections are intended to enhance the deflection of waves and reduce wave refraction around the ends of the breakwater into the berth area.

Figure 14 - Breakwater



The length of the breakwater is suggested as 3 x beam widths either side of the berth, plus the berth itself. That equates to:

- 3 x 45m (for each ship) plus
- (say) 15m (for the berth) plus
- (say) 2 x 25m (for the end sections)

which makes an end-to-end breakwater length of 335m

Specific marine/civil engineering advice should be sought on the breakwater size and layout.

No specific details of low visibility events have been found in public domain documents. Snow only occurs in the northern inland parts of Myanmar so is not considered a problem.

6.2 Jetty Length

An island berth is suggested, positioned so that the FSRU is moored to the north side and the transferring LNG carrier to the south side. Both bows should be positioned to the south west. There is no trestle from the jetty head to shore.

6.3 Marine traffic

No details of the number of movements or type of ship has been identified. Location 4 is close to the channel into Myanmar's main ports of Yangon and Thilawa. Consultations are required with Myanmar Port Authority to determine traffic levels and whether ships regularly transverse this area. The jetty could be moved a few miles to the east without major modifications to accommodate existing transit routes. Marine traffic levels are assumed to be heavy.

6.4 Towage

Yangon appears to have at least one tug of sufficient size although no details appear in international. Marine databases. However, this vessel is no longer under Class which suggests that it is in poor condition and therefore may not be suitable for use.

Figure 15 – Yangon based tug

Port services such as tugs would therefore have to be purchased or brought in from another location.

6.5 Port Rules

It is anticipated that Location 4 would come under an extension of the port rules for Yangon and Thilawa. No details of these port rules have been identified. There are two small refineries at Thilawa so it is assumed that the port rules have some relevance to hydrocarbon shipping.

7 Access to gas pipelines

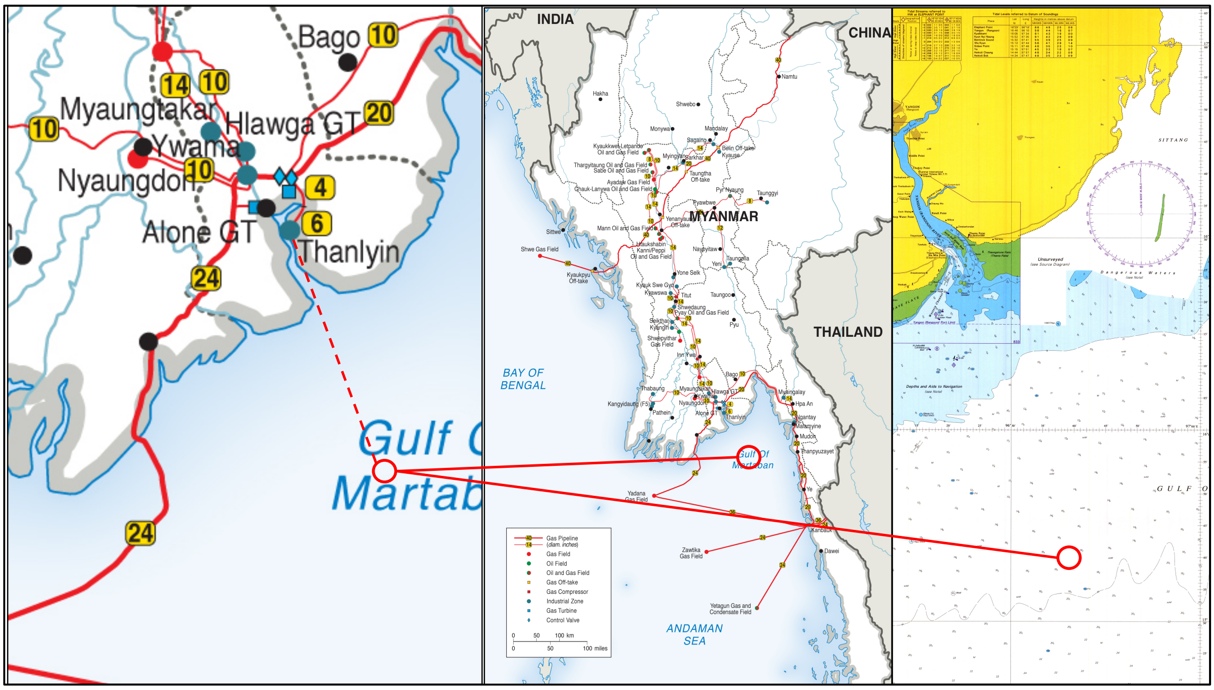
The purpose of this section is to provide an analysis of the issues concerning access to Myanmar's high-pressure gas pipeline network, focussing on costs in the following areas.

- Overview of Location 4 and associated issues
- Review of offshore gas transmission pipeline costs.
- Review of onshore gas transmission pipeline costs.
- Gas network reinforcement costs.
- Concluding discussion.

7.1 Overview of Location 4 and associated issues

Given the location of Location 4 in the Gulf of Martaban some 130 km from Yangon the most obvious requirement will be the need to build a subsea gas pipeline from the FSRU berth to Yangon. The following diagram shows Location 4 in relation to the gas supply network and in particular Yangon. It should be noted that the actual pipeline landing point in Yangon and any associated onshore gas transmission pipeline will ultimately be subject to a more detailed gas pipeline routing study.

Figure 16 – Overview of Location 4 for FSRU



7.2 Review of offshore gas transmission pipeline costs

The length of the offshore gas pipeline from the FSRU berth to Yangon will depend on the choice of landing point for the pipeline and the onshore logistics of connecting to any power plants and the local gas network. The Project Team have used a combination of 90 km for the offshore gas pipeline and 50 km for the onshore pipeline to tie into the existing gas transmission system. However, different lengths of offshore and onshore pipelines may be appropriate subject to logistics. [2]

Figure 17 – Overview of possible offshore pipeline landing points

Table 2 – Summary of offshore gas transmission pipeline costs for Site 4

Site description	Offshore gas transmission pipeline	Cost ($ million)
Subsea connection to Yangon	90 km of 30" offshore gas transmission pipeline at $1.8 million per km	162

7.3 Review of onshore gas transmissions costs

Therefore, when considering the route and cost of the onshore connecting pipeline the Project Team have assumed that at least some of the RLNG will be delivered into the local gas network using the existing ROWs in the area, with the most likely connection being on the 20" pipeline in Yangon.

[2] *Navigation in the Yangon River is difficult as there are shoals and shallows. A subsea pipeline, particularly if surface laid, would add further navigation hazards. Therefore the Project Team propose to land the offshore pipeline as shown in the map to the bulbous point to the south east, reducing the subsea line length and increasing the onshore length. This also seems the most likely location since power plant construction is expected in this area too.*

Figure 18 – Potential RLNG connecting pipeline point on 20 inch pipeline for Site 4

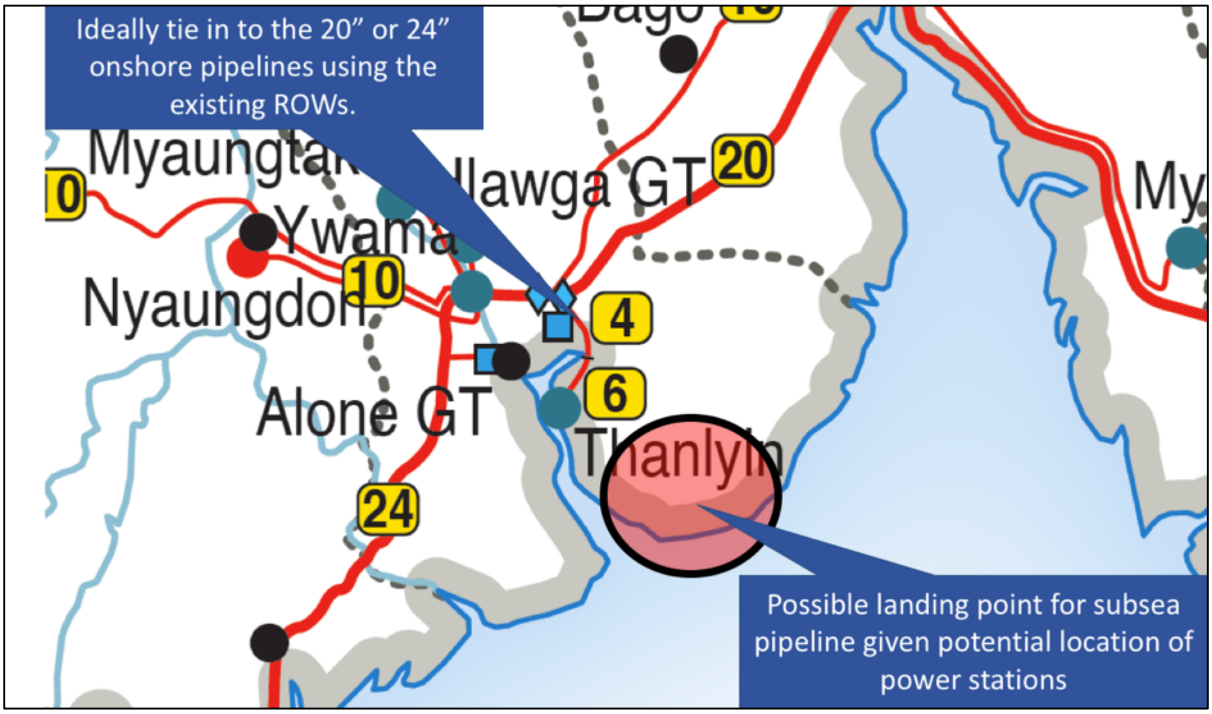


Table 3 – Summary of onshore gas transmission pipeline costs for Site 4

Site description	Onshore gas transmission pipeline	Cost ($ million)
Site 4 – Onshore gas transmission pipeline	50 km of 30" onshore gas transmission pipeline at $1.2 million per km	60.0

7.4 Gas network reinforcement costs

As part of this process the Project Team raised a number of questions with MOGE regarding local reinforcement costs. Whilst not all these questions were answered the Project Team did learn that the 20" pipeline between Yangon and Mawlamyine is in a poor state of repair with a current capapcity of 25 MMCFD, whilst its capacity will increase as MOGE undertakes pipeline repairs and replacements this is very slow at the rate of 10-30 miles per year depending on budget availability.

Therefore the Project Team has made the working assumption that little or no spare capacity will be available in the existing gas network to accommodate new supplies, without significant additional investment in pipeline infrastructure. However, this may not be a problem if the majority of the RLNG is consumed by power generation plant in the vicinity of the subsea landing point. In addition, given that the landing point of the subsea pipeline will be within a relatively short distance of the existing 20" and 24" pipelines supplying Yangon the Project Team have allowed for 50 km onshore connection on the basis it would be technically and strategically benefical to be able to supply even limited quantities of RLNG into Myanmar's gas network.

7.5 Discussion on pipelines

In the light of the above the following table provides a summary of the estimated costs associated with connecting and delivering the RLNG into Myanmar's gas transmission network as follows:

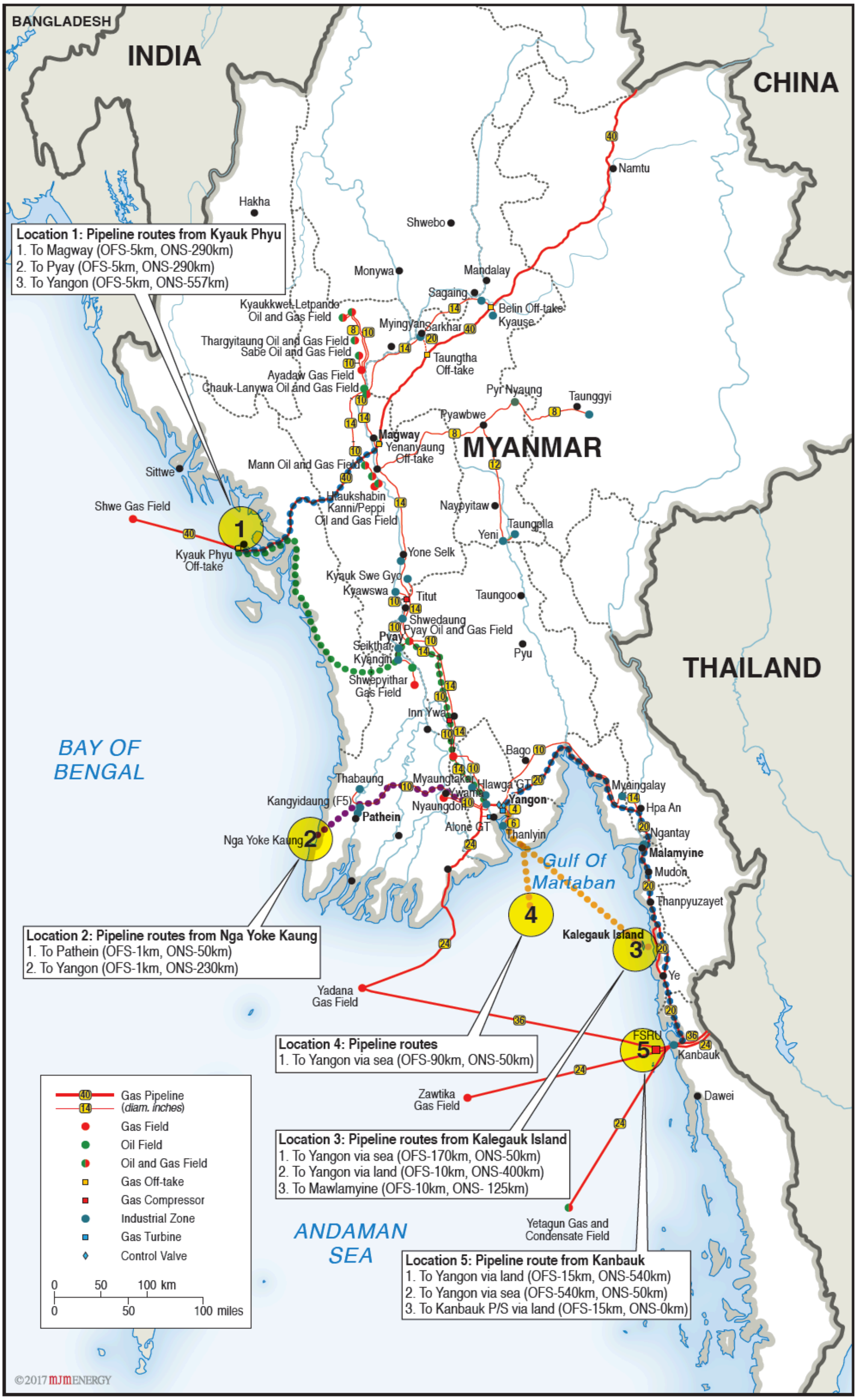
Table 4 – Summary of gas pipeline costs for Site 4

Type of gas transmission infrastructure	Details of pipeline infrastructure	Cost ($ million)
Offshore gas transmission pipeline	90 km of 30" gas transmission pipeline at $1.8 million per km	162
Onshore gas transmission pipeline	50 km of 30" gas transmission pipeline at $1.2 million per km	60
Total estimated cost for delivering RLNG into the Myanmar network		222

7.6 Location 4 in relation to other analysis

Since this report on Location 4 is an addendum to the overall analysis for five possible LNG inport locations for Myanmar, the following figure 19 has been included to place the analysis of Location 4 into the wider context.

Figure 19 – All five Locations



8 Infrastructure

There is no infrastructure at the proposed location. An island jetty will need to be created.

Yangon is the closest city although Mawlamyine is also relatively close by boat (or helicopter). All services for the LNG facility are anticipated to be supplied out of Yangon (or Thilawa) port.

Yangon, the previous capital of Myanmar and still the country's commercial hub has all the facilities in terms of support activities, banking, legal, foreign embassies etc. with only port services appearing to be restricted. The city represents about one fifth of the national economy, 23% of the national GDP in 2010-11. Manufacturing accounts for a sizable share of employment.

There are over 20 universities and colleges in the city. Students from around the country still have to come to study in Yangon as some subjects are offered only at its universities. Some of Yangon's universities including Yangon Technological University, University of Computer Studies and Myanmar Maritime University are the most selective in the country and offer skills likely to be required for the FSRU.

Public hospitals including the flagship Yangon General Hospital lack many of the basic facilities and equipment. Wealthier Yangonites have access to country's best medical facilities and internationally qualified doctors however most travel abroad, usually Bangkok or Singapore, for treatment.

Yangon International Airport is the country's main gateway for domestic and international air travel and has direct flights to many regional cities in Asia including Hong Kong, Tokyo, Bangkok and Singapore. Yangon Central Railway Station is the main terminus of Myanmar Railways' 5,403 kilometre rail network. Much of the country's imports and exports go through Thilawa Port, the largest and busiest port in Myanmar.

9 Results of analysis

The purpose of this section is to present a summary of the results of the analysis, however as previously highlighted the broader context for this analysis and in particular the methodology used by the Project Team is contained in the main report.

Key ares covered in this section include the following:

- The traffic light scores.
- Technologty and site selection.

9.1 The traffic light scores

This study is necessarily limited within the TOR, and cannot provide a full assessment of the feasibility of LNG importation at the potential sites. This study is therefore a screening activity to the full site selection process and is only aimed at highlighting major issues that might prevent a later, more detailed approach being successful. As study work and data are not available in detail at this stage, a qualitative ranking system is acceptable. The primary ranking system is based on the familiar worldwide concept of traffic lights, which provide a visually clear means of recording the site selection process. Green is go or in this case good, red is stop or bad. To improve granularity both yellow and orange are used as intermediary points, with yellow being closer to green and orange being closer to red. Qualitative by definition means comparison in a loose way between sites and international norms, and not specific scores against attributes to form a numerical conclusion.

The traffic light approach is summarised in the figure below.

Figure 20 – The traffic light approach

Colour	Implication
	A red light indicates that the site has an issue which may prevent the site being cost effectively developed as an LNG facility. One red light may not be sufficient to stop the project, but will impact cost and/or schedule in a major way. Multiple red lights indicates the project is not viable
	An orange light indicates that the site has significant issues that will impact either capital expenditure or schedule
	A yellow light indicates that the site has some issues but these are anticipated to be corrected with only minor capital expenditure or short schedule delays
	A green light indicates that the site has no significant issues and could reflect worldwide best practice in the LNG industry

The traffic light scoring for Site 4 is shown in the following table.

Table 5 – Site 4 traffic light scoring

		Near shore Site 4						
		Onshore terminal	FSRU on Jetty	Midwater FSRU	Deepwater FSRU	FSU on Jetty	LNGRV in Deepwater	GBS
GETTING LNG TO THE TERMINAL								
1	How much dredging is required to create a channel to the terminal?							
2	What Jetty length is required to be able to moor a near shore FSRU/LNG Carrier?							
OR	What Subsea pipeline length is required to connect a midwater or deepwater FSRU or LNGRV							
3	How much marine traffic is currently being experienced?							
4	Are there local visibility limitations?							
5	Are there any other factors that limit the site?							
STORING LNG								
1	What is the wave environment like?							
2	How variable is the wind/wave environment?							
3	Might the LNG facility be impacted by extreme weather?							
4	Will the site cause any destruction or exclusion to environmentally sensitive areas?							
5	Will the site cause any destruction or exclusion to culturally and historically sensitive areas?							
6	Will the site development and operation impact the local community in any detrimental way?							
7	Will the site development and operation increase the risk of harm/fatality to the local community?							
8	Are there risks to the LNG facility from geological events?							
GETTING GAS TO MARKET					Onshore pipeline			
1	Can LNG be vaporised in sufficient volume and in an environmentally acceptable way?							
2	What is the onshore pipeline length?							
3	What is the difficulty in laying the onshore pipeline?							
4	What is the offshore pipeline length?							
5	What is the difficulty in laying the offshore pipeline?							
LOCAL INFRASTRUCTURE								
1	Is there sufficient towage available to berth the LNG carrier?							
2	Is there currently any port rules and infrastructure appropriate to hydrocarbon importation at the proposed LNG site?							
3	Is there sufficient infrastructure to accommodate workers and their families, expatriates and vendor personnel?							
4	Is there emergency response and Health care capability?							
5	Education and Skills?							
6	Is there access to a major port with connecting roads?							
7	Is there access to an international airport with road/rail links?							
8	How adequate is the marine infrastructure?							

9.2 Technology & site selection

9.2.1 Site selection

In terms of site selection, given its location, apart from the metocean issues previously discussed, the only other issue will be silt from the Thanlwin and Sittoung Rivers which may siltate around the breakwater. The impact can only be assessed by more detailed analysis and options/location needs to be confirmed prior to this taking place.

9.2.2 Viable technology options (A jetty mounted FSRU)

Based on the exposed location of the proposed jetty and the Project Teams analysis of the metocean conditions it our suggestion that a breakwater is developed in conjunction with a jetty mounted FSRU.

9.2.3 Analysis of Site 4 using the Site Prioritisation Tool (SPT)

Having identified the viable technology options for Site 4, the Project Team have undertaken an analysis of Site 4 based on the main parameters.

- ***FSRU details*** – A current "industry standard" FSRU of 170,000m^3 is moored in 17 m of water on a fixed island jetty.
- ***Use of breakwater*** – The FSRU is protected by a 335 m breakwater.
- ***Dredging*** – No dredging is required.
- ***FSRU export rates*** – Gas from the FSRU is vaporised at an average rate of 250 mmscfd (50% of 500 mmscfd) using an open loop sea water system.
- ***Pipelines (Offshore)*** – The RLNG from the FSRU is injected into a new 90 km, 30", subsea pipeline which makes landfall to the east of the river.
- ***Pipelines (Onshore)*** – A short, 50 km 30" onshore pipeline connects the gas to the existing network and to existing and future CCGT power plants to the south east of Yangon.

Based on the above parameters and the general analysis of Site 4 and its associated metocean, technical and environmental parameters the Project Team undertook the analysis using the SPT. A summary of the paramters used and the results are shown in the following table.

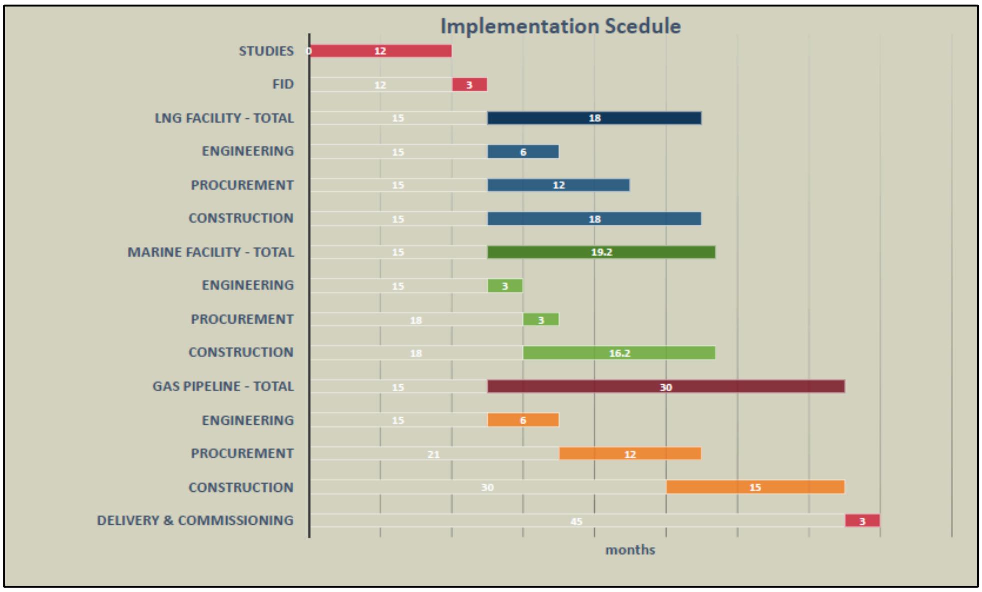
Table 6 – Summary data inputs for the analysis for Site 4

PHYSICAL PARAMETRS:		Data
LNG facility size		170,000 m^3 stored with 500 mmscfd vaporiser capacity
LNG facility type		FSRU
Location		Nearshore
Ownership		Lease
Geology		<0.4 g acceleration
Jetty length		0 m, jetty head only
Breakwater		335 m
Dredging		None
Gas pipeline		90 km of 30" offshore pipeline + 50 km of 30" onshore
Design LNG ship		163,000 m^3
FINANCIAL AND ECONOMIC PARAMETERS:		Data
Project start year		2017
LNG import term		10 years
Discount rate		10%
Lease rate		140,000 US$/day
Fuel oil cost		470 US$/ton 380 cs Singapore
Electricity cost		0.05 US$/kWh (70 kyats/kWh)
Tug cost		US$ 15,000/day each (4 days mobilisation)
CAPITAL COSTS: Description of key areas		Value
FSRU		0 US$ million (lease)
Jetty		46.2 US$ million
Breakwater		44.4 US$ million
Dredging		0 US$ million
Gas pipeline		222.2 US$ million
Local infrastructure		0 US$ million
TOTAL		312.8 US$ million
Note 1 : No BOT/BOOT purchase payment was assumed at the end of the contract life.		
OPERATING COSTS: Description of key areas		**Operating costs**
FSRU lease		51 US$ million pa
Fixed costs	Labour	3 US$ million pa
	Insurance	2 US$ million pa
	Inspection and maintenance	2 US$ million pa
	Supporting infrastructure	2 US$ million pa
Variable costs	Fuel oil	6.48 US$ million pa
	Electricity	0 US$ million pa
	Towage	14.58 US$ million pa
TOTAL		81 US$ million pa

9.2.4 Schedule to implementation

The following design/construction schedule has been estimated with a total completion time of 42 months. The gas pipeline is the longest schedule activity. Marine facilities construction has a similar but longer schedule as the FSRU.

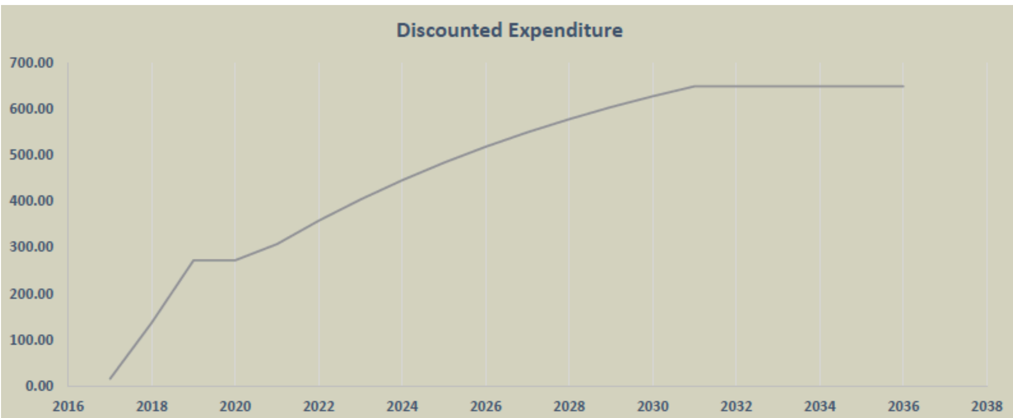
Figure 21 – Estimated design/construction schedule for Site 4



9.2.5 Discounted Expenditure

The above parameters have been combined into a discounted expenditure figure of: 649 US$ million, which is shown in the following chart.

Figure 22 – Breakdown of the discounted expenditure for Site 4



10 Conclusions and recommendations

10.1 Conclusions

Key points to note in relation to this site are as follows:

- ***Marine perspective*** – By combining the FSRU finger jetty with a breakwater the exposed nature of the site can be mitigated.
- ***Geographical location*** – Whilst the remote location of the jetty offshore does pose some logistical challenges the close vicinity of Yangon as a commercial and technical centre is helful.
- ***Pipeline connections*** – In many respects the subsea offshore pipeline from the FSRU jetty to the coast near Yangon is relatively straightforward, although its length will depend on the landing point. In the theory the offshore pipeline could be shorter than we have proposed on the basis that it lands on the coast nearest the FSRU jetty, however this will then result in a much longer onshore section. In this analysis the Protect Team opted for mid-case solution.

Please find below a summary of the results produced by the SPT model.

Table 7 – Summary of discounted expenditure analysis

Site	Schedule (Months)	Capital Investment (US$ million)	Operating Expense (US$ million per annum)	Discounted Expenditure (DEX) (US$ million)
Site 4	48	312.8	81.0	649.0

10.2 Recommendations

As previously stated this analysis has been relatively high-level with a minimal engagement with the authorities in Myanmar apart from MOGE. Therefore if this Site 4 is going to be progressed further the following activities should take place.

- ***Engagement with the appropriate marine authorities*** – It will be important to take the time to enage with the MPA (Myamar Port Authority), the Myanmar Navy and other stakeholders involved in marine activities in order to have a fuller understanding of developing Site 4.
- ***Offshore gas pipeline study –*** As one would expect Site 4 is sensitive to subsea pipeline construction costs in particular the length and landing point of the subsea pipeline. Therefore, given the disparity between MOGE's initial offshore pipeline costs and international benchmarks we recommend that MOGE undertake a feasibility study of the offshore subsea pipeline costs from Site 4 to Yangon.
- ***Onshore gas pipeline study –*** Whilst the proposed length of the onshore gas pipeline may vary from the proposed 30km by +/- 20km the overall impact on the project will not be huge. However, it will be important to have a good understanding of the condition of the local gas transmission network in Yangon and its ability to absorb additional RLNG not consumed in the local power stations. In addition, laying onshore gas transmission pipelines in the vicinity of large congested city such as Ynagon can be complex and expensive. Therefore, we recommend that MOGE undertake a commercial and operational study of the proposed connecting pipeline to establish a more accurate estimate of its cost.