Annex 5D

Discussion on Potential Initiating Events and Hazardous Scenario Development

5D DISCUSSION ON POTENTIAL INITIATING EVENTS AND HAZARDOUS SCENARIO DEVELOPMENT

This *Annex* summarises the discussion on potential initiating events and hazardous scenarios development as follows:

- ***Section 5D.1*** – Potential Initiating Events;
- ***Section 5D.2*** – Natural Hazards;
- ***Section 5D.3*** – Aircraft Crash;
- ***Section 5D.4*** – Helicopter Crash; and
- ***Section 5D.5*** – Hazardous Scenario Development.

5D.1 POTENTIAL INITIATING EVENTS

Based on the review of industry incidents and the HAZID workshop, the potential initiating events for the Project components are presented below.

5D.1.1 QRA Study for Marine Transit of the LNGC and the FSRU Vessel to the LNG Terminal

Ship Collision

Although the marine traffic level is considered low in the vicinity of the LNGC or FSRU Vessel transit route, the LNGC or FSRU Vessel may collide with other passing vessels due to various reasons (e.g. loss of navigation, failure of propulsion equipment, environmental factors etc.). Although the inherent design of the LNGC/FSRU Vessel (including forward collision bulkhead and double hull) could absorb part of the collision energy, the remaining collision energy may still be sufficient to penetrate and cause a hole in the outer hull. This will lead to potential breach of LNG cargo containment and subsequent safety/environmental impact.

Marine traffic simulation [1] was conducted to determine the ship collision frequency and associated LNG release frequency for further assessment in the QRA Study.

Grounding

Grounding of the LNGC or FSRU Vessel may occur along the transit route due to various reasons (e.g. loss of navigation, failure of propulsion equipment, environmental factors etc.). The grounding frequency along the transit route has been estimated [1] for further assessment in the QRA Study.

(1) BMT Asia Pacific Limited, Hong Kong Offshore LNG Terminal Marine Impact Assessment, R.9331.08, Issue 1.

Sinking or Foundering

Extreme weather conditions, such as high wave, may lead to difficulty in controlling the LNGC or FSRU Vessel. The chance of vessel collision and grounding events may increase leading to damage to structural hull, potential breach of LNG cargo containment and subsequent safety/environmental impact. Nevertheless, typical LNGC and FSRU Vessel are designed according to significant wave height and period criteria. For overall strength, a ship's hull must be capable of withstanding design values of still water and wave induced loads within specified stress criteria. The capability of modern weather prediction would also enable avoidance of LNGC and FSRU Vessel transition in severe conditions above the design criteria. Given the 40 years of operation of LNGC and FSRU Vessel, a sinking event has never occurred.

In addition, cargo mismanagement or operational failure of the ballast system may also lead to potential sinking event. However, the LNGC and FSRU Vessel are provided with computerized cargo management system and ballast water transfer is not anticipated during approach and berthing at the LNG Terminal. The vessels are also designed in accordance with the vessel class codes which allow for excessive trim and list without capsizing or sinking. Hence the associated risk of grounding was not considered as a significant contributor to the overall risk and not further assessed in the QRA Study.

LNG Storage Containment Failure

The LNG storage containment in the LNGC and FSRU Vessel may deteriorate due to material degradation and construction defects etc., leading to potential piping or flange leak and subsequent loss of LNG storage containment. However, the cargo tanks are designed with double containment barrier, where the secondary containment is able to contain the whole volume of the primary containment should it fail.

As per OGP database(1), the catastrophic rupture frequency of double containment tank is 2.5×10^{-8} per tank per year. Since five (5) LNG cargo tanks are provided in the LNGC and FSRU Vessel, the total catastrophic rupture frequency of double containment tanks in the LNGC and FSRU Vessel is 1.25×10^{-7} per year. It is expected that the LNGC or FSRU Vessel will transit within Hong Kong waters for a maximum duration of 3 hours. Therefore the presence factor of the LNGC or FSRU Vessel in Hong Kong waters was estimated as:

$$75 \text{ trips per year} \times 3 \text{ hours} / 8{,}760 \text{ hours per year} = 2.6\times10^{-2}$$

The total failure frequency of a double containment cargo tanks in Hong Kong waters during transit was estimated to be 3.25×10^{-9} per year, which was subsequently modelled and assessed in the QRA Study.

(1) *OGP Risk Assessment Data Directory, Report No. 434-3, March 2010*

Sloshing

Under high wind or sea conditions, excessive motion while operating partially-filled LNG cargo tanks may lead to membrane damage and loss of membrane structural integrity. In addition, boil off gas will be vented to atmosphere, where safety impact may occur if the vent gas is ignited. The cargo tanks are generally either full (inbound voyage) or empty (outbound voyage), hence the chance of sloshing during transit is minimized. In case of the unforeseen need to depart the berth before fully unloading of LNG, the LNGC or FSRU Vessel can conduct an internal cargo transfer between tanks such that sloshing would not be a potential hazard. Annulus between membrane and ship structure is also monitored for hydrocarbon presence, with vent to safe location. Flame arrestors are also provided at vent location to minimize the chance of vent gas ignition. Therefore, considering adequate safety systems are in place to minimize the chance of sloshing, this scenario was not considered as a significant contributor to the overall risk and not further assessed in the QRA Study.

5D.1.2 QRA Study for the LNG Terminal

Ship Collision

Passing vessels and service vessels may collide with the LNGC and FSRU Vessel at the Jetty, leading to loss of containment of LNG and natural gas. Similarly, as described in ***Section 5D.1.1***, the ship collision frequency and associated LNG release frequency at the LNG Terminal were calculated for further assessment in the QRA Study.

Grounding

Similar to the description in ***Section 5D.1.1***, the grounding frequency was calculated for further assessment in the QRA Study.

Mooring Line Failure

The mooring lines at the Jetty may fail due to various reasons such as extreme loads, fatigue, corrosion and wear, and improper selection of mooring lines etc. Upon failure of the mooring lines, drifting of LNGC or FSRU Vessel may occur leading to potential failure of unloading arms and collision impact with the Jetty or another vessel, with ultimately potential release of LNG or natural gas. Mechanical integrity program (including testing and maintenance) for the mooring lines, as well as tension monitoring system for the mooring lines are provided at the Jetty. The mooring line failure has been taken into account in the unloading arm failure frequency, as suggested in the UK HSE (1), which was incorporated and assessed in the QRA Study.

(1) UK HSE, Failure Rate and Event Data for use within Risk Assessment, 28 June 2012.

Dropped Objects from Supply Crane Operation

Supply cranes are provided at the Jetty and FSRU Vessel for lifting operations. Swinging or dropped objects from crane operation may lead to potential damage on the LNG or natural gas pipework and subsequent loss of containment. Generally, lifting activity is not expected at the Jetty and FSRU Vessel during normal operation. However, during certain circumstances where lifting is required; safety management system will be in place to minimize the dropped object hazard.

Even with supply crane operation, the lifting equipment operation procedure will be in place to ensure that any lifting operation near or over live equipment should be strictly minimised. If such lifting operation cannot be avoided, lifting activities will be assessed. Also, adequate protection covers will be provided on the existing facilities in case the operation of lifting equipment has a potential to impact live equipment at the Jetty and FSRU. Process isolation will also be achieved in case that live equipment protection becomes impractical.

A Job Safety Analysis will be conducted for the supply crane operation, to identify and anlayse hazards associated with the lifting operation. Also, risk from lifting operation will be minimised through the work permit system, strict supervision and adequate protection covers on live equipment. The potential for a dropped object to cause damage on the live equipment and cause a release event is therefore considered included in the generic leak frequency in ***Table 5F.9***.

General Equipment/ Piping Failure

Loss of integrity of the equipment and piping may occur because of material defects, construction defects, external corrosion etc., and leading to loss of containment of LNG and natural gas. Material defect may occur due to wrong materials being used during construction. Construction defect may result from poor welding. The generic failure frequency of the equipment and piping for the QRA Study was obtained from the International Association of Oil and Gas Producers (OGP) [(1)], which was subsequently incorporated and assessed in the QRA Study.

LNG Storage Containment Failure

As illustrated in ***Section 5D.1.1***, the total catastrophic rupture frequency of double containment tanks in the FSRU Vessel is 1.25×10^{-7} per year.

With regard to the LNGC at the LNG Terminal, considering that the maximum stay-over time of LNGC at the LNG Terminal is 48 hours and the maximum annual transit frequency is 75 times, the total catastrophic rupture frequency of double containment tanks in the LNGC at the LNG Terminal is 5.14×10^{-8} per

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

year, which was already included in identified hazardous section HKLONG_02 "LNG Storage Tanks" for the LNG Terminal and assessed in the QRA Study.

5D.1.3 *QRA Study for the Subsea Pipelines*

Anchor Drop

The decision for a mariner when to drop an anchor depends on the particular circumstances and the proximity of the pipeline route to the flow of marine traffic, port/harbour areas and designated anchorage locations. In fairways, traffic will normally be underway where the necessity to drop anchor is expected to be low. The pipeline route will be identified on nautical charts as per normal practice. The mariner is then provided with the necessary information to avoid anchor drop where the pipeline could be damaged. Emergency situations may arise such as machinery failure, adverse weather condition, or collision; thereby limiting the choice where to drop anchor. Anchor drop along the subsea pipeline route was taken into consideration in the QRA Study when assigning failure frequencies for anchor damage.

Anchor Drag

Anchor drag occurs due to poor holding ground or adverse environmental conditions affecting the holding power of the anchor. The drag distance depends on properties of the seabed soil, the mass of ship and anchor and the speed of the vessel. If there is a subsea pipeline along the anchor drag path, anchor dragging onto the pipeline may result in localised buckling or denting of the pipeline, or over-stressing from bending if the tension on the anchor is sufficient to laterally displace the pipeline. A dragged anchor may also hook onto a pipeline during retrieval causing damage as a result of lifting the pipeline. Anchor dragging was taken into consideration in the QRA Study when assigning failure frequencies for anchor damage.

Vessel Sinking

Vessel sinking in the vicinity of the pipeline may cause damage to the pipeline resulting in loss of containment. Vessel sinking depends on the intensity of marine activity in the given area. For the years of 1996 to 2016, there were 551 incidents of vessel sinking in Hong Kong waters (1) which gives an average of about 26 cases per year. Most of the recorded incidents occurred in Victoria Harbour and the Ma Wan Channel and involved mainly smaller vessels of less than 1,000 dwt, which will have less impact on a pipeline buried 3 m below the seabed. The probability that a vessel sinking incident will impact the proposed pipeline was therefore considered to be low, in comparison to anchor impact damage. Additionally, pipeline damage due to vessel sinking was included in the historical pipeline failure data (2) used in the QRA Study.

(1) Marine Department, Hong Kong Government, Statistics on Marine Accidents, 1990-2016, www.mardep.gov.hk

(2) Mott MacDonald Ltd., *The Update of Loss of Containment Data for Offshore Pipelines (PARLOC 2001), Revision F*, June 2003.

Fishing Activity

Fishing activity is identified along the proposed subsea pipeline routes to the BPPS and LPS. Many of the techniques involves deployment of a variety of equipment close to the seabed. Pipelines damage from fishing gear can occur due to impact, snagging of nets on the pipeline or a "pull over" sequence. Impact loads mainly cause damage to the coating whilst pull over situations can cause much higher loads, which could lead to damage of steel pipeline itself.

Considering the size and weight of marine vessels for fishing activity and since the pipeline will be lowered to at least one (1) meters below seabed and protected by rock armour for the entire route, pipeline damage due to fishing activity is not possible and not considered further in the QRA Study.

Dredging Activity

Dredging vessels could cause damage due to dredging operations involving cutting heads. They could also cause damage to the subsea pipeline by anchor drop. Nevertheless, it is assumed that dredging operations will be closely monitored and controlled and therefore there is no potential for pipeline damage due to dredging.

Subsea Cable Maintenance Activity

Subsea cables are located in the vicinity of the subsea pipelines to the BPPS and LPS. During maintenance activities of the subsea cable, there could be potential of damaging the subsea pipeline. Nevertheless, it is assumed that maintenance activity will be closely monitored and controlled and therefore there is no potential for pipeline damage due to cable maintenance activity.

General Pipeline Failure

Corrosion is one of the main contributors to pipeline failures. Corrosion is attributed mainly to the environment in which they are installed (external) and the substances they carry (internal). Mechanical failure of the pipeline could occur for various reasons, including material defect, weld failure, etc. Stringent procedures for pipeline material procurement, welding and hydrotesting should largely mitigate against these hazards.

The frequency of subsea pipeline failure due to external corrosion and mechanical failure was estimated based on *PARLOC 2012* (1) and *PARLOC 2001* (2) database for further assessment in the QRA Study.

(1) Energy Institute, London and Oil & Gas UK, *Pipeline and Riser Loss of Containment 2010 – 2012 (PARLOC 2012), 6th Edition of PARLOC Report Series*, March 2015.

(2) Mott MacDonald Ltd., *The Update of Loss of Containment Data for Offshore Pipelines (PARLOC 2001), Revision F*, June 2003.

5D.1.4 *QRA Study for the GRSs at the BPPS and LPS*

General Equipment/Piping Failure

Loss of integrity of the equipment and piping may occur because of material defects, construction defects, external corrosion etc., and leading to loss of containment of natural gas. Material defect may occur due to wrong construction materials being used. Construction defect may result due to poor welding. The generic failure frequency of the equipment and piping for the QRA Study was obtained from Hawsley [1], which was subsequently incorporated and assessed in the QRA Study.

5D.2 NATURAL HAZARDS

5D.2.1 *Earthquake*

Studies by the Geotechnical Engineering Office [2] and Civil Engineering Development Department [3] conducted in the last decades indicate that Hong Kong is a region of low seismicity. The seismicity in the vicinity of Hong Kong is considered similar to that of the areas of Central Europe and the Eastern areas of the U.S. [4]. As Hong Kong is a region of low seismicity, an earthquake is an unlikely event.

An earthquake has the potential to cause damage to the LNG Terminal, subsea pipelines, and proposed GRSs at the BPPS and LPS, due to ground movement and vibration.

It is noted that the generic failure frequencies [5] [6] adopted in the QRA Study are based on historical incidents that included earthquakes in the causes of failure. With consideration that Hong Kong is not at disproportionate risk from earthquakes compared to other similar facilities worldwide, it is deemed appropriate to use these generic frequencies [1] [2] without adjustment. Hence, separate assessment of earthquakes in the QRA Study was not considered.

5D.2.2 *Subsidence*

The GRSs at the BPPS and LPS may be impacted from subsidence. For subsidence which would result in failure of process pipework, the ground movement must be relatively sudden and severe. Normal subsidence events occur gradually over a period of months and thus appropriate mitigation action

(1) Hawksley, J.L., *Some Social, Technical and Economic Aspects of the Risks of Large Plants*, CHEMRAWN III, 1984.

(2) GEO Publication No. 1/2012, *Review of Earthquake Data for the Hong Kong Region*, Geotechnical Engineering Office, Civil Engineering and Development Department, The Government of the Hong Kong Special Administrative Region, September 2012.

(3) GCO, *Review of Earthquake Data for the Hong Kong Region*, GCO Publication No. 1/91, Civil Engineering Services Department, Hong Kong Government, 1991.

(4) Scott, D.N., Pappin, J.W., Kwok, M.K.Y., *Seismic Design of Buildings in Hong Kong*, Hong Kong Institution of Engineers, Transactions, Vol. 1, No. 2, p.37-50, 1994.

(5) OGP, *Risk Assessment Data Directly, Report No. 434-.1*, March 2010.

(6) Hawksley, J.L., *Some Social, Technical and Economic Aspects of the Risks of Large Plants*, CHEMRAWN III, 1984.

can be taken to prevent failures. In the worst cases, the GRSs could be shut down with relevant equipment isolated and depressurised. The GRS facilities are built on coastal land with solid foundation. No undue risk from subsidence is foreseen; therefore it is deemed that the failure due to subsidence has been included in generic failure frequencies [1] [2] adopted in the QRA Study.

5D.2.3 *Tidal Waves, Storm Surges and Flooding*

The impact of tidal waves and storm surge on LNGC and FSRU Vessel during marine transit is not envisaged due to sufficient water depth along the transit route. At the LNG Terminal, tidal waves and storm surge may create excessive movement, impacting the mooring lines and unloading arm operation. The failure frequency of mooring lines and unloading arm has been estimated based on UK HSE [1], which was incorporated and assessed in the QRA Study.

For the subsea pipelines to the BPPS and LPS, the tidal waves may have more impact on the pipelines located in shallower water area (near the shore) where the subsea pipeline attracts a higher level of environmental loads. Nevertheless, the subsea pipelines will be designed to withstand these environmental loads and the subsea pipelines in the seabed will not be exposed directly to 100 year return wave loads. Hence it is considered that there is no disproportionate risk of tidal waves/storm surge to the subsea pipelines. These causes of failure are in any case included in the generic failure frequency [1] [2] derived from the historical database.

For GRSs at the BPPS and LPS, flooding from heavy rainfall is considered not possible due to the coastal location of the GRS facilities. The slopes of the natural terrain will channel water to the sea. In general, storm surges are limited to several metres. The GRS facilities, which are located at +6 mPD above sea level, are therefore protected against any risk from storm surges, waves and other causes of flooding. As a result, storm surges and flooding were not further assessed in the QRA Study.

5D.2.4 *Tsunami*

Similar to storm surges, the main hazard from tsunamis is the rise in sea level and possible floatation of process equipment and pipework. The highest rise in sea level ever recorded in Hong Kong due to a tsunami was 0.3 m [2], and occurred as a result of the 1960 earthquake in Chile, the largest earthquake ever recorded in history at magnitude 9.5 on the Richter scale. The GRS facilities are approximately at +6 mPD and hence the effect of tsunami on GRS facilities is considered negligible.

The reason for the low impact of tsunamis on Hong Kong may be explained by the extended continental shelf in the South China Sea which effectively

(1) K HSE, Failure Rate and Event Data for use within Risk Assessment, 28 June 2012.

(2) Hong Kong Observatory.

dissipates the energy of a tsunami. Moreover, presence of the Philippine Islands and Taiwan acts as an effective barrier against seismic activity in the Pacific [(1)]. Secondary waves that pass through the Luzon Strait diffract and lose energy as they traverse the South China Sea.

Seismic activity with the South China Sea area may also produce tsunamis. Earthquakes on the western coast of Luzon in the Philippines have produced localised tsunamis but there is no record of any observable effects in Hong Kong. Also, with the shelter effects offered by Lamma Island, Lantau Island and Hong Kong islands, tsunami comes from South East of Hong Kong cannot affect the BPPS and LPS. As a result, tsunami was not taken into account in the QRA Study.

5D.2.5 Lightning

Lightning strikes have led to a number of major accidents worldwide. For example, a contributory cause towards the major fire at the Texaco refinery in the UK in 1994 was thought to be an initial lightning strike on process pipework. The Project components will be protected with lightning conductors connected the Earth. The grounding will be inspected regularly. The potential for a lightning strike to hit the Project components leading to a release event is therefore deemed to be unlikely. Failures due to lightning strikes have been included in the generic failure frequencies [(2)] [(3)] adopted in the QRA Study.

5D.2.6 Hill Fire

Hill fires are relatively common in Hong Kong, and could potentially occur near the GRS facilities at the BPPS and LPS. Recent statistics for hill fires in Hong Kong country parks have been reviewed. Although the GRSs at the BPPS and LPS are not located in a country park, some of the surrounding terrain and vegetation are similar to those typically found in country parks. According to Agriculture, Fisheries and Conservation Department (AFCD) statistics [(4)], the average number of hill fires is 27.6 per year during the ten years 2007-2016 (range: 16 to 49). The area affected by fire each year is available from AFCD annual reports for 2008-2015, see ***Table 5D.1***. These are compared to the total area of country parks in Hong Kong of 44,004 – 44,239 ha.

Averaging the data for the 8-year period suggests that about 1% of vegetation areas are affected by fire each year, or equivalently, the frequency of a hill fire affected a specific site is 0.01 per year.

(1) Lee, B. Y., *Report of Hong Kong in the International Tsunami Seminar in the Western Pacific Region*, International Tsunami Seminar in the Western Pacific Region, Tokyo, Japan, 7-12 March 1988.

(2) OGP, *Risk Assessment Data Directly, Report No. 434-.1*, March 2010.

(3) Hawksley, J.L., *Some Social, Technical and Economic Aspects of the Risks of Large Plants*, CHEMRAWN III, 1984.

(4) Agriculture, Fisheries and Conservation Department, Hong Kong Government, Useful Statistics, 2007-2016, www.afcd.gov.hk

Table 5D.1 Hill Fire Data for Hong Kong [(1)]

Year	Area Affected (ha)	Country Park Area (ha)	% of Total Country Park Affected
2015	147	44,300	0.06
2014	97	44,300	0.06
2013	546	44,300	0.06
2012	79	44,239	0.18
2011	27	44,239	0.06
2010	897	44,239	2.03
2009	275	44,004	0.62
2008	501	44,004	1.14

The GRS at the BPPS is protected from external fires (e.g. hill fire) by a firebreak line in BPPS Landscape Plan and regular inspection to ensure the firebreak line is properly maintained, while the GRS at the LPS is also protected from external fires by locating far away from any hill area.

Also, the vicinity of GRS area is patrolled by station security, who will report to Fire Services Department and central control room immediately in case of hill fires.

Moreover, there are no incident record of any hill fire in the vicinity of the BPPS and the LPS, as well as the safety management measures, hill fire leading to impact at GRS facilities was considered unlikely and thus not taken into account in the QRA Study.

5D.3 AIRCRAFT CRASH

The BPPS and LPS site do not lie within the flight path of Chek Lap Kok, being more than 10 km from the nearest runway. The frequency of aircraft crash was estimated using the methodology of the HSE [(2)], as per the EIA Report [(3)] that was previously approved by the EPD. The model takes into account specific factors such as the target area of the proposed hazard site and its longitudinal (x) and perpendicular (y) distances from the runway threshold. The crash frequency per unit ground area (per km^2) is calculated as:

$$g(x,y) = NRF(x,y)$$

(Equation 1)

where:

N is the number of runway movements per year

R is the probability of an accident per movement (landing or take-off)

$F(x,y)$ gives the spatial distribution of crashes and is given by:

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

(2) Byrne, J. P., *The Calculation of Aircraft Crash Risk in the UK*, HSE\R150, 1997.

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

Landings

$$F_L(x,y)=\frac{(x+3.275)}{3.24}e^{\frac{-(x+3.275)}{1.8}}\left[\frac{56.25}{\sqrt{2\pi}}e^{-0.5(125y)^2}+0.625e^{-\frac{|y|}{0.4}}+0.005e^{-\frac{|y|}{5}}\right]$$

(Equation 2)

for $x > -3.275$ km

Take-off

$$F_T(x,y)=\frac{(x+0.6)}{1.44}e^{\frac{-(x+0.65)}{1.2}}\left[\frac{46.25}{\sqrt{2\pi}}e^{-0.5(125y)^2}+0.9635e^{-4.1|y|}+0.08e^{-|y|}\right]$$

(Equation 3)

for $x > -0.6$ km

Equation 2 and *Equation 3* are valid only for the specified range of x values. If x lies outside this range, the impact probability is zero.

As per the EIA Report (2) that was previously approved by the EPD, the accident frequency for the approach to landings is 2.7×10^{-8} per flight and the accident frequency for take-off/climb is 4.0×10^{-8} per flight.

The number of flights at Chek Lap Kok in 2020 and 2030 has been estimated as 470,770 and 617,600 respectively (assumed as linear growth of a period from 1999 to 2016); while the estimated number of flights in 2020 is in the same order of magnitude with the estimated number of flights as 620,000 in 2032 from the approved EIA Report for *Expansion of Hong Kong International Airport into a Three-Runway System* (1).

Considering landings on runway 25L for example, the values for *x* and *y* to the Project Site are about 2.9 km and 12.1 km respectively. Applying *Equation 2* gives $F_L = 2.7\times10^{-5}$ km^{-2}. Substituting this into *Equation 1* gives:

g(x,y) = NRF(x,y) = 617,600 / 8 × 2.7 × 10^{-8} × 2.7 × 10^{-5} = 5.6 × 10^{-8} per km^2-year for Year 2020

Note that the number of plane movements has been divided by eight (8) to take into account the 8 flight routes in the approved EIA Report for *Expansion of Hong Kong International Airport into a Three-Runway System* (1). This effectively assumes that each runway is used equally and the wind blows in each direction with equal probability.

The target area is estimated at 29,000 m^2 (0.029 km^2). This gives a frequency for crashes into the Project Site associated with landings on runway 25L as 1.6 ×

(1) Mott MacDonald, EIA for *Expansion of Hong Kong International Airport into a Three-Runway System*, (Register No.: AEIAR-185/2014), November 2014.

10^{-9} per year. Repeating the calculation for landings and take-offs from all runways gives the results shown in ***Table 5D.2*** to ***Table 5D.4***.

Table 5D.2 Aircraft Crash Frequency for proposed GRS at the BPPS

Runway	Year 2020		Year 2030	
	Landing (per year)	Take-off (per year)	Landing (per year)	Take-off (per year)
07R	-	1.28×10^{-10}	-	1.69×10^{-10}
07C	-	7.54×10^{-10}	-	9.90×10^{-10}
07L	-	No take off at 07L*	-	No take off at 07L*
25L	4.27×10^{-8}	-	5.61×10^{-8}	-
25C	No landing at 25C*	-	No landing at 25C*	-
25R	8.18×10^{-8}	-	1.07×10^{-7}	-
Total	1.25×10^{-7}	8.83×10^{-10}	1.63×10^{-7}	1.16×10^{-9}

*: The preferred operation mode is referred to the approved EIA Report (1).

Table 5D.3 Aircraft Crash Frequency for proposed GRS at the LPS

Runway	Year 2020		Year 2030	
	Landing (per year)	Take-off (per year)	Landing (per year)	Take-off (per year)
07R	-	1.46×10^{-15}	-	1.91×10^{-15}
07C	-	2.48×10^{-16}	-	3.26×10^{-16}
07L	-	No take off at 07L*	-	No take off at 07L*
25L	1.06×10^{-10}	-	1.40×10^{-10}	-
25C	No landing at 25C*	-	No landing at 25C*	-
25R	5.55×10^{-11}	-	7.29×10^{-11}	-
Total	1.62×10^{-10}	1.71×10^{-15}	2.12×10^{-10}	2.24×10^{-15}

*: The preferred operation mode is referred to the approved EIA Report (1).

Table 5D.4 Aircraft Crash Frequency for the LNG Terminal

Runway	Year 2020		Year 2030	
	Landing (per year)	Take-off (per year)	Landing (per year)	Take-off (per year)
07R	-	1.11×10^{-12}	-	1.46×10^{-12}
07C	-	2.53×10^{-13}	-	3.31×10^{-13}
07L	-	No take off at 07L*	-	No take off at 07L*
25L	2.93×10^{-8}	-	3.84×10^{-8}	-
25C	No landing at 25C*	-	No landing at 25C*	-
25R	1.63×10^{-8}	-	2.14×10^{-8}	-
Total	4.56×10^{-8}	1.36×10^{-12}	5.99×10^{-8}	1.79×10^{-12}

*: The preferred operation mode is referred to the approved EIA Report (1).

5D.4 HELICOPTER CRASH

Helicopter accidents during take-off and landings are confined to small area around the helipad. 93% of accidents occur within 100 m of the helipad and remaining 7% occur between 100 m and 200 m of the helipad (2). Since there is

(1) Mott MacDonald, EIA for *Expansion of Hong Kong International Airport into a Three-Runway System*, (Register No.: AEIAR-185/2014), November 2014.

(2) Byrne, J. P., The Calculation of Aircraft Crash Risk in the UK, HSE\R150, 1997.

no helipad within 200 m of the Project components, the helicopter crash was therefore not considered in the QRA Study.

Regarding passing helicopters, there are no helicopter flight paths in the vicinity of the Project components, except the proposed LNG Terminal in vicinity of "Hong Kong – Macau Helicopter Routes" (depicted at ***Figure 5D.1***), as per Hong Kong Aeronautical Information Services [(1)].

Only one (1) helicopter flight path, "Route B", is identified to have potential crash impact on the proposed LNG Terminal based on proximity consideration from HSE [(1)].

Based on HSE [(1)], the helicopter crash rate per area was proposed to estimate based on following equations:

$$C_A = N_A \times R_A \times afac / alt$$

where:
C_A: Helicopter Crash Rate (per yr km^2)
N_A: Annual Number of Helicopter Flight
R_A: Reliability (1×10^{-7} per flight km as per HSE [(1)])
afac: Refer to *Table 9 "Area Factors Used in Airway Calculations"* of HSE [(1)], 0.03
alt: Mean Altitude of the Airway (259 m)

According to online available information [(2)], the mean altitude for "Route B" airway is 259 m and the minimum separation distance between "Route B" flight path and the proposed LNG Terminal is 635 m. As such, the estimated number of helicopter crash rate per area is $1,016 \times 10^{-7} \times 0.03 / 259$ = 1.18E-08 per km^2-year. Considering the proposed LNG Terminal area as 0.04 km^2, the impact frequency due to passing helicopter failures is 4.71E-10 per year.

The failure rate due to passing helicopter crashes are still insignificant compared with generic failure frequencies (in an order of magnitude at 1E-06 to 1E-05), as such, it was not considered separately but are deemed to be included in the generic failure frequencies.

5D.5 *HAZARDOUS SCENARIO DEVELOPMENT*

Based on the above analysis, the hazardous scenarios for the Project components were identified for further assessment in the QRA Study. The Project components were divided into a number of hazardous sections for detailed analysis in the QRA Study based on the location of emergency shutdown valves and process conditions (e.g. operating temperature and pressure).

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

5D.5.1 *Marine Transit of the LNGC and the FSRU Vessel to the LNG Terminal*

Two (2) scenarios (collision release and grounding release) were modelled and the release parameters for these scenarios are listed in the following table:

Table 5D.5 Inventory Release Details for Marine Transit of the LNGC and FSRU Vessel to the LNG Terminal

Parameter	**Collision Release**	**Grounding Release**
Large LNGC and FSRU Vessel (270,000 m^3)		
LNG Inventory (kg)	2.2×10^7	2.2×10^7
Pressure (barg)	0.7	0.7
Temperature (°C)	-156	-156
Density (kg/m^3)	414.2	414.2
Small LNGC (170,000 m^3)		
LNG Inventory (kg)	1.2×10^7	1.2×10^7
Pressure (barg)	0.7	0.7
Temperature (°C)	-156	-156
Density (kg/m^3)	414.2	414.2

5D.5.2 *FSRU Vessel, the Jetty, and the LNGC Unloading at the LNG Terminal*

A total of twenty-five (25) hazardous sections were identified for the FSRU Vessel, the Jetty and LNGC unloading at the LNG Terminal. The details of the identified hazardous sections are presented in ***Table 5D.6***.

Table 5D.6 Hazardous Section Details for the FSRU Vessel, the Jetty and the LNGC Unloading Operation at the LNG Terminal

Hazardous Section Code	Description	Fluid Phase	Temperature (degC)	Pressure (barg)	Density (kg/m³)	Length of Pipe (m)	Pipe Diameter (inch)	Flow Rate (kg/hr)	Isolation Success Case (120 seconds): Iso-Section Inventory (1) (kg)	Isolation Failure Case (1,800 seconds): Iso-Section Inventory (1) (kg)
HKOLNGT_01	LNG Loadout from LNGC, via Jetty, to LNG Storage Tank in FSRU Vessel	Liquid	-156	5	414	290	24 (3)	5,000,000	77,000	201,000
HKOLNGT_02	LNG Storage Tanks	Liquid	-156	0.7	414	N/A	N/A	N/A	N/A	22,148,063(6)
HKOLNGT_03	LNG Transfer from LNG Storage Tank Pump to LNG Booster Pump	Liquid	-156	7	414	300	10	2,000,000	82,000	1,000,000
HKOLNGT_04	LNG Booster Pump to Regasification Unit	Liquid	-140	90	388	80	10	485,000	18,000	244,000
HKOLNGT_05	Regasification Trains	Vapour	3	90	77	400	12	214,000	9,000	109,000
HKOLNGT_06	Natural gas from Regasification Unit, via metering, to Jetty (including HP Gas Loading Arm)	Vapour	5	88	74	200	12	713,000	25,000	357,000
HKOLNGT_07	Natural gas in Jetty to ESDV of Riser for BPPS Subsea Pipeline	Vapour	5	88	74	170	30	713,000	30,000	362,000
HKOLNGT_08	Riser for BPPS Subsea Pipeline	Vapour	5	88	74	0	30	713,000	1,000,000	1,000,000
HKOLNGT_10	Natural gas in Jetty to ESDV of Riser for LPS Subsea Pipeline	Vapour	5	88	74	170	20	713,000	26,000	359,000
HKOLNGT_11	Riser for LPS Subsea Pipeline	Vapour	5	88	74	0	20	713,000	299,000	632,000
HKOLNGT_13	LNG Transfer from LNG Storage Tank to Vaporisation Unit	Liquid	-156	7	414	270	12	166,000	14,000	91,000
HKOLNGT_14	Natural gas in Vaporisation Unit for Fuel Gas Generation	Vapour	5	6	5	80	6	13,000	500	7,000
HKOLNGT_15	BOG from LNG Storage Tank to BOG Compressor	Vapour	-120	0.5	2	270	20	30	177,000 (4)	177,000 (4)
HKOLNGT_16	Compressed BOG for fuel gas use in power generation	Vapour	10	6	5	80	12	70	30	60
HKOLNGT_17	Compressor BOG to Reliquefyer	Vapour	-60	6	7	80	12	100	40	90
HKOLNGT_18	LNG from Reliquefyer to LNG Storage Tank	Liquid	-156	6	174	270	12	43,000	5,000	25,000
HKOLNGT_19	BOG in Gas Combustion Unit	Vapour	-120	0.5	2	30	20	30	10	30

Hazardous Section Code	Description	Fluid Phase	Temperature (degC)	Pressure (barg)	Density (kg/m³)	Length of Pipe (m)	Pipe Diameter (inch)	Flow Rate (kg/hr)	Isolation Success Case (120 seconds): Iso-Section Inventory (1) (kg)	Isolation Failure Case (1,800 seconds): Iso-Section Inventory (1) (kg)
HKOLNGT_20	LNGC Vapour (BOG) return line during loadout operation	Vapour	-120	2	2	60	16	30	20	30
HKOLNGT_21	FSRU Vapour (BOG) return line during loadout operation	Vapour	-120	2	2	60	16	30	20	30
HKOLNGT_22	Fuel gas line from Regasification Unit	Vapour	5	6	5	80	6	13,000	500	7,000
HKOLNGT_23	Diesel (Heavy Fuel Oil) Storage System	Liquid	25	1	745(7)	0	-	N/A (5)	3,000,000	3,000,000
HKOLNGT_24	Marine Diesel Oil Storage System	Liquid	25	1	745(7)	0	-	N/A (5)	596,000	596,000
HKOLNGT_25	Lubricating Oil Storage System	Liquid	25	1	745(7)	0	-	N/A (5)	75,000	75,000

Note:

(1): For Hazardous Section HKOLNGT_01, a shorter release time (i.e. 30 seconds) for isolation success case was adopted due to the presence of operators in the vicinity who can initiate emergency shutdown of the unloading arm (in addition to the fire and gas detection system), and also due to the provision of detectors for excessive movement of the unloading arm which will initiate an automatic shutdown.
(2): For Hazardous Section HKOLNGT_01, a shorter release time (i.e. 2 minutes) for isolation failure case of one unloading arm was adopted. Duration longer than 2 minutes is not considered significant given that the transfer pumps on the LNG Carrier can be tripped, which will stop any further release.

(3): 24" (i.e. LNG unloading arm for FSRU connection) was selected as the representative pipe diameter for the Hazardous Section HKOLNGT_01.

(4): Partial vaporization of LNG in one LNG Cargo Tank, upon leakage of Hazardous Section HKOLNGT_15, was also considered in the inventory estimation.

(5): Release from the storage tanks of Diesel/Marine Diesel Oil/Lubricating Oil was modelled in the QRA Study.
(6): Only isolation failure case was consideration for Hazardous Section HKOLNGT_02 "LNG Storage Tanks" in the QRA Study, and the estimated mass for one LNG storage tank at FSRU Vessel is 22,148,063 kg.
(7): Diesel, marine diesel (typically containing between C8 and C21) and lubricating oil (generally with high viscosity petroleum, typically C12+) are conservatively assumed as Dodecance (C12) which has the density of about 745 kg/m³ for consequence modelling modelled in the QRA Study.

5D.5.3 *Subsea Pipelines to the BPPS and LPS*

The subsea pipelines were modelled and the release parameters for these subsea pipelines are listed in ***Table 5D.7***.

Table 5D.7 ***Hazardous Section Details for the Subsea Pipelines to the BPPS and LPS***

Parameter	30″ BPPS Pipeline	20″ LPS Pipeline
Pressure (barg)	88	88
Temperature (°C)	16	16
Density (kg/m^3)	70	70
Length of Pipeline (km)	45	18
Natural Gas Inventory (kg)	1.43×10^6	2.58×10^5

5D.5.4 *GRSs at the BPPS and LPS*

Eight (8) hazardous sections were identified for the proposed GRS at the BPPS and nineteen (19) hazardous sections were identified for the existing GRS at the BPPS. The details of the identified hazardous sections are presented in ***Table 5D.8***.

In addition, thirty-five (35) hazardous sections were identified for the proposed GRS at the LPS and ten (10) hazardous sections were identified for the existing GRS at the LPS. The details of the identified hazardous sections are presented in ***Table 5D.9***.

Table 5D.8 Hazardous Section Details for the GRS at the BPPS

Hazardous Section Code	Description	Fluid Phase	Temperature (degC)	Pressure (barg)	Density (kg/m³)	Length of Pipe (m)	Pipe Diameter (mm)	Flow Rate (kg/hr)	Isolation Success Case (120 seconds): Iso-Section Inventory (kg)	Isolation Failure Case (1800 seconds): Iso-Section Inventory (kg)
BPPS_NGRS_01	Above ground piping from shore end to pig receiver of New GRS	Vapour	20	88	68	40	762	624,000	22,000	313,000
BPPS_NGRS_02	Piping from Pig Receiving Station to Gas Filter of New GRS	Vapour	20	88	68	20	711	624,000	21,000	312,000
BPPS_NGRS_03	Piping from Gas Filter to Metering Station of New GRS	Vapour	20	88	68	65	711	624,000	23,000	314,000
BPPS_NGRS_04	Piping from Metering Station to WBH of New GRS	Vapour	20	88	68	104	711	624,000	24,000	315,000
BPPS_NGRS_05	WBH piping of New GRS	Vapour	20	88	68	114	508	624,000	22,000	313,000
BPPS_NGRS_06	Piping from WBH to Pressure Reduction Station of New GRS	Vapour	60	88	56	52	508	624,000	21,000	312,000
BPPS_NGRS_07	Piping from Pressure Reduction Station to Mixing Station of New GRS	Vapour	20	38	27	220	711	624,000	23,000	314,000
BPPS_NGRS_08	Pig Receiver of New GRS	Vapour	20	88	68	9	813	624,000	21,000	312,000
BPPS_GRS_01	Above ground piping from shore end to pig receiver of Y13-1 GRS	Vapour	21	150	118	160	700	364,000	19,000	189,000
BPPS_GRS_02	Piping from receiver to slug catcher of Y13-1 GRS	Vapour	21	150	118	35	700	364,000	14,000	183,000
BPPS_GRS_03	Piping from slug catcher to inlet gas filter separators of Y13-1 GRS	Vapour	21	150	118	40	700	364,000	14,000	184,000
BPPS_GRS_04	Piping from inlet gas filter separator to gas heater of Y13-1 GRS	Vapour	21	150	118	105	700	364,000	17,000	187,000
BPPS_GRS_05	Piping from gas heaters to pressure reduction station, including PRS of Y13-1 GRS	Vapour	21	150	118	95	700	364,000	16,000	186,000
BPPS_GRS_06	Piping from pressure reduction station to outlet gas filter separator of Y13-1 GRS	Vapour	21	150	118	20	700	364,000	13,000	183,000
BPPS_GRS_07	Piping from outlet gas filter separator to manifold, including sales gas meter unit of Y13-1 GRS	Vapour	21	38	25	45	700	364,000	13,000	182,000
BPPS_GRS_08	Pig receiver of Y13-1 GRS	Vapour	21	150	118	9	700	364,000	13,000	182,000
BPPS_GRS_11	Above ground piping from shore end to pig receiver of Dachan GRS	Vapour	20	55	41	70	700	364,000	13,000	183,000
BPPS_GRS_12	Piping from receiver to gas filter of Dachan GRS	Vapour	20	55	41	95	700	364,000	14,000	183,000

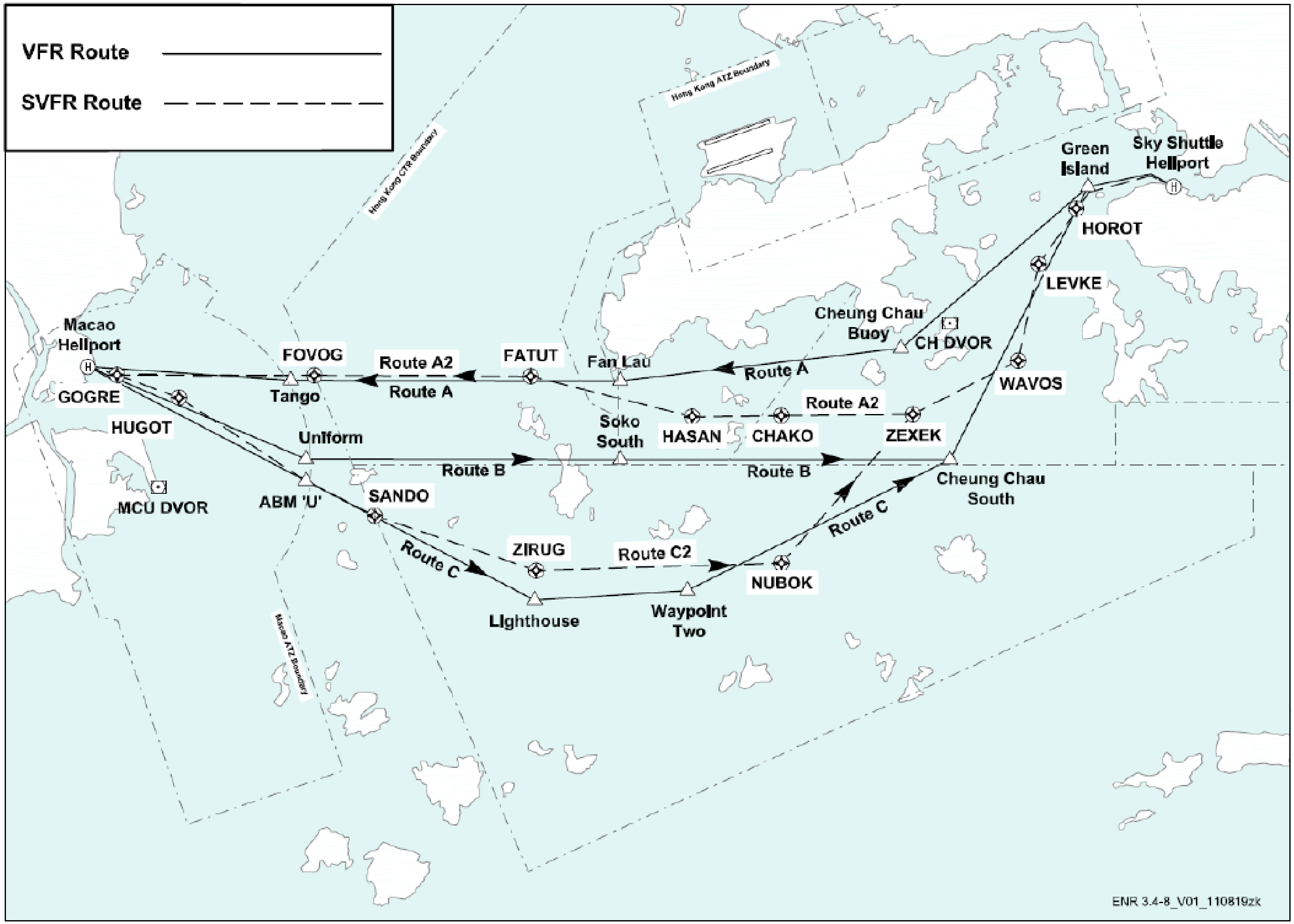
Hazardous Section Code	Description	Fluid Phase	Temperature (degC)	Pressure (barg)	Density (kg/m³)	Length of Pipe (m)	Pipe Diameter (mm)	Flow Rate (kg/hr)	Isolation Success Case (120 seconds): Iso-Section Inventory (kg)	Isolation Failure Case (1800 seconds): Iso-Section Inventory (kg)
BPPS_GRS_13	Filter & inlet/outlet piping of Dachan GRS	Vapour	20	55	41	15	400	364,000	12,000	182,000
BPPS_GRS_14	Piping from filter to metering station of Dachan GRS	Vapour	20	55	41	45	700	364,000	13,000	183,000
BPPS_GRS_15	Piping from metering station to heaters, including metering runs of Dachan GRS	Vapour	20	55	41	80	700	364,000	13,000	183,000
BPPS_GRS_16	Heater Piping of Dachan GRS	Vapour	20	55	41	40	350	364,000	12,000	182,000
BPPS_GRS_17	Piping from heater to PRS, including PRS of Dachan GRS	Vapour	20	55	41	35	700	364,000	13,000	182,000
GRS_18	Piping from PRS to manifold, including HIPPS of Dachan GRS	Vapour	41	38	26	265	700	364,000	15,000	184,000
GRS_19	Pig receiver of Dachan GRS	Vapour	20	55	41	8.71	800	364,000	12,000	182,000

Table 5D.9 Hazardous Section Details for the GRS at the LPS

Hazardous Section Code	Description	Fluid Phase	Temperature (degC)	Pressure (barg)	Density (kg/m³)	Length of Pipe (m)	Pipe Diameter (mm)	Flow Rate (kg/hr)	Isolation Success Case (120 seconds): Iso-Section Inventory (kg)	Isolation Failure Case (1800 seconds): Iso-Section Inventory (kg)
LPS_NGRS_01	Above ground 20" piping from shore to Inlet of each New GRS Metering Train A	Vapour	16	88	70	311	508	226,000	12,000	118,000
LPS_NGRS_02	Piping from Existing Gas Header to Inlet ESDVs of each New GRS Metering Train B	Vapour	16	88	70	273	457	226,000	11,000	116,000
LPS_NGRS_03	Piping from Filter Skid to Metering Skid of New GRS (Train 1A)	Vapour	16	88	70	54	219	57,000	2,000	28,000
LPS_NGRS_04	Piping from Filter Skid to Metering Skid of New GRS (Train 1B)	Vapour	16	88	70	53	219	57,000	2,000	28,000
LPS_NGRS_05	Piping from Metering Skids to Mixer of New GRS (Train 1)	Vapour	16	88	70	23	219	57,000	2,000	28,000
LPS_NGRS_06	Piping from Mixer to Water Bath Heater of New GRS (Train 1)	Vapour	16	88	70	28	219	57,000	2,000	28,000
LPS_NGRS_07	Piping from Water Bath Heater to Pressure Reduction Station of New GRS (Train 1)	Vapour	51	88	58	35	219	57,000	2,000	28,000
LPS_NGRS_08	Piping from Pressure Reduction Station of New GRS (Train 1) to associated CCGT	Vapour	20	41	29	42	356	57,000	2,000	28,000
LPS_NGRS_09	Piping from Filter Skid to Metering Skid of New GRS (Train 2A)	Vapour	16	88	70	54	219	57,000	2,000	28,000
LPS_NGRS_10	Piping from Filter Skid to Metering Skid of New GRS (Train 2B)	Vapour	16	88	70	53	219	57,000	2,000	28,000
LPS_NGRS_11	Piping from Metering Skids to Mixer of New GRS (Train 2)	Vapour	16	88	70	23	219	57,000	2,000	28,000
LPS_NGRS_12	Piping from Mixer to Water Bath Heater of New GRS (Train 2)	Vapour	16	88	70	28	219	57,000	2,000	28,000
LPS_NGRS_13	Piping from Water Bath Heater to Pressure Reduction Station of New GRS (Train 2)	Vapour	51	88	58	35	219	57,000	2,000	28,000
LPS_NGRS_14	Piping from Pressure Reduction Station of New GRS (Train 2) to associated CCGT	Vapour	20	41	29	42	356	57,000	2,000	28,000
LPS_NGRS_15	Piping from Filter Skid to Metering Skid of New GRS (Train 3A)	Vapour	16	88	70	54	219	57,000	2,000	28,000

Hazardous Section Code	Description	Fluid Phase	Temperature (degC)	Pressure (barg)	Density (kg/m³)	Length of Pipe (m)	Pipe Diameter (mm)	Flow Rate (kg/hr)	Isolation Success Case (120 seconds): Iso-Section Inventory (kg)	Isolation Failure Case (1800 seconds): Iso-Section Inventory (kg)
LPS_NGRS_16	Piping from Filter Skid to Metering Skid of New GRS (Train 3B)	Vapour	16	88	70	53	219	57,000	2,000	28,000
LPS_NGRS_17	Piping from Metering Skids to Mixer of New GRS (Train 3)	Vapour	16	88	70	23	219	57,000	2,000	28,000
LPS_NGRS_18	Piping from Mixer to Water Bath Heater of New GRS (Train 3)	Vapour	16	88	70	28	219	57,000	2,000	28,000
LPS_NGRS_19	Piping from Water Bath Heater to Pressure Reduction Station of New GRS (Train 3)	Vapour	51	88	58	35	219	57,000	2,000	28,000
LPS_NGRS_20	Piping from Pressure Reduction Station of New GRS (Train 3) to associated CCGT	Vapour	20	41	29	42	356	57,000	2,000	28,000
LPS_NGRS_21	Piping from Filter Skid to Metering Skid of New GRS (Train 4A)	Vapour	16	88	70	54	219	57,000	2,000	28,000
LPS_NGRS_22	Piping from Filter Skid to Metering Skid of New GRS (Train 4B)	Vapour	16	88	70	53	219	57,000	2,000	28,000
LPS_NGRS_23	Piping from Metering Skids to Mixer of New GRS (Train 4)	Vapour	16	88	70	23	219	57,000	2,000	28,000
LPS_NGRS_24	Piping from Mixer to Water Bath Heater of New GRS (Train 4)	Vapour	16	88	70	28	219	57,000	2,000	28,000
LPS_NGRS_25	Piping from Water Bath Heater to Pressure Reduction Station of New GRS (Train 4)	Vapour	51	88	58	35	219	57,000	2,000	28,000
LPS_NGRS_26	Piping from Pressure Reduction Station of New GRS (Train 4) to associated CCGT	Vapour	20	41	29	42	356	57,000	2,000	28,000
LPS_NGRS_27	Pig Receiver of New GRS	Vapour	20	88	68	62	508	226,000	8,000	114,000
LPS_NGRS_28	Piping from Existing Gas Header to Inlet ESDV (L10 Stream A)	Vapour	16	88	70	29	457	226,000	8,000	113,000
LPS_NGRS_29	Piping from Inlet ESDV to Filter Skid (L10 Stream A)	Vapour	16	88	70	12	219	57,000	2,000	28,000
LPS_NGRS_30	Piping from Filter Skid, via Metering Skid and Mixer, to Heater (L10 Stream A)	Vapour	16	88	70	48	219	57,000	2,000	28,000
LPS_NGRS_31	Piping from Heater to Pressure Reduction Station (L10 Stream)	Vapour	41	88	61	39	219	57,000	2,000	28,000
LPS_NGRS_32	Piping from Pressure Reduction Station (L10 Stream) to L10	Vapour	>10	41	31	26	356	57,000	2,000	28,000

Hazardous Section Code	Description	Fluid Phase	Temperature (degC)	Pressure (barg)	Density (kg/m³)	Length of Pipe (m)	Pipe Diameter (mm)	Flow Rate (kg/hr)	Isolation Success Case (120 seconds): Iso-Section Inventory (kg)	Isolation Failure Case (1800 seconds): Iso-Section Inventory (kg)
LPS_NGRS_33	Piping from New Gas Header to Inlet ESDV (L10 Stream B)	Vapour	16	88	70	17	457	57,000	2,000	28,000
LPS_NGRS_34	Piping from Inlet ESDV to Filter Skid (L10 Stream B)	Vapour	16	88	70	12	219	57,000	2,000	28,000
LPS_NGRS_35	Piping from Filter Skid, via Metering Skid to Mixer (L10 Stream B)	Vapour	16	88	70	28	219	57,000	2,000	28,000
LPS_GRS_01	Above ground existing piping from shore to existing GRS Trains	Vapour	16	88	70	80	508	339,000	12,000	171,000
LPS_GRS_02	Piping from Filter Skid to Metering Skid (GT57 Stream)	Vapour	16	88	70	40	219	57,000	2,000	28,000
LPS_GRS_03	Piping from Metering Skid to Heater (GT57 Stream)	Vapour	16	88	70	30	219	57,000	2,000	28,000
LPS_GRS_04	Piping from Heater to Pressure Reduction Station (GT57 Stream)	Vapour	50	88	58	60	273	57,000	2,000	29,000
LPS_GRS_05	Piping from Pressure Reduction Station (GT57 Stream) to GT57	Vapour	>10	29	21	45	356	57,000	2,000	28,000
LPS_GRS_06	Piping from Filter Skid to Metering Skid (L9 Stream)	Vapour	16	88	70	60	219	57,000	2,000	29,000
LPS_GRS_07	Piping from Metering Skid to Heater (L9 Stream)	Vapour	16	88	70	45	273	57,000	2,000	29,000
LPS_GRS_08	Piping from Heater to Pressure Reduction Station (L9 Stream)	Vapour	41	88	61	65	273	57,000	2,200	29,000
LPS_GRS_09	Piping from Pressure Reduction Station (L9 Stream) to L9	Vapour	>10	41	31	120	356	57,000	2,000	29,000
LPS_GRS_10	Pig Receiver of the existing GRS	Vapour	16	88	70	35	508	339,000	12,000	170,000



Hong Kong - Macao VFR/SVFR Helicopter Routes

Figure 5D.1

Hong Kong - Macao VFR/ SVFR Helicopter Routes

Environmental Resources Management

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