CONTENTS

ANNEXES

2 CONSIDERATION OF SOUTH SOKO TERMINAL ALTERNATIVES

The following section presents a consideration of the alternatives for the South Soko terminal. The section has been divided into a discussion of the following:

- Consideration of Different Layouts and Design Options;
- Consideration of Alternative Construction Methods;
- Consideration of Pipeline Alignment; and,
- Consideration of Power and Water Supply.

Based on the above considerations, the Environmental Impact Assessment of the preferred South Soko terminal scenario is presented in subsequent sections.

2.1 CONSIDERATION OF DIFFERENT LAYOUTS AND DESIGN OPTIONS

In accordance with *Clause 3.3.4* of the EIA Study Brief (*ESB-126/2005*), this section presents considerations of the different layouts and design options that have been assessed as part of the overall assessment of alternatives for the South Soko LNG terminal. The methodology, criteria and findings are presented.

The assessment was conducted to investigate the environmental considerations of each preliminary layout and design option and to examine the engineering aspects for each. The assessment thus considers both the difficulties of the construction and operation of each facility as well as the associated potential environmental impacts.

2.1.1 *Layout Options*

The basic requirements of a LNG receiving terminal in Hong Kong have been described in detail in *Part 1 - Section 3*. Justifications for South Soko Island being considered as one of two sites for the LNG receiving terminal in Hong Kong have been presented in *Part 1 – Section 4*.

Several terminal layout options on South Soko Island have been considered. As there is relatively limited flat land on South Soko Island to accommodate the necessary infrastructure, the method of providing sufficient land, either by reclamation or excavation of the existing hillsides has been considered. In addition, due to the outline of the coastline, several options for the location of the LNG carrier berth have been considered. These provide differences in dredging requirements and marine navigation complexity due to the delineation of the approach channel and turning basin.

Three layouts have been selected for further assessment in order to provide a comprehensive assessment of different design options. The layouts present a wide range of engineering options and subsequent environmental considerations for the construction and operation of the South Soko Island terminal. Each of the layouts has been prepared so that distances between the facilities within the LNG terminal show broad compliance with *EN 1473*. The three layouts are presented below in terms of the general design and construction methods.

Option 1 – Base Case

The Base Case layout (Option 1) is derived from a combination of reclamation and excavation, for the purpose of maintaining a balance between the cut and fill quantities (*Figure 2.1*). The excavation on the northern side of the site will be undertaken to provide sufficient land area, initially for two tanks with provision for a third tank in the future. The tank excavation area is completely within the northern hillside for two purposes:

1. To enable the tanks to be founded directly onto rock which will permit the use of pad/raft foundations thus negating the need for deep foundations; and

2. To screen the tanks from the visually sensitive receivers on the south side of Lantau Island to the extent reasonably practicable.

The excavation on the southern side of the site will be undertaken to provide sufficient land area for the process plant and associated facilities to maintain the regulatory safe distances from the storage tanks in accordance with *EN 1473*. The elevation of these facilities will be up to +10mPD in order to reduce the volume of cutting and to provide a raised platform to prevent wave overtopping to the process area.

Land will be reclaimed immediately to the west of the former detention centre for the proposed utility pier, and to the east of the platform for the proposed service jetties.

The LNG carrier jetty will be located at the northwestern side of South Soko Island, which is sheltered from offshore wave conditions. The approach channel leading to the jetty will be longer and will require more precise manoeuvring for the transit and turning. The dredging quantities required to create the approach channel and turning basin will be comparatively higher than the other design options as the existing water depth is slightly shallower.

Option 2 – Full Reclamation

The Full Reclamation layout (Option 2) was considered to reduce the amount of land excavation by increasing the area of reclamation within the Sai Wan Bay (*Figure 2.2*). For this option, the 3 tanks are located further south towards the existing reclamation platform. The excavation of the southern side of the site will be undertaken to provide sufficient land area for the process plant and associated facilities. The elevation of these facilities will be up to +10mPD in order to reduce the volume of cutting and to provide a raised platform to prevent wave overtopping to the process area.

Area will be reclaimed within the Sai Wan Bay to house the proposed gas turbine substation, utility area and laydown area. The area to the east of the platform will be for the service jetties.

As in Option 1 the LNG carrier jetty will be located at the northwestern side of South Soko Island.

Option 3 – South East Jetty

The basic plan of the South East (SE) Jetty layout (Option 3) is also similar to Option 1 with the three tanks located within the north side of the site (*Figure 2.3*). The excavation on the southern side of the site will be undertaken to a platform of up to +10mPD to house the process plant and associated facilities.

The location of the jetty in Option 3 is revised to suit the 'no reclamation' layout as the design distance requirement between the berthing head and the process area/storage tanks may be satisfied with a shorter trestle. The jetty is therefore moved closer to the shore. The estimated land area required is slightly larger than in Options 1 and 2 and is measured to be 38.6 ha. A small amount of land will be reclaimed immediately to the west of the existing platform for the proposed utility pier, and to the east of the platform for the proposed service jetties.

The main difference between this option and the above two options is that the LNG carrier jetty will be located at the southeastern side of South Soko Island. This location has the advantage of having the shortest approach channel and fewer manoeuvres to berth the carrier alongside the jetty. Less dredging will be also be required as the water depth on the southeast side of the island is generally deeper.

Engineering Works Criteria

In order to satisfy each of the terminal requirements described in *Part 1 - Section 3*, it is necessary to undertake site formation, dredging and reclamation works at each of the layout options at South Soko Island. The key engineering works criteria for each layout option are summarised in *Table 2.1.*

Table 2.1 Summary of Engineering Works Criteria (based on conceptual indicative site layouts – numbers are approximate)

Engineering Criteria	Option 1 (Base Case)	Option 2 (Full Reclamation)	Option 3 (SE Jetty)
Site Area (ha)	29	35	38.6
Volume of Dredging for Reclamation at South Soko Island (10^6m^3)	0.18	0.22	0.18
Volume of Dredging for Approach Channel & Turning Basin (10^6m^3)	3.36	3.36	1.07
Volume of Dredging for Submarine Gas Pipeline (10^6m^3)	1.44	1.44	1.44
Volume of Excavation Disposed (10^6m^3)	0.04	0	0.12
Volume of Fill Imported (10^6m^3)	0.28	1.26	0.14
Size of Reclamation (hs)	1.7	13	1.7
Length of Natural Coastline Affected (m)	450	600	450
Length of Seawall (m)	1,100	1,360	1,100
Seawall modification (ha)	1.3	0.5	1.3
Length of Trestle (m)	200	200	240

The layouts described above have been assessed and compared in terms of the engineering works required and the potential for environmental impacts through construction and operation. Each of these assessments is presented below and the findings combined to determine preferred overall site layout.

2.1.2 *Engineering Assessment*

Overall Engineering Assessment Criteria

A set of key engineering assessment criteria have been established to enable a quantitative comparison of the three layout options to be scored and ranked in accordance with their relative merits and demerits. As each of the assessment criteria do not have an equivalent impact on the overall construction of the terminal facility, a relative importance factor has been applied to each as shown in *Table 2.2*.

Table 2.2 Overall Engineering Assessment Criteria & Associated Relative Importance Factors

Engineering Assessment Criterion	Relative Importance Factor
Construction of site formation works	0.30
Construction of site reclamation works	0.30
Construction of approach channel and turning basin	0.20
Marine navigation	0.10
Construction of facility foundations	0.10
Total	**1.00**

The rationale for the relative importance factor is given below.

- It was considered logical for the sum of the relative importance factors to add up to unity. In this manner each relative importance factor also directly represents the percentage importance to the whole process.

- The major engineering works for each of the layout options is considered to be the construction of the site formation and reclamation. These assessment criterions are therefore given an equally high relative importance factor of 30% each.

- The next major engineering works for the layout options is the construction of the approach channel and turning basin. This assessment criterion is therefore assigned a reasonable importance factor of 20%.

- South Soko Island is only accessible from the sea and therefore construction boats and barges will be used for the import and export of materials to the site. Marine craft will also be employed for the dredging of the approach channels. Since the approach to the site will be remote to major marine thoroughfares a relatively low importance factor of 10% is assigned to this criterion.

- The construction of the facility foundations and the receiving terminal facility itself will generally employ conventional construction techniques which will be similar to all sites with only minor differences resulting from accessibility and specific location constraints. A relatively low weighting of 10% is therefore applied for these criteria.

Parameters for Each Engineering Assessment Criterion

In order to make a quantitative assessment of the relative advantages and disadvantages of each layout for each of the engineering assessment criterion defined in *Table 2.2*, a set of engineering parameters reflecting the main tasks to be undertaken under each activity have been developed. Each parameter carries a weighting to represent the relative significance and impact on the overall engineering assessment criterion. It was considered logical for the sum of the relative weighting factors to add up to unity. In this manner each relative weighting also directly represents the percentage importance to the whole process. The parameters used in the evaluation of the sites for each engineering assessment criterion is detailed in *Tables* 2.3 to *2.7* and described below.

Construction of Site Formation Works

The engineering assessment criterion for site formation considers nine main parameters as shown in *Table 2.3*.

Table 2.3 Engineering Parameters and Associated Relative Used for the Assessment of the Construction of Site Formation Works

Engineering Assessment Criterion	Parameter	Relative Weighting
Construction of site formation works	Volume of excavation in soil	0.05
	Volume of excavation in rock	0.25
	Volume of soil to be disposed of	0.20
	Volume of rock to be disposed of	0.05
	Impact on construction programme	0.10
	Slope stabilisation measures required	0.10
	Slope maintenance	0.05
	Future slope hazard	0.05
	Blasting risks	0.15
	Total	**1.00**

The rationale for the selection of each relative weighting factor is given below

- The most difficult and time consuming activity is usually the excavation of rock material, which generally comprises very good quality granite. The excavation of this material will require significant effort using blasting and heavy mechanical equipment for which stringent engineering controls will be required. The excavation works are also generally intimately linked with the commencement of construction of the storage tanks, which have a long construction duration and are therefore critical path activities. As such the rock excavation has a significant impact on the construction programme. The highest weighting of 25% is therefore assigned to this parameter.

- The excavation of soil is a relatively easy and quick task utilising mechanical equipment and therefore only a low weighting of 5% is assigned. The volume of soil excavation is also generally small.

- The disposal of the soil material is given a high weighting of 20% as it will need to be taken to one of the Public Fill facilities, which should be avoided to the extent practicable or possible. High scores are therefore awarded to sites which limit disposal of soil and make the best use of the material.

- The disposal of rock is given a low weighting of 5%, as it will likely be reused for construction in Hong Kong. The generation of such material is therefore not deemed to be as highly negative activity compared to soil, which may have limited beneficial use.

- The construction period for the terminal facility needs to be minimised to meet the required project operational target date. As the site formation works impact directly on the construction programme, a medium weighting factor of 10% is considered appropriate to favour the sites that can be constructed in the shortest duration.

- Blasting will need to comply with extensive and stringent regulation requirements. Incorporation of these measures will impact on the construction programme; and therefore, a medium level relative weighting of 15% is applied to these works to favour the sites that do not require blasting.

- The slope stabilisation works associated with the facility will need to comply with the regulation requirements which are reasonably stringent and can be extensive for large slopes. The quantity of stabilisation works therefore needs to be reduced as far as possible. A medium relative weighting factor of 10% is applied to these works.

- Slope maintenance and slope hazards are both events that will be under the control of the LNG terminal facility during operation. These can therefore be reasonably managed and as such a low weighting of 5% has been assigned to each.

Construction of Site Reclamation Works

The engineering assessment criterion for reclamation considers ten main parameters as shown in *Table 2.4*.

Table 2.4 Engineering Parameters and Associated Relative Used for the Assessment of the Construction of Site Reclamation Works

Engineering Assessment Criterion	Parameter	Relative Weighting
Construction of site reclamation works	Area of reclamation	0.10
	Volume of dredging material	0.20
	Total volume of fill material required	0.05
	Total volume of imported fill (sand + rock)	0.20
	Length of natural coastline affected	0.15
	Length of artificial coastline affected	0.05
	Length of seawall required	0.10
	Construction time for dredging and filling	0.05
	Time for consolidation after construction	0.05
	Need for ground improvement	0.05
	Total	**1.00**

The rationale for the selection of each relative weighting factor is given below.

- The most significant activities are the dredging of the underlying soft material and the importation requirements for subsequent back filling works. For the latter case a lower amount of imported material is considered more favourable as it indicates that a better balance is being made with the excavated materials from the site formation works. A high weighting of 20% is therefore assigned to these parameters.

- As the volume of imported material has already been considered, the total volume of fill material required is less important if the majority is sourced from within the site and therefore only a 5% weighting is assigned.

- The length of natural coastline affected by the reclamation is a measure of the extent of the engineering works on the natural site areas. A 15% weighting is therefore assigned to this parameter.

- The length of artificial coastline affected by the reclamation is considered to be less of an effect and therefore a 5% weighting is applied.

- The length of seawall and the area of reclamation are indicators of the extent of the reclamation. For these parameters a medium weighting of 10% is deemed appropriate.

- The time for construction, time for consolidation and the need for ground improvement are important but less significant engineering issues. A lower weighting of 5% is therefore assumed for these parameters.

Construction of Approach Channel and Turning Basin

The engineering assessment criterion for the construction of the approach channel and turning basin considers five main parameters as shown in *Table 2.5*.

Table 2.5 Engineering Parameters and Associated Relative Used for the Assessment of the Construction of Approach Channel and Turning Basin

Engineering Assessment Criterion	Parameter	Relative Weighting
Construction of approach channel and turning basin	Total length of approach channel + turning basin	0.20
	Volume of dredging	0.35
	Rock excavation in dredged zone	0.20
	Impact on existing utilities	0.15
	Siltation & maintenance dredging	0.10
	Total	**1.00**

The rationale for the selection of each relative weighting factor is given below.

(i) For approach channel and turning basin the most significant activity is the dredging works. A high weighting of 35% is therefore assigned to this parameter.

(ii) The length of the approach channel and the extent of rock excavation will affects the programme and progress of the overall dredging works and are therefore each assigned a high to medium weighting of 20%.

(iii) The impact on existing utilities is considered to be localised and secondary effects on the overall dredging works and is therefore assigned a medium weighting of 15%.

(iv) The siltation/maintenance for the approach channels are factors that affects the long-term operation for which a low to medium weighting of 10% is considered appropriate.

Marine Navigation

The engineering assessment criterion for marine navigation considers four main parameters as shown in *Table 2.6*.

Table 2.6 Engineering Parameters and Associated Relative Weighting Used for the Assessment of Marine Navigation

Engineering Assessment Criterion	Parameter	Relative Weighting
Marine navigation	Marine traffic	0.50
	Grounding potential	0.10
	Striking berth by LNG Carrier	0.10
	Striking of the moored carrier by passing traffic	0.30
	Total	**1.00**

The rationale for the selection of each relative weighting factor is given below:

- Although historically, LNG carriers have had an excellent safety record, the main hazards are the potential for collision with the carrier while in transit to the jetty or from passing traffic striking the carrier while moored. The probability for such occurrences and consequences will be dependent upon traffic density and discipline of shipboard personnel complying with underway regulations. As these are the main considerations a weighting of 0.5 and 0.3 are awarded for marine traffic and the striking of the moored carrier by passing traffic respectively

- The consequence of grounding and striking of the marine berth is significantly lower than the above considerations, therefore, a lower but equal weighting of 10% is assigned to each.

Construction of Facility Foundations

The Engineering assessment criterion for construction of facility foundations considers three main parameters as shown in *Table 2.7* below.

Table 2.7 Engineering Parameters and Associated Relative Weighting Used for the Assessment of the Construction of Facility Foundation

Engineering Assessment Criterion	Parameter	Relative Weighting
Construction of facility foundations	Terminal facility structures	0.30
	Jetty piling works	0.50
	Water front access	0.20
	Total	**1.00**

The rationale for the selection of each relative weighting factor is given below

- The most difficult foundation construction works for the proposed site is the construction of the marine piling works for the jetty structures, as it will be undertaken over water. A weighting of 50% is therefore assigned to these works.

- The land based foundation construction works for the terminal facility structures and the water front access areas are considered to be slightly easier and therefore a weighting factor of 30% and 20% are awarded respectively. The slightly higher weighting is given to the terminal facility works, as the quantity is significantly greater.

2.1.3 *Site Comparison Scoring System*

Parameters and Relative Weighting for Each Engineering Assessment Criterion

In order to make a quantitative assessment of the relative advantages and disadvantages of each site for each of the engineering assessment criterion defined above, a set of engineering parameters reflecting the main tasks to be undertaken under each criterion have been developed as described above. Each of the engineering criterion and their associated parameters are assigned a relative weighting as shown in *Tables 2.2 to 2.7*.

Scoring Matrices

Using the parameters described above, each of the different layout options has been evaluated and compared against the base case based upon an assessment of the merits and demerits of each. For this purpose an options evaluation matrix has been created to compare the South Soko Island base case layout against each of the two alternative layouts.

Firstly, a relative comparison matrix summarising the quantities associated with each assessment parameter is established within separate matrices for each engineering construction criterion. The matrices are presented in *Annex 2-A*.

Using the relative comparison matrices an overall score is established for each layout option and each engineering assessment criterion by assigning a relative score for each parameter of between 0 and 5 which is dependent upon the relative magnitude or impact of the parameter value on the works as compared to the base case as shown in *Table 2.8*. The base case will receive an average median score of 3 for each parameter. For the two option layouts, a higher relative score is given to a site parameter with a lower impact on the construction works when compared to same parameter of the base case, and a lower relative score given to a site parameter with a higher impact on the construction works when compared to the base case. The best layout site will, therefore, achieve the highest overall score for ease of identification.

Table 2.8 Scoring System Applied to Assessment Criteria

Impact on the Construction of the Works as Compared with Base Case	**Score**
Significantly lower Impact relative to base case	5
Slightly lower Impact relative to base case	4
Similar Level of Impact to Base Case	3
Slightly higher Impact relative to base case	2
Significantly higher Impact relative to base case	1

The scores are tabulated in a relative comparison scoring matrix for each engineering criterion. A total score for each engineering criterion is determined from the sum of the weighted individual scores assigned to each parameter depending upon their relative impact.

The results of the scoring for each engineering assessment criteria are based on the summary quantity matrices shown in *Annex 2-A*.

Overall Engineering Ranking of the Layout Options

Having assigned a score to each of the parameters within each of the engineering assessment criteria, the result is multiplied by the relative weightings given in *Tables 2.3 to 2.7* from which a total score for each site for each engineering assessment criterion is derived. These scores are then normalised to a maximum value of 5 to enable a quantitative comparison to be made. These values are referred to as 'normalised scores' in *Annex 2-A*.

These normalised scores for each engineering works activity matrix are applied to the overall ranking matrix. The relative importance factors given in *Table 2.2* are applied to each of the normalised scores within the overall ranking matrix in order to determine an overall score for each option.

Engineering Assessment Results

Having evaluated each layout option for the South Soko Island terminal separately with respect to each engineering assessment criterion, the results of each individual assessment have been used to produce an overall score. These scores have then been used to rank the layouts in order of preference to enable selection of the preferred option on the basis of the highest score from the engineering assessment. The results for each engineering assessment criterion developed in *Annex 2-A* have been collated and are summarised in *Table 2.9*.

Table 2.9 Engineering Comparison of Layout Options at South Soko Island

Engineering Assessment Criterion	Relative Importance Factor	Option 1 (Base case)		Option 2 (Full Reclamation)		Option 3 (SE Jetty)	
		Score	FS*	Score	FS*	Score	FS*
Construction of Site Formation Works	0.30	3.57	1.07	5.00	1.50	2.98	0.89
Construction of Site Reclamation Works	0.30	5.00	1.50	2.08	0.63	5.00	1.50
Construction of Approach Channel & Turning Basin	0.20	3.66	0.73	3.66	0.73	5.00	1.00
Marine Navigation	0.10	4.69	0.47	4.69	0.47	5.00	0.50
Construction of Facility Foundations	0.10	5.00	0.50	4.00	0.40	4.17	0.42
Total Score			**4.27**		**3.73**		**4.31**
Site Ranking		**2**		**3**		**1**	

Note: * FS = Factored Score (i.e., Score x Relative Importance Factor)

On the basis of the engineering assessment for the construction and operation of the proposed LNG receiving terminal at South Soko Island, the result of the site layout comparison is as follows:

- Preferred layout: Option 3 – SE Jetty
- Second choice: Option 1 – Base Case
- Third choice: Option 2 – Full Reclamation

Alternative Layout for Option 3 – South East Jetty

A variation on the alternative site layout for the preferred layout Option 3 is shown in *Figure 2.4,* which has been developed to explore the possibility of achieving further engineering merit. The layout is similar to that of the preferred Option 3 layout with the jetty at the south eastern side of South Soko Island. However, for the alternative layout the provisional third tank is moved slightly to the southwest onto the reclaimed platform area at +6mPD thus reducing the quantity of rock excavation required. The alternative layout option is termed Option 3D.

In order to undertake a technical comparison and assessment of the engineering works required for Option 3 and Option 3D, a quantitative comparison of the two layouts has been undertaken to score and rank each of the engineering assessment criteria according to their relative merits and demerits as shown in *Table 2.2*. The outcome for all engineering assessment criteria, with the exception of Site Formation, is the same for the two layouts as they are unchanged. In view of this, the two layout options have been assessed and compared using the Site Formation criterion only. The detailed comparison of the site formation requirements for Option 3 and Option 3D is presented in *Annex 2-A*.

The results of the engineering comparison are shown below in *Table 2.10*. The total weighted score for each layout has been derived using the weightings given in *Table 2.3*. For comparison purposes Option 3 is given a score of 3.0 for each parameter and the Option 3D layout is scored relative to it for each parameter. For the Option 3D site layout, a higher relative score is given to a site parameter with a significantly lower impact on the construction works when compared to same parameter of the Option 3 layout case, and similarly a lower relative score is given to a site parameter with a significantly higher impact on the construction works. The best layout site will therefore achieve the highest overall score.

Table 2.10 Scoring for Option 3 and 3D at South Soko Island for Construction of Site Formation Works

Parameter	**Weight**	**Option 3 (SE Jetty – 3 tanks within cutting)**		**Option 3D (SE Jetty – 2 tanks within cutting)**	
		Score	**WS***	**Score**	**WS***
Volume of excavation in soil	0.05	3.00	0.15	4.00	0.20
Volume of excavation in rock	0.25	3.00	0.75	4.00	1.00
Volume of soil to be disposed of	0.20	3.00	0.60	4.00	0.80
Volume of rock to be disposed of	0.05	3.00	0.15	3.00	0.15
Impact on construction programme	0.10	3.00	0.30	4.00	0.40
Slope stabilisation measures required	0.10	3.00	0.30	5.00	0.50
Slope maintenance	0.05	3.00	0.15	5.00	0.25
Future slope hazard	0.05	3.00	0.15	5.00	0.25
Blasting risks	0.15	3.00	0.45	5.00	0.75
Total Weighted Score			**3.00**		**4.30**

From the comparison of the site formation construction criteria, it is found that the Option 3D site layout is preferred to the Option 3 site layout for South Soko Island. It also offers significant programme savings due to the reduced quantity of rock excavation.

Summary of Engineering Assessment

Two comparative engineering assessments have been made to study the relative merits and demerits of possible layouts for the proposed South Soko Island terminal. The first assessment compared the original base case layout with two other possible layouts to identify the preferred layout of the three. The second assessment investigated the benefits of modifying the preferred layout to consider an alternative design. The comparisons have been made based on the following engineering assessment criteria:

- Construction for the site formation;
- Construction of any reclamation that may be required;
- Construction of the approach channel and turning basins;
- Marine navigation; and,
- Construction of the facility foundations.

Several engineering assessment parameters have been derived for each engineering criteria and a quantitative scoring system applied to each. An overall score for each site has then been established by applying an importance factor to each of the assessment criteria.

The assessment has determined that the Option 3D – South East Jetty layout is preferred from an engineering standpoint. This option achieves the best balance between reclamation and excavation quantities. The location of the jetty at the southeast corner also reduces the dredging volumes for the approach channel and turning basin.

2.1.4 *Environmental Assessment*

The three options for the South Soko terminal layout have been assessed in environmental terms through an environmental impact scoping and preliminary assessment exercise (*Figures 2.1* to *2.3*). This method allows a high level qualitative comparison of each option through the application of pre-defined impact terminology. A description of the methodology is presented below [1] .

(1) It is noted that the methodologies for environmental and engineering comparisons of alternatives differ in this section of the EIA and other such as *Part 1 Section 5* and *Part 3 Section 2*. This is appropriate as the input information in the comparison process has to be treated differently, some of the source information is quantitative and some qualitative and hence the approaches have been tailored to the context of the assessment.

Impact Scoping

Potential impacts have been identified using a "Scoping Matrix". Identified activities and key potential sources of impacts (i.e., hazards) have been listed down the vertical column of the matrix while environmental resources or receptors are listed across the horizontal axis. Each square on the scoping matrix represents a potential interaction between an activity and an environmental resource/ receptor (i.e., potential impact). Resources/receptors are based on the technical requirements of the EIA Study Brief (*ESB-126/2005*).

Due to the nature of the construction of each layout option, described above in the engineering assessment, a single scoping matrix has been developed. Although each layout differs in terms of its design, the functional requirements of the terminal result in similar interactions between activities and environmental resource/ receptors. Differences appear in the severity of potential impacts. The scoping matrix is presented in *Table 2.11*.

Table 2.11 Impact Scoping Matrix

	Air			Noise	Waste		Water			Terr. Ecol.		Marine Ecology					Fisheries*			Landscape and Visual			Cultural Heritage			Hazard to Life	
Activity/Hazard	Air Pollution	Dust	Global Warming	Airborne Noise	Waste Storage Facilities	Waste Disposal Facilities	Hydrodynamics	Water Quality	Groundwater Characteristics	Habitat and Vegetation	Wildlife, Birds and Aquatic Fauna	Intertidal Habitats	Subtidal Habitats	Marine Mammals	Underwater Noise	Ecological Risk	Spawning and Nursery Habitat	Fisheries Resources	Fishing Operations	Landscape	Visual (Aesthetics)	Tourism/Recreation	Designated Buildings	Archaeological Sites	Cultural Resources/Graves	Onsite Health and Safety	Offsite Health and Safety
Construction																											
Accidental Spills/ Leaks/ Dropped Objects								■	■	■	■	■	■	■			■	■									
Air Emissions	■		■																		■						
Run-off								■	■			■	■				■	■			■						
Blasting	■	■		■						■	■			■	■			■								■	■
Discharges to Soil/ Groundwater								■	■	■	■																
Effluents (Cleaning/Recycling/Disposal)								■	■			■	■				■	■									
Excavation		■		■						■	■									■	■		■	■	■		
Marine Anchoring								■					■														
Marine Dredging and Disposal						■		■				■	■	■	■		■	■	■		■	■		■			
Marine Traffic	■													■	■				■								■
Noise				■							■			■				■				■				■	
Piling				■										■	■												
Reclamation		■		■			■	■				■	■	■			■	■	■	■	■	■		■			
Site Formation				■	■	■				■	■									■	■	■	■	■	■		
Waste Generation and Disposal	■	■			■	■																					
Operation																											
Accidental Spills/ Leaks/ Dropped Objects								■	■	■	■	■	■	■			■	■									
Air Emissions	■		■																		■						
Run-off								■	■			■	■				■	■			■						
Biocides								■				■	■			■	■	■	■								
Cooled Water Discharge								■				■	■				■	■	■								
Discharges to Soil/ Groundwater								■	■	■	■																
Effluents (Cleaning/Recycling/Disposal)												■	■				■	■									
Layout Characteristics							■	■												■	■	■			■		
Marine Anchoring								■					■														
Marine Dredging and Disposal (Maintenance)							■	■				■	■	■			■	■	■								
Marine Traffic	■													■					■								■
Noise				■							■											■				■	
Waste Generation and Disposal					■	■																					

Key

No Interaction: □ (blank cell)

Potential Interaction: ■ (shaded cell)

* Underwater noise for fisheries has not been assessed as no underwater blasting would be conducted

It should be noted that the list of activities/ hazards is not intended to be exhaustive but rather an identification of key aspects of both construction and operation phases of the LNG terminal that have the potential to interact with the environment and subsequently have the potential to cause environmental impacts. The list of environmental receptors/ resources is also a focused list of the key aspects of the environment that are considered vulnerable or important in the context of the construction and operation of the LNG terminal.

Evaluation of Impacts

In evaluating the degree of potential impacts, the following factors have been taken into consideration:

- Impact Severity: The severity of an impact is a function of a range of considerations including the following:
  - impact magnitude;
  - impact duration;
  - impact extent;
  - legal and guideline compliance; and,
  - characteristics of the receptor/ resource that is affected.
- Likelihood of Occurrence: How likely is the impact to occur?

Severity Criteria for Environmental Impacts

In evaluating the severity of potential environmental impacts, the following factors have been taken into consideration:

- Receptor/ Resource Characteristics: The nature, importance and sensitivity to change of the receptors or resources that could be affected;
- Impact Magnitude: The magnitude of the change that is induced;
- Impact Duration: The time period over which the impact is expected to last;
- Impact Extent: The geographical extent of the induced change; and
- Regulations, Standards & Guidelines: The status of the impact in relation to regulations (eg. discharge limits), standards (eg. environmental quality criteria) and guidelines.

Impact severity has been categorised using the following subjective scale:

- Slight;
- Low;

- Medium; and
- High.

Likelihood of Occurrence

The likelihood (probability) of the pre-identified events occurring has been ascribed using the following qualitative scale of probability categories (in increasing order of likelihood):

A. Extremely unlikely (eg never heard of in the industry);

B. Unlikely (eg heard of in the industry but considered unlikely);

C. Low likelihood (eg such incidents/impacts have occurred but are uncommon);

D. Medium likelihood (eg such incidents/impacts occur several times per year within the industry); and

E. High likelihood (eg such incidents/impacts occurs several times per year at each location where such works are undertaken).

Likelihood is estimated on the basis of experience and/ or evidence that such an outcome has previously occurred. Impacts resulting from routine/planned events (i.e., normal operations) are classified under category (E).

Impact Significance

The significance of each impact is determined by assessing the impact severity against the likelihood of the impact occurring as summarised in the impact significance assessment matrix provided in *Table 2.12*.

Table 2.12 Impact Significance

	Impact Likelihood				
Impact Severity	Extremely Unlikely	Unlikely	Low Likelihood	Medium Likelihood	High Likelihood
Slight	Negligible Impact	Negligible Impact	Negligible Impact	Negligible Impact	Negligible Impact
Low	Negligible Impact	Negligible Impact	Negligible Impact	Negligible to Low Impact	Low Impact
Medium	Negligible Impact	Negligible Impact	Low Impact	Low to Medium Impact	Medium Impact
High	Negligible to Low Impact	Low Impact	Medium Impact	High Impact	High to Unacceptable Impact

Significance criteria for negative/adverse impacts (i.e., relative ranking of importance) are defined in *Table 2.13*. It is important to note that impacts are considered without the implementation of mitigation measures. The need for and appropriate method of mitigation would be determined on the basis of the impact assessment.

Table 2.13 Significance Criteria

Significance	Definition
Positive Impact	An impact that is considered to represent an improvement on the baseline or introduces a new desirable factor
Negligible Impact	Non-detectable change
Low Impact	Detectable but not significant
Medium Impact	Significant; amenable to mitigation; should be mitigated where practicable
High Impact	Significant; amenable to mitigation; require the adoption of management or mitigation

- *Positive Impacts* are classified under a single category; they are then evaluated qualitatively with a view to their enhancement, if practical.

- *Negligible* or *Low Impacts* will require little or no additional management or mitigation measures (on the basis that the magnitude of the impact is sufficiently small, or that the receptor is of low sensitivity).

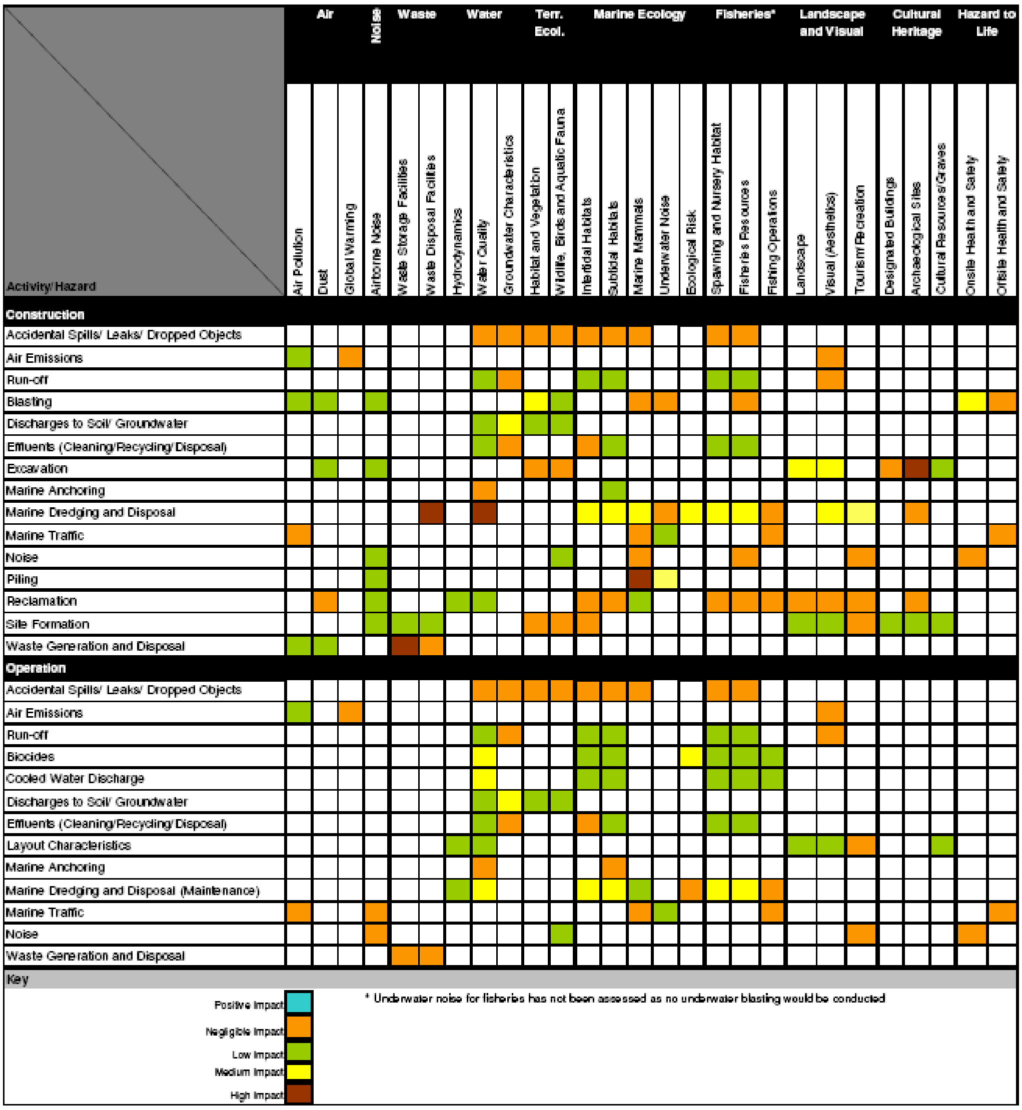
- *Medium* or *High Impacts* require the adoption of management or mitigation measures.

- *High Impacts* always require further management or mitigation measures to limit or reduce the impact to an acceptable level.

Evaluation of Potential Environmental Impacts

An evaluation of the above identified potential impacts as a result of the construction and operation of each of the South Soko terminal options has been undertaken using the concepts described above. The results of these evaluations are presented in detail in *Annex 2-B*. The impact assessment matrices for each of the three layout options for the South Soko terminal are presented below in *Tables 2.14* to *2.16*. Key impacts, i.e., those activities/ hazards which have the potential to result in high impacts to environmental resources/ receptors are highlighted for each option. Following this, environmental impacts that differentiate between the layout options are presented.

Table 2.14 Impact Assessment Matrix: Option 1 - Base Case



Key potential impacts, i.e., high impacts that are considered to be significant and must be mitigated, associated with the construction and operation of the South Soko terminal according to the Option 1 – Base Case layout have been identified as the following:

- Construction Marine Dredging and Disposal Impacts to Water Quality;
- Construction Piling Works on Marine Mammals;
- Construction Waste Generation and Disposal on Waste Storage Facilities; and,
- Construction Excavation to Archaeological Site.

Details on each of the above are presented in *Annex 2-B*.

Table 2.15 Impact Assessment Matrix: Option 2 - Full Reclamation

Activity/Hazard	Air			Noise	Waste		Water			Terr. Ecol.		Marine Ecology					Fisheries*			Landscape and Visual			Cultural Heritage			Hazard to Life	
	Air Pollution	Dust	Global Warming	Airborne Noise	Waste Storage Facilities	Waste Disposal Facilities	Hydrodynamics	Water Quality	Groundwater Characteristics	Habitat and Vegetation	Wildlife, Birds and Aquatic Fauna	Intertidal Habitats	Subtidal Habitats	Marine Mammals	Underwater Noise	Ecological Risk	Spawning and Nursery Habitat	Fisheries Resources	Fishing Operations	Landscape	Visual (Aesthetics)	Tourism/Recreation	Designated Buildings	Archaeological Sites	Cultural Resources/Graves	Onsite Health and Safety	Offsite Health and Safety
Construction																											
Accidental Spills/ Leaks/ Dropped Objects								Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible			Negligible	Negligible									
Air Emissions	Low		Negligible																		Negligible						
Run-off								Low	Negligible			Low	Low				Low	Low			Negligible						
Blasting	Low	Low		Low						Medium	Low			Negligible	Negligible			Negligible								Medium	Negligible
Discharges to Soil/ Groundwater								Low	Medium	Low	Low																
Effluents (Cleaning/Recycding/Disposal)								Low	Negligible			Negligible	Low				Low	Low									
Excavation		Negligible		Low						Negligible	Negligible									Negligible	Negligible		Negligible	High	Low		
Marine Anchoring								Negligible					Low														
Marine Dredging and Disposal						High		High				Medium	Medium	Medium	Negligible	Medium	Medium	Medium	Negligible		Medium	Medium		Negligible			
Marine Traffic	Negligible													Negligible	Low				Negligible								Negligible
Noise				Low							Low			Negligible	Low			Negligible				Negligible				Negligible	
Piling				Low										High	Medium												
Reclamation		Negligible		Low			Low	Low				Low	Low	Medium			Low	Low	Low	Medium	Medium	Medium		Negligible			
Site Formation				Low	Low	Low				Negligible	Negligible	Low								Low	Low	Negligible	Low	Low	Low		
Waste Generation and Disposal	Negligible	Negligible			Positive	Negligible																					
Operation																											
Accidental Spills/ Leaks/ Dropped Objects								Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible			Negligible	Negligible									
Air Emissions	Low		Negligible																		Negligible						
Run-off								Low	Negligible			Low	Low				Low	Low			Negligible						
Biocides								Medium				Low	Low			Medium	Low	Low	Low								
Cooled Water Discharge								Medium				Low	Low				Low	Low	Low								
Discharges to Soil/ Groundwater								Low	Medium	Low	Low																
Effluents (Cleaning/Recycding/Disposal)								Low	Negligible			Negligible	Low				Low	Low									
Layout Characteristics							High	Medium												Low	High	Medium			Low		
Marine Anchoring								Negligible					Negligible														
Marine Dredging and Disposal (Maintenance)							Low	Medium				Medium	Medium	Low		Negligible	Medium	Medium	Negligible								
Marine Traffic	Negligible			Negligible										Negligible	Low				Negligible								Negligible
Noise				Negligible							Low											Negligible				Negligible	
Waste Generation and Disposal					Negligible	Negligible																					

Key

Positive Impact
Negligible Impact
Low Impact
Medium Impact
High Impact

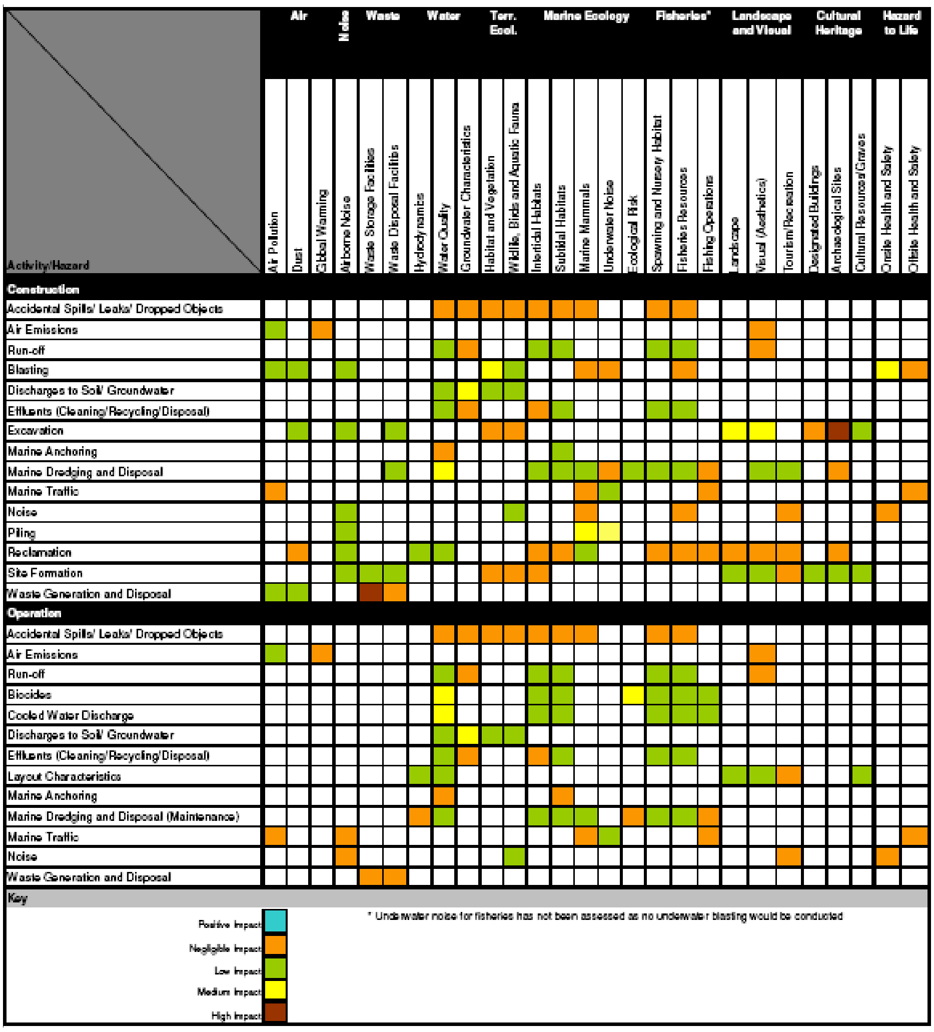
* Underwater noise for fisheries has not been assessed as no underwater blasting would be conducted

Key potential impacts associated with the construction and operation of the South Soko terminal according to the Option 2 – Full Reclamation layout have been identified as the following:

- Construction Marine Dredging and Disposal Impacts to Water Quality;
- Construction Piling Works on Marine Mammals;
- Construction Excavation to Archaeological Site;
- Operation Layout Characteristics on Hydrodynamics; and,
- Operation Layout Characteristics on Visual (Aesthetics).

Details on each of the above are presented in *Annex 2-B.*

Table 2.16 Impact Assessment Matrix: Option 3 - South East Jetty



Key potential impacts associated with the construction and operation of the South Soko terminal according to the Option 3 – SE Jetty layout have been identified as the following:

- Construction Waste Generation and Disposal on Waste Storage Facilities; and,
- Construction Excavation to Archaeological Site.

Details on the above are presented in *Annex 2-B.*

Environmental Differentiators

A summary of the key environmental differentiators between the three options is presented below.

Marine Dredging and Disposal

According to the engineering design of the three layouts for the South Soko terminal one of the major differences appears to be in the dredging and subsequent disposal requirements of marine sediments. *Table 2.1* above indicates that both Option 1 – Base Case and Option 2 – Full Reclamation have been estimated to require approximately 3.36 Mm^3 of marine sediments to be removed in order to dredge the approach channel and turning basin to the required depth for safe LNG carrier passage (approximately -15 mPD). In contrast, Layout 3 – SE Jetty will only require approximately 1.07 Mm^3 of marine sediments to be removed.

The primary difference is the shorter length of the approach channel and turning basin for this layout has been designed to only come into the southeastern side of South Soko Island, which is in contrast to Options 1 and 2 where the channel circumnavigates the southern, eastern and northern sides of the island before ending at the northwest near Sai Wan bay.

The increased dredging requirements of Options 1 and 2 will have subsequent increases in potentially adverse consequences to resources and receptors, such as those to water quality, marine habitats (both intertidal and subtidal), marine mammals, as well as fisheries resources and operations. These differences have been reflected in the impact severity and likelihood assessments.

Piling

Piling operations will be required for all layouts in order to construct the jetty and trestle for the LNG carrier. Piling operations have the potential to result in adverse impacts to underwater noise and subsequently marine mammals. Layout Options 1 and 2 of the South Soko terminal would require the jetty to be constructed in the northwestern Sai Wan Bay of South Soko Island, whereas, Option 3 will have the jetty located on the southeastern side of the island.

Recent monitoring by CAPCO as well as long-term monitoring of marine mammal abundance and distribution in these waters (*Part 2 – Section 9*) indicates that marine mammal sightings are more frequent in the waters in the vicinity of Options 1 and 2, in comparison to those in the waters surrounding the jetty in Option 3. As a result, it would be expected that the potential for adverse impacts to occur to marine mammals as a result of marine piling operations would be considered likely to be higher for Options 1 and 2 when compared to Option 3.

Reclamation

The engineering design of Option 2 – Full Reclamation will require the reclamation of approximately 13 hectares (ha) of existing marine habitats. The majority of reclamation will occur to the west of the existing platform to house the proposed turbine substation, utility area and laydown area. The area to the east of the platform will be used for the service berth.

In comparison, both Options 1 and 3, Base Case and SE Jetty respectively, will require only approximately 1.7 ha of marine habitats to be reclaimed. This will primarily be needed for the utility pier on the west of the platform (or for Tank 3 for the SE Jetty layout) and to the east for the service berths.

The differences in reclamation area will result in subsequent increases in potential impacts to resources and receptors, such as those to water quality, marine habitats (both intertidal and subtidal), marine mammals, fisheries resources and operations as well as visual and aesthetics. These differences have been reflected in the impact severity and likelihood assessments.

Waste Generation and Disposal

All options will require the excavation of rock from the existing hillsides in order to provide sufficient flat land to meet the functional requirements of the LNG terminal. However, as the Option 2 layout design will involve the construction of a comparatively large area of reclamation, it has been estimated that all excavated material under this design will be able to be reused in the reclamation. In addition, it is expected that up to 1,261,000 m^3 of fill will need to be imported, possibly from existing construction and demolition (C&D) waste storage facilities. Hong Kong is currently storing surplus C&D material, thus the necessity to import such material would be considered to be a positive impact for the Option 2 layout.

In contrast to Option 2, the design of Options 1 and 3, the Base Case and SE Jetty, respectively, will result in a smaller requirement for import of fill than Option 2.

Layout Characteristics

The reclamation requirements for layout Option 2, Full Reclamation, may be expected to potentially change the hydrodynamics in the surrounding waters. Impacts as a result of these changes may occur to water quality, marine ecological and fisheries sensitive receivers. In addition, the extended footprint of the site would likely increase the exposure to visual sensitive receivers, such as those on Lantau Island. Such operational impacts are considered to be a disadvantage of this layout in comparison to the others under investigation.

Environmental Assessment Results

The results of the environmental impact scoping and assessment allows a comparison of each layout and design option to be presented based on the number of issues. Each option has been ranked in order of preference against the other on the basis of the number of impacts compared to the other two options, i.e., the lower number of impacts the better. On the basis of these ranks, the average rank has been determined for each option to determine the order of preference in both the construction and operation phases of the potential South Soko terminal. The result of the comparison is presented in *Table 2.17*.

Table 2.17 Comparison of Layout Options at South Soko Island in terms of Environmental Assessment

Option	Positive Impact		Negligible Impact		Low Impact		Medium Impact		High Impact		
	Count	Rank	Count	Rank	Count	Rank	Count	Rank	Count	Rank	Ave. Rank
Construction											
Base Case	0	2.0	49	2.0	39	1.0	14	2.0	5	3.0	1.93
Full Reclamation	1	1.0	45	1.0	41	2.0	16	3.0	4	2.0	1.90
South East Jetty	0	2.0	51	3.0	46	3.0	8	1.0	2	1.0	1.80
Operation											
Base Case	0	1.0	30	2.0	32	2.0	9	2.0	0	1.0	1.73
Full Reclamation	0	1.0	29	1.0	29	1.0	11	3.0	2	3.0	1.80
South East Jetty	0	1.0	31	3.0	36	3.0	4	1.0	0	1.0	1.80
Average Rank											
Base Case											**1.83**
Full Reclamation											**1.85**
South East Jetty											**1.80**

On the basis of the environmental assessment for the construction and operation of the potential South Soko terminal, the result of the layout comparison is as follows:

- Preferred layout: Option 3 – SE Jetty
- Second choice: Option 1 – Base Case
- Third choice: Option 2 – Full Reclamation

Option 3 is preferred based on the following reasons:

- Reduced reclamation size;
- Reduced amount of natural coastline disturbed as a result of reduction in reclamation works; and
- Significantly reduced dredging volumes by orientating the LNG jetty to the southeast of South Soko Island.
- Option 3 avoids having to site the jetty (and therefore not have to dredge the turning basin and approach channel) in the area between the North and South Soko Islands which has been highlighted by EPD in the Study Brief as an area where impacts should be avoided/reduced.

Option 3 layout has resulted in a substantial reduction in ecological, fisheries and water quality impacts through reduction in reclamation, dredging and natural coastline loss. The reduction in dredging will also have a benefit in reducing off site impacts during disposal of dredged muds and ease the burden on the capacity of existing disposal sites.

Alternative Layout for Option 3 – South East Jetty

As with the engineering assessment, an alternative layout for the preferred option has been examined in terms of comparing the layout from an environmental perspective (see *Figure 2.4*). As the design of the alternative option for the SE Jetty, termed Option 3D, is similar to that of the original Option 3, with principal changes being on-land configuration, the impact scoping and assessment methodology applied for the comparison of the three layout options would not be sensitive enough to differentiate between the two options. A comparative methodology of preference is therefore presented below (*Table 2.18*). As above, resources/ receptors have been based on the technical requirements of the Study Brief (*ESB-126/2005*).

Table 2.18 ***Comparison of Environmental Preference between Option 3 (SE Jetty -3 Tanks) and Option 3D (SE Jetty - 2 Tanks)***

Resource/Receptor	Option 3 (SE Jetty - 3 Tanks)	Option 3D (SE Jetty - 2 Tanks)
Air	[yellow]	[green]
Noise	[orange]	[orange]
Waste	[yellow]	[green]
Water	[yellow]	[green]
Terr. Ecol.	[yellow]	[green]
Marine Ecology	[yellow]	[green]
Fisheries	[yellow]	[green]
Landscape and Visual	[yellow]	[green]
Cultural Heritage	[orange]	[orange]
Hazard to Life	[orange]	[orange]
Key		
No Difference	[orange]	
Most Preferred	[green]	
Least Preferred	[yellow]	

On the basis of the above, the indication is that the layout for Option 3D (SE Jetty – 2 Tanks) would be preferable from an environmental perspective. With the exception of cultural heritage and hazard to life, Option 3D would be preferred for all environmental resources/ receptors under the *EIAO-TM*. Rationale for each assessment is presented below.

Air

According to the engineering assessment, the combined volume of soil and rock to be excavated from Option 3 during construction works would be approximately 2.3 Mm^3, whereas, for Option 3D an estimated combined volume of 2.06 Mm^3 of material would be required to be excavated. Assuming the material would be removed through similar processes, air quality impacts associated with the excavation of this material through construction works, such release of particulates and dust, would therefore be expected to be lower for Option 3D. Operational impacts would be expected to be similar for both options. As a result, Option 3D would be preferred over Option 3 from an air quality perspective.

Noise

Given that the sensitive receivers at Shek Pik are located at approximately 6 km away from the site, the construction and operational noise would be expected to be similar for both options.

Water

Due to the relocation of the utility pier to Tung Wan bay to the east of the platform, Option 3D would not require a dredged approach channel in Sai Wan bay when compared to Option 3. Refinements to the approach channel for the LNG Carrier to the south east of the island would also reduce dredging requirements.

In addition to the above, the layout of Option 3D proposes that the outfall for the cooled water be located to the south east of the island, with the discharge point approximately 10 m offshore and in close proximity to the jetty for the LNG carrier. For Option 3 the outfall has been located directly south of Yuen Kong Chau, the small island to the east of Tung Wan Bay. The relocation of the outfall to the south of the island in Option 3D allows the discharge point to be located in an area of increased current flows, thereby potentially allowing more immediate dispersion and assimilation of the cooled water. In addition, the installation of a 10 m outfall for Option 3D in comparison to an approximate 400 m outfall for Option 3 would result in lower dredging requirements.

The reduction in dredging requirements described above would result in a decrease in the potential for impacts to water quality to occur through the sediment plumes as a result of the release of suspended solids and through any changes in general hydrodynamics. On this basis, Option 3D would be preferred over Option 3 from a potential impacts to water quality perspective.

Terrestrial Ecology

As with the comparison for air and noise impacts, the reduction in excavation requirements at Fei Kei Teng and Sheung Tsuen will result in a reduced impact to terrestrial ecology. Assuming excavation methods will be similar between options, the total area of habitat loss, and therefore potential to impact terrestrial flora and fauna, will be less for Option 3D than for Option 3 (for approximately 1 ha). Based on this, Option 3D would be preferred over Option 3 from a terrestrial ecology perspective.

Marine Ecology

As impacts to water quality are likely to be lower with Option 3D when compared to Option 3, it would be reasonable to assume that indirect impacts to marine ecology would also be lessened. Similarly, direct impacts would be lower due to a reduction in disturbed habitat through dredging works.

Fisheries

The potential to limit impacts to Sai Wan Bay and Pak Tso Wan through a reduction in dredging works would be considered to be favoured in terms of reducing the potential for impacts to occur to fisheries resources. These waters have previously been identified as an area supporting fish fry habitat, and as such, unacceptable impacts to water quality in this bay may have the potential to result in consequences to fish fry (see *Part 2 – Section 10*). Option 3D would, therefore, be preferred over Option 3 in terms reducing the potential to impact fisheries resources, and subsequently fishing operations.

Landscape and Visual

The configuration of the on-land facilities associated with layout Option 3 would result in excavation of the majority of the southern slope of Fei Kei Teng. Whilst this natural slope will provide some degree of shielding for Tanks 1 and 2 of the design, the top of future Tank 3 would remain visible from a number of visual sensitive receivers to the south of Lantau, albeit predominantly from the south east of Lantau and at some considerable distance from the source. In contrast, Option 3D, by leaving a larger portion of the natural southern slope of Fe Kei Teng intact, the future Tank 3, which would be located south of Tank 2 would likely be shielded from view from the majority of sensitive receivers. In addition, from an aesthetic point of view, it would be considered favourable to leave the natural terrain in place as much as possible. As a result, Option 3D would be considered to be preferred from a Landscape and Visual perspective.

Cultural Heritage

Recent surveys of areas or deposits of potential archaeological interest or cultural heritage importance (*Part 2 – Section 12*) indicate that the majority of deposits of archaeological potential or existing graves are located in areas that are in common for both Option 3 and Option 3D. As such, similar mitigation measures would be proposed for each of the two layouts to limit any impacts to cultural heritage and as a result, there would be no preference between the two sites from a cultural heritage perspective.

Hazard to Life

As with potential impacts to cultural heritage, the design of each site is similar such that the potential hazard to life would be considered no different between the two. A minor difference may be in that potentially less blasting would be required during the construction of Option 3D when compared to Option 3, however, as both would require blasting neither site is considered to be preferable over the other from a Hazard to Life perspective.

Summary of Environmental Assessment

As with the engineering assessment, two comparative environmental studies have been made to assess the relative merits and demerits of possible layouts for the proposed South Soko terminal. The first study compared the base case layout with two other possible layouts to identify the preferred layout of the three. The second study investigated the benefits of modifying the preferred layout to consider an alternative design. The comparisons have been made based on the potential for impacts to occur to resources/ receptors identified under the *EIAO-TM* and the technical requirements of the Study Brief (*ESB-126/2005*).

As it is not considered appropriate to apply an importance factor to environmental criteria, potential impacts to resources/ receptors have been firstly identified through the potential for interaction, followed by a qualitative assessment of the likely severity of impact.

The assessment has determined that the Option 3D – South East Jetty layout is preferred from an environmental perspective. This option offers lower excavation requirements as well as a reduction in dredging volumes. The potential for subsequent impacts to the environment have, therefore, been considered to be lower for this layout option.

2.1.5 *Summary of Consideration of Different Layouts and Design Options*

The above section has considered different layouts and design options for the South Soko terminal as part of the overall assessment of alternatives. The assessment has been conducted to investigate not only the environmental considerations of each preliminary layout and design options, but to include an examination of the engineering aspects for various layouts. The assessment has thus considered both the difficulties of the construction and operation of each facility as well as the potential environmental impacts associated with such.

Both the engineering and environmental assessments have identified layout Option 3D – South East Jetty as the most preferable for the construction and operation of the South Soko terminal. This option achieves the best balance between reclamation and excavation quantities. The location of the jetty at the southeast corner also reduces the dredging volumes for the approach channel and turning basin. The engineering consequences and subsequent environmental impacts are considered to be lower for this layout option.

The South East Jetty Option 3D Layout was therefore taken forward as the preferred layout for the South Soko terminal in the Environmental Impact Assessment. However, it should be noted that a further revision to the layout was made during the EIA as a result of information gathered from the baseline environmental surveys. This layout change and the resulting adopted layout are presented in *Section 2.5*.

2.1.6 *Tank Technology Selection*

The Hong Kong LNG Terminal Project has selected the above-ground full containment LNG tank system for the import re-gasification terminal in Hong Kong SAR (as discussed in *Part 1 Section 3*). This selection is applicable to either South Soko Island or Black Point, the two sites being considered for the LNG terminal. A technical note has been prepared that discusses the main reasons for selecting an above-ground full containment LNG storage tank system over other methods, such as an in-ground system and this is presented in full in *Annex 2D*.

2.2 *CONSIDERATION OF ALTERNATIVE CONSTRUCTION METHODS & SEQUENCES*

In accordance with *Clause 3.3.5* of the EIA Study Brief (*ESB-126/2005*), this section presents the consideration of alternative construction methods and sequence of works that have been assessed as part of the overall assessment of alternatives for the South Soko terminal.

The assessment has been conducted to investigate potential methods and plant for the construction of the proposed terminal as well as associated facilities such as the submarine cable, water main and natural gas pipeline. The objective of the assessment is to identify the preferred alternative with a view to avoid the likelihood of unacceptable adverse environmental impacts.

Alternative construction sequences have been investigated in the EIA , specifically in the water quality section (*Section 6*) in order to avoid localised cumulative effects and to avoid adverse impacts to the maximum practical extent.

The basic requirements of a LNG terminal in Hong Kong have been described in *Part 1 – Section 3*. Justifications for South Soko Island being considered as one of the two sites for a LNG receiving terminal in Hong Kong have been presented in *Part 1 – Section 4*.

On the basis of these requirements, it is considered that the following are the key facilities to be constructed, to which alternative methods have been considered:

- Reclamation;
- Seawalls;
- Jetty;
- Approach Channel and Turning Basin; and
- Submarine Gas Pipeline, Water Main and Power Cable.

As the onsite facilities, such as the LNG storage, gasification plant, administration office, canteen, ancillary buildings and sewerage treatment plant etc, will be constructed to best industry standard, alternatives for construction will not be discussed.

2.2.1 *Reclamation*

The preferred layout for the South Soko terminal (see *Part 2 – Section 2.1*) would involve mainly site formation works and approximately 1.7 ha of reclamation. The relatively small-scale reclamation is predominantly for the construction of breakwater and service berths. The layout for the preferred South Soko terminal is presented in *Figure 2.4*.

Traditionally the method to construct the reclamation area has been to dredge away all soft seabed materials under the entire reclamation area. This would be considered as a 'Fully Dredged Method'. However, recently in Hong Kong there has been an increasing reliance on only dredging soft mud from beneath the seawall and main drainage culverts and to leave the soft mud under the proposed reclamation area. According to the Practice Note for Authorized Persons and Registered Structural Engineers (PNAP) No. 252 issued by the Buildings Department, project proponents must plan projects on the assumption of keeping the mud in place. Time for consolidation and consequential programme constraints shall be allowed for in programming. In order to reduce the long term ongoing settlement of the soft mud under the overlying reclamation fill, ground improvement works would be necessary. Such a construction method would be considered as a 'Partially-dredged Method'. In line with local construction practice and government policy, this method will be adopted for the project. It is noted that the partially dredged option minimises the quantities of materials dredged on site and therefore disposal offsite resulting in a net environmental benefit.

Partially-dredged Method

For this method, dredging would be limited to only the area beneath the seawall. The mud is not dredged from beneath the reclamation area but rather sand fill is placed over the soft mud to initially raise the ground level to +2.5 mPD after which, public fill is compacted in layers to the finished level of +6 mPD. There are two key engineering issues to be considered with this method as follow:

- The soft marine mud will consolidate significantly under the weight of the overlying fill. This consolidation may well be up to 3 metres and will take many years to complete if no additional ground improvement works are put in place;

- The initial layers of sand fill need to be placed very carefully to avoid the generation of mud waves which can significantly affect the long term performance of the reclamation.

The second issue is usually rectified by protecting the mud by a layer of geotextile followed by hydraulically placed sand.

Ground movements due to consolidation settlement have a significant impact on the operation of the facility. The most sensitive structures will need to be necessarily piled in order to mitigate these effects of ground movement. However, it will not be sensible to support all plant and services at the site on piles. In these areas ground improvement measures will be essential to reduce ground movements to acceptable levels. Two commonly used ground improvement methods suitable for use in reclamation areas include the following: -

- Installation of vertical drains together with surcharge pre-loading; and
- Vibro-replacement / vibro displacement.

In view of the tight construction programme, cost-effectiveness and the sensitive nature of cryogenic equipment, the use of vertical drains with surcharge pre-loading is considered the most suitable method of ground improvement.

Vertical Drains with Surcharge Pre-loading

The use of vertical drains (often called band drains) for construction of reclamations has the effect of shortening the drainage paths of the relatively impermeable marine clay and/or alluvial clay. The consolidation settlement due to the site formation can therefore be achieved within a shorter period. Drains are typically inserted on a triangular grid at 1.2 to 1.5m spacing down to the interface between marine deposits/alluvial clay layer (sometimes penetrated through the alluvium, depending on its engineering characteristics).

The surcharge preloading serves the following purposes: -

- To significantly speed up the consolidation;
- If suitable additional surcharging height or time duration is allowed, it can substantially eliminate the settlement due to the future imposed load from low rise buildings and other light weight structures.

The design height and duration of placement for the surcharge mound will depend upon the time allowed in the construction programme. For projects with a tight construction programme such as this, the surcharge mound would need to be high. It is currently estimated that the height of the surcharge mound would need to be approximately 5m above the future formation level of +6mPD which will achieve acceptable long-term settlement performance of the reclamation.

The cryogenic pipelines and facility structures will require very tight settlement criteria as the movement tolerances are very small. The proposed foundation schemes for the structures are still under development and thus a detailed settlement / differential settlement analysis shall be carried out at a later stage.

2.2.2 *Seawalls*

Dredging is required to remove the soft material beneath the seawall to ensure that the seawall is stable and can be built within an optimum timeframe, thereby reducing the potential for environmental impacts to occur. In addition to the conventional method of carrying out full dredging of the marine deposits before filling up for the seawall, two other alternatives have been considered.

The first alternative makes use of ground improvement technique, such as Deep Cement Mixing (DCM), to enhance the strength of the marine deposits before filling up for the seawall. In DCM, the soft soil is mixed *in-situ* with an appropriate additive using an auger or other mixing device. The additive used is typically cement or lime. No spoil removal is required. A similar technique called Deep Cement Method was developed in Japan, using cement slurry. Previous studies have investigated the use of cement stabilization work as part of the ground improvement method, however, these have only been performed on the bench-scale test but such technology has not been taken forward on site with pilot trial (1). The efficiency and cost-effectiveness of the improvement method has not been tested and as such it is not possible to assess the environmental and safety impact attached to this alternative. The use of Deep Cement Mixing is therefore not the preferred construction alternative for the current study.

The second alternative requires a long counter fill on the seaward side of the seawall to provide toe stability against slip failure during construction. The use of this method is, however, considered to be unsuitable for this project as it is likely to lead to significant ongoing settlement of the sea wall after the LNG terminal is in operation.

On the basis of the above, neither of the alternative methods is preferred over the conventional method of dredging beneath the seawall. As such, the conventional method of carrying out full dredging of the marine deposits before filling up for the seawall is recommended as the preferred alternative for the construction of the seawalls for the LNG terminal.

2.2.3 *Jetty*

A piled jetty is required for creation of the berthing facility for the LNG carrier at the South Soko terminal. Piled structures are preferable to blockwork or closed structure designs as they are less likely to result in adverse impacts to

(1) Aas, PM & Engen A (1993) Hong Kong Seawall Design Study. GEO Report No. 31. Geotechnical Engineering Office, Civil Engineering and Development Department, Hong Kong SAR Government.

water quality and subsequently marine ecology, due to the minimal disturbance to hydrodynamics.

For the construction of the LNG Jetty, two alternatives are available for the installation of marine piles. These are bored or percussive piling methods. A discussion of each of these methods in terms of the environmental advantages and disadvantages is presented below.

Bored Piles

Noise created by bored piling methods tends to be a less intensive continuous noise, rather than the pulsed high power sounds emitted through percussive piling [(1)]. A summary of potential impacts from bored piling methods are presented below.

- a large casing must be driven into the seabed in order to support the boring equipment which will necessitate a longer construction period;
- socketing into the bedrock will require the use of a chisel (noise impacts from socketing may be mitigated by using the reverse circulation drilling method); and,
- placing concrete to the bored pile (potential leakage of cementitious materials from sacrificial casing during this process).

Percussive Piles

The sounds emitted from percussive hammer pile driving activities have their highest energy at lower frequency (20 Hz to 1 kHz) and loud sounds have been identified to cause (short-term) behavioural reactions such as increased swimming speed in cetaceans [(2)]. Studies in Hong Kong have, however, determined that with measures such as bubble jackets and bubble curtains, marine mammal behaviour does not change substantially during percussive piling operations [(3)].

Based on the well-proven track record for the successful employment of these measures, it is proposed that either method be used for the construction of the LNG Jetty as part of the South Soko terminal. Detailed assessments of the impacts of both methods are also mentioned in other sections in this EIA Report.

2.2.4 *Approach Channel and Turning Basin*

An approach channel and turning basin will be required to allow for the safe transit of the LNG carrier to the jetty. In order to meet the required draft of

(1) B Wursig, C.R. Greene, T. A Jefferson (2000) Development of an air bubble curtain to reduce underwater noise of percussive piling. Marine Environmental Research (49), 79-93.

(2) B Wursig, C.R. Greene, T. A Jefferson (2000) *Op cit*.

(3) B Wursig, C.R. Greene, T. A Jefferson (2000) *Op cit*.

the carrier, both the channel and turning basin will be required to be dredged to approximately -15 mPD. There are two common dredging plant that are employed for the removal of marine sediments in Hong Kong. These are grab dredgers or trailing suction hopper dredgers (TSHD). Each plant would be available as alternatives for the construction of the approach channel and turning basin. The potential environmental benefits and dis-benefits of each are discussed below.

Grab Dredgers

A grab dredger comprises a rectangular pontoon on which is mounted a revolving crane equipped with a grab. The dredging operation consists of lowering the grab to the bottom, closing the grab, raising the filled grab to the surface and discharging the contents into a barge. Grab dredgers are usually held in position while working by anchors and moorings but some have a spud or pile, which can be dropped onto the bottom while the dredger is operating.

Grab dredgers may release sediment into suspension by the following mechanisms:

- Impact of the grab on the seabed as it is lowered;
- Washing of sediment off the outside of the grab as it is raised through the water column and when it is lowered again after being emptied;
- Leakage of water from the grab as it is hauled above the water surface;
- Spillage of sediment from over-full grabs;
- Loss from grabs which cannot be fully closed due to the presence of debris;
- Release by splashing when loading barges by careless, inaccurate methods;
- Disturbance of the seabed as the closed grab is removed.

During the transport of dredged materials, sediment may be lost through leakage from barges. However, dredging permits in Hong Kong include requirements that barges used for the transport of dredging materials shall have bottom-doors that are properly maintained and have tight-fitting seals in order to prevent leakage.

Sediment is also lost to the water column when discharging material at disposal sites. The amount that is lost depends on a large number of factors including material characteristics, the speed and manner in which it is discharged from the vessel, and the characteristics of the disposal sites.

Trailing Suction Hopper Dredgers

Trailing Suction Hopper Dredgers (TSHD) are designed to use a suction mouth at the end of a long pipe. As the barge moves, the suction hopper trails along and sucks up the soft seabed sediments. During dredging the drag head will sink below the level of the surrounding seabed and the seabed sediments will be extracted from the base of the trench formed by the passage of the draghead. The main source of sediment release is the bulldozing effect of the draghead when it is immersed in the mud. This mechanism means that sediment is generally lost to suspension very close to the level of the surrounding seabed.

During dredging marine sediments are pumped into the vessel's hopper. Once the hopper is loaded the dredging operation will be stopped and the vessel will sail to a designated disposal area. A TSHD is usually positioned by dynamic positioning, thus they have no anchor wires. In comparison to grab dredgers, TSHDs generally have a higher production rate.

Both Grab dredgers and Trailing Suction Hopper Dredgers (TSHD) are commonly used in Hong Kong. As such, the employment of both plant are considered viable options.

2.2.5 *Gas Pipeline, Water Main and Power Cable*

Due to the geological profile of the proposed alignments for the natural gas pipeline, water main and power cable (each of which are discussed further in the following sections), the installation of these facilities will require dredging/trenching operations for the offshore and nearshore sections. Dredging will be employed at each of the associated facilities launching and landing sites, due to the proximity of these locations to the shoreline requiring accurate removal of potential marine muds and rock fill. In addition, dredging and backfilling with a combination of gravel and rock armour will be required when these facilities cross fairways and other specific locations in order to provide adequate protection from third party damage.

Offshore, along the routes of each installation, there is the potential to employ jetting in order to trench these facilities to the required depths. Whilst dredging methods are discussed above, a description of the jetting method is presented below.

Jetting

The jet machine will either be self-propelled or be towed by barge. The self-propelled machine has wheels resting on the pipeline and uses the pipe for traction. Stability is achieved with the use of buoyancy aids. A 'Non-conventional' jetting machine may be utilised, as it does not use air to assist with discharge of the sediment. This results in less adverse effect on the water quality of the surrounding areas.

From the soil data, a nozzle configuration that best suits the *in-situ* soil characteristics will be determined. The method is based on fluidising the muds allowing the pipe to sink to the chosen depth.

During the installation of the submarine utilities using jetting technology, it would be expected that seabed sediment would be released close to the seabed and will settle out relatively quickly. The sediment would therefore only be in suspension for a short period of time and as such, the potential for impacts to occur, such as through the exertion of the oxygen demand on the receiving waters, will be limited.

Preferred Installation Techniques for Submarine Gas Pipeline

Data gathered during the EIA on marine ecological resources along the submarine gas pipeline route indicated that there were two key sensitive areas ie, West Lantau where dolphins are abundant and along the boundary of the Sha Chau Lung Kwu Chau Marine Park. Consequently, during the preliminary engineering design of the submarine pipeline an analysis of different techniques was undertaken to select the method that produced the better overall environmental performance.

<u>West Lantau</u>

In West Lantau there were two options for the route, one was aligned inshore and the other offshore close to the boundary of Hong Kong waters. The option to use jetting was only available inshore as the offshore route required a larger dredged trench with additional armour rock backfill as protection from anchor drop and drag. For this reason for the offshore option it was proposed that a trailing suction hopper dredger (TSHD) be employed. The impact on water quality was examined for both of the options as shown in *Figure 2.5*.

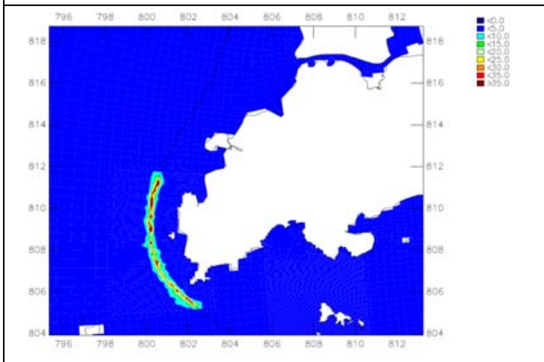
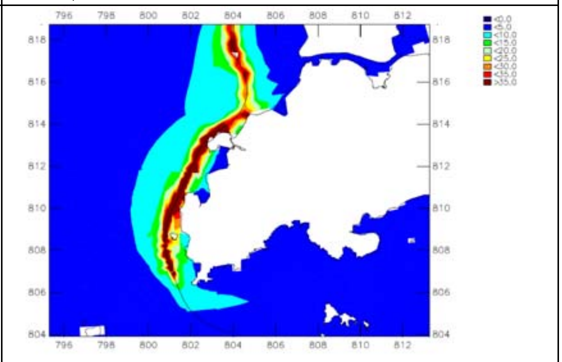
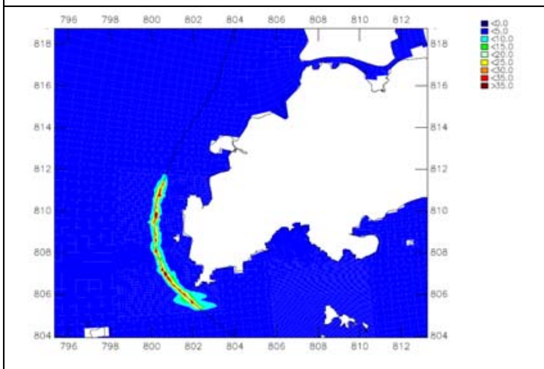
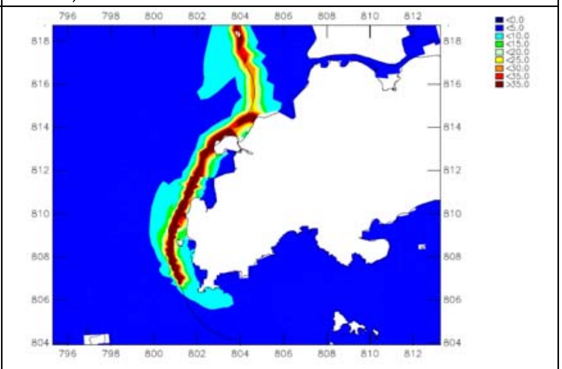
TSHD Dredging **–** Maximum SS Elevation in the Dry Season	***Jetting*** **–** Maximum SS Elevation in the Dry Season (jetting has to be carried out on a inshore route)
	
TSHD Dredging **–** Maximum SS Elevation in the Wet Season	***Jetting*** **–** Maximum SS Elevation in the Wet Season (jetting has to be carried out on a inshore route)
	

Figure 2.5 ***Contour plots of maximum suspended solids elevations generated in West Lantau using Jetting (45 m hr^{-1} working 24 hours per day) or TSHD Dredging (4,600 m^{3} trip^{-1} working 24 hours per day)*** [1]

The results show the spread of suspended sediment generated by the jetting machine extends further and is more concentrated than the TSHD. It is noted from the plots that in both the wet and dry seasons the SS elevations exceed 30 mg L^{-1} along some of the coastal areas of West Lantau some areas of which

(1 It should be noted that these plots show the highest level recorded in each model grid cell over the entire 15 day cycle and are hence a worse case image. They do not represent simultaneous snap shots and therefore should not be interpreted against the WQO as the SS elevations in one grid cell (ie area) will occur during a different day/hour than in another grid cell.

would be within the boundary of the Proposed Southwest Lantau Marine Park (eg Peaked Hill) whereas for the TSHD the plumes generated do not touch the coastline areas. The areal exceedance of the water quality objective is also larger for the jetting machine than the TSHD. The impacts produced by the inshore jetting option are unlikely to be acceptable without additional mitigation measures whereas the impacts of the TSHD are not unacceptable.

The jetting machine does not generate any mud to be disposed offsite unlike the TSHD. However, given the expected water quality impacts of the inshore jetted route this concern is considered to be secondary.

For this section of the gas pipeline a grab dredger was not considered a suitable engineering solution to form a trench of the required size at the given location compared to a TSHD. The advantages of using a TSHD over grab dredgers are summarised as follows :

1) In this region the water depth is deeper and the current velocities much higher than along other sections of the pipeline route. The grab, which is connected only by winches to the derrick barge, would be affected by these marine conditions, which will result in a less accurate dredging profile. The barges also use only simple global positioning systems, which leads to crude positioning and depth control, typically resulting in over-dredging of the channel.

   The TSHD has an attached trailer which is lowered onto the seabed when dredging. The greater rigidity of the trailer typically results in more accurate dredging even in strong currents and deep water. The vessel is also equipped with sophisticated satellite positional (DGPS) and depth control systems and hence they are able to cut the trench profile more accurately.

2) The dredged profile in this section requires a much larger trench width than elsewhere along the route. It is therefore more suited towards the more efficient TSHD operation which can dredge more than 4 times the daily volume of mud compared to a single grab dredger.

   Due to their slower work rate, there is also a concern that the use of grab dredgers could lead to slumping of the trench sides as pore water pressures recover within the low permeability clay material. Slumping of the trenches would lead to additional remedial dredging, and hence mud disposal needs, as well as additional impacts on water quality and marine ecology that could otherwise be avoided through the use of the TSHD.

3) A grab dredger needs to work with a split-bottom barge to store the dredged mud, and also tug boats, hoppers, pontoons, etc. To make up for the grab's smaller capacity, more of these vessels would be required which increases the risks to marine traffic. The TSHD is a self-contained barge with a container to store the dredged mud sucked up by the trailer via

pipelines. Therefore only one vessel will be required at the dredging location which reduces the marine traffic risk.

Northwest Lantau

The pipeline alignment in Northwest Lantau passes along the corridor between the Sha Chau Lung Kwu Chau Marine Park and the western boundary of Hong Kong waters. The water depths in the areas are too shallow to utilise a TSHD and hence the options for burying the pipeline were to jet following pipelay or to use grab dredgers to pre-trench. The impact on water quality was examined for both of the options as shown in *Figure 2.6*.

The results show the spread of suspended sediment generated by the jetting machine extends further and is more concentrated than the grab dredgers. It is noted from the plots that in both the wet and dry seasons the SS elevations exceed 10 mg L^{-1} inside the boundary of the Marine Park whereas for the grab dredgers the SS elevations meet the allowable WQO exceedance just inside the boundary of the Marine Park. The areal exceedance of the water quality objective is also much larger for the jetting machine than the grab dredgers. Although the impacts from the jetting machine can be mitigated to an extent, through the adoption of movable standing silt curtains, the WQO would still be marginally exceeded inside the park. It is noted that the practicalities of installing a movable silt curtain in the narrow corridor between the pipeline works area and the boundary of the Marine Park where current velocities are high would require investigation.

The jetting machine does not generate any mud to be disposed offsite unlike the grab dredging. Should grab dredgers be adopted for the section of the alignment along the Marine Park boundary it would be uneconomical and not practical to utilise a jetting machine for the remaining areas close to Black Point and South Soko (ie less than 8 km). Consequently, the adoption of grab dredging would signify that the dredged mud volumes would increase by 0.62 Mm^3. Of this mud approximately 50% would require Type 2 disposal (ie at East of Sha Chau) and 37% would require unconfined open sea disposal.

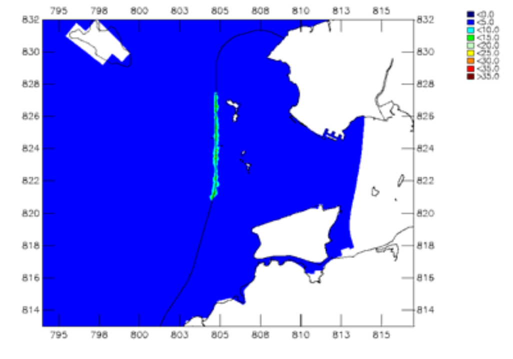
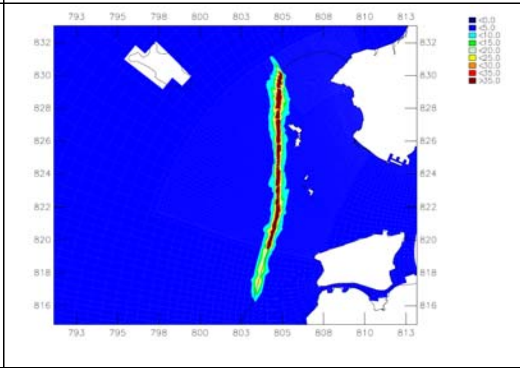
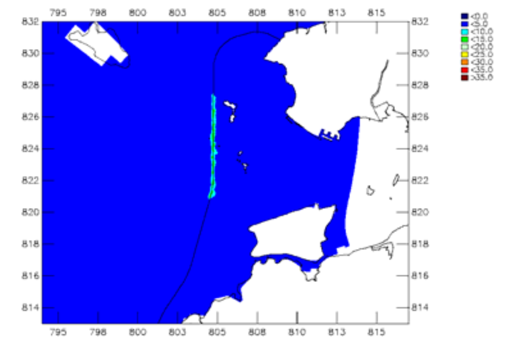
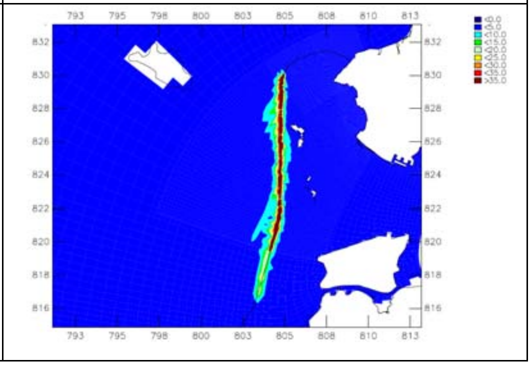
Grab Dredging – Maximum SS Elevation in the Dry Season	*Jetting* – Maximum SS Elevation in the Dry Season
	
Grab Dredging – Maximum SS Elevation in the Wet Season	*Jetting* – Maximum SS Elevation in the Wet Season
	

Figure 2.6 ***Contour plots of maximum suspended solids elevations generated in West Lantau using Jetting (21 m hr^{-1} working 12 hours per day) or Grab Dredging (4,000 m^3 hr^{-1} per dredger with 4 dredgers working 12 hours per day)*** (1)

Taking the above into consideration it was considered that the preferred approach for Northwest Lantau would be to adopt grab dredging and for West Lantau dredging using TSHD.

<u>Remaining sections of the pipeline route</u>

For the remaining sections of the submarine gas pipeline route, ie the sections that approach the landing points at Black Point and South Soko the decision was taken that grab dredgers would be used. The rationale behind the selection of equipment along these sections is that the spread of suspended sediment can be controlled through adjusting dredging rates and employing silt curtains if considered necessary. Also these two sections of the gas pipeline route are relatively shallow and hence suitable for grab dredgers to work in.

(1) It should be noted that these plots show the highest level recorded in each model grid cell over the entire 15 day cycle and are hence a worse case image. They do not represent simultaneous snap shots and therefore should not be interpreted against the WQO as the SS elevations in one grid cell (ie area) will occur during a different day/hour than in another grid cell.

Construction Sequencing

The water quality modelling results for the TSHD and grab dredging has indicated that the works can proceed in either dry or wet season without there being appreciably different levels of impact. From a marine ecological perspective it is noted that the density of sightings of marine mammals in the Northwest and West Lantau do not appreciably differ between seasons in the year (see *Annex 9 – Figure 9.4*). However, it has been noted that research on the Indo-Pacific Humpback Dolphin has indicated, based on stranding information, that in these two areas although calving occurs throughout the year the peak period would appear to be between March and August with the highest frequency in May and June (1).

The *EIAO-TM* specifies the priorities for addressing ecological impacts is avoidance and minimization. This philosophy was referred to in designing the marine works construction programme. There was a consensus among the leading local marine mammal specialists (Würsig, Jefferson, Hung pers comm.) that reducing the overall duration of marine works is the most effective approach to reduce impacts on marine mammals.

The marine mammal assessment (*Section 9.7*) has indicated that there is little risk of the gas pipeline installation works causing either physical harm or water quality related impacts to dolphin mothers and their calves and hence no apparent technical basis to avoid the March through August peak calving period. However, the submarine gas pipeline programme was reviewed and it became apparent that the dredging works for the submarine gas pipeline could be scheduled to take place during the period September through February in West and Northwest Lantau. Consequently, the preferred programme for the Project has adopted this scheduling measure.

The other issue concerning the sequencing of works is whether they would be scheduled to take place over 24 hours or just during daylight hours. Grab dredging works in Hong Kong typically take place during daylight hours and the same approach will be adopted for this project in West and Northwest Lantau. TSHDs usually would operate round the clock as they are not available in Hong Kong and have to be brought in from overseas so they therefore try to maximise production rates over each day. For this project the schedule for dredging works in West and Northwest Lantau can accommodate daylight hour dredging and hence this measure will be adopted. Because of marine traffic constraints, grab dredgers may need to operate 24 hours on the pipeline section which crosses the Urmston Road channel off Black Point enabling completion in the shortest possible time.

It is important to note that adoption of the above two measures in Northwest and West Lantau (ie 12 hour dredging during daylight hours and dredging

(1) Jefferson, T. A. (ed.). 2005. Monitoring of Indo-Pacific humpback dolphins (*Sousa chinensis*) in Hong Kong waters – data analysis: final report. Unpublished report submitted to the Hong Kong Agriculture, Fisheries and Conservation Department

only during September though February) is for dredging only. In order to achieve the master construction programme for the South Soko option all other activities associated with the pipeline installation, ie pipelaying and the placement of armour rock protection will operate over 24 hour periods and throughout the year. Neither of these works activities cause adverse impacts to the marine environment as discussed in *Section 3.3.4*.

2.3 CONSIDERATION OF PIPELINE ALIGNMENT

This *Section* of the EIA for the proposed LNG terminal at South Soko Island describes the criteria that have been used for establishing the routing of the gas pipeline connection to Black Point. As specified in the EIA Study Brief (*No. ESB-126/2005, Clause 3.3.6*), the EIA shall explore different pipeline options including underground pipeline option. Construction options for the submarine pipeline have been discussed in *Section 2.2* above. The Study Area for the routing exercise covers western Hong Kong, including Lantau Island.

2.3.1 *Connection to the Existing Yacheng Pipeline*

Connecting to the existing Yacheng Pipeline is one of the alternatives that has been examined for the LNG supply from South Soko to Black Point. The gas pipeline route would depart South Soko Island via the Sai Wan launching point and head generally west, crossing the HKSAR boundary to the north of Guishan Dao and passing to the north of Niutao Dao and Qing Zhou. The route would continue in a WNW direction, intersecting the Yacheng Pipeline in an area north of the Qing Zhou Traffic Separation Scheme. The total length of the submarine connection would be approximately 22 km and is displayed in *Figure 2.7* below.

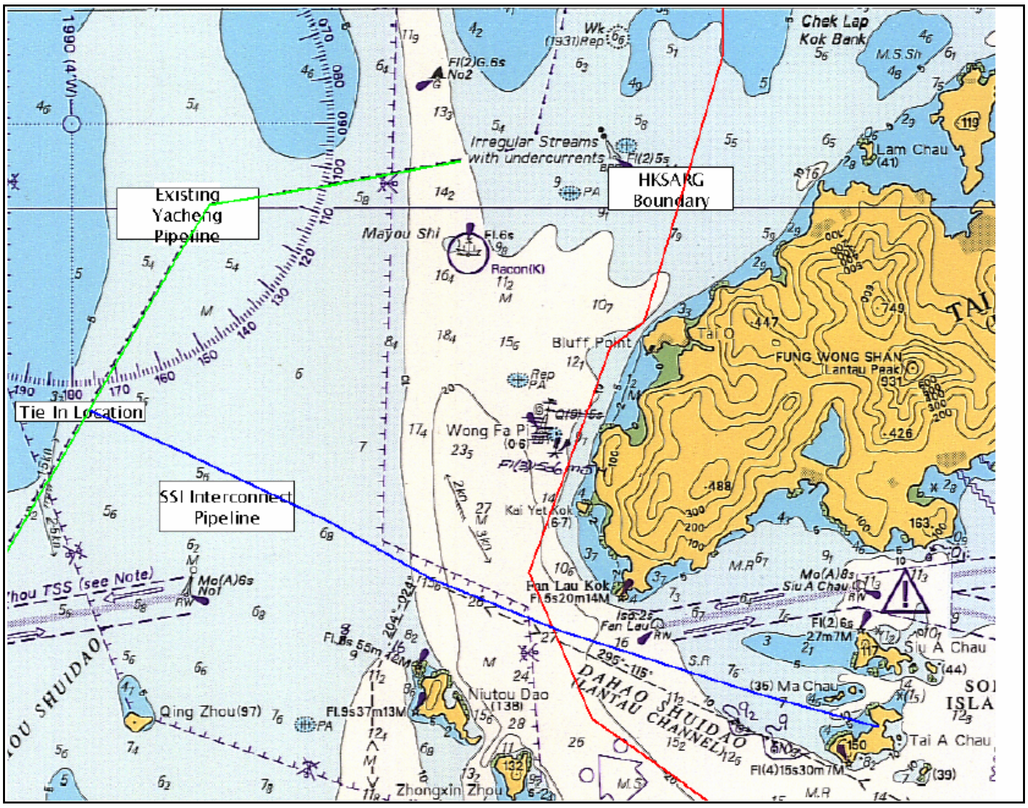


Figure 2.7 *Connection to the Existing Yacheng Pipeline*

This route was considered as a technically possible option; however, several associated issues make it impractical in terms of the overall project objectives which are detailed below [(1)] .

Technical Approach

It would be possible to install a connection to the existing 28" Yacheng pipeline that supplies natural gas to BPPS, using currently available technology.

A simple hot-tap would be insufficient because it would be necessary to install a check valve preventing gas from flowing back towards the Yacheng production facilities. Accordingly, the line would need to be cut and a piping assembly that incorporates a check valve (or non-return valve) would have to be installed. To achieve this, the following activities would need to be undertaken:

- The pipeline does not belong to CAPCO and therefore a commercial agreement would have to be reached with the pipeline owner (CNOOC/BP/Kufpec) enabling the modifications to the pipeline and its ongoing use by CAPCO to transport regasified LNG.

(1) Aker Kvaerner Yacheng Connection Study for CAPCO. 2006

- Implementing the modifications would entail significant engineering and advance planning culminating in the following actions:

  - Design, procure and construct an insert assembly comprising a tee piece with associated isolation and check valves. These items will be special designs suited to subsea service.

  - Plan an outage of BPPS enabling the shut down of the Yacheng pipeline and evacuation of gas enabling safe working whilst installing the insert assembly.

  - Detailed planning of the construction work using above-water methods. It is considered that whilst underwater methods are available for pipeline intervention work, the water depth and visibility conditions in the PRD would make such methods impractical.

  - Locate and expose the Yacheng pipeline at the chosen site (a recent survey confirmed that the pipeline is buried along the entire Pearl River Delta section) using suction dredging methods. A long length of the pipeline would need to be exposed to provide sufficient "slack" enabling lifting the line to the surface to facilitate performance of the work above water. Comprehensive marine traffic control measures would have to be adopted for the duration of the work for safety of the worksite and passing vessels.

  - The pipeline would be cut in two places and the prefabricated, pre-tested assembly welded in. The tie-in welds would be subject to rigorous non-destructive testing ensuring they are free from defects. At this stage a "stub" would be provided for later connection of the LNG line.

  - The assembly would then be coated with anti-corrosion material, compatible with the existing pipeline protection system and lowered to the seabed.

  - The pipeline, complete with the new assembly, would be jetted into the seabed, achieving the same depth of cover as previously.

  - The LNG pipeline would be laid and tied-in to the subsea assembly and commissioned.

  - Gas supply could be resumed.

- Consideration could be given to performing the intervention work subsea; however, the conditions are estimated to be even more difficult using that approach, including a complete lack of visibility, as shown by recent survey work in the area.

Important Considerations and Constraints

Whilst the above concept is technically possible, there are a number of constraints that would have a significant impact on CAPCO's ability to supply power from BPPS:

1) BPPS Fuel Shutdown

It is estimated that the work would involve a shutdown of the gas supply to BPPS of approximately two months. During that time BPPS would not be able to sustain operations even on liquid fuel, because the liquid fuel supply system was not designed to cater for an extended outage. The current practical limit of operation on liquid fuel is estimated to be in the order of 6 – 7 days and a significant cost impact would occur as a result of the higher cost of liquid fuel. Arrangements could be made to increase the capability of BPPS to burn liquid fuel over an extended period. Issues that would require resolution include:

- Increasing the liquid fuel import capacity to enable replenishment of the tanks at BPPS meeting the fuel demand of the generation units burning liquid fuel on a continuous basis. The existing fuel unloading berth at BPPS would need to be dredged and enlarged to cater for larger fuel barges/tankers and the existing fuel unloading system would have to be modified to increase the delivery and offloading capacity.

- Increasing the demineralised water treatment capacity enabling the use of liquid fuel on a continuous basis while meeting emissions standards. The use of LSIDO in the BPPS generator units requires a 1:1 ratio of demineralised water to fuel to keep NOX emissions at an acceptable level. Arrangements would have to be made with WSD to increase the water supply to BPPS and the existing demineralization facilities would need to be expanded.

Both of these actions would require considerable lead time and require a significant capital investment to implement.

2) Yacheng Supply Shutdown

Shutting down the Yacheng supply would have a significant impact on the production facilities owned and operated by CNOOC/BP/Kufpec, and a new commercial arrangement would be necessary covering the situation.

3) Wastage of Gas

Depressurizing and evacuating the Yacheng pipeline would result in a significant wastage of gas by venting to atmosphere or flaring. The quantity would be equivalent to several days' supply to BPPS and it would be necessary because whilst much of the inventory in the pipeline could be used to fuel the power station in the initial phase of depressurization, ultimately the line pressure would fall below the practical minimum required to supply the power station (2,800 kPa or 400 psi) and therefore the remaining gas would need to be vented to a low pressure vent/flare.

4) Gas Characteristics

BPPS gas turbines have been engineered specifically to burn Y13 gas (Modified Wobbe index = 43+/-5%) with a narrow range of variation of gas composition. The existing combustors cannot burn regasified LNG (Wobbe index = 51 +/- 5%) directly or any mixture of Y13/LNG without modification because combustion characteristics of LNG differ from those of Y13 gas significantly. The simple mixing of the two gases will result in unstable combustion performance and frequent tripping of generator units therefore replacement combustors will be required. A phased transition is planned to convert generating units one or two at a time from Y13 gas fuel to LNG fuel as the Y13 gas supply is depleted. Use of the Yacheng pipeline to deliver LNG gas to BPPS would necessitate conversion of all units at once and prevent the further use of Yacheng gas. Again, there is no provision for this in the existing gas supply contract and a variation would need to be negotiated with the suppliers.

5) Generator Unit Conversion

The replacement of combustors of all Black Point units will require advance planning and require a shutdown of several months. This could be performed in parallel with the required modification to the Yacheng pipeline; however, CAPCO would be required to burn an increased amount of coal at CPPS to satisfy power demand over that period. An alternative approach would be to convert units one at a time whilst keeping BPPS operational on liquid fuel, however, this would carry a significant cost penalty as a result of the higher cost of liquid fuel. There are also limitations as to how much liquid fuel can be burned over a period of time due to supply constraints as discussed above.

6) High Risk Operation

The work required to modify the Yacheng pipeline constitutes a major intervention that carries a very high risk of unforeseen events occurring. The exercise would be very complex and there are many factors that could give rise to in an extended shutdown greatly in excess of that planned for the work. This would leave BPPS without a viable fuel supply for a long period of time and carry commercial, environmental and social impacts including:

- the requirement to burn more coal at CPPS satisfying the demand for power,
- contractual impacts related to postponing the supply of LNG pending the ability to transport gas to BPPS,
- liability for any damage to the Yacheng pipeline,

- standing down the operations workforce at BPPS for an extended period.

7) Multiple Jurisdictions

It is anticipated that constructing the BPPS supply pipeline across the HKSAR border would necessitate a complex approvals process that could impose significant schedule risk on the project.

Accordingly this option was excluded from the detailed assessment.

2.3.2 *Routes within Hong Kong*

Although the routing corridors have been broadly defined (see *Figure 2.8*), the environmental and physical constraints within, and in proximity to, the corridors have been reviewed to further define the pipeline routes.

2.3.3 *Route Selection Criteria*

As part of the route selection exercise, environmental, physical and risk constraints within the three corridors were reviewed to determine the most appropriate pipeline corridor and landing areas where environmental impacts can be managed and mitigated.

Environmental Issues

Areas of known environmental importance that have been identified during the route selection process. Although not possible to avoid all environmentally important areas the design process has sought to reduce impacts to the extent practicable. The environmentally important areas and issues for the pipeline routing are illustrated in *Figures 2.9& 2.10* and discussed in *Table 2.19*.

Table 2.19 Environmental Issues

Issues	Notes
Land Based	
• Sites of Special Scientific Interest (SSSIs)	There are several SSSIs located within the Study Area which have been designated for a variety of reasons. Some of the SSSIs support important vegetation population, eg No 32 Ma Cheung Po and No 61 San Chau on Lantau island, whereas others have been designated for the wildlife, eg No 38 Lung Kwu Chau, Tree island, Sha Chau for bird and No 62 Ngong Ping for Romers' Tree Frog.
• Designated Country Parks	There are two Country Parks at North and South Lantau and one proposed Country Park Extension at North Lantau in the Study Area, both of them abut the coastline. Country Parks are gazetted for conservation, recreation and educational purposes and are under the control of the Country and Marine Parks Authority (CMPA).

Issues	Notes
• Coastal Protection Areas/ Conservation Areas/Green Belt	The Planning Department has designated several areas as Coastal Protection Areas (CPA) and Conservation Areas (CA) on the Outline Zoning Plans for specific locations within the Study Area.
• Land sites of cultural heritage (declared monuments and archaeological sites)	There are declared monuments located throughout the Study Area. Consultation should be initiated if necessary with the Antiquities & Monuments Office of the Leisure & Cultural Services Department.
Marine Based	
• Marine Parks	There is one designated Marine Park at Sha Chau and Lung Kwu Chau and two proposed Marine Park at Fan Lau and Soko in the Study Area. Marine Parks are gazetted for conservation, recreation and educational purposes and are under the control of the Country and Marine Parks Authority (CMPA).
• Potential Marine Parks	There are two potential marine parks in the Study Area at Fan Lau and around the Soko Islands. Neither of these parks has statutory status.
• Fish Culture Zones	There is one small Fish Culture Zone within the Study Area, which is located at Cheung Sha Wan. Impacts to FCZs are controlled by the *Water Pollution Control Ordinance* and the *Marine Fish Culture Ordinance*. Developments within 500m of an FCZ are subject to claims for *ex gratia* allowances. FCZs can be regarded as water quality sensitive receivers.
• Seawater intake points	Seawater intake points are located at Tuen Mun (WSD Intake), Airport, the Black Point Power Station and the Castle Peak Power Station. Intakes have their own water quality standards that have to be met during construction.
• Gazetted bathing beaches	There are several gazetted bathing beaches in South Lantau and near Tuen Mun.
• Sites of Special Scientific Interest (SSSIs)	There are two marine SSSIs located within the Study Area which have been designated for ecological reasons. The SSSI at San Tau Beach (No 58) was established because of the seagrass bed, whereas Tai Ho stream (No 63) was established because of the natural stream, seagrass and mangrove stands at the southern end of Tai Ho Wan.
• Gazetted artificial reef deployment sites	Artificial reefs (ARs) have been deployed in the Sha Chau and Lung Kwu Chau Marine Parks and Airport. ARs are deployed to enhance fisheries and marine ecological resources and are under the jurisdiction of AFCD.
• Spawning ground of commercial fisheries resources	Spawning ground of commercial fisheries resources is located in the North Lantau Waters.
• Nursery area of commercial fisheries resources	Nursery area of commercial fisheries resources is located in the Southern Hong Kong Waters covering a large area.
• Seagrass	Seagrasses are located mainly in San Tau, Tai Ho Bay, Yam O and Deep Bay.

Issues	Notes
• Mangrove	Mangrove stands are located mainly in sheltered bays, i.e., Tung Chung, Tai Ho Bay, Tai O, Yam O and Deep Bay.
• Intertidal mudflat	Intertidal mudflats are located mainly in sheltered bays, i.e., Tung Chung, Tai Ho Bay, Tai O, Yam O and Deep Bay.
• Horseshoe crab breeding habitat	Horseshoe crabs are known to breed within the Study Area.
• Marine mammal habitats	There are two resident species of cetacean in Hong Kong's waters, the Finless Porpoise and the Indo-Pacific Humpback Dolphin. The Finless Porpoise only occurs in the southern and eastern waters of Hong Kong. The Indo-Pacific Humpback Dolphin can be observed mainly in the western waters of Hong Kong. The sighting density of both dolphin and porpoise with corrected survey effort per km^2 is presented in *Figure 2.10*. The highest marine mammal sightings are recorded in West Lantau.

2.3.4 *Physical Constraints*

The physical constraints that were considered during the route selection included those shown in *Figure 2.11* and discussed in *Table 2.20.*

Table 2.20 *Physical Constraints*

Constraints	Notes
Land	
• Areas of steep topography/ hillslopes	Avoidance of such geographical features is recommended in order to limit the amount of slope cutting required and to limit the risks of boulder falls or landslides damaging the pipelines.
• Areas requiring multiple bends/ curves	From engineering perspective, planning a pipeline with a minimum number of bends is preferable as it reduces the construction difficulties.
• Areas close to present or planned utilities that may require maintenance.	Utilities are present on land which may have to be avoided during the route planning. These include water pipes, electricity cables and gas pipelines.
• Reservoir	The Shek Pik Reservoir is considered to be a constraint to the pipeline and Water Supplies Department (WSD) are the lead authority for the reservoir.
• Shek Pik Prison	The Shek Pik Prison is considered to be a constraint to the pipeline.
• Shek Pik Fault, Sha Lo Wan Fault and Sham Wat Fault	Seven geological faults cross the proposed tunnel alignment. Major faults include Shek Pik Fault, Sha Lo Wan Fault and Sham Wat Fault. The nature of each fault is uncertain and requires geological site investigation.
• Habitation	Populated areas may have to be avoided to the extent

Constraints	Notes
	practical during the route planning.
Marine	
• Designated areas of marine dredging and mud disposal	Although there are no active dredging areas within the Study Area there are several mud disposal sites located in North Lantau, including the new contaminated mud pits at the east and north of the Hong Kong International Airport, which should be avoided to limit disturbance to the disposed dredged muds. West Soko marine sand borrow area is located to the west of the North Soko Island. South Cheung Chau Disposal area is located to the east of the South Soko Island.
• Restricted areas	There are three types of restricted areas in Hong Kong waters, based on restrictions in vessel air-draught. These areas should be avoided.
• Existing and proposed anchorage	An Immigration Anchorage (IA) is located close to Tuen Mun. The IA should be avoided due to the potential for damage to the pipelines. If the IA cannot be avoided then pipeline protection measures will be required.
• Heavily trafficked marine vessel fairways	The South Lantau Channel is a busy fairway mainly used by smaller cargo vessels to and from the southwest and the high speed ferries to and from Macau. If the fairway cannot be avoided, then pipeline protection measures will be required.
• Zhujiang Estuary Vessel Routing System (Trial)	The Zhujiang Estuary Vessel Routing System (Trial) is located in the southwest of Hong Kong Waters and may have to be avoided during the route planning.
• Potential bridge/ highway development	The potential Northshore Lantau Highway Corridor and Hong Kong-Zhuhai-Macau Bridge may have to be avoided during the route planning. Where crossings are necessary, these are preferably conducted at right angles to limit the chances of disturbance to the potential bridge/ highway development.
• Areas of current, future or proposed reclamation	There are several areas that are proposed to be reclaimed at North Lantau, including proposed Logistics Park and Container Terminal 10. This area should be avoided where possible. If these possible development areas cannot be avoided then robust pipeline protection measures will be required.
• Typhoon shelters	The Tuen Mun Typhoon Shelters should be avoided because these are anchorage areas.
• Utilities (cables, pipelines and outfalls)	Utilities may have to be avoided during the route planning. These include water pipes, electricity cables and gas pipelines. Where crossings are necessary, these are preferably conducted at right angles to limit the chances of disturbance to the existing utility.

In addition, general risk constraints were also identified along the route corridors to reduce the potential risk to the public during the operation of the pipeline. The potential risk constraints that were considered during the route corridor selection process include the following:

- the general avoidance of populated areas;
- the avoidance, where practical, of areas that were considered to have a high degree of risk associated with their activities (e.g. anchorage areas, major fairways); and
- the selection of the most direct route between the two sites, to reduce the length of pipeline required.

A summary map illustrating all of the environmental issues and physical constraints is presented in *Figure 2.12*. The map also illustrates the four options highlighted for examination following the review of potential constraints.

2.3.5 *Routes Selected for Review*

Base Case Marine Route (Entirely Offshore Route Passing West of Lantau)

The Base Case route departs South Soko Island and heads generally west, turning north to stay within the HKSAR boundary. The route follows the boundary (nominally 100 - 200 m to the east) passing to the west of the proposed Marine Park at the western extremity of Lantau Island, at Fan Lau, the potential port development area, across the planned route of the Hong Kong – Zhuhai – Macau Bridge and between the HKSAR waters boundary and the western boundary of the Sha Chau and Lung Kwu Chau Marine Park. The route then curves to the east, maintaining a nominal 100 m clearance south, of the existing Yacheng pipeline and lands at Black Point Power Station in the vicinity of the existing gas receiving station. The total length of the route is approximately 38 km.

Option 1 (Route Crossing Lantau Island Overland to the West)

The *Option 1* (A and B) pipeline route begins at the PIG launching facility at the LNG terminal on South Soko Island with an offshore section from the western side of South Soko Island to a landfall on west Lantau Island in the vicinity of Tai Long Wan. From Tai Long Wan the route generally parallels the existing steep narrow Keung Shan mountain road until a fork. *Option 1A* turns to the west and on to the Tai O Road and *Option 1B* proceeds from the fork directly north to Sham Wat Wan. Then before reaching the coast, the pipeline route proceeds east outside the Country Park boundary until it reaches Sham Wat Wan (*Option 1B* joins here) where it crosses the shore northward and skirts the western side of the Sha Chau and Lung Kwu Chau Marine Park generally following (within) the HKSAR boundary. The route approaches the existing Yacheng pipeline, turning east to land at a shore crossing within the existing gas receiving station at Black Point. The length of the marine based segment for *Option 1* is approximately 29 km and the land based segment for *Options 1A* and *1B* are approximately 10 km and 7 km respectively.

Option 2 (Route Crossing Lantau Island Through a Tunnel)

The South Soko Island onshore portion and the marine portions of *Option 2* route are the same as for *Option 1*. However, the Lantau onshore portion of the route is replaced by a straight tunnelled crossing between the two landfalls at Tai Long Wan and Tit Tak Shue (Sham Wat Wan) with potentially an intermediate access at Keung Shan. As for *Option 1*, the length of the marine based segment for *Option 2* is approximately 29 km and the land based segment (mainly tunnel with diameter of approximately 3.5 m) for *Option 2* is approximately 6 km.

Option 3 (Route Crossing Lantau Island Overland to the East)

The proposed *Option 3* pipeline route with an overland crossing of Lantau Island features an offshore section departing South Soko Island on the eastern side and passing east of North Soko to a landing point in the vicinity of upper Cheung Sha Beach. The route then generally follows Tung Chung Road north through the South Lantau and North Lantau Country Parks and across the Lantau Expressway (North Lantau Highway) to a shore (near Tai Ho) crossing point east of Tung Chung new town and Hong Kong International Airport (HKIA). The final offshore portion would be required to avoid the airport exclusion zone and follow the Urmston Road, crossing a sewerage line and past Castle Peak Power Station to Black Point Power Station. It is possible that this route would have to cross pipelines/cables servicing HKIA and seven cables at South Lantau waters. The total length of the route is approximately 41 km comprising about 29 km marine based segment and about 12 km land based segment.

The options as identified above are further reviewed in terms of their potential for environmental and risk impacts in *Sections 2.3.4* and *2.3.5*.

2.3.6 *Environmental Review of Route Options*

This section provides a preliminary review of the environmental impacts associated with each option. A description of the potential impacts associated with each option has been provided in the following sections and classified in accordance with the above categories.

Land Use Constraints

Base Case (Entirely Offshore Route Passing West of Lantau)

There is no land use constraint as the route is entirely offshore passing to the west of Lantau. The project would be subject to the *EIAO*, and an EP would be required prior to construction. Furthermore, the project would be subject to the *Foreshore and Seabed (Reclamations) Ordinance (Cap 127) (FSRO)* and would require approval from the Director of Lands for the gazettal of the affected area of the seabed in which the pipeline is to be installed.

Option 1 - Route Crossing Lantau Island Overland to the West

The *Option 1* (A and B) pipeline route begins at the PIG launching facility at the LNG terminal on South Soko Island with an offshore section from the western side of South Soko Island to a landfall on west Lantau Island in the vicinity of Tai Long Wan. From Tai Long Wan the route generally parallels the existing steep narrow Keung Shan mountain road until a fork. *Option 1A* turns to the west and on to the Tai O Road and *Option 1B* proceeds from the fork directly north to Sham Wat Wan. Then before reaching the coast, the pipeline route proceeds east outside the Country Park boundary until it reaches Sham Wat Wan (*Option 1B* joins here) where it crosses the shore northward and skirts the western side of the Sha Chau and Lung Kwu Chau Marine Park generally following (within) the HKSAR boundary. The route approaches the existing Yacheng pipeline, turning east to land at a shore crossing within the existing gas receiving station at Black Point.

The segment of the pipeline that traverses from Tai Long Wan Tsuen to Sham Wat, *Option 1A* would pass through areas designated by the Town Planning Board (TPB) as "Green Belt" (GB) and "Site of Special Scientific Interest" (SSSI) and the Country and Marine Park Board as "Country Park" (CP), while *Option 1B* would pass through areas designated by the Town Planning Board (TPB) as "Green Belt" (GB) and the Country and Marine Park Board as "Country Park" (CP), shown in *Figures 2.13 & 2.14*. The land use planning designations have been assigned to these areas for multiple purposes, amongst which include retaining their existing natural character and to provide a high degree of protection based on their conservation value.

The project would be subject to the *EIAO*, and an EP would be required prior to construction. Further, the project would be subject to the *Foreshore and Seabed (Reclamations) Ordinance (Cap 127) (FSRO)* and would require approval from the Director of Lands for the gazettal of the affected area of the seabed in which the pipelines are to be installed. Prior to development within these areas, permission for the routing of the pipelines would need to be obtained in advance from the Country and Marine Parks Authority (CMPA), under the *Country Parks Ordinance*, and from the TPB under the *Town Planning Ordinance*. In addition, approvals from relevant government departments (i.e., Highway Department and Lands Department) should also be obtained for the road sections.

Option 2 - Route Crossing Lantau Island Through a Tunnel

Option 2 has similar routing as *Option 1* except that the segment between Shek Pik and Tit Tak Shue (Sham Wat Wan) uses a tunnel.

The option would be subject to the EIAO, and an EP would be required prior to construction. Furthermore, the project would be subject to the *Foreshore and*

Seabed (Reclamations) Ordinance (Cap 127) (FSRO) and would require approval from the Director of Lands for the gazettal of the affected area of the seabed in which the pipelines are to be installed and reclamation required for access for portal construction and spoil handling during tunnel excavation.

For the land based portion of the project, similar approvals would be required those specified above for Option 1. In order to investigate the geological conditions and rockhead levels along the proposed tunnel alignment (the proximity and quantities of the existing geotechnical information available are considered insufficient), site-specific ground investigation will be required. Prior to the ground investigations within Country Park, permission would need to be obtained in advance from the Country and Marine Parks Authority (CMPA), under the *Country Parks Ordinance*.

In addition to the land right required for a potential intermediate access, the subsurface rights may also need to be obtained from the owners of each of the lots that are affected by the tunnel. Given the density of lots within the Keung Shan area stakeholder issues would need to be resolved before land applications could be processed. In addition, approvals from relevant government departments (i.e., Highways Department and Lands Department) should also be obtained for the intermediate shaft as well as approvals for access and associated road strengthening or extension.

Planning approvals will be required at both of the landing points. The landfall at Tai Long Wan will require a Section 16 application as the land is zoned as Green Belt. The northern landing point is not within an area controlled by a town plan but is potentially within an SSSI, depending on the final alignment, and this would require clearance from Planning Department.

Option 3 - Route Crossing Lantau Island Overland to the East

Similar approvals would be required for *Option 3* as described for the land based segment of *Option 1*.

The segment of the pipeline that traverses from Cheung Sha to Tai Ho would pass through areas designated by the Town Planning Board (TPB) as "Green Belt" (GB) and "Coastal Protection Area" (CA) and the Country and Marine Park Board as "Country Park" (CP), as shown on *Figure 2.13 & 2.14*. The land use planning designations have been assigned to these areas for multiple purposes, amongst which include retaining their existing natural character and for providing a high degree of protection based on their conservation value.

Option 3 would cross a number of submarine utilities (more than 10 cables and a pipeline), consents from each utility owner would be required before Lands Department can gazette the submarine route.

Water Quality Impacts

Base Case (Entirely Offshore Route Passing West of Lantau)

The proposed route for the submarine pipelines would pass through the Southern Water Control Zone (WCZ), the Second Southern Supplementary WCZ, the North Western WCZ, the North Western Supplementary WCZ and Deep Bay WCZ. In accordance with the *Water Pollution Control Ordinance (WPCO)*, the project would be required to comply with the Water Quality Objectives for this area and all discharges during the project implementation and operation phases would be required to comply with the *Technical Memorandum for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters (TM) issued under Section 21 of the WPCO,* which defines acceptable discharge limits for different receiving waters.

The Southern Hong Kong Waters are influenced by the semi diurnal tidal regime of the South China Sea and dominated by the freshwater flows of the Pearl River Delta, particularly during the wet season. The riverine influence is generally stronger in the western and northern parts of the southern waters.

In the North Western part of Hong Kong marine waters at the mouth of the Pearl River Estuary are heavily influenced by the freshwater flows from the hinterland. The estuarine influence is especially pronounced in the wet summer months when the freshwater flows are greatest and strong salinity and temperature stratification is prominent. During winter months water conditions are more typically marine (with lower nutrient levels and higher DO levels) and salinity and other parameters vary less with depth. Ebb tide currents are towards the southeast where the flood tide currents move to the northwest. Current velocities in areas near to Sha Chau can reach up to 2.0 ms^{-1}.

In Deep Bay, the hydrodynamic regime of the Deep Bay area is unidirectional and the current direction reverses during ebb and flood tides. Tidal flow is dynamic and complex in the Deep Bay areas due to the seasonal influx of freshwater from the Pearl River to the Urmston Road. The water quality of Deep Bay is poor in general, characterised by high organic and inorganic pollutants and low dissolved oxygen levels.

For those areas in which the pipeline is to be laid into a pre-dredged trench, during the dredging process, some quantity of the sediment removed from the sea bed would be lost to suspension and would be dispersed through tidal currents. For the section of the pipeline that would be installed by jetting, a fluidised mixture of water and sediment would be formed close to the sea bed and dispersed by tidal currents. Although, the suspended sediments are expected to settle rapidly, there is the potential for impacts to occur to nearby sensitive ecological receivers as a result of elevated suspended solids.

The water quality sensitive receivers identified along the proposed pipeline route include: water intake at Black Point Power Station, Artificial Reefs at Sha

Chau and Lung Kwu Chau Marine Park, fisheries spawning and nursery areas and other areas of ecological interest (including the Sha Chau and Lung Kwu Chau Marine Park, proposed Fan Lau Marine Park, proposed Soko Islands Marine Park, Finless Porpoise and Indo-Pacific Humpback Dolphin habitats, intertidal mudflat, seagrass, mangrove and horseshoe crab breeding habitat). The pipeline corridor has been defined to avoid these areas, where practical.

As such, it is expected that the potential impacts to water quality could be controlled through measures such as defining equipment requirements (requiring the use of watertight grabs, bottom sealed barges, etc) and through programme modification (controlling the dredging and jetting rates). The need for such measures would be determined by detailed computer modelling of water quality. It is believed that with the implementation of the necessary mitigation measures, impacts to water quality can be controlled to within acceptable levels. Successful examples of gas pipeline installation in Hong Kong include the recently installed gas pipelines for Hongkong Electric and Towngas, both of these pipelines have been installed in areas of high ecological value.

Option 1 - Route Crossing Lantau Island Overland to the West

For the marine based aspects of *Option 1*, the proposed route for the submarine pipelines, similar to the *Base Case*, would pass through the designated Southern, North Western and Deep Bay WCZs and compliance with the same regulations would be required.

The water quality sensitive receivers identified along the proposed pipeline route include: water intake at Black Point Power Station, Artificial Reefs at Sha Chau and Lung Kwu Chau Marine Park, fisheries spawning and nursery areas and other areas of ecological value (including the Sha Chau and Lung Kwu Chau Marine Park, Finless Porpoise and Indo-Pacific Humpback Dolphin habitats, intertidal mudflat, seagrass, mangrove and horseshoe crab breeding habitat). The pipeline corridor has been defined to avoid these areas to the extent practical.

Similar to the *Base Case*, it is expected that the potential impacts to water quality could be controlled through measures and through programme modification. However, the major difference from the *Base Case* is that there would be two additional landing/ launching points. Additional measures may be required to control the water quality impacts due to the construction works at the landing/ launching points at Lantau. The need for such measures would be determined by detailed computer modelling of water quality.

For the land based segment of *Option 1*, it is expected that extensive slope cutting and stabilisation will be required along the roads (Keung Shan Road and Tai O Road for *Option 1A*, and Keung Shan Road and Sham Wat Road for *Option 1B*), in particular the segment at the northern end (between Hang Mei and Sai Tso Wan for *Option 1A*, and along Sham Wat Wan for *Option 1B*) due to the narrow, torturous and steep gradient nature of the roads. Before the pipeline installation, the existing roads may require considerable upgrading to enable pipeline transport and stringing.

Water quality impacts may occur during construction works as a result of runoff and drainage containing increased loads of suspended solids and other contaminants (such as oil and chemical waste from heavy machinery and cement derived materials used for road pavement). The runoff may result in physical effects including the blockage of drainage channels, increased suspended solids concentrations in receiving waters and accretion of suspended solids with high pH from cement derived materials in the catchwaters and Shek Pik Reservoir. Potential biological effects may also occur from these activities which may affect aquatic life within the receiving water courses, in particular Sham Wat Stream and Tai O Stream.

It is expected that with good site management, runoff may be controlled from entering the surrounding waters. The types of measures that may be required to reduce the impacts include: containment of stockpiled materials, proper collection of spent cement mix or other paving materials, undertaking extensive slope cutting work outside the wet season as well as other measures to prevent runoff from occurring. Because of the marine and aquatic potential water quality issues, *Options 1A* and *1B* may require extensive mitigation measures (i.e., taking extensive land within the Country Parks for site runoff treatment and slope stabilisation to prevent erosion or slope slippage) to reduce impacts to an acceptable level and may result in residual impacts, even with the implementation of mitigation measures.

Option 2 - Route Crossing Lantau Island Through a Tunnel

The marine based segment of *Option 2* shares largely the same routing as *Option 1*, and therefore the water quality issues would be the same for both of the *Options 1* and *2*.

During the construction stage, temporary reclaimed platforms would need to be formed along the shoreline of each of the portal locations (ie at Sham Wat Wan and Tai Long Wan to provide sufficient working area for machine launching, spoil handling, stockpiling, barging, loading of tunnel segments, allocation of the blast doors and noise barriers (for drill and blast method only) and settlement treatment/treatment tanks for water discharge (*Figures 2.15 & 2.16*) [1]. The required reclamation areas at each of the selected portal locations (either end of the tunnel) are expected to be approximately 15,000 m^2 each (100 m wide x 150 m long). The reclamations would be formed within shallow water typically less than 2 m depth, which will not permit the access of marine barges. Vertical seawalls would therefore be required along the farthest edge of the reclamation in conjunction with associated dredging works to form a channel with at least 3 m draft. Additional measures will

(1) Aker Kvaerner & ARUP 2006 Tunnel Reports to CAPCO

expect to be required to control the water quality impacts due to the dredging and reclamation works at the landing/ launching points at Lantau. The need for such measures would be determined by detailed computer modelling of water quality. Upon completion of the works the platforms would then be decommissioned and removed from the sites. Impacts of the decommissioning activities would need to be examined.

It is expected that the land-based segment of *Option 2* (through a tunnel), which avoids most of the sensitive receivers (including most of the catchwaters, Shek Pik Reservoir and Sham Wat Stream), has relatively lower water quality impacts compared with the land based segment of *Option 1*. However, in the event that the construction of the intermediate portal and access is required this may have potential impacts on the catchwaters and Tai O Stream, as well as the rural areas in Keung Shan (*Figure 2.17*). In addition, the ground investigations during detailed design stage may cause water quality and ecological impacts on the sensitive receivers (including catchwaters, Shek Pik Reservoir, Sham Wat Stream and Tai O Stream). At least 32 vertical land drillholes (with 13 located within Country Park), 15 inclined land drillholes (with 7 located within Country Park), 7 horizontal drillholes (with 2 located within Country Park) and 4 vertical marine drillholes will be required for the ground investigations. It is expected that similar measures as those described for *Option 1* could be adopted to control land-based water quality impacts to an acceptable level.

Option 3 - Route Crossing Lantau Island Overland to the East

For the marine based aspects of *Option 3*, the proposed route for the submarine pipelines, similar to *Option 1*, would pass through the designated Southern, North Western and Deep Bay WCZs. The water quality sensitive receivers identified along the proposed pipeline route include: water intakes (at Airport and along the southwest coastline of New Territories), Artificial Reefs at Sha Chau and Lung Kwu Chau Marine Park and Airport, fisheries spawning and nursery areas, gazetted bathing beaches in South Lantau and Tuen Mun and other areas of ecological value (including the Sha Chau and Lung Kwu Chau Marine Park, Finless Porpoise and Indo-Pacific Humpback Dolphin habitats, intertidal mudflat, seagrass, mangrove and horseshoe crab breeding habitat).

Similar to *Option 1*, it is expected that the potential impacts to water quality could be controlled through measures and through programme modification. The need for such measures would be determined by detailed computer modelling of water quality.

For the land based segment of *Option 3*, water quality impacts addressed in *Option 1* could be limited due to the potential reduction of slope cutting and stabilisation after the improvement of Tung Chung Road (currently the subject of improvement works) if the gas pipeline route can be followed with the alignment of the improved road. However, the ecologically sensitive Tung Chung and Cheung Sha Streams would still potentially be affected during the construction. In general, *Option 3* is expected to have higher impacts than those described above for *Option 1* (considering the longer length).

Ecological Impact

Base Case (Entirely Offshore Route Passing West of Lantau)

The marine ecological sensitive receivers in the area include:

- Numerous intertidal habitats in West Lantau including Yi O, Tai O, Sham Wat, San Tau and Tung Chung, in general, which have been reported as supporting intertidal mudflat, seagrass and mangrove;
- Horseshoe crab breeding ground reported along the north western coastline of Lantau Island from Yi O to Tung Chung;
- Finless Porpoise and Indo-Pacific Humpback Dolphin habitat;
- Sha Chau and Lung Kwu Chau Marine Park;
- Proposed Fan Lau Marine Park;
- Proposed Soko Islands Marine Park;
- Fisheries spawning and nursery areas; and
- Artificial Reef Deployment Areas at Sha Chau and Lung Kwu Chau Marine Park.

The marine ecological sensitive receivers for this option have been taken into consideration, to the extent practical, during the route selection process; therefore, direct disturbance to these areas would be either avoided or reduced. During the installation of the gas pipeline, short term elevations (in the order of hours or days) in suspended solids concentrations would occur as a result of dredging/jetting operations associated with the pipeline deployment. The suspended sediment generated during dredging will cause a short-term increase in turbidity in the water column and result in higher rates of deposition on the seabed. Such elevated suspended sediment levels may cause sediment deposition onto benthic organisms.

It is expected that water quality impacts can be controlled through standard measures (described above) which would in turn control impacts to ecological and fisheries resources. Marine ecological impacts are expected to be short-term in nature and mitigated through standard practices. Successful examples include the recently installed gas pipelines for Hongkong Electric (total length of 92 km, 20 inches diameter pipe) and Towngas (total length of 31.5 km, 18 inches diameter twin pipes), both of which have been installed in areas of high ecological value. The Hongkong Electric pipeline route passes through Finless Porpoise habitat (southern Lamma waters) and close to coral habitats (which are sensitive to elevated suspended solids and sediment deposition) in particular at Tung Ping Chau and Po Toi. As reported in the Monthly EM&A Reports, there was no Action/Limit Level exceedance recorded in the ecological sensitive receivers (Tung Ping Chau, southern Po Toi and Lamma) for all of the water quality parameters during the Hongkong Electric pipeline installation works (4th June to 19th July 2005) (1).

The Towngas pipeline route is located close to (most within 500 m) high ecological value sessile hard coral and black coral communities along the subtidal shores of Tolo Channel as well as proximal to the Marine Parks of Tung Ping Chau and Hoi Ha Wan. No exceedances of environmental performance limits (both water quality and coral criteria) attributable to the Towngas pipeline installation works were recorded (2). The Towngas pipeline environmental monitoring results over the period 1 April 2005 to 25 May 2006 indicated that the works did not cause any significant impacts on the water quality and marine ecology in the works areas.

Option 1 - Route Crossing Lantau Island Overland to the West

The marine ecological sensitive receivers in the area include:

- Intertidal habitats at Sham Wat which have been reported as supporting Intertidal mudflat, mangrove and horseshoe crab nursery ground;
- Horseshoe crab breeding ground reported along the coastline of Sham Wat;
- Finless Porpoise and Indo-Pacific Humpback Dolphin habitat;
- Sha Chau and Lung Kwu Chau Marine Park;
- Proposed Soko Islands Marine Park;
- Fisheries spawning and nursery areas; and
- Artificial Reef Deployment Areas at Sha Chau and Lung Kwu Chau Marine Park.

The sensitive areas of marine ecological value have been avoided, to the extent practical, during the route selection process. However, indirect impacts to marine ecology may occur, as described for the *Base Case*, due to impacts to water quality, in particular to the Sha Chau and Lung Kwu Chau Marine Park. Although sediment plume modelling would be required to more accurately predict potential impacts, it is expected that water quality impacts can be controlled through standard measures (see *Base Case*) which will in turn

(1) Cinotech Consultants Limited (2005) Lamma Power Station Extension – Supply and Installation of Submarine Gas Pipeline. Water Quality Monitoring During Post-trenching Works. Impact Monitoring Report (June & July 2005).

(2) Meinhardt Infrastructure and Environment Limited (2006) FEP-01B/167/2003/D Proposed Submarine Gas Pipeline from Cheng Tou Jiao Liquefied Natural Gas Receiving Terminal, Shenzhen to Tai Po Gas Production Plant, Hong Kong. Final EM&A Summary Report.

control impacts to ecology and fisheries resources. Therefore, impacts have been classified as moderate potential for the marine portion of this project.

The terrestrial ecological sensitive receivers along the land based segment of *Option 1* between Tai Long Wan Tsuen and Sham Wat Wan, include:

Option 1A

- South Lantau Country Park;
- North Lantau Country Park;
- San Chau SSSI (support the largest known population of *Rhododendron championae* in Hong Kong);
- Numerous stream courses segmenting the roadway; and
- Tai O Stream.

Option 1B

- South Lantau Country Park;
- North Lantau Country Park;
- Numerous stream courses segmenting the roadway; and
- Sham Wat Stream.

Except for the northern end of the land based segment (the segment between Hang Mei to Sai Tso Wan for *Option 1A* and the segment at Sham Wat Wan for *Option 1B*), most of the pipeline route runs along the existing roads with dense woodland situated on both sides. As the roads, as well as the proposed pipeline route, directly pass through or run along the Country Park, it is expected that direct impacts (including potentially extensive tree cutting and subsequent disturbance to wildlife would occur during construction. Due to the importance of this area for local flora and fauna, protection measures would be required as well as extensive mitigation measures for any areas directly affected.

For *Option 1A*, a significant amount of land may be disturbed during the installation of the pipelines between Hang Mei to Sai Tso Wan where only a narrow footpath exists. Land would also be required along the pipeline corridor (3m either side) to act as a reserve for maintenance access. Potential impacts may also result from development within the San Chau SSSI which may affect the population of *Rhododendron championae*, which is considered as one of the rarest native rhododendrons in Hong Kong. All wild rhododendrons are protected species in Hong Kong.

For *Option 1B*, the segment at the northern end of Lantau is situated on or next to the intertidal mudflat, mangrove and horseshoe crab nursery ground at Sham Wat Wan. Such habitats are considered to be of high ecological value (see *Figure 2.14*).

It is expected that any development situated along the proposed route (both *Options 1A* and *1B*) would require disturbance to the natural vegetation in the area which comprises mainly secondary woodland and shrubland which are classified as being of high and medium ecological value, respectively (see *Figure 2.14*).

Option 2 - Route Crossing Lantau Island Through a Tunnel

The marine based segment of *Option 2* shares the same routing as *Option 1*, but the temporary platforms that would need to be constructed (and later decommissioned) would directly disturb the natural shorelines (mainly rocky shore) at Tai Long Wan and Sham Wat Wan and soft-bottomed subtidal habitats at the portal areas (at least 100 m at either end of the tunnel). It is noted that the shallow subtidal habitat at the Sham Wat Wan portal is considered to be habitat and spawning grounds of the Horseshoe Crab. As a consequence, the marine ecological impacts of *Option 2* would be higher compared with the *Option 1*.

It is expected that the land based segment of *Option 2* (through a tunnel), which avoids most of the land-based sensitive receivers (including SSSI, Country Parks, Sham Wat Stream and Tai O Stream), has relatively lower ecological impacts compared with the land based segment of *Option 1* although in the event the intermediate portal and access is required this will have potential impacts on the rural habitats and associated wildlife in Keung Shan. In general, *Option 2* is expected to have less land-based ecological impacts when compared to those described for *Option 1*.

Option 3 - Route Crossing Lantau Island Overland to the East

The marine ecological sensitive receivers in the area include:

- Numerous intertidal habitats in South and North Lantau including Shui Hau, Cheung Sha, San Tau, Tung Chung and Tai Ho, in general, which have been reported as supporting sandy beach, intertidal mudflat, seagrass, mangrove and horseshoe crab nursery ground;
- Horseshoe crab breeding ground reported Tung Chung Bay and coastal areas near Tong Fuk;
- Finless Porpoise and Indo-Pacific Humpback Dolphin habitat;
- Sha Chau and Lung Kwu Chau Marine Park;
- Proposed Soko Islands Marine Park;

- Fisheries spawning and nursery areas; and
- Artificial Reef Deployment Areas Sha Chau and Lung Kwu Chau Marine Park and Airport.

The sensitive areas of ecological value have been avoided, to the extent practical, during the route selection process. However, indirect impacts to marine ecology have the potential to occur, as described for the *Base Case*, due to impacts to water quality. Although water quality modelling would be required to more accurately predict potential impacts, it is expected that such impacts can be controlled through standard measures (see *Base Case*) which will in turn control impacts to ecological and fisheries resources.

For the land based segment of *Option 3*, ecological impacts addressed in *Option 1* could be limited if the gas pipeline route can be followed with the alignment of the improved Tung Chung Road (currently under improvement). The extent of the slope cutting and stabilisation could be reduced if managed properly. However, the North Lantau and South Lantau Country Parks, woodlands located along the Tung Chung Road, Tai Ho and the ecologically sensitive Tung Chung Stream and Cheung Sha Stream and habitats for wildlife and plant species of conservation interest (including Hong Kong Newt *Paramesotriton hongkongensis,* Lesser Spiny Frog *Paa (Rana) exilispinosa*, Romer's Tree Frog *Philautus romeri*, Beijiang Thick-lipped Barb *Acrossocheilus beijiangensis*, the tree *Artocarpus hypargyreus*, the shrub *Pavetta hongkongensis,* the orchids *Liparis viridiflora* and *Acampe rigida*) are still potentially affected. In general, *Option 3* is expected to have similar impacts as those described above for *Option 1* and it is expected that similar measures as those described for *Option 1* could be adopted to control ecological impacts to acceptable levels.

Landscape/Visual Impacts

Base Case (Entirely Offshore Route Passing West of Lantau)

There are no expected landscape and visual impacts associated with the marine works for the implementation of the *Base Case*. The pig launching facility at the South Soko site and gas receiving station at Black Point are common to all options and so are not discussed here.

Option 1 - Route Crossing Lantau Island Overland to the West

There are no expected landscape and visual impacts associated with the marine works for the implementation of *Option 1*, aside from construction of landing sites, which are not considered to be of major significance.

The land based pipeline route from Tai Long Wan Tsuen to Sham Wat, is expected to be located within rural areas which, due to the topography of the area, would require extensive slope cutting and stabilisation works for installation. The pipeline would traverse either near or within areas designated on the *Outline Zoning Plan* as "Green Belt" (GB), "Site of Special Scientific Interest" (SSSI) and "Country Park" (CP) for *Option 1A* and "Green Belt" (GB) and "Country Park" (CP) for *Option 1B*. These areas are considered to be important in terms of their landscape value and visual amenity and are considered to be areas of high landscape and recreational value.

During installation of the pipelines, direct removal of vegetation is expected to be required which, due to the project requirements for a maintenance reserve area, will not be reinstated back to the original condition. Furthermore, depending upon the area selected, tree felling and vegetation removal may be required for slope cutting and stabilisation.

In order to develop within this area, prior approval would be required from the CMPA and TPB. The impacts associated with these works, particularly if undertaken within the North and South Country Parks, are considered to be significant.

Option 2 - Route Crossing Lantau Island Through a Tunnel

Similar to the case for Option 1, there are no expected landscape and visual impacts associated with the marine works for the implementation of Option 2, aside from the construction of a tunnel portal at both ends of the tunnel and the temporary reclaimed platform. The natural landscape would be modified due to the construction of the tunnel portals including slope cutting and stabilisation works. The visual impacts associated with the tunnel portals and the temporary reclaimed platforms (each of approximately 1.5 ha) at South and North of Lantau, as well as any required intermediate portal, are considered to be significant due to the close proximity to populated areas particularly at Tai Long Wan and Keung Shan.

During construction of the portals and associated access particularly in Keung Shan, direct removal of vegetation is expected to be required which will not be reinstated back to the original condition due to the requirement of provision of maintenance access. Furthermore, depending upon the area selected, tree felling and vegetation removal may be required for slope cutting and stabilisation. In addition, the land based construction works associated with *Option 2* would be similar to those identified at the southern end (near Tai Long Wan Tsuen and designated on the *Outline Zoning Plan* as "Green Belt" (GB)) for *Option 1*.

Option 3 - Route Crossing Lantau Island Overland to the East

There are no expected landscape and visual impacts associated with the marine works for the implementation of *Option 3*, aside from construction of landing sites, which are not considered to be of major significance.

The majority of the land based pipeline route from Cheung Sha to Tai Ho, is expected to be located within rural areas which, due to the topography of the area, may require extensive slope cutting and stabilisation works for installation (subject to the compatibility of the improved Tung Chung Road). The pipeline would traverse either near or within areas designated on the *Outline Zoning Plan* as "Green Belt" (GB), "Coastal Protection Area" (CPA) and "Country Park" (CP). These areas are considered to be important in terms of their landscape value and visual amenity and are considered to be areas of high landscape and recreational value.

During installation of the pipeline, direct removal of vegetation is expected to be required which, due to the project requirements for a maintenance reserve area, could not be reinstated back to the original condition. The extent of the impacts is subject to the final design. Furthermore, depending upon the area selected, tree felling and vegetation removal may be required for the slope cutting and stabilisation.

In order to develop within this area, prior approval would be required from the CMPA and TPB. The impacts associated with these works, particularly if undertaken within the North and South Lantau Country Parks, are considered to be significant.

Waste

Base Case (Entirely Offshore Route Passing West of Lantau)

Waste materials likely to be generated by the proposed option include dredged marine sediment, minor quantities of chemical waste generated from machinery, and minor quantities of solid waste from the construction workers.

Marine sediments will be required to be dredged to provide protection to the pipelines crossing the Urmston Road, Adamasta Channel and potentially on the western edge of the Port Development and eastern side of the Zhujiang Estuary Vessel Routing System. The sediments in this area are not expected to be contaminated but would require verification as part of the sediment classification scheme under *ETWBTC 34/2002; Management of Dredged/ Excavated Sediment*. Furthermore, sediments would be likely to be required to be dredged at the shore ends at Black Point and South Soko. The disposal of these sediments would be undertaken in accordance with the *ETWBTC*.

The impacts associated with dredging marine sediments are addressed in the water quality and ecology sections of this review. Potential impacts are expected to be controlled through standard mitigation measures.

Option 1 - Route Crossing Lantau Island Overland to the West

The potential waste impacts associated with the marine based work described for *Option 1* would be similar to those for the *Base Case*. However, it is expected that there would be a comparatively smaller amount of sediment that would be required to be dredged and disposed due to the shorter marine route.

Land based waste impacts would be limited to the construction phase of the project and are expected to be significant. Due to the nature of the terrain (steep) along the land based route, extensive slope cutting may be required and adequate temporary storage areas may not be permitted. As a consequence, most of the excavated material would not be used on site. It is expected that *Option 1A* would generate more excavated materials than *Option 1B* due to the longer land based route (approximately 3.2 km longer than *Option 1B*). Small amounts of construction and demolition waste would be produced from the projects, such as wood from form work, broken asphalt, equipment and vehicle maintenance parts and unusable surplus concrete grouting mixes. Chemical wastes would also be produced in small quantities from equipment maintenance and small quantities of solid waste would be generated by construction workers. It is expected that these waste materials can be controlled by the contractor through standard waste management procedures.

Option 2 - Route Crossing Lantau Island Through a Tunnel

The impacts associated with waste materials from marine based construction works are the same as those described for *Option 1* but additional dredging for the marine barge access for the spoil transport and equipment loading at the temporary reclaimed platforms would be required.

Depending on the design, Option 2 tunnelling, may generate large amounts of excavated materials that would necessitate disposal. Further to the preliminary estimation based on approximate 3.5 m excavated diameter, the total volume of the *in-situ* rock spoil to be excavated from the tunnel is approximately 75,000 m^3. All rock spoil from the tunnel would be temporarily stored in a muck bin on the Tai Long Wan reclamation and double handled onto a barge for periodic removal.

Option 3 - Route Crossing Lantau Island Overland to the East

The potential waste impacts associated with the marine based work described for *Option 3* would be similar for *Option 1*. However, it is expected that there would be a comparatively smaller amount of sediment that would be required to be dredged and disposed due to the shorter marine route due to avoidance of West Lantau, although there would be a number of utilities crossings required.

The impacts associated with waste material disposal from land based construction works are similar to those described for *Option 1* but with more excavated materials due to the longer length (approximately 12 km).

Noise/Air Quality Impacts

Base Case (Entirely Offshore Route Passing West of Lantau)

The noise sensitive receivers along the proposed marine route include Fan Lau Tsuen, Yi O San Tsuen, village/ residential houses in Tai O and Sham Shek Tsuen. The background noise levels in the area are considered to be generally low and are dominated by aircraft and road traffic at Tai O.

Based on the expected equipment requirements, noise levels are expected to comply with noise criteria as nearest sensitive receivers would be situated more than 200 m from the proposed pipeline route. Noise levels (induced only during construction) can be controlled by standard measures and do not impose major project constraints.

Air quality impacts are not expected to arise from the marine based portion of the pipeline during installation. The pig launching facility at the South Soko site and gas receiving station at Black Point are common to all options and so are not discussed here.

Option 1 - Route Crossing Lantau Island Overland to the West

Sensitive receivers located along the *Option 1* pipeline route include Tai Long San Tsuen, Sha Tsui Detention Centre, Shek Pik Prison, rural village developments along Keung Shan Road (Shek Pi Garden), rural village/ residential development areas along Tai O Road (San Tsuen, Lung Tin Estate, Tai O sheds and Hang Mei, only apply for *Option 1A*) and rural village developments at Sai Tso Wan and Sham Wat Wan. As standard measures are expected to be able to control noise to an acceptable level under the EIAO TM, impacts are not considered to be significant for the marine section.

For the land based segment, the potential for noise and dust impacts would be limited to the construction phase of the project.

Sensitive receivers are located along the *Option 1* pipeline route include Tai Long San Tsuen, Sha Tsui Detention Centre, Shek Pik Prison, rural village developments along Keung Shan Road (Shek Pi Garden), rural village/ residential development areas along Tai O Road (San Tsuen, Lung Tin Estate, Tai O sheds and Hang Mei, only apply for *Option 1A*) and rural village developments at Sai Tso Wan and Sham Wat Wan.

The background noise levels of areas along the route are generally low and will be limited to vehicles travelling along the local road system. Based on experience from similar projects, noise generated from powered mechanical equipment required for the installation of the pipelines and associated facilities (including: hand held breakers, excavators, generators, lorries, compactors, etc.) are the major noise sources affecting the sensitive receivers. It is expected that noise levels can be mitigated to within the *EIAO-TM* limit and in accordance with the *Technical Memorandum for the Assessment of Noise* *from Places Other Than Domestic Premises, Public Places or Construction Sites (IND-TM).*

The potential air quality impacts arising from the construction of the pipeline are related to dust nuisance from slope cutting and excavation activities. It is expected that these sources of nuisance can be controlled through measures stipulated in the *Air Pollution Control (Construction Dust) Regulations* employed in the worksite.

Option 2 - Route Crossing Lantau Island Through a Tunnel

The potential for air and noise impacts for both of the marine and land based segments would be the same as the *Option 1*, but with fewer sensitive receivers as the majority of the route is underground. Sensitive receivers include Tai Long San Tsuen, Sha Tsui Detention Centre, Shek Pik Prison and rural village developments at Sai Tso Wan and Sham Wat Wan. Standard measures are expected to be able to control noise and dust impacts to an acceptable level under the *EIAO TM*.

Option 3 - Route Crossing Lantau Island Overland to the East

The potential for air and noise impacts would be similar to those identified for the marine based aspects of *Base Case*. Sensitive receivers include Cheung Sha Ha Tsuen, Butterfly Crest, South Lantau Hospital and Pak Mong. Standard measures are expected to be able to control noise to an acceptable level under the *EIAO TM*.

For the land based segment, the potential for noise and dust impacts would be limited to the construction phase of the project. Noise and dust would be generated during the excavation of the trenches for the pipeline. Sensitive receivers are located along the pipeline route include Cheung Sha Ha Tsuen, Butterfly Crest, South Lantau Hospital, rural village developments along Tung Chung Road (Shek Mun Kap, Lung Tseng Tau and Wong Ka Wai), Tung Chung New Town (Yat Tung Estate, Fu Tung Estate, Caribbean Coast, etc) and Pak Mong.

The background noise levels of areas along the route are generally low (in South Lantau rural areas) to moderate (in highly developed areas, i.e., Tung Chung New Town) and are dominated by aircraft noise and road traffic. It is expected that the noise levels generated during the construction can be mitigated to within the *EIAO-TM* and in accordance with the *Technical Memorandum for the Assessment of Noise from Places Other Than Domestic Premises, Public Places or Construction Sites (IND-TM)*.

It is expected that dust nuisance can be controlled through measures stipulated in the *Air Pollution Control (Construction Dust) Regulations* being employed in the worksite.

Cultural Heritage

Base Case (Entirely Offshore Route Passing West of Lantau)

There are some shipwrecks of marine archaeological interest recorded in western Hong Kong waters (database maintained by the United Kingdom Hydrographic Office in Taunton). Geophysical surveys along the Base Case alignment identified six anomalies, which on further investigation, proved not to be of archaeological potential. Furthermore, there is a known archaeological site on land at South Soko (the landing site and the proposed PIG station location), though this has been disturbed in the past (due to the construction of the detention centre which has be demolished).

Option 1 - Route Crossing Lantau Island Overland to the West

As noted above, there are no shipwrecks of marine archaeological interest recorded in western Hong Kong waters. For both *Options 1A* and *1B*, the area of potential constraint to the project is the potential impact on a declared monument named Shek Pik Rock Carving, and three archaeological sites, comprising Tai Long Wan Archaeological Site, Sham Wat Archaeological Site and Nam Tin Archaeological Site. The project must avoid the impact to the Shek Pik Rock Carving. As the pipeline and associated development was located within Tai Long Wan Archaeological Site and Sham Wat Archaeological Site, archaeological survey would be required to obtain field data for subsequent impact assessment to evaluate the extent of impact and recommend appropriate mitigation measures to reduce the impact.

Option 2 - Route Crossing Lantau Island Through a Tunnel

As for *Option 2*, there are no shipwrecks of marine archaeological interest recorded in western Hong Kong waters. For this Option, the area of potential constraint to the project is the potential impact on a declared monument named Shek Pik Rock Carving, and three archaeological sites, comprising Tai Long Wan Archaeological Site, Sham Wat Archaeological Site and Nam Tin Archaeological Site. The project must avoid the impact to the Shek Pik Rock Carving. As the pipeline and associated development was located within Tai Long Wan Archaeological Site and Sham Wat Archaeological Site, archaeological survey would be required to obtain field data for subsequent impact assessment to evaluate the extent of impact and recommend appropriate mitigation measures to reduce the impact.

The access portal at Keung Shan would have to be constructed in a careful manner in order to avoid disturbances to the heritage sites in this area.

Option 3 - Route Crossing Lantau Island Overland to the East

Shipwrecks of marine archaeological interest recorded in western Hong Kong waters may be located close to the proposed pipeline route. There is one known area of archaeological significance (Tung Chung Fort) situated next to

Tung Chung Road. Protective measures would be required if the pipelines were located close to this area.

Summary/ Ranking of Potential Impacts

The potential impacts associated with each Option are summarised in *Table 2.21*.

Table 2.21 Summary of Potential Environmental Impacts

Issue Area	Impact Type	Base Case (Marine)	Option 1A & B (Marine + Road)	Option 2 (Marine + Tunnel)*	Option 3 (Marine + Road)
Water Quality	Short-term	Moderate/High	Moderate/High	Moderate/High	High
	Long-term	Negligible	Negligible	Moderate	Negligible
Terrestrial Ecology	Short-term	Negligible	High	Moderate/High	Moderate/ High or High
	Long-term	Negligible	Low/Moderate	Low	Low/Moderate
Marine Ecology	Short-term	Moderate/High	Moderate	Moderate/High	Moderate
	Long-term	Negligible	Negligible	Moderate	Negligible
Landscape/Visual	Short-term	Negligible	High	Moderate/High	High
	Long-term	Negligible	Low	Moderate/High	Low
Waste	Short-term	Moderate	Moderate/High	High	Moderate/High
	Long-term	Negligible	Negligible	Low	Negligible
Noise/Air Quality	Short-term	Low	Moderate	Low/Moderate	Moderate
	Long-term	Negligible	Negligible	Negligible	Negligible
Cultural Heritage	Short-term	Low	Moderate/High	Moderate/High	Low/Moderate
	Long-term	Negligible	Moderate	Moderate	Negligible

Notes: The categories of the severity of potential impact shown in the table above are defined as follows:

- *Negligible potential* = impacts not expected to occur.
- ***Low potential*** for adverse impacts and represents impacts that are not considered to be unacceptable without mitigation.
- ***Low/moderate potential*** for adverse impacts which can be mitigated through good working practices without residual impacts.
- ***Moderate potential*** for adverse impacts which are slightly greater than low/moderate impacts and can likely be mitigated through the application of standard measures and working practices.
- ***Moderate/high potential*** for adverse impacts which, although resulting in a greater impact than those of moderate potential, could still be mitigated through the application of mitigation measures.
- ***High potential*** for adverse impacts which would require extensive mitigation measures to reduce impacts to an acceptable level and may result in residual impacts, even with the implementation of mitigation measures.
- ***Long-term*** refers to an impact that may last for several months/years or is permanent – whereas ***short-term*** refers to impacts that are transient and are on the scale of weeks/months
- * higher rating would apply if the intermediate portal is required

On the basis of the environmental assessment for the construction and operation of the gas pipeline, the result of the route comparison is as follows:

- Preferred layout: Base Case (Marine)
- Second choice: Option 2 (Marine + Tunnel)
- Third choice: Option 3 (Marine + Road)
- Fourth choice: Option 1 A & B (Marine + Road)

The route crossing Lantau Island overland to the west, *Option 1A* and *1B*, and the route crossing Lantau Island overland to the east, *Option 3*, are the least preferred. Both options have greater potential for water quality, ecological and landscape impacts within the Country Parks (North Lantau and South Lantau) and along the roads in Lantau.

Option 2, the route crossing Lantau Island through a tunnel, would avoid most of the land based sensitive receivers but generate more waste materials. The portals would cause the permanent loss of natural habitats, long term landscape and visual impacts and potential impacts on the Tai Long Wan Archaeological Site and Sham Wat Archaeological Site. The construction of the pipeline section passing through the tunnel will have a longer duration, which has a greater potential to delay project completion. The dredging and reclamation due to the construction of the tunnel portals have greater water quality impacts, and therefore additional measures (determined by detailed computer modelling of water quality) will expect to be required to control the impacts. In addition, the ground investigations for the tunnel option during detailed design stage may cause water quality and ecological impacts on the sensitive receivers (including catchwaters, Shek Pik Reservoir, Sham Wat Stream and Tai O Stream).

With consideration of the programme and scale of the *Base Case* submarine pipeline, as well as the previous similar pipeline installation works in Hong Kong (ie Hongkong Electric and Towngas pipelines), water quality and marine ecological impacts are expected to be short-term in nature and mitigated through standard practices. A discussion on the acceptability of ecological impacts with reference to previous pipeline installation projects in Hong Kong is given in *Section 9.7.1*. No long term and operation impacts would be expected. The pipeline installation works within the dolphin habitats in West Lantau will use jetting method to avoid dredging and reduce the water quality impacts, and the construction period for such section are predicted to last for not more than 2 months. The *Base Case* is preferred as it also avoids impacts to land based sensitive receivers (i.e., Country Parks) and the potential terrestrial ecological impacts and other environmental impacts (i.e., noise, air, cultural heritage, waste, landscape and visual impacts).

The preferred route is, therefore, the *Base Case* from the perspective of overall environmental impacts and impact duration.

2.3.7 *Preliminary Risk Review*

Risk Constraints

This *Section* provides a qualitative review of the potential risks associated with each option and identifies the preferred option which would result in the least risk to the public.

Land Based Risk

As part of the pipeline system a Pipeline Inspection Gauge (PIG) launching/receiving facility and a Gas Receiving Station (GRS) are also proposed to be developed. A buffer area would be required around these components of the project and the potential risks associated with their operation are considered to be localised to within the required separation distance and would need to meet the relevant standards imposed by the *GSO*. Therefore, the risks associated with this aspect of the project are considered to be common for all options.

For gas pipelines installed on land, there are two constraining requirements listed in the *Hong Kong Planning Standards and Guidelines (HKPSG), Chapter 7, Section 3.3.4.* These are:

- a restriction on development within 3 m of high pressure pipelines; and
- a requirement to perform a Hazard Assessment for gas works to ensure that risks to the public are limited.

Thus, a major constraint on the routing of the pipelines relate to the required compliance with the Hong Kong Risk Guidelines (HKRG).

Based on an analysis of the consequences of a pipeline release using standard correlations for various releases [(1)] [(2)],pipelines should typically maintain a distance of more than 125 m from developments, to the extent practical.

Pipeline Tunnel Option

Option 2 involves laying a 30" gas pipeline at about 100 barg in a tunnel about 6 km long beneath the Lantau hills. This tunnel option presents construction safety, operational and maintenance challenges. Maintenance and repair of the pipeline as well as maintenance of the tunnel could also pose significant constraints. Provision of leak detection and ventilation systems, employment

(1) Chamberlain (July 1987) Developments in Design Methods for Predicting Thermal Radiation from Flares Chem Eng Res Des Volume 65

(2) CCPS (1994) Guidelines for Evaluating the Characteristics of Vapour Cloud Explosions, Flash Fires and BLEVEs

of equipment of electrical classification requirement and external pipe corrosion protection will be required. During operation, confined space entry and ventilation would also be required. Considering other factors such as maintenance and repair constraints, the tunnel option is less preferable than other options.

Land Based Option

Option 3 involves traversing the island. Locating the pipeline above land or buried on land introduces potential fire and explosion hazards. The hazard to life aspects of this option make it less preferable.

Marine Based Risks

The route selection should seek to avoid passing through the Immigration Anchorage and other anchorage areas, where practicable.

Hazard to Life due to Pipeline Failure

A review of shipping traffic information demonstrates that there is less population on the sea as compared with on the land (*Table 2.22*). In terms of the location of the pipelines for the *Base Case* the pipeline would be laid in the sea bed and thus avoid areas of high population.

Table 2.22 Estimated Population Density - Marine Vessels / Land

Type	**Density**	**Length of Segment (km)**				
	(Population per m²)	**Base Case**	**Option 1A**	**Option 1B**	**Option 2**	**Option 3**
Rural population	0.005	0	10	7	6	10
Urban population	0.01	0	0	0	0	2
Shipping population						
High	$1.2x10^{-7}$	6.4	6	6	6	5
Moderate	$1.\ 2x10^{-8}$	13	11	11	11	17
Low	$4x10^{-9}$	19.5	12	12	12	7

On the basis of the hazard to life due to pipeline failure, the result of the route comparison is as follows:

- Preferred layout: Base Case (Marine)
- Second choice: Option 2 (Marine + Tunnel)
- Third choice: Option 1 A & B (Marine + Road)
- Fourth choice: Option 3 (Marine + Road)

It can be concluded, therefore, that *Option 3* would be the least preferable, as it is largely land based. It should also be noted that, as discussed above, the tunnel option (*Option 2*) is considered less preferable. Therefore the *Base Case* is considered to be the preferred option.

2.3.8 *Technical Considerations concerning the Tunnel and the Marine Route*

The information above concerning environmental and safety issues has indicated that the marine route and the tunnel routes have advantages over the on land routes across Lantau. As described above the marine route is considered to have environmental and safety advantages over the tunnel route and is preferred by CAPCO. The marine route has significant advantages over the tunnel route, many of which are related to engineering complexity, planning, schedule and air emission benefits.

Despite the above, the Study Brief in clause 2.1 (v) indicates that alternatives should be examined with a view to avoiding and minimising the potential impacts on marine waters and ecologically sensitive areas. The following presents information as to why the tunnel is not a practical or reasonable alternative to avoiding potential impacts to the western Lantau area of dolphin habitat.

Design Considerations

- In order to investigate the geological conditions in more detail specific site investigation would need to be carried out. At least 32 vertical, 15 inclined and 7 horizontal drillholes would need to be carried out. *In-situ* tests, including standard Penetration Testing, falling head permeability tests, water adsorption, impression packer survey, acoustic borehole televiewer survey and chemical tests for groundwater samples as well as laboratory tests for each of the drill holes would have to be carried out. Part of the site investigation works would need to be carried out in the Lantau North and Lantau South Country Parks to allow for a full interpretation of the geological conditions along the proposed tunnel alignment. It is expected that difficulty will be encountered with the permit applications due to environmental concerns and regulations. There is no existing access to the proposed site investigation stations, which will necessitate access by helicopter. Several of the proposed boreholes will be in the range of 200-300m deep. To locate the drill rods and related plant, site areas of approximately 10m x 10m will be required for each site investigation station, which will present a significant constraints to these operations within a protected country park area.

- In order to access the site and commence preliminary excavation working platforms, formed through reclamation, would be required. The reclaimed platforms would occupy around 1.5 ha each. Alternative piled structures would have a more adverse environmental impact and floating platforms would not be able to withstand the weight of a Tunnel Boring Machine. Each reclamation would be formed in an area of natural coastline and some dredging would be required to access the site.

Planning Considerations

- Liaison will be required with Highways Department concerning the potential alignment and landing point facilities for the Hong Kong Zhuhai Macau Bridge.

- At the Shek Pik end the tunnel runs underneath the catchment area of the Shek Pik Reservoir and hence water drawdown will be an issue requiring careful consideration and detailed discussions with Water Supplies Department.

- There remain planning uncertainties if a tunnel option is to be adopted. Planning approvals for the Southern Portal are not believed to impact the critical path of the project as it is to be constructed within the existing South Lantau Coast OZP. Uncertainties relate to approvals for the Northern Portal, the Intermediate Ventilation Shaft Building (if adopted) and a permanent pier. Both the Northern Portal and Ventilation Shaft Building are significant structures of size 50m wide x 20m high x 20m deep and 15m wide x 10m high x 15m deep respectively. The Northern pier would be some 3m wide x 50 m long to cater for the limited depth of the existing approach. To date it is still not clear whether an OZP would or would not be required.

Construction Issues

- As noted above working platforms would be required to provide access to the Tunnel Boring Machine (TBM). The TBM would operate 24 hours per day and would require a power supply. During construction 11kV power supply would be from Tai Long Wan supplied via OHL lines. During the operational phase dual 132kV supply from both ends would be required. These could be supplied via overhead lines or submarine cables.

- Analysis of geological maps obtained from the GEO indicates that at least 7 geological faults cross the proposed tunnel alignment. Extended weakness zones with highly to completely decomposed materials, shear planes with soft clay infill and high water seepage could be anticipated as the tunnel excavation approaches any fault zone. Soft ground tunnelling techniques could need to be adopted when excavating through these fault zones. The tunnel option adopts a construction methodology which safety statistics and the insurance market confirm as having a high risk. The impact of a tunnel fire due to the limited egress points for line workers would be severe.

- Some 75,000 m^3 of *in situ* excavated rock material would have to be disposed off site. Although not a huge quantity by itself the number of projects presently in the inception stage means that this could be a major logistical issue. Unfortunately the excavated tunnel material could not be used as backfill material for the reclamation, as the reclamation has to be constructed first to allow access to commence tunnel construction.

Operation and Maintenance Issues

- The tunnel after it is completed is classified as a confined space. Safety mitigation measures need to be taken to regularly purge the tunnel of gases before workers go into the tunnel.

- In the permanent condition ventilation fans would need to be adopted. Large fans housed in a ventilation building would be required as up to 3 air changes an hour are required to initially purge the tunnel of gases. Such fans have a noise impact even though dampers will have to be used.

- Diesel, grease, oils and chemicals (e.g. admixtures) would need to be stored on each of the sites. All of these items need to adopt the use of drip trays and in the case of chemicals, self closing enclosures in the case of fire. There is also the issue of disposal of chemical waste, sewage and general refuse.

Schedule Issues

The installation works for the submarine pipeline are scheduled to take place over 3-5 months in the West Lantau area (which is the key area avoided by the tunnel option). It is to be noted that these works are undertaken in sequences (pre-trenching, pipelay and backfilling) and in specific areas at a time. The tunnel option would, however, take around 49 months to construct. A breakdown of the key schedule differentiators is presented in *Table 2.23*.

Table 2.23 Key Schedule Differentiators: Marine vs Tunnel

	Marine Route	**Tunnel**
Temporary reclamations	n/a	5 months
Portal construction	n/a	5 months
Tunnel Boring machine setup	n/a	2 months
Tunnel Excavation	n/a	22 months
Tunnel E&M Fitout	n/a	6 months
Onshore Pipeline Installation	n/a	2 months
Jetting	28 - 48 days (not on critical path)	n/a
- Lay pipeline (W. Lantau/Tunnel Section)	8 - 16 days (not on critical path)	n/a
- Rock dumping	40 days	n/a
Hydrotesting and pre-commissioning	(included in overall)	2 months
Tie-in to offshore pipeline	n/a	1 month
Remove Reclamation Platforms	n/a	3 months
BD Occupation Permit	(included in overall)	1 month
Total Lantau Area Construction	**3 – 5 months**	**49 months**
Total Delay in First Gas	**0 months**	**15 to 26 months**

Implications for Meeting Government Policy on Air Emissions

The LNG project schedule delays presented above that would arise with the tunnel option of 15 to 26 months would have a significant impacts on air emissions and CAPCO's ability to comply with the Government's policy on emission reductions. With the tunnel option additional use of coal will be required through the startup of the LNG terminal and the incremental emission of pollutants will total over 100,000 tons as shown in *Table 2.24* below.

Table 2.24 Incremental emission of pollutants as a result of a delay in first gas

Pollutant (Kilotonnes - KT)	18 Months	24 Months
Total Suspended Particulates	2.34	3.1
Sulphur Dioxide	46.5	59.0
Nitrogen Oxides	29.5	38.9
Total	**78.3**	**100.0**

A summary of the key differentiators between these options is presented in *Table 2.25*. It is clear from the table that in terms of meetings the need for this project, ie a replacement gas source for Black Point Power Station that allows CAPCO to meet the Government's emission objectives, the tunnel option is not a reasonable or practical alternative to the marine option via West Lantau.

Table 2.25 Summary of Key Differentiators between the Tunnel and Marine Option

Issue	Marine Route	Tunnel Route
Construction Safety/Risk	Lower Risk Construction Methodology	Higher Risk Construction Methodology
Operational Safety	Protected to reduce risk of damage/leak	Gas detectors present in tunnel. Tunnel in both construction and operation modes is classified as a confined space
Cost	No Impact	Increases Overall Pipeline cost by ~ 30% (HK$0.5 billion)
Duration of West Lantau Occupation	3 – 5 months	49 months
Impact on LNG Delivery Schedule	First gas in 4Q 2011	Overall Schedule Impact of 15 – 26 months assuming no complications in EIA, town planning procedures or FSRO gazettal
Community Position	Concerns regarding the pipeline routing have been focused on marine	Potential for additional objections from local communities and Green

Issue	Marine Route	Tunnel Route
	issues	Groups due to disturbances to remote sections of Lantau Island and Country Parks
Environment	• No reclamations • No areas of natural coastline related to the marine option • Two dredged approaches • No impacts to land based sensitive receivers	• Two reclamations (3 ha) • Two areas of natural coastline loss • Four dredged approaches • Additional land based construction impacts on air, noise, landscape, visual, terrestrial ecology and heritage sensitive receivers • Tunnel excavation creates an additional spoil handling and disposal issues ~ 75,000m^3 • 18 months delay causes an increase of SOX emissions of 46 KT and NOX emissions of 29 KT • 24 month delay causes an increase of SOX emissions of 59 KT and NOX emissions of 39 KT • 2010 Emissions targets cannot be met

2.3.9 *Summary*

The tunnel option is a more uncertain undertaking resulting in a minimum delay to the LNG Receiving facility of 15 - 26 months and an additional cost of HK$0.5 billion. There are significant uncertainties *inter alia* unexpected ground conditions, planning issues, community issues related to private lots and potential extra EIA studies which could increase the delay further. The conclusion is that when compared to the pipeline option, the tunnel (and other land based options) are not practicable alternatives when the risks and schedule uncertainties are all considered.

Considering the environmental constraints and safety issues, as well as the physical constraints, presented in the discussions above it is concluded that the Marine Route remains the preferred gas pipeline route option. From a scheduling aspect the marine route can be installed without resulting in delays in commissioning of the LNG terminal whereas the other options will lie on the critical path and introduce significant delays to project start-up. The schedule delays brought about by the non-marine option will mean that CAPCO cannot meet the Government's 2010 emission initiatives.

2.4 CONSIDERATION OF POWER AND WATER SUPPLY

Power and water supplies are required for the routine operation of the LNG terminal. Historically, one submarine cable and one water main connected South Soko Island to South Lantau, via Shek Pik, providing power and water to the Detention Centre. The capacity of decommissioned cable system is insufficient to meet the electricity demand for the LNG Terminal during construction and operation. Due to poor condition, the cable system must be replaced. New power cables would therefore be required to be installed for the South Soko LNG terminal.

The conditions of the existing water main are unknown. In order to determine the integrity of the pipeline a number of detailed tests would be required which would take time and may prove the lack of integrity of the water main. It is also of note that ownership of the water main remains unclear. For the purposes of this EIA, it is therefore considered that in order to examine the potential worst case scenario, the installation of a new water main will be investigated.

The purpose of this section is to present the considerations of alternative routes for the power cables and water main. The assessment has been conducted to investigate not only the environmental considerations of each route, but to include an examination of potential engineering aspects. The assessment thus considers both the difficulties of the construction and operation of each route as well as the potential environmental impacts.

2.4.1 *Route Options*

The basic requirements of a LNG receiving terminal in Hong Kong have been described in detail in *Part 1 – Section 3*. Justifications for South Soko Island being considered as one of two sites for a LNG receiving terminal in Hong Kong have been presented in *Part 1 – Section 4*.

On the basis of the requirements, both a reliable power and water supply must be provided to the proposed terminal. Due to the island location of the potential South Soko terminal there are a number of potential routes that the necessary power cables and water main may traverse (*Figure 2.18*). Typical Sections through the submarine water main and power line are shown in *Figures 2.19* and *2.20*.

2.4.2 *Power and Water Supply Route Selection Process*

Selecting the Launching Site

The selection of launching site was based on avoidance to the extent practical of the following considerations (*Figure 2.21*):

- Gazetted bathing beaches;
- Country Park;

- Coastal Protection Areas and Green Belt;
- Locations with conservation interest;
- Archaeological Site; and,
- Selecting technically feasible areas (i.e., soft muds) to limit the construction difficulties.

Marine Route Planning Consideration

There are some existing physical constraints to the proposed cable and water main route, which have confined the alignment of the cable (*Figure 2.21*). As it is allowed to lay submarine utilities within the gazetted marine borrow area, the Soko Marine Borrow Area is not considered to be a constraint for the routing. The following constraints have, however, been taken into consideration:

- Minimising crossing or encroaching on the existing submarine cable or water main to South Soko, thereby ensuring that cable laying operations do not cause any disturbance to the existing utility systems should they still be viable for future use;
- Avoiding locations with high ecological interest, high dolphin and porpoise sighting density in South Lantau waters;
- Avoiding the existing sand deposit area as it would pose installation difficulties; and,
- Avoiding shallow sediment areas or areas with rock outcrops to facilitate burial requirements.

In addition to the avoidance of the aforementioned constraints, the following considerations have also been taken into account:

- For simultaneous cable burial/laying operation it is necessary to avoid sharp bends of the cable alignment and try to ensure that the power and water pipe routes are as straight as possible; and,
- To provide the shortest interface with the major marine vessel fairway (South Lantau Channel), the existing water main and cable and seawalls, keep the cable circuit/ water pipe crossing the fairway, utilities and seawalls perpendicular as far as possible.

Preferred Route for the Power Cable and Water Main

With consideration of the route selection process as discussed above, *Option 1* is the preferred route for the power cable and water main (nearly parallel to each other). *Option 1* has the shortest route and avoids most of the major elements including the Country Park, Green Belt, existing sand deposit area locations of high dolphin and porpoise sighting density.

2.5 *SELECTION OF PREFERRED SCENARIO*

The preferred scenario/alternative to be taken forward to the EIA stage at South Soko is Layout Option 3D, the Base Case submarine gas pipeline alignment and Option 1 for the proposed power cable and water main. Full details of the components of the preferred scenario are detailed in *Part 2-Section 3* of this EIA report.

The selection of the preferred scenario has brought about a series of environmental and engineering benefits to the Project as presented in *Figures 2.22* to *2.25*. These benefits have arisen through modifications to the engineering layout stimulated by issues raised during consultations with stakeholders in Government, District Councils, Rural Committees, NGOs and the Advisory Council on the Environment, as well as through engineering optimisation.

One of the main environmental outcomes of this process was the orientation of the LNG jetty to the southeast of South Soko Island has brought about a significant reduction in dredging volumes from approximately 4 Mm^3 to approximately 1.07 Mm^3.

Following discussions with NGO groups and feedback from various Government departments concerning findings of the Marine Ecology baseline surveys presented in *Annex 9*, CAPCO has re-examined the layout of the site to determine whether the amount of reclamation can be reduced further in the eastern bay of Tung Wan. The purpose of the reduction in reclamation is to reduce the disturbance to the marine habitats in Tung Wan and in particular the habitat of amphioxus (*Branchiostoma belcheri*). The layout review concluded the following:

- By removing the jetty in Tung Wan marine vessels during construction and operation of the terminal will need to access the site in Sai Wan during periods of adverse weather. This will result in reduction in dredging in Tung Wan but a slight increase in dredging in Sai Wan to allow for access by construction barges. Overall though there is a net decrease in dredging of 60,000 m^3.

- The northern coastline in Tung Wan will not require reclamation by relocating the Control Room, Maintenance Workshop and Administration building to the southern side of the terminal. The relocation will result in a reduction in coastline loss but moving the process areas will necessitate additional excavation into the hillside. The excavation works are not expected to cause unacceptable impacts to terrestrial ecology as they will take place in areas of low to moderate ecological value shrubland. No rare or protected fauna or flora have been recorded in this area.

- The changes above will necessitate, in order to comply with the safety codes for the terminal design a minor relocation of facilities within the existing footprint of the site. No significant changes in environmental (eg air, noise, waste, landscape visual) or risk issues are expected from these modifications.

- The net reduction in reclamation arising from the above changes is 1.1 ha resulting in a overall reclamation area of 0.6 ha.

- The net reduction in natural coastline loss is 150 m resulting in a overall loss of natural coastline of 300 m.

The above changes have resulted in a reduction in ecological, fisheries and water quality impacts through reduction in reclamation, dredging and natural coastline loss. The reduction in dredging will also have a benefit in reducing off site impacts during disposal of dredged muds and ease the burden on existing disposal sites.

- Improvement in visual impacts through relocation of LNG tanks to the western side of the Island and behind prominent topographical features.

Further details are presented on *Figures* 2.22 to 2.25.

Figure 2.22 Design Adopted in Pre-EIA Studies

	Design Adopted in Pre-EIA Studies
Details	The layout initially studied included approximately 13 ha of reclamation to accommodate the LNG terminal facilities. Total dredging volumes exceeded 4 Mm^3.
Layout	
Issues	Field work conducted on the island revealed the generally low ecological value of the terrestrial habitats. Consequently members of the ESMG and various NGOs questioned whether less reclamation could be involved and more land on the island utilised.

Figure 2.23 Design Presented in the Project Profile

	Design Presented in the Project Profile
Details	A modified layout was presented in the Project Profile which reduced reclamation (< 5 ha) and utilised more land of the Island.
Layout	
Issues	The Study Brief identified the need to avoid permanent impacts to habitats in between the North and South Soko Islands. NGOs and ACE members questioned whether the LNG jetty could be located in the deeper waters to the south of the island to reduce dredging and avoid the waters between the North and South Soko Islands.

Figure 2.24 Scenario Design at the commencement of the EIA

	Scenario Design at the commencement of the EIA
Details	During the early stages of this EIA, as described in the sections above the CAPCO team has examined various layouts taking into account: • Issues raised during consultations with ACE, Rural Committees, District Councils, NGOs, Fishermen, LegCo members; • Ongoing process, civil and marine engineering reviews; and, • Updated findings of environmental baseline surveys. The outcome of this work was the production of a layout as presented below for examination during the EIA.
Layout	
Benefits	The resultant layout has a reduction in reclamation to approximately 1.7 ha in Sai Wan and Tung Wan. The relocation of jetty to southeast has meant that dredging volumes are reduced to approximately 1.4 Mm^3 at the terminal. These changes have brought about an overall reduction in water quality, ecological, fisheries and waste impacts. The positioning of the tanks has resulted in an improvement in visual impacts.

Figure 2.25 Preferred Scenario Design Finalised as part of this EIA

	Preferred Scenario Design Assessed in this EIA
Details	During the later stages of the EIA, as described in the sections above the CAPCO team has examined various layouts taking into account: • Ongoing process, civil and marine engineering reviews; and, • Updated findings of environmental baseline surveys including the identification of the presence of Amphioxus in Tung Wan. The outcome of this work has been the production of preferred layout as presented below.
Layout	
Benefits	The resultant layout has a reduction in reclamation to approximately 0.6 ha in Sai Wan and no reclamation in Tung Wan. The new layout serves to reduce the magnitude of impacts on the coastal resources of South Soko Island.

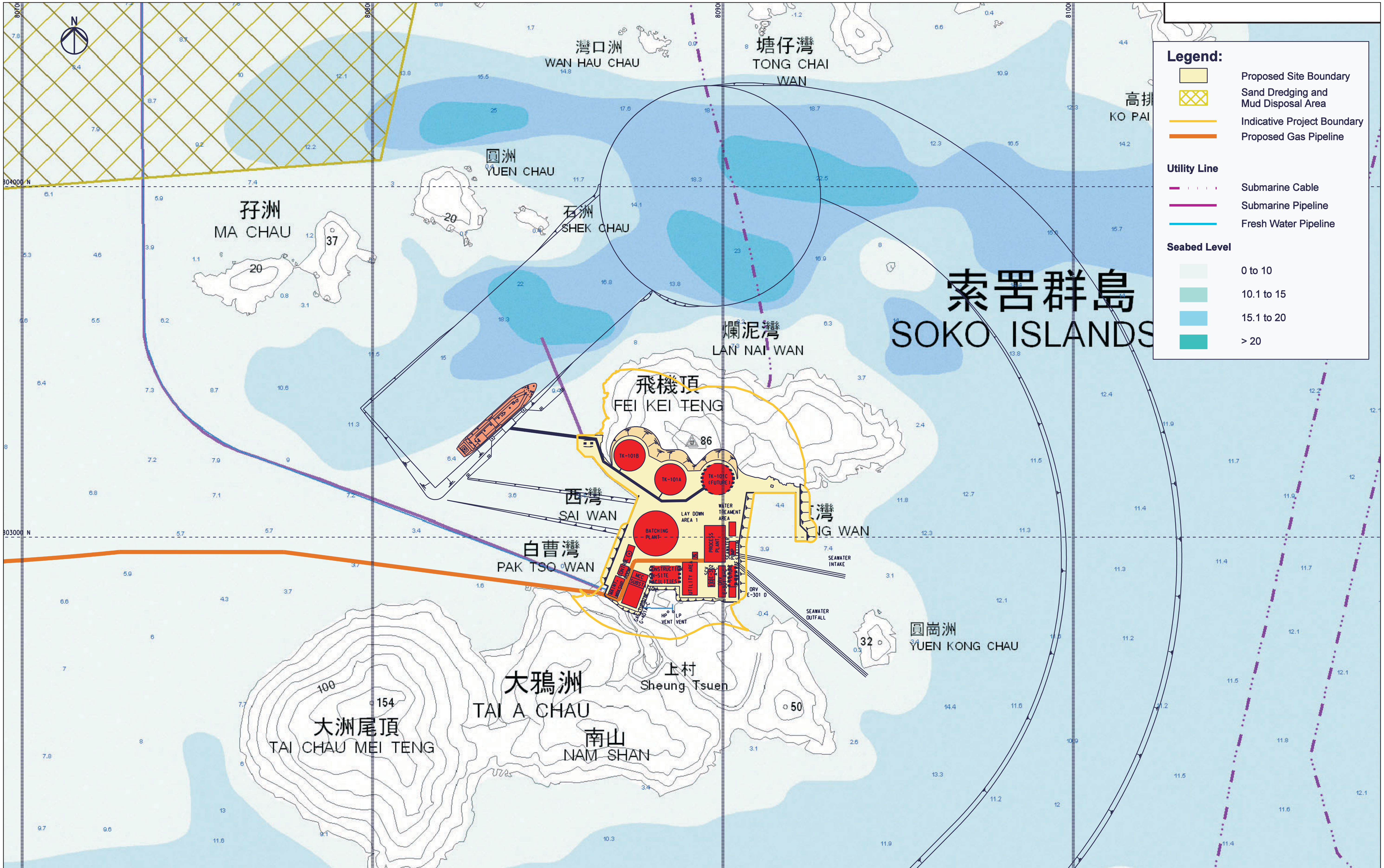


Figure 2.1

South Soko Island
(Option 1 - Base Case)

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24443_SSSK001-C3_Fig 2.1.pdf
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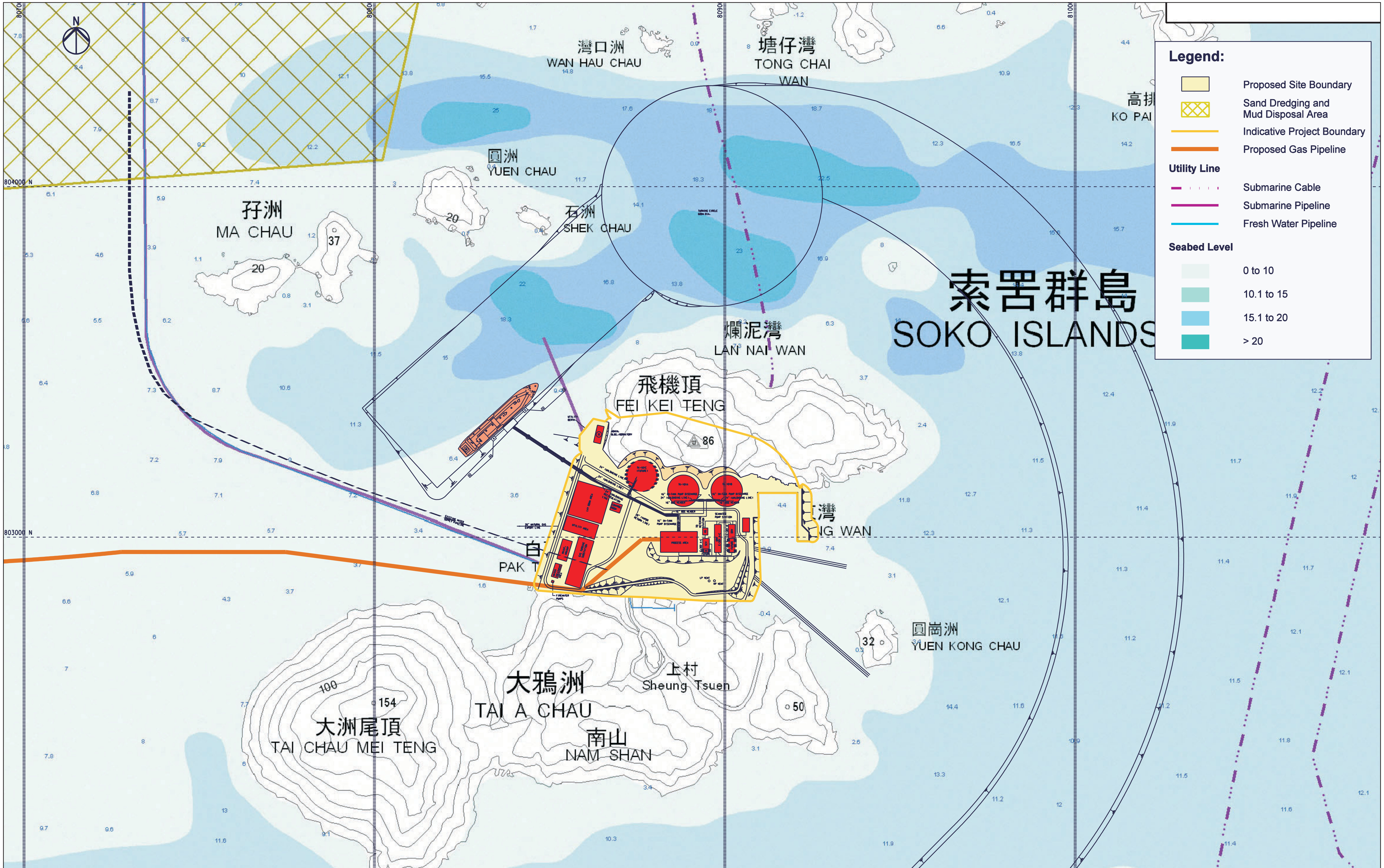

Figure 2.2

South Soko Island
(Option 2 - Full Reclamation)

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Figure 2.3

South Soko Island
(Option 3 - SE Jetty 3 Tanks)

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Figure 2.4

South Soko Island
(Option 3D - SE Jetty 2 Tanks)

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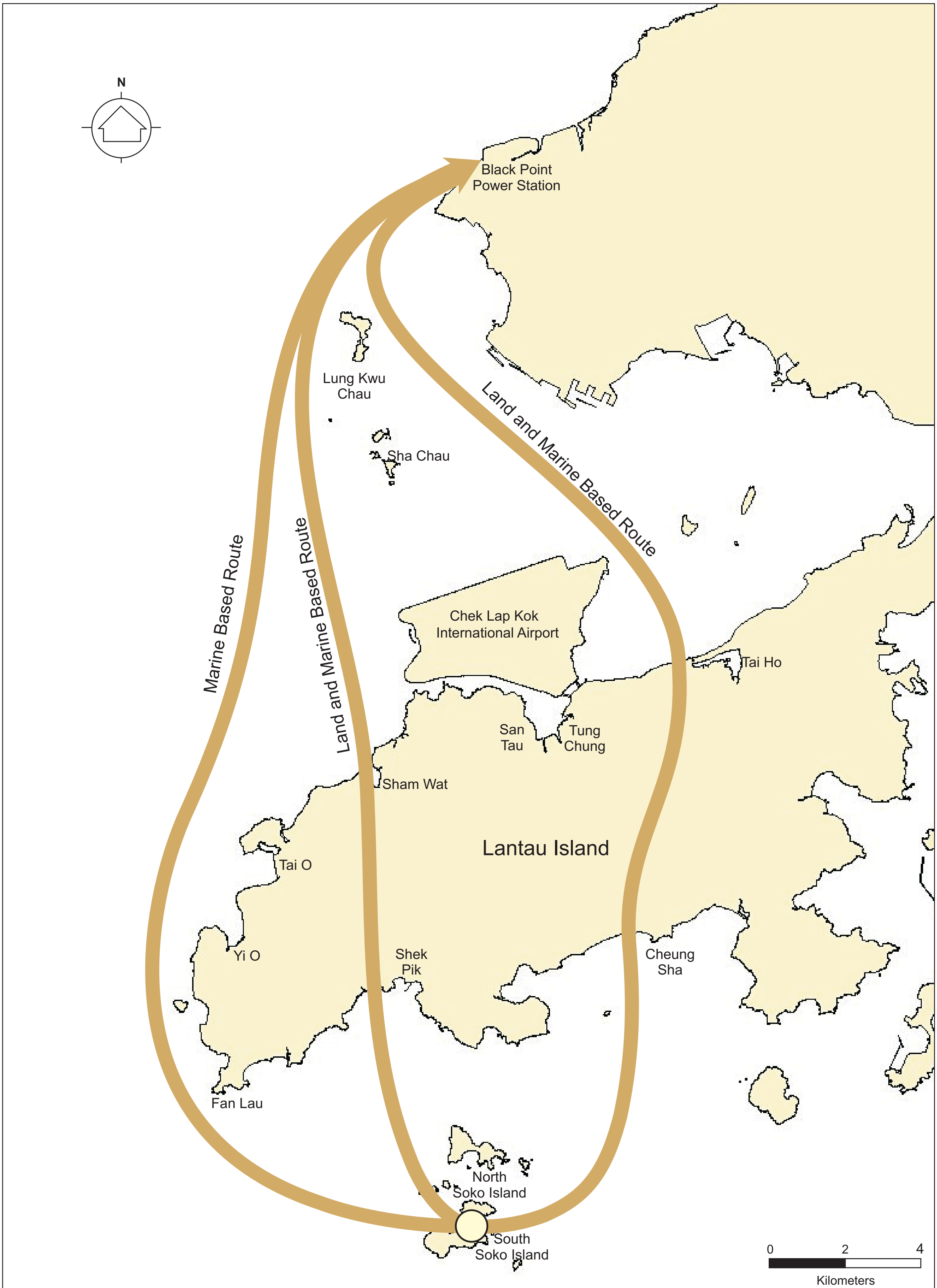

Figure 2.8

Route Options for Proposed Gas Pipeline from South Soko to Black Point Power Station

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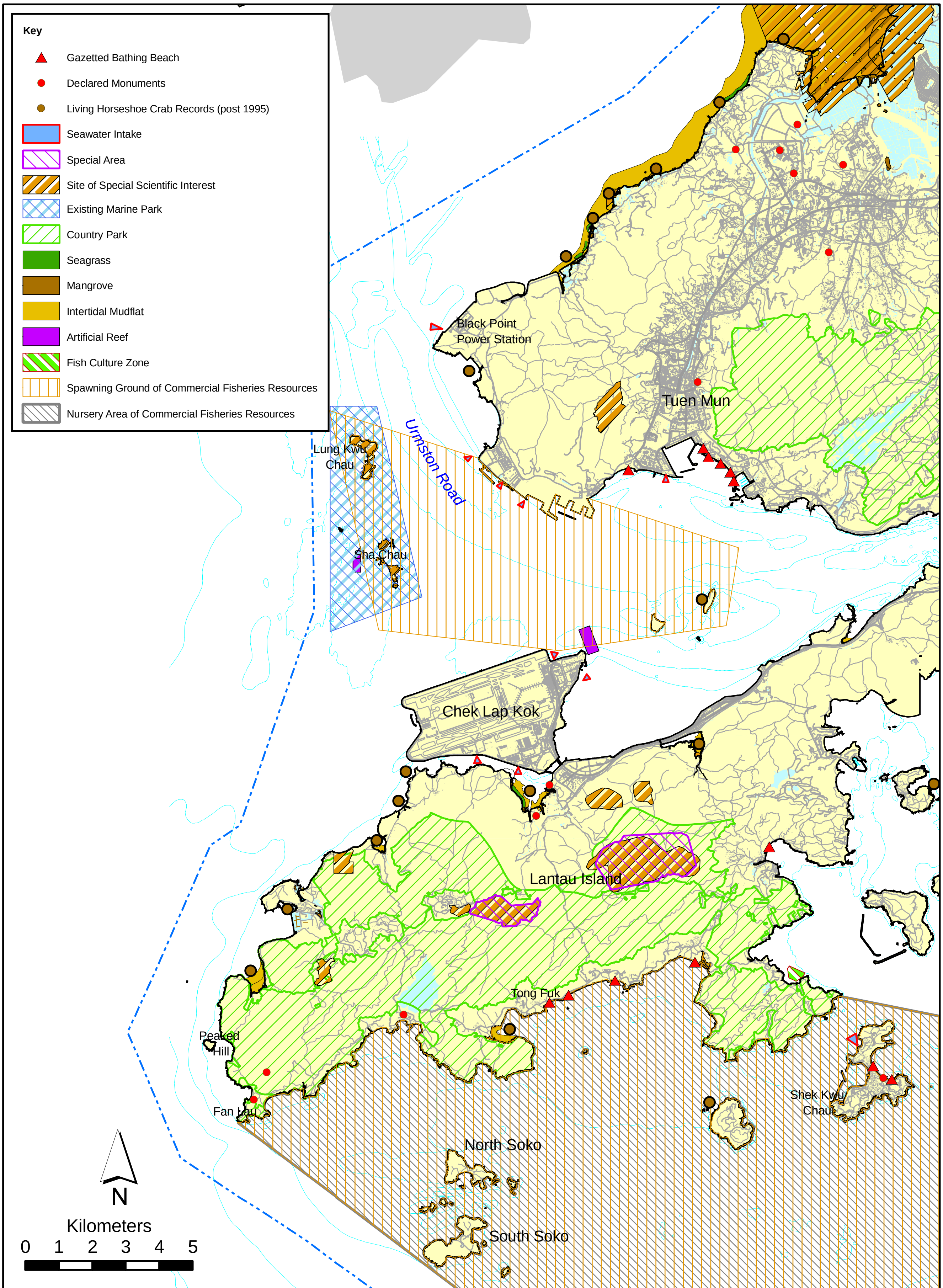

FIGURE 2.9

Environmental Constraints to the Routing of a Gas Pipeline from South Soko to Black Point

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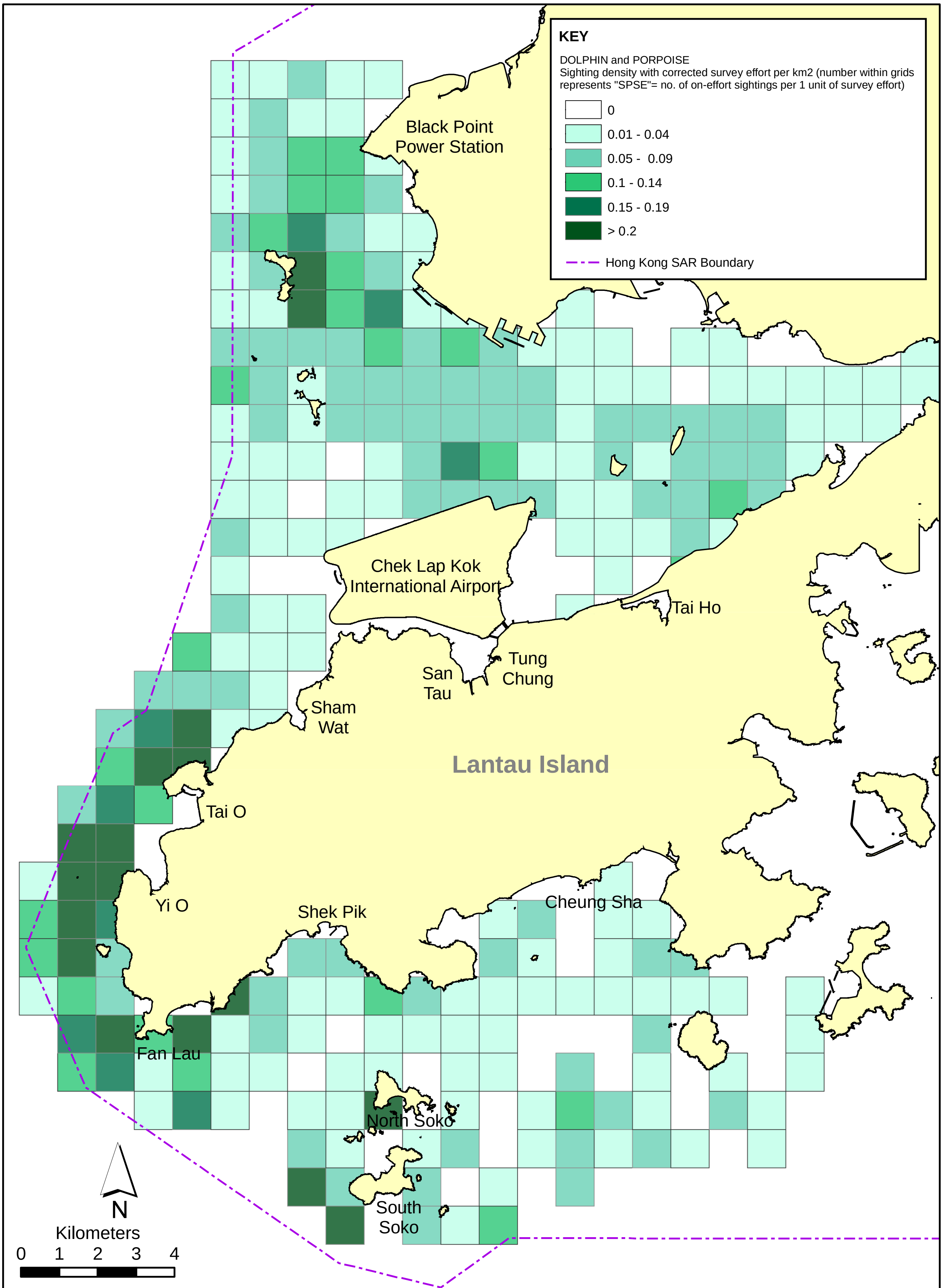

FIGURE 2.10

Sighting of Humpback Dolphin and Finless Porpoise Standardized for Survey Effort (AFCD 2005)

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Date: 13/11/2006

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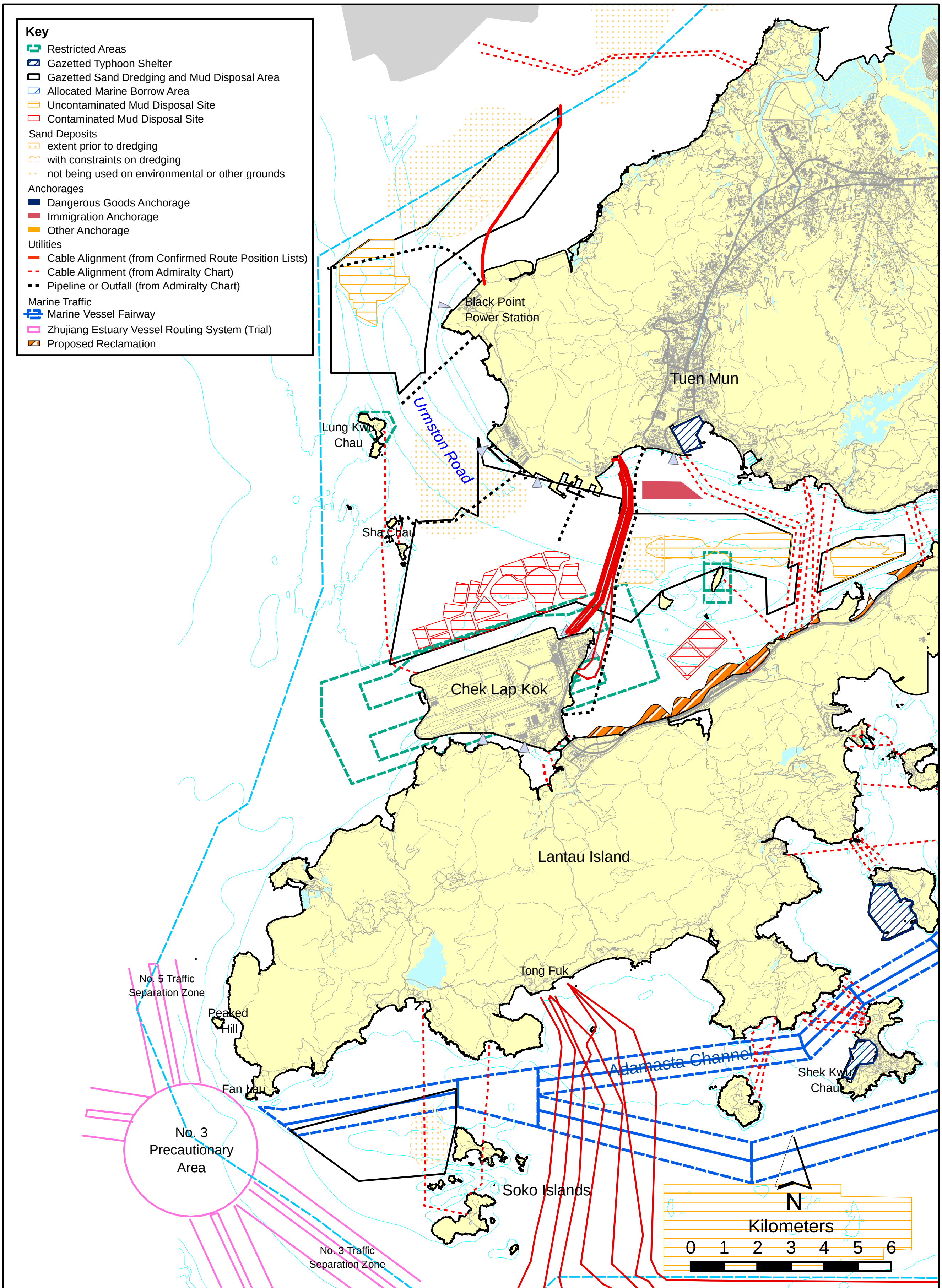

FIGURE 2.11

Physical Constraints to the Routing of
a Gas Pipeline from South Soko to Black Point

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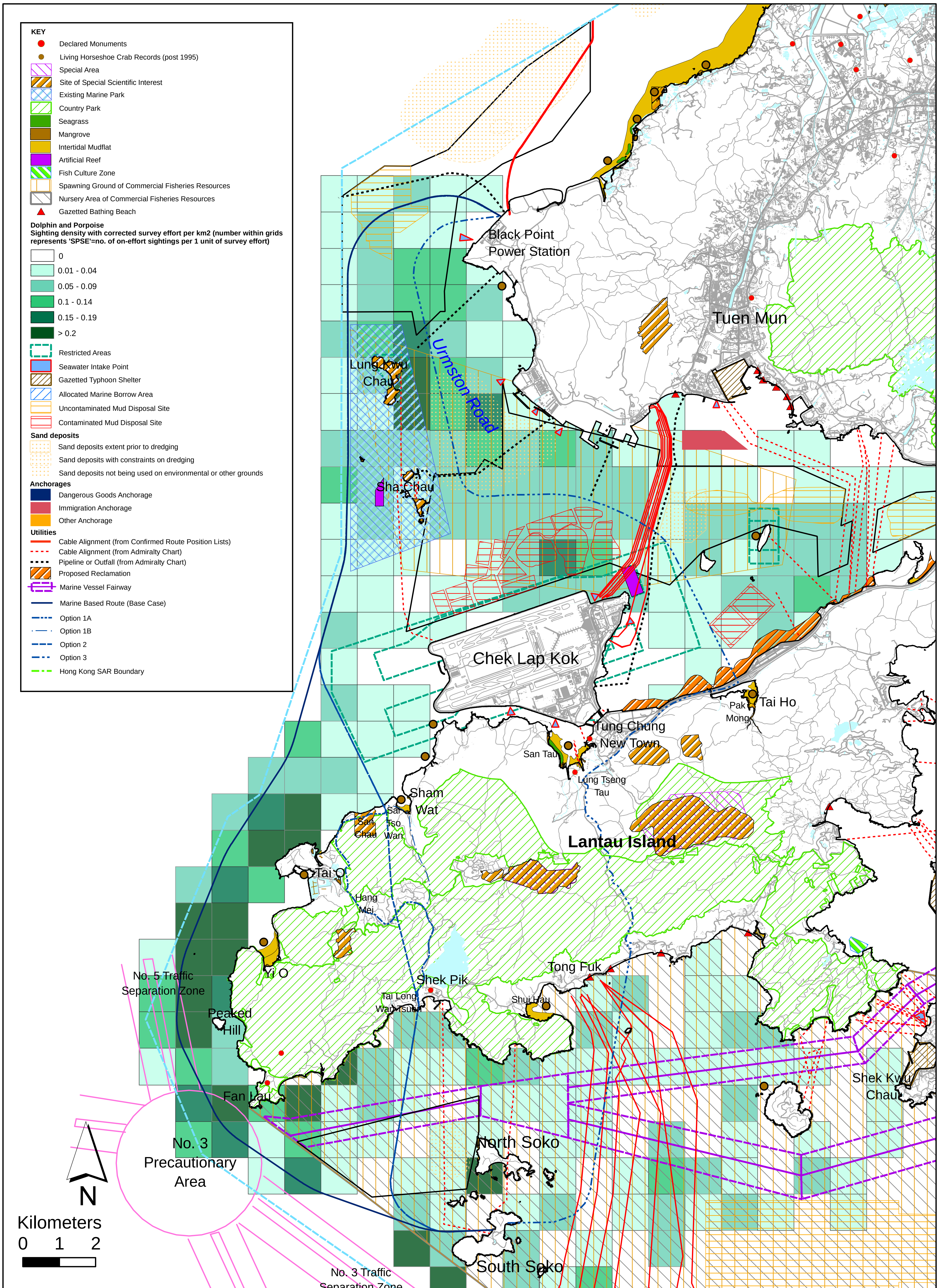

FIGURE 2.12

Environmental and Physical Constraints and the Alternative Pipeline Routing Options

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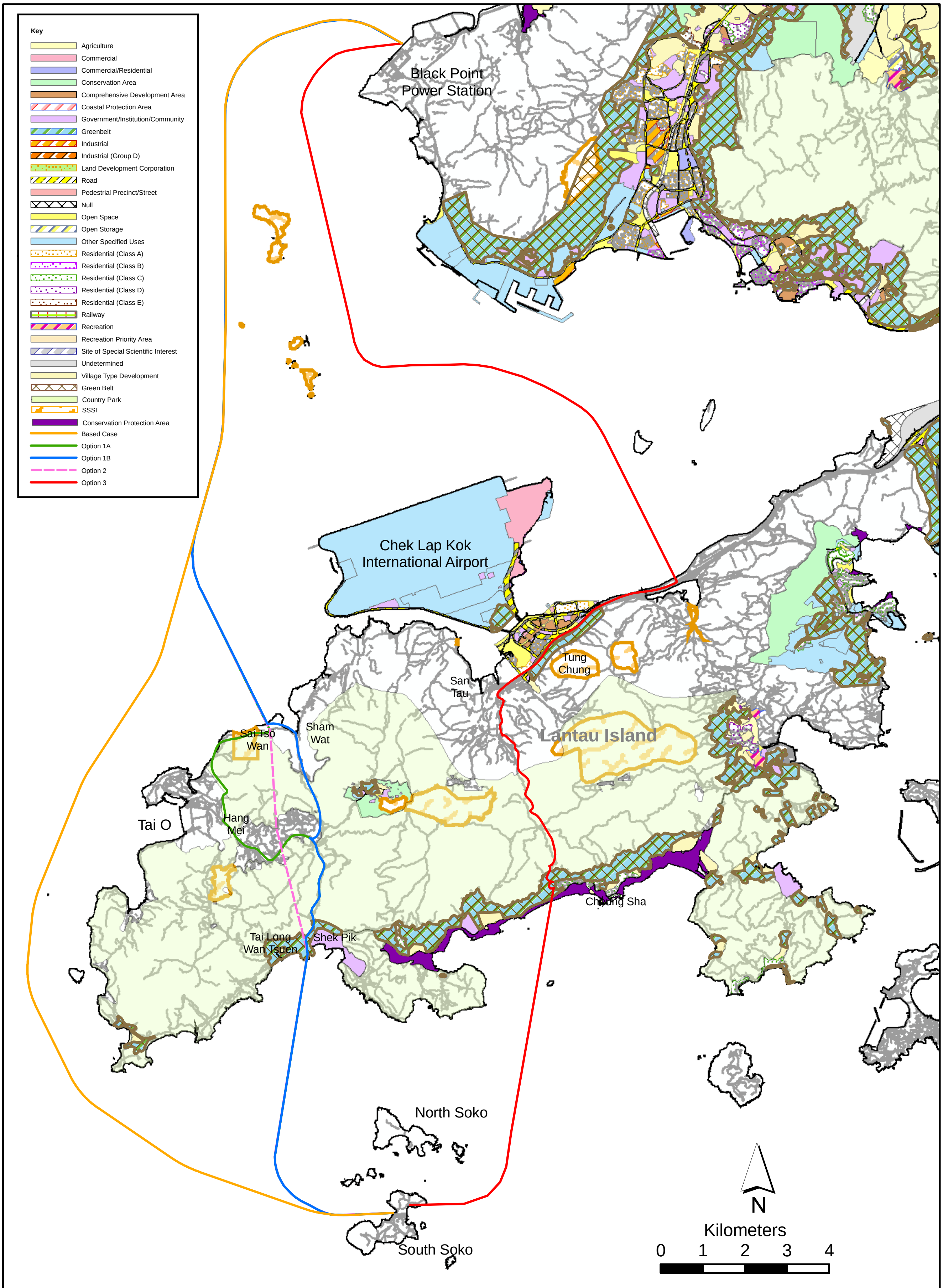

FIGURE 2.13

Outline Zoning Plan Along Route Options

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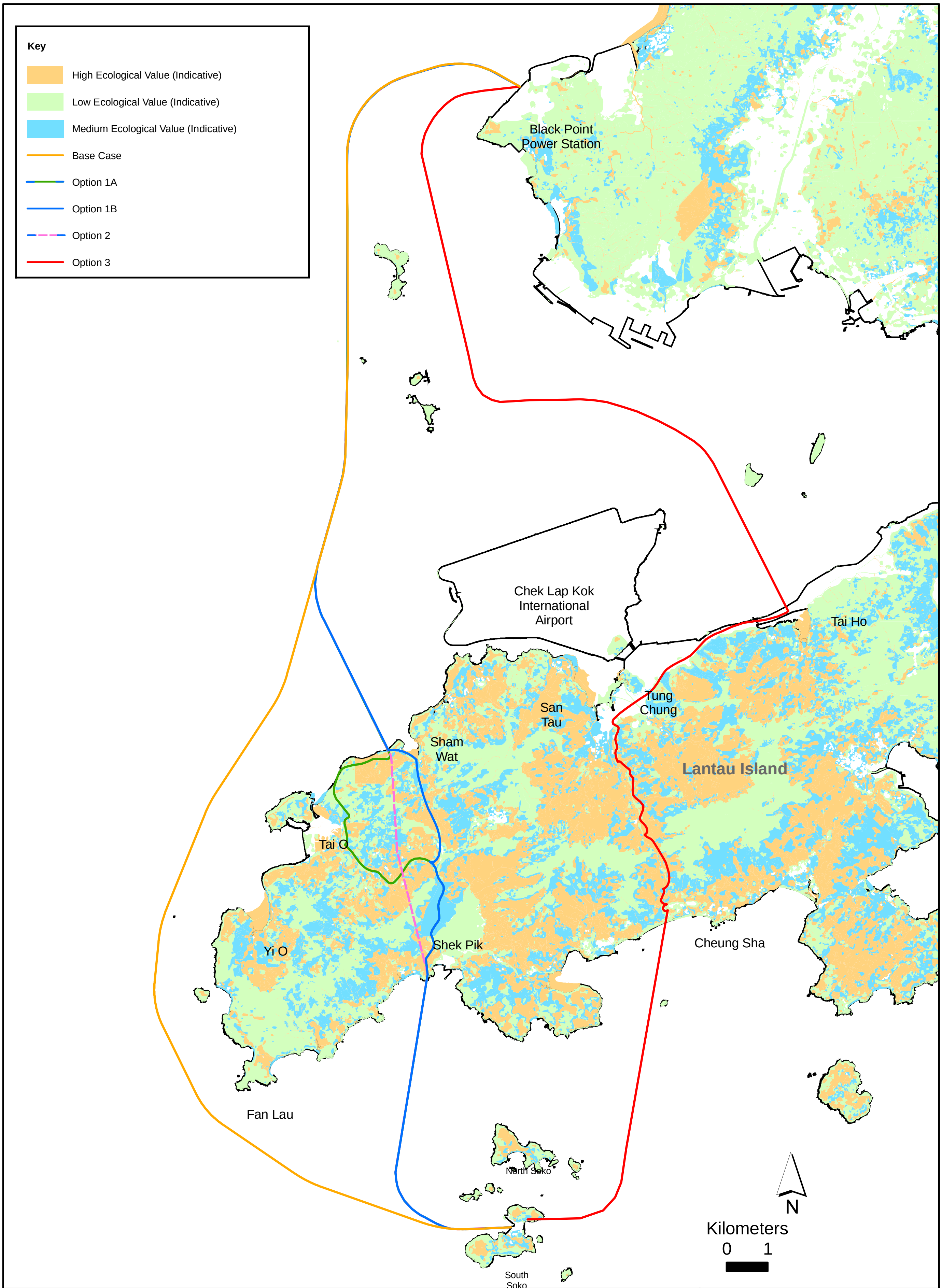

FIGURE 2.14

Conservation Ranking Along Route Options
(Information extracted from Study in Terrestrial Habitat Mapping
and Ranking Based on Conservation Value)

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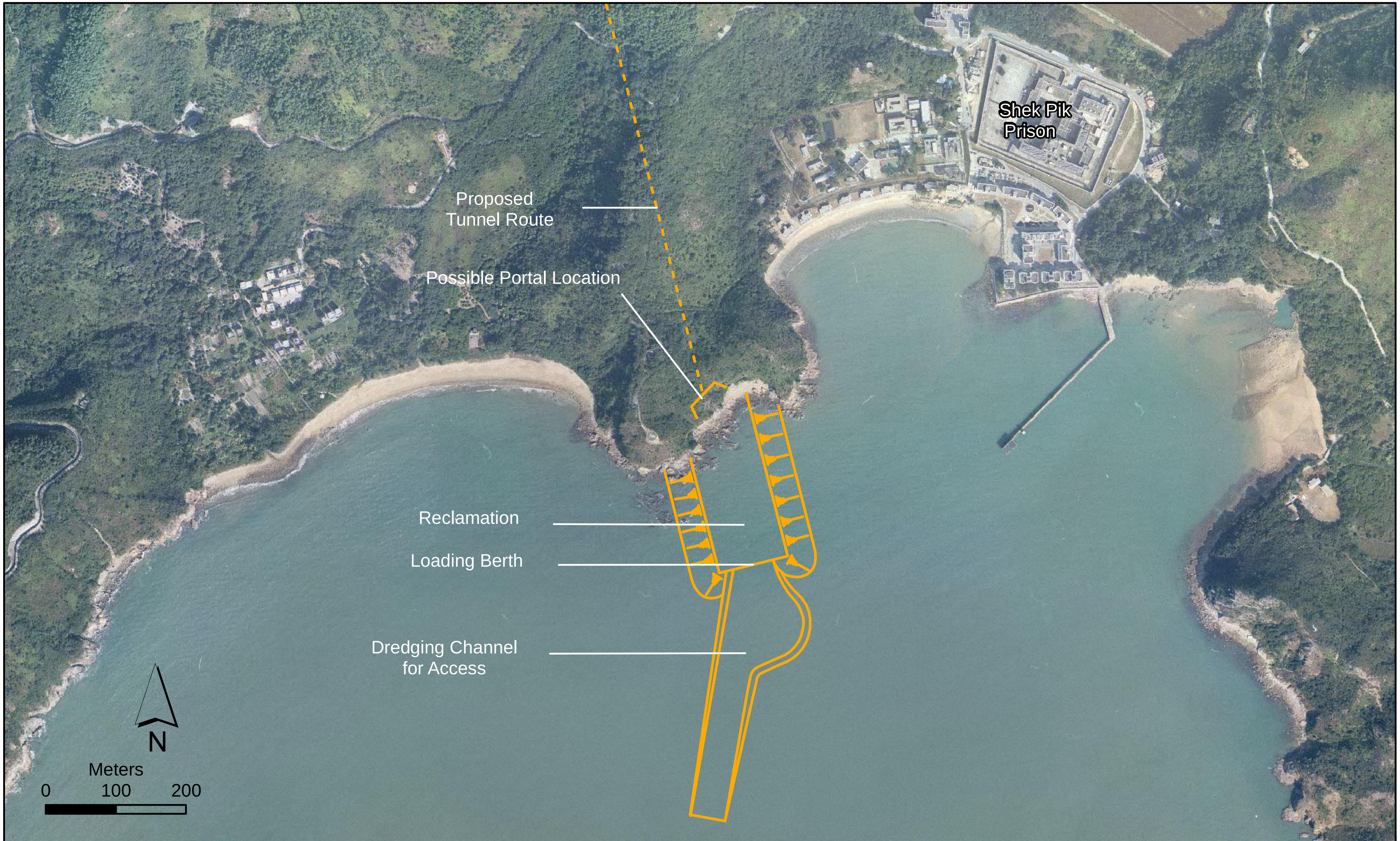

Figure 2.15

Proposed Landfall at South Lantau for Option 2 (Indicative)

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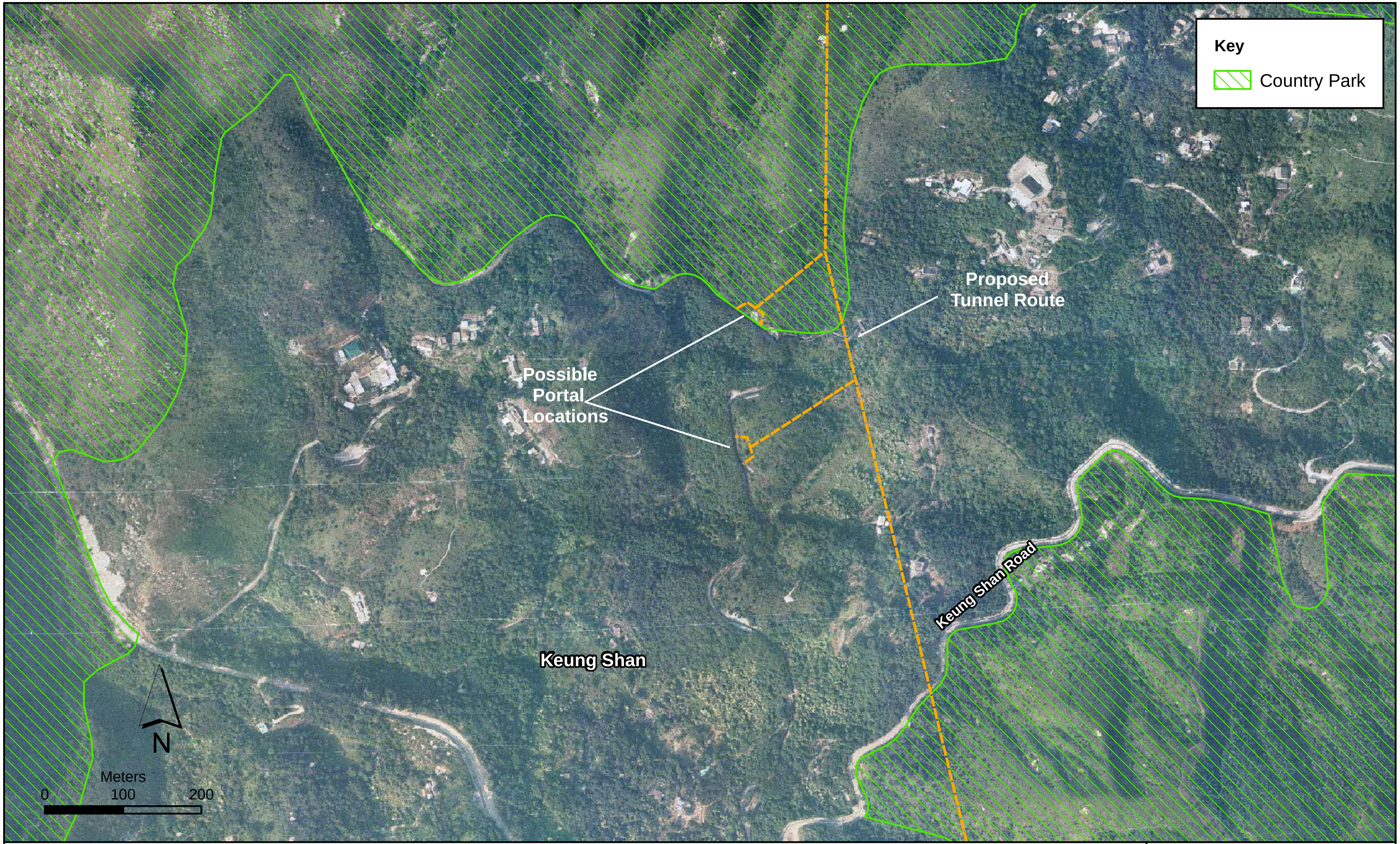

Figure 2.16

Proposed Intermediate Portal at Keung Shan for Option 2 (Indicative)

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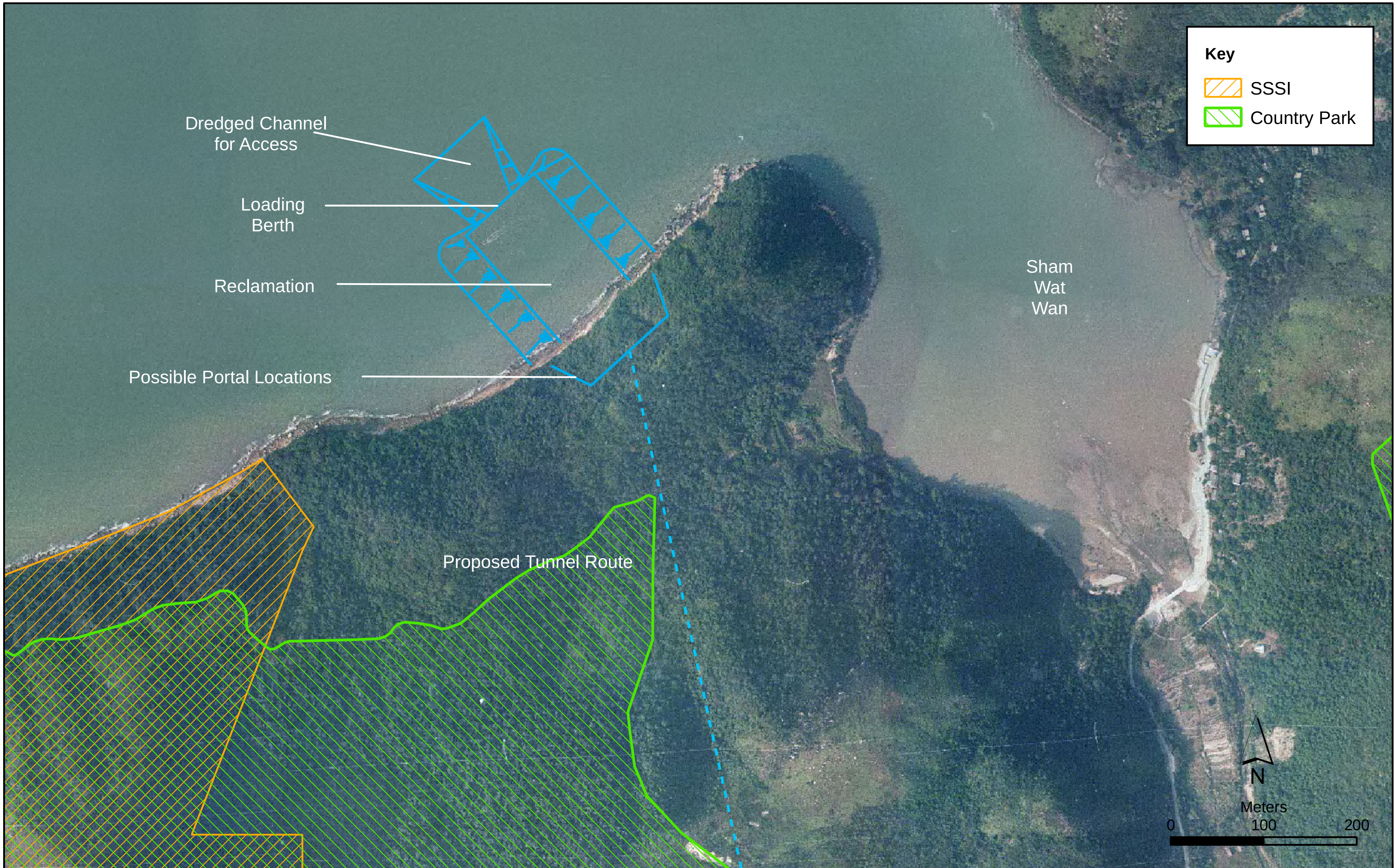

Figure 2.17

Proposed Landfall at North Lantau for Option 2

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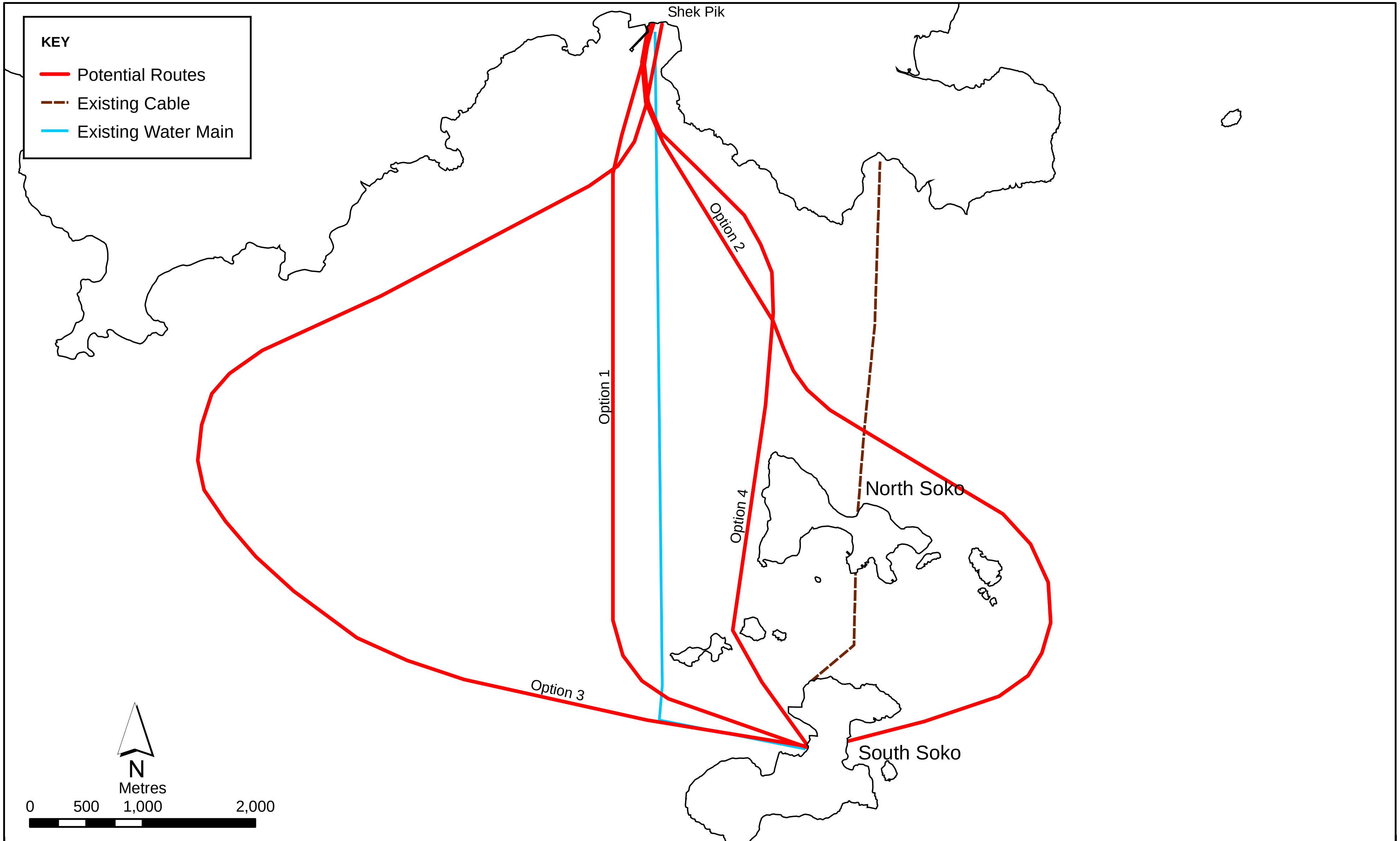

Figure 2.18

Potential Routes for the Proposed Power Cable and Water Main

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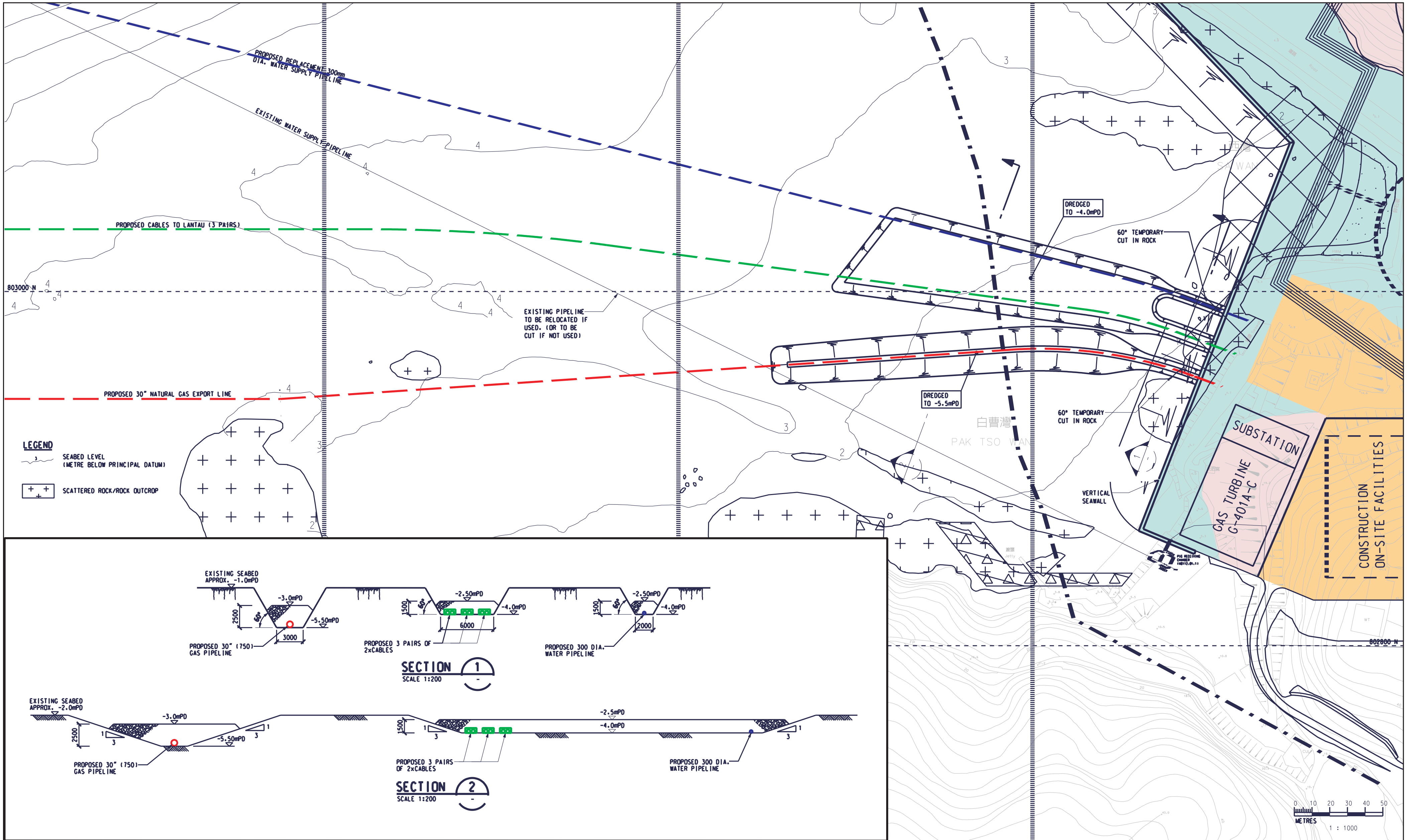

Figure 2.19

Proposed Water Supply Pipeline
Shore Approach to South Soko Island

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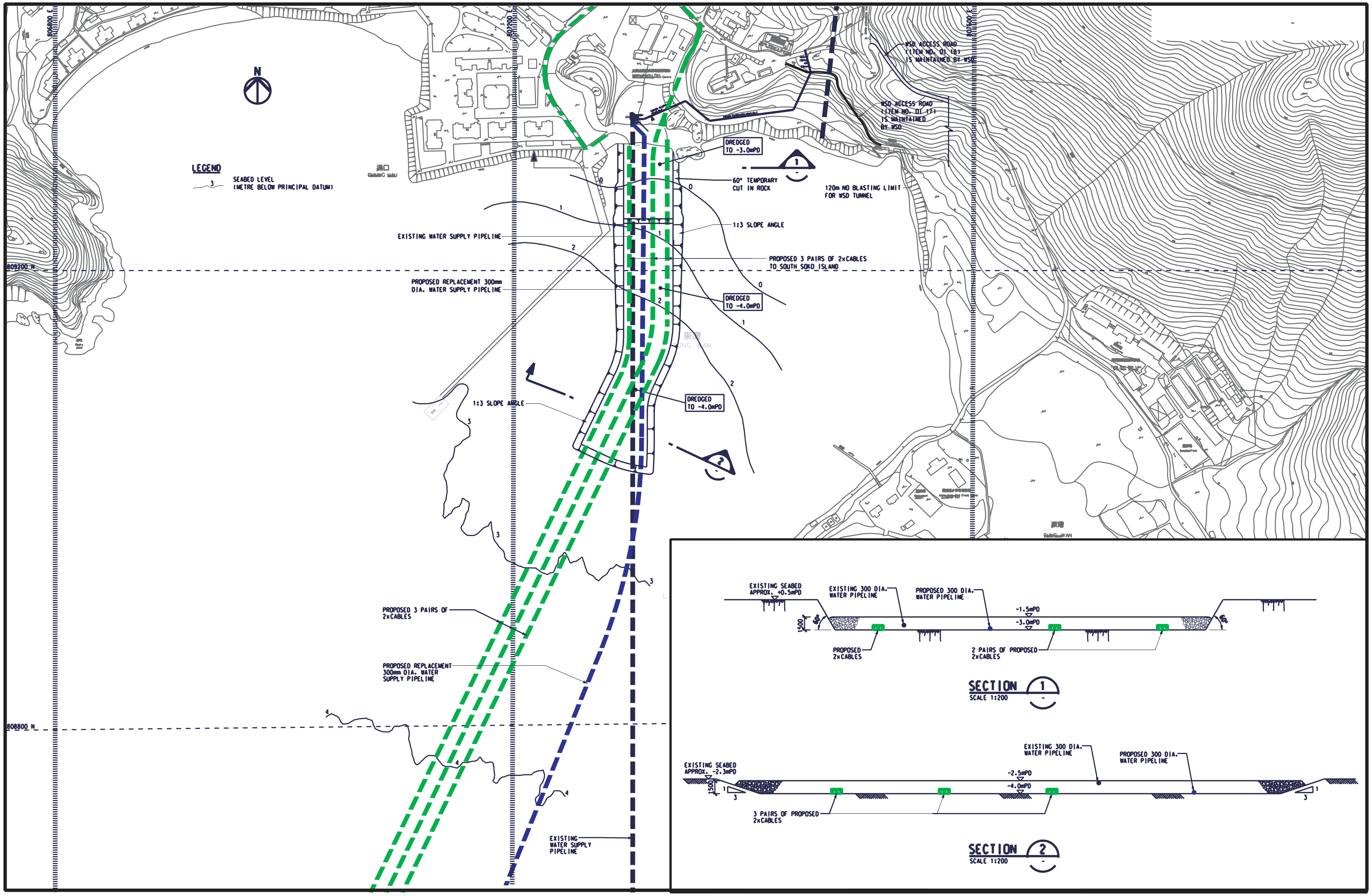

Figure 2.20

Proposed Water Supply Pipeline
Shore Approach to Shek Pik

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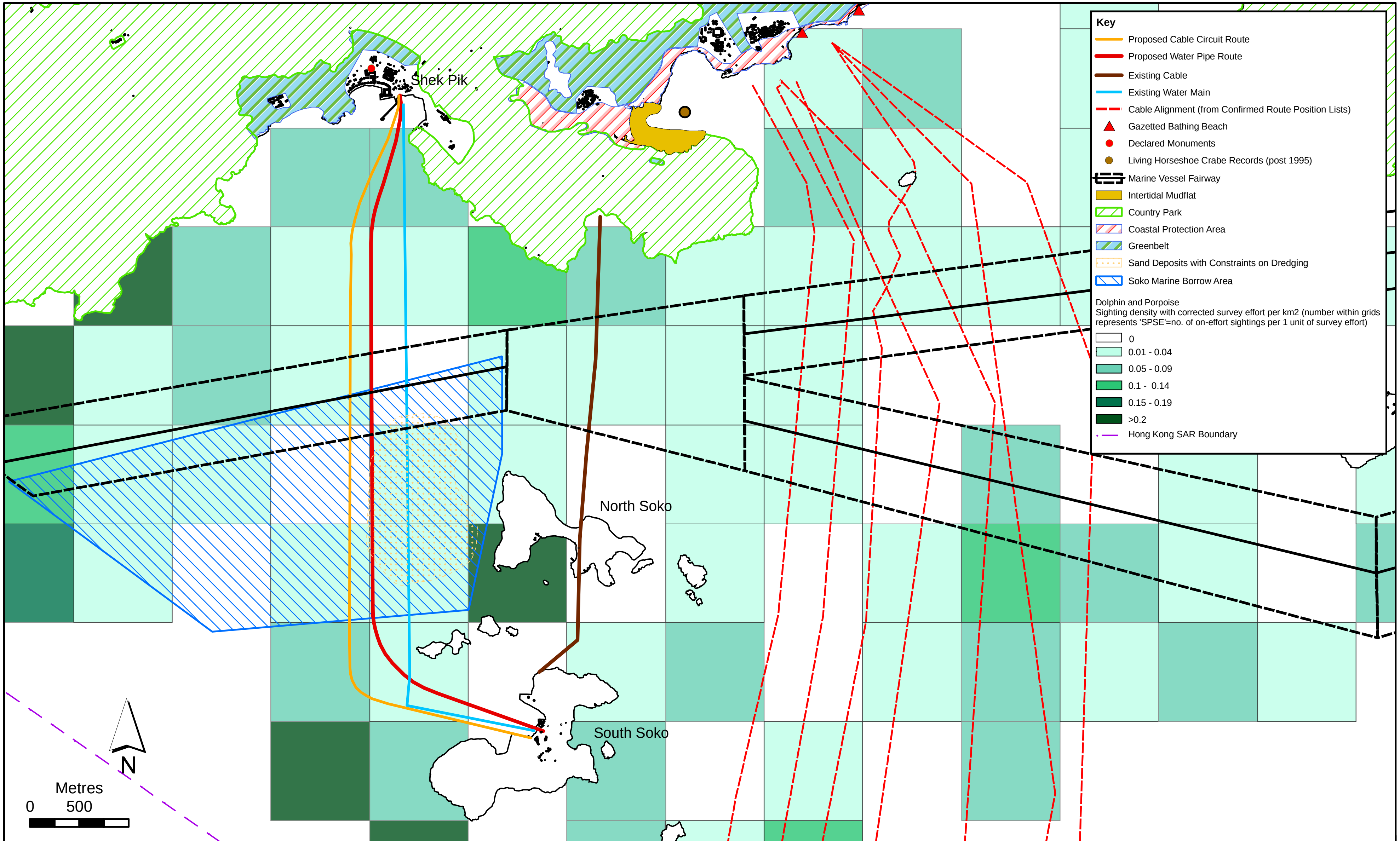

Figure 2.21

Preferred Alignments for the Submarine Water Main and Cable Circuit and Identified Major Elements in South Lantau

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Annex 2A

Engineering Assessment of Different Layouts

Annex 2-A-A

Construction of Site Formation Works for the South Soko Location

It should be noted that the numbers used in this document are approximate and based on preliminary conceptual design details.

A1 Construction of Site Formation Works

A1.1 General

In order to construct the proposed LNG Receiving Terminal facility it is necessary to form at least 20-25ha of land. Where the available land area is insufficient it is necessary to undertake reclamation to make up the difference. A comparison of the offshore reclamation requirements for the site layouts is given in Annex B1.

In order to remain clear of the tidal effects in Hong Kong a minimum platform level of +6mPD is proposed although higher levels may be considered during detailed design stage to reduce cuttings and effects of wave overtopping where necessary.

The site formation layout has been largely dictated by the following criteria: -

- Maximisation of the use of the existing reclamation area at the site which was formed in the early 1980's for the Vietnamese refugee detention camp to reduce further disturbance to the island.
- Reduction of reclamation in the environmentally sensitive waters around South Soko Island
- Creation of sufficient space for two tanks with provision for a third future tank.
- Maintenance of safe distances between the storage tanks and associated process facilities.

A1.2 Assessment Parameters

In order to assess the engineering implications of the on-land formation works at each layout option at South Soko the following engineering assessment parameters have been considered: -

- Volume of excavation in soil
- Volume of excavation in rock
- Volume of soil and rock to be removed from site
- Impact of formation works on the overall construction programme
- Extent of slope stabilisation measures required
- Slope maintenance requirements
- Potential future hazard from slopes
- Blasting restrictions

A2 Volume of Excavation in Soil and Rock

A2.1 Option 1 – Base Case

The excavation for this option will be essentially undertaken within the slopes on either side of the existing reclamation platform, which is at a level of between +5mPD and +6mPD.

The excavation on the northern side of the site will be undertaken to provide sufficient land area for the two initial tanks with provision for a third tank in the future. The excavation is to be undertaken completely within the hillside for two purposes: -

1) To enable the tanks to be founded directly onto rock which will permit the use of raft foundations thus negating the need for deep foundations.
2) To screen the tanks from the visually sensitive receivers on the south side of Lantau Island

The excavation on the southern side of the site will be undertaken to provide sufficient land area for the process plant and associated facilities to maintain the safe distances from the storage tanks. The elevation of these facilities will be mainly at +10mPD in order to reduce the volume of cutting.

On the northern side of the site the existing hillside slopes are steep with average angles of between approximately 60° at the base to 35° higher up. In order to create a platform of sufficient area to house the three storage tanks on the northern side of the site at a level of +6mPD will require a cutting up to approximately 72m in height. This is based on the assumption that the existing slope comprises approximately 5m of completely decomposed rock over slightly to moderately decomposed rock as indicated from the available drillhole data on the hillside. It is assumed that the rock slopes will be cut at an angle of between approximately 60° and 80° with 1.5m wide benches typically every 10m in accordance with local practice and supported with rock bolts and dowels as necessary. The soil slopes will be similarly cut to an angle of between approximately 30° and 45° and supported with soil nails as necessary. The precise slope geometry will be determined during the detailed design stage.

On the southern side of the site the existing hillside slope is similarly steep at the base with average angles of about 60° but with a flatter profile on the upper levels with angles of between 25° and 35°. In order to create a platform of sufficient area to house the process facilities on the southern side of the site at a level of +10mPD will require a cutting up to 30m in height. This is based on the assumption that the existing slope comprises approximately 5m to 15m of completely decomposed rock over slightly to moderately decomposed rock as indicated from the available drillhole data on the hillside. It is assumed that the rock slopes will be cut at an angle of between approximately 60° and 70° with 1.5m wide benches every 10m in accordance with local practice and supported with rock bolts and dowels as necessary. The soil slopes will be similarly cut to an angle of between approximately 30° and 45° and supported with soil nails as necessary. The precise slope geometry will be determined at the detailed design stage.

Adopting this arrangement it is estimated that a total volume of approximately 0.44 x 10^6m^3 of soil and 1.63 x 10^6m^3 of rock material will be excavated from the existing slope cuttings. The total excavated volume will be about 2.07 x 10^6m^3.

A2.2 Option 2 – Full Reclamation

Similar to Option 1, the excavation for the site will be essentially undertaken within the slopes on either side of the existing reclamation platform. The excavation on the northern side of the site will be undertaken to provide sufficient land area for the two initial tanks with provision for a third tank. However since the tanks will be located further to the south, the excavation volume for this option is smaller than that of Option 1.

The excavation on the southern side of the site will be undertaken to provide sufficient land area for the process plant and associated facilities to maintain the regulatory safe distances from the storage tanks. The elevation of these facilities will be mainly at +10mPD in order to reduce the volume of cutting.

In order to create a platform of sufficient area to house the three storage tanks on the northern side of the site at a level of +6mPD will require a cutting up to 64m in height, using the same geological assumption as in Option 1. It is assumed that the rock slopes will be cut at an angle of between approximately 60° and 70° with 1.5m benches every 10m in accordance with local practice and supported with rock bolts and dowels as necessary. The soil slopes will be similarly cut to an angle of between approximately 30° and 45° and supported with soil nails as necessary. The precise slope geometry will be determined at the detailed design stage.

On the southern side of the site a platform at a level of +10mPD will be created to allow sufficient area to house the process facilities. This is based on the assumption that the existing slope comprises approximately 5m to 15m of completely decomposed rock over slightly to moderately decomposed rock as indicated from the available drillhole data on the hillside. It is assumed that the rock slopes will be cut at an angle of approximately 70° with 1.5m benches every 10m in accordance with local practice and supported with rock bolts and dowels as necessary. The soil slopes will be similarly cut to an angle of between approximately 30° and 45° and supported with soil nails as necessary. The precise slope geometry will be determined at the detailed design stage.

Adopting this arrangement it is estimated that a total volume of 0.34 x $10^6 m^3$ of soil and 0.97 x $10^6 m^3$ of rock material will be excavated from the existing slope cuttings. The total excavated volume will be about 1.31 x$10^6 m^3$.

A2.3 Option 3 – SE Jetty

For Option 3, the excavation profile at the northern side of the site will be similar to that of Option 1 in terms of quantities. A platform at a level of +6mPD will be formed to house the three storage tanks on the northern side of the site which will require a cutting up to 72m height, using similar ground profile assumption previously.

On the southern side, a platform at a level of +10mPD will be created to allow sufficient area to house the process facilities.

Excavation will also be required along the proposed pipe trestle, which will run from the newly formed platform through the southern hills to the jetty located at the southeast corner of South Soko Island.

All of the rock and soil slope will be cut at a profile as in Option 1 and 2, and supported with soil nails, rock bolts and dowels as necessary.

Adopting this arrangement it is estimated that a total volume of 0.52 x $10^6 m^3$ of soil and 1.77 x $10^6 m^3$ of rock material will be excavated from the existing slope cuttings. The total excavated volume will be about 2.29 x $10^6 m^3$.

A3 Volume of Spoil to be Removed from Site

A3.1 Option 1 – Base Case

For site formation to be cost effective and sustainable, a balance between cut and fill quantities is required. However for the Option 1 layout Island this is not feasible as the reclamation requirement is purposely low for environmental reasons. The reclamation fill requirement is estimated at 0.52 x 10^6 m^3 (Ref. Annex B), which is significantly smaller than the amount of spoil excavated from the hillside. Approximately 95% of the soil material will be suitable for use within the reclamation and exportation of this material will not be required. The remaining 5% is assumed to be top-soil, which is unsuitable for reclamation purposes and will be used for landscaping to the extent practical on the site.

The excavated rock material will be suitable for use in the following areas: -

- Beneath the sea walls.

- As rock armour along the sea walls.
- Potentially as rock armour protection for the proposed submarine gas pipeline to Black Point Power Station and the new submarine watermain.

Due to the relative timing of the works the rock spoil material will need to be initially removed to leave sufficient working area at the site. Given the large quantity of rock material being exported from the site a separate stockpile site will need to be established, preferably, nearby to the South Soko Island to store, sort, grade and possibly crush the rock materials to create suitable engineering materials for use on the site.

A surplus of approximately 0.04 x 10^6 m³ will be created from the formation works at this site.

A3.2 Option 2 – Full Reclamation

The total fill requirements for option 2 is estimated to be 1.93 x 10^6 m³, which exceeds the amount of spoil excavated from the hillside. If all of the generated spoil is to be reused for reclamation purposes, then no surplus material will result. However, due to the relative timing of the excavation and reclamation works it will be necessary for the rock spoil to be taken off to a stockpile site for crushing and sorting before transporting back to South Soko Island for further reuse as described in Section A3.1.

A3.3 Option 3 – SE Jetty

As in the case of the Option 1 layout, the excavation quantity of the Option 3 layout far exceeds the reclamation and filling requirement although a high proportion of the excess material may be used as protection to the proposed submarine pipeline to Black Point Power Station. The recycling and reusing strategy of the waste material will be similar to that of Option 1.

A surplus of approximately 0.12 x 10^6 m³ is estimated to be created from the formation works at this site.

A4 Extent of Slope Stabilisation Measures

A4.1 Option 1 – Base Case

The cuttings for the tank structures will extend to a height of approximately 72m and will be predominantly in rock. The face area of the slope is estimated to be approximately 22,000m^2. The rock mass forming the hillside will likely be jointed and fractured for which extensive stabilisation measures will be required including rock bolting, dowelling and buttressing as necessary to prevent toppling, wedge and sliding failures. The soil slopes will be similarly stabilised with soil nails. The natural slope above the cut slope will also require inspection and possibly some stabilising works. Appropriate drainage measures will be required to drain surface run-off away to reduce infiltration into the slopes.

A4.2 Option 2 – Full Reclamation

The cuttings for the tank structures will extend to a height of approximately 64m and will be predominantly in rock. The face area of the slope is estimated to be approximately 20,000m^2. The stabilisation measures required for the soil and rock slopes will be similar to Option 1. The slope stabilisation works in this case may be classified as on a smaller scale than of Option 1 and therefore given a relative score of 5.

A4.3 Option 3 – SE Jetty

The cuttings for the tank structures will extend to a height of approximately 72m and will be predominantly in rock. The face area of the slope is estimated to be approximately 22,000m^2. The cuttings for the pipe trestle will extend to a height of approximately 20m and the face area of the slope is estimated to be approximately 10,000m^2. The stabilisation measures required for the soil and rock slopes will be similar to Option 1. The slope stabilisation works in this case may be classified as on a larger scale than Option 1 and therefore given a relative score of 2.

A5 Slope Maintenance Requirements

The cut slopes created for the site formation works are large and extensive i.e., >5m height and will therefore be subject to registration with the government. The slopes will be classified as Category 1 in view of their consequence to life. As such the slopes will be subject to Routine Maintenance Inspections each year and Engineer Inspections for Maintenance every 5 years. The slope maintenance requirements may therefore be considered as being the same for all options, for the pipe trestle.

A6 Long Term Slope Hazard

The terminal facility will be located adjacent to a high cut slope in soil and rock with an extensive natural slope above it. Even with the slope stabilisation measures and long term maintenance activities there is a risk of future instability. The risk is classified as being the same for the first two options, with Option 3 having the highest risk as the slope area created is larger due to the additional excavation for the pipe trestle.

A7 Impact of Site Formation Works on Construction Programme

A7.1 Option 1 – Base Case

The construction of the storage tanks is on the critical path for the construction of the receiving terminal facility. The excavation within the hillside to create the formation for the tanks is therefore also on the critical path. Assuming an excavation rate of approximately 42,000m^3 per week the excavation works will take approximately 270 days. The impact on the program is given a relative score of 3.

A7.2 Option 2 – Full Reclamation

Since the excavation volume for the Option 2 layout is significantly smaller than of Option 1, the excavation works will take only 160 days. The impact on the programme is therefore given a relative score of 5.

A7.3 Option 3 – SE Jetty

Similar to Option 1, the excavation within the hillside to create the formation for the tanks is on the critical path. Assuming an excavation rate of 42,000m^3 per week the excavation works will take approximately 290 days. The impact on the programme is therefore given a relative score of 3.

A8 Blasting Restrictions

The South Soko Island site is approximately 6km south of Lantau Island. There are no significant residential areas near to the site. The only restriction to blasting will be with the supply of emulsion explosive to the site, which is controlled by the Mines and Quarries Department of Hong Kong. However, given the remoteness of the site it is likely that a magazine storage and explosive manufacturing plant will be established on the site, which will overcome this issue. Restrictions to blasting are therefore considered to be low and equal for all three options.

A9 Summary for Site Formation Construction

A summary of the parameter values and relative scores derived from the engineering assessment for the site formation construction is given in Table A1 below.

Table A1 - Summary for Site Formation Construction

Parameter	Option 1 (Base Case)	Option 2 (Reclamation)	Option 3 (SE Jetty)
Volume of excavation in soil ($10^6 m^3$)	RS = 3 (0.44)	RS = 5 (0.34)	RS = 2 (0.52)
Volume of excavation in rock ($10^6 m^3$)	RS = 3 (1.63)	RS = 5 (0.97)	RS = 2 (1.77)
Volume of soil to be disposed of ($10^6 m^3$)	RS = 3 (0.04)	RS = 5 (0)	RS = 2 (0.12)
Volume of rock to be disposed of ($10^6 m^3$)	RS = 3 (0)	RS = 3 (0)	RS = 3 (0)
Impact on construction programme (months)	RS = 3 (12)	RS = 5 (9)	RS= 3 (13)
Slope stabilisation measures required	RS = 3	RS = 3	RS = 3
Slope maintenance	RS = 3	RS = 3	RS = 3
Future slope hazard	RS = 3	RS = 3	RS = 3
Blasting risks	RS = 3	RS = 3	RS = 3

RS = Relative Score

A10 Scoring for Site Formation Construction

Each of the parameters summarised above in Table A1 have been scored in accordance with the procedure described in Section 2.1.3. The results are shown below in Table A2. The table also shows the total score for each layout derived using the relative weightings given in *Table 2.3*.

Table A2 – Scoring for Each Layout Option at South Soko Island for Site Formation Construction

Parameter	Weight	Option 1 (Base Case)		Option 2 (Full Reclamation)		Option 3 (SE Jetty)	
		Score	WS	Score	WS	Score	WS
Volume of excavation in soil	0.05	3	0.15	5	0.25	2	0.10
Volume of excavation in rock	0.25	3	0.75	5	1.25	2	0.50
Volume of soil to be disposed of	0.20	3	0.60	5	1.00	2	0.40
Volume of rock to be disposed of	0.05	3	0.15	3	0.15	3	0.15
Impact on construction programme	0.10	3	0.30	5	0.50	3	0.30
Slope stabilisation measures required	0.10	3	0.30	3	0.30	3	0.30
Slope maintenance	0.05	3	0.15	3	0.15	3	0.15
Future slope hazard	0.05	3	0.15	3	0.15	3	0.15
Blasting risks	0.15	3	0.45	3	0.45	3	0.45
Total Weighted Score			3.00		4.30		2.45
Normalised Score		3.57		5.00		2.98	

From the result of the assessment of all parameters for site formation construction, Option 2 is the preferred layout.

Annex 2-A-B

Construction of Site Reclamation Works for the South Soko Location

B1 Construction of Site Reclamation Works

B1.1 General

In order to construct the proposed LNG Receiving Terminal facility it is necessary to form at least 25ha of land area. Where the available land area, even with excavation is insufficient it is necessary to undertake reclamation to make up the difference. A comparison of the reclamation requirements for the three different layout options at South Soko Island is given in the sections below in order to assess the relative merits and demerits in this regard.

At all locations the reclamation areas are expected to be underlain by a significant thickness of compressible marine deposits. Using the partially dredged method these clays will be largely left in place during the reclamation process.

The South Soko Island site is between the two islands of Fei Kei Teng and Tai A Chau. The proposed site includes the existing reclamation platform, which was previously formed to accommodate the earlier Vietnamese Detention Camp at the site. Additional reclamation will be required along the shore to increase the land area as necessary.

B1.2 Assessment Parameters

In order to create a cost effective and sustainable site formation, a balance between cut and fill quantities is required. A combination of on-shore cutting and off-shore reclamation is typically adopted unless other considerations do not permit this. Generally for each layout a level platform of +6mPD will be created to be sufficiently above the high tide level. The formation of the reclamation will involve the filling of significant quantities of soil and rock material which will need to be sourced either from the land excavation works or from external sources depending upon the balance achieved. In order to assess the engineering implications of the off-shore reclamation at each of the sites the following assessment parameters have been considered: -

- Area of sea reclaimed.
- Volume of dredging material.
- Volume of filling material and how much is imported.
- Length of coastline affected.
- Length of seawall required.
- Time for dredging and filling and for consolidation.
- Ground improvement measures.

B2 Area of Sea Reclaimed

B2.1 Option 1 – Base Case

Land will be reclaimed immediately to the west of the existing platform previously formed for the Vietnamese Refugee Detention camp for the proposed Utility Pier, and to the east of the platform for the proposed loading and unloading berth.

The total area to be reclaimed is estimated to be about 16,700 m².

B2.2 Option 2 – Full Reclamation

A significant area will be reclaimed to the west of the existing platform to house the proposed turbine substation, utility area and layout area. The area to the east of the platform will be for the loading and unloading berth.

The total area to be reclaimed is estimated to be about 130,000 m².

B2.3 Option 3 – SE Jetty

The reclamation profile is identical to Option 1.

The total area to be reclaimed is estimated to be about 16,700 m².

B3 Volume of Dredging and Filling Materials

B3.1 Option 1 – Base Case

The estimated total volume of dredging and subsequent reclamation fill required to form the terminal area including the seawall are as follows: -

Volume of dredging = 0.18×10^6 m³

Volume of reclamation fill = 0.52×10^6 m³

B3.2 Option 2 – Full Reclamation

The estimated total volume of dredging and subsequent reclamation fill required to form the terminal area including the seawall are as follows: -

Volume of dredging = 0.22×10^6 m³

Volume of reclamation fill = 0.79×10^6 m³

B3.3 Option 3 – SE Jetty

The estimated total volume of dredging and subsequent reclamation fill required to form the terminal area including the seawall are as follows: -

Volume of dredging = 0.18×10^6 m³

Volume of reclamation fill = 0.52×10^6 m³

B4 Reuse of Excavated Material

For the use of excavated materials within the reclamation refer to Annex A1.

The reclamation can be formed using the excavated material from the site formation works, which are expected to comprise largely moderately to slightly decomposed granite material. However, in order to achieve the required grading for reclamation standards it will be necessary for the material to undergo primary, secondary and possibly tertiary crushing with associated sorting and mixing off-site at an appropriate stockpile site.

B5 Length of Seawall and Natural Coastline Affected

B5.1 Option 1 – Base Case

The site formation will require a total seawall length of 1,100m only to form the boundary of the proposed terminal. A total of 1,370m of existing coastline, of which 450m is natural coastline, will be affected by this construction.

B5.2 Option 2 – Full Reclamation

The site formation will require a total seawall length of 1,360m only to form the boundary of the proposed terminal. A total of 1,520m of existing coastline, of which 600m is natural coastline, will be affected by this construction

B5.3 Option 3 – SE Jetty

The site formation will require a total seawall length of 1,100m for the boundary of the proposed terminal. A total of 1,370m of existing coastline, of which 450m is natural coastline, will be affected by this construction.

B6 Time for Construction

B6.1 Option 1 – Base Case

It is estimated 11 months will be required to complete the dredging and filling operation for the reclamation works.

B6.2 Option 2 – Full Reclamation

It is estimated that the dredging and filling operation will be completed within 14 months.

B6.3 Option 3 – SE Jetty

It is estimated 11 months will be required to complete the dredging and filling operation for the reclamation works.

B7 Ground Improvement and Time for Consolidation

Since the marine deposits are largely left in place under the reclamation, ground improvement work will be required in the form of vertical drains plus surcharge pre-loading. This significantly reduces the ongoing creep settlement within the sand fill layer and speed up the consolidation process.

B7.1 Option 1 – Base Case

It is estimated 4 months will be required to complete the surcharging and consolidation process for the reclamation works.

B7.2 Option 2 – Full Reclamation

It is estimated that the surcharging and consolidation process will be completed within 14 months.

B7.3 Option 3 – SE Jetty

It is estimated 4 months will be required to complete the surcharging and consolidation process for the reclamation works.

B8 Summary for Site Reclamation Construction

A summary of the parameter values and relative scores assigned to each from the engineering assessment for the site reclamation construction is given in Table B1 below.

Table B1 - Summary for Site Reclamation Construction

Parameter	Option 1 (Base Case)	Option 2 (Full Reclamation)	Option 3 (SE Jetty)
Area of reclamation (10^3 m²)	RS = 3 (16.7)	RS = 1 (130)	RS = 3 (16.7)
Volume of dredging material (10^6 m³)	RS = 3 (0.18)	RS = 1 (0.22)	RS = 3 (0.18)
Total volume of fill material required (10^6 m³)	RS = 3 (0.52)	RS = 1 (0.79)	RS = 3 (0.52)
Volume of imported fill (sand + rock) (10^6 m³)	RS = 3 (0)	RS = 1 (0.18)	RS = 3 (0)
Length of natural coastline affected (m)	RS = 3 (450)	RS = 1 (600)	RS = 3 (450)
Length of artificial coastline affected (m)	RS = 3 (920)	RS = 3 (920)	RS = 3 (920)
Length of seawall required (m)	RS = 3 (1,100)	RS = 1 (1,360)	RS = 3 (1,100)
Construction time for dredging and filling (months)	RS = 3 (11)	RS = 2 (14)	RS = 3 (11)
Time for consolidation after construction (months)	RS = 3 (4)	RS = 1 (14)	RS = 3 (4)
Need for ground improvement	RS = 3	RS = 3	RS = 3

RS = Relative Score

B9 Scoring for Site Reclamation Construction

Each of the parameters summarised above in Table B1 have been scored in accordance with the procedure described in Section 2.1. 3. The results for each of the layout options are shown below in TableB3. The table also shows the total score for each layout derived using the relative weightings given in *Table 2.4*.

Table B3 – Scoring for Each Layout Option for Site Reclamation Construction

Parameter	Weight	Option 1 (Base Case)		Option 2 (Full Reclamation)		Option 3 (SE Jetty)	
		Score	WS	Score	WS	Score	WS
Area of reclamation	0.10	3	0.30	1	0.10	3	0.30
Volume of dredging material	0.20	3	0.60	1	0.20	3	0.60
Total volume of fill material	0.05	3	0.15	1	0.05	3	0.15
Volume of imported fill	0.20	3	0.60	1	0.20	3	0.60
Length of natural coastline	0.15	3	0.45	1	0.15	3	0.45
Length of artificial coastline	0.05	3	0.15	3	0.15	3	0.15
Length of seawall required	0.10	3	0.30	1	0.10	3	0.30
Construction time for dredging & filling	0.05	3	0.15	2	0.10	3	0.15
Time for consolidation after construction	0.05	3	0.15	1	0.05	3	0.15
Need for ground improvement	0.05	3	0.15	3	0.15	3	0.15
Total Weighted Score			3.00		1.25		3.00
Normalised Score		5.00		2.08		5.00	

From the result of the assessment of all parameters for site reclamation construction, it is clear that layout options 1 and 3 are preferred.

Annex 2-A-C

Construction of Approach Channel & Turning Basins for the South Soko Location

C1 Construction of Approach Channel & Turning Basin

C1.1 General

In order to reduce dredging, it is necessary to construct the jetty for berthing of LNG carriers in water as deep as –15mPD and as close as possible to marine fairways where the deep water exists. The jetty will be located in an area free from marine services and traffic. In all site layouts considered, the dredging of the turning circle and approach channels are undertaken to approximately –15mPD which will require significant maintenance dredging as well as affecting tidal flows in the vicinity.

The available investigation information indicates that the dredging is likely to be wholly within the soft Marine Deposit layer, which will require side slopes of about 1:4 for long-term stability. It has been assumed that the dredged sediment is not significantly contaminated and can be dumped at an uncontaminated mud disposal ground. Rock excavation for the construction of approach channel and turning basin should be avoided in order to reduce impacts on the seabed and surrounding water environment.

South Soko Island is located where the marine service and marine traffic is unrestricted. The potential access for LNG carrier will be from the deep waterway to the south of the island to the proposed jetty. In order to facilitate the LNG berthing a significant amount of dredging is required for a turning circle and approach channel.

C1.2 Assessment Parameters

In order to assess the engineering implications of the marine dredging at each of the sites the following assessment parameters have been used: -

- Total length of approach channel & turning basin.
- Volume of dredging.
- Rock excavation in dredged zone.
- Impact on existing utilities.
- Siltation & maintenance.

C2 Total Length of Approach Channel and Turning Basin

C2.1 Option 1 – Base Case

The position of the jetty head results in a significant amount of dredging to give access to the jetty from the navigation channel. The total length of the approach channel and turning basin is estimated to be 6.3km from the deep water with a seabed level of approximately -15mPD.

C2.2 Option 2 – Full Reclamation

The route of the approach channel and turning basin and the location of the jetty of Option 2 are the same as that of Option 1.

C2.3 Option 3 – SE Jetty

The location of the jetty at the southeast corner of South Soko Island helps reduce the length of the approach channel and turning basin to 2.2km from the deep water.

C3 Volume of Dredging

C3.1 Option 1 – Base Case

Dredging is required for both the approach channel and the turning basin. The total volume of dredging and subsequent rock excavation is estimated to be 3.36 x $10^6 m^3$.

C3.2 Option 2 – Full Reclamation

The approach channels and turning basins are the same as Option 1.

C3.3 Option 3 – SE Jetty

The total volume of dredging and subsequent rock excavation of the shorter approach channel and turning basin is estimated to be 1.07 x $10^6 m^3$.

C4 Rock Excavation in Dredged Zone

The quantity of the rock required to be excavated is estimated at about 0.03 x 10^6 m^3 for all options.

C5 Impact on Existing Utilities

Dredging of the approach channel and turning basin is not likely to encounter any existing submarine cables.

C6 Siltation & Maintenance

Siltation study recently carried out suggests that siltation rate in the vicinity of South Soko Island is estimated at 0.5cm/yr for all options, which is relatively minor, and hence the need for maintenance dredging is low.

C7 Summary for the Approach Channel & Turning Basin

A summary of the parameter values and relative scores derived from the engineering assessment for the construction of the approach channel and turning basin is given in Table C1 below.

Table C1 - Summary for Approach Channel and Turning Basin Construction

Parameter	Option 1 (Base Case)	Option 2 (Full Reclamation)	Option 3 (SE Jetty)
Total length of approach channel + turning basin (km)	RS = 3 (6.3)	RS = 3 (6.3)	RS = 5 (2.2)
Volume of dredging (10^6 m³)	RS = 3 (3.36)	RS = 3 (3.36)	RS = 5 (1.07)
Rock excavation in dredged zone ($10^6 m^3$)	RS = 3 (0.03)	RS = 3 (0.03)	RS = 3 (0.03)
Impact on existing utilities	RS = 3	RS = 3	RS = 3
Siltation and maintenance dredging (cm/yr)	RS = 3 (0.5)	RS = 3 (0.5)	RS = 3 (0.5)

RS = Relative Score

C8 Scoring for the Approach Channel & Turning Basin

Each of the parameters summarised above in Table C1 have been scored in accordance with the procedure described in Section 2.1.3. The results are shown below in Table C2. The table also shows the total score for each site derived using the relative weightings given in Table 2.5.

Table C2 – Scoring for Each Layout Option for the Approach Channel and Turning Basin

Parameter	Weight	Option 1 (Base Case)		Option 2 (Full Reclamation)		Option 3 (SE Jetty)	
		Score	WS	Score	WS	Score	WS
Total length of Approach Channel + turning basin	0.2	3	0.60	3	0.60	5	1.00
Volume of dredging	0.35	3	1.05	3	1.05	5	1.75
Rock excavation in dredged zone	0.2	3	0.60	3	0.60	3	0.60
Impact on existing utilities	0.15	3	0.45	3	0.45	3	0.45
Siltation & maintenance	0.1	3	0.30	3	0.30	3	0.30
Total Weighted Score			3.00		3.00		4.10
Normalised Score		3.66		3.66		5.00	

From the result of the assessment of all parameters for the approach channel and turning basin, it is found that layout option 3 is preferred.

Annex 2-A-D

Effect on Existing Marine Navigation for the South Soko Location

D1 Marine Navigation

D1.1 General

The principal hazards associated with a LNG carrier underway to and from a terminal within Hong Kong waters have been adopted as guiding criteria for site assessment. The following assessment parameters have been adopted to assess marine access to the sites:

- Marine Traffic (Carrier striking or being struck by any self propelled ship whilst underway to an LNG terminal within Hong Kong territorial waters, or at anchor);
- Grounding (when the carrier comes to a complete stop during transit to/from the terminal and is no longer able to manoeuvre) as a result of impacting the seabed or shoreline;
- The LNG carrier striking a navigation aid or the jetty structure, and
- Striking moored LNG Carrier by passing traffic.

Although no breach of containment has occurred from collision incidents in over three decades of LNG carrier operation, release of LNG is possible if there is sufficient penetration energy. That energy depends on the displacement, speed, design and angle of contact of the striking vessel.

The probability of the occurrence of a collision between LNG carrier and other vessel is governed by:

- Mechanical failure (propulsion or steering gear);
- Non-compliance with the Collision Regulations;
- Density of traffic within navigable waterway restricting room to manoeuvre;
- Environmental factors (visibility, current velocity and wind speed and direction); and
- Human error (pilot inexperience with carrier manoeuvrability, wrong helm instruction or incorrect application of helm command).

Grounding refers to the incident of an LNG carrier coming to a complete stop and no longer able to manoeuvre as a result of impacting the seabed or shoreline. Although no breach of containment has occurred from grounding incidents in over three decades of LNG carrier operation, there is potential for release of cargo after grounding. For a smooth seabed of sand or mud, penetration energy is usually spread over a large area of the carrier and with cushioning effect, penetration through the double hull into the containment system is less likely. Rocky bottoms cause more jagged penetrations with the impact being absorbed over a much smaller area and hence the greater risk for damage to the containment.

The probability of the occurrence of a powered grounding is governed by:

- Carrier draft versus projected water depth;
- Navigable channel dimensions;
- Navigation aids missing or not in charted position;
- Environmental factors (visibility, current velocity and wind speed and direction);
- Collision avoidance manoeuvre;
- Incomplete passage plan; and
- Inexperience of pilot with carrier manoeuvrability.

Impact with structures refers to the LNG carrier making unplanned contact with the channel approach or turning circle navigation aids (allision) or with the jetty during the approach manoeuvre.

The potential for a breach of containment as a result of a LNG carrier striking a fixed object in the vicinity of the terminal would be dependent upon the speed and angle of impact. In order for such an incident to occur, there would have to be a failure in navigational procedures, tug control, mechanical failure, or excessive speed during the approach manoeuvre.

Grounding incidents are not a common occurrence in Hong Kong waters given the provision of delineated navigable fairways, deep water and traffic control. The consequence of grounding at slow speed during the carrier approach and departure is unlikely to include breach of containment but could cause operational limitations if the outer hull is penetrated.

In the final approach to the jetty laden (arriving) LNG carriers should be under tug control and as such this hazard is of a lesser order than collision or grounding as significant damage to the LNG carrier hull is unlikely.

The probability of the occurrence for an LNG carrier striking the jetty structure during approach is governed by:

- Mechanical failure (carrier propulsion or steering gear);
- Environmental conditions (wind speed exceeds forecast, current velocity and direction not as predicted);
- Number and performance of assist tugs;
- Mechanical failure of tug(s);
- Human error (pilot inexperience in docking manoeuvre); and
- Excessive approach speed without parallel landing on fenders.

Impact resulting from an LNG carrier being struck while moored at the jetty is also a potential hazard. The factors impacting the potential for impact while moored are similar to those presented above for ship collision. The probability of striking the LNG carrier at the jetty is governed by:

- Proximity to other traffic;
- Nature and volume of local traffic;
- Metocean conditions;
- Level of ship handling experience on passing traffic personnel;
- Mechanical failure, propulsion or steering gear; and
- Passing traffic intruding into the prescribed safe distance.

D2 South Soko Island

D2.1 General

The passage of an LNG carrier to the South Soko Island site, based on pilot boarding south of Lamma, can be summarised as follows:

1) From entry to Hong Kong waters, approach to pilot boarding at South Lamma Dangerous Goods Anchorage - This is an open run that does require crossing the outbound ocean going traffic in East Lamma Channel from Hong Kong. No onshore populations are exposed in this node.
2) From pilot boarding at South Lamma Dangerous Goods Anchorage, transit through PRC waters south of spoil grounds, to re-entry to Hong Kong waters and run up the east side of South Soko Island before entering the start of a dredged approach channel on the east side of South Soko Island.
3) Turning basin and short tug assisted manoeuvre to South Soko Island Terminal and reversal to jetty with berthing operation.

The transit south of HKSAR waters will be undertaken in an "open sea" environment with low traffic density, although the crossing of small fishing vessels and fast launches is a concern (although not posing a hazard to the LNG carrier).

Transits to South Soko will require the passage of the LNG carrier within the Zhujiang Estuary Traffic Separation Scheme (TSS). This Scheme has undergone trials and is now being proposed for permanent implementation with the IMO. LNG carriers (assumed to approach HKSAR waters from the East) will enter the westward arm of the Dangan TSS (south of Lantau), and divert northwards near the termination of the TSS to pick up a pilot. The carrier will then re-enter Mainland waters and transit towards the entrance to the Lantau TSS. Just prior to the entrance to the TSS the LNG carrier will turn north to enter the dredged approach channel. For all access manoeuvres the LNG carrier will be travelling in a direction consistent with the TSS. On departure the vessel must cross the TSS to head eastward and should navigate in accordance with the *Collision Regulations, Rule 10 (c)*.

The specific risks associated with each of the three site layouts at South Soko Island are considered in the following sections.

D2.2 Option 1 – Base Case

The approach channel is directly from deep water around the east side of South Soko Island to a turning basin immediately to the south of the Island, with a berthing pocket for the LNG carrier just off the jetty. The jetty is relatively well protected from the monsoon and typhoon waves from the Lantau Island from the north. The route to South Soko Island is largely open waters and there are few vessels.

D2.3 Option 2 – Full Reclamation

The jetty location is the same a Option 1 and therefore the risks are the same.

D2.4 Option 3 – SE Jetty

The approach channel is directly from deep water to a turning basin, with a berthing pocket for the LNG carrier just off the jetty. The jetty is not well protected from typhoon waves. However, it is considered that carriers will not be permitted at these times and will seek shelter elsewhere. The route to South Soko Island is largely open waters and there are few vessels.

D3 Summary for Marine Navigation

While comparing the sites at South Soko it may be identified that the Options 1 & 2 with the long curving dredged access channel pose a greater risk of grounding than the SE jetty. A summary of the parameter values and relative scores derived from the engineering assessment for the construction of the approach channel and turning basin is given in Table D1 below.

Table D1 - Summary for Marine Navigation

Parameter	Option 1 (Base Case)	Option 2 (Full Reclamation)	Option 3 (SE Jetty)
Marine traffic	RS = 3	RS = 3	RS = 3
Grounding potential	RS = 3	RS = 3	RS = 5
LNG carrier striking jetty	RS = 3	RS = 3	RS = 3
Striking of the moored carrier by passing traffic	RS = 3	RS = 3	RS = 3

RS = Relative Score

D4 Scoring for Marine Navigation

Each of the parameters summarised above in Table E1 have also been scored in accordance with the procedure described in Section 2.1.3. The results are shown below in Table D2 for each of the layout sites at South Soko Island. The table also shows the total score for each site derived using the weightings given in Table 2.6.

Table D2 – Scoring for Layout Options at South Soko Island for Marine Navigation

Parameter	Weight	Option 1 (Base Case)		Option 2 (Full Reclamation)		Option 3 (SE Jetty)	
		Score	WS	Score	WS	Score	WS
Marine traffic	0.50	3	1.50	3	1.50	3	1.50
Grounding potential	0.10	3	0.30	3	0.30	5	0.50
LNG carrier striking jetty	0.10	3	0.30	3	0.30	3	0.30
Striking of the moored carrier by passing traffic	0.30	3	0.90	3	0.90	3	0.90
Total Weighted Score			3.00		3.00		3.20
Normalised Score		4.69		4.69		5.00	

From the result of the assessment of all parameters for the marine navigation, it is found that Option 3 is the preferred layout.

Annex 2-A-E

Construction of Facility Foundations for the South Soko Location

E1 Construction of Facility Foundations

E1.1 General

The terminal structures such as pipe racks, terminal facilities and buildings will be mostly supported on ground bearing structures as the area is expected to be underlain by good quality rock. However, where the rock is not present or where filling is undertaken piled foundations will likely be required to reach the rock material beneath, particularly for the heavier structures. The LNG tanks are located within the cut slope areas for which ground bearing raft foundations are anticipated depending on the suitability of the rock beneath the formation level.

The jetty extends from the proposed seawalls to the approach channel for berthing of LNG carriers. The berthing head, trestle, mooring and breasting dolphins will be constructed on a series of pile caps supported on marine bored and/or driven piles founded on rock. The potential access for LNG carriers will be via the waterway entering the approach channel and turning basin before berthing. Piling for the jetty will be constrained by the construction limitations due to significant marine traffic in fairways and restricted areas. These factors are important in the site assessment and comparison process. Mitigation measures will be considered to reduce the length of jetty and the noise and vibrations associated with the pile installation works. During construction, bubble jackets and/or bubble curtain may be considered for the marine piling works, in conjunction with low noise and vibration techniques to reduce the impacts on the surrounding area.

The receiving terminal requires the use of marine access for normal terminal operation, construction plant, materials and labour during construction. Sites with alternative land access will definitely have programme advantages in both construction and operation stages.

E1.2 Assessment Parameters

In order to assess the engineering implications of the marine and on-land installation works at each of the sites the following assessment parameters have been considered: -

- Terminal facility structures
- Jetty piling works
- Water front access

E2 Terminal Facility Structure

E2.1 Option 1 – Base Case

The pipe racks and terminal infrastructures are mainly located on areas of cutting and it is likely that these structures will be founded directly on rock using either pad or piled foundations. All three LNG tanks will be located behind the cut slope and will be supported on a raft foundation on rock.

E2.2 Option 2 – Full Reclamation

The pipe racks and many of the terminal infrastructures are located on reclaimed land to the west of the existing platform and will therefore be supported on piles. The rest of the terminal infrastructure will be located on areas of cutting and it is likely that these structures will be founded directly on rock using pad or pile foundations. All three LNG tanks will be located within the cut slope and will therefore likely be supported on a raft foundation bearing directly onto rock if the quality is found to be sufficient.

E2.3 Option 3 – SE Jetty

The pipe racks and terminal infrastructures are mainly located on areas of cutting and it is likely that these structures will be founded directly on rock using pile foundations. Two of the LNG tanks will be located behind the cut slope and will be supported on a raft foundation on rock. The third future tank is mainly located on reclamation and will be piled.

E3 Jetty Piling Works

E3.1 Option 1 – Base Case

In order to reduce amount of dredging for the approach channel and turning basin, the estimated length of jetty is about 200m. The structure will be supported on either bored or driven piles. The location of the jetty is close to known marine mammal areas and therefore mitigation measures will be required to reduce the noise impact during marine piling installation. This may significantly slow the rate of progress of the works and is therefore less preferable.

E3.2 Option 2 – Full Reclamation

The option 2 site layout has the same jetty as Option 1 and therefore the impact is the same.

E3.3 Option 3 – SE Jetty

In order to reduce the amount of dredging for the approach channel and turning basin, the estimated length of jetty is about 240m. The structure will be supported on either bored or driven piles. The surrounding waters have been identified as a potentially sensitive location for marine life and therefore mitigation measures will be required to reduce the noise impact during marine piling installation. This may significantly slow the rate of progress of the works and is therefore less preferable.

E4 Water Front Access

South Soko is an island site and requires the use of marine plant access for labour and construction materials, which is available for all site layout options.

E5 Summary for Facility Foundation Construction

A summary of the parameter values and relative scores derived from the engineering assessment for the facility foundation construction is given in Table E1 below.

Table E1 - Summary for Facility Foundation Construction

Parameter	Option 1 (Base Case)	Option 2 (Reclamation)	Option 3 (SE Jetty)
Terminal facility structures piling works	RS = 3	RS = 1	RS = 3
Jetty piling works length (m)	RS = 3 (200)	RS = 3 (200)	RS = 2 (240)
Water front access	RS = 3	RS = 3	RS = 3

RS = Relative Score

E6 Scoring for Facility Foundation Construction

Each of the parameters summarised above in Table E1 have been scored in accordance with the procedure described in Section 2.1.3. The results are shown below in Table E2 for each layout option. The table also shows the total score for each layout derived using the weightings given in Table 2.6.

Table E2 – Scoring for Each Layout Option at South Soko Island for Facility Foundation Construction

Parameter	Weight	Option 1 (Base Case)		Option 2 (Full Reclamation)		Option 3 (SE Jetty)	
		Score	WS	Score	WS	Score	WS
Terminal facility structures piling works	0.3	3	0.90	1	0.30	3	0.90
Jetty piling works length	0.5	3	1.50	3	1.50	2	1.00
Water front access	0.2	3	0.60	3	0.60	3	0.60
Total Weighted Score			3.00		2.40		2.50
Normalised Score		5.00		4.00		4.17	

From the result of the assessment of all parameters for the construction of the facility foundations, Option 1 is the preferred layout followed by the Option 3 and Option 2 layout.

Annex 2-A-F

Comparison of the SE Jetty Options for the South Soko Location

F1 Construction of Site Formation Works

F1.1 Assessment Parameters

In order to assess the engineering implications of the on-land formation works at Option 3 and 3D at South Soko the following engineering assessment parameters have been considered: -

- Volume of excavation in soil
- Volume of excavation in rock
- Volume of soil and rock to be removed from site
- Impact of formation works on the overall construction programme
- Extent of slope stabilisation measures required
- Slope maintenance requirements
- Potential future hazard from slopes
- Blasting restrictions

F2 Volume of Excavation in Soil and Rock

F2.1 Option 3 – SE Jetty (3 Tanks Within Cuttings)

An estimated total volume of 0.52 x $10^6 m^3$ of soil and 1.77 x $10^6 m^3$ of rock material will be excavated from the existing slope cuttings. The total excavated volume will be about 2.29 x 10^6 m^3.

F2.2 Option 3D – SE Jetty (2 Tanks Within Cuttings)

The relocation of the provisional third tank to the platform area to the south of the northern hill will reduce the amount of cutting required. This however will be slightly offset by the excavation needed at the hillside near the loading and unloading berth for the purpose for siting the maintenance workshop, control room and administration building.

It is estimated that a total volume of 0.50 x 10^6 m^3 of soil and 1.56 x 10^6 m^3 of rock material will be excavated from the existing slope cuttings. The total excavated volume will be about 2.06 x 10^6 m^3.

F3 Volume of Spoil to be Removed from Site

F3.1 Option 3 – SE Jetty (3 Tanks Within Cuttings)

A minimum surplus of approximately 0.12 x 10^6 m^3 will be created from the site formation works.

F3.2 Option 3D – SE Jetty (2 Tanks Within Cuttings)

Due to the reduced quantity of excavated material generated, the quantity of spoil to be removed is approximately 0.10 x 10^6 m^3.

F4 Extent of Slope Stabilisation Measures

F4.1 Option 3 – SE Jetty (3 Tanks Within Cuttings)

The cuttings for the tank structures will extend to a height of approximately 72m and will be predominantly in rock. The face area of the slope is estimated to be approximately 22,000 m^2. The cuttings for the pipe trestle will extend to a height of approximately 20m and the face area of the slope is estimated to be approximately 10,000 m^2. The rock mass forming the hillside will likely be jointed and fractured for which extensive stabilisation measures will be required including rock bolting, dowelling and buttressing as necessary to prevent toppling, wedge and sliding failures. The soil slopes will be similarly stabilised with soil nails. The natural slope above the cut slope will also require inspection and possibly some stabilising works. Appropriate drainage measures will be required to drain surface run-off away to reduce infiltration into the slopes which could otherwise lead to high water pressure build up and potential failure.

F4.2 Option 3D – SE Jetty (2 Tanks Within Cuttings)

The cuttings for the tank structures will extend to a height of approximately 72m and will be predominantly in rock. The face area of the slope is estimated to be approximately 14,000 m^2. The cuttings for the pipe trestle will extend to a height of approximately 20m and the face area of the slope is estimated to be approximately 10,000 m^2. The stabilisation measures required for the soil and rock slopes will be similar to Option 3, albeit in a much smaller scale.

F5 Slope Maintenance Requirements

The cut slopes created for the site formation works are large and extensive i.e., >5m height and will therefore be subject to registration with the government. The slopes will be categorised as Category 1 in view of their consequence to life. As such the slopes will be subject to Routine Maintenance Inspections each year and Engineer Inspections for Maintenance every 5 years. The slope maintenance requirements may therefore be considered as being similar for both options, with Option 3D having the lower risk of the two as the slope area involved in smaller due to the relocation of the provisional third tank.

F6 Long Term Slope Hazard

The terminal facility will be located adjacent to a high cut slope in soil and rock with an extensive natural slope above it. Even with the slope stabilisation measures and long term maintenance activities there is a risk of future instability. The risk is classified as being similar for both options, with Option 3D having the lower risk of the two as the slope area involved in smaller due to the relocation of the provisional third tank.

F7 Impact of Site Formation Works on Construction Programme

F7.1 Option 3 – SE Jetty (3 Tanks Within Cuttings)

The construction of the storage tanks is on the critical path for the construction of the receiving terminal facility. The excavation within the hillside to create the formation for the tanks is therefore also on the critical path. Assuming an excavation rate of 42,000m^3 per week the excavation works will take approximately 290 days.

F7.2 Option 3D – SE Jetty (2 Tanks Within Cuttings)

Similar to Option 3, the excavation within the hillside to create the formation for the tanks is on the critical path. Assuming an excavation rate of 42,000m^3 per week the excavation works will take approximately 250 days. The impact on the programme is therefore classified as lower than of Option 3.

F8 Blasting Restrictions

The South Soko Island site is approximately 6km south of Lantau Island. There are no significant residential areas near to the site. The only restriction to blasting will be with the supply of emulsion explosive to the site, which is controlled by the Mines and Quarries Department of Hong Kong. However, given the remoteness of the site it is likely that a magazine storage and explosive manufacturing plant will be established on the site, which will overcome this issue. Restrictions to blasting are therefore considered to be low for both options.

F9 Summary for Site Formation Construction

A summary of the parameter values and relative scores derived from the engineering assessment for the site formation construction is given in Table A1 below.

Table F1 - Summary for Site Formation Construction

Parameter	Option 3 (SE Jetty – 3 Tanks Within Cuttings)	Option 3D (SE Jetty – 2 Tanks Within Cuttings)
Volume of excavation in soil (10^6 m³)	RS = 3 (0.52)	RS = 4 (0.50)
Volume of excavation in rock (10^6 m³)	RS = 3 (1.77)	RS = 4 (1.56)
Volume of soil to be disposed of (10^6 m³)	RS = 3 (0.12)	RS = 4 (0.10)
Volume of rock to be disposal of (10^6 m³)	RS = 3 (0.)	RS = 3 (0)
Impact on construction programme (months)	RS = 3 (10)	RS = 4 (8)
Slope stabilisation measures required	RS = 3	RS = 5
Slope maintenance	RS = 3	RS = 5
Future slope hazard	RS = 3	RS = 5
Blasting Risks	RS = 3	RS = 5

F10 Conclusion for Site Formation Construction

It is clear by directly comparing the results of the parameters for each layout in Table F1 above that Option 3D would generate less excavated material and have a smaller impact on the construction programme. Hence Option 3D is the preferred layout.

Annex 2–B

Comparison of South Soko Alternatives

Environmental Assessment

CONTENTS

1 *ENVIRONMENTAL ASSESSMENT*

An evaluation of the potential impacts identified in *Part 2 – Section 2.1* as a result of the construction and operation of each of the South Soko terminal options has been undertaken to determine the key issues. The importance (ie significance) of potential impacts has been evaluated using the concepts described within the aforementioned section. The result of this evaluation is presented below. From these results, a comparison of each preliminary layout (the Layout) and design option is presented based on the number of important or significant issues.

1.1 *ACCIDENTAL SPILLS/LEAKS/DROPPED OBJECTS*

LNG receiving terminals have an excellent safety record, accidental events such as spills and leaks, vessel grounding/ collisions, dropped objects and loss of materials either on land or into the sea during construction or operation of the LNG terminal are potential scenarios which may result in adverse impacts on the environment and personnel injury.

The severity of impacts as a result of accidental events will depend on a number of factors including the nature of the event (ie type of hazard – hazardous material release, physical impact etc.), the magnitude of the event (eg quantities of material actually released) as well as the sensitivity of the environment at the accident location/ impact site.

Whilst the consequences (ie scale of damage) resulting from accidental events may be severe, the likelihood of their occurrence is typically unlikely to very unlikely. However, this resultant low level of risk associated with such events is traditionally only achieved by the application of the highest standards of HSE management including hazard identification, risk assessment and the implementation of extensive control and recovery measures. Nevertheless, regardless of the layout and design each option is considered to have a negligible impact due to the unlikely event of such an event occurring.

The evaluation of impacts as a result of accidental spills/leaks/dropped objects for each of the South Soko terminal layout options are presented in *Table 1.1*.

Table 1.1 Evaluation of Impacts for Accidental Spills/Leaks/Dropped Objects

		Air			Noise	Waste		Water			Terr. Ecol.		Marine Ecology					Fisheries*			Landscape and Visual			Cultural Heritage			Hazard to Life	
Activity/Hazard	Option	Air Pollution	Dust	Global Warming	Airborne Noise	Waste Storage Facilities	Waste Disposal Facilities	Hydrodynamics	Water Quality	Groundwater Characteristics	Habitat and Vegetation	Wildlife, Birds and Aquatic Fauna	Intertidal Habitats	Subtidal Habitats	Marine Mammals	Underwater Noise	Ecological Risk	Spawning and Nursery Habitat	Fisheries Resources	Fishing Operations	Landscape	Visual (Aesthetics)	Tourism/Recreation	Designated Buildings	Archaeological Sites	Cultural Resources/Graves	Onsite Health and Safety	Offsite Health and Safety
Construction																												
Accidental Spills/ Leaks/ Dropped Objects	Base Case								Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible			Negligible	Negligible									
	Full Reclamation								Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible			Negligible	Negligible									
	South East Jetty								Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible			Negligible	Negligible									
Operation																												
Accidental Spills/ Leaks/ Dropped Objects	Base Case								Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible			Negligible	Negligible									
	Full Reclamation								Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible			Negligible	Negligible									
	South East Jetty								Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible			Negligible	Negligible									

Key

- Positive Effect (blue)
- Negligible Effect (orange)
- Low Impact (green)
- Medium Impact (yellow)
- High Impact (brown)

* Underwater noise for fisheries has not been assessed as no underwater blasting would be conducted

1.2 *AIR EMISSIONS*

Air quality impacts may potentially arise through the following:

- Construction vehicle/equipment/ vessels engine exhaust emissions (eg. primarily NOx, CO, NMHC (non methane hydrocarbon) and small quantities of SO_2, particulates and smoke);
- Construction emissions from concrete batching plant; and,
- Operational emissions from SCVs, LNG carrier generators during unloading of LNG, gas-turbine generators, onsite vehicles, emergency generators, diesel-driven firewater pumps and the hydrocarbon emissions from emergency venting (e.g., NOx, CO, SO_2 and HC).

Due to the relatively remote location of the South Soko terminal and the implementation of good site practice and the control measures stipulated in the *Air Pollution Control (Construction Dust) Regulation*, the adverse air quality impact arising from the above potential sources during construction phase is not expected.

Associated impacts are therefore considered to be negligible for all options. Emissions associated with the concrete batching plant to be located during construction works may, however, result in low impacts to air quality, regardless of layout design. Similarly, as each layout would require the installation of provisions for emergency venting of gas, potentially low impacts to air quality may result during operations. Impacts to air quality may also affect visibility, hence aesthetics, albeit likely to be of negligible impact for all layout options.

The evaluation of impacts to air emissions for each of the South Soko terminal layout options are presented in *Table 1.2*.

Table 1.2 Evaluation of Impacts for Air Emissions

Activity/Hazard	Option	Air			Noise	Waste		Water			Terr. Ecol.		Marine Ecology					Fisheries*			Landscape and Visual			Cultural Heritage			Hazard to Life	
		Air Pollution	Dust	Global Warming	Airborne Noise	Waste Storage Facilities	Waste Disposal Facilities	Hydrodynamics	Water Quality	Groundwater Characteristics	Habitat and Vegetation	Wildlife, Birds and Aquatic Fauna	Intertidal Habitats	Subtidal Habitats	Marine Mammals	Underwater Noise	Ecological Risk	Spawning and Nursery Habitat	Fisheries Resources	Fishing Operations	Landscape	Visual (Aesthetics)	Tourism/Recreation	Designated Buildings	Archaeological Sites	Cultural Resources/Graves	Onsite Health and Safety	Offsite Health and Safety
Construction																												
Air Emissions	Base Case	Low Impact		Negligible Effect																		Negligible Effect						
	Full Reclamation	Low Impact		Negligible Effect																		Negligible Effect						
	South East Jetty	Low Impact		Negligible Effect																		Negligible Effect						
Operation																												
Air Emissions	Base Case	Low Impact		Negligible Effect																		Negligible Effect						
	Full Reclamation	Low Impact		Negligible Effect																		Negligible Effect						
	South East Jetty	Low Impact		Negligible Effect																		Negligible Effect						

Key

- Positive Effect (cyan)
- Negligible Effect (orange)
- Low Impact (green)
- Medium Impact (yellow)
- High Impact (brown)

* Underwater noise for fisheries has not been assessed as no underwater blasting would be conducted

1.3 RUN-OFF

Potential sources of impact through run-off during the construction and operation of the LNG terminal may include:

- Rainfall run-off from disturbed site areas/ construction material stockpiles; and,
- Entrainment of debris and refuse in stormwater run-off resulting in the fouling of receiving water resources.

Runoff and drainage from the earthworks and construction areas may contain elevated sediment loads resulting in increased turbidity in the surrounding waters. Such increases may subsequently affect marine organisms that inhabit these waters. Run-off may also contain debris (litter) as well as other contaminants (eg oil, grease, fuels etc) unless effectively controlled on-site.

It is considered that although control measures will likely be enforced to reduce surface run-off in each of the layout options, environmental impacts to resources/receptors would range from negligible (ie aesthetics) to those which may be considered to be of low impact (ie water quality, intertidal/ subtidal habitats, etc) due to the ecological value of these sensitive receivers. Such impacts would be unlikely to differentiate between layout design during either construction or operation of the LNG terminal.

The evaluation of impacts from run-off for each of the South Soko terminal layout options are presented in *Table 1.3*.

Table 1.3 Evaluation of Impacts for Run-off

		Air			Noise	Waste		Water			Terr. Ecol.		Marine Ecology					Fisheries*			Landscape and Visual			Cultural Heritage			Hazard to Life	
Activity/Hazard	Option	Air Pollution	Dust	Global Warming	Airborne Noise	Waste Storage Facilities	Waste Disposal Facilities	Hydrodynamics	Water Quality	Groundwater Characteristics	Habitat and Vegetation	Wildlife, Birds and Aquatic Fauna	Intertidal Habitats	Subtidal Habitats	Marine Mammals	Underwater Noise	Ecological Risk	Spawning and Nursery Habitat	Fisheries Resources	Fishing Operations	Landscape	Visual (Aesthetics)	Tourism/Recreation	Designated Buildings	Archaeological Sites	Cultural Resources/Graves	Onsite Health and Safety	Offsite Health and Safety
Construction																												
Run-off	Base Case								Low Impact	Negligible Effect			Low Impact	Low Impact				Low Impact	Low Impact			Negligible Effect						
	Full Reclamation								Low Impact	Negligible Effect			Low Impact	Low Impact				Low Impact	Low Impact			Negligible Effect						
	South East Jetty								Low Impact	Negligible Effect			Low Impact	Low Impact				Low Impact	Low Impact			Negligible Effect						
Operation																												
Run-off	Base Case								Low Impact	Negligible Effect			Low Impact	Low Impact				Low Impact	Low Impact			Negligible Effect						
	Full Reclamation								Low Impact	Negligible Effect			Low Impact	Low Impact				Low Impact	Low Impact			Negligible Effect						
	South East Jetty								Low Impact	Negligible Effect			Low Impact	Low Impact				Low Impact	Low Impact			Negligible Effect						

Key

Positive Effect
Negligible Effect
Low Impact
Medium Impact
High Impact

* Underwater noise for fisheries has not been assessed as no underwater blasting would be conducted

1.4 BLASTING

Potential sources of impact through blasting works during the construction of the LNG terminal may include:

- Acute increases in environmental noise and subsequent impacts to biological and human sensitive receivers within proximity to works; and

- Exposure to hazardous substances with subsequent concerns to health and safety.

Each of the three layout options will involve the use of explosive materials to conduct blasting operations during the excavation of rock from the existing hillsides. Regardless of the volume of blasting to be required, magazine storage and explosive manufacturing plant will be temporarily located on site. The storage and use of such materials have the potential to result in adverse impacts through direct exposure to blast materials, ie habitat and terrestrial flora and fauna, and indirect impacts through increased noise, vibration and noise. Although underwater blasting is not necessary for the construction of any of the potential layouts, it can be expected that terrestrial works may have adverse consequences on marine habitats and organisms, albeit likely to be of negligible consequence. Due to the requirement for such works at all sites, impacts are considered to be of a similar severity between layout options.

The evaluation of impacts associated with blasting during construction for each of the South Soko terminal layout options are presented in *Table 1.4*.

Table 1.4 Evaluation of Impacts for Blasting

Activity/Hazard	Option	Air			Noise	Waste		Water			Terr. Ecol.		Marine Ecology					Fisheries*			Landscape and Visual			Cultural Heritage			Hazard to Life	
		Air Pollution	Dust	Global Warming	Airborne Noise	Waste Storage Facilities	Waste Disposal Facilities	Hydrodynamics	Water Quality	Groundwater Characteristics	Habitat and Vegetation	Wildlife, Birds and Aquatic Fauna	Intertidal Habitats	Subtidal Habitats	Marine Mammals	Underwater Noise	Ecological Risk	Spawning and Nursery Habitat	Fisheries Resources	Fishing Operations	Landscape	Visual (Aesthetics)	Tourism/Recreation	Designated Buildings	Archaeological Sites	Cultural Resources/Graves	Onsite Health and Safety	Offsite Health and Safety
Construction																												
Blasting	Base Case	Low Impact	Low Impact		Low Impact						Medium Impact	Low Impact			Negligible Effect	Negligible Effect			Negligible Effect								Medium Impact	Negligible Effect
	Full Reclamation	Low Impact	Low Impact		Low Impact						Medium Impact	Low Impact			Negligible Effect	Negligible Effect			Negligible Effect								Medium Impact	Negligible Effect
	South East Jetty	Low Impact	Low Impact		Low Impact						Medium Impact	Low Impact			Negligible Effect	Negligible Effect			Negligible Effect								Medium Impact	Negligible Effect

Key

- Positive Effect (turquoise)
- Negligible Effect (orange)
- Low Impact (green)
- Medium Impact (yellow)
- High Impact (brown)

* Underwater noise for fisheries has not been assessed as no underwater blasting would be conducted

1.5 DISCHARGES TO SOIL/ GROUNDWATER

Potential sources of soil and groundwater contamination associated with the construction and operation of the LNG terminal may include:

- Inappropriate storage/ handling and disposal of waste materials;
- Accidental spills and leaks of environmentally hazardous materials (oils, cleaning residues, hazardous materials etc); and
- Inappropriate management and control of on-site operations (including effluents, fuel and hazardous material storage and use etc).

Minor spills during re-fuelling, lube/ hydraulic oil, oil filter etc. change-outs from construction equipment (eg generator sets) and vehicles have the potential to result in localised contamination. A leak from a temporary fuel storage tank has the potential to cause significant soil and groundwater contamination. Risks of soil and groundwater contamination can be controlled via effective operational and hardware control measures. Providing such measures are identified and are implemented in an effective manner, risks of contamination can be maintained to within acceptable levels. For the purposes of this consideration of alternatives, it has been determined that each layout would have the potential to result in similar environmental impacts to resources/receptors, regardless of configuration or design.

The evaluation of impacts associated with discharges to soil/groundwater for each of the South Soko terminal layout options are presented in *Table 1.5*.

Table 1.5 Evaluation of Impacts for Discharges to Soil/Groundwater

		Air			Noise	Waste		Water			Terr. Ecol.		Marine Ecology					Fisheries*			Landscape and Visual			Cultural Heritage			Hazard to Life	
Activity/Hazard	Option	Air Pollution	Dust	Global Warming	Airborne Noise	Waste Storage Facilities	Waste Disposal Facilities	Hydrodynamics	Water Quality	Groundwater Characteristics	Habitat and Vegetation	Wildlife, Birds and Aquatic Fauna	Intertidal Habitats	Subtidal Habitats	Marine Mammals	Underwater Noise	Ecological Risk	Spawning and Nursery Habitat	Fisheries Resources	Fishing Operations	Landscape	Visual (Aesthetics)	Tourism/Recreation	Designated Buildings	Archaeological Sites	Cultural Resources/Graves	Onsite Health and Safety	Offsite Health and Safety
Construction																												
Discharges to Soil/ Groundwater	Base Case								Low Impact	Medium Impact	Low Impact	Low Impact																
	Full Reclamation								Low Impact	Medium Impact	Low Impact	Low Impact																
	South East Jetty								Low Impact	Medium Impact	Low Impact	Low Impact																
Operation																												
Discharges to Soil/ Groundwater	Base Case								Low Impact	Medium Impact	Low Impact	Low Impact																
	Full Reclamation								Low Impact	Medium Impact	Low Impact	Low Impact																
	South East Jetty								Low Impact	Medium Impact	Low Impact	Low Impact																

Key

- Positive Effect (turquoise)
- Negligible Effect (orange)
- Low Impact (green)
- Medium Impact (yellow)
- High Impact (brown)

* Underwater noise for fisheries has not been assessed as no underwater blasting would be conducted

1.6 *EFFLUENTS (CLEANING/RECYCLING/DISPOSAL)*

Potential impacts to resources/receptors through effluent (cleaning/recycling/disposal) associated with the construction and operation of the LNG terminal may include:

- Wastewater from typical construction activities (eg. concreting, dredged spoil storage/ removal, painting etc);
- Sanitary effluents from temporary chemical toilets for construction workers' day use; and
- Routine disposal of operational effluents (ie 'black water' composed of human body wastes from toilets and urinals and 'grey water' from showers, sinks, laundries, kitchens etc) from operational staff.

In order to clean/recycle/dispose of effluents generated through the construction and operation of the LNG terminal it is expected that a small-scale package, such as a Blivet Sewage Treatment Works or RBC plant, will be installed during both phases of works. Treated construction phase effluent will be discharge through a temporary outfall.

During the operational phases, effluent is expected to be treated and disposed offshore via a combined sewage and cooled water discharge outfall. Although all effluent will be treated to meet the required discharge standards prior to mixing within the outfall, the potential for impacts to the surrounding water body and consequently the marine flora and fauna located within it, would be expected to have the potential to undergo an increase in impact likelihood. Such impacts would, however, be expected to be of limited time duration and low severity.

For the purposes of this consideration of alternatives, it has been determined that each layout would have the potential to result in similar environmental impacts to resources/receptors as a result of effluent generation and discharge, regardless of configuration or design.

The evaluation of impacts from effluents (cleaning/recycling/disposal) for each of the South Soko terminal layout options are presented in *Table 1.6*.

Table 1.6 Evaluation of Impacts for Effluents (Cleaning/Recycling/Disposal)

Activity/Hazard	Option	Air			Noise	Waste		Water			Terr. Ecol.		Marine Ecology					Fisheries*			Landscape and Visual			Cultural Heritage			Hazard to Life	
		Air Pollution	Dust	Global Warming	Airborne Noise	Waste Storage Facilities	Waste Disposal Facilities	Hydrodynamics	Water Quality	Groundwater Characteristics	Habitat and Vegetation	Wildlife, Birds and Aquatic Fauna	Intertidal Habitats	Subtidal Habitats	Marine Mammals	Underwater Noise	Ecological Risk	Spawning and Nursery Habitat	Fisheries Resources	Fishing Operations	Landscape	Visual (Aesthetics)	Tourism/Recreation	Designated Buildings	Archaeological Sites	Cultural Resources/Graves	Onsite Health and Safety	Offsite Health and Safety
Construction																												
Effluents (Cleaning/Recycling/Disposal)	Base Case								Low Impact	Negligible Effect			Negligible Effect	Low Impact				Low Impact	Low Impact									
	Full Reclamation								Low Impact	Negligible Effect			Negligible Effect	Low Impact				Low Impact	Low Impact									
	South East Jetty								Low Impact	Negligible Effect			Negligible Effect	Low Impact				Low Impact	Low Impact									
Operation																												
Effluents (Cleaning/Recycling/Disposal)	Base Case								Low Impact	Negligible Effect			Negligible Effect	Low Impact				Low Impact	Low Impact									
	Full Reclamation								Low Impact	Negligible Effect			Negligible Effect	Low Impact				Low Impact	Low Impact									
	South East Jetty								Low Impact	Negligible Effect			Negligible Effect	Low Impact				Low Impact	Low Impact									

Key: Positive Effect; Negligible Effect; Low Impact; Medium Impact; High Impact

* Underwater noise for fisheries has not been assessed as no underwater blasting would be conducted

1.7 EXCAVATION

Excavation will be required for each layout option as part of the construction of the South Soko terminal for the following reasons:

- To enable the tanks to be founded directly onto rock which will permit the use of pad/raft foundations, thus negating the need for deep foundations; and
- To screen the tanks from the visually sensitive receivers on the south side of Lantau island.

Impacts associated with the excavation of material associated with the construction will primarily occur through dust generated from excavation activities, increase in terrestrial noise and visual and aesthetic impacts through alteration of the existing landscape. In addition, due to the identification of sites of archaeological interest and cultural resources within the areas required to be excavated, impacts to such will occur.

On the basis of the designs of each layout, Options 1 and 3 will require the excavation of approximately 2.1 Mm^3 and 2.3 Mm^3, respectively, of soil and rock. In contrast, Option 2 will only require the excavation of approximately 1.3 Mm^3 of soil and rock. As the location of the removal of material is relatively similar, ie either the northern or southern hill slopes, or both, it would be fair to assume that the differences in excavated material requirements would have similar differences in the potential for impacts to occur. As such, Option 2 is considered to have less severity of impact than Options 1 and 3.

The evaluation of impacts from excavation for each of the South Soko terminal layout options are presented in *Table 1.7*.

Table 1.7 Evaluation of Impacts for Excavation

Activity/Hazard	Option	Air			Noise	Waste		Water			Terr. Ecol.		Marine Ecology					Fisheries*			Landscape and Visual			Cultural Heritage			Hazard to Life	
		Air Pollution	Dust	Global Warming	Airborne Noise	Waste Storage Facilities	Waste Disposal Facilities	Hydrodynamics	Water Quality	Groundwater Characteristics	Habitat and Vegetation	Wildlife, Birds and Aquatic Fauna	Intertidal Habitats	Subtidal Habitats	Marine Mammals	Underwater Noise	Ecological Risk	Spawning and Nursery Habitat	Fisheries Resources	Fishing Operations	Landscape	Visual (Aesthetics)	Tourism/Recreation	Designated Buildings	Archaeological Sites	Cultural Resources/Graves	Onsite Health and Safety	Offsite Health and Safety
Construction																												
Excavation	Base Case		Low Impact		Low Impact																Medium Impact	Medium Impact		Negligible Effect	High Impact	Low Impact		
	Full Reclamation		Negligible Effect		Low Impact																Negligible Effect	Negligible Effect		Negligible Effect	High Impact	Low Impact		
	South East Jetty		Low Impact		Low Impact																Medium Impact	Medium Impact		Negligible Effect	High Impact	Low Impact		

Key

- Positive Effect (turquoise)
- Negligible Effect (orange)
- Low Impact (green)
- Medium Impact (yellow)
- High Impact (brown)

* Underwater noise for fisheries has not been assessed as no underwater blasting would be conducted

1.8 MARINE ANCHORING

Vessel anchoring (anchor deployment and recovery) within the vicinity of the construction site will result in localised seabed sediment/ substrate disturbance and alterations to the seabed profile. Anchor operations may also result in secondary impacts on water quality (local increases in turbidity) and harm to the subtidal marine fauna living in the seabed. It is likely that any impacts that may occur would be more severe during construction operations when there will be increased marine traffic to the site and the higher likelihood of anchoring occurring. Impacts, however, would be expected to be similar between options regardless of layout design.

The evaluation of impacts from marine anchoring for each of the South Soko terminal layout options are presented in *Table 1.8*.

Table 1.8 Evaluation of Impacts for Marine Anchoring

Activity/Hazard	Option	Air			Noise	Waste		Water			Terr. Ecol.		Marine Ecology					Fisheries*			Landscape and Visual			Cultural Heritage			Hazard to Life	
		Air Pollution	Dust	Global Warming	Airborne Noise	Waste Storage Facilities	Waste Disposal Facilities	Hydrodynamics	Water Quality	Groundwater Characteristics	Habitat and Vegetation	Wildlife, Birds and Aquatic Fauna	Intertidal Habitats	Subtidal Habitats	Marine Mammals	Underwater Noise	Ecological Risk	Spawning and Nursery Habitat	Fisheries Resources	Fishing Operations	Landscape	Visual (Aesthetics)	Tourism/Recreation	Designated Buildings	Archaeological Sites	Cultural Resources/Graves	Onsite Health and Safety	Offsite Health and Safety
Construction																												
Marine Anchoring	Base Case								Negligible Effect					Low Impact														
	Full Reclamation								Negligible Effect					Low Impact														
	South East Jetty								Negligible Effect					Low Impact														
Operation																												
Marine Anchoring	Base Case								Negligible Effect					Negligible Effect														
	Full Reclamation								Negligible Effect					Negligible Effect														
	South East Jetty								Negligible Effect					Negligible Effect														

Key

- Positive Effect (turquoise)
- Negligible Effect (orange)
- Low Impact (green)
- Medium Impact (yellow)
- High Impact (brown)

* Underwater noise for fisheries has not been assessed as no underwater blasting would be conducted

1.9 *MARINE DREDGING AND DISPOSAL*

Marine dredging operations during construction may release sediment into suspension within the surrounding waters by the following mechanisms:

- Impact of the dredging equipment (eg grab, trailer arm) on the seabed as it is lowered;
- Washing of sediment off the outside of the grab as it is raised through the water column and when it is lowered again after being emptied;
- Leakage of water from the grab as it is hauled above the water surface;
- Spillage of sediment from over-full grabs;
- Loss from grabs which cannot be fully closed due to the presence of debris;
- Release by splashing when loading barges by careless, inaccurate methods;
- Disturbance of the seabed as the closed grab is removed, which may be exacerbated by the release of gas (if present) from the disturbed sediments;
- During the transport of dredging materials, sediment may be lost through leakage from barges;
- Changes in hydrodynamics due to changes in bathymetry; and,
- Aesthetic impacts through generation of sediment plumes.

The disposal of this dredged spoil material has the potential to result in a range of direct and indirect adverse impacts including:

- Water column impact (elevated suspended solids levels during spoil discharge);
- Indirect effects on marine ecology due to degraded water quality;
- Alteration of seabed sediments (accumulation of dredged material);
- Smothering effects on benthic (seabed) ecology;
- Indirect effects on fisheries due to both degraded water quality as well as seabed deposition of spoil; and,

- Aesthetic impacts through generation of sediment plumes.

According to the engineering design of the three layouts for the South Soko terminal one of the major differences appears to be in the dredging and subsequent disposal requirements of marine sediments. Both Option 1 – Base Case and Option 2 – Full Reclamation have been estimated to require approximately 3.36 Mm^3 of marine sediments to be removed in order to dredge the approach channel and turning basin to the required depth for safe LNG carrier passage (-15mPD). In contrast, Layout 3 – SE Jetty will only require 1.07Mm^3 of marine sediments to be removed.

The primary difference is the approach channel and turning circle for this layout has been designed to only come into the southeastern side of South Soko Island, which is in contrast to Options 1 and 2 where the channel circumnavigates the southern, eastern and northern sides of the island before ending at the northwest near Sai Wan Bay.

The increased dredging requirements of Options 1 and 2 will have subsequent increases in potentially adverse consequences to resources and receptors, such as those to water quality, marine habitats (both intertidal and subtidal), marine mammals, as well as fisheries resources and operations. These differences have been reflected in the impact severity and likelihood assessments.

The evaluation of impacts from marine dredging and disposal for each of the South Soko terminal layout options are presented in *Table 1.9*.

Table 1.9 Evaluation of Impacts for Marine Dredging and Disposal

Activity/Hazard	Option	Air			Noise	Waste		Water			Terr. Ecol.		Marine Ecology					Fisheries*			Landscape and Visual			Cultural Heritage			Hazard to Life	
		Air Pollution	Dust	Global Warming	Airborne Noise	Waste Storage Facilities	Waste Disposal Facilities	Hydrodynamics	Water Quality	Groundwater Characteristics	Habitat and Vegetation	Wildlife, Birds and Aquatic Fauna	Intertidal Habitats	Subtidal Habitats	Marine Mammals	Underwater Noise	Ecological Risk	Spawning and Nursery Habitat	Fisheries Resources	Fishing Operations	Landscape	Visual (Aesthetics)	Tourism/Recreation	Designated Buildings	Archaeological Sites	Cultural Resources/Graves	Onsite Health and Safety	Offsite Health and Safety
Construction																												
Marine Dredging and Disposal	Base Case						High		High				Medium	Medium	Low	Negligible	Medium	Medium	Medium	Negligible		Medium	Medium		Negligible			
	Full Reclamation						High		High				Medium	Medium	Low	Negligible	Medium	Medium	Medium	Negligible		Medium	Medium		Negligible			
	South East Jetty						Low		Medium				Low	Low	Low	Negligible	Low	Low	Low	Negligible		Low	Low		Negligible			
Operation																												
Marine Dredging and Disposal (Maintenance)	Base Case							Low	Medium				Medium	Medium	Low		Negligible	Medium	Medium	Negligible								
	Full Reclamation							Low	Medium				Medium	Medium	Low		Negligible	Medium	Medium	Negligible								
	South East Jetty							Negligible	Low				Low	Low	Low		Negligible	Low	Low	Negligible								

Key

- Positive Effect
- Negligible Effect
- Low Impact
- Medium Impact
- High Impact

* Underwater noise for fisheries has not been assessed as no underwater blasting would be conducted

1.10 MARINE TRAFFIC

Construction will generate additional marine traffic within and into the study area. Marine vessel traffic generated by the project will include vessels for dredging, construction barges, delivery of equipment, materials and supplies and removal of marine dredged material. These additional construction vessel movements have the potential to cause:

- Increased marine accidents;
- Interference with vessels approaching, departing and moored in the immediate surroundings;
- Interference with other marine vessels, eg recreational, fishing vessels etc.;
- Increase in terrestrial and underwater noise; and
- Increase in likelihood for collision with marine mammals.

For the purposes of this consideration of alternatives, it has been determined that each layout would have the potential to result in similar environmental impacts to resources/receptors as a result of marine traffic, regardless of configuration or design.

The evaluation of impacts from marine traffic for each of the South Soko terminal layout options are presented in *Table 1.10*.

Table 1.10 Evaluation of Impacts for Marine Traffic

		Air			Noise	Waste		Water			Terr. Ecol.		Marine Ecology					Fisheries*			Landscape and Visual			Cultural Heritage			Hazard to Life	
Activity/Hazard	Option	Air Pollution	Dust	Global Warming	Airborne Noise	Waste Storage Facilities	Waste Disposal Facilities	Hydrodynamics	Water Quality	Groundwater Characteristics	Habitat and Vegetation	Wildlife, Birds and Aquatic Fauna	Intertidal Habitats	Subtidal Habitats	Marine Mammals	Underwater Noise	Ecological Risk	Spawning and Nursery Habitat	Fisheries Resources	Fishing Operations	Landscape	Visual (Aesthetics)	Tourism/Recreation	Designated Buildings	Archaeological Sites	Cultural Resources/Graves	Onsite Health and Safety	Offsite Health and Safety
Construction																												
Marine Traffic	Base Case	Negligible													Negligible	Low				Negligible								Negligible
	Full Reclamation	Negligible													Negligible	Low				Negligible								Negligible
	South East Jetty	Negligible													Negligible	Low				Negligible								Negligible
Operation																												
Marine Traffic	Base Case	Negligible			Negligible										Negligible	Low				Negligible								Negligible
	Full Reclamation	Negligible			Negligible										Negligible	Low				Negligible								Negligible
	South East Jetty	Negligible			Negligible										Negligible	Low				Negligible								Negligible

Key

Positive Effect	(turquoise)
Negligible Effect	(orange)
Low Impact	(green)
Medium Impact	(yellow)
High Impact	(brown)

* Underwater noise for fisheries has not been assessed as no underwater blasting would be conducted

1.11 NOISE

The principal sources of noise during construction activities will include:

- Piling (hydraulic hammer type piling rig);
- Blasting (explosives);
- General construction equipment (eg. compressors, cranes, generators sets etc.) and activities (hammering, cutting, grinding, welding etc.); and
- Transport vehicles (cars and trucks)/construction vessels.

It is assumed that the equipment to be employed during the construction of the site would be similar regardless of which layout design would be constructed. Operational noise associated with the terminal is not expected to be severe.

For the purposes of this consideration of alternatives, it has been determined that each layout would have the potential to result in similar environmental impacts to resources/receptors as a result of noise, regardless of configuration or design.

Note that potential ecological impacts and impacts on fisheries associated with underwater noise generated during piling works are included in *Section 1.12* below.

The evaluation of impacts from noise for each of the South Soko terminal layout options are presented in *Table 1.11*.

Table 1.11 Evaluation of Impacts for Noise

		Air			Noise	Waste		Water			Terr. Ecol.		Marine Ecology					Fisheries*			Landscape and Visual			Cultural Heritage			Hazard to Life	
Activity/Hazard	Option	Air Pollution	Dust	Global Warming	Airborne Noise	Waste Storage Facilities	Waste Disposal Facilities	Hydrodynamics	Water Quality	Groundwater Characteristics	Habitat and Vegetation	Wildlife, Birds and Aquatic Fauna	Intertidal Habitats	Subtidal Habitats	Marine Mammals	Underwater Noise	Ecological Risk	Spawning and Nursery Habitat	Fisheries Resources	Fishing Operations	Landscape	Visual (Aesthetics)	Tourism/Recreation	Designated Buildings	Archaeological Sites	Cultural Resources/Graves	Onsite Health and Safety	Offsite Health and Safety
Construction																												
Noise	Base Case				Low Impact							Low Impact			Negligible Effect	Low Impact			Negligible Effect				Negligible Effect				Negligible Effect	
	Full Reclamation				Low Impact							Low Impact			Negligible Effect	Low Impact			Negligible Effect				Negligible Effect				Negligible Effect	
	South East Jetty				Low Impact							Low Impact			Negligible Effect	Low Impact			Negligible Effect				Negligible Effect				Negligible Effect	
Operation																												
Noise	Base Case				Negligible Effect							Low Impact											Negligible Effect				Negligible Effect	
	Full Reclamation				Negligible Effect							Low Impact											Negligible Effect				Negligible Effect	
	South East Jetty				Negligible Effect							Low Impact											Negligible Effect				Negligible Effect	

Key

Positive Effect
Negligible Effect
Low Impact
Medium Impact
High Impact

* Underwater noise for fisheries has not been assessed as no underwater blasting would be conducted

1.12 PILING

Piling will cause vibration in the surrounding seabed/ ground. Driving of piles in water will generate a certain amount of underwater sound. Other underwater sound generation will occur from additional marine construction activity, such as dredging as well as support vessel operations.

Excessive underwater sound generation has the potential to disturb marine life (eg. fish, turtles, mammals etc.). Marine mammals rely on acoustic information to communicate and to explore their environment. Therefore, it is desirable to attenuate any sound generated that has the potential to significantly disrupt communication or echolocation activities of marine mammals near construction activities.

Piling operations will be required for all layouts in order to construct the jetty and trestle for the LNG carrier. Layout Options 1 and 2 of the South Soko terminal would require the jetty to be constructed in the northeastern Sai Wan Bay of South Soko Island, whereas, Option 3 will have the jetty located on the southeastern side of the island.

Long-term monitoring of marine mammal abundance and distribution in these waters (*Part 2 – Section 10*) indicates that marine mammal sightings in the general area of South Soko were infrequent, with more sightings in the waters in the vicinity of Options 1 and 2, compared with waters surrounding the jetty in Option 3. Given the low density of marine mammals near to proposed piling activity, the potential for adverse impacts to occur to marine mammals as a result of marine piling operations is lowest for Option 3.

The evaluation of impacts from piling activities for each of the South Soko terminal layout options are presented in *Table 1.12*.

Table 1.12 Evaluation of Impacts for Piling

		Air			Noise	Waste		Water			Terr. Ecol.		Marine Ecology					Fisheries*			Landscape and Visual			Cultural Heritage			Hazard to Life	
Activity/Hazard	Option	Air Pollution	Dust	Global Warming	Airborne Noise	Waste Storage Facilities	Waste Disposal Facilities	Hydrodynamics	Water Quality	Groundwater Characteristics	Habitat and Vegetation	Wildlife, Birds and Aquatic Fauna	Intertidal Habitats	Subtidal Habitats	Marine Mammals	Underwater Noise	Ecological Risk	Spawning and Nursery Habitat	Fisheries Resources	Fishing Operations	Landscape	Visual (Aesthetics)	Tourism/Recreation	Designated Buildings	Archaeological Sites	Cultural Resources/Graves	Onsite Health and Safety	Offsite Health and Safety
Construction																												
Piling	Base Case				Medium Impact										High Impact	Medium Impact												
	Full Reclamation				Medium Impact										High Impact	Medium Impact												
	South East Jetty				Medium Impact										Medium Impact	Medium Impact												

Key

- Positive Effect (cyan)
- Negligible Effect (orange)
- Low Impact (green)
- Medium Impact (yellow)
- High Impact (dark red)

* Underwater noise for fisheries has not been assessed as no underwater blasting would be conducted

1.13 RECLAMATION

The engineering design of Option 2 – Full Reclamation will require the reclamation of approximately 13 hectares (ha) of existing marine habitats. The majority of reclamation will occur to the west of the existing platform to house the proposed turbine substation, utility area and laydown area. The area to the east of the platform will be used for the service berth.

In comparison, both Options 1 and 2, Base Case and SE Jetty respectively, will require only approximately 1.7 ha of marine habitats to be reclaimed. This will primarily be needed for the utility pier on the west of the platform (or for Tank 3 for the SE Jetty layout) and to the east for the service berth.

The differences in reclamation area will result in subsequent increases in potential impacts to resources and receptors, such as those to water quality, marine habitats (both intertidal and subtidal), marine mammals, fisheries resources and operations as well as visual and aesthetics. These differences have been reflected in the impact severity and likelihood assessments.

The evaluation of impacts from reclamation for each of the South Soko terminal layout options are presented in *Table 1.13*.

Table 1.13 Evaluation of Impacts for Reclamation

Activity/Hazard	Option	Air			Noise	Waste		Water			Terr. Ecol.		Marine Ecology					Fisheries*			Landscape and Visual			Cultural Heritage			Hazard to Life	
		Air Pollution	Dust	Global Warming	Airborne Noise	Waste Storage Facilities	Waste Disposal Facilities	Hydrodynamics	Water Quality	Groundwater Characteristics	Habitat and Vegetation	Wildlife, Birds and Aquatic Fauna	Intertidal Habitats	Subtidal Habitats	Marine Mammals	Underwater Noise	Ecological Risk	Spawning and Nursery Habitat	Fisheries Resources	Fishing Operations	Landscape	Visual (Aesthetics)	Tourism/Recreation	Designated Buildings	Archaeological Sites	Cultural Resources/Graves	Onsite Health and Safety	Offsite Health and Safety
Construction																												
Reclamation	Base Case		Negligible					Low	Low				Negligible	Negligible	Negligible			Negligible	Negligible	Negligible	Negligible	Negligible	Negligible		Negligible			
	Full Reclamation		Negligible					Low	Low				Low	Low	Low			Low	Low	Low	Medium	Medium	Medium		Negligible			
	South East Jetty		Negligible					Low	Low				Negligible	Negligible	Negligible			Negligible	Negligible	Negligible	Negligible	Negligible	Negligible		Negligible			

Key

- Positive Effect
- Negligible Effect
- Low Impact
- Medium Impact
- High Impact

* Underwater noise for fisheries has not been assessed as no underwater blasting would be conducted

1.14 *SITE FORMATION*

Site formation works at each option will involve the consideration of the volume of excavated materials, the potential for afteruse, slope stabilisation and maintenance. It is noted that volumes of excavated material and afteruse are considered under excavation and waste generation and disposal, therefore for the purposes of assessing the environmental consequences of site formation the focus has been to identify any key differences between overall site formation, stabilisation and maintenance.

Each of the three layout options will be prepared, excavated and stabilised in similar formats (see *Section 1.7* above). As such, it is expected that the differences between the three layouts will not be significant enough to differentiate between in terms of environmental impacts. Similar impacts to waste generation and disposal as well as landscape, aesthetics and archaeological resources may then be expected to occur for each layout. Thus, for the purposes of this consideration of alternatives, it has been determined that each layout would have the potential to result in similar environmental impacts to resources/receptors as a result of site formation , regardless of configuration or design.

The evaluation of impacts from site formation for each of the South Soko terminal layout options are presented in *Table 1.14*.

Table 1.14 Evaluation of Impacts for Site Formation

		Air			Noise	Waste		Water			Terr. Ecol.		Marine Ecology					Fisheries*			Landscape and Visual			Cultural Heritage			Hazard to Life	
Activity/Hazard	Option	Air Pollution	Dust	Global Warming	Airborne Noise	Waste Storage Facilities	Waste Disposal Facilities	Hydrodynamics	Water Quality	Groundwater Characteristics	Habitat and Vegetation	Wildlife, Birds and Aquatic Fauna	Intertidal Habitats	Subtidal Habitats	Marine Mammals	Underwater Noise	Ecological Risk	Spawning and Nursery Habitat	Fisheries Resources	Fishing Operations	Landscape	Visual (Aesthetics)	Tourism/Recreation	Designated Buildings	Archaeological Sites	Cultural Resources/Graves	Onsite Health and Safety	Offsite Health and Safety
Construction																												
Site Formation	Base Case					Low Impact	Low Impact														Low Impact	Low Impact	Negligible Effect	Low Impact	Low Impact	Low Impact		
	Full Reclamation					Low Impact	Low Impact														Low Impact	Low Impact	Negligible Effect	Low Impact	Low Impact	Low Impact		
	South East Jetty					Low Impact	Low Impact														Low Impact	Low Impact	Negligible Effect	Low Impact	Low Impact	Low Impact		
Operation																												

Key

- Positive Effect (blue)
- Negligible Effect (orange)
- Low Impact (green)
- Medium Impact (yellow)
- High Impact (brown)

* Underwater noise for fisheries has not been assessed as no underwater blasting would be conducted

1.15 *WASTE GENERATION AND DISPOSAL*

All options will require the excavation of rock from the existing hillsides in order to provide sufficient flat land to meet the functional requirements of the LNG terminal. However, as the Option 2 layout design will involve the construction of a comparatively large area of reclamation, it has been estimated that all excavated material under this design will be able to be reused in the reclamation. In addition, it is expected that up to 1,261,000 m^3 of fill will need to be imported, possibly from existing construction and demolition (C&D) waste storage facilities. Hong Kong is currently storing surplus C&D material, thus the necessity to import such material would be considered to be a positive impact for the Option 2 layout.

In contrast to Option 2, the design of Options 1 and 3, the Base Case and SE Jetty, respectively, will result in a surplus of approximately 0.04 and 0.12 Mm^3 of soil following excavation and construction works. This material will be exported to allocated waste disposal facilities and would be considered as a potentially high impact to such facilities.

The evaluation of impacts waste generation and disposal for each of the South Soko terminal layout options are presented in *Table 1.15*.

Table 1.15 Evaluation of Impacts for Waste Generation and Disposal

		Air			Noise	Waste		Water			Terr. Ecol.		Marine Ecology					Fisheries*			Landscape and Visual			Cultural Heritage			Hazard to Life	
Activity/Hazard	Option	Air Pollution	Dust	Global Warming	Airborne Noise	Waste Storage Facilities	Waste Disposal Facilities	Hydrodynamics	Water Quality	Groundwater Characteristics	Habitat and Vegetation	Wildlife, Birds and Aquatic Fauna	Intertidal Habitats	Subtidal Habitats	Marine Mammals	Underwater Noise	Ecological Risk	Spawning and Nursery Habitat	Fisheries Resources	Fishing Operations	Landscape	Visual (Aesthetics)	Tourism/Recreation	Designated Buildings	Archaeological Sites	Cultural Resources/Graves	Onsite Health and Safety	Offsite Health and Safety
Construction																												
Waste Generation and Disposal	Base Case	Low Impact	Low Impact			High Impact	Negligible Effect																					
	Full Reclamation	Negligible Effect	Negligible Effect			Positive Effect	Negligible Effect																					
	South East Jetty	Low Impact	Low Impact			High Impact	Negligible Effect																					
Operation																												
Waste Generation and Disposal	Base Case					Negligible Effect	Negligible Effect																					
	Full Reclamation					Negligible Effect	Negligible Effect																					
	South East Jetty					Negligible Effect	Negligible Effect																					

Key

- Positive Effect
- Negligible Effect
- Low Impact
- Medium Impact
- High Impact

* Underwater noise for fisheries has not been assessed as no underwater blasting would be conducted

1.16 ANTIFOULANTS

During the operation of the LNG terminal discharges will include cooled water, as seawater will be used for warming the LNG in the Open Rack Vaporizers. For operational reasons, the discharges will likely contain antifoulants. Although all discharges will be designed to comply with the *Water Pollution Control Ordinance Technical Memorandum on Standards for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters,* impact(s) to marine ecological and fisheries habitats within the surrounding waters needs to be assessed and managed.

For the purposes of this consideration of alternatives, it has been determined that each layout would have the potential to result in similar environmental impacts to resources/receptors as a result of antifoulant discharge, regardless of configuration or design.

The evaluation of impacts from antifoulants for each of the South Soko terminal layout options are presented in *Table 1.16*.

Table 1.16 Evaluation of Impacts for Antifoulants

		Air			Noise	Waste		Water			Terr. Ecol.		Marine Ecology					Fisheries*			Landscape and Visual			Cultural Heritage			Hazard to Life	
Activity/Hazard	Option	Air Pollution	Dust	Global Warming	Airborne Noise	Waste Storage Facilities	Waste Disposal Facilities	Hydrodynamics	Water Quality	Groundwater Characteristics	Habitat and Vegetation	Wildlife, Birds and Aquatic Fauna	Intertidal Habitats	Subtidal Habitats	Marine Mammals	Underwater Noise	Ecological Risk	Spawning and Nursery Habitat	Fisheries Resources	Fishing Operations	Landscape	Visual (Aesthetics)	Tourism/Recreation	Designated Buildings	Archaeological Sites	Cultural Resources/Graves	Onsite Health and Safety	Offsite Health and Safety
Operation																												
Anitfoulants	Base Case								Medium				Low	Low			Medium	Low	Low	Low								
	Full Reclamation								Medium				Low	Low			Medium	Low	Low	Low								
	South East Jetty								Medium				Low	Low			Medium	Low	Low	Low								

Key

Key	
Positive Effect	Blue
Negligible Effect	Orange
Low Impact	Green
Medium Impact	Yellow
High Impact	Brown

* Underwater noise for fisheries has not been assessed as no underwater blasting would be conducted

1.17 *COOLED WATER DISCHARGE*

As mentioned above, the operation of the terminal is expected to involve the intake of seawater into open rack vaporisers and the discharge of cooled seawater. The volume of seawater intake and the cooled seawater in the effluent has the potential to impact marine ecological and fisheries habitats in the surrounding waters through a localised reduction in water temperature.

As with antifoulants, for the purposes of this consideration of alternatives, it has been determined that each layout would have the potential to result in similar environmental impacts to resources/receptors as a result cooled water discharge, regardless of configuration or design.

The evaluation of impacts from cooled water discharge for each of the South Soko terminal layout options are presented in *Table 1.17*.

Table 1.17 Evaluation of Impacts for Cooled Water Discharge

		Air			Noise	Waste		Water			Terr. Ecol.		Marine Ecology					Fisheries*			Landscape and Visual			Cultural Heritage			Hazard to Life	
Activity/Hazard	Option	Air Pollution	Dust	Global Warming	Airborne Noise	Waste Storage Facilities	Waste Disposal Facilities	Hydrodynamics	Water Quality	Groundwater Characteristics	Habitat and Vegetation	Wildlife, Birds and Aquatic Fauna	Intertidal Habitats	Subtidal Habitats	Marine Mammals	Underwater Noise	Ecological Risk	Spawning and Nursery Habitat	Fisheries Resources	Fishing Operations	Landscape	Visual (Aesthetics)	Tourism/Recreation	Designated Buildings	Archaeological Sites	Cultural Resources/Graves	Onsite Health and Safety	Offsite Health and Safety
Operation																												
Cooled Water Discharge	Base Case								Medium Impact				Low Impact	Low Impact				Low Impact	Low Impact	Low Impact								
	Full Reclamation								Medium Impact				Low Impact	Low Impact				Low Impact	Low Impact	Low Impact								
	South East Jetty								Medium Impact				Low Impact	Low Impact				Low Impact	Low Impact	Low Impact								

Key

- Positive Effect (turquoise)
- Negligible Effect (orange)
- Low Impact (green)
- Medium Impact (yellow)
- High Impact (brown)

* Underwater noise for fisheries has not been assessed as no underwater blasting would be conducted

1.18 LAYOUT CHARACTERISTICS

The construction of the reclamation, jetty and dredged areas will result in localised alterations in the water flows (both in terms of velocity and direction). Altered water flows have the potential to result in secondary effects on the sedimentary regime in the vicinity of the site; increased or changed water flow patterns have the potential to result in localised scour (ie. resuspension) of seabed sediments. Conversely the creation of areas of calmer or lower velocity water flows have the potential to result in increased sedimentation effects.

The reclamation requirements for layout Option 2, Full Reclamation, may be expected to potentially change the hydrodynamics in the surrounding waters. Impacts as a result of these changes may occur to water quality, marine ecological and fisheries sensitive receivers. In addition, the extended footprint of the site would likely increase the exposure to visual sensitive receivers, such as those on Lantau Island. Such operational impacts are considered to be a disadvantage of this layout in comparison to the others under investigation.

The evaluation of impacts from the layout characteristics for each of the South Soko terminal layout options are presented in *Table 1.18*.

Table 1.18 Evaluation of Impacts for Layout Characteristics

		Air			Noise	Waste		Water			Terr. Ecol.		Marine Ecology					Fisheries*			Landscape and Visual			Cultural Heritage			Hazard to Life	
Activity/Hazard	Option	Air Pollution	Dust	Global Warming	Airborne Noise	Waste Storage Facilities	Waste Disposal Facilities	Hydrodynamics	Water Quality	Groundwater Characteristics	Habitat and Vegetation	Wildlife, Birds and Aquatic Fauna	Intertidal Habitats	Subtidal Habitats	Marine Mammals	Underwater Noise	Ecological Risk	Spawning and Nursery Habitat	Fisheries Resources	Fishing Operations	Landscape	Visual (Aesthetics)	Tourism/Recreation	Designated Buildings	Archaeological Sites	Cultural Resources/Graves	Onsite Health and Safety	Offsite Health and Safety
Operation																												
Layout Characteristics	Base Case							Low Impact	Low Impact												Low Impact	Low Impact	Negligible Effect			Low Impact		
	Full Reclamation							High Impact	Medium Impact												Low Impact	High Impact	Medium Impact			Low Impact		
	South East Jetty							Low Impact	Low Impact												Low Impact	Low Impact	Negligible Effect			Low Impact		

Key

- Positive Effect (cyan)
- Negligible Effect (orange)
- Low Impact (green)
- Medium Impact (yellow)
- High Impact (brown)

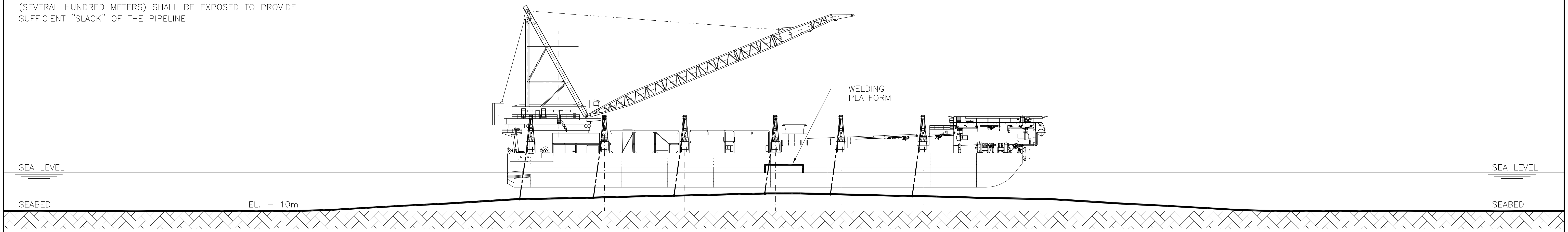
* Underwater noise for fisheries has not been assessed as no underwater blasting would be conducted

Annex 2C

Yacheng Gas Pipeline Information

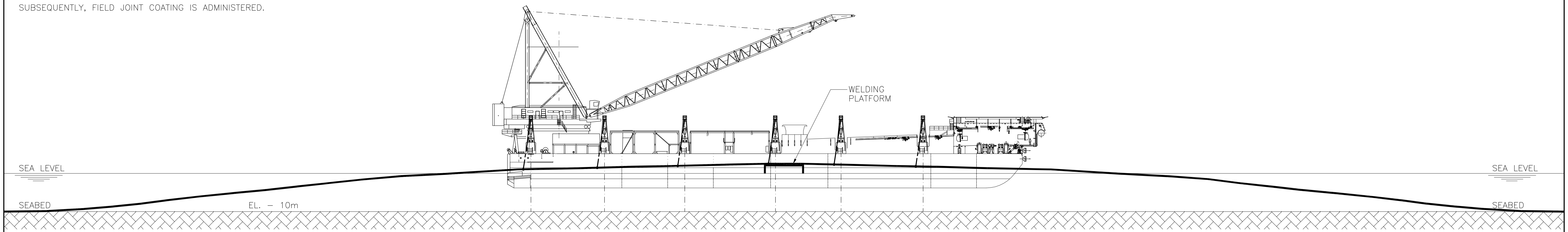
STEP 1

YACHENG PIPELINE IS LIFTED UP USING DAVIT LIFTS AFTER SUCTION DREDGING IS COMPLETED. CONSIDERABLE AMOUNT OF PIPELINE LENGTH (SEVERAL HUNDRED METERS) SHALL BE EXPOSED TO PROVIDE SUFFICIENT "SLACK" OF THE PIPELINE.



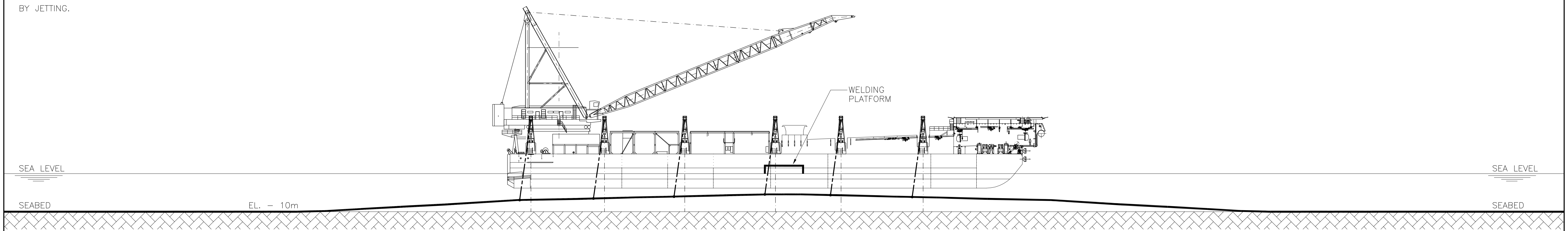
STEP 2

ON BARGE, YACHENG PIPELINE IS CUT FOR A CERTAIN LENGTH TO ACCOMMODATE THE TIE–IN PIECE. WELDED TIE–IN IS FIXED AND SUBSEQUENTLY, FIELD JOINT COATING IS ADMINISTERED.



STEP 3

FOLLOWING COMPLETION OF TIE–IN WELDS THE ASSEMBLY WOULD BE LOWERED TO THE SEABED. BURIAL OF THE PIPE WOULD BE PERFORMED BY JETTING.



中華電力 CLP Power

CLP POWER HONG KONG LTD

AKER KVÆRNER™ Aker Kvaerner SEA Sdn. Bhd.

PROJECT TITLE : CLP - LNG TERMINAL PIPELINE ENGINEERING

KECS PROJECT NO. : 8028.01

SIZE : A3

SCALE : AS SHOWN

TITLE : TIE - IN STEPS

CAD FILENAME : –

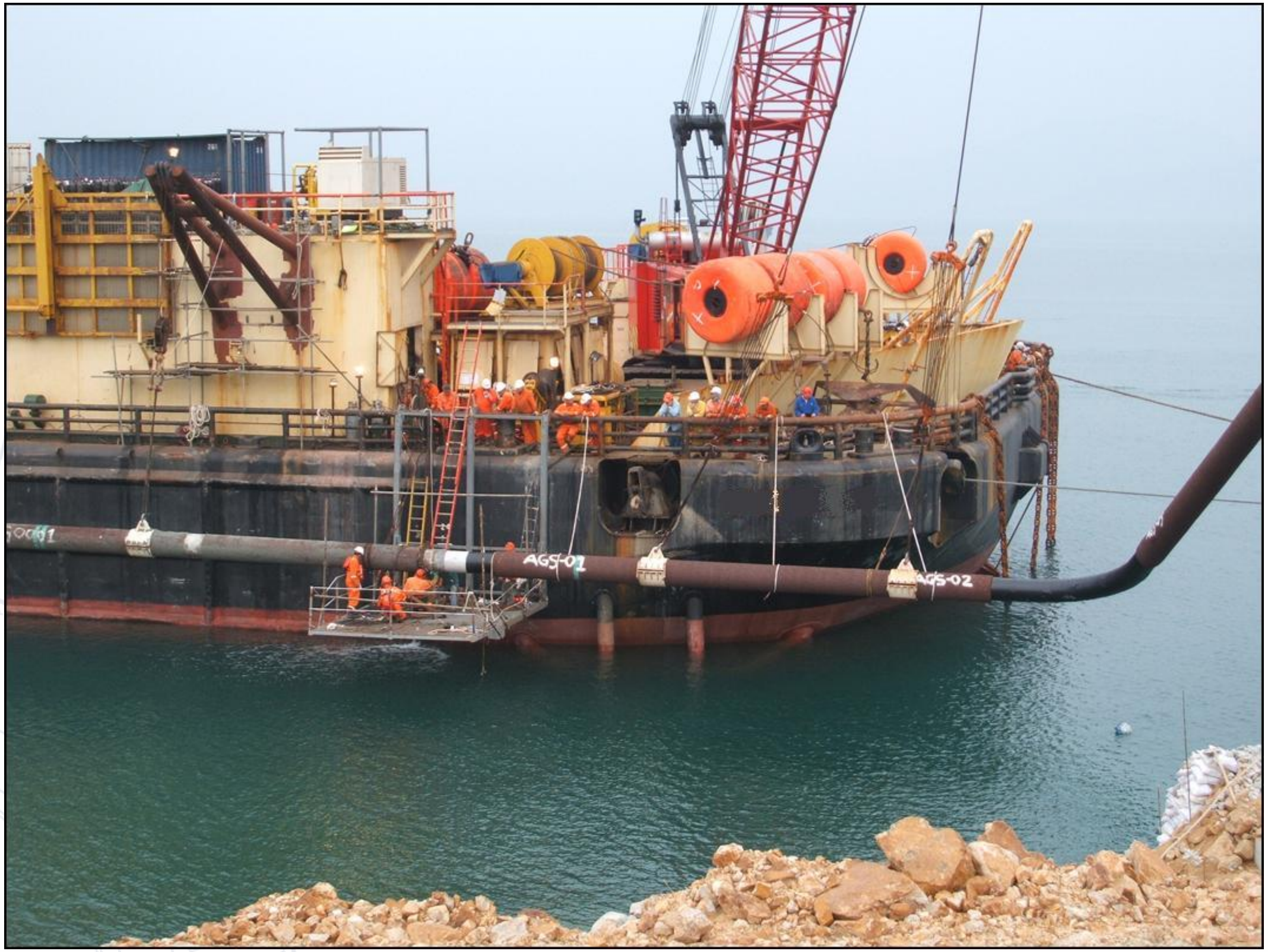
DRAWING NO. SKETCH - 02

SHT NO. -

REV. -

Typical Surface Tie-in

Typical Surface Tie-in



AKER KVÆRNER™

part of the Aker group

Typical Surface Tie-in

AKER KVÆRNER™

part of the Aker group

Annex 2D

Tank Technology Study

Tank Technology Selection Study

For the

Hong Kong LNG Terminal

Initial Issue	January 2006
Revision A	December 2006

Table of Contents

1.0 INTRODUCTION

1.1 Hong Kong LNG Terminal Tank Technology Selection

The Hong Kong LNG Terminal Project has selected the above-ground full containment LNG tank system for the import re-gasification terminal in Hong Kong SAR. This selection is applicable to either South Soko Island or Black Point, the two sites being considered for the LNG terminal.

1.2 Purpose

This document discusses the main reasons for selecting an above-ground full containment LNG storage tank system over an in-ground system. Specifically, our study focuses on the following main aspects of LNG tank storage systems:

- Technical drivers and industry experience
- Environmental impacts
- Economics
- Design and construction standards
- Construction, Operation and Maintenance

2.0 SUMMARY AND CONCLUSIONS

2.1 Summary

In response to questions from the Hong Kong Environmental Protection Department and the Planning Department, this document discusses the main technical reasons for selecting an above-ground LNG storage tank system.

In consideration of the environmental conditions and design drivers, design maturity, construction schedule demand, contractor availability, and cost, we have selected the above-ground full containment tank technology over an in-ground tank design. In-ground tanks would not meet our project schedule to ensure a timely and uninterruptible gas supply to CAPCO.

2.2 Conclusions

In consideration of environmental impacts, design maturity, construction schedule demand, contractor availability, and cost, we have selected the above-ground full containment tank technology over an in-ground membrane tank design for this Project.

- The Hong Kong SAR is a region of low seismic activity. Therefore, the principal design driver of having lower seismic motion amplification offered by in-ground tanks is not utilized.

- The above-ground full containment tank system employs well understood and tested technology for design, construction and commissioning that has been successfully applied world-wide.

- International tank construction contractors have over thirty years of experience of building full containment above-ground tanks. Capable and experienced full containment LNG tank contractors are available from Europe, America and Japan.

- There is a significant cost advantage for above ground full containment tanks. If in ground tanks were employed, a cost increase of at least $3.1 billion HKD is anticipated.

- There is a schedule advantage of approximately two years in constructing above-ground full containment tanks. Given CAPCO's LNG import requirement, the in-ground tank construction would not be able to meet the timely and uninterruptible gas supply schedule due to its longer construction time.

- In-ground tanks require a significant increase in energy consumptions with an associated increase in operating costs.

  – An incremental 1,500 kW would be required to provide the necessary heat freeze protection for operation of the boil off compressors.

- Environmentally, there is a significant improvement by using above-ground tanks versus in-ground tanks.
  - From a Landscape Visual perspective, there would not be a significant improvement in the overall visual impact at the South Soko terminal site if tanks were placed in-ground, as there are significant excavations to be made in either case, and the terminal process area, jetty and LNG carrier would remain visible.
  - From a Waste Management perspective, in-ground tanks would require additional excavation of at least 800,000 m^3 of rock. This represents more than a 50% increase in the total South Soko excavation quantities, and would increase the off-site disposal requirements by 400%.
  - From an Air Quality perspective, this would require the consumption of an additional 66,000 tons of natural gas over the facility life, resulting in incremental CO_2 emissions of 180,000 tons.

3.0 LNG STORAGE AND RETENTION SYSTEMS

All field erected LNG storage tanks have a primary and a secondary containment system. The primary container is for normal operation and the secondary containment is for the highly unlikely event of a leak in the primary container. World wide a variety of storage tank types have been developed and constructed over the years. Those that have been successful can be categorized into the following types:

1. Single containment types have a cylindrical metal primary tank and an earthen dike or bund wall secondary containment. Single containment tanks were the first type developed and are now used mainly in remote locations.

2. Double containment types have a cylindrical metal primary tank and an independent metal or reinforced concrete, open top secondary containment outer tank. This type was developed for small sites; however few have been built because the full containment type, below, was soon developed.

3. Full containment type tanks have a cylindrical metal inner primary tank and metal or pre-stressed concrete outer secondary containment tank structurally independent but combined into one structure. Today full containment tanks are the most common type used.

4. Full containment membrane type has a cylindrical thin metal membrane primary container structurally supported by an outer pre-stressed concrete cylindrical tank. The outer concrete tank also serves as the secondary leak containment. Applications of membrane tanks have been far less than the other types of tanks except in Japan and Korea.

5. Even though all of the above listed structures can be built in-ground, only membrane tanks, type 4, have been regularly built below grade. The outer wall of an in-ground tank is not pre-stressed. The outer wall is held in compression by soil pressure which in turn also supports the LNG's hydrostatic load.

The approximate number of field erected LNG tanks operating worldwide is summarized in the following list[1]:

Single Containment Type	320
Double Containment Type	15
Full Containment Type	110
Membrane Containment Type	30
Membrane In-ground Containment Type	50

[1] The World LNG Source Book, 2004, Gas Technology Institute.

3.1 International LNG Standards

There are two standards normally used to build LNG facilities in the world: the North American standard of NFPA 59A (Incorporates an LNG tank standard of API 620 Appendix Q) and the European standard of EN 1473 (Incorporates an LNG tank standard of BS 7777). The HK LNG facility has elected the European standard (EN 1473 and BS 7777) for it's LNG design standard.

A description of LNG storage tank categories can be found in the European Standard for LNG Facilities (EN1473).

British Standard BS 7777 provides rules for the design, construction and testing of above ground tank types 1 through 3 above. Above ground and in-ground membrane tanks are presently built to proprietary company standards, and are not included in either the European LNG tank standard BS 7777 or the American tank standard API 620Q. It is anticipated that a new European Standard EN 14620 replace BS 7777 and may contain design, construction and testing rules for in-ground and membrane tanks. The Hong Kong Terminal LNG tanks are based on BS 7777, which is a proven standard around the world, available to all LNG tank contractors and has an excellent performance record.

For illustration purpose, we highlight the design characteristics of a full containment tank system, which have been adopted by most recent LNG projects world-wide. Full containment tanks have been selected for this project.

3.2 Full Containment Tank

A tank designed and constructed so that the self-supporting inner tank, which is constructed of 9% Ni steel, contains the LNG. The secondary reinforced and pre-stressed concrete outer tank is capable of containing the LNG and vapor. The inner tank contains LNG under normal operating conditions of near ambient pressure and minus 162^{O}C. The outer tank is capable of both containing any leakage of LNG and controlled venting of vapor created from any LNG leakage. A full containment tank does not require a dike or bund wall to contain any leakage, resulting in saving of space. It is noted that EN1473 does not recognize any failure mode for the full containment LNG tank storage system. Full design, construction and testing requirements for full containment tanks are covered in BS 7777.

4.0 COMPARISON OF FULL CONTAINMENT AND IN-GROUND TANKS

4.1 Environmental

- Being mostly below grade, in-ground tanks have lower visual impact than an above-ground full containment tank. However, in the case of the South Soko Island site, the only visually sensitive receivers are recreational, Tin Hau temple, and grave descendant's visitors to the site. There would not be a significant improvement in the overall visual impact because: 1) there are significant excavations to be made to the site, affecting the visual character, in either case, and 2) the terminal process area, jetty and LNG carrier have a greater degree of visual exposure to the recreational visitor than the tanks.

- The construction of three 180,000 m^3 in-ground LNG tanks requires the removal and disposal of between 800,000 and 1,350,000 m^3 of rock and soil. This represents a 50% to 100% increase in the blasting and excavation required, and would increase rock disposal requirements between 5 and 9 times.

- Construction of in-ground tanks requires over three times as much concrete to construct.

- Because the wall insulation system on a membrane tank is also a structural component it's efficiency is only about one-half of the wall insulation on a full containment tank. Lower thermal efficiency creates boil-off gas that must be removed by compressors. The additional boil-off gas flow increases power consumption by about 750 kW. Therefore, over the 25 year life of the tanks approximately 33,000 tons of additional fuel gas will be consumed generating 90,000 tons of carbon dioxide.

- The storage of LNG in tanks removes small but significant quantities of heat from adjacent surroundings. For in-ground LNG storage systems, electric heating cables are required to eliminate the formation of ice in the surrounding soil. Ice formation can create huge frost heave loads capable of damaging tank foundations and walls. These heaters are in continuous operation.

  Above-ground tanks only require a base heating system, which operates intermittently. Heat from solar gain assists in providing replacement energy. The three 180,000 m^3 in-ground tanks will consume about 680 kW more electrical heating power. Power generation will require approximately 27,000 tons of natural gas and produce about 75,000 tons of CO_2 over a 25 year tank life.

- In most cases, in-ground LNG tanks penetrate natural ground water levels. Ground water can be detrimental to the construction and operation of in-ground LNG tanks. In this regard dewatering wells will be spaced around the tank to lower ground water levels. These well points will operate for the life of the tanks constantly discharging water at the surface. Before in-ground tanks can be utilized, a ground water investigation and a study on the impacts of long term ground water pumping and disposal need to be conducted.

- The life of the facility is assumed to be about 25 years at which time the LNG tanks would be removed and the site returned to previous or other uses. The steel and concrete of a full containment tank can be removed and recycled, creating a useable level plot area. Recycling the concrete from the outer wall of an in-ground tank would be very difficult, if not impossible. Any destruction of the outer wall may cause the earth sides to collapse. Only the top portion of the wall could be reclaimed. To make the area reusable, the holes would need to be filled and compacted with approximately the same amount of rock and soil that was removed.

4.2 Economics

- The capital cost of constructing an in-ground LNG tank is over twice that of a full containment tank. The capital cost increase over full containment tanks is estimated to be greater than HKD $3.1 billion.

- In-ground tanks consume more electrical energy for increased boil-off compression, soil and foundation heating and ground water pumping. The extra power consumption is approximately a constant 1,500 kW load. Assuming the cost of power is HKD $0.88 per kw-hr, and the operating life of the in-ground tanks are 25 years there is an operating cost increase of approximately HKD $290 million over full containment tanks.

4.3 Design and Safety

- When LNG tanks are located in areas of possible aircraft impact full containment tanks have a higher chance of impact than in-ground tanks. However, the Hong Kong LNG Terminal is in a very low impact risk location.

- Structures that are built into the ground generally have reduced acceleration loads generated from seismic events. This is because motions of in-ground storage system follow the seismic ground shaking and are not amplified through the structure of the tank as is the case for an above ground storage system. In addition, sloshing responses of LNG tanks resulting from seismic activity are lower for underground tanks. This however does not mean that an in-ground tank is safer than an above ground tank. It means that an aboveground tank is designed to higher seismic loads than an in-ground tank. In all cases LNG tanks are designed to maximum seismic activity for each tank type and its location.

- Based on the seismic hazard studies, the Hong Kong region is an area of low seismic activity. For example, seismic loading is not explicitly considered for general building design in Hong Kong. Hence, the design driver for selecting underground tank system to lower seismic loads is not applicable and the above-ground storage tanks are an appropriate choice for this location.

- Ground water can be very problematic for in-ground LNG tanks. The density of LNG is less than one-half that of water. If for some reason ground water was to rise around an in-ground tank or leak into it, buoyant forces could lift the tank or displace LNG over the tank wall. However such an event is considered highly unlikely.

4.4 Construction

- From the time of contractor release for the construction of a full containment tank, approximately 36 months are required to design, manufacture, erect, test and prepare for LNG tank cool-down. Approximately 60 months are required for these same activities for in-ground tanks. Because of this two years incremental duration of construction, a facility based on in-ground LNG tanks would not meet the gas supply time line required by CAPCO's LNG import requirement.

- Whereas over 400 above ground LNG storage tanks have been constructed world-wide, about 50 in-ground storage systems have been constructed and these are principally in Japan. With this high number of above-ground LNG tank systems in operations, there is a number of international tank construction contractors proficient with all aspects related to the design, construction, and commissioning of these tanks. The technology involved is well understood and is documented in international codes and standards. As a result a relatively optimized contracting, design and construction process for the above ground tanks is available for the Hong Kong Terminal Project.

- In-ground LNG tanks were developed in Japan making Japan the only source of experienced designers and constructors. Owners outside of Japan have difficulty in locating interested contractors capable of building in-ground tanks outside of Japan.

- Construction of membrane tanks are more labor intensive and require higher skilled workers which are in short supply in Hong Kong.

- Ground water management during construction will likely be difficult at the Hong Kong Terminal site.

- The transportation, storage and use of blasting materials for in-ground hole excavation will create additional construction hazards.

- The membrane on an in-ground tank is only 1.5 mm thick which makes it more likely to be damaged during construction. The thickness of inner tank plates for a full containment tank average about 25 mm.

4.5 Operation and Maintenance

- The soil heating cables on an in-ground tank are located such that they are almost impossible to repair. Redundant heating cables will be installed to lessen the possibility of failure.

- Since most equipment and piping is located on the roof of an LNG tank, access to this equipment is generally easier for in-ground tanks.

- Above-ground LNG tanks do not require the operation and maintenance of dewatering pumps.

- Because much on an in-ground is covered with soil, tank inspection and monitoring is difficult and possible problems may go unnoticed. When problems do occur, it is much harder to repair them. For example, the in-ground tanks in Yung-An (Taiwan) have been leaking for years, but due to the difficulty in pinpointing the leak location and accessibility, have elected not to try to repair the leak.