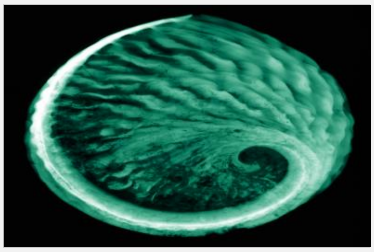
ANNEX A

ENVIRONMENTAL REVIEW REPORT FOR THE MARINE TRANSIT ROUTES OF FSRU VESSEL AND LNG CARRIERS







Hong Kong Offshore LNG Terminal Project

Environmental Review Report for the Marine Transit Routes of FSRU Vessel and LNG Carriers

20 April 2023

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Hong Kong Offshore LNG Terminal Project

Environmental Review Report for the Marine Transit Routes of FSRU Vessel and LNG Carriers

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CONTENTS

Appendix

List of Tables

List of Figures

1. INTRODUCTION

1.1 Background

To support the increased use of natural gas in Hong Kong from 2020 onwards, Castle Peak Power Company Limited (CAPCO) and The Hongkong Electric Co., Ltd. (HK Electric) have identified that the development of an offshore liquefied natural gas (LNG) receiving terminal in Hong Kong using Floating Storage and Regasification Unit (FSRU) technology ('the Project') presents a viable additional gas supply option that will provide energy security through access to competitive gas supplies from world markets. The Project will involve the construction and operation of an offshore LNG import facility to be located in the southern waters of Hong Kong, a double berth jetty, and subsea pipelines that connect to the gas receiving stations (GRS) at the Black Point Power Station (BPPS) and the Lamma Power Station (LPS). The location plan of the Project is shown in ***Figure 1.1***.

According to Section 3.5.1 of the approved Environmental Impact Assessment (EIA) Report (EIAO Register No. AEIAR-218/2018), the visiting LNG carriers (LNGC) would arrive the LNG Terminal from the south and will enter HKSAR waters at the south of the LNG Terminal (see ***Figure 1.2*** for the indicative marine transit route presented in the approved EIA Report). On arrival in HKSAR waters, the LNGC will pick up a Pilot en route to the Jetty, and tugs will accompany the LNGC and assist as necessary along the designated transit route to the Jetty. The tugs will provide assistance in aligning the LNGC in its approach to the Jetty and will control the LNGC speed to enable safe berthing onto the Jetty Breasting Dolphin fenders, until the LNGC is safely and securely moored to the Mooring Dolphins. A 'guard' tug will remain on stand-by in close proximity to the LNG Terminal throughout the LNG Unloading and Loading operations.

As the Project progresses, due to the associated pilotage arrangement, the marine transit routes of FSRU Vessel and LNGC have been further discussed with the relevant authorities. Consequently, the marine transit routes ('Principal Arrival Route' and 'South Departure Route') are determined and agreed with the relevant authorities for implementation to support the operation of the Project. The Principal Arrival Route for the FSRU Vessel and LNGC will enter HKSAR waters at the due east side of the existing CEDD's South Cheung Chau Disposal Ground and will be subject to the prevailing conditions at time being. The South Departure Route for the FSRU Vessel and LNGC with tugs and supporting vessels will need to pass through the South Lantau Marine Park (SLMP) and then travel to the south to Dangan Channel. Navigation simulation analysis was conducted to verify the Principal Arrival Route and South Departure Route based on various constraints (e.g. water depth, sea conditions, marine traffic, etc). The indicative Principal Arrival Route and South Departure Route for FSRU Vessel and LNGC is presented in ***Figure 1.3*** [(1)].

An environmental review is undertaken to assess the potential environmental impact as a result of the update to the marine transit route to the LNG Terminal.

1.2 Purpose of this Report

This *Environmental Review Report* (ERR) is prepared to provide the information of the proposed marine transit routes for the FSRU Vessel and LNGC, and review the likely environmental impacts, particularly hazard to life and ecological impacts assessed in the approved EIA Report. This ERR also provides recommendations as to whether any modification and/or refinement of proposed mitigation measures and monitoring and audit requirements is needed.

(1) It should be noted that the indicative marine routing for LNGC (i.e. Principal Arrival Route for LNGC and South Departure Route for LNGC) has to pass through the South Lantau Marine Park during transit as presented in ***Figure 1.3***. The environmental review presented in this report has considered and assessed the worst case scenario of LNGC passing through the South Lantau Marine Park during marine transit.

1.3 Structure of this Report

Following this introductory section, the remainder of this ERR is organised as follows:

- Section 2 describes the relevant information on marine transit route to the LNG Terminal presented in the approved EIA Report;
- Section 3 presents the proposed marine transit route to the LNG Terminal;
- Section 4 describes the potential impacts associated with the proposed marine transit route to the LNG Terminal;
- Section 5 includes a review of the environmental monitoring and audit requirements; and
- Section 6 provides the conclusions of this environmental review.

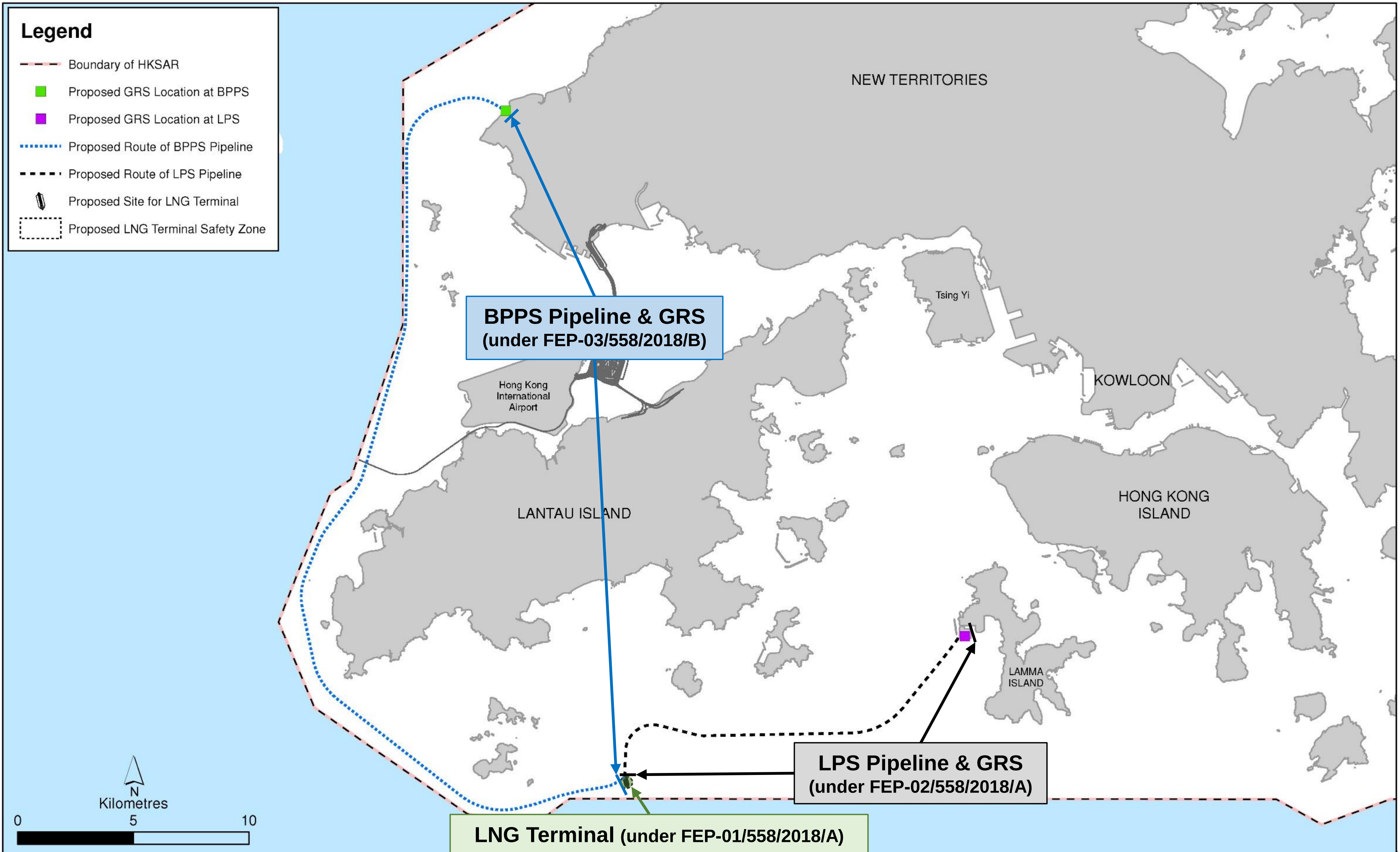

Figure 1.1

Indicative Location of Key Project Components

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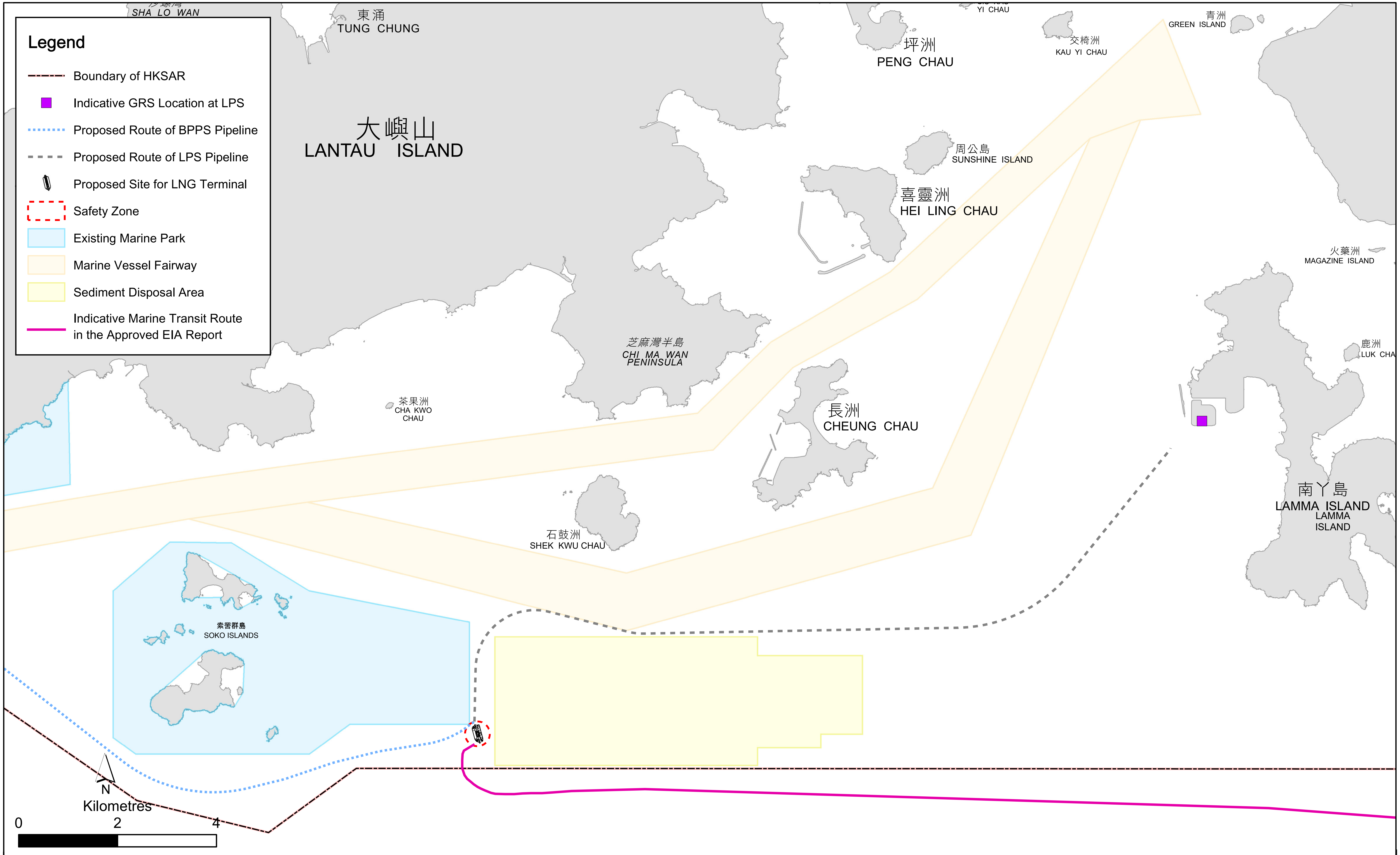

Figure 1.2

Indicative Marine Transit Route in the Approved EIA Report

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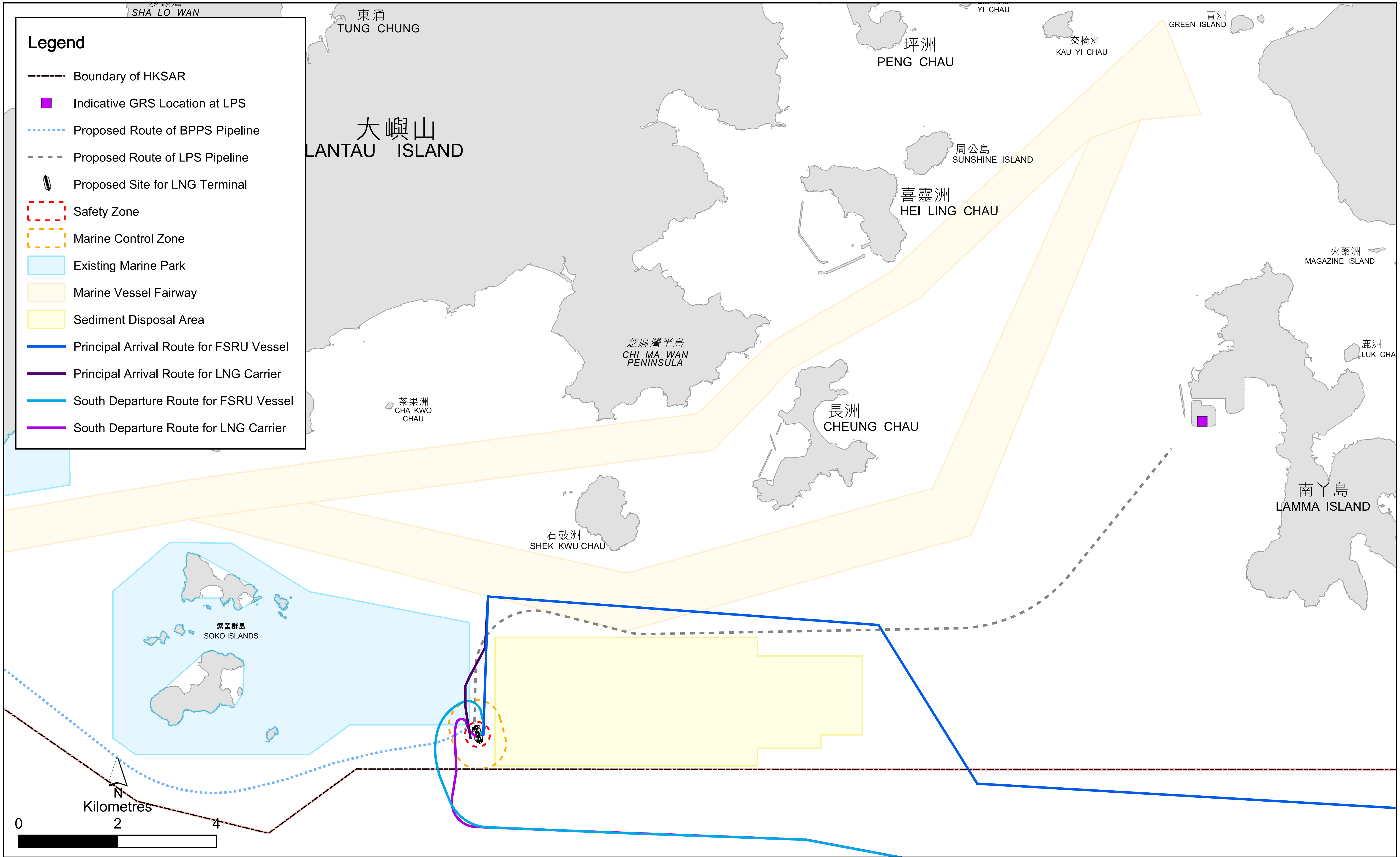

Figure 1.3

Indicative Proposed Marine Transit Route

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2. RELEVANT INFORMATION ON MARINE TRANSIT ROUTE TO THE LNG TERMINAL IN THE APPROVED EIA REPORT

2.1 Description of the Marine Transit Route to the LNG Terminal

According to Section 3.5.1 of the approved EIA Report, the visiting LNGC would arrive the LNG Terminal from the south and will enter HKSAR waters at the south of the LNG Terminal (***Figure 1.2***). This is also the transit route that the FSRU Vessel will follow to arrive at the LNG Terminal. On arrival in HKSAR waters, the LNGC will pick up a Pilot en route to the Jetty, and tugs will accompany the LNGC and assist as necessary along the designated transit route to the Jetty. The tugs will provide assistance in aligning the LNGC in its approach to the Jetty and will control the LNGC speed to enable safe berthing onto the Jetty Breasting Dolphin fenders, until the LNGC is safely and securely moored to the Mooring Dolphins. A 'guard' tug will remain on stand-by in close proximity to the LNG Terminal throughout the LNG Unloading and Loading operations.

Based on the estimated annual gas demand at the BPPS and the LPS that will drive FSRU Vessel throughput, the frequency of LNG deliveries (on average) will be one LNGC arriving every five to eight days. The LNGC will not pass through the SLMP during manoeuvring to the Jetty.

The FSRU Vessel will be permanently moored at the Jetty during normal operations. Due to its safe operational requirement, the FSRU Vessel will need transit through the SLMP during manoeuvring to the Jetty and after typhoon event, which is anticipated to be 3-4 times a year, under pilotage, with the stand-by vessel in attendance and under tug control at a low manoeuvring speed.

Maintenance dredging of jetty area may be required for the LNG Terminal about once every five years (subject to actual site conditions) to ensure continued access and manoeuvrability by the FSRU Vessel and LNGC. It was assumed that the maintenance dredging would be conducted using one grab dredger and the maximum working rate would be 5,500 m^3 day^{-1} (24 hours each day) with the use of a single layer of silt curtain with silt removal efficiency of 75% reduction.

2.2 Key Environmental Impacts Assessed

2.2.1 Air Quality

With reference to Section 4.9.1 of the approved EIA Report, the air quality impact due to visiting LNGC transit was assessed. Given that the LNG deliveries are infrequent and the visiting LNGCs will be operated using boil off gas or low sulphur marine fuel, no unacceptable change to air quality due to LNGC transit will be induced. In addition, no air sensitive receiver (ASR) has been identified within at least 4km from the marine transit route of the visiting LNGCs. Due to the large separation distance between the LNGC marine transit route and the nearest ASR, adverse air quality impact associated with the marine emissions from visiting LNGCs is not anticipated.

2.2.2 Hazard to Life

As presented in Section 5.4 of the approved EIA Report, the support of tug fleet for access to/from the LNG Terminal can enable adequate control capability to mitigate events when LNGC or FSRU Vessel encounter engine or control system failure during the approaching to the LNG Terminal. The individual risk and societal risk associated with the transits of the LNGC and FSRU Vessel are in compliance with the risk criteria stipulated in Section 2 of Annex 4 of the Technical Memorandum on Environmental Impact Assessment Process (EIAO-TM).

2.2.3 Water Quality

With reference to Section 7.8.5 of the approved EIA Report, water quality modelling has been conducted to evaluate the potential elevation of suspended solids (SS) at the nearby water sensitive receiver (WSR) due to the maintenance dredging of jetty area, taking into account the potential concurrent marine works nearby (open sea disposal at South Cheung Chau Disposal Ground). Since the dredging works would be remote from most WSRs, an assessment of the predicted maximum SS elevation at the nearest observation point of the SLMP was made and the modelling results showed that the predicted maximum SS elevation at southeastern boundary of SLMP would be below the corresponding WQO criteria in both wet and dry seasons. No unacceptable water quality impact from maintenance dredging would be expected.

2.2.4 Ecology

With reference to Sections 9.5.2, 9.6.2 and 9.7.2 of the approved EIA Report, the key impacts on marine ecological resources, marine mammals and marine parks relevant to the marine transit routes of FSRU Vessel and LNGC are underwater sound from FSRU Vessel and LNGC transit, increased marine traffic from LNG Terminal operation, temporary habitat loss and disturbance from maintenance dredging and short-term changes in water quality from maintenance dredging, each is summarised below.

2.2.4.1 Underwater Sound from FSRU Vessel and LNGC Transit

It is expected that vessel movements from visiting LNGC and stand-by vessel for day-to-day operation of the LNG Terminal is low and the underwater sound characteristics of the vessels involved are very much similar to those in the area at present from similar marine traffic. Given that marine organisms, including marine mammals, in these waters are habituated to the background level of underwater sound, a small increase in vessel activity associated with the operation of this Project is not anticipated to result in unacceptable impacts on marine ecological resources, including marine mammals, if temporarily present.

The continuous and low level of underwater sound transmitted into the surrounding waters is expected to be of low energy and in lower frequencies (e.g. 20Hz to 2.5kHz between 155 and 185 dB re 1 μPa at 1 m for the FSRU Vessel) which is below the peak range of 8 - 90 kHz and 142 kHz reported for dolphins and porpoises respectively. Thus, Chinese White Dolphins (CWD) and Finless Porpoises (FP) are not expected to be acoustically disturbed. Moreover, since CWD are rarely sighted near the LNG Terminal, impacts on CWD due vessel movement from LNGC transit is negligible. On the other hand, FP inhabit the waters of the LNG Terminal which are high frequency specialists and potential acoustic disturbance impacts would be limited. The functionality of key habitats nearby such as the eastern portion of the SLMP is also not expected to be affected. Thus, impacts of increased underwater sound level from visiting LNGC on marine mammals and the functionality of the SLMP for the conservation of these species are not anticipated.

In addition, most of the sound generated by the LNG Terminal and visiting LNGC will be from engine for power generation and machinery mounted on the decks and platform above the waterline, i.e. airborne. Though continuous, the low level of vibration and underwater sound transmitted into the surrounding waters and the seabed from Project operation is expected to be of low energy and in lower frequencies. This is likely to be absorbed by natural and traffic related background sound. Given that marine organisms, including marine mammals, are habituated to background underwater ground, unacceptable impacts on marine ecological resources, including marine mammals, are not expected if temporarily present.

2.2.4.2 Increased Marine Traffic from LNG Terminal Operation

Vessel movements from visiting LNGC and stand-by vessel expected for the day-to-day operation of the LNG Terminal is low. During operation, tugs will also be used to assist the visiting LNGC at slow speed until berthed alongside the Jetty. Considering the slow speed of these vessels, it is not expected there would be a significant risk of vessel strike due to these vessel movements. Unacceptable adverse impacts of increased marine traffic on marine mammals are not anticipated.

The FSRU Vessel will be permanently moored at the Jetty except during evacuation during typhoon events which is expected to be 3-4 times a year. During evacuation, the FSRU Vessel will need to transit through the SLMP, at a low maneuvering speed. While the LNGC will not pass through the SLMP during maneuvering to the Jetty and after typhoon event. It is expected that no impact to the marine buoy at the corner of SLMP during berthing of the FSRU Vessel and LNGC will incur. In addition, other boats expected for day-to-day operation of the LNG Terminal will travel through the designated fairways and avoid traversing sensitive habitats such as marine parks where practicable. The 10-knot vessel speed limit of the Marine Parks and Reserves Regulations (*Cap. 476A*) will be strictly followed when the stand-by-vessel used in the Project travel through the SLMP. Thus, unacceptable adverse impacts associated with the increased marine traffic on the functionality of the existing, proposed and planned marine parks are not anticipated given the slow speed and low frequency of these vessels.

2.2.4.3 Temporary Habitat Loss, Disturbance and Short-term Changes in Water Quality from Maintenance Dredging

Maintenance dredging at the LNG Terminal may be required once every around five years (subject to site condition) to maintain sufficient clearance for safe navigation of the LNGC. Short-term direct impacts to subtidal bottom assemblages may occur as a result of maintenance dredging if needed, although once completed seabed would be available for recolonisation by benthic fauna. Given the low ecological value of the associated benthic assemblages, no unacceptable impacts are expected.

Potential water quality impacts on ecological assemblage and nearby sensitive receivers from operation phase maintenance dredging would be much less significant than similar activities during construction phase. Sensitive receivers identified are considered to be of sufficient distance from the potential maintenance dredging area and are unlikely to be affected indirectly by impacts to water quality. With the implementation of mitigation measures proposed in the water quality impact assessment, such as the use of silt curtains and appropriate working rate, potential impacts to marine ecological resources are expected to be reduced to within acceptable. Consequently, unacceptable impacts to organisms in the vicinity of the dredging areas arising from elevated SS and nutrient levels, sediment deposition, and depletion of Dissolved Oxygen (DO) are not anticipated.

In the context of the size of the range of marine mammals, the size of the area where maintenance dredging may be needed would be small, which will be confined to the area within the LNG Terminal and will not encroach into SLMP. Considering the infrequent, small scale and temporary nature of the disturbance and the implementation of mitigation measures proposed in the water quality impact assessment such as the use of silt curtains and appropriate working rate, unacceptable impacts on marine mammals and the functionality of marine parks are not expected.

2.2.5 Fisheries

As presented in Section 10.5.2 of the approved EIA Report, impact to fisheries resources due to underwater sound of the FSRU Vessel and visiting LNGC transit was assessed. The vessel movement for the day-to-day operation of the LNG Terminal is very low and the underwater sound characteristics of the vessels involved would be very much similar to those of the existing marine traffic in the area. Fish in these waters are habituated to the background level of underwater sound, and a small increase in vessel activity associated with the operation of this Project is not anticipated to result in unacceptable impacts on fisheries resources.

The scale and extent of maintenance dredging would be much smaller than the marine works of the construction phase. Thus, the potential water quality impacts on fisheries sensitive receivers from operation phase maintenance dredging are considered much lower than those for the construction phase. With the implementation of mitigation measures, such as the use of silt curtains and appropriate working rate, potential impacts to fisheries would be reduced to within acceptable levels.

3. PROPOSED MARINE TRANSIT ROUTES FOR THE FSRU VESSEL AND LNGC

As the Project progresses, due to the associated pilotage arrangement, the marine transit routes of FSRU Vessel and LNGC have been further discussed with the relevant authorities. Consequently, the marine transit routes ('Principal Arrival Route' and 'South Departure Route') is determined and agreed with the relevant authorities for implementation to support the operation of the Project. The Principal Arrival Route for the FSRU Vessel and LNGC will enter HKSAR waters at the due east side of the existing CEDD's South Cheung Chau Disposal Ground and will be subject to the prevailing conditions at time being. The South Departure Route for the FSRU Vessel and LNGC with tugs and supporting vessels will need to pass through the SLMP and then travel to the south to Dangan Channel. Navigation simulation analysis was conducted to verify the Principal Arrival Route and South Departure Route based on various constraints (e.g. water depth, sea conditions, marine traffic, etc). The indicative Principal Arrival Route and South Departure Route for the FSRU Vessel and LNGC are presented in ***Figure 1.3***.

The marine transit routes for the FSRU Vessel and LNGC and the possible maintenance dredging works around the LNG Terminal are discussed in the following sections.

3.1 Proposed Marine Transit Routes

3.1.1 Principal Arrival Route

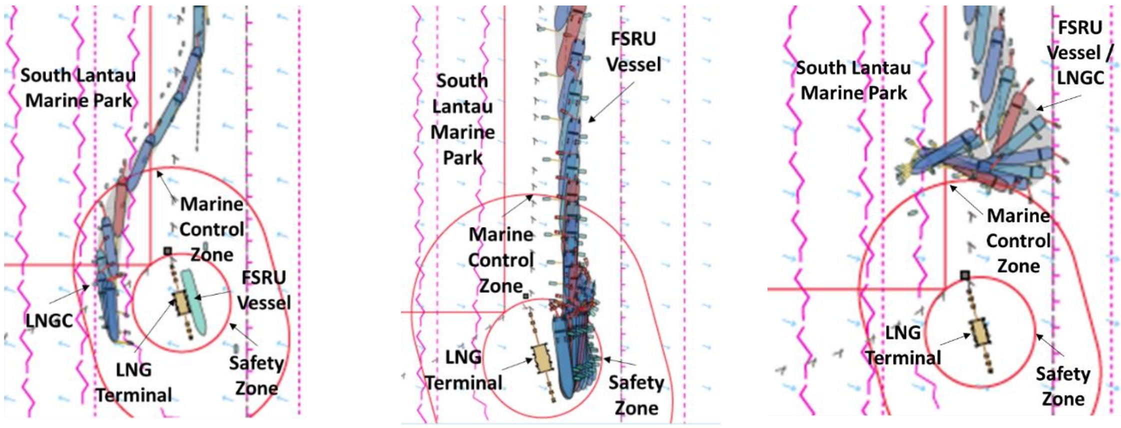
The Principal Arrival Route for FSRU Vessel and LNGC arrival to the LNG Terminal is described as follows.

On arrival in HKSAR waters, the FSRU Vessel / LNGC will firstly enter Hong Kong waters at the due east side of the existing CEDD's South Cheung Chau Disposal Ground for compulsory pilotage en route to the Jetty with tugs assistance and control. Other supporting vessels will accompany the FSRU Vessel / LNGC as necessary along the designated transit route, travelling along north of CEDD's South Cheung Chau Disposal Ground and approaching the LNG Terminal. It is anticipated that during the transit, LNGC with tugs and supporting vessels will need to pass through the SLMP with a duration of about 30 minutes until berthing at the LNG Terminal. The FSRU Vessel will not pass through the SLMP during manoeuvring to the Jetty. However, in the unlikely / emergency event (e.g. loss of power), the FSRU Vessel with tugs / supporting vessels may need to pass through the SLMP for safe manoeuvring to the Jetty. Examples of navigation simulation plots for LNGC and FSRU Vessel adopting Principal Arrival Route to LNG Terminal are presented in ***Figure 3.1***.

No stopping over or anchoring of vessels will be necessary during the transit.

Figure 3.1 Examples of Navigation Simulation Plots for LNGC and FSRU Vessel adopting Principal Arrival Route to the LNG Terminal

(a) LNGC (Normal Operation) | (b) FSRU Vessel (Normal Operation) | (c) FSRU Vessel / LNGC (Emergency Event)



3.1.2 South Departure Route

The South Departure Route is the principal route for the departure of the FSRU Vessel / LNGC. On departure from the LNG Terminal, the manoeuvres of the FSRU Vessel / LNGC will be executed by the HK Pilots and captains of FSRU Vessel. Once the ship is clear of the berth and in a safe position before joining Dangan Channel, the tugs will be let go and the Pilots disembarked. The departure route as shown in ***Figure 1.3*** for FSRU Vessel and LNGC with tugs and supporting vessels will need to pass through the SLMP with a duration of about 30 minutes.

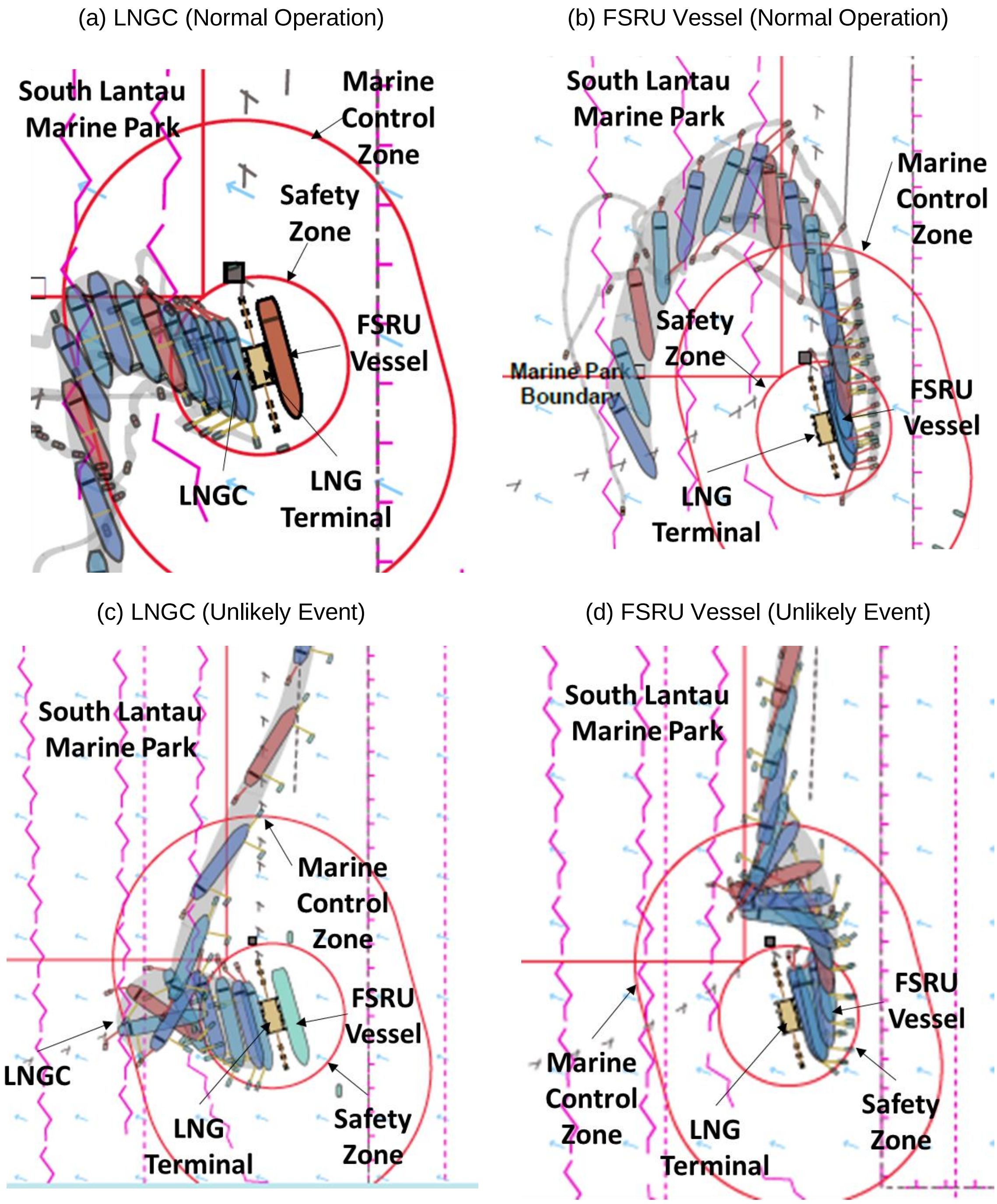
In the unlikely event that this southern departure route cannot be used (e.g. structural blockage at sea), the FSRU Vessel / LNGC will need to travel north to follow the same Principal Arrival Route back to the waters south of Cheung Chau before navigating to Dangan Channel. It is anticipated that during the transit of FSRU Vessel and LNGC, both FSRU Vessel and LNGC as well as the tugs and supporting vessels will need to pass through SLMP with a duration of about 30 minutes until turning to north of CEDD's South Cheung Chau Disposal Ground.

Examples of navigation simulation plots for LNGC and FSRU Vessel departing the LNG Terminal are presented in ***Figure 3.2***.

No stopping over or anchoring of vessels will be necessary during the transit.

It should be noted that during the arrival and departure of the FSRU Vessel and LNGC, there might be adjustment to the proposed marine transit routes described in ***Sections 3.1.1 and 3.1.2*** to suit the navigation safety and weather conditions.

Figure 3.2 Examples of Navigation Simulation Plots for LNGC and FSRU Vessel departing the LNG Terminal



3.2 Transit Frequency of FSRU Vessel and LNGC

3.2.1 FSRU Vessel

The FSRU Vessel will be permanently moored at the Jetty during normal operations, except for general maintenance which is anticipated to be once every 3 to 5 years. During incidents (e.g. typhoons) and emergency conditions, the FSRU Vessel with tugs control and other supporting vessels in attendance, will sail away to suitable anchorage area located away from the adverse weather outside Hong Kong through the Dangan Channel Traffic Separation Scheme or open sea as a precautionary measure to minimize accidental events. After typhoon and emergency conditions, which are anticipated to be 3-4 times a year, the FSRU Vessel will sail back to the LNG Terminal via the Principal Arrival Route.

3.2.2 LNGC

For LNG delivery and unloading, LNGC transit with tugs control and other supporting vessels in attendance, to the LNG Terminal is required around once every 7 days. A maximum of about 52 LNGC trips is expected to arrive at the LNG Terminal for fuel delivery in a year.

3.3 Maintenance Dredging

To ensure safe access and manoeuvrability by the FSRU Vessel and LNGC in the vicinity of LNG Terminal, maintenance dredging may be required to allow sufficient water depths and clearance for the transit of FSRU Vessel and LNGC, subject to the findings of bathymetric survey to be carried out at a frequency of once every 2-3 years to 5 years during operation of the Project if necessary. Maintenance dredging within the SLMP would not be necessary for the Project. The maintenance dredging is expected to be conducted using a grab dredger and the maximum working rate would be 5,500 m^3 day^{-1} (24 hours each day) with the use of a single layer of silt curtain with silt removal efficiency of 75% reduction.

If maintenance dredging is planned to be carried out, a maintenance dredging plan, containing the information relating to the scale and scope of dredging, works programme of dredging and environmental mitigation measures for carrying out the dredging, will be prepared before the commencement of maintenance dredging works for the Project in accordance with the Further Environmental Permit FEP-01/558/2018/A.

4. POTENTIAL IMPACTS ON THE ENVIRONMENT

4.1 Key Environmental Issues Associated with the Proposed Marine Transit Routes for the FSRU Vessel and LNGC

Table 4.1 identifies the potential environmental impacts associated with the proposed marine transit routes for the FSRU Vessel and LNGC.

Table 4.1 Potential Environmental Issues

Aspect	Any Potential Impact?	Remarks
Air Quality	✓	The potential impacts to air quality are discussed in ***Section 4.2***.
Hazard to Life	✓	The potential impacts to hazard to life are discussed in ***Section 4.3***.
Noise	×	No noise sensitive receivers (NSRs) were identified within the 300m Assessment Area; as discussed in Sections 6.5 and 6.6 of the approved EIA Report, unacceptable adverse noise impacts due to the proposed marine transit route are not anticipated.
Water Quality	✓	The potential impacts to water quality are discussed in ***Section 4.4***.
Waste Management Implications	✓	The potential waste management implications are discussed in ***Section 4.5***.
Ecology	✓	Impacts to terrestrial ecology and offshore avifauna are not expected. The potential impacts to marine ecology are discussed in ***Section 4.6***.
Fisheries	✓	The potential impacts to fisheries are discussed in **Section 4.7.**
Visual	×	According to Section 11.6 of the approved EIA report, operational visual impacts are expected to be minimal and arise from the presence and operation of the LNG Terminal. No change of visual impact is expected from the proposed marine transit route.
Cultural Heritage	×	As the transit of FSRU Vessel and LNGC to the LNG Terminal will not disturb the seabed along the marine transit routes, no marine archaeological impact is expected for the proposed marine transit routes.

Notes:
(a) '✓' = Possible, '×' = Not Expected

A description and evaluation, where appropriate, of potential impacts on air quality, water quality, marine ecology and fisheries, the environmental changes arising from the proposed variations, and how the environment and the community might be affected by the proposed variations, are provided in the following sections.

4.2 Air Quality

While it is mentioned in Section 3.5.1 of the EIA Report that the frequency of LNG deliveries (on average) will be one LNGC arriving every five to eight days, the proposed transit frequency for LNGC is expected to be around once every 7 days which is within the estimation stated in the approved EIA Report. Given the low frequency of vessel movement (once every 7 days for LNGC and 3-4 times a year for FSRU Vessel) for visiting LNGC / FSRU Vessel adopting the proposed marine transit routes and the use of boil off gas or low sulphur marine fuel for these vessels, no unacceptable change to air quality due to the transit of LNGC and FSRU Vessel will be anticipated. In addition, no ASR has been identified within 1.5 km from the proposed marine transit routes of the visiting LNGCs. The nearest identified ASR is Shek Kwu Chau Treatment and Rehabilitation Centre located at more than 1.5 km away from the proposed marine transit routes as indicated in ***Figure 4.1***. Due to the large separation

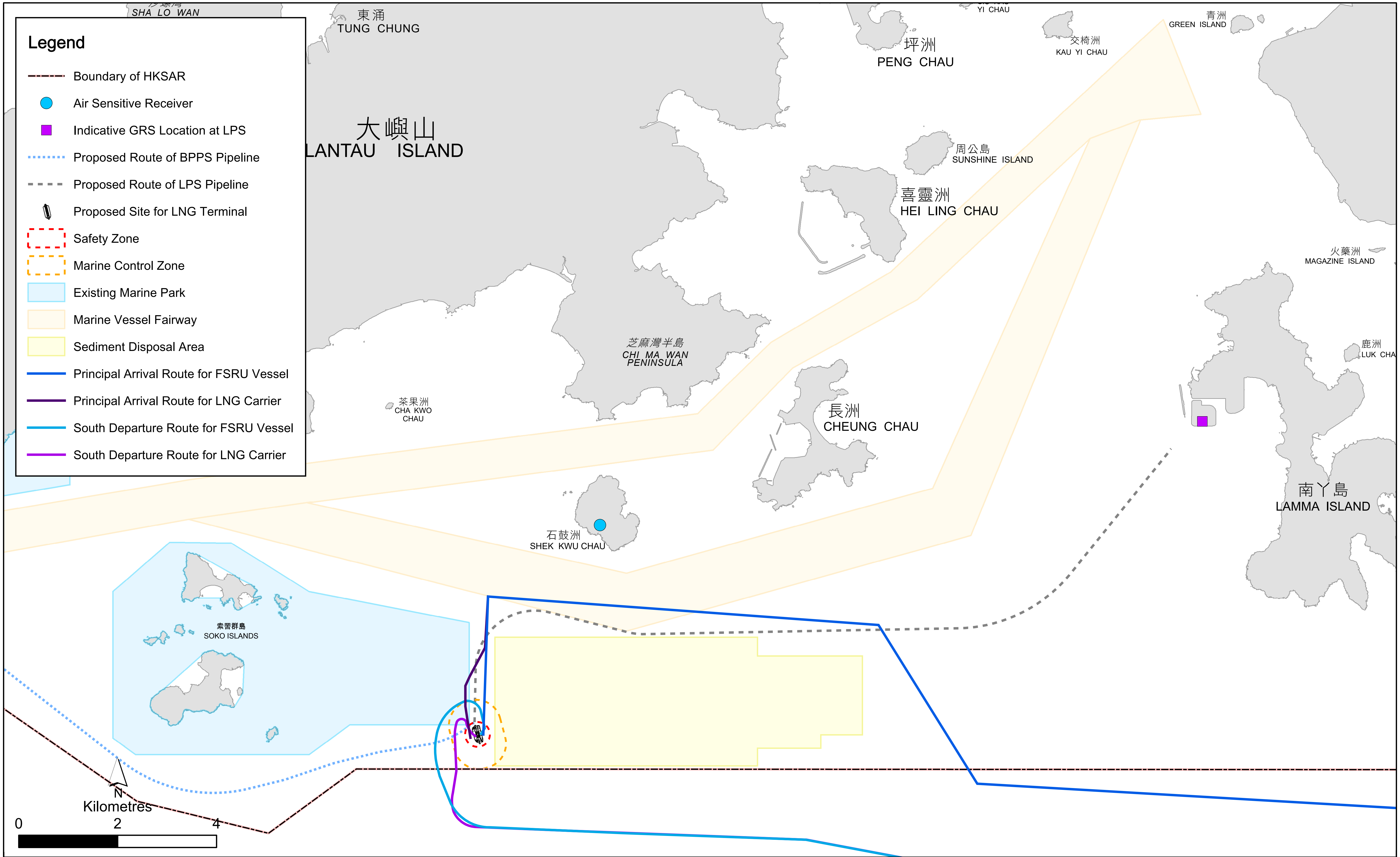


Figure 4.1

Identified Representative Air Sensitive Receiver

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between the proposed marine transit routes to the nearest ASR, adverse air quality impacts associated with the marine emissions from visiting LNGC / FSRU Vessel and supporting vessels are not anticipated. The associated impacts arising from vessel movement adopting the proposed marine transit routes for the FSRU Vessel and LNGC would remain unchanged as those predicted in the approved EIA Report.

While it is mentioned in Section 3.5.1 of the EIA Report that maintenance dredging may be required for the LNG Terminal about once every five years, the frequency will be reviewed subject to actual site conditions to ensure continued access and manoeuvrability by the FSRU Vessel and LNGC. The proposed update of maintenance dredging arrangement will also be subject to the findings of bathymetric survey to be carried out at a frequency of once every 2-3 years to 5 years during operation of the Project if necessary. The maintenance dredging works will be conducted around the LNG Terminal which is located approximately 4 km away from the identified ASR. Due to large separation distance between the maintenance dredging works and the nearest ASR, adverse dust impact arising from the maintenance dredging works of the Project is not anticipated.

Overall, the proposed update of marine transit routes and maintenance dredging arrangement would not result in any adverse air quality impact on the ASRs. There are no other changes to the operation of the LNG Terminal as described in the approved EIA Report.

4.3 Hazard to Life

Quantitative risk assessment (QRA) was conducted to assess the risk due to marine transits of LNGC / FSRU Vessel using the proposed marine transit routes. Different scenarios were considered including the transits of LNGC / FSRU Vessel using the proposed marine transit routes. The assessment methodology followed the same adopted in the approved EIA Report. The assessment methodology, assumptions and details of QRA are presented in ***Annex A***. The QRA showed that the individual and societal risks for marine transits of LNGC / FSRU Vessel using the proposed marine transit routes during operation of the Project is in compliance with the risk criteria in *Section 2* of *Annex 4* of the *EIAO-TM*.

Based on the latest information, the LNGC and FSRU Vessel annual visit frequency is expected to be about 56 trips per year, which is lower than 75 trips assumed in the approved EIA Report. The risks of collision with the Jetty are thus expected not to be greater or worse than those predicted in the approved EIA Report. In addition, manoeuvring of LNGC/ FSRU Vessel access to/ from the Jetty would be supported by tug boats to minimise the collision risks near Jetty for both proposed marine transit routes and the original route in EIA study. As such, the proposed marine transit routes will not cause adverse impacts on the Jetty (e.g. increase in the risk of collision with the Jetty) when the LNGC or the FSRU Vessel is manoeuvring around the Jetty to approach or depart from the Jetty, compared with the original arrival and departure routes proposed in the EIA report.

Overall, the proposed marine transit route arrangement would not cause adverse impact on the Jetty when comparing with those predicted in the approved EIA Report.

4.4 Water Quality

There would be adequate clearance between FSRU Vessel / LNGC and the seabed at all states of the tide along the proposed marine transit routes. In addition, there would not be operational discharges from the FSRU Vessel and LNGC as these marine vessels would be in transit to and from the LNG Terminal. Therefore, unacceptable water quality impacts at the nearby WSRs, including the SLMP, due to the proposed marine transit route arrangement are not anticipated.

As indicated in ***Section 3.3***, maintenance dredging may be required to allow sufficient water depths and clearance for the transit of FSRU Vessel and LNGC. Maintenance dredging within the SLMP would not be necessary for the Project. The information on the extent and volume of the maintenance dredging are currently not available. It is expected that the maintenance dredging will be conducted around the LNG Terminal and outside SLMP, and will adopt a work rate in the approved EIA Report, which is 5,500 m^3 day^{-1} (24 hours each day) with the use of a single layer of silt curtain with silt removal efficiency of 75% reduction. It is expected that the potential dredging area around the LNG Terminal would be at least 200 m away from the nearby WSR (South Lantau Marine Park) and no maintenance dredging within SLMP would be necessary for the Project. The worst case assumption as presented in the approved EIA report made for the modelling exercise, including the selection of sediment source to the closest to the nearby WSRs within the potential dredging area is thus still valid. From the modelling assessment conducted in the approved EIA Report, this would not result in unacceptable water quality impact at the nearby WSR (South Lantau Marine Park) locating at about 200 m away from the maintenance dredging location. The proposed Principal Arrival Route will have at least 200 m away from the identified water sensitive receivers outside SLMP and suitable water quality mitigation measures as recommended in approved EIA report will be implemented during dredging works, including control of work rate and use of silt curtain. The associated water quality impacts arising from maintenance dredging around the LNG Terminal would remain unchanged as those predicted in the approved EIA Report.

4.5 Waste Management

As indicated in ***Section 3.3***, maintenance dredging may be required to allow sufficient water depths and clearance for the transit of FSRU Vessel and LNGC. The information on the extent and volume of the maintenance dredging around the LNG Terminal are currently not available. The marine sediment quality testing would follow the requirement set out in the Management Framework for Disposal of Dredged/ Excavated Sediment *(PNAP ADV-21*). The final disposal site would be determined by the Marine Fill Committee (MFC) and a dumping licence will be obtained from the Environmental Protection Department (EPD) prior to the commencement of the maintenance dredging works.

The barges to be used for any marine sediment transport and disposal will be fitted with seals to prevent leakage of sediment, and no overloading of material and sediment laden water will be allowed during loading or transportation. As such no adverse impact on water quality and marine ecology associated with this marine transport and disposal is expected.

4.6 Ecology

Potential impacts to marine ecological resources, marine mammals and marine parks due to the proposed marine transit routes include underwater sound from FSRU vessel and LNGC transit, increased marine traffic from LNG Terminal operation, temporary habitat loss and disturbance from maintenance dredging and short-term changes in water quality from maintenance dredging. These impacts are discussed below.

4.6.1 Underwater Sound from FSRU Vessel and LNGC Transit

As indicated in ***Section 3.2***, the frequency of FSRU vessel and LNGC transit will be 3-4 times a year and once every 7 days respectively. The expected frequency travelling through the proposed marine transit routes remain unchanged as assessed in the approved EIA Report. Given the low frequency of vessel movement expected for the day-to-day operation of the LNG Terminal, and the underwater sound characteristics of the vessels involved are very much similar to those in the area at present from similar marine traffic, marine organisms and marine mammals in these waters are habituated to the background level of the underwater sound. No unacceptable impacts to marine organisms and marine mammals are expected due to the small increase in vessel activity.

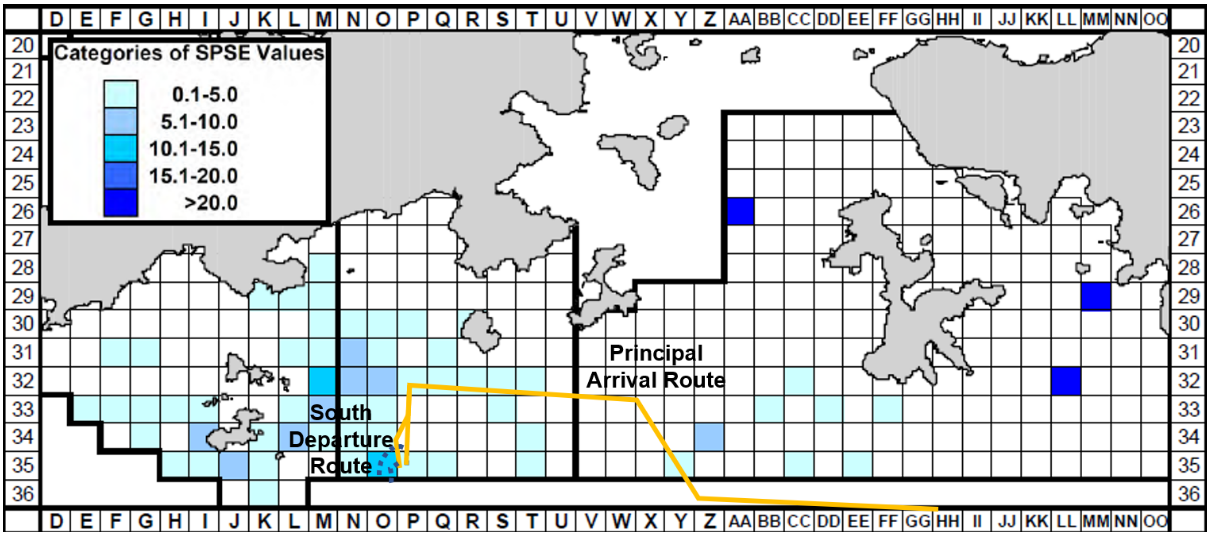
The proposed marine transit routes for FSRU Vessel and LNGC transit will require vessel entry to SLMP occasionally. Given the vessels are slow-moving in nature, the duration of SLMP entry is short (about 30 minutes each time) and the frequency of SLMP entry will be low, adverse impacts on the functionality of SLMP caused by vessel transition through the proposed marine transit routes is not anticipated. Moreover, the continuous and low level of underwater sound which is of low energy and lower frequencies will be below the peak range of dolphins and porpoises and thus Chinese White

Dolphins (CWD) and Finless Porpoises (FP) are not expected to be acoustically disturbed. The associated underwater sound from FSRU Vessel and LNGC during transit of the proposed marine transit routes would be similar as those predicted in the approved EIA Report.

4.6.2 Increased Marine Traffic

A review of the distribution of CWD and FP was conducted with reference to the AFCD's latest marine mammal monitoring report in Hong Kong Waters (2021-22) [(2)]. The important CWD habitats were concentrated along the West Lantau coastline as well as the western end of South Lantau waters, mainly extending from Tai O Peninsula toward Fan Lau Peninsula, which are located far away from the proposed marine transit routes. The important FP habitats were mainly located to the east and west of the Soko Islands and the majority of the proposed marine transit routes did not overlap with the waters with higher FP density as presented in ***Figure 4.2***. As a precautionary measure, the FSRU Vessel and LNGC will travel through the proposed marine transit routes at a speed of 10 knots or below when moving within the areas frequented by Finless Porpoise, including the waters between Soko Islands and Shek Kwu Chau.

Figure 4.2 Density of Finless Porpoises in Southern Waters of Hong Kong during Dry Season (December to May) using Data Collected during 2017-21 (Source: AFCD's Marine Mammal Monitoring Report in Hong Kong Waters (2021-22))



Remark: DPSE = no. of porpoises per 100 units of survey effort

FSRU Vessel will be permanently moored at the Jetty and therefore not expected to pose risk of vessel collision with marine mammals. In addition, the frequency for LNGC transit is low and tugs will be used to manoeuvre at slow speed until berthed alongside the jetty during LNGC transit. Given the infrequent and slow vessel movement, unacceptable adverse impacts on marine mammals are not anticipated with the adoption of the proposed marine transit routes.

FSRU Vessel, LNGCs and supporting vessels will pass through the SLMP during transit to and from LNG Terminal. Given vessel movements will be controlled by tugs and a pilot boat at a low speed, no impact to the marine buoy at the corner of SLMP will be anticipated during transit. Upon entry to the SLMP, the 10-knot vessel speed limit of the Marine Parks and Reserves Regulations (*Cap. 476A*) for all vessels will be observed and strictly followed. No anchorage or stop-over is expected in SLMP. Adverse impacts to the functionality of SLMP is not anticipated.

(2) HKCRP (2022). Monitoring of Marine Mammals in Hong Kong Waters (2021-22). Submitted to AFCD under Contract Ref. AFCD/SQ/260/20/C.

The associated impacts due to increased marine traffic would remain unchanged as those predicted in the approved EIA Report.

4.6.3 Temporary Habitat Loss, Disturbance and Short-term Changes in Water Quality from Maintenance Dredging

Maintenance dredging may be required to maintain sufficient clearance for safe navigation of the LNGC. The potential maintenance dredging area is expected to be located in the vicinity of LNG Terminal. Short-term direct impacts to subtidal bottom assemblages may occur as a result of maintenance dredging, although once completed seabed would be available for recolonisation by benthic fauna. Given the low ecological value of the associated benthic assemblages, no unacceptable impacts are expected.

Maintenance dredging within the SLMP would not be necessary for the Project. Sensitive receivers identified (including the SLMP) are considered to be of sufficient distance from the potential maintenance dredging area and are unlikely to be affected indirectly by impacts to water quality. As discussed in ***Section 4.4***, the associated water quality impacts arising from maintenance dredging in the vicinity of LNG Terminal would remain unchanged and not be greater or worse than those predicted in the approved EIA Report. With the implementation of water quality mitigation measures, such as the use of silt curtain and appropriate working rate, potential impacts to marine ecological resources, including marine mammals, and the functionality of SLMP would be reduced to within acceptable levels. Unacceptable impacts on marine ecological resources, including marine mammals, and the functionality of SLMP due to maintenance dredging are not anticipated. The associated impacts due to maintenance dredging would remain unchanged as those predicted in the approved EIA Report.

4.7 Fisheries

The vessel movement from transit of LNGC / FSRU Vessel for the day-to-day operation of the LNG Terminal is very low (once every 7 days for LNGC and 3-4 times a year for FSRU Vessel) and the underwater sound characteristics of the vessels involved would be very much similar to those of the existing marine traffic in the area. No unacceptable change to fisheries resources is anticipated with the use of the proposed marine transit routes for LNGC / FSRU Vessel during operation of the LNG Terminal.

As discussed in ***Section 4.4***, maintenance dredging within the SLMP would not be necessary for the Project. The associated water quality impacts arising from maintenance dredging around the LNG Terminal would remain unchanged and not be greater or worse than those predicted in the approved EIA Report. With the implementation of water quality mitigation measures, such as the use of silt curtain and appropriate working rate, potential impacts to fisheries would be reduced to within acceptable levels. No unacceptable indirect impact on fisheries sensitive receivers from the maintenance dredging around the LNG Terminal is expected.

The associated impacts arising from vessel movement adopting the proposed marine transit routes and the maintenance dredging around the LNG Terminal would remain unchanged as those predicted in the approved EIA Report.

4.8 Assessment of the Proposed Changes against EIAO-TM Section 6

The proposed marine transit routes have been evaluated to consider whether the change may constitute a material change to a designated project or to an environmental impact (Section 6 of the EIAO-TM refers). In accordance with Section 6.2 of the EIAO-TM, *the environmental impact of a designated project, for which an environmental permit has been issued, is considered to be materially changed if the environmental performance requirements set out in the EIA report for this project may be exceeded or violated, even with the mitigation measures in place*.

An assessment of the potential environmental impacts associated with the proposed marine transit routes is provided in detail in ***Sections 4.1-4.7***. The proposed change is considered as conforming to the information and requirements set out in the approved EIA Report. Hence, it is considered that the proposed change of marine transit routes will not lead to a material change to the designated project, or an environmental impact in accordance with Section 6.2 of the EIAO-TM.

5. REVIEW OF PROPOSED MITIGATION MEASURES & ENVIRONMENTAL MONITORING AND AUDIT (EM&A) REQUIREMENTS

The findings of this review of environmental impacts associated with the proposed marine transit routes have indicated that no unacceptable adverse environmental impacts would be anticipated. It is considered that the proposed mitigation measures and EM&A requirements recommended in the approved EIA Report and outlined in the Project's Updated EM&A Manual are adequate and no additional mitigation measures and EM&A requirements will be required.

6. CONCLUSION

The proposed marine transit routes ('Principal Arrival Route' and 'South Departure Route') of FSRU Vessel and LNGC has been determined and agreed with the relevant authorities for implementation to support the operation of the Project. The Principal Arrival Route for the FSRU Vessel and LNGC should enter HKSAR waters between Lamma Island and Cheung Chau for pilotage, and travel within Hong Kong waters to the LNG Terminal. The South Departure Route for the FSRU Vessel and LNGC with tugs and supporting vessels will need to pass through the SLMP and then travel to the south to Dangan Channel. An environmental review is undertaken to assess the potential environmental impact as a result of the update to the marine transit routes.

The review indicates that no unacceptable adverse impacts are anticipated from the proposed marine transit routes with respect to the assessment criteria stipulated in the EIAO-TM and relevant environmental legislation, and the same environmental performance requirements set out in the approved EIA Report will apply. The proposed marine transit routes will not result in a material change to the designated project, or an environmental impact in accordance with Section 6 of the EIAO-TM. The Project fully complies with the EIAO-TM requirements.

It is considered that the EM&A requirements recommended in the approved EIA Report are adequate and no additional mitigation measures and EM&A requirements will be required.

APPENDIX A

QUANTITATIVE RISK ASSESSMENT

A1 INTRODUCTION

A1.1 Background

The proposed marine transit routes of FSRU Vessel and LNGC from and to the LNG Terminal have been determined and agreed with the relevant authorities for implementation to support the operation of the Project. The Principal Arrival Route for the FSRU Vessel and LNGC will enter HKSAR waters at the due east side of the existing CEDD's South Cheung Chau Disposal Ground and will be subject to the prevailing conditions at time being. The South Departure Route for the FSRU Vessel and LNGC with tugs and supporting vessels will need to pass through the South Lantau Marine Park (SLMP) and then travel to the south to Dangan Channel. As part of the environmental review, a Quantitative Risk Assessment (QRA) is conducted to assess the risk due to marine transits of LNGC / FSRU Vessel adopting the proposed marine transit routes.

This report summaries the proposed methodology, key assumptions, key approaches, and study findings.

A1.2 Scope of Works

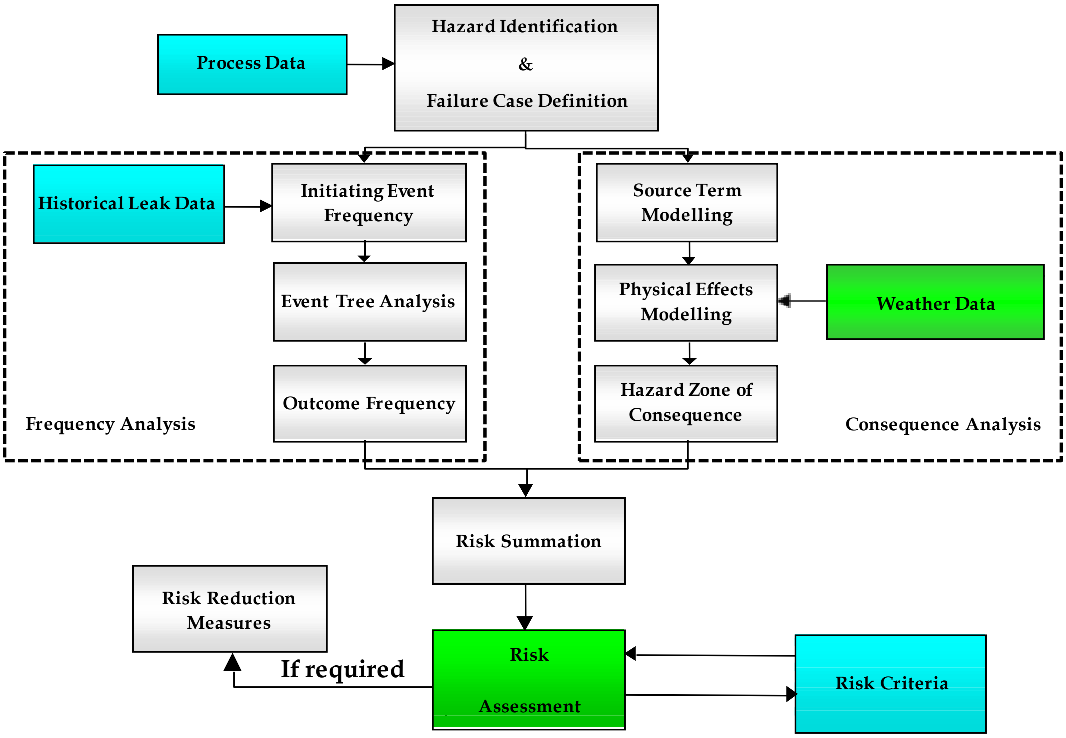
The proposed scope of works for this QRA Study is to evaluate the risk associated with the LNGC/ FSRU Vessel along the proposed marine transit route (in particular the Principal Arrival Route located within Hong Kong waters), depicted at ***Figure A3.1***), to the LNG Terminal under normal operations, bad weather conditions and maintenance for Year 2023 and Year 2030. The following proposed scenarios were covered in this QRA Study for the detailed analysis:

- Year 2023: Principal Arrival Route; and
- Year 2030: Principal Arrival Route;

A2 PROPOSED QUANTITATIVE RISK ASSESSMENT METHODOLOGY

The proposed QRA methodology is consistent with the approved Hazard to Life Quantitative Risk Assessment of EIA Report for the Hong Kong Offshore LNG Terminal Project. All the associated elements of this QRA Study are depicted in ***Figure A2.1*** and each of the elements is depicted as follows.

Figure A2.1 Proposed QRA Methodology



A2.1 Hazard Identification

This QRA concerns the fire hazards associated with the LNGC/ FSRU Vessel during the marine transit. The associated failure may be partial or catastrophic as a result of corrosion, fatigue, etc. These failures are taken into account for the detailed analysis in this QRA.

A2.2 Frequency Analysis

This task involves the frequency analysis for each of the identified hazardous scenarios.

A2.3 Consequence Analysis

Consequence analysis involves the modelling of the physical effects, and *SAFETI 6.7*, was adopted in this QRA. Consequence modelling results was used to establish levels of harm to critical equipment at varying distances from the identified hazards. Probit equations are used to relate levels of harm to exposure.

A2.4 Risk Summation and Risk Assessment

Risk summation was conducted using *SAFETI 6.7* which calculates the risk based on different failure outcomes, failure event location, and weather conditions prevailing proximity to the LNGC/ FSRU Vessel marine transit route. This step involves the integration of consequence and frequency data to give the risk results in terms of the required risk measures.

The products of the frequency and consequence for each outcome event above are summed and the total risk expressed in individual risk. Individual risk results were presented as iso-risk contours overlaid on the LNGC/ FSRU Vessel marine transit route.

A3 DESCRIPTION OF THE MARINE TRANSITS FOR LNGC AND FSRU VESSEL

A3.1 Description of LNGC Process System

A3.1.1 LNG Storage and Unloading System

3.1.1.1 Types of LNGC

Two (2) types of LNGC with double hull are typically used in the market to deliver LNG cargoes, namely:

- Membrane type; and
- MOSS type (spherical LNG storage tank)

More than 90% LNGCs are membrane type at the current LNGC market, as such, the LNGC of membrane type was selected as the representative case for the QRA Study.

3.1.1.2 Size of LNGC

The size the Large LNGC (with five (5) membrane-type LNG Cargo Tanks) is about 216,000 m^3 capacity, with each LNG storage tank capacity of about 43,200 m^3.

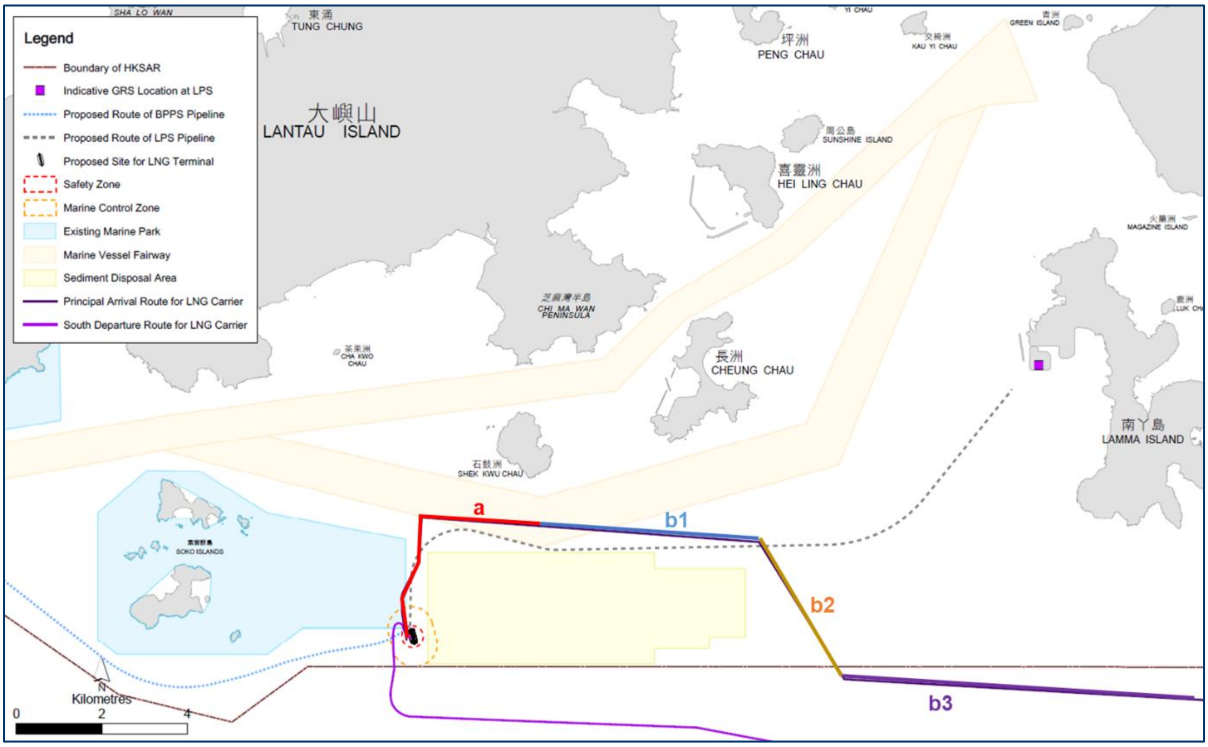
Membrane type double containment system for the LNG cargo storage tanks are provided for the LNGC. The containment system will be designed as per international standards including the *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)*. The containment system will be provided with a full secondary liquid-tight barrier capable of safely containing all potential leakages through the primary barrier and, in conjunction with the thermal insulation system, of preventing lowering of the temperature of the ship structure to an unsafe level.

In-tank LNG storage pumps are submerged in the LNG cargo tanks. During LNG unloading operation at the LNG Terminal, the LNG in the cargo tanks of the LNGC will be pumped through the unloading arms, via the Jetty, to the LNG cargo tanks of the FSRU Vessel.

A3.2 Proposed Principal Arrival Route Alignment

Figure A3.1 presents the indicative LNGC transit route to the LNG Terminal, and the FSRU Vessel will use similar transit route as the marine transit to the LNG Terminal, but berthing at the east side of the LNG Terminal. The worst case scenario of LNGC passing through the South Lantau Marine Park during marine transit has been considered for assessment purpose. The length of the transit route and the sub-segments for the indicative LNGC transit route are presented in ***Table A3.1***.

Figure A3.1 Route Alignment and Sub-Segments



Remark: The indicative marine transit routes for LNG Carrier is illustrated, which is the worst case scenario for assessment purpose.

Table A3.1 Length of Route Alignment and Sub-Segments

Principal Arrival Route	**22,453 m**
Sub-Segment	Length of Sub-Segment (m)
a	5,673
b1	5,190
b2	3,858
b3	7,732

A3.2.1 LNGC/ FSRU Vessel Route

Table A3.2 presents the two (2) cases regarding the arrival and departure route for Year 2023 and Year 2030.

Table A3.2 Arrival/ Departure Routes for Year 2023 and Year 2030

Case	Route Alignment	Assumption
2023	Principal Arrival Route	Arrival via Principal Arrival Route; Departure via Principal Arrival Route (Note 1)
2030		Arrival via Principal Arrival Route; Departure via Principal Arrival Route (Note 1)

Note 1: It should be noted that LNGC / FSRU Vessel will primarily adopt the South Departure Route for departure, which will make use of Dangan Channel outside Hong Kong waters. Therefore, departure via Principal Arrival Route is considered as the worst case scenario for the QRA study.

A3.2.2 LNGC Approach to the LNG Terminal

When LNGC is approaching the LNG Terminal, tugboats and other supporting vessels will assist in controlling the heading and speed of the LNGC while entering into and manoeuvring within the turning area as well as for the final approach towards the LNG Terminal. The tugboats will continue to assist until the mooring operation has been completed. A total of four (4), of 80T bollard pull or higher are anticipated to support the safe manoeuvring of the LNGC to the LNG Terminal.

According to the Marine Traffic Impact Assessment (MTIA) Report for the LNG Terminal, the support of a tug fleet for access to/from the LNG Terminal ensures that even with engine or control system failure on the LNGC or FSRU Vessel during the approaching the LNG Terminal, there will be adequate control capability to mitigate such events. Tugs / supporting vessels, of 80T bollard pull or higher are anticipated to support all LNGC's scheduled arrivals and departures, and FSRU Vessel arrival and departures due to typhoon. In addition, tugs will also be required to assist departures prior to the onset of a typhoon. These tugs will have the necessary electrical system compliance and gas detection to be safe to work in close proximity with the LNG Terminal.

A3.3 Transit Frequency

The annual frequencies for different operating scenarios are presented in ***Table A3.3*** below.

Table A3.3 Annual Frequencies for different operating scenarios

Type	Scenario	Arrival	Departure
LNGC	Normal Operation	52	52
FSRU	Initial Arrival	1	-
	Typhoon Evacuation	10 (Note 1)	10 (Note 1)
	Maintenance/ Emergency	2 (Note 2)	2 (Note 2)

Note 1: While typhoon and emergency conditions are anticipated to be 3-4 times a year, the assessment adopted a more conservative scenario of 10 times a year for typhoon evacuation.
Note 2: While general maintenance of the FSRU Vessel is anticipated to be once every 3 to 5 years, the assessment adopted a more conservative scenario of 2 times a year for maintenance/ emergency.

A3.3.1 Transit of LNGC/ FSRU Vessel under Adverse Weather Condition

Prior to the transit of an LNGC to the LNG Terminal for LNG unloading operation, the transit route and the weather forecast for the transit area will be reviewed and analyzed to determine the suitability and safety of the LNGC transit. It is expected that the LNGC will only be allowed to transit and enter Hong Kong waters if the forecasted weather condition is within an agreed weather envelope. Therefore, it is highly unlikely that an LNGC will be at berth at the Jetty when a typhoon is predicted. In case the on-set of a typhoon occurs during the LNG unloading operation at the Jetty, the LNGC will, depending on weather conditions and at the discretion of the Master head, depart the berth to an area of open sea outside HKSAR waters.

In case of adverse weather condition (e.g. typhoon, monsoon), the FSRU Vessel berthed at the Jetty will also, depending on weather conditions and at the discretion of the Master head, depart the berth to an area of open sea outside HKSAR waters. Although it was identified from the prior mooring capability assessment that the FSRU Vessel could maintain at the LNG Terminal in winds associated with Typhoon Signal 3 (sustained speeds of 41-62 km/hr), FSRU will depart from Jetty upon Typhoon Signal No.3 or higher.

A3.3.2 Transit of FSRU Vessel under Maintenance/ Emergency Situation

In the case of an emergency situation (e.g. uncontrolled fire event at the Jetty), the FSRU Vessel berthed at the Jetty at the time of the emergency will be required to depart the berth to an area of open sea outside HKSAR waters. In addition, standby vessel is available to provide an emergency response and will have the capability to assist the FSRU Vessel depart the berth.

A4 DESCRIPTION OF SURROUNDING

A4.1 Surrounding Marine Population

The marine traffic in the vicinity of the LNGC/ FSRU Vessel marine transit route includes fishing vessels, rivertrade coastal vessels, ocean-going vessels, fast launches, fast ferries, and other types of smaller vessels.

The marine vessel population used in the QRA Study are given in ***Table A4.1***. The maximum population of fast ferries is assumed to be 450, based on the maximum capacity of the largest ferry operating in the area. However, the average load factors for fast ferries to Macau and Pearl Rivers ports are 62% and 47% respectively. Hence, a distribution in ferry population was assumed as indicated in ***Table A4.1***. This distribution gives an overall load factor of about 58% which is conservative and covers any future increase in marine vessel population. There is an additional category in the traffic volume data called "Others". These are assumed to be small marine vessels with a population of 5.

Table A4.1 Marine Vessel Population

Type of Marine Vessel	Average Population per Vessel	
Ocean-Going Vessel	21	
Rivertrade Coastal Vessel	5	
Fast Ferries	450	(largest ferries with max population)
	350	(typical ferry with max population)
	280	(typical ferry at 80% capacity)
	175	(typical ferry at 50% capacity)
	105	(typical ferry at 30% capacity)
	35	(typical ferry at 10% capacity)
Tug and Tow	5	
Others	5	

A4.1.1 Protection Factors for marine vessel

Population on marine vessels is considered to be provided with some protection from the vessel structure. The degree of protection offered depends on factors such as:

- Size of vessel;
- Construction material and likelihood of secondary fires;
- Speed of vessel and hence its exposure time to the flammable cloud;
- The proportion of passengers likely to be on deck or in the interior of the vessel; and
- The ability of gas to penetrate into the interior of the vessel and form a flammable mixture.

Small vessels such as fishing boats provide little protection while larger vessels such as ocean-going vessels provide greater protection. Fast ferries are air conditioned and have limited rate of air exchange with outside environment. Based on these considerations, the fatality probabilities and the population at risk adopted for each type of marine vessel are in line with the previous studies that have been approved by EPD and other relevant authorities.

Table A4.2 Population at risk

Marine Vessel Type	Population	Fatality Probability(1)(2)	Population at Risk (1)(2)
Ocean-Going Vessel	21	0.1	2
Rivertrade Coastal Vessel	5	0.3	2
Fast Ferries			
(largest ferries with max population)	450	0.3	135
(typical ferry with max population)	350	0.3	105
(typical ferry at 80% capacity)	280	0.3	84
(typical ferry at 50% capacity)	175	0.3	53
(typical ferry at 30% capacity)	105	0.3	32
(typical ferry at 10% capacity)	35	0.3	11
Tug and Tow	5	0.9	5
Others	5	0.9	5

Notes:

(1): Data collected from ERM, EIA for *Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities* (Register No.: AEIAR-106/2007), December 2006

(2): Data collected from ERM, EIA for *Black Point Gas Supply Project* (Register No.: AEIAR-150/2010), February 2010

A4.1.2 Estimation of Number of Marine Vessels per day

In the QRA Study, the marine traffic population in the vicinity of the LNGC/ FSRU Vessel marine transit route has been considered as both point receptors and average density values. The population of all marine vessels was treated as an area average density except for fast ferries which are treated as point receptors.

As shown in ***Figure A4.1***, the marine area in the vicinity of the Project components has been divided into 12.67 km^2 grid cells, each grid being approximately 3.6 km × 3.6 km. The time for a marine vessel to traverse a grid was calculated based on the travel distance divided by the marine vessel's average speed. The average speed and transit time for different vessel types are presented in ***Table A4.3***, in line with the previous EIA Reports that were approved by the EPD and other relevant authorities.

Table A4.3 Average Speed and Transit Time of Different Marine Vessel Type

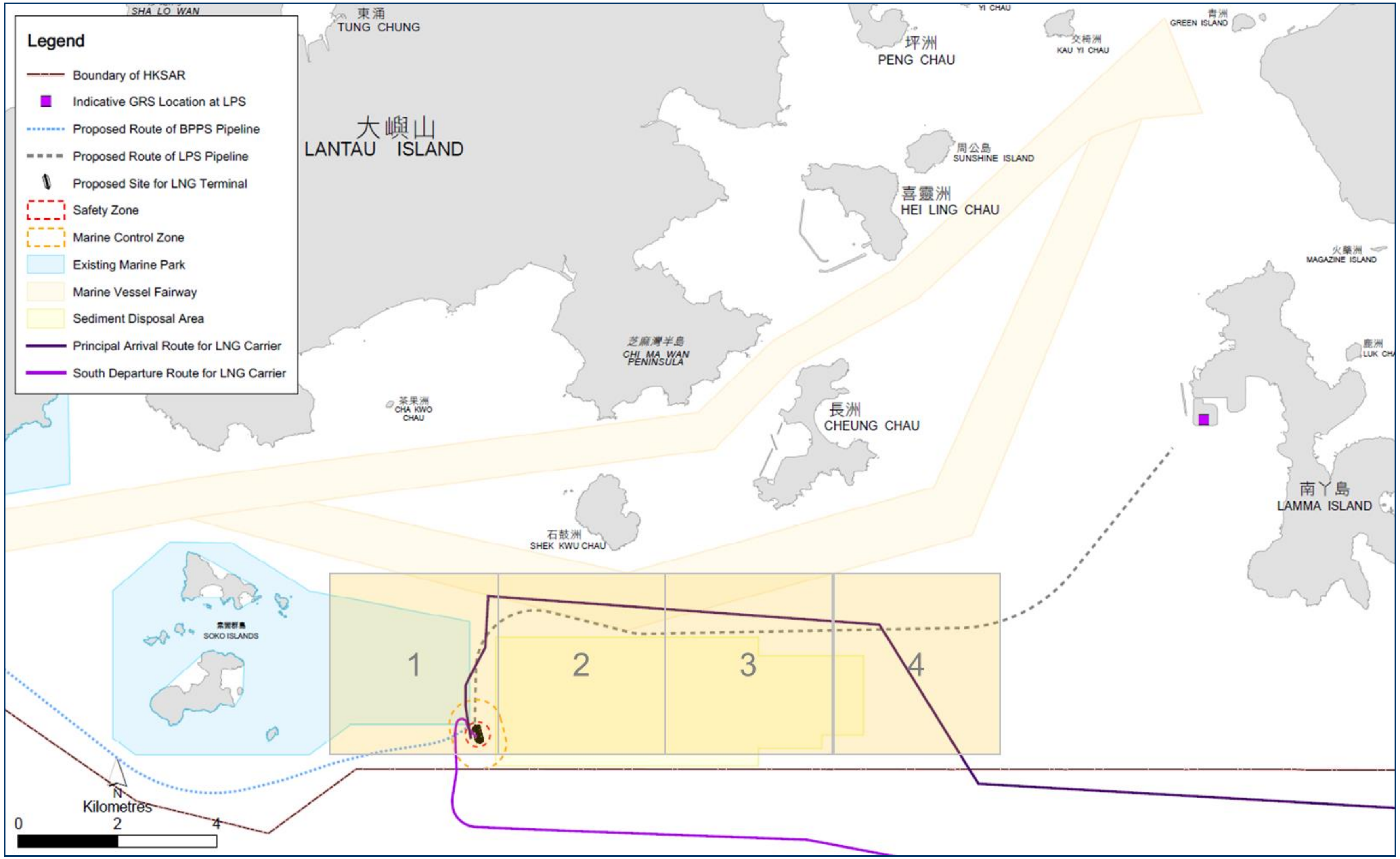
Marine Vessel Type	Typical Speed (m s^{-1}) (1)(2)	Transit Time (min) (1)(2)
Ocean-Going Vessel	6.0	9.9
Rivertrade Coastal Vessel	6.0	9.9
Fast Ferries	15.0	4.0
Tug and Tow	2.5	23.7
Others	6.0	9.9

Notes:

(1): Data collected from ERM, EIA for *Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities* (Register No.: AEIAR-106/2007), December 2006

(2): Data collected from ERM, EIA for *Black Point Gas Supply Project* (Register No.: AEIAR-150/2010), February 2010

Figure A4.1 Grid Cell Scheme for marine transit route for LNGC/FSRU Vessel



Remark: The indicative marine transit routes for LNG Carrier is illustrated, which is the worst case scenario for assessment purpose.

The number of marine vessels present within each grid cell at any instant in time was then calculated from:

Number of vessels = No. of vessels per day × Grid length / 86,400 / Speed *(Equation 1)*

The values obtained represent the number of marine vessels present within a grid cell at any instant in time. Values of less than one are interpreted as the probability of a vessel being present. The number of marine vessels per day is summarised in ***Table A4.4.***

Table A4.4 Number of marine vessels per day

Grid No.	Average Number of Marine Vessel per Day									
	2023					2030				
	OG	RT	TT	FF(*)	OTH	OG	RT	TT	FF(*)	OTH
1	0	57	8	0	147	0	65	10	0	178
2	0	97	17	0	246	0	113	17	0	305
3	0	112	13	0	253	0	128	14	0	307
4	2	120	8	0	212	3	137	10	0	257

OG: Ocean-Going Vessel
RT: Rivertrade Costal Vessel
TT: Tug & Tow Vessels
FF: Fast Ferries
OTH: Others
(*): Fast ferries are treated separately

A4.1.3 Estimation of Marine Populations (Average Density Approach)

The average marine population for each grid was calculated by combining the number of marine vessels in each grid as per *Equation 1* with the population at risk for each marine vessel shown in ***Table A4.2***. The estimated marine populations for Year 2023 and Year 2030 are summarised in ***Table A4.5*** below. This grid population is assumed to apply to all time periods.

Table A4.5 Estimated Marine Populations for Year 2023 and Year 2030

Marine Grid No.	2023	2030
Grid No. 1	8.61	10.30
Grid No. 2	14.81	17.70
Grid No. 3	15.29	18.08
Grid No. 4	13.87	16.61

It is noted however that fast ferries are excluded since they were treated separately in the analysis (refer to Section 4.1.4).

When simulating a possible release scenario, the impact area was calculated from dispersion modelling. In general, only a fraction of the grid area was affected and hence the number of fatalities within a grid was calculated using the following equation, in line with the previous studies that have been approved by the EPD and other relevant authorities.

Number of Fatality = Grid Population × Impact Area / Grid Area *(Equation 2)*

A4.1.4 Estimation of Fast Ferry Population (Point Receptor Approach)

The average density approach, described above, effectively dilutes the population over the area of the grid. Given that fast ferries have a much higher population than other classes of vessel, combined with a relatively low presence factor due to their higher speed, the average density approach would not adequately address the impact of fast ferries on the F-N curves. Fast ferries were therefore treated differently in the QRA Study.

In reality, if a fast ferry is affected by an accident scenario, the whole ferry will likely be affected. The likelihood that the ferry is affected, however, depends on the size of the hazard area and the density of ferry vessels. To model this, the population is treated as a concentrated point receptor, i.e. the entire population of the ferry is assumed to remain focused at the ferry location. The ferry density is calculated the same way as described above (Equation 1), giving the number of ferries per grid at any instant in time, or equivalent a "presence factor". A hazard scenario, however, will not affect a whole grid, but some fraction determined by the area ratio of the hazard footprint area and the grid area.

In line with the previous studies that have been approved by the EPD and other relevant authorities, the presence factor corrected by this area ratio was then used to modify the frequency of the hazard scenario using the following equation:

Probability that ferry is affected = Presence Factor × Impact Area / Grid Area *(Equation 3)*

The fast ferry population distribution adopted is described in ***Table A4.6***. Information from the main ferry operators suggested that 25% of ferry trips take place at night time (between 7 pm and 7 am), while 75% occur during daytime. Day and night ferries are therefore assessed separately in the QRA Study. This approach is consistent with the previous EIA studies that were approved by the EPD and other relevant authorities.

Table A4.6 Fast Ferry Population Distribution for Day and Night Time Periods

Population	Population at Risk	% of Day Trips	% of Night Trips	% of All Trips (= 0.75 × day + 0.25 × night)
450[a]	135	5	-	3.75
350[b]	105	5	-	3.75
280[c]	84	30	-	22.50
175[d]	53	60	30	52.50
105[e]	32	-	50	12.50
35[f]	11	-	20	5.00

Note:
a: largest ferries with max population
b: typical ferry with max population
c: typical ferry at 80% capacity
d: typical ferry at 50% capacity
e: typical ferry at 30% capacity
f: typical ferry at 10% capacity

The ferry presence factor *(Equation 1)* and probability that a ferry is affected by a release scenario *(Equation 2)* were calculated for each ferry occupancy category and each time period.

A4.2 Meteorological Data

The proximity weather station to the marine transit that records wind distribution is Cheung Chau Weather Station (CCH). Therefore, wind speed, wind stability and direction data taken from Cheung Chau weather station from year 2012 to 2016 was adopted for this QRA Study.

With reference to "Guidelines For Quantitative Risk Assessment, CPR 18E (Purple Book)", at least six (6) representative weather classes are recommended to be used in this QRA Study, covering the stability conditions of stable, neutral and unstable, low and high wind speed. At least the following six (6) weather classes have to be covered in terms of Pasquill classes.

Stability class	Wind speed (1)
B	Medium
D	Low
D	Medium
D	High
E	Medium
F	Low

NOTE:

: Low wind speed corresponding to 1 – 2 m s^{-1}

Medium wind speed corresponding to 3 – 5 m s^{-1}

High wind speed corresponding to 6 – 9 m s^{-1}

The probability of each weather state for each direction are rationalized for analysis based on the requirements presented in "Guidelines For Quantitative Risk Assessment, CPR 18E (Purple Book)", and summarised at ***Table A4.7***.

The wind speeds are quoted in units of meters per second, (m s^{-1}). The atmospheric stability classes refer to:

A – Turbulent

B – Very Unstable

C – Unstable

D – Neutral

E – Stable

F – Very Stable

Atmospheric stability suppresses or enhances the vertical element of turbulent motion. The vertical element of turbulent motion is a function of the vertical temperature profile in the atmosphere (i.e the greater the rate of decrease in temperature with height, the greater the level of turbulent motion). Category D is neutral and neither enhances nor suppresses turbulence.

Table A4.7 Meteorological Data from Cheung Chau Weather Station (2012-2016)

	Day				Night			
Wind Speed (m s-1)	**2.5**	**3.0**	**7.0**	**2.0**	**2.5**	**3.0**	**7.0**	**2.0**
Atmospheric Stability	**B**	**D**	**D**	**F**	**B**	**D**	**D**	**F**
Wind Direction								
0°	4.14%	0.81%	7.77%	0.54%	0.00%	0.86%	12.73%	2.22%
30°	3.61%	1.04%	4.25%	0.66%	0.00%	1.16%	6.20%	2.38%
60°	2.68%	0.69%	2.48%	0.42%	0.00%	0.92%	5.03%	2.29%
90°	3.37%	0.62%	10.94%	0.33%	0.00%	1.11%	21.03%	2.47%
120°	10.73%	0.75%	9.91%	0.34%	0.00%	0.54%	11.19%	2.39%
150°	6.16%	0.55%	2.19%	0.28%	0.00%	0.22%	3.07%	1.44%
180°	3.67%	0.53%	1.59%	0.26%	0.00%	0.24%	3.74%	1.40%
210°	5.38%	0.51%	3.48%	0.15%	0.00%	0.28%	5.34%	1.30%
240°	2.42%	0.30%	0.87%	0.16%	0.00%	0.31%	2.25%	1.54%
270°	1.15%	0.29%	0.70%	0.20%	0.00%	0.21%	2.17%	1.25%
300°	0.60%	0.26%	0.29%	0.18%	0.00%	0.14%	0.40%	0.97%
330°	0.96%	0.16%	0.50%	0.14%	0.00%	0.09%	0.58%	0.56%

A5 HAZARD IDENTIFICATION

A5.1 Overview

The hazardous scenarios associated with the marine transits of the LNGC and FSRU Vessel to the LNG Terminal were identified though the following tasks:

- Review of hazardous materials;
- Review of potential Major Accident Events (MAEs);
- Review of relevant industry incidents; and
- Review of potential initiating events leading to MAEs.

A5.2 Review of Hazardous Material

LNG on board the LNGC and FSRU Vessel was the major hazardous material considered in the QRA Study, while other dangerous goods including diesel, marine diesel oil, and lubricating oil were also considered. The details of the storage of LNG and other dangerous goods on board the LNGC and FSRU Vessel during marine transit are summarised in ***Table A5.1*** and ***Table A5.2*** respectively.

Table A5.1 LNG Associated with LNGC during Marine Transit

Chemical	Dangerous Goods Classification*	Maximum Storage Quantity	Temperature (°C)	Pressure (barg)
LNG for LNGC	-	216,000 m^3	-156	0.7
Diesel (Heavy Fuel Oil)	Category 5	~6,000 m^3	25	ATM
Marine Diesel Oil	Category 5	≤ 800 m^3	25	ATM
Lubricating Oil	-	≤ 100 m^3	25	ATM
Calibration Gas^	Category 2	1 cylinder	25	137

Notes:

*: The dangerous goods category is classified based on "Fire Protection Notice No. 4, Dangerous Goods General" by Fire Services Department.

^: The key composition of the calibration gas for Gas Chromatograph is methane (90 vol%), ethane (5 vol%), Nitrogen (2.5 vol%), and carbon dioxide (1 vol%) and propane (1 vol%).

Table A5.2 LNG & Other Dangerous Goods Associated with FSRU Vessel during Marine Transit

Chemical	Dangerous Goods Classification*	Maximum Storage Quantity	Temperature (°C)	Pressure (barg)
LNG	-	265,000 m^3	-156	0.7
Diesel (Heavy Fuel Oil)	Category 5	~6,000 m^3	25	ATM
Marine Diesel Oil	Category 5	≤ 800 m^3	25	ATM
Lubricating Oil	-	≤ 100 m^3	25	ATM
Calibration Gas^	Category 2	1 cylinder	25	137

Notes:

*: The dangerous goods category is classified based on "Fire Protection Notice No. 4, Dangerous Goods General" by Fire Services Department.

^: The key composition of the calibration gas for Gas Chromatograph is methane (90 vol%), ethane (5 vol%), Nitrogen (2.5 vol%), and carbon dioxide (1 vol%) and propane (1 vol%).

The detailed description of each identified hazardous material is provided below.

A5.2.1 LNG

LNG is an extremely cold, non-toxic, non-corrosive and flammable substance.

If LNG is accidentally released from a temperature-controlled container, it is likely to come in contact with relatively warmer surfaces and air that will transfer heat to the LNG. The heat will begin to vapourise some of the LNG, returning it to its gaseous state.

The relative proportions of liquid LNG and gaseous phases immediately following an accidental release depends on the release conditions. The released LNG will form a LNG pool on the surface of the sea in the vicinity of the LNGC/ FSRU Vessel which will begin to "boil" and vapourise due to heat input from the surrounding environment. The vapour cloud may only ignite if it encounters an ignition source while its concentration is within its flammability range.

Any person coming into contact with LNG in its cryogenic condition will be subjected to cryogenic burns.

A5.2.2 Diesel (Heavy Fuel Oil), Marine Diesel Oil and Lubricating Oil

Diesel, marine diesel oil and lubricating oil have a relatively higher flash point (greater than 66 °C), which is above ambient temperature, and with a high boiling point. Thus, evaporation from a liquid pool is expected to be minimal.

A5.2.3 Calibration Gas

The volume of the compressed gas inside the cylinders is limited and the associated inventory available is small, and those compressed gas cylinders are located at machinery room. Should loss of containment occur for the compressed gas cylinders, there is no off-site impact on surrounding marine population. Hence, it is not further assessed in the QRA Study.

A5.3 Review of Potential Major Accident Events

Leakage or rupture scenarios of process equipment, pipeline or pipework handling flammable materials can result in a flammable gas cloud, which may be ignited if it encounters an ignition source while its concentration lies within the flammable range. In some cases, static discharge may also cause immediate ignition of flammable gas release.

Potential hazardous scenarios to be evaluated in this QRA Study include:

- Flash fire; and
- Pool fire;

The characteristics of the hazardous scenarios are described separately in ***Section A7.2***.

A5.4 Review of Potential MAEs

A5.4.1 LNG

The possible hazardous scenarios considered in the QRA Study, upon the ignition of any released LNG during the marine transits of the LNGC or FSRU Vessel with consideration of operating conditions, are:

- Pool fire; and
- Flash fire.

A5.4.2 Diesel (Heavy Fuel Oil), Marine Diesel Oil and Lubricating Oil

Considering the high flash point temperature of the other dangerous goods such as marine diesel oil present in the LNGC and FSRU Vessel, the possible hazardous scenarios considered in the QRA Study are pool fire and flash fire.

A5.5 Review of Relevant Industry Incidents

To further investigate possible hazardous scenarios from the LNGC and FSRU Vessel, review of the applicable past industry incidents at similar facilities worldwide was conducted based on the following incident/ accident database:

- Institution of Chemical Engineers (IChemE) accident database;
- eMARS;
- ERNS;
- Major Hazard Incident Data Service (MHIDAS) database; and
- Society of International Gas Tanker and Terminal Operators (SIGTTO).

A5.6 Review of Potential Initiating Events leading to MAEs

The key potential hazardous scenarios arising from marine transits of the LNGC and FSRU Vessel were identified as loss of containment of LNG. The potential initiating events which could result in the loss of containment of LNG are listed below:

- Ship Collision;
- Groundings;
- Sinking or foundering;
- General equipment/piping failure (due to corrosion, construction defects etc.);
- LNG containment system failure; and
- External effects - adverse weather (typhoon, poor visibility, storm surge, extreme tide), tsunami, and lightning.

A5.7 Development of Hazardous Sections

Different scenarios (collision release, grounding release, maintenance and emergency evacuation) were modelled and the release parameters for these scenarios are listed in ***Table A5.3***.

Table A5.3 Inventory Release Details for Marine Transit of LNGC and FSRU Vessel to the LNG Terminal

Parameter	Collision, Grounding, Maintenance & Evacuation
FSRU Vessel (265,000 m^3)	
LNG Inventory (kg)	2.4×10^7
Pressure (barg)	0.7
Temperature (°C)	-156
Parameter	**Collision & Grounding**
Large LNGC (216,000 m^3)	
LNG Inventory (kg)	1.9×10^7
Pressure (barg)	0.7
Temperature (°C)	-156

A6 FREQUENCY ANALYSIS

A6.1 Ship Collision Frequency Analysis

A ship collision frequency analysis was conducted following the approach adopted in the previous EIA Report that was approved by the EPD. DYMTRI (Dynamic Marine Traffic simulation) model was adopted as the platform for the marine traffic simulation to predict the collision frequencies along the LNGC and FSRU Vessel transit route.

The key steps of the ship collision frequency analysis included:

- Identification of Modelled Marine Traffic
- Hazard Identification
- Model Validation
- Marine Traffic Forecasts
- Scenario Development
- Collision Frequency Assessment
- Collision Energy Distribution.

Table A6.1 present the collision frequencies of different operating scenarios along the sub-segments of Principal Arrival Route for Year 2023 and Year 2030.

Table A6.1 Collision Frequency

Year	Route	Type	Scenario	Release Frequency of Sub-Segments			
				a	b1	b2	b3
2023	Principal Arrival Route	LNGC	Normal Operation	0.00E+00	0.00E+00	3.02E-09	2.22E-09
		FSRU	Initial Arrival	0.00E+00	0.00E+00	2.98E-11	2.31E-11
			Maintenance	0.00E+00	0.00E+00	1.17E-10	9.08E-11
			Evacuation	0.00E+00	0.00E+00	5.84E-10	4.53E-10
2030		LNGC	Normal Operation	0.00E+00	0.00E+00	4.02E-09	2.92E-09
		FSRU	Initial Arrival	0.00E+00	0.00E+00	3.98E-11	3.04E-11
			Maintenance	0.00E+00	0.00E+00	1.56E-10	1.19E-10
			Evacuation	0.00E+00	0.00E+00	7.80E-10	5.95E-10

A6.2 Grounding Frequency

The anticipated grounding frequency for the LNGC and FSRU Vessel during their transits to and from the LNG Terminal has been developed from a review of historical incidents in Hong Kong waters associated with vessels over 200 m Length Overall (LOA). ***Table A6.2*** presents the grounding frequency and ***Table A6.3*** presents the grounding release frequency adopted in the QRA study.

Table A6.2 Grounding Frequency

Route	Section Length (km)	Annual Transit (1)	Grounding Frequency (2) (/year)	Grounding Frequency (/km/year)	Grounding Frequency (/km/transit)
Urmston Road - East Lamma	70	10,990	0.3	4.3E-03	3.9E-07

Notes:

(1) Annual transit along Urmston Road to the East Lamma Channel is about 60 transits per day, and around 50% of OG vessels in Urmston Rd is greater than 200m.

(2) 3 grounding incidents (LOA >200m) were recorded over the past 10 years (2012-2021).

Table A6.3 Grounding Release Frequency

Type	Scenario	Grounding Frequency (/km/transit)	No. of Transits (/year)	Grounding Frequency (/km/year)	Grounding Release Frequency (1) (/km/year)
LNGC	Normal Operation	3.9E-07	52	2.0E-05	5.1E-07
FSRU	Initial Arrival	3.9E-07	1	3.9E-07	9.8E-09
	Maintenance	3.9E-07	4	1.6E-06	3.9E-08
	Evacuation	3.9E-07	20	7.8E-06	2.0E-07

Notes:

(1) A conditional probability of 0.025 was applied to calculate the LNG release frequency upon grounding events, as per the approved EIA Report.

A6.3 Release Hole Sizes

The release hole sizes and associated penetration energy selected are as per the previous EIA Report that was approved by the EPD, are presented in ***Table A6.4***.

Table A6.4 Release Hole Sizes and Penetration Energy

Release Hole Size	Penetration Energy (MJ)
250 mm	100 to 110 MJ
750 mm	111 to 150 MJ
1,500 mm	>150 MJ

A6.4 Ignition Probability

As per the approved EIA Report, the immediate ignition probability for the collision scenarios was selected as 0.8; and the immediate ignition probability for the grounding scenarios was selected as 0.2 for the QRA Study.

A6.5 Event Tree Analysis

An event tree analysis was performed to model the development of each hazardous scenario outcomes (pool fire and flash fire) from an initial release scenario. The event tree analysis considered whether there is immediate ignition or delayed ignition, with consideration of the associated ignition probability as discussed above. The development of the event tree for Year 2023 Principal Arrival Route Case and Year 2030 Principal Arrival Route Case are presented in ***Table A6.5*** and ***Table A6.6*** respectively.

Table A6.5 Hazardous Scenario Frequency due to Collision Events (Year 2023 Principal Arrival Route)

Type	Scenario	Hole Size	Hazardous Scenario Frequency in Sub-Segment "b2" (/year/m)		Hazardous Scenario Frequency in Sub-Segment "b3" (/year/m)	
			Pool Fire	Flash Fire	Pool Fire	Flash Fire
LNGC	Normal Operation	Small	1.82E-11	2.28E-12	6.07E-11	7.59E-12
		Medium	1.33E-10	1.66E-11	7.38E-11	9.23E-12
		Large	1.42E-09	1.77E-10	1.02E-09	1.28E-10
FSRU	Initial Arrival	Small	2.88E-13	3.60E-14	1.09E-12	1.36E-13
		Medium	3.63E-13	4.54E-14	6.60E-13	8.24E-14
		Large	1.48E-11	1.85E-12	1.03E-11	1.28E-12
	Maintenance	Small	1.13E-12	1.42E-13	4.28E-12	5.34E-13
		Medium	1.43E-12	1.79E-13	2.59E-12	3.24E-13
		Large	5.83E-11	7.28E-12	4.04E-11	5.04E-12
	Evacuation	Small	5.75E-12	7.18E-13	2.13E-11	2.67E-12
		Medium	7.25E-12	9.06E-13	1.30E-11	1.62E-12
		Large	2.91E-10	3.64E-11	2.01E-10	2.51E-11

Table A6.6 Hazardous Scenario Frequency due to Collision Events (Year 2030 Principal Arrival Route)

Type	Scenario	Hole Size	Hazardous Scenario Frequency in Sub-Segment "b2" (/year/m)		Hazardous Scenario Frequency in Sub-Segment "b3" (/year/m)	
			Pool Fire	Flash Fire	Pool Fire	Flash Fire
LNGC	Normal Operation	Small	2.37E-11	2.96E-12	8.13E-11	1.02E-11
		Medium	1.77E-10	2.21E-11	9.78E-11	1.22E-11
		Large	1.89E-09	2.36E-10	1.34E-09	1.67E-10
FSRU	Initial Arrival	Small	3.85E-13	4.82E-14	1.46E-12	1.82E-13
		Medium	4.86E-13	6.08E-14	8.84E-13	1.10E-13
		Large	1.98E-11	2.48E-12	1.35E-11	1.68E-12
	Maintenance	Small	1.52E-12	1.90E-13	5.73E-12	7.16E-13
		Medium	1.91E-12	2.39E-13	3.47E-12	4.34E-13
		Large	7.79E-11	9.73E-12	5.29E-11	6.61E-12
	Evacuation	Small	7.66E-12	9.57E-13	2.86E-11	3.57E-12
		Medium	9.66E-12	1.21E-12	1.74E-11	2.17E-12
		Large	3.88E-10	4.86E-11	2.64E-10	3.30E-11

A7 CONSEQUENCE ANALYSIS

Consequence analysis was involved the following steps:

- Source term modelling, which comprises the application of appropriate discharge rate models to define the release rate, release duration and the quantity of release;
- Physical effects modelling, which involves estimating the effect zone of the various hazardous scenarios; and
- Consequence end-point criteria, which involves assessing of the impact of hazardous scenarios on the exposed population.

A7.1 Source Term Modelling

The gas dispersion modelling of SAFETI 6.7 was adopted to estimate the release rates. The source term modelling output forms the inputs to physical effects modelling such as the dispersion and fire modelling, and was used to determine the immediate ignition probability.

A7.2 Physical Effects Modelling

PHAST was used to perform the physical effects modelling to assess the effects zones for the following hazardous scenarios:

- Flash fire; and
- Pool fire

A7.2.1 Flash Fire Effects

In the event that a release is not ignited immediately, the gas will disperse with the wind and may subsequently be ignited if it reaches an ignition source. Portions of the cloud within flammability limits will then burn in a flash fire. The dispersion distance to the LFL will be used as the hazard footprint. Dispersion modelling will be performed using SAFETI 6.7 for the representative weather conditions at a particular site surrounding.

7.2.2 Pool Fire Effects

In case of an early ignition of a liquid pool, an early pool fire will be formed and the maximum pool fire diameter can be obtained by matching the burning rate with the release rate. Under such conditions, the size of the pool fire will not further increase and will be steady. In case of a delay ignition, the maximum pool radius is reached when the pool thickness at the centre of the pool reaches the maximum thickness.

A7.3 Consequence Analysis

7.3.1 Thermal Radiation

The fatality effects associated with thermal radiation from pool fires were estimated based on the Probit from Purple Book:

$$Pr = -36.38 + 2.56 \times \ln(Q^{4/3} \times t)$$

where:
Pr = probit value
Q = thermal radiation (kW/ m^2)
t = duration of exposure (seconds)
$Q^{4/3} \times t$ = thermal dose

The fatality levels for outdoor population are estimated based on the above probit equation assuming a 20-second exposure time.

With regard to a flash fire, the criterion chosen is that a 100% fatality was adopted for any person outdoor within the flash fire envelope, which was conservatively selected as 0.85 of the Lower Flammable Limit (LFL).

7.3.2 Consequence Analysis Results

The detailed consequence analysis results were summarised in Appendix A-1.

A8 RISK SUMMATION

The risk summation for the LNGC and FSRU Vessel transits was modelled using SAFETI, which is in line with the previous EIA Report that was approved by EPD.

The inputs to the software comprise of:

- Release cases file detailing all identified hazardous scenarios, and their associated frequencies and probabilities;
- Release location of hazardous scenarios either at given points or along given routes;
- Weather probabilities file that details the local meteorological data according to a matrix of weather class (speed/stability combinations) and wind directions;
- Population data with the number of people and polygonal shape as well as indoor faction; and
- Ignition sources with ignition probabilities in a given time period.

A8.1 Risk Criteria

A8.1.1 Individual Risk

Individual risk is the predicted increase in the chance of fatality per year to a hypothetical individual who remains at a given stationary point for 100% of the time. The individual risk guidelines specify that the maximum level of off-site individual risk associated with a hazardous installation should not exceed 1 in 100,000 per year, i.e. 1×10^{-5} per year.

A8.1.2 Societal Risk

Societal risk expresses the risks to the surrounding off-site population in the vicinity of a hazardous installation. The societal risk is expressed in terms of frequency (F) of fatalities against number of fatalities (N) in the population from incidents at a hazardous installation. Two F-N risk lines are used to demark “Acceptable” or “Unacceptable” regions. The region between the two F-N risk lines indicates the acceptability of the societal risk is borderline and should be reduced to As Low As Reasonably Practicable (ALARP) level. This seeks to ensure that all practicable and cost-effective mitigation measures which can reduce societal risk are considered. In order to avoid major incidents resulting in more than 1,000 fatalities, there is a vertical cut-off line at the 1,000 fatalities level extending down to a frequency of 1 in a billion years.

A9 RESULTS AND DISCUSSION

A9.1 Individual Risk Results

The individual risk contours for the LNGC and FSRU Vessel Principal Arrival Route during Year 2023 and Year 2030 were depicted at ***Figure A9.1*** and ***Figure A9.2***. The individual risk contour of 10^{-5} per year was not reached for the LNGC and FSRU Vessel Principal Arrival Route, thus the individual risk criterion stipulated in Hong Kong Risk Guidelines was met.

Figure A9.1 Year 2023 Principal Arrival Route Individual Risk Contours

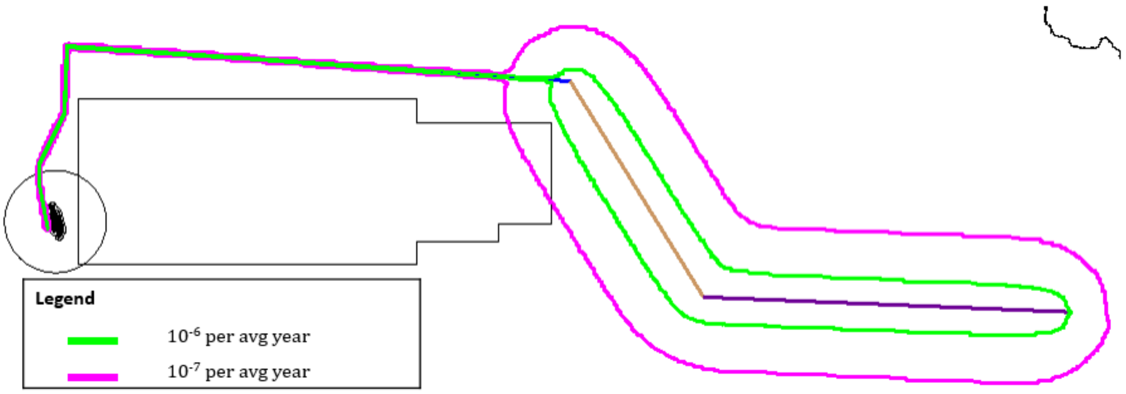
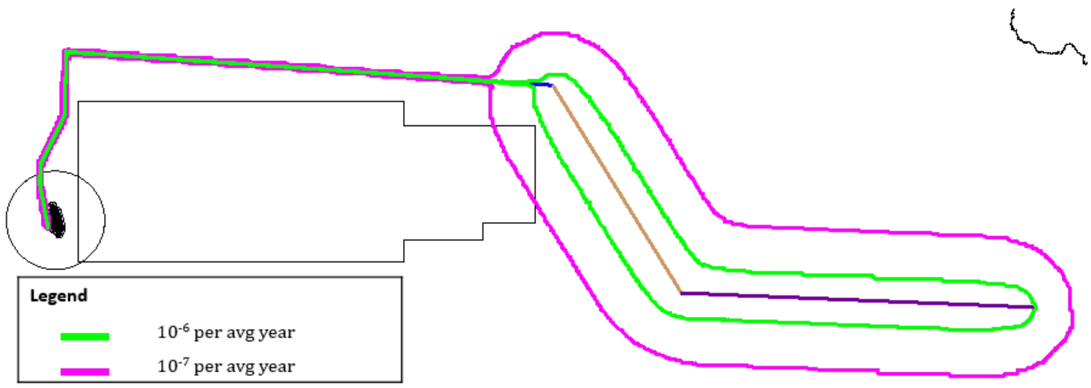


Figure A9.2 Year 2030 Principal Arrival Route Individual Risk Contours



A9.2 Societal Risk Results

The societal risk for the LNGC and FSRU Vessel transit was calculated based on the associated process risks and the surrounding off-site marine traffic populations. The societal risks for Year 2023 Principal Arrival Route Case and Year 2030 Principal Arrival Route Case, in terms of F-N curves, depicted at ***Figure A9.3***, lie within the Acceptable Region. As such the societal risk criteria stipulated in Hong Kong Risk Guidelines were met for all proposed scenarios.

The top risk contributors associated with Year 2023 Principal Arrival Route Case and Year 2030 Principal Arrival Route Case were summarised in ***Table A9.1*** and ***Table A9.2***.

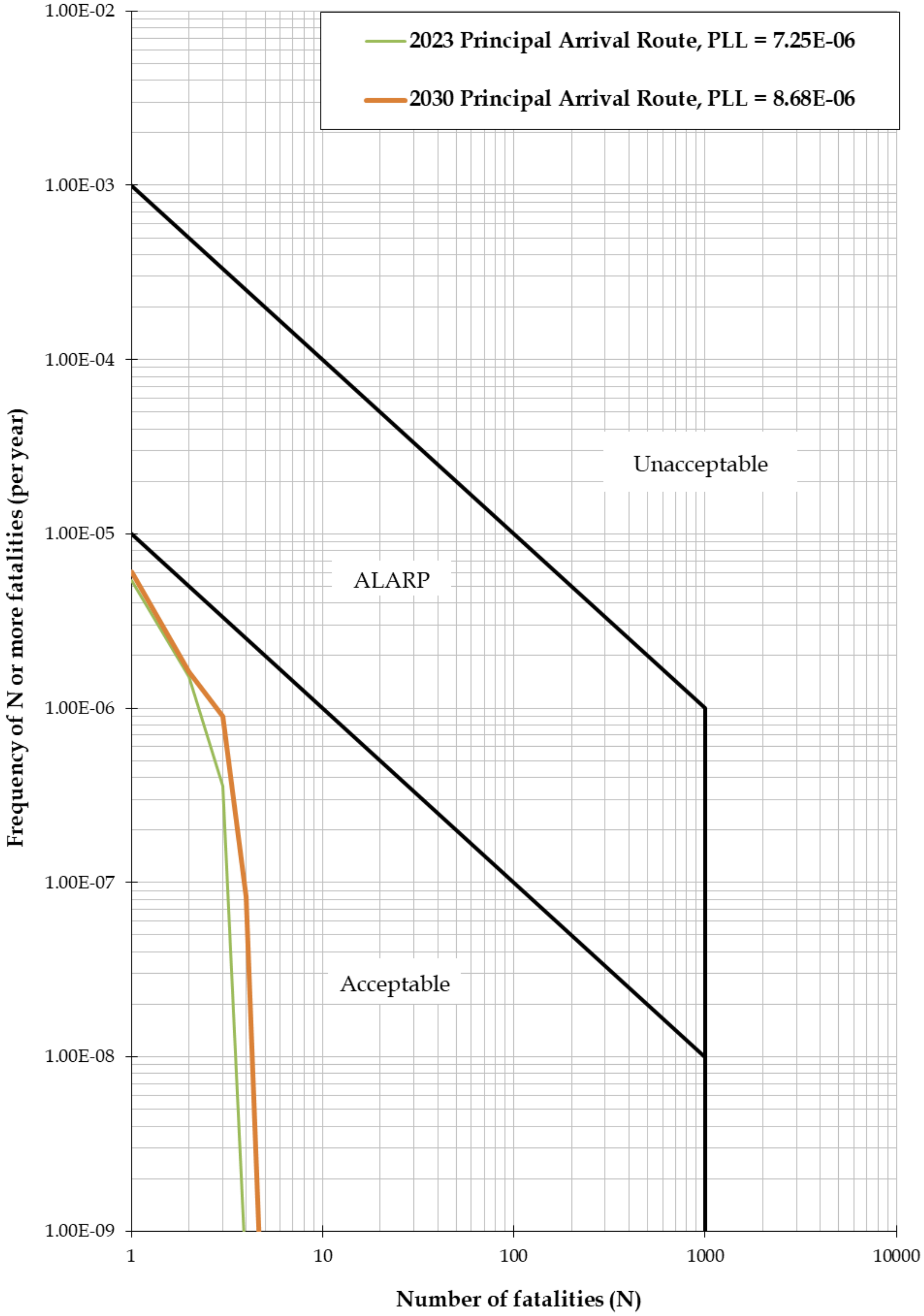
Table A9.1 Major Risk Contributors for Year 2023 Principal Arrival Route

Ranking	Event	Description	PLL	Percentage
1	Collision_1500 mm_WN_b2	Flammable effect (pool fire and flash fire) of a large hole size (1,500 mm) release scenario due to collision for LNGC during marine transit approaching the LNG Terminal during night time	5.14E-06	35%
2	Collision_1500 mm_WD_b2	Flammable effect (pool fire and flash fire) of a large hole size (1,500 mm) release scenario due to collision for LNGC during marine transit approaching the LNG Terminal during day time	5.14E-06	35%
3	Collision_1500 mm_WD_FSRU_BW_E	Flammable effect (pool fire and flash fire) of a large hole size (1,500 mm) release scenario due to collision for FSRU during marine transit departing the LNG Terminal due to bad weather, emergency events in day time	1.06E-06	7%
4	Collision_1500 mm_WN_FSRU_BW_E	Flammable effect (pool fire and flash fire) of a large hole size (1,500 mm) release scenario due to collision for FSRU during marine transit departing the LNG Terminal due to bad weather, emergency events in night time	1.06E-06	7%
5	Maintenance_1500 mm_WN_FSRU_b2	Flammable effect (pool fire and flash fire) of a large hole size (1,500 mm) release scenario due to collision for FSRU during marine transit departing the LNG Terminal due to maintenance in night time	2.11E-07	1%
	Other		1.89E-06	13%
	Total		1.45E-05	100%

Table A9.2 Major Risk Contributors for Year 2030 Principal Arrival Route

Ranking	Event	Description	PLL	Percentage
1	Collision_1500 mm_WN_b2	Flammable effect (pool fire and flash fire) of a large hole size (1,500 mm) release scenario due to collision for LNGC during marine transit approaching the LNG Terminal during night time	6.16E-06	35%
2	Collision_1500 mm_WD_b2	Flammable effect (pool fire and flash fire) of a large hole size (1,500 mm) release scenario due to collision for LNGC during marine transit approaching the LNG Terminal during day time	6.16E-06	35%
3	Collision_1500 mm_WD_FSRU_BW_E	Flammable effect (pool fire and flash fire) of a large hole size (1,500 mm) release scenario due to collision for FSRU during marine transit departing the LNG Terminal due to bad weather, emergency events in day time	1.27E-06	7%
4	Collision_1500 mm_WN_FSRU_BW_E	Flammable effect (pool fire and flash fire) of a large hole size (1,500 mm) release scenario due to collision for FSRU during marine transit departing the LNG Terminal due to bad weather, emergency events in night time	1.27E-06	7%
5	Maintenance_1500 mm_WN_FSRU_b2	Flammable effect (pool fire and flash fire) of a large hole size (1,500 mm) release scenario due to collision for FSRU during marine transit departing the LNG Terminal due to maintenance in night time	2.53E-07	1%
	Other		2.25E-06	13%
	Total		1.74E-05	100%

Figure A9.3 F-N Curve for LNGC and FSRU Vessel Transit



A10 CONCLUSION

As part of the environmental review, a Quantitative Risk Assessment (QRA) is conducted to assess the risk due to marine transits of LNGC / FSRU Vessel to the LNG Terminal adopting the proposed marine transit route. The study findings showed that the individual and societal risks associated with Year 2023 Principal Arrival Route and Year 2030 Principal Arrival Route are in compliance with the risk criteria stipulated in Hong Kong Risk Guidelines.

A11 REFERENCE

ERM, EIA for Hong Kong Offshore LNG Terminal (Register No.: AEIAR-256/2018), October 2018.

ERM, EIA for Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities (Register No.: AEIAR-106/2007), December 2006.

DNV GL, SAFETI

Guidelines for Quantitative Risk Assessment, “Purple Book”, 2005.

Cox, Lees and Ang, Classification of Hazardous Locations, IChemE.

OGP, Risk Assessment Data Directly, Report No. 434-.1, March 2010.

UK HSE, Failure Rate and Event Data for use within Risk Assessment, 2019

TNO, Methods for the Determination of Possible Damage to People and Objects Resulting from Releases of Hazardous Materials (The Green Book), Report CPR 16E, The Netherlands Organisation of Applied Scientific Research, Voorburg, 1992

Center for Chemical Process Safety of the American Institute of Chemical Engineer, Guidelines for Chemical Process Quantitative Risk Analysis, Second Edition, 2000.

Pierorazio et al., An Update to the Baker-Strehlow-Tang Vapour Cloud Explosion Prediction Methodology Flame Speed Table, 4 January 2005, Wiley InterScience, DOI 10.1002/prs.10048.

ERM, EIA for Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities (Register No.: AEIAR-106/2007), December 2006.

ERM, EIA for Black Point Gas Supply Project (Register No.: AEIAR-150/2010), February 2010.

https://www.ais.gov.hk/HK_AIP/AIP/ENR/HK_ENR3.4.pdf.

APPENDIX A-1

DETAILED CONSEQUENCE ANALYSIS RESULTS

Consequence Analysis

Isolatable Sections	Leak Size (mm)	Hazard Effects	End-Point Criteria	Hazard Extent (m) Weather Condition 2.5B	3.0D	7.0D	2.0F
LNGC_Collision	250	Pool Fire	35.35 kW/m^2	82	86	102	78
			28.3 kW/m^2	94	97	111	90
			19.5 kW/m^2	113	116	126	109
			9.8 kW/m^2	152	154	162	149
		Flash Fire	0.85 LFL	142	184	191	67
	750	Pool Fire	35.35 kW/m^2	190	197	232	182
			28.3 kW/m^2	217	224	256	208
			19.5 kW/m^2	262	268	294	254
			9.8 kW/m^2	354	359	376	348
		Flash Fire	0.85 LFL	229	272	256	77
	1500	Pool Fire	35.35 kW/m^2	326	337	394	313
			28.3 kW/m^2	370	381	435	358
			19.5 kW/m^2	447	457	501	435
			9.8 kW/m^2	605	613	641	595
		Flash Fire	0.85 LFL	186	203	393	95
LNGC_Grounding	250	Pool Fire	35.35 kW/m^2	69	72	86	65
			28.3 kW/m^2	79	82	95	75
			19.5 kW/m^2	96	99	108	93
			9.8 kW/m^2	130	132	139	128
		Flash Fire	0.85 LFL	90	175	87	64
Diesel Storage	10	Pool Fire	35.35 kW/m^2	4	4	6	3
			28.3 kW/m^2	5	5	7	3
			19.5 kW/m^2	6	6	8	4
			9.8 kW/m^2	7	7	9	6
		Flash Fire	0.85 LFL	1	1	3	1
	25	Pool Fire	35.35 kW/m^2	6	6	8	4
			28.3 kW/m^2	7	7	10	5
			19.5 kW/m^2	9	9	11	7
			9.8 kW/m^2	12	12	14	10
		Flash Fire	0.85 LFL	1	1	2	1
	50	Pool Fire	35.35 kW/m^2	7	7	9	6
			28.3 kW/m^2	9	9	11	7
			19.5 kW/m^2	13	13	16	10
			9.8 kW/m^2	17	17	19	15
		Flash Fire	0.85 LFL	1	1	2	1
	Catastrophic Rupture	Pool Fire	35.35 kW/m^2	0	0	0	0
			28.3 kW/m^2	0	0	0	0
			19.5 kW/m^2	67	67	68	68
			9.8 kW/m^2	79	79	87	72
		Flash Fire	0.85 LFL	1	1	2	1

Isolatable Sections	Leak Size (mm)	Hazard Effects	End-Point Criteria	Hazard Extent (m) Weather Condition			
				2.5B	3.0D	7.0D	2.0F
Marine Diesel Oil Storage	10	Pool Fire	35.35 kW/m^2	4	4	6	3
			28.3 kW/m^2	5	5	7	3
			19.5 kW/m^2	6	6	8	4
			9.8 kW/m^2	7	7	9	6
		Flash Fire	0.85 LFL	1	1	3	1
	25	Pool Fire	35.35 kW/m^2	6	6	8	4
			28.3 kW/m^2	7	7	10	5
			19.5 kW/m^2	9	9	11	7
			9.8 kW/m^2	12	12	14	10
		Flash Fire	0.85 LFL	1	1	2	1
	50	Pool Fire	35.35 kW/m^2	7	7	9	6
			28.3 kW/m^2	9	9	11	7
			19.5 kW/m^2	13	13	16	10
			9.8 kW/m^2	17	17	19	15
		Flash Fire	0.85 LFL	1	1	2	1
	Catastrophic Rupture	Pool Fire	35.35 kW/m^2	0	0	0	0
			28.3 kW/m^2	0	0	0	0
			19.5 kW/m^2	67	67	68	68
			9.8 kW/m^2	79	79	87	72
		Flash Fire	0.85 LFL	1	1	2	1
Lubricating Oil Storage	10	Pool Fire	35.35 kW/m^2	4	4	6	3
			28.3 kW/m^2	5	5	7	3
			19.5 kW/m^2	6	6	8	4
			9.8 kW/m^2	7	7	9	6
		Flash Fire	0.85 LFL	1	1	3	1
	25	Pool Fire	35.35 kW/m^2	6	6	8	4
			28.3 kW/m^2	7	7	10	5
			19.5 kW/m^2	9	9	11	7
			9.8 kW/m^2	12	12	14	10
		Flash Fire	0.85 LFL	1	1	2	1
	50	Pool Fire	35.35 kW/m^2	7	7	9	6
			28.3 kW/m^2	9	9	11	7
			19.5 kW/m^2	13	13	16	10
			9.8 kW/m^2	17	17	19	15
		Flash Fire	0.85 LFL	1	1	2	1
	Catastrophic Rupture	Pool Fire	35.35 kW/m^2	0	0	0	0
			28.3 kW/m^2	0	0	0	0
			19.5 kW/m^2	67	67	68	68
			9.8 kW/m^2	79	79	87	72
		Flash Fire	0.85 LFL	1	1	2	1