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PAK: Engro Fast Track LNG Regasification Project

Prepared by Environmental Management Consultants (EMC) for Engro Elengy Terminal Private Limited

ANNEX – I

(AIR DISPERSION MODELING)

ANNEX I

SUPARCO

AIR DISPERSION MODELING FOR ETPL LNG TERMINAL

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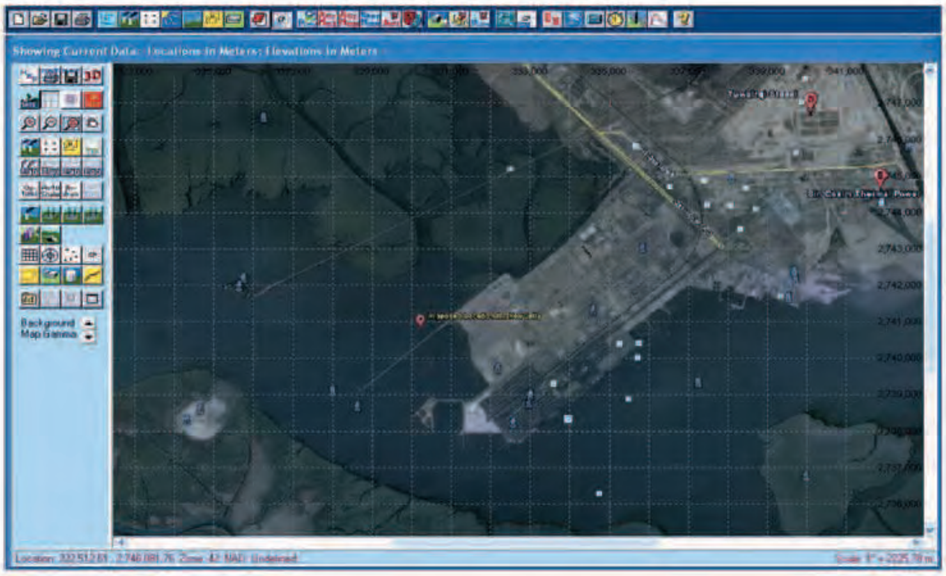
ANNEX I

Air Dispersion Modeling

1. INTRODUCTION

ETPL intends to follow a phased approach towards developing the LNG import terminal in order to bridge the gap between supply and demand of energy. The proposed LNG Import Terminal project will be sited in Port Qasim area which comes under the jurisdiction of Port Qasim Authority, Government of Pakistan. The site is located between 24°46'18.62"N, 67°18'43.51"E in the side bay next to existing (Brown Field) Site where EVTL Chemical terminal and other terminals are located.



2. METEOROLOGY

The entire coastal area of Sindh is included in the warm monsoon climatic region. Seasonal fluctuations in temperature and monsoon rains characteristically indicate the climate of dry tropical and sub-tropical climate zone. Atmospheric aridity is the chief characteristic feature of this area.

ANNEX I

Air Dispersion Modeling

Pakistan lies on the western boundary of the monsoon region, which is one of the major climate regions of the world. This region extends from Pakistan to Japan and northern Australia in the east. The monsoon is associated with prevailing winds and wet or dry weather that reverse with the seasons. The causes of the reversal of the wind system are related to the large size of the Asian continent and adjacent oceans and the very high and extensive mountain ranges of the continent.

The climate of Pakistan is more continental with less rainfall than in other parts of the Indian subcontinent, which come under a more typical monsoon regime. There are four well defined seasons, with variations to their duration. The seasons of Pakistan are:

- Cool Weather Season: mid-December through March
- Hot Weather Season: April through June
- Monsoon Season: July through September
- Post- Monsoon Season: October through mid-December

The mean maximum daily temperature varies from 40°C to 46°C (105° to 114°F). The highest temperatures are recorded in the south and southwestern parts of Pakistan.

The monsoon season is characterized by maritime influences, i.e. moderate temperatures, cyclones of variable frequency, which can cause significant rainfall, and persistent south-west winds. The change in wind direction is due to the establishment of low -pressure -systems over the Indo-Pakistan subcontinent in May and June.

The post-monsoon season is characterized by retreat of the monsoon regime, and is a transitional period between October and December and cool season conditions. The high-pressure systems begin to establish itself over Pakistan in mid-November. Without any active wind systems, the

ANNEX I

weather produces generally dry conditions with the least rainfall in October and November.

2.1 Wind Speed & Direction

The wind is another important feature of coastal region. It is variable and is stronger in summer than in winter. The maximum speed has been observed during monsoon. The speed increases during the day from morning to evening. In the morning hours, northerly and north-easterly winds prevail during winter and rest blow westerly and south-westerly. The wind blows at the rate of 4.3 to 14.1 Knots during summer.

The wind direction determines the board transport of the pollutant and the sector of the compass into which it is dispersed. Wind speed can affect dispersion in two ways; by increasing the initial dilution of pollutants and by inhibiting pollutant dispersion. As the wind passes a pollutant source, the pollutant is diluted in proportion to the wind speed. Hourly metrological data was used to run this model. Monthly averages of wind data is given in table-1.

In Port Qasim Area, wind blows throughout the year with highest velocities. During summer it has direction from south-west to west and during winter, wind blows from north to northeast and shift southwest to west in the evening hours.

Table-1: Wind Data

Sr. #	Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
1	Mean air Temperature	18.9	20.3	24.4	27.5	30.0	30.9	30.0	28.6	28.1	27.5	24.2	20.3	25.9
2	Mean Max Air Temperature	25.0	26.1	29.4	32.2	33.9	33.9	32.8	31.1	31.1	32.8	30.6	26.7	30.6
3	Mean Min, Air Temperature	12.8	14.4	19.4	22.8	26.1	27.8	27.2	26.1	25.0	22.2	17.8	13.9	21.1
4	Absolute Max.	31.7	33.9	41.1	43.9	47.8	45.6	43.3	37.2	41.1	42.2	37.8	32.8	47.8

ANNEX I

Air Dispersion Modeling

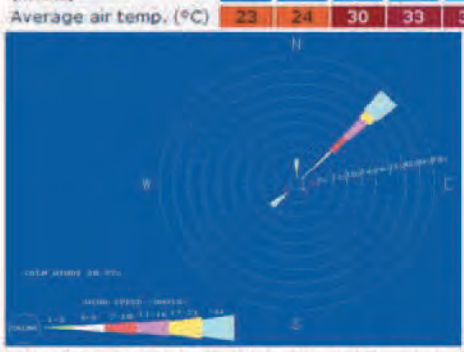
	Air Temperature													
5	Absolute Min. Air Temperature	4.4	6.1	8.3	13.9	18.3	20.0	22.8	22.8	20.6	13.9	8.9	3.9	3.0
6	Mean Relative Humidity (%)	54	61	58	75	78	78	81	82	80	70	59	55	70
7	Mean Precipitation (mm)	13	10	8	3	3	18	84	41	13	2	3	5	203
8	Max Precipitation (mm)	69	51	56	131	60	183	392	428	252	69	41	66	676
9	Mean Sunshine (hrs)	279	244	295	306	319	213	118	130	225	301	279	273	2982
10	Mean Wind Speed (m/sec)	3.3	3.6	4.3	5.1	6.1	6.7	6.7	6.2	5.2	3.5	2.8	3.1	4.7
11	Wind Direction	NE	SW	SW	SW	SW	SW	SW	SW	W	SW	NE	NE	SW

2.2 Wind Roses

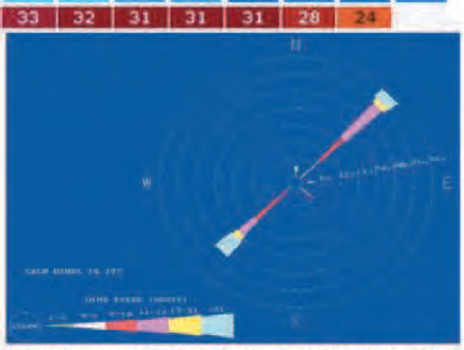
Statistics based on observations taken between 4/2009 - 11/2010 daily from 7am to 7pm local time.

(Ref: http://windfinder.com/windstats/windstatics_jinnah_airport_karachi.htm)

Month of year	Jan 01	Feb 02	Mar 03	Apr 04	May 05	Jun 06	Jul 07	Aug 08	Sep 09	Oct 10	Nov 11	Dec 12	SUM 1-12
Average Wind speed (Knots)	6	8	10	10	13	12	12	11	10	7	8	6	9
Average air temp. (°C)	23	24	30	33	33	33	32	31	31	31	28	24	



Hourly average wind at Karachi Airport for the months of January, 2009

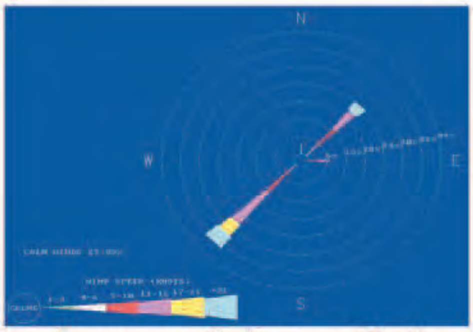


Hourly average wind at Karachi Airport for the months of February, 2009

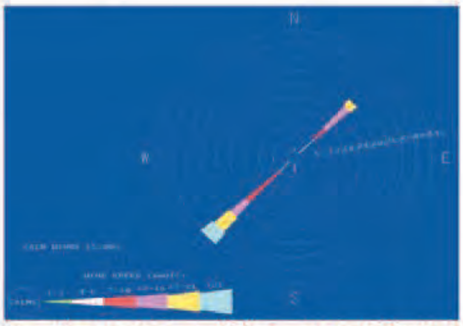
4

ANNEX I

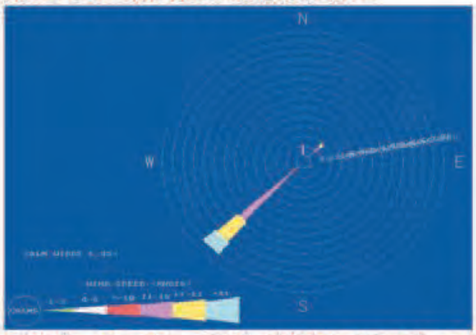
Air Dispersion Modeling



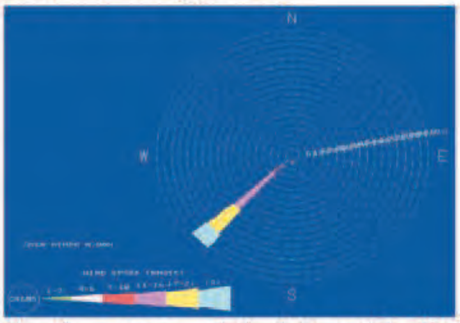
Hourly average wind at Karachi Airport for the months of March, 2009



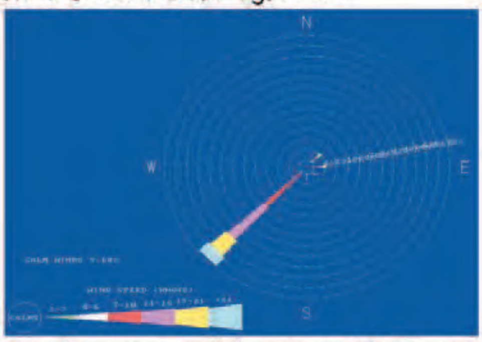
Hourly average wind at Karachi Airport for the months of April, 2009



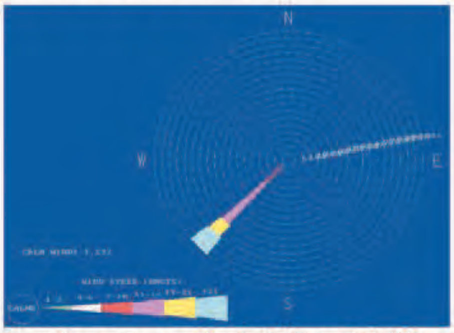
Hourly average wind at Karachi Airport for the months of May, 2009



Hourly average wind at Karachi Airport for the months of June, 2009



Hourly average wind at Karachi Airport for the months of July, 2009

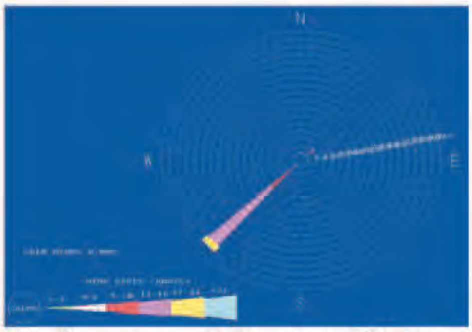


Hourly average wind at Karachi Airport for the months of August, 2009

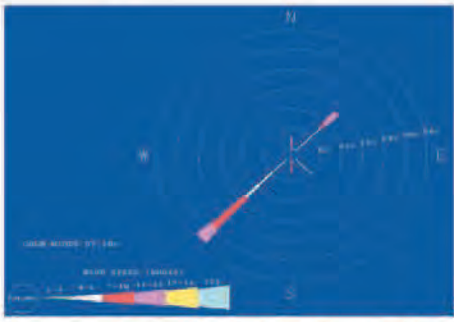
5

ANNEX I

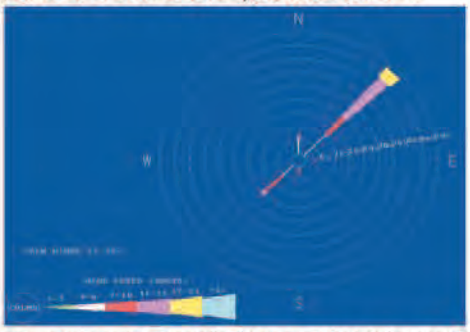
Air Dispersion Modeling



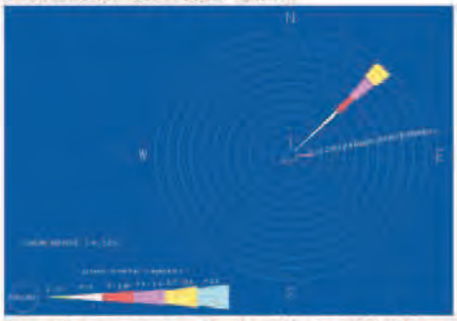
Hourly average wind at Karachi Airport for the months of September, 2009



Hourly average wind at Karachi Airport for the months of October, 2009



Hourly average wind at Karachi Airport for the months of November, 2009



Hourly average wind at Karachi Airport for the months of December, 2009

2.3 Rainfall

The annual precipitation takes place mainly during summer. It is unevenly distributed. According to the meteorological record maximum averages rainfall in three years time was recorded 100.4 mm, most of which falls in monsoon season, form April to September. Monthly rainfall data collected from meteorological office, Karachi, from 2003 to 2006. Yearly Mean is presented is shown in the Table 2:

Table 2: Amount of Precipitation (mm)

Year	Mean
2007	46.9
2008	100.4
2009	55.8

6

ANNEX I

Air Dispersion Modeling

2.4 Humidity

Humidity is an important factor in coastal region. It is generally higher in morning than in the afternoon. It also varies from place to place depending upon the nearness to the sea. Mean Yearly average data is given in Table 3.

Table 3: Mean Relative Humidity (Mean)

Year	Mean
Mean Relative Humidity (Mean) At 0300 UTC (%)	
2007	70.5
2008	69.4
2009	68.9
Mean	69.6
Mean Relative Humidity (Mean) At 1200 UTC (%)	
2007	47.3
2008	47.8
2009	45.8
Mean	46.97

3. MODELING METHODOLOGY

The TANK4.0 software is employed for evaluation of emission from Liquefied Natural Gas (LNG) storage tanks on floating LNG ship. {Equally applicable to mobile sources provided coordinates are available. [Ref: http://www.epa.gov/ttnchie1/software/tanks/]. The TANK software calculates emissions based on the methodology developed by American Petroleum Institute (API). The physical information of FSRU and physical and chemical properties of the Liquefied Natural Gas (LNG) were used for evaluation emissions for various scenarios enlisted for various normal and emergency conditions.

7

ANNEX I

Air Dispersion Modeling

Air dispersion modeling was carried out to describe the status of the air shed of proposed locations. AERMOD Prime and Industrial Source Complex ISC models was adapted to predict the down wind transportation of gaseous emissions from the operation of the existing and new power units.

BEEST is especially designed to support the EPA's regulatory modeling manager programs. This model includes ISCST3, ISC-Prime and AerMod models and graphic tools with user options for their application.

The US Clean Air Act allows the use of air dispersion modeling to determine or predict ground level concentration of pollutants from point, area, volume and open pit sources as well as from line sources. The adoption of air dispersion models in the local scenario. Specific electronic file formats on the meteorological conditions and terrain is prepared to form input in the model sub-preprocessors to successfully run the program.

4. DISPERSION MODELING SCENARIOS

4.1 Dispersion Cases:

Following modeling cases have taken based on the various environmental, storage and decking conditions:

i) Loss of containment due to failure of temperature control system resulting in emission of LNG

Vapor Clouds. As LNG leaves a temperature-controlled container, it begins to warm up, returning the liquid to a gas. Initially, the gas is colder and heavier than the surrounding air. It creates a fog – a vapor cloud – above the released liquid. As the gas warms up, it mixes with the surrounding air and begins to disperse. The vapor cloud will only ignite if it encounters an ignition source while concentrated within its flammability range (As a liquid, LNG is not

8

ANNEX I

explosive. LNG vapor will only explode if in an enclosed space. LNG vapor is only explosive if within the flammable range of 5%-15% when mixed with air) [Source: http://www.energy.ca.gov/lng/faq.html]. Safety devices and operational procedures are intended to minimize the probability of a release and subsequent vapor cloud having an affect outside the facility / FSRU as a mobile source.

ii) Loss of LNG in explosion condition

Explosion. An explosion happens when a substance rapidly changes its chemical (physical-liquid to gas) state i.e., is ignited – or is uncontrollably released from a pressurized state. For an uncontrolled release to happen, there must be a structural failure i.e., something must puncture the container or the container must break from the inside. LNG tanks stores the liquid at an extremely low temperature, about -256°F (-160°C), so no pressure is required to maintain its liquid state. Sophisticated containment systems prevent ignition sources from coming in contact with the liquid. Since LNG is stored at atmospheric pressure – i.e., not pressurized – a crack or puncture of the container will not create an immediate explosion. Moreover FSRU has more than one tank therefore cracking of all the tanks simultaneously will not occur.

5. MODELING APPLICATIONS:

The TANKS 4.0 software was used for estimating the emissions. The emissions were calculated according to US EPA's AP-42. The available information requisite for the use of software was input and emissions for the storage tank on floating ship containing LNG were calculated. The software has evaluated the emission related the above scenarios assumed for modeling. These emissions are summarized in the table 4:

ANNEX I

Air Dispersion Modeling

Table 4: Emissions in two scenarios

Scenario	Emission in gm/sec	Contents
(i)	1196.316494	LNG Vapors
(ii)	2850.6456	LNG Vapors

Gaussian dispersion model AerMod software has been used for evaluating the Ground Level Concentrations (GLC) i.e. quantitative amount of vapor emissions from the storage tanks of Liquefied Natural Gas (LNG). Monthly Meteorological Data of Karachi Airport has been used for the Dispersion Modeling. *(Modeling requires data extending over many years. PQA has not established a recording station that would cater to the required parameters).* The dispersions of emissions including LNG emissions as per given scenarios have been evaluated at distances of -100, 0, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 2000, 3000 meters from the source towards 16 direction radically keeping north at 0 Degree. *(-100 is to account for the ambient level on the –ve side of the source)*

6. MODELING INPUTS

LNG molecular weight = 18

LNG Density (at 1013.25 mbar at atm. Pressure equilibrium) = 420 kg / m³.

LNG Density = 423 kg / m³ or 3.530106 lb/gal (US). LNG Liquid phase @ -161.6°C

Vapor Density = 0.681 kg / m³ @ 0°C

Vapor pressure (psia) at 40°F =0.07117, Vapor pressure (psia) at 50°F =0.07117

Vapor pressure (psia) at 60°F = 0.06827, Vapor pressure (psia) at 70°F= 0.06827

Vapor pressure (psia) at 80°F= 0.06685,Vapor pressure (psia) at 90°F =0.065427

Vapor pressure (psia) at 100°F =0.064005

ANNEX I

Air Dispersion Modeling

6.1 Mixing Height

The mixing height (or depth) can be described as "the height above the surface through which relatively vigorous vertical mixing occurs". The mixing height is therefore well defined under neutral or unstable conditions and is undefined in stable conditions. A mixing height of 200 and 250 meters were assumed for neutral and unstable conditions respectively.

6.2 Stability

The atmospheric stability category associated with maximum concentrations varies depending on the dispersion coefficient and the source height. The maximum concentration of pollutant generally increases with decreasing wind speeds. Wind stability class B (unstable), & D (neutral) were used.

6.3 Main Assumptions

The following assumptions were made for the air dispersion model:

- The plume spread has a Gaussian (normal) distribution in both the horizontal and vertical planes;
- The mean wind speed; (a) is high enough to ignore the diffusion effect in the lee-ward direction; (b) is constant throughout the layer where the plume is being transported; and c) the wind speed remains constant during travel and for that particular month;
- The Pasquill Stability Categories considered are B & D (B: representing semi-turbulent conditions in summer within the transporting wind field and D: representing neutral conditions which prevail during winter months of Nov. to Feb. in the area);
- The stack emission rate is uniform and continuous;

11

Annex I

- Turbulence is assumed same everywhere during the period under consideration;

7. MODELING RESULTS

Scenario 1) Emission of liquefied natural gas (LNG) vapors (Loss of containment) due to failure of temperature control system)

Tables, color contour graphical and spatial representations of the dispersion of gaseous pollutants emitted for emergency scenarios of failure of temperature control system are given in tables 5, 6 and 7.

Table-5: Average annual emissions (μg/m³)

Direction (Degrees)	Distance (Meters)						
	100	200	300	400	500	600	700
22.5	269.72	365.94	538.60	907.69	779.64	2614.47	3288.20
45	313.58	424.53	624.18	1053.19	907.64	2969.44	3808.68
67.5	292.50	398.70	591.63	1012.01	899.52	2814.31	3685.16
90	503.95	679.89	994.26	1657.97	1004.01	3505.02	4798.07
112.5	860.62	1161.20	1696.25	2819.48	1159.83	4430.46	7035.55
135	269.10	377.34	582.83	1067.65	1248.80	4328.77	5816.64
157.5	214.10	300.97	466.24	858.55	1059.63	3984.98	5174.05
180	162.64	227.77	351.00	642.96	732.61	2665.94	3670.40
202.5	215.18	300.13	459.84	831.55	920.89	3059.30	4233.34
225	184.59	254.48	383.67	675.50	968.23	2495.03	3156.13
247.5	130.19	182.18	280.61	513.31	735.59	2163.31	2855.88
270	199.89	273.38	408.01	707.32	638.59	1872.99	2636.66
292.5	225.54	304.79	447.63	757.22	812.13	2371.48	2986.35
315	234.59	323.21	487.04	855.29	1054.55	2951.77	3763.48
337.5	259.77	352.79	519.96	877.05	1022.84	2654.59	3120.64
360	223.27	302.19	443.75	746.93	755.59	2084.91	2593.96

Direction (Degrees)	Distance (Meters)						
	800	900	1000	2000	3000	4000	5000
22.5	3263.14	3011.91	2746.96	2506.78	2280.52	2077.21	1896.78
45	3892.17	3644.43	3327.38	3021.85	2732.34	2474.11	2247.65
67.5	3803.04	3578.01	3274.54	2975.08	2688.11	2430.49	2202.87

ANNEX I

Air Dispersion Modeling

90	5088.20	4931.53	4646.59	4333.37	3997.77	3677.61	3381.69
112.5	7981.34	7965.69	7616.28	7162.43	6645.04	6138.31	5662.61
135	5912.90	5405.20	4760.07	4144.87	3602.22	3141.76	2757.28
157.5	5096.05	4568.70	3974.51	3430.30	2964.63	2574.06	2250.22
180	3722.71	3380.53	2954.55	2554.86	2208.34	1917.73	1676.62
202.5	4359.40	4013.58	3552.45	3106.13	2711.27	2374.01	2090.33
225	3182.26	2924.53	2605.18	2302.47	2031.06	1797.80	1599.73
247.5	2894.10	2639.61	2317.92	2011.90	1744.47	1518.50	1329.94
270	2838.78	2717.29	2488.30	2242.57	2006.82	1796.02	1611.94
292.5	2983.78	2749.54	2482.68	2235.79	2009.15	1810.73	1638.25
315	3827.34	3552.44	3194.10	2845.20	2525.08	2245.63	2005.46
337.5	3081.21	2860.33	2623.29	2404.59	2193.39	2001.61	1829.74
360	2627.24	2461.98	2262.57	2072.36	1886.23	1717.65	1567.29

Figure 1: Color average annually contour map for vapor emission scenario

Table-6: Average monthly emissions (μg/m³)

Direction (Degrees)	Distance (Meters)						
	100	200	300	400	500	600	700
22.5	718.24	959.08	1376.82	2221.47	2919.32	6633.25	7879.22
45	703.96	936.95	1343.66	2174.62	2333.72	5991.20	5438.05

13

ANNEX I

Air Dispersion Modeling

67.5	618.73	809.79	1134.31	1754.77	2318.66	5377.19	5318.87
90	788.49	1047.94	1509.87	2480.78	3116.86	6700.48	7118.13
112.5	1645.14	2175.56	3077.96	4805.54	3838.95	10595.30	11529.34
135	426.42	588.55	887.39	1558.99	3467.30	7749.06	8905.40
157.5	451.51	610.59	897.31	1521.94	3229.38	10748.29	10614.75
180	352.69	486.32	731.45	1286.33	1817.71	4994.92	5515.85
202.5	371.60	514.93	780.25	1391.07	3719.37	8174.73	8459.18
225	387.27	541.53	830.95	1502.47	4446.00	7803.62	7028.92
247.5	282.26	390.04	590.10	1046.90	2457.07	5139.08	5916.69
270	632.43	849.71	1232.56	2020.42	2024.41	4769.54	4892.08
292.5	539.04	721.82	1046.25	1725.17	2839.15	7107.78	7072.00
315	636.53	863.09	1271.00	2148.33	3167.91	7756.83	7131.48
337.5	442.45	605.16	895.22	1506.57	3137.35	6411.06	6187.03
360	509.94	678.94	972.41	1564.18	2989.21	5121.40	5670.49

Direction	Distance (Meters)						
(Degrees)	800	900	1000	2000	3000	4000	5000
22.5	7625.09	6982.97	6378.35	5857.55	5362.35	4916.02	4515.47
45	6017.35	5926.34	5615.29	5258.67	4877.76	4515.70	4179.62
67.5	7105.32	7241.37	6715.54	6001.98	5297.75	4663.05	4113.43
90	8234.64	8582.54	8162.40	7474.17	6730.80	6027.19	5395.63
112.5	10856.58	11245.67	10810.26	10059.83	9204.97	8370.99	7811.28
135	8730.80	7787.09	6717.37	5752.05	5022.06	4391.96	3860.03
157.5	8607.09	7047.82	6353.79	5622.78	4946.51	4352.78	3843.66
180	5732.56	5483.11	4948.72	4387.48	3869.87	3421.08	3039.57
202.5	7402.79	6188.12	5613.68	4966.48	4367.79	3840.98	3393.81
225	6729.42	6641.95	6083.35	5419.56	4780.81	4213.65	3727.91
247.5	5670.08	5037.02	4354.31	3736.08	3213.16	2820.53	2508.72
270	5164.61	5203.19	5040.13	4801.82	4502.65	4198.99	3905.81
292.5	6374.37	5671.10	5095.60	4621.02	4202.51	3836.30	3512.97
315	7493.25	7257.81	6723.53	6140.85	5565.88	5043.53	4581.54
337.5	5447.10	4748.71	4301.58	3943.87	3594.29	3276.56	3022.77
360	5159.60	4400.62	3690.07	3473.46	3276.38	3077.86	2885.07

14

ANNEX I

Air Dispersion Modeling

Figure 2: Color average monthly contour map for vapor emission scenario

Table-7: Average 24-hourly emissions (µg/m³)

Direction (Degrees)	Distance (Meters)						
	100	200	300	400	500	600	700
22.5	3438.10	4680.20	6985.95	11929.14	30156.01	36419.77	35627.20
45	5428.46	7047.64	9717.73	14994.48	19543.25	40135.69	44593.19
67.5	5179.23	6746.77	9556.74	15095.75	24913.80	59399.99	45935.64
90	7792.29	10055.24	13671.46	19754.71	21098.32	61092.19	61949.52
112.5	5958.37	7584.65	10118.80	15427.97	20316.86	79208.87	77622.33
135	7329.50	9485.85	12965.12	18962.07	27187.21	65376.64	54257.46
157.5	10898.95	14304.07	19938.40	30125.85	31653.21	61734.16	59257.14
180	3043.78	3993.27	6066.08	10957.20	42289.09	61290.47	56981.54
202.5	3758.89	5059.63	7429.59	12407.71	31582.35	46273.96	48570.39
225	2442.82	3141.33	4247.45	6436.85	14175.71	53801.36	51856.67
247.5	4337.40	5519.98	7361.88	10297.48	45772.05	55122.63	34438.38
270	3910.16	5239.68	7585.00	12296.14	20423.39	44131.35	49061.40
292.5	5518.89	7270.80	10241.56	16082.91	20013.76	43644.73	34051.85
315	5700.83	7371.05	10092.16	14935.36	21224.74	62624.60	56602.27
337.5	5163.21	6666.93	9067.16	13103.49	28357.77	43123.95	38448.05
360	4973.15	6366.81	8575.80	12267.41	32083.93	37738.30	33098.46

15

ANNEX I

Air Dispersion Modeling

Direction (Degrees)	Distance (Meters)						
	800	900	1000	2000	3000	4000	5000
22.5	42077.98	43907.19	41194.02	37012.82	32788.01	28892.00	25686.11
45	43194.90	44963.70	41966.16	37548.81	35198.36	32984.21	30648.04
67.5	43579.37	43471.43	39543.27	34797.45	30618.63	28786.34	27052.74
90	56646.24	48056.59	40069.45	33423.91	29175.63	27370.81	25711.89
112.5	60233.75	45412.77	40816.13	36821.33	32673.51	28935.16	27370.63
135	45841.19	40765.35	37645.49	33439.20	29310.87	25631.55	23916.51
157.5	49996.52	42191.86	38719.05	37233.50	40006.96	41610.20	42216.23
180	46709.63	47630.11	44411.92	39794.82	35144.31	30934.75	27311.52
202.5	47069.41	41532.38	35516.89	30150.90	28985.56	27275.37	25364.93
225	39759.25	29747.11	25825.71	23171.83	20490.71	18056.72	15945.86
247.5	40989.71	40617.22	36833.91	32359.16	28159.26	24498.20	21415.16
270	54762.88	55304.23	50763.07	44963.48	39369.57	34418.07	30190.47
292.5	33263.75	35328.07	34847.77	33592.67	31828.51	30016.32	28253.02
315	50532.54	50886.76	46517.36	41040.37	35797.62	31186.59	27271.42
337.5	36274.16	36111.41	32894.36	28978.44	26209.00	24277.88	22317.20
360	27506.45	24474.84	22419.77	20334.42	19654.07	19133.62	18453.51

Figure 3: Color average 24-hourly contour map for vapor emission scenario

16

ANNEX I

Air Dispersion Modeling

Scenario 2) Loss of LNG in explosion condition (100%)

Tables, color contour graphical and spatial representations of the dispersion of gaseous pollutants emitted for emergency scenarios of failure of temperature control system are given in tables 8, 9 and 10:

Table-8: Average annual emissions (µg/m³)

Direction (Degrees)	Distance (Meters)						
	100	200	300	400	500	600	700
22.5	614.97	834.34	1228.02	1777.57	5961.00	7497.09	7439.96
45	714.95	967.93	1423.12	2069.42	6770.33	8683.78	8874.14
67.5	666.89	909.04	1348.91	2050.90	6416.61	8402.17	8670.92
90	1149.00	1550.15	2266.90	2289.15	7991.43	10939.58	11601.08
112.5	1962.21	2647.52	3867.47	2644.43	10101.46	16041.07	18197.46
135	613.55	860.34	1328.85	2847.26	9869.58	13261.93	13481.38
157.5	488.15	686.21	1063.03	2415.95	9085.75	11796.86	11618.98
180	370.83	519.32	800.29	1670.36	6078.36	8368.52	8487.79
202.5	490.62	684.30	1048.44	2099.63	6975.19	9652.00	9939.43
225	420.87	580.21	874.76	2207.56	5688.65	7195.99	7255.57
247.5	296.83	415.37	639.78	1677.15	4932.33	6511.42	6598.55
270	455.75	623.31	930.27	1455.99	4270.42	6011.57	6472.42
292.5	514.24	694.92	1020.59	1851.65	5406.96	6808.88	6803.01
315	534.86	736.92	1110.45	2404.38	6730.05	8580.72	8726.33
337.5	592.27	804.36	1185.51	2332.08	6052.46	7115.06	7025.17
360	509.05	688.99	1011.75	1722.75	4753.60	5914.23	5990.11

Direction (Degrees)	Distance (Meters)						
	800	900	1000	2000	3000	4000	5000
22.5	6867.14	6263.07	5715.45	5199.59	4736.04	4324.66	2069.52
45	8309.32	7586.42	6889.81	6229.73	5640.96	5124.65	2401.27
67.5	8157.85	7465.97	6783.19	6128.87	5541.51	5022.55	2307.37
90	11243.86	10594.24	9880.11	9114.92	8384.97	7710.26	3780.17
112.5	18161.75	17365.11	16330.31	15150.65	13995.40	12910.74	6428.40
135	12323.83	10852.96	9450.30	8213.06	7163.21	6286.60	2434.24
157.5	10416.63	9061.87	7821.08	6759.37	5868.86	5130.50	1957.48
180	7707.59	6736.37	5825.09	5035.01	4372.42	3822.70	1465.96
202.5	9150.98	8099.57	7081.96	6181.69	5412.73	4765.96	1895.93
225	6667.95	5939.80	5249.63	4630.81	4098.98	3647.38	1540.13

17

Annex I

Air Dispersion Modeling

247.5	6018.32	5284.85	4587.14	3977.39	3462.18	3032.25	1170.34
270	6195.44	5673.32	5113.06	4575.55	4094.91	3675.23	1612.69
292.5	6268.95	5660.50	5097.61	4580.87	4128.46	3735.20	1726.47
315	8099.57	7282.55	6487.06	5757.17	5120.03	4572.46	1950.06
337.5	6521.53	5981.09	5482.47	5000.92	4563.67	4171.80	1999.66
360	5613.31	5158.65	4724.98	4300.60	3916.25	3573.41	1703.01

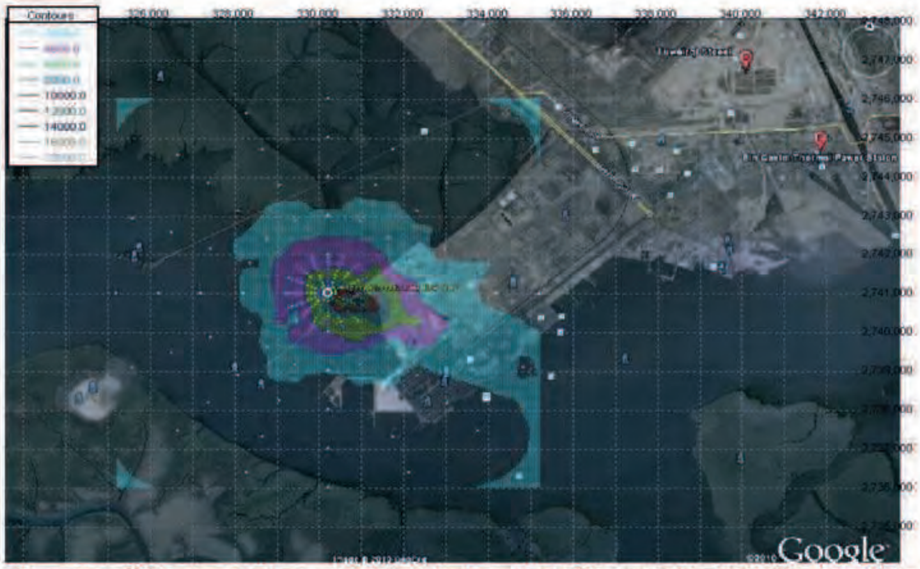


Figure 4: Color average 24-hourly Contour Map for LNG in explosion condition (100%)

Table-9: Average monthly emissions (μg/m³)

Direction (Degrees)	Distance (Meters)						
	100	200	300	400	500	600	700
22.5	1637.58	2186.69	3139.15	6656.05	15123.79	17964.60	17385.20
45	1605.03	2136.24	3063.54	5320.89	13659.93	12398.74	13719.55
67.5	1410.70	1846.32	2586.22	5286.54	12259.99	12127.01	16200.14
90	1797.76	2389.31	3442.50	7106.45	15277.10	16229.34	18774.99
112.5	3750.93	4960.27	7017.74	8752.80	24157.28	26286.91	24752.99
135	972.24	1341.90	2023.24	7905.45	17667.87	20304.32	19906.24
157.5	1029.44	1392.14	2045.87	7362.99	24506.11	24201.62	19624.17
180	804.14	1108.81	1667.70	4144.37	11388.42	12576.14	13070.24

18

ANNEX I

Air Dispersion Modeling

202.5	847.25	1174.04	1778.97	8480.17	18638.37	19286.92	16878.36
225	882.98	1234.70	1894.57	10136.88	17792.26	16025.93	15343.07
247.5	643.55	889.30	1345.43	5602.13	11717.12	13490.06	12927.79
270	1441.93	1937.34	2810.24	4615.65	10874.54	11153.94	11775.31
292.5	1229.01	1645.76	2385.46	6473.25	16205.74	16124.16	14533.55
315	1451.28	1967.84	2897.88	7222.85	17685.58	16259.78	17084.61
337.5	1008.79	1379.76	2041.10	7153.16	14617.23	14106.42	12419.38
360	1162.67	1547.98	2217.09	6815.40	11676.79	12928.71	11763.88

Direction (Degrees)	Distance (Meters)						
	800	900	1000	2000	3000	4000	5000
22.5	15921.17	14542.63	13355.21	12226.16	11208.52	10295.28	5064.96
45	13512.05	12802.86	11989.77	11121.30	10295.80	9529.54	4958.14
67.5	16510.34	15311.42	13684.54	12078.88	10631.75	9378.63	4000.88
90	19568.19	18610.26	17041.07	15346.20	13741.99	12302.04	5656.18
112.5	25640.13	24647.38	22936.42	20987.33	19085.85	17809.71	10956.65
135	17754.56	15315.60	13114.69	11450.30	10013.66	8800.88	3554.51
157.5	16069.03	14486.64	12819.93	11278.04	9924.33	8763.53	3470.03
180	12501.50	11283.09	10003.45	8823.30	7800.07	6930.22	2932.84
202.5	14108.91	12799.18	11323.58	9958.58	8757.44	7737.88	3171.64
225	15143.63	13870.04	12356.59	10900.25	9607.12	8499.62	3425.63
247.5	11484.42	9927.83	8518.26	7326.00	6430.80	5719.89	2386.93
270	11863.27	11491.48	10948.14	10266.05	9573.71	8905.26	4606.56
292.5	12930.11	11617.97	10535.93	9581.72	8746.76	8009.58	3933.39
315	16547.80	15329.66	14001.13	12690.19	11499.26	10445.91	4898.21
337.5	10827.05	9807.60	8992.03	8194.99	7470.56	6891.91	3434.97
360	10033.43	8413.35	7919.49	7470.15	7017.52	6577.95	3566.33

ANNEX I

Air Dispersion Modeling

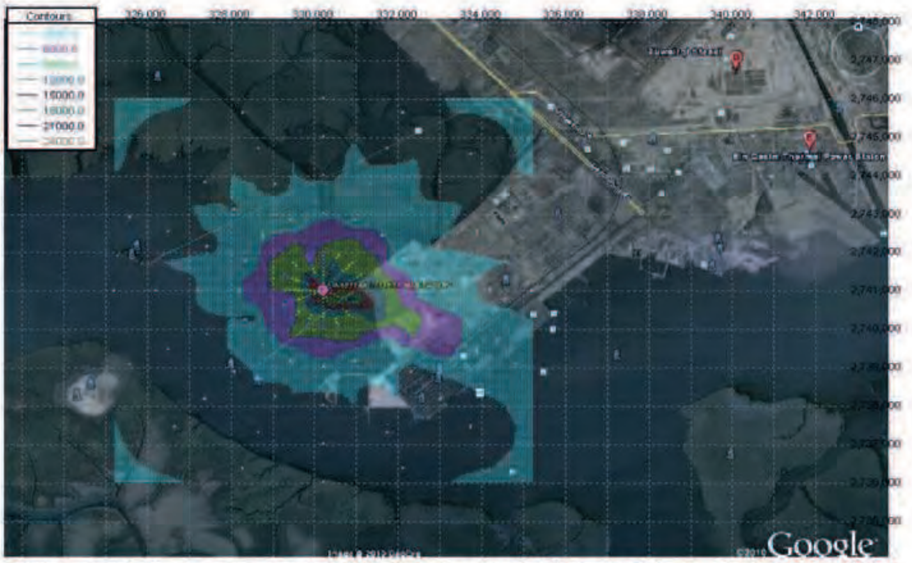


Figure 5: Color average monthly Contour Map for LNG in explosion condition (100%)

Table-10: Average 24-hourly emissions (µg/m³)

Direction (Degrees)	Distance (Meters)						
	100	200	300	400	500	600	700
22.5	12376.88	16068.62	22156.43	44558.62	91509.38	101672.48	98484.37
45	8915.17	11946.46	17293.79	46565.34	100619.48	111859.99	124859.37
67.5	9889.28	12585.56	16785.08	104360.28	125679.61	78519.50	93456.49
90	17766.41	22925.94	31170.94	48104.16	139290.19	141244.89	129153.44
112.5	13585.09	17293.01	23070.87	46322.43	180596.20	176978.89	137332.94
135	16711.25	21627.74	29560.46	61986.84	149058.73	123707.03	104517.91
157.5	24849.61	32613.28	45459.53	72169.31	140753.88	135106.28	113992.04
180	6939.82	9104.65	13830.65	96419.13	139742.27	129917.91	106497.95
202.5	8570.26	11535.95	16939.46	72007.74	105504.63	110740.48	107318.24
225	5569.64	7162.23	9684.18	32320.62	122667.05	118233.20	90651.09
247.5	7838.86	10670.84	15927.96	68755.70	83037.07	81230.03	95937.78
270	12583.07	16577.42	23350.76	45631.38	99509.98	77638.22	75841.34
292.5	11808.65	15382.63	21789.37	56803.46	135431.97	104733.27	99360.96
315	12997.89	16806.00	23010.12	48392.40	142784.09	129053.19	115214.22
337.5	11772.12	15200.60	20673.12	64655.70	98322.58	87661.54	82705.09
360	11338.77	14516.32	19552.83	73151.36	86043.30	75464.47	62714.70

20

Annex I

Air Dispersion Modeling

Direction (Degrees)	Distance (Meters)						
	800	900	1000	2000	3000	4000	5000
22.5	102517.23	95682.85	85611.30	80252.26	75204.01	69877.52	34187.43
45	126093.63	115739.80	102516.71	89762.66	78473.20	68834.26	28035.20
67.5	92607.27	83981.29	73778.88	64203.11	55855.91	48826.56	23478.25
90	109569.02	91358.32	76206.51	66520.42	62405.46	58623.13	45040.75
112.5	103541.09	93060.76	83952.63	74495.60	65972.16	62405.04	35175.77
135	92945.00	85831.70	76241.36	66828.77	58439.94	54529.63	43233.50
157.5	96197.45	88279.44	84892.37	91215.88	94871.25	96253.00	68686.95
180	108596.66	101259.19	90732.18	80129.02	70531.20	62270.26	24982.40
202.5	94693.82	80978.48	68744.05	66087.08	62187.85	57832.04	28289.58
225	67823.41	58882.61	52831.78	46718.81	41169.33	36356.55	14676.01
247.5	100108.39	93922.34	84389.23	74756.67	65873.76	58564.32	27198.44
270	80547.98	79452.90	76591.28	72568.99	68437.19	64416.88	36669.04
292.5	99114.84	90158.66	79338.16	69810.46	65632.84	61680.23	34418.32
315	116021.85	106059.57	93572.06	81618.58	71105.40	62178.85	34052.63
337.5	82333.99	74999.14	66070.84	59756.53	55353.57	50883.22	29875.96
360	55802.62	51117.07	46362.47	44811.28	43624.65	42074.00	27969.68

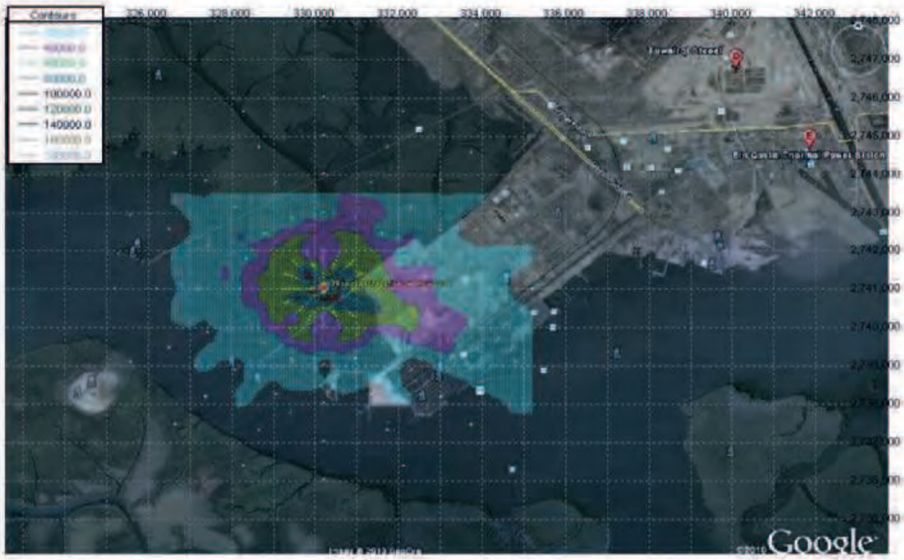


Figure 6: Color annual Contour Map for LNG in explosion condition (100%)

21

ANNEX I

Air Dispersion Modeling

8. CONCLUSION

Scenarios	Direction Degrees	Distance (Meters)	Avg. Conc µg/m³	Ave	Lower Explosive or Flammable Limit (LEL/LFL) (5% of Methane) 50,000ppm / 36810x10³ µg/m³
LNG Vapor emissions due to failure of temperature control system	112.5	600	79208.87	24-HR	Non- Combustible Mixture
	112.5	700	11529.34	Month	Non- Combustible Mixture
	112.5	800	7981.34	Annual	Non- Combustible Mixture
Explosion	112.5	400	18059620	24-HR	Non- Combustible Mixture
	112.5	600	26286.91	Month	Non- Combustible Mixture
	112.5	700	18197.46	Annual	Non- Combustible Mixture

Note:

LEL i.e.CH4 = 50,000 ppm = 36809.82 mg/m³ at /molecular weight of LNG = 18

Reference: *Los Alamos National Laboratory USA*

Table 11: Travel time of plume for indicated distance from the source in various months

Distance (Meters)	Time in seconds												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
100	5.5	6	7.17	8.5	10.17	11.17	11.17	10.33	8.67	5.83	4.67	5.17	7.83
200	11	12	14.33	17	20.33	22.33	22.33	20.67	17.33	11.67	9.33	10.33	15.67
300	16.5	18	21.50	25.5	30.5	33.5	33.5	31	26	17.5	14	15.5	23.5
400	22	24	28.67	34	40.67	44.67	44.67	41.33	34.67	23.33	18.67	20.67	31.33
500	27.5	30	35.83	42.5	50.83	55.83	55.83	51.67	43.33	29.17	23.33	25.83	39.17
600	33	36	43	51	61	67	67	62	52	35	28	31	47
700	38.5	42	50.17	59.5	71.17	78.17	78.17	72.33	60.67	40.83	32.67	36.17	54.83
800	44	48	57.33	68	81.33	89.33	89.33	82.67	69.33	46.67	37.33	41.33	62.67
900	49.5	54	64.5	76.5	91.5	100.5	100.5	93	78	52.5	42	46.5	70.5
1000	55	60	71.67	85	101.67	111.67	111.67	103.33	86.67	58.33	46.67	51.67	78.33
2000	110	120	143.33	170	203.33	223.33	223.33	206.67	173.33	116.67	93.33	103.33	156.67
3000	165	180	215	255	305	335	335	310	260	175	140	155	235
4000	220	240	286.67	340	406.67	446.67	446.67	413.33	346.67	233.33	186.67	206.67	313.33
5000	275	300	358.33	425	508.33	558.33	558.33	516.67	433.33	291.67	233.33	258.33	391.67

22

ANNEX I

Air Dispersion Modeling

The above Tables and contour maps leads to the conclusion that gaseous emissions at normal atmospheric conditions for the proposed LNG project at Brown Field site would not add any of the priority pollutants beyond the limits set by World Bank Guidelines and would not degrade the quality of airshed. The limits set by NEQS also suggest that the quality of airshed would not be altered to hazardous state by the emissions from the LNG Project. Adequate risk management and mitigation measures are required to avoid such an eventuality.

Establishment of Proposed LNG Project at proposed Brown Field site would therefore be an environmentally safe proposition.

23

ANNEX - II

(PEPA 1997)

ANNEX II

The Gazette of Pakistan

EXTRAORDINARY
PUBLISHED BY AUTHORITY

ISLAMABAD, SATURDAY,, DECEMBER 6,1997

PART I

Acts, Ordinances, President's Orders and Regulations

SENATE SECRETARIAT

Islamabad, the 6th December, 1997

No. F. 9(46)/97-Legis.- The following Acts of Majlis-e-Shoora (Parliament) received the assent of the Acting President on 3rd December, 1997 are hereby published for general information :-

Act No. XXXIV OF 1997

An Act to provide for the protection, conservation, rehabilitation and improvement of the environment, for the prevention and control of pollution, and promotion of sustainable development

WHEREAS it is expedient to provide for the protection, conservation, rehabilitation and improvement of the environment, prevention and control of pollution, promotion of sustainable development, and for matters connected therewith and incidental thereto;

1. Short title, extent and commencement.---(1) This Act, shall be called the Pakistan Environmental Protection Act, 1997

(2) It extends to the whole of Pakistan.

(3) It shall come into force at once.

2. Definitions.—In this Act, unless there is anything repugnant in the subject or context,—

(i) "adverse environmental effect" means impairment of, or damage to, the environment and includes—

(a) impairment of, or damage to, human health and safety or to biodiversity or property;

ANNEX II

(b) pollution; and

(c) any adverse environmental effect as may be specified in the regulations;

(ii) "agricultural waste" means waste from farm and agricultural activities including poultry, cattle farming, animal husbandry residues from the use of fertilizers, pesticides and other farm . chemicals;

(iii) "air pollutant" means any substance that causes pollution of air and includes soot, smoke, dust particles, odour, light, electro-magnetic, radiation, heat, fumes, combustion exhaust, exhaust gases, noxious gases, hazardous substances and radioactive substances;

(iv) "biodiversity" or "biological diversity" means the variability among living organisms from all sources, including inter alia terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part, including diversity within species, between species and of ecosystems;

(v) "Council" means the Pakistan Environmental Protection Council established under section 3;

(vi) "discharge" includes spilling, leaking, pumping, depositing, seeping, releasing, flowing out, pouring, emitting, emptying or dumping;

(vii) "ecosystem" means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit;

(viii) "effluent" means any material in solid, liquid or gaseous form or combination thereof being discharged from industrial activity or any other source and includes a slurry, suspension or vapour;

(ix) "emission standards" means the permissible standards established by the Federal Agency or a Provincial Agency for emission of air pollutants and noise and for discharge of effluent and waste;

(x) "environment" means—

(a) air, water and land;

(b) all layers of the atmosphere;

(c) all organic and inorganic matter and living organisms;

(d) the ecosystem and ecological relationships;

(e) buildings, structures, roads, facilities and works;

ANNEX II

(f) all social and economic conditions affecting community life; and

(g) the inter-relationships between any of the factors specified in sub-clauses (a) to (f);

(xi) "environmental impact assessment" means an environmental study comprising collection of data, prediction of qualitative and quantitative impacts, comparison of alternatives, evaluation of preventive, mitigatory and compensatory measures, formulation of environmental management and training plans and monitoring arrangements, and framing of recommendations and such other components as may be prescribed;

(xii) "Environmental Magistrate" means the Magistrate of the First Class appointed under Section 24 ;

(xiii) "Environmental Tribunal" means the Environmental Tribunal constituted under section 20 ;

(xiv) "Exclusive Economic Zone" shall have the same meaning as in the Territorial Waters and Maritime Zones Act, 1976 (LXXXII of 1976);

(xv) "factory" means any premises in which industrial activity is being undertaken;

(xvi) "Federal Agency" means the Pakistan Environmental Protection Agency established under section 5, or any Government Agency, local council or local authority exercising the powers and functions of the Federal Agency;

(xvii) "Government Agency" includes—

(a) a division, department, attached department, bureau, section, commission, board, office or unit of the Federal Government or a Provincial Government;

(b) a developmental or a local authority, company or corporation established or controlled by the Federal Government or Provincial Government; and

(c) a Provincial Environmental Protection Agency. ; and

(d) any other body defined and listed in the Rules of Business of the Federal Government or a Provincial Government.

(xviii) "hazardous substance" means—

(a) a substance or mixture of substances, other than a pesticide as defined in the Agricultural Pesticides Ordinance, 1971 (II of 1971), which, by reason of its chemical activity or toxic, explosive, flammable, corrosive, radioactive or other characteristics,

ANNEX II

causes, or is likely to cause, directly or in combination with other matters an adverse environmental effect; and

(b) any substance which may be prescribed as a hazardous substance;

(xix) "hazardous waste" means waste which is or which contains a hazardous substance or which may be prescribed as hazardous waste and includes hospital waste and nuclear waste;

(xx) "historic waters" means such limits of the waters adjacent to the land territory of Pakistan as may be specified by notification under section 7 of the Territorial Waters and Maritime Zones Act, 1976 (LXXXII of 1976);

(xxi) "hospital waste" includes waste medical supplies and materials of all kinds, and waste blood, tissue, organs and other parts of the human and animal bodies, from hospitals, clinics and laboratories;

(xxii) "industrial activity" means any operation or process for manufacturing, making, formulating, synthesising, altering, repairing, ornamenting, finishing, packing or otherwise treating any article or substance with a view to its use, sale, transport, delivery or disposal, or for mining, for oil and gas exploration and development, or for pumping water or sewage, or for generating, transforming or transmitting power or for any other industrial or commercial purpose;

(xxiii) "industrial waste" means waste resulting from an industrial activity;

(xxiv) "initial environmental examination" means a preliminary environmental review of the reasonably foreseeable qualitative and quantitative impacts on the environment of a proposed project to determine whether it is likely to cause an adverse environmental effect for requiring preparation of an environmental impact assessment;

(xxv) "local authority" means any agency set up or designated by the Federal Government or a Provincial Government, by notification in the official Gazette, to be a local authority for the purposes of this Ordinance;

(xxvi) "local council" means a local council constituted or established under a law relating to local government;

(xxvii) "motor vehicle" means any mechanically propelled vehicle adapted for use upon land whether its power of propulsion is transmitted thereto from an external or internal source, and includes a chassis to which a body has not been attached, and a trailer, but does not include a vehicle running upon fixed rails;

(xxviii) "municipal waste" includes sewage, refuse, garbage, waste from abattoirs, sludge and human excreta and the like;

ANNEX II

(xxix) "National Environmental Quality Standards" means standards established by the Federal Agency under clause (e) of sub-section (1) of section 6 and approved by the Council under clause (c) of sub-section (1) of section 4;

(xxx) "noise" means the intensity, duration and character of sounds from all sources, and includes vibration;

(xxxi) "nuclear waste" means waste from any nuclear reactor or nuclear plant or other nuclear energy system, whether or not such waste is radioactive;

(xxxii) "person" means any natural person or legal entity and includes an individual, firm, association, partnership, society, group, company, corporation, co-operative society, Government Agency, non-governmental organization, community-based organization, village organization, local council or local authority and, in the case of a vessel, the master or other person having for the time being the charge or control of the vessel;

(xxxiii) "pollution" means the contamination of air, land or water by the discharge or emission of effluent or wastes or air pollutants or noise or other matter which either directly or indirectly or in combination with other discharges or substances alters unfavourably the chemical, physical, biological, radiational, thermal or radiological or aesthetic properties of the air, land or water or which may, or is likely to make the air, land or water unclean, noxious or impure or injurious, disagreeable or detrimental to the health, safety, welfare or property of persons or harmful to biodiversity;

(xxxiv) "prescribed" means prescribed by rules made under this Act;

(xxxv) "project" means any activity, plan, scheme, proposal or undertaking involving any change in the environment and includes—

(a) construction or use of buildings or other works;

(b) construction or use of roads or other transport systems;

(c) construction or operation of factories or other installations;

(d) mineral prospecting, mining, quarrying, stone-crushing, drilling and the like;

(e) any change of land use or water use; and

(f) alteration, expansion, repair, decommissioning or abandonment of existing buildings or other works, roads or other transport systems, factories or other installations;

(xxxvi) "proponent" means the person who proposes or intends to undertake a project;

(xxxvii) "Provincial Agency" means a Provincial Environmental Protection Agency established under section 8;

ANNEX II

(xxxviii) "regulations" means regulations made under this Act;

(xix) "rules" means rules made under this Act;

(xl) "sewage" means liquid or semi-solid wastes and sludge from sanitary conveniences, kitchens, laundries, washing and similar activities and from any sewerage system or sewage disposal works;

(xli) "standards" means qualitative and quantitative standards for discharge of effluent and wastes and for emission of air pollutants and noise either for general applicability or for a particular area, or from a particular production process, or for a particular product, and includes the National Environmental Quality Standards, emission standards and other standards established under this Act and the rules and regulations;

(xlii) "sustainable development" means development that meets the needs of the present generation without compromising the ability of future generations to meet their needs;

(xliii) "territorial waters" shall have the same meaning as in the Territorial Waters and Maritime Zones Act, 1976 (LXXXII of 1976);

(xliv) "vessel" includes anything made for the conveyance by water of human beings or of goods; and

(xlv) "waste" means any substance or object which has been, is being or is intended to be, discarded or disposed of, and includes liquid waste, solid waste, waste gases, suspended waste, industrial waste, agricultural waste, nuclear waste, municipal waste, hospital waste, used polyethylene bags and residues from the incineration of all types of waste.

3. Establishment of the Pakistan Environmental Protection Council.— (1) The Federal Government shall, by notification in the official Gazette, establish a Council to be known as the Pakistan Environmental Protection Council consisting of—

(i) Prime Minister or such other person as the Prime Minister may nominate in this behalf.	Chairperson
(ii) Minister incharge of the Ministry or Division dealing with the subject of environment.	Vice Chairperson
(iii) Chief Ministers of the Provinces.	Members
(iii) Ministers Incharge of the subject of environment in the Provinces.	Members
(iv) Such other persons not exceedingthirty-five as the federal Government may appoint, of which at least	Members

ANNEX II

twenty shall be non-officials including five representatives of the Chambers of Commerce and Industry and industrial associations and one or more representatives of the Chambers of Agriculture, the medical and legal professions, trade unions, and non-governmental organizations concerned with the environment and development, and scientists, technical experts and educationists

(v) Secretary to the Government of Pakistan, incharge of the Ministry or Division dealing with the subject of environment — Member/ Secretary

(2) The Members of the Council, other than ex-officio members, shall be appointed in accordance with the prescribed procedure and shall hold office for a term of two years.

(3) The Council shall frame its own rules of procedure.

(4) The Council shall hold meetings, as and when necessary, but not less than two meetings, shall be held in a year.

(5) The Council may constitute committees of its members and entrust them with such functions as it may deem fit, and the recommendations of the committees shall be submitted to the Council for approval.

(6) The Council, or any of its committees, may invite any technical expert or representative of any Government Agency or non-governmental organization or other person possessing specialized knowledge of any subject for assistance in performance of its functions.

4. Functions and powers of the Council.—(1) The Council shall—

(a) co-ordinate and supervise enforcement of the provisions of this Act; and

(b) approve comprehensive national environmental policies and ensure their implementation within the framework of a national conservation strategy as may be approved by the Federal Government from time to time;

(c) approve the National Environmental Quality Standards;

(d) provide guidelines for the protection and conservation of species, habitats, and biodiversity in general, and for the conservation of renewable and non-renewable resources.

ANNEX II

(e) co-ordinate integration of the principles and concerns of sustainable development into national development plans and policies;

(f) consider the National Environment Report and give appropriate directions thereon;

(2) The Council may, either itself or on the request of any person or organization, direct the Federal Agency or any Government Agency to prepare, submit, promote or implement projects for the protection, conservation, rehabilitation and improvement of the environment, the prevention and control of pollution, and the sustainable development of resources or to undertake research in any aspect of environment.

5. Establishment of the Pakistan Environmental Protection Agency.----(1) The Federal Government shall, by notification in the official Gazette, establish the Pakistan Environmental Protection Agency to exercise the powers and perform the functions assigned to it under this Act and the rules and regulations made thereunder.

(2) The Federal Agency shall be headed by a Director-General who shall be appointed by the Federal Government on such terms and conditions as it may determine.

(3) The Federal Agency shall have such administrative, technical and legal staff, as the Federal Government may specify, to be appointed in accordance with such procedure as may be prescribed.

(4) The powers and functions of the Federal Agency shall be exercised and performed by the Director-General.

(5) The Director-General may, by general or special order, delegate any of the powers and functions to staff appointed under sub-section (3).

(6) For assisting the Federal Agency in the discharge of its functions the Federal Government shall establish Advisory Committees for various sectors and appoint as members thereof eminent representatives of the relevant sector, educational institutions, research institutes and non-governmental organizations.

6. Functions of the Federal Agency.—(1) The Federal Agency shall—

(a) administer and implement this Act and the rules and regulations made;

(b) prepare, in co-ordination with the appropriate Government Agency and in consultation with the concerned sectoral Advisory Committees, national environmental policies for approval by the Council;

(c) take all necessary measures for the implementation of the national environmental policies approved by the Council;

ANNEX II

(d) prepare and publish an annual National Environment Report on the state of the environment;

(e) prepare, establish and revise the National Environmental Quality Standards with approval of the Council:

Provided that before seeking approval of the Council, the Federal Agency shall publish the proposed National Environmental Quality Standards for public opinion in accordance with the prescribed procedure; and

(f) ensure enforcement of the National Environmental Quality Standards;

(g) establish standards for the quality of the ambient air, water and land, by notification in the official Gazette in consultation with the Provincial Agency concerned:

Provided that—

(i) different standards for discharge or emission from different sources and for different areas and conditions may be specified;

(ii) where standards are less stringent than the National Environmental Quality Standards prior approval of the Council shall be obtained;

(iii) certain areas, with the approval of the Council, may exclude from carrying out specific activities, projects from the application of such standards;

(h) co-ordinate environmental policies and programmes nationally and internationally;

(i) establish systems and procedures for surveys, surveillance, monitoring, measurement, examination, investigation, research, inspection and audit to prevent and control pollution, and to estimate the costs of cleaning up pollution and rehabilitating the environment in various sectors;

(j) take measures to promote research and the development of science and technology which may contribute to the prevention of pollution, protection of the environment, and sustainable development;

(k) certify one or more laboratories as approved laboratories for conducting tests and analysis and one or more research institutes as environmental research institutes for conducting research and investigation for the purposes of this Act

(l) identify the needs for and initiate legislation in various sectors of the environment;

ANNEX II

(m) render advice and assistance in environmental matters including such information and data available with it as may be required for carrying out the purposes of this Act:

Provided that the disclosure of such information shall be subject to the restrictions contained in the proviso to sub-section (3) of section 12;

(n) assist the local councils, local authorities, Government Agencies and other persons to implement schemes for the proper disposal of wastes so as to ensure compliance with the standards established by it;

(o) provide information and guidance to the public on environmental matters;

(p) recommend environmental courses, topics, literature and books for incorporation in the curricula and syllabi of educational institutions;

(q) promote public education and awareness of environmental issues through mass media and other means including seminars and workshops;

(r) specify safeguards for the prevention of accidents and disasters which may cause pollution, collaborate with the concerned person in the preparation of contingency plans for control of such accidents and disasters, and co-ordinate implementation of such plans;

(s) encourage the formation and working of non-governmental organizations, community organizations and village organizations to prevent and control pollution and promote sustainable development;

(t) take or cause to be taken all necessary measures for the protection, conservation, rehabilitation and improvement of the environment, prevention and control of pollution and promotion of sustainable development; and

(u) perform any function which the Council may assign to it.

(2) The Federal Agency may—

(a) undertake inquiries or investigation into environmental issues, either of its own accord or upon complaint from any person or organization;

(b) request any person to furnish any information or data relevant to its functions;

(c) initiate with the approval of the Federal Government, requests for foreign assistance in support of the purposes of this Act and enter into arrangements with foreign agencies or organizations for the exchange of material or information and participate in international seminars or meetings;

ANNEX II

(d) recommend to the Federal Government the adoption of financial and fiscal programmes, schemes or measures for achieving environmental objectives and goals and the purposes of this Act, including—

(i) incentives, prizes awards, subsidies, tax exemptions, rebates and depreciation allowances; and

(ii) taxes, duties, cesses and other levies;

(e) establish and maintain laboratories to help in the performance of its functions under this Act and to conduct research in various aspects of the environment and provide or arrange necessary assistance for establishment of similar laboratories in the private sector; and

(f) provide or arrange, in accordance with such procedure as may be prescribed, financial assistance for projects designed to facilitate the discharge of its functions.

7. Powers of the Federal Agency.—Subject to the provisions of this Act, the Federal Agency may—

(a) lease, purchase, acquire, own, hold, improve, use or otherwise deal in and with any property both moveable and immovable;

(b) sell, convey, mortgage, pledge, exchange or otherwise dispose of its property and assets;

(c) fix and realize fees, rates and charges for rendering any service or providing any facility, information or data under this Act or the rules and regulations;

(d) enter into contracts, execute instruments, incur liabilities and do all acts or things necessary for proper management and conduct of its business;

(e) appoint with the approval of the Federal Government and in accordance with such procedures as may be prescribed, such advisers, experts and consultants as it considers necessary for the efficient performance of its functions on such terms and conditions as it may deem fit;

(f) summon and enforce the attendance of any person and require him to supply any information or document needed for the conduct of any enquiry or investigation into any environmental issue;

(g) enter and inspect and under the authority of a search warrant issued by the Environmental Court or Environmental Magistrate, search at any reasonable time, any land, building, premises, vehicle or vessel or other place where or in which there are reasonable grounds to believe that an offence under this Act has been, or is being, committed;

Annex II

(h) take samples of any materials, products, articles or substances or of the effluent, wastes or air pollutants being discharged or emitted or of air, water or land in the vicinity of the discharge or emission;

(i) arrange for test and analysis of the samples at a certified laboratory;

(j) confiscate any article used in the commission of the offence where the offender is not known or cannot be found within a reasonable time:

Provided that the power under clauses (f), (h), (I) and (j) shall be exercised in accordance with the provisions of the Code of Criminal Procedure, 1898 (Act V of 1898), or the rules made under this Act and under the direction of the Environmental Court or Environmental Magistrate; and

(k) establish a National Environmental Co-ordination Committee comprising the Director-General as its chairman and the Director Generals of the Provincial Environmental Protection Agencies and such other persons as the Federal Government may appoint as its members to exercise such powers and perform such functions as may be delegated or assigned to it by the Federal Government for carrying out the purposes of this Act and for ensuring inter provincial co-ordination in environmental policies.

8. Establishment, powers and functions of the Provincial Environmental Protection Agencies.—(1) Every Provincial Government shall, by notification in the official Gazette, establish an Environmental Protection Agency, to exercise such powers and perform such functions as may be delegated to it by the Provincial Government under sub-section (2) of section 26.

(2) The Provincial Agency shall be headed by a Director-General who shall be appointed by the Provincial Government on such terms and conditions as it may determine.

(3) The Provincial Agency shall have such administrative, technical and legal staff as the Provincial Government may specify, to be appointed in accordance with such procedure as may be prescribed.

(4) The powers and functions of the Provincial Agency shall be exercised and performed by the Director-General.

(5) The Director General may, by general or special order, delegate any of the powers and functions to staff appointed under sub-section (3).

(6) For assistance of the Provincial Agency in the discharge of its functions, the Provincial Government shall establish Sectoral Advisory Committees for various sectors and appoint members from amongst eminent representatives of the relevant sector, educational institutions, research institutes and non-governmental organizations.

ANNEX II

9. Establishment of the Provincial Sustainable Development Funds.— (1) There shall be established in each Province a Sustainable Development Fund.

(2) The Provincial Sustainable Development Fund shall be derived from the following sources, namely:—

(a) grants made or loans advanced by the Federal Government or the Provincial Governments;

(b) aid and assistance, grants, advances, donations and other non-obligatory funds received from foreign governments, national or international agencies, and non-governmental organizations; and

(c) contributions from private organizations and other persons.

(3) The Provincial Sustainable Development Fund shall be utilized in accordance with such procedure as may be prescribed for—

(a) providing financial assistance to the projects designed for the protection, conservation, rehabilitation and improvement of the environment, the prevention and control of pollution, the sustainable development of resources and for research in any aspect of environment; and

(b) any other purpose which in the opinion of the Board shall help achieve environmental objectives and the purposes of this Act.

10. Management of the Provincial Sustainable Development Fund.—(1) The Provincial Sustainable Development Fund shall be managed by a Board known as the Provincial Sustainable Development Fund Board consisting of—

(i) Chairman, Planning and Development Board/Additional Chief Secretary Planning and Development Department	Chairperson
(ii) such officers of the Provincial Governments, not exc-- eeding six, as the Provincial Government may appoint including Secretaries incharge of the Finance, Industries and Environment Departments	Members
(iii) such non-official persons not exceeding ten as the Prov- incial Government may appoint including representatives of the Provincial Chamber of Commerce and Industry, non governmental organizations, and major donors.	Members
(iv) Director-General of the Provincial Agency	Member/Secretary

ANNEX II

(2) In accordance with such procedure and such criteria as may be prescribed, the Board shall have the power to—

(a) sanction financial assistance for eligible projects;

(b) invest moneys held in the Provincial Sustainable Development Fund in such profit - bearing Government bonds, savings schemes and securities as it may deem suitable; and

(c) take such measures and exercise such powers as may be necessary for utilization of the Provincial Sustainable Development Fund for the purposes specified in sub-section (3) of section 9.

(3) The Board shall constitute committees of its members to undertake regular monitoring of projects financed from the Provincial Sustainable Development Fund and to submit progress reports to the Board which shall publish an Annual Report incorporating its annual audited accounts and performance evaluation based on the progress reports.

11. Prohibition of certain discharges or emissions.—(1) Subject to the provisions of this Act and the rules and regulations no person shall discharge or emit or allow the discharge or emission of any effluent or waste or air pollutant or noise in an amount, concentration or level which is in excess of the National Environmental Quality Standards or, where applicable, the standards established under sub-clause (I) of clause (g) of sub-section (1) of section 6.

(2) The Federal Government may levy a pollution charge on any person who contravenes or fails to comply with the provisions of sub-section (1), to be calculated at such rate, and collected in accordance with such procedure as may be prescribed.

(3) Any person who pays the pollution charge levied under sub-section (2) shall not be charged with an offence with respect to that contravention or failure.

(4) The provisions of sub-section (3) shall not apply to projects which commenced industrial activity on or after the thirtieth day of June, 1994.

12. Initial environmental examination and environmental impact assessment.—(1) No proponent of a project shall commence construction or operation unless he has filed with the Government Agency designated by Federal Environmental Protection Agency or Provincial Environmental Protection Agencies, as the case may be, or, where the project is likely to cause an adverse environmental effects an environmental impact assessment, and has obtained from the Government Agency approval in respect thereof.

(2) The Government Agency shall subject to standards fixed by the Federal Environmental Protection Agency—

ANNEX II

(a) review the initial environmental examination and accord its approval, or require submission of an environmental impact assessment by the proponent; or

(b) review the environmental impact assessment and accord its approval subject to such conditions as it may deem fit to impose, require that the environmental impact assessment be re-submitted after such modifications as may be stipulated or reject the project as being contrary to environmental objectives.

(3) Every review of an environmental impact assessment shall be carried out with public participation and no information will be disclosed during the course of such public participation which relates to—

(i) trade, manufacturing or business activities, processes or techniques of a proprietary nature, or financial, commercial, scientific or technical matters which the proponent has requested should remain confidential, unless for reasons to be recorded in writing, the Director General of the Federal Agency is of the opinion that the request for confidentiality is not well-founded or the public interest in the disclosure outweighs the possible prejudice to the competitive position of the project or its proponent; or

(ii) international relations, national security or maintenance of law and order, except with the consent of the Federal Government; or

(iii) matters covered by legal professional privilege.

(4) The Government Agency shall communicate its approval or otherwise within a period of four months from the date the initial environmental examination or environmental impact assessment is filed complete in all respects in accordance with the prescribed procedure, failing which the initial environmental examination or, as the case may be, the environmental impact assessment shall be deemed to have been approved, to the extent to which it does not contravene the provisions of this Act and the rules and regulations.

(5) Subject to sub-section (4) the appropriate Government may in a particular case extend the aforementioned period of four months if the nature of the project so warrants.

(6) The provisions of sub-sections (1), (2), (3), (4) and (5) shall apply to such categories of projects and in such manner as may be prescribed.

(7) The Government Agency shall maintain separate registers for initial environmental examination and environmental impact assessment projects, which shall contain brief particulars of each project and a summary of decisions taken thereon, and which shall be open to inspection by the public at all reasonable hours and the disclosure of information in such registers shall be subject to the restrictions specified in sub-section (3).

ANNEX II

13. Prohibition of import of hazardous waste.—No person shall import hazardous waste into Pakistan and its territorial waters, Exclusive economic Zone and historic waters.

14. Handling of hazardous substances.—Subject to the provisions of this Act, no person shall generate, collect, consign, transport, treat, dispose of, store, handle or import any hazardous substance except—

(a) under a licence issued by the Federal Agency and in such manner as may be prescribed; or

(b) in accordance with the provisions of any other law for the time being in force, or of any international treaty, convention, protocol, code, standard, agreement or other instrument to which Pakistan is a party.

15. Regulation of motor vehicles.---(l) Subject to the provisions of this Act, and the rules and regulations, no person shall operate a motor vehicle from which air pollutants or noise are being emitted in an amount, concentration or level which is in excess of the National Environmental Quality Standards, or where applicable the standards established under clause (g) of sub-section (l) of section 6.

(2) For ensuring compliance with the standards mentioned in sub-section (1), the Federal Agency may direct that any motor vehicle or class of vehicles shall install such pollution control devices or other equipment or use such fuels or undergo such maintenance or testing as may be prescribed.

(3) Where a direction has been issued by the Government Agency under subsection (2) in respect of any motor vehicles or class of motor vehicles, no person shall operate any such vehicle till such direction has been complied with.

16. Environmental protection order.---(1) Where the Federal Agency or a Provincial Agency is satisfied that the discharge or emission of any effluent, waste, air pollutant or noise, or the disposal of waste, or the handling of hazardous substances, or any other act or omission is likely to occur, or is occurring, or has occurred, in violation of the provisions of this Act, rules or regulations or of the conditions of a licence, and is likely to cause, or is causing or has caused an adverse environmental effect, the Federal Agency or, as the case may be, the Provincial Agency may, after giving the person responsible for such discharge, emission, disposal, handling, act or omission an opportunity of being heard, by order direct such person to take such measures that the Federal Agency or Provincial Agency may consider necessary within such period as may be specified in the order.

(2) In particular and without prejudice to the generality of the foregoing power, such measures may include—

ANNEX II

(a) immediate stoppage, preventing, lessening or controlling the discharge, emission, disposal, handling, act or omission, or to minimize or remedy the adverse environmental effect;

(b) installation, replacement or alteration of any equipment or thing to eliminate, control or abate on a permanent or temporary basis, such discharge, emission, disposal, handling, act or omission;

(c) action to remove or otherwise dispose of the effluent, waste, air pollutant, noise, or hazardous substances; and

(d) action to restore the environment to the condition existing prior to such discharge, disposal, handling, act or omission, or as close to such condition as may be reasonable in the circumstances, to the satisfaction of the Federal Agency or, Provincial Agency.

(3) Where the person, to whom directions under sub-section (1) are given, does not comply therewith, the Federal Agency or Provincial Agency may, in addition to the proceedings initiated against him under this Act, the rules and regulations, itself take or cause to be taken such measures specified in the order as it may deem necessary and may recover the reasonable costs of taking such measures from such person as arrears of land revenue.

17. Penalties.—(1) Whoever contravenes or fails to comply with the provisions of sections 11, 12, 13 or section 16 or any order issued thereunder shall be punishable with fine which may extend to one million rupees, and in the case of a continuing contravention or failure, with an additional fine which may extend to one hundred thousand rupees for every day during which such contravention or failure continues:

Provided that if contravention of the provisions of section 11 also constitutes contravention of the provisions of section 15, such contravention shall be punishable under sub-section (2) only.

(2) Whoever contravenes or fails to comply with the provisions of section 14 or 15 or any rule or regulation or conditions of any licence, any order or direction, issued by the Council or the Federal Agency or Provincial Agency, shall be punishable with fine which may extend to one hundred thousand rupees, and in case of continuing contravention or failure with an additional fine which extend to one thousand rupees for every day during which such contravention continues.

(3) Where an accused has been convicted of an offence under sub-sections (1) and (2), the Environmental Court and Environmental Magistrate, as the case may be, shall, in passing sentence, take into account the extent and duration of the contravention or failure constituting the offence and the attendant circumstances.

(4) Where an accused has been convicted of an offence under sub-section (1) and the Environmental Court is satisfied that as a result of the commission of the offence

Annex II

monetary benefits have accrued to the offender, the Environmental Court may order the offender to pay, in addition to the fines under sub-section (1), further additional fine commensurate with the amount of the monetary benefits.

(5) Where a person convicted under sub-sections (1) or sub-section (2) had been previously convicted for any contravention under this Act, the Environmental Court or, as the case may be, Environmental Magistrate may, in addition to the punishment awarded thereunder—

(a) endorse a copy of the order of conviction to the concerned trade or industrial association, if any, or the concerned Provincial Chamber of Commerce and Industry or the Federation of Pakistan Chambers of Commerce and Industry;

(b) sentence him to imprisonment for a term which may extend to two years;

(c) order the closure of the factory;

(d) order confiscation of the factory, machinery, and equipment, vehicle, material or substance, record or document or other object used or involved in contravention of the provisions of the Act:

Provided that for a period of three years from the date of commencement of this Act the sentence of imprisonment shall be passed only in respect of persons who have been previously convicted for more than once for any contravention of sections 11, 13, 14 or 16 involving hazardous waste;

(e) order such person to restore the environment at his own cost, to the conditions existing prior to such contravention or as close to such conditions as may be reasonable in the circumstances to the satisfaction of the Federal Agency or, as the case may be, Provincial Agency; and

(f) order that such sum be paid to any person as compensation for any loss, bodily injury, damage to his health or property suffered by such contravention.

(6) The Director-General of the Federal Agency or of a Provincial Agency or an officer generally or specially authorised by him in this behalf may, on the application of the accused compound an offence under this Act with the permission of the Environmental Tribunals or Environmental Magistrate in accordance with such procedure as may be prescribed.

(7) Where the Director-General of the Federal Agency or of a Provincial Agency is of the opinion that a person has contravened any provision of Act he may, subject to the rules, by notice in writing to that person require him to pay to the Federal Agency or, as the case may be, Provincial Agency an administrative penalty in the amount set out in the notice for each day the contravention continues; and a person who pays an administrative

Annex II

penalty for a contravention shall not be charged under this Act with an offence in respect of such contravention.

(8) The provisions of sub-sections (6) and (7) shall not apply to a person who has been previously convicted of offence or who has compounded an offence under this Act who has paid an administrative penalty for a contravention of any provision of this Act.

18. Offences by bodies corporate.— Where any contravention of this Act has been committed by a body corporate, and it is proved that such offence has been committed with the consent or connivance of, or is attributed to any negligence on the part of, any director, partner, manager, secretary or other Officer of the body corporate, such director, partner, manager, secretary or other officer of the body corporate, shall be deemed guilty of such contravention along with the body corporate and shall be punished accordingly:

Provided that in the case of a company as defined under the Companies Ordinance, 1984 (XLVII of 1984), only the Chief Executive as defined in the said Ordinance shall be liable under this section.

Explanation.— For the purposes of this section, "body corporate" includes a firm, association of persons and a society registered under the Societies Registration Act, 1860 (XXI of 1860), or under the Co-operative Societies Act, 1925 (VII of 1925).

19. Offences by Government Agencies, local authorities or local councils.—Where any contravention of this Act has been committed by any Government Agency, local authority or local council, and it is proved that such contravention has been committed with the consent or connivance of, or is attributable to any negligence on the part of, the Head or any other officer of the Government Agency, local authority or local council, such Head or other officer shall also be deemed guilty of such contravention along with the Government Agency, local authority or local council and shall be liable to be proceeded against and punished accordingly.

20. Environmental Tribunals.—(1) The Federal Government may, by notification in the official gazette, establish as many Environmental Tribunals as it consider necessary and, where it establishes more than one Environmental Tribunals, it shall specify territorial limits within which, or the class of cases in respect of which, each one of them shall exercise jurisdiction under this Act.

(2) An Environmental Tribunal shall consist of a Chairperson who is, or has been, or is qualified for appointment as, a judge of the High Court to be appointed after consultation with the Chief Justice of the High Court and two members to be appointed by the Federal Government of which at least one shall be a technical member with suitable professional qualifications and experience; in the environmental field as may be prescribed.

ANNEX II

(3) For every sitting of the Environ mental Tribunal, the presence of the Chairperson and not less than one Member shall be necessary.

(4) A decision of an Environmental Tribunal shall be expressed in terms of the opinion of the majority of its members, including :the Chairperson, or if the case has been decided by the Chairperson and only one of the members and a there is a difference of opinion between them, the ;decision of the Environmental Tribunal shall be expressed in terms of the opinion of the Chairperson.

(5) An environmental Tribunal shall not, merely be reason of a change in its composition, or the absence of any member from any sitting, be bound to recall and rehear any witness who has given evidence, and may act on the evidence already ;recorded by, or produced, before it.

(6) An Environmental Tribunal may hold its sittings at such places within its territorial jurisdiction as the Chairperson may decide.

(7) No act or proceeding of an Environmental Tribunal shall be invalid by reason only of the existence of a a vacancy in, or defect in the constitution, of, the Environmental Tribunal.

(8) The terms and conditions of service of the Chairperson and members of the Environmental Tribunal shall be such as may be prescribed.

21. Jurisdiction and powers of Environmental Tribunals.—(1) An Environmental Tribunal shall exercise such powers and perform such functions as are, or may be, conferred upon or assigned to it by or under this Act or the rules and regulations made thereunder.

(2) All contravention punishable under sub-section (1) of section 17 shall exclusively be triable by an Environmental Tribunal.

(3) An Environmental Tribunal shall not take cognizance of any offence triable under sub-section (2) except on a complaint in writing by--

(a) the Federal Agency or any Government Agency or local council; and

(b) any aggrieved person, who has given notice of not less than thirty days to the Federal Agency, or the Provincial Agency concerned, of the alleged contravention and of his intention to make a complaint to the Environment Tribunal.

(4) In exercise of its criminal jurisdiction, the Environmental Tribunals shall have the same powers as are vested in Court of Session under the Code of Criminal Procedure, 1898 (Act V of 1898).

ANNEX II

(5) In exercise of the appellate jurisdiction under section 22 the Environmental Tribunals shall have the same powers and shall follow the same procedure as an appellate court in the Code of Civil Procedure, 1908 (Act V of 1908).

(6) In all matters with respect to which no procedure has been provided for in this Act, the Environmental Tribunal shall follow the procedure laid down in the Code of Civil Procedure, 1908 (Act V of 1908).

(7) An Environmental Tribunal may, on application filed by any officer duly authorised in this behalf by the Director-General of the Federal Agency or of Provincial Agency, issue bailable warrant for the arrest of any person against whom reasonable suspicion exist, of his having been involved in contravention punishable under sub-section (1) of Section 17:

Provided that such warrant shall be applied for, issued, and executed in accordance with the provisions of the Code of Criminal Procedure, 1898 (Act V of 1898):

Provided further that if the person arrested executes a bond with sufficient sureties in accordance with the endorsement on the warrant he shall be released from custody, failing which he shall be taken or sent without delay to the officer in-charge of the nearest police station.

(8) All proceedings before the Environmental Tribunal shall be deemed to be judicial proceedings within the meaning of section 193 and 228 of the Pakistan Penal Code (Act XLV of 1860), and the Environ mental Tribbunal shall be deemed to be a court for the purpose of section 480 and 482 of the Code of Criminal Procedure, 1898 (Act V of 1898).

(9) No court other than an Environmental Trib unal shall have or exercise any jurisdiction with respect to any matter to which the jurisdiction of an Environmental Tribunal extends under this Act, the rules and regulations made thereunder.

(10) Where the Environmental Tribunal is satisfied that a complaint made to it under sub-section (3) is false and vexatious to the knowledge of the complainant, it may, by an order, direct the complainant to pay to the person complained against such compensatory costs which may extend to one hundred thousand rupees.

22. Appeals to the Environmental Tribunal.—(1) Any person aggrieved by any order or direction of the Federal Agency or any Provincial Agency under any provision of this Act, and rules or regulations may prefer an appeal with the Environmental Tribunal within thirty days of the date of communication of the impugned order or direction to such person.

(2) An appeal to the Environmental Tribunal shall be in such form, contain such particulars and be accompanied by such fees as may be prescribed.

ANNEX II

23. Appeals from orders of the Environmental Tribunal.---(I) Any person aggrieved by any final order or by any sentence of the Environmental Tribunal passed under this Act may, within thirty days of communication of such order or sentence, prefer an appeal to the High Court.

(2) An appeal under sub-section (I) shall be heard by a Bench of not less than two Judges.

24. Jurisdiction of Environmental Magistrates.—(I) Notwithstanding anything contained in the Code of Criminal Procedure, 1898 (Act V of 1898), or any other law for the time being in force, but subject to the provisions of this Act, all contravention punishable under sub-section (2) of section 17 shall exclusively be triable by a judicial Magistrate of the first class as Environmental Magistrate especially empowered in this behalf by the High Court.

(2) An Environmental Magistrate shall be competent to impose any punishment specified in sub-sections (2) and (4) of section 17.

(3) An Environmental Magistrate shall not take cognizance of an offence triable under sub-section (I) except on a complaint in writing by—

(a) the Federal Agency, Provincial Agency, or Government Agency or a local council; and

(b) any aggrieved person.

25. Appeals from orders of Environmental Magistrates.—Any person convicted of any contravention of this Act or the rules or regulations by an Environmental Magistrate may, within thirty days from the date of his conviction, appeal to the Court of Sessions whose decision thereon shall be final.

26. Power to delegate.—(1) The Federal Government may, by notification in the official Gazette, delegate any of its or of the Federal Agency's powers and functions under this Act and the rules and regulations to any Provincial Government, any Government Agency, local council or local authority.

(2) The Provincial Government may, by notification in the official Gazette, delegate any of its or of the Provincial Agency's powers or functions under this Act and the rules and regulations to any Government Agency of such Provincial Government or any local council or local authority in the Province.

27. Power to give directions.—In the performance of their functions under this Act-

(a) the Federal Agency and Provincial Agencies shall be bound by the directions given to them in writing by the Federal Government; and

ANNEX II

(b) a Provincial Agency shall be bound by the directions given to it in writing by the Provincial Government.

28. Indemnity.—No suit, prosecution or other legal proceedings shall lie against the Federal or Provincial Governments, the Council, the Federal Agency or Provincial Agencies, the Director-Generals of the Federal Agency and the Provincial Agency, members, officers, employees, experts, advisers, committees or consultants of the Federal or Provincial Agencies or the Environmental Tribunal or Environmental Magistrates or any other person for anything which is in good faith done or intended to be done under this Act or the rules or regulations made thereunder.

29. Dues recoverable as arrears of land revenue.—Any dues recoverable by the Federal Agency or Provincial Agency under this Act, or the rules or regulations shall be recoverable as arrears of land revenue.

30. Act to override other laws.—The provisions of this Act shall have effect notwithstanding anything inconsistent therewith contained in any other law for the time being in force.

31. Power to make rules.—The Federal Government may, by notification in the official Gazette, make rules for carrying out the purposes of this Act including rules for implementing the provisions of the international environmental Agreements, specified in the Schedule to this Act.

32. Power to amend the Schedule.__The Federal Government may, by notification in the official Gazette, amend the Schedule so as to add any entry thereato or modify or omit any entry therein.

33. Power to make regulations.---(1) For carrying out the purposes of this Act, the Federal Agency may, by notification in the official Gazette and with the approval of the Federal Government, make regulations not inconsistent with the provisions of this Act or the rules made thereunder.

(2) In particular and without prejudice to the generality of the foregoing power, such regulations may provide for—

(a) submission of periodical reports, data or information by any Government agency, local authority or local council in respect of environmental matters;

(b) preparation of emergency contingency plans for coping with environmental hazards and pollution caused by accidents, natural disasters and calamities;

(c) appointment of officers, advisers, experts, consultants and employees;

ANNEX II

(d) levy of fees, rates and charges in respect of services rendered, actions taken and schemes implemented;

(e) monitoring and measurement of discharges and emissions;

(f) categorization of projects to which, and the manner in which, section 12 applies;

(g) laying down of guidelines for preparation of initial environmental examination and environmental impact assessment and Development of procedures for their filing, review and approval;

(h) providing procedures for handling hazardous substances; and

(i) installation of devices in, use of fuels by, and maintenance and testing of motor vehicles for control of air and noise pollution.

34. Repeal, savings and succession.—(1) The Pakistan Environmental Protection Ordinance 1983 (XXXVII of 1983) is hereby repealed.

(2) Notwithstanding the repeal of the Pakistan Environmental Protection Ordinance, 1983 (XXVII of 1983), any rules or regulations or appointments made, orders passed, notifications issued, powers delegated, contracts entered into, proceedings commenced, rights acquired liabilities incurred, penalties, rates, fees or charges levied, things done or action taken under any provisions of that Ordinance shall, so far as they are not inconsistent with the provisions of this Act be deemed to have been made, passed, issued, delegated, entered into, commenced, acquired, incurred, levied, done or taken under this Act.

(3) On the establishment of the Federal Agency and Provincial Agencies under this Act, all properties, assets and liabilities pertaining to the Federal Agency and Provincial Agencies established under that Ordinance shall vest in and be the properties, assets and liabilities, as the case may be, of the Federal Agency and Provincial Agency established under this Act.

ANNEX II

SCHEDULE

(See section 31)

1. International Plant Protection Convention, Rome, 1951.

2. Plant Protection Agreement for the South-East Asia and Pacific Region (as amended), Rome, 1956.

3. Agreement for the Establishment of a Commission for Controlling the Desert Locust in the Eastern Region of its Distribution Area in South-West Asia (as amended), Rome, 1963.

4. Convention on Wetlands of International Importance Especially as Waterfowl Habitat, Ramsar, 1971 and its amending Protocol, Paris, 1982.

5. Convention Concerning the Protection of World Cultural and Natural Heritage (World Heritage Convention), 1972.

6. Convention on International Trade in Endangered Species of Wild Funa and Flora (CITES), Washington, 1973.

7. Convention on the Conservation of Migratory Species of Wild Animals, Bonn, 1979.

8. Convention on the Law of the Sea, Montego Bay, 1982.

9. Vienna Convention for the Protection of the Ozone Layer, Vienna, 1985.

10. Montreal Protocol on Substances that Deplete the Ozone Layer, Montreal, 1987 and amendments thereto.

11. Agreement on the Network of Agriculture Centres in Asia and the Pacific, Bangkok, 1988.

12. Convention on the Control of Transboundary Movements of Hazardous Waste and Their Disposal, Basel, 1989.

13. Convention on Biological Diversity, Rio de Janeiro, 1992.

14. United Nations Framework Convention on Climate Change, Rio De Janeiro, 1992.

ANNEX – III

(PEPA REVIEW OF IEE/EIA REGULATIONS 2000)

ANNEX III

PAKISTAN ENVIRONMENTAL PROTECTION AGENCY (REVIEW OF IEE AND EIA) REGULATIONS, 2000

S.R.O. 339 (1)/2001. - In exercise of the powers referred by section 33 of the Pakistan Environmental Protection Act, 1997 (XXXIV of 1997), Pakistan Environmental Protection Agency, with the approval of the Federal Government is pleased to make the following Rules, namely : -

1. Short title and commencement

(1) These regulations may be called the Pakistan Environmental Protection Agency Review of Initial Environmental Examination and Environmental Impact Assessment Regulations, 2000.

(2) They shall come into force at once.

2. Definitions

(1) In these regulations, unless there is anything repugnant in the subject or context –

(a) "Act" means the Pakistan Environmental Protection Act, 1997 (XXXIV of 1997);

(b) "Director-General" means the Director-General of the Federal Agency;

(c) "EIA" means an environmental impact assessment as defined in section 2(xi);

(d) "IEE" means an initial environmental examination as defined in section 2(xxiv); and

(e) "section" means a section of the Act.

(2) All other words and expressions used in these regulations but not defined shall have the same meanings as are assigned to them in the Act.

3. Projects requiring an IEE

A proponent of a project falling in any category listed in Schedule I shall file an IEE with the Federal Agency, and the provisions of section 12 shall apply to such project.

4. Projects requiring an EIA

A proponent of a project falling in any category listed in Schedule II shall file an EIA with the Federal Agency, and the provisions of section 12 shall apply to such project.

ANNEX III

5. Projects not requiring an IEE or EIA

(1) A proponent of a project not falling in any category listed in Schedules I and II shall not be required to file an IEE or EIA:

Provided that the proponent shall file –

(a) an EIA, if the project is likely to cause an adverse environmental effect;

(b) for projects not listed in Schedules I and II in respect of which the Federal Agency has issued guidelines for construction and operation, an application for approval accompanied by an undertaking and an affidavit that the aforesaid guidelines shall be fully complied with.

(2) Notwithstanding anything contained in sub-regulation (1), the Federal Agency may direct the proponent of a project, whether or not listed in Schedule I or II, to file an IEE or EIA, for reasons to be recorded in such direction:

Provided that no such direction shall be issued without the recommendation in writing of the Environmental Assessment Advisory Committee constituted under Regulation 23.

(3) The provisions of section 12 shall apply to a project in respect of which an IEE or EIA is filed under sub-regulation (1) or (2).

6. Preparation of IEE and EIA

(1) The Federal Agency may issue guidelines for preparation of an IEE or an EIA, including guidelines of general applicability, and sectoral guidelines indicating specific assessment requirements for planning, construction and operation of projects relating to particular sector.

(2) Where guidelines have been issued under sub-regulation (1), an IEE or EIA shall be prepared, to the extent practicable, in accordance therewith and the proponent shall justify in the IEE or EIA any departure therefrom.

7. Review Fees

The proponent shall pay, at the time of submission of an IEE or EIA, a non-refundable Review Fee to the Federal Agency, as per rates shown in Schedule III.

8. Filing of IEE and EIA

(1) Ten paper copies and two electronic copies of an IEE or EIA shall be filed with the Federal Agency.

ANNEX III

(2) Every IEE and EIA shall be accompanied by –

(a) an application, in the form prescribed in Schedule IV; and

(b) copy of receipt showing payment of the Review Fee.

9. Preliminary scrutiny

(1) Within 10 working days of filing of the IEE or EIA, the Federal Agency shall –

(a) confirm that the IEE or EIA is complete for purposes of initiation of the review process; or

(b) require the proponent to submit such additional information as may be specified; or

(c) return the IEE or EIA to the proponent for revision, clearly listing the points requiring further study and discussion.

(2) Nothing in sub-regulation (1) shall prohibit the Federal Agency from requiring the proponent to submit additional information at any stage during the review process.

10. Public participation

(1) In the case of an EIA, the Federal Agency shall, simultaneously with issue of confirmation of completeness under clause (a) of sub-regulation (1) of Regulation 9, cause to be published in any English or Urdu national newspaper and in a local newspaper of general circulation in the area affected by the project, a public notice mentioning the type of project, its exact location, the name and address of the proponent and the places at which the EIA of the project can, subject to the restrictions in sub-section (3) of section 12, be accessed.

(2) The notice issued under sub-regulation (1) shall fix a date, time and place for public hearing of any comments on the project or its EIA.

(3) The date fixed under sub-regulation (2) shall not be earlier than 30 days from the date of publication of the notice.

(4) The Federal Agency shall also ensure the circulation of the EIA to the concerned Government Agencies and solicit their comments thereon.

(5) All comments received by the Federal Agency from the public or any Government Agency shall be collated, tabulated and duly considered by it before decision on the EIA.

ANNEX III

(6) The Federal Agency may issue guidelines indicating the basic techniques and measures to be adopted to ensure effective public consultation, involvement and participation in EIA assessment.

11. Review

(1) The Federal Agency shall make every effort to carry out its review of the IEE within 45 days, and of the EIA within 90 days, of issue of confirmation of completeness under Regulation 9.

(2) In reviewing the IEE or EIA, the Federal Agency shall consult such Committee of Experts as may be constituted for the purpose by the Director-General, and may also solicit views of the sectoral Advisory Committee, if any, constituted by the Federal Government under sub-section (6) of section 5.

(3) The Director-General may, where he considers it necessary, constitute a committee to inspect the site of the project and submit its report on such matters as may be specified.

(4) The review of the IEE or EIA by the Federal Agency shall be based on quantitative and qualitative assessment of the documents and data furnished by the proponent, comments from the public and Government Agencies received under Regulation 10, and views of the committees mentioned in sub-regulations (2) and (3) above.

12. Decision

On completion of the review, the decision of the Federal Agency shall be communicated to the proponent in the form prescribed in Schedule V in the case of an IEE, and in the form prescribed in Schedule VI in the case of an EIA.

13. Conditions of approval

(1) Every approval of an IEE or EIA shall, in addition to such conditions as may be imposed by the Federal Agency, be subject to the condition that the project shall be designed and constructed, and mitigatory and other measures adopted, strictly in accordance with the IEE/EIA, unless any variation thereto have been specified in the approval by the Federal Agency.

(2) Where the Federal Agency accords its approval subject to certain conditions, the proponent shall –

(a) before commencing construction of the project, acknowledge acceptance of the stipulated conditions by executing an undertaking in the form prescribed in Schedule VII;

ANNEX III

(b) before commencing operation of the project, obtain from the Federal Agency written confirmation that the conditions of approval, and the requirements in the IEE/EIA relating to design and construction, adoption of mitigatory and other measures and other relevant matters, have been duly complied with.

14. Confirmation of compliance

(1) The request for confirmation of compliance under clause (b) of sub-regulation (2) of Regulation 13 shall be accompanied by an Environmental Management Plan indicating the measures and procedures proposed to be taken to manage or mitigate the environmental impacts for the life of the project, including provisions for monitoring, reporting and auditing.

(2) Where a request for confirmation of compliance is received from a proponent, the Federal Agency may carry out such inspection of the site and plant and machinery and seek such additional information from the proponent as it may deem fit:

Provided that every effort shall be made by the Federal Agency to provide the requisite confirmation or otherwise within 15 days of receipt of the request, with complete information, from the proponent.

(3) The Federal Agency may, while issuing the requisite confirmation of compliance, impose such other conditions as the Environmental Management Plan, and the operation, maintenance and monitoring of the project as it may deem fit, and such conditions shall be deemed to be included in the conditions to which approval of the project is subject.

15. Deemed approval

The four-month period for communication of decision stipulated in sub-section (4) of section 12 shall commence from the date of filing of an IEE or EIA in respect of which confirmation of completeness is issued by the Federal Agency under clause (a) of sub-regulation (1) of Regulation 9.

16. Extension in review period

Where the Federal Government in a particular case extends the four-month period for communication of approval prescribed in sub-section (5) of section 12, it shall, in consultation with the Federal Agency, indicate the various steps of the review process to be taken during the extended period, and the estimated time required for each step.

17. Validity period of approval

(1) The approval accorded by a Federal Agency under section 12 read with Regulation 12 shall be valid, for commencement of construction, for a period of three years from the date of issue.

ANNEX III

(2) If construction is commenced during the initial three year validity period, the validity of the approval shall stand extended for a further period of three years from the date of issue.

(3) After issue of confirmation of compliance, the approval shall be valid for a period of three years from the date thereof.

(4) The proponent may apply to the Federal Agency for extension in the validity periods mentioned in sub-regulations (1), (2) and (3), which may be granted by the Federal Agency in its discretion for such period not exceeding three years at a time, if the conditions of the approval do not require significant change:

Provided that the Federal Agency may require the proponent to submit a fresh IEE or EIA, if in its opinion changes in location, design, construction and operation of the project so warrant.

18. Entry and inspection

(1) For purposes of verification of any matter relating to the review or to the conditions of approval of an IEE or EIA prior to, during or after commencement of construction or operation of a project, duly authorized staff of the Federal Agency shall be entitled to enter and inspect the project site, factory building and plant and equipment installed therein.

(2) The proponent shall ensure full cooperation of the project staff at site to facilitate the inspection, and shall provide such information as may be required by the Federal Agency for this purpose and pursuant thereto.

19. Monitoring

(1) After issue of approval, the proponent shall submit a report to the Federal Agency on completion of construction of the project.

(2) After issue of confirmation of compliance, the proponent shall submit an annual report summarizing operational performance of the project, with reference to the conditions of approval and maintenance and mitigatory measures adopted by the project.

(3) To enable the Federal Agency to effectively monitor compliance with the conditions of approval, the proponent shall furnish such additional information as the Federal Agency may require.

20. Cancellation of approval

(1) Notwithstanding anything contained in these Regulations, if, at any time, on the basis of information or report received or inspection carried out, the Federal Agency is of the opinion that the conditions of an approval have not been complied with, or that the information supplied by a proponent in the approved IEE or EIA is incorrect, it

ANNEX III

shall issue notice to the proponent to show cause, within two weeks of receipt thereof, why the approval should not be cancelled.

(2) If no reply is received or if the reply is considered unsatisfactory, the Federal Agency may, after giving the proponent an opportunity of being heard:

(i) require the proponent to take such measures and to comply with such conditions within such period as it may specify, failing which the approval shall stand cancelled; or

(ii) cancel the approval.

(3) On cancellation of the approval, the proponent shall cease construction or operation of the project forthwith.

(4) Action taken under this Regulation shall be without prejudice to any other action that may be taken against the proponent under the Act or rules or regulations or any other law for the time being in force.

21. Registers of IEE and EIA projects

Separate Registers to be maintained by the Federal Agency for IEE and EIA projects under sub-section (7) of section 12 shall be in the form prescribed in Schedule VIII.

22. Environmentally sensitive areas

(1) The Federal Agency may, by notification in the official Gazette, designate an area to be an environmentally sensitive area.

(2) Notwithstanding anything contained in Regulations 3, 4 and 5, the proponent of a project situated in an environmentally sensitive area shall be required to file an EIA with the Federal Agency.

(3) The Federal Agency may from time to time issue guidelines to assist proponents and other persons involved in the environmental assessment process to plan and prepare projects located in environmentally sensitive areas.

(4) Where guidelines have been issued under sub-regulation (3), the projects shall be planned and prepared, to the extent practicable, in accordance therewith and any departure therefrom justified in the EIA pertaining to the project.

23. Environmental Assessment Advisory Committee

For purposes of rendering advice on all aspects of environmental assessment, including guidelines, procedures and categorization of projects, the Director-General shall constitute an Environmental Assessment Advisory Committee comprising –

(a) Director EIA, Federal Agency ... Chairman

ANNEX III

(b)	One representative each of the Provincial Agencies	...	Members
(c)	One representative each of the Federal Planning Commission and the Provincial Planning and Development Departments	...	Members
(d)	Representatives of industry and non-Governmental organizations, and legal and other experts	...	Members

24. Other approvals

Issue of an approval under section 12 read with Regulation 12 shall not absolve the proponent of the duty to obtain any other approval or consent that may be required under any law for the time being in force.

ANNEX III

SCHEDULE I
(*See* Regulation 3)

List of projects requiring an IEE

A. Agriculture, Livestock and Fisheries

1. Poultry, livestock, stud and fish farms with total cost more than Rs.10 million
2. Projects involving repacking, formulation or warehousing of agricultural products

B. Energy

1. Hydroelectric power generation less than 50 MW
2. Thermal power generation less than 200 KW
3. Transmission lines less than 11 KV, and large distribution projects
4. Oil and gas transmission systems
5. Oil and gas extraction projects including exploration, production, gathering systems, separation and storage
6. Waste-to-energy generation projects

C. Manufacturing and processing

1. Ceramics and glass units with total cost more than Rs.50 million
2. Food processing industries including sugar mills, beverages, milk and dairy products, with total cost less than Rs.100 million
3. Man-made fibers and resin projects with total cost less than Rs.100 million
4. Manufacturing of apparel, including dyeing and printing, with total cost more than Rs.25 million
5. Wood products with total cost more than Rs.25 million

D. Mining and mineral processing

1. Commercial extraction of sand, gravel, limestone, clay, sulphur and other minerals not included in Schedule II with total cost less than Rs.100 million
2. Crushing, grinding and separation processes

ANNEX III

3. Smelting plants with total cost less than Rs.50 million

E. Transport

1. Federal or Provincial highways (except maintenance, rebuilding or reconstruction of existing metalled roads) with total cost less than Rs.50 million

2. Ports and harbor development for ships less than 500 gross tons

F. Water management, dams, irrigation and flood protection

1. Dams and reservoirs with storage volume less than 50 million cubic meters of surface area less than 8 square kilometers

2. Irrigation and drainage projects serving less than 15,000 hectares

3. Small-scale irrigation systems with total cost less than Rs.50 million

G. Water supply and treatment

Water supply schemes and treatment plants with total cost less than Rs.25 million

H. Waste disposal

Waste disposal facility for domestic or industrial wastes, with annual capacity less than 10,000 cubic meters

I. Urban development and tourism

1. Housing schemes

2. Public facilities with significant off-site impacts (e.g. hospital wastes)

3. Urban development projects

J. Other projects

Any other project for which filing of an IEE is required by the Federal Agency under sub-regulation (2) of Regulation 5

ANNEX III

SCHEDULE II
(*See* Regulation 4)

List of projects requiring an EIA

A. Energy

1. Hydroelectric power generation over 50 MW
2. Thermal power generation over 200 MW
3. Transmission lines (11 KV and above) and grid stations
4. Nuclear power plans
5. Petroleum refineries

B. Manufacturing and processing

1. Cement plants
2. Chemicals projects
3. Fertilizer plants
4. Food processing industries including sugar mills, beverages, milk and dairy products, with total cost of Rs.100 million and above
5. Industrial estates (including export processing zones)
6. Man-made fibers and resin projects with total cost of Rs.100 M and above
7. Pesticides (manufacture or formulation)
8. Petrochemicals complex
9. Synthetic resins, plastics and man-made fibers, paper and paperboard, paper pulping, plastic products, textiles (except apparel),printing and publishing, paints and dyes, oils and fats and vegetable ghee projects, with total cost more than Rs.10 million
10. Tanning and leather finishing projects

C. Mining and mineral processing

1. Mining and processing of coal, gold, copper, sulphur and precious stones
2. Mining and processing of major non-ferrous metals, iron and steel rolling
3. Smelting plants with total cost of Rs.50 million and above

ANNEX III

D. Transport

1. Airports

2. Federal or Provincial highways or major roads (except maintenance, rebuilding or reconstruction of existing roads) with total cost of Rs.50 million and above

3. Ports and harbor development for ships of 500 gross tons and above

4. Railway works

E. Water management, dams, irrigation and flood protection

1. Dams and reservoirs with storage volume of 50 million cubic meters and above or surface area of 8 square kilometers and above

2. Irrigation and drainage projects serving 15,000 hectares and above

F. Water supply and treatment

Water supply schemes and treatment plants with total cost of Rs.25 million and above

G. Waste Disposal

1. Waste disposal and/or storage of hazardous or toxic wastes (including landfill sites, incineration of hospital toxic waste)

2. Waste disposal facilities for domestic or industrial wastes, with annual capacity more than 10,000 cubic meters

H. Urban development and tourism

1. Land use studies and urban plans (large cities)

2. Large-scale tourism development projects with total cost more than Rs.50 million

I. Environmentally Sensitive Areas

All projects situated in environmentally sensitive areas

J. Other projects

1. Any other project for which filing of an EIA is required by the Federal Agency under sub-regulation (2) of Regulation 5.

2. Any other project likely to cause an adverse environmental effect

ANNEX III

SCHEDULE III
(See Regulation 7)

IEE/EIA Review Fees

Total Project Cost	IEE	EIA
Upto Rs.5,000,000	NIL	NIL
Rs.5,000,001 to 10,000,000	Rs.10,000	Rs.15,000
Greater than Rs.10,000,000	Rs.15,000	Rs.30,000

ANNEX III

PAKISTAN ENVIRONMENTAL PROTECTION AGENCY (REVIEW OF IEE AND EIA) REGULATIONS, 2000

SCHEDULE IV
[*See* Regulation 8(2)(a)]

Application Form

1.	Name and address of proponent		Phone: Fax: Telex:	
2.	Description of project			
3.	Location of project			
4.	Objectives of project			
5.	IEE/EIA attached?	IEE/EIA :	Yes/No	
6.	Have alternative sites been considered and reported in IEE/EIA?		Yes/No	
7.	Existing land use		Land requirement	
8.	Is basic site data available, or has it been measured?	(only tick yes if the data is reported in the IEE/EIA)	Available	Measured
		Meterology (including rainfall)	Yes/No	Yes/No
		Ambient air quality	Yes/No	Yes/No
		Ambient water quality	Yes/No	Yes/No
		Ground water quality	Yes/No	Yes/No
9.	Have estimates of the following been reported?		Estimated	Reported
		Water balance	Yes/No	Yes/No
		Solid waste disposal	Yes/No	Yes/No
		Liquid waste treatment	Yes/No	Yes/No
10.	Source of power		Power requirement	
11.	Labour force (number)	Construction: Operation:		

Verification. I do solemnly affirm and declare that the information given above and contained in the attached IEE/EIA is true and correct to the best of my knowledge and belief.

Date ________

Signature, name and ______
designation of proponent
(with official stamp/seal)

14

ANNEX III

SCHEDULE V
[*See* Regulation 12]

Decision on IEE

1. Name and address of proponent ______________________________
____

2. Description of project ______________________________

3. Location of project ______________________________

4. Date of filing of IEE ______________________________

5. After careful review of the IEE, the Federation Agency has decided –

(a) to accord its approval, subject to the following conditions:

____
____

or (b) that the proponent should submit an EIA of the project, for the following reasons –

____
____

[Delete (a) or (b), whichever is inapplicable]

Dated ________

Tracking no.__

Director-General
Federal Agency
(with official stamp/seal)

Annex III

SCHEDULE VI
[*See* Regulation 12]

Decision on EIA

1. Name and address of proponent ______________________
____

2. Description of project ______________________

3. Location of project ______________________

4. Date of filing of EIA ______________________

5. After careful review of the EIA, and all comments thereon, the Federation Agency has decided –

(a) to accord its approval, subject to the following conditions:

____
____

or (b) that the proponent should submit an EIA with the following modifications-

____
____

or (c) to reject the project, being contrary to environmental objectives, for the following reasons:

____
____

[Delete (a)/(b)/(c), whichever is inapplicable]

Dated ________

Tracking no.___

Director-General
Federal Agency
(with official stamp/seal)

ANNEX III

PAKISTAN ENVIRONMENTAL PROTECTION AGENCY (REVIEW OF IEE AND EIA) REGULATIONS, 2000

SCHEDULE VII
[*See* Regulation 13(2)]

Undertaking

I, (full name and address) as proponent for (name, description and location of project) do hereby solemnly affirm and declare that I fully understand and accept the conditions contained in the approval accorded by the Federal Agency bearing tracking no. _____ dated _________, and undertake to design, construct and operate the project strictly in accordance with the said conditions and the IEE/EIA.

Date _______

Signature, name and ______
designation of proponent
(with official stamp/seal)

Witnesses
(full names and addresses)

(1) _______________

(2) _______________

17

ANNEX III

SCHEDULE VIII

(*See* Regulation 21)

Form of Registers for IEE and EIA projects

S. No.	Description	Relevant Provisions
1	2	3
1.	Tracking number	
2.	Category type (as per Schedules I and II)	
3.	Name of proponent	
4.	Name and designation of contact person	
5.	Name of consultant	
6.	Description of project	
7.	Location of project	
8.	Project capital cost	
9.	Date of receipt of IEE/EIA	
10.	Date of confirmation of completeness	
11.	Approval granted (Yes/No)	
12.	Date of approval granted or refused	
13.	Conditions of approval/reasons for refusal	
14.	Date of Undertaking	
15.	Date of extension of approval validity	
16.	Period of extension	
17.	Date of commencement of construction	
18.	Date of issue of confirmation of compliance	
19.	Date of commencement of operations	
20.	Dates of filing of monitoring reports	
21.	Date of cancellation, if applicable	

ANNEX – IV

(NEQS 2010)

ANNEX IV

REGISTERED No. M - 302 / L.-7646

The Gazette of Pakistan

EXTRAORDINARY
PUBLISHED BY AUTHORITY

ISLAMABAD, FRIDAY, NOVEMBER 26, 2010

PART II

Statutory Notifications (S. R. O.)

GOVERNMENT OF PAKISTAN

MINISTRY OF ENVIRONMENT

NOTIFICATIONS

Islamabad, the 18th October, 2010

S. R. O. 1062(I)/2010.—In exercise of the powers conferred under clause (c) of sub-section (I) of section 6 of the Pakistan Environmental Protection Act, 1997 (XXXIV of 1997), the Pakistan Environmental Protection Agency, with the prior approval of the Pakistan Environmental Protection Council, is pleased to establish the following National Environmental Quality Standards for Ambient Air.

National Environmental Quality Standards for Ambient Air

Pollutants	Time-weighted average	Concentration in Ambient Air: Effective from 1st July, 2010	Concentration in Ambient Air: Effective from 1st January 2013	Method of measurement
Sulphur Dioxide (SO_2)	Annual Average* 24 hours**	80 µg/m³ 120 µg/m³	80 µg/m³ 120 µg/m³	-Ultraviolet Fluorescence method
Oxides of Nitrogen as (NO)	Annual Average* 24 hours**	40 µg/m³ 40 µg/m³	40 µg/m³ 40 µg/m³	- Gas Phase Chemiluminescence

(3205)

[2944(2010)/Ex. Gaz.] *Price: Rs. 5.00*

ANNEX IV

Pollutants	Time-weighted average	Concentration in Ambient Air: Effective from 1st July, 2010	Concentration in Ambient Air: Effective from 1st January 2013	Method of measurement
Oxides of Nitrogen as (NO_2)	Annual Average*	40 µg/m³	40 µg/m³	- Gas Phase Chemiluminescence
	24 hours**	80 µg/m³	80 µg/m³	
O^3	1 hour	180 µg/m³	130 µg/m³	-Non dispersive UV absorption method
Suspended Particulate Matter (SPM)	Annual Average*	400 µg/m³	360 µg/m³	- High Volume Sampling, (Average flow rate not less than 1.1 m3/minute).
	24 hours**	550 µg/m³	500 µg/m³	
Respirable Particulate Matter. PM_{10}	Annual Average*	200 µg/m³	120 µg/m³	-β Ray absorption method
	24 hours**	250 µg/m³	150 µg/m³	
Respirable Particulate Matter. $PM_{2.5}$	Annual Average*	25 µg/m³	15 µg/m³	-β Ray absorption method
	24 hours**	40 µg/m³	35 µg/m³	
	1 hour	25 µg/m³	15 µg/m³	
Lead Pb	Annual Average*	1.5 µg/m³	1 µg/m³	- ASS Method after sampling using EPM 2000 or equivalent Filter paper
	24 hours**	2 µg/m³	1.5 µg/m³	
Carbon Monoxide (CO)	8 hours**	5 mg/m³	5 mg/m³	- Non Dispersive Infra Red (NDIR) method
	1 hour	10 mg/m³	10 mg/m³	

*Annual arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform interval.

** 24 hourly /8 hourly values should be met 98% of the in a year. 2% of the time, it may exceed but not on two consecutive days.

S. R. O. 1063(I)/2010.— In exercise of the powers conferred under clause (c) of sub-section (1) of section 6 of the Pakistan Environmental Protection Act, 1997 (XXXIV of 1997), the Pakistan Environmental Protection Agency, with the prior approval of the Pakistan Environmental Protection Council, is pleased to establish the following National Standards for Drinking Water Quality.

ANNEX IV

National Standards for Drinking Water Quality

Properties/Parameters	Standard Values for Pakistan	Who Standards	Remarks
Bacterial			
All water intended for drinking (e.Coli or Thermotolerant Coliform bacteria)	Must not be detectable in any 100 ml sample	Must not be detectable in any 100 ml sample	Most Asian countries also follow WHO standards
Treated water entering the distribution system (E.Coli or thermo tolerant coliform and total coliform bacteria)	Must not be detectable in any 100 ml sample	Must not be detectable in any 100 ml sample	Most Asian countries also follow WHO standards
Treated water in the distribution system (E. coli or thermo tolerant coliform and total coliform bacteria)	Must not be detectable in any 100 ml sample In case of large supplies, where sufficient samples are examined, must not be present in 95% of the samples taken throughout any 12-month period.	Must not be detectable in any 100 ml sample In case of large supplies, where sufficient samples are examined, must not be present in 95% of the samples taken throughout any 12 month period.	Most Asian countries also follow WHO standards
Physical			
Colour	≤ 15 TCU	≤ 15 TCU	
Taste	Non objectionable/Acceptable	Non objectionable/Acceptable	
Odour	Non objectionable/Acceptable	Non objectionable/Acceptable	
Turbidity	< 5 NTU	< 5 NTU	
Total hardness as $CaCO_3$	< 500 mg/l	---	
TDS	< 1000	< 1000	
pH	6.5 - 8.5	6.5 - 8.5	
Chemical			
Essential Inorganic	***mg/Litre***	***mg/Litre***	
Aluminium (Al) mg/l	≤ 0.2	0.2	

ANNEX IV

Properties/Parameters	Standard Values for Pakistan	Who Standards	Remarks
Antimony (Sb)	≤ 0.005 (P)	0.02	
Arsenic (As)	≤ 0.05 (P)	0.01	Standard for Pakistan similar to most Asian developing countries
Barium (Ba)	0.7	0.7	
Boron (B)	0.3	0.3	
Cadmium (Cd)	0.01	0.003	Standard for Pakistan similar to most Asian developing countries
Chloride (Cl)	< 250	250	
Chromium (Cr)	≤ 0.05	0.05	
Copper (Cu)	2	2	
Toxic Inorganic	***mg/Litre***	***mg/Litre***	
Cyanide (CN)	≤ 0.05	0.07	Standard for Pakistan similar to Asian developing countries
Fluoride (F)*	≤ 1.5	1.5	
Lead (Pb)	≤ 0.05	0.01	Standard for Pakistan similar to most Asian developing countries
Manganese (Mn)	≤ 0.5	0.5	
Mercury (Hg)	≤ 0.001	0.001	
Nickel (Ni)	≤ 0.02	0.02	
Nitrate (NO_3)*	≤ 50	50	
Nitrite (NO_2)*	≤ 3 (P)	3	
Selenium (Se)	0.01(P)	0.01	
Residual chlorine	0.2-0.5 at consumer end 0.5-1.5 at source	—	
Zinc (Zn)	5.0	3	Standard for Pakistan similar to most Asian developing countries

* indicates priority health related inorganic constituents which need regular monitoring.

ANNEX IV

PART II] THE GAZETTE OF PAKISTAN, EXTRA., NOVEMBER 26, 2010 3209

Properties/Parameters	Standard Values for Pakistan	Who Standards	Remarks
Organic			
Pesticides mg/L		PSQCA No. 4639-2004. Page No. 4 Table No. 3 Serial No. 20- 58 may be consulted.***	Annex II
Phenolic compounds (as Phenols) mg/L		≤ 0.002	
Polynuclear aromatic hydrocarbons (as PAH) g/L		0.01 (By GC/MS method)	
Radioactive			
Alpha Emitters bq/L or pCi	0.1	0.1	
Beta emitters	1	1	

*** PSQCA: Pakistan Standards Quality Control Authority.

Proviso:

The existing drinking water treatment infrastructure is not adequate to comply with WHO guidelines. The Arsenic concentrations in South Punjab and in some parts of Sindh have been found high then Revised WHO guidelines. It will take some time to control arsenic through treatment process. Lead concentration in the proposed standards is higher than WHO Guidelines. As the piping system for supply of drinking water in urban centres are generally old and will take significant resources and time to get them replaced. In the recent past, Lead was completely phased out from petroleum products to cut down Lead entering into environment. These steps will enable to achieve WHO guidelines for Arsenic, Lead, Cadmium and Zinc. However, for bottled water, WHO limits for Arsenic, Lead, Cadmium and Zinc will be applicable and PSQCA Standards for all the remaining parameters.

S. R. O. 1064(I)/2010.—In exercise of the powers conferred under clause (c) of sub-section (1) of section 6 of the Pakistan Environmental Protection Act, 1997 (XXXIV of 1997), the Pakistan Environmental Protection Agency, with the prior approval of the Pakistan Environmental Protection Council, is pleased to establish the following National Environmental Quality Standards for Noise.

ANNEX IV

3210 THE GAZETTE OF PAKISTAN, EXTRA., NOVEMBER 26, 2010 [PART II

National Environmental Quality Standards for Noise

S. No.	Category of Area / Zone	Effective from 1st July, 2010		Effective from 1st July, 2012	
		Limit in dB(A) Leq *			
		Day Time	Night Time	Day Time	Night Time
1.	Residential area (A)	65	50	55	45
2.	Commercial area (B)	70	60	65	55
3.	Industrial area (C)	80	75	75	65
4.	Silence Zone (D)	55	45	50	45

Note: 1. Day time hours: 6.00 a. m to 10.00 p. m.

2. Night time hours: 10.00 p. m. to 6.00 a.m.

3. Silence zone: Zones which are declared as such by the competent authority. An area comprising not less than 100 meters around hospitals, educational institutions and courts.

4. Mixed categories of areas may be declared as one of the four above-mentioned categories by the competent authority.

*dB(A) Leq: Time weighted average of the level of sound in decibels on scale A which is relatable to human hearing.

[No. F. 1(12)/2010-11-General.]

MUHAMMAD KHALIL AWAN,
Section Officer (PEPC).

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ANNEX - V

(NEQS 2000)

ANNEX V

REGISTERED No. M-302
L. 7646

The Gazette of Pakistan

EXTRAORDINARY
PUBLISHED BY AUTHORITY

ISLAMABD, THURSDAY, AUGUST 10, 2000

PART-II

Statutory Notification (S.R.O)

GOVERNMENT OF PAKISTAN

MINISTRY OF ENVIRONMENT, LOCAL GOVERNMENT AND RURAL DEVELOPMENT

NOTIFICATION

Islamabad, the 8th August 2000

S.R.O. 549 (I)/2000.___ In exercise of the powers conferred under clause (c) of sub-section (1) of section of 6 of the Pakistan environmental Protection Act. 1997 (XXXIV of 1997), the Pakistan Environmental Protection Agency, with the prior approval of the Pakistan Environmental Protection Council, is pleased to direct that the following further amendments shall be made in its Notification No. S.R.O. 742(I)/93, dated the 24th August, 1993, namely: ___

In the aforesaid Notification, in paragraph 2._____

(1289)

[4138(2000)/Ex.GAZ]

Price : Rs. 5.00

ANNEX V

1290 THE GAZETTE OF PAKISTAN, EXTRA, AUGUST 10, 2000 [PART-II]

(1) for Annex, I the following shall be substituted, namely:____

Annex-I

"NATIONAL ENVIRONMENTAL QUALITY STANDARDS FOR MUNICIPAL AND LIQUID INDUSTRIAL EFFLUENTS (mg/I, UNLESS OTHERWISE DEFINED)

S. No.	Parameter	Existing Standards	Revised Standards Into Inland Waters	Into Sewage Treatment (5)	Into Sea ( )
1	2	3	4	5	6
1.	Temperature or Temperature Increase *	40^0C	$\leq 3°C$	$\leq 3°C$	$\leq 3°C$
2.	pH value (H^+)	6-10	6-9	6-9	6-9
3.	Biochemical Oxygen Demand $(BOD)_5$ at 20^0C (1)	80	80	250	80**
4.	Chemical Oxygen Demand (COD) (1)	150	150	400	400
5.	Total Suspended Solids (TSS)	150	200	400	200
6.	Total Dissolved Solids (TDS)	3500	3500	3500	3500
7.	Oil and Grease	10	10	10	10
8.	Phenolic compounds (as phenol)	0.1	0.1	0.3	0.3
9.	Chloride (as Cl^-)	1000	1000	1000	SC***
10.	Fluoride (as F^-)	20	10	10	10
11.	Cyanide (as CN^-) total ..	2	1.0	1.0	1.0
12.	An-ionic detergents (as MBAS) (2)	20	20	20	20
13.	Sulphate (SO_4^{2-})	600	600	1000	SC***
14.	Sulphide (S^{2-})	1.0	1.0	1.0	1.0
15.	Ammonia (NH_3)	40	40	40	40
16.	Pesticides (3)	0.15	0.15	0.15	0.15

ANNEX V

1	2	3	4	5	6
17.	Cadmium (4)	0.1	0.1	0.1	0.1
18.	Chromium (trivalent and hexavalent (4).. ..	1.0	1.0	1.0	1.0
19.	Cooper (4)	1.0	1.0	1.0	1.0
20.	Lead (4)	0.5	0.5	0.5	0.5
21.	Mercury (4)	0.01	0.01	0.01	0.01
22.	Selenium (4)	0.5	0.5	0.5	0.5
23.	Nickel (4).. ..	1.0	1.0	1.0	1.0
24.	Silver (4)	1.0	1.0	1.0	1.0
25.	Total toxic metals	2.0	2.0	2.0	2.0
26.	Zinc	5.0	5.0	5.0	5.0
27.	Arsenic (4)	1.0	1.0	1.0	1.0
28.	Barium (4)	1.5	1.5	1.5	1.5
29.	Iron	2.0	8.0	8.0	8.0
30.	Manganese	1.5	1.5	1.5	1.5
31.	Boron (4)	6.0	6.0	6.0	6.0
32.	Chlorine	1.0	1.0	1.0	1.0

Explanations:

1. Assuming minimum dilution 1:10 on discharge, lower ratio would attract progressively stringent standards to be determined by the Federal Environmental Protection Agency. By 1:10 dilution means, for example that for each one cubic meter of treated effluent, the recipient water body should have 10 cubic meter of water for dilution of this effluent.

2. Methylene Blue Active Substances; assuming surfactant as biodegradable.

3. Pesticides include herbicides, fungicides, and insecticides.

4. Subject to total toxic metals discharge should not exceed level given at S. N. 25.

5. Applicable only when and where sewage treatment is operational and BOD_5=80mg/l is achieved by the sewage treatment system.

ANNEX V

PART-II] THE GAZETTE OF PAKISTAN, EXTRA, AUGUST 10, 2000 1292

6. Provided discharge is not at shore and not within 10 miles of mangrove or other important estuaries.

* The effluent should not result in temperature increase of more than 3°C at the edge of the zone where initial mixing and dilution take place in the receiving body. In case zone is not defined, use 100 meters from the point of discharge.

** The value for industry is 200 mg/I

*** Discharge concentration at or below sea concentration (SC).

Note:_____ 1. Dilution of liquid effluents to bring them to the NEQS limiting values is not permissible through fresh water mixing with the effluent before discharging into the environment.

2. The concentration of pollutants in water being used will be substracted from the effluent for calculating the NEQS limits" and

(2) for Annex-II the following shall be substituted, namely:___

Annex-II

"NATIONAL ENVIRONMENTAL QUALITY STANDARDS FOR INDUSTRIAL GASEOUS EMISSION (mg/Nm^3, UNLESS OTHERWISE DEFINED)."

S. No.	Parameter	Source of Emission	Existing Standards	Revised Standards
1	2	3	4	5
1.	Smoke	Smoke opacity not to exceed	40% or 2 Ringlemann Scale	40% or 2 Ringlemann Scale or equivalent smoke number
2.	Particulate matter	(a) Boilers and Furnaces		
	(1)	(i) Oil fired	300	300
		(ii) Coal fired	500	500
		(iii) Cement Kilns	200	300
		(b) Grinding, crushing, Clinker coolers and Related processes, Metallurgical Processes, converter, blast furnaces and cupolas.	500	500
3.	Hydrogen Chloride	Any	400	400

ANNEX V

1	2	3	4	5
4.	Chlorine	Any	150	150
5.	Hydrogen Fluoride	Any	150	150
6.	Hydrogen Sulphide	Any	10	10
7.	Sulphur Oxides (2) (3)	Sulfuric acid/Sulphonic acid plants		
		Other Plants except power Plants operating on oil and coal	400	1700
8.	Carbon Monoxide	Any	800	800
9.	Lead	Any	50	50
10.	Mercury	Any	10	10
11.	Cadmium	Any	20	20
12.	Arsenic	Any	20	20
13.	Copper	Any	50	50
14.	Antimony	Any	20	20
15.	Zinc	Any	200	200
16.	Oxides of Nitrogen	Nitric acid manufacturing unit.	400	3000
	(3)	Other plants except power plants operating on oil or coal:		
		Gas fired	400	400
		Oil fired	-	600
		Coal fired	-	1200

Explanations:-

1. Based on the assumption that the size of the particulate is 10 micron or more.
2. Based on 1 percent Sulphur content in fuel oil. Higher content of Sulphur will case standards to be pro-rated.
3. In respect of emissions of Sulphur dioxide and Nitrogen oxides, the power plants operating on oil and coal as fuel shall in addition to National Environmental Quality Standards (NEQS) specified above, comply with the following standards:-

ANNEX V

A. **Sulphur Dioxide**

Sulphur Dioxide Background levels Micro-gram per cubic meter (ug/m³) Standards.

Background Air Quality (SO_2 Basis)	Annual Average	Max. 24-hours Interval	Criterion I Max. SO_2 Emission (Tons per Day Per Plant)	Criterion II Max. Allowable ground level increment to ambient (ug/m³) (One year Average)
Unpolluted	<50	<200	500	50
Moderately Polluted*				
Low	50	200	500	50
High	100	400	100	10
Very Polluted**	>100	>400	100	10

* For intermediate values between 50 and 100 ug/m³ linear interpolations should be used.

** No projects with Sulphur dioxide emissions will be recommended.

B. Nitrogen Oxide

Ambient air concentrations of Nitrogen oxides, expressed as NO_x should not be exceed the following:-

Annual Arithmetic Mean	100ug/m³ (0.05 ppm)

Emission level for stationary source discharge before missing with the atmosphere, should be maintained as follows:-

For fuel fired steam generators as Nanogram (10^9-gram) per joule of heat input:

Liquid fossil fuel	130
Solid fossil fuel	300
Lignite fossil fuel	260

Note:- Dilution of gaseous emissions to bring them to the NEQS limiting value is not permissible through excess air mixing blowing before emitting into the environment.

[File No. 14(3)/98-TO-PEPC.]

HAFIZ ABDULAH AWAN
DEPUTY SECRETARY (ADMN)

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ANNEX – VI

(WB/WHO/IFC STANDARDS)

ANNEX VI

INTERNATIONAL GUIDELINES FOR NOISE AND SEWAGE DISCHARGES

World bank Guidelines for Noise levels [3]

No.	Receptor	Day (07:00-22:00)	Night (22:00-07:00)
1.	Residential, institutional educational	55	45
2.	Industrial, commercial	70	70

Source: Pollution Prevention and Abatement Handbook World Bank Group (1998)
Notes: a Maximum allowable log equivalent (hourly measurements) in dB(A)

WHO Guideline Values for Community Noise in Specific Environments

Specific Environment	LAeq (dB)	Averaging Time (hours)	LAmax, Fast (dB)
Outdoor living area	55	16	-
Dwelling (indoors)	35	16	-
School classrooms (indoors)	35	During Class	-
Hospital, ward rooms, night time (indoors)	30	8	40
Industrial, commercial, shopping and traffic areas (indoors and outdoors)	70	24	110

Indicative IFC Values of Treated Sanitary Sewage Discharges [3]

Pollutants	Units	Guideline Value
pH	pH	6-9
Biological oxygen demand (BOD)	mg/l	30
Chemical Oxygen demand (COD)	mg/l	125
Total nitrogen	mg/l	10
Total phosphorus	mg/l	2
Oil and grease	mg/l	20
Total suspended solids (TSS)	mg/l	50
Total Coliform bacteria	MPNb/100ml	400

Notes
a Not applicable to centralized, municipal, wastewater treatment systems which are included in EHS Guidelines for Water and Sanitation.
b MPN = Most Probable Number

ANNEX – VII

(LNG PROPERTIES AND HAZARDS)

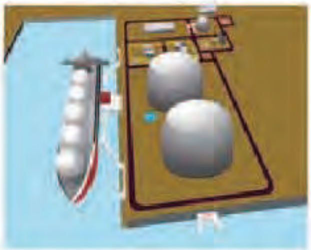
ANNEX VII

ioMosaic
discovering solutions

LNG Properties and Hazards

Understand LNG Rapid Phase Transitions (RPT)

An ioMosaic Corporation Whitepaper



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Annex VII

Understand LNG Rapid Phase Transitions (RPT)

G. A. Melhem, Ph.D., ioMosaic Corporation, Salem, New Hampshire
S. Saraf, Ph.D., ioMosaic Corporation, Houston, Texas
H. Ozog, ioMosaic Corporation, Salem, New Hampshire

Abstract

The growing public concern over potential terror threats to LNG carriers and the expected increase in LNG shipping traffic led to several recent LNG safety studies[1,2,3]. All of these studies addressed the consequences of LNG spills on water; however, none of these recent reports satisfactorily addressed the LNG rapid phase transition phenomenon.

Although rapid phase transitions are well researched, the literature published so far does not explicitly quantify the RPT phenomenon. The objective of this paper is to provide a clear understanding of how rapid phase transitions develop and how overpressure is generated.

We present a thermodynamic treatment of rapid phase transitions and discuss the estimation of hazard potential based on the superheat limit. ioMosaic's SuperChems Expert software is used to model multi-component LNG spills and to illustrate how LNG composition influences the development of rapid phase transitions and overpressure generation.

Introduction

A rapid phase transition is the very rapid (near spontaneous) generation of vapor as the cold LNG is vaporized from heat gained from the underlying spill surface or from large volumes of water contacting LNG in a storage tank. Because the vapor is evolved very rapidly, localized overpressure is created. This is also sometimes described as a physical explosion.

Following a release of liquefied natural gas (LNG) from a ship or storage tank, a liquid pool forms and spreads on the surroundings spill surface. Rapid phase transitions have been

---

[1]. ABS Consulting report for FERC, "Consequence Assessment Methods for Incidents Involving Releases from Liquefied Natural Gas Carriers", FERC04C40196, May, 2004

[2]. R. M. Pitblado, J. Baik, G.J. Hughes, C. Ferro, and S. J. Shaw, "Consequences of LNG marine incidents", Center for Chemical Process Safety (CCPS) Conference, Orlando, June 29 – July 1, 2004

[3]. M. Hightower, L. Gritzo, A. Luketa-Hanlin, J. Covan, S. Tieszen, G. Wellman, M. Irwin, M. Kaneshige, B. Melof, C. Morrow, and D. Ragland, "Guidance on Risk Analysis and Safety Implications of a Large Liquefied Natural Gas (LNG) Spill Over Water", A Report Prepared by Sandia National Laboratories (SNL) for the U.S. Department of Energy (DOE), SAND2004-6258, Dec. 2004.

ANNEX VII

shown to occur during or following an LNG spill. The hazard potential of rapid phase transitions can be severe, but is highly localized within or in the immediate vicinity of the spill area.

Rapid phase transitions are especially a concern for LNG ships because (a) the pressure rating of the actual LNG cargo tanks is low, and (b) the LNG cargo tanks pressure relief system may not be able to actuate quickly enough to relieve the large volumes of vapor that can be spontaneously generated by an LNG rapid phase transition[4]. Three scenarios of interest are addressed in this paper:

1. An LNG spill on water from the LNG ship cargo tanks from a large hole above the water line causing a rapid phase transition near the outer hull of the ship close to the release point.

2. An LNG spill into the water from the LNG ship cargo tanks from a large hole below the water line causing a rapid phase transition near the outer hull of the ship at the release point.

3. Water inflow into a partially full LNG cargo tank such that the large hole is below the water line but above the LNG liquid level in the LNG cargo tank.

RPT Scenarios of Concern for LNG Ships

A large hole in an LNG tanker storage vessel can be caused by a collision of the LNG tanker with another ship, grounding of the LNG tanker, and/or intentional acts of sabotage or terrorism. The location of the hole with respect to the water line, the initial LNG liquid level in the tanks, and the depth of the ship will influence the rapid phase transition outcome.

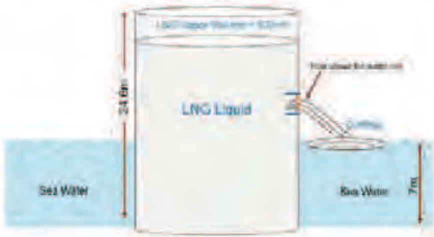
Hole above the Water Line:
In this case the LNG tank is near full, say 98 %, and breach occurs above the water line causing LNG to be released from the tank onto the water surface (see Figure 1). Rapid phase transitions will occur near the release point with potential damage to the outer ship hull, but not the tank. A liquid pool will form adjacent to the tanker. The extent of the hazard footprint and possible escalation events will depend on whether the LNG vapors ignition is immediate or delayed.

[4] This assumes that the tanks are not first damaged by the high levels of overpressure created by the rapid phase transition itself.

ioMosaic

ANNEX VII

Figure 1: LNG Outflow from a Hole above the Water Line

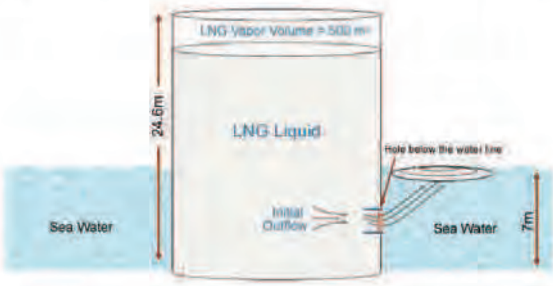


Source: ioMosaic Corporation

Hole below the Water Line:

In this case the LNG tank is near full, say 98 %, and breach occurs below the water line causing LNG to be released initially from the tank into the surrounding water medium (see Figure 2). The initial flow rate is driven by the LNG liquid head which is larger than the liquid head of the surrounding water. Rapid phase transitions will occur near the release point with potential damage to the outer ship hull, but not the tank. This mode of release will continue until the pressure inside the LNG tank equilibrated with the pressure exerted by the surrounding water. At this point, gravity flow will cause water to intrude into the LNG tank and LNG to flow out. It is likely that this type of flow will lead to small rapid phase transitions that can cause damage to the outer hull of the ship but not the tank.

Figure 2: LNG Outflow from a Hole below the Water Line



Source: ioMosaic Corporation

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4

ANNEX VII

Table 1: Hole below the Water Line Typical Scenario Data

Release Variable	Moss spherical vessel	Membrane vessel
Single tank capacity	27,450 m^3	27,450 m^3
Tank dimensions	37.5 m inner diameter	W=34.5m, L=32m, H=24.6m
Typical vessel draft	11.5 m	11.5 m
Bottom of tank below the waterline	9.5 m	7 m
Initial LNG hydrostatic head	33.8 m	23.6 m
Water backpressure head	0.87 barg	0.63 barg
Assumed initial water entry to create 0.2 barg pressure	90 kg	90 kg
Pressure differential between LNG at hole to seawater at hole	0.71 barg	0.54 barg
Initial LNG discharge rate	2100 kg/s (0.75 m hole) 8300 kg/s (1.5 m hole)	1800 kg/s (0.75 m hole) 7200 kg/s (1.5 m hole)
Initial LNG discharge velocity	11.1 m/s	9.6 m/s
Equilibrium point (% of tank level)	43 %	43 %

Any LNG vapor generated as the water intrudes into the LNG storage tank will create higher pressure on the LNG side and will cause the water intrusion to stop. It is possible for this meta-stable equilibrium state to continue for a very long time.

This scenario has also been addressed by two recent papers by Shaw[5] and Fay[6]. The example presented by Shaw is summarized in Table 1. Note that tank is initially 98 % full with 500 m^3 of vapor space and that the hole considered is 0.5 meters above the bottom of the tank. A small amount of water is required to raise the pressure inside the tank by 0.2 barg.

Hole below the Water Line but above LNG Liquid Level:

In this case the LNG tank is partially full, say 25 %, and breach occurs below the water line but above the LNG liquid level (see Figure 3). If the hole size is sufficiently large, say 5 meters in diameter, it is possible for enough water to enter the LNG tank and mix with the cold LNG at the LNG surface causing an RPT inside the tank. As the water mixes with the LNG it gives up its sensible heat as liquid until it freezes, it then gives up its heat of fusion, and finally its sensible heat as solid as its temperature drops from 273.15 K to the boiling point of LNG, 111 K.

The RPT localized overpressure can be as high as 36 bars as shown later in this paper and can cause severe damage to the tank walls. In addition, the near instantaneous vapor generation[7] from one second of water flow from a 5 meter hole into a typical LNG tank that is 25 % full can raise the vapor space pressure to the design limit of the tank. In order to

[5] Shaw et al, "Consequences of underwater releases of LNG", AIChE Spring Meeting, Atlanta, GA, April 10 – 14, 2004.

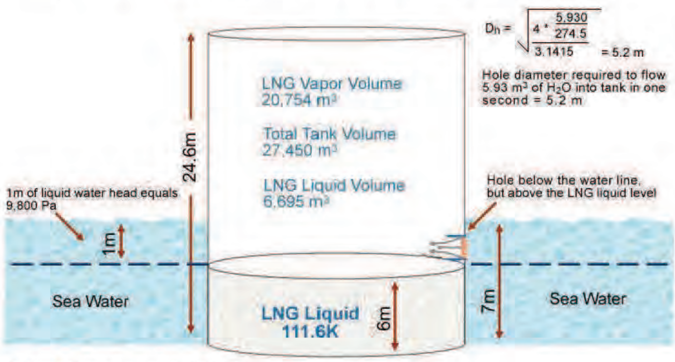
[6] Fay, "Model of spills and fires from LNG and oil tankers", JHM, B98, 2003, 171 – 188

[7] Assumes that the water gives up its heat content very rapidly

ANNEX VII

stop water ingress into the tank, the pressure in the vapor space of the tank has to be equal or greater than the pressure imposed by the difference between the water and LNG liquid levels.

Figure 3: Hole below the Water Line but above LNG Liquid Level



DATA:
- Water Temperature = 283.15K
- Total Available Heat in one Kg of H_2O = 615,748 Joules
- Amount of CH_4 Vapor Created per Kg of H_2O Entering Tank = 1.21 $\frac{Kg\ CH_4}{Kg\ H_2O}$
- CH_4 Vapor Volume Created per Kg of H_2O Entering Tank = 0.7 $\frac{m^3\ CH_4}{Kg\ H_2O}$
- 5.93 m^3 of H_2O Will Raise Vapor Space Pressure to = 1.2 barg

Source: ioMosaic Corporation

Although one can show this hypothetical scenario where the integrity of one or more of the LNG storage tanks may be at risk from a RPT or the rapid vapor generation associated with a RPT, we must keep in mind that this particular scenario requires the tanks to be partially empty. If the fill level is low enough, the potential fire and flammable dispersion impact zones may be smaller than other scenarios considered where the tanks are near full.

Prediction of RPT Hazard Potential

Rapid phase transitions are also referred to as physical explosions. This type of explosion does not involve combustion or a chemical reaction to create mechanical explosion energy. Instead, mechanical or explosion energy is created from the rapid expansion of a high pressure meta-stable fluid to ambient pressure.

A fluid can be made thermodynamically unstable (meta-stable) by rapidly changing its temperature and pressure such that it cannot exist at those conditions in its initial state (all liquid).

Even during very rapid heating or very rapid depressurization, all fluids must change phase ultimately. These phase change limits (also called the thermodynamic stability limits) can

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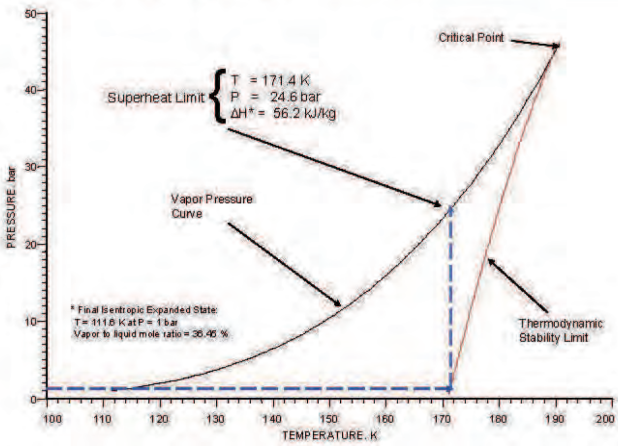
ANNEX VII

be determined accurately using an equation of state. An LNG rapid phase transition can be explained using the thermodynamic stability limit (also called the superheat limit).

We illustrate the rapid heating process of LNG leading to a rapid phase transition on a phase diagram. LNG consists predominantly of methane. Certain LNG compositions will contain higher fractions of ethane and some propane and as a result their phase diagram is different from that of pure methane.

First let's look at how the superheat limit is reached for pure liquid methane. This is illustrated graphically in Figure 4.

Figure 4: The Superheat Limit for Pure Methane



Source: SuperChems Expert v5.7, ioMosaic Corp.

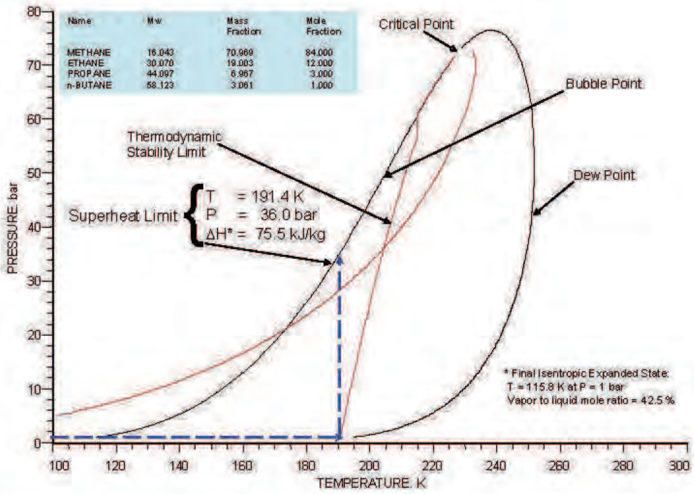
Follow the dashed blue line at the bottom of Figure 4. Pure liquid methane boils at 111.6 K (-258.8 F) at ambient pressure. Rapid heating at ambient pressure causes methane to reach the thermodynamic stability limit of 171.4 K (-151.15 F). Once heated to that temperature, methane becomes a superheated liquid, i.e. a saturated liquid with a vapor pressure of 24.6 bars. Methane reaches the superheated state and has to give up its superheat by expanding because the ambient pressure is 1 bar. If we assume that the expansion process is reversible/isentropic (we can bring methane back to its superheated state by adding back the same amount of energy it lost when it expanded) methane will expand to 1 bar and exert 56.2 kJ/kg in mechanical work (physical or pressure-volume) or energy (on the surroundings) that can be used to create overpressure, i.e. explosion energy.

ANNEX VII

In reality, the expansion process is not reversible and its efficiency at best is around 50 % as established by actual testing[8]. This is because the expansion process loses energy as it creates turbulence and as the liquid flashes to vapor. As a result, the maximum possible rapid phase pressure that methane can reach is 24.6 bars and its mechanical explosion energy is 28.1 kJ/kg. This is equivalent to burning 0.56 grams of methane vapor. In other words, on per unit mass basis, the methane combustion process produces 1,780 times more energy than a rapid phase transition. This is why, historically, rapid phase transition overpressure estimates were excluded from LNG risk assessments and considered to be negligible and localized.

Now let's repeat the same process for an LNG mixture. An LNG mixture containing high fractions of ethane and propane is more likely to undergo a rapid phase transition than pure methane. This is observed in real LNG spills and can also be proven theoretically as illustrated in later sections of this paper.

Figure 5: The Superheat Limit for an LNG Mixture



Source: SuperChems Expert v5.7, ioMosaic Corp.

Instead of a vapor pressure curve, an LNG mixture has a phase envelope consisting of a bubble point curve and a dew point curve as illustrated in Figure 5.

Follow the dashed blue line at the bottom of Figure 5. This LNG mixture boils at 115.8 K at ambient pressure. Rapid heating at ambient pressure causes the LNG mixture to reach

[8] G. A. Melhem, "Advanced Consequence Analysis", Arthur D. Little Inc., 1998.

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8

ANNEX VII

the thermodynamic stability limit of 191.4 K. Once heated to that temperature the LNG mixture becomes a superheated liquid, i.e. a saturated liquid with a bubble point pressure of 36.0 bars. The LNG mixture reaches the superheated state and has to give up its superheat by expanding because the ambient pressure is 1 bar. If we assume that the expansion process is reversible/isentropic, the LNG mixture will expand to 1 bar and exerts 75.5 kJ/kg in mechanical work or energy that can be used to create overpressure, i.e. explosion energy.

As mentioned earlier, the expansion process is not reversible and its efficiency at best is around 50 %. As a result, the maximum possible rapid phase pressure that the LNG mixture can reach is 36.0 bars and its mechanical explosion energy is 37.75 kJ/kg. An LNG mixture rapid phase transition produces 1,325 times less overpressure energy per unit mass than the combustion process.

The explosion energy predicted by the superheat limit at 37.75 kJ/kg or (20.7 kJ/liter) is consistent with recent spill data measured by Shell[9] at 5.6 kJ/liter. Until a more detailed model is developed to better represent the rapid phase transition process, we recommend the use of the superheat limit explosion yield of 20.7 kJ/liter. This number can easily be established for other LNG compositions of interest.

Although not recommended by this author, the explosion yield of 20.7 kJ/liter can be used with a simple TNT[10] equivalency method to predict overpressure contours from a rapid phase transition with a specified amount of LNG. Note that TNT equivalence will over predict near field overpressure values and is therefore considered to be a conservative method.

Even if we were to consider the physically impossible, i.e., the entire contents of one LNG storage tank (say 25,000 m3) participated in a single RPT at the same time (only a small portion of the liquid spilled on water that is in intimate contact with the spill surface has been shown to participate in an RPT in large scale field trials), the overpressure hazard radius to 1.0 psi would be estimated at 0.82 miles from the center of the RPT. The RPT hazard radius is well within distances of concern of LNG flammable dispersion to ½ LFL for releases from hole sizes ranging from 1 to 5 meters.

Predicting RPTs from LNG Spills

Existing modeling methods fall short from being able to identify with accuracy what fraction of an LNG spill will participate in a rapid phase transition[11]. However, there are advanced modeling techniques that can tell us if a rapid phase transition will occur and at what approximate time during the spill it will occur.

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[9] V. T. Nguyen, "Rapid Phase Transformations: Analysis of the large scale field trials at Lorient", Shell Research Limited, External Report TNER.86.058, February 1987

[10] TNT equivalence will over-estimate overpressure in the near field because the TNT charts are based on the use of a solid explosive and not a physical explosion (PV energy)

[11] F. Briscoe and G. J. Vaughn, "LNG/Water Vapour Explosions – Estimates of Pressures and Yields", UKAEA SRD R 131, October 1978.

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9

Annex VII

Before discussing RPT modeling, one needs to understand the different boiling regimes based on the temperature difference between the heating medium and the cold liquid. Figure 6 illustrates the various boiling regimes for methane and nitrogen.

The process of forming vapor in all liquids (also referred to as flashing) usually involves what is called nucleation sites. For example, in a process vessel, these nucleation sites can be small imperfections on the vessel inner surface or tiny colloidal suspensions of dirt or dissolved gas in the liquid. Nucleation is a process where vapor bubbles start to form in these surface imperfections when a liquid is heated to a boiling state. The nucleation process requires mass and heat transfer in order to produce vapor. If heating occurs at an extremely rapid rate, these nucleation sites are rendered inactive as they do not have enough time to complete the mass and energy transfer/exchange required to generate the vapor bubbles, i.e. nucleate. The same effect can be produced by dropping the pressure of a saturated fluid very fast.

When LNG is spilled on land or water, LNG is initially very cold (110 K or -261.67 °F). The spill surface (land or water) is initially very hot compared to the temperature of LNG. Even cold ocean water is typically around 60 °F or 289 K. The initial difference between the LNG and the water surface is 289-110 or 179 K (322 °F). This high temperature difference causes the LNG to start boiling. Because the difference in temperature is so high initially, a vapor film is formed at the contact point between the LNG and the underlying spill surface (see Figure 3).

This vapor film will persist until the spill surface cools enough and/or until the LNG bubble point temperature gets high enough as methane is preferentially depleted from the liquid LNG spill. As long as the vapor film exists between the LNG and the spill surface, heat transfer is greatly reduced (vapor layer acts as an insulator also). When the difference in temperature between the LNG and the spill surface gets smaller, the vapor film is destroyed and a different (faster) heat transfer mode begins (see Figure 3). The rate of heat exchange between the cold LNG and the warmer spill surface is now orders of magnitude larger than it was with the vapor film intact. As a result, the LNG is heated very rapidly (almost instantaneously to the superheat limit) and a rapid phase transition occurs.

ANNEX VII

Figure 6: Boiling Regimes for Methane and Nitrogen

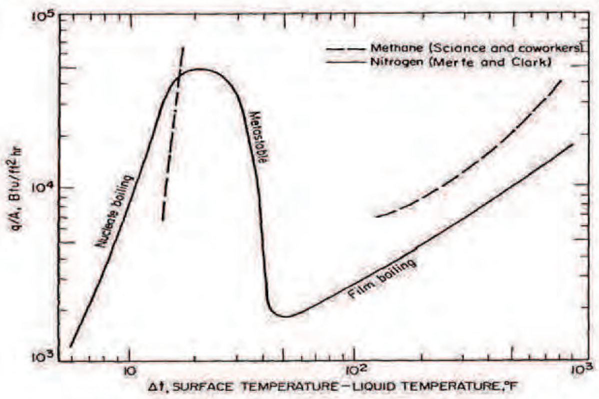
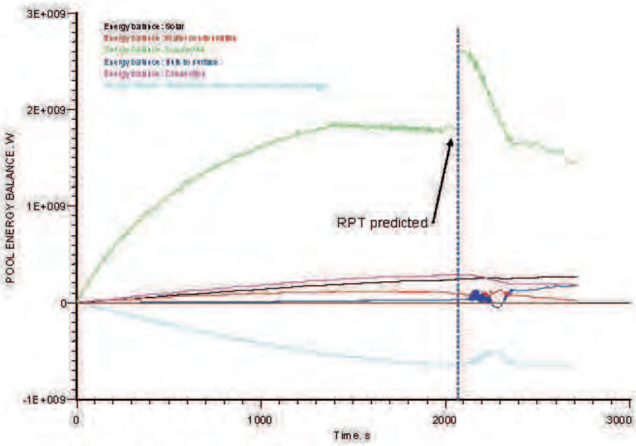


Figure 7: Detailed liquid pool energy balance for an LNG mixture spilled on water



Source: SuperChems Expert v5.7, ioMosaic Corp.

We illustrate this advanced modeling methodology using an example. We contrast a large liquid spill of LNG consisting of pure methane to that of an LNG mixture containing high fractions of ethane and propane. The liquid spill occurs over 33 minutes at a rate of 5,300 kg/s (equivalent to spilling the entire contents of a 25,000 m3 LNG sphere from a 1 m hole) on water with a water initial temperature of 295 K at an atmospheric stability class F and a

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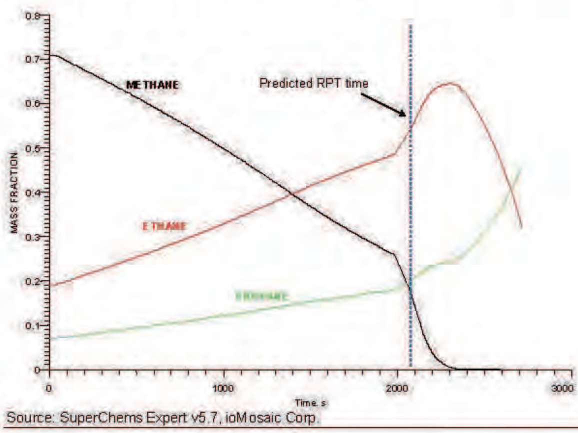
ANNEX VII

10 m wind speed of 2 m/s. Details of the pool spreading and vaporization model are available in one of our recent publications[12].

This liquid pool simulation was generated using SuperChems Expert. The pool spreading is calculated based on a differential solution of the Shallow water equations. SuperChems considers in detail the different liquid spreading regimes and the pool energy balance. The spilled liquid is divided into a bulk liquid phase and a small liquid phase at the surface/interface. Heat transfer between the spilled liquid and the spill surface occurs as a function of time, depth, and radial position. This particular simulation shows that a rapid phase transition will occur at approximately 2,080 seconds (shortly after the spill ends) as evidenced by the increased rate of conductive heat transfer caused by the transition from film to pool boiling (see Figure 4).

As shown by Figure 8, the rapid phase transition coincides with decreasing methane concentrations in the liquid pool. As the pool spreads and exchanges heat with the spill surface, methane is preferentially boiled off, leading to higher concentrations of ethane and propane. This theoretical finding is supported by actual spill field tests (see Appendix A).

Figure 8: LNG pool mixture composition



Source: SuperChems Expert v5.7, ioMosaic Corp.

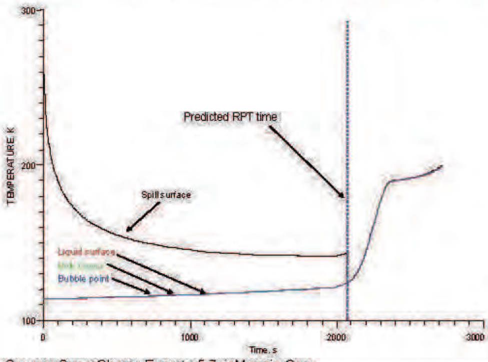
The rapid phase transition occurs when the bulk methane composition in the pool is less than 20 % by weight and the ethane fraction is more than 50 % by weight. As ethane, propane, and butane fractions in the pool increase, the mixture boiling point becomes much higher than that of pure methane. This is illustrated in Figure 9. Note that the bulk liquid temperature, bubble point, and pool surface/interface temperature as essentially the same since the liquid is at its boiling point the entire time. The spill surface temperature

12. S. R. Saraf and G. A. Melhem, "Modeling LNG Pool Spreading and Vaporization", AIChE Spring Meeting, Atlanta, GA, April 10 – 14, 2005.

ANNEX VII

decreases with time as the interface cools and the bubble point of the mixture increases as methane is depleted preferentially from the pool. As the temperature difference between the surface and LNG reduces, the boiling regime changes from film boiling to nucleate boiling resulting in higher heat transfer rates.

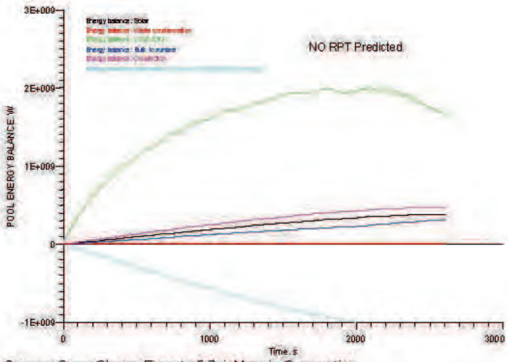
Figure 9: Predicted LNG mixture and pool surface interface temperatures



Source: SuperChems Expert v5.7, ioMosaic Corp.

A rapid phase transition is not predicted for the same spill consisting of pure methane as illustrated in Figure 10. In this example because the critical temperature difference to transit from film boiling to nucleate/pool boiling is not reached. As shown by the Shell data in Appendix A for methane, when the substrate temperature is low boiling or cold, ice formation is observed. The behavior turns violent as the substrate temperature increases.

Figure 10: Detailed energy balance for a pure methane spill on water



Source: SuperChems Expert v5.7, ioMosaic Corporation

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13

ANNEX VII

Conclusions

We have surveyed the open literature about LNG rapid phase transitions. Data summaries and details can be found in Appendix A. Several conclusions and insights can be obtained from the published data:

1. Rapid phase transitions were observed in many but not all field trials.
2. Rapid phase transitions are more likely to occur in LNG mixtures containing very high fractions of ethane and propane. LNG composition is a critical parameter.
3. Spill rate, spill duration, and the spill surface conditions influence the rapid phase transition process. Higher spill rates and longer spill durations are more likely to produce rapid phase transitions. Critical temperature difference leading to nucleate/pool boiling heat transfer is more likely to be reached if more cold liquid is spilled or if cold liquid is spilled over a long duration.
4. Only a small fraction of the spilled LNG was observed to undergo rapid phase transitions.
5. The superheat limit theory for rapid phase transition provides an upper bound on the explosion yield that can be used in risk assessments and safe separation distance studies.

The explosion energy predicted by the superheat limit at 37.75 kJ/kg or (20.7 kJ/liter) is consistent with recent spill data measured by Shell[13] at 5.6 kJ/liter. Until a more detailed model is developed to better represent the rapid phase transition process, we recommend the use of the superheat limit explosion yield of 20.7 kJ/liter. This number can easily be established for a wide range of LNG compositions of interest.

The hazard potential of rapid phase transitions can be severe, but is highly localized within the spill area.

[13] V. T. Nguyen, "Rapid Phase Transformations: Analysis of the large scale field trials at Lorient", Shell Research Limited, External Report TNER.86.058, February 1987.

ANNEX VII

Appendix A: RPT Test Data Summaries

Nakanishi and Reid[1]

Test Setup

A variety of spills were performed in a 200 ml. Dewar flask at the MIT laboratory in 1971.

Test Condition

Component	Condensed pipeline gas (CPG)	Liquefied methane gas (LMG)	Liquefied ethane gas (LEG)	Synthetic liquefied natural gas (SLNG)
	wt %			
Methane	92.7	100	-	80 – 90
Ethane	Trace	-	100	-
Propane	0.0	-	-	20 – 10
Nitrogen	7.3	-	-	0 – 2

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15

Annex VII

Test Data

Test series	Spilled liquid	Volume (µm3)	T (°C)	Substrate	Substrate volume (µm3)	Substrate T (°C)	Observation
A	Water			CPG			Freezing of water droplets; popping sound reported when the drops were exposed to air or water
A				LN2			Freezing of water droplets
B	Water	200	5	CPG or LMG or LEG or LN2	200		No explosion
C	CPG or LMG or LEG	1 – 5		Water		5 – 10	Ice formation
	CPG or LMG or LEG	1 – 5		Water		80	Ice formation; ice fragments foamed up and popped
C	LN2			Water		5 – 10	Ice formation
C	LN2			Water		80	Ice formation
E	CPG			Ice		- 150	Foaming and gas bubbles
E	LN2			Ice		- 150	Foaming and gas bubbles
E	CPG			Ice		- 5	Foaming and gas bubbles
E	LN2			Ice		- 5	Gas bubbles
F	CPG			3 wt % NaCl in water		15	Ice formation
F	LN2			3 wt % NaCl in water		15	Ice formation
F	CPG			20 wt% ethylene glycol in water		15	Ice formation; ice fragments foamed up and popped
F	LN2			20 wt% ethylene glycol in water		15	Ice formation

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16

ANNEX VII

Test series	Spilled liquid	Volume (µm3)	T (°C)	Substrate	Substrate volume (µm3)	Substrate T (°C)	Observation
G	LN2			ethylene glycol or cyclohexane or n-butyl alcohol			Ice formation
G	CPG or LMG or LEG	50 - 100		ethylene glycol or cyclohexane or n-butyl alcohol			Eruption reported
G	LN2			n-hexane or n-pentane or methyl cyclohexane			Ice formation
	CPG	<10		n-hexane			Ice formation, ice fragments foamed up and popped
G	CPG, SLNG	10 - 100		n-hexane or n-pentane or methyl cyclohexane			Explosion
H	CPG, LMG, LEG, or	50		1 mm n-hexane film on water[1]			Explosion
H	CPG			Mercury or mercury coated with ethylene glycol or n-butyl alcohol			Rapid evaporation
H	CPG			Mercury coated with n-hexane or n-pentane or n-butane or methylcyclohexane			Explosion
H	CPG			Mercury coated with water or cyclohexane			No explosion
H	CPG			Benzene film on water			No explosion
H	CPG			Toluene film on water			Explosion
H	CPG			p-xylene film on water			No explosion
H	SLNG			Water coated with pentane or gasoline			Explosion

Notes: 1. No explosion noted if the film was frozen
2. LN2 – liquefied nitrogen

The authors propose that if the substrate is chemically "similar" to the cryogen spilled and the interfacial liquid has a low freezing point, then an explosion may occur.

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17

ANNEX VII

Bureau of Mines[2]

Test Setup

The U.S. Bureau of Mines conducted LNG spills onto water in strip mine lane near Florence, PA.

Spill dimensions
The lake was approximately 67 m wide at the midpoint.

Instrumentation and data acquisition system
N/A

Test Conditions

LNG composition

Series 1:

Storage duration	Methane	Ethane	Propane	Butane	Pentane	Ethane Plus Heavies
	mol %					
First week (avg.)	86.9	11.3	1.3	0.4	0.06	11.8
Second week (avg.)	87.8	10.6	1.2	0.3	0.06	11.0
Third week (avg.)	85.6	12.7	1.3	0.3	0.05	13.1
Fourth week (avg.)	81.3	16.5	1.7	0.4	0.06	17.0
Fifth week (avg.)	77.4	20.1	2.0	0.4	0.07	20.6
36th day	72.2	24.6	2.5	0.6	0.07	25.3
37th day	51.5	41.5	5.6	1.2	0.19	42.9
38th day	55.2	38.7	4.9	1.0	0.14	39.8
42nd day	0.5	67.6	25.8	5.3	0.82	73.7

ANNEX VII

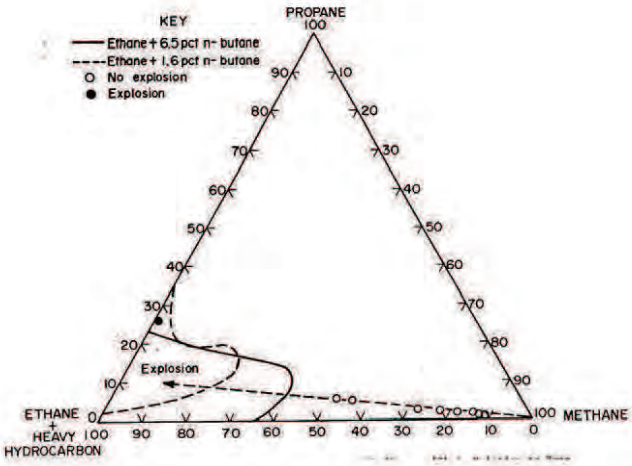
Series 2:

Date	Methane	Ethane	Propane	Butane	Pentane
(1971)	mol %				
12th Oct.	88.8	9.2	0.81	0.15	0.03
19th Oct.	78.3	19.5	1.8	0.34	0.06
21st Oct.	56.2	39.7	3.3	0.66	0.16

Test Data

Series 1: Through the 39th day of evaporation when 0.038 m^3 (10 gallons) of LNG remained in the tank the methane concentration was about 50%, the weathered LNG gave nothing more than crackling noise. On the 42nd day when 0.01 m^3 (2.5 gallons) of LNG remained, the weathered LNG gave an immediate, violent explosion on water. Based on the observations a vapor explosion – composition diagram was proposed (Figure 11). The

Figure 11: Aging curve for LNG and vapor-explosion behavior[2]



solid curve of the figure encloses explosive concentrations of weathered LNG when the n-butane mole fraction of LNG is 6.5 % of the ethane mole fraction. The dashed curve encloses a smaller explosive zone when there is less n-butane in the LNG.

Series 2: About 7.6 m^3 (2000 gallons) of Series 2 weathered LNG (low concentrations of butane and higher heavies) was released on water in three tests without any audible explosions.

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19

ANNEX VII

UMCP[3]

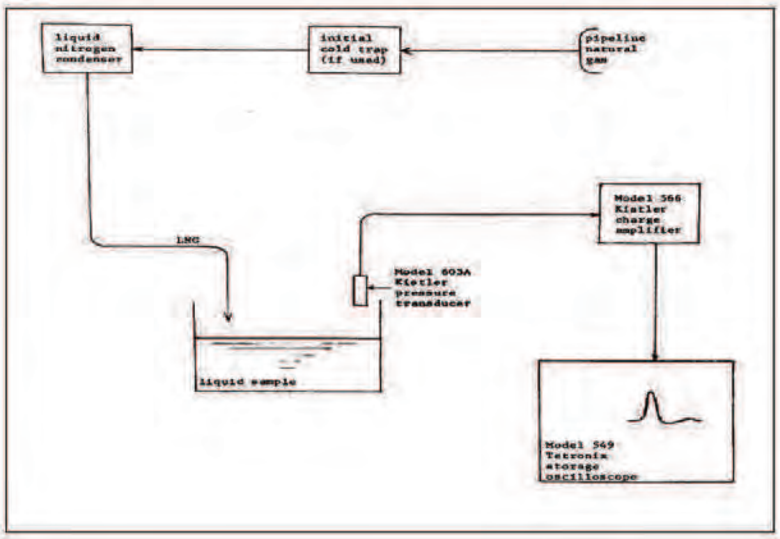
Small-scale tests were performed with methane-rich LNG spilled onto water, pure organic liquids, and water-organic mixtures.

Test Setup

Spill dimensions
5 – 200 μm^3 (5 – 200 ml) of LNG was spilled.

Instrumentation and data acquisition system
The experimental setup is shown in Figure 12. Temperature or pressure was followed by the appropriate measuring device and displayed on an oscilloscope.

Figure 12: UMCP RPT studies[3]



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ANNEX VII

Test Conditions

LNG composition

Component	%
Methane	95.1
Ethane	3.0
Propane	0.8
Butane	0.3
Pentane (all isomers)	0.1
Carbon dioxide	0.7
Nitrogen	0.01

Test Data

Test series	LNG volume	Substrate	Substrate volume	Result
	µm3		µm3	
A-1				
	5 – 20	Distilled water	40	No RPT
		Distilled water with 8.8 wt % NaCl	40	No RPT
		Distilled water saturated with CO_2	40	No RPT
A-2				
		Toluene, methanol mixture	40	No RPT
		Toluene, methanol, water mixture	40	No RPT
		Toluene, s-butyl alcohol, water mixture	40	No RPT
		Chlorobenzene	40	No RPT
		n-hexane mixture	40	No RPT
		Water, chlorobenzene, toluene mixture	40	No RPT
		1-butanol	40	No RPT
		sec-butyl alcohol	40	No RPT
		n-hexane, water mixture	40	No RPT
		n-hexane, water, toluene mixture	40	No RPT
		Toluene, chloroform mixture	40	No RPT
		Methyl cyclohexane mixture	40	No RPT
A-3				
	45 – 55	Water	40	No RPT
B-1[1]				
	10 – 100	1 mm hexane film on water	100	RPT reported
		1 mm toluene film on water	100	RPT reported

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ANNEX VII

Test series	LNG volume	Substrate	Substrate volume	Result
	µm3		µm3	
	100 – 200	Hexane	-	RPT reported
B-2[2]				
	≥ 50	1 mm hexane film on water	-	RPT
	Up to 200	1 mm toluene film on water		No RPT
C-1				
	10 – 100	Hexane film on water	-	RPT
C-2[3]				
	150 – 200	Pure hexane	-	RPT
C-3[4]				
	100	Pure hexane	100	RPT

Notes: 1. Pipeline gas was passed through a –25 °C cold trap before condensation.

2. Pipeline gas was passed through a dry ice/methanol cold trap (-78 °C) and condensed in liquid nitrogen cold trap.

3. Observed ΔP_{max} varied with hexane volume.

Hexane	ΔP_{max}
μm^3	kPa
189	2836.4
122	2127.3
77	1823.4

4. Un-pretreated LNG was repeatedly dropped onto hexane.

The authors concluded that composition of LNG is important in noticing RPT behavior and that the presence of a hydrocarbon film on water increases the probability of RPT occurrences.

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ANNEX VII

Shell[4]

Test Setup

A series of spill experiments involving hydrocarbons and hydrocarbon mixtures on ambient and hot water were performed at Shell to study the RPT phenomenon.

Test Conditions

N/A.

Test Data

Table 2: RPT data for hydrocarbons on water

Compound	Sp. Gr. at NBP	NBP	Water Temp., range tested	Results
		°C	°C	
Iso-butane	0.63	- 11.7	18 – 89	Boiling, no ice
			93 – 99	Vapor explosions
Freon 22	~ 1.2	- 40.8	41 – 43	Ice
			46 – 82	Vapor explosions
Propane	0.57	- 42.1	0 – 52	Ice
			53 – 70	Vapor explosions
			71 – 82	Rapid pops
Propylene	0.61	- 47.7	38 – 41	Ice
			42 – 75	Vapor explosions
			80 – 85	Rapid pops
Ethane	0.55	- 88.6	7 – 64	Ice forms, no pops
LNG (95 % methane)	0.43	- 161.5	0 – 32	Ice
			35 – 65	Disk boiling, pops
Nitrogen	0.81	-195.7	14 – 49	Ice forms, no pops

Note: RPTs are referred as vapor explosions

It has been reported that explosive boiling of LNG on ambient water can be produced when the methane content is less than 40 mol% along with a few mole percent n-butane.

Vapor explosion cannot occur with propane in excess of 20 mol %. Pure ethane did not produce a RPT on ambient water. Generally, small addition of heavier hydrocarbons increased the probability of RPT occurrence.

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ANNEX VII

ESSO/API test[5]

Test Setup

A total of 17 spills were performed by ESSO Research and Engineering Company under contract with American Petroleum Institute (API) during Oct. 22 – Nov. 21, 1971.

Spill dimensions
0.95 – 9.5 m^3 (250 – 2500 gallons) of LNG spills was discharged into Matagorda Bay in Texas at 18.9 m^3/min (5000 gallons/min).

Instrumentation and data acquisition system
Downwind concentrations were monitored by hydrocarbon detectors at various elevations.

Test Conditions

LNG composition

Run no.	Spill size m^3	Methane[a] mol %	Spill duration sec.
1	0.78	85.2	-
2	0.73	85.8	5.6
3	0.84	85.3	5.8
4	0.93	88.0	5.2
5	0.93	87.6	-
6	0.79	87.4	-
7	0.79	87.4	7.0
8	7.12	85.1[b]	25.0
9	7.42	88.8	25.0
10A	5.22	93.0	21.0
11	10.22	93.3	35.0
12	0.93	92.8	6.2
13	0.93	92.8	6.3
14	0.93	92.8	6.7
15	2.50	87.6	12.0
16	7.57	92.7	28.0
17	8.36	94.1	31.0

Notes: a. Runs 1 - 10A: % methane calculated from material balance data.
Runs 11 – 17: % methane calculated from samples obtained by capillary method.
b. Average composition calculated from a heel of 60% methane and fresh material of 94% methane.

ioMosaic discovering solutions

24

ANNEX VII

Meteorological information

Run no.	Date (1971)	Wind speed m/s	Temp. °C	Rel. humidity %
1	Oct. 22	5.4	24	74
2	Oct. 22	5.4	24	74
3	Oct. 24	2.2 – 2.7	25	60-70
4	Oct. 26	9.4	26	79
5	Oct. 28	5.4	29	78
6	Oct. 28	4.9	29	79
7	Oct. 28	4.5	28	78
8	Nov. 1	4.9	29	78
9	Nov. 9	0 – 1.4	24	82
10	Nov. 11	2.2	20	54
11	Nov. 13	8.1	27	78
12	Nov. 14	8.0 – 8.5	25	75
13	Nov. 14	8.0 – 8.5	25	75
14	Nov. 14	6.7 – 7.6	25	72
15	Nov. 16	5.8	25	80
16	Nov. 20	0.0	18	62
17	Nov. 21	4.0	17 - 18	85-86

Notes: The water temperature was 22.2 – 23.3 °C

Test Data

"Explosions" occurred during test 8. LNG was poured onto water over a period of 25 seconds. Four explosions occurred in quick successions 42 second after the start (17 seconds after the end) of the spill period.

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Annex VII

MIT LNG Research Center[6,7]

Test Setup

Spills were made with six pure hydrocarbons (ethane, propane, iso-butane, n-butane, propylene, isobutylene) on water and other substances over a wide range of temperature. Five binary-hydrocarbon mixtures of ethane or ethylene with heavier hydrocarbons (propane, n-butane, n-pentane) were also studied.

Spill dimensions
Normally 0.0005 m^3 (500 cm^3) of hydrocarbons were spilled on a water area of 0.02 m^2 (200 cm^2, ~ 16 cm diameter).

Instrumentation and data acquisition system
RPTs were monitored with a high frequency quartz pressure transducer located at the bottom of a polycarbonate hot-liquid container.

Test Conditions

LNG composition
Not applicable.

Meteorological information
Laboratory experiments

Test Data

Pure alkanes and alkenes

Cryogen	Substrate	Substrate temperature K	Result Reproducibility[1]
Ethane	Water	278 – 313	Boiling, ice forms
Ethane	Ammonia – Water	271 – 297	Boiling, no ice forms
Ethane	Methanol	264 – 305	Eruptions
		306 – 331	Weak RPTs (100%)
Ethane	Methanol – water	276 – 295	Boiling, foamy slush
		296 – 304	RPTs (100 %)
		303 – 319	Popping
Propane	Water	319 – 325	Boiling, ice forms
		326 – 334	RPTs (85 %)

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26

ANNEX VII

Cryogen	Substrate	Substrate temperature K	Result Reproducibility[1]
		335 – 356	Popping, Occasional RPTs (12%)
Propane	Ethylene Glycol	317 – 358	Boiling
Isobutane	Water	358 – 372	Boiling, Occasional popping RPTs (12 %)
Isobutane	Ethylene Glycol	298 – 348	Nucleate boiling
		352 – 377	Violent boiling
		379 – 393	Film boiling, popping
Isobutane	Ethylene Glycol – Water	370 – 373	Violent boiling
		374 – 379	RPTs (100%)
		381 – 388	Film boiling
n-butane	Water	363 – 372	Boiling, popping
Propylene	Water	303 – 312	Boiling, ice forms
		313 – 316	Popping
		317 – 346	RPTs (100%)
		347 – 363	Film boiling
Isobutylene	Ethylene Glycol	376 – 378	Eruptions
		379 – 408	RPTs (100%)

Notes: [1]. Reproducibility = 100 * Number of spills with RPT / total number of spills

Binary mixture spills on water

Mixture	Water Temperature K	RPT range mol % of heavy component	Result Reproducibility
Ethane: Propane	293	15 – 30	75
	278	4.5 – 8	100
Ethane: n-butane	283	4.5 – 8	100
	293	2.5 – 9	100
	303	4.5 – 16	100
Ethane: n-pentane	293	2 – 9	100
Ethylene: n-butane	293	9 – 23	100
Ethylene: n-pentane	293	5 – 18	100

Peak pressures recorded were about 600 – 800 kPa (6 – 8 bars) and occurred within 4 ms from the start of an RPT. Spills were also made with mixtures containing methane and it was observed that the addition of as little as 10 mol % methane inhibited RPTs and none were ever obtained with methane concentrations in excess of 19 mol%.

ANNEX VII

Burro Series[8]

Test Setup

Eight LNG spills were performed at Naval Weapons Center, China Lake, CA in the summer of 1980.

Spill dimensions
These experiments involved 24 – 39 m^3 of LNG onto water.

Instrumentation and data acquisition system
There were 25 gas stations and 5 turbulence stations arranges in arcs at 57 m, 140 m, 400 m, and 800 m from the spill point. Seven of the gas stations and one turbulence center measured humidity. In addition there were 20 wind field stations equipped with anemometers.

ANNEX VII

Table 3: Burro experiment and meteorological data summary

Test	Date (1980)	Spill vol. m^3	Spill rate m^3/min	Avg. wind speed m/s	Spill duration sec.	Avg. wind direction Deg.	Atm. stability	Rel. humidity (avg. upstream & downstream) %	Temp. at 2-m ht. °C
Burro-2	18 Jun.	34.3	11.9	5.4	173	221	Unstable	7.1	37.6
Burro-3	2 July	34.0	12.2	5.4	167	224	Unstable	5.2	33.8
Burro-4	9 July	35.3	12.1	9.0	175	217	Slightly unstable	2.8	35.4
Burro-5	16 July	35.8	11.3	7.4	190	218	Slightly unstable	5.75	40.5
Burro-6	5 Aug.	27.5	12.8	9.1	129	220	Slightly unstable	5.0	39.2
Burro-7	27 Aug.	39.4	13.6	8.4	174	208	Neutral to slightly unstable	7.1	33.7
Burro-8	3 Sept.	28.4	16.0	1.8	107	235	Slightly stable	4.6	33.1
Burro-9	17 Sept.	24.2	18.4	5.7	79	232	Neutral	13.1	35.4

Notes: Atmospheric stability based on Richardson number.

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29

ANNEX VII

Test Conditions

LNG composition

Test	Component (mol %)		
	Methane	Ethane	Propane
Burro-2	91.3	7.2	1.5
Burro-3	92.5	6.2	1.3
Burro-4	93.8	5.1	1.1
Burro-5	93.6	5.3	1.1
Burro-6	92.8	5.8	1.43
Burro-7	87.0	10.4	2.6
Burro-8	87.4	10.3	2.3
Burro-9	83.1	13.9	3.0

Meteorological information

Please refer to Table 3.

Test Data[9]

Test	Spill plate depth (10^{-2}) m	Pond temp.	RPT explosion	Max. Point source yield[1] kg TNT
Burro-2	5	Greater than 17 °C	-	-
Burro-3	5		-	-
Burro-4	Below water		-	-
Burro-5	At water level		-	-
Burro-6	-		Large delayed	-
Burro-7	Above water		-	-
Burro-8	Above water		-	-
Burro-9	5 (initially)		Large early	3.5

Notes: TNT equivalence is based on the assumptions that the explosion is a point source and that the surface shock waves reflection produces an overestimate of the explosive energy by a factor of 1.8.

During the test a spill plate was located at the spill point in order to keep LNG from impinging upon and eroding the pond bottom. This plate was adjustable from a location slightly above the water surface to about 30 cm below it. No early RPTs occurred when the spill plate was located at or above the water surface while the largest RPTs occurred when the spill plate was absent.

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30

ANNEX VII

The largest RPT observed was during the Burro-9 experiment where there was no spill plate and the spill rate was near maximum. Details of the times and magnitude of RPT explosions for Burro-9 are summarized in Table 4.

Table 4: Burro-9 RPT details[9]

Time[1]	Side-on pressure[2]	TNT equivalence[3]
sec.	kPa	kg
6.5	827	0.036
7.1	1034	0.064
9.2	1861	0.295
21.4	3928	1.890
35.1	4962	3.500
43.2	689	0.023
46.0	827	0.036
54.1	827	0.036
54.9	896	0.045
66.9	1309	0.120
72.7	827	0.036

Notes: 1. t = 0 is start of spill valve opening.

2. Measured as a distance of 30 m

3. Equivalent free-air point-source explosion of TNT

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ANNEX VII

Coyote Series[10]

Test Setup

The Coyote Series was conducted by Lawrence Livermore National Laboratory (LLNL) and Navy Weapons Center (NWC) in the summer and fall of 1981 at China Lake, CA, under the joint sponsorship of DOE and GRI, to investigate further Rapid Phase Transition (RPT) explosions and to determine the characteristics of fires resulting from ignition of vapor clouds of LNG spills. The series consisted of ten experiments, five emphasizing vapor cloud fires and five for investigating RPT explosions.

Spill dimensions

Coyote-1 was a small spill (14 m^3) at a rate of 6 m^3/min as a result of spill malfunction. The remaining RPT spills (Coyote 4 and 8-10) consisted of three spills each. The first vapor burn experiment Coyote-2 was conducted to assess instrument capability and survivability in vapor fires. Coyote 3, 5, and 6 involved larger spills of LNG ranging from 14.6 to 28 m^3. Coyote-7 and Coyote-8 were methane spills and Coyote-9 was performed with liquid nitrogen. In the vapor burn experiments dispersion data prior to ignition was obtained. The meteorological array and sensors were operational for Coyote-3 – 10.

Instrumentation and data acquisition system

The arrays of wind-field and gas-plus-turbulence stations are modifications of those used in the Burro series. All but six of the 31 gas and turbulence stations and five of the 20 wind field stations were located between 140 and 400 m. A total of 89 gas-concentration sensors were deployed on twenty-four gas stations and five of the six turbulence stations. LNG impact pressures and exit temperatures were measured at the spill point along with LNG composition. In addition, LNG vapor concentrations were measured at three different locations in the pond as shown in. Blast-gauges to measure RPT blast overpressures were provided at five different locations above and below the water surface and are illustrated in. No data were obtained from underwater blast gauges during any of the tests due to an electrical grounding problem.

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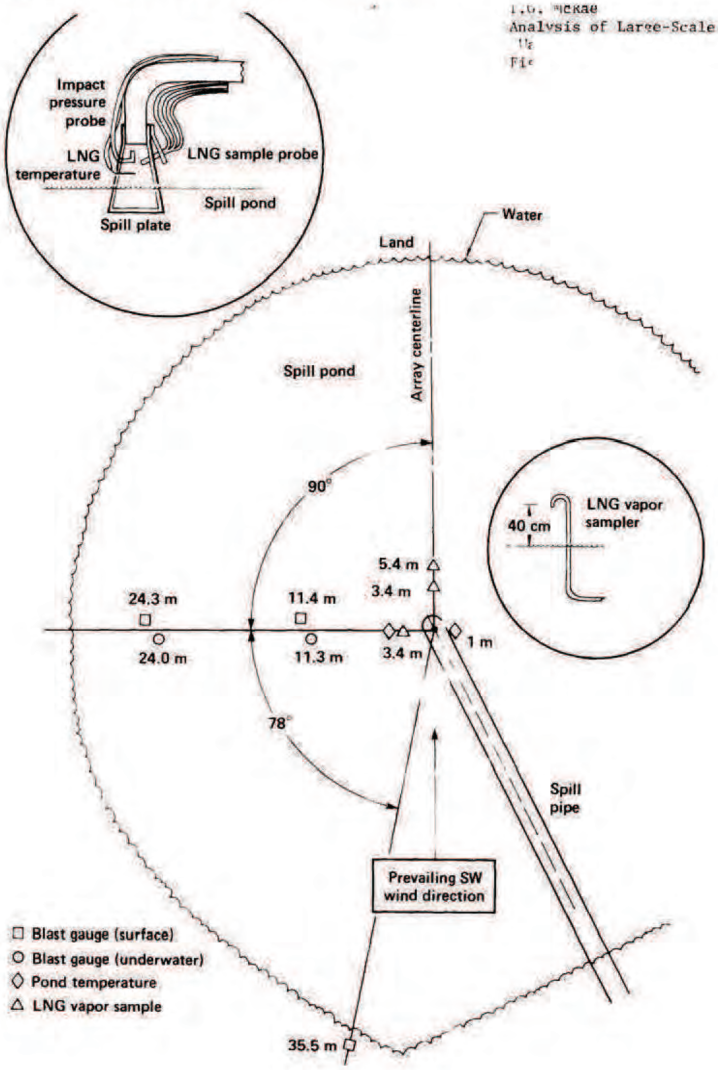
32

ANNEX VII

Figure 13: Array of RPT diagnostic instrumentation[10]



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33

ANNEX VII

Table 5: Coyote experiment and meteorological data summary

Test	Test type	Date (1981)	Spill rate m^3/min	Spill vol. m^3	Spill duration sec.	Avg. wind speed m/s	Avg. wind direction Deg.
Coyote-1	RPT	30 July	6	14	-	-	-
Coyote-2	Vapor burn	20 Aug.	16	8	-	-	-
Coyote-3	Vapor burn	3 Sept.	13.5	14.6	65	6	205
Coyote-4	RPT	25 Sept.	6.8 12.1 18.5	3.8 6.0 5.2	34 30 17	6.2 6 7.4	181 190 197
Coyote-5	Vapor burn	7 Oct.	17.1	28	98	9.7	229
Coyote-6	Vapor burn	27 Oct.	16.6	22.8	82	4.6	220
Coyote-7[a]	Vapor burn	12 Nov.	14.0	26	111	6.0	210
Coyote-8[a]	RPT	13 Nov.	7.5 14.2 19.4	3.7 5.4 9.7	30 23 30	8.4 9.0 8.5	206 209 214
Coyote-9[b]	RPT	16 Nov.	7.2 9.9 13.3	3.6 3.3 8.2	30 20 37	2.6 4.2 4.2	158 193 187
Coyote-10	RPT	24 Nov.	13.8 19.3 18.8	4.6 4.5 5.0	20 14 16	7.6 8.6 7.2	223 229 248

Notes: a. Liquid Methane spill; b. Liquid nitrogen spill

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34

ANNEX VII

Test Conditions

LNG composition

Test	Component (mol %)		
	Methane	Ethane	Propane
Coyote-1	-	-	-
Coyote-2	-	-	-
Coyote-3	79.4	16.4	4.2
Coyote-4	78.8	17.3	3.9
Coyote-5	74.9	20.5	4.6
Coyote-6	81.8	14.6	3.6
Coyote-7	99.5	0.5	-
Coyote-8	99.7	0.3	-
Coyote-9	-	-	-
Coyote-10	70.2	17.2	12.6

Test Data

Test		Spill plate depth (10^2)	Impact pressure (kPa)		Pond temp.	RPT explosions	Max. point source yield
		m	Max.	Avg.	°C		kg TNT
Coyote-1		30	5.5	1.4	30	Small early Large delayed	-
Coyote-2		2.5	34.5	34.5	27.6	Small early	0.23
Coyote-3		2.5	68.9	41.3	22.8	-	-
Coyote-4	a.	25	16.5	2.8	22.4	Small early	0.001
	b.	25	34.5	20.7	20.6	-	-
	c.	25	68.9	34.5	20.2	Large early	1.5
Coyote-5		6	89.6	55.1	17.2	Large delayed	3.0
Coyote-6		5	89.6	55.1	15	-	-
Coyote-7		33	103.4	41.3	13.6	-	-
Coyote-8	a.	33	13.8	4.1	12.8	-	-
	b.	33	68.9	27.6	12.7	-	-
	c.	33	96.5	75.8	12.3	-	-
Coyote-9	a.	36	13.8	1.4	14.1	-	-
	b.	36	55.1	20.7	14.8	-	-
	c.	36	103.4	68.9	15.8	-	-
Coyote-10	a.	36	55.1	34.5	10.6	-	-
	b.	36	96.5	68.9	10.6	-	-
	c.	removed	82.7	62.0	11.6	Small early	0.005

RPT yield correlates favorably with spill rate. The data indicates an apparent threshold or abrupt increase in the RPT explosive yield at a spill rate of about 15 m^3/min.[9] For large scale spills large RPTs can occur for initial methane composition as high as 90%.[9]

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35

ANNEX VII

Falcon Series[11]

Test Setup

A series of five LNG spills on water up to 66 m^3 in volume were performed within a vapor barrier structure at Frenchman Flat on Nevada Test Site by Lawrence Livermore National Laboratory (LLNL) for the Department of Transportation (DOT) and the Gas Research Institute (GRI) in the summer of 1987. These tests were performed to evaluate the effectiveness of vapor fences as a mitigation technique for accidental release of LNG.

Spill dimensions

Test	Date	Spill rate	Spill vol.	Spill duration
	(1987)	m^3/min	m^3	sec.
Falcon-1	12 June	28.7	66.4	138.8
Falcon-2	18 June	15.9	20.6	77.7
Falcon-3	29 June	18.9	50.7	160.9
Falcon-4	21 Aug.	8.7	44.9	309.7
Falcon-5	29 Aug.	30.3	43.9	86.9

Instrumentation and data acquisition system

A barrier was placed upwind of the pond inside the fence to generate turbulence typical of a storage tank. Gas concentration, wind field, turbulence, temperature, heat flux, humidity, and air pressure were measured during each experiment.

Test Conditions

LNG composition

Test	Component (mol%)	
	Methane	Heavies
Falcon-1	94.7	3.9
Falcon-2	95.6	3.7
Falcon-3	91.0	8.0
Falcon-4	91.0	8.0
Falcon-5	88	10

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36

ANNEX VII

Meteorological information

Test	Avg. wind speed at 2-m ht. m/s	Avg. wind direction at 2-m ht Deg.	Rel. humidity %	Stability class
Falcon-1	1.7	5.46	-	G
Falcon-2	4.7	8.27	-	D
Falcon-3	4.1	8.41	4	D
Falcon-4	5.2	5.82	12	D/E
Falcon-5	2.8	7.70	13.7	E/F

Test Data[12]

Test	Notes
Falcon-1	Significant overfilling of vapor barrier structure causing excessive spilling early in the test
Falcon-2	-
Falcon-3	-
Falcon-4	RPT explosions started at 60 s
Falcon-5	RPT explosions started at 60 s. Fire started at 81 s

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ANNEX VII

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ANNEX – VIII

(LNG POLICY 2011)

ANNEX VIII

GOVERNMENT OF PAKISTAN
Ministry of Petroleum & Natural Resources

LIQUEFIED NATURAL GAS (LNG)POLICY, 2011

ANNEX VIII

TABLE OF CONTENTS

ANNEX VIII

-3-

1. Introduction

Pakistan's policy for the sustainable development of the energy sector, including the provision of reliable and competitively-priced energy is based on the following objectives:

(a) Optimization of the primary energy mix, based on economic and strategic considerations;

(b) Maximizing the utilization of indigenous energy resources;

(c) Enhancing private sector participation in the energy sector by strengthening the regulatory framework and institutional capacity;

(d) Developing energy infrastructure; and

(e) Developing human resources with emphasis on energy sector-specific technical skills and expertise

Natural gas plays a key role in Pakistan's energy balance which is currently around 50% of the country's primary energy supplies. With accelerating economic growth, the demand for gas is projected to increase sharply and the country's recoverable indigenous gas reserves will be insufficient to meet this demand. Gas shortages have already emerged and shall increase substantially in the following years if indigenous supply is not supplemented through imports. In order to address the shortage, strong emphasis is being laid on importing gas from neighbouring gas-producing countries through cross-border gas pipelines and also in the form of liquefied natural gas ("LNG"). Necessary measures are being taken for installation of LNG receiving, storage, re-gasification facilities and expansion of gas transmission infrastructure, for the distribution and sale of regasified LNG ("RLNG") in the domestic market.

The LNG Policy 2006 has been modified to facilitate expeditious implementation of the LNG Projects.

2. LNG Import Project Structure

An LNG import project may be structured under one of the following alternatives:

(a) **Integrated project structure**, under which a private or public sector party, joint venture or consortium (hereinafter referred to as "LNG Developer") is responsible for purchasing LNG supplies, transporting them to its LNG import terminal (comprising of receiving, storage and re-gasification facilities) and supplying RLNG to the domestic market and/or for its own use. The LNG Developer would enter into a Gas Sales and Purchase Agreement (GSPA) directly with a Government-designated buyer, gas utility or any customers (hereinafter referred to as "RLNG Buyer(s)"); or

(b) **Unbundled project structure**, under which:

i. A Government designated buyer, gas utility, any consumer or any LNG supplier (hereinafter referred to as "LNG Buyer(s) would directly import the LNG under a LNG Sale and Purchase Agreement ("SPA") either on a delivered ex ship (DES) basis, or a free-on-board (FOB) basis, or C&F basis.

ANNEX VIII

ii. For FOB purchase, the LNG Buyer would in addition, enter into an agreement with a shipping company to transport LNG to the receiving terminal.

iii. The LNG Buyer(s) would enter into an agreement with the LNG Terminal Owner and/or Operator (hereinafter referred to as the "LNG TO/O") for the provision of LNG receiving, storage and re-gasification services at its terminal under a tolling agreement.

3. LNG Procurement

3.1. An LNG Developer or LNG Buyer as the case may be, will be allowed to import LNG in accordance with applicable import laws, rules and regulation. While issuing licence to an LNG Developer or RLNG Seller, the Oil and Gas Regulatory Authority (OGRA will take into account Government policy guidelines and will adopt following criteria to ensure sustainability of LNG chain:

(a) For the LNG Developer, at least one member of the consortium will be required to have technical and commercial experience along the LNG supply chain.

(b) LNG Developer or LNG Buyer /RLNG Seller will provide evidence of sufficient purchase commitment (in the form of a HOA) from end users for a minimum volume of RLNG sufficient to support the terminal investment and the potential for further sales, if necessary, in order to cover the full contractual LNG purchase commitment.

(c) Notwithstanding the above, LNG imports can also be made on spot purchases based on market and commercial considerations.

(d) For avoidance of any doubt, it is stated that a licence will not be required for import of LNG by LNG Developer and LNG Buyer, as the case may be.

3.2. Procurement of LNG by the LNG Buyer(s) will be undertaken through one of the following approaches:

(a) Direct negotiations with one or more LNG suppliers for supply of LNG for a reasonable time to be determined by OGRA;

or

(b) International competitive bidding for the supply of LNG for a reasonable time to be determined by OGRA;

or

(c) Direct purchase from the LNG spot market based on market and commercial considerations on a competitive basis, excluding supply to public sector gas utilities.

3.3. If procurement of LNG is undertaken by a public sector entity, the Government may authorize the entity to adopt the direct negotiation approach with a group of LNG suppliers if the demand-supply dynamics of LNG require this approach to be adopted.

Annex VIII

-5-

4. Ownership & Operation of the LNG Terminal

4.1 The LNG Developer or LNG TO/O, as the case may be, will obtain a license to design, construct, operate and own a LNG terminal from OGRA under the Oil and Gas Regulatory Authority Ordinance, 2002 subject to satisfying the following criteria:

(a) **Technical:** At least one member of the consortium of LNG Developer or LNG TO/O, as the case may be, should have experience in developing and operating a liquefaction plant or a regasification terminal. The LNG terminal will be constructed based on technical standards as prescribed by the OGRA from time to time, in consultation and approval of Department of Explosives, including internationally acceptable industry technical standards as stipulated in Appendix-1.

(b) **Financial:** The LNG Developer or LNG TO/O consortium (on a several or joint and several basis) should have liquidity, revenues, net income and net worth above prescribed minimum thresholds (to be set by OGRA taking into consideration the financial obligations associated with the development and operation of the LNG import terminal).

(c) **Health, Safety & Environmental ("HSE") Standards:**

i. The LNG Developer, LNG TO/O or LNG Buyer as the case may be, will ensure that the project complies with World Bank HSE Guidelines, Pakistan's Environmental Protection Act 1997 rules, regulations and guidelines made thereunder, National Environmental Quality Standards, Pakistan's health, environment and safety standards and is consistent with the best international LNG industry practices.

ii. The LNG Developer or LNG TO/O will undertake a comprehensive environmental impact assessment of the design, construction and operational aspects of the project including impact assessment of shipping associated with the project, in accordance with international standards and practices. The studies and approvals required at the planning, construction, commissioning and operating phases are defined in the Pakistan Environmental Protection Act, 1997.

iii. All LNG terminals shall be surrounded by safety zones which shall meet the industry standards set forth in safety codes of the National Fire Protection Association of USA and as per the risk assessment studies so as to ensure protection of neighbouring communities and shipping traffic.

(d) **Site approval:** The site (either land based terminal or offshore terminal of any type) for setting up an LNG terminal shall be selected by LNG Developer or LNG TO/O, as the case may be, taking into account the following factors:

i. Existing and projected population and demographic characteristics of the location;

ii. Existing and proposed land use near the location;

iii. Physical aspects of the location;

ANNEX VIII

iv. Medical, law enforcement and fire protection capabilities near the location that can cope with a risk caused by the facility;

v. Exclusion zone distances from the terminal to property and population as per international standards are complied with;

vi. Proximity to existing gas infrastructure and market;

vii. Need to encourage remote sitting;

viii. Any other significant community concerns; and

ix. Environmental considerations.

4.2 In applying for the licence, the LNG Developer or LNG TO/O will have the onus of demonstrating compliance with the above criteria through risk assessment and simulation studies.

4.3 Port Authorities will convey their decision on acceptance of site within one month of submission of NOC from SEPA, QRA study and navigational simulation study.

4.4 The licensee shall:

(a) ensure delivery of LNG on fast track basis,

(b) furnish guarantee against it commitment.

4.5 In case of licensee's failure to deliver LNG by stipulated date its right to Third Party Access will be subject to cancellation / review by OGRA.

5. RLNG Marketing & Transportation

5.1. An LNG Developer or LNG Seller, as the case may be, will obtain a license to market and sell RLNG in the domestic market including in the areas covered by the gas pipeline network of SSGC and SNGPL from OGRA under the provisions of OGRA Ordinance, 2002 and subject to the terms and conditions of the licenses issued by OGRA to SSGC and SNGPL.

5.2. Subject to para 6.4 below, an LNG Developer or LNG Seller, as the case may be, will be required to obtain a license to construct and operate gas pipelines from OGRA under the provisions of the OGRA Ordinance 2002.

5.3. Parties interested in the local small scale production, transportation and distribution of LNG produced from domestic gas, for example through LNG trucks will be required to obtain a license from OGRA.

6. Regulatory Framework

6.1. **Construction period:** At the construction stage, OGRA will ensure that the following parameters are included in the license to be issued to the LNG Developer or LNG TO/O, as the case may be, and the licensee comply with the same:

(a) **Technical parameters:** The terminal complies with internationally recognized and proven standards for LNG installations prescribed by OGRA from time to time including those specified in Appendix-1.

(b) **HSE standards:** The project meets the HSE standards specified in the license.

ANNEX VIII

-7-

(c) **Other permits and approvals:** Permits and licenses from Government departments such as Ministry of Defence, Port Authorities, Environmental Protection Agency, Chief Inspector of Explosives and provincial and local government agencies have been obtained.

6.2. **Operating period:** During the operating period, OGRA will regulate the following:

(a) **Access rights:** All LNG terminals and associated facilities will be operated on a system of regulated third party access ("RTPA") based on published / negotiated tolling tariffs in an objective competitive environment without discrimination excluding however tolling tariff for public sector shall require OGRA's approval.

Exceptions from such regulation will be given to those LNG terminals and associated facilities that are developed for own or dedicated use. Access to such terminals will be based on negotiated third party access ("NTPA"). RTPA and NTPA will be administered by OGRA through a clear regulatory mechanism. It is clarified that the LNG Developer will have priority access to its own LNG terminal capacity provided it has firm capacity utilization plan for own or dedicated use for a minimum period of 10 years.

(b) **Terminal tariff and returns:** In case of sale to public sector gas utility OGRA will approve tolling tariff negotiated between the utility companies and LNG TO/O on the basis of following components:

i. Capacity or fixed element covering capacity reservation and other fixed charges;

ii. Variable elements covering the variable operation and maintenance charges of the LNG terminal.

iii. Utilization of capacity.

(c) In order to ensure that the capacity of an LNG terminal is optimally utilized, OGRA will adopt and implement the mechanism of "Use-it-or-lose-it".

(d) **Reporting requirements:** The LNG Developer or LNG TO/O, as the case may be, will have to publish capacity utilization rates and tariffs as approved by OGRA and at such regular intervals as may be determined by OGRA.

(e) **LNG Storage Facility:** Gas storage facility may be developed by the LNG Developer/ LNG TO/O. Gas Storage may be allowed at a tariff determined by OGRA.

6.3. **Gas Pricing:**

(a) For RLNG supply to SSGC and SNGPL, the RLNG price will be an input for determining the weighted average cost of gas in Pakistan, determined by OGRA, for GoP specified consumers and industry.

(b) The LNG Developer/ LNG Buyer will have the right to sell RLNG to end users directly based on a negotiated price.

(c) SSGCL/SNGPL will not sell gas priced under 6.3 (a) to industries which are selected by GoP to use RLNG from time to time.

ANNEX VIII

-8-

6.4. **Gas Transmission:** OGRA will ensure that subject to capacity being available, the LNG Developer or LNG Seller or RLNG Buyer, as the case may be, will have access to the SSGC and SNGPL pipeline network or any other new entity at a transportation tariff to be determined under Third Party Access (TPA) Rules even after privatization of these two entities. If SSGC/SNGPL do not have available capacity, the LNG Developer or LNG Buyer or RLNG Buyer, as the case may be, can request SSGC/SNGPL or any other operator of pipeline to expand capacity based on technical and economical considerations or may construct its own pipeline subject to grant of license by OGRA. In determining available capacity, OGRA would consider the capacity that could be made available by swapping gas between SSGC and SNGPL systems.

6.5. **RLNG Quality:** The quality of RLNG which is to be injected into the transmission and distribution network of the gas companies shall be compatible with the quality of gas in such system and which shall be reviewed by the Gas Companies according to OGRA's notified gas specifications.

(a) The blending/dilution of RLNG to meet the quality required shall be the responsibility of the LNG Developer / LNG Seller.

7. Government Incentives

7.1 The following fiscal incentives will be granted to the LNG Developer, LNG TO/O or LNG Buyer as applicable:

(a) Zero percent customs duty will be charged on imported LNG. LNG Buyer or LNG Developer importing LNG will also be exempted from withholding tax at import stage in respect of such import. FBR will issue necessary notification in this regard.

(b) Exemption from custom duty in excess of 5% with total exemption from sales tax in respect of plant, equipment and machinery, not locally manufactured, imported by that LNG Developer or LNG TO/O, as the case may be, by expanding the scope of SRO 678(1)/2004, dated 7/08/2004. Import of such plant, machinery and equipment and parts will also be exempted from withholding tax at import stage as allowed under clause 56(vii) of the part (vi) of the second schedule to the Income Tax Ordinance, 2001;

(c) Initial Allowance will be admissible at the rate of 50% of the cost of depreciable assets under section 23 of the Income Tax Ordinance, 2001. In addition, normal deprecation at the rate of 10% will be also allowed on plant and machinery.

(d) Exemption from withholding tax on interest payments to foreign lenders will be allowed as permissible under various provisions of the Income Tax Ordinance, 2001.

(e) Sales tax and Federal excise duty will be charged on import and supply of LNG at applicable rates.

7.2 When an LNG Developer or LNG TO/O, as the case may be, has identified a suitable site (whether land based or offshore), the Government will actively assist the LNG Developer or LNG TO/O, as the case may be, in obtaining land and port facilities for an LNG terminal at a reasonable cost and within a reasonable time frame.

ANNEX VIII

-9-

7.3 The Government will encourage the participation of multi-lateral development banks (MDBs) in LNG import projects to facilitate the financing of such projects inter alia through equity participation by MDBs and MDB instruments such as political risk guarantees and partial credit guarantees.

7.4 A Task Force headed by the Secretary, Petroleum and Natural Resources and comprising Additional Secretary of Finance, Defence, Industries, Ports and Shipping Divisions, a representative of OGRA, Member (Customs)-FBR, Chairman of the concerned seaport authority, Director Generals of the concerned EPA, Coast Guards and Maritime Security Agency and Commander Karachi or COMCOAST Gawadar, to facilitate the implementation of LNG import Projects, as notified under LNG Policy, 2006, will remain intact. This Task Force will act as a "one-stop-shop" to address all issues concerning LNG import projects, including the interpretation of policies and regulations.

8. Pricing of RLNG

8.1. With an integrated or an unbundled approach, RLNG will be procured by gas utilities / RLNG Buyer(s) in the public / Private sector for Medium / Long Term from a LNG Developer or RLNG Seller who offers the lowest price at a designated point of delivery. This price will be the input price to the weighted average cost of gas in Pakistan as per para 6.3(a) above.

8.2. In case LNG/RLNG is procured by the public sector, the price of RLNG will be determined by the OGRA at the terminal flange based on (i) the LNG purchase price; (ii) the direct and indirect costs of transportation, storage, and re-gasification incurred by the LNG Developer / TO/O, and (iii) a reasonable return on the investment made by the LNG Developer / TO/O.

8.3. RLNG can also be procured by private sector, by public sector or in public-private partnership based on lowest price demonstrable to the regulator.

9. Government Guarantee

The Government shall not provide any guarantee for LNG import projects. However, Government support may be considered, if needed, to secure long term, LNG supplies to Pakistan.

10. Freedom to Participate in the LNG Business

All interested parties who meet the criteria provided herein will be free to participate in any segment of the LNG value chain.

11. Technical Codes and Standards

11.1 The design, construction and operation of the LNG import project facilities will comply with internationally recognized and proven codes and standards for LNG installations including those specified in Appendix-1.

11.2 No second-hand or refurbished LNG plant, equipment, machinery or part thereof will be installed at the LNG terminal or at associated facilities. In case of offshore LNG terminals, used LNG ships utilized for either conversion into a floating LNG terminal or for storage of LNG in association with an offshore LNG terminal will be allowed by OGRA as long as the vessels maintain their classification status certified by one of the IACS member classification

Annex VIII

societies as approved by Director General Port and Shipping and hold all valid class and flag state statutory certificates.

11.3 OGRA will issue a license for an LNG terminal based on a suitable, tested and proven internationally acceptable technology for the design, construction, and operation of the LNG terminal and associated facilities.

11.4 Following receipt of a complete application, covering all relevant aspects of the proposed LNG project including a comprehensive feasibility study undertaken by a project proponent through a consultant of international repute, OGRA will undertake a full review and audit of the proposed project at the cost of the project proponent (including the cost related to outsourcing of the expertise, if necessary) and take a decision regarding issuance of a license or rejection of the application within 90 days.

11.5 All LNG ships entering Pakistan's maritime zones shall comply with International Maritime Organization's regulations.

12. Shipping of LNG

All LNG ships transporting LNG to Pakistan will have to be registered with an acceptable international classification society.

13. Other Permits and Licenses

The LNG Developer, LNG TO/O, LNG Buyer or RLNG Seller will have to obtain permits and licenses from Government departments such as Ministry of Defence, Naval Headquarters, Port Authorities, Environmental Protection Agency, Chief Inspector of Explosives, and provincial and local government agencies, as per applicable laws, rules and regulations.

14. Other Measures

14.1 In order to facilitate early start of an LNG import project, OGRA will take a decision regarding issuance of a license or rejection of the application under OGRA Ordinance, 2002 for setting-up and operation of an LNG terminal and related facilities to a qualified selected applicant, having the requisite technical and financial credentials, for a specified location within 90 days provided however, that the applicant has submitted a complete application along with detailed feasibility study. If the applicant does not achieve financial close within 12 months of issuance of the license, OGRA may terminate the license on one month's notice.

14.2 The Government may issue instructions to OGRA from time to time for implementation of this Policy and/or in respect of matters related thereto, as may be considered necessary.

14.3 If any difficulty arises in giving effect to any provision of this Policy, the Government may issue such order as may appear to it to be necessary for the purpose of removing the difficulty.

Annex VIII

-11-

15. Applicability and Effect of the Policy

This Policy will come in force with immediate effect and will apply to all LNG import projects in Pakistan.

ANNEX VIII

-12-

Appendix: 1

TECHNICAL CODES AND STANDARDS

The design, construction and operation of the LNG terminal and allied facilities will satisfy *inter-alia* the following internationally recognized and proven codes, standards and guidelines for land based and offshore LNG installations (or equivalent):

Shipping and Marine Facilities

Standards

- Standard for the Production, Storage and Handling of Liquefied Natural Gas (LNG) – 2006, NFPA 59A, NFPA.
- Installations and Equipment for Liquefied Natural Gas – Design of Onshore Installations – 1997, (BS EN 1473) CEN.
- Installations and Equipment for Liquefied Natural Gas – Design and Testing of Loading/Unloading Arms – 1996, (BS EN 1474) CEN.
- Installations and Equipment for Liquefied Natural Gas – Ship to Shore Interface for Liquefied Natural Gas – 1996, (BS EN 1532) CEN.
- Installations and Equipment for Liquefied Natural Gas – General Characteristics of Liquefied Natural Gas – 1997, (BS EN 1160) CEN.
- Maritime Structures – Part 1, General Criteria – 1984, (BS 6349), BSI.
- Maritime Structures – Part 4, Code of Practice for Design of Fendering and Mooring Systems – 1994, (BS 6349), BSI.
- IGC Code – IMO-104E – International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk – IGC Code, 1993 including amendments.
- Guidance Notes, Classification and Certification of Floating Offshore Liquefied Gas Installations – Lloyd's Register, April 2004, Revision 2.
- Guidance Notes, Classification and Certification of Offshore Gravity Based Liquefied Gas Terminals – Lloyd's Register, April 2004, Revision 1.

Guidelines

- Site Selection and Design for LNG Ports and Jetties – 1997, SIGTTO, ISBN 1 85609 129 5.
- Recommendations on the Safe Transport of Dangerous Cargoes and Related Activities in Port Areas – 1995, (IMO 290E) IMO, ISBN 92-801-1329-1.
- Dangerous Goods in Ports: Recommendations for Port Designers and Port Operators – 1985, PIANC.
- Mooring Equipment Guidelines – 1996, (OCIMF) Oil Companies International Marine Forum, ISBN 1 85609 088 4.

13

- Prediction of Wind Loads on Large Liquefied Gas Carriers – 1985, SIGTTO, ISBN 0 90088697 8.
- Big Tankers and their Reception – 1974, PIANC.
- Guidelines on Port Safety and Environmental Protection – 1989, IAPH.

Operating Practices

- Accident Prevention – the Use of Hoses and Hard-Arms at Marine Terminals Handling Liquefied Gas – 1996 SIGTTO, ISBN 1 85609 1147.
- Manual on Chemical Pollution: Section 1: Problem Assessment and Response Arrangements – 1987, (IMO 630E) IMO, ISBN 92-801-1223-6.

ANNEX VIII

-13-

- A Guide to Contingency Planning for Marine Terminals Handling Liquefied Gases in Bulk – 1989, SIGTTO, ISBN 0 948691 81 6.
- APELL: Awareness and Preparedness for Emergencies at Local Level – 1988, (UNEP) United Nations Environment Programme, ISBN 92807 1183 0 – 00900P.
- Offshore Loading Safety Guidelines with Special Relevance to Harsh Weather Zones – 1999, OCIMF, ISBN 1 85609 1481.
- Tug Use in Port – H Hensen, Nautical Institute, 1997, ISBN 1 870077 39 3.
- Guidelines for Hazard Analysis as an Aid to Management of Safe Operations – 1992, SIGTTO, ISBN 1 85609 054 X.

Onshore LNG Terminal

Standards

- Standard for the Production, Storage and Handling of Liquefied Natural Gas (LNG) – 2006, NFPA 59A, NFPA.
- Design and Construction of Large, Welded, Low – Pressure Storage Tanks, Appendix R - Low pressure Storage tanks for Refrigerated Products, (API 620 R).
- Installations and Equipment for Liquefied Natural Gas – Design of Onshore Installations – 1997, (BS EN 1473) CEN.
- Flat-Bottomed, Vertical, Cylindrical Storage Tanks for Low Temperature Service, (BS 7777).
- Installations and Equipment for Liquefied Natural Gas – General Characteristics of Liquefied Natural Gas – 1997, (BS EN 1160) CEN.
- Criteria for design and construction of refrigerated liquefied gas storage tanks – 'EEMUA 147'.

ANNEX – IX

(APPROVALS FROM EPA SINDH)

Reference No: EPA/2011/2/21/EIA/58

ENVIRONMENTAL PROTECTION AGENCY
GOVERNMENT OF SINDH

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Facsimile: 5065940

Dated: 07-07-2011

Subject: DECISION ON ENVIRONMENTAL IMPACT ASSESSMENT (EIA).

1.	**Name & Address of Proponent:**	**Sheikh Imran ul Haque** **Chief Executive Officer,** **Engro Vopak Terminal Limited,** **Port Qasim, Karachi.**
2.	**Description of Project:**	**Construction and Operation of Liquefied Natural Gas terminal at Port Qasim.**
3.	**Location of Project:**	**Port Qasim, Karachi.**
4.	**Date of Filing of EIA:**	**01-02-2011**

5. After careful review of the Environmental Impact Assessment (EIA) report, the Environmental Protection Agency (EPA), Sindh has decided to accord its Approval subject t to the following conditions:

   i. that Proponent will ensure state of the Art and International Standards for Safety of terminal, storage facility and all other installation to prevent any safety related hazard. In case of any unfortunate incident of leakage, fire and leading disaster the proponent will be responsible for compensation to any affected people, also for damage caused to environment and natural resources. To cope with the hazard emergency response, contingency plan should be developed prior to operational phase of the project.

   ii. that the proponent will ensure that adequate passage is provided on the Phitti Creek in order to avoid disturbance to fishing boats and other maritime activities approaching towards Korangi Fish Harbour. For this purpose dimension of terminal, storage vessel, berthing of importing ship and distance for security buffer will be kept to an optimum requirement. The construction and operation of proposed LNG terminal should not pose any threat to the livelihood of local fishermen and communities. In case of any damage to boats and equipment etc the proponent will provide compensation.

iii. that the LNG terminal, Storage vessel, berthing ship and security buffer should be restricted to an area in accordance to the recommendation of PQA. Cutting of mangroves will not allowed for construction of terminal and associated installation.

iv. that the proponent will utilize the clearance available within the mangroves plantation for passing the pipeline from storage vessel to the onshore transportation facilities and will not resort to cutting of mangroves plantation. Any damage to the mangroves plantation during the laying this pipe will have to be compensated by planting mangroves on 10 times of the area affected by the damage under the supervision and certification of IUCN,WWF and forest department, Govt of Sindh. For this purpose funds will be allocated ensure to maximum survival rate and monitoring till their sustainable growth.

v. that the proponent shall comply with National Environmental Quality Standard (NEQs) for air emissions and waste water to be generated during operational activities of the project.

vi. that all mitigation measures recommended in the EIA report must be strictly adhered to minimize negative environmental impact on the marine ecosystem.

vii. that standards for noise levels will be implemented in order to minimize noise level during construction and operation phase of the project.

viii. that dredged material will only be disposed off or used after its analyses from the laboratory for observance of contaminants. Approval of EPA will obtained for mode and place of its disposal on submission of lab analysis report.

ix. Adequate and proper maintenance of all pumps, valves and pipelines must be ensured to limit any fugitive natural gas and LPG emissions.

x. The seismic risk factor will be taken into account during the designing of structural facilities.

xi. Discharging and dumping of any kind of waste material into harbor waters will not be allowed, all importing ships will compile international maritime standards for disposal of their waste.

xii. Complete code of health, safety and environment (HSE) will be developed, which should include efficient parameters at specific work place. For this purpose HSE setup should be established supervised by a designated HSE officer at the senior level with sufficient administrative and technical authority to perform the designated function. Proponent will ensure that the operating instructions and emergency actions are made available to every worker/ commuter at the sight.

xiii. An independent environmental monitoring consultant will be engaged to monitor the implementation of EMP during construction and operation phase of the project and proponent will submit report to EPA Sindh on quarterly basis.

xiv. EVTL will carry out self-monitoring and reporting and will submit report to EPA Sindh, for the recommended parameters with their appropriate frequencies as listed in self –monitoring and reporting rules. All of the parameters should be ensured for compliance of NEQS limits. In case of exceeding the permissible limits, immediate appropriate arrangement will be taken including that of to shut down the operations.

xv. An effective solid waste management system will be developed which would cater to collection, transfer, recycling and final disposal of waste to a designated landfill site. The plan must address on site segregation of solid waste to promote its reuse and recycling. The oily sludge generated from oil storage tank during construction and operation of the project will be disposed off in accordance to best available practices, for which an inventory will be maintained for inspection and verification.

xvi. Due to project location and low liying area, a plan will be developed for conservation and rehabilitation of mangroves. For this purpose proponent will sponsor for plantation of mangroves in the existing swamps. This plan should be developed in consultation with the Fisheries Department, Government of Sindh, NGO's like WWF and IUCN Pakistan.

xvii. The proponent shall ensure facilitation to the EPA officer(s)/official(s) for the regular inspections to verify the compliance of the PEP Act, Rules and Regulations framed there under and the conditions contained in this approval.

xviii. Proper Coordination must be maintained with PQA on transportation and safety issues and they should be informed if any fire outbreaks to ensure timely mitigation. A contingency and emergency response plan will be developed in coordination with the concerned organizations to effectively address any risk/hazard caused during operational phase.

xix. Implementation of Environmental management plan and mitigation measures, monitoring, communication and documentation and environmental training will be the sole responsibly of Chief Executive of the EVTL. Change management orders would be informed to EPA Sindh for subsequent permission from this office.

xx. The proponent will submit progress report on quarterly basis, during construction of the project describing therein whether the project has been constructed in compliance with the Environmental Laws/Rules/Guidelines/Instructions and Conditions laid down in this approval.

xxi. All unskilled jobs will be provided to the local people. Skilled jobs will also be offered to local people after providing proper training.

6. This approval shall be treated as null and void if the conditions mentioned in this approval are not complied with or any violation of PEP Act, Rules, Regulations, Guidelines and instructions is observed by this office.

7. The proponent shall be liable for compliance of Regulations 13, 14 and 18 of EIA/IEE Regulation, 2000.

8. The proponent shall be liable for compliance of Regulations 17 of EIA/IEE Regulation, 2000, which permits the authority i.e. Environmental Protection Agency to enter, inspect and monitor the development of the project so that the conditions are effectively monitored.

9. This approval does not absolve the proponent of the duty to obtain any other approval or consent that may be required under any law in force.

10. This approval is accorded only for the proposed project activity described in the EIA report. Proponent shall submit separate EIA or IEE as required under regulations for any enhancement or change in the design of proposed project.

11. All relevant conditions of this approval shall be incorporated in the terms and conditions of tender documents of the project for strict compliance. However overall responsibility for compliance of conditions of this approval shall be on the proponent. EPA Sindh at any stage of construction and operation of the project reserves the right to issue instruction for an independent audit to ensure that the project is being constructed and operated under strict compliance of Environmental legislation and conditions of this approval.

Naeem Ahmed Mughal
Director General

Reference No: EPA/2012/7/17/IEE/321

ENVIRONMENTAL PROTECTION AGENCY
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Dated: 08-10-2012

Subject: DECISION ON INITIAL ENVIRONMENTAL EXAMINATION(IEE).

1.	**Name & Address of Proponent:**	Sheikh Imranul Haque Chief Executive Officer Elengy Terminal Pakistan Limited Karachi.
2.	**Description of Project:**	Construction/laying of a High pressure transmission pipeline including construction of Nitrogen Blending Facility at Linde Pakistan, Port Qasim.
3.	**Location of Project:**	Port Qasim and barren area in Northeast corner of the intersection of the Pakistan Railway line and National Highway N-5.
4.	**Date of Filing of IEE:**	17-07-2012

5. After careful review of the Initial Environmental Examination (IEE) report, the Environmental Protection Agency (EPA), Sindh has accord its approval subject t to the following conditions:

- **i.** that the proponent is allowed to proceed with the construction of new facility at Port Qasim in the PQA master plan which must permit to setup the project within the rules required for the same.
- **ii.** Mitigation measures recommended in the IEE report shall be strictly adhered to minimize any adverse impact on soil, ambient air quality, biological resources and marine ecosystem in the project area.
- **iii.** All issues of dust emissions, handling of constructions waste, water consumption, vibration and noise, fuel storage, air quality, traffic flow, effluent, solid waste management and disposal, energy requirement will be dealt in accordance to the environmental management plan provided in the IEE report.
- **iv.** Clearing of vegetation/mangroves along the right of way of the pipeline will be minimized.

v. Restoration of sections of ROW will be completed immediately after the laying of pipeline.

vi. To reduce volume of concentration of pollutant appropriate techniques for recycling and reuse will be applied, treated water can be used for washing operation.

vii. The proponent shall comply self-monitoring and reporting procedures during the operation of the project and shall be submitted to the EPA Sindh. All of the parameters should be ensured for compliance of NEQS limits. In case of exceeding the limits, immediate appropriate arrangement will be taken including that of to shut down the plant operations.

viii. An effective solid waste management system will be developed which would cater to collection, transfer, recycling and final disposal of waste to a designated landfill site. The plan must address on site segregation of solid waste to promote its reuse and recycling.

ix. Best available techniques will be introduced for control of noise levels and vibration during construction and operation of project. Noise levels will be monitored and informed in the reports submitted to EPA Sindh.

x. Due to project location and low lying area, a plan will be developed for conservation and rehabilitation of mangroves in the PQA limits. For this purpose proponent will sponsor for plantation of mangroves in the existing swamps. This plan should be developed in consultation with the NGO's like WWF and IUCN Pakistan and Forest Department Govt.of Sindh. Company management shall make extensive tree plantation in and around the area, for the improvement of aesthetic/environmental conditions and to compensate the production of carbon dioxide by the activity.

xi. Proper Coordination must be maintained with PQA on transportation and safety issues and they should be informed if any fire outbreaks to ensure timely mitigation. A contingency and emergency response plan will be develop coordination with the concern organization to effectively address any risk or hazards caused during operational phase of the project. The project will have emergency response plan for risk within the plant and RoW will participate contingency planning of the PQA.

xii. A comprehensive Health, Safety and Environmental plan shall be submitted by the proponent within a period of 30 days. Environmental management system shall be made in place during the operation of the project needing towards third party environmental audit and for achievement of ISO14000 standards.

6. This approval shall be treated as null and void if the conditions mentioned in this approval are not complied with or any violation of PEP Act, Rules, Regulations, Guidelines and instructions there under is committed by the proponent or his/her agent or employee.

7. A qualified and experienced Independent Monitoring Consultancy firm would be engaged by the proponent to monitor the implementation of the EMP and the conditions of this approval.

8. The proponent shall be liable for compliance of Regulations 13, 14 and 18 of EIA/IEE Regulation, 2000.

9. The proponent shall be liable for compliance of Regulations 17 of EIA/IEE Regulation, 2000, which permits the authority i.e. Environmental Protection Agency to enter, inspect and monitor the development of the project so that the conditions are effectively monitored.

10. This approval does not absolve the proponent of the duty to obtain any other approval or consent that may be required under any law in force.

11. This approval is accorded only for the proposed project activity described in the IEE report. Proponent shall submit separate EIA or IEE as required under regulations for any enhancement or change in the design of proposed project.

Rafiuddin
Director General

Reference No: EPA/2012/11/8/IEE/48/

ENVIRONMENTAL PROTECTION AGENCY

GOVERNMENT OF SINDH

Plot # ST-2/1, Sector 23, KIA, Karachi-74900
Ph: 5065950, 5065598, 5065637
5065532, 5065946, 5065621
epasindh@cyber.net.pk
Facsimile: 5065940

Dated: 21-11-2012

Subject: DECISION ON INIITAL ENVIRONMENTAL EXAMINATION (IEE).

1.	**Name & Address of Proponent:**	Sheikh Imran ul Haque Chief Executive Officer, Engro Vopak Terminal Limited. Port Qasim, Karachi.
2.	**Description of Project:**	Up-gradation of existing jetty and construction/laying of a High pressure transmission pipeline to connect EVTL RLNG facility to the SSGC distribution network.
3.	**Location of Project:**	Port Qasim, Karachi.
4.	**Date of Filing of IEE:**	28-08-2012

5. After careful review of the Initial Environmental Examination (IEE) report, the Environmental Protection Agency (EPA), Sindh has decided to accord its approval subject t to the following conditions:

   i. that all mitigation measures recommended in the IEE report must be strictly adhered to minimize negative environmental impact on the marine ecosystem.

   ii. that Proponent will ensure state of the Art and International Standards for Safety of terminal, storage facility and all other installation to prevent any safety related hazard. In case of any unfortunate incident of leakage, fire and leading disaster the proponent will be responsible for compensation to any affected people, also for damage caused to environment and natural resources. To cope with the hazard emergency response, contingency plan should be developed prior to operational phase of the project.

   iii. that the proponent shall comply with National Environmental Quality Standard (NEQs) for air emissions and waste water to be generated during operational activities of the project.

iv. that national standards for noise levels will be implemented in order to minimize noise level during construction and operation phase of the project.

v. Adequate and proper maintenance of all pumps, valves and pipelines must be ensured to limit any fugitive natural gas and LPG emissions.

vi. Discharging and dumping of any kind of waste material into harbor waters will not be allowed, all importing ships will compile international maritime standards for disposal of their waste.

vii. Complete code of health, safety and environment (HSE) will be developed, which should include efficient parameters at specific work place. For this purpose HSE setup should be established supervised by a designated HSE officer at the senior level with sufficient administrative and technical authority to perform the designated function. Proponent will ensure that the operating instructions and emergency actions are made available to every worker/ commuter at the sight.

viii. An independent environmental monitoring consultant will be engaged to monitor the implementation of EMP during construction and operation phase of the project and proponent will submit report to EPA Sindh on quarterly basis.

ix. EVTL will carry out monitoring report and will submit report to EPA Sindh, for the recommended parameters with their appropriate frequencies as listed in self – monitoring and reporting rules. All of the parameters should be ensured for compliance of NEQS limits. In case of exceeding the permissible limits, immediate appropriate arrangement will be taken including that of to shut down the operations.

x. An effective solid waste management system will be developed which would cater to collection, transfer, recycling and final disposal of waste to a designated landfill site. The plan must address on site segregation of solid waste to promote its reuse and recycling. The oily sludge generated from oil storage tank during construction and operation of the project will be disposed off in accordance to best available practices, for which an inventory will be maintained for inspection and verification.

xi. The proponent shall ensure facilitation to the EPA officer(s)/official(s) for the regular inspections to verify the compliance of the PEP Act, Rules and Regulations framed there under and the conditions contained in this approval.

xii. Proper Coordination must be maintained with PQA on transportation and safety issues and they should be informed if any fire outbreaks to ensure timely mitigation. A contingency and emergency response plan will be developed in coordination with the concerned organizations to effectively address any risk/hazard caused during operational phase.

xiii. Implementation of Environmental management plan and mitigation measures, monitoring, communication and documentation and environmental training will be the sole responsibly of Chief Executive of the EVTL. Change management orders would be informed to EPA Sindh for subsequent permission from this office.

6. This approval shall be treated as null and void if the conditions mentioned in this approval are not complied with or any violation of PEP Act, Rules, Regulations, Guidelines and instructions is observed by this office.

7. The proponent shall be liable for compliance of Regulations 13, 14 and 18 of EIA/IEE Regulation, 2000.

8. The proponent shall be liable for compliance of Regulations 17 of EIA/IEE Regulation, 2000, which permits the authority i.e. Environmental Protection Agency to enter, inspect and monitor the development of the project so that the conditions are effectively monitored.

9. This approval does not absolve the proponent of the duty to obtain any other approval or consent that may be required under any law in force.

10. This approval is accorded only for the proposed project activity described in the IEE report. Proponent shall submit separate EIA or IEE as required under regulations for any enhancement or change in the design of proposed project.

Rafiuddin
Director General

ANNEX - X

(QRA STUDY)

Engro Vopak Terminal Ltd

Port Qasim LNG Regasification Terminal

Quantified Risk Assessment Report

Lloyd's Register EMEA

QRA Report No. : TID7171 Rev. Final

April 2011

Lloyd's Register

LIFE MATTERS

1. Report No. TID7171	2. Report date April 2011	3. Revision date	4. Type of report Technical –Rev. Final
5. Title & Subtitle ENGRO VOPAK TERMINAL LTD PORT QASIM FLOATING LNG REGASIFICATION TERMINAL QUANTIFIED RISK ASSESSMENT REPORT			6. Security classification of this report Commercial in Confidence 7. Security classification of this page Commercial in Confidence
8. Author(s) T Koliopulos Manager Special Projects , Energy M. Pavic Senior Marine Specialist Technical Investigation Dept			9. Authorisation Zahid Rahman General Manager Marine Business MEA
10. Reporting organisation name and address Lloyd's Register EMEA 71 Fenchurch Street London EC3M 4BS			11. Reporting organisation reference(s) None 12. This report supersedes Rev.0
13. Sponsoring organisation name and address Engro Vopak Terminal Ltd			14. Sponsoring organisation reference(s) 15. No. of pages 262

16. Summary

This binder report details the results of the Quantitative Risk Assessment (QRA) study which constitutes part of Engro Vopak Terminal Ltd's work for the development of a LNG Regasification Terminal at Port Qasim, in Karachi, Pakistan.
The major hazard events related to marine failure, regasification system and/or operating failure have been considered in all aspects of the proposed design.
None of the scenarios assessed gave rise to a 'high' risk to members of the public.

17. Key words FSRU, LNGC, STS, ESD, PQA	18. Distribution statement Engro Vopak Terminal Ltd Lloyd's Register EMEA

Executive Summary

This report details the results of the HAZID Study, Manoeuvrability Simulations Study and Risk Assessment Study, which constitute part of Engro Vopak Terminal Ltd's Quantitative Risk Assessment (QRA) work for the development of a LNG Regasification Terminal at Port Qasim, in Karachi, Pakistan.

The studies undertook a detailed examination of the LNG vessels jetty approach/berthing operations, the regas export system, the proposed jetty terminal facility and the ship-to-ship (STS) LNG transfer operations.

The major hazard events related to marine failure, regasification system and/or operating failure have been considered in all aspects of the proposed design. None of the identified hazards are thought to be unusual and appropriate safety/operational measures to mitigate risk have been proposed.

All off site risks from the site were found to be low; it was observed that none of the scenarios modelled has the potential to harm members of the public on the mainland. Furthermore, a 200m safety distance of other vessels from the facility provides mitigation of the potential effects of accidents on or from passing vessels.

Table of Contents

Glossary of Terminology and Abbreviations

ALARP	As Low As Reasonably Practicable
CFD	Computerised fluid dynamics
ERS	Emergency Release System
ESD	Emergency Shut Down
ESDV	Emergency Shut Down Valve
EVTL	Engro Vopak Terminal Ltd.
EX	Explosion
FF	Flash fire
FSRU	Floating Storage and Re-gasification Unit
HAZID	Hazard Identification
HAZOP	Hazard and Operability
HSE	Health, Safety & Environmental
JF	Jet Fire
LR	Lloyd's Register EMEA
LNG	Liquefied Natural Gas
LNGC	LNG Carrier
MAH	Major Accident Hazard
NG	Natural Gas
PF	Pool Fire
PIANC	International Navigation Association
PQA	Port Qasim Authority
QC/QD	Quick Connect/Quick Dissconect
QRA	Quantitative Risk Assessment
RPT	Rapid Phase Transition
SIGTTO	Society of International Gas Tankers Terminal Operators
SIS	Safety Instrumented System
SSL	Ship-Shore link
STS	Ship to Ship
UKC	Under Keel Clearance
VTS	Vessel Traffic Control System

1. Introduction

1.1 Scope

At the request of Engro Vopak Terminals (EVTL), Lloyd's Register EMEA (LR) carried out a Quantitative Risk Assessment for the proposed development of a floating LNG Regasification (Regas) terminal in the area of Port Qasim Pakistan.

At this stage EVTL is conducting studies in order to establish the best feasible site for developing the Regas LNG terminal. Three possible sites, the first located offshore at Khiprianwala Island, the second located offshore at Chhan Waddo Creek and the third at the existing brown field site in Port Qasim, are short listed. The selection of the final site will depend on site evaluation against the International Safety Standards, risk assessment results and the required work for the site development.

Based on the above the main objectives of LR's QRA work were as follows:

- identify all hazards and critical issues related to LNG shipment, regasification operations and gas export;
- undertake ship simulation study in order to establish the approach navigation and safe manoeuvrability for the largest type of proposed vessel (FSRU and LNGC) and finalise jetty size, location, area dredging and port tug requirements/supports;
- quantify all potential LNG/gas releases based on credible hazard scenarios identified and establish that potential risk to PQA facilities, population and environment is at an acceptable As Low As Reasonably Practicable (ALARP) level;
- establish project compliance with appropriate International Codes and Standards for this type of Installation.

The QRA has been carried out in five key phases. These are:

Phase 1 - Local survey of the proposed sites and Port Qasim facility;

Phase 2 - Hazard Identification (HAZID) review with the participation of EVTL and PQA;

Phase 3 - Navigational Simulation sessions for determination of the maximum size of LNGC, size/position of jetty facility, extend of dredging, size/number of tugs/support provisions;

Phase 4 - Comparison of the Port Qasim transit with industry criteria from PIANC, SIGTTO and determination of marine failure frequencies;

Phase 5 - Hazard consequence analysis and overall risk quantification.

2. Overview

2.1 General

Port Qasim is located in northwest wedge of Indus Delta system which is characterised of long and narrow creeks. The access to existing port terminals is through a 45km long channel marked with channel buoys. The port allows night navigation for 250 LOA vessels with draught 11.5 m having bow thrusters (vessels without bow thrusters must have maximum LOA 115 m and 10 m draught) , currently the maximum vessel operational draught is 12m. The proposed sites for the EVTL Regas terminal are:

- Green field site at Khiprianwala Island – Latitude 24°46'50'' N, Longitude 67°12'42'' E - Phitti Creek channel;
- Green field site at Chhan Waddo Creek – Latitude 24°42'40'' N, Longitude 67°11'30'' E;
- Brown field site next to the existing EVTL chemical and LPG terminal - Lattitude 24°46' N , Longitude 67° 19'E

Approximate site positions are shown on Figure 1.

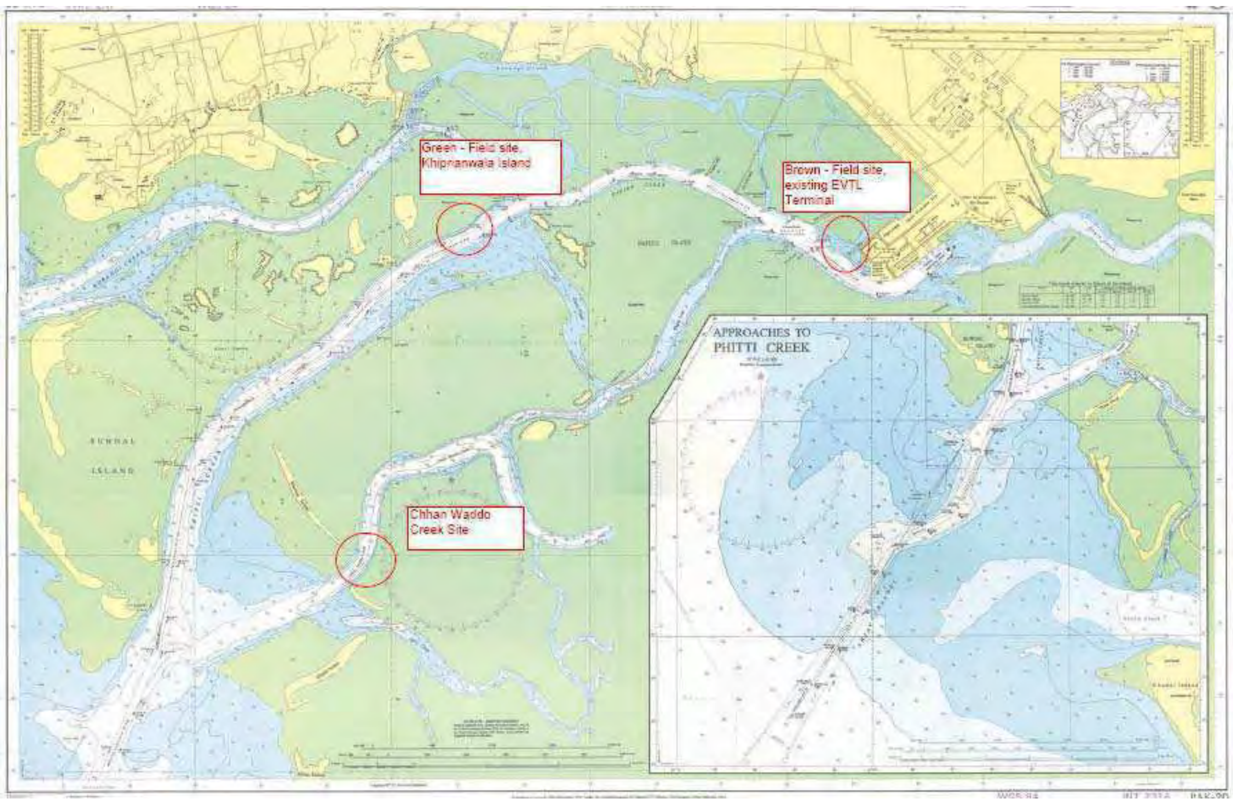

Figure 1: Approximate LNG Terminal site positions

The key features related to shuttle LNG carrier (LNGc) operations at the proposed LNG Terminal sites are as follows:

Existing channel features

- approach channel – two bend approach channel relatively unprotected from the environment (Figure 2);
- approach channel width 200 m to 600 m, dredged depth to 14.5m;
- current port operations are carried out through Phitti Creek channel only;
- phitti Creek channel width 200 m to 320 m, dredged depth to 13 m;
- 45 km long Phitti Creek channel,
- negligible cross channel current in the Phitti Creek channel;
- existing turning area in the proximity of brown field site,
- ship traffic 4 ships per day, (average 1200 ships / year);
- VTMS system not existing,
- Port Qasim Authority requirements for channel depth / vessel draught ratio is 1.15 for outer channel and 1.1 for inner channel;
- Chhan Waddo Creek is not currently operational;
- unidirectional traffic.

Desirable Channel Features

- current port operational procedures need to be updated to include operations with LNG ships;
- VTMS system;
- minimum four escort tugs should be introduced as follows: one for escort service, two for extreme weather condition escort service and four for berthing. The tugs minimum bollard pull should be 60t;
- new turning area in the proximity of Khiprianwala Island site;
- new turning area in Chhan Waddo Creek;
- widening of the approach channel.

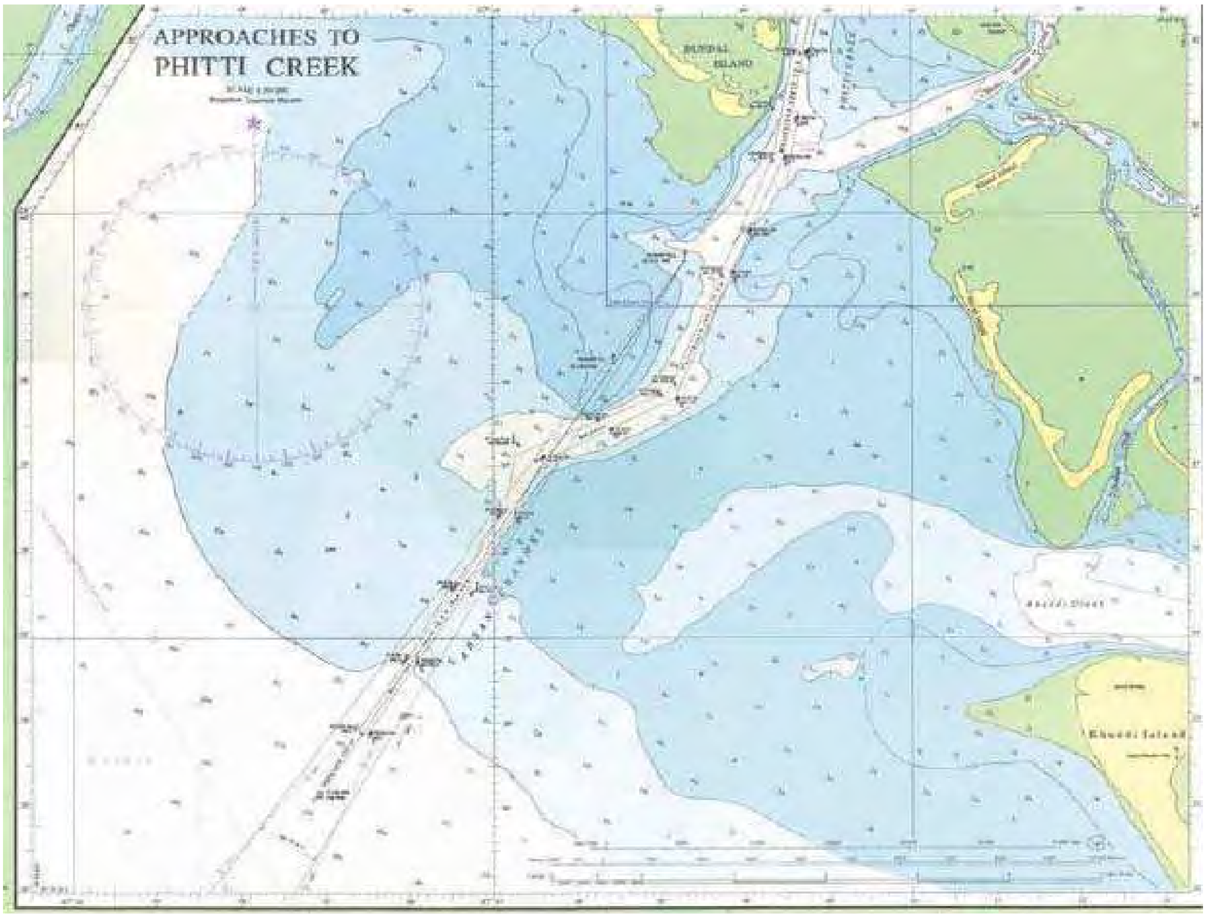

Figure 2: Two bend approach channel

2.2 Environmental Conditions

Port Qasim weather conditions are characterized by southwest (SW) monsoon in the summer and northeast (NE) monsoon in the winter. The port is located in a dry climate zone, the average of two decades (70s and 80s) show that rainfall varies between 150 and 250 mm during the year and the wettest months are July and August. Visibility in the port depends on dust storm, rainfall, fog, clouds and haze. In general the visibility is governed by haze; mornings are often affected by haze that disappears in mid day. Visibility in the port generally ranges up to 10 nautical miles. In SW monsoon period however, the visibility is reduced to about 2 to 5 nautical miles with the sky mostly cloudy while in NE monsoon period the sky is clear but the visibility is occasionally less than 1 nautical mile due to dust storms. The dust storms occur 3 to 4 days a month in a winter.

The southwest (summer) and north east (winter) monsoons are two distinct seasons that characterize wind conditions in the area. The highest wind velocities have been recorded during the summer months (from June to August), when the wind direction is southwest to west. Inter-monsoon transitions occur from October to November and March to May. The wind direction and speed between the summer and winter monsoon seasons are unsettled and large variations are recorded both with respect to speed and direction. During winter or during the northeast monsoon (from December to March), wind directions are northeast and north, shifting southwest to west in the evening hours. The wind speed data for Karachi area are presented in Table 1 below.

Wind Speed (m/s) at 12:00 UTS													
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2001	2.6	3.4	4.3	5.6	7.5	8.1	6.8	7.3	5.5	3.7	2.0	2.4	4.9
2002	3.6	3.9	4.0	6.5	8.5	8.2	9.8	7.3	7.7	3.3	2.9	3.2	5.7
2003	4.0	5.0	5.4	5.2	7.7	8.8	6.7	7.1	6.0	3.2	3.1	3.0	5.4
2004	3.4	3.7	4.0	6.0	8.0	9.0	10.0	9.5	7.3	3.8	1.0	2.5	5.7
2005	3.6	4.2	4.8	5.1	7.1	7.5	9.0	6.9	6.4	3.9	2.0	1.5	5.2
2006	2.0	3.0	3.0	6.2	8.0	7.7	8.3	6.2	4.7	4.2	2.2	3.0	4.9
2007	2.0	3.7	4.0	4.0	6.0	6.3	N/A	N/A	N/A	N/A	N/A	N/A	4.3
2008	4.3	7.6	8.2	10.5	12.6	7.6	11.0	9.3	8.7	6.6	5.1	3.9	7.9
2009	7.0	7.2	7.9	9.3	9.8	9.7	9.5	9.3	9.1	6.1	5.0	3.9	7.8
Source: Pakistan Meteorological Department													

Table 1: Wind Speed Data – Karachi

During the southwest monsoon period the maximum wave height recorded in the approach channel was between 3m and 4m. In the inner channel (creek system) the maximum wave height is about 0.5m.

In the approach channel the maximum current velocity is 2 – 2.5 kn (1kn average) without much difference between ebb and flood current velocity. In the creek system ebb tide is generally stronger and the maximum recorded velocity was 3.6kn. At the entrance to the approach channel the flood current direction is at an angle of about 40° to the navigational channel and the velocity is less than 1kn. The ebb current is roughly in line with navigational channel.

According to admiralty chart the tide levels are as follows:

Tidal Levels referred to Datum of Soundings

Place	Lat N	Long E	Heights in metres above datum			
			MHHW	MLHW	MHLW	MLLW
Ghizri Creek	24°46'	67°06'	2.6	2.5	1.2	0.5
Bundal Island	24 42	67 08	2.9	2.3	1.2	0.6
Hasan Point	24 47	67 14	2.9	2.8	1.3	0.6
Port Muhammad Bin Qasim	24 47	67 21	3.4	2.7	1.4	1.0

Figure 3: Tide Levels

2.3 Terminal Design Options

The terminal development will involve the construction of an offshore jetty, dredging for vessels access, and the laying of a gas pipeline. It is proposed that a regasification vessel (FSRU) will remain moored to the pier for an intended period of (10 years due to lease contracts etc) 3-5 years with continuous high gas demand. Supply LNGCs, using Ship-to-Ship (STS) cargo transfer, will periodically come alongside and unload LNG, which will be regasified and injected to the gas pipeline through a high pressure unloading arm. Gas export is expected to between 300-600 MMSCFD, being compatible with the maximum send-out capacity of the FSRU.

The following Terminal Design Options are currently considered for development at the EVTL proposed sites:

- Option 1 -
  Offshore jetty facility able to berth FSRU/FSU and LNGC up to a size of 151,000 m^3 in a double banked STS mooring arrangement;

- Option 2 -
  Offshore jetty facility able to berth and moor an FSRU/FSU at one side and a LNGC at the opposite side (up to a size of 151,000 m^3) of the jetty, in other words an across – jetty arrangement;

- Option 3 -
  Offshore jetty facility able to berth FSRU/FSU and LNGC up to a size of 151,000 m^3 in a tandem STS mooring arrangement.

A berthing jetty with mooring dolphins will be constructed. The size of the jetty will be sufficient to provide berthing and mooring facility based on the FSRU and largest shuttle LNGC operating (length of QFLEX vessel). The available area of the jetty should be appropriate to accommodate as a minimum the re-gasification arm, export gas pipeline, pressure protection skid, service piping to the FSRU, local control room and boarding facility.

The turning basin will require the dredging of islands in order to fulfill the required area, equivalent to a turning platform of an elliptic form with a maximum axis (350 m radius to cover QFlex) which has been finalized by the navigation simulation studies.

The FSRU's vaporisation (re-gasification) facilities are designed to deliver upto 600 MMSCFD of vaporised LNG at a maximum send-out pressure of 100 barg. The system is capable of operating at send-out rates between 100 MMSCFD and 600 MMSCFD, with an anticipated normal rate of 500 MMSCFD.

The regas cargo transfer will take place via a high pressure (HP) gas unloading arm with the vessel moored at the terminal jetty. The arm is an "S" type double counterweighted design which is fully balanced in all positions.

It is noted that EVTL will also consider the construction of a re-gasification plant on the jetty/land/barge. In this case, it will no longer be necessary to have a FSRU in port, but LNG carriers/FSU will remain moored to the pier as storage buffer tanks until all LNG has been re-gasified in the plant. This will require storage vessel in case of continuous supply of RLNG using either of the terminal designs.

2.4 Codes and Standards

2.4.1 Marine Standards

The standards published by the International Navigation Association (PIANC) and Society of International Gas Tankers and Terminal Operators (SIGTTO) are well defined and practiced industry standards and recommendations. These standards consider both the layout and operational aspects of approaches to ports and LNG terminals. The specific aim of these standards is minimising associated risks to ALARP (As Low As Reasonably Practical) levels.

SIGTTO

SIGTTO recommendations for channel and turning basin dimensions indicate the following:

- approach channels should have a uniform cross sectional depth, with minimum width of five times the beam of the vessel;
- the channel depth depends on the site location and site particulars;
- where current effect is minimal the minimum diameter for turning circles is twice the length of the vessel. Where the current is not minimal, the diameter should be increased by anticipated drift.

SIGTTO also recommends a Vessel Traffic Control (VTS) System service in place for the ports with LNG tanker operations. The number and size of tugs have to be sufficient to control a LNG vessel in maximum permitted operating condition assuming the vessel's engines are not available. Usually the combined tug bollard pull is between 120 – 140 tonnes and the tugs should be able to exert approximately half of total power at the each end of the ship.

LNG operation provisions suitable for a specific port have to be established by port authority prior commencing the LNG operations. Operating limits expressed in terms of wind speed, wave height and current should be established for each jetty. Separate sets of limits should be established for berthing, stopping cargo transfer, hard arm disconnection and departure from the berth.

PIANC

The following Table 2 establishes PIANC recommendations for a Channel Concept Design as it is applicable to Port Qasim operations.

PIANC Channel Width Calculations			
	Approach Channel	Inner Channel	PQA characteristics
Basic manoeuvring lane	1.50	1.50	moderate
Vessel speed	0.00	0.00	slow to moderate speed 8 - 12kn
Cross wind	0.40	0.40	Moderate wind > 15kn - 33kn
Cross current	0.70	0.00	Negligible
Longitudinal current	0.00	0.10	moderate 1.5 - 3 kn
Wave height	1.00	0.00	3>Hs>1, moderate speed
Aids to navigation	0.20	0.20	Average
Bottom surface smooth and soft	0.10	0.10	depth <1.5T
Depth of waterway	0.20	0.40	D<1.25T approach, D<1.15T inner
Cargo hazard	1.00	0.80	High
Bank clearance	0.00	0.50	sloping edges
TOTAL	**5.10**	**4.00**	
Additional width for two-way traffic			
Vessel speed	1.60	1.40	moderate speed 8-12kn
Encounter traffic density	0.00	0.00	low 0-1 vessel per hour
TOTAL	**13.40**	**10.80**	

Table 2: PIANC Recommendations

Based on the table for unidirectional traffic and a ship with a high risk cargo (PIANC definition) the channel width should be 5.1 times the breadth of the vessel for outer channel and 4 times the breadth of a vessel for inner channel. This relates to the PIANC guidance and the ship transit operating under moderate interpretation of conditions.

PIANC does not give explicit recommendations for turning circle.

However it specifies the bend radius for the channel. In calm water with no wind and current, a hard-over turn can be accomplished with the ship with average – to – good manoeuvrability within the channel bend radius of 1.8 to 2 times the ship length in deep water. For shallow water, depth/draught ratio this channel bend radius increases to 2.8 times the ship length. Both specified radii assume that ship is unaided by tugs.

The minimum PIANC requirement for water depth / ship draught ratio is 1.10 for sheltered waters, 1.3 in waves up to 1m in height and 1.5 in higher waves. Froude Depth Number F_{nh} has to be less then 0.7. Froude Depth Number is defined as:

$$F_{nh} = \frac{V}{\sqrt{hg}}$$ where,

V is ship speed through water in m/s,
H is water depth in m, and
g is acceleration due to gravity.

Table 3 below establishes conservative F values, assuming that vessel speed is 12kn (6.2m/s) for Port Qasim inner and outer channel.

	Minimum Water depth (m)	Froude Depth Number F_{nh}
Outer Channel	13.5	0.54
Inner Channel	12.5	0.56

Table 3: Froude Number Calculations

Port Qasim current requirements are: water depth / ship draught ratio 1.15 for outer channel and 1.1 for inner channel and maximum ship draught 12m. The Port Qasim Froude Depth Number F_{nh} is less than 0.7 and thus is acceptable according to PIANC.

2.4.2 Onshore Standards

As LNG ship regasification and export is a relatively new type of operation there are not specific standards related to regas terminals. NFPA 59 A is considered the most commonly used code for LNG terminal facilities but this code relates to LNG storage and LNG export facilities rather than to regasification and HP gas export. However, the code provides useful information related to Emergency Shut Down ESD isolation and LNG offloading systems which relate to operations taking place on both the onshore and offshore regasification jetty.

2.5 LNGC Size Assessment

The following sizes of LNGCs have been assessed against industry standards:

- 148k MOSS type vessel;
- 151k Membrane type vessel;
- QFLEX vessel (up to 210k).

2.5.1 Phitti Creek, Gharo Creek and Kadhiro Creek Channel (Inner Channel)

Based on the PIANC and SIGTTO guidelines the assessment results for three the sizes of LNGCs are given in Table 4 below:

	Industry Guidance			Minimum Actual Channel size (approach channel) (m)	Minimum Actual Channel size (inner channel) (m)	Typical LNGc Dimensions			Acceptable Y/N
	SIGGTO (appoach channels)	PIANC (approach channel)	PIANC (inner channel)			MOSS 148K	Membrane 151K	QFLEX	
Channel Width (m)				200	200				
Ship Beam (m)						43.4	43.4	50.0	
Ratio Channel width / ship beam	> 5	> 5.1	> 4						
PQA Approach Channel: channel width / ship beam ratio						4.61	4.61	4.00	N see Section 2.5.3
PQA Inner Channel: channel width / ship beam ratio						4.61	4.61	4.00	Y
PQA Maximum allowable draught (m)						12.0	12.0	12.0	
Ship Design Draught (m)						11.5	11.5	12.2	Y see note 1
Turning Basin Size	2 x ship length								
Ship Length LOA (m)						283.0	283.0	315.0	
Required Turning basin diameter SIGGTO						566.0	566.0	630.0	Y

Table 4: Comparison of Industry Standards vs. LNG ships

Note 1 on Table 4, refers to the 12m maximum ship draught already handled in Port Qasim, deepening by 1 m will be needed to accommodate QFLEX size LNGCs.

In general the turning diameter of two times ship length is adopted as an industry standard if the vessel is assisted with tugs. Furthermore, LNG terminal projects have been known to allow 1.5 times LOA after full risk assessments have been carried out.

It is considered that SIGTTO recommendations for channel width are more conservative than those established by PIANC. SIGTTO recommends a minimum width of five times ship beam irrespective of actual site configuration and weather conditions. PIANC recommends more detailed assessment based on actual site particulars. As the assessment for the Phitti Creek Channel was carried out using PIANC recommendations it is concluded that the channel width is sufficient for all three assessed sizes of LNGCs (Table 2).

According to information available from Port Qasim Authority's website, the maximum vessel draught already handled is 12m. Hence it is expected that LNG vessels operating in the Port Qasim will require having a draught less then or equal to 12m.

In general the design draught should not govern the selection of applicable size of the LNGC for the following reasons:

- although the design draught of QFLEX LNG vessels in departure design condition (condition leaving the loading terminal) can be 12.2 m, it is logical to expect that in the arrival condition (condition at the arrival at Port Qasim) the draught will be less then that (due to fuel consumption);
- the LNGC can be loaded to meet Port Qasim requirements, ie partial loading;
- Port Qasim intention is to deepen the channel in near future.

After the industry standards based assessment of Port Qasim particulars the following can be concluded:

- 148k MOSS and 151K Membrane size LNGC can be operated in Phitti Creek Channel without additional widening or deepening of the navigational channel, ie in existing channel conditions;
- QFLEX size LNGC can be operated in Phitti Creek Channel after deepening;
- QFLEX size FSRU can be operated in Phitti Creek Channel in existing channel conditions without additional widening or deepening of the channel (with tidal advantage, planned operational window, one time activity).

2.5.2 Chhan Waddo Creek Channel

Chhan Waddo Creek Channel is currently not operational. The channel will need to be deepened in the short area north - east from the approach channel as indicated on Figure 4.

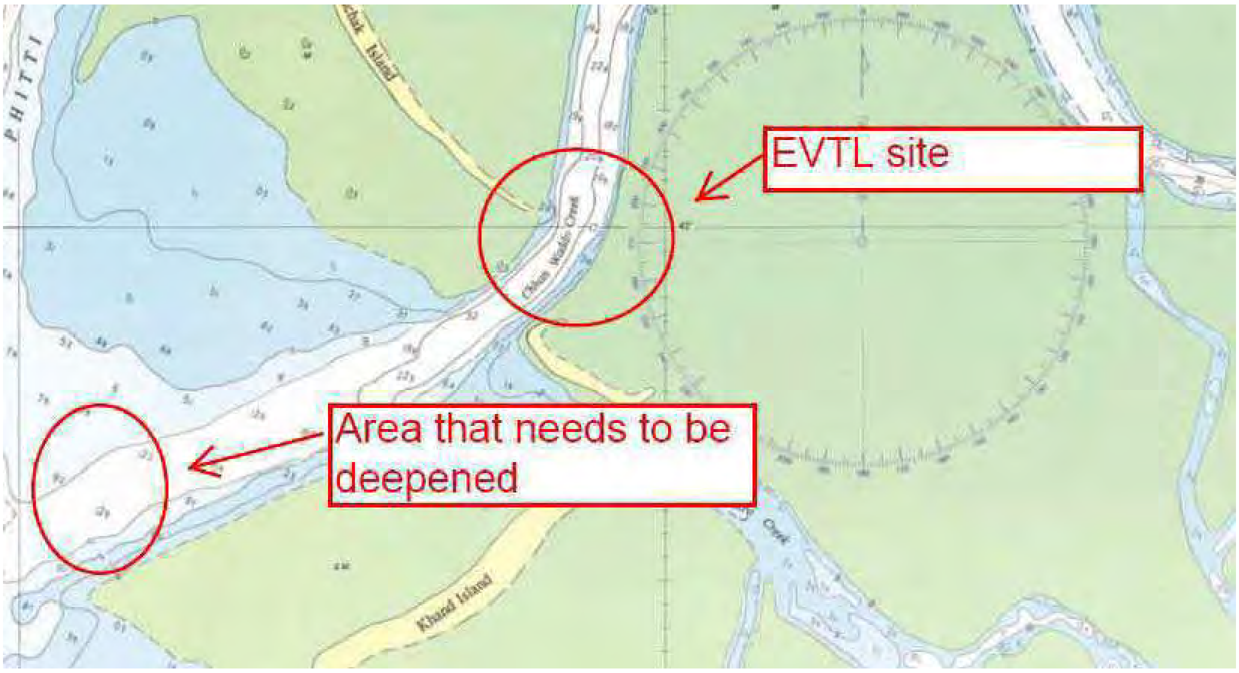

Figure 4: Area that needs to be deepened for Chhan Waddo Creek site

The proposed EVTL site is at the entrance of Chhan Waddo Creek Channel and the channel width at that position is larger than 250m. Which corresponds with PIANC and SIGTTO recommendations for a 50m breadth vessel.

Assuming the deepening will be carried out to match the depths in the vicinity of the area required to be dredged, and using current Port Qasim water depth / ship draught requirements, the allowed ship draught would be: 15m / 1.15 = 13m, allowable draught.

Based on the above assessment it is concluded that after undertaking deepening work QFlex size LNGC and QFlex size FSRU can be operated in Chhan Waddo Creek location.

2.5.3 Approach Channel – Ahsan Channel

According to Port Qasim letter dated 22nd October 2010, the dredged channel depth is 14.5m indicating allowable draught of 14.5 / 1.15 = 12.6 m. This implies that based on design draught all assessed ship sizes can operate in the approach channel.

The width of the channel is 200m to 600m, consequently in the sections of the channel with 200m width all three assessed ship sizes do not meet PIANC or SIGTTO recommendations for channel width / ship breadth ratio. According to PIANC the minimum channel width should be 220m for 148k MOSS and151k Membrane type vessel. For QFlex size vessel the minimum channel width should be 255m. However, it should be noted that PIANC assessment was undertaken using the adverse weather conditions for Port Qasim area with wind speed of 15 to 30kn and cross current of 3kn. Also it has been assumed that the vessel has moderate, manoeuvrability and that vessel is not assisted by tugs. In reality the wind speed (average of 15 kn) rarely exceeds 15kn and the tug support will be available. To assess the suitability of the approach channel the real time ship simulations were carried out for adverse condition used in the PIANC assessment. The simulation results are discussed in Section 5 of this report.
PIANC channel width calculations for the mild wind, wind speed less the 15kn and waves less than 1m height, are given in Table 5 below.

PIANC Channel Width Calculations			
	Approach Channel	Inner Channel	
Basic manoeuvring lane	1.50	1.50	
Vessel speed	0.00	0.00	slow to moderate speed 8 - 12kn
Cross wind	0.00	0.00	mild wind < 15kn
Cross current	0.70	0.00	moderate in the approach channel
Longitudinal current	0.00	0.10	moderate 1.5 - 3 kn
Wave height	0.00	0.00	3>Hs>1, moderate speed
Aids to navigation	0.20	0.20	average
Bottom surface smooth and soft	0.10	0.10	depth <1.5T
Depth of waterway	0.20	0.40	D<1.25T approach, D<1.15T inner
Cargo hazard	1.00	0.80	high
Bank clearance	0.00	0.50	sloping edges
TOTAL	**3.70**	**3.60**	

Table 5 PIANC Recommendations – mild wind

According to Table 5, PIANC recommendations for mild wind conditions yield the following:

- approach channel width 3.7 times ship breadth, or 185m required channel width for QFLEX size vessel;

- inner channel width 3.6 times ship breadth, or 180m required channel width for QFLEX vessel.

In case of adverse conditions of wind speeds higher then 20kn or cross currents higher then 2 kn, tug support is suggested in the approach channel. The minimum number of escort tugs should be two with 60t bollard pull.

3. Hazard Identification (HAZID)

3.1 Methodology

The HAZID study took place in locations arranged by EVTL in Karachi, Pakistan. The team review was led by a Chairman (LR) assisted by a Recorder. The remainder of the HAZID team comprised specialists from EVTL's project design and operations, PQA's marine operators, PQA's design consultants and LR Technical Investigation Department (TID) specialists.

The objectives of the HAZID study were:

- identify all potential hazards associated with the FSRU and LNGC port approach and berthing operations at the proposed LNG terminal sites;
- identify potential hazards associated with the proposed terminal Options with regards to the near shore location, installation and operation of a regasification and gas export facility;
- identify potential hazards associated with the aspects of the design and operation of the STS LNG cargo system;
- assess the adequacy of the proposed marine facilities, layout design and piping systems for ensuring the integrity of the installation;
- assess the adequacy of the existing safeguards and port support assets and identify the Regulatory requirements for project compliance;
- perform a round table discussion of potential failure mode scenarios and emergency response procedures and identify remedial measures that will reduce the potential hazards and minimise risks.

Each part of the proposed operations and the area(s) which would take place either on the jetty or onboard the FSRU was reviewed in turn by the HAZID team, applying the guide words or considering potential scenarios, to identify potential hazards. Causes of the potential hazards and resultant consequences were then identified, together with any safeguards and mitigating measures. The following operations and related systems were examined:

1. EBRV/LNGC Marine Operations within Port Qasim;
2. EBRV/LNGC Berthing and Mooring Operations;
3. Jetty Safety Lay-out and Fire Protection;
4. Export Operations.

3.2 Findings

The HAZID review findings and recommendations were recorded on the HAZID work sheets, which are presented in the HAZID Study Report No OGL/DA/100260, Appendix 1 of the QRA. In general the following apply:

- The proposed EVTL jetty regasification operations supported by LNG STS cargo transfer and export gas pipeline have been assessed for their suitability to handle major hazards and based on the findings of the HAZID study, is judged that the proposed installation generates potential hazards which are significantly less than those found to be acceptable for conventional LNG onshore terminals.

- The HAZID has identified a number of potential Major Accident Hazards (MAH) and their potential consequence and the frequency with which they might occur has been addressed by the Risk Assessment Study Appendix 3 of the QRA report.

- Based on the HAZID review and critical considerations on typical berthing conditions and turn around basins for up to 151,000 m3 vessels, both Options 1 and Options 3 (refer to section 2.3) have been identified as feasible for development at any of the proposed green sites at Khiprianwala Island or Chhan Waddo Creek and the existing EVTL Brown field site. Project to decide on commercial acceptability based on the results of the simulation navigation study and the extent for the necessary dredging and also the costs of the civil and LNG arms/piping engineering works for the proposed jetty sizes.

- The HAZID team examined the Brown field and identified a number of operational advantages:
  - Existing turning basin maintained at13.0 m depth
  - Potential of provision of anchorage pocket inside Chara Creek to facilitate bi-directional traffic.
  - Full time monitoring traffic in the area by PQA control.
  - Close proximity to PQA's support vessels jetty.
  - Most tug operations take place in the area, hence a high tug availability during STS operations.
  - Existing high 'awareness' in the area of all shipping and offloading operations.
  - Successful long term LPG offloading operations at EVTL facility, with established safety training and emergency response plans in place.

  The main drawback of the Brown field is the close proximity of the LNG terminal to the main port terminal facilities, industrial facilities, working population and accommodation facilities. Any potential medium to large release of gas under the current prevailing wind conditions is likely to have a potential impact on to the adjacent facility. However, it can be argued that the closest facility to the future LNG terminal is the EVTL's LPG/chemicals plant which has been purposely designed to mitigate against such type of hazard event. Also the proposed 'GasPort' facility is not like a typical LNG terminal as it is very small, employs only a gas export facility with limited volumes (600 mmscfd max) and does not have any onshore LNG storage tanks or processing facility.

- It is recommended that the lay-out area available by the options for any future onshore regasification equipment needs to be addressed by project at an early stage. It is noted that any future onshore expansion will benefit from pre-installed LNG arms and piping on the jetty as has been proposed for Option 3.

- With regards to the extend of the dredging in order to establish an adequate turning basin it is also noted that future PQA plans include for a development of other gas ports one in the Korangi Creek opposite buoys 6 and 7 and one behind it facing the Korangi Fish Harbour area and two terminals before EVTL proposed site . There is justifications for the terminal developers to discuss with PQA the possibility of a common turning basin to be used for both facilities. The potential benefit on such arrangement would be the need to dredge only a channel connecting the basin with the proposed EVTL jetty in order to enable safe FSRU/LNGC berthing. The benefits of above against creating own turning basin in front of EVTL Green field site needs to addressed in the economic evaluation of the project.

  Dedicated turning basin at the EVTL green field site is also an acceptable option.

4. Manoeuvring Simulations

4.1 Scope

To fully understand the risks associated with all vessel movements, and the interaction with terminal layout, and navigation aids, Lloyd's Register believe that simulation is the only viable solution. This follows the recommendation on simulated assessment given by SIGTTO in their guidance on terminal selection. Simulation has been used in this project to assess the following:

- the maximum size of the LNGCs that can be operated at three possible LNG terminal sites;
- the maximum size of the floating LNG storage (re-gasification vessel) that can be operated at three possible LNG Terminal sites;
- number and size of tugs required for transit and berthing operation of LNGC;
- consequences of the typical failure events for similar Re-gas LNG Terminal – LNG shuttle tanker operations.

A navigation simulations study was carried out at BMT ARGOSS during February and March 2011, the study is presented in Appendix 2 of this QRA. A total of 36 real time navigation simulation runs were carried out using the "PC REMBRANDT" tool. PC REMBRANDT is a BMT ARGOSS software based tool interacting with an electronic chart, covering the approach channel and possible terminal areas. It is a PC based real time ship manoeuvring simulator where a project ship is mathematically modelled to imitate the actual ship movement. The simulations take account of bathymetry and introduced external factors of wind, current and wave height (Hs).

The manoeuvres that were considered in this study focused on a single ship that was selected as being representative of the least manoeuvrable ship expected to operate at the EVTL LNG Regas terminal jetty. This was a148K steam driven, LNG carrier with spherical tanks (MOSS type). The main dimensions of this size MOSS type LNGC, match the main dimensions of the 151K membrane type vessel. Additionally, at EVTL's request, the simulations were carried out with a QFLEX size LNG carrier. The typical particulars of 148k Moss LNG carrier and QFLEX size LNG carrier are presented in Figures 5 and 6 below:

Length Overall	283.0 m
Beam	43.4 m
Depth	27.0 m
Design Draft	11.5 m
Capacity	148,000 cbm
DWT	77,351 tonnes
Displacement	107,000 tonnes
Speed	19.5 Kts
Complement	28

Figure 5: 148 k Moss Type LNG Carrier

Length Overall	315.0 m
Beam	50.0 m
Depth	26.0 m
Design Draft	12.2 m
Capacity	210,000 cbm
DWT	87,300 tonnes
Displacement	123,700 tonnes
Speed	20.0 Kts
Complement	28

Figure 6: QFLEX Size LNG Carrier

The assistance of tugs was also appropriately simulated. In the report the convention for referring to tugs in use is as follows:

- Tug 1 bow centre lead;
- Tug 2 working at the ship's shoulder (port or starboard side, as appropriate);
- Tug 3 working at the ship's quarter (port or starboard side, as appropriate);
- Tug 4 stern centre lead.

The turning area with a radius of 350m was assumed in the vicinity of the Khiprianwala site and in Chhan Waddo Creek.

The simulation list is given in Table 6 below:

Run	Operation	Ship	Wind		Current	Tugs
			Dir	Spd		
1	Arrival	Moss Ship (Loaded)	225	30kts	Spring Flood	-
2A, B, C	Arrival	Moss Ship (Loaded)	225	30kts	Spring Flood	-
3	Arrival	Moss Ship (Loaded)	225	20kts	Spring Flood	3
4	Arrival	Moss Ship (Loaded)	225	30kts	Spring Flood	3
5	Arrival	Moss Ship (Loaded)	225	30kts	Spring Flood	3
6	Arrival	Moss Ship (Loaded)	225	30kts	Spring Flood	4
7	Arrival	Moss Ship (Loaded)	225	30kts	Spring Flood	4
8	Arrival	Moss Ship (Loaded)	225	30kts	Spring Flood	4
9	Arrival	Q-Flex (Loaded)	225	30kts	Spring Flood	-
10	Arrival	Q-Flex (Loaded)	225	30kts	Spring Flood	1
11	Arrival	Q-Flex (Loaded)	225	30kts	Spring Flood	4
12	Arrival	Q-Flex (Loaded)	225	20kts	Spring Flood	1
13	Departure	Moss Ship (Ballast)	225	30kts	Spring Flood	2
14	Departure	Moss Ship (Ballast)	225	30kts	Spring Ebb	2
15	Arrival	Q-Flex (Loaded)	225	20kts	Spring Flood	-
16	Arrival	Q-Flex (Loaded)	225	20kts	Spring Flood	4
17	Arrival	Moss Ship (Loaded)	225	30kts	Spring Flood	4
18	Departure	Moss Ship (Ballast)	225	30kts	Spring Flood	4
19	Arrival	Q-Flex (Loaded)	225	20kts	Spring Flood	4

20	Departure	Q-Flex (Ballast)	225	20kts	Spring Flood	2
21	Departure	Q-Flex (Ballast)	225	20kts	Spring Ebb	2
22	Arrival	Q-Flex (Loaded)	225	20kts	Slack Water	4
23	Arrival	Moss Ship (Loaded)	225	20kts	Spring Flood	1
24	Arrival	Moss Ship (Loaded)	225	20kts	Spring Flood	1
25	Arrival	Moss Ship (Loaded)	225	20kts	Spring Flood	1
26	Arrival	Moss Ship (Loaded)	225	20kts	Spring Flood	1
27	Arrival	Moss Ship (Loaded)	225	20kts	Spring Flood	1
28	Arrival	Moss Ship (Loaded)	225	20kts	Spring Flood	2 (3)
29	Arrival	Moss Ship (Loaded)	225	20kts	Slack Water	2 (3)
30	Arrival	Moss Ship (Loaded)	225	20kts	Spring Flood	1
31	Arrival	Moss Ship (Loaded)	225	20kts	Spring Flood	4
32	Arrival	Q-Flex (Loaded)	225	20kts	Slack Water	4
33	Arrival	Q-Flex (Loaded)	225	20kts	Spring Flood	1
34	Departure	Q-Flex (Loaded)	225	20kts	Spring Flood	2

Table 6: Simulation Matrix

For each simulation run, the following variables were entered:

- wind speed and direction;
- current rate and direction;
- ballast or loaded condition;
- ship heading and initial speed;
- tugs as required.

4.2 Methodology

All simulations were conducted by a Pilot with experience of over 500 port entry and departures. The Pilot controlled the vessel directly (i.e. without issuing orders) through a control console replicating actual ship controls and manoeuvred the tugs using the external function display. The Pilot had the following information available in real-time:

- the electronic chart view (ECDIS) showing the position of the vessel on the chart and other information such as the dredged channel, under keel clearance (UKC), turning circles and exclusion zones;
- an out-of-the-window 3D view from the ship's bridge (switched to the bridge wings when required);
- run information such as the vessel speed over the ground (ahead/astern and lateral), rate of turn, heading and course over the ground. Also, depth profile and engine/rudder values (actual and demanded);
- position and percentage of power usage for each tug.

The vessels initial speed, for the arrival, was set at around 10kts outside the approach channel entrance. For departure manoeuvres, the simulations started with the vessel alongside the berth (stopped) and the speed was gradually increased as appropriate to the conditions.

It was recognised that the Pilot was aware of impending equipment failures, and so there was relatively little element of surprise. Therefore, in an attempt to ensure representative response times, the Pilot was not permitted to take any action or alert the tugs for 30 seconds immediately after a failure, to simulate the minimum time taken for an alert bridge crew to realise there was a problem, for the Pilot to verify that there was a problem and to start to react to the situation.

To give an understanding of relative safety for each manoeuvre the difficulties grading matrix shown on Figure 7 has been introduced in order to establish the criticality of each manoeuvre (refer to Manoeuvring Simulation Appendix 2).

1	2	3	4	5	6	7	8
Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

Figure 7: Grading Matrix

The difficulty level assigned to each manoeuvre was based on Pilot experience and observations carried out during the actual simulation runs. It should be noted that the Pilot operated in Port Qasim area for the first time; hence assigned difficulty levels are somewhat conservative. Port Qasim pilots should comment on the manoeuvre grading based on their extensive experience of operations in Port Qasim area.
In general the manoeuvres graded as difficult should be avoided or additional pilot training provided.

4.3 Presentation of Results

4.3.1. 148k Vessel

The first simulations objective was to assess maximum size LNGC that can be operated in Port Qasim. Special attention was given to the approach channel. The simulation runs 1, 2A and 2B were carried out using 148K LNGC without tug support. The following environmental conditions were entered:

- wind speed 30kn (for runs 2A and 2B);
- flood current 3kn;
- wave height 3.4m.

The difficulty grading for all three runs were 'Not demanding'. The environmental conditions used for the runs were matching considerably adverse environmental conditions for the Port Qasim area, yet the vessel completed manoeuvres with 'Not demanding' difficulty grade. Consequently it was concluded that 148k size MOSS type (151k size membrane type) LNGC can be navigated in the approach channel and Phitty Creek channel up to the Khiprianwala green – field site.

The simulation runs 2C, 3, 4, 5 and 6 were carried out to assess the number of tugs required for berthing operation and the size of the vessel that can be berthed at Khiprianwala green – field site. The assumed turning area radius was 350m. The environmental conditions were as follows:

- wind speed 30kn (except for run 3 where the wind speed is reduced to 20kn);
- flood current 3kn.

The simulations showed that the swing manoeuvre under the above environmental conditions is 'Challenging' but achievable if the vessel is supported with three tugs. If the vessel is supported with four tugs the manoeuvre was rated as 'Not demanding'. As noted before, although the experienced pilot was performing manoeuvres he was not familiar with actual Port Qasim particulars, hence it can be concluded that the appointed difficulty rating is conservative.

To investigate berthing issues at the Khiprianwala green – field site further, port side vessel berthing and 'swing when departing' manoeuvres were carried out in the runs 17 and 18. These proved to be very simple manoeuvres. As such it is recommended that this is adopted as the standard arrival/departure technique for the Khiprianwala green – field site.

Runs number 7 and 8 investigated how difficult is to navigate 148k MOSS vessel to the existing brown – field site and to swing the vessel at the existing turning area at IOCB. In order to simulate the worst case scenario a vessel was placed on the LPG berth and the Oil terminal berth. Some difficulty (scale not easy) was experienced both in making the initial turn in the channel and also in swinging the vessel with 4 tugs.

Runs 13 and 14 were used to simulate emergency departure for starboard berthed 148k MOSS vessel at Khiprianwala green – field site; this proved to be a very simple manoeuvre.

4.3.2 QFLEX Vessel

Runs 9 and 10 investigated QFLEX navigation through the approach channel. The environmental conditions used were:

- wind speed 30kn for run 9 and 20kn for run 10;
- flood current 3kn;
- extra 1m tide was used to simulate future water depth after dredging.

For run 10 the escort tug was connected at position 4. In both runs difficulty was experienced in making the dogleg turn at the start of the channel.

In runs 11 and 12 the QFLEX vessel was navigated to the Khiprianwala green field site and the starboard swing was attempted using 4 support tugs. The wind speed of 30kn did not allow successful swing and for run 12 it was reduced to 20kn. The swing at run 12 was successful with the difficulty grade of 'Not easy'.

Runs 19 investigated the possibility of berthing by the port at Khiprianwala green – field site. The wind speed in the all three runs was set to 20kn. The manoeuvre was carried out with 4 tugs and it was successful.

Runs 20 and 21 investigated the emergency departure of a port side berthed vessel. The wind speed was set to 20kn and only two tugs were used for support. Manoeuvres proved possible but challenging. Similarly as for the MOSS type vessel the port side berthing should be considered as standard procedure at Khiprianwala green – field site

Run 22 investigated navigation of the QFLEX vessel to the existing brown-field site and swing at the existing turning area. The wind speed was set to 20kn, and 4 tugs were used for support. Manoeuvres proved possible but not easy.

4.3.3. Failure Simulations

The following failure simulations were carried out:

Vessel Type	Wind Speed (kn)	Current Speed (kn)	Failure
148K MOSS	20	2	Rudder failure, stuck at full defection in the beginning of the approach channel
148K MOSS	20	2	Engine failure in the approach channel
148K MOSS	20	2	Crash stop
148K MOSS	20	2	Black out in Phitti Creek Channel
148K MOSS	20	2	Rudder failure, stuck at full defection in Phitti Creek Channel
148K MOSS	20	2	Tug failure during swing manoeuvre
148K MOSS	20	-	Tug failure during swing manoeuvre, failure occurring later in the swing
			Vessel passing Khiprianwala green – field site and then having engine failure and drifting to LNGC
148K MOSS	20	3	LNGC experiencing failure when passing existing LPG berth
QFLEX	20	3	LNGC experiencing failure when passing existing LPG berth

Table 7: List of failure simulations

In general all the manoeuvres required to control the ship after the above specified failures were graded as 'Not demanding'. It was assumed that the LNGC will always be supported with at least one tug.

The likelihood of the failures is discussed in Section 5 of this report.

4.3.4 Chhan Waddo Creek - channel

Runs 33 and 34 investigate possibility of using the Chhan Waddo Creek channel. QFlex vessel was used and the following environmental conditions were entered:

- Wind speed 20kn,
- Flood current 3kn.

The vessel was navigated into channel and swung at the berth place the manoeuvres were conducted without any difficulties.

Detailed findings and conclusions are presented in the Manoeuvring Simulation Report No L30090.1.1R in Appendix 2 of the QRA.

5. Risk Assessment

5.1 Overview

The risk assessment study has comprised the following steps:

- identification of major accident hazards (MAHs);
- assessment of the consequences of potential MAHs;
- assessment of the frequency of potential MAHs;
- determination of the risks from potential MAHs (using risk matrices); and,
- consideration of further measures that might be taken to reduce the risks, where appropriate.

The identified MAHs were assessed in terms of their potential consequences, and the frequency with which they might occur. Consequences were expressed in terms of a 'Severity Category', as defined in Table 2 of the Risk Assessment Study in Appendix 3.

The list of identified scenarios related to possible releases from equipment on board the FSRU or the jetty are presented in Table 7 below.

Reference	Description	Size / Type
L1	Release of LNG from the pipework between the FRSU tanks and the HP Pump Suction Drums.	S
		M
		L
L2	Release of LNG from the HP Pump Suction Drums and pipework feeding the HP Pumps.	S
		M
		L
L3	Release of LNG from the HP Pumps discharge pipework up to the Vaporisers.	S
		M
		L
L4	Release of LNG from a transfer hose during ship to ship transfer.	S
		M
		L
G1	Release of natural gas from the pipework between the vaporiser outlets and the ship-side ESDV upstream of the gas unloading arm.	S
		M
		L
G2	Release of natural gas from the pipework between the ship-side ESDV upstream of the gas unloading arm and the first jetty ESDV.	S
		M
		L
G3	Release of natural gas from the pipework between the first jetty ESDV and the second Jetty ESDV.	S
		M
		L
G4	Release of natural gas from the pipework between the second Jetty ESDV and the third Jetty ESDV (at the entry to the natural gas pipeline).	S
		M
		L
G5	Releases of natural gas from the FSRU relief system under fire conditions.	Single valve

Key:
S: Small, M: Medium, L: Large

Table 8: Major Accident Hazard Scenario List

5.2 Consequence Assessment

Using the above scenarios and design specification data based on a similar regas facility utilising the same FSRU export capacity and equipment a list of cases for consequence assessment was developed. Each case was then modelled using the DNV PHAST software version 6.53.1. The list of cases for PHAST modelling is presented in the Risk Assessment Study in Appendix 3 of the QRA.

The PHAST results were used to select the appropriate severity category for each MAH scenario. Separate severity categories were assigned for on-site and off-site effects. When determining the appropriate severity category, the distance from the release source to potential receptors was taken into account. The results are displayed in the Risk Assessment Study in Appendix 3 of this QRA.

5.3 Frequency Assessment

Frequency categories have been assigned to each MAH scenario by reference to a range of frequency data sources related to hydrocarbon releases or equipment failures. In the majority of cases, the process followed was to:

- assign a frequency category for occurrence of the *release* (e.g. the frequency of a small leak of gas from a piece of equipment);
- modify the frequency to account for the probability of a leak becoming an *effect* (e.g. ignition of a leak to give a jet fire); and,
- modify the frequency to account for the probability of the effect giving rise to a defined *outcome*, namely the severity of the consequences defined in the consequence assessment (e.g. a jet fire from an ignited leak pointing towards an occupied area and causing a fatality).

Data were obtained from the Health and Safety Executive Hydrocarbon Release Database (data for 1992 – 2009) and from Publication Series on Dangerous Substances (PGS 3). Guideline for quantitative risk assessment 'Purple book' CPR 18E, VROM, 2005. It was assumed that there will be a delivery of LNG every 4 to 5 days and that small releases are a factor of 10 more frequent than medium sized releases.

5.4 Marine Event Frequency Assessment

Frequencies were evaluated for incidents that could result in a loss of control of the LNGC with possible grounding or collision consequence, and for collision by a passing vessel. Although other incidents such as collision with a tug could lead to a loss of life onboard the tug, this does not directly lead to a major incident for the LNGC itself. The results are established in Table 8 below:

EVENT	PROBABILITY per year	
Vessel passing the LNG offloading site and then having engine failure and drifting to LNGC.	$2.39 \cdot 10^{-6}$	
LNGC vessel experienced machinery failure; vessel control is lost and the vessel can run aground or collide with other vessel	Khiprianwala green – field site	$3.3 \cdot 10^{-6}$
	Brown – field site	$7.47 \cdot 10^{-6}$
	Chhan Waddo Creek site	$2.08 \cdot 10^{-6}$
LNGC vessel experienced steering gear failure: vessel control is lost and the vessel can run aground or collide with other vessel	Khiprianwala green – field site	$3.07 \cdot 10^{-7}$
	Brown – field site	$6.96 \cdot 10^{-7}$
	Chhan Waddo Creek site	$1.94 \cdot 10^{-7}$
LNGC vessel experienced steering gear or machinery failure during berthing: vessel control is lost and the vessel can collide with FSRU	$4.2 \cdot 10^{-7}$	

Overall these failure frequencies should be compared against industry acceptable criteria.

In extreme cases a release of LNG from the LNGc could result from grounding of the LNGc or collision with another vessel. Collision between the FRSU and another vessel could also result in a release of LNG.

Marine accidents of this type have been subjected to detailed analysis by the Sandia National Laboratories in the USA (6). The study considered accidental and deliberate (i.e. due to terrorist attack) breaches of LNGc cargo tanks. Fine element modelling was used to calculate breach sizes. Spill rates and thermal flux hazard ranges from LNG pool fires on water were calculated. Dispersion of natural gas vapour following un-ignited LNG releases was analysed using computerised fluid dynamics (CFD).

The authors used the results of the analysis to generate a set of public safety zones, reproduced in Table 9 below.

Event	Potential Ship Damage and Spill	Potential Hazard	Potential Impact on Public Safety		
			High	Medium	Low
Collisions: Low speed	Minor ship damage, no spill	Minor ship damage	None	None	None
Collisions: Low speed	LNG cargo tank breach and small – medium spill	Damage to ship and small fire	~250 m	~250-750 m	> 750 m
Grounding: < 3m high object	Minor ship damage, no breach	Minor ship damage	None	None	None

Table 9 Recommended Public Safety Zones for Accidental Breaches (Sandia)

All ship operations in Port Qasim area are considered low speed operations. Additionally restriction of 6kn ship speed is in place for ships passing the terminal. The Sandia Report (6) specifies the required velocity to cause a breach of an LNG cargo tank during a 90 deg collision with a large vessel to be 6-7 knots. Collisions at shallower angles would need to be several knots higher in order to penetrate an LNG cargo tank. This implies that passing vessel collision with FSRU can not cause a breach of the cargo tanks at FSRU.

LNGc vessel will have a tug escort during the passage and it is expected that the PQA procedures will address safe LNGc speed. Current passage speed is based on unassisted navigation and it is set to 10kn or less. Were 10kn is considered as a speed for the vessel effective manoeuvring under the adverse weather conditions. For the navigation assisted by the tugs this passage speed can be reduced as shown during the navigational simulation study.

Hence it is not expected that any of the incident events investigated can cause breach in the cargo tank of FSRU or LNGc.

To further investigate consequence of the marine incidents the event frequencies are compared with the acceptable frequency-fatality plots (FN curves), in the ports where explosives are handled (Figure 8). The plots are showing the cumulative frequencies (F) of events involving N or more fatalities, are taken from UK HSE's "Risks from Handling Explosives in Ports" (note: (Sample chart)).

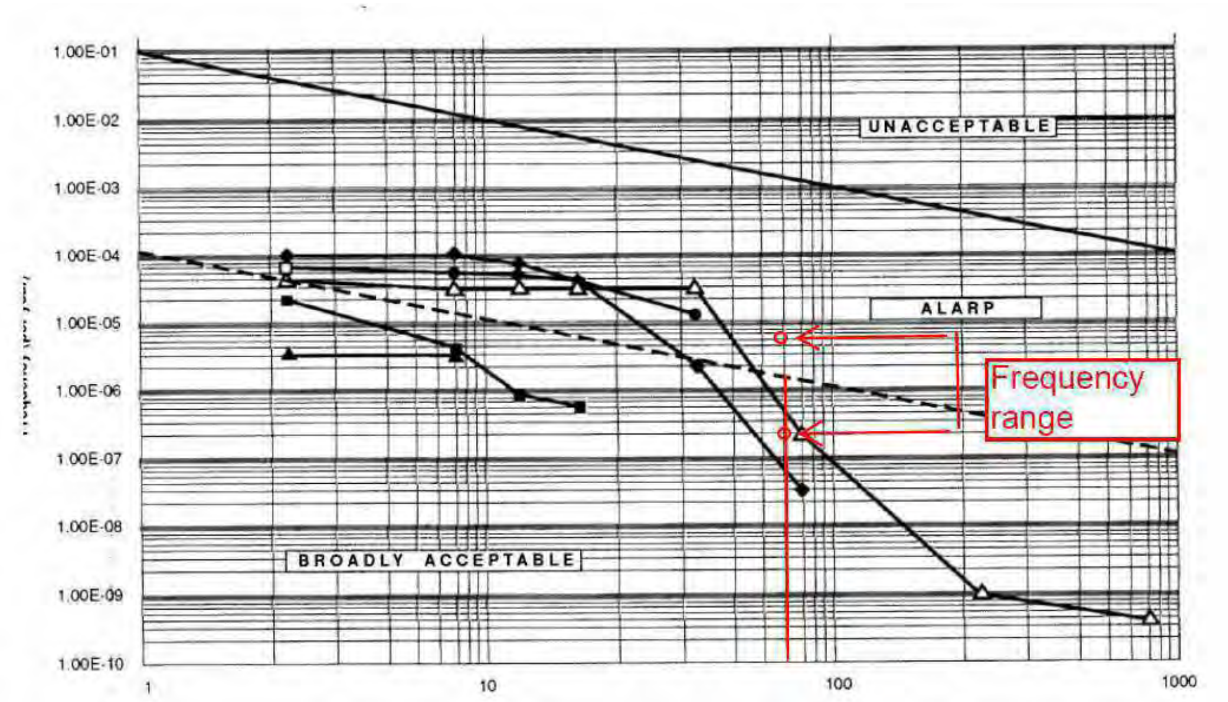

Figure 8. HSE Guidance on Acceptable risk Levels

Assuming the worst case scenario which may involve up to 60 personnel onboard FSRU and LNGC, frequency range of the marine incidents is shown on the Figure 8. All the frequencies are in the 'broadly acceptable' or 'As low as reasonably practicable (ALRP)' regions.

It should be noted that the frequencies calculated are the incident happening frequencies, actual frequencies for cargo tank breach and LNG spill will undoubtedly be much lower and all of them will lay in 'broadly acceptable' region.

5.5 Risk Matrix

Each MAH scenario has been plotted on the on-site risk matrix and the off-site risk matrix using the assigned severity and frequency categories. The assigned severity, frequency and risk categories are summarised in of the Risk Assessment Study in Appendix 3 of the QRA. The on-site risk matrix is displayed in the off-site matrix is shown in of the Risk Assessment Study in Appendix 3 of the QRA.

6. Recommendations

The detailed recommendations identified are presented in the integral studies of the QRA Report namely HAZID study, Manoeuvrability Simulations study and Risk Assessment study. A summary of the main findings is presented below:

<u>HAZID</u>

- Based on the HAZID review and critical considerations on typical berthing conditions and turn around basins for upto 151,000 m^3 vessels, both Options 1 and 3 have been identified as feasible for development at any of the proposed green sites at Khiprianwala Island or Chhan Waddo Creek and also at EVTL's existing brown field site. A project will be needed to decide on commercial acceptability based on the results of the simulation navigation study which will establish the extent for the necessary dredging and also the costs of the civil and LNG arms/piping engineering works for the proposed jetty sizes.

- For the preferred Option a project will be needed to provide the basic layout of the jetty facility to address the size (m^2) of the proposed jetty and the mooring arrangement including the number and position of dolphins. The design will need to establish the distance:
  - between the jetty and the outer line of sailing channel;
  - between a 151,000 m^3 size FSRU moored at the jetty and the outer line of sailing channel.

  It is recommended that based on the consequence analysis a minimum safety distance of 200m, to be maintained between the double banked ship arrangement and the channel traffic.

- A project will be needed to undertake mooring simulation studies to address and finalise the following:
  - size position and number of dolphins;
  - actual mooring lines configuration for double banked or tandem options;
  - load requirements and proposed size of hooks (single wire per hook recommended);
  - wind, current impact on to double bank mooring arrangement;
  - impact on passing vessel on to mooring arrangement (worst case scenario)
  - Line pretension requirements;
  - verify mooring integrity with loss of one line as per OCIMF requirements
  - passing traffic scenarios should also be addressed by real time navigation simulations as a part of FEED.

- A project will be needed to establish a Safety and Fire Protection Philosophy. The philosophy should identify the following as a minimum:
  - size of fire pumps based on maximum firewater requirement;
  - deluge system coverage;
  - size/reach of remote controlled water monitors;
  - coverage of dry powder and AFFF provisions;
  - number, type and position of the gas detectors on the jetty.

Also project to address ESD function on gas detection (ESD1 for 2 out of 3 or 1 out of 2 detectors.). Cause and Effects to be examined by HAZOP with participation of the FSRU operator during the FEED Study.

- Emergency Procedures will need to be developed prior to commissioning to address the disconnection and mooring release of shuttle vessel. Issues to be addressed include:
  - number of stand-by tugs available and sail time requirement;
  - necessity for mooring quick release of ships (ship from ship, and ship or ships from jetty);
  - operation of jetty side quick release hooks, whether all together, singly, or group release;
  - authorisation of sail away by ship captain or PQA;
  - sail away window of operations impact of tide, traffic convoy etc.

Manoeuvrability Simulations

- The maximum LNGC sizes that can be operated at the Khiprianwala green field and existing brown field site are 148K MOSS type vessel and 151K membrane type vessel.

- Consideration should be given to securing escort towage that is capable of indirect towage shortly after the pilot boards as the width of the entrance channel is such that any emergency that occurs in this area could block the channel. The tug that is tasked for this may need to be rated at a higher bollard pull (80 ton) than others, as it was shown that during all the berthing this tug alone had the most work to do.

- After the dredging of the approach channel and Phitti Creek channel (1m deepening), a QFlex size vessel can be operated at Khiprianwala green field and the existing brown field site.

- The maximum size FSRU that can be currently used at the Khiprianwala green field and the existing brown field site is QFLEX size FSRU – it is considered that navigation of the FSRU through the approach channel and Phitti Creek channel is a one time event and favourable tide and environmental conditions can be used,

- The Chhan Waddo Creek channel site is a realistic option for an LNG Regas terminal and based only on evaluation of navigation risks this option is also a practical one. After dredging (see Figure 4) QFLEX size FSRU and LNGC can be operated at the Chhan Waddo Creek site.

<u>On- Site Risk Assessment</u>

Three MAH scenarios were identified to give rise to a 'high' on site risk:

- pool or jet fires following a large continuous release from a ship to ship LNG transfer hose and immediate ignition, with failure to isolate the release;
- flash fires following a large continuous release from a ship to ship LNG transfer hose and delayed ignition, with failure to isolate the release; and,
- jet fires from the system on the FSRU, originating from releases between the vaporisers and the ESDV upstream of the unloading arm.

The hazard contours of the above events are presented in Figures 9, 10, 11 and 12 below :

Figure 9 : Rupture of transfer hose, with failure of ESD. Pool fire radiation ellipse
SW Monsoon / Day-time conditions, SW wind
Blue: 4 kW/m2; Green: 12.5 kW/m2; Yellow: 37.5 kW/m2

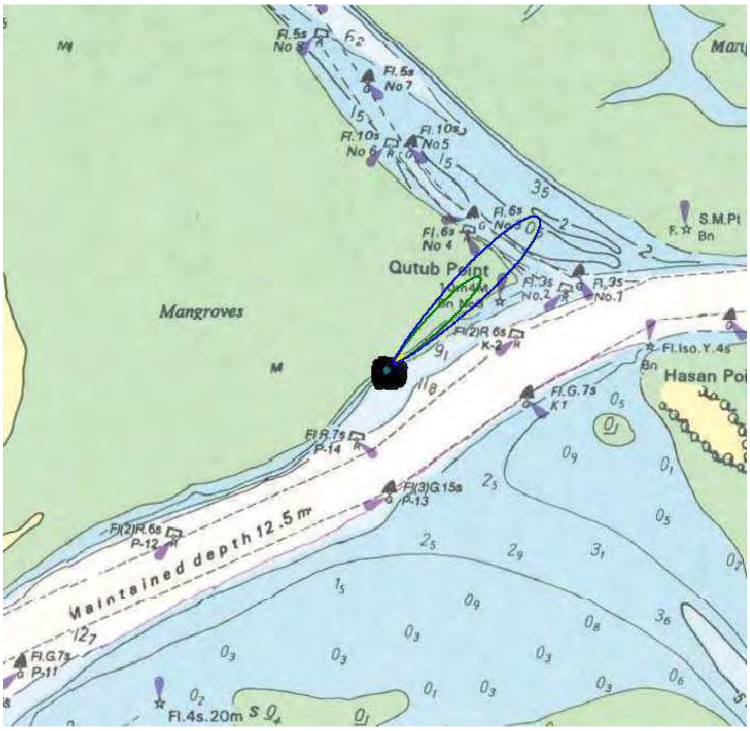

Figure 10: Rupture of transfer hose, with failure of ESD.Flash fire cloud footprintSW Monsoon / Day-time conditions, SW wind
Blue: ½ LFL; Green: LFL; Yellow: UFL

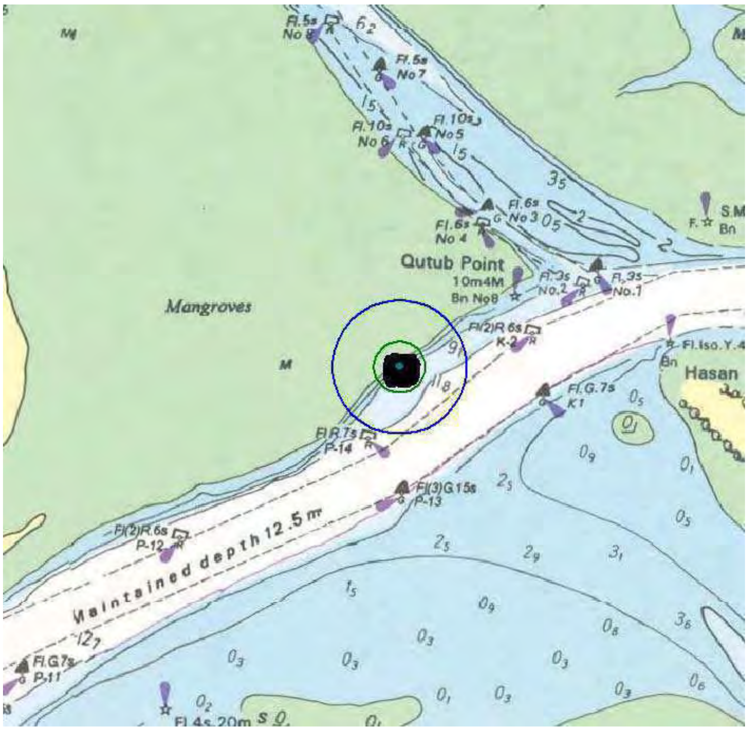

Figure 11 : Rupture of gas pipe on jetty, with failure of ESD. Flash fire radii (max. distance)
SW Monsoon / Day-time conditions
Blue: ½ LFL; Green: LFL

Figure 12 : Rupture of gas pipe on jetty, with failure of ESD. Jet fire radiation ellipse
SW Monsoon / Day-time conditions, wind from SW
Blue: 4 kW/m2; Green: 12.5 kW/m2; Yellow: 37.5 kW/m2

It is noted that all the above events are expected to be greatly reduced by the development of an appropriate Safety Fire Protection and Detection system as an integral part of the terminal's detailed design process.

A number of appropriate safety design recommendations have been identified by the HAZID study. It is noted that the proposed EVTL FSRU has already been provided with an Emergency Release System (ERS) on each hose. The QC/QD couplings are linked to a HPU on the upper deck of the FSRU vessel with hydraulic release mechanism manually operated by individual levers allowing greater control over hoses. An automatic system linked to the ESD system is also made available for use.

It is also noted that the recommendation of a Hazard Operability (HAZOP) study to address STS operations and examine a most appropriate ESD system for the terminal has been adopted by EVTL as the next activity on the project as a part of the FEED

Off- Site Risk Assessment

Off-site risks from the site were found to be considerably lower than on-site risks. In particular, it was observed that none of the scenarios modelled has the potential to harm members of the public on the mainland. This is largely attributable to the distance to the nearest receptor on land (3.2 km from the Khiprianwala facility (Also brownfield site would effect only industrial population and not the residential public)). Furthermore, the distance of other vessels from the facility (200 m safety distance) provides mitigation of the potential effects of accidents on passing vessels.

The following recommendations apply:

- a project is needed to establish a 200m safety exclusion zone as minimum around the terminal site

- a project is needed to establish strict access rules to a berth and these will be controlled and required by the ISPS code. In addition all unauthorised and approved vessels should be excluded from the area very close to the berth (200 m distance) by a Permanent Exclusion zone.

Marine Operations Risk Assessment

The risks identified fell within the ALARP zone of the risk matrix. While these are acceptable risks there are cost effective measures that can reduce them further.

The following recommendations apply.

- It is important that the movements of the commercial vessels are properly controlled as they approach and leave their various berths. The Port and Pilots currently do this on basis hand-held communication devices. With traffic levels increasing and more LNGC's visiting it is important that traffic movements are properly and formally controlled. Thus one of the recommendations is that a Vessel Traffic Control System (VTS) is established for the port.

- A number of navigational aids have been identified that will reduce risks, as listed below:

    1. navigational warning lights on the jetty head and the trestle;
    2. leading lights and marks to assist with positioning during the approach to the LNG berth. Alternatively an electronic pilot navigation and docking aid to plan monitor and execute the vessel passage and berthing, both inbound and outbound could be used;
    3. installing a shore based Alarm and Information System (AIS) and radar monitoring system;
    4. installing AIS equipment on tugs, pilot boats and Agents launches and other service craft;
    5. preparation and dissemination of NAVWARNINGS and chart corrections on the position of the berth. (This is already a current practice).

- The tugs play a critical role in the safety of the approach, turning off the berth and berthing. They can only undertake their role effectively as mooring tugs if they are in position and made fast before the LNGC begins the approach to the berth. The tugs effectively give a completely independent and additional braking and manoeuvring system. Thus it is most important that the tugs are of the right size, design and bollard pull to be able to perform this function effectively. The simulations and calculation have shown that these tugs must be certified effective static 60 t or more bollard pull ASD tugs with appropriate static winches to perform this role for the expected range of vessels.

- Four tugs are recommended for the berthing operation. For the navigation through the channel one tug should be used as an escort as a minimum. The tug that is tasked for this may need to be rated at a higher bollard pull (80t) than others as it was shown that during all the berthing this tug alone had the most work to do.

7. Overall Conclusions

The major hazard events related to marine failure, STS LNG Transfer, regasification system and operating failure have been considered in all aspects of the proposed design. None of the identified hazards are thought to be unusual and appropriate safety/operational measures have been proposed for inclusion in the design during FEED which will further reduce all hazards to an ALARP level.

The identified hazards were subjected to a quantitative risk assessment in order to assess the potential risks to people on-site and off-site. Off site risks were found to be considerably lower than on-site risks. In particular, it was observed that none of the scenarios modelled has the potential to harm members of the public on the mainland.

It is noted that many of the proposed mitigating measures are operational and procedural, which can be readily introduced, but require a willingness from all parties to do so. The developers and the LNG terminal's managers and staff will play a key role, but they will require the support and co-operation of the Port, Harbourmaster, other berth owners and operators, fishermen and other mariners who work and use the Port Qasim channels.

8. References

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Appendices

1 Hazard Identification Study Report No. OGL/DA/10026 Revision Final
2 Risk Assessment Study Report No. 2542214-R01 Revision Final
3 Manoeuvring Simulation Study Report No.L30090.1.2R Final

Lloyd's Register

LIFE MATTERS

Engro Vopak LNG Terminals Ltd

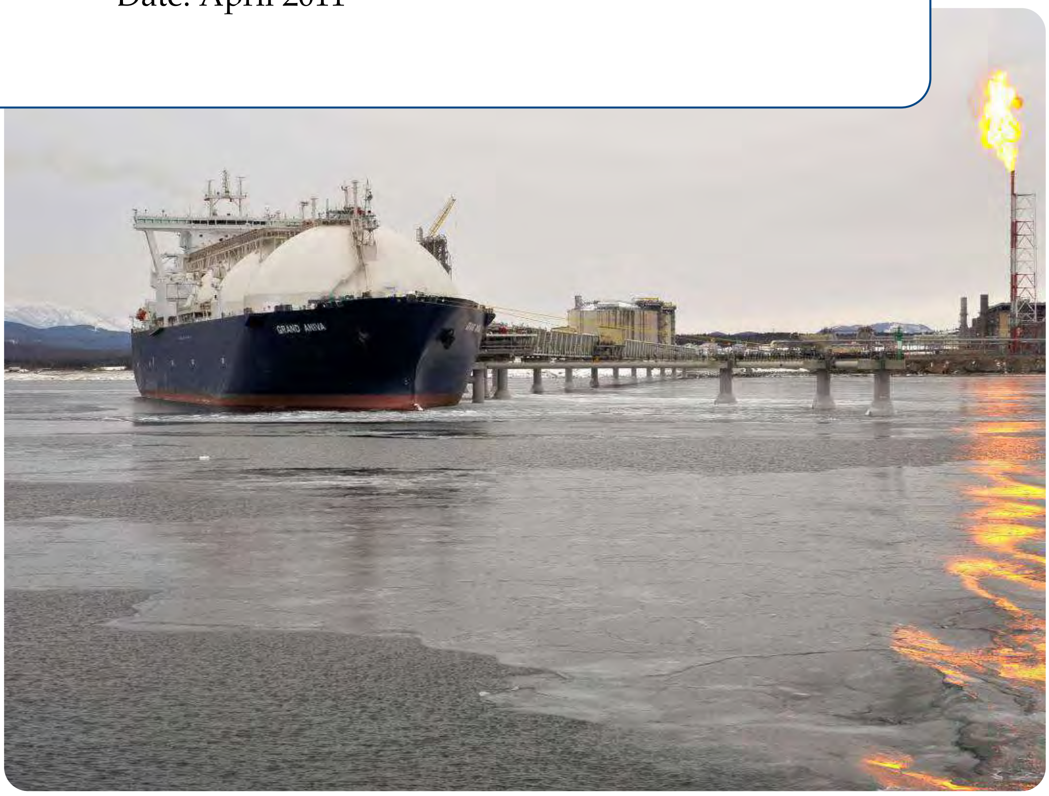
Port Qasim LNG Regasification Terminal

Hazard Identification Study

Report No. OGL/DA/10026

Revision: Final

Date: April 2011



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16. Summary

This report details the results of the Hazard Identification (HAZID) for Engro Vopak LNG Regasification Terminal in Port Qasim, Pakistan.

The objective of the HAZID was to address the various proposed Terminal Options and identify potential system failures and hazard consequences associated with the proposed LNG regasification and LNG STS operations at port. The results of the study show that the proposed systems and operations are considered to be acceptable provided that implementation of the actions identified will be incorporated in the project scope of work and addressed by operation procedures as appropriate.

17. Key words FSRU, LNGC, STS, ESD, PQA	18. Distribution statement Engro Vopak Terminal Ltd Lloyd’s Register EMEA

EXECUTIVE SUMMARY

This report details the results of the marine HAZID study, which constitutes part of Engro Vopak Terminal's QRA for a LNG Regasification Terminal at Port Qasim in Karachi, Pakistan.

The study undertook a detailed examination of the proposed Terminal Options, the vessels jetty approach/berthing operations, the receiving terminal facilities and the proposed ship-to-ship (STS) LNG transfer operations. The applied review process was in compliance with the formal HAZID and HAZOP methodologies.

The major events related to marine system failure and/or operating failure have been considered in all aspects of the proposed design and appropriate safety/operational measures have been proposed. The consequences of potential hazards associated with all aspects of the LNG STS cargo transfer and gas export operations have been critically examined and will be further evaluated by QRA activities.

None of the identified hazards is thought to be unusual or to pose a level of risk which is higher from typical LNG offloading jetty terminal operations and all can be mitigated by appropriate design and operational measures.

CONTENTS

APPENDICES

1. INTRODUCTION

1.1 General

Lloyd's Register EMEA (LR) has been engaged by Engro Vopak Terminal Ltd (EVTL) to carry out a Hazard Identification (HAZID) study on the marine systems, the regas export and the LNG STS transfer operations which will facilitate the LNG regasification and gas export at Khiprianwala island at Port Qasim.

The LNG terminal will employ a new jetty/berthing facility with a regas arm export installation, and a new gas pipeline. The terminal will enable a regasification vessel (FSRU) to remain at berth for long term operations by receiving LNG cargo from shuttle LNG carriers (LNGCs).

1.2 Port Qasim Channel

The main channel is part of numerous waterways constituting the historic Indus Delta. The channel was initially dredged in 1978 and has a total length of 43.7 km from Buoys Number 1 and Number 2 to the marginal wharf turning basin. The channel can be considered in three sections, namely:

- The exposed Outer (Ahsan) Channel between the open sea and Bundal Island
- The more sheltered Inner Channel from Bundal Island to the Iron Ore and Coal Berth (IOCB)
- The 'Reach' from the IOCB to the marginal wharfs.

The EVTL proposed site for the LNG terminal is identified on the Marine Chart in Appendix 2. A second proposed 'Brown Option' site is also shown adjacent to the existing EVTL's chemicals terminal.

The general issues with regards to Port Qasim Authority (PQA) navigation are as follows.

- The existing channel depth at the entrance is about 14.5 m and up to 12m maximum draft ships are currently allowed.
- The PQ channel is a tidal channel and currently the port allows night navigation for 250 LOA vessels with draught 11.5 m having bow thrusters (vessels without bow thrusters must have maximum LOA 115 m and 10 m draught).

- There are a few sharp bends in the channel and various other small bends upstream in the channel where currents are strong (3 to 5 knots) and may lead to vessel drift.

- High siltation occurs in the outer navigation channel (Ashan channel) in particular during SW Monsoon season. Access is liable to shift as a result of this situation.

- Due to the strong currents and windage effect during the Monsoon season the transit ship traffic has to maintain high speeds in the channel (10 to 12 knots). This may result in high surge impact on to any moored ships/jetties and speed limits may need to be introduced.

- There is not a VTMS system currently in operation by PQA.

- Potential environmental impact issues will need to be addressed as there are extensive mangrove forests, sustaining rich marine and bird life in the area.

1.3 Terminal Options

The terminal development will involve the construction of an offshore jetty, the dredging for vessels access, and the laying of a gas pipeline. It is proposed that a FSRU regasification vessel will remain moored to the pier for the period of 3-5 years with continuous high gas demand. Supply LNGCs, using Ship-to-Ship (STS) cargo transfer, will periodically come alongside and unload LNG, which will be regasified and injected to the gas pipeline through a high pressure unloading arm. Gas export is expected to between 400-600 MMSCFD, being compatible with the maximum send-out capacity of the FSRU.

Khipriawala island is located at approximately 31 km from the PQA channel entry. The site is composed of low-lying sand dunes that extend above the high tide line. It is uninhabited. There are extended areas of mangroves, but there is an area outside the main navigation channel approximately 500 m wide and 1000 m long free of mangroves, which would suit the LNG terminal development.

The following Terminal Design Options are currently considered for development at the EVTL proposed sites:

- Option 1 -
  Offshore jetty facility able to berth FSRU/FSU and LNGC up to a size of 151,000 m^3 in a double banked STS mooring arrangement;

- Option 2 -
  Offshore jetty facility able to berth and moor an FSRU/FSU at one side and a LNGC at the opposite side (up to a size of 151,000 m^3) of the jetty, in other words an across – jetty arrangement;

- Option 3 -
  Offshore jetty facility able to berth FSRU/FSU and LNGC up to a size of 151,000 m^3 in a tandem STS mooring arrangement.

2.1 Terminal Facilities

Jetty/Mooring

A berthing jetty with mooring dolphins will be constructed. The size of the jetty will be sufficient to provide berthing and mooring facility based on the FSRU and largest shuttle LNGC operating (length 315 m). The available area of the jetty should be appropriate to accommodate as a minimum the regasification arm, export gas pipeline, pressure protection skid, service piping to the FSRU, local control room and boarding facility.

The turning basin will require the dredging of islands in order to fulfill the required area, equivalent to a turning platform of an elliptic form with a maximum axis which will be finalized by navigation simulation studies.

Regasification/Export

The FSRU's vaporisation facilities are designed to deliver 600 MMSCFD of vaporised LNG at a send-out pressure of 100 barg. The system is capable of operating at send-out rates between 100 MMSCFD and 600 MMSCFD, with an anticipated normal rate of 500 MMSCFD.

The regas cargo transfer will take place via a high pressure (HP) gas unloading arm with the vessel moored at the terminal jetty.

The arm is an "S" type double counterweighted design which is fully balanced in all positions. Two independent counterweight systems are used to balance the inboard and outboard sections of the arm. The "S" or supported version is designed to separate the 12 inch diameter gas carrying line from the mechanical structure. The design of the arm is OCIMF compliant, the structure weights approximately 65 tonnes incorporating gas swivels rated for a design pressure of 134 barg.

It is noted that EVLT will also consider the construction of a regasification plant on the jetty. In this case, it will no longer be necessary to have a FSRU in port, but LNG carriers will remain moored to the pier as storage buffer tanks until all LNG has been regasified in the plant.

STS LNG Transfer

For continuous terminal operations it is proposed to provide shuttle LNGCs offloading LNG to FSRU berthed at the terminal jetty. For double banked STS arrangement (Option 1) the shuttle LNGCs will be moored and connected portside of the FSRU as this will enable both vessels' manifolds to be in line, with a maximum tolerance of 2 m fore and aft.

The proposed transfer system is based on the use of standard 8" composite hoses. The following typical data apply:

-type	composite hose
-diameter	8"
-bending radius	min 0.65m
-length	15 m
-max. capacity	1,000 m^3/h
-quantity	total 8 pieces
-supplier	GUTTELING

The hoses will be connected by spool pieces on both the LNGC and the FSRU manifolds. The spool pieces provide connection for two hoses on every liquid line (3 x 2 hoses) and for two (2) hoses on the vapour return line; this also allows one extra liquid line for redundancy.

A storage rack is provided on the deck of FSRU to allow for storage of the hoses (8 hoses, 15 m length) and also to facilitate easy handling by the vessel's manifold crane.

For across the jetty and tandem STS arrangements (Options 2 and 3) it is expected that the LNGC offloading and FSRU loading will take place by the use of typical LNG 'chicksan' type loading arms and interconnecting LNG piping on the jetty.

Control Systems

The emergency system of the FSRU and the LNGC will be connected to the jetty's system by the ship to shore interface which will drive the ESD system and works as Ship to Shore data communication Link (SSL). A typical programmable logic controller (PLC) with SCADA system may be installed. This system will allow operating the entire system from the control room.

A control room integrated with all gas pipeline main services will be provided, and it will typically include:

- VHF/UHF communications
- telephone service and computer network

- control system (PLC-SCADA)
- safety instrumented system for ESD
- CCTV
- weather station with data record
- electrical equipment room
- instrumentation equipment room
- UPS for critical services
- fire system center for the jetty and the export facilities in general
- operating/service room

Safety Systems

All LNG and gas piping will be equipped with safety valves. Process transmitters, alarms and push buttons connected with the process/safety system will be provided. The safety system for the jetty facilities will incorporate dedicated firewater pumps, water/foam deluge via two new monitors, F&G and low temperature detectors and an ESD system capable to trip transfer operations and to emergency disconnect the FSRU.

Additional safety redundancy will be provided by the ship-to-shore ESD which can be activated both automatically and manually. The ESD system will shutdown the ship's unloading pumps and close the LNG and gas flow valves both on the ship and shore within 30 seconds. In addition, the regasification unloading arm is typically fitted with emergency release couplings which allow for automatic disconnection. This disconnection can take place within 30 seconds limiting the amount of possible LNG spillage.

2. RISK ASSESSMENT

2.2 HAZID Study

The HAZID study took place in EVTL's offices in Karachi, Pakistan. The team review was led by a Chairman assisted by a Recorder. The remainder of the HAZID team comprised specialists from EVTL's project design and operations, PQA's marine operators, PQA's design consultants and LR Technical Investigation (TID) specialists (see Appendix 1 for attendees).

The objectives of the HAZID study were:

- Identify potential hazards associated with the FSRU and LNGC port approach and berthing operations at the proposed LNG Terminal facility

- Identify potential hazards associated with the proposed Terminal Options with regards to the near shore location, installation and operation of a regasification and gas export facility.

- Identify potential hazards associated with the aspects of the design and operation of the STS LNG cargo system

- Assess the adequacy of the proposed marine facilities, layout design and piping systems for ensuring the integrity of the installation.

- Assess the adequacy of the existing safeguards and port support assets and identify the Regulatory requirements for project compliance.

- Perform a round table discussion of potential failure mode scenarios and emergency response procedures and identify remedial measures that will reduce the potential hazards and minimise risks.

The study was led by a Chairman whose main responsibilities were:

- Produce procedure schedule and plans study sequence to achieve the scope of the HAZID

- Run and progress the study using an appropriate format of guide words. Achieve the scope and schedule whilst limiting individual sessions to the recommended duration.

- Summarise the main study findings and issue a HAZID Report in conjunction with the Recorder.

The Chairman was assisted by a Recorder who suitably 'word processed' all actions, recommendations and clarifications raised by the team during the study sessions.

Prior to HAZID study, the Chairman derived a series of guide words comprising potential failures and consequences, which could be used for identifying hazards associated with gas port operations. The guide words were supplemented by discussion of potential hazards and scenarios based on the project's experience on engineering activities at similar regasification terminals. The guide words used were as follows:

Marine Ops failure
Leakage/Rupture
Impacts/Loads
Release/Fire/Explosion
Structural integrity
Mechanical/system failure
Export Ops failure

Each part of the proposed operations and the area(s) which would take place either on the jetty or onboard the FSRU was reviewed in turn by the HAZID team, applying the guide words or considering potential scenarios, to identify potential hazards. Causes of the potential hazards and resultant consequences were then identified, together with any safeguards and mitigating measures. The following operations and related systems were examined:

1. EBRV/LNGC Marine Operations within PQA
2. EBRV/LNGC Berthing and Mooring Operations
3. Jetty Safety Lay-out and Fire Protection
4. Export Operations

For the above phases of operations the safety controls, disconnection/release and emergency response provisions were also identified and discussed.

Where necessary, recommendations were made with respect to changes in the design and/or implementation of procedures to minimise risk levels.

The team discussions were recorded on the HAZID work sheets, which are presented in Appendix 1. The work sheets are divided into the following categories:

- Item(operation/system)
- Hazard
- Cause (of Hazard)
- Potential Effects (of Hazard)
- Safeguards
- Recommendations (Action allocation)

2.3 Hydrocarbon Inventories

An assessment of the LNG inventories has taken place in order to establish the flammability and hence the probability of ignition of the gases and liquids involved.

In order for a fire to start in the presence of a fuel-air mixture, there must be an ignition source of sufficient heat intensity to cause ignition. However, after the fire has started, the heat required to sustain combustion is usually supplied by the combustion process itself.

A flammable gas or vapour burns in air only over a limited range of concentration. Below a certain concentration of the flammable gas, the Lower Flammability Limit (LFL), the mixture is too 'lean', whilst above a certain concentration, the Upper Flammability Limit (UFL), it is too 'rich'. The concentrations between those limits constitute the flammable range.

The lower and upper flammability limits are also called, respectively, the lower and upper explosive limits.

The actual flammable limits for hydrocarbons in air depend on the composition of the fuel. For example, methane is flammable between 5 – 15 v/v% and propane between 2.1 – 9.5 v/v%. Ignition will only occur if a gas or vapour cloud finds an ignition source within its flammable range.

The flash point of a flammable liquid is the temperature at which the vapour pressure is sufficient to result in a concentration of vapour in the air corresponding to the lower flammable limit. A hydrocarbon liquid, which has a flash point below ambient temperature when released to atmospheric pressure, has the potential to ignite. A liquid with a high flash point, such as diesel or fuel oil, could also ignite if raised in temperature above its flash point by an external heat source, or if the release is a high-pressure spray, which encourages vaporisation. Flash point is the main parameter in the hazard classification of flammable liquids.

A flammable gas, or vapour, can be readily ignited, by a small flame or spark, whereas a non-volatile liquid would require a much more intensive heat source. This is because it is necessary to first heat the liquid sufficiently to cause vaporisation.

There is a minimum, ignition energy required in order to give rise to a continuing flame through the remaining gas cloud. The minimum energy varies with type of gas and concentration and usually occurs close to the stoichiometric mixture. A minimum energy of approximately 0.25mJ is necessary to ignite hydrocarbon vapours, whereas high flash point liquids, such as diesel and fuel oil, require much higher energy ignition sources, usually an existing fire, unless atomised or soaked into lagging.

The flammability of fluids and material present at typical FSRU and LNGC have been assessed using the Flammability Hazard Rating from NFPA 325M under the categories as shown in the table below. Flammable liquid classes referred to in the table below are explained in IP15.

In general, materials with a flammability rating of 3 and 4 represent fire hazards that are relatively easily, ignited. Materials with flammability rating of 1 or 2 require pre-heating. In general, these are only of concern from the possibility of escalation, due to flame impingement from an existing fire.

Table 1 – NFPA 325M Flammability Rating

Flammability Rating	Description
4	This degree includes flammable gases, pyrophoric liquids and class IA flammable liquids. The preferred method of fire attack is to stop the flow of material or to protect exposures while allowing the fire to burn itself out.
3	This degree includes Class IB and IIC flammable liquids and materials that can be easily ignited under almost all normal temperature conditions. Water may be ineffective in controlling or extinguishing fire in such materials.
2	This degree includes materials that must be moderately heated before ignition will occur and includes Class II and IIIA combustible liquids and solids and semi-solids that readily give off ignitable vapours. Water spray may be used to extinguish fire in these materials because the materials can be cooled below their flash points.
1	This degree includes materials that must be pre-heated before ignition will occur, such as Class IIIB combustible liquids and solids and semi-solids whose flash point exceeds 93.4°C, as well as most ordinary combustible materials. Water may cause frothing if it sinks below the surface of the burning liquid and turns to steam. However, a water fog that is gently applied to the surface of the liquid will cause frothing that will extinguish the fire.
0	This degree includes any material that will not burn.

The properties of the various flammable inventories present on the FSRU/LNGC are summarised in the Table 2.

Table 2- Physical Properties of FSRU Hydrocarbon Inventories

Fluid	Mol Wt	Flash Point	Auto Ign Temp (C)	Ign Energy 10-5 cal	Boil. Point (C)	Flammable Concentration Limits (%)		Den. (kg/m³)	Spec. Grav.	Liquid Burn Rate (kg/m²/s)	Heat of Comb. (MJ/kg)	NFPA Flamm-ability Rating
						Lower	Upper	Gas	Liquid			
Methane	16	-	637	6.9	-162	5.3	15	0.71	0.55	0.078	50.2	4
Hexane	86	-22	225	5.5	69	1.0	7.4	N/A	0.66	0.074	44.2	3
Diesel	-	38	-	-	-	-	-	N/A	0.90	0.035	-	2
Lube Oil	-	76	248	-	-	-	-	N/A	0.90	0.035	-	2

3. CONCLUSIONS AND RECOMMENDATIONS

The proposed EVTL jetty regasification operations supported by LNG STS cargo transfer and export gas pipeline have been assessed for their suitability to handle major hazards and based on the findings of the HAZID study, is judged not to present any intolerable risks, nor any risks significantly greater than those found to be acceptable for conventional LNG onshore terminals. The following conclusions apply:

3.1 Terminal Options

- For Option 1 project to provide the basic layout of the jetty facility to address double banked mooring arrangement. The proposed arrangement should identify the size (m^2) of the proposed jetty including the number and position of dolphins. The design to establish the distance:
  - Between the jetty and the outer line of sailing channel.
  - Between a 151,000 m^3 size FSRU moored at the jetty and the outer line of sailing channel.

  It is recommended that a minimum safety distance of 200m to be maintained between the double banked ship arrangement and the channel traffic. Passing traffic scenarios should also be addressed by real time navigation simulations.

  Based on the HAZID preliminary review and critical considerations on typical berthing conditions and turn around basins for 138,000 m^3 to 151,000 m^3 vessels, Option 1 is considered a feasible solution. Project would need to address the commercial acceptability based on the civil engineering development costs for the jetty/associated pipeline and also on the extent of the necessary dredging.

  It is noted that an adequately sized lay-out area on the jetty will be able to accommodate a project expansion to include an onshore regasification module. The terminal will operate without the need for a FSRU but a permanently berthed LNGC will be required in order to provide the LNG buffer space capacity to maintain continuous feed to the regasification and gas export installation. Double banked STS operations with hoses may continue but LNG offloading arms and piping will need to be provided to facilitate LNG transfer from the buffer LNGC to the regasification system. It is noted that the commercial benefits versus the drawbacks of such an installation will largely depend on to the potential future growth of gas demand in the area.

- Based on the previous experience with STS /export operations at both sides of a jetty Option 2 is also considered a feasible solution. However the HAZID identified numerous critical issues, especially related to the extent of dredging required in order for the FSRU to berth portside on the jetty side nearest to shore. Potential limitations have also been identified due to the available space for the LNGC to dock starboard side as it may be very close to the traffic channel lane. The STS LNG transfer across the jetty will typically necessitate the installation of LNG unloading/loading arms and LNG piping on the jetty.

LNG transfer operation via rigid 'chiksan' type arms and piping substantially improves cargo transfer times due to the system size and higher flow velocities achieved. The feasibility of choosing Option 2 with an FSRU on site may carry potentially more commercial drawbacks than benefits. However, with onshore regasification such an installation will be able to operate without additional changes to the LNG transfer arrangements and will benefit from a substantial reduction in berthing, mooring and cargo transfer times.

- Project to provide basic layout of jetty facility for Option 3 to address tandem mooring arrangement. The proposed arrangement should establish the following:
  - Length of berthing area to accommodate two (2) 151,000 LNGCs with a minimum separation distance of 100 m
  - Jetty area (m^2) able to accommodate rigid LNG arms for shuttle LNG carrier offloading and LNG arms for FSRU LNG loading. The two arm systems will be connected with all the appropriate transfer and utilities piping.

  Based on the HAZID review and critical considerations on typical berthing conditions and turn around basin, Option 3 is considered a feasible solution. It is recommended that the lay-out area available for onshore regasification equipment to be addressed by project at an early stage. Similarly with Option 2 any future onshore expansion will benefit from pre-installed LNG arms and piping on the jetty. Project to decide on commercial acceptability based on the results of the simulation navigation study which will establish the extent for the necessary dredging and also the costs of the civil and LNG arms/piping engineering works for the proposed jetty size.

- With regards to the extend of the dredging in order to establish an adequate turning basin it is also noted that future PQA plans include for a development of other gas ports one in the Korangi Creek opposite buoys 6 and 7 and one behind it facing the Korangi Fish Harbour area and two terminals before EVTL proposed site . There is justifications for the terminal developers to discuss with PQA the possibility of a common turning basin to be used for both facilities. The potential benefit on such arrangement would be the need to dredge only a channel connecting the basin with the proposed EVTL jetty in order to enable safe FSRU/LNGC berthing. The benefit of the above against creating own turning basin in front of EVTL Green field site needs to addressed in the economic evaluation of the project.

- The HAZID team examined the Brown Site Option and identified a number of operational advantages:
  - Existing turning basin maintained at13.0 m depth
  - Potential of provision of anchorage pocket inside Chara Creek to facilitate bi-directional traffic.
  - Full time monitoring traffic in the area by PQA control.
  - Close proximity to PQA's support vessels jetty.
  - Most tug operations take place in the area, hence a high tug availability during STS operations.

- Existing high 'awareness' in the area of all shipping and offloading operations.
- Successful long term LPG offloading operations at EVTL facility, with established safety training and emergency response plans in place.

The main drawback of the Brown Option is the close proximity of the LNG terminal to the main port terminal facilities, industrial facilities, working population and accommodation facilities. Any potential medium to large release of gas under the current prevailing wind conditions is likely to have a potential impact on to the adjacent facility. However, it can be argued that the closest facility to the future LNG terminal is the EVTL's LPG/chemicals plant which has been purposely designed to mitigate against such type of hazard event (hazardous area classification, non sparking certified 'EXe' equipment, ESD system, F&G detection, safety procedures etc.).
It is likely that PQA will prefer the current industrial trend which favours the separation of LNG terminals from refineries or port facilities within the same area, but it should be noted that this trend applies only to full LNG storage and processing terminals. The proposed 'GasPort' type terminal for PQ is in comparison very small, employs only a gas export facility with limited volumes (600 mmscfd max) and does not have any onshore LNG storage tanks or processing facility.

3.2 Marine and Jetty Safety

The major events of marine failure, gas release, operational failure and control/isolation failure have been considered in all aspects of the proposed system, and mitigation measures were identified to reduce the risks.
The detailed recommendations and actions identified are presented in the HAZID Work Sheets Appendix 1 of this report. A summary of the main findings is presented below:

- Project to address maritime climate, wind and waves study for local conditions and calculate wave height and period. Operability Analysis to be undertaken in order to the define limit of local operations and establish window of operations available with time (window % per year). It is recommended that the operability analysis be based on the largest FSRU design (151,000 m3) able to sail existing channel waters in order to define limit of local operations. Project to request updated data for both Hs and Tp (channel and jetty location) from PQA in order to be used in studies.

- The PQA general requirement is for a safety allowance in outer channel of 15% (10% inner channel) of vessel's draft measured from zero datum (0). (1.8m clearance for 12m draught vessel). Project may consider the minimum allowance factor of 10% equating to 1.2 m clearance inside the channel (from bottom of the vessel's draft). This would need the confirmation of the FSRU and shuttle tanker operators.

- A navigation simulation study to be conducted to analyse FSRU and LNGC approach manoeuvring and docking with real time failure scenarios. The following to be addressed:
  - Basic speed of approach/speed reduction at passage of critical areas on the channel and potential squat while maintaining keel clearance.
  - Max turning circle and docking manoeuvre to determine number of tugs, bollard size, effective tug assistance, and potential scenario limitations with one tug failure.
  - Potential restrictions due to insufficient area dredging, traffic limitations, insufficient marking
  - Potential for bi-directional traffic at predetermined channel areas and limitations due to minimum speed of crossing requirements.
  - Input/participation of masters and local port pilots is essential

- Project to identify PQA requirements and potential limitations and address:
  - Passive or active tug escorted passage (not current procedure by PQA).
  - Number of pilots/ availability.
  - Pilots training requirements for LNGC (up to FSRU size)
  - Availability of tugs and time required for a tug to reach entry or mid-channel locations.
  - Requirement for full time stand-by fire tug and or pilot at jetty during STS cargo transfer operations.
  - Frequency of survey especially at high silting areas. Frequency of dredging operations
  - Any other location specific requirements

- It is noted that PQA's current operating procedures would need to be updated in order to address issues in line with typical LNG port operations and any critical findings of the simulation studies. The following apply:
  - Based on the existing experience from LNG operations within similar channels and terminals and with the view of future increase traffic in the area PQA should consider investing in a VTMS system
  - PQA to address the provision of three (3) 60 tonnes bollard pull ESD tugs (based on experience at similar size LNGCs), fendering tug and provision of mooring personnel at site for the required time as a minimum
  - Also in line with common practice it is recommended that procedures are reviewed and commented by LNGC operating companies.

- Project to undertake mooring simulation studies to address and finalise the following:
  - Size position and number of dolphins
  - Actual mooring lines configuration for double banked or tandem options
  - Load requirements and proposed size of hooks (single wire per hook recommended)
  - Wind, current impact on to double bank mooring arrangement

- Impact on passing vessel on to mooring arrangement (worst case scenario)
- Line pretension requirements
- Verify mooring integrity with loss of one line as per OCIMF requirements

- Civils jetty design to provide available layout area to include the following typical equipment as a minimum:
  - Regas export arm (typically 65t weight, 2x10 m foot area),
  - ESD valve skid
  - Gas metering skid
  - Pipe rack to include gas export pipeline, utilities piping to FSRU (fuel, water)
  - Crane pedestal with lay-down area for heavy equipment.
  - Two (2) independent fire pumps.
  - Two (2) tower fire monitors
  - Gangway to FSRU
  - Also consider available area for potential installation of a regasification module (s).

- Project to establish a Fire Protection Philosophy. The philosophy should identify the following as a minimum:
  - Size of fire pumps based on maximum firewater requirement.
  - Deluge system coverage
  - Size/reach of remote controlled water monitors
  - Coverage of dry powder and AFFF provisions
  - Number, type and position of the gas detectors on the jetty.

  Also project to address ESD function on gas detection (ESD1 for 2 out of 3 or 1 out of 2 detectors.). Cause and Effects to be examined by HAZOP with participation of the FSRU operator.

- QRA study to address release scenarios from the FSRU, typical gas export equipment and piping and estimate plume generation with time for the predominant wind direction. The analysis to address ignition events with resulting fire/explosions and establish potential pressure and thermal loads within the jetty area. This study should be integral part of the overall QRA required for the terminal installation.

3.3 Operations Safety

A summary of the main findings is presented below:

- Project to develop Commissioning Procedure and issue to FSRU for comments. The Procedure to address the following as a minimum:
  - ESDV leak testing (without pressure on one side)
  - Rump-up vaporisation process (steps up 100 mmscfd up to a max 450)
  - Purging/venting process

- Arm testing process in order to pressurize and operate the arm when pressurizing the system. A minimum of two separate stops of commissioning process are required for the arm commissioning.
- Drying operations after pressure testing /inerting to eliminate any water traces
- Mutual Operation Procedure
- LNG Transfer Procedures

- Project to address in detail ESD actuation for FSRU/LNGC combined system. 'Cause and Effect' study to be updated to address the interconnection and operation of the ESD system for both vessels when they are connected and also FSRU ESD connection with the jetty Control Room. Project to undertake HAZOP of P&IDs to ensure safe control/ shutdown, elimination of locked in inventories and ability to purge all piping sections.

- Emergency Procedures to be developed to address disconnection and mooring release of shuttle vessel. Issues to be addressed:
  - Number of stand-by tugs available and sail time requirement
  - Necessity for mooring quick release of ships (ship from ship, and ship or ships from jetty).
  - Operation of jetty side quick release hooks, whether all together, singly, or group release.
  - Authorisation of sail away by ship captain or PQA
  - Sail away window of operations impact of tide, traffic convoy etc.

- Operation procedures to address potential LNG leakage and/or fire event at manifolds. Emergency procedures to address the following:
  - Requirement for standby fire tugs during the STS operations
  - Requirement for standby engine operations for LNGC
  - Ability of LNGC mooring lines disconnection and sail away with pilot onboard
  - Ability of jetty terminal to provide fire fighting assistance to the permanently moored FSRU
  - Address personnel escape/evacuation. For LNGC provision of escape ladders at manifolds (fixed or temporary) enabling personnel to escape without going under the hoses. For the FSRU position of gangway to jetty
  - Address escape/evacuation to sea on the LNGC via fwd lifeboat or via supporting tug
  - Safe communications between ships and with jetty

- In case of emergency disconnection especially in adverse weather conditions a cargo plan is required for LNGC to prevent sloshing effects due to partial filling. (Note LNGC designed to carry an LNG 'heel' in one tank). Project to establish best unloading sequence to avoid sloshing effects with input from Class and tank designer. Operation procedures to be established.

4. REFERENCES

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3. Port Mohammed Bin Qasim, Admiralty Chart
4. Port Mohammed Bin Qasim, Tide Tables
5. Brief of Safety and Security Criteria foe Establishment of Terminals at Port Qasim, by PQA
6. General Arrangement for Exmar 150,900 m^3 LNG Regasification Vessel, by DSME
7. NFPA 59A Standard for the Production, Storage and Handling of Liquefied Natural Gas (LNG), 2009 Edition
8. Lloyd's Register Rules for Ships for Liquefied Gases, 2009 Edition

Appendix 1

HAZID Worksheets

HAZID Review Team Members

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15: Capt Nouman, PQA
16: John Maguire, LR
17: Atique Baig, LR

Project : EVTL LNG Terminal			Drawings: Maritime Chart :		**HAZID sheet 1**
Area: PQA			Revision: 1		Date: 17/01/2011
System : FSRU, LNGC marine operations					
ITEM	**HAZARD**	**CAUSE**	**POTENTIAL EFFECTS**	**SAFEGUARDS**	**RECOMMENDATIONS**
1.1 FSRU/LNGC Approach to channel entry	Inability to approach entrance to channel	Pilot unable to board, bad visibility/ weather	Uncontrolled approach, Impact collision with other vessel, grounding Emergency dropped anchors	Pilot service for all vessels, pilot station operates requiring 12 hr notice prior to pilot's board. Pilot is boarding prior to entering the channel area. In case of delays there is anchorage area 4 x 2 nm available for use. This area is shown on marine charts.	**1.1.1** PQA to confirm the operation and the method of monitoring the number and the exact position of vessels within or outside the anchorage area. Use of specified anchorage areas would need to be enforced and monitored especially with the potential increase of traffic in the area. **Action: PQA**
	High environmental loads, reduced navigation.	SW Monsoon affects local operations, between months May to September with Max winds of 16-25 knots (gusting to 35kn)	Reduced manoeuvrability due to wind and wave height, reduced visibility, inability to operate pilot service, potential for human and equipment failure, potential for grounding As above	PQA states that based on historical information pilots manage to navigate vessels in channel even during SW monsoon (up to 12 m draught size vessels already operated in channel).	**1.1.2** Project to address • Maritime climate, wind and waves study for local conditions and calculate wave height and period • Operability Analysis to define limit of local operations and establish window of operations available in time (%). • Also with reference to sloshing

Project : EVTL LNG Terminal	Drawings: Maritime Chart :	HAZID sheet 1
Area: PQA	Revision: 1	Date: 17/01/2011
System : FSRU, LNGC marine operations		

ITEM	HAZARD	CAUSE	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
					limitations if partial cargos involved confirm operating envelope with the proposed shuttle LNGC and FSRU operators **Action : EVTL** **1.1.3** It is recommended that the operability analysis be based on the largest FSRU design (151,000 m3) able to sail existing channel waters in order to define limit of local operations. It is recommended that operability be calculated for both time and probability (window % per year). LR to provide appropriate documentation for guidance to project. **Action : EVTL/LR** **1.1.4** Project to request updated data for both Hs and Tp (channel and jetty location) from PQA in

Project : EVTL LNG Terminal	Drawings: Maritime Chart :	**HAZID sheet 1**
Area: PQA	Revision: 1	Date: 17/01/2011
System : FSRU, LNGC marine operations		

ITEM	**HAZARD**	**CAUSE**	**POTENTIAL EFFECTS**	**SAFEGUARDS**	**RECOMMENDATIONS**
					order to be used in studies. **Action: EVTL/PQA**
	Cyclonic weather. Inability to enter channel waters	Cyclonic conditions (Historical evidence of 47 storms in 90 years in Arabian sea)	Inability to sail within the area, inability to safely anchor at or near shore areas.	Early weather notification of cyclonic conditions and also Cyclone Warning at the South Pakistan area is expected to be issued for all approaching vessels to PQA and all sailing activities near the area. No vessel operations will take place for the duration of the event.	
1.2 FSRU/LNGC Channel Entry Ahsan to Bundal island buoy P-14	Shallow water depth main channel	Insufficient draft clearance from seabed (all areas), combined impact of weather and tidal conditions	Vessel grounding, structural impact, potential loss of cargo, commercial impact and environmental impact on area/ port Qasim operations	Current PQA operations include 12 m draft vessel which enter at mean and high tide. 14.7 m depth currently water depth in outer channel (Bundal island FI CII beacon), 13m depth in inner channel.	**1.2.1** The PQA general requirement is for a safety allowance in outer channel of 15% (10% inner channel) of vessel's draft measured from zero datum (0). (1.8m clearance for 12m draught vessel). Project may consider the minimum allowance factor of 10% equating to 1.2 m clearance inside the channel

Project : EVTL LNG Terminal	Drawings: Maritime Chart :	**HAZID sheet 1**
Area: PQA	Revision: 1	Date: 17/01/2011
System : FSRU, LNGC marine operations		

ITEM	HAZARD	CAUSE	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
					(from bottom of the vessel's draft). This would need the confirmation of the FSRU and shuttle tanker operators. **Action: EVTL/FSRU/ LR to advice** **1.2.2** Project to further analyse real ship motions for other shuttle LNGCs in order to finalise common criteria which will apply to all operating vessels. Issues to be addressed are basic speed of approach/speed of passage at critical areas (to be defined by PQA) in the channel and potential squat while maintaining 1.2 m keel clearance. **Action: EVTL/LNGC/PQ**.
	Restricted channel manoeuvrability due to prevailing environment and also available	Insufficient speed reduction, turning ability, effects of tide/waves/wind during passage.	Vessel grounding, structural impact, potential loss of cargo, commercial impact and environmental impact on	Current PQA operating procedures, existing traffic is guided through marked channel by floating buoys and onshore beacons (at bends)	**1.2.3** A navigation simulation study to be conducted to address approach manoeuvring and docking with real time failure scenarios. The following to be

Project : EVTL LNG Terminal	Drawings: Maritime Chart :	HAZID sheet 1
Area: PQA	Revision: 1	Date: 17/01/2011
System : FSRU, LNGC marine operations		

ITEM	HAZARD	CAUSE	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
	channel width and depth at specific areas.	Insufficient sail time clearance in channel, problems with bi-directional traffic operation.	area/ port Qasim operations.		addressed: • Basic speed of approach/speed reduction at passage of critical areas on the channel and potential squat while maintaining keel clearance. • Max turning circle and docking manoeuvre to determine number of tugs, bollard size, effective tug assistance, and potential scenario limitations with one tug failure. • Potential restrictions due to insufficient area dredging, traffic limitations, insufficient marking • Potential of bi-directional traffic at certain predetermined areas and any limitations due to the minimum speed of crossing requirements. • Input/participation of masters

Project : EVTL LNG Terminal			Drawings: Maritime Chart :		**HAZID sheet 1**
Area: PQA			Revision: 1		Date: 17/01/2011
System : FSRU, LNGC marine operations					
ITEM	**HAZARD**	**CAUSE**	**POTENTIAL EFFECTS**	**SAFEGUARDS**	**RECOMMENDATIONS**
					and local port pilots is essential **Action: LR/EVTL/PQA**
	Vessel at distress condition inside channel route	Loss of power/steering, Navaids failure, onboard fire, human error, bad visibility or weather	Channel traffic will be stopped for all vessels with long delays on overall PQA operations. Channel traffic also influenced by favourable tide conditions and day light operations.	Vessels entering channel without tugs – current procedure	**1.2.4** Project to identify Port Authority requirements and potential limitations and address: • Passive or active tug escorted passage (not current procedure). • Number of pilots/ availability. • Pilots training requirements for LNGC (up to FSRU size) • Availability of tugs and reduction of time required for a tug to reach entry or mid-channel locations. • Requirement for full time stand-by tug and or pilot at jetty • Frequency of survey especially in high silting areas. Frequency

Project : EVTL LNG Terminal	Drawings: Maritime Chart :	**HAZID sheet 1**
Area: PQA	Revision: 1	Date: 17/01/2011
System : FSRU, LNGC marine operations		

ITEM	HAZARD	CAUSE	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
					of dredging. • Plus any other location specific requirements **Action : EVTL/PQA**
	Bi-directional traffic within channel	Vessel drift due to large windage exposure or tide impact	Potential impact collision or vessel grounding, structural impact, commercial impact and environmental impact on area/ port Qasim operations	One way traffic only. Due to direction and speeds at passing any potential of collision is for side area with very low possibility of LNG cargo tank penetration and LNG consequent release.	**1.2.5** Project to examine potential of bi-directional traffic between LNG shuttle tankers and any other traffic (including following vessel) currently as operated by PQA. In order to increase factor of safety PQA to address bidirectional traffic only at certain areas and also at minimum speeds in order to avoid any possibility of drift because of tide and wind conditions. PQA to provide specific data for inclusion in real time simulation. **Action: LR/PQA** **1.2.6** Based on the existing experience from LNG operations

Project : EVTL LNG Terminal	Drawings: Maritime Chart :	**HAZID sheet 1**
Area: PQA	Revision: 1	Date: 17/01/2011
System : FSRU, LNGC marine operations		

ITEM	HAZARD	CAUSE	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
					within similar channels and terminals and with the view of future increase traffic in the area PQA should consider investing in a VTMS system. **Action: PQA**
	Inadequate LNG Port Terminal procedures in place				**1.2.7** It is noted that PQA's current operating procedures would need to be updated in order to address issues in line with typical LNG port operations and any critical findings of the simulation studies. Also in line with common practice it is recommended that procedures are reviewed and commented by LNG operating companies. **Action: PQA**

Project : EVTL LNG Terminal			Drawings: Maritime Chart :		**HAZID sheet 1**
Area: PQA			Revision: 1		Date: 17/01/2011
System : FSRU, LNGC marine operations					
ITEM	**HAZARD**	**CAUSE**	**POTENTIAL EFFECTS**	**SAFEGUARDS**	**RECOMMENDATIONS**

Appendix 1

System: EVTL LNG Terminal	Drawings: GasPort GA (typical)	**HAZID sheet 2**
Area: Jetty Options	Revision: 1	
Equipment : FSRU/LNGC berthing, Mooring dolphins and gas export equipment		

ITEM	HAZARD	CAUSE	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
2.1 Option 1 FSRU/ LNGC Docking & Mooring	LNGC power/ steering, loss of tug support, fendering failure, mooring line/hook/dolphins failure, dock structural integrity, bad weather impact at dock	Engine malfunction, critical tug malfunction Critical variable wind speed. Insufficient jetty onshore mooring arrangements	Uncontrolled approach fendering/pier integrity loss		**2.1.1** Project to provide basic layout of jetty facility for Option 1 to address double banked mooring arrangement. The propose arrangement should establish the size (m^2) of the proposed jetty including number and position of dolphins. The design to establish the distance: • Between the jetty and the outer Line of sailing channel. • Between a 151,000 m^3 size FSRU (291 m) moored at the jetty and the outer line of sailing channel. **Action: EVTL/LR** **2.1.2** Project to undertake simulation study to address maximum turning cycle requirements for safe berth of

System: EVTL LNG Terminal	Drawings: GasPort GA (typical)	**HAZID sheet 2**
Area: Jetty Options	Revision: 1	
Equipment : FSRU/LNGC berthing, Mooring dolphins and gas export equipment		

ITEM	**HAZARD**	**CAUSE**	**POTENTIAL EFFECTS**	**SAFEGUARDS**	**RECOMMENDATIONS**
					FSRU and LNGC for worst case condition i.e. number of tugs, tide wind and wave (PQA to provide environmental input). Based on the findings of the simulation project to accept viable solution for jetty and estimate the required dredging area and depth. **Action: EVTL/LR** **2.1.3** Based on the HAZID preliminary review and critical considerations on typical berthing conditions and turn around circle for 138K to 151K FSRU, Option 1 is considered a feasible solution. Project to decide on commercial acceptability based on the results of the simulation navigation study which will establish the extent for the necessary dredging and also costs of the civil

System: EVTL LNG Terminal	Drawings: GasPort GA (typical)	HAZID sheet 2
Area: Jetty Options	Revision: 1	
Equipment : FSRU/LNGC berthing, Mooring dolphins and gas export equipment		

ITEM	HAZARD	CAUSE	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
					engineering works for the proposed jetty size. **Action: EVTL**
	Loss of mooring integrity	Line/hook/dolphins failure, dock structural integrity, bad weather impact at dock, passing vessel impact at mooring system	Excessive ship motions, potential ESD initiation, interruption of regas operations	Typical arrangement wires and hooks	**2.1.2** Project to undertake mooring simulation studies to address and finalise the following: • size position and number of dolphins • actual mooring lines configuration for double banked option • load requirements and proposed size of hooks (single wire per hook recommended) • wind current impact on to double bank mooring arrangement • impact on passing vessel on to mooring arrangement (worst

System: EVTL LNG Terminal	Drawings: GasPort GA (typical)	**HAZID sheet 2**
Area: Jetty Options	Revision: 1	
Equipment : FSRU/ LNGC berthing, Mooring dolphins and gas export equipment		

ITEM	HAZARD	CAUSE	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
					case scenario) • line pretension requirements • verify mooring integrity with loss of one line as per OCIMF requirements **Action: EVTL** .
2.2 Option 2 FSRU/ LNGC Docking & Mooring	LNGC power/ steering, loss of tug support, fendering failure, mooring line/hook/dolphins failure, dock structural integrity, bad weather impact at dock	Engine malfunction, critical tug malfunction Critical variable wind speed. Insufficient jetty onshore mooring arrangements	Uncontrolled approach fendering/pier integrity loss		**2.2.1** Refer to actions **2.1.1** and **2.1.2** above **2.2.2** Based on the HAZID preliminary review Option 2 is also considered feasible solution. However the HAZID review identified numerous critical issues, especially related to the extend of dredging required in order for the FSRU to berth on the jetty side nearest to shore tanker and also because of the

System: EVTL LNG Terminal	Drawings: GasPort GA (typical)	**HAZID sheet 2**
Area: Jetty Options	Revision: 1	
Equipment : FSRU/ LNGC berthing, Mooring dolphins and gas export equipment		

ITEM	**HAZARD**	**CAUSE**	**POTENTIAL EFFECTS**	**SAFEGUARDS**	**RECOMMENDATIONS**
					limitations of available space for the LNGC to dock port side. The review also identified that additional equipment to be installed will necessitate LNG unloading arms and LNG piping on the jetty. The feasibility of choosing Option 2 with an FSRU in place maybe entails more commercial drawbacks than benefits. However, Option 2 would appear to carry more benefits with the regas system installed on the jetty. EVTL to consider commercial acceptability. **Action: EVTL**
2.3 Option 3 FSRU/ LNGC Docking & Mooring	LNGC power/ steering, loss of tug support, fendering failure, mooring line/hook/dolphins	Engine malfunction, critical tug malfunction Critical variable wind speed.	Uncontrolled approach fendering/pier integrity loss		**2.3.1** Project to provide basic layout of jetty facility for Option 3 to address tandem mooring arrangement. The propose arrangement should establish the

System: EVTL LNG Terminal	Drawings: GasPort GA (typical)	**HAZID sheet 2**
Area: Jetty Options	Revision: 1	
Equipment : FSRU/LNGC berthing, Mooring dolphins and gas export equipment		

ITEM	HAZARD	CAUSE	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
	failure, dock structural integrity, bad weather impact at dock	Insufficient jetty onshore mooring arrangements			following: • Length of Berthing area to accommodate two (2) 151k LNGCs with minimum separation distance of 100 m • Jetty area (m^2) able to accommodate LNG arms (chiksan type) for shuttle LNG carrier offloading and LNG arms for FSRU LNG loading. The two arm systems will be connected with all the appropriate transfer and utilities piping. **Action: EVTL** **2.3.2** Based on the HAZID preliminary review and critical considerations on typical berthing conditions and turn around circle for 138K to 151K vessels, Option 3 is considered a feasible solution. It is noted that

System: EVTL LNG Terminal	Drawings: GasPort GA (typical)	**HAZID sheet 2**
Area: Jetty Options	Revision: 1	
Equipment : FSRU/ LNGC berthing, Mooring dolphins and gas export equipment		

ITEM	HAZARD	CAUSE	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
					in addition to marine/ access issues related to Option 1 the HAZID also identified additional LNG loading arm and piping lay-out issues which need to be addressed by project. Project to decide on commercial acceptability based on the results of the simulation navigation study which will establish the extend for the necessary dredging and also costs of the civil and arms/piping engineering works for the proposed jetty size **Action: EVTL**
2.4 'Brown' Site Option FSRU/ LNGC Docking & Mooring	LNGC power/ steering, loss of tug support, fendering failure, mooring line/hook/dolphins failure, dock	Engine malfunction, critical tug malfunction Critical variable wind speed. Insufficient jetty	Uncontrolled approach fendering/pier integrity loss		**2.4.1** The Brown Site Option potentially provides a number of operational advantages. The main drawback of the Brown Option is the close proximity of the LNG terminal to main port terminal

System: EVTL LNG Terminal	Drawings: GasPort GA (typical)	**HAZID sheet 2**
Area: Jetty Options	Revision: 1	
Equipment : FSRU/LNGC berthing, Mooring dolphins and gas export equipment		

ITEM	**HAZARD**	**CAUSE**	**POTENTIAL EFFECTS**	**SAFEGUARDS**	**RECOMMENDATIONS**
	structural integrity, bad weather impact at dock	onshore mooring arrangements			facilities, industrial facilities, working population and accommodation facilities. Any potential medium to large release of gas under the current prevailing wind conditions is likely to have a potential impact on to the adjacent facility. However, it can be argued that the closest facility to the future LNG terminal is the EVLT LPG/chemicals plant which has been purposely designed to mitigate against such type of event (hazardous area classification, non ignition electrical 'Exe' equipment, ESD system, F&G detection etc.). Project to further address based on the QRA results for plume dispersion. **Action: EVTL**

System: EVTL LNG Terminal	Drawings: GasPort GA (typical)	HAZID sheet 2
Area: Jetty Options	Revision: 1	
Equipment : FSRU/LNGC berthing, Mooring dolphins and gas export equipment		

ITEM	HAZARD	CAUSE	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
2.5 FSRU to LNGC (double banked) mooring	Insufficient mooring arrangement	Inadequacy of mooring system to support double banked ships at jetty. Incompatible mooring equipment on between FSRU/LNGC to complete mooring arrangement. Inadequate number and size of tugs to complete mooring manoeuvre.	Loss of moorings, loss of line tensioning, impact collision with jetty other vessel , emergency disconnection, potential release of gas or LNG, potential major accident event	Fendering main equipment is Yokohama (3.3m x 6.5m) which is considered consumable therefore maintained as per ISO standard. FSRU/ host vessel is fendered starboard using a support vessel, which carries the entire string of fenders. A safety wire is rigged between the first and second fender to prevent losing the entire string in case of lead wire failure. Fore and aft placement of the fenders can be further adjusted using the mooring winch Typical mooring lines configuration for 138k/151k vessels is a 2-4-2 arrangement forward and a 4-4-2 arrangement aft in compliance to OCIMF requirements.	**2.5.1** Ship compatibility study to ensure the compatibility of FSRU and class of LNG shuttle tanker. Based on these address: • Size, number, position of fenders on FSRU • Exact number of mooring lines and size of steel and soft lines and pennants and address mooring configurations to be examined by mooring analysis, (PORTMOOR or equivalent) It is recommended that project should include compatibility study as part of the contractual agreement between FSRU and LNGC. **Action: FSRU /LNGC owners** **2.5.2** PQA to address the provision of three 60t bollard pull ESD tugs (based on experience at similar facilities), fendering tug

System: EVTL LNG Terminal	Drawings: GasPort GA (typical)	**HAZID sheet 2**
Area: Jetty Options	Revision: 1	
Equipment : FSRU/LNGC berthing, Mooring dolphins and gas export equipment		

ITEM	HAZARD	CAUSE	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
				An 18 hook/100-150 ton arrangement is considered capable to accommodate up to Q-Max size of LNGC. Integrity of fendering system for side collision to be based on Rule and OCIMF requirement.	and provision of mooring personnel at site for the required time as a minimum **Action: PQA** **2.5.3** STS procedures will have to be developed by FSRU operator and put forward to approval by PQA and project. **Action: PQA** **2.5.4** EVTL and LNGC operators to discuss priority berthing wrights with PQA. **Action: EVTL**

System: EVTL LNG Terminal	Drawings:	**HAZID sheet 3**
Area: Integrity ,Safety and Fire Protection	Revision: 1	
Equipment : Regas arm, piping, controls, utilities, F&G, Safety equipment		

ITEM	**HAZARD**	**CAUSE**	**POTENTIAL EFFECTS**	**SAFEGUARDS**	**RECOMMENDATIONS**
3.1 Jetty design integrity	Integrity loss due to impact loads, Inadequacy in civils specification Deficiency in platform lay-out design	Inadequate safe distances between gas transfer equipment and piping Inadequate Access and Escape facilities Inadequate vessel utilities provisions for FSRU	Impact on emergency response, impact on Escape, Evacuation Rescue, impact on F&G detection and fire protection	The jetty will be a new construction with new fendering and mooring dolphins system Dolphins and fendering capacity design will comply with OCIMF requirements	**3.1.1** Project to ensure that sea bed integrity, foundation design and bathymetric studies are in line with jetty specification requirements. Integrity of design of jetty to include seismic loads, side impact loads (ship), corrosion aspects and environmental loads. **Action:EVTL/civil designer** **3.1.2** Civils jetty design to provide available layout area to include the following typical equipment: • Regas export arm (65t weight, 2x10m foot area), • ESD valve skid • Gas metering skid • Pipe rack to include gas export pipeline, utilities piping to FSRU (fuel, water) • Crane pedestal with lay down area for heavy equipment.

System: EVTL LNG Terminal	Drawings:	HAZID sheet 3
Area: Integrity ,Safety and Fire Protection	Revision: 1	
Equipment : Regas arm, piping, controls, utilities, F&G, Safety equipment		

ITEM	HAZARD	CAUSE	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
					• Two (2) independent fire pumps. • Two (2) tower fire monitors • Gangway to FSRU. **Action:EVTL/civil designer**
3.2 Terminal Safety Systems	Hydrocarbon release onboard ships or jetty	Leakage with high pressure gas release at jetty, EBRV tank emergency venting with plume impact on jetty and LNGC, impact collision with cargo LNG release, hose failure with LNG release etc	Potential ignition leading to jet fire, explosion Potential LNG release on water leading to RPT or LNG thermal on ship's hull structure Requirement for jetty operating personnel evacuation Impact on escape routes	Arm coupling area surrounded by water spray deluge system aimed at the ERS system. F&G detection system to be based on a grid philosophy. Typically fire protection is by water, AFFF foam and dry powder. Dedicated remote control fire monitors positioned on both sides of the jetty in accordance to OCIMF requirements (typically 350 m^3 firewater for cooling) No personnel on platform following connection Ship's side area to be covered by water curtain	**3.2.1** Project to establish a Fire Protection Philosophy. The philosophy should identify the following as a minimum: • Size of fire pumps based on max. firewater requirement. • Deluge system coverage • Size/coverage of remote controlled water monitors • Coverage of dry powder and AFFF provisions **Action:EVTL** **3.2.2** Project to address number, type and position of the gas detectors on the jetty. Also address ESD function on gas

System: EVTL LNG Terminal	Drawings:	**HAZID sheet 3**
Area: Integrity ,Safety and Fire Protection	Revision: 1	
Equipment : Regas arm, piping, controls, utilities, F&G, Safety equipment		

ITEM	**HAZARD**	**CAUSE**	**POTENTIAL EFFECTS**	**SAFEGUARDS**	**RECOMMENDATIONS**
				Any gas release from arm and jetty piping leading to jet fire will be of very short duration due to small isolatable sections.	detection (ESD1 for 2 out of 3 or 1out of 2 detectors.). Cause and Effects to be examined by HAZOP with participation of the FSRU operator. **Action: EVTL/FSRU** **3.2.3** QRA study to address typical release scenarios from equipment and piping and estimate plume generation with time for the predominant wind direction. QRA study to address Fire/explosion event with ignition and establish pressure and thermal loads within the jetty area (Based on typical GasPort facility) **Action: LR** **3.2.4** For **Options 2 and 3** with

System: EVTL LNG Terminal	Drawings:	**HAZID sheet 3**
Area: Integrity ,Safety and Fire Protection	Revision: 1	
Equipment : Regas arm, piping, controls, utilities, F&G, Safety equipment		

ITEM	**HAZARD**	**CAUSE**	**POTENTIAL EFFECTS**	**SAFEGUARDS**	**RECOMMENDATIONS**
					LNG transfer piping on the jetty a cryogenic protection system will be required. This should include for concrete protection under liquid flanges with stainless steel plating and specific drainage to eliminate pool formation under equipment. **Action:EVTL**
	Hydrocarbon release onboard ships or jetty	Leakage with high pressure gas release at jetty, FSRU tank emergency venting.	Potential of ignition, jet fire, flash fire		**3.2.5** Project to establish an Escape Evacuation and Rescue plan (EER) and address: • max number of operating personnel on the jetty during commissioning • the number of personnel during normal operation and address the available means of evacuation from the jetty facility; • Provide alternative jetty evacuation route via the

System: EVTL LNG Terminal	Drawings:	**HAZID sheet 3**
Area: Integrity ,Safety and Fire Protection	Revision: 1	
Equipment : Regas arm, piping, controls, utilities, F&G, Safety equipment		

ITEM	HAZARD	CAUSE	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
					dolphins and by a support vessel from the port facility. • If the attending vessel is not available the provision of the davit launched lifeboat nearest to the shore side should be considered. **Action : EVTL**

System: EVTL LNG Terminal	Drawings: GasPort P&ID (typical)	**HAZID sheet 4**
Area: Operations	Revision: 1	
Equipment : LNGC STS system, FSRU, regas export system, jetty system		

ITEM	HAZARD	CAUSE	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS

System: EVTL LNG Terminal	Drawings: GasPort P&ID (typical)	**HAZID sheet 4**
Area: Operations	Revision: 1	
Equipment : LNGC STS system, FSRU, regas export system, jetty system		

ITEM	HAZARD	CAUSE	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
4.1 FSRU connection and commissionin g operations	Commissioning programme imposes flow variation – ramping up and down and interruptions.	Downstream consumers not able to handle flow variation	Unable to export		**4.1.1** Commissioning process to check maximum capacity that the consumers/downstream people can handle. **Action : EVTL** **4.1.2** Project to develop commissioning Procedure and issue to FSRU for comments. The Procedure to address the following as a minimum: • ESDV leak testing (without pressure on one side) • Rump-up vaporisation process (steps up 100 mmscfd up to a max 450) • Purging/venting process • Arm testing process in order to pressurize and operate the arm when pressurizing the system. A minimum of two separate stops of commissioning process are

System: EVTL LNG Terminal			Drawings: GasPort P&ID (typical)		**HAZID sheet 4**
Area: Operations			Revision: 1		
Equipment : LNGC STS system, FSRU, regas export system, jetty system					
ITEM	**HAZARD**	**CAUSE**	**POTENTIAL EFFECTS**	**SAFEGUARDS**	**RECOMMENDATIONS**
					required for the arm commissioning. • Drying operations after pressure testing /inerting to eliminate any water traces • Mutual Operation Procedure; • LNG Transfer Procedures. **Action : EVTL/FSRU**
4.2 Gas Export Start-up Operations	Valve malfunction. High Pressure differential between FSRU and shore	Design Error Insufficient Operating Procedures	Unable to start-up export	Pressurization from ship side will be take place by small pump rated at 100 bar but with low flow Valve will open on 2 bar differential pressure between ship and terminal sides	**4.2.1** Project to develop jetty piping P&IDs to address equalisation between two ESDVs in line and pressure protection equipment. Project need to undertake HAZOP of design and establish Operating Procedures to cover the pressure equalisation between upstream and downstream of pressure protection skid. **Action : EVTL**

System: EVTL LNG Terminal	Drawings: GasPort P&ID (typical)	**HAZID sheet 4**
Area: Operations	Revision: 1	
Equipment : LNGC STS system, FSRU, regas export system, jetty system		

ITEM	**HAZARD**	**CAUSE**	**POTENTIAL EFFECTS**	**SAFEGUARDS**	**RECOMMENDATIONS**
4.3 Gas Export normal operations	Inaccurate pressure control	Design Error Insufficient Operating Procedures	HH- pressure at onshore skid will initiate ESD and close SDVs. Export shut downs continuously due to pressure limits	FSRU typical pressure control is on the output of the vaporiser. This is achieved by two totally independent pressure transmitters which throttle LNG flow to the vaporisers. The combined stream out of the vaporisers is metered in order to maintain set parameters.	**4.3.1** Operating parameters Low Temp, High Pressure and Flow need to daily pre-set in a typical FSRU regas system. Project to establish process of communications to define these parameters **Action :EVTL/FSRU** **4.3.2** Project to undertake HAZOP of P&IDs to ensure safe control/ shutdown, elimination of locked in inventories and ability to purge all piping sections **Action :EVTL**
4.4 Operations shutdown/ ESD	ESD initiated by FSRU ESD 1 due to: - Arm event shut down - Spurious - System fault - Fire	Gas release, Fire event, equipment malfunction, excessive arm movement due to excessive weather conditions, loss of mooring integrity,	Export shutdown, valve isolation, potential arm disconnection	Emergency Procedures	**4.4.1**. Project to address in detail ESD actuation for FSRU/LNGC combined system. 'Cause and Effect' study to be updated to address the interconnection and operation of the ESD system for both vessels when they are connected and also FSRU ESD

System: EVTL LNG Terminal	Drawings: GasPort P&ID (typical)	HAZID sheet 4
Area: Operations	Revision: 1	
Equipment : LNGC STS system, FSRU, regas export system, jetty system		

ITEM	HAZARD	CAUSE	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
	ESD 2 – Arm disconnection	human error			connection with jetty Control Room. **Action :EVTL/FSRU/LNGC** **4.4.2** Emergency Procedures to be developed to address disconnection and mooring release of shuttle vessel. Issues to be addressed: • Number of stand-by tugs available- sail time requirement • Necessity for mooring quick release of ships (ship from ship, and ship or ships from jetty). • Operation of jetty side quick release hooks, whether all together, singly, or group release. • Authorisation of sail away by ship captain or PQA

System: EVTL LNG Terminal			Drawings: GasPort P&ID (typical)		**HAZID sheet 4**
Area: Operations			Revision: 1		
Equipment : LNGC STS system, FSRU, regas export system, jetty system					
ITEM	**HAZARD**	**CAUSE**	**POTENTIAL EFFECTS**	**SAFEGUARDS**	**RECOMMENDATIONS**
					• Sail away window of operations impact of tide, traffic convoy etc. **Action :FSRU/LNGC/PQA** **4.4.3** Operation procedures to address potential LNG leakage and/or fire event at manifolds. Emergency procedures to address the following: • Requirement for standby fire tugs during the STS operations • Requirement for standby engine operations for LNGC • Ability of LNGC mooring lines disconnection and sail away with pilot onboard • Ability of jetty terminal to provide fire fighting assistance to the permanently moored FSRU

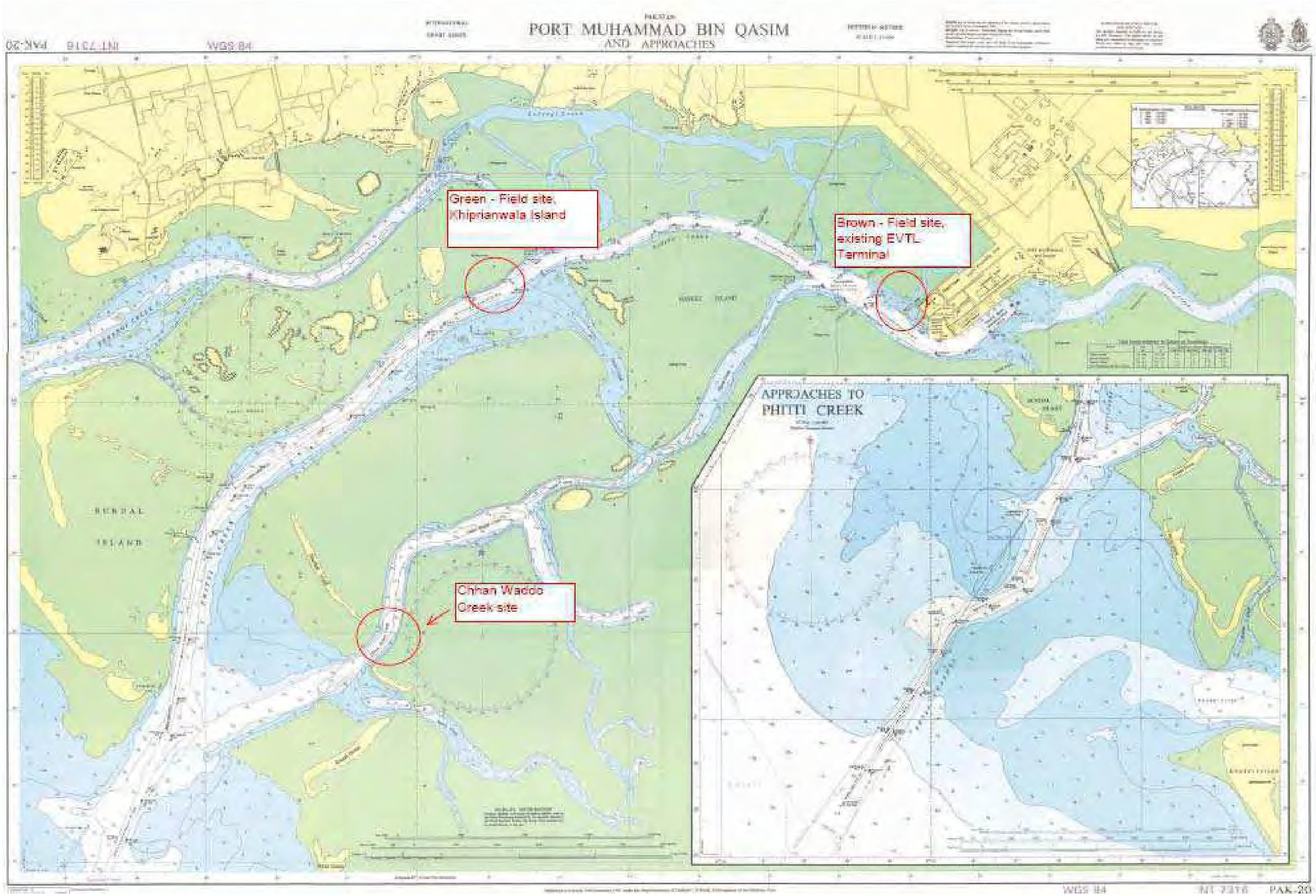
System: EVTL LNG Terminal	Drawings: GasPort P&ID (typical)	HAZID sheet 4
Area: Operations	Revision: 1	
Equipment : LNGC STS system, FSRU, regas export system, jetty system		

ITEM	HAZARD	CAUSE	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
					• Address personnel escape/evacuation. For LNGC provision of escape ladders at manifolds (fixed or temporary) enabling personnel to escape without going under the hoses. For the FSRU position of gangway to jetty • Address escape/evacuation to sea on the LNGC via fwd lifeboat or via supporting tug • Safe communications between ships and with jetty **Action: EVTL/FSRU/ LNGC/PQA** **4.4.4** In case of emergency disconnection especially in adverse weather conditions a cargo plan is required for LNGC to prevent sloshing effects due to partial filling. (Note LNGC

System: EVTL LNG Terminal			Drawings: GasPort P&ID (typical)		**HAZID sheet 4**
Area: Operations			Revision: 1		
Equipment : LNGC STS system, FSRU, regas export system, jetty system					
ITEM	**HAZARD**	**CAUSE**	**POTENTIAL EFFECTS**	**SAFEGUARDS**	**RECOMMENDATIONS**
					designed to carry an LNG ‘heel’ in one tank). Project to establish best unloading sequence to avoid sloshing effects with input from Class and tank designer. Operation procedures to be established. **Action :FSRU/LNGC**

Appendix 2

Marine Charts

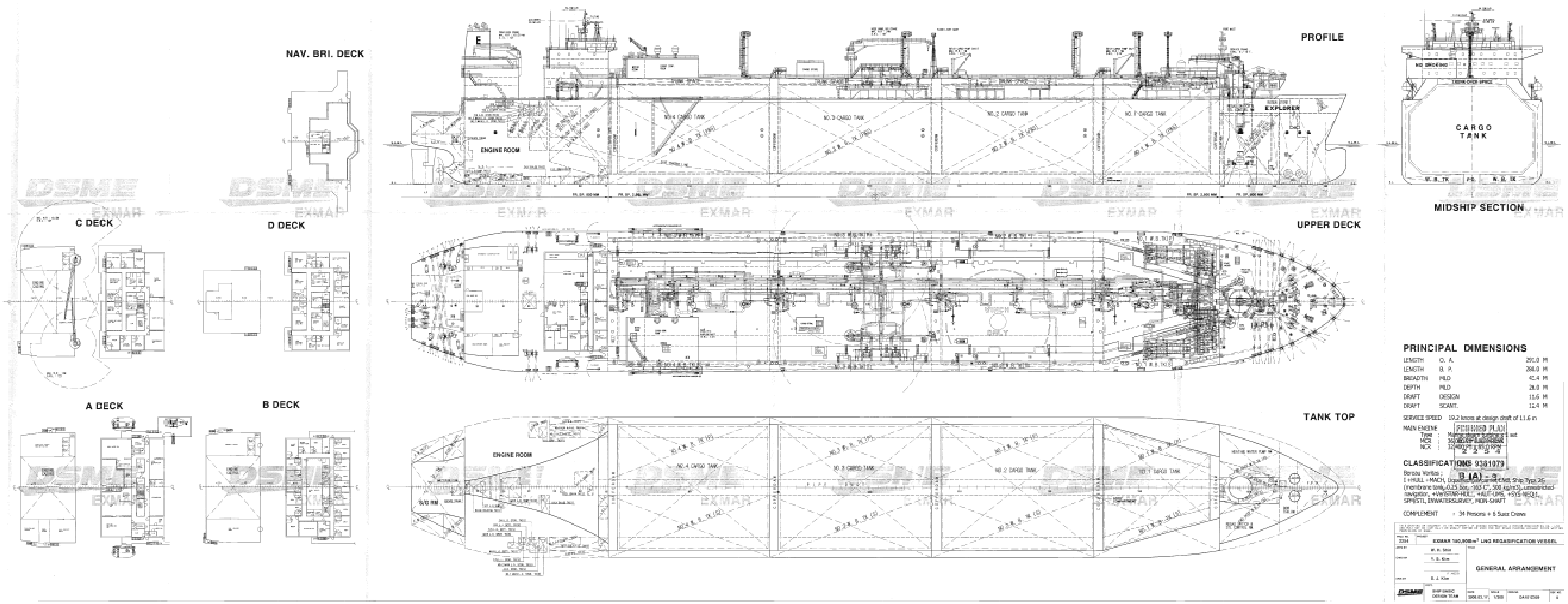

PORT MUHAMMAD BIN QASIM
AND APPROACHES
WGS 84
INT 7316
PAK 20
Green - Field site, Khiprianwala Island
Brown - Field site, existing EVTL Terminal
Chhan Waddo Creek site
BUNDAL ISLAND
APPROACHES TO PHITTI CREEK

Appendix 2

Appendix 3

FSRU General Arrangement (Typical)

GENERAL ARRANGEMENT

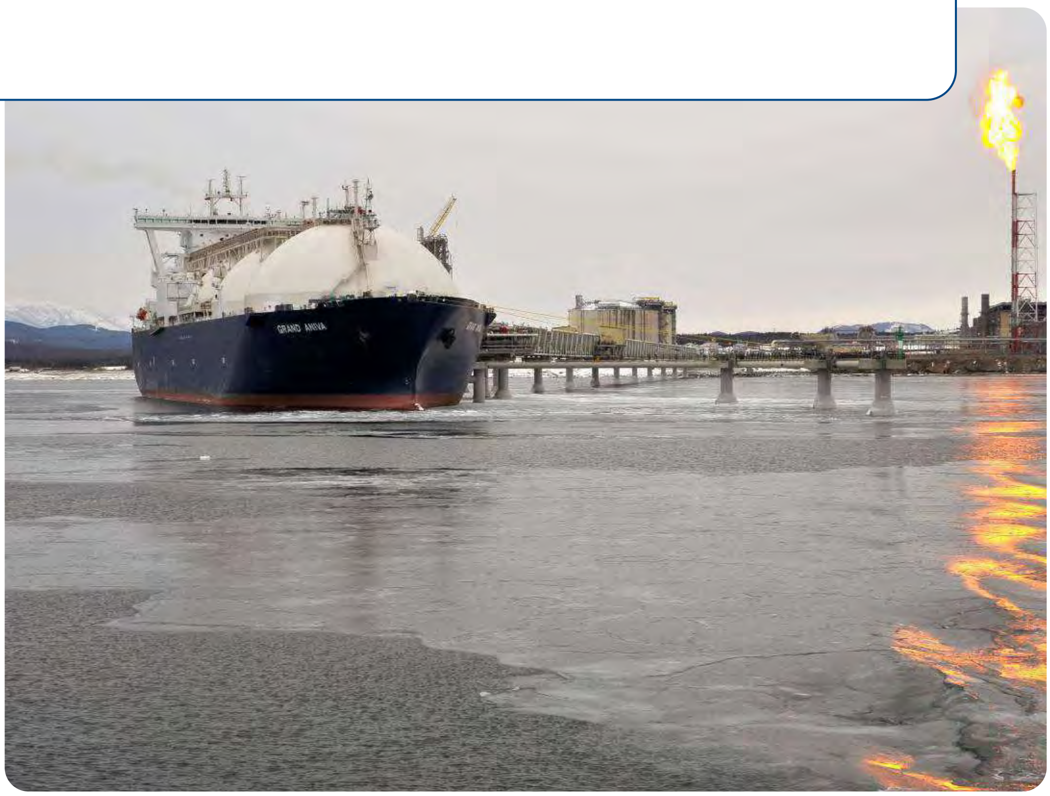


Engro Vopak LNG Terminal Risk Assessment Study

Engro Vopak, Port Qasim, Pakistan

Report No.: 2542214-R01 Rev Final

Date April 2011



LIFE MATTERS

Technical Report Document Page

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17. Summary

This report describes a risk assessment study of a proposed LNG Terminal in Port Qasim, near Karachi, Pakistan. The development project comprises a Floating Storage and Re-gasification Unit (FRSU) that will be replenished by shuttle tanker. The major hazard risks have been assessed and plotted on risk matrices.

18. Key words	19. Distribution statement
LNG Terminal, FRSU, risk assessment	

Contents

Glossary of Terminology and Abbreviations

ALARP	As Low As Reasonably Practicable.
CFD	Computerised fluid dynamics
ESD	Emergency Shut Down
ESDV	Emergency Shut Down Valve
EVTL	Engro Vopak Terminal Ltd.
EX	Explosion
FF	Flash fire
FSRU	Floating Storage and Re-gasification Unit
HAZID	Hazard Identification
HAZOP	Hazard and Operability
JF	Jet Fire
LNG	Liquefied Natural Gas
LNGc	LNG Carrier
MAH	Major Accident Hazard
NG	Natural Gas
PF	Pool Fire
RPT	Rapid Phase Transition
SIS	Safety Instrumented System
SSL	Ship-Shore link
STS	Ship to Ship

1. Introduction

This report describes a risk assessment study of the proposed Engro Vopak Terminal Ltd (EVTL) liquefied natural gas (LNG) terminal at Port Qasim, Pakistan. The study has focussed on the assessment of major accident hazards with the potential to affect people at the facility or off-site.

1.1 Project Description

A number of options are under consideration for the Terminal design and location. The option that is currently preferred, and that is considered by this study, comprises:

- a jetty at Khiprianwala Island, in Phitti Creek, approximately 9-10 km west of the existing Engro Vopak facility in Port Qasim;
- a Floating Storage and Re-gasification Unit (FSRU) moored at the jetty;
- a gas pipeline, sub-sea for most of its length, carrying gas to shore;
- replenishment of the FSRU by ship-to-ship transfer from LNG shuttle tankers, mooring alongside the FSRU in a 'double banked' arrangement; and,
- ship-to-ship transfer using cryogenic hoses.

The location under consideration is shown in Figure 1.

The 'green field' location at Khiprianwala Island is similar in many respects to another potential green field location in Chhan Waddo Creek. The Khiprianwala Island location was selected for analysis since it is closer to both the mainland and Port Qasim. The risk profile for the Khiprianwala Island location therefore also provides a conservative estimate of the risks for the Chhan Waddo location.

The FSRU will store between 125,000 and 150,000 m^3 of LNG in its tanks. The LNG will be re-gasified on board and exported via a Chicksan arm to the jetty. Details are not yet available, but it is likely that equipment on the jetty will include emergency shutdown valves (ESDVs), a fire and gas detection system, and a pressure protection system. A control room will also be located on the jetty. A ship-shore link (SSL) between the FSRU and the jetty-side safety instrumented system (SIS) will be provided.

The gas unloading arm will be provided with ranging alarms and emergency release couplings. In the event that movement of the FSRU relative to the jetty exceeds acceptable limits, shutdown is initiated (shutting down the ship's pumps and closing ESDVs on the FSRU and the jetty). Ultimately the emergency release couplings operate, preventing a significant release of gas.

The anticipated sendout rate of natural gas from the FSRU is in the range 500-575 MMscfd. The pressure in the gas will be sufficient to enter the onshore network, and will be in the range 75-100 barg.

The maximum frequency of re-supply by LNG tanker is every 4-5 days (assuming a FSRU storage volume of 150,000 m^3, a tanker capacity of 135,000 m^3 and a gas sendout rate of 500 MMscfd).

Ship-to-ship (STS) transfer is by means of cryogenic hoses. Typically up to 6 no. 8" diameter hoses are used, with a total transfer rate of around 5000 m^3/h. Each hose is equipped is equipped with an emergency release coupling.

1.2 Hazards of Natural Gas and Liquefied Natural Gas

1.2.1 Properties of Natural Gas

Natural gas (NG) is a mixture of methane (the main constituent) and other low molecular weight hydrocarbons (such ethane and propane). LNG is natural gas that is kept in liquid form at extremely low temperatures and pressures close to atmospheric. The liquefaction process requires that contaminants such as water and carbon dioxide are removed, so that the concentration of such contaminants in LNG, and natural gas produced by vaporising LNG, is extremely low. The physical properties of methane, ethane and propane are summarised in Table 1.

Table 1: Physical Properties of Natural Gas Constituents

Property	Substance		
	Methane	Ethane	Propane
Chemical Formula	CH_4	C_2H_6	C_3H_8
Molecular weight	16.04	30.07	44.09
Atmospheric boiling point (°C)	-161.5	-88.6	-42.1
Liquid specific gravity (relative to water = 1)	0.422 (at -160°C)	0.546 (at -88.6°C)	0.590 (at -50°C)
Gas specific gravity (relative to air = 1)	0.55	1.1	1.5
Lower Flammable Limit (% v/v)	5	2.9	2.1
Upper Flammable Limit (% v/v)	15	13	9.5
Source: Cheremisinoff, N P (2000). *Handbook of Hazardous Chemical Properties*			

Natural gas's hazards arise from its flammability and vapour dispersion properties. LNG presents an additional hazard in the form of extreme cold (being held at a temperature of approximately -162°C). Note that natural gas is not toxic (although it may act as an asphyxiant by displacing air).

1.2.2 Fire and Explosion Hazards

Natural gas, when released from containment as a gas, or when generated by vaporisation of a release of LNG, forms flammable mixtures in air between concentrations of 5 and 15 % vol/vol. Although natural gas at ambient temperature is less dense than air, the natural gas vapour generated by LNG at -162°C is approximately 1.5 times denser than air at 25°C. Hence natural gas as a gas under pressure at ambient temperature rapidly becomes buoyant upon release. However, the cold vapour generated by vaporisation of LNG behaves as a dense cloud. Although as the cold vapour mixes with air it becomes warmer and less dense, the cloud will tend to remain negatively buoyant until after it has dispersed below its lower flammability limit (LFL).

Different types of fire hazard may arise, depending on whether it is gaseous natural gas or LNG that is released. These fire hazards include jet fires, flash fires and pool fires. In certain circumstances, vapour cloud explosions (VCEs) may also occur.

1.2.2.1 Jet Fires

A jet fire is a strongly directional flame caused by burning of a continuous release of pressurised flammable gas (in this case natural gas) close to the point of release. Ignition may occur soon after the release begins; or may be delayed, with the flame burning back through the cloud (i.e. as a flash fire, see below) to the source. Jet fires may result from ignited leaks from process equipment (vessels, pipes, gaskets etc.) and pipelines.

A jet fire may be directed horizontally or vertically (or at some angle in between). A jet fire may impinge on structures or other process equipment, giving a potential for escalation of the incident. The intensity of thermal radiation emitted by jet fires can be sufficient to cause harm to exposed persons.

1.2.2.2 Flash Fires

Flash fires result from ignition of a cloud of flammable gas or vapour, when the concentration of gas within the cloud is within the flammable limits. In this case, the flammable cloud may be generated by:

- A release of pressurised flammable gas (i.e. natural gas); or,
- Vaporisation of a pool of volatile flammable liquid (i.e., LNG).

Typically a flash fire occurs as a result of delayed ignition, once the flammable cloud has had time to grow and reach an ignition source. In the absence of confinement or congestion, burning within the cloud takes place relatively slowly, without significant over-pressure. It is assumed that thermal effects are generally limited to within the flame envelope where there is a very high probability of death.

1.2.2.3 Pool Fires

Ignited releases of flammable liquids (including LNG) tend to give rise to pool fires. As with jet fires, ignition of the liquid pool may occur soon after the release begins, or may occur as a result of flashback from a remote ignition source if the liquid is sufficiently volatile to generate a cloud of flammable vapour.

1.2.2.4 Vapour Cloud Explosions

When a cloud of flammable gas occupies a region which is confined or congested, and is ignited, a vapour cloud explosion results. The presence of confinement (in the form of walls, floors and / or a roof) or congestion (such as the pipes, vessels and other items associated with process plant) in and around the flammable cloud results in acceleration of the flame upon ignition. This flame acceleration generates blast over-pressure. The strength of the blast depends on a number of factors, including:

- The reactivity of the fuel;
- The degree of confinement or congestion;
- The size of the congested / confined region occupied by the flammable cloud; and,
- The strength of the ignition source.

It should be noted that a variety of objects may act as confinement / congestion, in addition to those normally encountered on process plant. Investigation of the explosion and fire at Buncefield, UK, in 2005 suggested that areas of dense vegetation bordering the site had provided sufficient congestion to result in flame acceleration and generation of damaging levels of overpressure.

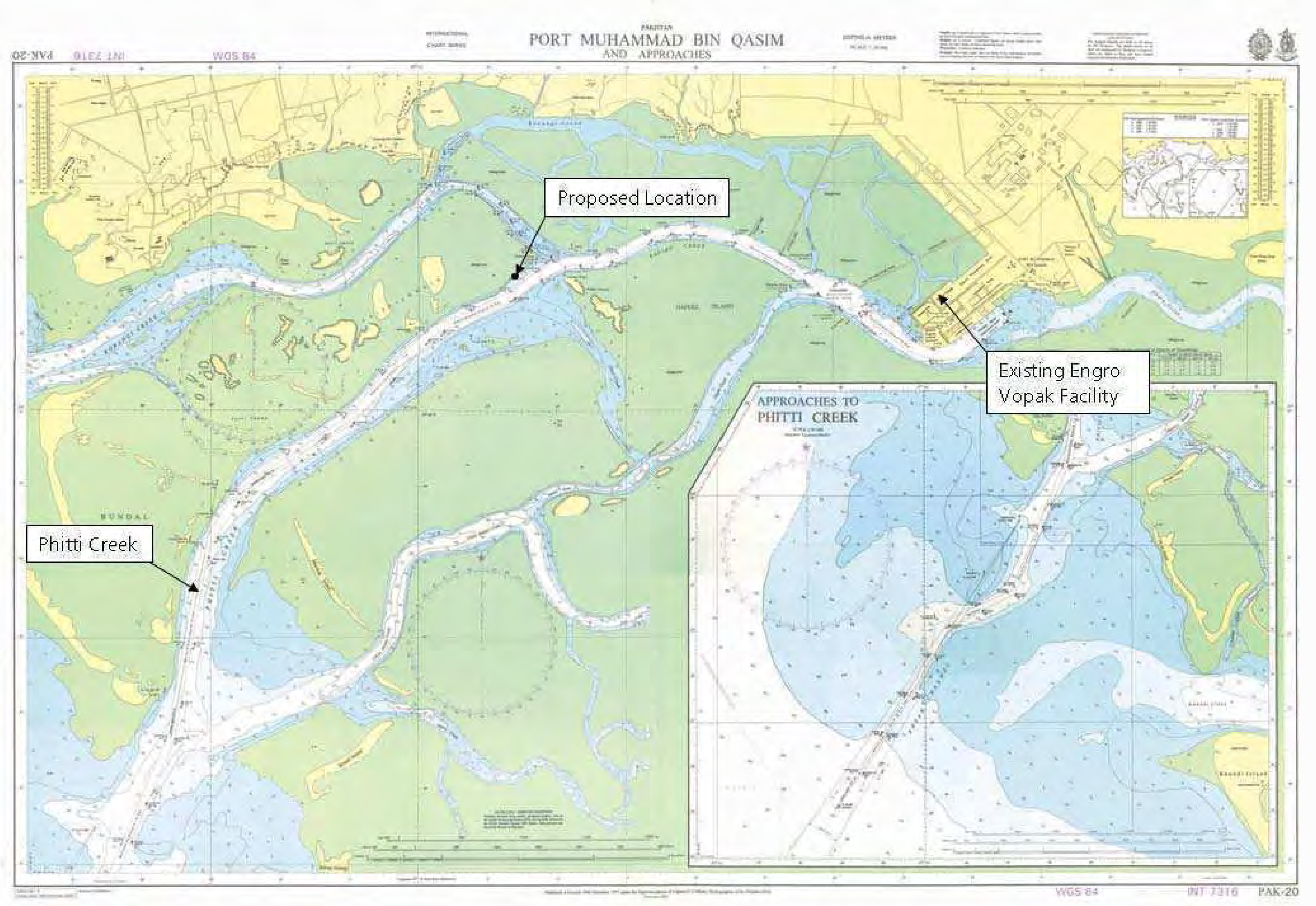
1.2.3 Cryogenic Burns

The extremely low (cryogenic) temperature of LNG means that it can cause burns if it comes into contact with exposed skin. Furthermore, inhalation of the cold vapours generated by LNG can cause damage to the lungs (so-called 'frosting of the lungs').

1.2.4 Rapid Phase Transition

If LNG is spilt on to water it usually forms a boiling pool on the water surface. However, under certain circumstances, LNG can released on to water can change from liquid to vapour virtually instantaneously. The effect has been observed in some experiments involving LNG but is not well understood. A Rapid Phase Transition (RPT) can generate overpressure and a 'puff' of dispersing vapour. Any damage from the overpressure generated tends to be quite localised. Rapid phase changes have not resulted in any known major incidents involving LNG.

Figure 1: Proposed Terminal Location



2. Overview of Risk Assessment Methodology

The risk assessment study has comprised the following steps:

- identification of major accident hazards (MAHs);
- assessment of the consequences of potential MAHs;
- assessment of the frequency of potential MAHs;
- determination of the risks from potential MAHs (using risk matrices); and,
- consideration of further measures that might be taken to reduce the risks, where appropriate.

The identification of hazards has been reported separately (Lloyd's Register Report No. OGL/DA/100260). Each of the subsequent steps is described in more detail in the remaining sections of this report.

The identified MAHs were assessed in terms of their potential consequences, and the frequency with which they might occur. Consequences were expressed in terms of a 'Severity Category', as defined in Table 2. For each MAH, severity categories were assigned for both personnel at the facility (i.e. 'on-site') and for members of the public (i.e. 'off-site'). The corresponding frequencies were expressed as a 'Frequency Category', as defined in Table 3.

Table 2: Severity Categories

Category	Definition
A	No fatalities. Some serious injuries or health effects.
B	At most 1 fatality.
C	More than one and up to ten fatalities.
D	More than ten fatalities and up to thirty fatalities
E	More than thirty fatalities

Table 3: Frequency Categories

Category	Frequency, F (per year)
1	$F < 10^{-6}$
2	$10^{-6} \leq F < 10^{-5}$
3	$10^{-5} \leq F < 10^{-4}$
4	$10^{-4} \leq F < 10^{-3}$
5	$F \geq 10^{-3}$

Each MAH was then plotted on an on-site risk matrix and an off-site risk matrix, as shown in Figure 2 and Figure 3 respectively.

Figure 2: On-Site Risk Matrix

		Severity				
		A	B	C	D	E
Frequency	5	M	H	H	H	H
	4	M	M	M	H	H
	3	L	M	M	M	H
	2	L	M	M	M	M
	1	L	L	L	M	M

Key

H	High Risk. Actions required to reduce risk as a matter of priority
M	Medium Risk. Consider whether further risk reduction would be beneficial.
L	Low Risk. Check against regulatory compliance and relevant good practice.

Figure 3: Off-Site Risk Matrix

		Severity				
		A	B	C	D	E
Frequency	5	H	H	H	H	H
	4	M	H	H	H	H
	3	M	M	M	H	H
	2	L	M	M	M	H
	1	L	L	M	M	M

Key

H	High Risk. Actions required to reduce risk as a matter of priority
M	Medium Risk. Consider whether further risk reduction would be beneficial.
L	Low Risk. Check against regulatory compliance and relevant good practice.

3. Major Accident Hazard Scenarios

Using the HAZID output, a set of major accident hazard scenarios was developed for risk assessment. The scenarios related to leaks from equipment of either gaseous natural gas or LNG, arising from a variety of causes. The list of scenarios is presented in Table 5.

A separate assessment of marine events (i.e. accidents involving the LNG carrier whilst in transit and accidents involving vessels passing the FSRU location) has also been performed. The marine events assessed were:

- Vessel experiencing engine failure whilst passing the LNG offloading facility and drifting into the LNG carrier (LNGc);
- LNGc experiencing machinery failure resulting in loss of vessel control, LNGc runs aground or collides with another vessel;
- LNGc experiencing steering failure resulting in loss of vessel control, LNGc runs aground or collides with another vessel; and,
- LNGc experiencing machinery failure or steering failure resulting in loss of vessel control, LNGc collides with FSRU.

Table 5: Major Accident Hazard Scenario List

Reference	Description	Size / Type
L1	Release of LNG from the pipework between the FRSU tanks and the HP Pump Suction Drums.	S
		M
		L
L2	Release of LNG from the HP Pump Suction Drums and pipework feeding the HP Pumps.	S
		M
		L
L3	Release of LNG from the HP Pumps discharge pipework up to the Vaporisers.	S
		M
		L
L4	Release of LNG from a transfer hose during ship to ship transfer.	S
		M
		L
G1	Release of natural gas from the pipework between the vaporiser outlets and the ship-side ESDV upstream of the gas unloading arm.	S
		M
		L
G2	Release of natural gas from the pipework between the ship-side ESDV upstream of the gas unloading arm and the first jetty ESDV.	S
		M
		L
G3	Release of natural gas from the pipework between the first jetty ESDV and the second Jetty ESDV.	S
		M
		L
G4	Release of natural gas from the pipework between the second Jetty ESDV and the third Jetty ESDV (at the entry to the natural gas pipeline).	S
		M
		L
G5	Releases of natural gas from the FSRU relief system under fire conditions.	Single valve

Key:
S: Small
M: Medium
L: Large

4. Consequence Assessment

4.1 Consequence Modelling

4.1.1 Modelling Cases

Using the Major Accident Hazard scenario list in Table 5 and the information sources in Table 4, a list of cases for consequence assessment was developed. Each case was then modelled using the DNV PHAST software version 6.53.1. The list of cases for PHAST modelling is presented in Table 6.

Table 6: PHAST Modelling Cases

Ref.	Description	Size	Hole Size (mm)	Maximum Line Dia. (mm)	Pressure (Bara)	Temp (°C)	Released Material	Elevation above sea level (m)	Comments
L1	Release from pipework between the FRSU tanks and the HP Pump Suction Drums.	S M L	5 25 300	300	10	-161.4	LNG	15	Liquid flow limited by system pump rate. Potential for explosion in regassification area.
L2	Release from the HP Pump Suction Drums and pipework feeding the HP Pumps.	S M L	5 25 200	200	3	-161.4	LNG	20	Liquid flow limited by system pump rate. Potential for explosion in regassification area.
L3	Release from the HP Pumps discharge pipework up to the Vaporisers.	S M L	5 25 100	100	100	-161.4	LNG	20	Liquid flow limited by system pump rate. Potential for explosion in regassification area.
L4	Release from a transfer hose during ship to ship transfer.	S M L	5 25 300	300	10	-161.4	LNG	10	Liquid flow limited by system pump rate.
G1	Release from the pipework between the vaporiser outlets and the ship-side ESDV upstream of gas unloading arm.	S M L	5 25 300	300	5	-161.4	LNG	5 (above deck)	Liquid flow limited by system pump rate. Potential for explosion in regassification area.
G2	Release from the pipework between the ship-side ESDV upstream of the gas unloading arm and the first jetty ESDV.	S M L	5 25 40	400	100	10	Natural Gas	20	Liquid flow limited by system pump rate. Section contains the articulated loading arm.
G3	Release from the pipework between the first jetty ESDV and the second Jetty ESDV.	S M L	5 25 400	400	100	10	Natural Gas	10	
G4	Release from the pipework between the second Jetty ESDV and the third Jetty ESDV.	S M L	5 25 400	400	100	10	Natural Gas	5	
G5	Release from the FSRU relief system under fire conditions.		Single Relief valve	490 (vent)	1.25	-158	Natural Gas	30	Thermal effects from relief flame calculated under maximum flow conditions.

4.1.2 Weather

Detailed information on weather stability classes is not available. Inspection of the climate data for the area provided in the Environmental and Social Impact Report (EMC, 2011), for the proposed scheme leads to the following assumptions for the stability classes and wind speeds to be used for modelling purposes are detailed in Table 7.

Table 7: Weather Conditions

Weather Conditions	Time of Day	Stability Class	Temperature (°C)	Relative Humidity (%)	Wind Direction (from) (°)	Wind Speed (m/s)
South West Monsoon	Day	D	33	64	225	9
	Night	D	27	28	225	2
North East Monsoon	Day	B	27	4	45	4
	Night	F	12	63	45	2

Many of the releases considered are momentum-driven releases of gas. Modelling of releases of this type are not particularly sensitive to assumptions about stability class.

4.1.3 Assumptions

4.1.3.1 Maximum Flowrates

Where material is released from a system downstream of a pump it has been assumed that the maximum flowrate is limited to the normal pumping rate plus 20%. This accounts for pump operation at overspeed with reduced discharge head.

Where a PHAST 'modelled case' result gave a flowrate in excess of the assumed maximum, the case was converted to a 'user-defined' case at the assumed maximum rate.

4.1.3.2 Release Duration and Release Limits

When assessing systems for the transfer of LNG or natural gas it has been assumed that releases can be either isolated (i.e. emergency shutdown successful) or unisolated (i.e. emergency shutdown fails). For the case of isolated releases it is assumed that isolation of the leak by automated systems is relatively rapid, shutting down pumps and closing automatic valves within either 30 or 60 seconds, depending upon the scenario being considered and information from the system HAZID. Unisolated releases are assumed to be of 600 seconds duration; the time required to manually shut down the process.

The maximum quantity of LNG or natural gas has been limited in each case to the quantity released prior to isolation plus the quantity remaining in the isolated system (pipework, vessels etc.).

It has also been assumed that the rate of release after isolation is the same as the release before isolation. This is considered to be a worst case assumption as in reality the release rate will tend to decrease following isolation.

4.1.3.3 Release Elevation and Orientation

Release elevations have been used are based on elevations that are typical for the FRSU, associated offloading systems and jetty i.e.

- FRSU Deck: 15 m above water level.

- FRSU topside process: Average of 5 m above the FRSU deck.
- FRSU relief system vent: 15 m above deck level.
- Jetty: 4 m above water level.

Releases of LNG during ship to ship transfer are assumed to be released downwards onto water and releases from relief system are assumed to be released vertically.

4.1.3.4 Bunding

It has been assumed that releases of LNG on the tanker deck can form pools. Modelling has been based on these pools being unconfined.

4.1.3.5 Flammable clouds

Flammability has been assumed to extend to the concentration that is 50% of the lower flammable limit.

4.1.3.6 Explosions

Explosions have been assessed where releases have the potential for a build up of gas in the regassification area of the FRSU. These are the cases where LNG and natural gas (prior to offloading) may be released; scenarios L1, L2, L3 and G1. As relatively small releases of liquid can produce enough gas to fill this area only one explosion scenario has been considered for each section.

4.1.3.7 Release Composition

LNG/natural gas has been assumed to be 100% methane for the purposes of modelling.

4.1.3.8 Impact Distances

Review of the area surrounding the proposed terminal location indicate the following features that may be at risk from a release on LNG or NG.

Table 8: Location of Populations

Feature	Distance (m)	Direction	Comments
Khiprianwala Island			
FRSU Supply Vessel and Jetty	0-150	All directions	Personnel on tanker or involved in Jetty operations at risk.
Tanker safety distance	200	Towards traffic in the shipping channel	Recommended safety distance (from Hazard Identification Study). Beyond this distance other river users are at risk.
Korangi Fish Harbour	3200	North West	Closest land based routinely occupied area (members of the public)
Brown – field site			
FRSU Supply Vessel and Jetty	0-150	All directions	Personnel on tanker or involved in Jetty operations at risk.
Tanker safety distance	200	Towards traffic in the shipping channel	Recommended safety distance (from Hazard Identification Study). Beyond this distance other river users are at risk.
EVTL existing Jetty	500	South West	

FAP Terminal	850	South East	
IOCB Jetty	900	North West	
Premises of QITC boundary	1200	South East	

4.1.3.9 *Impact Criteria*

The criteria shown in Table 9 were used for the analysis.Table 9: Impact Criteria

Event	Level 1	Level 2	Level 3	Units
Jet or Pool Fire	4	12.5	37.5	kW/m^2
Flash Fire	½ LFL	-	-	-
Explosion	0.02068	0.1379	0.2068	bar
Key: LFL: lower flammability limit				

A description of the impact criteria effects is shown in Table 10, based on information presented in Reference (3).

Table 10: Impact Criteria Effects

Impact Value	Units	Effect
Thermal Impact		
37.5	kW/m^2	Intensity at which damage is caused to process equipment
12.5	kW/m^2	Intensity at which piloted ignition of wood occurs
4	kW/m^2	Sufficient to cause pain in exposed skin after about 15s, blistering after about 30s.
Fire		
½ LFL	-	Extent of flammable region of gas cloud
Overpressure		
0.02068	bar	Window breakage
0.1379	bar	Significant damage to masonry structures
0.2068	bar	Distortion of steel framed structures

4.1.4 **Results**

The PHAST modelling results are displayed in Table 11.

Table 11: PHAST Results

Ref.	Description	Size	Outcome	SW Monsoon - Day Level 1	SW Monsoon - Day Level 2	SW Monsoon - Day Level 3	SW Monsoon - Night Level 1	SW Monsoon - Night Level 2	SW Monsoon - Night Level 3	NE Monsoon - Day Level 1	NE Monsoon - Day Level 2	NE Monsoon - Day Level 3	NE Monsoon - Night Level 1	NE Monsoon - Night Level 2	NE Monsoon - Night Level 3
L1	Release from pipework between the FRSU tanks and the HP Pump Suction Drums.	S	JF	FL:8.7			FL:12.4			FL:10.2			FL:12.4		
		M	JF	62	44	FL:34	76	57	FL:48	71	51	FL:40	76	57	FL:48
		L	JF	227	173	139	273	217	182	261	199	161	273	217	182
		S	FF	25			18			17			19.7		
		M	FF	76			105			49			99		
		L	FF	743			514			614			481		
		S	PF	7.1	5.5	4.3	8.6	5.7	3.1	8.1	5.6	3.6	9.9	6.6	3.4
		M	PF	90	62	43	105	64	36	108	68	43	104	64	36
		L	PF	380	252	170	443	270	151	469	291	181	443	270	153
		L	EX	676	131	98	680	132	99	680	132	99	692	134	101
L2	Release from the HP Pump Suction Drums and pipework feeding the HP Pumps.	S	JF	FL:7.2			FL:10.3			FL:8.5			FL:10.3		
		M	JF	45		FL:28 m	56		FL:40 m	52		FL:33 m	56		FL:40 m
		L	JF	233	177	141	286	226	186	271	206	165	286	226	187
		S	FF	27			20			16			21		
		M	FF	90			56			49			71		
		L	FF	341			728			893			745		
		S	PF	3.6	3.1	3	5.1	3.6	2.8	4.6	3.4	3.3	7.7	5.2	3.1
		M	PF	64	44	31	75	46	26	76	48	31	75	47	26
		L	PF	179	121	82	182	112	62	199	124	78	180	110	62
		L	EX	676	131	98	680	132	99	680	132	99	692	134	101
L3	Release from the HP Pumps discharge pipework up to the Vaporisers.	S	JF	FL: 12			FL:17.1			FL:14.1			FL: 17.1		
		M	JF	92	62	44	100	84	FL:69	103	77	FL:57	110	84	FL:68
		L	JF	102	274	52	121	94	75	114	85	FL	121	94	FL:
		S	FF	34			28			25			28		
		M	FF	114			117			85			113		
		L	FF	242			346			327			349		
		S	PF	18	13	8.1	19	12	6.4	19	13	7.6	22	14	7.3
		M	PF	161	108	74	177	108	60	188	117	74	176	108	61
		L	PF	179	121	82	182	112	62	199	124	78	180	111	62
		L	EX	676	131	98	680	132	99	680	132	99	692	134	101
L4	Release from a transfer hose during ship to ship transfer.	S	JF	FL: 7.8			FL:11			FL:9.2			FL: 11.2		
		M	JF	57	41	FL: 30	69	53	43	65	48	Fl: 36	69	53	43
		L	JF	270	207	169	328	261	218	313	240	195	328	261	219
		S	FF	22			15			14			9.5		
		M	FF	61			171			60			115		

Ref.	Description	Size	Outcome	SW Monsoon - Day Level 1	SW Monsoon - Day Level 2	SW Monsoon - Day Level 3	SW Monsoon - Night Level 1	SW Monsoon - Night Level 2	SW Monsoon - Night Level 3	NE Monsoon - Day Level 1	NE Monsoon - Day Level 2	NE Monsoon - Day Level 3	NE Monsoon - Night Level 1	NE Monsoon - Night Level 2	NE Monsoon - Night Level 3
		L	FF	1015			695			964			658		
		S	PF	5.6	4.6	4.1	5.4	3.5	2.7	5.8	4.3	3.2	5.4	3.6	2.7
		M	PF	64	44	22	63	38	16	69	44	21	62	37	16
		L	PF	194	130	73	188	111	51	209	131	71	186	110	52
G1	Release from the pipework between the vaporiser outlets and the ship-side ESDV upstream of gas unloading arm.	S	JF	FL: 6.1			FL: 7.7			FL: 7.7			FL: 7.5		
		M	JF	48	FL: 37		47	FL: 32		50	FL: 33		47	FL: 37	
		L	JF	183	140	105	191	130	89	200	140	99	191	130	90
		S	FF	13			13			11			12		
		M	FF	57			62			52			57		
		L	FF	196			213			166			217		
		L	EX	676	131	98	680	132	99	680	132	99	692	134	101
G2	Release from the pipework between the ship-side ESDV upstream of the gas unloading arm and the first jetty ESDV.	S	JF	FL: 8			FL: 7.7			FL: 7.7			FL: 7.5		
		M	JF	53	39	FL: 37	52	35	FL: 32	54	38	FL: 33	52	35	FL: 31
		L	JF	181	143	113	192	135	99	200	144	105	192	135	100
		S	FF	12			12			11			11		
		M	FF	54			60			51			56		
		L	FF	217			245			202			241		
G3	Release from the pipework between the first jetty ESDV and the second Jetty ESDV.	S	JF	FL: 8			FL: 7.7			FL: 7.7			FL: 7.5		
		M	JF	53	44	35	53	40	29	55	42	32	53	40	29
		L	JF	180	143	118	192	137	102	200	145	107	192	137	102
		S	FF	12			12			10			11		
		M	FF	48			54			47			54		
		L	FF	305			27			264			270		
G4	Release from the pipework between the second Jetty ESDV and the third Jetty ESDV.	S	JF	FL: 8			FL: 7.7			FL: 7.7			FL: 7.5		
		M	JF	53	39	FL: 37	52	35	FL: 32	54	38	FL: 33	52	35	FL: 31
		L	JF	181	143	113	192	135	99	200	144	105	192	135	100
		S	FF	12			12			11			11		
		M	FF	54			60			51			56		
		L	FF	217			245			202			241		
G5	Release from the FSRU relief system under fire conditions	Single Fire	JF	72	NR	NR	49	NR	NR	78	NR	NR	49	NR	NR

Key:
NR: Impact level not reached
JF: Jet Fire
FF: Flash Fire
PF: Pool Fire
EX: Explosion.
Fl: Flame Length (Reported when the impact criteria is relatively close to the flame).

4.2 Severity Categories

The PHAST results were used to select the appropriate severity category for each MAH scenario. Separate severity categories were assigned for on-site and off-site effects. When determining the appropriate severity category, the distance from the release source to potential receptors was taken into account. The severity categories used are defined in Table 2. The results are displayed in Table 12 below.

Table 12: Assigned Severity Categories

No.	Description	Size	Outcome	On-Site Severity	Comment	Off-Site Severity	Comment
L1	Release from pipework between the FSRU tanks and the HP Pump Suction Drums.	S	JF	B	Jet flame on FSRU. Potential for harm to personnel on the FSRU if close to the jet flame. Minimal impact at areas beyond the FSRU.	A	No off-site impact.
		M	JF	C	Flame and 12.5 kW/m^2contour within FSRU area. Potential for harm to personnel on the FSRU, possible harm to personnel on supply tanker depending on flame direction. Less potential for harm to people on jetty as they are at a lower level.	A	4 kW/m^2 contour could extend beyond FSRU/supply tanker boundary but not beyond the river exclusion zone.
		L	JF	D	4 kW/m^2contour in FSRU area and could impact the supply tanker and jetty. Potential for harm to personnel on the FSRU, supply tanker and jetty.	B	4 kW/m^2 contour could extend beyond the river exclusion zone. Some potential for harm to people on passing vessels if close to the site.
		S	FF	C	Flash fire limited to FSRU. Fatal to personnel if in the area affected.	A	No off-site impact.
		M	FF	D	Flash fire within FSRU area. Potential for harm to personnel on the FSRU, possible harm to personnel on supply tanker or jetty,	A	Flash fire could extend beyond FSRU/supply vessel boundary but not beyond river exclusion zone.
		L	FF	E	Flash fire extends up to 890 m. Severe impact on personnel on the FSRU, jetty and supply tanker	D	Flash fire extent covers the river and would be harmful to people on passing vessels.
		S	PF	B	Potential for harm to personnel on the FSRU if close to the pool fire.	A	No off-site impact.
		M	PF	C	4 kW/m^2contour within FSRU area. Potential for harm to personnel on the FSRU, possible harm to personnel on supply tanker or jetty.	A	4 kW/m^2 contour could extend beyond FSRU/supply tanker boundary but not beyond river exclusion zone.
		L	PF	D	4 kW/m^2contour on the FSRU deck, could impact the supply tanker and jetty. Potential for harm to personnel on the FSRU, supply tanker and jetty. Burning liquid could fall onto river surface and into FSRU.	B	4 kW/m^2 contour could extend beyond the river exclusion zone. Some potential for harm to people on passing vessels if close to the site.
		L	EX	E	Very high overpressures on the FSRU, jetty and supply vessel. 0.2068 bar contour covers the majority of the area.	C	Damage to vessels on river if in the area. Possible fatalities / injuries on vessels.
L2	Release from the HP Pump Suction Drums and pipework feeding the HP Pumps.	S	JF	B	Jet flame on FSRU. Potential for harm to personnel on the FSRU if close to the jet flame. Minimal impact at areas beyond the FSRU.	A	No off-site impact.
		M	JF	C	Flame and 12.5 kW/m^2contour within FSRU area. Potential for harm to personnel on the FSRU, possible harm to personnel on supply tanker depending on flame direction. Less potential for	A	4 kW/m^2 contour could extend beyond FSRU/supply tanker boundary but not beyond river exclusion zone.

No.	Description	Size	Outcome	On-Site Severity	Comment	Off-Site Severity	Comment
					harm to people on jetty as they are at a lower level.		
		L	JF	D	4 kW/m^{2}contour in FSRU area and could impact the supply tanker and jetty. Potential for harm to personnel on the FSRU, supply tanker and jetty.	B	4 kW/m^2 contour could extend beyond the river exclusion zone. Some potential for harm to people on passing vessels if close to the site.
		S	FF	C	Flash fire limited to FSRU. Fatal to personnel if in the area affected.	A	No off-site impact.
		M	FF	D	Flash fire within FSRU area. Potential for harm to personnel on the FSRU, possible harm to personnel on supply tanker or jetty.	A	Flash could extend beyond FSRU/supply tanker boundary but not beyond river exclusion zone.
		L	FF	E	Flash fire extends up to 743 m. Severe impact on personnel on the FSRU, jetty and supply tanker.	D	Flash fire extent covers the river and would be harmful to people on passing vessels.
		S	PF	B	Potential for harm to personnel on the FSRU if close to the pool fire.	A	No off-site impact.
		M	PF	C	4 kW/m^{2}contour within FSRU area. Potential for harm to personnel on the FSRU, possible harm to personnel on supply tanker or jetty.	A	4 kW/m^2 contour could extend beyond FSRU/supply tanker boundary but not beyond river exclusion zone.
		L	PF	D	4 kW/m^{2}contour on the FSRU deck, could impact the supply vessel and jetty. Potential for harm to personnel on the FSRU, supply tanker and jetty. Burning liquid could fall onto river surface and into FSRU.	A	4 kW/m^2 contour does not extend into the river exclusion zone. Slight potential for harm to people on passing vessels if close to the site.
		L	EX	E	Very high overpressures on the FSRU, jetty and supply vessel. 0.2068 bar contour covers the majority of the area.	C	Damage to vessels on river if in the area. Possible fatalities / injuries on vessels.
L3	Release from the HP Pumps discharge pipework up to the Vaporisers.	S	JF	B	Jet flame on FSRU. Potential for harm to personnel on the FSRU if close to the jet flame. Minimal impact at areas beyond the FSRU.	A	No off-site impact.
		M	JF	C	Flame and 37.5 kW/m^{2}contour within FSRU area. Potential for harm to personnel on the FSRU, possible harm to personnel on supply tanker and jetty.	A	4 kW/m^2 contour could extend beyond FSRU/supply tanker boundary but not beyond river exclusion zone.
		L	JF	D	4 kW/m^{2}contour on the FSRU deck, could impact the supply tanker and jetty. Potential for harm to personnel on the FSRU, supply tanker and jetty. Burning liquid could fall onto river surface and into FSRU.	C	37.5 kW/m^2 contour could extend beyond the river exclusion zone. Significant potential for harm to people on passing vessels if close to the site.
		S	FF	C	Flash fire limited to FSRU. Fatal to personnel if in the area affected.	A	No off-site impact.
		M	FF	D	Flash fire within FSRU area. Potential for harm to personnel on the FSRU, possible harm to personnel	A	Flash could extend beyond FSRU/supply vessel boundary but not beyond river exclusion zone.

No.	Description	Size	Outcome	On-Site Severity	Comment	Off-Site Severity	Comment
					on supply tanker or jetty,		
		L	FF	E	Flash fire extends up to 350 m. Severe impact on personnel on the FSRU, jetty and supply tanker.	C	Flash fire extent reaches the river and would be harmful to people on passing vessels.
		S	PF	B	Potential for harm to personnel on the FSRU if close to the pool fire.	A	No off-site impact.
		M	PF	C	4 kW/m^{2}contour within FSRU area. Potential for harm to personnel on the FSRU, possible harm to personnel on supply tanker or jetty.	A	4 kW/m^2 contour could extend beyond FSRU/supply tanker boundary but not beyond river exclusion zone.
		L	PF	D	4 kW/m^{2}contour on the FSRU deck, could impact the supply tanker and jetty. Potential for harm to personnel on the FSRU, supply tanker and jetty. Burning liquid could fall onto river surface and into FSRU.	A	4 kW/m^2 contour could extend beyond FSRU/supply tanker boundary and just into the river exclusion zone. Unlikely to cause harm on the river.
		L	EX	E	Very high overpressures on the FSRU, jetty and supply tanker. 0.2068 bar contour covers the majority of the area.	C	Damage to vessels on river if in the area. Possible fatalities on vessels.
L4	Release from a transfer hose during ship to ship transfer.	S	JF	B	Jet flame from hose/piping. Potential for harm to personnel on the FSRU or supply vessel if close to the jet flame/transfer area. Minimal impact at areas beyond the FSRU/supply vessel. Could strike the side of a vessel.	A	No off-site impact.
		M	JF	C	Flame and 37.5 kW/m^{2}contour within the within FSRU/supply vessel Potential for harm to personnel on the FSRU and supply vessel depending on flame direction. Less potential for harm to people on jetty as they are at a lower level and may be sheltered.	A	4 kW/m^2 contour could extend beyond FSRU/supply tanker boundary but not beyond the river exclusion zone.
		L	JF	D	Severe damage to FSRU and supply vessel irrespective of flame direction. 37.5 kW/m^{2}contour could extend beyond the vessels to the jetty.	B	4 kW/m^2 contour could extend beyond the river exclusion zone. Some potential for harm to people on passing vessels if close to the site.
		S	FF	B	Flash fire limited to the FSRU/supply tanker area with the main effects at river level between the vessels. Unlikely to lead to fatalities on the vessels. Could possibly affect the jetty.	A	No off-site impact.
		M	FF	C	Flash fire would be at river level the most significant risk would be to people on the jetty although there may be some protection as the main fire would be between the vessels. Some risk to personnel on the vessels.	A	Flash could extend beyond FSRU/supply vessel boundary but not beyond river exclusion zone.
		L	FF	E	Flash fire extends up to 1015 m. Severe impact on personnel on the FSRU, jetty and supply tanker	D	Flash fire extent covers the river and would be harmful to people on passing vessels.

No.	Description	Size	Outcome	On-Site Severity	Comment	Off-Site Severity	Comment
		S	PF	B	Pool fire between supply vessel and FSRU. Possible harm to someone on a vessel if on deck close to the area.	A	No off-site impact.
		M	PF	C	Large pool fire between the FSRU and the supply tanker, this could envelop vessels and extend to the jetty area.	A	4 kW/m^2 contour could extend beyond FSRU/supply tanker boundary but not beyond river exclusion zone.
		L	PF	E	Very large pool fire surrounding vessels and potentially affecting the jetty area. 37.5 kW/m^{2}contour could extend for over 70 m, causing severe damage to vessels and harm to personnel.	B	4 kW/m^2 contour could extend beyond the river exclusion zone. Some potential for harm to people on passing vessels if close to the site.
G1	Release from the pipework between the vaporiser outlets and the ship-side ESDV upstream of gas unloading arm.	S	JF	B	Jet flame on FSRU. Potential for harm to personnel on the FSRU if close to the jet flame. Minimal impact at areas beyond the FSRU.	A	No off-site impact.
		M	JF	C	4 kW/m^{2}contour within FSRU area. Potential for harm to personnel on the FSRU, possible harm to personnel on supply tanker depending on flame direction. Less potential for harm to people on jetty as they are at a lower level.	A	4 kW/m^2 contour could extend beyond FSRU/supply tanker boundary but not beyond the river exclusion zone.
		L	JF	D	4 kW/m^{2}contour in FSRU area and could impact the supply tanker and jetty. Potential for harm to personnel on the FSRU, supply tanker and jetty.	A	4 kW/m^2 contour could extend to the edge of the river exclusion zone. No severe harm to someone on a river vessel.
		S	FF	C	Flash fire on vessel FSRU deck possible effects on the jetty if the vapour cloud is blown in that direction. Fatal to personnel if in the area affected.	A	No off-site impact.
		M	FF	D	Large flash fire on vessel FSRU deck possible effects on the jetty if the vapour cloud is blown in that direction. Fatal to personnel if in the area affected.	A	No off-site impact.
		L	FF	E	Very large flash fire affecting personnel on the vessels and jetty	B	Could possibly extend into the river beyond the exclusion zone.
		L	EX	E	Very high overpressures on the FSRU, jetty and supply vessel. 0.2068 bar contour covers the majority of the area.	C	Damage to vessels on river if in the area. Possible fatalities on vessels.
G2	Release from the pipework between the ship-side ESDV upstream of the gas unloading arm and the first jetty ESDV	S	JF	B	Jet flame on FSRU or jetty. Potential for harm to personnel on the FSRU or jetty if close to the jet flame. Minimal impact at areas beyond the FSRU/Jetty.	A	No off-site impact.
		M	JF	C	4 kW/m^{2}contour within FSRU and jetty area. Potential for harm to personnel on the FSRU and jetty. Dependant upon flame direction.	A	4 kW/m^2 contour could extend beyond FSRU/supply vessel boundary but not beyond the river exclusion zone.
		L	JF	D	4 kW/m^{2}contour within FSRU and jetty area.	A	4 kW/m^2 contour could extend to the edge of

No.	Description	Size	Outcome	On-Site Severity	Comment	Off-Site Severity	Comment
	(includes the gas unloading arm).				Potential for harm to personnel on the FSRU and jetty. Dependant upon flame direction.		the river exclusion zone. No severe harm to someone on a river vessel.
		S	FF	C	Flash fire on vessel FSRU deck and the jetty. Fatal to personnel if in the area affected.	A	No off-site impact.
		M	FF	D	Large flash fire on vessel FSRU deck and jetty cloud is blown in that direction. Fatal to personnel if in the area affected.	A	No off-site impact.
		L	FF	E	Very large flash fire affecting personnel on the vessels and jetty	B	Could possibly extend into the river beyond the exclusion zone.
G3	Release from the pipework between the first jetty ESDV and the second Jetty ESDV.	S	JF	B	Jet flame on FSRU or jetty. Potential for harm to personnel on the FSRU or jetty if close to the jet flame. Minimal impact at areas beyond the FSRU/Jetty.	A	No off-site impact.
		M	JF	C	4 kW/m^{2}contour within FSRU and jetty area. Potential for harm to personnel on the FSRU and jetty. Dependant upon flame direction.	A	4 kW/m^2 contour could extend beyond FSRU/supply tanker boundary but not beyond the river exclusion zone.
		L	JF	D	4 kW/m^{2}contour within FSRU and jetty area. Potential for harm to personnel on the FSRU and jetty. Dependant upon flame direction.	A	4 kW/m^2 contour could extend to the edge of the river exclusion zone. No severe harm to someone on a river vessel.
		S	FF	C	Flash fire on the jetty. Fatal to personnel if in the area affected.	A	No off-site impact.
		M	FF	D	Large flash fire on the jetty Fatal to personnel if in the area affected.	A	No off-site impact.
		L	FF	E	Very large flash fire affecting personnel on the jetty. Could harm the personnel on the vessels, although they may be protected.	B	Could possibly extend into the river beyond the exclusion zone.
G4	Release from the pipework between the second Jetty ESDV and the third Jetty ESDV.	S	JF	B	Jet flame on FSRU or jetty. Potential for harm to personnel on the FSRU or jetty if close to the jet flame. Minimal impact at areas beyond the FSRU/Jetty.	A	No off-site impact.
		M	JF	C	4 kW/m^{2}contour within FSRU and jetty area. Potential for harm to personnel on the FSRU and jetty. Dependant upon flame direction.	A	4 kW/m^2 contour could extend beyond FSRU/supply vessel boundary but not beyond the river exclusion zone.
		L	JF	D	4 kW/m^{2}contour within FSRU and jetty area. Potential for harm to personnel on the FSRU and jetty. Dependant upon flame direction.	A	4 kW/m^2 contour could extend to the edge of the river exclusion zone. No severe harm to someone on a river vessel.
		S	FF	C	Flash fire on the jetty. Fatal to personnel if in the area affected.	A	No off-site impact.
		M	FF	D	Large flash fire on the jetty Fatal to personnel if in the area affected.	A	No off-site impact.

No.	Description	Size	Outcome	On-Site Severity	Comment	Off-Site Severity	Comment
		L	FF	E	Very large flash fire affecting personnel on the jetty. Could harm the personnel on the vessels, although they may be protected.	B	Could possibly extend into the river beyond the exclusion zone.
G5	Release from the FSRU relief system under fire conditions	Single Fire	JF	B	High levels of thermal radiation on the FSRU. Could lead to fatalities if unable to shelter. Note – in event of actual fire relief conditions the fire itself would have more severe consequences.	A	No off-site impact.

4.3 Consequences of Marine Accidents

In extreme cases a release of LNG from the LNGc could result from grounding of the LNGc or collision with another vessel. Collision between the FRSU and another vessel could also result in a release of LNG. The frequencies of such events are very low, as discussed in Section 5.4.

Marine accidents of this type have been subjected to detailed analysis by the Sandia National Laboratories in the USA (5). The study considered accidental and deliberate (i.e. due to terrorist attack) breaches of LNGc cargo tanks. Fine element modelling was used to calculate breach sizes. Spill rates and thermal flux hazard ranges from LNG pool fires on water were calculated. Dispersion of natural gas vapour following un-ignited LNG releases was analysed using computerised fluid dynamics (CFD). Note that intentional breaches fall outside the scope of this risk assessment.

The authors used the results of the analysis to generate a set of public safety zones, reproduced in Table 13 below.

Table 13 Recommended Public Safety Zones for Accidental Breaches (Sandia)

Event	Potential Ship Damage and Spill	Potential Hazard	Potential Impact on Public Safety		
			High	Medium	Low
Collisions: Low speed	Minor ship damage, no spill	Minor ship damage	None	None	None
Collisions: Low speed	LNG cargo tank breach and small – medium spill	Damage to ship and small fire	~250 m	~250-750 m	> 750 m
Grounding: < 3m high object	Minor ship damage, no breach	Minor ship damage	None	None	None

For a nominal accidental spill, the report indicates that hazard ranges (to LFL) from dispersing vapour could extend up to 1700 m.

Sandia performed a re-assessment of their study in 2008, to account for the largest LNG carriers that were then coming into service (6). The 2008 study did not result in any changes to the Public Safety Zones; and focussed on intentional breaches.

With regards to the proposed EVTL facility, for the greenfield sites (Khiprianwala Island and Chhan Waddo Creek) it is noted that the Public Safety Zones defined in Table 13 do not reach members of the public on the mainland (see Table 8). The nearest point on the mainland is also beyond the 1700 m distance quoted in the 2004 Sandia report for vapour dispersion from a nominal accidental breach. However, there is clearly a potential for spills following accidental breaches to impact other users of the shipping channel.

The closest facility to the brownfield site, 500m distance, is the EVTL's LPG/chemicals plant. According to Sandia Report this is outside the region of the most significant impact to public safety and property. Furthermore EVTL's LPG/chemicals plant has been purposely designed to mitigate against such type of risk (hazardous area classification, non sparking certified 'EXe' equipment, ESD system, F&G detection, safety procedures etc.). The distance to other facilities in the vicinity (Table 8) is above 750m i.e. in the region of Low Potential Impact to Public Safety (Table 13). The facilities in question are not residential and potential upgrade or specific operational procedures can be considered to further assure against the consequences of accidental breaches. Similar to the greenfield sites there is clearly a potential for spills following accidental breaches to impact other users of the shipping channel.

The detailed discussion about possible LNG Terminal sites is given in Section 3.1 of HAZID Study OGL/DA/10026 (Appendix 1).

5. Frequency Assessment

5.1 Assessment Process

Frequency categories have been assigned to each MAH scenario by reference to a range of frequency data sources, which are described later in this Section. In the majority of cases, the process followed was to:

- assign a frequency category for occurrence of the *release* (e.g. the frequency of a small leak of gas from a piece of equipment);
- modify the frequency to account for the probability of a leak becoming an *effect* (e.g. ignition of a leak to give a jet fire); and,
- modify the frequency to account for the probability of the effect giving rise to a defined *outcome*, namely the severity of the consequences defined in the consequence assessment (e.g. a jet fire from an ignited leak pointing towards an occupied area and causing a fatality).

5.2 Frequency Data Sources

5.2.1 Ignition Probabilities

Ignition probability assumptions are based on Appendix IX, Table IX.6.2 of Reference (1). These data are reproduced in Table 14.

Table 14: Generic Ignition Probabilities

Release Rate Category	Release Rate (kg/s)	Ignition Probability (Immediate)	Ignition Probability (Delayed)
Small	<5	0.005	0.02
Medium	5-25	0.04	0.2
Large	>25	0.3	0.9

5.2.2 Failure Rates

5.2.2.1 Failures of Process Equipment

Data were obtained from Reference (2). While a full parts count has not been performed the lengths of pipework have been included in the assessment.

These data have been used to inform the selection of a release frequency category during the frequency assessment process, taking into account the equipment present.

5.2.2.2 Failures of the Natural Gas Offloading Arm

The UK Health and Safety Executive have developed a set of failure frequency data for failure of LNG unloading arms on the basis of fault tree analysis. Hence data were obtained from Reference (2), with the conservative assumption made that transfer of gas through the offloading arm is continuous.

5.2.2.3 *Failures of LNG Ship to Ship Transfer Hoses*

It is noted that the ship-to-ship transfer method considered here, using cryogenic hoses, is relatively new technology and therefore specific frequency data for such systems are not available. This represents an area of uncertainty within the assessment.

Data were obtained from Reference (3), which contains generic frequency data for frequencies of leaks during transfer of cargoes of dangerous substances. It was assumed that there will be a delivery of LNG every 4 to 5 days and that small releases are a factor of 10 more frequent than medium sized releases.

5.3 Results

The frequency assessment results are displayed in Table 15.

Table 15: Frequency Assessment Results

Ref.	Description	Size	Outcome	Leak Frequency Category	Effect Frequency Category	On-Site Outcome Frequency Category	Comments	Off-Site Outcome Frequency Category	Comments
L1	Release from pipework between the FRSU tanks and the HP Pump Suction Drums.	S	JF	4	2	1	Low probability of ignition for small leaks. Presence factor – someone would have to be close to the jet fire to be harmed.	1	No off site impact
		M	JF	4	3	2	Directional probability – jet flame would have to be directed towards occupied areas.	1	No off site impact
		L	JF	3	2	2	Directional probability – very likely to have personnel present within the areas that could be affected	1	Vessel would have to be close to the area for harm to occur. Jet would have to be towards the vessel.
		S	FF	4	1	1	Release would have to be undetected, low probability of ignition for small leaks. High chance of people in area affected.	1	No off site impact
		M	FF	4	1	1	Release would have to be undetected. High chance of people in area affected.	1	Vessel would have to be close to the area for harm to occur.
		L	FF	3	1	1	Release would have to be undetected. High probability of people in area affected. High probability of ignition of prolonged release.	1	Vessel would have to be close to the area for harm to occur.
		S	PF	4	2	1	Low probability of ignition for small leaks. Presence factor – someone would have to be close to the pool fire to be harmed.	1	No off site impact
		M	PF	4	3	3	Personnel will be present on the FSPU, high probability of personnel in area.	1	Vessel would have to be close to the area for harm to occur.
		L	PF	3	2	2	Personnel will be present on the FSPU, high probability of personnel in area.	1	Vessel would have to be close to the area for harm to occur.
		L	EX	3	1	1	Release would have to be undetected, and lead to build up	1	Vessel would have to be close to the area for harm to occur.

Ref.	Description	Size	Outcome	Leak Frequency Category	Effect Frequency Category	On-Site Outcome Frequency Category	Comments	Off-Site Outcome Frequency Category	Comments
							of gas in the congested area. High probability of people in area affected. High probability of ignition of prolonged release.		
L2	Release from the HP Pump Suction Drums and pipework feeding the HP Pumps.	S	JF	4	2	1	Low probability of ignition for small leaks. Presence factor – someone would have to be close to the jet fire to be harmed.	1	No off site impact
		M	JF	3	2	1	Directional probability – jet flame would have to be directed towards occupied areas.	1	No off site impact
		L	JF	2	1	1	Directional probability – very likely to have personnel present within the areas that could be affected	1	Directional probability – jet flame would have to be towards a vessel on the river.
		S	FF	4	1	1	Release would have to be undetected, low probability of ignition for small leaks. High chance of people in area affected.	1	No off site impact
		M	FF	3	1	1	Release would have to be undetected. High chance of people in area affected.	1	Vessel would have to be close to the area for harm to occur.
		L	FF	2	1	1	Release would have to be undetected. High probability of people in area affected. High probability of ignition of prolonged release.	1	Vessel would have to be close to the area for harm to occur.
		S	PF	4	2	1	Low probability of ignition for small leaks. Presence factor – someone would have to be close to the pool fire to be harmed.	1	No off site impact
		M	PF	3	2	2	Personnel will be present on the FSPU, high probability of personnel in area.	1	Vessel would have to be close to the area for harm to occur.
		L	PF	2	1	1	Personnel will be present on the FSPU, high probability of personnel in area.	1	Vessel would have to be close to the area for harm to occur.
		L	EX	4	2	2	Release would have to be	1	Vessel would have to be close to

Ref.	Description	Size	Outcome	Leak Frequency Category	Effect Frequency Category	On-Site Outcome Frequency Category	Comments	Off-Site Outcome Frequency Category	Comments
							undetected, and lead to build up of gas in the congested area. High probability of people in area affected. High probability of ignition of prolonged release.		the area for harm to occur.
L3	Release from the HP Pumps discharge pipework up to the Vaporisers.	S	JF	3	1	1	Low probability of ignition for small leaks. Presence factor – someone would have to be close to the jet fire to be harmed.	1	No off site impact
		M	JF	3	2	1	Directional probability – jet flame would have to be directed towards occupied areas.	1	No off site impact
		L	JF	3	2	2	Directional probability – very likely to have personnel present within the areas that could be affected	1	Vessel would have to be close to the area for harm to occur. Jet would have to be towards the vessel.
		S	FF	3	1	1	Release would have to be undetected, low probability of ignition for small leaks. High chance of people in area affected.	1	Unchanged, no off site impact
		M	FF	3	1	1	Release would have to be undetected. High chance of people in area affected.	1	Vessel would have to be close to the area for harm to occur.
		L	FF	3	2	2	Release would have to be undetected. High probability of people in area affected. High probability of ignition of prolonged release.	1	Vessel would have to be close to the area for harm to occur.
		S	PF	3	1	1	Low probability of ignition for small leaks. Presence factor – someone would have to be close to the pool fire to be harmed.	1	No off site impact
		M	PF	3	1	1	Personnel will be present on the FSPU, high probability of personnel in area.	1	Vessel would have to be close to the area for harm to occur.
		L	PF	3	2	2	Personnel will be present on the FSPU, high probability of	1	Vessel would have to be close to the area for harm to occur.

Ref.	Description	Size	Outcome	Leak Frequency Category	Effect Frequency Category	On-Site Outcome Frequency Category	Comments	Off-Site Outcome Frequency Category	Comments
							personnel in area.		
		L	EX	3	2	2	Release would have to be undetected, and lead to build up of gas in the congested area. High probability of people in area affected. High probability of ignition of prolonged release.	1	Vessel would have to be close to the area for harm to occur.
L4	Release from a transfer hose during ship to ship transfer.	S	JF	5	4	2	Directional probability – release would have to be directed towards personnel. Personnel may not be present.	1	No off site impact
		M	JF	5	4	3	Directional probability but large flame. Personnel would have to be in the area.	1	No off site impact
		L	JF	5	4	4	Very large jet fire, high probabilities of ignition and affecting areas where personnel are present.	2	Vessel would have to be close to the area for harm to occur. Jet would have to be towards the vessel.
		S	FF	5	3	1	Personnel would be unlikely to be in the area affected by the flash fire.	1	No off site impact
		M	FF	5	3	2	Personnel could be within the area affected.	1	No off site impact
		L	FF	5	3	3	Very large flash fire, likely that personnel would be in the area affected, particularly on the jetty.	2	Vessels would have to be present in the area for harm to occur.
		S	PF	5	3	1	Low probability of ignition for small leaks. Presence factor – as fire is between vessels there is a low probability of someone being present.	1	No off site impact
		M	PF	5	3	2	Personnel will be present on the FSPU, high probability of personnel in area.	1	No off site impact
		L	PF	5	3	3	Personnel will be present on the FSPU and jetty.	2	Vessels would have to be present in the area for harm to occur.
G1	Release from the pipework	S	JF	5	3	1	Low probability of ignition for small leaks. Presence factor –	1	No off site impact

Ref.	Description	Size	Outcome	Leak Frequency Category	Effect Frequency Category	On-Site Outcome Frequency Category	Comments	Off-Site Outcome Frequency Category	Comments
							someone would have to be close to the jet fire to be harmed.		
		M	JF	5	3	2	Directional probability – jet flame would have to be directed towards occupied areas.	1	No off site impact
		L	JF	4	4	4	Directional probability – very likely to have personnel present within the areas that could be affected	1	Vessel would have to be close to the area for harm to occur. Jet would have to be towards the vessel.
	between the vaporiser outlets and the ship-side ESDV upstream of gas unloading arm.	S	FF	5	2	1	Release would have to be undetected, low probability of ignition for small leaks. High chance of people in area affected.	1	No off site impact
		M	FF	5	2	2	Release would have to be undetected. High chance of people in area affected.	1	Vessel would have to be close to the area for harm to occur.
		L	FF	4	2	2	Release would have to be undetected. High probability of people in area affected. High probability of ignition of prolonged release.	1	Vessel would have to be close to the area for harm to occur.
		L	EX	4	2	2	Release would have to be undetected, and lead to build up of gas in the congested area. High probability of people in area affected. High probability of ignition of prolonged release.	1	Vessel would have to be close to the area for harm to occur.
G2	Release from the pipework between the ship-side ESDV upstream of the gas unloading arm and the first jetty ESDV.	S	JF	5	3	1	Low probability of ignition for small leaks. Presence factor – someone would have to be close to the jet fire to be harmed.	1	No off site impact
		M	JF	5	3	2	Directional probability – jet flame would have to be directed towards occupied areas.	1	No off site impact
		L	JF	5	3	3	Directional probability – very likely to have personnel present within the areas that could be affected	1	Vessel would have to be close to the area for harm to occur. Jet would have to be towards the

Ref.	Description	Size	Outcome	Leak Frequency Category	Effect Frequency Category	On-Site Outcome Frequency Category	Comments	Off-Site Outcome Frequency Category	Comments
									vessel.
		S	FF	5	2	1	Release would have to be undetected, low probability of ignition for small leaks. High chance of people in area affected.	1	No off site impact
		M	FF	5	2	2	Release would have to be undetected. High chance of people in area affected.	1	Vessel would have to be close to the area for harm to occur.
		L	FF	5	2	2	Release would have to be undetected. High probability of people in area affected. High probability of ignition of prolonged release.	1	Vessel would have to be close to the area for harm to occur.
G3	Release from the pipework between the first jetty ESDV and the second Jetty ESDV.	S	JF	2	1	1	Low probability of ignition for small leaks. Presence factor – someone would have to be close to the jet fire to be harmed.	1	No off site impact
		M	JF	2	1	1	Directional probability – jet flame would have to be directed towards occupied areas or personnel on the jetty.	1	No off site impact
		L	JF	1	1	1	Directional probability – very likely to have personnel present within the areas that could be affected	1	Vessel would have to be close to the area for harm to occur. Jet would have to be towards the vessel.
		S	FF	2	1	1	Release would have to be undetected, low probability of ignition for small leaks. High chance of people in area affected.	1	No off site impact
		M	FF	2	1	1	Release would have to be undetected. High chance of people in area affected.	1	Vessel would have to be close to the area for harm to occur.
		L	FF	1	1	1	Release would have to be undetected. High probability of people in area affected. High probability of ignition of	1	Vessel would have to be close to the area for harm to occur.

Ref.	Description	Size	Outcome	Leak Frequency Category	Effect Frequency Category	On-Site Outcome Frequency Category	Comments	Off-Site Outcome Frequency Category	Comments
							prolonged release.		
G4	Release from the pipework between the second Jetty ESDV and the third Jetty ESDV.	S	JF	3	1	1	Low probability of ignition for small leaks. Presence factor – someone would have to be close to the jet fire to be harmed.	1	No off site impact
		M	JF	3	1	1	Directional probability – jet flame would have to be directed towards occupied areas or personnel on the jetty.	1	No off site impact
		L	JF	2	1	1	Directional probability – very likely to have personnel present within the areas that could be affected	1	Vessel would have to be close to the area for harm to occur. Jet would have to be towards the vessel.
		S	FF	3	1	1	Release would have to be undetected, low probability of ignition for small leaks. High chance of people in area affected.	1	No off site impact
		M	FF	3	1	1	Release would have to be undetected. High chance of people in area affected.	1	Vessel would have to be close to the area for harm to occur.
		L	FF	2	1	1	Release would have to be undetected. High probability of people in area affected. High probability of ignition of prolonged release.	1	Vessel would have to be close to the area for harm to occur.
G5	Release from the FSRU relief system under fire conditions	Single Fire	JF	4	3	2	Personnel present on FSRU – may have evacuated if a fire starts.	1	No off site impact

5.4 Frequency of Marine Accidents

Potential the frequencies of marine accidents have been calculated using the methodology detailed in Appendix 1. The results are summarised in Table 16.

Table 16 Summary of Marine Accident Frequencies

Event	Accident Frequency (per year)
Vessel passing LNG facility, suffering engine failure and drifting into LNGc.	2.4×10^{-6}
LNGc experiences machinery failure, loses control and runs aground or collides with another vessel.	3.3×10^{-6}
LNGc experiences steering gear failure, loses control and runs aground or collides with another vessel.	3.1×10^{-7}
LNGc experiences machinery or steering gear failure during berthing, loses control and collides with FSRU.	4.6×10^{-7}

It should be noted that these are the frequencies of accidents (collision, grounding etc.) and not the frequencies of spills as a result of an accident. Given the low relatively low vessel speeds in the channel and the robust, double-hull construction of the LNGc / FSRU, only a small fraction of accidents will result in breach of a cargo tank and spillage. Therefore, the frequency of accidents resulting in spillage is judged to be very low (less than 1×10^{-6} per year).

6. Risk Assessment

Each MAH scenario has been plotted on the on-site risk matrix and the off-site risk matrix using the assigned severity and frequency categories. Each MAH scenario has been assigned a 'tag' as follows:

NN_SS_EE

Where:

- NN is the system reference (L1, G1 etc. as defined in Table 5);
- SS is the release size (S for Small, M for Medium, L for Large); and,
- EE is the effect type (JF for jet fire, PF for pool fire, FF for Flash Fire, EX for Explosion).

The assigned severity, frequency and risk categories are summarised in Table 17. The on-site risk matrix is displayed in Figure 4; the off-site matrix is shown in Figure 5.

6.1 Risk from Marine Accidents

The frequency of marine accidents has been calculated to be very low (less than 1 x 10^{-6} per year, or category 1), as described in Section 5.4. The studies conducted by the Sandia National Laboratory in the USA (5, 6) indicate that members of the public on the mainland are unlikely to be affected by accidental breaches of either the LNGc or the FSRU, although other vessels using the shipping channel may be affected by such an accident (severity category D or E). Therefore the risk from marine accidents is judged to be in the 'medium' region.

Table 17: Summary of Assigned Frequency and Severity Categories

Ref.	Description	Size	Outcome	Tag	On-Site			Off-Site		
					Frequency	Severity	Risk	Frequency	Severity	Risk
L1	Release from pipework between the FRSU tanks and the HP Pump Suction Drums.	S	JF	L1_S_JF	1	B	L	1	A	L
		M	JF	L1_M_JF	2	C	M	1	A	L
		L	JF	L1_L_JF	2	D	M	1	B	L
		S	FF	L1_S_FF	1	C	L	1	A	L
		M	FF	L1_M_FF	1	D	M	1	A	L
		L	FF	L1_L_FF	1	E	M	1	D	M
		S	PF	L1_S_PF	1	B	L	1	A	L
		M	PF	L1_M_PF	3	C	M	1	A	L
		L	PF	L1_L_PF	2	D	M	1	B	L
		L	EX	L1_L_EX	1	E	M	1	C	M
L2	Release from the HP Pump Suction Drums and pipework feeding the HP Pumps.	S	JF	L2_S_JF	1	B	L	1	A	L
		M	JF	L2_M_JF	1	C	L	1	A	L
		L	JF	L2_L_JF	1	D	M	1	B	L
		S	FF	L2_S_FF	1	C	L	1	A	L
		M	FF	L2_M_FF	1	D	M	1	A	L
		L	FF	L2_L_FF	1	E	M	1	D	M
		S	PF	L2_S_PF	1	B	L	1	A	L
		M	PF	L2_M_PF	2	C	M	1	A	L
		L	PF	L2_L_PF	1	D	M	1	A	L
		L	EX	L2_L_EX	2	E	M	1	C	M
L3	Release from the HP Pumps discharge pipework up to the Vaporisers.	S	JF	L3_S_JF	1	B	L	1	A	L
		M	JF	L3_M_JF	1	C	L	1	A	L
		L	JF	L3_L_JF	2	D	M	1	C	L
		S	FF	L3_S_FF	1	C	L	1	A	L
		M	FF	L3_M_FF	1	D	L	1	A	L
		L	FF	L3_L_FF	2	E	M	1	C	M
		S	PF	L3_S_PF	1	B	L	1	A	L
		M	PF	L3_M_PF	1	C	L	1	A	L
		L	PF	L3_L_PF	2	D	M	1	A	L
		L	EX	L2_L_EX	2	E	M	1	C	M
L4	Release from a transfer hose during ship to ship transfer.	S	JF	L4_S_JF	2	B	M	1	A	L
		M	JF	L4_M_JF	3	C	M	1	A	L
		L	JF	L4_L_JF	4	D	H	2	B	M
		S	FF	L4_S_FF	1	B	L	1	A	L
		M	FF	L4_M_FF	2	C	M	1	A	L
		L	FF	L4_L_FF	3	E	H	2	D	M

Ref.	Description	Size	Outcome	Tag	On-Site			Off-Site		
					Frequency	Severity	Risk	Frequency	Severity	Risk
		S	PF	L4_S_PF	1	B	L	1	A	L
		M	PF	L4_M_PF	2	C	M	1	A	L
		L	PF	L4_L_PF	3	E	H	2	B	M
G1	Release from the pipework between the vaporiser outlets and the ship-side ESDV upstream of gas unloading arm.	S	JF	G1_S_JF	1	B	L	1	A	L
		M	JF	G1_M_JF	2	C	M	1	A	L
		L	JF	G1_L_JF	4	D	H	1	A	L
		S	FF	G1_S_FF	1	C	L	1	A	L
		M	FF	G1_M_FF	2	D	M	1	A	L
		L	FF	G1_L_FF	2	E	M	1	B	L
		L	EX	G1_L_EX	2	E	M	1	C	M
G2	Release from the pipework between the ship-side ESDV upstream of the gas unloading arm and the first jetty ESDV.	S	JF	G2_S_JF	1	B	L	1	A	L
		M	JF	G2_M_JF	2	C	M	1	A	L
		L	JF	G2_L_JF	3	D	M	1	A	L
		S	FF	G2_S_FF	1	C	L	1	A	L
		M	FF	G2_M_FF	2	D	M	1	A	L
		L	FF	G2_L_FF	2	E	M	1	B	L
G3	Release from the pipework between the first jetty ESDV and the second Jetty ESDV.	S	JF	G3_S_JF	1	B	L	1	A	L
		M	JF	G3_M_JF	1	C	L	1	A	L
		L	JF	G3_L_JF	1	D	M	1	A	L
		S	FF	G3_S_FF	1	C	L	1	A	L
		M	FF	G3_M_FF	1	D	M	1	A	L
		L	FF	G3_L_FF	1	E	M	1	B	L
G4	Release from the pipework between the second Jetty ESDV and the third Jetty ESDV.	S	JF	G4_S_JF	1	B	L	1	A	L
		M	JF	G4_M_JF	1	C	L	1	A	L
		L	JF	G4_L_JF	1	D	M	1	A	L
		S	FF	G4_S_FF	1	C	L	1	A	L
		M	FF	G4_M_FF	1	D	M	1	A	L
		L	FF	G4_L_FF	1	E	M	1	B	L
G5	Release from the FSRU relief system under fire conditions	SRV	JF	G5_SRV_JF	2	B	M	1	A	L

Figure 4: On-Site Risk Matrix - Results

Frequency		Severity				
		A	B	C	D	E
	5					
	4				L4_L_JF, G1_L_JF	
	3			L1_M_PF, L2_M_PF, L4_M_JF	L2_L_PF, G2_L_JF	L4_L_FF, L4_L_PF
	2		L2_M_JF, L2_S_PF, L4_S_JF, G5_SRV_JF	L1_M_JF, L4_M_FF, L4_M_PF, G1_M_JF, G2_M_JF	L1_L_JF, L1_L_PF, L3_L_JF, L3_L_PF, G1_M_FF, G2_M_FF	L2_L_EX, L2_L_EX, G1_L_FF, G2_L_FF, G1_L_EX
	1		L1_S_JF, L1_S_PF, L2_S_JF, L3_S_JF, L3_S_PF, L4_S_FF, L4_S_PF, G1_S_JF, G2_S_JF, G3_S_JF, G4_S_JF	L1_S_FF, L2_S_FF, L3_M_JF, L3_S_FF, L3_M_PF, G1_S_FF, G2_S_FF, G3_M_JF, G3_S_FF, G4_M_JF, G4_S_FF	L1_M_FF, L2_L_JF, L2_M_FF, L3_M_FF, L3_L_FF, G3_L_JF, G3_M_FF, G4_L_JF, G4_M_FF	L1_L_FF, L1_L_EX, L2_L_FF, G3_L_FF, G4_L_FF

Figure 5: Off-Site Risk Matrix - Results

		Severity				
		A	**B**	**C**	**D**	**E**
Frequency	**5**					
	4					
	3					
	2		L4_L_JF, L4_L_PF		L4_L_FF	
	1	L1_S_JF, L1_M_JF, L1_S_FF, L1_M_FF, L1_S_PF, L1_M_PF, L2_S_JF, L2_M_JF, L2_S_FF, L2_M_FF, L2_S_PF, L2_M_PF, L2_L_PF, L3_S_JF, L3_M_JF, L3_S_FF, L3_M_FF, L3_S_PF, L3_M_PF, L3_L_PF, L4_S_JF, L4_M_JF, L4_S_FF, L4_M_FF, L4_S_PF, L4_M_PF, G1_S_JF,G1_M_JF, G1_L_JF, G1_S_FF, G1_M_FF, G2_S_JF, G2_M_JF, G2_L_JF, G2_S_FF, G2_M_FF, G3_S_JF, G3_M_JF, G3_L_JF, G3_S_FF, G3_M_FF, G4_S_JF, G4_M_JF, G4_L_JF, G4_S_FF, G4_M_FF, G5_SRV_JF,	L1_L_JF, L1_L_PF, L2_L_JF, G1_L_FF, G2_L_FF, G3_L_FF, G4_L_FF	L1_L_EX, L2_L_EX, L3_L_JF, L3_L_EX, G1_L_EX	L1_L_FF, L2_L_FF, L3_L_FF	

7. Conclusions and Recommendations

Potential major accident hazards associated with the Engro Vopak LNG Regasification Terminal have been identified and subjected to a semi-quantitative risk assessment. Risks to people on-site and off-site have been assessed. The findings are discussed below.

7.1 On-Site Risk

The following MAH scenarios were found to give rise to a 'high' on-site risk:

- Pool or jet fires following a large continuous release from a ship to ship LNG transfer hose and immediate ignition, with failure to isolate the release;
- Flash fires following a large continuous release from a ship to ship LNG transfer hose and delayed ignition, with failure to isolate the release; and,
- Jet fires from the system on the FSRU, originating from releases between the vaporisers and the ESDV upstream of the unloading arm.

The pool fire generated on the river from a large release during ship-to-ship transfer would envelop the vessels and jetty and escape from the area could be difficult. It is recommended that measures to reduce the risk associated with this scenario are considered. This is discussed further in Section 7.4. However, it is also noted that there is some uncertainty in the failure frequencies for ship-to-ship transfers and it is recommended that this is investigated further as the design of the facility progresses.

High pressure jet fires from the FSRU regas system have the potential to affect personnel on the FSRU, on the jetty, and/or on a shuttle tanker offloading to the FSRU. The assessment of this scenario had necessarily been based on relatively conservative assumptions, since there is currently no detailed information on the likely distribution of personnel on the jetty, FSRU and shuttle tanker. Clearly this is a scenario that will require further investigation as the design progresses.

A number of scenarios were found to give rise to a 'medium' risk, including:

- flash fires, pool fires and some jet fires resulting from large or medium releases of LNG or natural gas on the FSRU. If events of this type occur they have a high potential for harming personnel on the FSRU and personnel on the shuttle tanker and jetty.
- pool and jet fires resulting from medium sized releases of LNG and flash fires resulting from large and medium sized releases of LNG during ship to ship transfer operations. These will mainly affect the area between the two vessels, with the consequences from jet fires depending upon the leak direction.
- flash fires resulting from large releases of natural gas from the gas offloading arm and pipework systems on the jetty. Personnel on the jetty would be at most risk from this scenario.
- explosions from large releases of LNG and natural gas on the FSRU where the cloud of gas formed is sufficient to fill the congested processing area prior to ignition.

Explosions of this magnitude would have catastrophic consequences for the whole of the jetty area, FSRU and supply vessel.

In view of the risks, it is considered appropriate to explore whether further risk reduction measures for these scenarios would be reasonably practicable. This is discussed further in Section 7.4. It is also clear that more detailed assessment of the risks to personnel associated with the facility will be required as the design progresses.

7.2 Off-Site Risk

Off site risks from the site were found to be considerably lower than on-site risks. In particular, it was observed that none of the scenarios modelled has the potential to harm members of the public on the mainland. This is largely attributable to the distance to the nearest receptor on land (3.2 km from the facility). For the brownfield site, the nearest facility is EVTL's chemical/LPG handling jetty, which has been purposely designed to mitigate against such type of hazard event (hazardous area classification, non sparking certified 'EXe' equipment, ESD system, F&G detection, safety procedures etc.). The detailed discussion about brownfield site option is given in Section 3.1 of HAZID Study OGL/DA/10026 (Appendix 1). Furthermore, the distance of other vessels from the facility (200 m safety distance) provides some mitigation of the potential effects of accidents on passing vessels.

None of the scenarios assessed gave rise to a 'high' risk to members of the public.

The scenarios giving rise to a 'medium' risk were those from flash fires resulting from large releases of LNG on the FSRU and during ship to ship transfer. These flash fires could affect large areas of the channel.

Explosion scenarios within the regas plant on the FSRU also have the potential to affect passing vessels, if present at the time of the accident.

It is considered appropriate to explore whether further risk reduction measures for these medium-risk scenarios would be reasonably practicable. This is discussed further in Section 7.4 below.

7.3 Marine Risk

The frequencies of marine accidents have been calculated as described in Appendix 1. The consequences of marine accidents have been estimated on the basis of studies performed by the Sandia National laboratories in the USA (5, 6). The results indicate that the frequencies of marine accidents are very low, and that the risks are in the 'medium' region.

7.4 Recommendations

7.4.1 Reduction of On-Site Risks

As described in the preceding Sections, it is recommended that measures to reduce the risk associated with the 'high' risk ship to ship LNG transfer accident scenario are considered. A number of 'good practice' measures were detailed in the HAZID, as follows:

- safety shut off systems on the LNG transfer systems (process transmitters, alarms, push buttons and shut-off valves);

- ship to shore Emergency Shut Down (ESD); allowing remote shut down of the LNG systems;
- firefighting systems on the jetty and FSRU (firewater pumps, water/foam deluge via monitors);
- fire and gas and low temperature detection systems on the jetty with automatic shutdown of the LNG STS transfer system, regassification unit and NG transfer system;
- the facility for emergency disconnection of the FSRU and emergency release couplings on the gas outloading arm;
- minimisation of the numbers of personnel present during normal operation;
- leak testing of equipment prior to use;
- emergency procedures covering transfer operations, quick release and sail away, fire fighting, escape and evacuation; and
- design of Safety Instrumented SIS to achieve the required Safety Integrity Level (SIL).

It is recommended that consideration be given to adopting all of these measures, if the company has not already done so. A recommendation for a Hazard and Operability (HAZOP) study of the system was also made during the HAZID, it is recommended that this study is undertaken.

An alternative configuration, also discussed during the HAZID, was transfer of LNG via hard arms over the jetty (as opposed to direct transfer from ship to ship using hoses). This may give some reduction in risk, since failure frequencies associated with hard arms are generally observed to be lower than those associated with hoses. It is recommended that such a configuration be evaluated further.

It is clear from this assessment that the risks to personnel 'on-site' (i.e. at the facility) are generally more significant than the risks to members of the public. Therefore it is recommended that more detailed, quantitative assessment of the risks to personnel at the facility is undertaken as the design progresses. Such studies may include:

- Escalation analysis (addressing the potential for small events at the jetty to escalate to the FSRU, and vice versa);
- Escape, Evacuation and Rescue assessment (particularly for personnel on the jetty);
- Jetty Control Room impairment frequency assessment;
- Accommodation impairment frequency assessment (particularly for accommodation facilities on the jetty, if provided); and,
- Quantitative risk assessment of the risks to personnel at the facility.

7.4.2 Reduction of Off-Site Risks

Off-site risks fall into the 'medium' risk zone, primarily because of the distance between the facility and land or river based populations. It is recommended that measures for excluding people from the area around the facility are considered. Specifically;

- the enforcement of the safety exclusion zone for river traffic around the site; and
- whether it would be practicable to increase the size of the safety exclusion zone around the facility (currently assumed to be 200 m).

As off site risks will be influenced by the measures taken to reduce on-site risks it is also recommended that the measures detailed in 7.4.1 are also considered as means of reducing off-site risks.

8. References

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Appendices

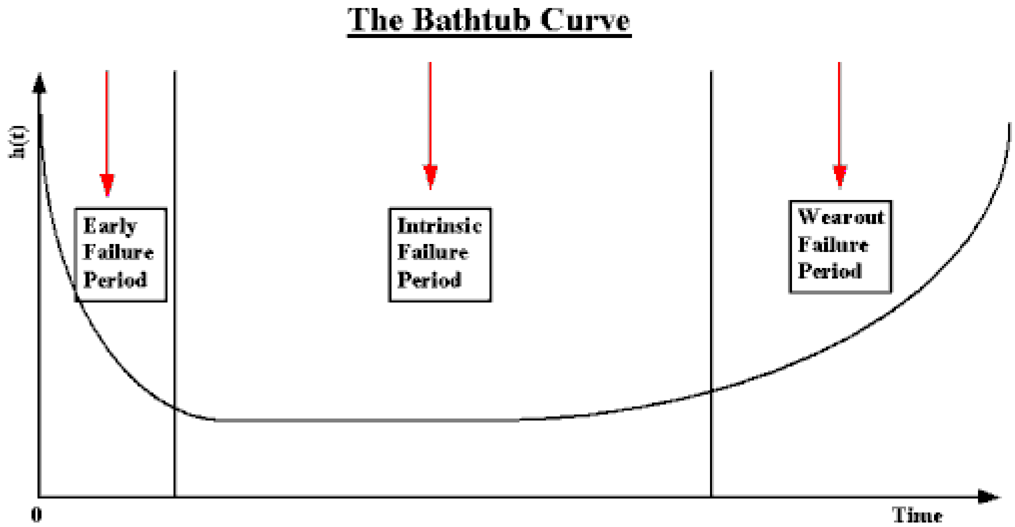
Appendix 1. Marine Accident Frequency Calculations

Marine Accident Frequency Calculations

An assessment of typical marine accident frequencies has been carried out in this study for inclusion in the wider EVTL assessment of the risks in future phases of the project.

The life of any mechanical and electrical system can be divided into three distinct periods. The initial period occurring during the early life of the system is characterized by a high but rapidly decreasing failure rate. This region is known as the Early Failure Period. After this period the failure rate levels off and generally remains roughly constant for the majority of the useful life of the system. This long period of near-constant failure rate is known as the Intrinsic Failure Period (or Stable Failure Period) and the constant failure rate level is called the Intrinsic Failure Rate. It should be noted that most systems spend the majority of their lifetimes operating in this period.

Finally, if the system remains in use long enough, the failure rate begins to increase as materials wear out and degradation failures occur at an ever increasing rate. This is called Wear-out Failure Period. This behaviour of the mechanical and electrical systems can be modelled by the reliability curve showed in the figure below. This curve is also known as a 'Bath tub curve' because of its shape.



Weibull Analysis can be used as a method of determining where a population of failures is on the bathtub curve. The Weibull distribution is a 3-parameter distribution. The three parameters are: β, η, and time T. The Weibull distribution is given by:

$$f(T) = \left[\frac{\beta}{\eta}\right] \cdot \left[\frac{T}{\eta}\right]^{[\beta-1]} \cdot e^{-\left[\frac{T}{\eta}\right]^{\beta}}$$

The Weibull parameter η is the 'characteristic life' and β is the shape factor. When:

$\beta < 1$ the failure rate is decreasing

$\beta = 1$ the failure rate is constant

$\beta > 1$ the failure rate is increasing

When β = 1, the failure rate is constant and the Weibull distribution becomes the exponential distribution. The exponential distribution is the model used for the Intrinsic Failure Period, signifying that failures are occurring randomly over time.

For sea going vessels most of the failures related to Early Failure Period are mitigated following harbour trials and vessel sea trials.

The vessels are frequently inspected by the classification societies throughout their design life. These inspections become more frequent if the owner wishes to use the vessel beyond its design life. Also, special life extension studies are usually required before life extension is approved. This provides some mitigation of failures during the 'Wear-out' period. Hence it can be concluded that most of the vessel system failures will have constant failure rate and fall into the Intrinsic Failure Period. As a result they can be modelled with exponential distribution.

The probability of failure of vessel systems, P(T), has been modelled using the exponential distribution as follows:

$$P(T) = 1 - e^{-\lambda T}$$

Where λ is the failure rate, and T is the time period of interest.

Lloyd's Register's vessel systems failure data for the last five years were used as the basis for the assessment.

Frequency of passing vessel system failure in the vicinity of the future LNG terminal

The frequency of a vessel passing the Khiprianwala green field site, experiencing engine failure and drifting into the LNGc or FSRU has been calculated.

This event is simulated in simulation run 30. It was demonstrated that a single standby tug (if sited by the LNG berth) would have sufficient time and power to prevent the passing ship drifting towards the LNGc or FSRU.

The frequency of a passing ship drifting and then colliding with LNGc or FSRU is calculated as follows:

$$F_1 = N \cdot P_{failure\_ship} \cdot P_{drift} \cdot P_{failure\_tug}$$

Where:

F_1 = frequency of accident (per year)

N = number of times a ship passes the facility per year

$P_{failure\_ship}$ = probability of failure of the ship system whilst passing the facility

P_{drift} = probability that a drifting ship collides with the FSRU / LNGc

$P_{failure\_tug}$ = probability of tug failure

According to the Port Qasim web site the maximum number of vessels handled in the port was 1238 in year 2008-2009. Assuming that the traffic will increase in the future, the number of ships using the port in one year is calculated as:

1238 x 1.15 = 1424

Each vessel will pass the facility twice, once on its way into the Port and once on the way out. Hence the number of times per year that a ship passes the facility is:

N = 2 x 1424 = 2848

It is conservatively assumed that every ship experiencing a failure within a distance of 1 nautical mile either side of the terminal will drift towards the facility. Also, it is assumed that the FSRU and LNGc cannot manoeuvre to avoid collision. Hence:

P_{drift} = 1

The probability of a ship's system failure within 1 nm either side of the facility is calculated using the exponential distribution. The time, T (hours) during which a failure would have to occur to result in collision is the time spent by the vessel within the 1 nm 'window' either side of the facility. Then, making a conservative assumption of a speed of 4kn:

$$T = \frac{2 \times 1}{4} = 0.5 \text{ hours}$$

The vessel failure rate was calculated using Lloyd's Register's failure database. The ships considered were oil tankers, bulk carriers, container ships and LPG tankers with deadweight in the range 10,000 to 50,000 t (i.e. the deadweight size that can be handled in Port Qasim port).

In the last five years, a total of 868 ships experienced 2041 failures that could be considered as failures that would cause the vessel to be inoperable.

Hence the failure rate, λ_{ship} (per hour) is calculated as:

$$\lambda_{ship} = \frac{2041}{868 \times 5 \times 365 \times 24} = 5.37 \times 10^{-5} \text{ per hour}$$

Inserting T and λ_{ship} into the expression for the exponential distribution gives:

$$P_{failure\_ship} = 1 - e^{-\lambda T} = 2.68 \times 10^{-5}$$

A similar approach has been adopted for calculation of the probability of tug failure. The relevant time 'window' for failure, T is estimated to be 3.5 hours, assuming that the tug works as a stand by vessel for ½ hour per ship (arrival and departure) and adding an additional 3 hours as a conservative time window of time to replace a failed stand by tug.

In terms of a failure rate, according to Lloyd's Register's database, in the last 10 years, 1346 tugs experienced 1054 failures that could be considered as failures that would prevent them performing their stand-by duty. Hence the tug failure rate (λ_{tug}) is calculated as:

$$\lambda_{tug} = \frac{1054}{1346 \times 10 \times 365 \times 24} = 8.94 \times 10^{-6} \text{ per hour}$$

Inserting T and λ_{tug} into the expression for the exponential distribution gives:

$$P_{failure\_tug} = (1 - e^{-\lambda T}) = 3.13 \times 10^{-5}$$

Then, the frequency of failure and collision with the FSRU / LNGc is:

$$F_1 = 2848 \times 2.68 \times 10^{-5} \times 1 \times 3.13 \times 10^{-5} = 2.39 \times 10^{-6} \text{ per year.}$$

It should be noted that this event requires the failure on the ship and the failure on the tug to occur within an extremely short period of time. This is because in the event of an incident on one system interim precautions would be taken to control the ship, thus minimizing the potential severity of an incident should further systems fail.

Frequency of loss of LNGc control due to machinery failure

The frequency of the LNGc vessel experiencing machinery failure, resulting in a loss of control and then either running aground or colliding with another vessel, has been calculated.

This event is simulated in simulation runs 24, 26 and 31. These simulations demonstrate that a single escort tug can successfully control the vessel.

The probability of the LNGc experiencing machinery failure and then running aground or colliding with another vessel is calculated using:

$$F_2 = N_{LNGc} . P_{failure\_LNGc} . P_{failure\_tug}$$

Where:

F_2 = frequency of accident (per year)

N_{LNGc} = number of LNGc deliveries per year

$P_{failure\_LNGc}$= probability of failure of the LNGc propulsion system during the period of interest

$P_{failure\_tug}$= probability that a tug failure leads to an inability to provide assistance when required

It is assumed, conservatively, that every such failure results in either collision or grounding.

The number of LNG deliveries per year (N_{LNGc}) is estimated to be 122 (one every three days).

The time 'window' for failure is the time the LNGc spends in the channel, approaching and departing from the facility. For the Khiprianwala site, the distance from the channel entrance to the terminal site is 16.74 nm. Assuming that the LNGc travels at 6 kn, then the time spent in the channel (T, hours) is:

$$T = \frac{2 \times 16.74}{6} = 5.6 \text{ hours}$$

The LNGc failure probability was calculated using Lloyd's Register's failure database. In the last five years a total of 117 ships had 494 propulsion related failures. Hence the failure rate (λ_{LNGc}) is calculated as:

$$\lambda_{LNGc} = \frac{494}{117 \times 5 \times 365 \times 24} = 9.64 \times 10^{-5} \text{ per hour}$$

Then the probability of failure during the time window of interest is:

$$P_{failure\_LNGc} = (1 - e^{-\lambda T}) = 5.4 \times 10^{-4}$$

It is assumed that a single escort tug will escort the LNGc for the entire period of time in the channel. The tug failure rate (λ_{tug}) is as quoted in the previous calculation:

λ_{tug} = 8.94 x 10^{-6} per hour

Then:

$$P_{failure\_tug} = (1 - e^{-\lambda T}) = 5.01 \times 10^{-5}$$

Hence:

$$F_2 = 122 \times 5.4 \times 10^{-4} \times 5.01 \times 10^{-5} = 3.30 \times 10^{-6} \text{ per year.}$$

Frequency of loss of LNGc control due to steering gear failure

The frequency of the LNGc vessel experiencing steering gear failure, resulting in a loss of control and then either running aground or colliding with another vessel, has been calculated.

This event is simulated in simulation runs 23 and 27. These simulations demonstrate that a single escort tug can successfully control the vessel.

The probability of the LNGc experiencing steering gear failure and then running aground or colliding with another vessel is calculated using a similar expression to the previous case:

$$F_3 = N_{LNGc} . P_{failure\_LNGc} . P_{failure\_tug}$$

Where:

F_3 = frequency of accident (per year)

N_{LNGc} = number of LNGc deliveries per year

$P_{failure\_LNGc}$ = probability of failure of the LNGc steering system during the period of interest

$P_{failure\_tug}$ = probability that a tug failure leads to an inability to provide assistance when required

It is assumed, conservatively, that every such failure results in either collision or grounding.

The number of LNG deliveries per year (N_{LNGc}) is estimated to be 122 (as before).

The time 'window' for failure is the same as the previous case (5.6 hours).

The LNGc failure probability was calculated using Lloyd's Register's failure database. In the last five years a total of 117 ships had 46 steering gear related failures. Hence the failure rate (λ_{LNGc}) is calculated as:

$$\lambda_{LNGc} = \frac{46}{117 \times 5 \times 365 \times 24} = 8.98 \times 10^{-6} \text{ per hour}$$

Then the probability of failure during the time window of interest is:

$$P_{failure\_LNGc} = (1 - e^{-\lambda T}) = 5.03 \times 10^{-5}$$

It is assumed that a single escort tug will escort the LNGc for the entire period of time in the channel. The tug failure rate (λ_{tug}) is and failure probability values are as quoted in the previous calculation:

$\lambda_{tug} =$ 8.94 x 10^{-6} per hour

And:

$$P_{failure\_tug} = (1 - e^{-\lambda T}) = 5.01 \times 10^{-5}$$

Hence:

$$F_3 = 122 \times 5.03 \times 10^{-5} \times 5.01 \times 10^{-5} = 3.07 \times 10^{-7} \text{ per year.}$$

Frequency of loss of control of LNGc due to machinery and steering gear failure during berthing

The frequency of the LNGc vessel experiencing machinery or steering gear failure during berthing, resulting in a loss of control and collision with the FSRU, has been calculated.

This event is simulated in runs 28, 29 and 32. These simulations demonstrate that a single escort tug can successfully control the vessel.

The probability of the LNGc experiencing machinery or steering gear failure during berthing and then colliding with the FSRU is calculated using:

$$F_4 = N_{LNGc}.P_{failure\_LNGc}.P_{failure\_tug}$$

Where:

F_4 = frequency of accident (per year)

N_{LNGc} = number of LNGc deliveries per year

$P_{failure\_LNGc}$= probability of failure of the LNGc steering or propulsion system during the period of interest

$P_{failure\_tug}$= probability that a tug failure leads to an inability to provide assistance when required

It is assumed, conservatively, that every such failure results in collision with the FSRU.

The number of LNG deliveries per year (NLNGc) is estimated to be 122 (as before).

The time 'window' for failure is the time required for LNGc berthing, which is 2 hours.

The LNGc failure probability was calculated using Lloyd's Register's failure database. In the last five years a total of 117 ships had 494 propulsion related failures and 46 steering gear failures. Hence the failure rate (λ_{LNGc}) is calculated as:

$$\lambda_{LNGc} = \frac{494+46}{117\times5\times365\times24} = 1.05\times10^{-4} \text{ per `hour}$$

Then the probability of failure during the time window of interest is:

$$P_{failure\_LNGc} = (1-e^{-\lambda T}) = 2.11\times10^{-4}$$

It is assumed that a single escort tug will escort the LNGc for the entire period of time in the channel. The tug failure rate (λ_{tug}) is as quoted in the previous calculation:

λ_{tug} = 8.94×10^{-6} per hour

Then:

$$P_{failure\_tug} = (1-e^{-\lambda T}) = 1.79\times10^{-5}$$

Hence:

$$F_4 = 122\times2.11\times10^{-4}\times1.79\times10^{-5} = 4.60\times10^{-7} \text{ per year.}$$

Summary

The calculation results are summarised in the table below.

Event	Frequency (per year)
Vessel passing the Khiprianwala green field site experiences engine failure and drifts into the LNGc or FSRU	2.4×10^{-6}
LNGc vessel experiences machinery failure, resulting in a loss of control and then either runs aground or collides with another vessel	3.3×10^{-6}
LNGc vessel experiences steering gear failure, resulting in a loss of control and then either runs aground or collides with another vessel	3.1×10^{-7}
LNGc vessel experiences machinery or steering gear failure during berthing, resulting in a loss of control and collides with the FSRU	4.6×10^{-7}

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LIFE MATTERS

A part of BMT in Maritime Transport

Manoeuvring Simulation Study for Proposed Port Qasim LNG Terminal (Risk Assessment for EVTL LNG Terminal)

Issue Date: 21st April 2011

Report No: L30090.1.2R

CONTENTS

Document Information		
Project	Manoeuvring Simulation Study for Proposed Port Qasim LNG Terminal	
Client	Lloyd's Register EMEA	
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Document History		
Version	Changes	By
1	Issue 1	MJW
1.1	Addressing client's comments	MJW
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1 TERMS OF REFERENCE

BMT ARGOSS Ltd (BMT) was instructed by Lloyd's Register EMEA (LR) on behalf of Engro Vopak (EVTL) to conduct a manoeuvring simulation study at the Port Qasim, Karachi for the proposed development of a new LNG terminal.

The study was undertaken by an experienced member of BMT staff and an independent Master Mariner / Pilot with the simulations being conducted using the PC Rembrandt ship handling and manoeuvring simulator, developed by BMT. This report describes the methodology adopted for this project and includes full simulation results (including track-plots) and appropriate recommendations for this project.

2 OBJECTIVES OF THE STUDY

The aim of the study was to test the entry and departure of various LNG vessels to several proposed sites for the LNG berth in different weather conditions.

The project had the following specific objectives:

- Inbound loaded to berth with introduced operational maximum parameters for wind, wave and tide. Critical systems failures on LNG tanker and tugs to be introduced in the approach channel, including the approach of other shipping.
- Outbound ballast from berth with introduced operational maximum parameters for wind, wave and tide. Critical systems failures on LNG tanker and tugs to be introduced in the approach channel.
- Inbound berthing with introduced operational maximum parameters for wind, wave and tide. Critical systems failures on LNG tanker and tugs to be introduced in the berthing and if applicable the turning basin.
- Outbound unberthing with introduced operational maximum parameters for wind, wave and tide. Critical systems failures on LNG tanker and tugs to be introduced in the berthing and turning basin.
- Staying berthed at the LNG berth with introduced operational maximum parameters for wind, wave and tide. The resultant loading by the LNG tanker on each component of the marine facilities to be confirmed against the individual component’s maximum safe working load.

Additional objectives were added during the workshop including investigating the ease of navigating to different terminal sites.

3 METHODOLOGY

The study was completed using BMT’s ship-handling simulator, PC Rembrandt. The PC Rembrandt system allows real and fast time simulations to be conducted using either ‘hands-on’ control (man-in-the-loop) or automated control using an auto-pilot function.

PC Rembrandt uses industry standard nautical electronic charts that provide the interactive back-drop to the simulations. It combines a high-fidelity mathematical ship model with 3-D ‘out of the window’ visuals and detailed environmental data to provide accurate, dynamic simulation of marine operations. Full reports on all simulations are produced and each simulation can be converted to a video replay file for presentation to interested parties.

The following sections describe the work undertaken in more detail.

3.1 The Electronic Chart

PC Rembrandt utilises standard Electronic Nautical Charts (ENC) produced to IHO 2-57 v3.1 standard. The latest chart was obtained and the coverage area is shown in ***Figure 1*** below.

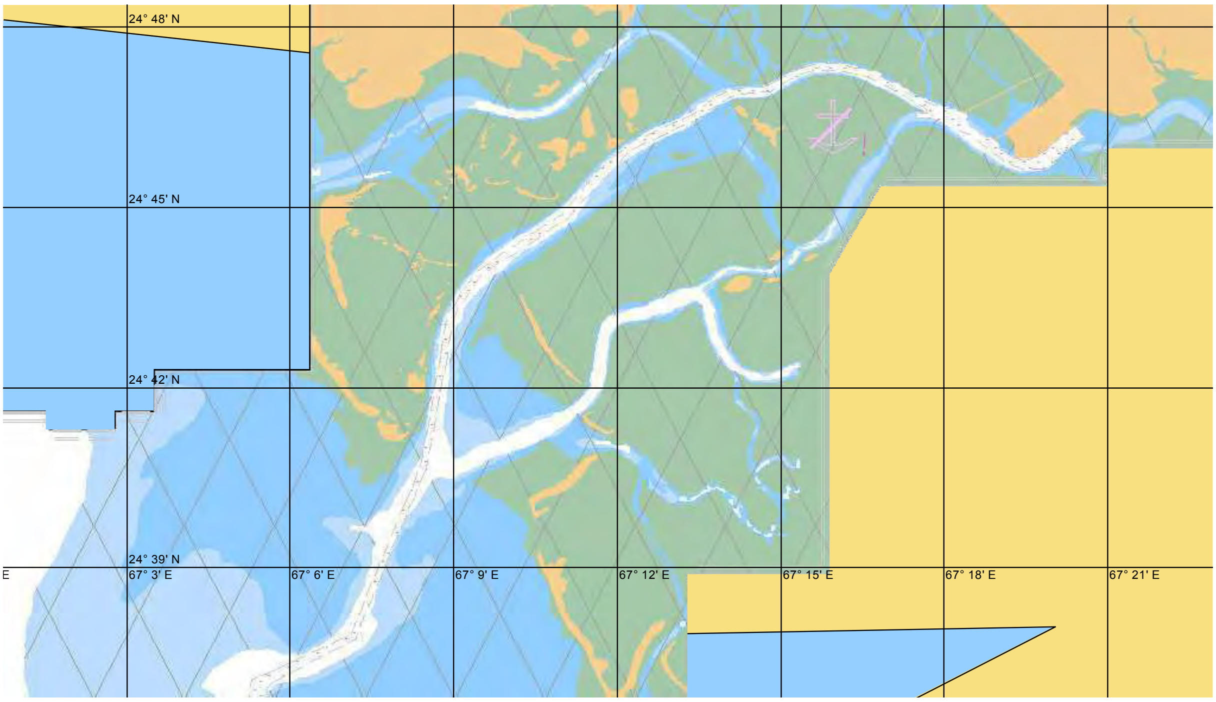


Figure 1 - Port Qasim Approach Channel

Figure 2 - 3D Visual Scene - LNGC Passing Moored Vessels

3.2 Current Modelling

In order to produce a more accurate set of simulations based on the proposed terminal's capabilities, BMT used assumed hydrodynamic current information. ***Figure 3*** & ***Figure 4*** show the currents inputted into PC Rembrandt for both a flood and ebb current at springs. Springs were chosen as they are classed as the extreme current conditions within which to manoeuvre a vessel.

Figure 3 - Spring Ebb with a 1.0m Height of Tide

Figure 4 - Spring Flood with a 1.0m Height of Tide

3.3 Vessel Mathematical Models

PC Rembrandt provides mathematical modelling of ships and other floating craft in 4 Degrees of Freedom (DoF), namely surge, sway, yaw and roll. Whilst wave effects are included, this is currently limited to the slowly varying wave drift forces and it does not provide rapidly varying motions associated with waves, i.e. vertical 'seakeeping' motions such as heave and pitch.

Two vessels were used for the simulation based on BMT's library of pre-modelled and validated ships. These vessels were a Steam Turbine driven Moss Ship (LNG 005) and a more modern and larger Q-Flex LNG Carrier (LNGC)(LNG 004). The ship models and their principal particulars are provided in ***Table 1*** below.

Parameter	*Length Overall (m)*	*Breadth (m)*	*Draught (m)*
Moss Ship (LNG 005)	283.0	43.4	11.5 (loaded) 9.5 (ballast)
Q-Flex (LNG 004)	315.2	50.0	12.2 (loaded) 9.5 (ballast)

Table 1 - Vessel Model Principal Particulars

The steam-driven LNG 005 was chosen as it represents the 'worst case scenario' of a relatively un-manoeuvrable and slow-to-respond vessel.

3.4 Use of Tugs

Within PC Rembrandt the tug force is assumed to be a vectored force acting at a specific location on the ship.

Tug forces in the longitudinal and lateral (X and Y respectively) are determined from the tug force set by the user (as a % of bollard pull) and the angle of the tug relative to the ships heading (see ***Figure 5***) The tug moment is calculated from the tug force and the offset of the tugs attachment to the ship from the ships centre of rotation. The tug moment is the turning moment (yaw) applied to the ship by the tug.

Tugs are programmed with a maximum bollard pull (tonnes) and selected from the on-screen panel by "clicking and dragging" to the attachment point on the vessel model. The tugs can push at any suitable location but can only pull at bollards. By colour coding the tugs the operator can adjust the angle to the vessel and percentage of maximum bollard pull upon the pilot's order.

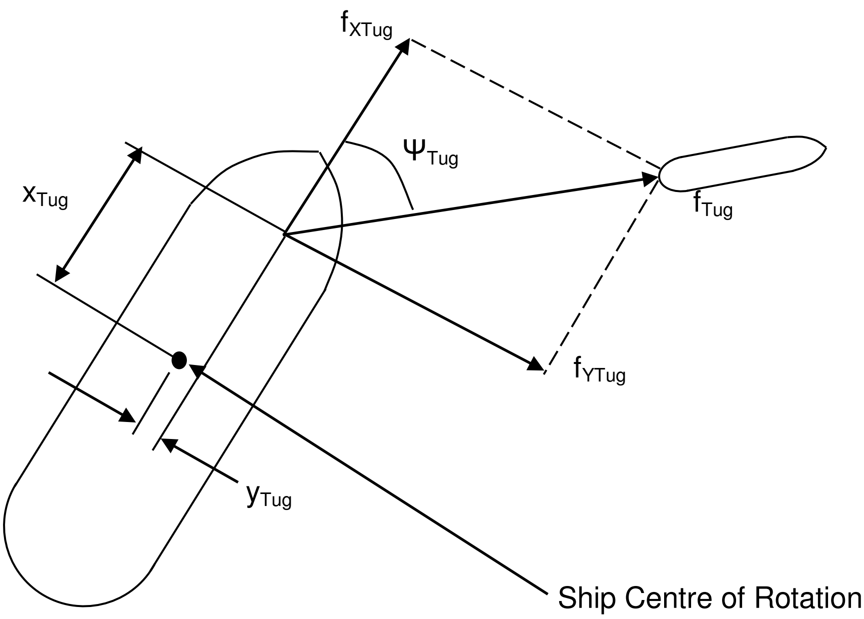


Figure 5 - Tug Forces and Moments

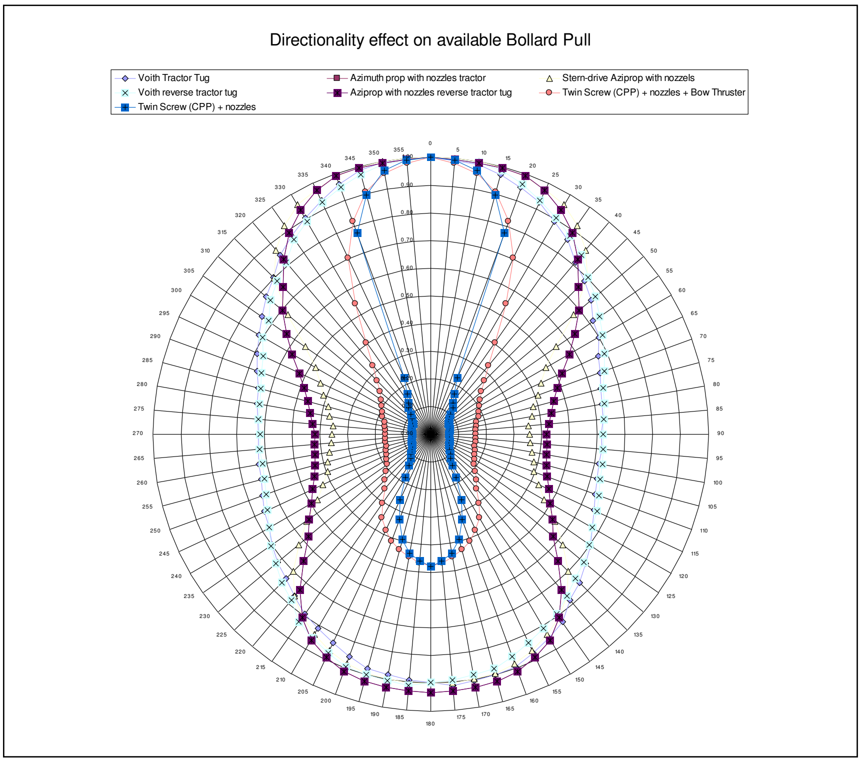


Figure 6 – Directionality Effects on Available Bollard Pull by Tug Type

In real life, the percentage of tug bollard pull achievable will depend upon the tug type (e.g. azimuthing stern drive, Voith - Schneider etc.) and the directional application of its power with relation to the wind/wave conditions and direction and the speed and aspect of the subject vessel. ***Figure 6*** illustrates the directionality effect on the available bollard pull for different tug types. In PC Rembrandt this degradation of power is applied by the operator adjusting the percentage power manually. Thus when the pilot requests full power, the operator will only apply the appropriate percentage of power applicable to the circumstances.

Within PC Rembrandt the tugs can be shown on the track plots in outline when not in use and filled in their respective colour when power is applied .Although the track plots show that the tugs are made fast from the beginning of the simulation, this is to facilitate the simulator operator during the exercise set-up. In practice the tugs were only assumed available just before entering the outer turning basin, when the vessel speed is reduced. Generally, the tugs orders were issued in a realistic and conservative manner based on the Pilot's experience and practice and tugs were never used in a way that would not be applicable in reality.

Four tugs were assumed available at Port Qasim. They were all deemed to be 60 tonnes bollard pull.

3.4 The Simulation Matrix

The simulation matrix was made up of 34 scenarios using the most extreme weather and current conditions. The table below shows the simulation matrix for the vessels used.

Run	Operation	Ship	Wind		Current	Tugs
			Dir	Spd		
1	Arrival	Moss Ship (Loaded)	225	30kts	Spring Flood	-
2A, B, C	Arrival	Moss Ship (Loaded)	225	30kts	Spring Flood	3
3	Arrival	Moss Ship (Loaded)	225	20kts	Spring Flood	3
4	Arrival	Moss Ship (Loaded)	225	30kts	Spring Flood	3
5	Arrival	Moss Ship (Loaded)	225	30kts	Spring Flood	3
6	Arrival	Moss Ship (Loaded)	225	30kts	Spring Flood	4
7	Arrival	Moss Ship (Loaded)	225	30kts	Spring Flood	4
8	Arrival	Moss Ship (Loaded)	225	30kts	Spring Flood	4
9	Arrival	Q-Flex (Loaded)	225	30kts	Spring Flood	-
10	Arrival	Q-Flex (Loaded)	225	30kts	Spring Flood	1
11	Arrival	Q-Flex (Loaded)	225	30kts	Spring Flood	4
12	Arrival	Q-Flex (Loaded)	225	20kts	Spring Flood	1
13	Departure	Moss Ship (Ballast)	225	30kts	Spring Flood	2
14	Departure	Moss Ship (Ballast)	225	30kts	Spring Ebb	2
15	Arrival	Q-Flex (Loaded)	225	20kts	Spring Flood	-
16	Arrival	Q-Flex (Loaded)	225	20kts	Spring Flood	4
17	Arrival	Moss Ship (Loaded)	225	30kts	Spring Flood	4
18	Departure	Moss Ship (Ballast)	225	30kts	Spring Flood	4
19	Arrival	Q-Flex (Loaded)	225	20kts	Spring Flood	4
20	Departure	Q-Flex (Ballast)	225	20kts	Spring Flood	2
21	Departure	Q-Flex (Ballast)	225	20kts	Spring Ebb	2
22	Arrival	Q-Flex (Loaded)	225	20kts	Slack Water	4
23	Arrival	Moss Ship (Loaded)	225	20kts	Spring Flood	1
24	Arrival	Moss Ship (Loaded)	225	20kts	Spring Flood	1
25	Arrival	Moss Ship (Loaded)	225	20kts	Spring Flood	1
26	Arrival	Moss Ship (Loaded)	225	20kts	Spring Flood	1
27	Arrival	Moss Ship (Loaded)	225	20kts	Spring Flood	1
28	Arrival	Moss Ship (Loaded)	225	20kts	Spring Flood	2 (3)
29	Arrival	Moss Ship (Loaded)	225	20kts	Slack Water	2 (3)
30	Arrival	Moss Ship (Loaded)	225	20kts	Spring Flood	1
31	Arrival	Moss Ship (Loaded)	225	20kts	Spring Flood	4
32	Arrival	Q-Flex (Loaded)	225	20kts	Slack Water	4
33	Arrival	Q-Flex (Loaded)	225	20kts	Spring Flood	1
34	Departure	Q-Flex (Loaded)	225	20kts	Spring Flood	2

Table 2 - Simulation Run Matrix

3.5 Simulation Methodology

All simulations were conducted by Chris Bordas, a pilot with experience of over 500 port entry and departures. The simulations were conducted as follows: the Pilot (Chris Bordas) controlled the vessel directly (i.e. without issuing orders) through a control console replicating actual ship controls and manoeuvred the tugs using the external function display. The Pilot had the following information available in real-time:

- The electronic chart view (ECDIS) showing the position of the vessel on the chart and other information such as the dredged channel, under keel clearance (UKC), turning circles and exclusion zones.

- An out-of-the-window 3D view from the ship's bridge (switched to the bridge wings when required).
- Run information such as the vessel speed over the ground (ahead/astern and lateral), rate of turn, heading and course over the ground. Also, depth profile and engine/rudder values (actual and demanded).
- Position and percentage of power usage for each tug.

The screen which is available to the pilot during the simulation is shown on ***Figure 7*** below:

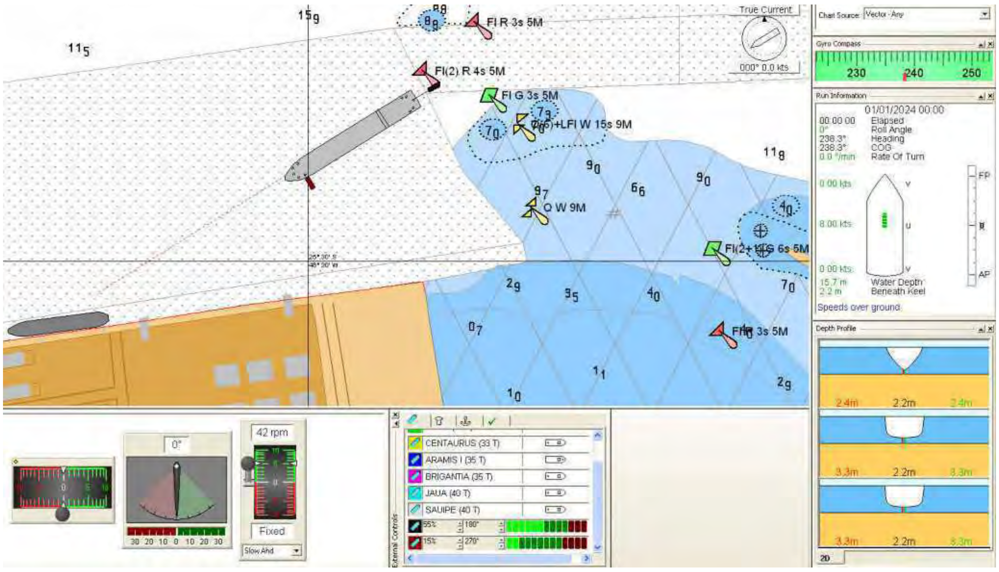


Figure 7 - Simulation Screen

Each run was set up with the met-ocean conditions and the ship's initial position, speed and course. The vessels initial speed, for the arrival, was set at around 10kts outside the harbour entrance. For departure manoeuvres, the simulations started with the vessel alongside the berth (stopped) and the speed was gradually increased as appropriate to the conditions.

At the end of each run, a run report form was completed. The run report forms are included in Annex A. They include a rudimentary grading (see ***Figure 8***) as to the difficulty of performing each manoeuvre as a means of comparison for the study. The contents of the report forms and the grading were completed upon the conclusion of each manoeuvre.

1	2	3	4	5	6	7	8
Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

Figure 8 - Simulation Grading Method

4 SIMULATION RESULTS

The run report forms for each run are presented in Annex A.

5 KEY CONCLUSIONS & RECOMMENDATIONS

- All runs were conducted at the most extreme weather and current conditions. During berthing manoeuvres' that involved swinging a loaded vessel this often necessitated all tugs running at 100% for prolonged periods. Care should be exercised to develop working procedures with regard to environmental conditions that mitigates this, such as berthing close to slack water.

- It is recommended that a standby tug be made available by the proposed LNG berth. This would be used to aid any vessel which experiences difficulties whilst passing the berth as shown in Run 30.

- Consideration should be given to securing escort towage that is capable of indirect towage shortly after the pilot boards as the width of the entrance channel is such that any emergency that occurs in this area could block the channel. The tug that is tasked for this may need to be rated at a higher bollard pull than others as it was shown that during all the berthings this tug alone had the most work to do.

- The simulations showed that berthing port side alongside the greenfield and brownfield site was much more effectively controlled and that swinging the tanker in ballast condition for the outward passage was also routinely achieved. The port will need to be consulted in order to develop suitable working practices for berthing, towage, line handling and VTS that will benefit all stakeholders.

Port Qasim LNG TerminalStudy

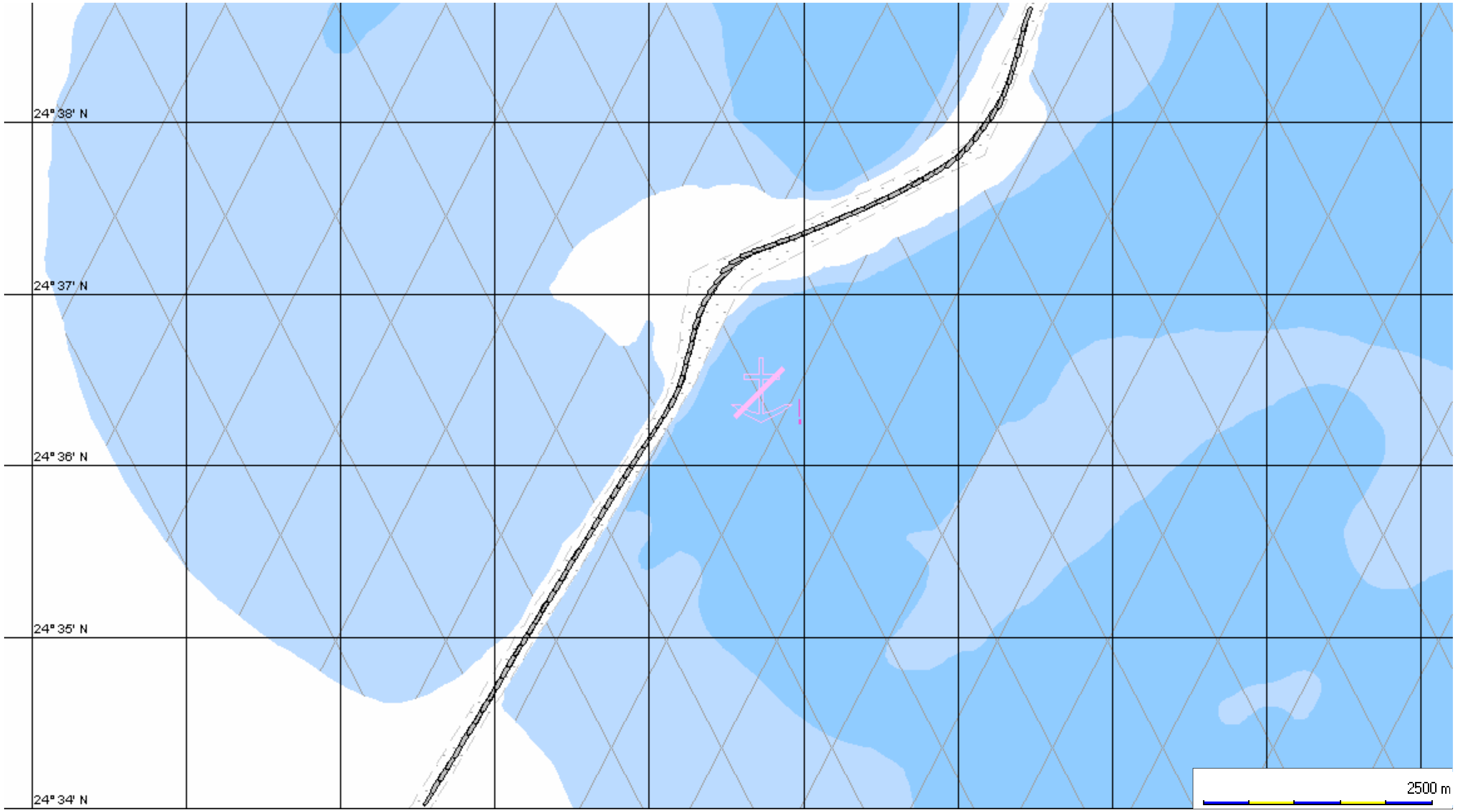
Simulation Run Reports

Project:	Port Qasim LNG TerminalStudy	Job No.:	L30090	Captain/Pilot:	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	28/02/2011				

Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
1	LNG 005	Loaded (11.5m)	Arrival		3kt Flood	-	3.4m	No
	Approach channel navigation conducted with flood tide and no wind. Rough sea state. No difficulties experienced.							

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

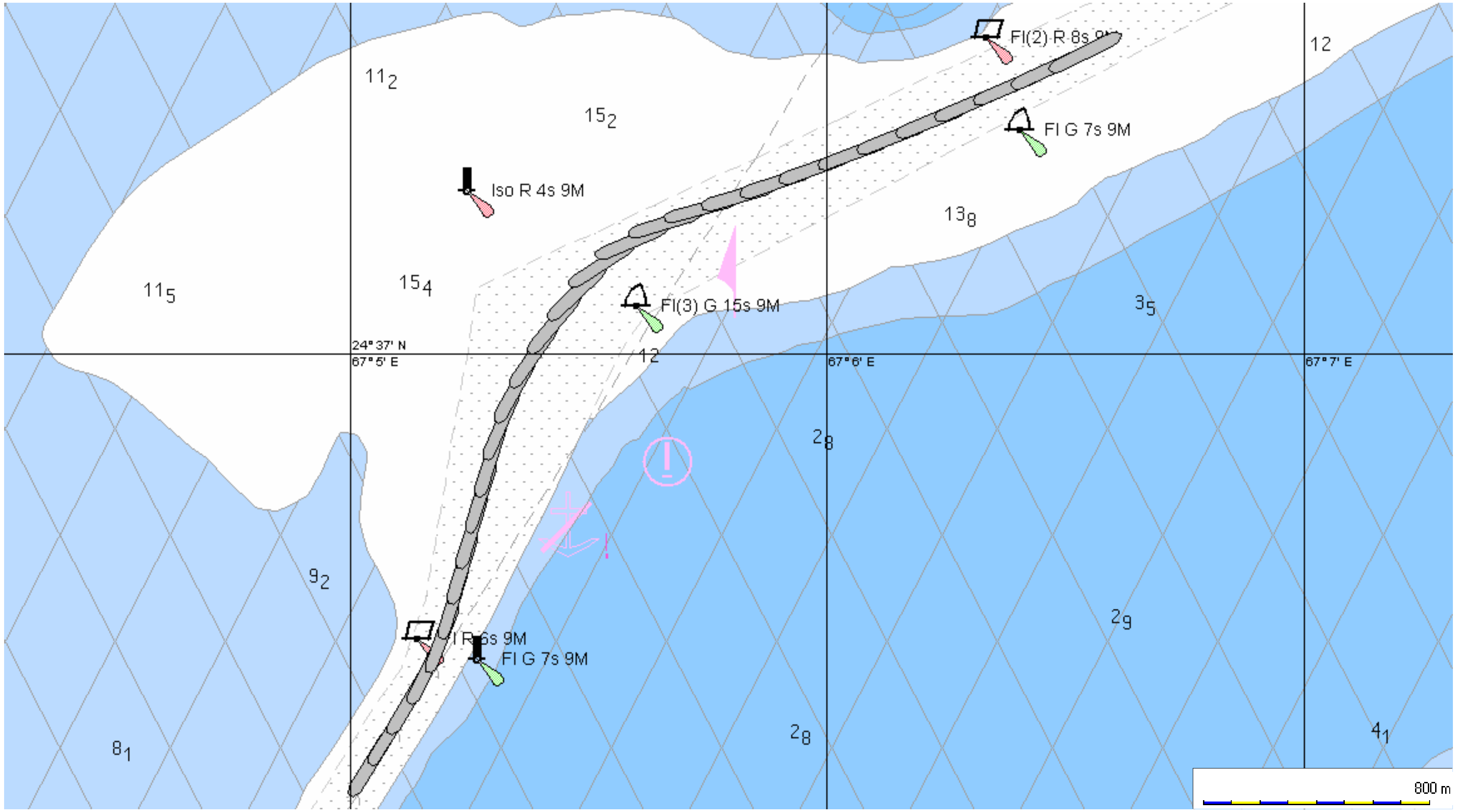
Vessel Track With Tugs



Vessel: LNG Carrier 005 (L)
Harbour: Qasim
Created: 28/02/2011

Wind: 0.00 kts 0 °
Current: 3 kts Flood
Depth: 1.0 m above Chart Datum

Vessel Track With Tugs



Vessel:	LNG Carrier 005 (L)
Harbour:	Qasim
Created:	28/02/2011

Wind:	0.00 kts 0 °
Current:	3 kts Flood
Depth:	1.0 m above Chart Datum

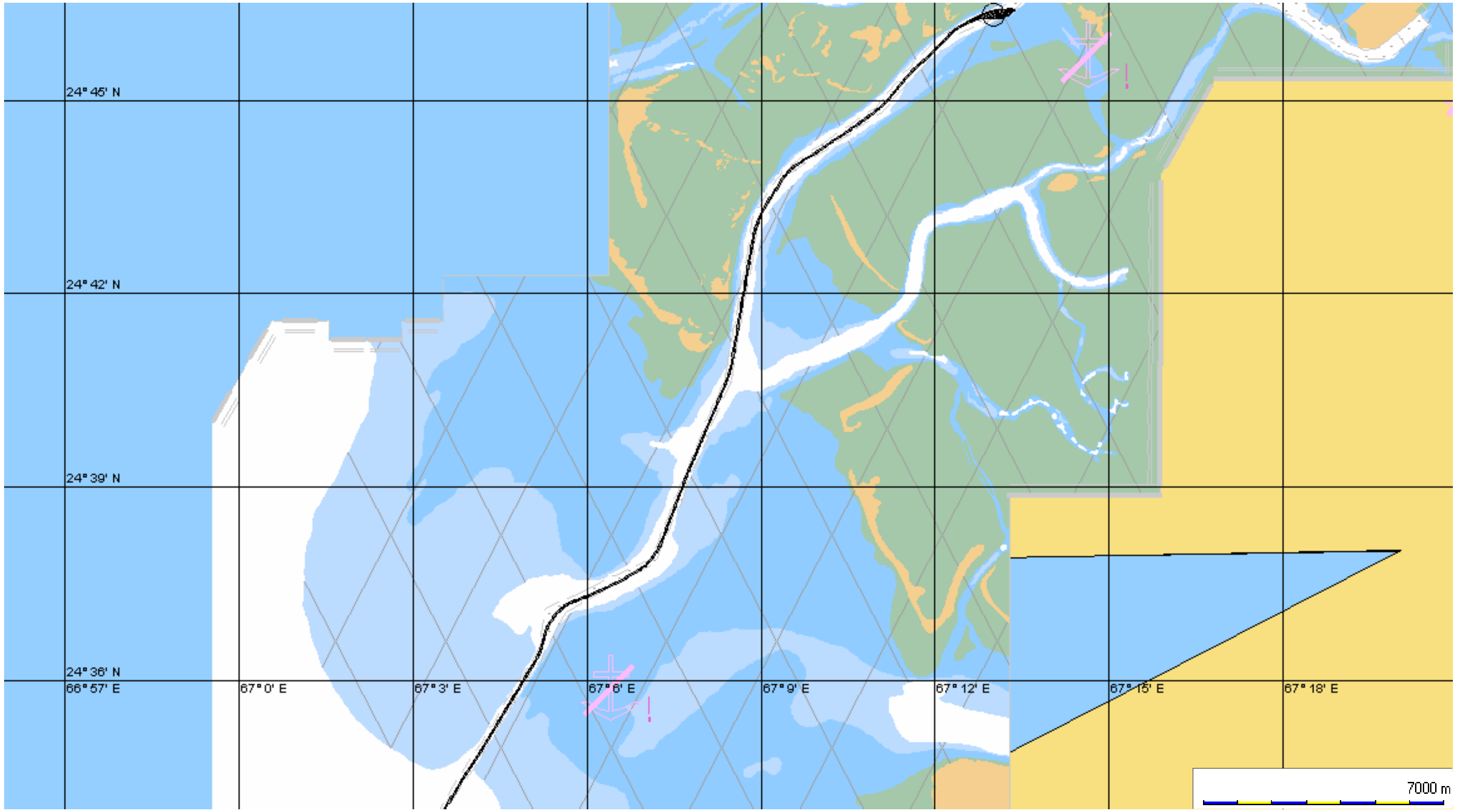
Project:	Port Qasim LNG Terminal Study		**Job No.:**	L30090		**Captain/Pilot:**	Chris Bordas	
Subject:	PC Rembrandt Simulation Study for Lloyd's Register							
Date:	28/02/2011							
Run No.	**Vessel**		**Access Condition**		**Environmental Conditions**			**Manoeuvre**
	Ship	**Condition**	**Type**	**No of Tugs Used**	**Current**	**Wind Speed (Direction from)**	**Waves (Ht/Period)**	**Thrusters used?**
2A	LNG 005	Loaded (11.5m)	Arrival		3kt Flood	30kts (225)	3.4m	No

<u>Passage</u>

Vessel navigated to proposed Greenfield site with a turning basin sited opposite the berth. No problems were experienced in navigating the approach channel.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding (circled)	Not easy	Challenging	Difficult	Impossible

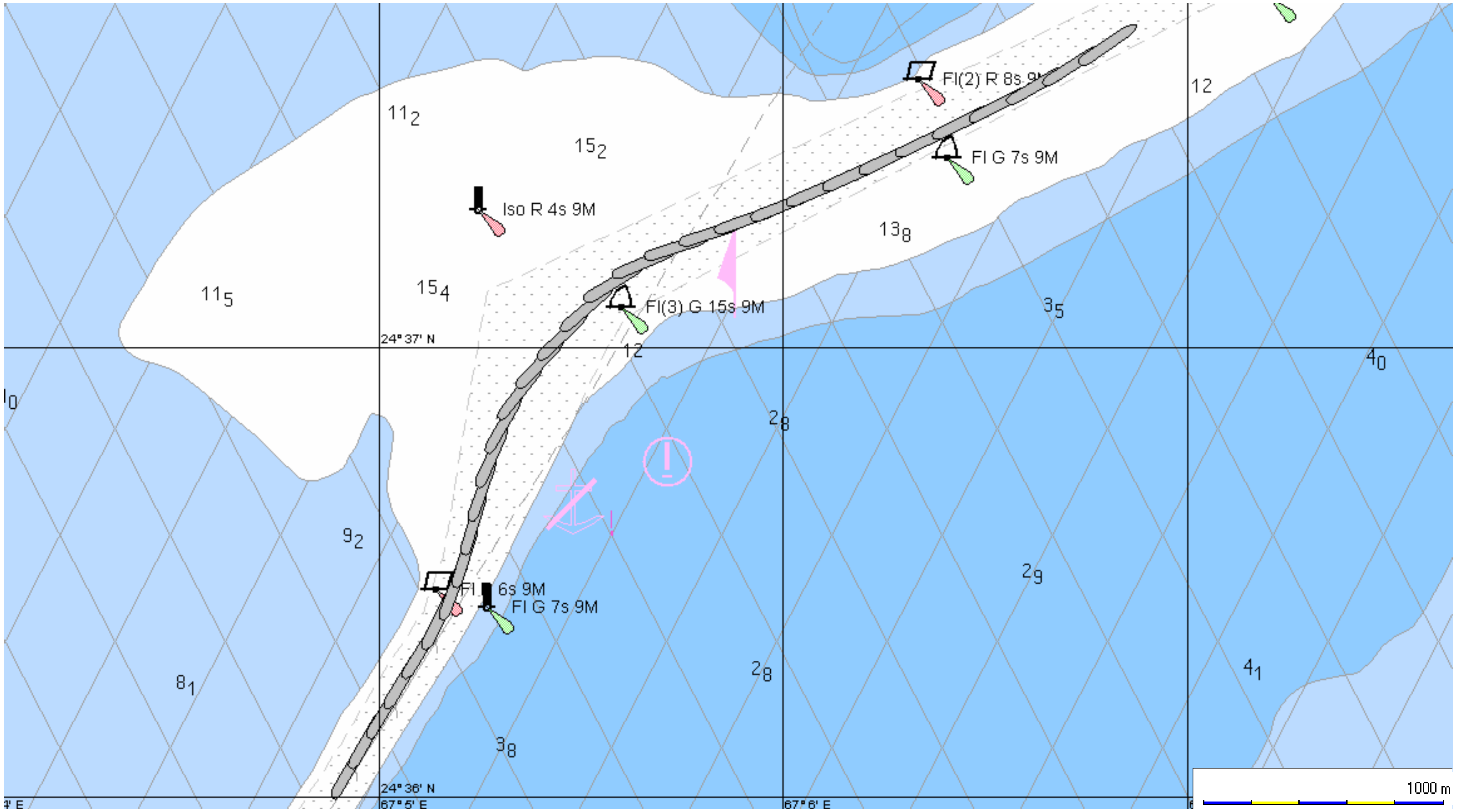
Vessel Track With Tugs



Vessel: LNG Carrier 005 (L) (+Tugs)
Harbour: Qasim
Created: 28/02/2011

Wind: 30.00 kts 225 °
Current: 3 kts Flood
Depth: Variable

Vessel Track With Tugs



Vessel:	LNG Carrier 005 (L) (+Tugs)
Harbour:	Qasim
Created:	28/02/2011

Wind:	30.00 kts 225 °
Current:	3 kts Flood
Depth:	Variable

Project:	Port Qasim LNG Terminal Study		**Job No.:**	L30090		**Captain/Pilot:**	Chris Bordas	
Subject:	PC Rembrandt Simulation Study for Lloyd's Register							
Date:	28/02/2011							
Run No.	**Vessel**		**Access Condition**		**Environmental Conditions**			**Manoeuvre**
	Ship	**Condition**	**Type**	**No of Tugs Used**	**Current**	**Wind Speed (Direction from)**	**Waves (Ht/Period)**	**Thrusters used?**
2B	LNG 005	Loaded (11.5m)	Arrival		3kt Flood	30kts (225)	3.4m	No

Approach to Berth

No difficulty was experienced in approaching the berth.

Ratings	1	2	3	4	5	6	7	8
	Easy	**Straight-forward**	**Comfortable**	**Not demanding**	**Not easy**	**Challenging**	**Difficult**	**Impossible**

(Rating 4 "Not demanding" circled)

Project:	Port Qasim LNG Terminal Study	Job No.:	L30090	Captain/Pilot:	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	28/02/2011				

Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
2C	LNG 005	Loaded (11.5m)	Arrival	3	3kt Flood	30kts (225)	-	Yes

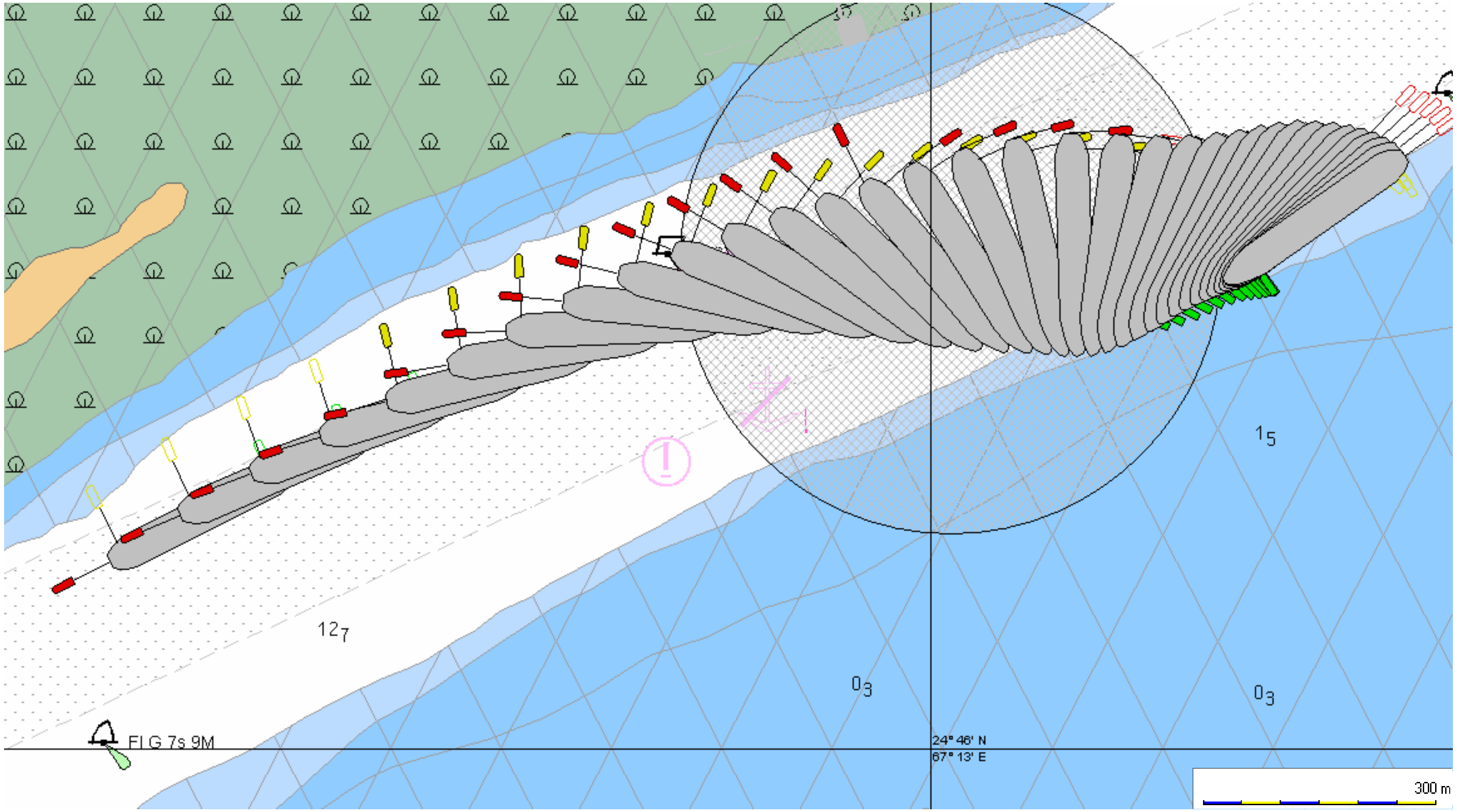
<u>Berthing Swing</u>

Some difficulty was experienced due to the combined effect of tide and wind pushing the vessel further up the channel. The pilot was unable to keep the vessel within the turning circle.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

(Rating 7 "Difficult" is circled.)

Vessel Track With Tugs



Vessel: LNG Carrier 005 (L) (+Tugs)
Harbour: Qasim
Created: 28/02/2011

Wind: 30.00 kts 225 °
Current: 3 kts Flood
Depth: Variable

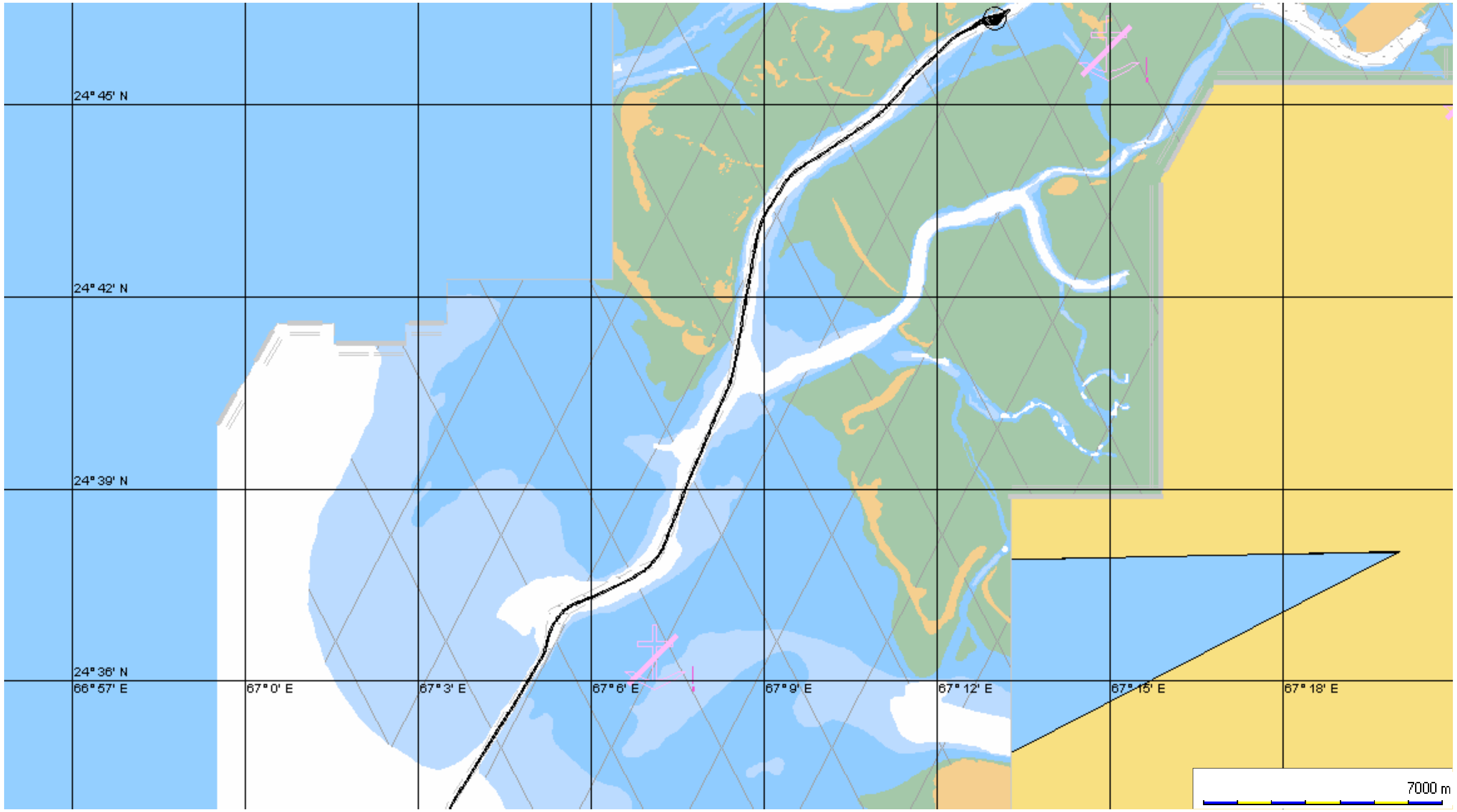
Project:	Port Qasim LNG Terminal Study	Job No.:	L30090	Captain/Pilot:	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	28/02/2011				

Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
3	LNG 005	Loaded (11.5m)	Arrival	3	3kt Flood	20kts (225)	-	Yes

The same as Run 2 except a slightly lower wind was used (20kts) and reduced sea state. The swing was far more comfortable than Run 2 but was still only achieved with some difficulty.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

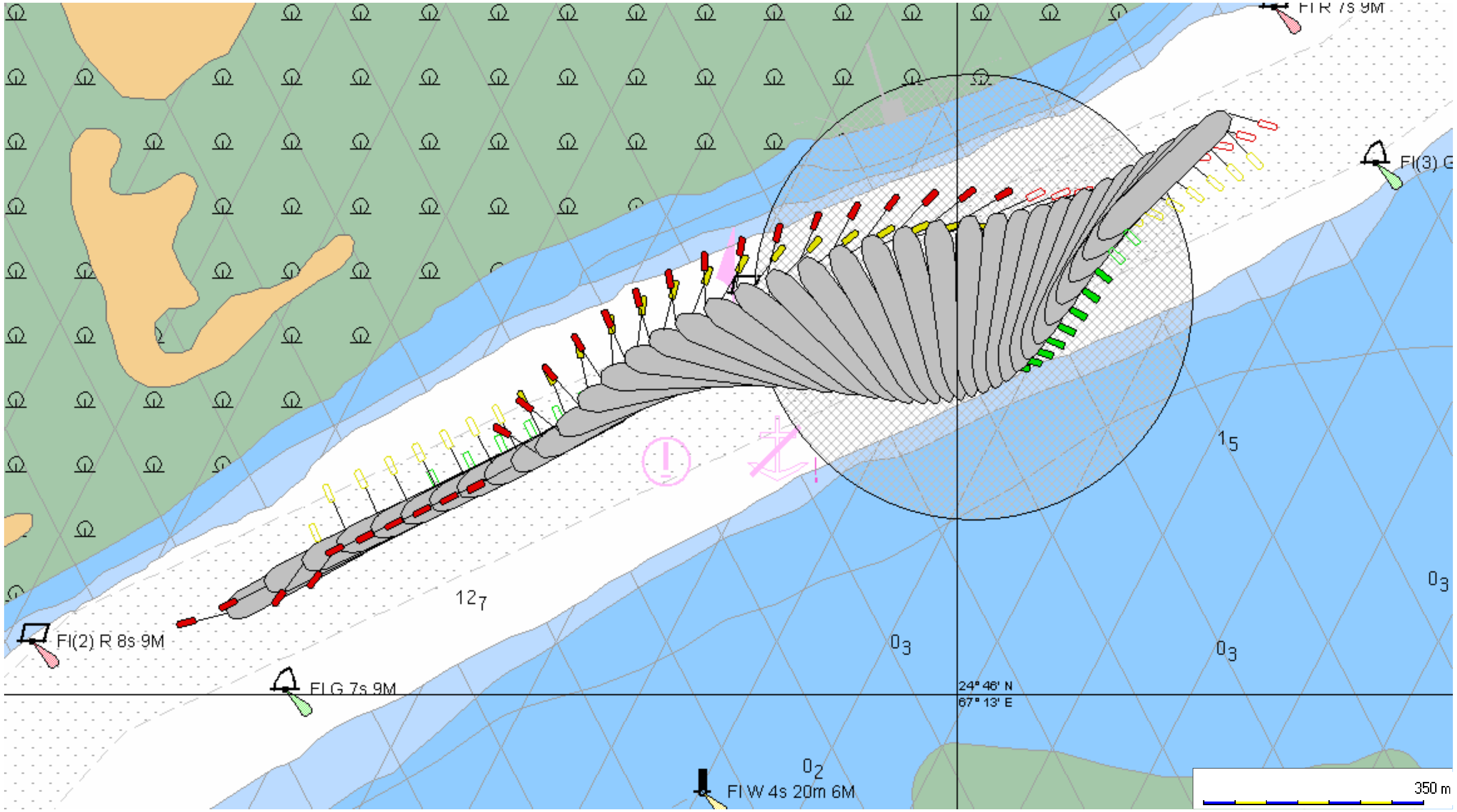
Vessel Track With Tugs



Vessel: LNG Carrier 005 (L) (+Tugs)
Harbour: Qasim
Created: 28/02/2011

Wind: Variable
Current: 3 kts Flood
Depth: Variable

Vessel Track With Tugs



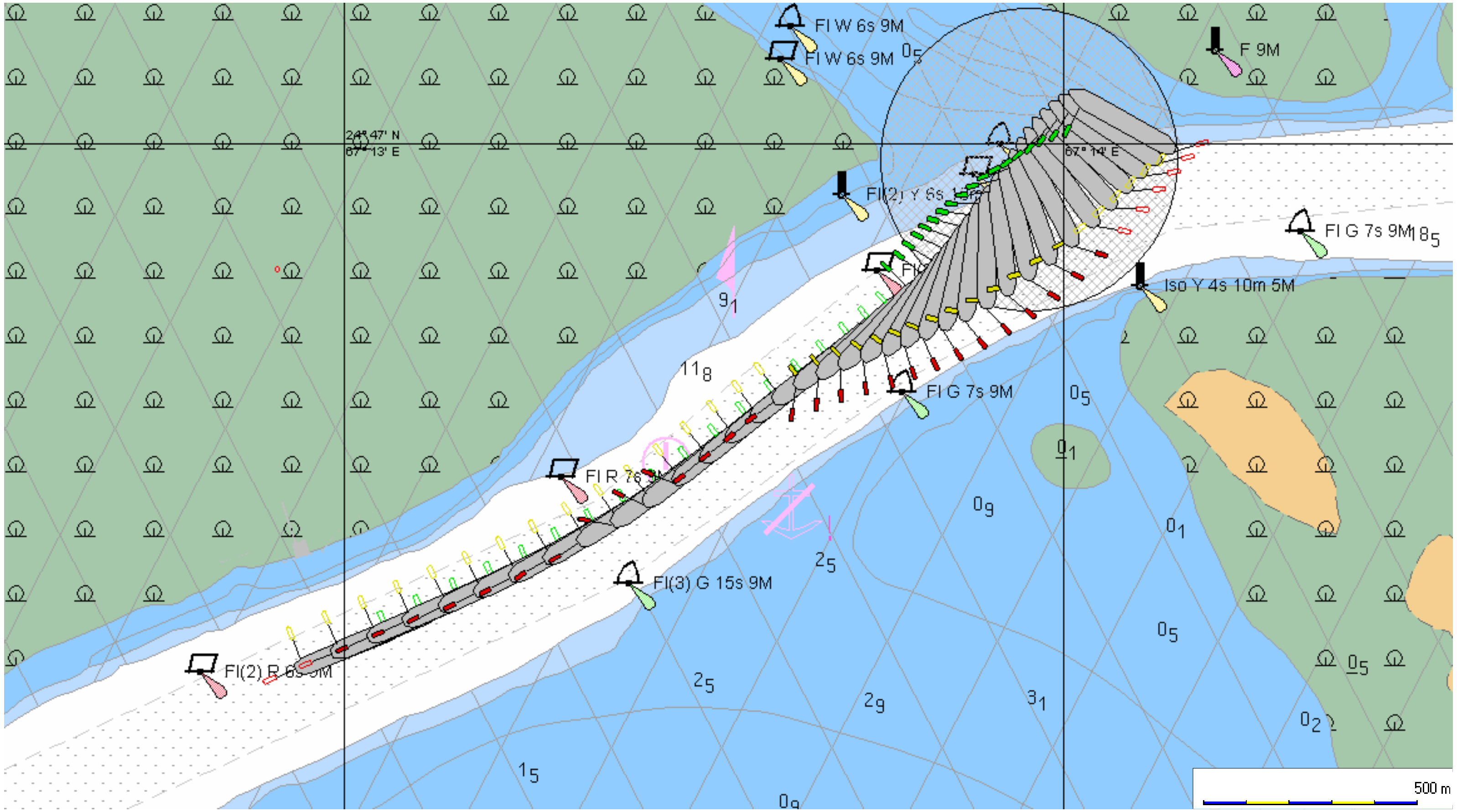
Vessel: LNG Carrier 005 (L) (+Tugs)
Harbour: Qasim
Created: 28/02/2011

Wind: Variable
Current: 3 kts Flood
Depth: Variable

Project:	Port Qasim LNG Terminal Study		Job No.:	L30090		Captain/Pilot:	Chris Bordas	
Subject:	PC Rembrandt Simulation Study for Lloyd's Register							
Date:	28/02/2011							
Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
4	LNG 005	Loaded (11.5m)	Arrival	3	3kt Flood	30kts (225)	-	Yes
	For Run 4 it was decided to attempt to swing the vessel in the mouth of the channel to the north of the proposed Greenfield site. Initially a swing to port was tried but this was unsuccessful due to the action of tide and wind. The vessel was unable to generate steerage power without moving too far north.							

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

Vessel Track With Tugs



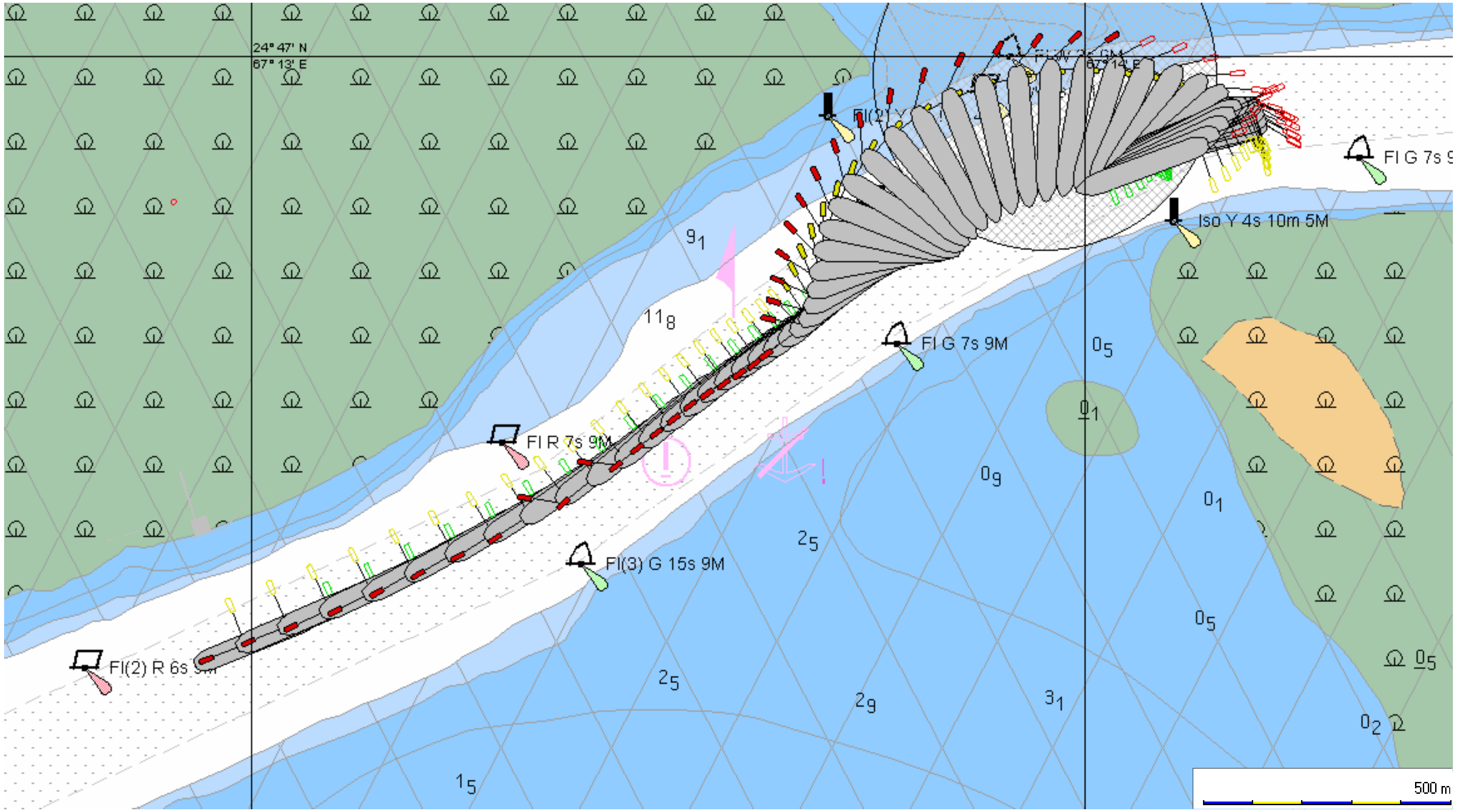
Vessel:	LNG Carrier 005 (L) (+Tugs)
Harbour:	Khiprianwala Island
Created:	28/02/2011

Wind:	30.00 kts 225 °
Current:	3 kts Flood
Depth:	Variable

Project:	Port Qasim LNG Terminal Study		**Job No.:**	L30090		**Captain/Pilot:**	Chris Bordas	
Subject:	PC Rembrandt Simulation Study for Lloyd's Register							
Date:	28/02/2011							
Run No.	**Vessel**		**Access Condition**		**Environmental Conditions**			**Manoeuvre**
	Ship	**Condition**	**Type**	**No of Tugs Used**	**Current**	**Wind Speed (Direction from)**	**Waves (Ht/Period)**	**Thrusters used?**
5	LNG 005	Loaded (11.5m)	Arrival	3	3kt Flood	30kts (225)	-	Yes
	This run was identical to run 4 except the vessel was swung to starboard. This proved far more effective and the vessel was successfully turned, albeit with difficulty.							

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

Vessel Track With Tugs



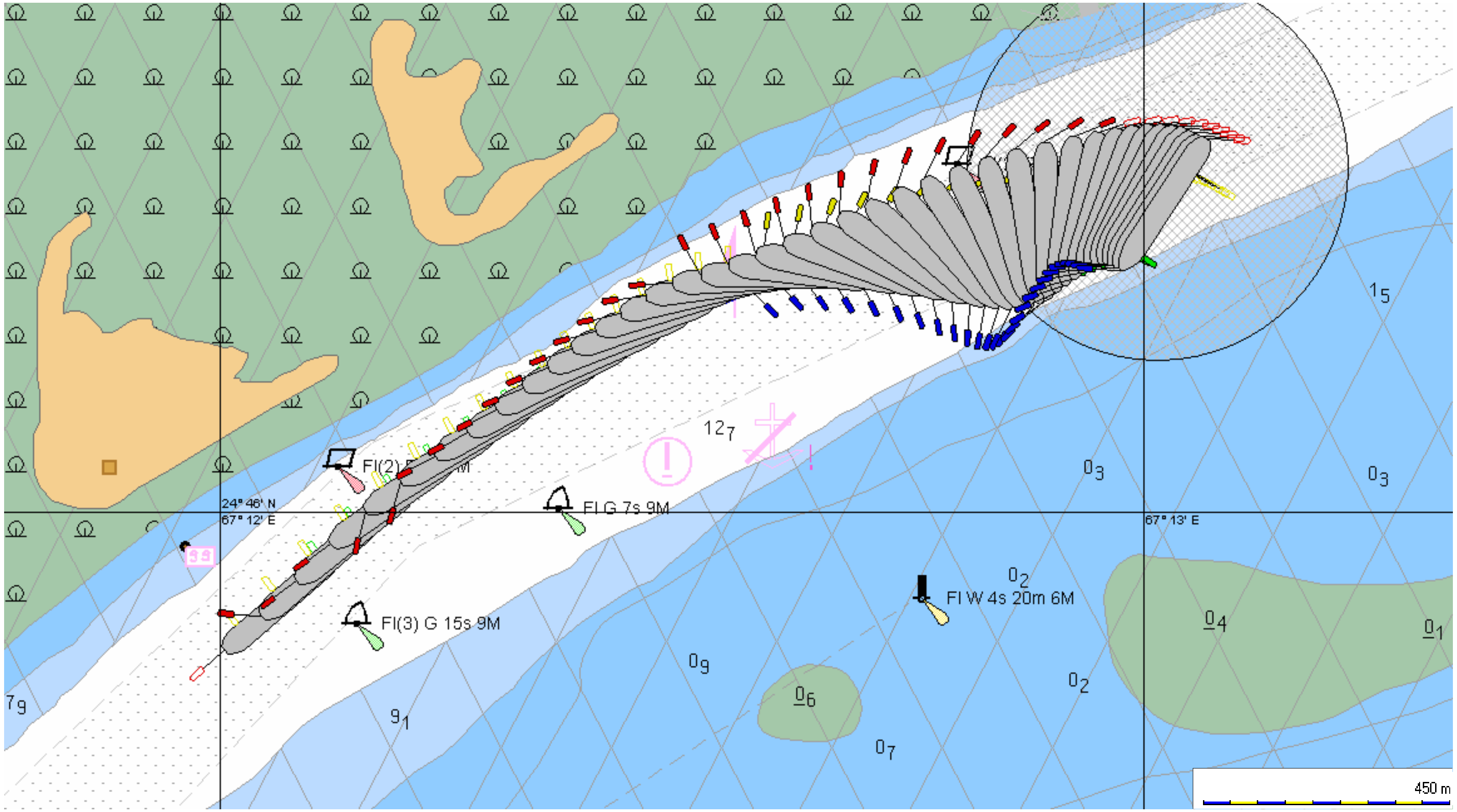
Vessel:	LNG Carrier 005 (L) (+Tugs)
Harbour:	Khiprianwala Island
Created:	28/02/2011

Wind:	30.00 kts 225 °
Current:	3 kts Flood
Depth:	Variable

Project:	Port Qasim LNG Terminal Study		**Job No.:**	L30090		**Captain/Pilot:**	Chris Bordas	
Subject:	PC Rembrandt Simulation Study for Lloyd's Register							
Date:	28/02/2011							
Run No.	**Vessel**		**Access Condition**		**Environmental Conditions**			**Manoeuvre**
	Ship	**Condition**	**Type**	**No of Tugs Used**	**Current**	**Wind Speed (Direction from)**	**Waves (Ht/Period)**	**Thrusters used?**
6	LNG 005	Loaded (11.5m)	Arrival	4	3kt Flood	30kts (225)	-	Yes
	This run was identical to run 3except and additional tug was used in order to see if this made the swing any easier/achievable. This proved to be the case and the vessel was swung within the turning basin and without too much difficulty.							

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

Vessel Track With Tugs



Vessel: LNG Carrier 005 (L) (+Tugs)
Harbour: Khiprianwala Island
Created: 28/02/2011

Wind: 30.00 kts 225 °
Current: 3 kts Flood
Depth: Variable

Project:	Port Qasim LNG Terminal Study	**Job No.:**	L30090	**Captain/Pilot:**	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	28/02/2011				

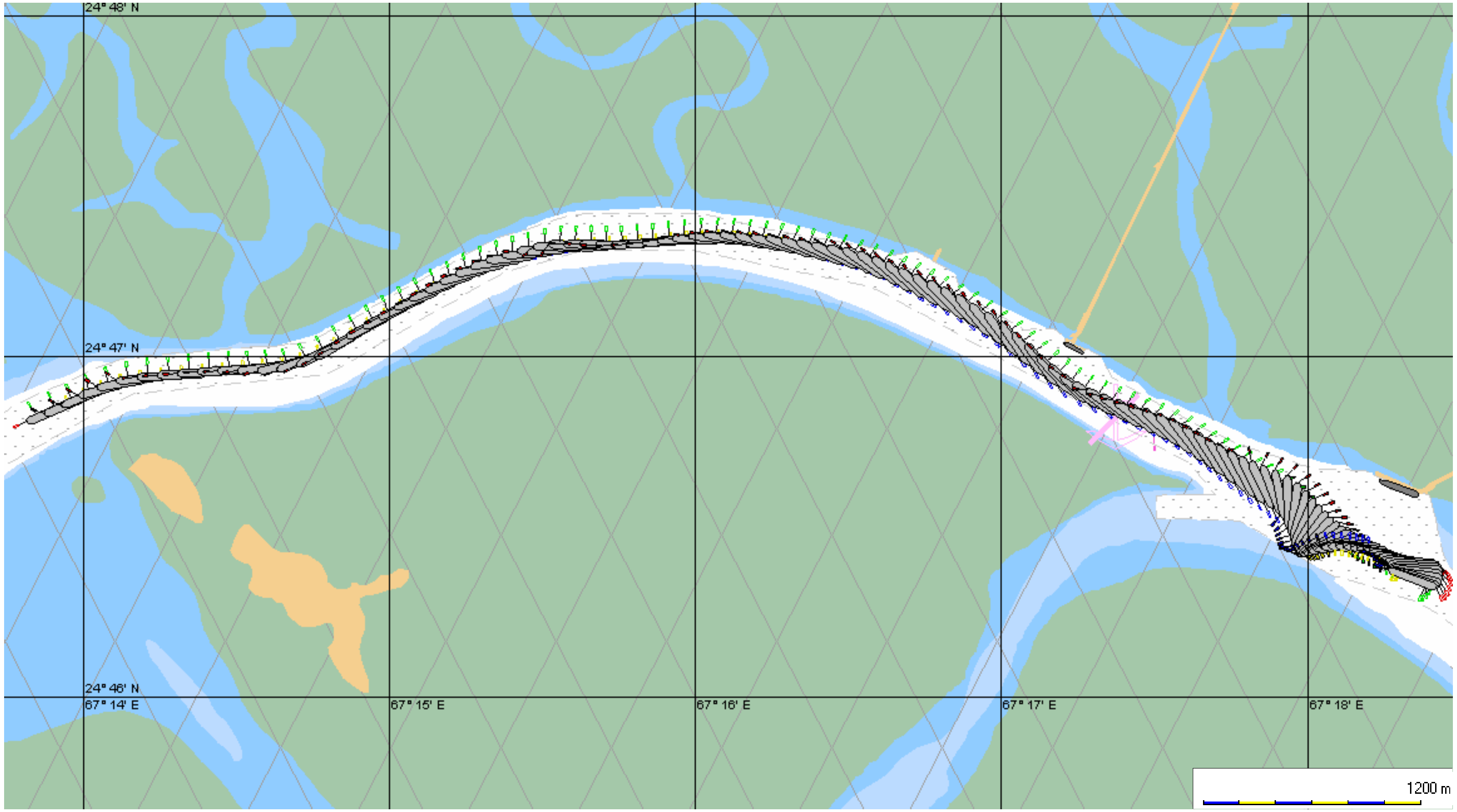
Run No.	**Vessel**		**Access Condition**		**Environmental Conditions**			**Manoeuvre**
	Ship	**Condition**	**Type**	**No of Tugs Used**	**Current**	**Wind Speed (Direction from)**	**Waves (Ht/Period)**	**Thrusters used?**
7	LNG 005	Loaded (11.5m)	Arrival	4	3kt Flood	30kts (225)	-	Yes

Run 7 was used to see how difficult navigation to the propose Brownfield site would be. In order to simulate a worst case scenario a vessel was placed on the LPG berth and the Oil terminal berth. It later transpired that these were incorrectly identified at the time and so later Runs were used to correct this.

4 tugs were used. Some difficulty was experienced both in making the initial turn in the channel and also in swinging the vessel opposite the last berth.

Ratings	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	Easy	**Straight-forward**	**Comfortable**	**Not demanding**	**Not easy**	**Challenging**	**Difficult**	**Impossible**

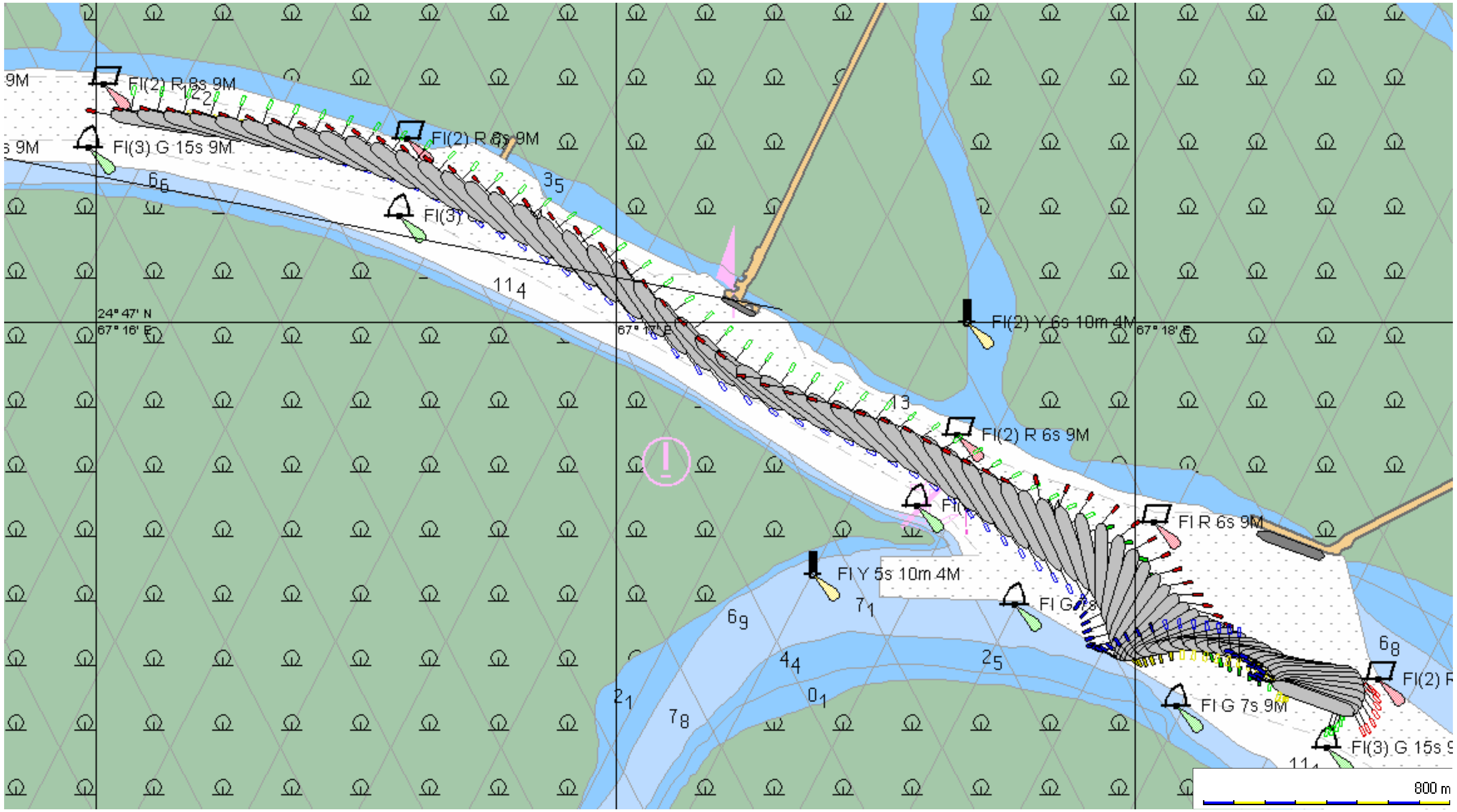
Vessel Track With Tugs



Vessel: LNG Carrier 005 (L) (+Tugs)
Harbour: Port Qasim
Created: 28/02/2011

Wind: 30.00 kts 225 °
Current: 3 kts Flood
Depth: Variable

Vessel Track With Tugs



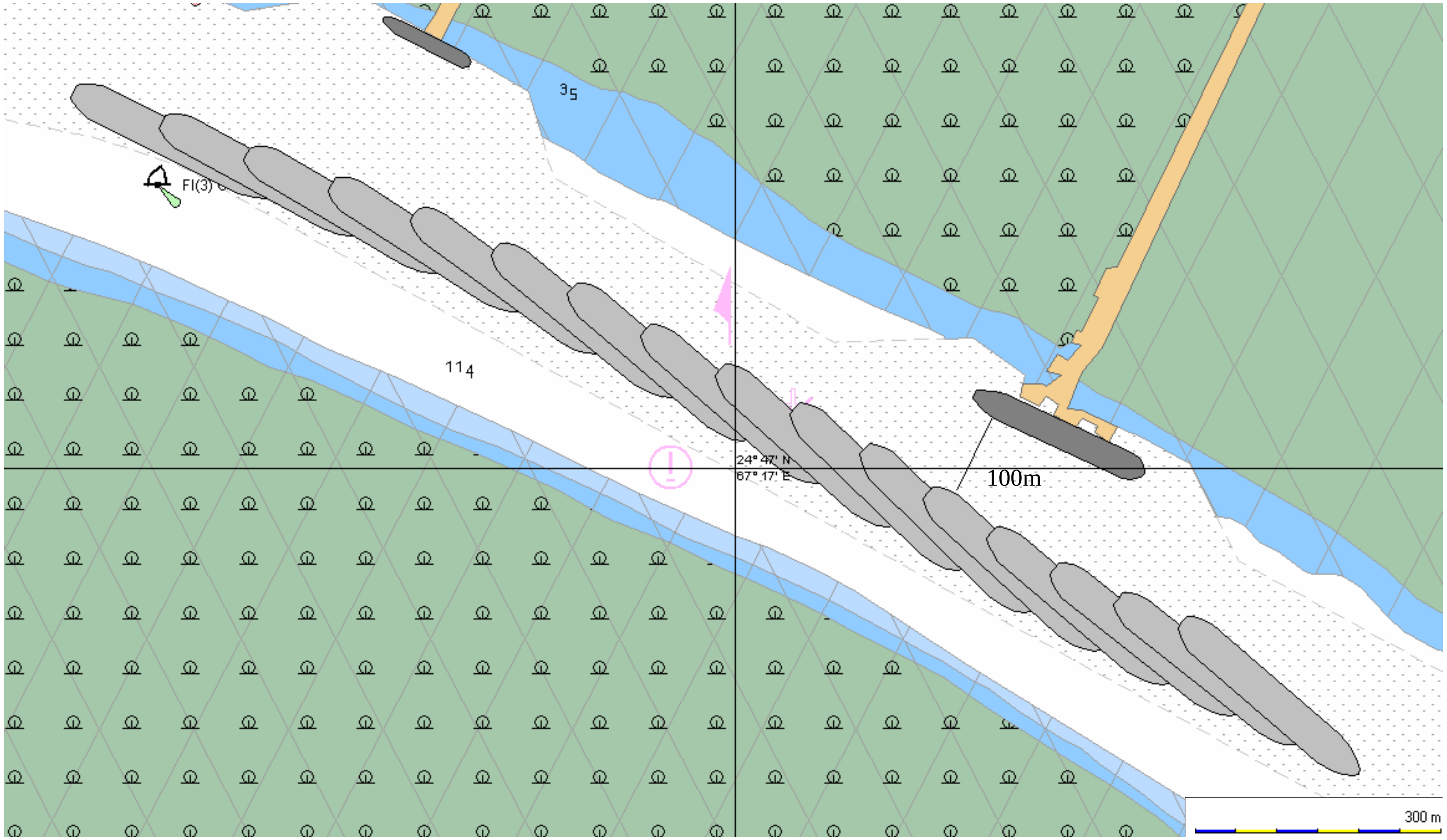
Vessel: LNG Carrier 005 (L) (+Tugs)
Harbour: Port Qasim
Created: 28/02/2011

Wind: 30.00 kts 225 °
Current: 3 kts Flood
Depth: Variable

Project:	Port Qasim LNG Terminal Study		**Job No.:**	L30090		**Captain/Pilot:**	Chris Bordas		
Subject:	PC Rembrandt Simulation Study for Lloyd's Register								
Date:	28/02/2011								
Run No.	**Vessel**		**Access Condition**		**Environmental Conditions**			**Manoeuvre**	
	Ship	**Condition**	**Type**	**No of Tugs Used**	**Current**	**Wind Speed (Direction from)**	**Waves (Ht/Period)**	**Thrusters used?**	
8	LNG 005	Loaded (11.5m)	Arrival	4	3kt Flood	30kts (225)	-	Yes	
	Run 8 was identical to Run 7 except the stationary vessels were placed on their correct berths. Some difficulty was experienced in staying to the south of the channel and a minimum clearance of 100m from the stationary Suezmax was seen.								
Ratings	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	Easy	**Straight-forward**	**Comfortable**	**Not demanding**	**Not easy**	**Challenging**	**Difficult**	**Impossible**	

(Rating 5 "Not easy" is circled.)

Vessel Track



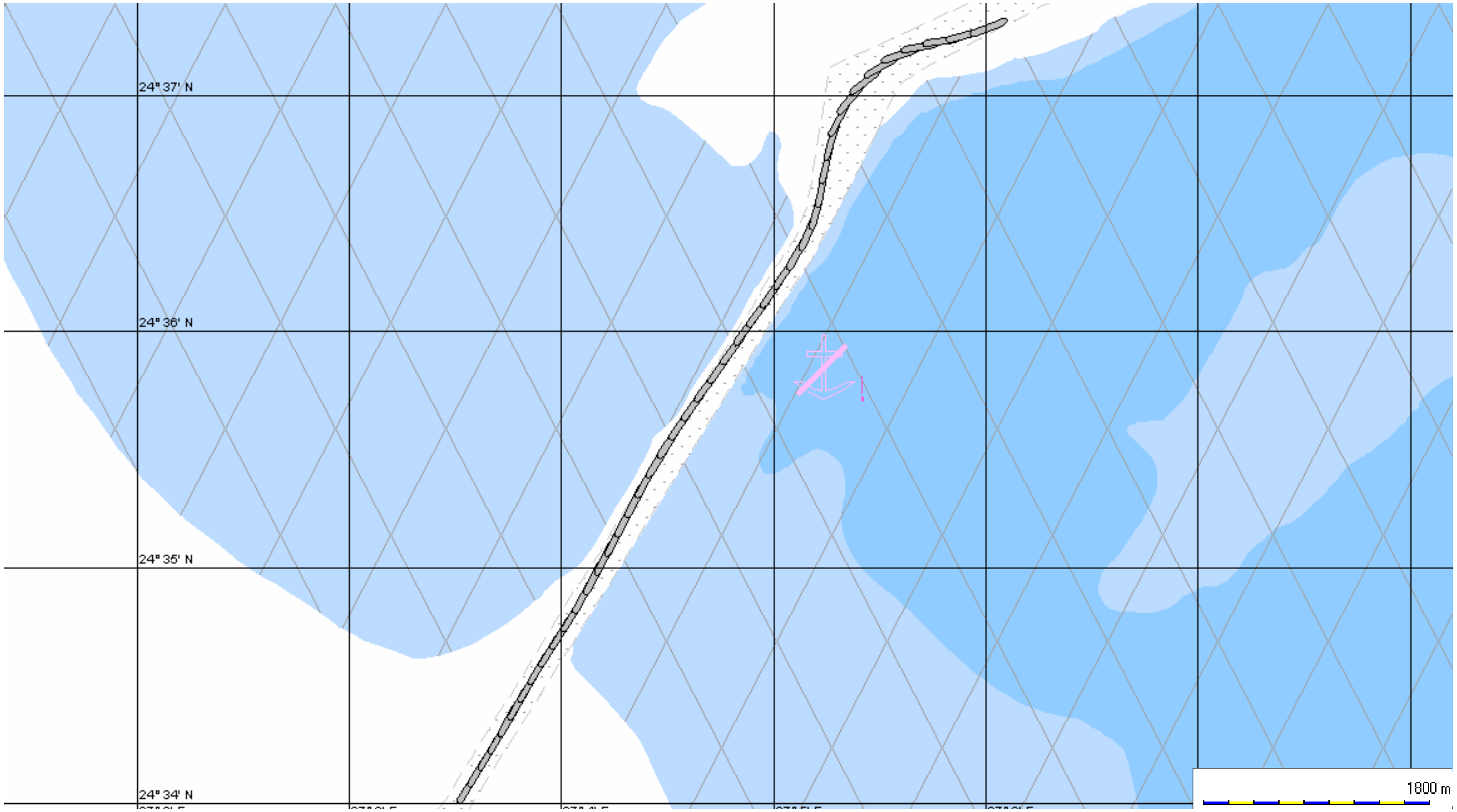
Vessel: LNG Carrier 005 (L) (+Tugs)
Harbour: Port Qasim
Created: 2/28/2011

Wind: 30.00 kts 225 °
Current: 3 kts Flood
Depth: Variable

Project:	Port Qasim LNG Terminal Study		**Job No.:**	L30090		**Captain/Pilot:**	Chris Bordas	
Subject:	PC Rembrandt Simulation Study for Lloyd's Register							
Date:	28/02/2011							
Run No.	**Vessel**		**Access Condition**		**Environmental Conditions**			**Manoeuvre**
	Ship	**Condition**	**Type**	**No of Tugs Used**	**Current**	**Wind Speed (Direction from)**	**Waves (Ht/Period)**	**Thrusters used?**
9	LNG 004	Loaded (12.2m)	Arrival	-	3kt Flood	30kts (225)	-	-
	Run 9 was used to see if a Q-Flex LNGC could successfully navigate the entrance channel. An extra 1m of tide was input in order to simulate planned dredging. Sufficient under keel clearance (UKC) was available for the whole channel but some difficulty was experienced in making the dogleg turn at the start of the channel.							

Ratings	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	Easy	**Straight-forward**	**Comfortable**	**Not demanding**	**Not easy**	**Challenging**	**Difficult**	**Impossible**

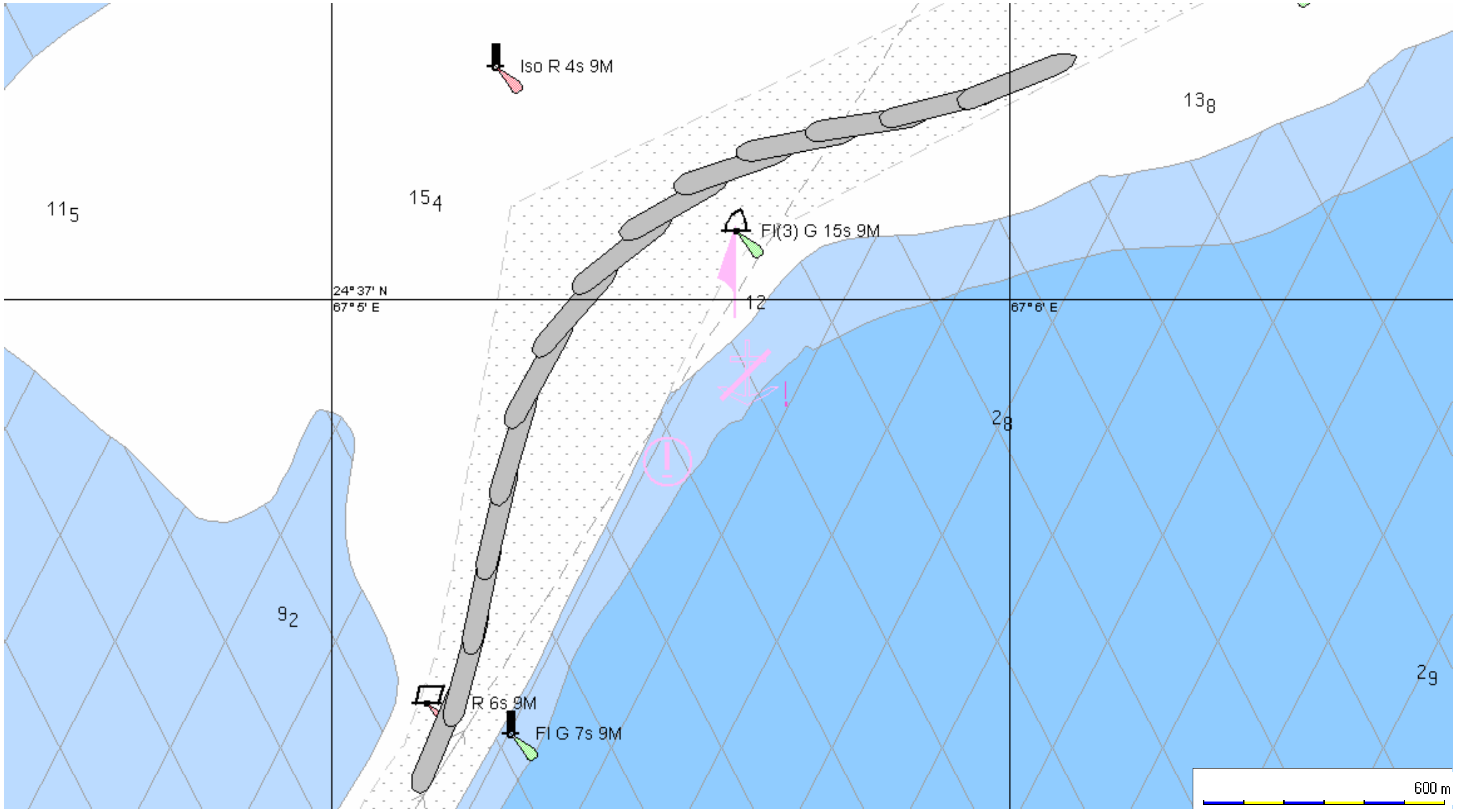
Vessel Track With Tugs



Vessel: LNG Carrier 004 (L)
Harbour: Qasim
Created: 28/02/2011

Wind: 30.00 kts 225 °
Current: 3 kts Flood
Depth: 2.5 m above Chart Datum

Vessel Track With Tugs



Vessel: LNG Carrier 004 (L)
Harbour: Qasim
Created: 28/02/2011

Wind: 30.00 kts 225 °
Current: 3 kts Flood
Depth: 2.5 m above Chart Datum

Project:	Port Qasim LNG Terminal Study	Job No.:	L30090	Captain/Pilot:	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	28/02/2011				

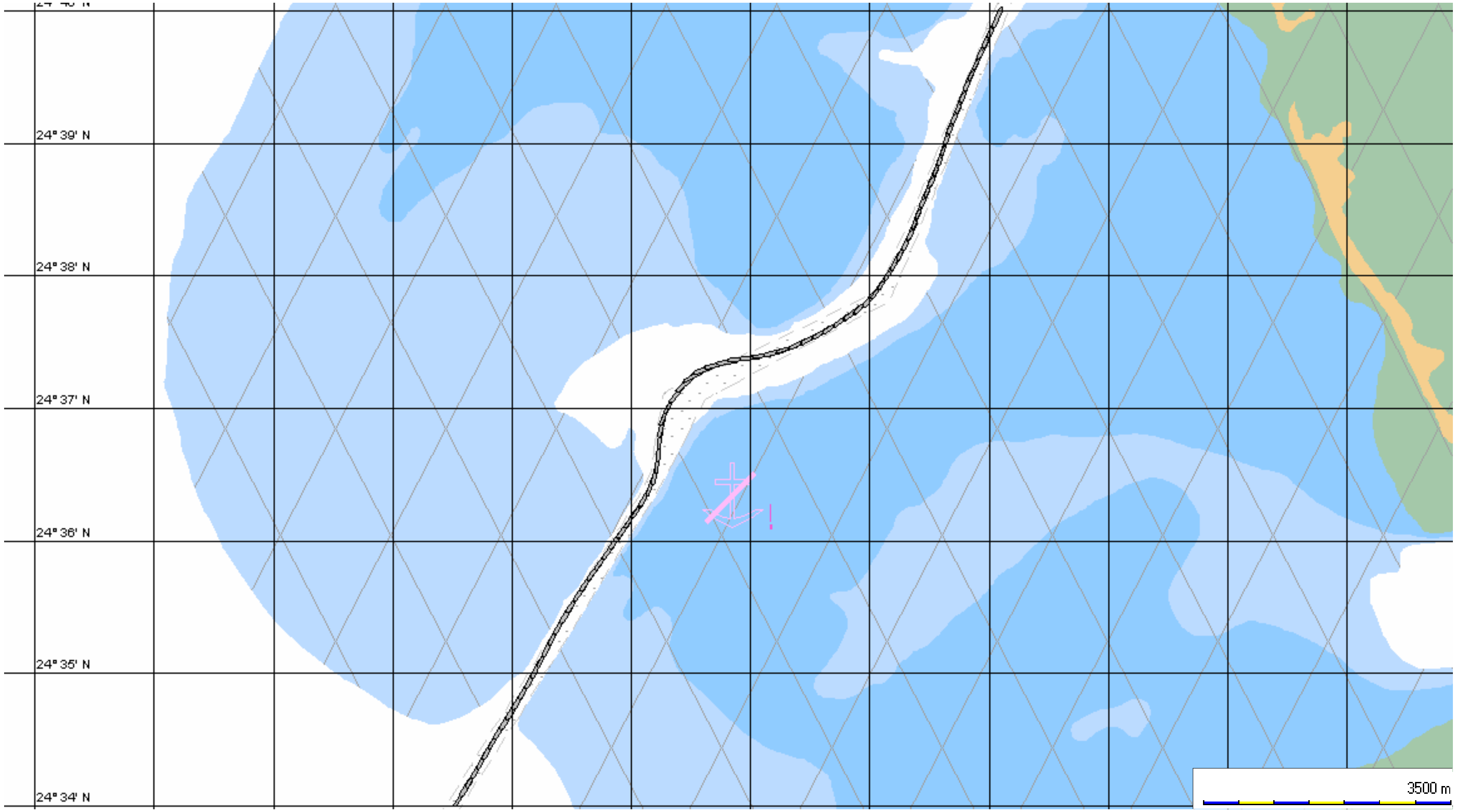
Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
10	LNG 004	Loaded (12.2m)	Arrival	1	3kt Flood	30kts (225)	-	-

Run 10 was repeat of Run 9 with an escort tug attached to the centre lead aft. This helps the vessel stay within the channel although the dogleg section still proved a challenge.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

(Rating 5 "Not easy" circled.)

Vessel Track With Tugs



Vessel: LNG Carrier 004 (L) (+Tugs)
Harbour: Qasim
Created: 28/02/2011

Wind: 30.00 kts 225 °
Current: 3 kts Flood
Depth: 2.5 m above Chart Datum

Vessel Track With Tugs

Vessel: LNG Carrier 004 (L) (+Tugs)
Harbour: Qasim
Created: 28/02/2011

Wind: 30.00 kts 225 °
Current: 3 kts Flood
Depth: 2.5 m above Chart Datum

Project:	Port Qasim LNG Terminal Study	Job No.:	L30090	Captain/Pilot:	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	28/02/2011				

Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
11	LNG 004	Loaded (12.2m)	Arrival	4	3kt Flood	30kts (225)	-	-

In Run 11 the Q-Flex was taken all the way to the Greenfield site and swung to starboard. And escort tug was used during the navigation section and 4 tugs were used to swing the vessel.
The swing to starboard could not be completed successfully.

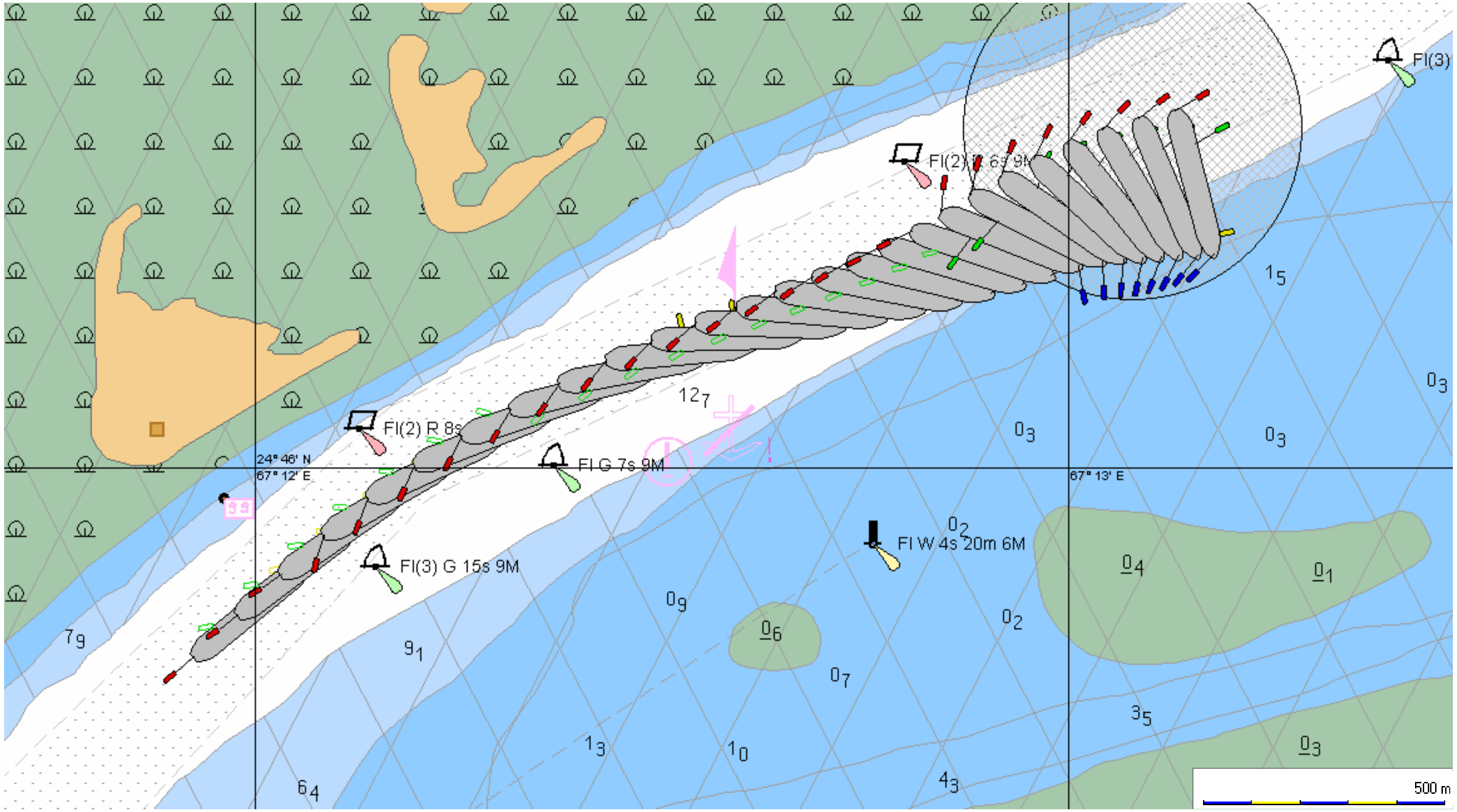
Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

Vessel Track With Tugs

Vessel:	LNG Carrier 004 (L) (+Tugs)
Harbour:	Qasim
Created:	01/03/2011

Wind:	30.00 kts 225 °
Current:	3 kts Flood
Depth:	Variable

Vessel Track With Tugs



Vessel: LNG Carrier 004 (L) (+Tugs)
Harbour: Qasim
Created: 01/03/2011

Wind: 30.00 kts 225 °
Current: 3 kts Flood
Depth: Variable

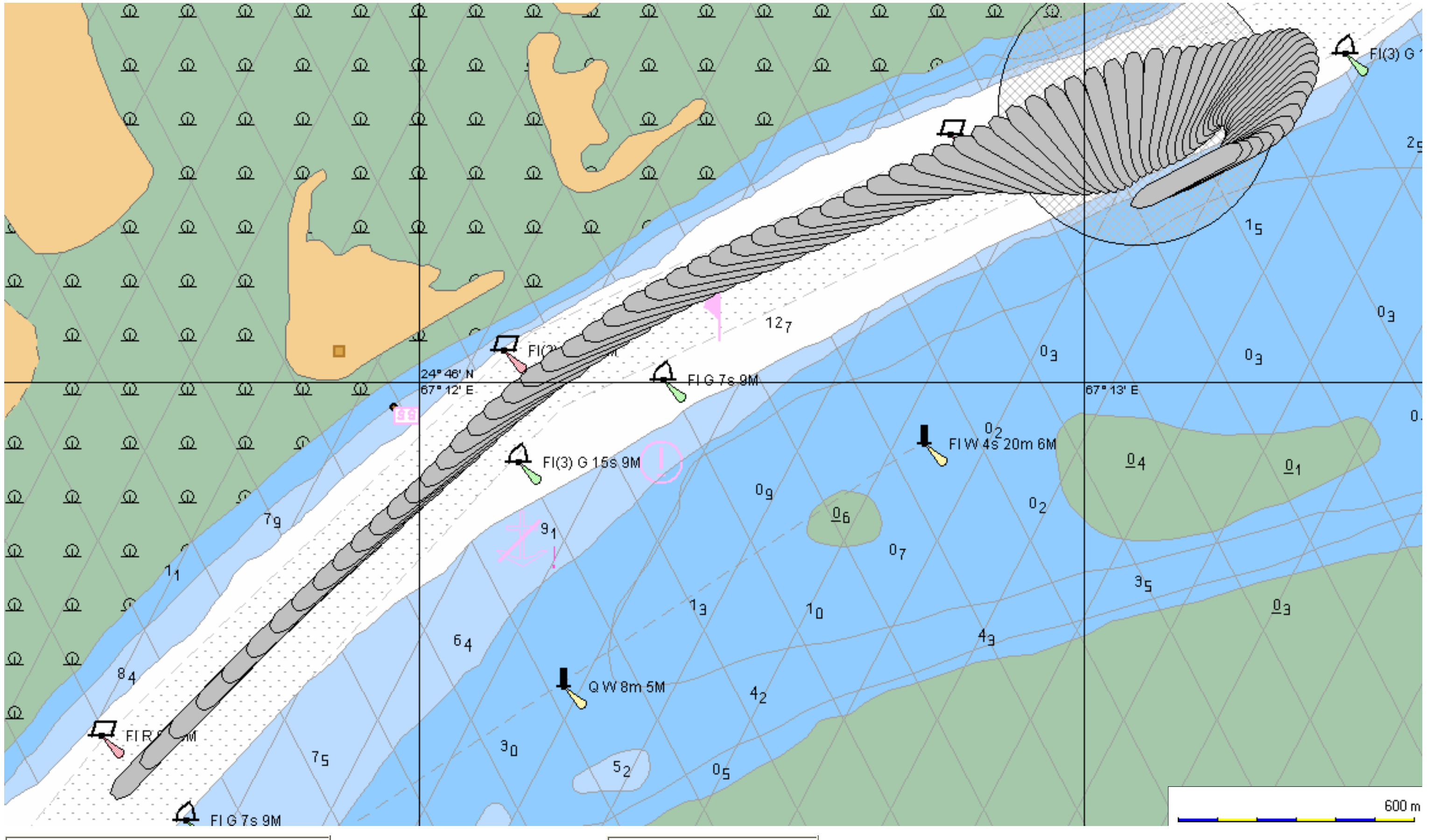
Project:	Port Qasim LNG Terminal Study	Job No.:	L30090	Captain/Pilot:	Chris Bordas			
Subject:	PC Rembrandt Simulation Study for Lloyd's Register							
Date:	28/02/2011							
Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
12	LNG 004	Loaded (12.2m)	Arrival	4	3kt Flood	20kts (225)	-	-

Run 12 was identical to run 11 except a slower wind speed (20kts) was used.
This allowed the swing to starboard to be successfully completed.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

(Rating 5 "Not easy" circled)

Vessel Track



Vessel: LNG Carrier 004 (L) (+Tugs)
Harbour: New Region
Created: 3/1/2011

Wind: 20.00 kts 225 °
Current: 3 kts Flood
Depth: Variable

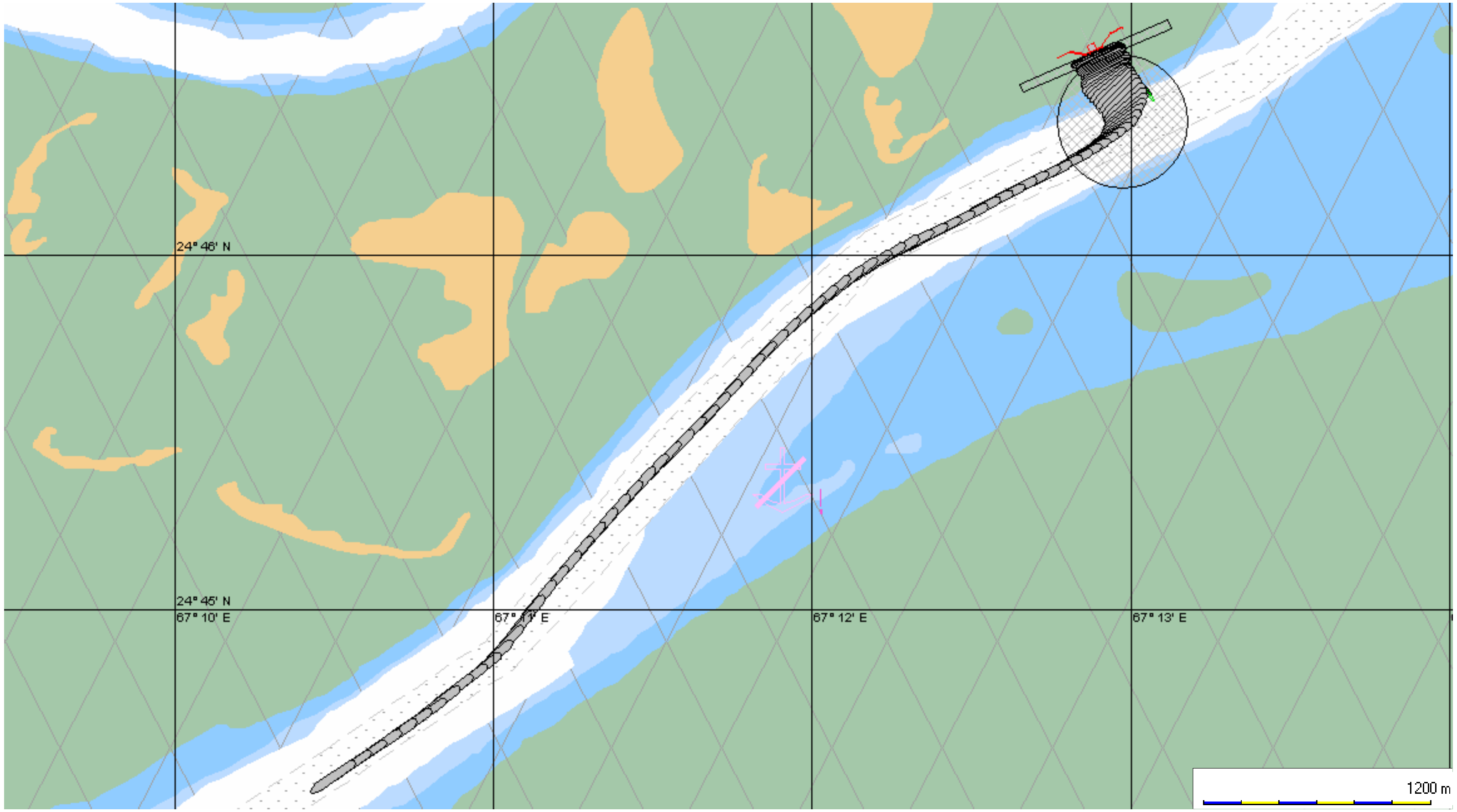
Project:	Port Qasim LNG Terminal Study	Job No.:	L30090	Captain/Pilot:	Chris Bordas			
Subject:	PC Rembrandt Simulation Study for Lloyd's Register							
Date:	28/02/2011							
Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
13	LNG 005	Ballast (9.5m)	Emergency Departure	2	3kt Flood	30kts (225)	-	Yes

Run 13 was used to simulate an emergency departure from the Greenfield site using the Moss Ship LNG 005 in a ballast condition. The vessel was assumed to be berthed starboard side to so no swing was required. 2 tugs were used to aid the ship getting off the berth.

No problems were experienced.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

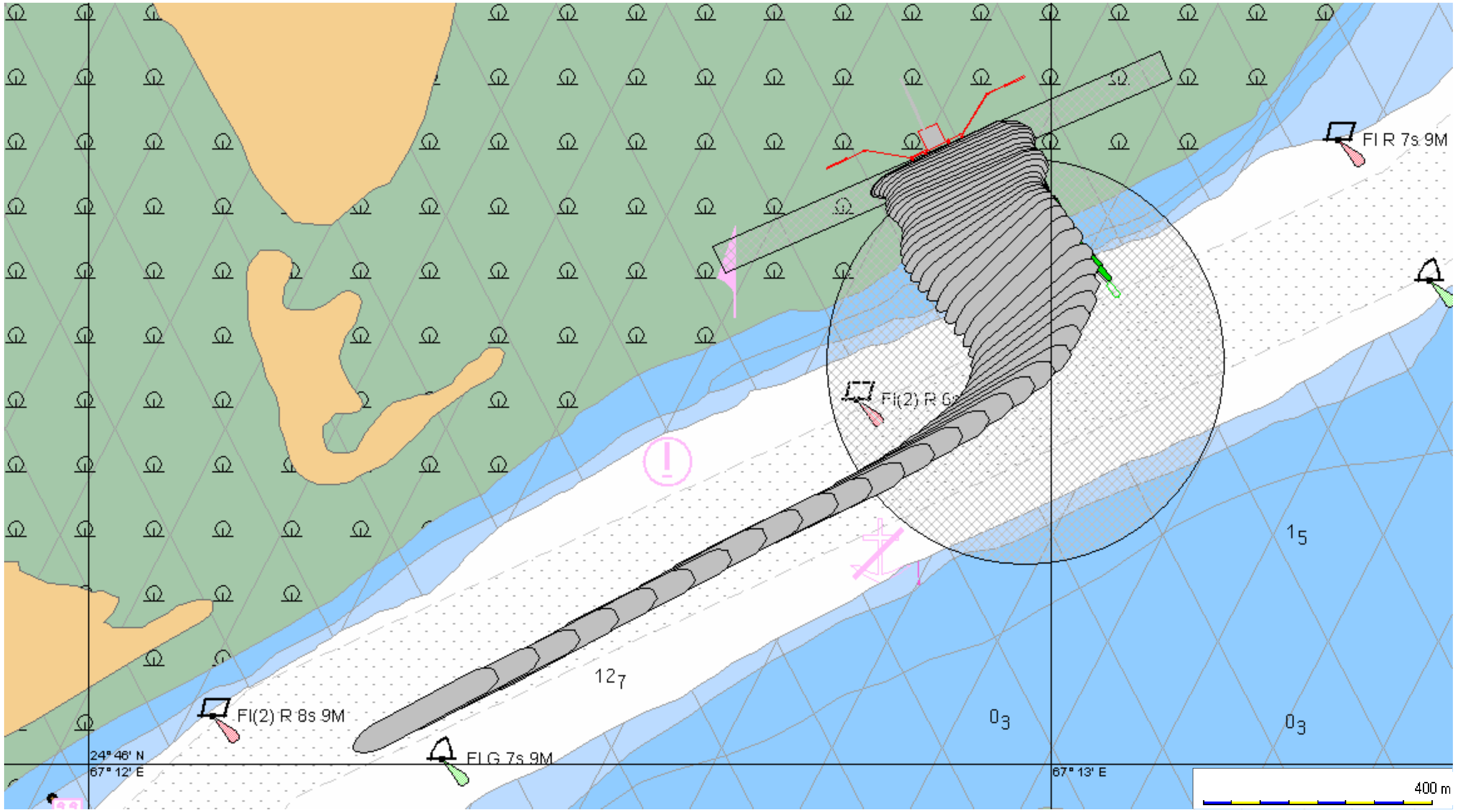
Vessel Track With Tugs



Vessel: LNG Carrier 005 (B) (+Tugs)
Harbour: Khiprianwala Island
Created: 01/03/2011

Wind: 30.00 kts 225 °
Current: 3 kts Flood
Depth: 1.0 m above 12.5 m

Vessel Track With Tugs



Vessel: LNG Carrier 005 (B) (+Tugs)
Harbour: Khiprianwala Island
Created: 01/03/2011

Wind: 30.00 kts 225 °
Current: 3 kts Flood
Depth: 1.0 m above 12.5 m

<table>
<tr><td>Project:</td><td>Port Qasim LNG Terminal Study</td><td>Job No.:</td><td>L30090</td><td>Captain/Pilot:</td><td colspan="4">Chris Bordas</td></tr>
<tr><td>Subject:</td><td colspan="8">PC Rembrandt Simulation Study for Lloyd's Register</td></tr>
<tr><td>Date:</td><td colspan="2">28/02/2011</td><td colspan="6"></td></tr>
<tr><td rowspan="2">Run No.</td><td colspan="2">Vessel</td><td colspan="2">Access Condition</td><td colspan="3">Environmental Conditions</td><td>Manoeuvre</td></tr>
<tr><td>Ship</td><td>Condition</td><td>Type</td><td>No of Tugs Used</td><td>Current</td><td>Wind Speed (Direction from)</td><td>Waves (Ht/Period)</td><td>Thrusters used?</td></tr>
<tr><td>14</td><td>LNG 005</td><td>Ballast (9.5m)</td><td>Departure</td><td>2</td><td>3kt Flood</td><td>30kts (225)</td><td>-</td><td>Yes</td></tr>
<tr><td></td><td colspan="8">Run 14was similar to run 13 except a 3kt ebb current was used. Additionally the vessel was navigated all the way to the mouth of the channel.

No difficulties were experienced.</td></tr>
</table>

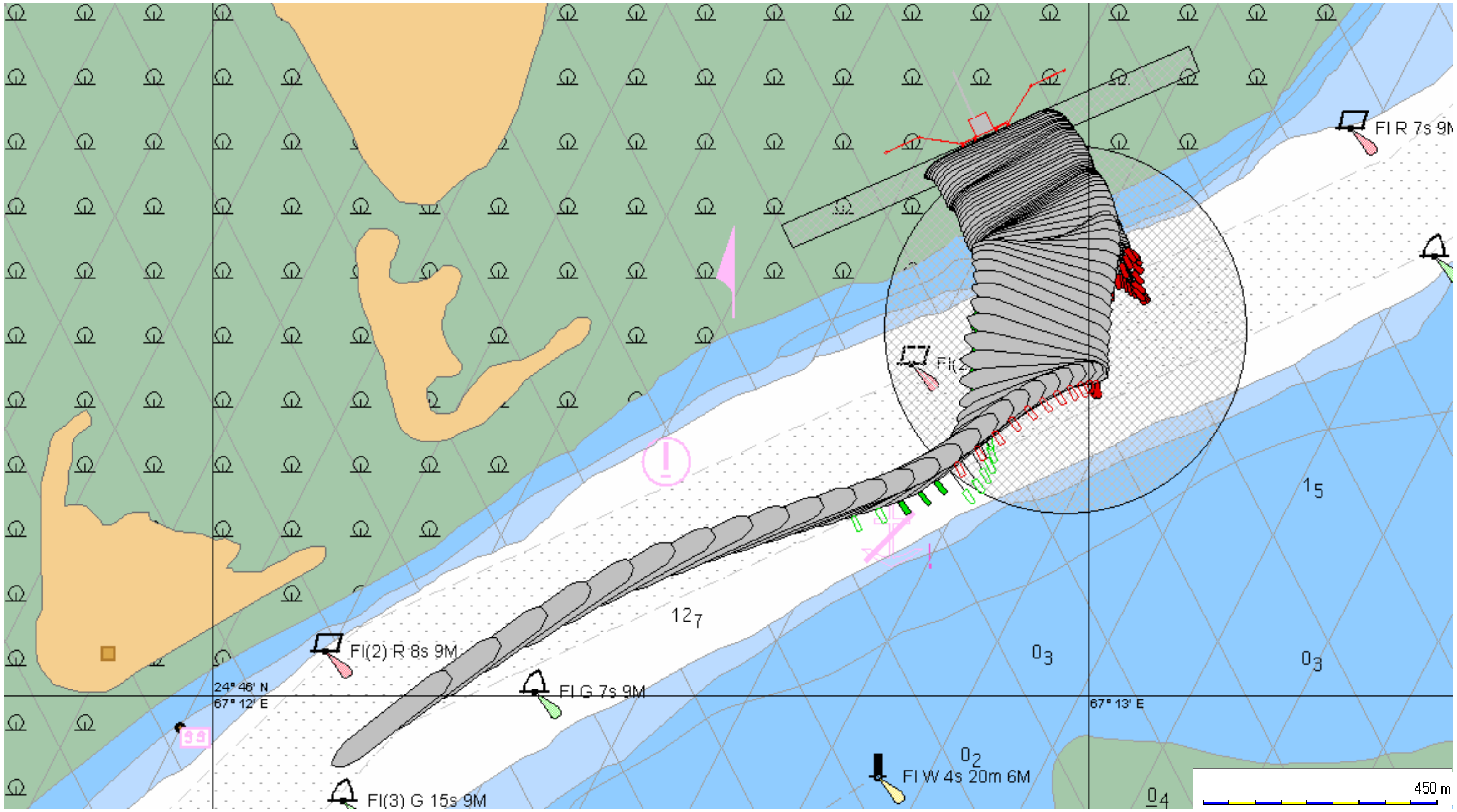
Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

Vessel Track With Tugs

Vessel: LNG Carrier 005 (B) (+Tugs)
Harbour: Khiprianwala Island
Created: 01/03/2011

Wind: 30.00 kts 225 °
Current: 3.5 kts Ebb
Depth: Variable

Vessel Track With Tugs



Vessel: LNG Carrier 005 (B) (+Tugs)
Harbour: Khiprianwala Island
Created: 01/03/2011

Wind: 30.00 kts 225 °
Current: 3.5 kts Ebb
Depth: Variable

Project:	Port Qasim LNG Terminal Study	Job No.:	L30090	Captain/Pilot:	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	28/02/2011				

Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
15	LNG 004	Loaded (12.2m)	Arrival	-	3kt Flood	20kts (225)	-	-
	A number of chart and current anomalies were experience during Run 15. For this reason the run was abandoned.							

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

Project:	Port Qasim LNG Terminal Study	Job No.:	L30090	Captain/Pilot:	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	28/02/2011				

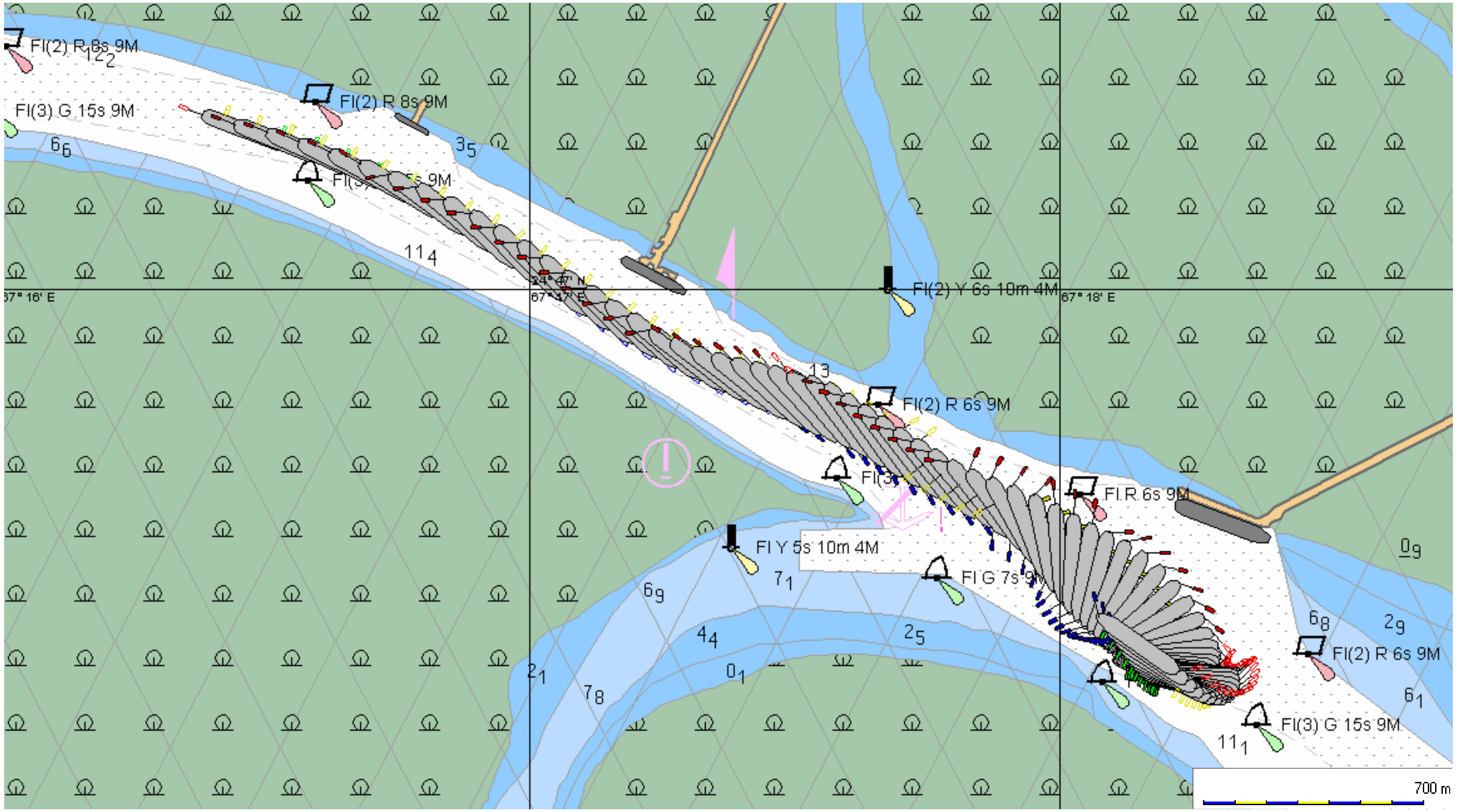
Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
16	LNG 004	Loaded (12.2m)	Arrival	4	3kt Flood	20kts (225)	-	-

For Run 16 the Q-Flex was taken from the Greenfield site to the Brownfield site. No problems were experienced either in navigating the channel or swinging the vessel.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

(Rating 4 "Not demanding" circled.)

Vessel Track With Tugs



Vessel:	LNG Carrier 004 (L) (+Tugs)
Harbour:	Port Qasim
Created:	01/03/2011

Wind:	20.00 kts 225 °
Current:	3 kts Flood
Depth:	1.0 m above Chart Datum

Project:	Port Qasim LNG Terminal Study	Job No.:	L30090	Captain/Pilot:	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	28/02/2011				

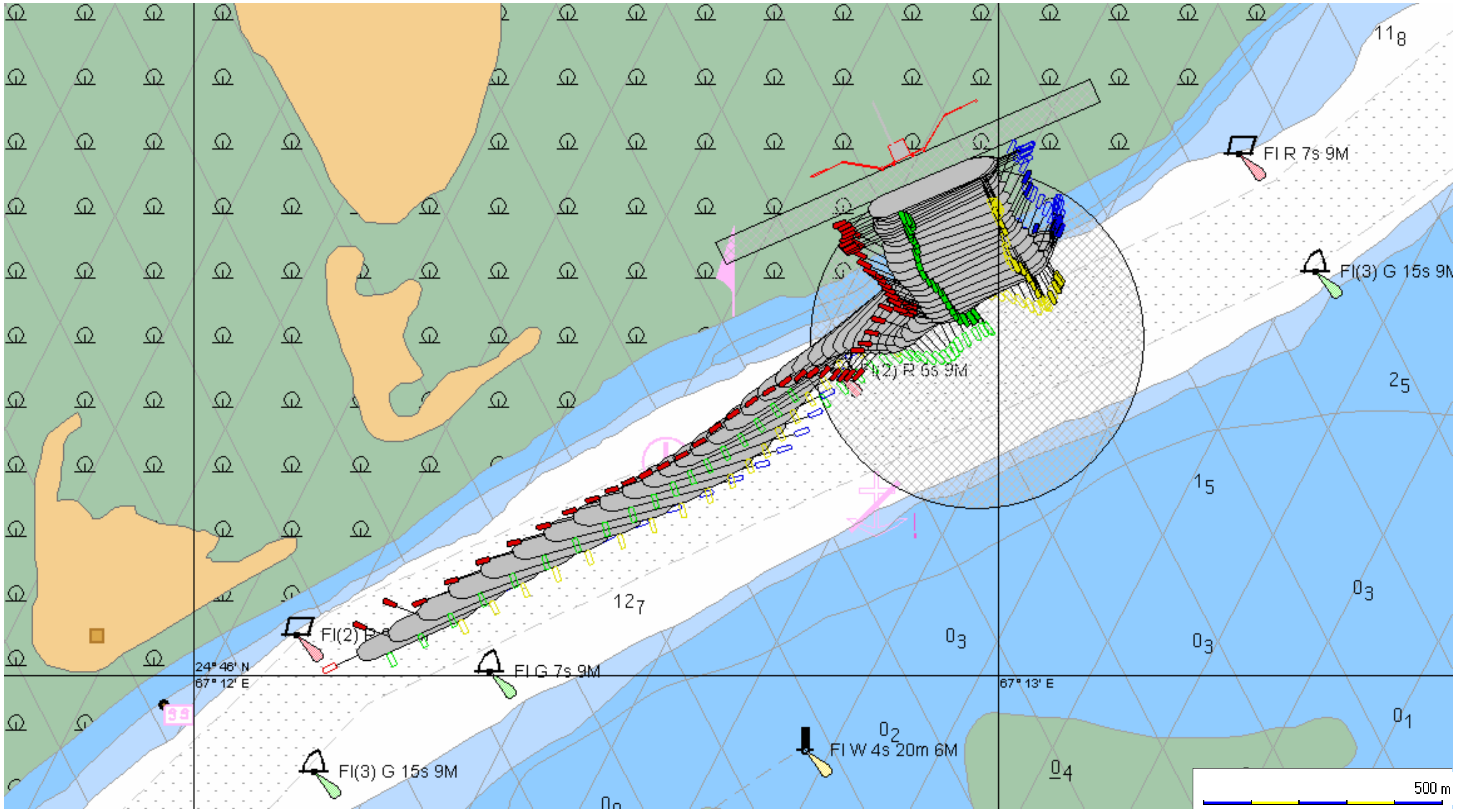
Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
17	LNG 005	Loaded (11.5m)	Arrival	4	3kt Flood	30kts (225)	-	Yes

Run 17 was used to investigate the ease with which a standard LNGC could be berthed port-side to in adverse weather conditions. 4 tugs were available for the manoeuvre.

This proved to be a very simple manoeuvre. For this it was decided that Run 18 would investigate the ease of departing by swinging off the berth in the same conditions.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

Vessel Track With Tugs



Vessel:	LNG Carrier 005 (B) (+Tugs)
Harbour:	Khiprianwala Island
Created:	01/03/2011

Wind:	30.00 kts 225 °
Current:	3 kts Flood
Depth:	1.0 m above 12.5 m

Project:	Port Qasim LNG Terminal Study	Job No.:	L30090	Captain/Pilot:	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	28/02/2011				

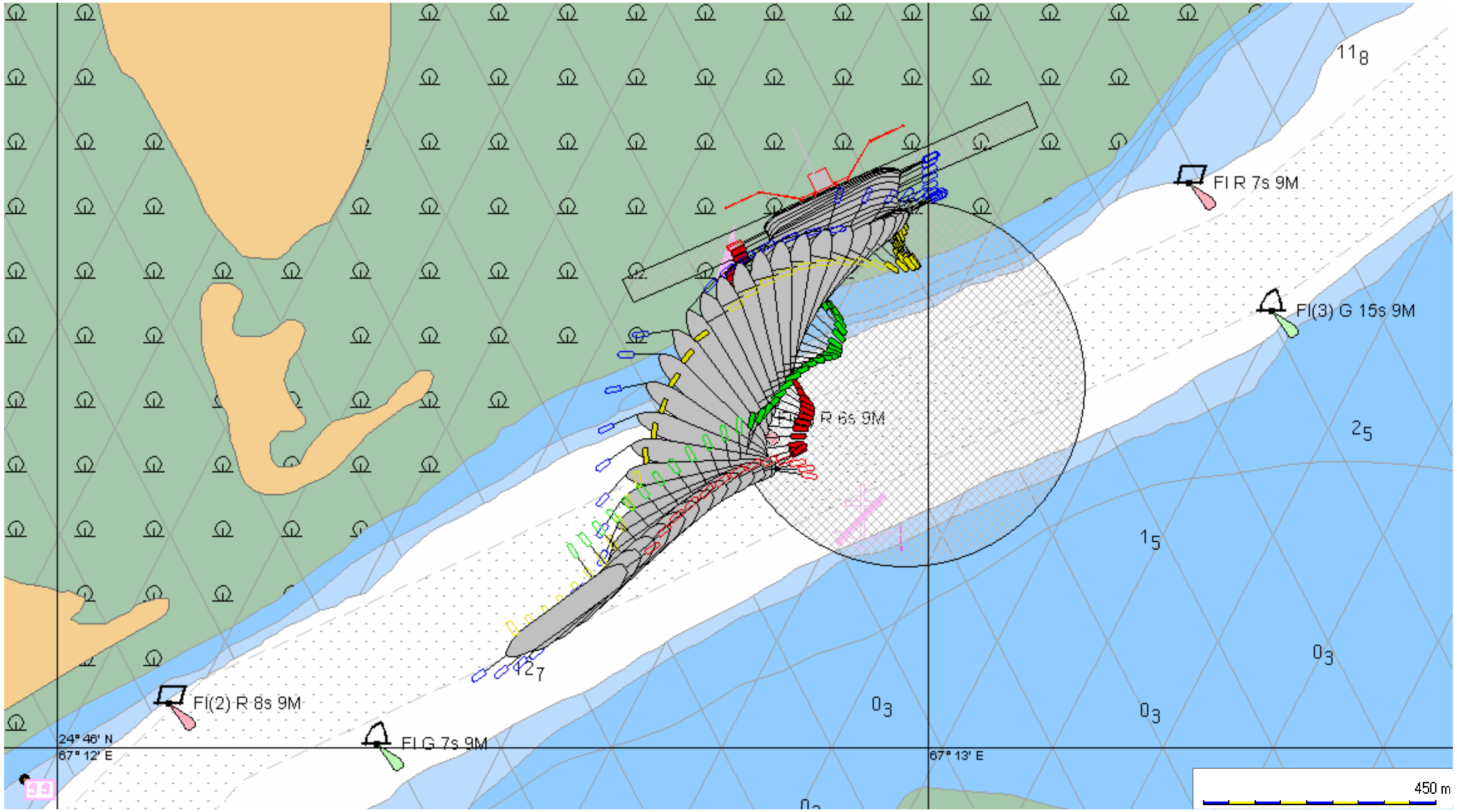
Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
18	LNG 005	Ballast (9.5m)	Departure	4	3kt Flood	30kts (225)	-	Yes

Run 18 investigated the ease of departing by swinging off the berth in the same conditions as Run 17.
Again this proved a relatively simple manoeuvre. As such it is recommended that this is adopted as the standard arrival/departure technique for this berth.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

(Rating 3 "Comfortable" circled)

Vessel Track With Tugs



Vessel: LNG Carrier 005 (B) (+Tugs)
Harbour: Khiprianwala Island
Created: 01/03/2011

Wind: 30.00 kts 225 °
Current: 3.5 kts Ebb
Depth: 1.0 m above 12.5 m

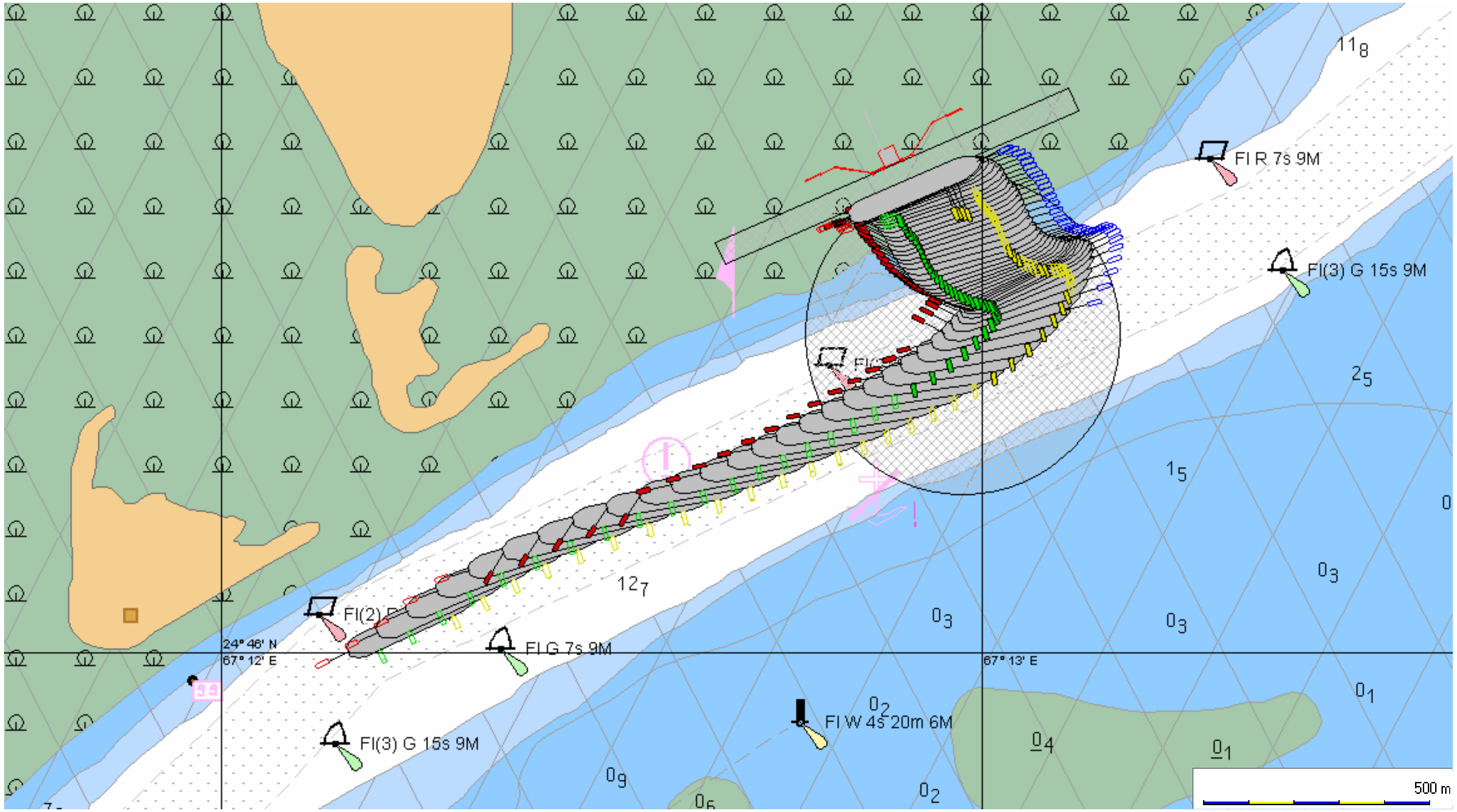
Project:	Port Qasim LNG Terminal Study	Job No.:	L30090	Captain/Pilot:	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	28/02/2011				

Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
19	LNG 004	Loaded (12.2m)	Arrival	4	3kt Flood	20kts (225)	-	-

Following on from run 17 it was decided to investigate using a similar approach technique for the Q-Flex. Again thus proved to be successful.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

Vessel Track With Tugs



Vessel: LNG Carrier 004 (L) (+Tugs)
Harbour: Khiprianwala Island
Created: 02/03/2011

Wind: 20.00 kts 225 °
Current: 3 kts Flood
Depth: 1.0 m above 12.5 m

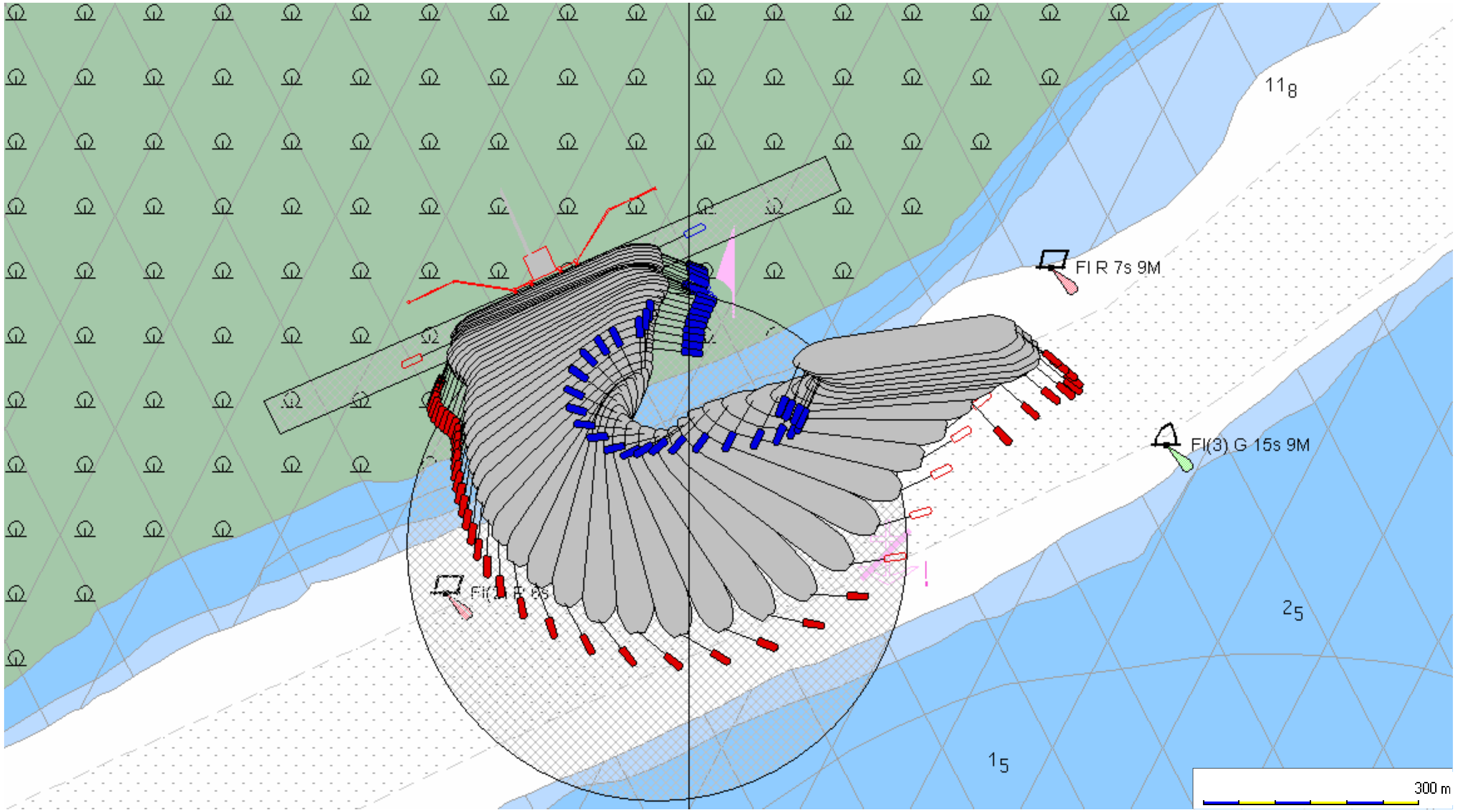
Project:	Port Qasim LNG Terminal Study	**Job No.:**	L30090	**Captain/Pilot:**	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	28/02/2011				

Run No.	**Vessel**		**Access Condition**		**Environmental Conditions**			**Manoeuvre**
	Ship	**Condition**	**Type**	**No of Tugs Used**	**Current**	**Wind Speed (Direction from)**	**Waves (Ht/Period)**	**Thrusters used?**
20	LNG 004	Ballast (9.5m)	Arrival	2	3kt Flood	20kts (225)	-	-

The vessel was swung off the berth as per previous runs. However on this occasion it was decided to try the manoeuvre with only 2 tugs. This proved to be possible but only with some difficulty.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

Vessel Track With Tugs



Vessel: LNG Carrier 004 (B) (+Tugs)
Harbour: Khiprianwala Island
Created: 02/03/2011

Wind: 20.00 kts 225 °
Current: 3 kts Flood
Depth: 1.0 m above 12.5 m

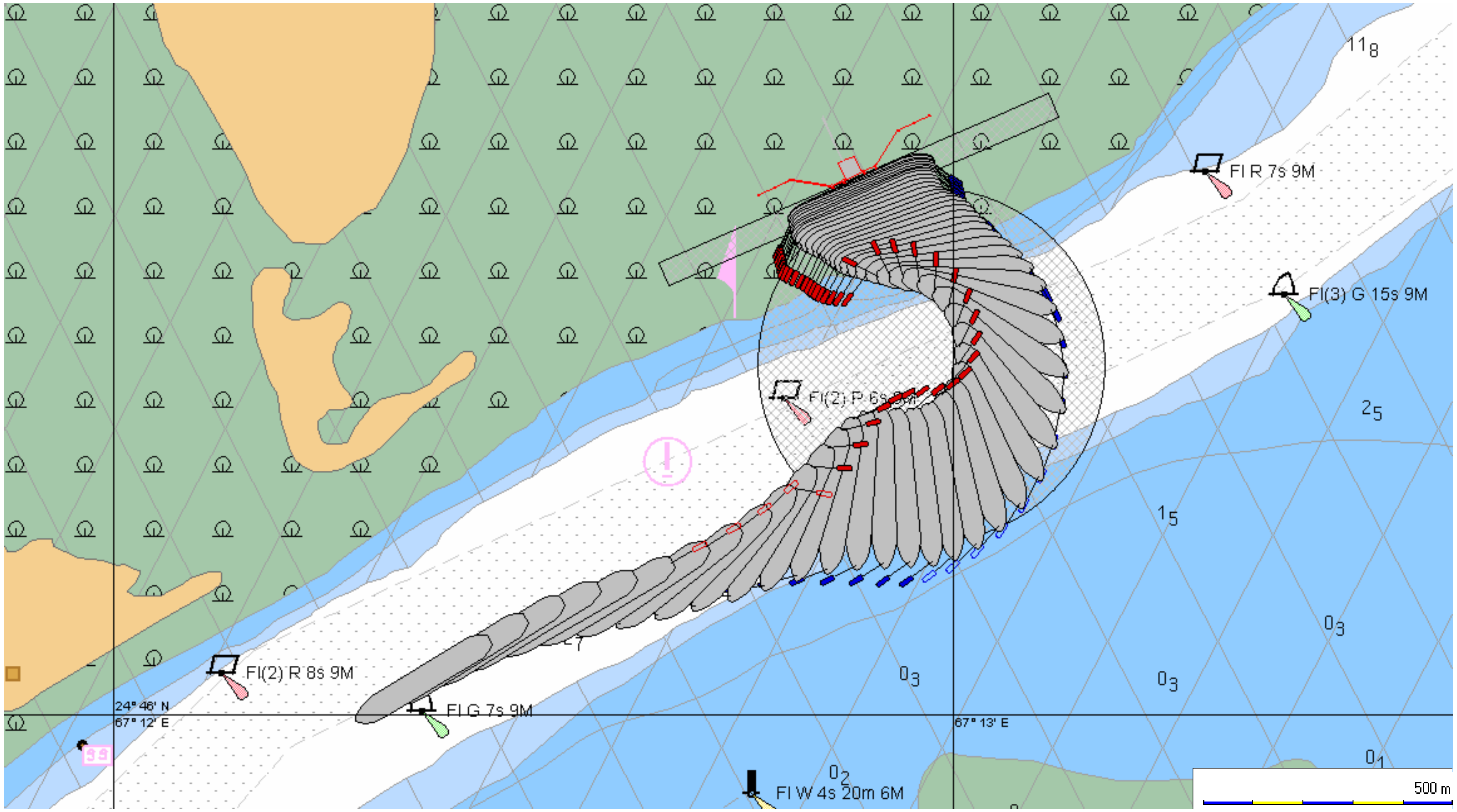
Project:	Port Qasim LNG Terminal Study		Job No.:		L30090	Captain/Pilot:	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register						
Date:	28/02/2011						
Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
21	LNG 004	Ballast (9.5m)	Departure	2	3.5kt Ebb	20kts (225)	-	-

This run was repeated Run 20 but in a 3.5kt ebb tide instead of flood.
Again the manoeuvre proved possible but challenging.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

(Rating 6 "Challenging" is circled.)

Vessel Track With Tugs

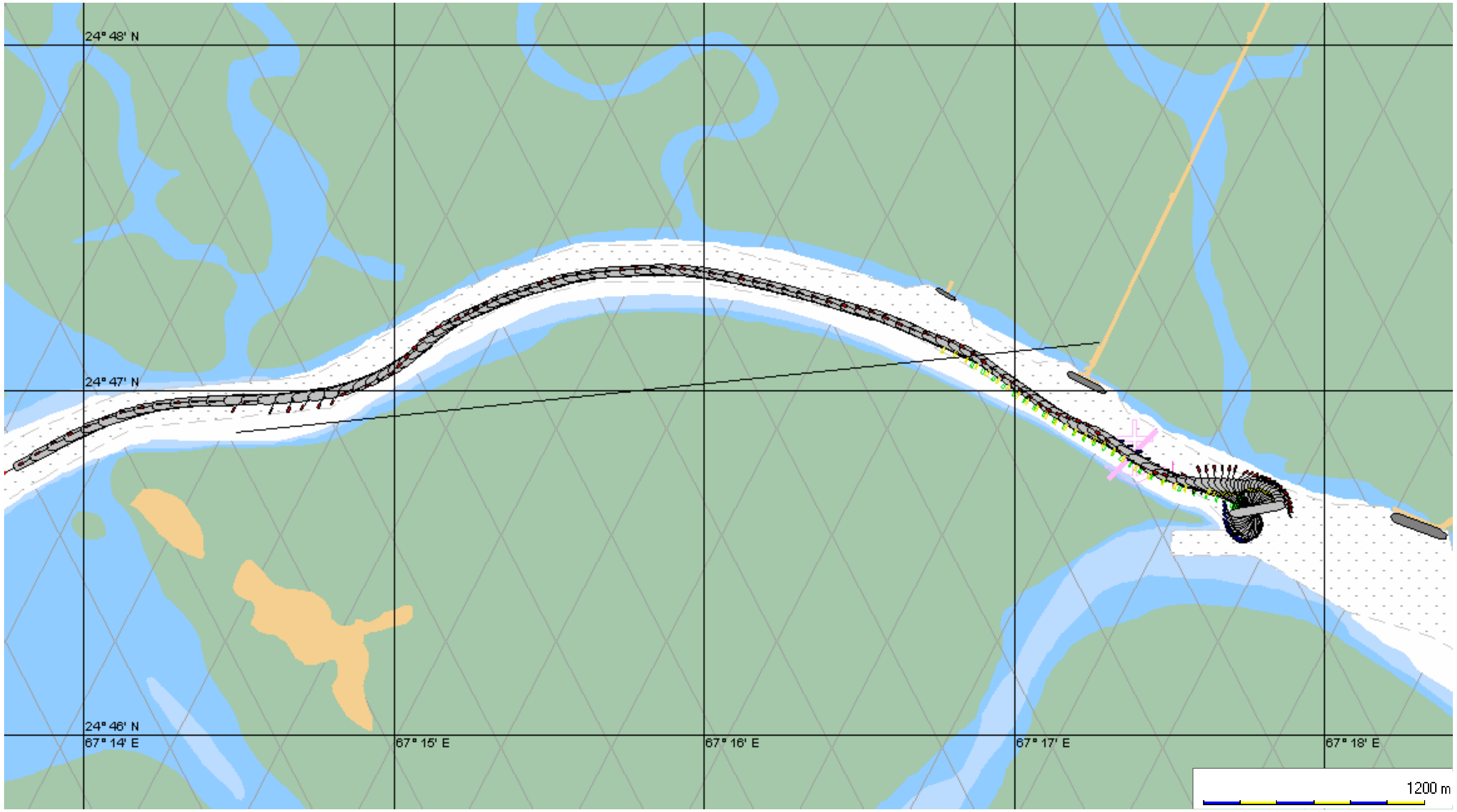


Vessel: LNG Carrier 004 (B) (+Tugs)
Harbour: Khiprianwala Island
Created: 02/03/2011

Wind: 20.00 kts 225 °
Current: 3.5 kts Ebb
Depth: 1.0 m above 12.5 m

Project:	Port Qasim LNG Terminal Study	Job No.:	L30090	Captain/Pilot:	Chris Bordas				
Subject:	PC Rembrandt Simulation Study for Lloyd's Register								
Date:	28/02/2011								
Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre	
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?	
22	LNG 004	Loaded (12.2m)	Arrival	4	Slack water	20kts (225)	-	-	
	This run was an attempted repeat of Run 15. In order to avoid some technical issues the run was assumed to be carried out at slack water (and with an extra 1m of tidal height). The south westerly wind pushed the vessel towards the north of the channel (and the moored vessels) which had to be overcome using frequent rudder inputs and tug corrections.								
Ratings	1	2	3	4	5	6	7	8	
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible	

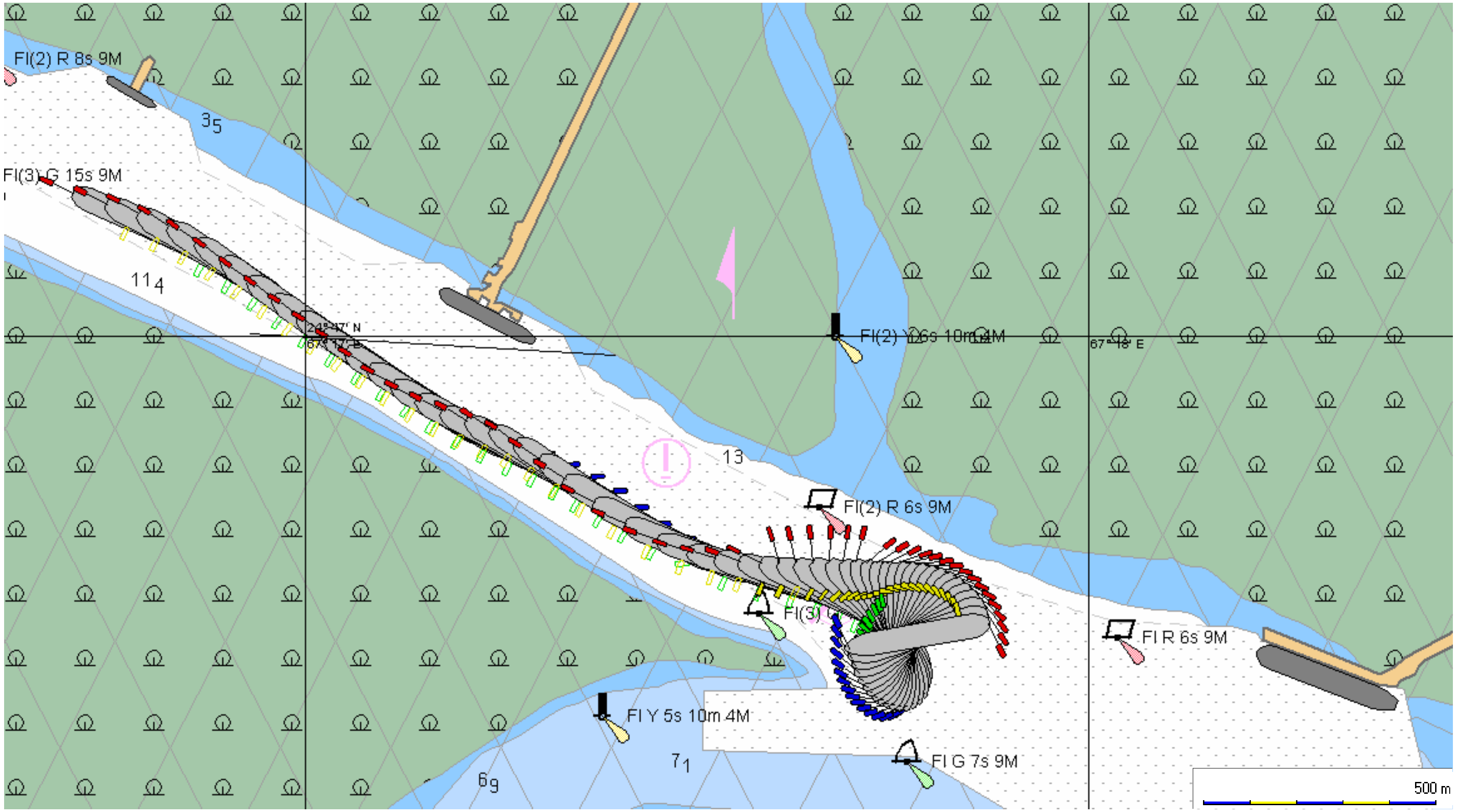
Vessel Track With Tugs



Vessel: LNG Carrier 004 (L) (+Tugs)
Harbour: Port Qasim
Created: 02/03/2011

Wind: 20.00 kts 225 °
Current: 0.00 kts 0 °
Depth: Variable

Vessel Track With Tugs



Vessel: LNG Carrier 004 (L) (+Tugs)
Harbour: Port Qasim
Created: 02/03/2011

Wind: 20.00 kts 225 °
Current: 0.00 kts 0 °
Depth: Variable

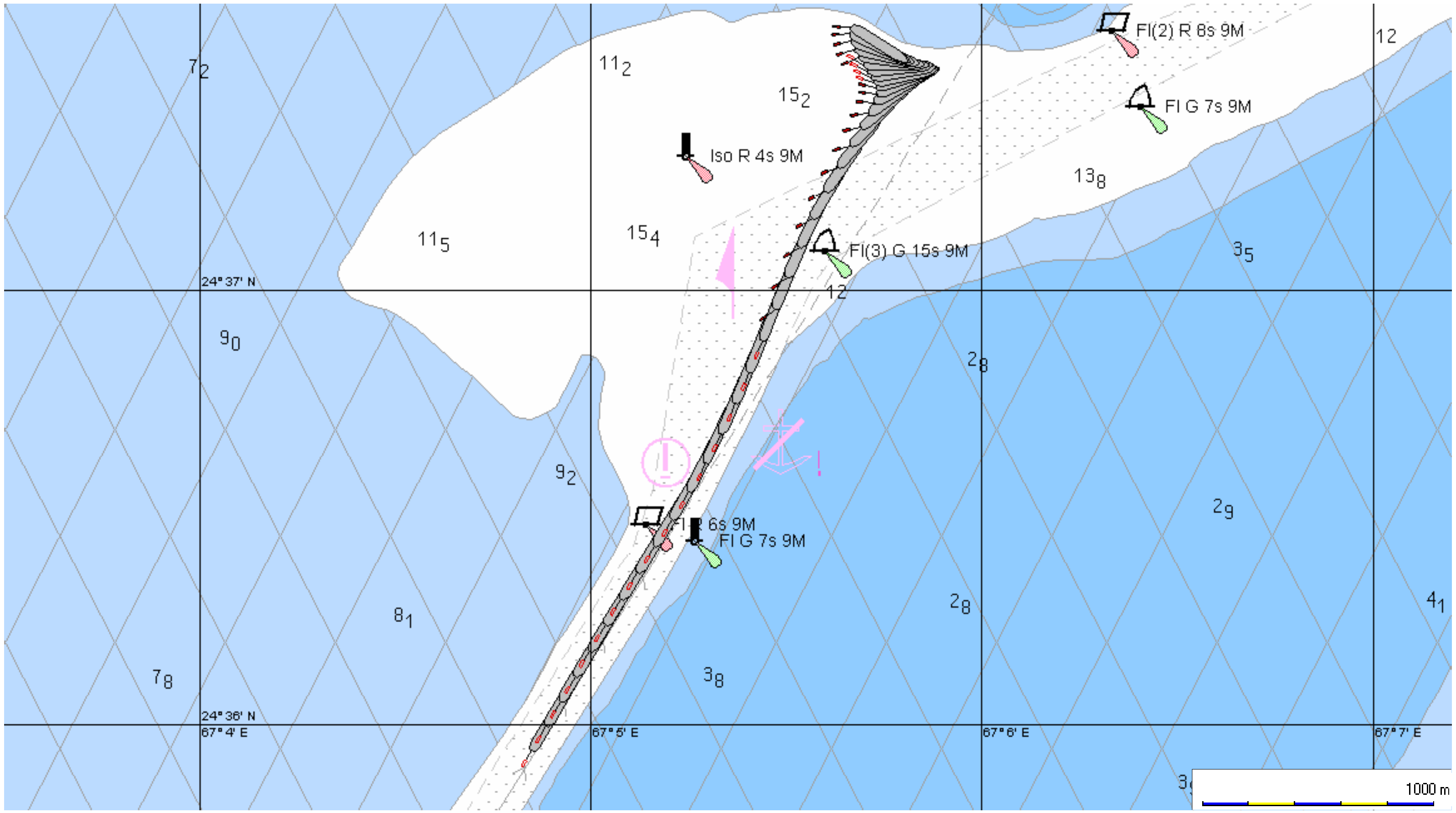
Project:	Port Qasim LNG Terminal Study	**Job No.:**	L30090	**Captain/Pilot:**	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	02/03/2011				

Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
23	LNG 005	Loaded (11.5m)	Arrival	1	2kt flood	20kts (225)	-	No

Run 23 was used to determine how a rudder failure (stuck on full defection) would affect a vessel transiting the port entrance. Both anchors were let go and the escort tug was used to ensure the vessel stayed clear of the main channel.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

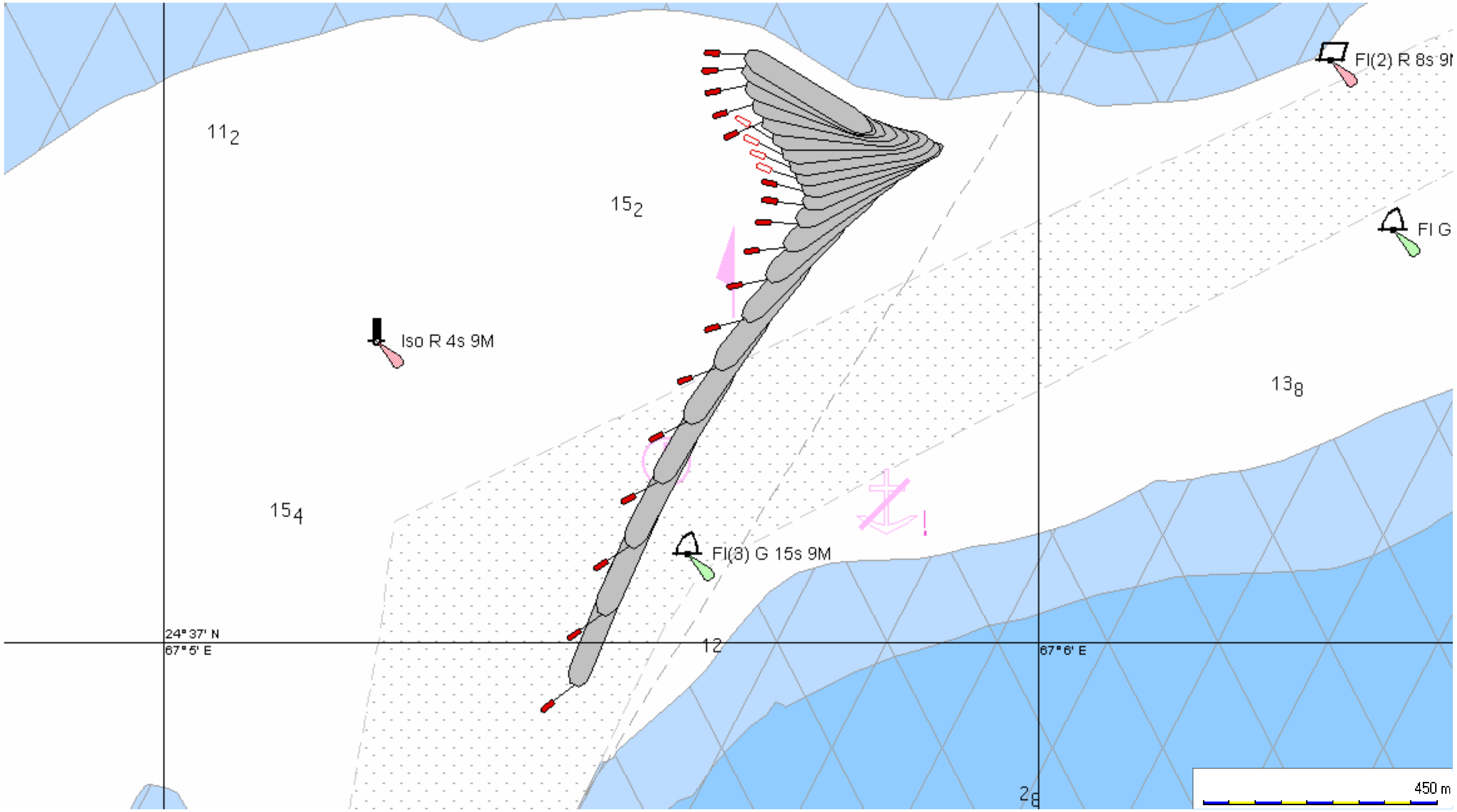
Vessel Track With Tugs



Vessel: LNG Carrier 005 (L) (+Tugs, Anchors)
Harbour: Qasim
Created: 02/03/2011

Wind: 20.00 kts 225 °
Current: 2.00 kts 30 °
Depth: 1.0 m above Chart Datum

Vessel Track With Tugs



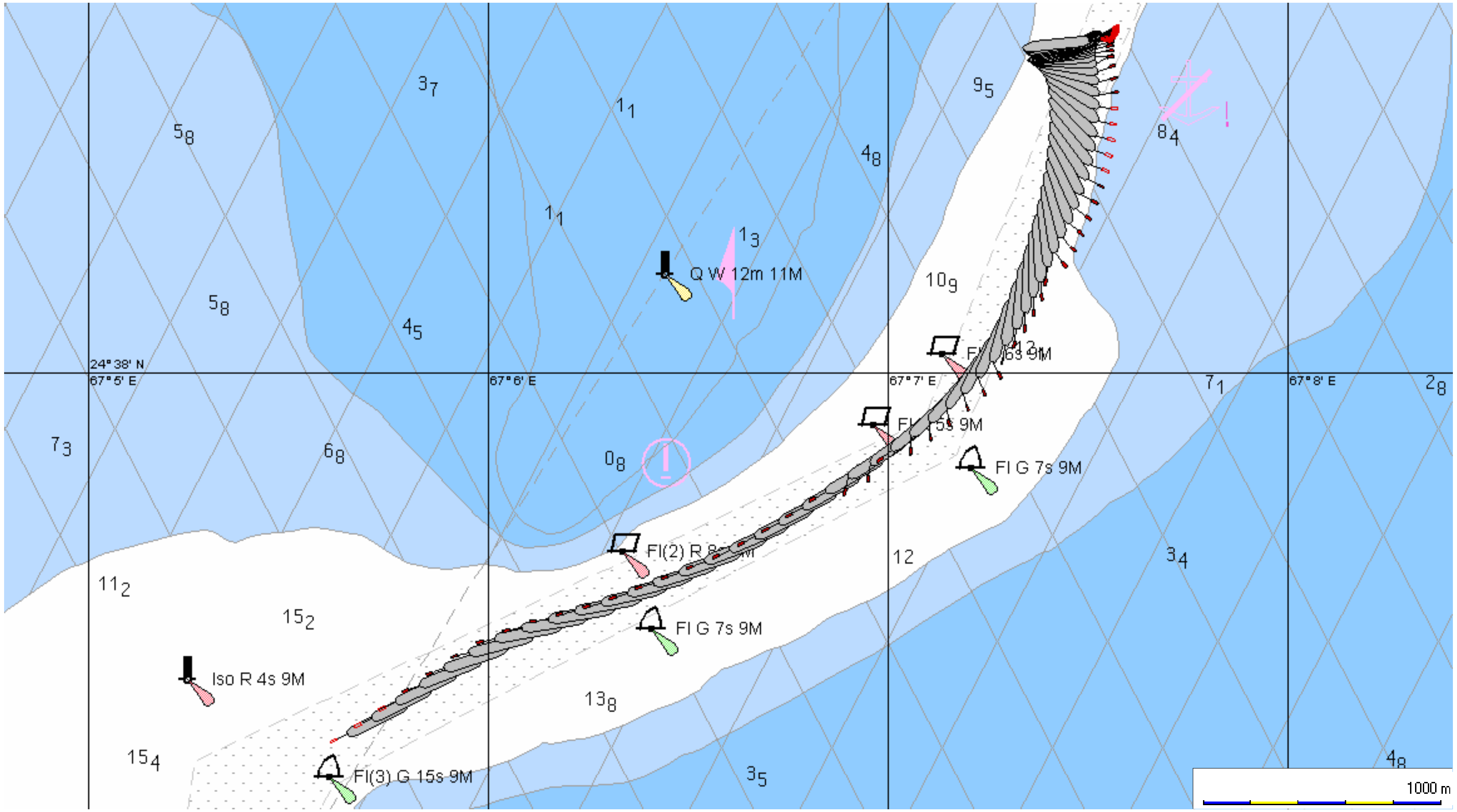
Vessel:	LNG Carrier 005 (L) (+Tugs, Anchors)
Harbour:	Qasim
Created:	02/03/2011

Wind:	20.00 kts 225 °
Current:	2.00 kts 30 °
Depth:	1.0 m above Chart Datum

Project:	Port Qasim LNG Terminal Study		**Job No.:**	L30090		**Captain/Pilot:**	Chris Bordas	
Subject:	PC Rembrandt Simulation Study for Lloyd's Register							
Date:	02/03/2011							
Run No.	**Vessel**		**Access Condition**		**Environmental Conditions**			**Manoeuvre**
	Ship	**Condition**	**Type**	**No of Tugs Used**	**Current**	**Wind Speed (Direction from)**	**Waves (Ht/Period)**	**Thrusters used?**
24	LNG 005	Loaded (11.5m)	Arrival	1	2kt flood	20kts (225)	-	No
	Run 24 was another failure test. Starting further in the channel an engine failure was simulated. Again using anchors and the escort tug the vessel as controlled albeit ending in the channel.							

Ratings	1	2	3	4	5	6	7	8
	Easy	**Straight-forward**	**Comfortable**	**Not demanding**	**Not easy**	**Challenging**	**Difficult**	**Impossible**

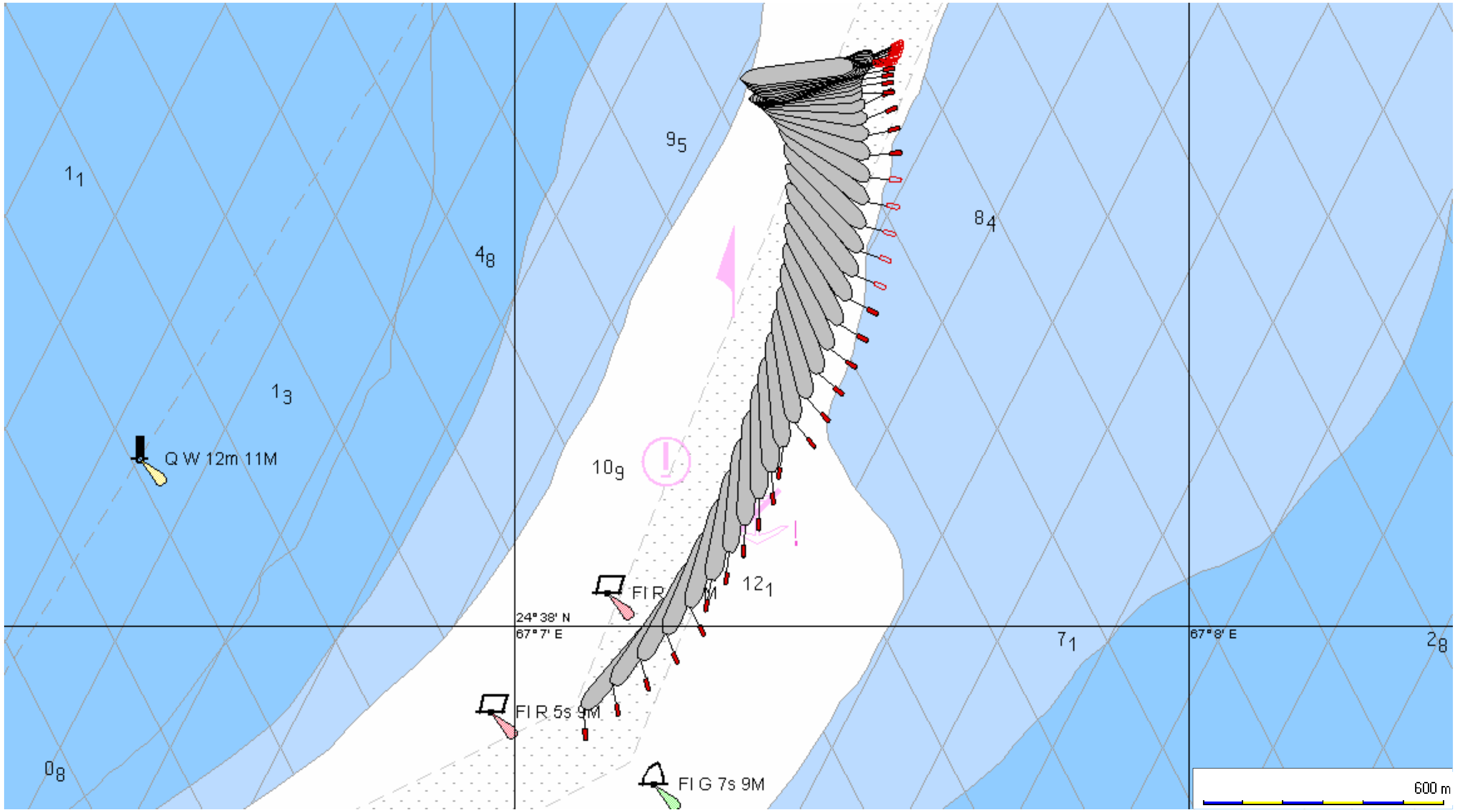
Vessel Track With Tugs



Vessel:	LNG Carrier 005 (L) (+Tugs, Anchors)
Harbour:	Qasim
Created:	02/03/2011

Wind:	20.00 kts 225 °
Current:	2.00 kts 40 °
Depth:	1.0 m above Chart Datum

Vessel Track With Tugs



Vessel:	LNG Carrier 005 (L) (+Tugs, Anchors)
Harbour:	Qasim
Created:	02/03/2011

Wind:	20.00 kts 225 °
Current:	2.00 kts 40 °
Depth:	1.0 m above Chart Datum

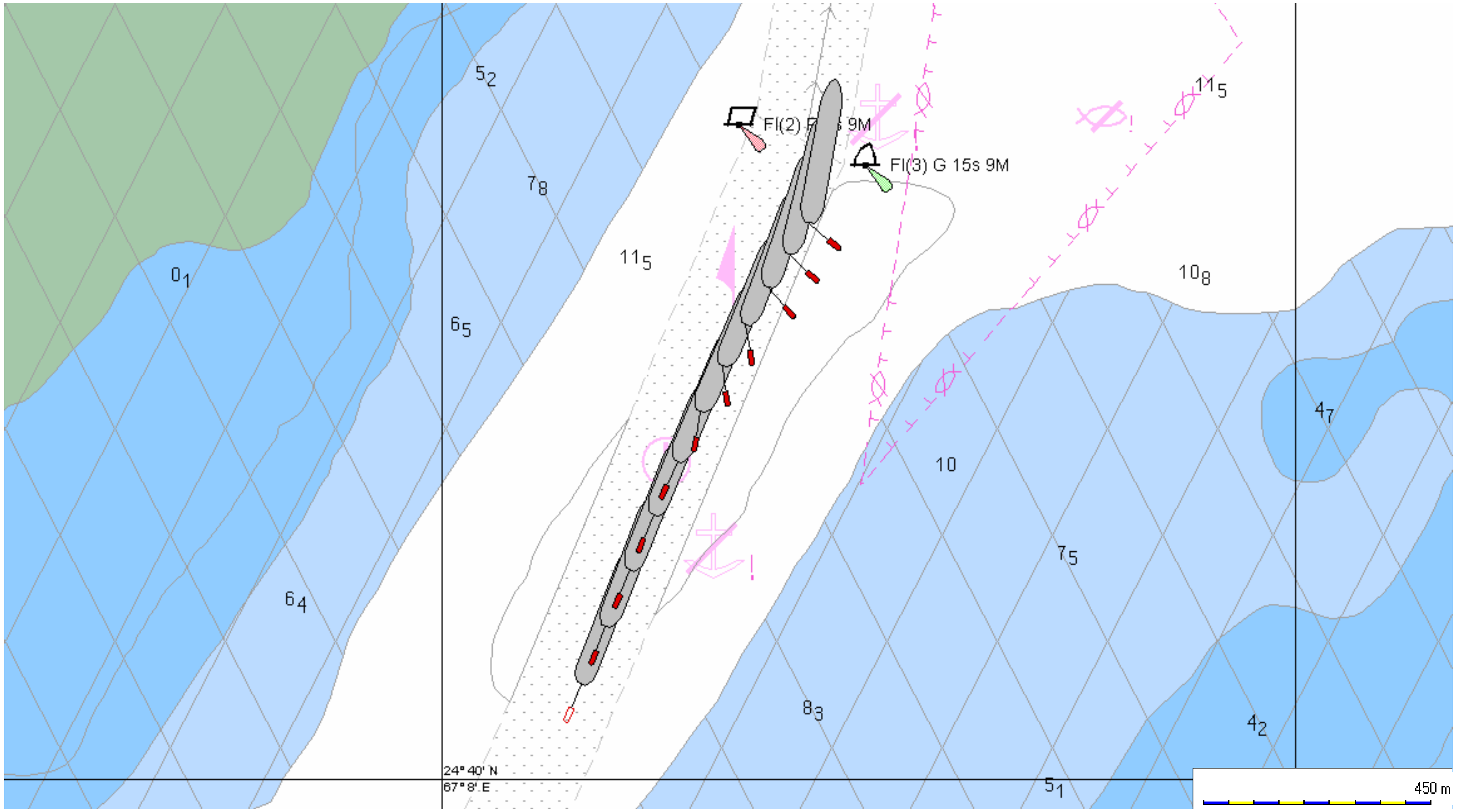
Project:	Port Qasim LNG Terminal Study	Job No.:	L30090	Captain/Pilot:	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	02/03/2011				

Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
25	LNG 005	Loaded (11.5m)	Arrival	1	2kt flood	20kts (225)	-	No

During Run 25 a crash stop was conducted. 2 ship lengths proved insufficient although speed had reduced to 3 kts and it was assumed a small fishing vessel or the like would have had time to move out of the way.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

Vessel Track With Tugs



Vessel: LNG Carrier 005 (L) (+Tugs, Anchors)
Harbour: Qasim
Created: 02/03/2011

Wind: 20.00 kts 225 °
Current: 2.00 kts 30 °
Depth: 1.0 m above Chart Datum

Project:	Port Qasim LNG Terminal Study	**Job No.:**	L30090	**Captain/Pilot:**	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	02/03/2011				

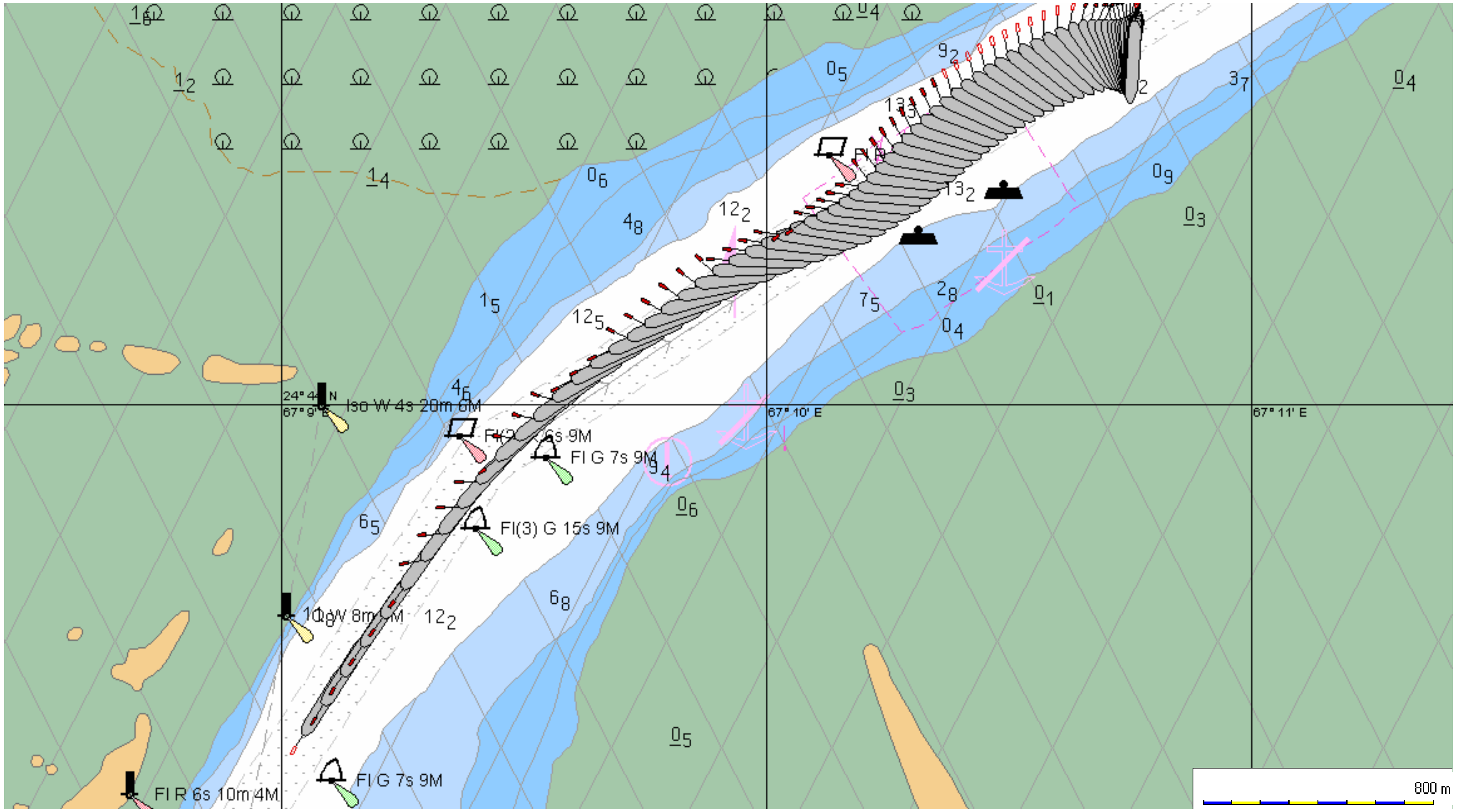
Run No.	**Vessel**		**Access Condition**		**Environmental Conditions**			**Manoeuvre**
	Ship	**Condition**	**Type**	**No of Tugs Used**	**Current**	**Wind Speed (Direction from)**	**Waves (Ht/Period)**	**Thrusters used?**
26	LNG 005	Loaded (11.5m)	Arrival	1 (possibly 4)	2kt flood	20kts (225)	-	No

A blackout was simulated at a point higher up the channel. Using the single tug and the ship's rudder good control was maintained. In addition the vessel passed the point in the channel where it was assumed the berthing tugs would join. As such it is likely that the vessel would be fully controllable using only tugs.

Ratings	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	Easy	**Straight-forward**	**Comfortable**	**Not demanding**	**Not easy**	**Challenging**	**Difficult**	**Impossible**

(Rating 4 "Not demanding" circled.)

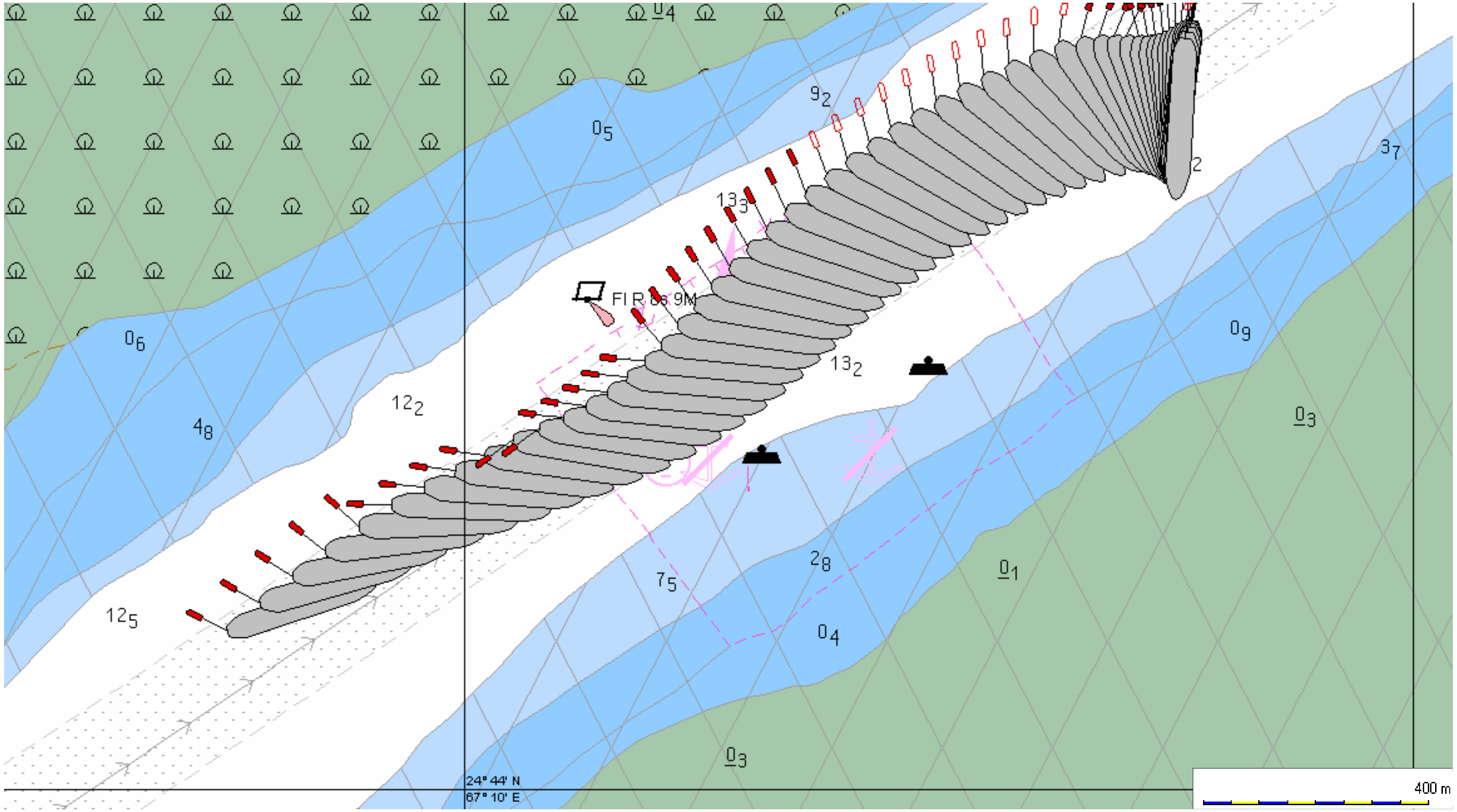
Vessel Track With Tugs



Vessel: LNG Carrier 005 (L) (+Tugs, Anchors)
Harbour: Qasim
Created: 02/03/2011

Wind: 20.00 kts 225 °
Current: 2.00 kts 40 °
Depth: 1.0 m above Chart Datum

Vessel Track With Tugs



Vessel: LNG Carrier 005 (L) (+Tugs, Anchors)
Harbour: Qasim
Created: 02/03/2011

Wind: 20.00 kts 225 °
Current: 2.00 kts 40 °
Depth: 1.0 m above Chart Datum

Project:	Port Qasim LNG Terminal Study	Job No.:	L30090	Captain/Pilot:	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	02/03/2011				

Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
27	LNG 005	Loaded (11.5m)	Arrival	1	2kt flood	20kts (225)	-	No

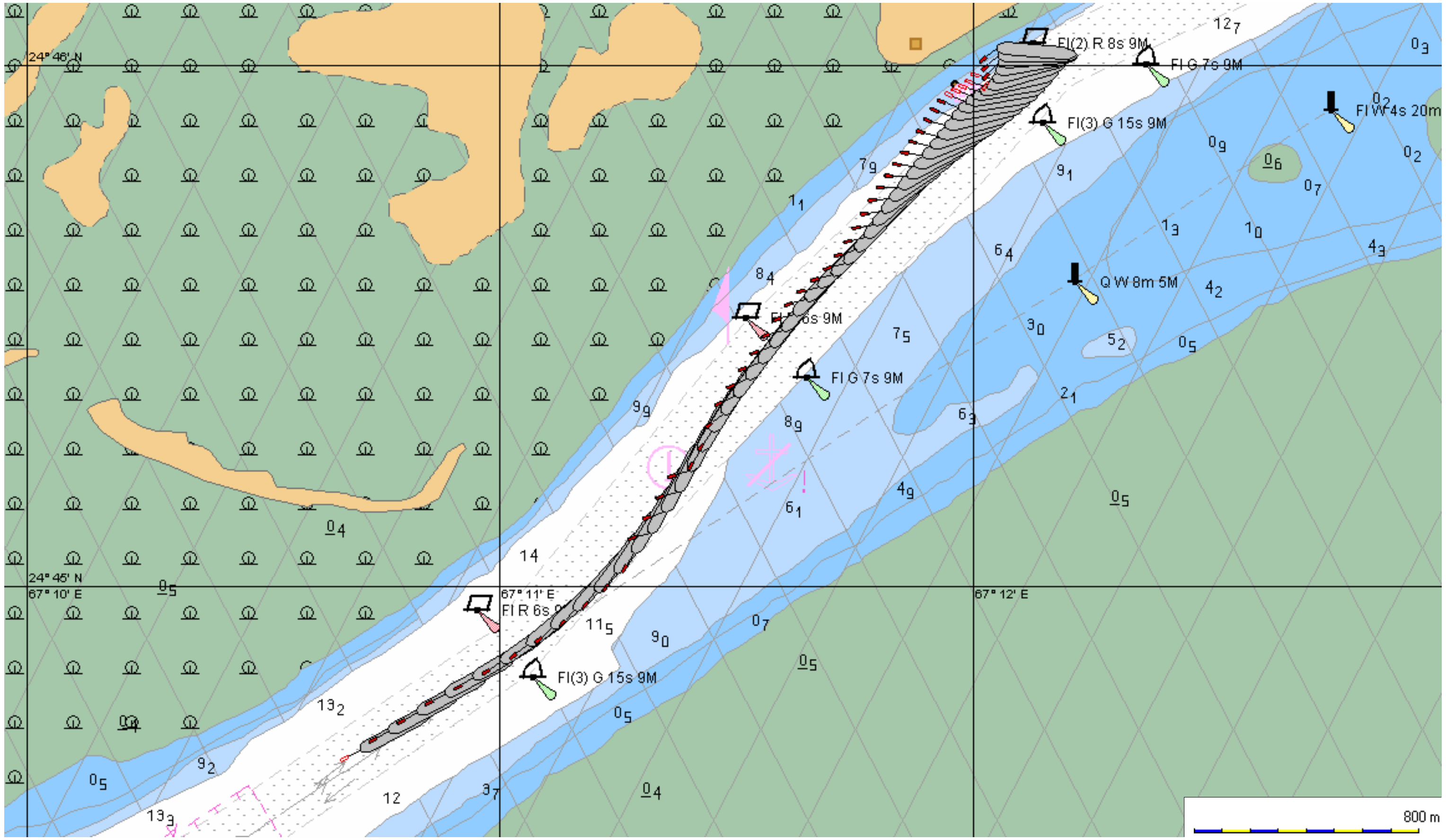
This was a repeat of Run 23 but with the vessel further in the channel. The vessel was brought under control using anchors and tugs.

At this point it was decided that a standby tug should be provided at all times in case of tug failure.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

(Rating 4 "Not demanding" circled.)

Vessel Track With Tugs



Vessel:	LNG Carrier 005 (L) (+Tugs, Anchors)
Harbour:	New Region
Created:	3/2/2011

Wind:	20.00 kts 225 °
Current:	2.00 kts 40 °
Depth:	1.0 m above Chart Datum

Project:	Port Qasim LNG Terminal Study	**Job No.:**	L30090	**Captain/Pilot:**	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	02/03/2011				

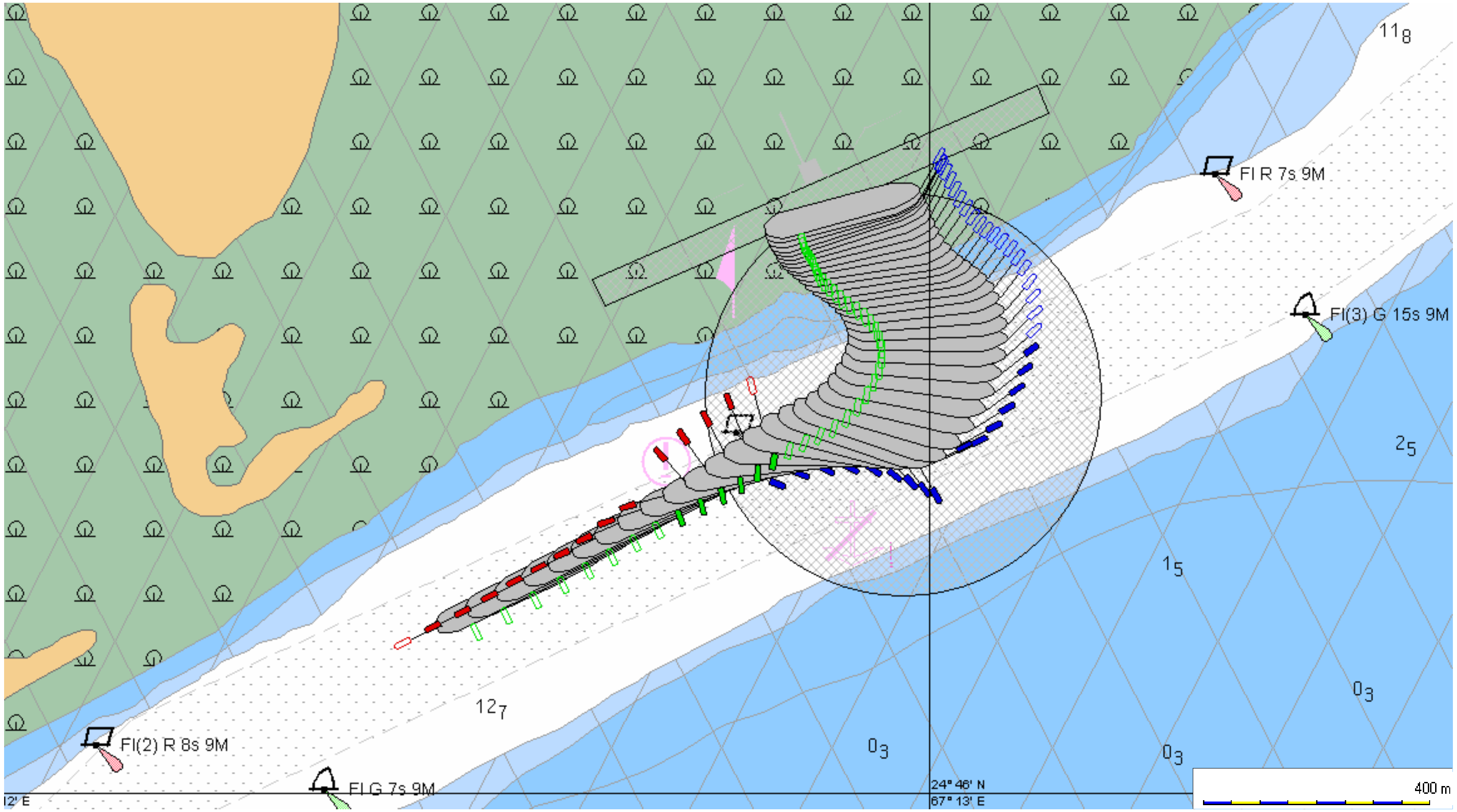
Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
28	LNG 005	Loaded (11.5m)	Arrival	3 then 2	2kt flood	20kts (225)	-	Yes

Run 28 was a simulation of a tug failure during an arrival swing manoeuvre. It was assumed that halfway through the swing the tug attached to the vessel's stern failed. At this point the swing was abandoned and the vessel was berth port-side to with no further problems.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

Rating circled: 4 (Not demanding)

Vessel Track With Tugs



Vessel: LNG Carrier 005 (L) (+Tugs)
Harbour: Khiprianwala Island
Created: 02/03/2011

Wind: 20.00 kts 225 °
Current: 2.00 kts 60 °
Depth: 1.0 m above 12.5 m

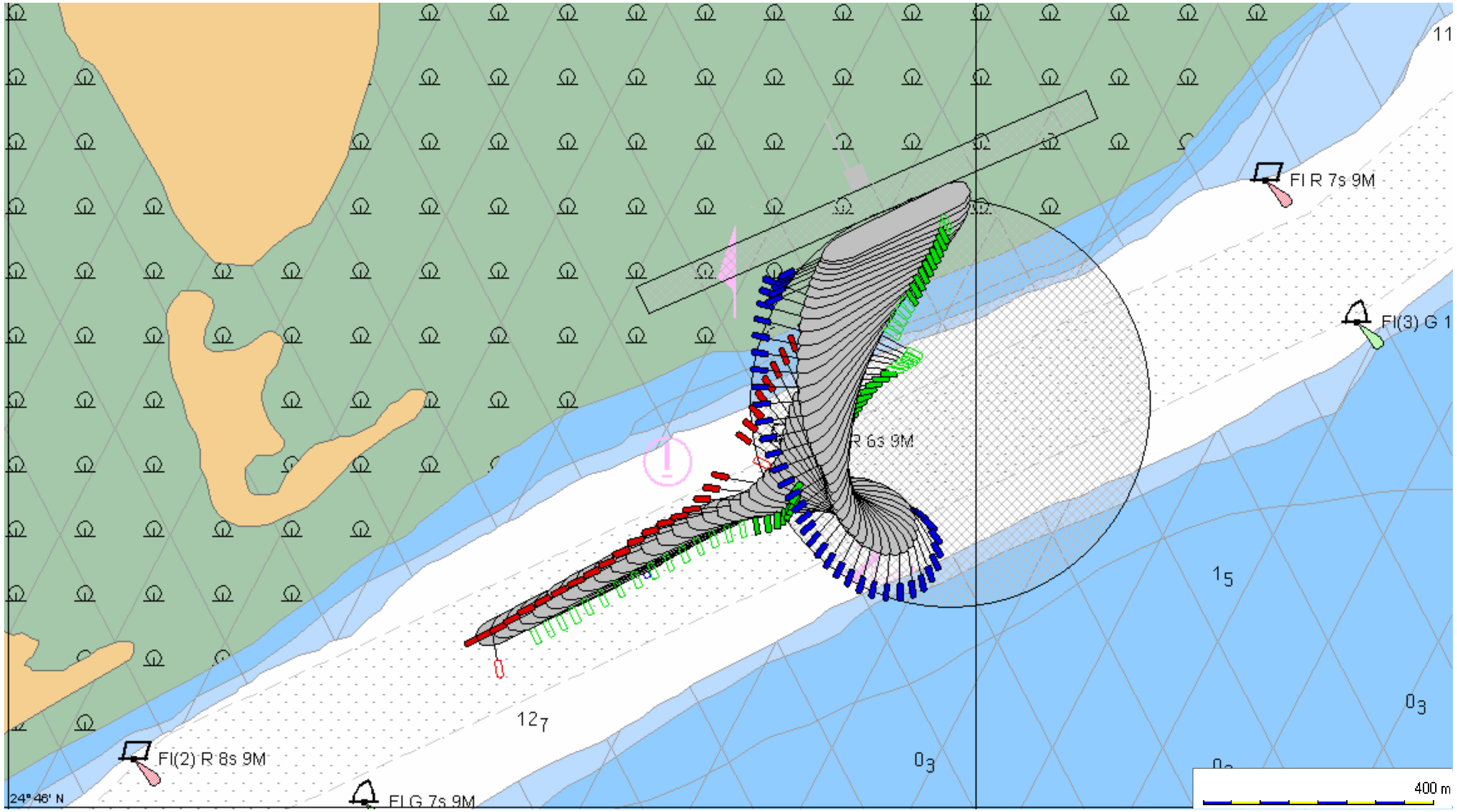
Project:	Port Qasim LNG Terminal Study	Job No.:	L30090	Captain/Pilot:	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	02/03/2011				

Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
29	LNG 005	Loaded (11.5m)	Passing	1	Slack water	20kts (225)	-	Yes

Run 29 was a repeat of Run 28 but with slack water and the tug failure occurring later in the swing. This was completed with no problems.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

Vessel Track With Tugs



Vessel: LNG Carrier 005 (L) (+Tugs)
Harbour: Khiprianwala Island
Created: 02/03/2011

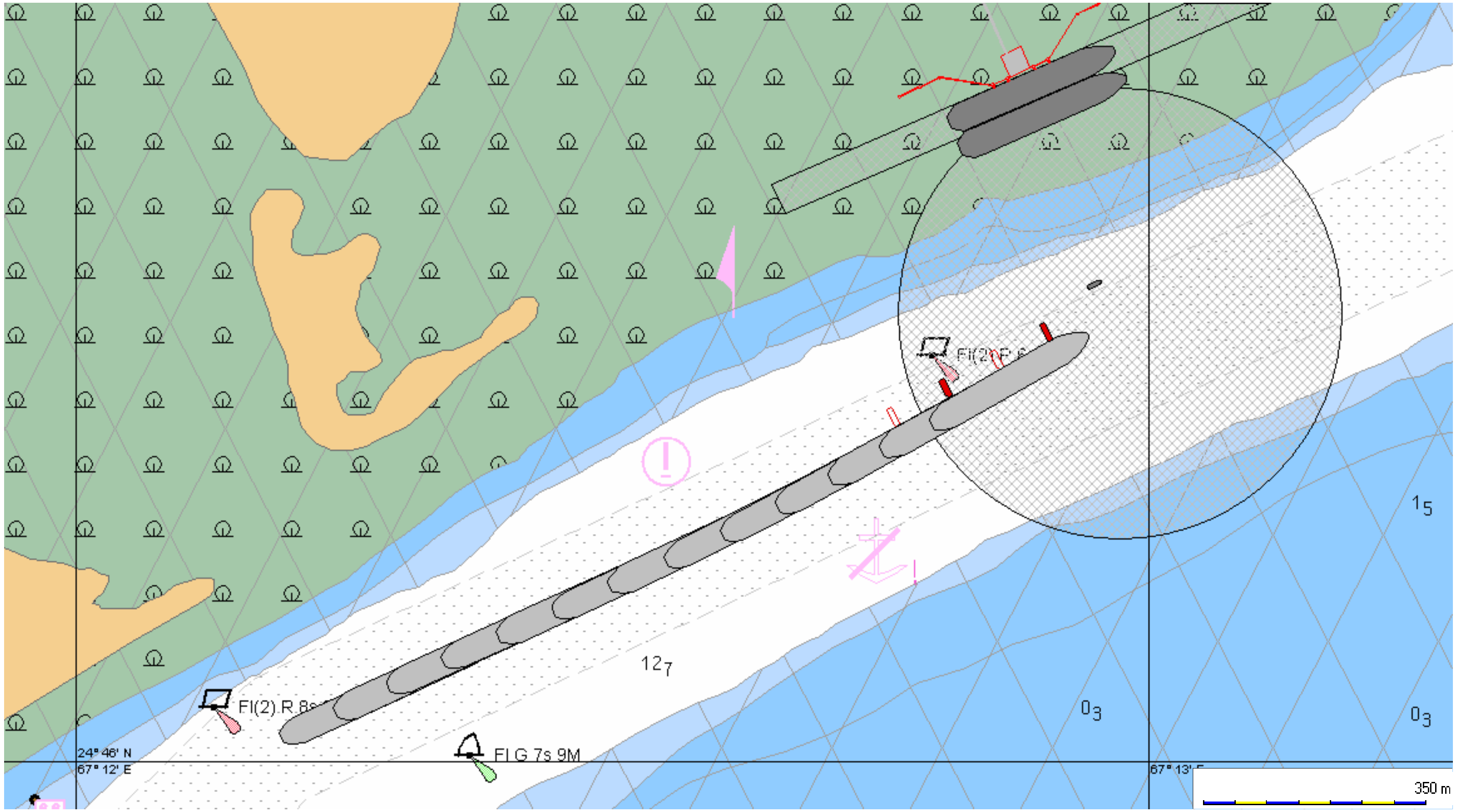
Wind: 20.00 kts 225 °
Current: 0.00 kts 60 °
Depth: Variable

Project:	Port Qasim LNG Terminal Study		Job No.:		L30090		Captain/Pilot:	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register							
Date:	02/03/2011							
Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
30	LNG 005	Loaded (11.5m)	Passing	1	Slack water	20kts (225)	-	No

Run 30 simulated a vessel passing the Greenfield LNG berth and then having an engine failure.
It was demonstrated that a single standby tug (if sited by the LNG berth) would have sufficient time and power to prevent the passing ship drifting towards the LNGCs.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

Vessel Track With Tugs



Vessel: LNG Carrier 005 (L) (+Tugs)
Harbour: Khiprianwala Island
Created: 02/03/2011

Wind: 20.00 kts 225 °
Current: 0.00 kts 60 °
Depth: 1.0 m above 12.5 m

Project:	Port Qasim LNG Terminal Study	Job No.:	L30090	Captain/Pilot:	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	02/03/2011				

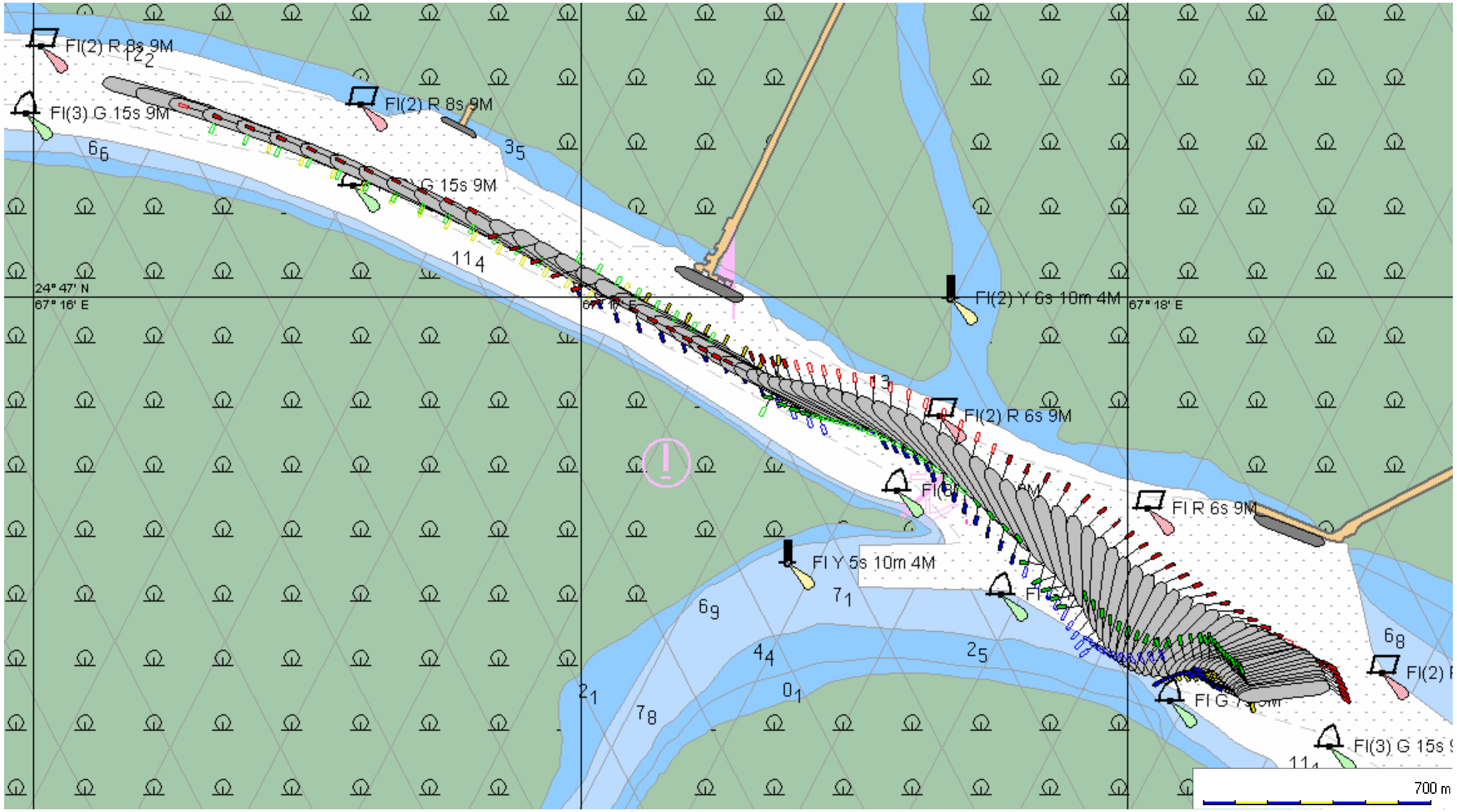
Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
31	LNG 005	Loaded (11.5m)	Arrival	4	3kt Flood	20kts (225)	-	No

Run 31 simulated a vessel engine failure on passing the LPG berth. Using the 4 tugs assumed to be available the vessel was easily controlled and even successfully swung in the turning basin.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

(Rating 3 – Comfortable – circled)

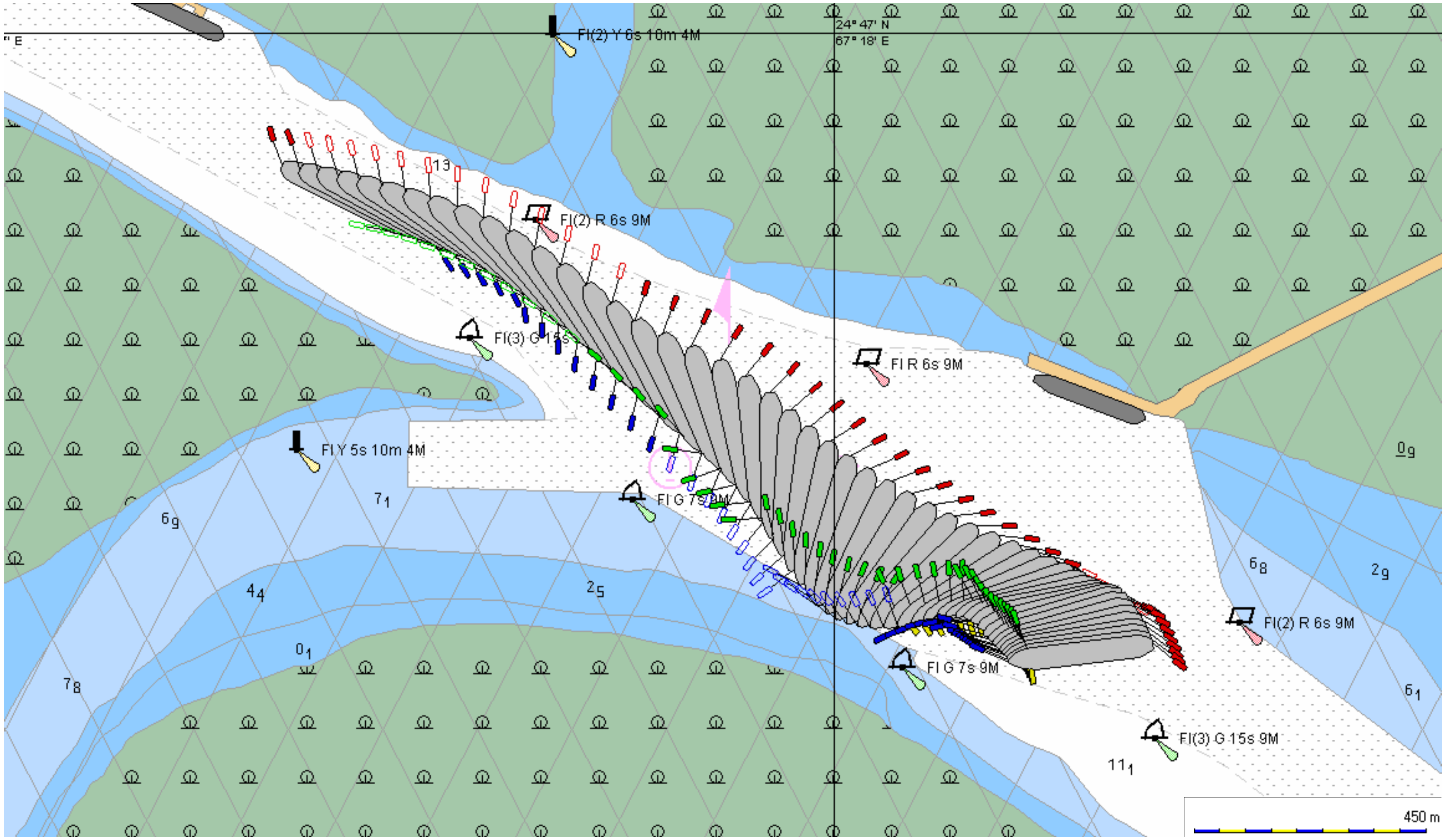
Vessel Track With Tugs



Vessel: LNG Carrier 005 (L) (+Tugs)
Harbour: New Region
Created: 02/03/2011

Wind: 20.00 kts 225 °
Current: 3.00 kts 115 °
Depth: Variable

Vessel Track With Tugs



Vessel:	LNG Carrier 005 (L) (+Tugs)
Harbour:	New Region
Created:	3/2/2011

Wind:	20.00 kts 225 °
Current:	3.00 kts 115 °
Depth:	Variable

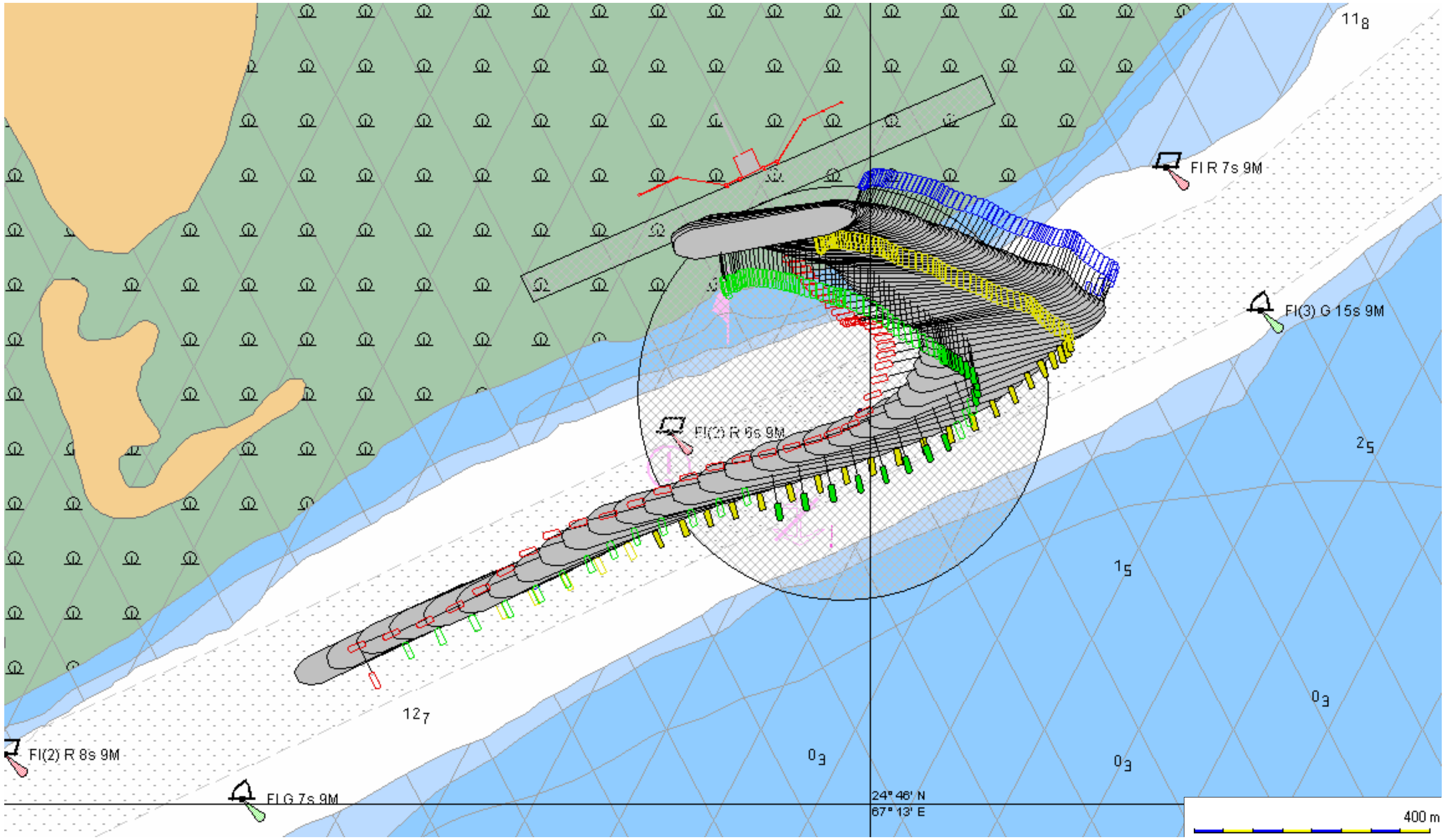
Project:	Port Qasim LNG Terminal Study	**Job No.:**	L30090	**Captain/Pilot:**	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	02/03/2011				

Run No.	**Vessel**		**Access Condition**		**Environmental Conditions**			**Manoeuvre**
	Ship	**Condition**	**Type**	**No of Tugs Used**	**Current**	**Wind Speed (Direction from)**	**Waves (Ht/Period)**	**Thrusters used?**
32	LNG 004	Loaded (12.2m)	Arrival	4	Slack water	20kts (225)	-	No

This run was a repeat of Run 28 (a tug failure during berthing swing) except a starting number of 4 tugs was used and a Q-Flex vessel. In this situation the vessel proved very easy to control and in fact only 2 tugs were employed for the vast majority of the manoeuvre.

Ratings	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	Easy	**Straight-forward**	**Comfortable**	**Not demanding**	**Not easy**	**Challenging**	**Difficult**	**Impossible**

Vessel Track With Tugs



Vessel: LNG Carrier 004 (L) (+Tugs)
Harbour: Khiprianwala Island
Created: 3/2/2011

Wind: 20.00 kts 225 °
Current: 0.00 kts 115 °
Depth: 1.0 m above 13.5 m

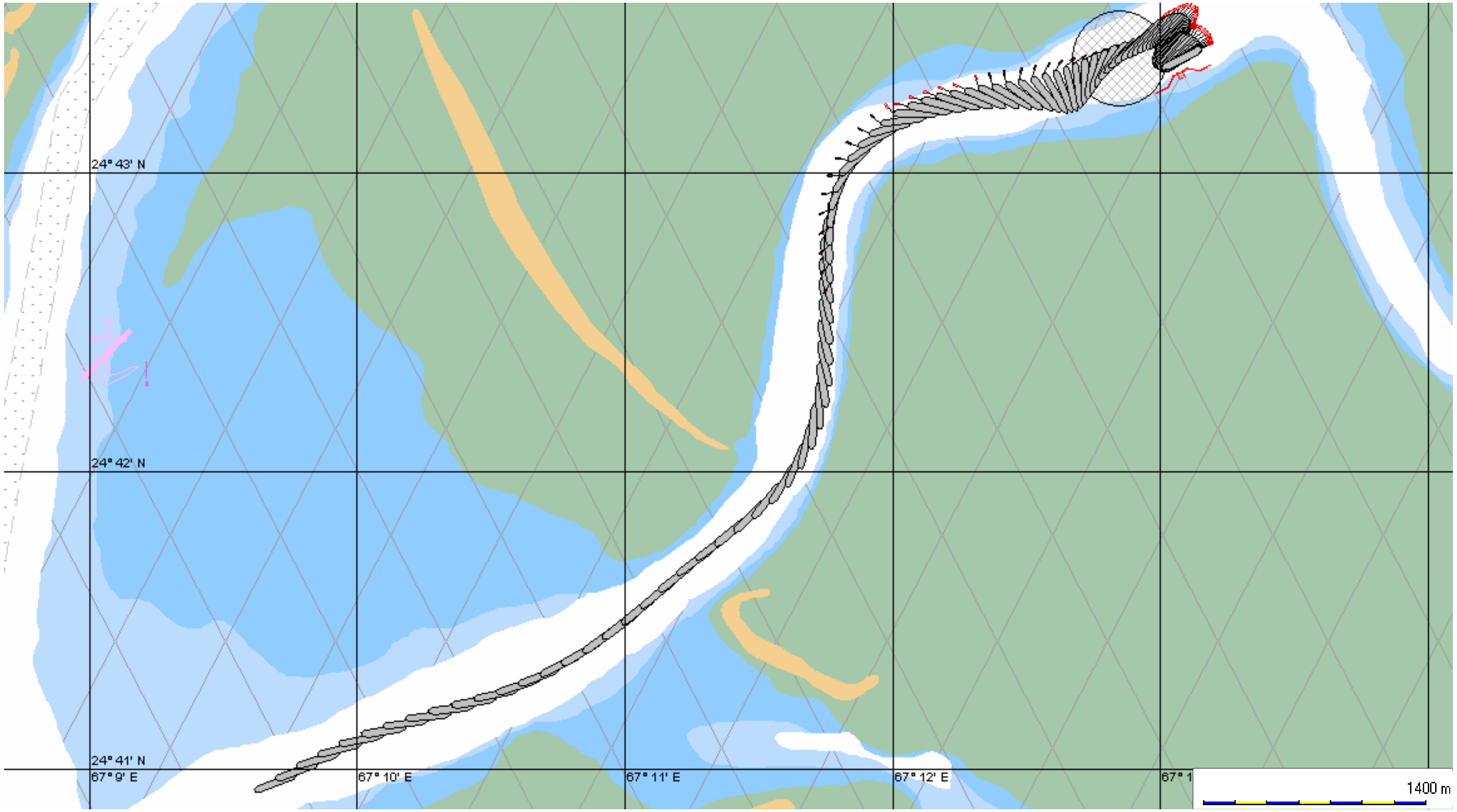
Project:	Port Qasim LNG Terminal Study	**Job No.:**	L30090	**Captain/Pilot:**	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	02/03/2011				

Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
33	LNG 004	Loaded (12.2m)	Arrival	1	3kt Flood	20kts (225)	-	No

Run 33 tested an arrival at the currently-unused Southern Channel. A berth was placed on the southern bank and the vessel navigated up the channel and swung. This was conducted without and difficulties.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

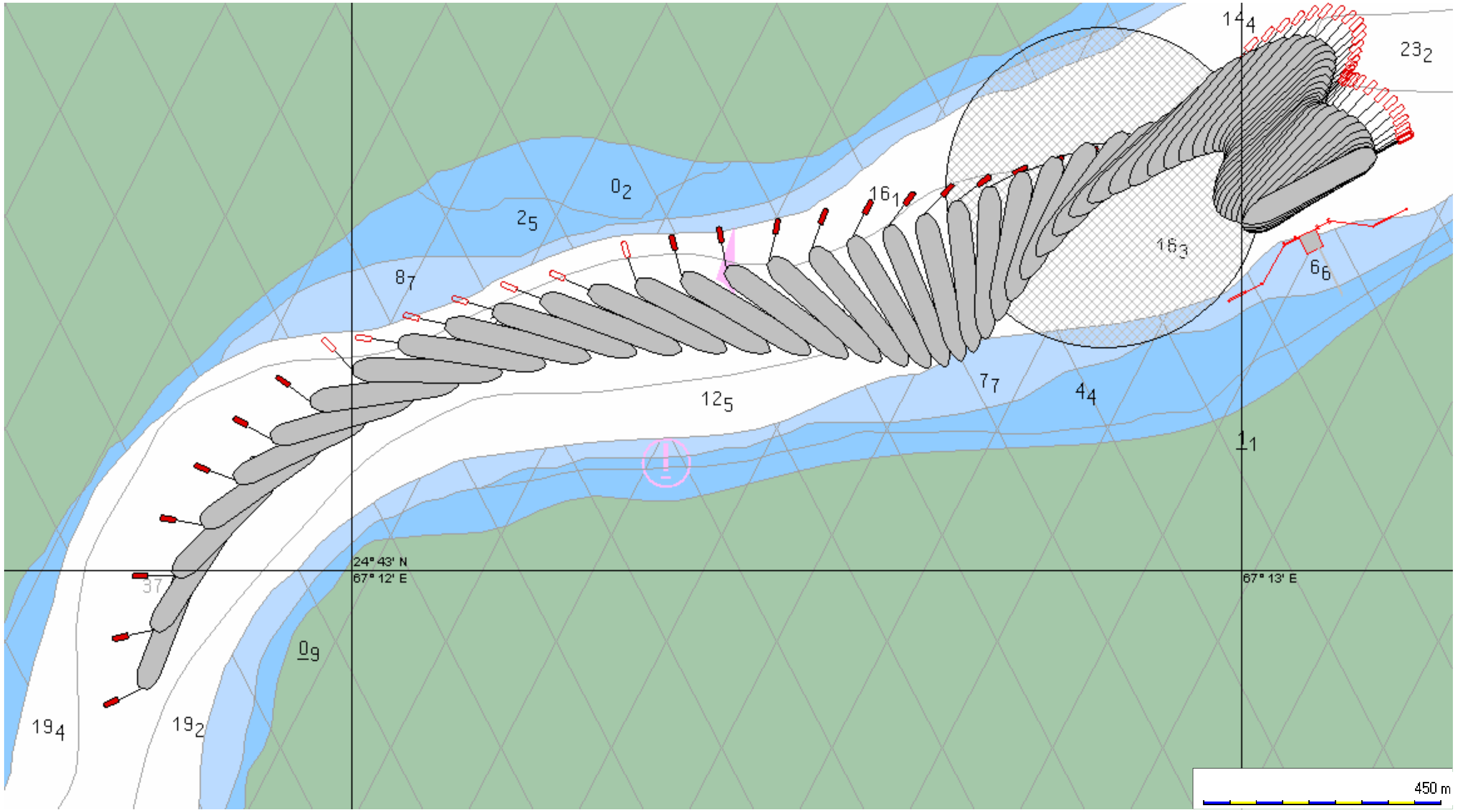
Vessel Track With Tugs



Vessel: LNG Carrier 005 (L) (+Tugs)
Harbour: Qasim
Created: 02/03/2011

Wind: 20.00 kts 225 °
Current: Variable
Depth: 1.0 m above Chart Datum

Vessel Track With Tugs



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Project:	Port Qasim LNG Terminal Study	Job No.:	L30090	Captain/Pilot:	Chris Bordas
Subject:	PC Rembrandt Simulation Study for Lloyd's Register				
Date:	02/03/2011				

Run No.	Vessel		Access Condition		Environmental Conditions			Manoeuvre
	Ship	Condition	Type	No of Tugs Used	Current	Wind Speed (Direction from)	Waves (Ht/Period)	Thrusters used?
34	LNG 004	Loaded (12.2m)	Departure	2	3kt Flood	20kts (225)	-	No

Following on from Run 33, Run 34 was a departure in the same channel. Heading into the flood current proved more challenging than following it but even so the run was completed with no real difficulties.

Ratings	1	2	3	4	5	6	7	8
	Easy	Straight-forward	Comfortable	Not demanding (circled)	Not easy	Challenging	Difficult	Impossible

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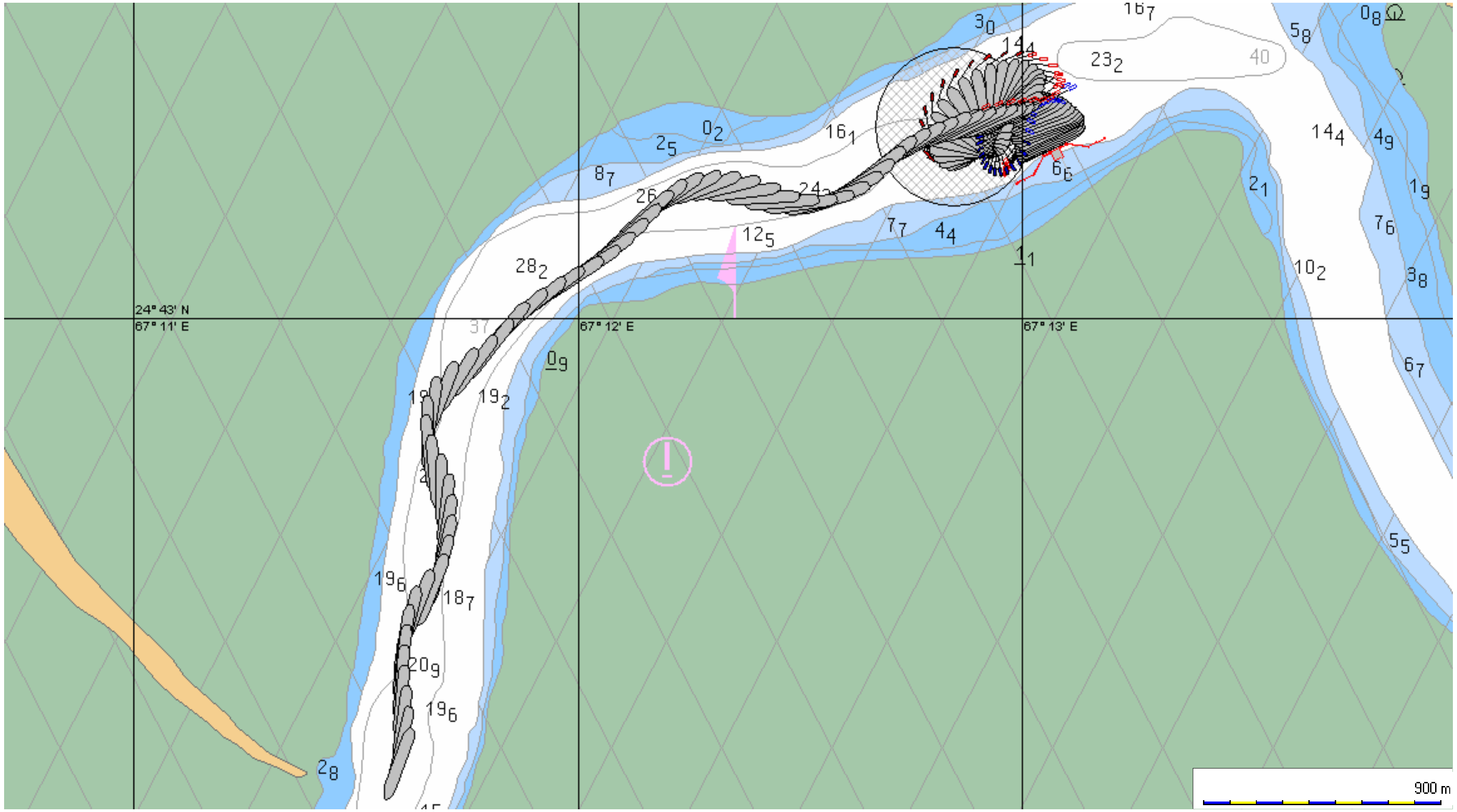

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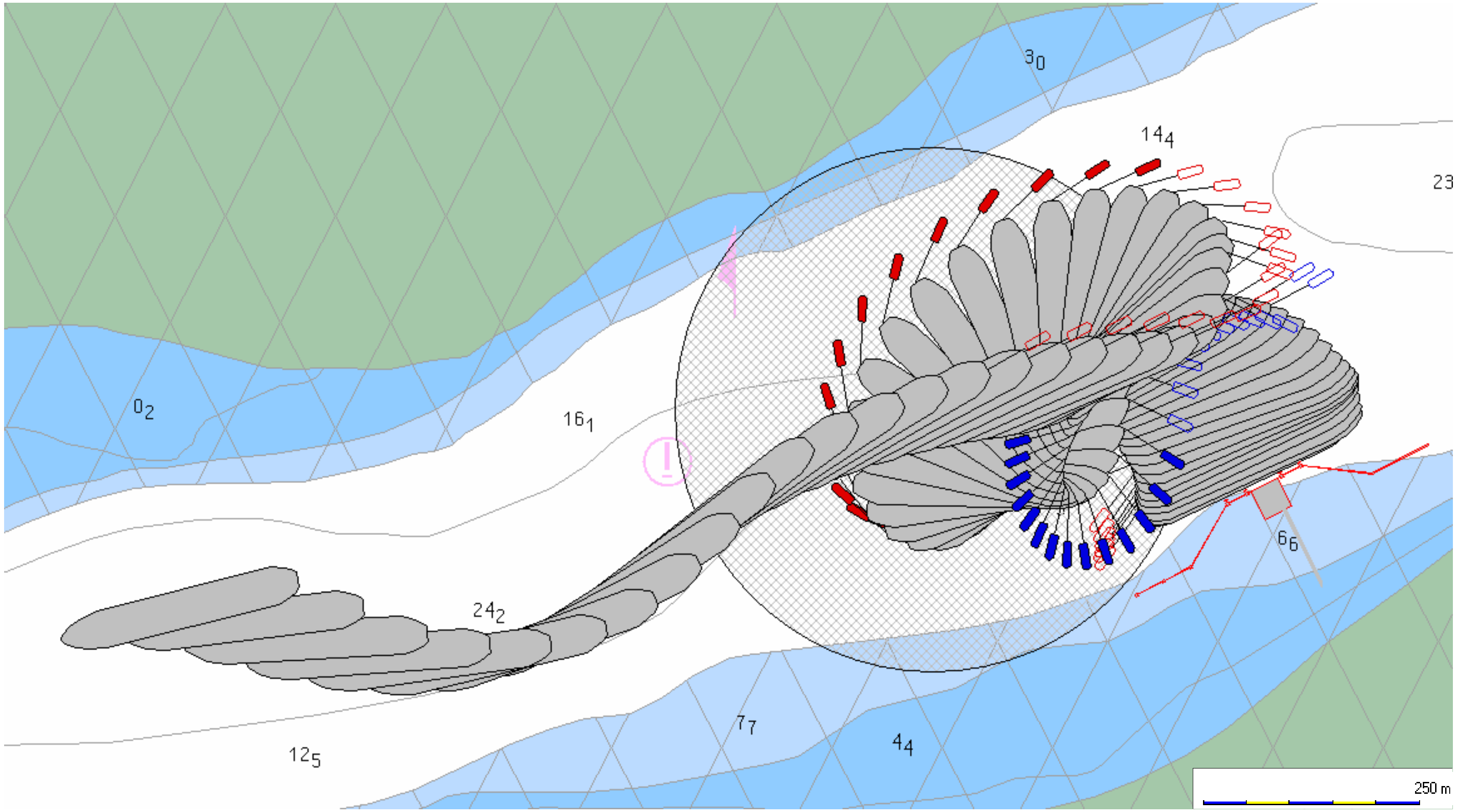

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Harbour: Qasim
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