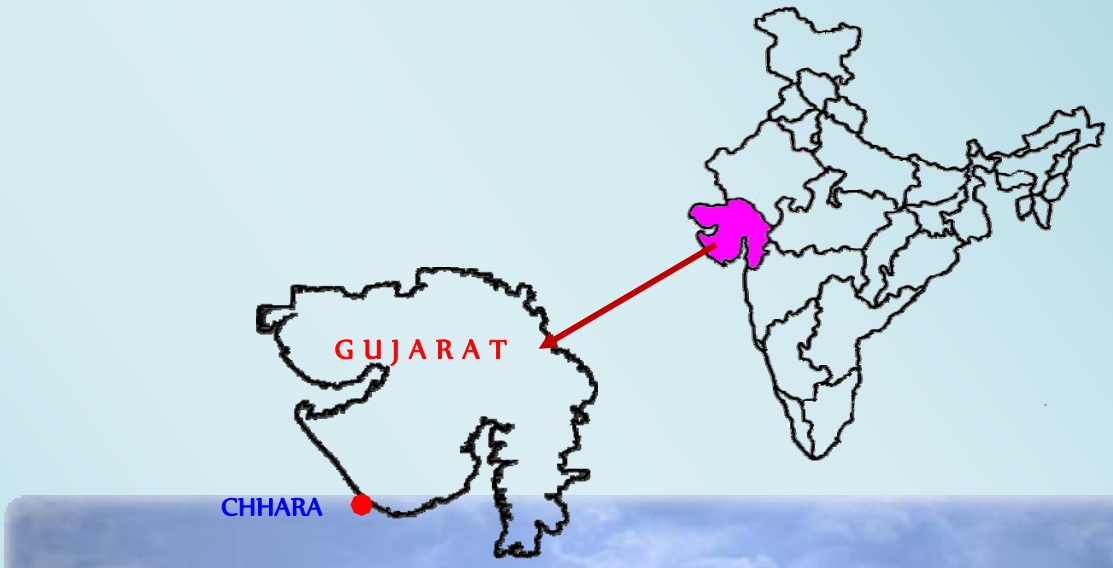
Risk Assessment Study for Proposed 10 MMTPA LNG Terminal at Chhara Village in Kodinar Taluka, District Gir Somnath, Gujarat

Sponsor

HPCL Shapoorji Energy Limited (HSEL)



CSIR-National Environmental Engineering Research Institute,
Nehru Marg, Nagpur

March 2015

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QUALITY CONTROL SHEET

Project	Revision No.	Date
Risk Assessment Study Report	-	March 2015

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Title: Risk Assessment Study for Proposed 10 MMTPA LNG Terminal at Chhara Village in Kodinar Taluka, District Gir Somnath, Gujarat

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Contents

List of Figures

List of Tables

Executive Summary

Project Description

Hindustan Petroleum Corporation Ltd., (HPCL) and SP Ports Pvt. Ltd., (SPPPL) are planning to develop a LNG Receiving, Storage and Regasification Terminal at Chhara Port in Junagarh district, in the state of Gujarat, India. Chhara site lies at extreme south coast of Gujarat state on the map of India. Chhara LNG Terminal is a part of Chhara Port expansion plan. It is proposed to implement project in two stages. Stage one will comprise of Floating Storage & Regasification Unit (FSRU) vessel that will be berthed at marine jetty on continuous basis and carrier vessel shall unload LNG on regular basis to FSRU. This LNG will be regasified on FSRU and supplied to gas gird. It will make RLNG available to customers much prior to completion of on-shore LNG import, storage and regasification terminal. Stage two is divided into two phases. Phase I is construction of 5 MMTPA on shore LNG storage and regasification facilities. Phase II is construction of additional 5 MMTPA on shore LNG storage and regasification facilities

Methodology for Risk Assessment

Hazard Identification:

The aim of this step is to identify events which pose a high risk to safety and the environment. Hazards are identified through computation of Fire and Explosion Index (FEI). It estimates the global risk associated with a process unit and classifies the units according to their general level of risk. FEI covers aspects related to the intrinsic hazard of materials, the quantities handled and operating conditions. Most of the units are under classified under light to moderate category.

Consequence Analysis:

Consequence analysis defines an accident with maximum damage distance, which is believed to be probable. In practice, the selection of accident scenarios for the analysis is carried out on the basis of engineering judgement and past accident analysis.

The Consequence Analysis was carried out for the process units using software package PHAST Professional v 6.51. Following scenarios were considered while carrying out consequence analysis:

- 25mm & 50mm leak

- Line Rupture
- Catastrophic rupture

For LNG carriers and LNG storage tanks the leak scenarios of 300mm and 1000mm were considered. The following accidental release scenarios were visualized to compute damage distances with recourse to consequence analysis:

- Jet Fire
- Pool fire
- Flash Fire
- Vapour Cloud Explosion

Conclusions and Recommendations

Following are the damage distances computed for specific scenarios and the recommendations based thereon

- Jet fire effect in LNG storage tank due to a leak scenario of 1000 mm for the heat load of 4.0 kW/m² is 261.46 m at 5D Condition. These damage distances are small but proper extinguishing system must be installed to counter if any incident occurs.
- Jet fire effect in LNG pipeline due to a leak scenario of 50 mm for the heat load of 4 kW/m² is 93.52 m at 2F Condition. These damage distances are well within the limits and it doesn't have any adverse effect on nearby units
- Maximum effect of flash fire in LNG pipeline due to line rupture at LFL concentration 44000 ppm and 2F condition is up to 335.06 m it may damage the nearby units. It is recommended that the fire fighting facilities should be provided as per OISD, NFPA guidelines
- In this Risk Assessment Study various assumptions for process conditions, equipment layout have been considered to carry out consequence analysis due to partial and full rupture scenarios. However, it is recommended to carry out Quantitative Risk Assessment (QRA) study during detailed engineering

Chapter 1
Introduction

1.1 Preamble

HPCL Shapoorji Energy Limited (HSEL) is a Joint Venture between SP Ports Pvt. Ltd. (SPPPL) and Hindustan Petroleum Corporation Ltd. HSEL proposes to develop LNG regasification terminal at village Chhara, taluka Kodinar, District Gir Somnath, Gujarat. On-shore LNG storage and regasification facilities for 5 MMTPA capacity (expandable to 10 MMTPA) are planned. Land for the LNG Terminal is within boundary of port being developed by M/s Simar Port Limited (SPL). Land will be leased to M/s HSEL by M/s SPL.

HPCL is a Government of India Enterprise with a Navratna Status, and a Forbes 2000 and Global Fortune 500 company. It had originally been incorporated as a company under the Indian Companies Act 1913. It is listed on the Bombay Stock exchange (BSE) and National Stock Exchange (NSE), India. HPCL has an annual sales/income from operations of Rs 2,32,188 Crores (US$ 38.75 Billions) during FY 2013-14, having about 20% Marketing share in India among PSUs and a strong market infrastructure. HPCL's Crude Throughput and Market Sales (including exports) are 15.51 Million Metric Tonnes (MMT) and 30.96 MMT respectively in the same period. It operates 2 major refineries producing a wide variety of petroleum fuels & specialties, one in Mumbai (West Coast) of 6.5 Million Metric Tonnes Per Annum (MMTPA) capacity and the other in Vishakapatnam, (East Coast) with a capacity of 8.3 MMTPA. HPCL holds an equity stake of 16.95% in Mangalore Refinery & Petrochemicals Limited, a state-of-the-art refinery at Mangalore with a capacity of 15 MMTPA. In addition, HPCL has constructed a 9 MMTPA refinery at Bathinda, in Punjab, with Mittal Energy Investments Pte. Ltd. as a Joint Venture.

HPCL also owns and operates the largest Lube Refinery in the India producing Lube Base Oils of international standards, with a capacity of 428 TMT. This Lube Refinery accounts for over 40% of the India's total Lube Base Oil production. Presently HPCL produces over 300+ grades of Lubes, Specialities and Greases.

HPCL's vast marketing network consists of 13 Zonal offices in major cities and 101 Regional Offices facilitated by a Supply & Distribution infrastructure comprising Terminals, Pipeline networks, Aviation Service Stations, LPG Bottling Plants, Inland Relay Depots & Retail Outlets, Lube and LPG Distributorships. HPCL, over the years, has moved from strength to strength on all fronts. The refining capacity steadily increased from 5.5 MMTPA in 1984/85 to 14.8 MMTPA presently.

Shapoorji Pallonji is a name which has become synonymous with trust and quality in India as well as internationally. Over the years the Shapoorji Pallonji Group has evolved and grown exponentially to become a huge conglomerate with multiple business segments. With a rich legacy, a progressive outlook and a consistently superior track record, the Group remains committed towards excellence.

Shapoorji Pallonji is a dynamic enterprise, which draws vital support from its various individual entities to be able to execute turnkey projects, swiftly and efficiently. Along with the flagship company Shapoorji Pallonji & Co. Pvt. Ltd. (specializing in construction, design and build and EPC), the other luminaries give the SP Group its tremendous strength and capability. Today, with over 30,000 employees and presence in more than 20 sectors, Shapoorji Pallonji has evolved and grown exponentially into multiple business segments with a progressive outlook and a thoroughly professional approach. The Group today has a strong presence in India and internationally including the Middle East and Africa. With a rich legacy of 150 years and a consistently superior track record, Shapoorji Pallonji remains committed towards excellence in each of its operation. The business interest covers construction (including residential, commercial, industrial and infrastructure), real estate, infrastructure (comprising coal mining, power, ports and roads), bio-fuels and agriculture, consumer products, electro-mechanical and MEP services, facades and interiors, engineering, textiles, business automation and shipping and logistics.

Shapoorji Pallonji has also taken a major step in the strategic area of Oil and Gas exploration for the country. Together with Bumi Armada Berhad – the Malaysian international offshore oil and gas services provider, it has successfully delivered the first Floating Production, Storage and Offloading Vessel (“FPSO”) for D1 field of ONGC in a record time of 16 months.

1.2 Purpose of the Study

HSEL is planning to set up LNG terminal in Gujarat which can cater to the entire region of northern and western India (Gujarat, Rajasthan, Madhya Pradesh, Maharashtra, Punjab, Haryana, Delhi, Uttar Pradesh, Goa, Himachal Pradesh, Uttarakhand, Jammu and Kashmir and Chandigarh). As per EIA Notification 2006, the project requires Prior Environmental Clearance and CRZ Clearance from Ministry of Environment, Forest, and Climate Change (MoEFCC) based on Comprehensive EIA study.

M/s HSEL had submitted application alongwith Form I to MoEFCC in January 2014. The proposal for was considered by the Expert Appraisal Committee (EAC) in its meetings held on 28th February 1st March, 2014 and 21st - 22nd April, 2014. MoEFCC vide letter dated 13th June, 2014, communicated following "Terms of Reference".

M/s HSEL retained CSIR-NEERI for carrying out Comprehensive EIA Study in compliance with TOR issued by MoEFCC. M/s HSEL, separately engaged following consultants and submitted reports to CSIR-NEERI for suitably incorporating in EIA study:

- National Institute of Oceanography (NIO) for Comprehensive Marine EIA Study
- Institute of Remote Sensing (IRS), Anna University, Chennai for preparation of CRZ Map and superimposing proposed facilities on CRZ Map.
- DHI Water & Environment (s) Pte Ltd., for 2-D Navigation Study, 3-D Full Mission Ship Simulations Study, Marine Modelling for Cyclones and Tsunami, and Littoral Drift Assessment Study

1.3 Scope of EIA

The scope of study as per the proposed ToR includes detailed characterization of the existing status of environment around the proposed project activity at Chhara for various environmental components viz., air, water, noise, land, socio-economic and biological components along with the parameters of human

interest, prediction and evaluation of significant environmental impacts and formulation of detailed Environmental Management Plan (EMP).

Under the scope of EIA, it is envisaged:

Preparation of environmental impact assessment reports incorporating baseline data for one and three seasons respectively, environmental impact statement based on identification, prediction and evaluation of impacts and environmental management plan for activities at proposed Project facilities.

1.4 Objectives of EIA

Preparation of environmental impact assessment study reports for obtaining environmental clearances from the regulatory agencies. The study will be conducted as per the MoEFCC notification for Environmental Impact Assessment covering baseline data covering three season data for land based facilities. The objectives of proposed study will be:

- Collection of primary data supported by secondary data in the region for assessment of baseline quality of marine environment including water, sediment and biological components and secondary data from state/local departments
- Collection of existing hydrography data supported by secondary data already collected in offshore region in the vicinity of the field during pre-monsoon and post-monsoon seasons
- Assessment of the present status of air, noise, water, land, biological and socio-economic components of environment including parameters of human interest upto 10 km radial distance from the site proposed for LNG terminal including pipeline route
- Identification of potential impacts on various environmental components due to activities envisaged during construction and operational phases of the proposed project
- Prediction of impacts on the various environmental components using appropriate mathematical/simulation models

- Preparation of environmental impact statement based on the identification, prediction and evaluation of impacts

- Delineation of accompanying assessments and plans required such as the Environmental Management Plan (EMP) outlining preventive and control strategies for minimising adverse impacts during construction and operational stages of the proposed projects along with the cost and time-schedule for implementation of EMP

- Formulation of environmental quality monitoring programmes for construction and operational phases to be pursued by the project proponent as per the requirements of statutory authorities

- Delineation of post project environment quality monitoring programme

- Assessment of proposed terminal site based on coastal zone regulation for obtaining clearance from Gujarat Coastal Zone management authority

- Provide assistance in Public Hearing to be conducted for the project as per the EIA Notification 2006 and the compliance of the issues raised by the public and incorporation in the EIA-EMP report and Technical Committee Meetings at State level and technical presentation and for environmental clearance (EC) from MoEFCC, New Delhi

1.5 Activities for each Environmental Component

The details of work plan under individual components of environment are as follows:

1.5.1 Air Environment

- Design of ambient air quality network after identifying zone of maximum Ground Level Concentrations (GLCs) using appropriate air quality screening models

- Assessment of existing levels of $PM_{2.5}$, PM_{10}, SO_2 and NO_X in ambient air and if required the levels of CO, H_2S and HC and any other site specific parameters (NMHCs and VOCs)

- Collection of meteorological data, viz., wind speed, wind direction, relative humidity, temperature, lapse rate and cloud cover concurrently with ambient air quality monitoring

- Inventory of point, line and area sources of air pollution and quantification of emission (secondary data source)

- Estimation of air emissions including fugitive emissions from the proposed project activities

- Evaluation of atmospheric emissions and prediction of Ground Level Concentrations of air pollutants through appropriate air quality models incorporating the requirements specified in the publication of Central Pollution Control Board "Assessment of Impact to Air Environment : Guidelines for conducting Air Quality Modelling"

- Assessment of anticipatory changes in air quality and suggesting mitigation measures

- Evaluation of the adequacy of the proposed pollution control measures to meet air quality emission standards and TLVs for the workers on site, dust separation and VOCs at Proposed developmental activities

1.5.2 Noise Environment

- Measurement of noise levels in residential/ commercial/sensitive zones in the study area

- Identification of high level noise zones requiring mitigation measures

- Monitoring of noise levels due to stationary and vehicular sources

- Studies on existing traffic movement and impact of proposed activities on existing transportation system. Keeping in view the increase in traffic movement, assessment of additional facilities to be created and suggestions on safety measures to be followed

- Prediction and evaluation of impacts due to increase in noise levels arising out of the proposed project on the surrounding environment

- Evaluation of existing and proposed noise pollution control measures
- Recommendations on mitigation measures for noise pollution and to control noise impact

1.5.3 Water Environment

- Study of existing ground and surface water resources with respect to its quantity and quality (physico-chemical, biological and bacteriological characterization including estuary and coastal marine water)
- Impact of project operations on water demand of other users vis-à-vis regional water balance
- Assessment of abiotic and biotic characteristics of water and sediment components of marine environment
- Assessment of mangrove forests/vegetation in the coastal and inter tidal zone
- Assessment of primary and secondary productivity in the coastal region
- Assessment of wastewater characteristics and quantity to be discharged from the proposed project
- Assessment of domestic waste (sewage) generation, treatment and disposal as an integrate part of wastewater management
- Study existing drainage pattern and impact of the project on drainage pattern
- Study the discharges (bilge, cargo residue, operational waste, wastewater) generated during shipping operations
- Prediction of impacts on quality of receiving water body using appropriate mathematical/simulation models
- Evaluation of proposed wastewater treatment systems
- Recommendations on water conservation measures

- Assessment of feasibility of water recycle and reuse for green belt development and irrigation
- Assessment and evaluation of impacts marine ecosystem through modeling due to accidental release of pollutants

1.5.4 Marine Environment

- Assessment of marine physical water quality, sea state condition (Hydrography)
- Assessment of water quality for chemical and biological parameters including planktons and primary productivity
- Assessment of sediment quality in terms of texture, particle size distribution organic pollutants and heavy metals
- Assessment of sediment quality for biotic parameters such as benthos (mieo and micro fauna)
- Assessment of mangrove ecosystem, corals in the vicinity of project site
- Bathymetric study to assess tranquility conditions at the proposed site
- Impact on shore line changes along the stretch. Suggestion on measures to be taken to prevent erosion in the area
- Details of reclamation and the impact of reclamation on the marine ecology
- Prediction of impacts due to dredging, disposal of dredged material (capital and maintenance) during construction phase through modeling and impacts of liquid emissions on biological life during operation phase
- Details of hydraulic studies and the dispersion model of the dredged dumping site

- Delineation of mitigation measures during construction including dredging and disposal of dredged material, accidental oil spill, operational oil spill to minimize the impacts
- Delineation of environmental management plan including post project monitoring
- Suggesting contingency plan, taking into account the accident scenario and natural disasters

1.5.5 Land Environment

- Study of land requirement for the proposed developments
- Study of existing landuse and cropping patterns, vegetation, forestry, wastelands Studies on soil characteristics in the study area
- Assessment of impacts on landuse pattern with respect to agriculture and forestry due to proposed projects
- Characterization of solid wastes likely to be generated and its disposal
- A regional developmental plan existing or new to be viewed for assessing impact of the project on the existing habitation and infrastructure
- Impact of other construction activities on the shore line and the terrestrial environment
- Delineation of environmentally compatible options for value added utilisation; and other management options for environmentally compatible disposal of solid and hazardous wastes
- Mathematical modelling studies for groundwater contamination, if needed
- Design of green belt and identification of suitable native plant species for the proposed green belt
- Delineation of regional land environment management plan

1.5.6 Biological Environment

- Collection of information about flora and fauna (terrestrial and marine) and determination of species diversity, density, abundance etc.
- Identification of rare and endangered species in the study area
- Collection of ecological information on aquatic ecosystems
- Assessment of potential impacts on aquatic flora and fauna due to effluent discharges
- Assessment of impacts on terrestrial flora and fauna due to air emissions and landuse changes
- Prediction of stress on biological environment in the study area
- Delineation of measures for abatement/reduction of biological stress and regional management plan for biological environment

1.5.7 Socio-economic and Health Environment

Collection of baseline data related to socio-economic profile of the study area with reference to:

- Stakeholders relevant to the Project
- Human settlements, male/female ratio, occupational pattern, employment and income
- Infrastructure resource base, viz., medical, education, water resources, power supply
- Economic resource base, viz., agriculture, industries, forest, trade and commerce
- Health Status, viz., morbidity pattern with reference to prominent and endemic diseases (e.g. fluorosis, malaria, filaria)
- Cultural and Aesthetic attributes in the study area including places of historical/ archaeological importance

- Assessment of economic benefits to community and environment due to existing and proposed developmental activities
- Socio-economic survey to assess the Quality of Life of the people in the study area and their perceptions about the projects
- Review of Resettlement and Rehabilitation Plan Prepared for the project
- Projection of anticipated changes due to the proposed projects, and delineation of measures to minimise the impacts
- Assessment of impacts on places of historical/archaeological importance and aesthetic impairment, if any
- Assessment of economic benefits to community and environment due to the proposed projects
- Delineation of regional socio-economic environment management plan through initiation of beneficial activities (welfare) for local communities providing financial support
- Assessment of impact due to the proposed activities on fishing and suggestion of management plan and provision to be made under CSR

1.6 Environmental Management Plan

- Environmental Management Plan (EMP) will be drawn separately for the construction and operational phase after identifying, predicting and evaluating the impacts on each component of the environment with a view to maximising the benefits from the project. Post-project Environmental Monitoring (PPEM) will be delineated with parameters and costs.
- Details of safety aspects associated with handling of LNG vis-à-vis other cargo in other facilities within the port

1.7 Approved Terms of Reference (ToR) for RA Study

The proposal for development of LNG storage and regasification terminal at village Chhara Taluka Kodinar, District Gir Somnath, Gujarat by M/s HPCL Shapoorji Energy Ltd., was considered by the EAC in its meetings held on 28th February - 1st March, 2014 and 21st - 22nd April, 2014. MoEFCC vide letter dated 13th June, 2014, communicated following "Terms of Reference" were finalized to be suitably added to those furnished by HSEL:

(i) Submit the details of the various applicable regulations including safety regulations along with the proposed compliances. Also details of safety aspects associated with handling of LNG other cargo in other facilities within the port.

(ii) Submit the details of the HAZOP analysis.

(iii) Submit the layout along with the port boundary.

(iv) Submit details of Risk Assessment, Disaster Management Plan including emergency evacuation during natural and man-made disaster like floods, cyclone, tsunami and earth quakes etc along with design details.

(v) Submit a copy of layout superimposed on the HTL/LTL map demarcated by an authorized agency on 1:4000 scale along with the recommendation of the SCZMA.

(vi) Submit the details of the storage and regasification, distribution network etc and vulnerability of human habitation Vis a Vis LNG associated risks.

(vii) Type of LNG carriers proposed taking into account the future growth in vessel sizes beyond the present day market trend and the handling aspects of such vessels from environmental considerations.

(viii) Submit the Hydrodynamic study as required under OM dtd. 3.11.2009.

(ix) Ship Navigation simulation studies covering approach channel and turning circle to ensure the safety of LNG carrier under various hydrodynamic conditions.

(x) Submit the details of the reclamation along with the source of materials and its quantity & quality.

(xi) Submit the details of shore line changes along with the shore protection if required.

(xii) Submit the details of Environmental Management Plan and Environmental Monitoring Plan with parameters and costs. The EIA report shall be based on the comprehensive marine data of not later than 3 years.

(xiii) Submit the details of the fishing activity and likely impact due to the activity.

(xiv) Submit the details of the land breakup along with land use plan and Details of green belt development.

(xv) Submit the details of the solid/liquid wastes generation and their management.

(xvi) Submit the details of Water requirement, source, impact on competitive users.

(xvii) Submit the details of the eco-sensitive areas, if any.

(xviii) Submit the details of Oil Spill Contingent Management Plan.

(xix) Submit the details of dredging sludge quantity quality in terms of its toxic metals (at least Cr^{+6}, Arsenic, Mercury, and lead) and its disposal with quantity (reclamation/ dredging disposal site) If disposal is in sea, location, the justification for selecting such location, the dispersal of dumping material, its effect on marine environment, effect of fishes.

(xx) Submit the details of study on connectivity and its carrying capacity (both road and railway).

General Guidelines

(i) The EIA document shall be printed on both sides, as far as possible.

(ii) The status of accreditation of the EIA consultant with NABETI QCI shall be specifically mentioned. The consultant shall certify that his accreditation is for the sector for which this EIA is prepared.

(iii) On the front page of EIA/EMP reports, the name of the consultant/ consultancy firm alongwith their complete details including their accreditation, if any shall be indicated. The consultant while submitting the EIA/EMP report shall give an undertaking to the effect that the model TORs have been complied with and the data submitted is factually correct (Refer MoEFCC Office Memorandum No. J11013/41/2006- IA.II (I) dated 4th August, 2009).

(iv) While submitting the EIA/EMP reports, the mime of the experts associated with/involved in the preparation of these reports and the laboratories through which the samples have been analysed should be stated in the report. It shall clearly be indicated whether these laboratories are approved under the Environment (Protection) Act, 1986 and the rules made there under (Please refer MoEFCC Office Memorandum No. J-11013/41/2006-IA.II(I) dated 4th August, 2009). The project leader of the EIA study shall also be mentioned.

(v) Environmental Management Plan presented before the EAC as a part of EIA report, shall be made part of Concessionaire Agreement / other relevant documents. Proponent shall submit an undertaking in this regard.

(vi) Since most of the environmental Issues are related to design parameters, following additional information should also be provided by PP apart from the information required as per Chapter 12 of the EIA Guideline manual for Highways (Disclosure of Consultant)

a) Name of the Design Consultant.

b) Name of the EIA consultant, EIA Coordinator, Functional Area Expert and details of accreditation.

(vii) The EIA report shall be prepared as per the EIA Notification, 2006, as amended from time to time.

Public hearing to be conducted for the project according to the provisions of Environmental Impact Assessment Notification, 2006 and the issues raised by the public should be addressed in the Environmental Management Plan.

A detailed draft EIA/EMP report should be prepared according to the above additional TOR and should be submitted to the Ministry according to the Notification.

The prescribed ToRs would be valid for a period of two years for submission of the EIA/EMP Reports, after public consultation.

Accordingly as per the approved ToR, EIA/EMP report is prepared based on the comprehensive monitoring carried out during the period winter, summer and pre-monsoon seasons (2014-15), covering all the environmental components viz. air, noise, water, land, biological and socio-economic including hydrography data of pre and post-monsoon seasons and marine environment (biotic and abiotic). The EIA report covers the prediction of impact for three seasons and accordingly environmental management plan.

Proposed Port Site

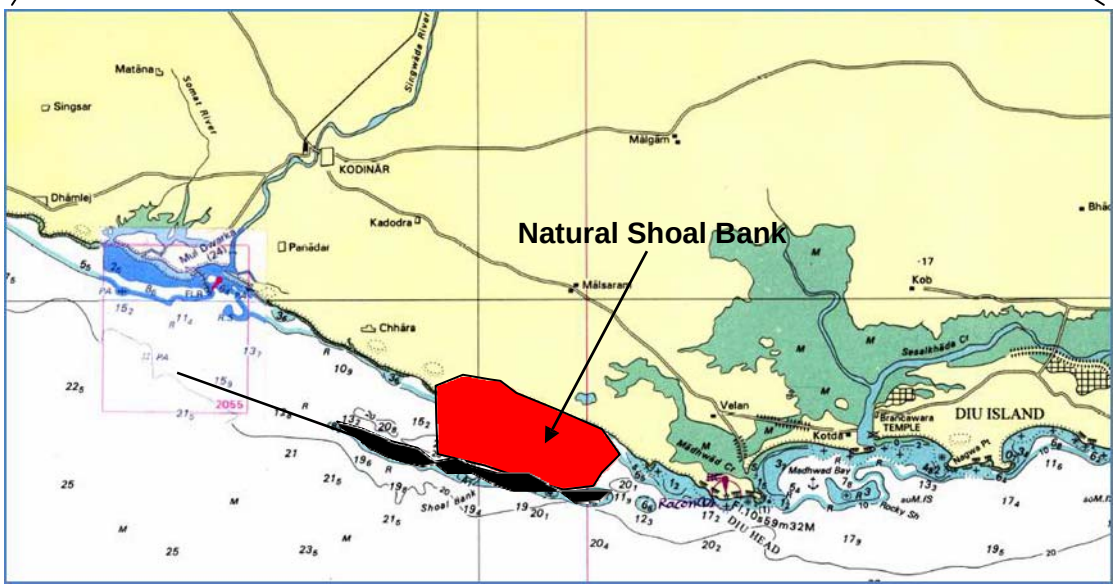


Fig. 1.1: Location of Proposed Chhara Port and LNG Terminal

Chapter 2
Project Description

2.1 Background

HPCL Shapoorji Energy Limited (HSEL) is a Joint Venture between SP Ports Pvt. Ltd. (SPPPL) and Hindustan Petroleum Corporation Ltd. HSEL proposes to develop LNG regasification terminal at village Chhara, taluka Kodinar, District Gir Somnath, Gujarat. On-shore LNG storage and regasification facilities for 5 MMTPA capacity (expandable to 10 MMTPA) are planned. Land for the LNG Terminal is within boundary of port being developed by M/s Simar Port Limited (SPL). Land will be leased to M/s HSEL by M/s SPL. Location of proposed LNG Terminal is shown in Google map in **Fig. 2.1**.

M/s Simar Port Limited (SPL), a Shapoorji Pallonji Group Company, is developing a deep draft, direct berthing, all weather port at Chhara in Gujarat. The Chhara port falls approximately between Latitude - 20° 43' 19.56" N and Longitude- 70° 44' 28.73" E. The port site has a shoal bank at 2.5 km distance from shore. The berthing area has water depth of 20 m below CD and can accommodate even a fully laden larger size vessel. MoEFCC has granted EC for construction of Breakwater (Length: 1700 m, Width : 75 m at bottom, Height: 10 m above CD level), Berth (One No., Length: 350 m, Width: 25 m), Approach trestle (Length: 2265 m, Width: 12 m); approach channel of width 300m and turning radius 600m, Capital Dredging 1.5 Million Cum, and allied infrastructure facilities. Environmental Clearance and CRZ Clearance based on Comprehensive EIA study for Phase I of the Port was granted by MoEFCC in Jan 2014. Facilities that have been granted EC & CRZ Clearance are listed in **Table 2.1**. For LNG facility, the length of breakwater shall be extended to 4700 m by SPL.

2.2 Need for LNG Terminal

It is well understood that the gas demand is likely to increase many folds from in the next two decades. Also, the envisaged growth of Indian economy will improve the affordability of the consumers over the time. Whilst the power sector is expected to remain the largest consumer category for gas, the Industrial and City Gas Distribution (CGD) sectors are likely to emerge as the fastest growing demand

centres. At the same time, gas supplies may not be able to keep pace with the growth in demand. Most of the gas production in India is by Oil and Natural gas Corporation Ltd. (ONGC) and Oil India Ltd. (OIL). Since most of the existing fields have been under production for over two decades, supply from these fields is projected to decline significantly over the next few years. Even after considering the plans of various players for developing newly discovered domestic fields and also the plans to expand/set up new LNG terminals, the demand-supply gap is envisaged to widen from 122 MMSCMD in FY13 to 687 MMSCMD by FY35.

In view these projections, HSEL is planning to set up LNG terminal in Gujarat which can cater to the entire region of northern and western India (Gujarat, Rajasthan, Madhya Pradesh, Maharashtra, Punjab, Haryana, Delhi, Uttar Pradesh, Goa, Himachal Pradesh, Uttarakhand, Jammu and Kashmir and Chandigarh).

2.3 Terminal Layout

The LNG plant layout has been arranged within premises of Chhara Port. Land use plan of LNG Terminal is presented in **Table 2.2**. The location of the plant is such that adequate safety distance is maintained from the other berths at Chhara Port. The LNG unloading jetty will be protected by the breakwaters on the South of the Jetty. Terminal Layout of Chhara Port is shown in **Fig. 2.2**. Proposed facilities were superimposed by Institute of Remote Sensing (IRS), Anna University on CRZ Map of scale 1:4000. These are shown in **Fig. 2.3** and listed in **Table 2.3**.

The marine component of the LNG terminal is expected to cater for a range of vessels size (80,000-266,000 m^3) as given in **Table 2.4**. The expected berth occupancy details for the LNG facility are summarized in **Table 2.5**.

2.4 Connectivity

2.4.1 Rail Connectivity

Chhara Port is proposed to be connected through broad gauge (BG) line with Kodinar. BG line from Somnath to Kodinar will be developed by Indian Railways. Railway Board has provided in-principle approval for Kodinar-Chhara rail line under Non-Government Railway policy. Connectivity to Chhara Port up to Kodinar has been included in Rail budget 2015-16 under Coastal Connectivity Program and INR 50 Cr budget has been allocated by Indian Railways. Envisaged rail connectivity is shown in **Fig. 2.4**.

2.4.2 Road Connectivity

NH 8E is approximately 6.5km from the Port on the North of Chhara Port. Road and Building department, Gujarat will be constructing road to connect Port with NH 8E. Envisaged road connectivity is shown in **Fig. 2.5**.

2.4.3 Pipeline Grid Connectivity

Proposed terminal will be connected to existing grid by GSPC as shown in **Fig. 2.6**.

2.5 LNG Regasification Process Description

LNG at atmospheric pressure and (-)162°C temperature will be transported by sea in specially designed and dedicated LNG vessels of 80,000 to 2,66,000 m^3 capacity at the Jetty to be located at Chhara. The LNG ships will be brought to the unloading jetty by Tug Boats from the mouth of channel with the guidance of experienced pilot. Channel width of approach channel in Chhara port will be 300 m. The turning area will be 600 m in diameter and depth of the approach channel will be (-)20 m CD. This will be adequate for bringing Q-Max ships (266,000 m^3 capacity). No additional dredging (beyond approved by MoEFCC for Simar Port, vide EC letter dated Jan 6, 2014) is envisaged for meeting LNG ship requirement.

LNG will be unloaded at the rate of 14,000 m^3/hr using unloading arms at the dedicated LNG berth. The unloading arms will be moved with a remote-controlled hydraulic system located on the berth. When they are lined up with the LNG carrier, the two will be then secured by bolts or quick connect couplings. After connection is completed, the communication cable will be connected to shore and the emergency shutdown system will be tested. After the unloading arms are cooled, the LNG will be transferred from the carrier to the storage tanks using the carrier's pumps. The discharge of LNG from the carrier will take 12-19 hours depending upon the capacity of the ship. In addition, approximately 3 hours will be required for mooring, cool down, connecting unloading arms, and approximately 3 hours will be required for arm purging, disconnecting arms, and unmooring.

LNG will be stored in tanks in on-shore terminal. Stored LNG will be re-gasified in order to be transported by gas pipeline to the end users. This will be accomplished via LNG Vaporizers using Water Glycol system. Once the LNG is vaporized, the gas will be then piped to the consumer.

LNG unloading & regasification facilities process flow is shown in **Fig. 2.6**.

2.6 LNG Terminal Description

Facilities proposed to be developed for on-shore terminal include receiving facility sized to allow unloading of carriers of 80 000 m^3 to 266 000 m^3, one main jetty with a provision for one standby Jetty, trestle for LNG unloading lines, 2 self-supporting full containment LNG storage tanks of 200,000 m^3 each, and LNG vaporization with shell & tube vaporizer (STV) and supplemented by submerged combustion vaporizer (SCV) for cold weather conditions. 18 MW gas based captive power plant will be main source of power with backup from State Grid. For evacuating RLNG, pipeline will be laid to connect to Gujarat State Petronet Limited (GSPL) Gas grid on Darod-Jafrabad section by GSPL. The LNG terminal buildings proposed include Security Gate house, Administration building, metering station, workshop, warehouse and watch towers. Detailed plot plan is shown in **Fig. 2.7** and list of facilities is presented in **Table 2.6**.

The LNG Terminal service-life will be:

- For onshore terminal facilities (piping and process) : 30 years
- For cryogenic transfer lines : 30 years
- For offshore marine facilities (dolphins, jetty head structure etc.) : 50 years,
- For LNG storage tanks: 50 years.

2.7 Description of Salient Facilities in LNG Terminal

2.7.1 LNG Storage Tankages

Following types of LNG storage tanks were considered for the proposed Terminal:

Single Containment Tank (SCT) - The outer tank wall and the outer tank roof are designed to protect and to retain the insulation of the inner tank, and to withstand the vapour gas pressure but not to withstand the refrigerated liquid in the event of leakage from the inner tank. Therefore, material used for the outer tank wall and roof is generally carbon steel.

Double Containment Tank (DCT) - In the double containment type, the outer tank is designed to protect insulation. The tank is also designed to withstand pressure and retain the spilled refrigerated liquid product resulting from a leakage of the inner tank. This secondary container is not designed to contain any vapour resulting from the vaporisation of the spilled LNG.

Full Containment Tank (FCT) - A full containment tank is a double tank designed such that both inner tank and outer tank are able to independently contain the refrigerated liquid stored. The outer tank is designed to withstand the full vapour pressure, the vertical loads induced by the inner tank and the pressure of all liquid spilled from the inner tank.

Comparison of SCT, DCT, and FCT based on safety considerations and layout implications is presented in **Tables 2.7 and 2.8**.

An above-ground, full containment design has been selected for LNG Tankages. LNG storage facility comprising two tanks of 200,000 m^3 each is planned and space has been provided for two additional tanks for future expansion. Full-containment LNG tanks will consist of the following:

- Primary inside tank - made of a "cryogenic material" such as 9% Nickel, steel, aluminum alloy or reinforced pre-stressed concrete.
- Insulation – loose insulation material (such as Perlite) surrounding the inner nickel-steel tank (sides, floor and roof) along with special sand, fibre glass etc.
- Outer tank – reinforced, pre-stressed concrete tank designed to independently store both the LNG liquid and vapour (if inner wall fails).
- Domed roof – reinforced, pre-stressed concrete.

An illustration of typical full containment tank is presented in **Fig. 2.8**.

The LNG tanks will have a top entry point for both the loading and unloading operations. Four submerged send-out pumps per tank will be suspended from the top of the tank to pump the LNG out of the tanks. All tanks will be designed to simultaneously send out (to the vaporizer units) and to receive LNG (from unloading LNG carriers). Pressure inside the tank will be controlled, and if pressure

starts increasing, gas will be discharged to the flare. In case, pressure control valve does not work, safety and breather valves have been provided to protect from vacuum and over-pressurization.

2.7.2 Regasification Technology

LNG vaporizers are an essential part of all LNG Terminal facilities and are used to re-gasify LNG before it can be sent to the end consumer. There are different methods for regasification, and the selection of an optimum vaporizer depends on plant site location, climatic conditions and the terminal capacity. Different types of vaporizers are:

- Shell and Tube Vaporizer (STV)
- Ambient Air Vaporizer (AAV)
- Open Rack Vaporizer (ORV)
- Submerged Combustion Vaporizers (SCV)

Factors considered in selection of regasification technology are:

- Capacity / operating parameters
- Operating flexibility and the reliability
- Environmental location of the terminal
- Availability of the utilities
- Source of heat
- Operating and the capital cost

Comparison of various regasification technologies is presented in **Table 2.9**. Selected vaporizer configuration for HSEL Chhara LNG Terminal is:

- 4 Nos. of Shell & tube vaporizers each of capacity of 174 T/hr. to meet 120% of send out capacity (5MMTPA). Each STV will have its dedicated glycol water loop including a circulation pump and an air heater

- 1 No of SCV of 174 T/hr (capacity equivalent to 1 STV) will be provided as spare for STV

Shell & tubes vaporizers (STV) consist of tubes assembly installed in a shell casing in which glycol water is circulated. These are specially designed heat exchangers for LNG service with LNG in tube side. Glycol water will be used as intermediate heating medium and the primary heat source will be ambient air. For ambient air temperatures below 24°C, SCV will support STVs.

Submerged combustion vaporizers (SCV) burn natural gas as their heat source and require electrical power to run the combustion air blower. The SCV vaporizes LNG contained inside stainless steel tubes in a submerged water bath with a combustion burner; the hot flue gases are fed into a bath of water, where the LNG vaporization coils are located.

Schematics of STV and SCV are shown in **Figs. 2.9** and **2.10**.

For heat recovery from GTG (Gas Turbine Generator), Cogeneration Heat Exchangers will be installed in the duct of GTG. The heat recovered in these exchangers will be transferred to Hot Water. Hot water (HW) will transfer its heat to Glycol Water (GW) in HW/GW Heat Exchanger. GW will transfer the heat to LNG for vaporization in STV. Accordingly, 1 No. of STV of capacity 107 T/hr will be considered for heat recovery from GTG exhaust.

2.7.3 Power Source

For Captive Power requirement, following options were considered -

- Grid as Power Source and Gas Engine as backup
- Gas Engine based Power Generation and Grid as backup
- Gas Turbine based Power Generation and Grid as backup

CPP configuration with Gas Turbine based Power Generation of 18 MW capacity is selected based on the following criteria -

- Maintenance & serviceability
- Continuous Uninterrupted Running time

- Turn Down
- Block load capability
- Emission

Design basis for CPP is presented in **Table 2.11**.

2.8 LNG Terminal Utilities Requirement

2.8.1 Power

Power will be supplied from 18 MW captive power plant with a provision of standby supply from nearest Gujarat State electric grid power supply of 66 KV available from Substation at Sarkhadi village, approx. 10 km from Project site.

In case of failure of CPP and Grid supply, Emergency Diesel Generator will be used.

2.8.2 Raw Water

During construction phase (4 years), the total water requirement of about 100 m^3/day will be met from local village wells. During operation phase, the total water requirement will be for:

- Service water - 500 m^3/day
- Make up water for fire water system - 200 m^3/day
- Horticulture purposes – 50 m^3/day
- Drinking water – 10 m^3/day

The water generated from the atmosphere (as condensate water) will be used for service water, makeup water for fire water system and horticulture water, whereas drinking water will be sourced from nearby villages.

2.8.3 Nitrogen

Nitrogen to the tune of 1500 Nm^3/hr will be required at the terminal for equipment purging and maintenance purposes. On-site nitrogen generation and storage facilities for liquid nitrogen will be provided at the terminal.

2.8.4 Compressed Air

Three air compressors will provide air required for instrument (750 Nm^3/hr), plant air (2350 Nm^3/hr) and Nitrogen (2000 Nm^3/hr).

2.8.5 Manpower

During Construction Phase: Approximately 2500 persons will be working during construction phase, which will include managerial (20%), skilled (25%) and unskilled (55%) people. Local people will be given preference for all types of worker/labour needs during the construction period.

During Operation Phase: The total manpower requirement during operation phase will be about 100, as detailed in proposed organization chart (**Fig. 2.11** and **Table 2.10**).

2.9 LNG Terminal Wastes/Emissions

2.9.1 Boil-Off Gas

Boil-off Gases (BOGs) are produced during normal terminal operations as a result of inevitable heat transfer arising from the storage and handling of LNG. This BOG will be captured and sent to the BOG compressor for re-condensing. During ship unloading operation, additional Boil-off gas is produced which will be handled by two additional BOG compressors. Compressed BOG will be sent to re-condenser. LNG liquid stream will flow from re-condenser to the High Pressure LNG pumps to raise the LNG to the send-out pressure before feeding the LNG to the LNG vaporizers. LNG will be heated and converted back to gas in the vaporizer unit by utilizing ambient heat and waste heat from gas engines/turbines.

2.9.2 Air Emissions

LNG terminal will produce various emissions during operations, as summarized below**:**

- Excess oxygen from Nitrogen generation unit;
- Exhaust gases from Emergency backup diesel generator
- Burned NG from flare
- Pressure safety valve NG vent from Knock out drum at jetty

- Pressure safety valve NG vent from Vaporizer
- Pressure Safety valve NG vent from LNG Tanks.

2.9.3 Noise

Major sources of noise will be:

- BOG Compressors
- HP LNG Pumps
- Gas Turbine Generators
- Emergency Diesel Generator

2.9.4 Wastewater

In LNG vaporization scheme normally no liquid waste is generated. Only domestic sewage (about 8 m^3/d) will be generated, which will be collected and treated in septic tanks.

Other sources, mainly due to spills or leaks are usually:

- Laboratory chemical wastewater;
- Leaks from diesel tanks;
- Lube oil leaks from transformers and rotary equipment, diesel generator, etc;

2.9.5 Solid Waste

Solid waste generation from process operation is not envisaged, whereas domestic solid waste to the tune of 50 kg/day will be generated.

2.9.6 Hazardous Waste

Hazardous waste generation from the process will be used oil (200 L/month). It will be sold to MoEF/CC/GPCB approved recyclers.

2.10 Environmental Management Plan as per DPR

2.10.1 Air Pollution Mitigation Plan

Methane Emission From Vents: The Terminal is designed on the philosophy of "minimum venting and flaring" with the following principles:

- In normal operation no gas will be flared.
- Thermal relief valve or vent discharges will be collected in a drain vessel itself. These will be connected, via the boil off gas header, to the LNG tanks vapour space.
- Under upset conditions, emergency process gas releases from pressure relief valves will be collected in a gaseous system connected to a central elevated flare stack. Discharges from LNG tank safety valves for excessive vapour rate production conditions & jetty KO drum will be released to the atmosphere at a safe location.

Flue Gases Emission From Flare: In flare, NOx emission will be negligible, since NOx are generated at flame temperature higher than 1600ºC, which the flare tip will not reach. Thus, NOx emissions are not expected through the flare.

Flue Gas Emission From SCV Stack: SCV operation will vary depending upon the terminal's operating requirements based on ambient temperature condition. The SCV will have facility for a NOx suppression system which injects water into the burner to lower flame temperature and reduce Nitrogen oxides formation.

Flue Gases From Combustion In Emergency Diesel Generators: Flue gases from combustion may include NO_X and CO_2 and particulate matter. All emissions requirements will be met by installing secondary emission control equipment. To mitigate these pollutants, the emergency diesel generator will be based on the technology that substantially lowers the amount of flue gases from the emissions.

2.10.2 Noise Mitigation Plan

The equipment would be carefully selected bearing in mind noise levels. In addition, noise is not expected to affect the surrounding population that is located far from the site. It is not possible to mitigate noise levels to a significant extent because

of the inherent sound of plant and machinery. However, the following mitigation measures will reduce the noise levels and also help in reducing the effect of increased noise on workers:

- DG sets will be encased in acoustic enclosure as required by Environment Protection Rules
- All other noise generating equipment will be provided with appropriate barriers / covers to reduce noise levels
- Workers in high noise area will be provided with ear plugs
- Duties of workers in high noise areas will be rotated to avoid continuous exposure to high noise for a long period.

2.10.3 Liquid Pollution Mitigation Plan

The disposal of liquid effluents in the terminal is designed on following principles:

- Oil/water separator will be installed to exclude the risk of polluting water or soils.
- The oil spillages and leaks will be locally collected and removed off site.

Sanitary wastewater from buildings will be collected and treated in Septic tanks and then sent to Soakpits in accordance with Local and National regulations.

2.11 Safety Aspects in LNG Handling

2.11.1 LNG Carriers

LNG carriers have insulated cargo tanks and are of double-hull design. The double hull provides the location for the segregated ballast and provides optimum protection for the integrity of the cargo tank containment in the unlikely event of collision or grounding.

Currently, a typical LNG carrier has a Length Overall (LOA) of approximately 285 m, a 43 m beam and a 12 m draft, with a cargo capacity of around 145,000 m^3. The LNG is transported in the tanks near atmospheric pressure and the

boil-off gas can be used to supplement liquid fuels for propulsion. LNG carriers of larger capacities have been developed. Recently LNG carriers of larger capacities, up to 2 66,000 m^3 are being operated and a carrier of this class has been selected for this EIA Study.

The LNG industry has an excellent safety record in all aspects of shipping, storage and re-gasification. This is due to both the high technical standards that are used in the design, construction and operation of LNG facilities and carriers.

LNG shipping has an outstanding safety record. LNG has been safely transported across the world's oceans for more than 50 years. There have been over 50,000 LNG carrier voyages covering more than 100 million miles without any loss of life in port or while at sea. The favorable safety record of LNG carriers is largely due to their double-hull design and multiple levels of protection associated with cargo operations, as well as the industry's focus on safety in Operations, maintenance and crew training.

LNG carriers also have safety equipment to facilitate ship and cargo system handling. The ship-handling safety features include sophisticated radar and positioning systems that enable the crew to monitor the carrier's position, traffic and identified hazards around the carrier. A global maritime distress system automatically transmits signals if there is an onboard emergency requiring external assistance. The cargo system safety features include an extensive instrumentation package that safely shuts down the system if it starts to operate outside of predetermined parameters. LNG carriers also have fire detection systems and gas leak detection within the cargo tank insulation, and nitrogen purging for hold space and inter barrier protection. Two safety relief valves are fitted to each cargo tank to provide vapour release to atmosphere thereby preventing over-pressuring of the tank from boil-off to take care of any eventuality of fire incidences. Marine Jetty facilities are provided with instrumentation to ensure that the prescribed approach velocity for the berth fenders is not exceeded. When moored, automatic mooring line monitoring provides individual line loads to help maintain the integrity of the mooring arrangement. When connected to the onshore system, the instrument systems and the shore-ship LNG transfer system acts as one system, allowing emergency shutdowns of the entire system from carrier and from shore.

A redundant safety system shuts down unloading operations when the carrier or unloading facility is not performing within the design parameters.

2.11.2 LNG Ship Navigation

M/s DHI Consultants have carried out a qualitative risk assessment study to assess the safety of LNG carriers (LNGCs) navigating to and from the jetty. Three sizes of LNGCs ranging from a 267,000 m^3 Q_{max}, a 145,617 m^3 Moss, to a smaller 65,252 m^3 membrane vessel were considered. Arrival and departure scenarios for the east and west jetties were undertaken selectively. The simulations were undertaken using one 5 SIMFLEX ship models. The displacements of the vessels are generally representative of the expected LNGCs displacements. All arrival scenarios were considered in loaded condition, and all departure scenarios were considered in ballast condition.

The principal dimensions of the 5 simulation models are presented in **Table 2.12** and the dimensions of the LNGCs expected to call at Chhara terminal are given in the **Table 2.13**.

Based on 2D ship simulation studies, it is concluded that:

- There is no significant concern for the all the three categories of LNGCs to navigate within the limits of the designated channel in the north and south flowing currents with wind speed of 15 knots.
- In adverse weather and high wave condition, there is a potential risk of the loaded Q_{max} and the large moss LNGC to ground in some stretches outside of the designated channel with water depths of (-) 13m CD.
- There is no significant concern for the 65,000 m^3 LNGC to navigate safely to and from the 2 jetties.

Further, DHI also carried out 3-D full mission simulator studies for Q_{max} and L_{moss}. During the full-mission simulations, the SMARTFORCE Full Mission Bridge was used. The key conclusions of the 3D simulation study are as follows-

- There is no significant concern for a Q_{max} size LNGCs to navigate within the limits of the designated channel in the north and south flowing currents with wind speed of 20 knots.

- There is minimal risk of the Q_{max} grounding outside of the designated channel as there are deep-water depths outside of the confines of the designated navigation channel.

- At a vessel speed of 7 knots, vessel encountered a set/drift between 3° to 9° at the outer channel due to strong cross-current. The maximum of 9° set/drift occurred during maximum south flood flowing current. This did not cause any significant concerns or problems under the simulated weather conditions as long as a strict track and speed control was maintained. The turning into the inner channel was also executed with no significant concern.

- There is sufficient room to swing the Q_{max} off the east main jetty with two tugs with no significant concern and well clear of the west jetty 600m exclusion zone.

Detailed DHI reports are provided separately.

2.11.3 LNG Terminal Safety Aspects

The LNG terminal will be designed in accordance with criteria of NFPA 59A, 2009 Edition (including informative annexures), considering 2 earthquake levels, OBE and SSE for tanks and cryogenic systems and IS 1893 (Part 1): 2002 Indian Standard “Criteria for Earthquake Resistant Design of Structures” for buildings and non process related structures. In the development of the project, the plant systems and their components will be classified on the basis of their importance. Such classification will be analysed during the hazard assessment.

The Safety philosophy is based on a staged approach:

- Well defined plant operating envelopes and a high level of plant automation (within the Process Control Systems);

- An extensive detection systems of abnormal conditions (within the Safety Control System);

- An Emergency Shutdown System to isolate affected plant parts and limit the effects of abnormal conditions (where practical on a “fail-safe” design practice), which is supplemented with;

- Passive design solutions within the plant to minimize the effects of accidents, such as selective LNG spill collection, avoiding the collapse of main structures from cold splash or fire heat-flux influence;

- An active protection system, inclusive stopping of uncontrolled sources of ignition and a fire protection system. The fire protection systems are important either to cool surrounding facilities or to segregate process area and reduce the risk of further escalations of incidents. The active fire fighting systems rely on permanent facilities and use the operation crew as first line of defense.

The LNG terminal will be monitored and controlled from a continuously manned Central Control Room (CCR) located in the control Room building. Emergency Shut Down (ESD) system is part of the main Plant Control & Monitoring system.

ESD will be designed to monitor key safety variables and equipment and respond automatically or to operator initiated commands, in such a way as to reduce the risk of hazardous or destructive incidents.

The ESD system will be independent of the primary control system and will perform the following functions regardless of availability of the PCS:

- ♦ Monitor dangerous conditions and take appropriate shut-down action.

- ♦ Rapidly and reliably detect a fire condition, a LNG spillage, a leakage of flammable gas or any other specific incident.

- ♦ Respond to manual requests for shut-down, Reset and override from the operator consoles or from the field as per requirements.

- ♦ Record on a suitable Sequence of Event Recorder (SER) all events / alarms and actions taken by the ESD system.

- ♦ Indicate to the control operator that a trip has been initiated and has been successfully completed/not completed.

The implementation of the ESD system will consist in selecting for each safety function, an architecture which satisfies the specifications of said function and / or ensuring the P&ID requirements which also correspond to the safety integrity requirements. The ESD System will be based on fail-safe dual redundant Programmable Logic Controller (PLC). I/O module, power supply module and communication module will be redundant. PLC will have watch dog timer for self diagnosis.

2.12 Statutory Regulations

Following statutory regulations related to the Gas processing industries will be complied, wherever applicable:

(a) General

- Factories Act.
- Indian Petroleum Rules.
- Tariff Advisory Committee Guidelines.
- Civil Aviation Rules.
- Indian Boiler Regulation Act.
- Indian Electricity Rules.
- Requirement of Chief Controller of Explosives.
- Oil Industry Safety Directorate (OISD) Guidelines.

(b) Environment

- Environmental (Protection) Act, 1986 Water (Prevention and Control of Pollution) Act, of 1974 and Cess Act of 1977. Environment Protection:
- Air (Prevention and Control of Pollution) Act of 1981
- The Noise Pollution (Regulation and Control) Rules, 2000 under Environment (protection) Act, 1986.
- Environmental Impact Assessment (EIA) Notification 2006.

- Coastal Regulation Zone Management Rule and Amendment August 2011.

List of Authorization/Statutory Permissions required at different stages for the construction of the LNG terminal is presented in **Table 2.14**.

Apart from the clearances for the overall project work, the construction contractor, before starting the construction work, has to obtain Clearances/NOCs listed in **Table 2.15** for operating his equipment and carrying out construction work.

2.13 Provision for Future Expansion

The plant layout has been developed in such a way that future extension can be realized from 5 MMTPA to 10 MMTPA. Trestle from Terminal to Main jetty is designed with spare space for accommodating LNG unloading pipeline for simultaneous unloading of LNG cargo from Main and Standby jetty.

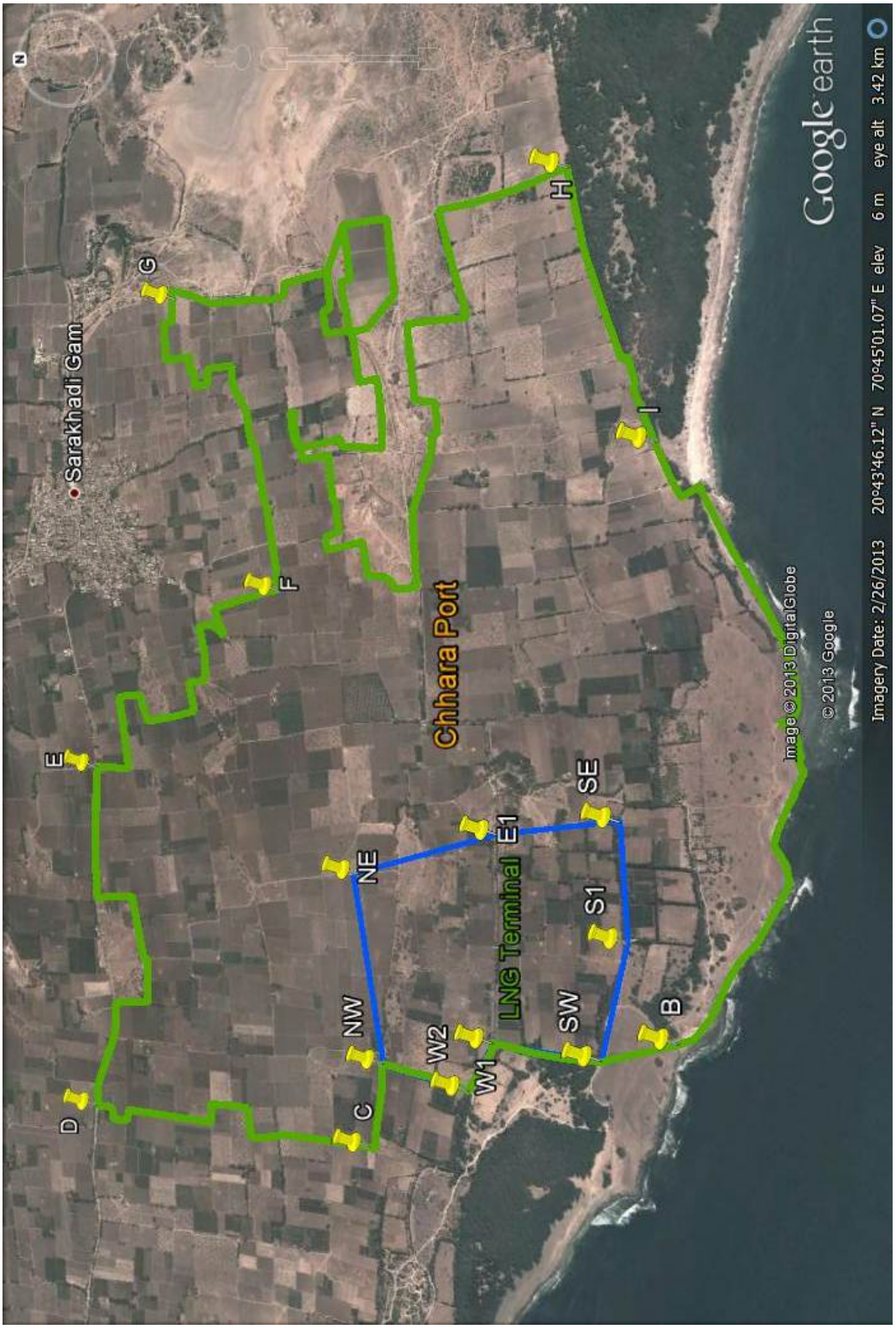


Fig. 2.1: Location of LNG Terminal on Google Map

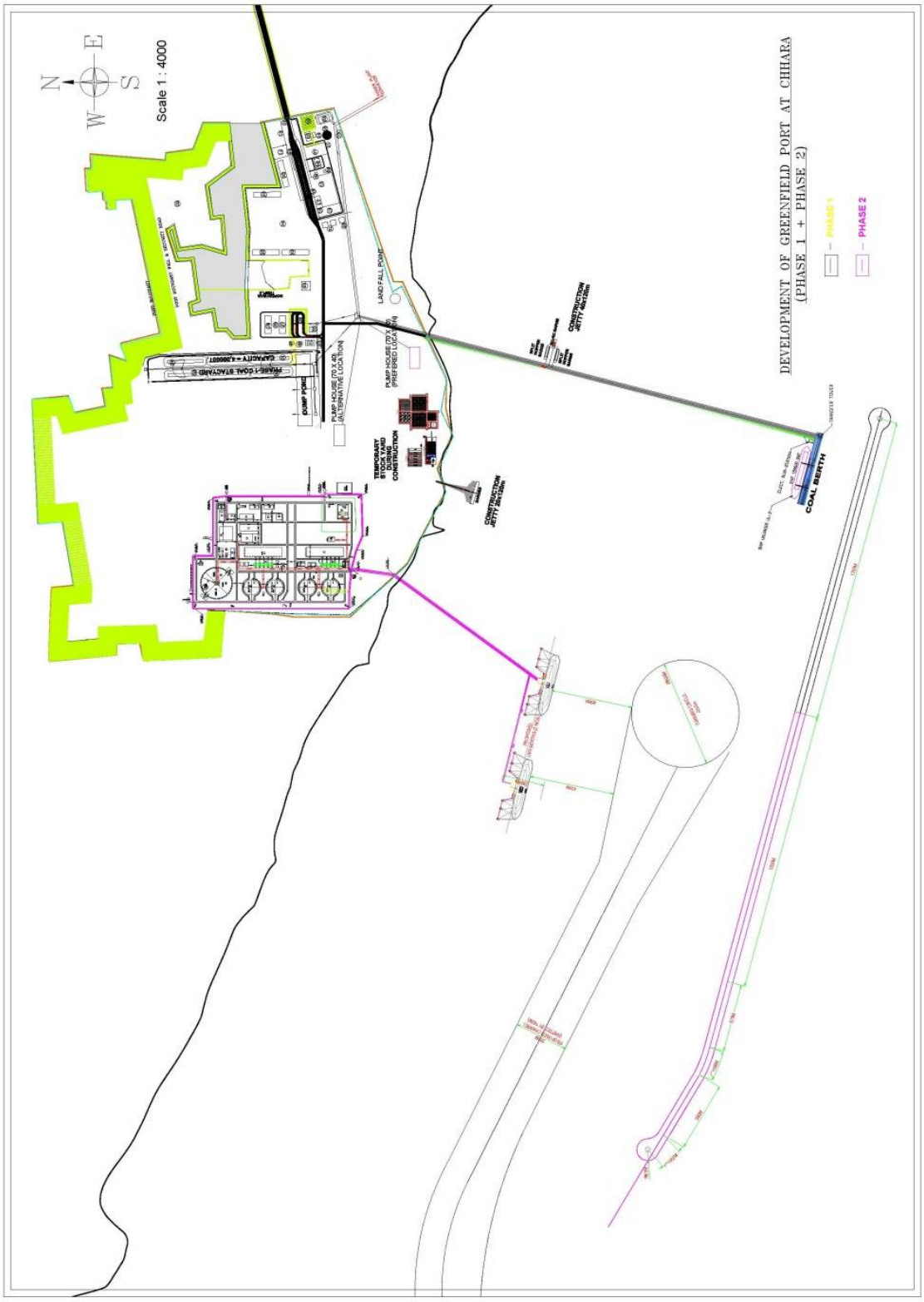


Fig. 2.2: Layout of LNG Terminal

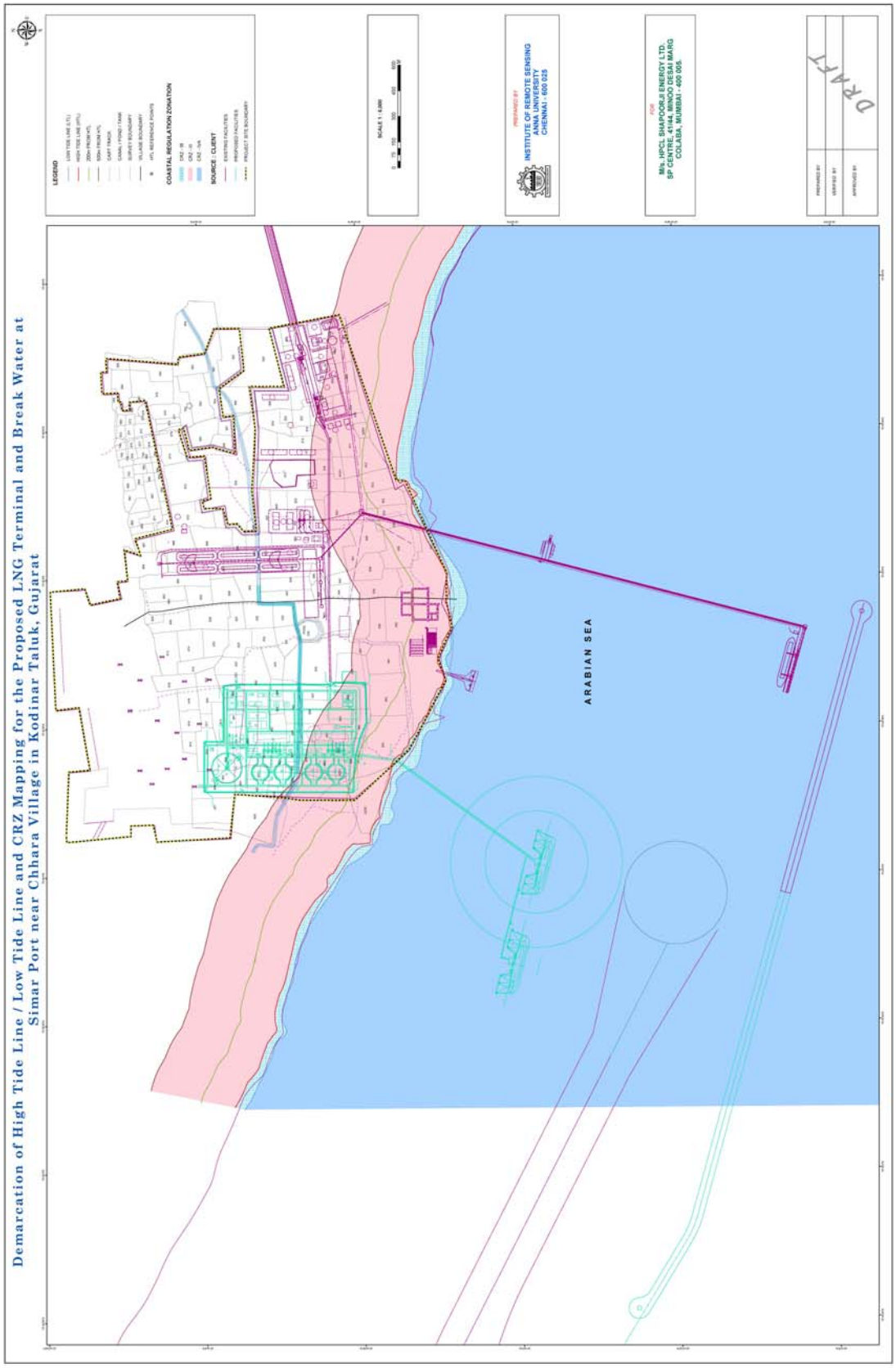


Fig. 2.3: LNG Terminal Plan Superimposed on CRZ Map

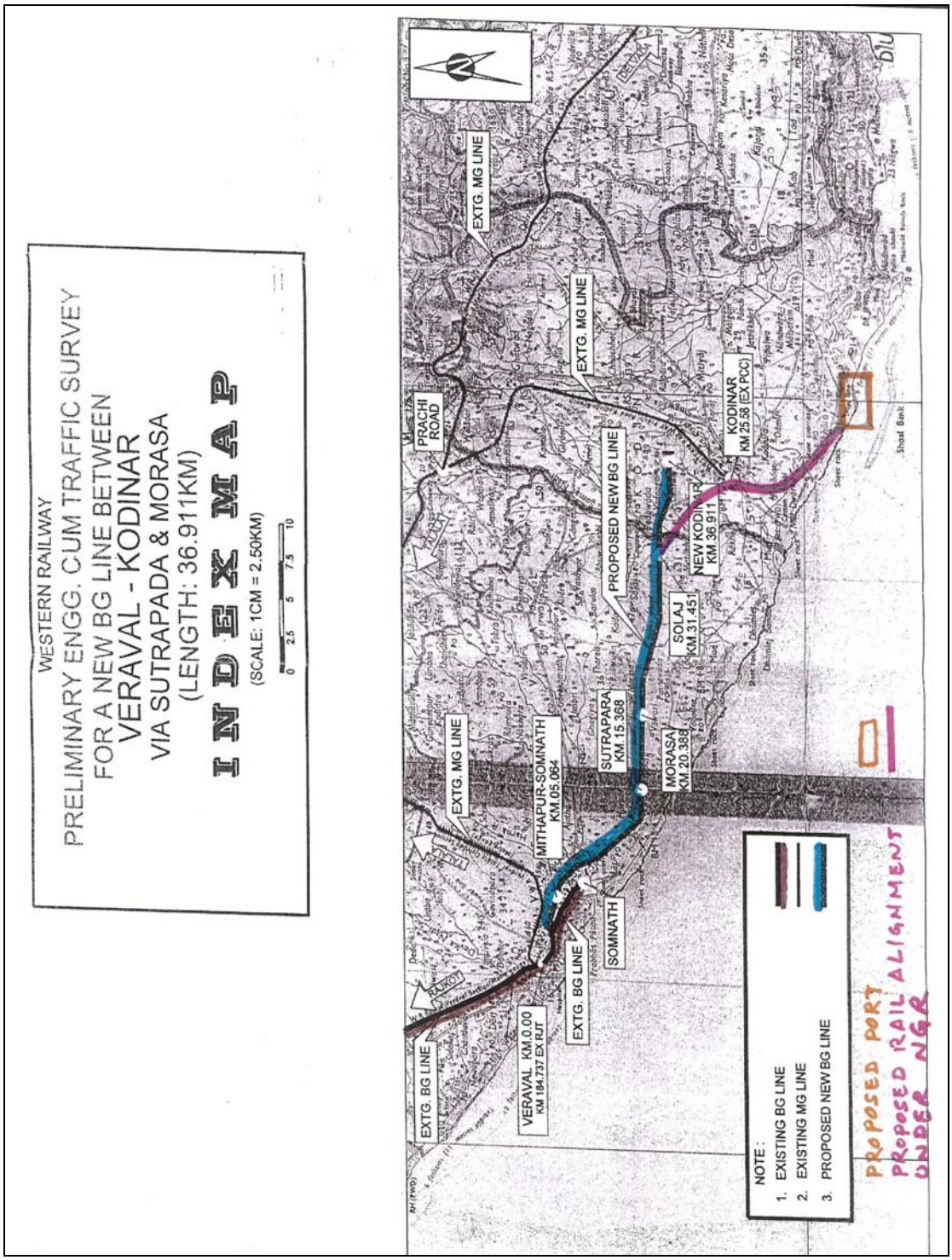


Fig. 2.4: Envisaged Rail Connectivity

Fig. 2.5: Envisaged Road Connectivity

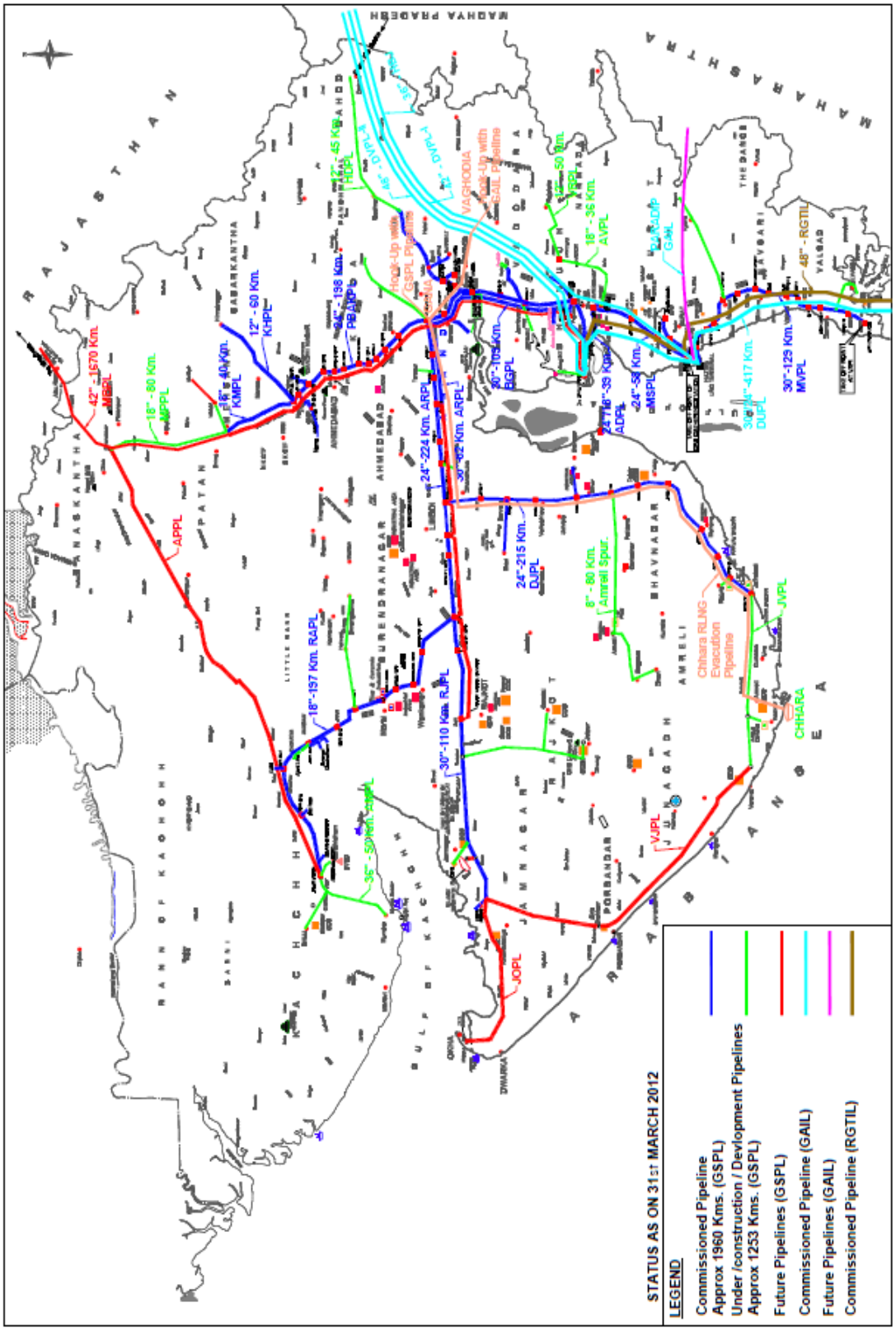


Fig. 2.6: Envisaged Pipeline Grid Connectivity

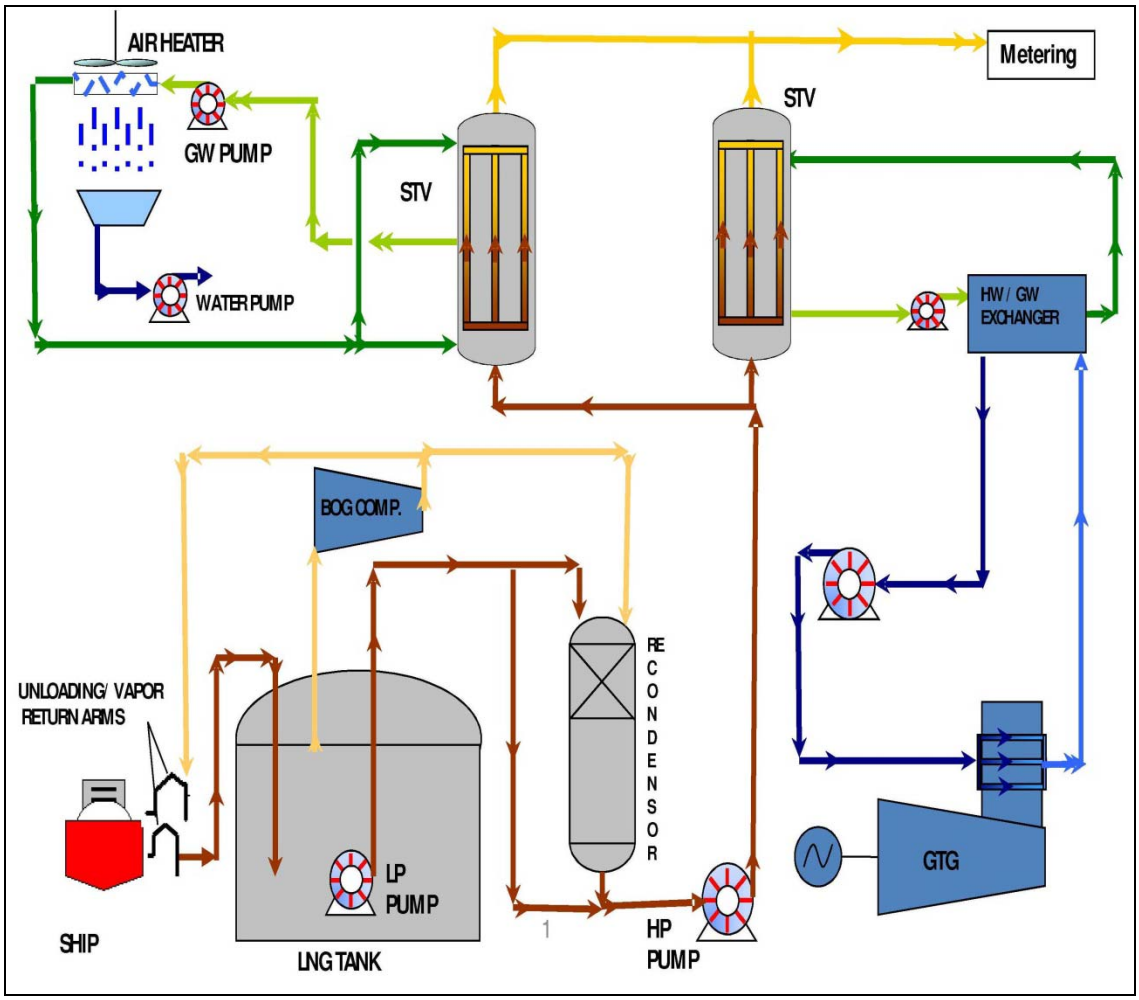


Fig. 2.7: LNG Unloading and Regasification Facilities Process Flow

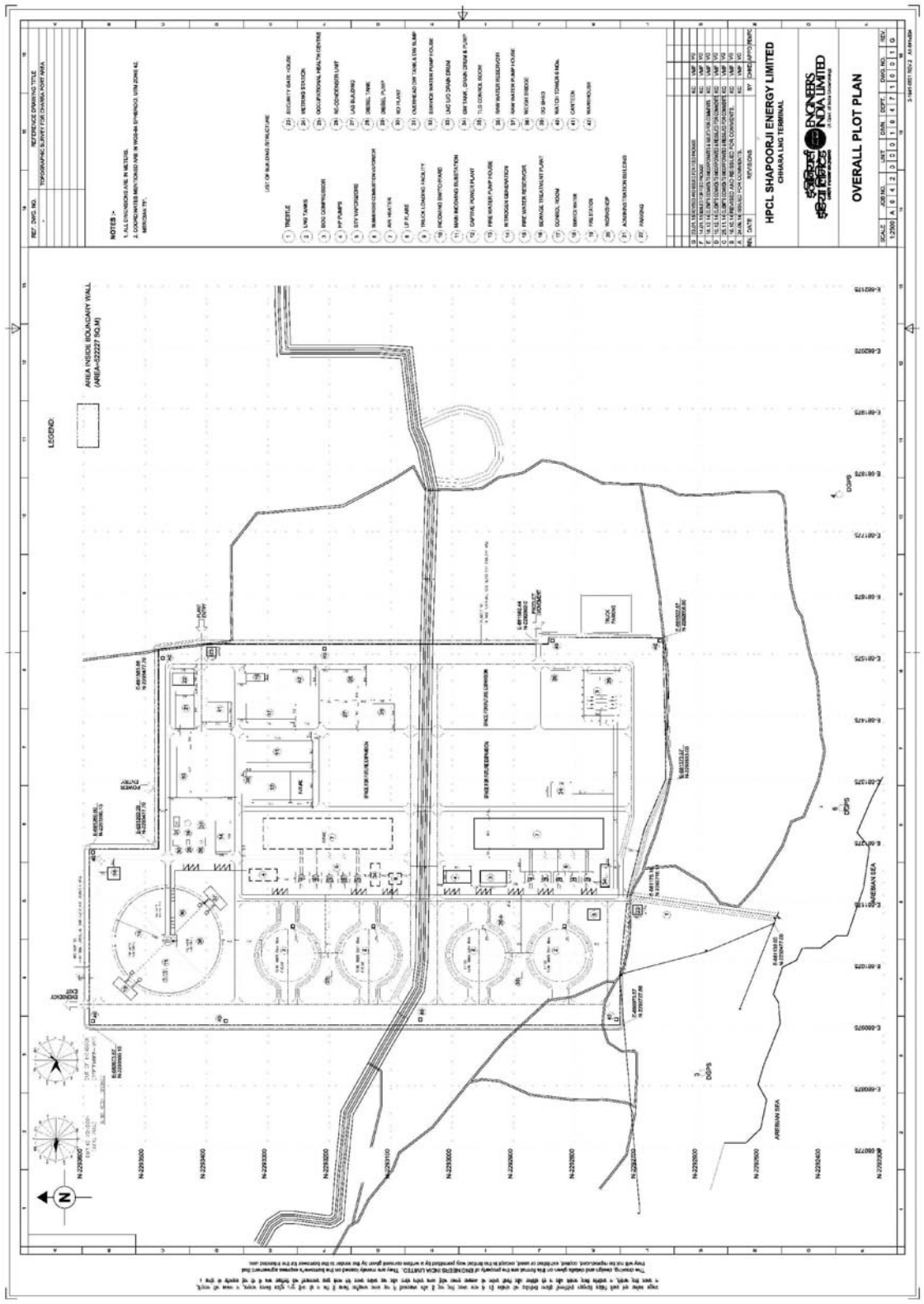


Fig. 2.8: LNG Terminal Detailed Plot Plan

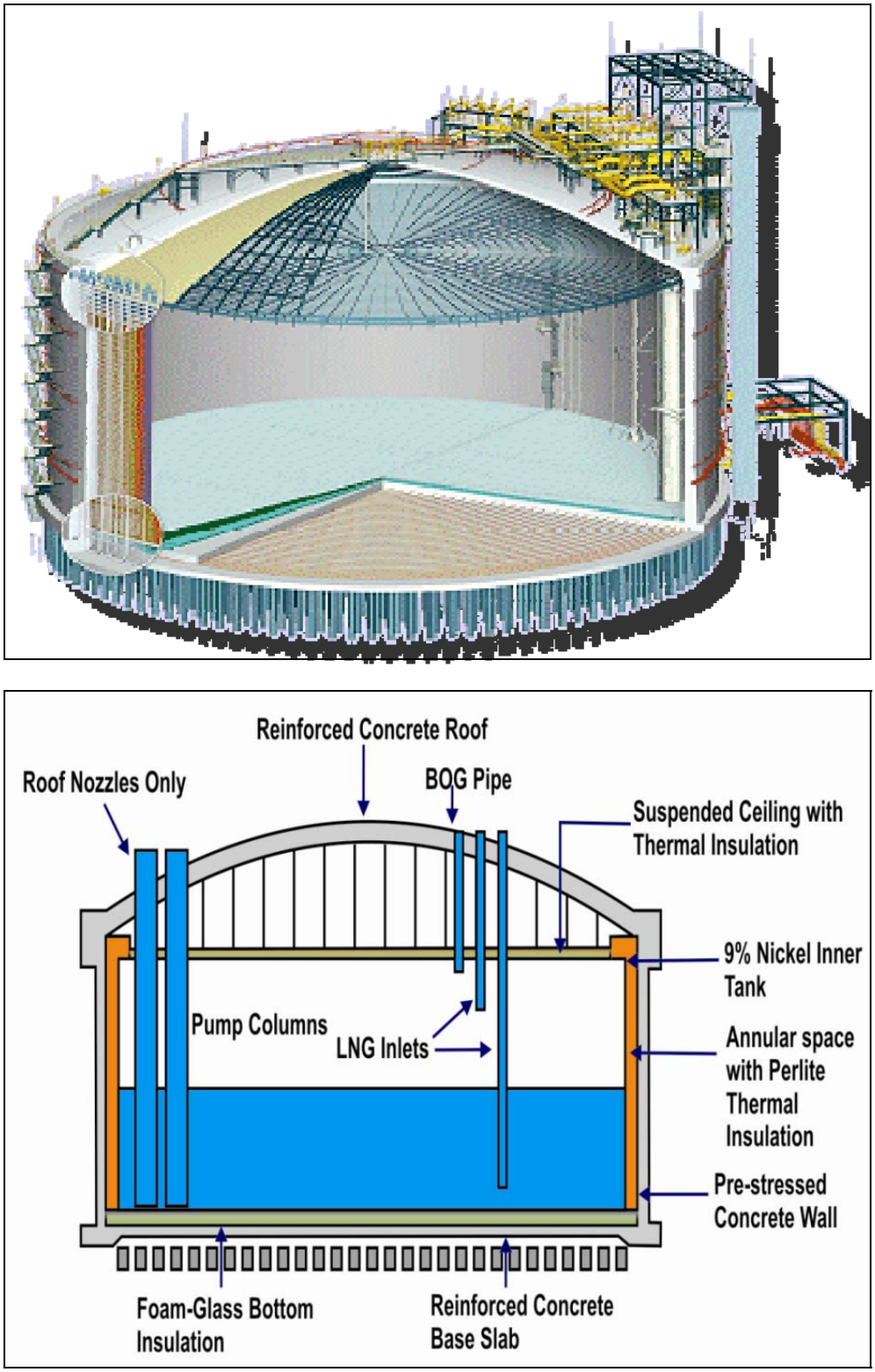


Fig. 2.9: Full Containment LNG Storage Tank

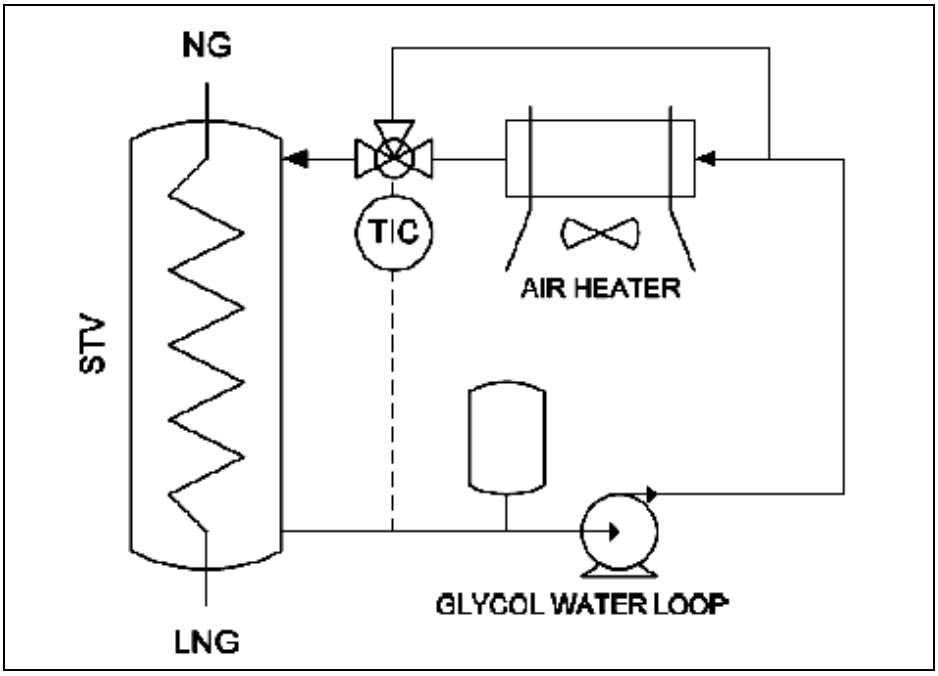


Fig. 2.10: Shell and Tube Vaporizer

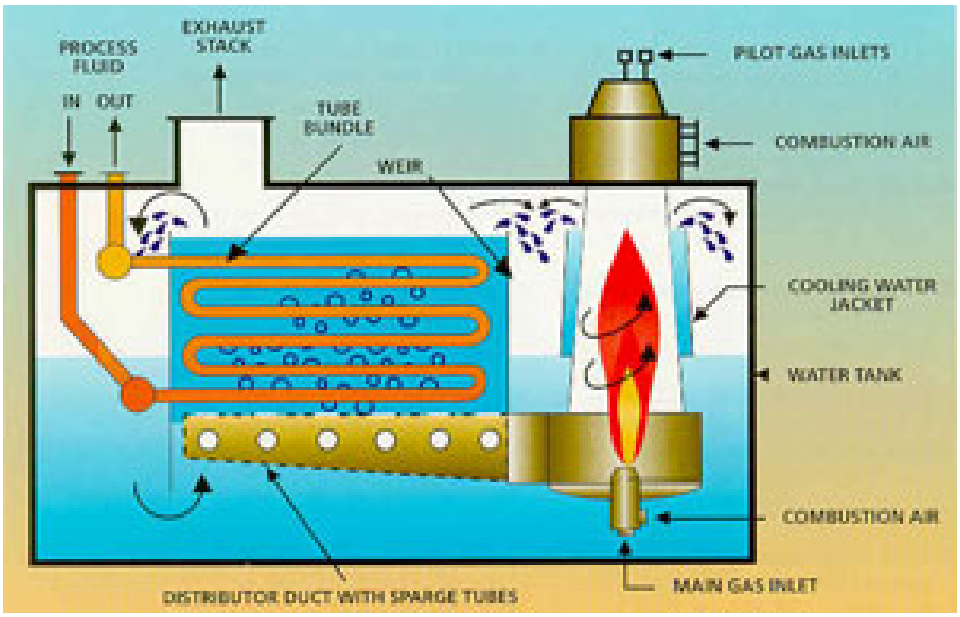


Fig. 2.11: Submerged Combustion Vaporizer

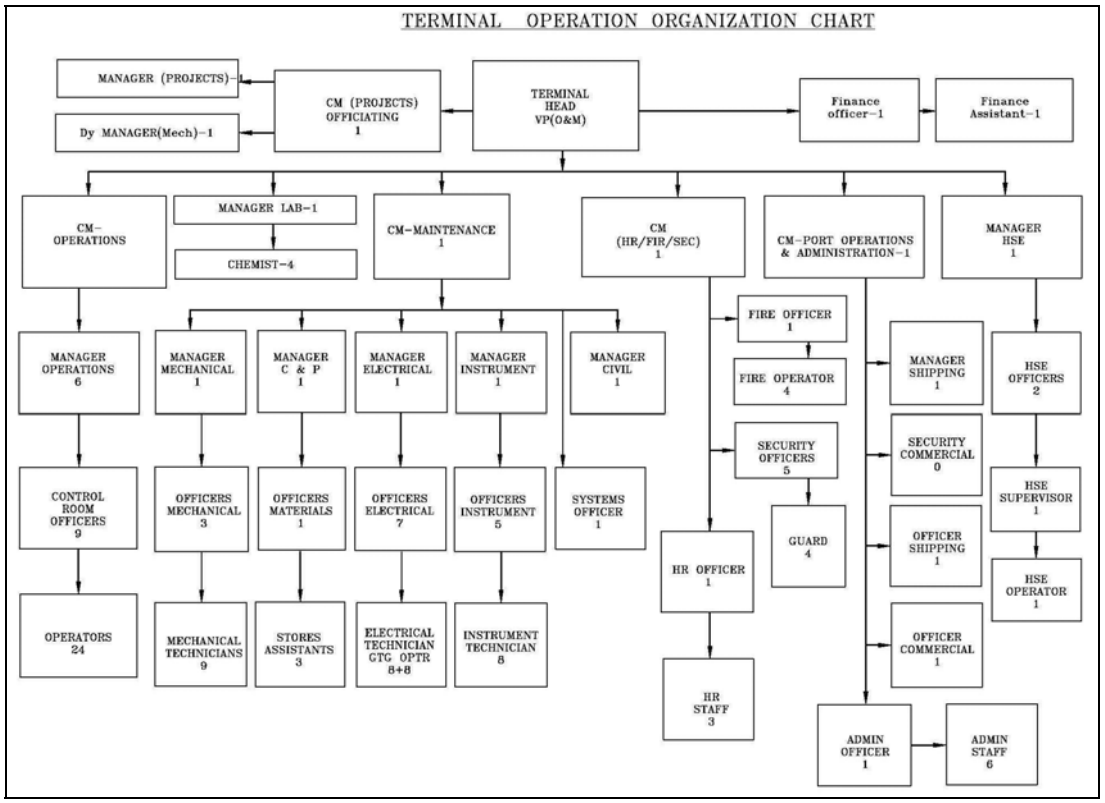


Fig. 2.12: Organization Chart during Operation Phase

Table 2.1

Activities Proposed by M/s Simar Port Limited in CRZ

(EC & CRZ Clearance granted by MoEFCC vide letter dated Jan. 6, 2014)

Activity	Description	CRZ IV LTL-12 Nt Miles	CRZ-I B LTL-HTL	CRZ III HTL-200m	CRZ III 200m-500m from HTL
Breakwater	Length: 1700 m, Width : 75 m at bottom, Height: 10 m above CD level	Fully			
Berth	One No., Length: 350 m Width: 25 m	Fully			
Approach Trestle	Length: 2265 m, Width: 12 m	Partly	Partly	Partly	
Construction Jetty	Two nos., Length: 120m Width : 40 m	Fully			
Capital Dredging	1.5 Million Cum	Fully			
Maintenance Dredging	150,000 Cum per annum	Fully			
Dredged Material Disposal	Locations decided through modeling	25-30 M MSL contour in sea			
Lighting, Electrical etc.		Partly	Partly	Partly	Partly
Internal Roads				Partly	Partly

Table 2.2

LNG Terminal Land Use Plan

Facility	Land in Acre
Tankage Area - Present	10.4
Tankage Area - Future	10.4
Flare Area	12.3
Process Area	18.9
Future Expansion	14.7
Gantry & Metering Area	5.7
Utility	7.2
Building	10.9
Internal Roads	15.1
Open Space	23.4
Total Area	**129.0**

Table 2.3

Activities Proposed by HSEL in CRZ

Activity	Description	CRZ IV LTL-12 Nt Miles	CRZ-I B LTL-HTL	CRZ III HTL-200m	CRZ III 200m-500m from HTL
LNG Jetty with unloading arms	1 Nos., 3 Nos. unloading arms	Fully			
Approach Trestle with pipelines	Length - 1225 m	Partly	Partly	Partly	
Dolphins	6 Mooring & 4 berthing	Fully			
LNG transfer lines	From jetty to storage tanks	Partly	Partly	Partly	Partly
Vapor return line	From tankages to jetty	Partly	Partly	Partly	Partly
Utilities	Firewater etc.	Partly	Partly	Partly	Partly
Storage tanks	2 nos. of 200,000 cum each (gross capacity)				Fully
Regasification facilities	BOG Compressor HP Pumps Shell and Tube Vaporizers, Submerged Combustion Vaporizer and air heaters Glycol water tanks and circulation system Re-condenser U/G LNG Drain drum				Fully
LNG Send out facilities	Truck Loading LNG Metering station Weigh bridge TLG Control room Truck parking				Fully
Security	Watch Tower Security Gate				Fully

Table 2.4

Design Vessels

Vessel Type/Capacity	Q_{max} – 266,000 m³	LNG Tanker – 125,000 m³	LNG Tanker 80,000 m³
LOA (m)	345.3	283	249.5
Draft (m)	12.2	11.5	10.6
Beam (m)	53.8	45	40.0
LBP (m)	332.0	270.0	237.0
Displacement (t)	178,579	100,000	71,600
DWT	128,000	67,000	50,000

Table 2.5

Berth Occupancy

Phase	Phase 1	Phase 2
Yearly throughput (MMTPA)	5	10
LNG yearly throughput (MMm³)	11	22
Average parcel size (m³)	135,000	150,000
No of vessels per year	81	145
Off loading rate (m³/hr)	14000	14000
Time for offloading, turn around (hrs)	19	21
Effective offloading rate (m³/hr)	7000	7000
Total time at berth (hrs)	1557	3114
Availability of port (maintenance, downtime, closure) – days	330	330
Availability of port (hrs)	7920	7920
Berth occupancy	20%	39%

Table 2.6

List of Facilities in Proposed LNG Terminal

Sr. No.	Name	Capacity / Size	Nos.
A.	Marine Facilities		
	Berthing Dolphin (inner + outer)	15.5 m x 15.5 m	4
	Mooring Dolphin (bow + stern)	15 m x 15 m	6
	LNG Spill containment system		1
	Catwalks	Catwalk bridges (approx.) length = (50 + 50 + 35) x 2m + 22 + 8 = 300m	8
	Unloading Platform	Size 40.3m x 33.5m	1
	Unloading Arms	5350 m^3/hr (Liquid Arms) 16000 m^3/hr (Vapor Arm)	3 (Liquid Arm) & 1 (Vapour Arm)
	Trestle – Main Jetty to Shore	Approx. length of trestle 1 km. x 14 m	1
	Trestle – Main Jetty to Standby Jetty	130 m x 14 m	1
	Jetty Control Room		1
B.	On-Shore Facilities		
1.	Trestle		1
2.	LNG Tanks	200,000 m^3	2
3.	BOG Compressor	12 T/hr	4
4.	HP Pumps	400 m^3/hr	5
5.	STV	174 T/hr	5
6.	SCV	174 T/hr	1
7.	Air Heater	92.5 T/hr	4
8.	LP Flare	135 T/hr	1
9.	Truck Loading Facility	70 m^3/hr	2 bays
10.	Incoming Switchyard		1
11.	Main Incoming Substation		1
12.	Captive Power Plant	18 MW	1
13.	Fire Water Pump House		1

Sr. No.	Name	Capacity / Size	Nos.
14.	Nitrogen Generation	280 Nm^3/hr	1+1
15.	Fire Water Reservoir	16800 m^3	1+1
16.	Sewage Treatment Plant		1
17.	Control Room		1
18.	Service Water		1
19.	Fire Station		1
20.	Workshop		1
21.	Administration Building		1
22.	Parking		1
23.	Security Gate House		2
24.	Metering Station		1
25.	Occupational Health Centre		1
26.	Re-condenser Unit	10 MMTPA	1
27.	Lab Building		1
28.	Diesel Tank	70 m^3	1
29.	Diesel Pump	11 m^3/hr	1+1
30.	RO Plant	Space Provision Only	
31.	Overhead DW Tank & DW Pump	RCC Overhead Drinking water tank of 30 cum capacity with U/G DW sump of 50 cum capacity.	1
32.	Service Water Pump House		1
33.	LNG U/G Drain Drum	19 m^3	1
34.	GW Tank, Drain Drum & Pump	GW Tank – 440 m^3 Drain Drum – 13.2 m^3 Pump – 2450 m3/hr	1 1 4+1
35.	TLG Control Room		1
36.	Raw Water Reservoir		1
37.	Raw Water Pump House		1
38.	Weigh Bridge		1
39.	DG Shed		1
40.	Watch Towers		9
41.	Canteen		1
42.	Warehouse		1

Table 2.7

Selection of LNG Tanks - Comparison With Respect To Safety

Sr. No.	Tank Hazard Scenarios	SCT	DCT	FCT
1.1	Gas external dispersion in case of inner container leak	Yes	Yes	No
1.2	Liquid external spillage in case of inner container leak	Yes	Yes	No
1.3	Tank roof collapse and tank internal fire	Yes	Yes	No
1.4	Safety valves relieve	Yes	Yes	Yes
1.5	Fire in tank impounding	Yes	Yes	No
1.6	Roof withstanding in case of external impact	No	No	Yes
1.7	Wall withstanding in case of external impact	No	Yes	Yes
	Safety Provisions			
2.1	Heat radiation from adjacent tank (or impounding) fire	Yes	Yes	No
2.2	Safety distance related to gas dispersion in case of inner container leak	Yes	Yes	No
2.3	Safety distance related to gas dispersion in case of safety valves relieve	Yes	Yes	Yes
2.4	Water spraying system on tank	Yes	Yes	No

SCT - Single containment tank
DCT - Double containment tank
FC - Full containment tank

Table 2.8

Selection of LNG Tanks - Comparison with respect to Layout Impact

Layout Impact	LNG Storage Tank Types		
	SC	DC	FC
Number of tanks	3	2	2
Tank capacity (net)	125 000	185 000	185 000
Plant surface	+ 25 acres	4.3 acres	basic case
Required tank valve nest, rack/tank top connections	3	2	2
LP pumps	3 x 3	2 x 3	2 x 3
Unloading blower	2	2	2(1)
Unloading compressors	45 t/h	45 t/h	12 t/h
Retention basins	3	-	-
Process rack extra length (meter)	+ 941	+ 361.5	-

Table 2.9

Selection of Regasification Technology

	Shell & Tube Vaporizer (AHV)	**Amb. Air Vaporizer (AAV)**	**Open Rack Vaporizer (ORV)**	**Submerged Combustion Vaporizers (SCV)**
Heat Source	Ambient air	Ambient Air	Sea water	Fuel Gas
Heating Medium	Heat Transfer Fluid (Indirect heat)	None (Direct heat)	None (Direct heat)	Hot water, Water Bath (Direct heat)
Major Equipment	STV, Air heater	Ambient vaporizer	Sea water intake facility	Blower, Burner
Key Design Parameters	Air temperature, Relative humidity	Air temperature	Sea water temperature, Allowable temperature drop	Emissions (NOx & CO_2)
Key Issues	Air temperature variations	Defrosting, temperature variations	Sea water intake facility maintenance, Environmental impact	High Operating cost, Environmental impact
Environmental Issues	HTF lea kage	Fogging	Marine life, low temperature, biocide injection	NOx and CO_2 Emission
Advantages	Proven technology	Not used in large scale plants	Proven technology	Proven technology
	nsive source of heat	Free Heat	Inexpensive source of heat (Sea Water)	High Thermal efficiency
	Low emissions, low maintenance	No emissions, low maintenance		Low capital Cost
Disadvantages	Medium plot size area	Large plot area	Large sea water Inlet	High Operating Cost
		Periodic defrosting	Periodic cleaning	
			Large power load	
			Sea water application - not permitted in USA	

Table 2.10

Manpower Requirement During Operation Phase

Sr. No.	Description	Grade	No. of Per Sons
1	Plant Manager	SM	1
2	Secretary	AE	5
3	Operation Manager	M	1
4	Operation Superintendent	DM	1
5	Technical Services & Process Engineers	SE	0
6	Warerhouse Keeper	SE	1
7	Site Supervisors	E	5
8	Shift Supervisor	E	0
9	Operators	AE	15
10	System Engineer	E	1
11	Maintenance &Material Manager	M	1
12	Mechanical Engineer	SE	1
13	Technicians	T	4
14	E&I Engineer	SE	1
15	Technicians	E	3
16	Material Management	SE	1
17	Purchaser	E	1
18	Contract follow up	SE	1
19	Civil, painting etc…	SE	1
20	Health, safety & environmental Manager	M	1
21	Deputy Manager	DM	1
22	Fire fighting and safety operators	AE	20
23	Medical care	M	2
24	Finance & Administration Manager	M	1
25	Security service	SP	20
26	Administration & personnel	SE	1
27	Financial Manager	M	0
28	Financial Executive	SE	1
29	Lab Chemists	AE	1
30	Staff	AE	2
			94

Designation	Designation	Grade
Senior Manager	Executive Trainee	ET
Manager	Asst. Engineer	AE
Deputy Manager	Technician	T
Sr. Engineer/Financial Exec	Security Personnel	SP
Engineer/ Supervisor		

Table 2.11

Design Basis for CPP

Ambient Condition	**Max. Design Ambient: 44°C Design Ambient: 29°C RH at above Design Temperature: 80% Barometric Pressure at site: 0.989 bar**
Make/ Model No	W16V34SG
GEG gross output, Mwe	7.744
Net Output, Mwe	7.594
Fuel consumption (Natural Gas)*	1 603 sm^3/hr
Exhaust Flow	12.31 kg/s +/- 5%
Exhaust Temp	381°C +/- 15°C
Emission-	
NOx	< 91 ppm at 15% dry Oxygen
PM_{-10}	<10 mg/Nm^3 at 15% dry oxygen
$PM_{-2.5}$	Below Detectable limits
CO	115 mg/Nm^3 at 15% dry oxygen

* Fuel Consumption is inclusive of ISO tolerance.

Table 2.12

SIMFLEX Simulation Ship Models Specifications

SIMFLEX Model	**Displacement (m^3)**	**LOA (m)**	**Beam (m)**	**Draft (m)**
3533 Qmax Loaded	170,780	345	53.8	12.0
3532 Qmax Ballast	132,033	345	53.8	9.6
3314 LMoss Loaded	102,400	289.5	49	11.4
3313 LMoss Ballast	85,326	289.5	49	9.4
3249 LPG Loaded	68,054	228	35.5	12.5

Table 2.13

Type of LNGCs and their Dimensions Expected to Call at the Terminal

LNG Carrier Range	Unit	Portovenere (65000 m^3)	Seri Ayu (145000 m^3)	Artic Princess (145000 m^3)	Q Max (267000 m^3)
Type		Membrane	Membrane	Moss	Membrane
Capacity	M3	65252	145659	145617	267000
Displacement (loaded)	M	52680	102709	106220	178564
LOA	M	261.14	283.0	288	345
Length between perpendiculars	M	205	270	274	332
Beam length	M	33.9	43.4	49	53.8
Moulded Depth (To main deck)	M	21.26	26	26.8	27
Loaded Draught	M	9.52	11.4	11.5	12
Ballast Draught	M	8.15	9.3	9.2	9.6

Table 2.14

Regulatory Requirement and Compliance Plan – HSEL

Sr. No.	Authorization/ Statutory Requirements	Stages of approval	Remark
1	Government of Gujarat (State level clearance) –Single Window clearance		
	State Investment approval Board	Submission of composite Application form	30 days initially for all Departments at the time of inception. • Municipal Administration and Urban • Development Authority – 15 days • Pollution Control Board - 10 days • Inspector of Factories – 7 days • Town and Country Planning – 7 days • Power – 1 week on existing lines and 4 weeks where new extensions are involved.
2	PNGRB Clearance (RLNG evacuation pipeline)		
2.1	G.S.R.340 (E)	During Authorization stage	For dedicated gas pipeline relevant pages of G.S.R.340 (E) to be taken by Gas transmission company
2.2	G.S.R 808 (E)	Engineering, construction, Commissioning & Operation and maintenance procedure	For dedicated gas pipeline relevant pages of G.S.R.808 (E) to be taken by Gas transmission company
3	Chief Controller of Explosives (CCOE)	During detail engineering and prior to construction	
4	Ministry of Environment , Forest and Climate Change (MoEFCC)	Environmental Clearance and CRZ Clearance	CRZ Clearance needs to be recommended by GCZMA
5	Permissions for Crossings		
5.1	Railway	Prior to start-up of construction	
5.2	National Highway	Prior to start-up of construction	
5.3	State highway	Prior to start-up of construction	
5.4	Irrigation department	Prior to start-up of construction	
5.5	Utilities owner	During detail engineering and prior to construction	
5.6	Permissions from water way authorities	During detail engineering and prior to construction	
6	OISD clearance	Prior to commissioning	

Table 2.15

Clearances required to be obtained by Contractor

Sr. No.	Construction Activity for which Clearance Required	Statute Under which Clearance is Required	Statutory Authority
1	Hot mix plants, Crushers and Batch plants	Air (Prevention and Control of Pollution) Act, 1981 and The Noise Pollution (Regulation and Control) Rules, 2000	Gujarat Pollution Control Board
2	Storage, handling and transport of hazardous materials	Hazardous Waste (Management and Handling) Rules, 1989 & Manufacturing, Storage and Import of Hazardous Chemicals Rules, 1989	Gujarat Pollution Control Board
3	Location and layout of workers camp, & equipment and storage yards	EP Act, 1986 Manufacturing, Storage and Import of Hazardous Chemicals Rules, 1989	Gujarat Pollution Control Board
4	Quarries	Environment (Protection) Act, 1986	Department of Mining, Govt. of Gujarat
5	Discharges from labour camp	Water (Prevention and Control of Pollution) Act, 1974	Gujarat Pollution Control Board

Chapter 3
Maximum Credible Accident (MCA) Analysis

3.1 Introduction

The increasing diversity of products manufactured by chemical process industries has made it more and more common for these industries to use hazardous substances at elevated temperatures and/or pressures. Increasing concern has, therefore, prompted the Ministry of Environment and Forests (MoEFCC), Government of India, to make Risk Assessment a mandatory requirement for chemical industry.

The possible impact on the safety of the surrounding population due to the capacity expansion of LNG Terminal is of primary concern. The conclusion of the assessment can help in the decision process to establish safety zones and modify the precautionary measures in and around the terminal. The assessment can also help in delineation of Disaster Management Plan (DMP) covering onsite and offsite scenarios. Risk Assessment involves the identification of hazards, consequences in case of accidental release of hazardous chemicals on human beings, structures and surrounding plants.

3.2 Methodology

The QRA methodology applied in this study is based on The Centre for Chemical Process Safety (CCPS, 2000) guidelines. A systematic approach has been made in the analysis of what can go wrong at the terminal. The normal conditions of operation of the system are defined and then the following questions asked.

- What can go wrong?
- What will be the consequences?
- How often?
- What is the significance of the resulting risk?

Objectives of the Study

The objectives of the study are as follows:

- Study of past accidents information to identify worst accident scenarios

- Identification of all hazards from the Chhara LNG Port storage tanks, pipelines through computation of hazard indices and their classification according to category of hazards.
- Generation of credible and worst case scenarios for accidental release of hazardous material during processing, handling and storage through Maximum Credible Accident (MCA) analysis
- Computation of damage distances on consequence and vulnerability analysis for various heat loads, wind velocities and atmospheric stability classes.
- Assessment of the magnitude and severity of the impact in terms of damage to property and injury to personnel through damage contour plots.
- Risk characterization by representing individual and societal scenarios against the risk acceptability criteria relevant to the situation
- Recommendation of risk mitigation measures to improve overall safety, prevent fire and explosion and implement emergency response plan.
- Delineation of approach to Disaster Management Plan (DMP) to tackle on-site and off-site emergency situations.

Hazards have been identified by computing Fire and Explosion Indices (FEI) and categorizing the units accordingly. Maximum Credible Accident (MCA) analysis has been carried out to find out the effective distances in case of partial or full rupture of the process equipment. The consequences have been studied at various wind velocities and atmospheric stability classes for various fire and explosion scenarios. MCA analysis does not include quantification of the probability of occurrence of an accident. In practice the selection of accident scenarios for MCA analysis is carried out on the basis of engineering judgement and expertise in the field of risk analysis especially in accident analysis.

The risk has been presented in the form of risk contours. Risk contours, also sometimes called individual risk contours, are defined as iso-risk line on the map at which hypothetical individual being there unprotected, without escape, for 24 hours per day would be subjected to a defined probability of fatal harm due to exposure to hazards induced by the facility on a per year basis.

In general, risk contours are calculated by determining the consequences by MCA analysis from a number of scenarios. Based on incident frequencies and effects from meteorological conditions, the contribution from each scenario to a point at a distance from the facility is calculated. By putting a grid over the area surrounding the facility and summing the contribution from all scenarios for each grid point a three dimensional (x, y, risk) picture emerges which then reduced to 2D by connecting points of equal risk. Societal risk has been graphed as F/ N curve where F is failure frequency and N is number of fatalities. A number of countries in the world like UK, Malaysia, Australia, Netherlands and Canada have established tolerability criteria to decide on separation distances between major industrial developments and the public in general. These criteria will be reviewed and compared with the risk contours resulting from the study.

3.3 Basic Data

The following data of LNG storage tanks, pipelines and pumps have been used for the risk assessment.

LNG Storage Tank (Capacity: 196,000 m^3)

Sr. No.	Parameters	Details
01	Operating Temperature °C	-162
02	Operating Pressure (Bar)	-10
03	Volume (m^3)	196,000

LNG Pipeline

Sr. No.	Parameters	Details
01	Operating Temperature °C	-165
02	Operating Pressure (Bar)	10.5
03	Flow Rate (m^3 / hr)	-
04	Length (Km)	18.5
05	Internal diameter (mm)	965.2

LP LNG Pumps

Sr. No.	Parameters	Details
01	Operating Temperature °C	-162
02	Operating Pressure (Bar)	18.9
03	Flow Rate (m^3/hr)	550

LNG Gas Composition

Description	Lean Gas (mole %)
Methane C1	97.21
Ethane C_2	2.49
Propane C_3	0.14
I-Butane iC_4	0.09
N-Butane nC_4	0.02
I-Pentane iC_5	0.00
N-Pentane nC_5	0.03
Hexane C_{6+}	0.00
Nitrogen N_2	0.02
Carbon CO_2	0.00
Oxygen	0.00
Total	100.00
LHV (Kcal/Kg)	11 906

3.4 Hazard Identification

Identification of hazards is an important step in Risk Assessment as it leads to the generation of accidental scenarios. The merits of including the hazard for further investigation are subsequently determined by its significance, normally using a cut-off or threshold quantity.

Once a hazard has been identified, it is necessary to evaluate it in terms of the risk it presents to the employees and the neighbouring community. In principle, both probability and consequences should be considered, but there are occasions where it either the probability or the consequence can shown to be sufficiently low or sufficiently high, decisions can be made on just one factor.

During the hazard identification component, the following considerations are taken into account.

- Chemical identities
- Location of process unit facilities for hazardous materials.
- The types and design of process units
- The quantity of material that could be involved in an airborne release

- The nature of the hazard (e.g. airborne toxic vapours or mists, fire, explosion, large quantities stored or processed handling conditions) most likely to accompany hazardous materials spills or releases

3.4.1 Fire and Explosion Index (FEI)

Fire and Explosion Index (FEI) is useful in identification of areas in which the potential risk reaches a certain level. It estimates the global risk associated with a process unit and classifies the units according to their general level of risk. FEI covers aspects related to the intrinsic hazard of materials, the quantities handled and operating conditions. This factor gives index value for the area which could be affected by an accident, the damage to property within the area and the working days lost due to accidents. The method for evaluation of FEI involves following stages.

- Selection of pertinent process unit which can have serious impact on plant safety
- Determination of Material Factor (MF): This factor for a given substance in the process unit gives intrinsic potential to release energy in case of fire or an explosion. Material Factor can be directly obtained from Dow's Fire and Explosion Index Hazard classification Guide of American Institute of Chemical Engineers, New York. The factor can also be evaluated from NFPA indices of danger, health, flammability and reactivity.
- Determination of Unit Hazard Factor: The Unit Hazard Factor is obtained by multiplication of General Process Hazard (GPH) factor and Special Process Hazard (SPH) factor. GPH factor is computed according to presence of exothermic reactions and loading and unloading operations. The penalties due to each of these reactions / operations are summed up to compute GPH factor. Similarly, SPH factor can be evaluated for the operations close to flammable range or pressures different from atmospheric. Penalties of these operations for both factors can be obtained from Dow's EFI index form.

Fire and explosion index is then calculated as the product of Material Factor (MF) and Unit Hazard Factor. Degree of hazards based on FEI is given in the following **Table 3.1**.

Table 3.1

Degree of Hazards Based on FEI

FEI Range	Degree of Hazard
0 – 60	Light
61-96	Moderate
97 - 127	Intermediate
128 - 158	Heavy
159 and Above	Severe

Preventive and protective control measures are recommended based on degree of hazard. Therefore, FEI indicates the efforts to be taken to reduce risks for a particular unit. FEI computed for various scenarios considered are presented in **Table 3.2**.

Table 3.2

Fire and Explosion Index for Process Units

Sr. No.	Unit Name	FEI	Category
1	LNG Carrier (266,000 m^3)	110	Intermediate
2	LNG Unloading Arm	65	Moderate
3	Vapor Return Arm	88	Moderate
4	LNG Pipelines	80	Moderate
5	LNG Storage Tank	123	Intermediate
6	LP LNG Pump	69	Moderate
7	HP Gas send out arm	104	Intermediate
8	HP LNG Pumps	65	Moderate
9	Shell and Tube LNG Vaporizers	129	Heavy
10	Submerged Combustion Vaporizer	134	Heavy
11	Pipeline connecting Terminal to nearest Gas grid	132	Heavy
12	Boil Off Gas Compressors	136	Heavy
13	KO Drum (Flare)	73	Moderate

3.5 Maximum Credible Accidents (MCA) Analysis

MCA analysis encompasses defined techniques to identify the hazards and compute the consequent effects in terms of damage distances due to heat

radiation for fire scenarios and pressure waves for explosion scenarios. A list of probable or potential accidents of the major units in the installation arising due to use, storage and handling of the hazardous materials are examined to establish their credibility. Depending upon the effective hazardous attributes and their impact on the event, the maximum effect on the surrounding environment and the respective damage caused can be assessed. Hazardous substance, on release can cause damage on a large scale. The extent of the damage is dependent upon the nature of the release and the physical state of the material. In the present report the consequences for LNG storage tanks, pumps and pipelines are considered and the damages caused due to such releases are assessed with recourse to MCA analysis.

Flammable substances on release may cause Jet fire and less likely unconfined vapour cloud explosion causing possible damage to the surrounding area. The extent of damage depends upon the nature of the release. The release of flammable materials and subsequent ignition result in heat radiation wave or vapour cloud depending upon the flammability and its physical state. Damage distances due to release of hazardous materials depend on atmospheric stability and wind speed. It is important to visualize the consequence of the release of such substances and the damage caused to the surrounding areas. Computation of damage distances are carried out at various atmospheric stability conditions for various wind velocities and the result is tabulated. Pasquill-Gifford atmospheric stability classes with corresponding weather conditions are listed in **Table 3.3**.

Table 3.3

Pasquill – Gifford Atmospheric Stability

Sr. No.	Stability Class	Weather Conditions
1.	A	Very unstable – sunny, light wind
2.	A/B	Unstable - as with A only less sunny or more windy
3.	B	Unstable - as with A/B only less sunny or more windy
4.	B/C	Moderately unstable – moderate sunny and moderate wind
5.	C	Moderately unstable – very windy / sunny or overcast / light wind
6.	C/D	Moderate unstable – moderate sun and high wind
7.	D	Neutral – little sun and high wind or overcast / windy night
8.	E	Moderately stable – less overcast and less windy night thand
9.	F	Stable – night with moderate clouds and light / moderate wind
10.	G	Very stable – possibly fog

3.5.1 Fire and Explosion Scenarios

Combustible materials within their flammable limits may ignite and burn if exposed to an ignition source of sufficient energy. On process plants, this normally occurs as a result of a leakage or spillage. Depending on the physical properties of the material and the operating parameters, the combustion of material in a plant may take on a number of forms like jet fire, flash fire and pool fire.The ignition source for fire and explosion scenario could be electric spark, a hot surface, and friction between moving parts of a machine or an open fire.

3.5.1.1 Jet Fire

Jet fire occurs when flammable material of a high exit velocity ignites. In process industries this may be due to design (flares) or an accidental. Ejection of flammable material from a vessel, pipe or pipe flange may give rise to a jet fire and in some instances the jet flame could have substantial “reach”. Depending on wind speed, the flame may tilt and impinge on pipeline, equipment or structures. The thermal radiation from these fires may cause injury to people or damage equipment some distance from the source of the flames.

3.5.1.2 Flash Fire

A flash fire is the non-explosive combustion of a vapour cloud resulting from a release of flammable material into the open air, which after mixing with air, ignites. A flash fire results from the ignition of a released flammable cloud in which there is essentially no increase in combustion rate.

Flash fire may occur due to its less vapour temperature than ambient temperature. Hence, as a result of a spill, they are dispersed initially by the negative buoyancy of cold vapours and subsequently by the atmospheric turbulence. After the release and dispersion of the flammable fuel the resulting vapour cloud is ignited and when the fuel vapour is not mixed with sufficient air prior to ignition, it results in diffusion fire burning. Therefore the rate at which the fuel vapour and air are mixed together during combustion determines the rate of burning in the flash fire.

The main dangers of flash fire are radiation and direct flame contact. The size of the flammable cloud determines the area of possible direct flame contact effects. Radiation effects on a target depend on several factors including its distance from the flames, flame height, flame emissive power, local atmospheric transitivity and cloud size. Most of the time, flash combustion lasts for no more than a few seconds.

3.5.1.3 Pool Fire

Releases of hydrocarbons in the absence of immediate ignition would form an unconfined pool, which on ignition would result in a pool fire. Radius of pool depends upon mass flow rate, ambient temperature, heat of vaporization of material released, type of container, vapour pressure of material released and discharge duration. Emissive power generated from the pool surface depends upon pool burning rate, heat of combustion of release material, atmospheric transitivity and area of pool.

The pool fire being either tank or bund fire consists of large volumes of flammable material at atmospheric pressure burning in an unconfined space. The flammable material will be consumed at the burning rate depending on factors including the prevailing winds. During combustion heat will be released in the form of thermal radiation. Temperatures close to the flame centre will be high but will reduce rapidly to tolerable temperatures over a relatively short distance. Any plant building or persons close to the fire or within the intolerable zone will experience burn damage with the severity depending on the distance from the fire and the time exposed to the heat of the fire. In the event of a pool fire the flames will tilt according to the wind speed and direction. The flame length and tilt angle affect the distance of thermal radiation generated.

3.5.1.4 Vapour Cloud Explosion

The Vapour Cloud Explosion (VCE) begins with a release of a large quantity of flammable vaporizing liquid or gas from a storage tank, transport vessel or pipeline producing a dangerous overpressure. These explosions follow a well-determined pattern. There are basically four features, which must be present for an effective vapour cloud explosion to occur with an effective blast. These are:

First, the release material must be flammable and at a suitable condition of temperature and pressure which depends on the chemical. The materials which come under this category, range from liquefied gases under pressure (e.g. butane, propane); ordinary flammable liquids (e.g. cyclohexane, naphtha) to non liquefied flammable gases (e.g. ethylene, acetylene)

Second, before the ignition, a cloud of sufficient size must have been formed. Normally ignition delays of few minutes are considered the most probable for generating the vapour cloud explosions

Third, a sufficient amount of the cloud must be within the flammable range of the material to cause extensive overpressure

Fourth, the flame speed determines the blast effects of the vapour cloud explosions, which can vary greatly

The flammable content of a gas cloud is calculated by three-dimensional integration of the concentration profiles, which fall within the flammable limits. If the gas cloud ignites, two situations can occur, namely non-explosive combustion (flash fire) and explosive combustion (flash fire + explosion).

3.5.2 Models for the Calculation of Heat load and Shock Waves

If a flammable gas or liquid is released, damage resulting from heat radiation or explosion may occur on ignition. Models used in this study for the effects in the event of the ignition of a gas cloud will be discussed in succession. These models calculate the heat radiation or peak overpressure as a function of the distance from the torch, the ignited pool or gas cloud. The physical significance of the various heat loads is depicted in **Table 3.4**.

Table 3.4

List of Damages Envisaged at Various Heat Loads

Sr. No.	Heat loads (kW/m^2)	Type of Damage Intensity	
		Damage to Equipment	Human Injury
1	37.5	Damage to process equipment	100% lethality in 1 min. 1% lethality in 10 sec
2	25.0	Minimum energy required to ignite wood	50% Lethality in 1 min. Significant injury in 10 sec
3	19.0	Maximum thermal radiation intensity allowed on thermally unprotected equipment	--
4	12.5	Minimum energy required to melt plastic tubing	1% lethality in 1 min
5	4.0	--	First degree burns, causes pain for exposure longer than 10 sec
6	1.6	--	Causes no discomfort on long exposures
Source: Techniques for assessing industrial hazards by world bank			

3.5.3 Model for Pressure Wave

A pressure wave can be caused by gas cloud explosion. The following damage criteria are assumed as a result of the peak overpressure of a pressure wave:

- 0.03 bar over pressure wave is taken as the limit for the occurrence of wounds as a result of flying fragments of glass
- Following assumptions are used to translate an explosion in terms of damage to the surrounding area:
  - Within the contour area of the exploding gas cloud, Casualties are due to burns or asphyxiation. Houses and buildings in this zone will be severely damaged.
  - In houses with serious damage, it is assumed that one out of eight persons present will be killed as a result of the building collapse. Within the zone of a peak over pressure of 0.3 bar the risk of death in houses is 0.9 x 1/8 = 0.1125, and in the zone with a peak over pressure of 0.1 bar the probability of death is 0.1 x 1/8 = 0.0125, i.e. one out of eighty people will be killed.

The significance of the peak over pressures 0.3 bar, 0.1 bar, 0.03 bar and 0.01 bar are depicted in **Table 3.5**.

Table 3.5

Damage Criteria for Pressure Waves

Human Injury		Structural Damage	
Peak Over Pressure (bar)	**Type of Damage**	**Peak Over Pressure (bar)**	**Type of Damage**
5-8	100% lethality	0.3	Heavy (90% damage)
3.5-5	50% lethality	0.1	Repairable (10% damage)
2-3	Threshold lethality	0.03	Damage of Glass
1.33-2	Severe lung damage	0.01	Crack of windows
1-1.33	50% Eardrum rupture	-	-
Source: Marshall, V.C. (1977)' How lethal Is explosive and toxic escape'.			

3.5.4 Computation of Damage Distances

Damage distances for the accidental release of LNG due to various leak sizes and Catastrophic rupture for the terminal have been computed at 2F, 3D and 5D weather conditions. In these conditions, 2, 3 and 5 are wind velocities in m/s and F and D are atmospheric stability classes. These weather conditions have been selected to accommodate worst case scenarios to get maximum effective distances. For the partial release scenarios, the leak location has been considered at the height of 1 meter from the bottom of the equipment.

DNV based **PHAST 6.51**software has been used to carry out consequence analysis. Damage distances computed for various credible scenarios for LNG storage tanks, LNG pipeline and LNG pumps are described below:

Jet Fire

For the visualisation of this scenario, leak sizes of 300mm and1000mm for LNG storage tanks, 25 mm and 50 mm for LNG pipeline and 25 mm and 50 mm for LNG pumps are considered. Consequences are analysed at various heat radiation levels under the different atmospheric stability classes and wind velocities. The damage distances due to 300 mm leak in LNG storage tank of capacity 196,000 m^3 at stability class 3D conditions are 109 m, 115 m and 124 m for heat loads of 37.5 kW/m^2 12.5kW/m^2 and 4 kW/m^2 respectively. The computed damage distances for other scenarios are given in **Table 3.6**.

Table 3.6

Consequence Analysis for Jet Fire Scenario

Scenario Considered Leak	Leak Size (mm)	Source Strength (kg/sec)	Weather condition	Damage Distance (m) for Various Heat Loads		
				37.5 kW/m²	12.5 kW/m²	4.0 kW/m²
LNG Carrier (266,000 m³)	300	140.48	2F	104.04	109.10	117.64
			3D	110.11	115.59	124.86
			5D	116.25	122.17	132.19
	1000	1560.91	2F	225.30	240.32	265.72
			3D	230.49	245.41	270.61
			5D	232.81	247.93	273.46
LNG Unloading Arms	25	11.85	2F	-	16.93	49.80
			3D	-	27.15	52.46
			5D	13.18	33.70	55.27
	50	47.41	2F	-	39.71	95.80
			3D	5.00	53.47	99.84
			5D	28.95	63.23	103.54
	Line Rupture	3132.53	2F	97.24	370.76	694.08
			3D	149.46	396.85	678.58
			5D	192.69	390.67	633.56
Vapour Return Arm	25	1.21	2F	-	7.41	20.76
			3D	-	12.37	21.22
			5D	-	14.39	23.17
	50	4.87	2F	37.5	18.45	39.37
			3D	-	24.03	40.02
			5D	11.44	26.57	43.06
	Line Rupture	327.18	2F	9.48	49.50	93.75
			3D	22.87	79.60	130.55
			5D	62.22	109.69	179.1
LNG Pipeline	25	8.88	2F	-	16.41	45.25
			3D	-	25.98	47.34
			5D	12.58	30.49	50.0
	50	35.43	2F	37.5	37.55	86.80
			3D	37.5	50.40	90.00
			5D	27.27	57.10	93.52
	Line Rupture	-	2F	160.27	496.43	894.64
			3D	-	-	-
			5D	249.48	494.13	798.76

Scenario Considered Leak	Leak Size (mm)	Source Strength (kg/sec)	Weather condition	Damage Distance (m) for Various Heat Loads		
				37.5 kW/m²	12.5 kW/m²	4.0 kW/m²
LNG Storage tank	300	195.41	2F	101.58	106.51	114.85
			3D	109.69	115.19	124.50
			5D	119.54	125.75	136.28
	1000	2171.3	2F	202.73	216.12	238.78
			3D	217.48	231.42	254.97
			5D	222.76	237.15	261.46
LP LNG Pump	25	11.79	2F	41.30	49.76	60.43
			3D	49.20	52.81	59.13
			5D	57.33	60.68	66.29
	50	47.19	2F	79.24	94.54	119.72
			3D	89.45	98.11	117.09
			5D	102.34	110.38	124.55
Hp Gas Send Out Arm	25	7.76	2F	30.74	38.80	49.57
			3D	31.46	39.34	49.69
			5D	32.89	40.39	49.87
	50	31.04	2F	56.16	72.70	96.11
			3D	57.37	73.74	96.22
			5D	59.93	75.70	96.25
	Line Rupture	-	2F	644.5	856.7	1196.5
			3D	657.3	854.9	1209.2
			5D	669.6	874.9	1229.1
HP LNG Pumps	25	26.71	2F	50.80	68.70	95.68
			3D	53.89	70.47	93.14
			5D	62.09	70.16	84.37
	50	106.85	2F	93.54	127.37	179.81
			3D	97.96	128.85	172.91
			5D	114.19	130.89	162.92
Shell and Tube LNG Vaporizers	25	25.86	2F	50.27	68.02	94.48
			3D	53.39	69.56	91.53
			5D	61.91	69.38	82.89
	50	103.46	2F	92.46	125.84	177.29
			3D	97.18	127.49	170.39
			5D	113.62	129.23	160.11

Scenario Considered Leak	Leak Size (mm)	Source Strength (kg/sec)	Weather condition	Damage Distance (m) for Various Heat Loads		
				37.5 kW/m²	12.5 kW/m²	4.0 kW/m²
Submerged Combustion Vaporizer	25	25.86	2F	50.27	68.02	94.48
			3D	53.39	69.56	91.53
			5D	61.91	69.38	82.89
	50	103.46	2F	92.46	125.84	177.29
			3D	97.18	127.49	170.39
			5D	113.62	129.23	160.11
Pipeline connecting Terminal to nearest Gas grid	25	9.76	2F	13.30	15.55	30.70
			3D	34.95	43.89	55.68
			5D	36.53	45.07	55.88
	50	39.04	2F	61.67	80.17	106.72
			3D	62.96	81.31	106.78
			5D	65.71	83.422	106.71
	Line Rupture	92.42	2F	238.06	312.94	449.29
			3D	240.98	318.09	450.79
			5D	244.45	325.08	449.45
Boil Off Gas Compressor	25	8.83	2F	42.50	45.56	50.85
			3D	47.08	50.00	54.89
			5D	56.08	58.77	63.24
	50	35.34	2F	77.53	84.98	102.14
			3D	84.74	91.83	105.75
			5D	99.39	105.93	117.04
KO Drum (Flare)	25	5.10	2F	38.46	40.54	43.90
			3D	44.20	46.17	49.31
			5D	46.34	48.28	51.35
	50	20.40	2F	69.06	73.74	82.77
			3D	77.62	82.81	90.86
			5D	84.78	89.68	97.39

Flash Fire

For the visualisation of this scenario, leak sizes of 300 mm and 1000mm for LNG storage tanks, 25 mm and 50 mm for LNG pipeline and 25 mm and 50 mm for LNG pumps are considered. Consequences are analysed at various heat radiation levels under the different atmospheric stability classes and wind velocities. Damage distance due to 25 mm leak in LNG pipeline at 2F condition is 10.02 m at LFL concentration. The computed damage distances for other scenarios are given in **Table 3.7**.

Table 3.7

Consequence Analysis for Flash Fire Scenario

Scenario Considered	LFL Conc. (ppm)	Leak Size (mm)	Source Strength (kg/sec)	Weather Condition	LFL Distance (m)
LNG Carrier 266000m^3	44000	300	140.48	2F	562.29
				3D	247.786
				5D	200.868
		1000	1560.91	2F	1632.66
				3D	516.362
				5D	454.745
LNG Unloading Arm	44000	25	11.85	2F	8.5
				3D	8.7
				5D	9.2
		50	47.41	2F	24.19
				3D	21.28
				5D	21.06
Vapor Return Arm	44000	25	1.21	2F	26.21
				3D	9.39
				5D	8.28
		50	4.87	2F	64.78
				3D	51.53
				5D	33.28
LNG Pipeline	44000	25	8.8	2F	10.02
				3D	9.81
				5D	10.02
		50	35.3	2F	36.79
				3D	28.82
				5D	23.61
		Line Rupture	5253.45	2F	335.06
				3D	320.48
				5D	387.14
LNG Storage Tank	44000	300	195.41	2F	658.73
				3D	282.83
				5D	213.27
		1000	2171.3	2F	1800.59
				3D	546.25
				5D	523.37

Scenario Considered	LFL Conc. (ppm)	Leak Size (mm)	Source Strength (kg/sec)	Weather Condition	LFL Distance (m)
LP LNG Pump	44000	25	11.79	2F	144.81
				3D	120.93
				5D	99.83
		50	47.19	2F	301.21
				3D	248.70
				5D	204.64
HP Gas Send Out Arm	44000	25	7.76	2F	30.60
				3D	28.60
				5D	27.68
		50	31.04	2F	74.87
				3D	70.15
				5D	71.67
		Line Rupture	-	2F	182.89
				3D	683.59
				5D	183.32
HP LNG Pumps	44000	25	26.71	2F	129.44
				3D	124.08
				5D	130.74
		50	106.85	2F	264.30
				3D	277.91
				5D	292.97
Shell and Tube LNG Vaporizer	44000	25	25.86	2F	129.22
				3D	124.33
				5D	130.29
		50	103.46	2F	261.59
				3D	275.03
				5D	291.73
Submerged Combustion Vaporizer	44000	25	25.86	2F	129.22
				3D	124.33
				5D	130.29
		50	103.46	2F	261.59
				3D	275.03
				5D	291.73

Scenario Considered	LFL Conc. (ppm)	Leak Size (mm)	Source Strength (kg/sec)	Weather Condition	LFL Distance (m)
Pipeline Connecting Nearest Gas Grid	44000	25	9.76	2F	35.75
				3D	33.55
				5D	33.13
		50	39.04	2F	87.81
				3D	82.16
				5D	84.24
		Line Rupture	92.42	2F	531.68
				3D	511.69
				5D	546.77
Boil Off Gas Compressor	44000	25	8.83	2F	123.21
				3D	107.58
				5D	86.11
		50	35.34	2F	244.62
				3D	214.61
				5D	174.86
KO Drum (Flare)	44000	25	5.10	2F	86.66
				3D	80.36
				5D	65.59
		50	20.40	2F	164.71
				3D	153.15
				5D	127.66

Pool Fire

For the visualisation of this scenario, leak sizes of 300 mm and 1000mm for LNG storage tanks, 25 mm and 50 mm for LNG pipeline and 25 mm and 50 mm for LNG pumps are considered. Consequences are analysed at various heat radiation levels under the different atmospheric stability classes and wind velocities. The damage distances due to Catastrophic rupture of LNG carriers at stability class 3D conditions are 1227 m, 1976 m and 3019 m for heat load 37.5 kW/m², 12.5 kW/m² and 4 kW/m² respectively. The computed damage distances for the scenarios considered are given in **Table 3.8**.

Table 3.8

Consequence Analysis for Pool Fire Scenario

Scenario Considered	Leak Size (mm)	Source Strength (kg/sec)	Pool Radius (m)	Weather	Damage Distance (m) for Various Heat Loads		
					37.5 kW/m²	12.5 kW/m²	4.0 kW/m²
LNG Carriers	300	140.48	0.19	2F	89.09	160.42	259.30
				3D	97.67	165.91	261.81
				5D	108.27	169.20	261.94
	1000	1560.9	0.63	2F	232.16	412.91	669.41
				3D	251.06	427.64	675.59
				5D	277.10	442.47	685.29
	Catastrophic rupture	-	-	2F	1235.6	1988.0	3045.3
				3D	1227.1	1976.6	3019.5
				5D	1373.7	2105.8	3113.1
LNG Unloading Arm	25	11.18	0.01	2F	-	-	-
				3D	-	-	-
				5D	-	-	-
	50	47.41	0.02	2F	-	-	-
				3D	-	-	-
				5D	-	-	-
	Line rupture	-	-	2F	55.1	59.0	62.9
				3D	44.6	50.3	55.2
				5D	-	69.9	70.2
Vapour Return Arm	25	1.21	0.01	2F	-	-	-
				3D	-	-	-
				5D	-	-	-
	50	4.87	0.02	2F	4.88	10.30	15.47
				3D	-	5.17	5.17
				5D	-	-	-
	Catastrophic rupture	-	-	2F	121.69	222.73	364.45
				3D	131.76	228.33	363.98
				5D	144.28	230.10	359.26
LNG Storage Tank	300	195.41	0.12	2F	102.89	184.75	298.82
				3D	113.10	191.68	302.11
				5D	125.35	195.89	302.75
	1000	2171.3	0.39	2F	257.74	457.78	741.94
				3D	279.31	474.91	749.54
				5D	308.05	492.04	761.04
	Catastrophic rupture	-	-	2F	1151.0	1862.5	2863.8
				3D	1146.4	1854.8	2842.0
				5D	1284.09	1973.13	2925.35

Scenario Considered	Leak Size (mm)	Source Strength (kg/sec)	Pool Radius (m)	Weather	Damage Distance (m) for Various Heat Loads		
					37.5 kW/m²	12.5 kW/m²	4.0 kW/m²
LP LNG Pump	25	11.79	0.01	2F	-	-	-
				3D	-	-	-
				5D	-	-	-
	50	47.19	0.02	2F	-	-	39.98
				3D	-	-	46.73
				5D	-	-	-
	Catastrophic rupture	-	-	2F	54.36	100.94	164.52
				3D	60.35	104.62	166.66
				5D	68.59	108.11	169.06
HP LNG Pumps	25	26.71	-	2F	-	-	-
				3D	-	-	-
				5D	-	-	-
	50	106.8	-	2F	-	-	-
				3D	-	-	-
				5D	-	-	-
	Catastrophic rupture	-	-	2F	49.19	91.50	149.06
				3D	54.69	94.81	150.95
				5D	62.19	97.99	152.97
Submerged Combustion Vaporizer	25	25.86	0.01	2F	-	-	-
				3D	-	-	-
				5D	-	-	-
	50	103.65	0.02	2F	-	-	-
				3D	-	-	-
				5D	-	-	-
	Catastrophic rupture	-	-	2F	49.40	91.88	149.6
				3D	54.92	95.22	151.60
				5D	62.56	98.58	153.91
Boil Off Gas Compressor	25	8.83	0.01	2F	-	-	-
				3D	-	-	-
				5D	-	-	-
	50	35.34	0.02	2F	-	34.49	34.49
				3D	-	-	41.56
				5D	-	-	43.65
	Catastrophic rupture	-	-	2F	28.35	53.31	86.52
				3D	31.63	55.50	87.92
				5D	36.12	57.27	88.54

Scenario Considered	Leak Size (mm)	Source Strength (kg/sec)	Pool Radius (m)	Weather	Damage Distance (m) for Various Heat Loads		
					37.5 kW/m²	12.5 kW/m²	4.0 kW/m²
KO Drum (Flare)	25	5.14	0.01	2F	-	-	-
				3D	-	-	-
				5D	-	-	-
	50	20.56	0.02	2F	24.24	29.77	35.08
				3D	26.93	29.11	31.37
				5D	28.08	29.88	31.59
	Catastrophic rupture	-	-	2F	98.07	179.46	292.83
				3D	108.80	187.78	298.79
				5D	123.38	195.25	304.06
Diesel Oil Storage	25	3.60	0.01	2F	13.96	24.11	39.56
				3D	13.96	26.15	40.56
				5D	13.95	28.61	41.66
	50	14.42	0.02	2F	-	24.21	50.54
				3D	-	25.56	53.62
				5D	-	26.88	56.66
	Catastrophic rupture	-	-	2F	-	41.10	89.55
				3D	-	41.18	95.65
				5D	-	41.90	102.82

Vapour Cloud Explosion

For the visualisation of this scenario, leak sizes of 300 mm and 1000mm for LNG storage tanks, 25 mm and 50 mm for LNG pipeline and 25 mm and 50 mm for LNG pumps are considered. Consequences are analysed at various heat radiation levels under the different atmospheric stability classes and wind velocities. The damage distances due to 25mm leak in LP LNG unloading pump at stability class 3D conditions are 297 m, 230 m and 204 m for overpressure wave of 0.03 bar, 0.1 bar and 0.3 bar respectively. The computed damage distances for other scenarios are given in **Table 3.9.**

Table 3.9

Consequence Analysis for VCE Scenario

Scenario Considered	Leak Size (mm)	Source Strength (kg/sec)	Weather	Damage Distance (m)		
				0.03bar	0.1bar	0.3bar
LNG Carriers	300	140.48	2F	1032.12	991.43	980.70
			3D	826.78	604.95	522.36
			5D	686.96	493.70	421.75
	1000	1560.91	2F	2490.71	2233.94	2141.63
			3D	1599.41	1125.82	1027.82
			5D	1623.82	1139.36	1009.55
	Catastrophic rupture	-	2F	6503.25	5140.72	5120.34
			3D	6283.16	3929.91	3102.16
			5D	6404.21	4706.42	4515.64
LNG Unloading Arms	25	11.18	2F	90.2	55.6	42.8
			3D	77.5	44.5	32.2
			5D	70.8	41.6	30.8
	50	47.41	2F	191.0	121.6	95.7
			3D	175.8	109.4	84.67
			5D	150.1	92.6	71.3
	Line Rupture	3132.53	2F	2537.0	2386.9	2352.3
			3D	1740.3	1506.7	1442.4
			5D	1531.9	1367.6	1350.6
Vapour Return Arm	25	1.21	2F	105.67	68.00	53.98
			3D	61.74	43.53	36.76
			5D	37.22	21.60	15.79
	50	4.87	2F	267.13	182.74	152.19
			3D	169.88	118.33	99.14
			5D	123.19	86.95	73.45
	Line Rupture	327.18	2F	811.54	538.12	509.02
			3D	893.45	636.50	553.14
			5D	952.79	681.63	580.68
LNG PIPELINES	25	10.64	2F	90.47	55.79	42.87
			3D	76.18	43.96	31.96
			5D	69.16	40.96	30.16
	50	42.56	2F	193.02	122.46	96.19
			3D	176.10	109.51	84.72
			5D	150.26	92.76	71.35
	Line Rupture	6328.36	2F	1045.81	675.45	537.54
			3D	983.42	645.37	538.02
			5D	962.43	654.75	573.26

Scenario Considered	Leak Size (mm)	Source Strength (kg/sec)	Weather	Damage Distance (m)		
				0.03bar	0.1bar	0.3bar
LNG Storage Tank	300	195.41	2F	1161.49	914.33	761.51
			3D	914.33	664.38	582.08
			5D	761.51	548.44	469.11
	1000	2171.3	2F	2443.18	2312.9	2288.8
			3D	1712.86	1202.9	1101.31
			5D	1653.19	1220.99	1090.32
	Catastrophic rupture	-	2F	6237.82	4261.31	4082.59
			3D	5712.09	3560.18	2924.28
			5D	5666.52	4326.2	4229.97
LP LNG Pump	25	11.79	2F	376.84	281.15	245.53
			3D	297.37	230.05	204.99
			5D	243.17	184	161.97
	50	47.19	2F	531.53	415.95	401.22
			3D	567.07	444.42	402.15
			5D	504.32	381.40	335.64
	Catastrophic rupture	-	2F	563.09	458.08	418.99
			3D	448.94	392.19	371.07
			5D	456.01	401.07	385.51
HP Gas send out arm	25		2F	110.89	87.44	78.70
			3D	106.98	85.77	77.87
			5D	105.75	85.24	77.61
	50	31.04	2F	271.05	218.83	199.39
			3D	262.01	214.97	197.46
			5D	271.08	224.58	207.26
	Line Rupture	-	2F	576.99	325.77	237.45
			3D	979.21	871.76	844.58
			5D	579.31	326.93	238.13
HP LNG Pumps	25	26.71	2F	429.28	349.4	319.66
			3D	389.88	321.12	295.53
			5D	347.34	280.04	254.98
	50	106.85	2F	484.35	354.90	345.64
			3D	498.06	387.35	348.62
			5D	528.65	407.87	363.87
	Catastrophic rupture	-	2F	566.55	476.76	443.33
			3D	436.53	375.43	352.68
			5D	406.35	353.92	336.94

Scenario Considered	Leak Size (mm)	Source Strength (kg/sec)	Weather	Damage Distance (m)		
				0.03bar	0.1bar	0.3bar
Shell and Tube LNG Vaporizers	25	25.86	2F	429.47	349.48	319.70
			3D	389.83	321.10	295.51
			5D	337.23	269.99	244.96
	50	103.46	2F	485.08	354.74	342.35
			3D	504.21	380.39	360.46
			5D	532.91	404.59	357.23
	Catastrophic rupture	-	2F	569.30	477.94	443.92
			3D	436.08	375.24	352.59
			5D	408.95	353.81	336.88
Submerged Combustion Vaporizer	25	25.86	2F	429.47	349.48	319.70
			3D	389.83	321.10	295.51
			5D	337.23	269.99	244.96
	50	103.46	2F	485.08	354.74	342.35
			3D	504.21	380.39	360.46
			5D	532.91	404.59	357.23
	Catastrophic rupture	-	2F	569.30	477.94	443.92
			3D	436.08	375.24	352.59
			5D	408.95	353.81	336.88
Pipeline connecting Terminal to nearest Gas grid	25	8.83	2F	289.72	206.13	188.04
			3D	263.44	198.38	174.15
			5D	214.60	160.34	140.14
	50	39.04	2F	369.77	290.62	275.29
			3D	349.08	302.14	291.05
			5D	337.55	274.16	257.06
	Line Rupture	92.42	2F	1008.39	785.47	742.67
			3D	1000.65	791.46	770.36
			5D	1040.26	870.32	853.84
Boil Off Gas Compressors	25	7.88	2F	194.42	143.31	136.58
			3D	192.60	158.81	149.39
			5D	193.52	145.62	127.78
	50	31.55	2F	279.52	241.52	230.74
			3D	278.22	251.31	245.64
			5D	233.14	205.18	197.58
	Catastrophic rupture	-	2F	366.84	288.36	259.14
			3D	277.92	221.76	200.85
			5D	253.98	211.55	195.75

Scenario Considered	Leak Size (mm)	Source Strength (kg/sec)	Weather	Damage Distance (m)		
				0.03bar	0.1bar	0.3bar
KO Drum (Flare)	25	5.14	2F	268.44	183.31	151.61
			3D	205.98	150.93	130.44
			5D	168.23	123.36	106.66
	50	20.56	2F	485.71	350.08	309.99
			3D	403.25	292.41	251.15
			5D	334.54	245.91	212.91
	Catastrophic rupture	-	2F	1150.56	1087.15	1063.52
			3D	807.66	671.35	620.61
			5D	799.30	654.99	622.45

3.6 Evaluation of Risk

Risk is quantified in terms of probability of occurrence of hazardous event and magnitude of its consequences. The consequence modelling was carried out in order to assess the extent of damage by visualizing accidental release scenarios for LNG storage tanks, LNG pipeline and LNG pumps. The risk to the human due to accidental release scenarios is represented in two ways viz. individual risk and societal risk. Individual risk associated with the various equipments of Chhara LNG terminal has been evaluated by analysing various scenarios which are described in subsequent sections.

Individual Risk

The Individual Risk (IR) level is more specifically defined as the Individual Risk Per Annum (IRPA), which is the calculated annual risk loading to a specific individual or group of individuals. Clearly this depends on the amount of time in a year that the individual spends in different risk areas. The individual risk calculation takes account of the fact that people move from one place to another.

When calculating individual risk from major accident scenarios, it is normal to take account of protection by buildings. Individual risk is typically depicted as contour plots on overall plot plan of a facility, the risk level falling off rapidly as one move away from the source of the leak / epicentre of potential explosions.

Societal Risk

Societal risk is used in quantified risk assessment (QRA) studies and is depicted on a cumulative graph called an F/N curve. The horizontal axis is the number of potential fatalities, N. The vertical axis is the frequency per year that N or

more potential fatalities could occur, F. This risk indicator is used by authorities as a measure for the social disruption in case of large accidents.

It is normal to take account of protection by buildings, and people's response. For large toxic release models, alarm and evacuation can be included. Because it is a cumulative curve, the curve always drops away with increasing N. Normally the F/N curve has a lower frequency cut-off at one in a billion (1 $x10^{-9}$ /yr). Regulators often split the graph into different regions, so that different actions have to be undertaken depending on where the F/N curve falls. Sometimes a maximum limit is placed on N (number of fatalities) possible for any event.

This type of curve is normal for plant type hazardous installations where a large group of people could be affected and their location is well established (housing estates, schools etc) relative to the event location (the plant). For pipelines however, because there is no single location for an event and the population affected varies along the pipeline route, this curve is not normally generated unless a large group of people can be affected over a reasonable distance.

3.6.1 Failure Frequencies

The frequency of releases from equipment has been determined by application of generic frequency data available from various sources. Following are the frequency data for the LNG terminal

LNG Storage Tanks

Failure Frequencies for LNG storage tanks have been used from “Failure Rate and Event Data for use within Land Use Planning Risk Assessments” by health & safety executive, UK. The failure frequencies for LNG storage tanks have been presented in **Table 3.10**.

Table 3.10

Failure Frequencies for LNG Storage Tanks (>12000 m^3)

Type of release	Failure Frequency (per year)
Catastrophic Rupture	$5x10^{-8}$
Major (1000mm) Leak	$1x10^{-6}$
Minor (300mm) Leak	$3x10^{-6}$

Pipeline and Pumps

Failure Frequencies for LNG pipeline and pumpshave been used from “Guideline for quantitative risk assessment; Purple book CPR 18E, Committee for the Prevention of Disasters, Netherlands. The failure frequencies for pipelines and pumps are given in **Table 3.11**.

Table 3.11

Failure Frequencies for Pipelines and Pumps

Type of Release	Failure Frequency
Pipeline (per meter per year)	
25 mm	$1.3x10^{-7}$
50 mm	5.2×10^{-8}
Line rupture	$2.6x10^{-8}$
Pumps (Per Year)	
25 mm	$3.1x10^{-7}$
Catastrophic Rupture	$7.8x10^{-8}$

3.6.2 Risk Acceptance Criteria

The level of risk in this study is quantified with an express purpose of comparing against typical acceptable risks. The acceptable risk levels can change with time and place. Although there are differences between the legislation adopted in the various countries, there appears to be broad consensus on the tolerability of risk. The majority of the countries would accept risk levels for the public around 10^{-5}/yr whilst the more stringent countries would set the tolerability level at 10^{-6}/yr. detailed guidelines available from various countries have been presented below.

United Kingdom

In the UK the "Control of Major Accident Hazards" (COMAH) regulations are in line with the latest EU "Seveso-2" Directive. The regulations do not formally require a quantitative risk assessment, but the guidance notes make clear that in some circumstances quantification will help or could be asked for by the UK regulator - the Health and Safety Executive (HSE) - and this is often done in practice.

To advise planning authorities on developments around industrial installations, the UK HSE has been developing risk acceptance criteria over the years. A comprehensive treatment of the subject of tolerability of risk was given in a report titled "Reducing Risks Protecting People". The report repeated the concept and criteria as argued by the Royal Society in 1983. It accepted the concept of tolerable Individual Risk as being the dividing line between what is just tolerable and intolerable and set the upper tolerable limit for workforce fatalities at 10^{-3}/yr (1 in a thousand) for workers and 10^{-4}/yr (1 in 10 thousand) for members of the public. A level at which risks might be broadly acceptable but not altogether negligible was set at 10^{-6}/yr (1 in a million). The region in between would be controlled by the ALARP concept.

ALARP can be demonstrated in a variety of ways, depending on the severity of the worst case scenario. These are expressed in HSE guidance to Inspectors Consultation Draft September 2002. When a QRA is carried out, then the F/N regions are defined as in the **Fig. 3.1**.

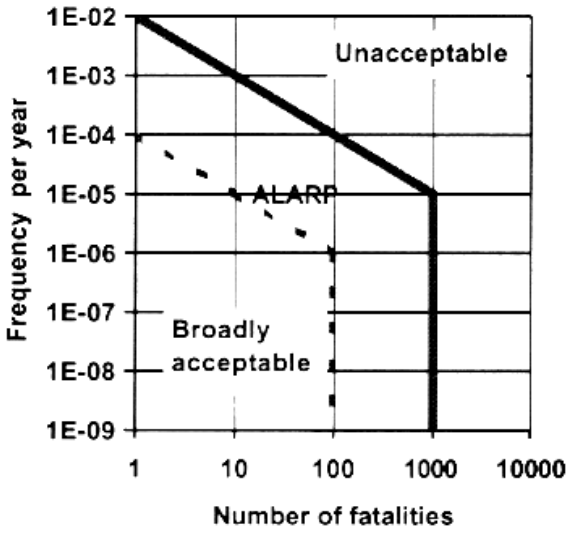


Fig. 3.1: United Kingdom Societal Risk Guidelines (risk to workforce and public)

Unlike the Netherlands (see below), the potential workforce fatalities are included in the F/N curve.

Canada: Major Industrial Accidents Council of Canada (MIACC)

The MIACC recommend individual risk levels for use in respect to hazardous substances risk from all sources, i.e. there is no need to distinguish between risk from a fixed facility at which hazardous substances may be found, or a pipeline or a transportation corridor. The acceptability levels are equally applicable. With these considerations in mind, the guidelines for acceptable levels of risk are given in **Table 3.12**. Also **Fig.3.2** indicates acceptable Individual risks for designated land zones

Table 3.12

Land use and Industrial Risk according to MIACC

Location (based on risk level)	Possible land uses
From risk source to 1 in 10,000 (10^{-4}) risk contour:	No other land uses except the source facility, pipeline or corridor
1 in 10,000 to 1 in 100,000 (10^{-4} to 10^{-5}) risk contours:	uses involving continuous access and the presence of limited numbers of people bút easy evacuation, e.g. open space (parks, golf courses, conservation areas, trails, excluding recreation facilities such ás arenas), warehouses, manufacturing plants
1 in100,000 to 1 in 1,000,000 (10^{-5} to 10^{-6}) risk contours	Uses involving continuous access but easy evacuation, e.g., commercial uses, low-densily residential areas, offices
Beyond the 1 in 1,000,000 (10^{-6}) risk contour	All other land uses without restriction including institutional uses, high-density residential areas, etc.

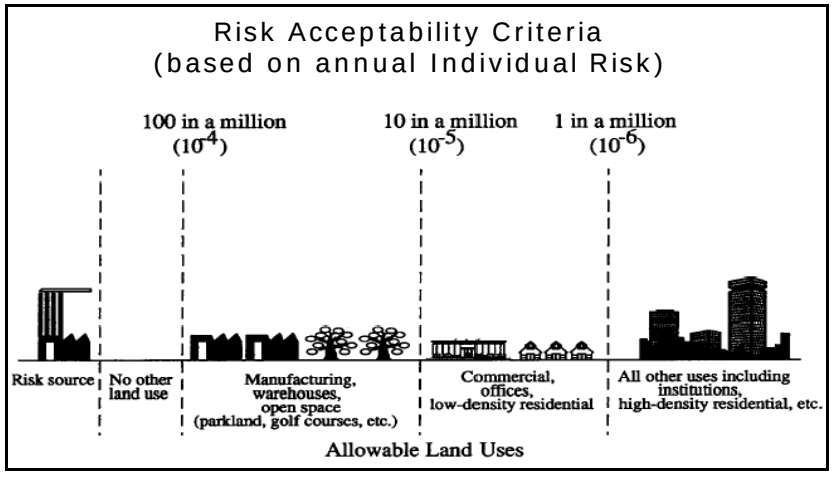


Fig. 3.2: Commonly Acceptable Individual Risks in Different Designated Land Zones

Malaysia

The criteria used by the Department of Environment (DOE) for existing facilities are outlined below for residential and industrial areas:

- Residential 1 x 10^{-6} fatalities / person / year
- Industrial 1 x 10^{-5} fatalities / person / year

In words, the acceptability criteria are as follows: the risk of death to persons in a residential area must not exceed 1 chance in a million per person per year and the risk of death to persons in a nearby industrial area must not exceed 1 chance in 100,000 per person per year.

If the quantified individual risk compares favourably with the acceptability criteria, then it is deemed acceptable. If not, the components of the overall risk are re-examined to determine where risk mitigation measures can be implemented cost effectively. Risk evaluation must also be conducted taking into account the fact that hazard analysis and consequence assessment only gives an estimation of risks from a facility.

Australia

The Western Australia (WA) Department of Planning has adopted risk criteria for hazardous installations. They are based on risk contours and can be summarised as follows:

- A risk level in residential zones of one in a million per year (1 x 10^{-6}/yr) or less, is so small as to be acceptable to the WA EPA (Environmental Protection Agency);
- A risk level in "sensitive developments", such as hospitals, schools, child care facilities and aged care housing developments, of between one half and one in a million per year (5 x 10^{-7} and 1 x 10^{-6}/yr) is so small as to be acceptable to the WAEPA;
- Risk levels from industrial facilities should not exceed a target of fifty in a million per year (1 in 20,000) at the site boundary for each individual industry, and the cumulative risk level imposed upon an industry should not exceed a target of one hundred in a million per year (1 in 10,000);
- A risk for any non-industrial activity, located in buffer zones between industrial and residential zones, of ten in a million per year or lower is so small as to be acceptable to the WA EPA;
- A risk level for commercial developments, including offices, retail centres and showrooms located in buffer zones between industrial facilities and residential zones, of five in a million per year or less, is so small as to be acceptable to the WA EPA.

The Netherlands

The policy statement approved by the Dutch Parliament states the following criteria for existing facilities. The risk is unacceptable if the 10^{-6}/yr risk

contours affect residential areas or the F/N curve is above 10 fatalities with a frequency of 10^{-5}/yr with a slope of -2. This is illustrated in **Fig. 3.3**:

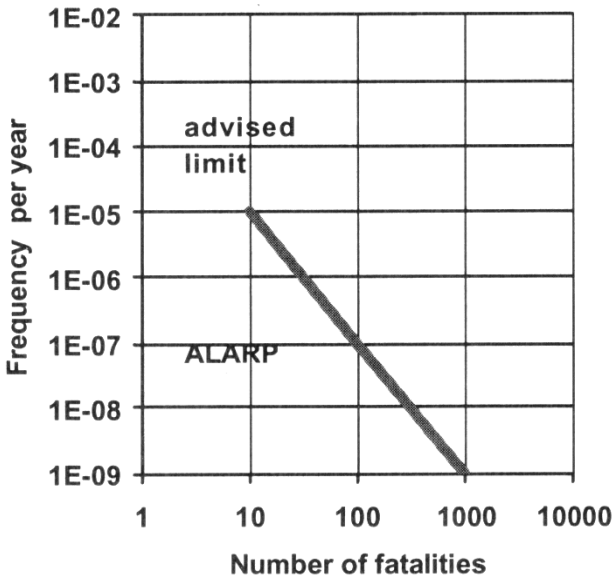


Fig. 3.3: Netherlands Societal Risk Guidelines (risk to public only)

Below the criteria, the ALARP, "As Low As Reasonably Practicable", principle should be used.

AH Dutch installations should meet the criteria for new facilities by the year 2005. For the Societal Risk it should be emphasised that the exposure or "presence" factor of population used for calculating the F/N curve during the day is 0.7 and 1 during night. Also the assumption is made that being indoors gives protection where the fraction of people being indoors is 0.93 during daytime and 0.99 during night time.

Hong Kong Government Criteria

The Hong Kong government has published "Interim Risk Guidelines for Potential Hazardous Installations". The guideline covers new installations and expansion of existing installations and also controls the development of land around installations. It should be pointed out that although these are described as "guidelines" they are very strictly applied in practice. They are seen as necessary because of the special circumstances of Hong Kong, where there is a dense population in close proximity to industrial facilities, and are mainly used for land-use planning decisions. Societal risk guidelines are shown in **Fig. 3.4** and set forth two criteria;

- A risk contour of 10^{-5}/yr for fatality as an upper limit of tolerability.

- The maximum F/N curve exceeds the line through the point of 10 fatalities at a frequency of 10^{-4}/yr with a slope of -1. No event at any frequency should take place which causes more than 1000 deaths.

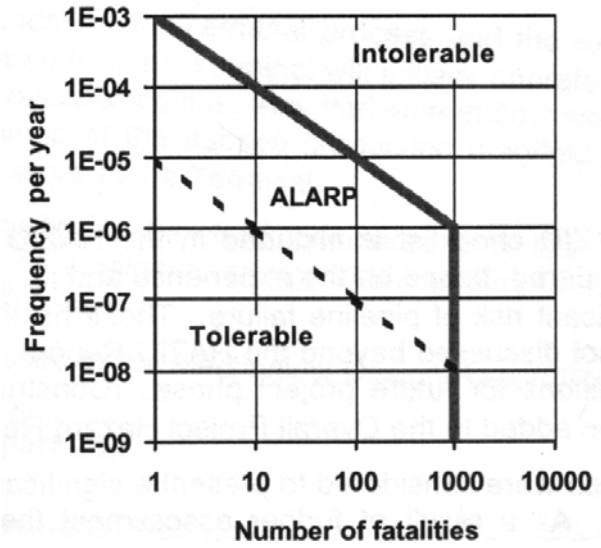


Fig. 3.4: Hong Kong Societal Risk Guidelines (risk to public only)

The Hong Kong regulators scrutinise each risk assessment closely and insist on the use of consistent methodology from case to case.

3.6.3 Individual and Societal Risk Contours

Individual risk and societal risk are computed using software **SAFETI MICRO 6.51** for storage tanks, pipeline and pump. Risk has been presented in terms of individual risk contours, risk transects and F/ N curves in the subsequent sections.

LNG Carrier

IR contours, risk transects and F/N curves have been presented in for both 266,000 m^3 capacity LNG carrier from **Fig. 3.5 to Fig. 3.7**.

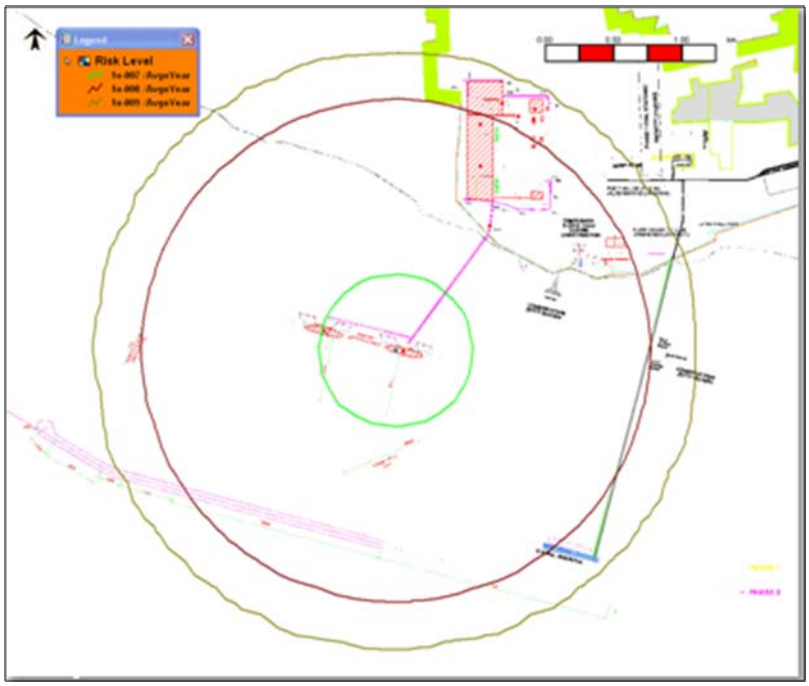


Fig. 3.5: Individual Risk Contours for LNG Carrier, 266,000 m^3

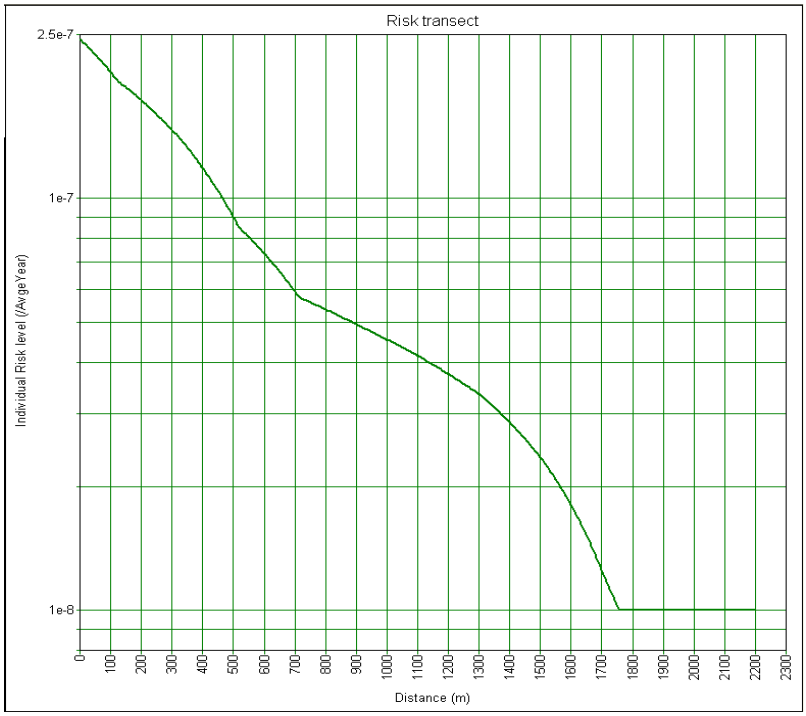


Fig. 3.6: Risk Transect for LNG Carrier, 266,000 m^3

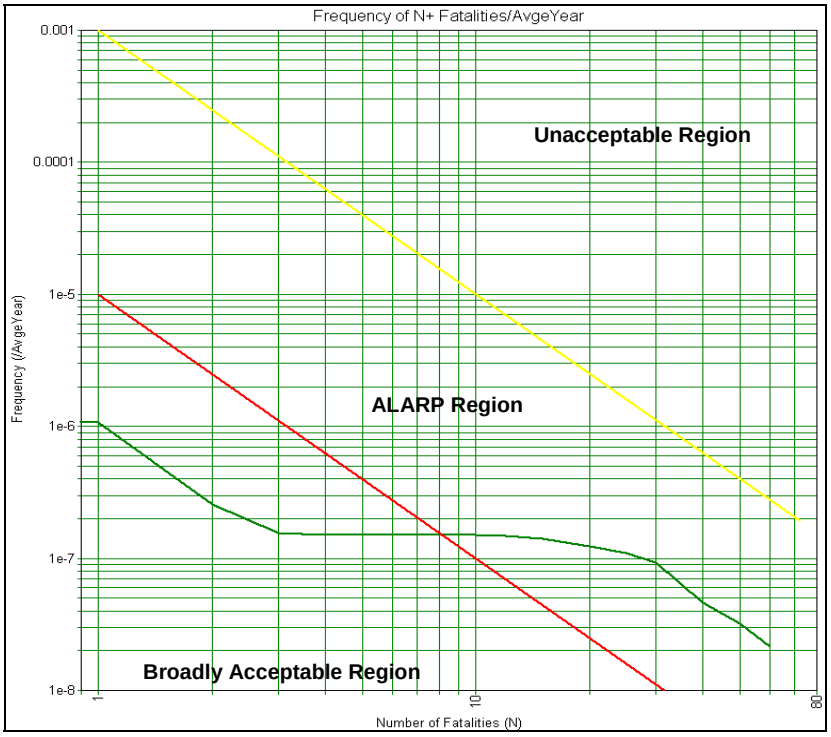


Fig. 3.7: F/N Curve for LNG Carrier, 266,000 m^3

Combined Scenario for 196,000m³ LNG Storage Tanks

IR contours, risk transects and F/N curves have been presented in case of simultaneous fire and explosion scenarios for 196, 000 m^3 capacity LNG storage tanks **Fig. 3.8 to Fig.3.10**.This scenario can be considered as the worst case scenarios involving the domino effect.

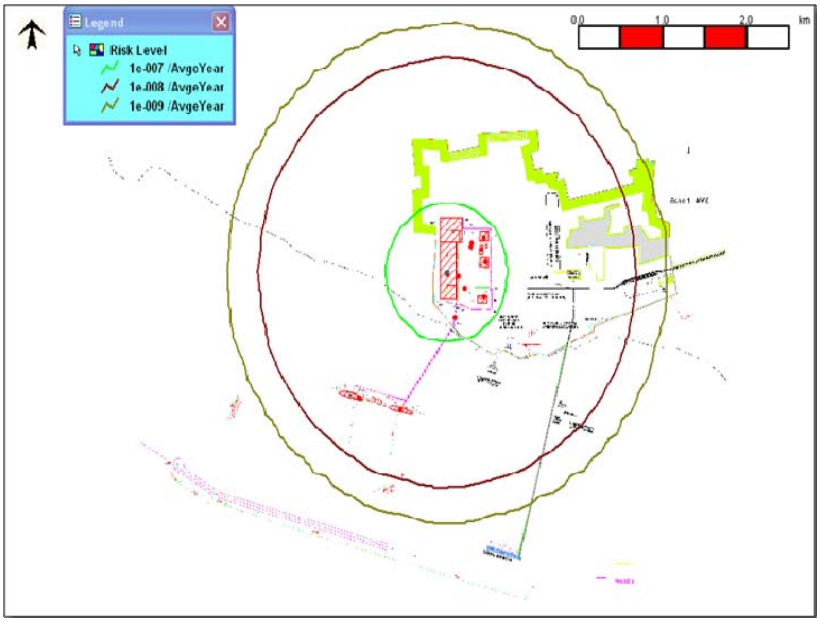


Fig. 3.8: Individual Risk Contours for 196,000 m³ LNG Storage Tanks

Fig. 3.9: Risk Transect for 196,000 m³ LNG Storage Tanks

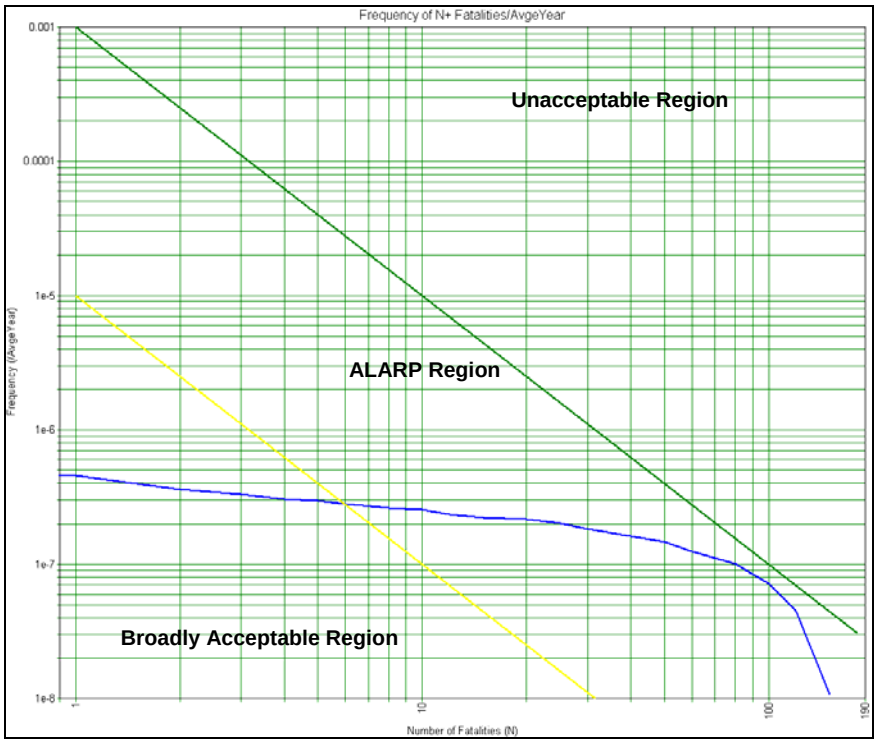


Fig. 3.10: F/N Curve for 196,000 m³ LNG Storage Tanks

LNG Pipeline

IR contours, risk transects and F/N curves for LNG pipeline have been presented in **Fig.3.11 to Fig.3.13** below for leak sizes in case of all possible fire and explosion scenarios

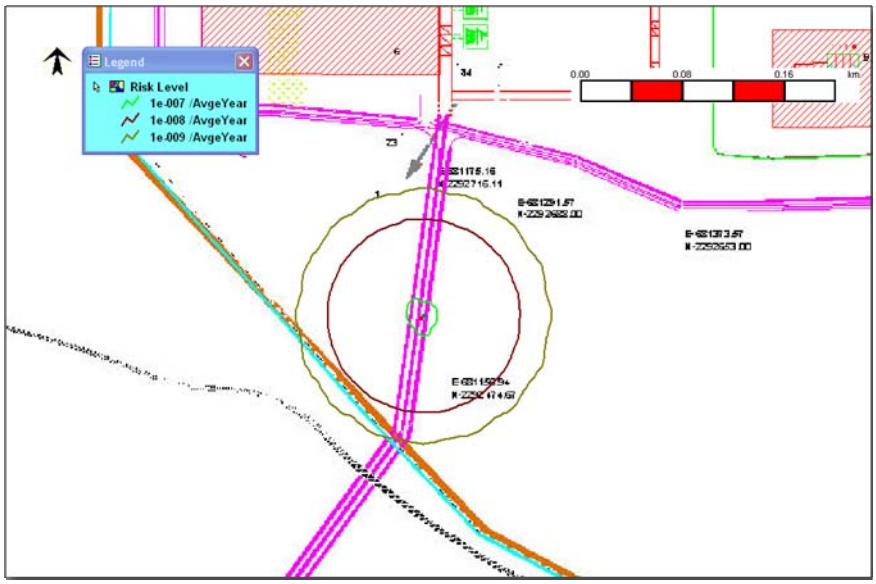


Fig. 3.11: Individual Risk Contours for LNG Pipeline

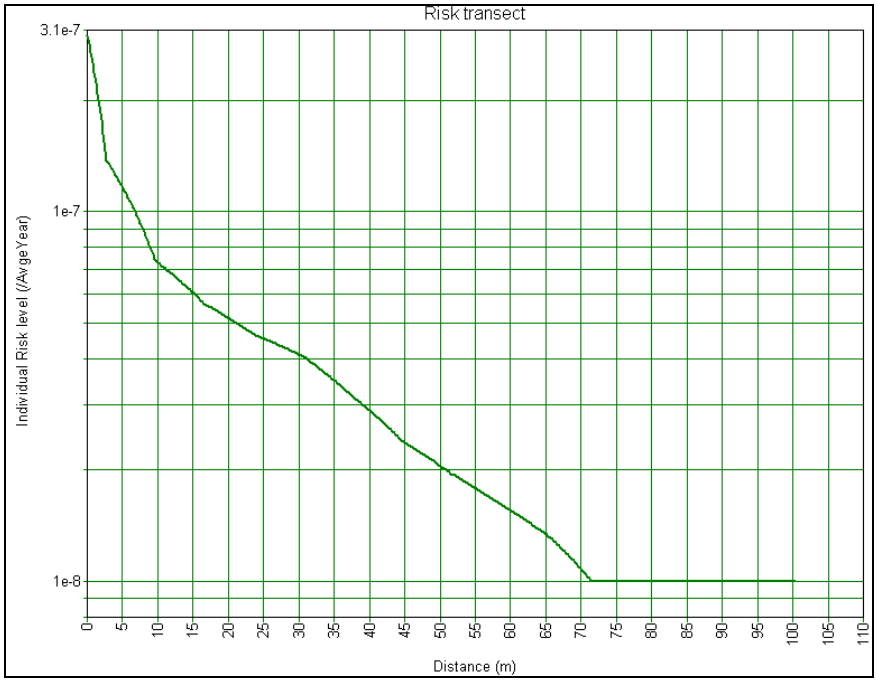


Fig. 3.12: Risk Transect for LNG Pipeline

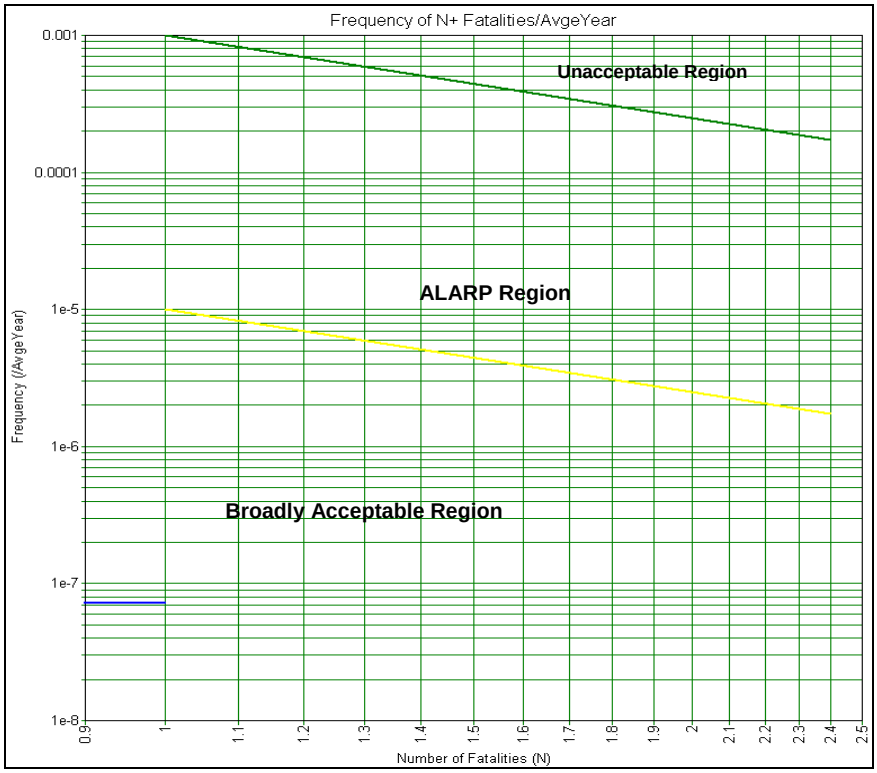


Fig. 3.13: F/N Curve for LNG Pipeline

LNG Pump

IR contours, risk transects and F/N curves for HP LNG pumps have been shown in **Fig. 3.14 to Fig.3.16** below for partial and full rupture in case of all possible fire and explosion scenarios.

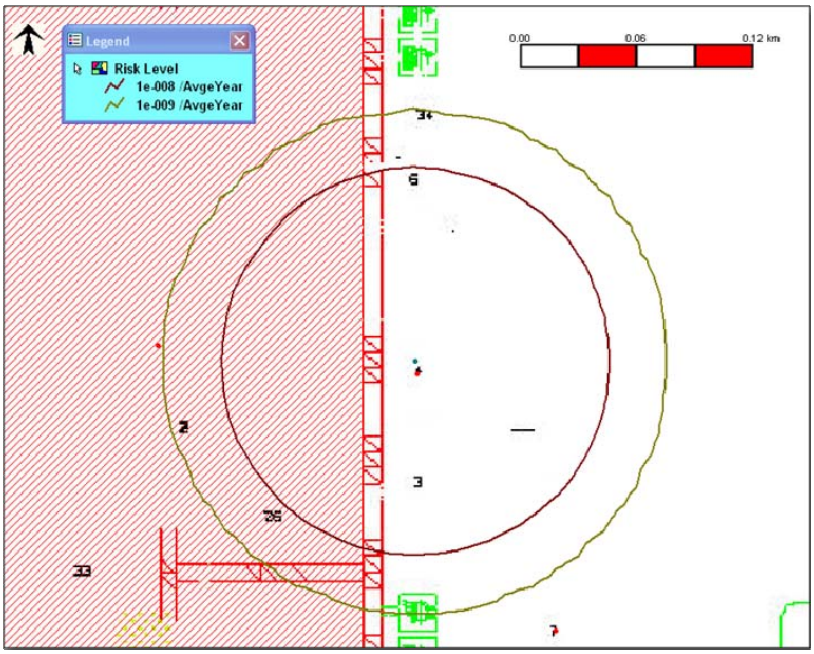


Fig. 3.14: Individual Risk Contours for HP LNG Pump

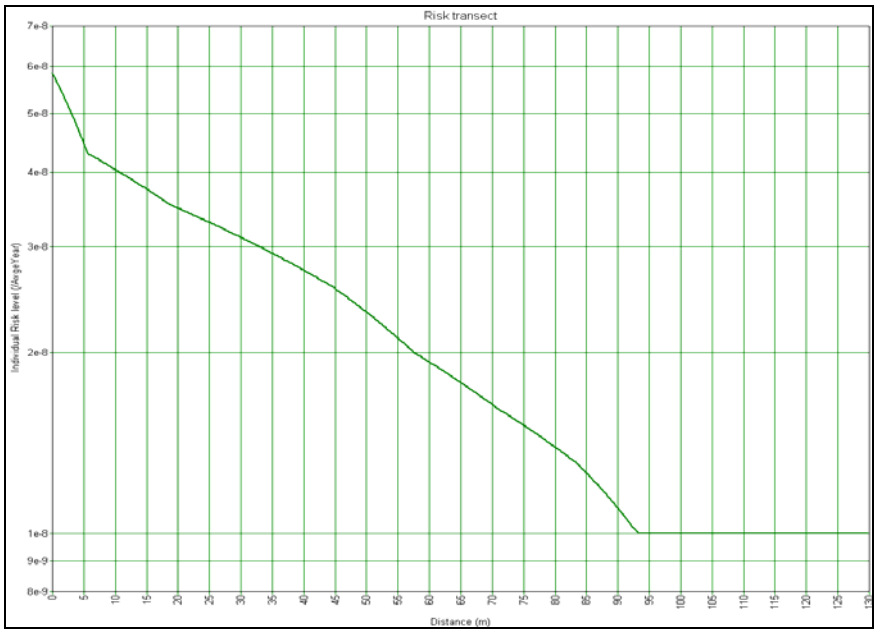


Fig. 3.15: Risk Transect for HP LNG Pump

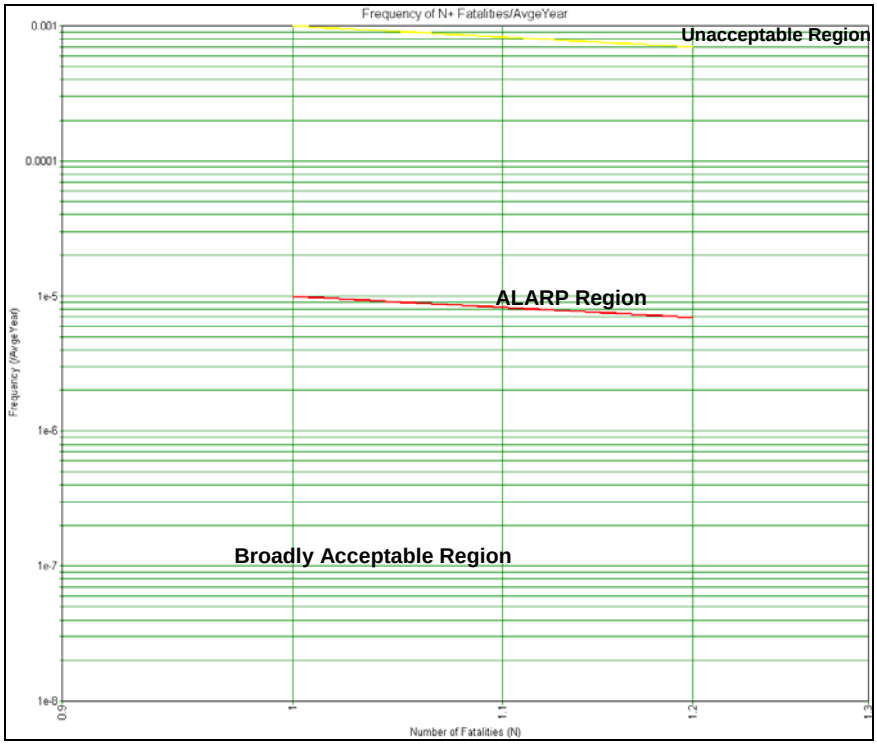


Fig.3.16: F/N Curve for HP LNG Pump

3.7 Conclusion

The risk has been evaluated for all the LNG storage tanks of 196,000 $m^3$for the leak sizes of 300 mm and 1000 mm. The contours developed are of 10^{-7} and below where the risk is negligible. It can be concluded that the individual risk due to partial rupture from single LNG tank is negligible. Risk transect have also been shown to recognize individual risk distance wise.

The societal risk as a relationship between frequency of an event and the number of people affected has also been evaluated for LNG storage tank of 196,000 m^3 capacity. It can be concluded from F/N curve that the societal risk for the tank is tolerable. The curve falls in the ALARP region. The Catastrophic rupture of the tank has been ruled out in the study as the failure frequency is 5×10^{-8} which is very low.

The combined effect due to simultaneous leakage from the storage tanks has also been presented. The maximum risk generated due to these scenarios is of 10^{-7} level which is within the terminal site and acceptable but not altogether negligible. The area within this 10^{-7} contour can be controlled with precautionary measures. The 10^{-8} contour extends to approximately 2200 m from the storage tanks. As all the activities are within the maximum effect zone, knock–on to other activities are possible. The societal risk due to the combined effect of these tanks is acceptable.

The individual risk due to the leakages or full rupture of LNG pipeline is 10^{-9} and above which is broadly acceptable. The societal risk also falls in the broadly acceptable region. The individual and societal risks have also been evaluated for partial or full rupture of LNG pumps and both types of risks are in broadly acceptable region.

Chapter 4
Risk Mitigation Measures

4.1 Risk Mitigation Measures

The scope of Risk Assessment study covers risk mitigation measures based on Maximum Credible Accident (MCA) analysis and quantification of risk through individual and societal damage contours. The Fire and Explosion Indices were computed for the identification and screening of vulnerable sections and consequence analysis was carried out for the accidental release scenarios of LNG storage tanks, pipelines and pumps. Damage distances were computed at various heat radiation levels and pressure waves. The overall objective is to compute the extent of damage distance in the event of accidental releases of hazardous chemicals.

The LNG industry has an exemplary safety record, with only eight accidents over the past 40 years. None of these accidents led to a loss of life. Even with this excellent safety record, consideration should be given to what might be the precautionary measures and the minimum time required to take the action if in case there is any emergency due to the accidental release of LNG leading to fire or explosion scenarios. The following risk mitigation measures are suggested based on the risk assessment study for worst case scenarios

4.1.1 General Recommendations

- Periodic maintenance of all protective and safety equipment
- Periodical training / awareness should be given to work force at the project as refresh courses handle many new emergency situation
- Periodic mock drills should be conducted so as to check the alertness and efficiency of the DMP and corresponding records should be maintained
- Signboard including emergency phone numbers and actions to be taken in case of emergency should be installed at various locations
- Necked flame, welding, smoking should be strictly prohibited at the terminal site
- LNG Terminal shall have adequate communication system

- All major units / equipments shall be provided with smoke / fire detection and alarm system
- Impurities should be controlled to obviate abnormal corrosion
- These measures should be backed up by relief systems such that the combination of vessel design, protection, quality control and relief eliminates the possibility of complete vessel failure
- Wind socks should be installed at suitable height and with proper visibilities to check the wind direction at the time of accident
- Co-ordination with local authorities such as fire, police, ambulance, district administration and nearby industries should be ensured to manage / control meet any eventuality
- All employees should wear cotton clothes to eliminate the hazard of static electricity
- Safety shoes should not have nails and steel toe caps
- All maintenance work should be carried out under Safety Work Permit system.
- All hot work should be conducted only at the times and in the places specifically authorized and under a Safety Work Permit system
- All vehicles moving in the jetty area and within the terminal should have spark arrestors (mufflers).
- All electrical equipment, switches, plugs, wiring, etc. used within the LNG terminal operational areas must be flameproof type.
- Safety audit for the jetty and terminal should be conducted annually.
- The glass windows of the Control Room should be heat and impact resistant.
- The terminal should have a dedicated Safety & Environment Officer, and fire fighting staff right from the construction stage.
- Fire is one of the major hazards, which can result from leak or rupture of the process equipment. Fire prevention and relevant code enforcement is one of the major areas of responsibility for the fire service. Hence the facility should be equipped with:

- Smoke and fire detection alarm system
- Water supply
- Fire hydrant and nozzle installation
- Foam system
- Water fog and sprinkler system
- Mobile Fire fighting equipment
- First aid appliances

LNG Jetty

- There should be no source of ignition source at all within the restricted area of the site at all times.
- General cargo, other than ship's stores for the LNG tanker, should not be handled within 30 metres of the point of transfer connection while LNG is being transferred through piping systems.
- Ship bunkering at the LNG jetty should not be permitted during LNG unloading operation.
- Vehicular traffic should be prohibited on the jetty within 30 metres of the unloading manifold while transfer operation is in progress.
- Warning signs or barricades should be used to indicate that transfer operation is in progress.
- Gas leak detectors should be provided for flanges as well as where there is cluster of flanges and at the unloading point.
- Any potential static electric charge will be mitigated by an appropriate earthing.
- Conductor system to be used while LNG is unloaded.

LNG Storage tank area

- All nozzles for the piping requirements shall be from the top of the storage tank. No bottom nozzles should be provided for the storage tank.
- Two independent type liquid level gauging devices should be considered for the LNG storage tank.

- For double/full containment tanks, water sprays should be provided on the tank shell including the roof and the equipment on the tank. The water application rate for the tank roof and walls should be 3 Lpm/m^2, required for cooling the outer shell of tanks in case of fire in the vicinity.
- The water application rate for the other equipment should be 10.2 lpm/m^2 for piping and valves manifolds.
- Automatic gas detection system for monitoring leakage of LNG should be installed on tank roof in the vicinity of roof nozzles and places where possibility of NG or LNG leak is possible. The gas leak detector setting should be set for 20% of the LFL.
- All storage tanks, pipelines containing LNG should be properly bonded and earthed to prevent accumulation of static electric charge.
- The discharges from the relief valves shall be located at a safe height and direction from adjoining operating areas.
- A minimum distance of 60 metres should be maintained between LNG storage tank and sub-station.
- Electrical classification of areas for electrical installation in LNG terminal should be as per OISD Standard 113 (as applicable).
- Electrical equipment must be of flame proof type and certified for Zone II, Gas group
- II 'A' and temperature class T3 requirements classification as per NFPA classification.
- All electrical cables should be armoured fire resistant type.
- Cathodic protection system for the pipe work should be installed, to deal with static charge build up.

Fire Protection System

The typical fire fighting system for the various facilities described under this project is outlined in this section. The exact details of the fire fighting systems and capabilities to be installed and developed shall be finalised after the completion of detailed engineering in consultation with the concerned process and equipment vendors and fire. It is also to be understood that not all facilities described below will

be applicable for every installation. The outline of the fire system proposed is described below.

Fire protection system shall be designed in accordance with the requirements of OISD, Tariff Advisory Committee (TAC) of India, NFPA standards, design requirements and safe engineering practices and will have full capability for early detection and suppression of fire. The system will primarily consist of:

- Hydrant system
- Foam protection system
- Portable fire extinguisher
- Fire detection and alarm system

Hydrant System: The system will essentially consists of firewater storage, pumping, system pressurisation and all inter connected pipe work and auxiliary fire fighting appliances. The water storage and pumping capacity and other features of this system will be finalised considering TAC recommendations.

Adequate number of engine driven / electric motor driven fire water pumps will be provided. The pumps will be started automatically in the event of drop in header pressure. The actuation will be through pressure switches, the setting of which will be staggered to achieve sequential starting of the pumps to meet the system demand. When power supply is available, the electric motor driven pump will start first and in case of further pressure drop the engine driven pump will start. However when electric power is not available, the engine driven pump will cut-in depending on the system demand. The pumping capacity would meet the simultaneous water demand for foam protection of one oil tank, and supplementary foam hose stream in the oil dyke area, which is the maximum water demand in a single occurrence of fire. The pumping capacity should also meet the guidelines of TAC for this size of plant, considering ordinary hazard occupancy.

The fire water system will be kept pressurised by the hydro-pneumatic tank, which will take care of small leakages from the fire water system. A jockey pump, sized as per the TAC guidelines will, automatically replenish the water level in the hydro-pneumatic tank at periodic intervals. Air required for pressurising the hydro-pneumatic tank will be supplied by an electric motor driven compressor.

The outdoor hydrant system will be provided all over the plant for exterior protection. The hydrant mains will be laid underground. Hose houses, complete with

all accessories, will be provided at suitable intervals. The overall plant will be divided in several fire zones, where the fire fighting action can be pursued effectively. The pressurised main will also be connected to Sprinkler/ emulsifier System for protection of transformers and Fuel Oil storage tanks.

Foam Protection System: Fuel oil storage tanks and the surrounding dyke areas will be protected with low expansion foam system, using fluoro-protein. The storage tanks will be provided with sub-surface foam injection system and the dyke area will be provided with supplementary foam hose stream for combating spill fires. The foam protection system will be designed as per the requirements of NFPA, OISD and TAC. A central foam preparation unit consisting of at least foam storage tank, proportionating devices etc. shall be provided, to supply foam solution to the foam protection system. Pressurised water for foam system will be tapped from the outdoor main hydrant.

Sprinkler System: Automatic deluge sprinkler system will be provided for the protection of power transformer. An array of spray nozzles will be provided all around the protected area. The nozzles will be connected to the automatic deluge valve. A set of heat or smoke detectors, located in the area will sense the fire. Deluge valve will automatically open once two independent detectors sense fire.

Manually initiated water spray system will be provided for exposure protection of oil storage tanks, so that when one tank is on fire, the other tank can be cooled to guard against exposure heating. Pressurized water supply to all sprinkler systems will be tapped from the outdoor hydrant main.

Portable Fire Extinguishers: Besides, fire hydrant arrangement, portable fire extinguishers of suitable categories will be placed at control rooms, electrical switchgear room and various utility buildings for immediate use in the event of fire. Three different kinds of extinguishers i.e. foam, CO_2 and multipurpose dry chemical (MPDC) will be provided. Each type of extinguisher has its own characteristic to fight a particular class of fire. The size and type of extinguishers will be decided as per recommendations of NFPA and relevant Indian Standard and will be placed in convenient accessible locations.

4.2 LNG Storage Tanks

Accidental release of LNG from the storage tanks can lead to various fire and explosion scenarios. Proper design considerations and preventive measures are recommended below

Design Safety

- The LNG cryogenic storage tank should be designed, constructed and commissioned in accordance to the international and Indian codes – EN 14620, BS 7777 and OISD 194.
- The tank should be designed for the higher seismic load as Chhara region falls in the moderate seismic zone.
- After completion of the tank construction, the integrity of the tank should be checked by Hydro test (Min 125% of hydraulic load of the LNG at full capacity), Vacuum Box test / Global test for the welding joints
- Purging and drying with regassified Nitrogen and dew point of at least -60°c should be achieved before introducing the LNG into the tanks
- Tank should be equipped with three independent Level transmitters which should be configured to trip the LNG receipt pump to avoid over flow of the tanks
- Secondary containment should be provided to hold the total liquid volume in case of over flow of the primary containment
- Pressure safety valve, pressure relief valve and reserved capacity relief valve should be provided to ensure the high pressure protection of the tank. All these three barriers should act independently and each barrier should get the signal from independent pressure sensors to make the system more reliable
- The low pressure integrity of the tank should be protected by Vacuum control valve and vacuum relief valve. Similar to the High pressure protection system, Vacuum protection should also have independent pressure sensing element.
- The Appurtenances and piping should be from the top of the tank penetrating through the tank dome to eliminate the possible leaks from the tank shell.
- The outer concrete tank should be pre-stressed and should withstand credible fire load in case of external fire in the adjacent areas.

Operational Safety

- The tank base heating system should be monitored continuously to avoid any damage to the tank bottom due to moisture
- The field personnel and Panel operator should monitor all the critical parameters of tanks and associated facilities proactively
- Alarms should be provided to alert operator in case of any deviation from operating limits.
- All the tank fire fighting facilities should be checked once in a week
- All the piping / valves associated with tank integrity should be checked through LO / LC system.

Asset Integrity Tests of the Tanks

- Thermography of the tanks should be carried out once in a year to map the temperature profile of the outer tank and ensure the tank integrity
- Civil RCM (Reliability Centered Maintenance) for the tanks should be carried out to ensure the integrity of the civil concrete structures.
- All Piping should be subjected to the Risk based inspection although LNG is a non corrosive service
- Equipments which are vital for tank integrity / safety should be listed as SCE (Safety Critical Equipments) and the performance of these equipments should be tracked / monitored regularly

4.3 Control Rooms

- The control room building shall be located upwind of the storage and handling facilities.
- Control room should be blast proof and shock proof
- Critical switches and alarm should be always kept in line
- Minimum number of doors shall be provided in the control room while at the same time the number of doors shall be adequate for safe exit
- Smoke detection system shall be provided for at appropriate locations
- To resist fire spread through ducts, dampers shall be installed in ducts

4.4 Pumps

- To prevent accidental spills at pump stations leak containment is provided; valves and pump stations will be kept to a minimum in most sensitive pipeline segments
- Pump stations will be electronically equipped to detect leaks and leak containment will be provided

4.5 Electricity Hazard

- All electrical equipments shall be provided with proper earthing. Earthed electrode shall periodically tested and maintained
- Emergency lighting shall be available at all critical locations including the operator's room to carry out safe shut down, ready identification of fire fighting facilities such as fire water pumps and fire alarm stations.
- All electrical equipments shall be free from carbon dust, oil deposits, and grease.
- Cable routing shall be planned away from heat sources, gas, water, oil, drain piping and air conditioning ducts.
- Use of approved insulated tools, rubber mats, shockproof gloves and boots, tester, fuse tongs, discharge rod, safety belt, hand lamp, wooden or insulated ladder and not wearing metal ring and chain.
- Flame and shock detectors and central fire annunciation system for fire safety should be provided.
- Temperature sensitive alarm and protective relays to make alert and disconnect equipment before overheating
- Prevent higher humidity and temperature near electric insulations.
- Danger from excess current due to overload or short circuit should be prevented by providing fuses, circuit breakers, thermal protection
- Use only carbon dioxide, halon or dry chemical fire extinguishers for electrical fires
- All tanks, vessels and pipelines containing flammable liquid or gases should be separately earthed.

- Liquid spillages and dust deposits should be removed as early as possible.

Electricity:

Electric Power:

- Nearest available Gujarat State electric grid power supply of 66 KV is available from Substation at Sarkhadi village approx. 10 km from Project site.
- Plant shall be designed for most optimum power from State Electricity Grid / Captive Power plant with 100% redundancy and Emergency Diesel Generator in case of failure of Grid and CPP.
- Solar Power is also considered for the non-critical loads of the Terminal.

Safety Measures:

The Safety philosophy is based on a staged approach from:

- Well defined plant operating envelopes and a high level of plant automation (within the Process Control Systems).
- An extensive detection systems of abnormal conditions (within the Safety Control System).
- An Emergency Shutdown System to isolate affected plant parts and limit the effects of abnormal conditions (based where practical on a “fail-safe” design practice), which is supplemented with, assisted by;
- Passive design solutions within the plant to minimise the effects of accidents, such as selective LNG spill collection, avoiding the collapse of main structures from cold splash or fire heat-flux influence, supplemented by;
- An active protection system, inclusive stopping of uncontrolled sources of ignition and a fire protection system. The fire protection systems are important either to cool surrounding facilities or to segregate process area and reduce the risk of further escalations of incidents. The active fire fighting systems rely on permanent facilities and use the operation crew as first line of defence.

- The safety philosophy approach aspects are described in the document “Fire Hazard and Safety systems” document No. P.004049 S78 1009.

The LNG terminal will be monitored and controlled from a continuously manned Central Control Room (CCR) located in the control Room building. Emergency Shutdown (ESD) system is part of the main Plant Control & Monitoring system.

ESD system shall be based on following principles:

ESD shall be designed to monitor key safety variables and equipment and respond automatically or to operator initiated commands, in such a way as to reduce the risk of hazardous or destructive incidents.

The ESD system shall be independent of the primary control system and will perform the following functions regardless of availability of the PCS:

- Monitor dangerous conditions and take appropriate shut-down action.
- Rapidly and reliably detect a fire condition, a LNG spillage, a leakage of flammable gas or any other specific incident.
- Respond to manual requests for shut-down, Reset and override from the operator consoles or from the field as per requirements.
- Record on a suitable Sequence of Event Recorder (SER) all events / alarms and actions taken by the ESD system.
- Indicate to the control operator that a trip has been initiated and has been successfully completed or has not been successfully completed.

The implementation of the ESD system shall consist in selecting for each safety function, an architecture which satisfies the specifications of said function and / or ensuring the P&ID requirements which also correspond to the safety integrity requirements.

- The ESD System shall be based on fail-safe dual redundant Programmable Logic Controller (PLC).
- I/O module, power supply module and communication module shall be redundant.
- PLC shall have watch dog timer for self diagnosis.

- Emergency Shut Down Philosophy (ESD) is described in document no. P.004049 J21 0558.

Provision for Future Expansion:

- The plant layout has been developed in such a way that future extension can be realized from 5 MMTPA to 10 MMTPA. Also, the area considered takes care of the plant expansion up to 10 MMTPA.
- Trestle from Terminal to Main jetty is designed with spare space for accommodating LNG unloading pipeline for simultaneous unloading of LNG cargo from Main and Standby jetty.

Details on Maximization of Rupee Cost:

In order to maximize the Rupee cost and to reduce foreign exchange outgo, to the extent possible local materials shall be utilized. Timely supply of materials to site will suitably minimize delays and overruns in cost and time schedule.

Following material could be procured locally:

- Most of the Civil Items such as Cement, reinforcement steel, Structural steel etc.
- Piping items, like Pipes, Flanges, Fittings, Valves, hardware, etc. for gas, and utilities services.
- Electrical items like HT & LT Motors, Switchgears, Control panels, Transformers, Generator, Battery, Cables & Trays, etc.
- Instrumentation items like DCS, PLC, Pressure, Temperature & Flow Instruments, Cables & Trays, etc.
- Fabricated equipment like exchangers, pressure vessels and pumps for general service. There are many competent fabricators who can manufacture Exchangers & Pressure Vessels locally.
- Gas Engine generators

However, following items will be imported due to their complexities in design and criticality and unavailability locally. These shall be offshore supplies:

- 9% Ni plates
- Cellular glass for tank bottom insulation
- Unloading arms

- LNG in-tank pumps
- LNG HP pumps
- Vaporizers
- BOG compressors
- BOG blowers
- Cryogenic valves
- Gas process valves
- All valve actuators
- Cryogenic pipe supports
- Insulation material
- Cryogenic and process control valves
- Cryogenic and process safety valves and vacuums breakers.
- Cryogenic flow meters
- Cryogenic level gauge
- Ship to shore link
- LNG Sampling system
- Perlite for tank shell insulation
- LNG Gauging
- Mooring hooks
- Berthing system

List of exclusions from feasibility report and further studies / work to be carried out:

FEED / EPC for LNG Terminal:

- Additional soil investigations for the proposed berth layouts and at tank location for accurate determination of foundation design
- Higher diffraction co-efficient may be envisaged once dredging has been carried out and hence wave modelling will need to be carried out

to assess the wave penetration within the harbour basin for proposed LNG Terminal.

- Optimization of approach channel dimensions can be carried out during detail engineering
- To assess the operational conditions within the harbour basins, 3D model studies will need to be conducted to assess the tranquillity conditions at the proposed LNG berths and ship motion studies.
- Assessment for berth unavailability persistency to be carried out during detail engineering based on the persistence of cyclonic conditions in the area.
- Ship simulation and manoeuvring studies can be conducted as an optional study for further optimization of the approach channel
- Siesmo tectonic study and Tsunami Wave record review
- Detailed QRA for Jetty and Regasification facilities

Conclusions and recommendations

In order to achieve the project schedule aiming to start the Plant operation in Dec 2017, the next steps would include:

- Contract award for engineering partner.
- Seismo- tectonic survey and soil investigation
- Obtaining the construction and operation permits
- Area grading, backfilling and soil improvement
- The negotiations for LNG supply in order to define the LNG sources and its characteristics. These sources and characteristic will allow a correct and optimum sizing of the equipment and tanks.
- Discussions / signing of MOU with Gas transmission companies (GSPL) for RLNG evacuation pipeline connectivity to Gas transmission network.
- Select the most appropriate EPC contractor.

Chapter 5
Disaster Management Plan

5.1 Approaches to Disaster Management Plan

Chemicals occupy an important segment of our economy and are also the source of large benefits to the society. In recent years, there has been a rapid increase in the number, variety and complexity of the chemicals being used in the industry and in our daily life. However, many of these chemicals are toxic, highly reactive, explosive or inflammable or have a combination of these characteristics and all these are classed as hazardous chemicals. Such chemicals are potential hazardous not only to the human beings, flora and fauna but also to all forms of property and our environment as a whole. Thus, extreme care is essential in handling such chemicals in any form and at all stages of manufacture, processing, treatment, package, storage, transportation, use, collection, destruction, conversion or sale.

Several agencies of the Government, both at the Central and State levels, such as the Directorate of Explosives, the Inspectorate of Factories and Port and Transport Authorities are entrusted with the responsibility of ensuring safe handling and management of hazardous chemicals under acts and rules made for the purpose. In spite of these measures, the possibility of accidents can not be ruled out. Human errors and mechanical, electrical, instrumental or system failures have, on occasions, led to severe disasters. Accidents occurred at Bhopal, Mexico and other parts of the world have made people concerned with the dangers of chemical accidents. Occurrence of such accidents makes it essential that the Central and State Governments as well as the local authorities are fully prepared to mitigate the sufferings and meet the eventualities resulting from any unfortunate occurrence of chemical accidents in our country. This Disaster Management Plan (DMP) is designed for LNG terminal.

5.1.1 Objectives of Disaster Management Plan

The purpose of DMP is to give an approach to detail organizational responsibilities, actions, reporting requirements and support resources available to ensure effective and timely management of emergencies associated to production and operations in the site. The overall objectives of DMP are to:

- Ensure safety of people, protect the environment and safeguard commercial considerations
- Immediate response to emergency scene with effective communication network and organized procedures
- Obtain early warning of emergency conditions so as to prevent impact on personnel, assets and environment
- Safeguard personnel to prevent injuries or loss of life by protecting personnel from the hazard and evacuating personnel from an installation when necessary
- Minimize the impact of the event on the installation and the environment, by:
  - Minimizing the hazard as far as possible
  - Minimizing the potential for escalation
  - Containing any release
- To provide guidance to help stack holders take appropriate action to prevent accidents involving hazardous substances and to mitigate adverse effects of accidents that do nevertheless occur. Following figure shows effect of loss of containment from the process

5.1.2 Different Phases of Disaster

Warning Phase

Many disasters are preceded by some sort of warning. For example, with the aid of satellites and network of weather stations, many meteorological disasters like cyclones and hurricanes can be predicted and actions can be taken to eliminate/reduce their effect to counteract them.

Period of Impact Phase

This is the period when the disaster actually strikes and very little can be done to lesson the effects of disaster. The period of impact may last for a few seconds (like fire, explosion, and gas leak) or may prolong for days (fire, gas leak, etc.). This is the time to bring the action plan in force.

The coordinators in organization structure will perform the responsibilities assigned to them. Needless to emphasize that prompt and well organized rescue operations can save valuable lives.

Rescue Phase

The rescue phase starts immediately after the impact and continues until necessary measures are taken to rush help and combat with the situation.

Relief Phase

In this phase, apart from organization and relief measures internally, depending on severity of the disaster, external help should also be summoned to provide relief measures (like evacuations to a safe place and providing medical help, food clothing etc.). This phase will continue till normalcy is restored.

Rehabilitation Phase

This is the final and longest phase. It includes rebuilding damaged property, estimating the damages, payment of compensation, etc. Help from revenue/insurance authorities need to be obtained to assess the damage, quantum of compensation to be paid etc.

5.1.3 Key Elements of DMP

Following are the key elements of Disaster Management Plan:

- Basis of the plan
- Accident/emergency response planning procedures
- On-site Disaster Management Plan
- Off-site Disaster Management Plan

5.1.3.1 Basis of the Plan

Identification and assessment of hazards is crucial for on-site emergency planning and it is therefore necessary to identify what emergencies could arise in production of various products and their storage. Hazard analysis or consequence analysis gives the following results.

- Hazards from spread of fire or release of flammable chemicals from the terminal
- Hazards due to formation of pressure waves due to vapor cloud explosion of flammable gases

5.1.3.2 Emergency Planning and Response Procedures

Emergency rarely occurs; therefore activities during emergencies require coordination of higher order than for planned activities carried out according to fixed time schedule or on a routine day-to-day basis. To effectively coordinate emergency

response activities, an organizational approach to planning is required. The important areas of emergency planning are Organization and Responsibilities, Procedures, Communication, Transport, Resource requirements and Control Center. Offsite emergency requires additional planning over and above those considered under onsite plans, which should be properly integrated to ensure better coordination.

The emergency planning includes anticipatory action for emergency, maintenance and streamlining of emergency preparedness and ability for sudden mobilization of all forces to meet any calamity.

5.1.3.3 On-site Disaster Management Plan

Purpose

- To protect persons and property of processing equipments in case of all kinds of accidents, emergencies and disasters
- To inform people and surroundings about emergency if it is likely to adversely affect them
- To inform authorities including helping agencies (doctors, hospitals, fire, police transport etc.) in advance, and also at the time of actual happening
- To identify, assess, foresee and work out various kinds of possible hazards, their places, potential and damaging capacity and area in case of above happenings. Review, revise, redesign, replace or reconstruct the process, plant, vessels and control measures if so assessed.

In order to handle disaster / emergency situations, an organizational chart entrusting responsibility to various personnel of the facility showing their specific roles should be available as shown in following **Fig. 5.1**.

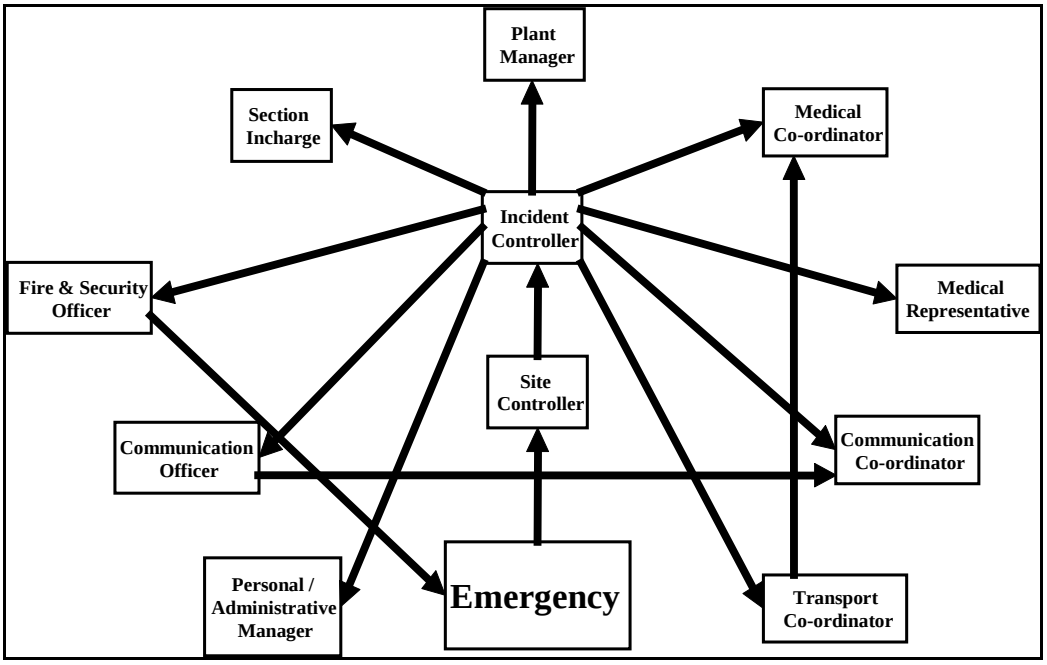


Fig. 5.1: Onsite DMP - Disaster Control/Management System

Before Crisis

- Prepare a plan of the storage, handling and pumping stations premises and surroundings showing therein the areas of various hazards like fire, explosion, toxic releases and also location of assembly points, fire station or equipments room, telephone room, first aid or ambulance room, emergency control room, main gate, emergency gates, normal wind direction, outside fire station, hospital and other services. Mention their distances from proposed activities.
- The fire protection equipment shall be kept in good operating condition at all time and fire fighting system should be periodically tested for people functioning logged for record and corrective action.
- The fire fighting training shall be provided to all officers, truck drivers and other employees who are likely to be present in installation
- There should be regular mock fire drills once a month record of such drills shall be maintained
- Every employee or authorized person working in the production shall be familiarized with the fire alarm signal and shall know the location of fire alarm point nearest to place of work
- Assign key personnel and alternate responsible for site safety

- Describe risk associated with each operation conducted.

During Crisis

- Monitor the behaviour of entrant for any effects that suggests they should be evacuated
- Evacuate the space if any hazard that could danger the entrant is detected
- Perform no other duties that may interfere with their primary responsibilities
- Notify the attendant if they experience any warning signs or symptoms of exposures or detect a dangerous condition
- Exit the permit space when instructed by attendant
- Reporting Procedure

In the event of fire from accidental release of flammable chemical, a person seeing the incident will follow the laid down procedure in the plant and report as follows:

- Will dial the nearest telephone
- Will state his name and exact location of emergency
- Will contact affected officers on duty
- People reporting the accident will remain near the location to guide emergency crew arriving at the scene

In case fire emergency person should activate the nearest available push button type instrument which will automatically sound an alarm in fire control room indicating the location of fire.

After Crisis

- Report injuries or blood or body fluid exposures to the appropriate supervisor immediately
- Assembly points:
  - Assembly points shall be set up farthest from the location of likely hazardous events, where pre-designed persons from the works, contractors and visitors would assemble in case of emergency. Up-

to-date list of pre-designed employees shift wise must be available at these points so that roll call could be taken. Pre-designated persons would take charge of these points and mark presence as the people come into it.

- Wash wounds and skin sites that have been affected with soap and water.
- Workers should be seen as soon as possible by a health professional.
- Provide information to the relevant public authority and community including other closely located facilities regarding the nature of hazard and emergency procedure in event of major accident.
- Record and discuss the lessons learned and the analysis of major accidents and misses with employees and employee representative.

Duties of the Management Team

The duties that will be performed by the key personnel during emergency are as follows:

Incident Controller

- Direct all operations to stop within the affected area taking into consideration priorities for safety of personnel, minimize damage to the plant, property and environment and minimize loss of material
- Provide advice and information to the Fire and Security Officers, the local fire service and the Personnel/Administrative Manager
- Ensure that all non-essential workers/staff of the areas affected are evacuated to the appropriate assembly points and the areas are searched for causalities
- Set up communication points and establish contact with Emergency Control Center (ECC) in the event of failure of electric supply, Public Address System (PAS) and internal telephones
- Report on all significant developments to the Communication Officer
- Have regard to the need to preserve the evidence so as to facilitate any enquiry into the cause and circumstances, which caused or escalated the emergency

- The police and fire brigade incident control vehicles should be located at pre-designated place at side. It is necessary to keep one lane clear for access / egress and spaces for vehicle passing.
- Assessments of the situation and any associated risks should be carried out by the emergency services before entering the hazard area.

Site Controller

- Assess the magnitude of the situation and decide if staff needs to be evacuated from their assembly points to identified safer places
- Exercise direct operational control over areas other than those affected
- Undertake a continuous review of possible developments and assess in consultation with key personnel as to whether shutting down of the plant or any section of the plant and evacuation of personnel are required
- Liase with senior officials of Police, Fire Brigade, Medical and Factories Inspectorate and provide advice on possible effects on areas outside the factory premises
- Look after rehabilitation of affected persons on discontinuation of emergency
- Issue authorized statements to news media and ensure that evidence is preserved for inquiries to be conducted by the statutory authorities

Personnel / Administrative Manager

- To ensure that causalities receive adequate attention arrange additional help if required and inform relatives
- To control traffic movements into the plant and ensure that alternative is available when need arises
- When emergency is prolonged, arrange for the relief of personnel and organize refreshments/catering facility

Communication Officer

- Advise the Site Controller of the situation, recommending (if necessary) evacuation of staff from assembly points

- Recruit suitable staff to act as runners between the Accident Controller and himself if the telephone and other system of communication fail.
- Maintain prior agreed inventory in Control Room
- Maintain a log of the incident on tape
- In case of a prolonged emergency involving risk to outside areas by windblown materials - contact local meteorological office to receive early notification of changes in weather conditions

Fire and Safety Officer

- To instruct all the security personnel to help in maintaining law and order
- To ensure that systematic and proper efforts are launched to avoid chaos or panic at site
- To ensure smooth evacuation, if necessary
- To close all gates except main gate, control traffic and allow only authorized persons to enter the plant
- To arrange additional fire fighting aids from nearby factories and district authorities and take care of rescue operation
- To cordon off the accident area and direct external help to respective coordinators
- Visit by media men to be arranged only through public Relations Coordinator, circumstances responsible for emergency and convey these findings confidentially to the Safety Coordinator
- To keep Chief Coordinator informed regarding status of fire, casualties, loss of property, methods adopted to combat fire, etc.
- To arrange for additional fire fighting crew / equipment, if required
- To inform Medical Coordinator regarding casualties, loss of life

Transport Coordinator

- To keep ambulances (own and others) along with drivers in readiness as per instructions of Medical Coordinator

- To keep all the vehicles and drivers in readiness and send vehicles as per requirement of various coordinators
- To requisition vehicles from outside agencies, if required

Medical Coordinator

- To inform hospitals regarding emergency at site and make them, ready in advance, to handle casualties
- To take charge of ambulances
- To requisition additional ambulances through Transport Coordinator, if required
- To arrange for first aid for the injured and send them for hospitalization

Media Representatives

- To assist in plant evacuation in co-ordination with transport coordinator
- To arrange for evacuation of neighbouring people, if warranted
- To inform latest situation to Chief Coordinator and Communications Coordinator
- To receive media, government officials, and consultants and impart information keeping the following in mind:
  - Communicate directly to avoid distortion by others
  - Impart factual information
  - Only official spokesman imparts information
  - Necessary facilities are made available to the media. Reasons for restriction on media-men be duly explained to them
  - Do not cover up facts as correct picture will finally emerge
  - Provide full information on safety measures to media for balanced reporting
- To inform insurance agency to assess damage
- To provide relief and rehabilitation to affected personnel

Communication Coordinators

- To keep all communication equipment viz. telephone radio-telephone, telex, fax, etc., in working condition
- To report to emergency site and take charge of communication equipment
- To inform local authorities from whom the help be required viz. fire brigade, hospitals, transporters, police station etc.
- To act as liaison between different coordinators
- To keep all communication lines free for use during emergency

Assembly Points

Assembly points shall be set up farthest from the location of likely hazardous events, where pre-designated persons from the works, contractors and visitors would assemble in case of emergency. Up-to-date list of pre-designated employees of various departments (shift-wise) must be available at these points so that roll call could be taken Pre-designated persons would take charge of these points and mark presence as the people come into it.

5.1.3.4 Disaster Management/Emergency Preparedness Program: Off-site

Emergency is a sudden unexpected event, which can cause serious damage to personnel life, property and environment as a whole, which necessitate evolving Off-site Emergency Plan to combat any such eventuality. In Offsite disaster management plan, many agencies like Revenue, Public Health, Fire Services, Police, Civil Defence, Home Guards, Medical Services and other Voluntary organization are involved. Thus, handling of such emergencies requires an organized multidisciplinary approach.

Evacuation of people, if required, can be done in orderly way. The different agencies involved in evacuation of people are Civil Administration (both state and central), non Govt. organizations, factory Inspectorate and Police authorities.

Fire

Effects of fire on population will be mainly due to thermal radiation. In such cases, houses situated to the proximity of disaster need to be evacuated, although a severe smoke hazard due to fire is to be reviewed periodically.

Explosion

An explosion will give a very little time to warn population and areas affected may be much longer than that in case of fire. The effects of explosion on population will be mainly due to shock waves, flying splinters, collapse of structures and exposure to thermal radiation.

Purpose

- To save lives and injuries and to prevent or reduce property losses
- To provide for quick resumption of normal situation or operation
- To make explicit the inter related be suggested if necessary
- To make explicit inter related set of actions to be undertaken in the event of an industrial accident posing hazards to the community
- To inform people and surrounding about emergency and disaster if it is likely to adversely affect machinery will be established for this purpose to guide the people in proper way
- To plan for rescue and recuperation of casualties and injuries. To plan for relief and rehabilitation
- To plan for prevention of harms, total loss and recurrence of disaster. It will be ensured that absolute safety and security is achieved within the shortest time

Before Crisis

This will include the safety procedure to be followed during an emergency through posters, talks and mass media in different languages including local language. Leaflets containing do's/ don'ts before and during emergency should be circulated to educate the people in vicinity

- People in vicinity of hazardous installation, and others who are potentially affected in the event of an accident, should be aware of the risks of accidents, know where to obtain information concerning the installation, and understand what to do in the event of an accident
- Non-governmental Organizations (NGO's) (Such as environmental, humanitarian and consumer group) should motivate their constituents and others, to be involved in risk reduction and accident prevention efforts. They should help to identify specific concerns and priorities

regarding risk reduction and prevention, preparedness and response activities

- NGO's should facilitate efforts to inform the public and should provide technical assistance to help the public analyze and understand information that is made available
- Public authorities (at all levels) and management of hazardous installation should established emergency planning activities/ program's for accidents involving the hazardous substance
- All parties who will be involved in emergency planning process. In this respect public health authorities, including experts from information centers should be involved in relevant aspects of offsite emergency planning
- Emergency warning alert system should be in place to warn the potentially affected public, or there is an imminent threat of an accident
- The system chosen should be effective and provide timely warning. Suitable warning system could include or a combination of for e.g.: sirens, automatic telephone message, and mobile public address system

During Crisis

- Central Control Committee: As the off-site plan is to be prepared by the government a central control committee shall be formed under the chairmanship of area head. Other officers from police, fire, factory, medical, engineering, social welfare, publicity, railway, transport and requisite departments shall be incorporated as members. Some experts will also be included for guidance. The functions of committee should be:
  - To work as main co-coordinating body constituted of necessary district heads and other authorities with overall command, coordination, guidance, supervision, policy and doing all necessary things to control disaster in shortest times
  - To prepare, review, alter or cancel this plan and to keep it a complete document with all details

- To take advice and assistance from experts in fields to make plan more successful
- To set in motion all machineries to this plan in event of disaster causing or likely to cause severe damage to public, property or environment
- The incident control committee, traffic control committee and press publicity committee will first be informed, as they are needed first

♦ Medical Help, Ambulance and Hospital Committee: This committee consisted of doctors for medical help to the injured persons because of disaster. Injuries may be of many types. As such doctors are rarely available we have to mobilize and utilize all available doctors in the area. Functions and duties of the committee include:

- To give medical help to all injured as early as possible
- Civil surgeon is the secretary who will organize his team
- On receiving information to rush to spot he will immediately inform his team and will proceed with all necessary equipments
- First aid and possible treatment shall be provided at the spot or at some convenient place and patients may be requested to shift to hospitals for further treatment
- All efforts shall be made on war basis to save maximum lives and to treat maximum injuries
- Continuity of the treatment shall be maintained till the disaster is controlled

♦ Traffic Control, Law and Order: The committee is headed by District Superintendent of Police. Functions and duties of this committee should be:

- To control traffic towards and near disaster , to maintain law and order
- To evacuate the places badly affected or likely to be affected
- To shift the evacuated people to safe assembly points
- To rehabilitate them after disaster is over.

- Necessary vehicles, wireless sets and instruments for quick communications shall be maintained and used as per need

After Crisis

- At the time of disaster, many people may badly be affected. Injured people shall be treated by medical help, ambulance and hospital committee, but those not injured but displaced kept at assembly points, whose relative or property is lost, houses collapsed and in need of any kind of help shall be treated by this welfare and restoration committee. Functions and duties of this committee are:
  - To find out persons in need of human help owing to disastrous effect. They may give first aid if medical team is not available
  - They will serve the evacuated people kept at assembly points. They will arrange for their food, water, shelter, clothing, sanitation, and guidelines to reach any needful places
  - They will look for removal and disposal of dead bodies, for help of sick, weak, children and needy persons for their essential requirements
  - The team will also work for restoration of detached people, lost articles, essential commodities etc.
  - The team will also look after the restoration of government articles
  - The team will also ensure that the original activities, services and systems are resumed again as they were functioning before the disaster
- Police Department
  - The police should assist in controlling of the accident site, organizing evacuation and removing of any seriously injured people to hospitals.
  - Co-ordination with the transport authorities, civil defence and home guards
  - Co-ordination with army, navy, air force and state fire services
  - Arrange for post mortem of dead bodies

- Establish communication centre

♦ Fire Brigade

- The fire brigade shall organize to put out fires and provide assistance as required.

♦ Hospitals and Doctors

- Hospitals and doctors must be ready to treat any injuries.
- Co-ordinate the activities of Primary Health Centers and Municipal Dispensaries to ensure required quantities of drugs and equipments
- Securing assistance of medical and paramedical personnel from nearby hospitals/institutions
- Temporary mortuary and identification of dead bodies

♦ Media

- The media should have ready and continuous access to designated officials with relevant information, as well as to other sources in order to provide essential and accurate information to public throughout the emergency and to help avoid confusion
- Efforts should be made to check the clarity and reliability of information as it becomes available, and before it is communicated to public
- Public health authorities should be consulted when issuing statements to the media concerning health aspects of chemical accidents
- Members of the media should facilitate response efforts by providing means for informing the public with credible information about accidents involving hazardous substances

♦ Non-governmental organizations (NGO)

- NGO's could provide a valuable source of expertise and information to support emergency response efforts. Members of NGOs could assist response personnel by performing specified tasks, as planned during the emergency planning process. Such

tasks could include providing humanitarian, psychological & social assistance to members of community and response personnel.

Duties of NGO are listed below:

- Evacuation of personnel from the affected area
- Arrangements at rallying posts and parking yards
- Rehabilitation of evacuated persons
- Co-ordination with other agencies such as police, medical, animal husbandry, agriculture, electricity board, fire services, home guards and civil defence.
- Establishing shelters for rescue, medical, fire fighting personnel.

Various organizations involved during emergencies are shown in **Fig. 5.2.**

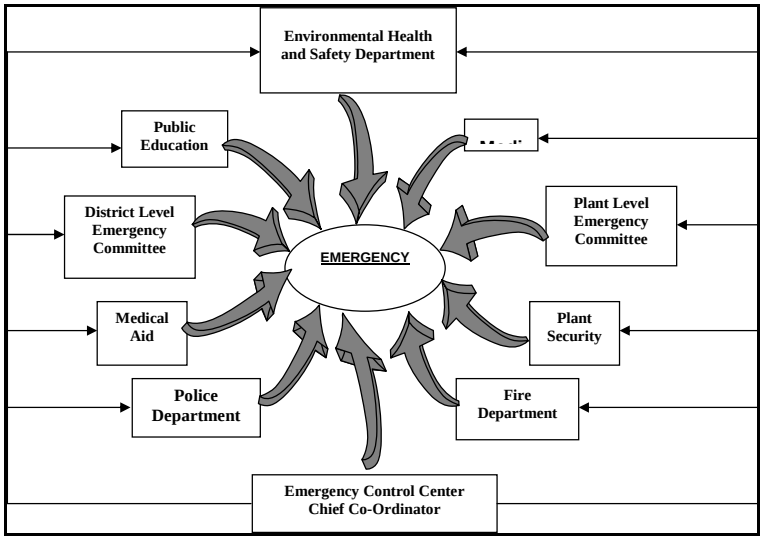


Fig. 5.2: Various Organizations Involved During Emergency

5.1.4 Management Plan for Natural disasters

5.1.4.1 Flood

The objectives in case of flood at the terminal are to provide timely rescue, immediate medical attention / evacuation and normalize the operations after the emergency is over. Following is the emergency alert process in case of flood at the LNG Terminal (**Fig. 5.3**).

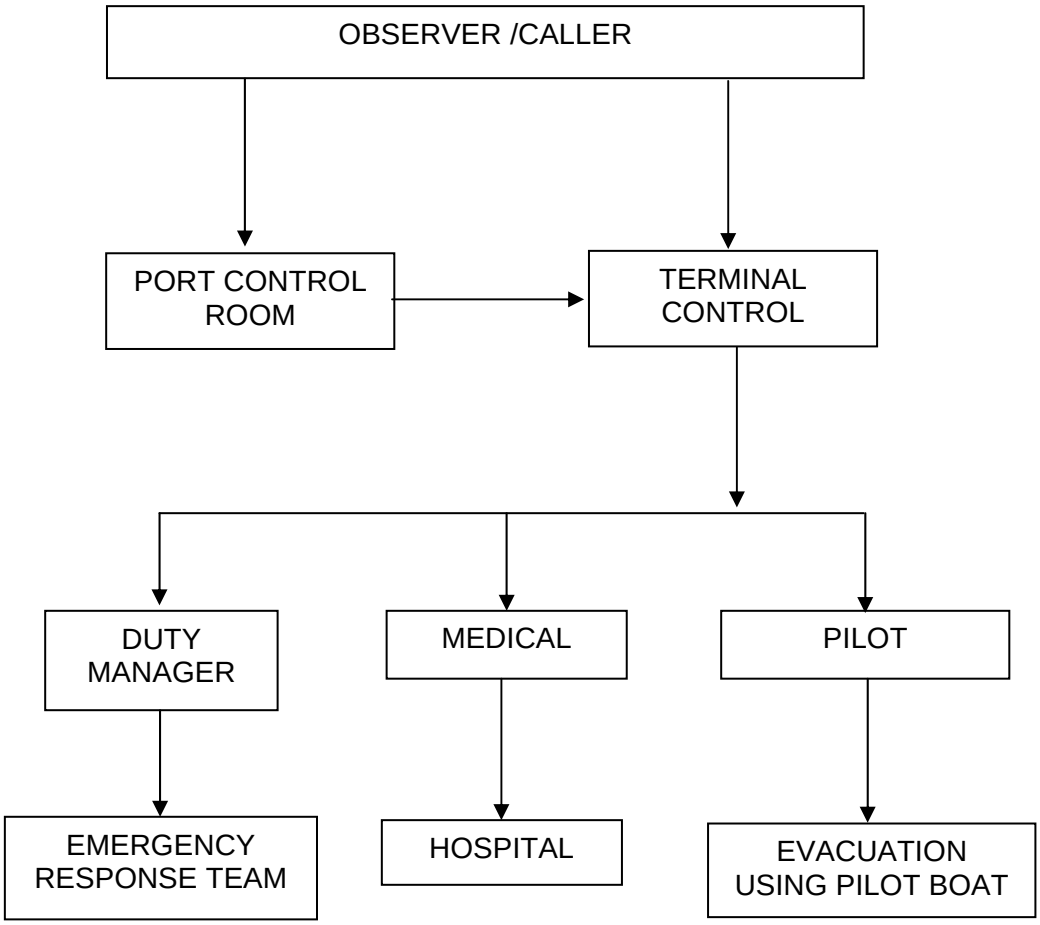


Fig. 5.3: Emergency Alert Process (Flood)

Following are the actions to be taken by various key persons and plant teams to tackle the floods effectively:

Observation	Action
Observer/Caller	• Inform Terminal Control room • Exact location of water flooding • Render first aid
Terminal Control Room	• Inform Port control room • Inform Duty Manager • Maintain safe operation of the plant, if not, then shut down
Duty Manager	• Ensure Communication with the site • Convey non-essential staff to stay at home • Evacuate trapped personnel • Utilise Port Pilot Boat to evacuate by river, if safe • Arrange Food/water for on-duty personnel • Arrange Shift Manpower changeover / Rest • Follow alternate road routes • Press water pumps in service • Ask ERT to operate from Surat
Medical	• Render Medical Assistance • Seek help of other neighbouring companies • Consult company doctor • Evacuation to Hospital

5.1.4.2 Earthquake

The objectives in case of earthquake at the terminal are to minimize the damage to terminal, protect environment and expedite the rescue operations. Following is the emergency alert process (**Fig. 5.4**) in case of earthquake at the LNG Terminal.

Seismic Zone III; Basic Horizontal seismic coefficient

Peak ground accelerations at 5% viscous damping are the following:

Operating basis earthquake (OBE) - 0.070 g (Hz) / 0.047 g (vertical)

Safeshut-down earthquake (SSE) - 0.120 g (Hz) / 0.08 g (Vertical)

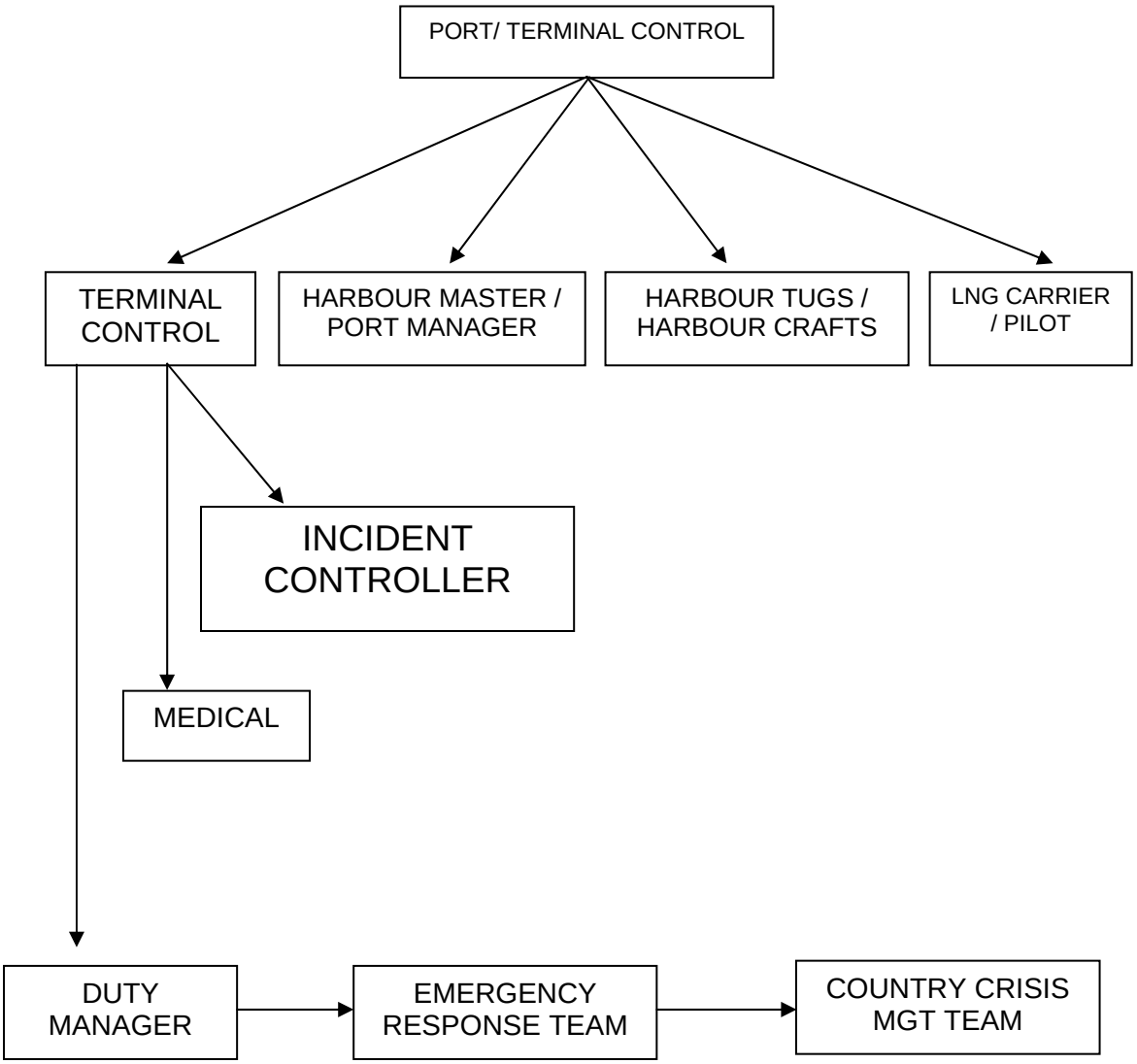


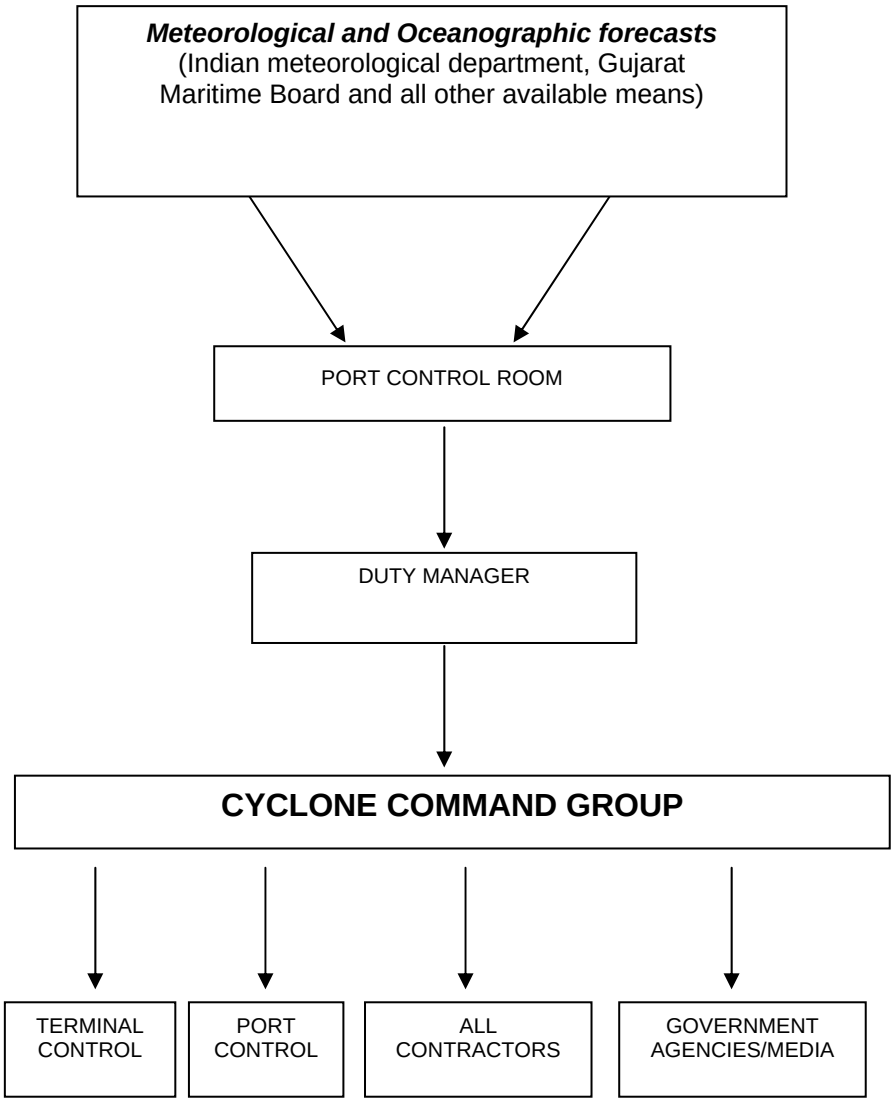
Fig. 5.4: Emergency Alert Process (Earthquake)

Following are the actions to be taken by various key persons and plant teams to tackle the floods effectively:

Observation	Action
Port Control Room	• Inform Terminal Control • Inform LNG Carrier / Pilot • Inform Harbour tugs/ crafts
Terminal Control	• Inform Duty Manager • Stop discharge from LNG Cargo • Inform customers • Stop Terminal & Pipeline operations, if it is unsafe to continue
Terminal Superintendent	• Stop LNG Cargo discharging • Head Count / safe Rescue of personnel • Isolate / water curtains • Stop Terminal Operations
LNG Cargo	• Inform Pilot • Stop Discharge of LNG, Isolate / ESD • Master Pilot to bridge • Vessels engines to immediate readiness • Prepare for vacating the berth
Pilot	• Tugs/mooring boats standby for use • Consider vacating the berth
Port Manager / Harbour	• To be in VHF contact with Pilot
Master	• Inform Emergency Response Team • Assess situation
Medical	• Medical assistance

5.1.4.3 Cyclone

The objectives in case of cyclone at the terminal are to prevent the loss to assets, prevent injury or casualties to the extent possible. Following is the emergency alert process in case of cyclone at the LNG Terminal.


Meteorological and Oceanographic forecasts
(Indian meteorological department, Gujarat Maritime Board and all other available means)
PORT CONTROL ROOM
DUTY MANAGER
CYCLONE COMMAND GROUP
TERMINAL CONTROL
PORT CONTROL
ALL CONTRACTORS
GOVERNMENT AGENCIES/MEDIA

Following are the actions to be taken by various key persons and plant teams to tackle the cyclones effectively:

Observation	Action
Port Control Room	• Collect / Receive cyclone warning information from available sources • Inform Harbor Master/ Port Manager • Inform Pilot / LNG C Ship • Inform Terminal Control • Inform Harbor tugs / crafts • Monitor communications
Duty Manager	• Constitute Cyclone Command Group • Assess situation • Vacate port (Ships and tugs/crafts to proceed to sea) • Secure Port • Hoist Storm signal and issue storm warnings • Liaise with Harbour tugs/crafts contractors • Maintain contact with Port Control
Cyclone Command Group	• Delegate duties/responsibilities • Execute Pre-cyclone activities • Transfer essential records to safe locations • Secure Port and Terminal • Free-standing scaffolds and planks from tied scaffolds taken down • Loose cladding on buildings and process equipment should not exist • Drainage and storm water channels checked for clearance • Oil drums removed to safe location or safely lashed • Rubbish bins secured to structure or safety lashed • Service hoses lashed to the nearby structures or removed to some room • Fire point cabinets closed. • Fire extinguishers stowed and lashed • Satellite phones and wireless sets working • Inform/instructions to contractors • Non-essential staff to be off site • Stock fuel, water and food • Staff on site to location of safety • Formulate evacuation/rescue team • Medical help on site • Maintain contact with Port Control and Terminal Control • Formulate and implement post cyclone start up plan

Observation	Action
Post Cyclone	• Report of current plant status • Review downgrading of the plant status depending upon damage • On return to work, all areas to demobilize cyclone tie down measures • Meet for de-brief session

5.1.4.4 Tsunami

Tsunamis are a series of enormous waves created by an underwater disturbance such as an earthquake, landslide, volcanic eruption, or meteorite. A tsunami can move about 500 miles per hour in the open ocean. Once the wave approaches the shore, it builds in height. The topography of the coastline and the ocean floor will influence the size of the wave. There may be more than one wave and the succeeding one may be larger than the one before. Drowning is the most common cause of death associated with a tsunami. Tsunami waves and the receding water are very destructive to structures. Warning or confirmation should be taken by meteorological stations, coast guards and from TV/Radio news. Following measures may be considered in terminal disaster management with respect to tsunami

- The terminal authorities should make arrangements with the Indian National Centre for Ocean Information Services (INCOIS), Hyderabad for linking up with their Early Warning System (EWS) for mitigation of Tsunami disaster. The system has the following features:
  - Seismic net-worth near real time monitoring of the potential tsunamigenic earthquakes.
  - Interconnected broadband seismic station for real time communication.
  - Bottom pressure recorder deployed in the deep ocean near Andaman and Nicobar islands.
  - Tide gauges located in the coasts with key sensors to provide early warning of tsunami.
- Suitable steps on war footing basis may be adopted to restore all the essential services like, electricity, water and food supply, telecommunication, transportation, etc. Proper steps should also ensure the protection and safeguard of properties.

- Tsunami monitoring and warning systems can allow sufficient lead time for preventive measures to be taken to reduce exposure or vulnerability of equipment. Emergency shutdown of processes that depend on pumps, motors or materials located in areas close to the shoreline would reduce the vulnerability that might be triggered by the tsunami.
- Warning would also provide some time, if adequate emergency procedures are established beforehand, to move materials and portable equipment out of harms way to avoid water damage or water intrusion, or to secure any objects, equipment, etc. that could become water borne and inflict debris damage on other equipment
- A series of public awareness campaign can be launched around the terminal area by various means including AIR, Doordarshan and other Media.
- A network of local knowledge centers (rural/urban) should be developed to provide necessary training and emergency communication during crisis time
- Information on tsunami hazards, evacuation routes and the actions to be taken in case of emergency should be provided to surrounding population by distributing pamphlets, organizing the awareness program etc.

5.1.4.5 Bomb scare / Terrorist Attack

- The site may receive unidentified call / information from intelligence sources about plantation of bombs in ships, jetty, terminal, offices, vehicles and expats residence. Safe evacuation of all staff would be ensured at the site in small groups but away from normal assembly points. Care would be exercised to distribute the staff in small groups preferably away from known assembly points. This is required as terrorists may send bomb scare at site and then explode devices by remote at assembly points to inflict greater damage. Bomb snuffing and diffusing squad would be requested from the police. All transport vehicles incoming and outgoing would be checked for unidentified objects.

- No personnel would be allowed to remain at site until site is declared safe
- In case of any terrorist attack on terminal/jetty area, efforts would be made to protect life of the people. No firearms are allowed in the terminal as per security guidelines. No action should be taken in haste by anyone as it could be misread by the terrorists. Police and other agencies would be informed and all support would be extended to them

5.1.5 Training, rehearsal and records

5.1.5.1 Training

The training should be conducted to ensure adequate understanding of the nature of potential hazards and the facilities and the equipment and procedures to be used to handle any emergency. Following trainings to various groups should be conducted

- Pre-incident Planning
- Emergency Response Training
- Basic Fire Fighting Training
- First Aid Training
- Permit To Work Training

5.1.5.2 Rehearsal / Drills

Drills will provide practical training on specific emergency equipment, means of escape and the procedures that personnel should follow in an emergency. Drills will also establish a routine so that personnel are more likely to follow the established procedures in the stress of a real emergency. The following should be the frequency of the drills.

Muster drills	Every Three Months
Breathing apparatus drills	Once in Months
Fire fighting drills	Monthly
Casualty handling drills	Every three months
First aid drills	Monthly
Marine incident drills	Every three months

5.1.5.3 Exercises

Exercises are required to demonstrate that personnel are able to respond effectively to an emergency, to identify the strengths and weaknesses in the emergency procedures and any training needs not yet fulfilled. Types of exercise should include:

- Individual plant emergencies based upon pre-planned scenarios which will test the shift teams and day workers ability to deal with local emergencies.
- Major in-house exercises which will test the overall state of readiness of the port and terminal to deal with a site emergency.

HSE department should co-ordinate the site emergency exercises on a quarterly basis and a crisis response (desktop exercise) at least annually. Shift Superintendents (incident controllers) will co-ordinate the local emergency exercise. Time taken by ambulance and emergency response team reaching to the site should be monitored.

5.1.5.4 Records and Updating the Plan

Recording Events

During an emergency an accurate log of events should be maintained. For a site emergency and crisis response, this should be the task of Duty Manager in the Emergency Control Center and the Panel operator in the Process control room. A board should also be maintained detailing the current status of the incident and the facilities involved. Any one of the Emergency response team members should carry out this task.

Updating Plan

The Plan should be reviewed and updated by HSE Manager in consultation with Port and Terminal Management team from time to time based on experience gathered from drills, exercises, incidents and emergencies.

Emergency Introduction Booklets

Emergency introduction booklets should be distributed to all staff and Contractors.