JAWAHARLAL NEHRU PORT TRUST (JNPT)

RISK ASSESSMENT REPORT

By

IRCLASS
Indian Register of Shipping

FEBRUARY - 2020

This is to state that at the request of Jawaharlal Nehru Port Trust (JNPT), the undersigned surveyors have carried out a risk assessment and prepared Disaster management plan. The scope of the analysis and the work undertaken are given in the attached report.

CONFIDENTIALITY CLAUSE

This work has been carried out for JNPT as per their work order dated 22nd October 2019 and is confidential. No part of this report may be released to any outside organization unless explicitly advised by the owners in writing.

ISSUED BY:

Indian Register of Shipping

Prepared by

Mr. Dipak Sonawane **Mr. Sudarshan Daga** **Mr. Somesh Gupta**

Reviewed by

Mr. A.R. Kar

Approved by

Mr. N. Girish

REPORT REVISION RECORD

Revision No.	Revision Details	Date
Draft	Draft report issued for review and comment to JNPT	30.03.2017
Final (Rev 0)	Final report issued to JNPT	12.06.2017
Draft (Rev 1)	Report issued for review and comment to JNPT	08.01.2020
Final (Rev 1)	Final report issued to JNPT	03.02.2020

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A strong team of highly qualified and experienced experts in various disciplines of engineering and marine sciences/technology is engaged in IRS to offer prompt technical solutions to marine and other industry.

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It is concluded that any usage/implementation/interpretation of the recommendation is at the client's risk. In particular, the recommendations should not be considered as certified, legal or otherwise.

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ACRONYMS

ACDS	Advisory Committee on Dangerous Substances
ADIOS	Automated Data Inquiry for Oil Spills
ALARP	As Low As Reasonably Practicable
ATF	Aviation Turbine Fuel
BLEVE	Boiling Liquid Expanding Vapor Explosion
BPCL	Bharat Petroleum Corporation Limited
DFPCL	Deepak Fertilizers & Petrochemicals Company Limited
DMP	Disaster Management Plan
DWT	Dead Weight Tons
ERDMP	Emergency Response Disaster Management Plan
ESD	Emergency Shut-Down
F	Frequency
F & EI	Fire and Explosion Index
FO	Furnace Oil
GBL	Ganesh Benzoplast Limited
GNOME	General NOAA Operational Modeling Environment
GPH	General Process Hazard
HAZID	Hazard Identification
HAZOP	Hazard & Operability Study
HSD	High Speed Diesel
HSE	Health, Safety and Environment
IOCL	Indian Oil Corporation Limited
JNPT	Jawaharlal Nehru Port Trust
LAB	Linear Alkyl Benzene

LCJ	Liquid Cargo Jetty
LFL	Lower Flammable Limit
LPG	Liquefied Petroleum Gas
LPM	Liters per minute
LSHF-HSD	Low Sulphur High Flash High Speed Diesel
MCP	Manual Call Point
MF	Material Factor
MoC	Material of Construction
MS	Motor Spirit
MSDS	Material Safety Data Sheet
MSIHC	Manufacture, Storage, Import of Hazardous Chemicals
MT	Metric Ton
NDMA	National Disaster Management Authority
N_F	Flammability Factor
NFPA	National Fire Protection Association, USA
N_H	Health Factor
N_R	Reactivity Factor
NOS-DCP	National Oil Spill Disaster Contingency Plan
NPP	Non Petroleum Products
OISD	Oil Industry Safety Directorate
OSCP	Oil Spill Contingency Plan
PHAST	Process Hazard Analysis Software Tool
PNGRB	Petroleum & Natural Gas Regulatory Board
POL	Petroleum Oil Lubricants
PPE	Personal Protective Equipment

QRA	Quantitative Risk Assessment
RIL	Reliance Industries Limited
RGSS	Reliance Group Support Services
ROSOV	Remote Operated Shut Off Valve
SCADA	Supervisory Control and Data Acquisition
SCBA	Self Contained Breathing Apparatus
SIMPL	Shell India Market Pvt. Ltd.
SKO	Superior Kerosene Oil
SoP	Safety Operating Procedure
SPH	Special Process Hazard
SWB	Shallow Water Berth
TLF	Tank Lorry Filling
TLV	Threshold Limit Values
UFL	Upper Flammable Limit.
UHF	Unit Hazard Factor
UVCE	Unconfined Vapor Cloud Explosion
VAM	Vinyl Acetate Monomer
VTS	Vehicle Traffic System

GLOSSARY OF TERMS

Acceptance Criteria	Defines the level of risk to which an individual is exposed, as either tolerable (negligible risk), intolerable or within the ALARP region.
Accident	An unintended event leading to loss of life, property, or damage to the environment. Examples of marine accidents include collisions, powered groundings, drift groundings, fire and explosion, and foundering.
ALARP	As Low As Reasonably Practicable. A concept where the balance between risk, cost and safety margin is reasonably achieved
Catastrophic Failure	The sudden opening up of a specified part of a containment system resulting in a rapid loss of contents.
Classification of Petroleum	Under The Petroleum Act, 1934 and The Petroleum Rules, 1976, the petroleum products are classified in to three classes as follows. a. "Petroleum Class A" means petroleum having a flash – point below 23 Deg C. b. "Petroleum Class B" means petroleum having a flash – point of 23 Deg C and above but below 65 Deg C. c. "Petroleum Class C" means petroleum having flash – point of 65 Deg C and above but below 93 Deg C.
Collision	Vessel to vessel impact – usually resulting in damage to one or other of the vessels.
Consequence	This is the severity associated with an event in terms of toxic doses, fire or explosion etc., i.e. the potential effects of a hazardous event.
Contact	Collision between a vessel and a wharf or other port structure.
Explosion	A sudden release of energy characterized by accompaniment of a blast wave.
Fire	A process of combustion characterized by heat or smoke or flame or any combination of these.
Frequency	The number of occurrences of an event per unit time.
Grounding	Action of a vessels hull, which has impacted with the sea bed/land.
Hazard	A characteristic of the system/plant process that represents a potential for an accident causing damage to people, property or the environment.
HAZID	Hazard Identification meeting. Structured meeting to achieve maximum information about hazards, causes and consequences.
IMO	International Maritime Organisation responsible for improving maritime safety and preventing pollution from ships.
Incident	Any occurrence, other than an accident, that is associated with the operation of a vessel and affects or could affect the safety of operation

Initiating Event	The first event in an event sequence.
Lower Flammable Limit	Lower end of the concentration range over which a flammable mixture of gas or vapour in air can be ignited at a given temperature and pressure.
Mitigating System	Equipment and/or procedures designed to respond to an accident event sequence by interfering with accident propagation and/or reducing the accident consequence.
Most Credible Loss Scenario	The credible scenarios which can culminate into an accident out of several major and minor scenarios, possible for the release of material and energy.
Persistent oil	Oils and petroleum products such as crude oils, fuel oils and lubrication oils that, when spilt, remains after weathering in a residual form in the environment for an appreciable period.
Probability	The expression for the likelihood of an occurrence of an event or an event sequence or the likelihood of the success or failure of an event on test or demand. By definition, probability must be expressed as a number between 0 and 1.
Risk	A measure of both the likelihood and consequence, if a hazard manifests itself.
Scenario	A sequence of events leading to an accident.
Sensitivity maps	Indication of the vulnerability of a specific area. This could be ecological but may also include socio-economic aspects.
Stranding	The ship becomes fixed on an underwater feature or object such that the vessel cannot readily be moved by lightening, floating off or with assistance from other vessels (e.g. tugs).
Upper Flammable Limit	That concentration in air of a flammable material above which combustion will not propagate.
Vapour Cloud Explosion	The preferred term for an explosion in the open air of a cloud made up of a mixture of a flammable vapour or gas with air.
Vessel traffic system (VTS)	A vessel traffic system whereby authorities monitor vessel movements within a waterway by radar surveillance and disseminate navigational information with regard to potential hazards.
Vulnerability	Extent to which an individual, community, sub-group, structure, service, or geographic area is likely to be damaged or disrupted by the impact of a particular (disaster) hazard.
Worst Credible Loss Scenario	The incident, which has the highest potential to cause an accident of maximum damage.

1. INTRODUCTION

1.1 Background

JNPT has approached IRS for carrying out Disaster Management Plan (DMP) within their port area.

1.2 Objectives and Scope

The objective of this project work is Preparation of DMP as per NDMA suggested structure.

The Risk assessment in this project covers consequences due to accidents only and does not address deliberate act of damage.

1.3 Methodology

The methodology/procedure used for the project is as follows:

- **Collection of the relevant information**

- **Hazard Analysis** – Identification of the fire and explosion hazards during handling of LPG, Ammonia, Naphtha, HSD and chemicals. Also, identification of the impact due to potential grounding & collision accidents using Brainstorming sessions and Bow-tie analysis;

- **Frequency Analysis** – Estimating the frequency based on data as available from published literature and JNPT supplied data;

- **Consequence Analysis** – Assessment of the consequence of Property loss, life loss and damage to Environment and Port Business. Oil spill quantity assessment has been done using ADIOS2 software and Oil spill trajectory analysis has been done using GNOME software;

- **Risk Analysis and Review** – Risk estimation has been done based on the consequence and frequency as assessed. The estimated risks have been categorized as low, medium or high to enable identification of control measures accordingly in order to bring down the risk to the ALARP level;

- **Reporting** – On completion of the study, a draft report has been developed for review by the JNPT. Comments on the draft report will be incorporated to finalise the report.

2. RELEVANT REGULATIONS

2.1 International Regulations

2.1.1 International Convention on Oil Pollution Preparedness Response and Cooperation (OPRC 90)

International Convention on Oil Pollution Preparedness, Response and Cooperation (OPRC) was adopted in London on 30 November 1990 and entered into force on May 13, 1995.

The OPRC Convention provides an international framework for cooperation in combating and responding to major incidents or threats of oil pollution. The Convention strives:

- to prevent marine pollution by oil, in accordance with the precautionary principle;
- to advance the adoption of adequate response measures in the event that oil pollution does occur;
- to provide for mutual assistance and cooperation between States for these aims.

2.1.2 International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978 related thereto (MARPOL 73/78)

The MARPOL Convention is the main International convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. It is a combination of two treaties adopted in 1973 and 1978 respectively and updated by amendments through the years.

a) MARPOL Annex II includes regulations for the control of pollution by noxious liquid substances in bulk. This mandatory technical annex details the discharge criteria and measures for the control of pollution by noxious liquid substances carried in bulk.

Table 2.1: - MARPOL Annex II: The new four-category categorization system for noxious liquid substances carried in bulk

Category	Description
Category X	Noxious Liquid Substances which, if discharged into the sea from tank cleaning or deballasting operations, are deemed to present a major hazard to either marine resources or human health and, therefore, justify the prohibition of discharge into the marine environment
Category Y	Noxious Liquid Substances which, if discharged into the sea from tank cleaning or deballasting operations, are deemed to present a hazard to either marine resources or human health or cause harm to amenities or other legitimate uses of the sea and therefore justify a limitation on the quality and quantity of the discharge into the marine environment
Category Z	Noxious Liquid Substances which, if discharged into the sea from tank cleaning or deballasting operations, are deemed to present a minor hazard to either marine resources or human health and

	therefore justify less stringent restrictions on the quality and quantity of the discharge into the marine environment
Other Substances	Substances which have been evaluated and found to fall outside Category X, Y or Z because they are considered to present no harm to marine resources, human health, amenities or other legitimate uses of the sea when discharged into the sea from tank cleaning of deballasting operations. The discharges of bilge or ballast water or other residues or mixtures containing these substances are not subject to any requirements of MARPOL Annex II

Alongside the revision of Annex II, the marine pollution hazards of thousands of chemicals have been evaluated by the IMO's Evaluation of Hazardous Substances Working Group (GESAMP), giving a resultant new GESAMP Hazard Profiles List, which indexes the substance according to its bio-accumulation; bio-degradation; acute toxicity; chronic toxicity; long-term health effects; and effects on marine wildlife and on benthic habitats.

b) MARPOL Annex III covers the prevention of pollution by harmful substances in packaged form. This optional technical annex contains general requirements for the issuing of detailed standards on packing, marking, labeling, documentation, stowage, quantity limitations, exceptions and notifications for preventing pollution by harmful substances.

2.1.3 Protocol on Preparedness, Response and Cooperation to Pollution Incidents by Hazardous and Noxious Substances, 2000 (OPRC-HNS Protocol)

The OPRC-HNS Protocol 2000 defines HNS as "*any substance other than oil which, if introduced into the marine environment, is likely to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the Sea*".

Parties to the OPR-HNS Protocol 2000 are required to establish measures for dealing with pollution incidents by HNS and more specifically the following is required from them:

- National and regional systems for preparedness and responding effectively to pollution incidents and to establish a national contingency plan for preparedness and response. In addition, parties are required, either individually or through cooperation, to establish equipment stockpiles, training and response exercise programmes and to cooperate in the field of information exchange;
- Emergency plans and reporting: Ships carrying hazardous and noxious liquid substances are required to carry a shipboard pollution emergency plan to deal specifically with incidents involving HNS;
- Enhancement of international cooperation in pollution response, technical cooperation and assistance, cooperation in R&D and information services.

2.1.4 Convention on the International Regulations for Preventing Collisions at Sea 1972 (COLREGS)

The COLREGS are often compared to as the "rules of the road" and prescribe requirements for the navigation and safe conduct of all vessels and requirements for collision avoidance.

2.1.5 International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)

The purpose of the code is to provide an international standard for the safe transport by sea in bulk of liquefied gases and certain other substances, by prescribing the design and construction standards of ships involved in such transport and the equipment they should carry so as to minimize the risk to the ship, its crew and to the environment, having regard to the nature of the products involved. The layout of this code is in line with the International Code for the Construction of Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code).

2.1.6 International Code for the Construction of Equipment of Ships carrying Dangerous Chemicals in Bulk (IBC Code)

The IBC Code gives international standards for the safe transport by sea in bulk of liquid dangerous chemicals, by prescribing the design and construction standards of ships involved in such transport and the equipment they should carry so as to minimise the risks to the ship, its crew and to the environment, having regard to the nature of the products carried. The IBC Code lists chemicals and their hazards and gives both the ship type required to carry that product as well as the environmental hazard rating. Each of the products may have one or more hazard properties which include flammability, toxicity, corrosivity and reactivity.

2.1.7 International Maritime Dangerous Goods Code (IMDG Code)

The IMDG Code was developed as a uniform international code for the transport of dangerous packaged goods by sea covering such matters as packing, container traffic and stowage, with particular reference to the segregation of incompatible substances. The IMDG Code contains regulations for dangerous goods and marine pollutants.

2.1.8 The 1992 Civil Liability Convention (CLC)

The 1992 Civil Liability Convention and the 1992 Fund Convention apply to pollution damage caused by spills of persistent oil from ships carrying oil in bulk as cargo, i.e., generally laden tankers, and to spills of bunker fuel oil from unladen tankers in certain circumstances, suffered in the territory (including the territorial sea) of a State Party to the Conventions, or in the exclusive economic zone (EEZ) or equivalent area of such a state.

Pollution damage includes the cost of preventive measures, i.e., reasonable measures to prevent or minimize pollution damage, as well as loss or damage caused by preventive measures. Expenses incurred for preventive measures are recoverable even when no spill occurs, provided there was a grave and imminent threat of pollution damage.

2.1.9 International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea (HNS Convention, 1996)

The HNS Convention is based upon the two-tier systems developed for oil pollution compensation under the CLC and Fund Conventions. However, given the nature of

impacts from an HNS pollution incident, the HNS Convention goes further by not only covering pollution damage, but also risks of fire and explosion, including loss of life or personal injury as well as loss of or damage to property outside of the ship. It also covers loss or damage by contamination of the environment, costs of preventative measures and further loss or damage caused by them.

2.2 National Regulations

Key legislative provisions applicable to the coastal areas in India includes Indian Fisheries Act, 1897; Indian Ports Act, 1908; Coast Guard Act, 1950; Merchant Shipping Act, 1958; Major Port Trust Act, 1963; Wildlife Protection Act, 1972 (amended in 2001); Water (Prevention and Control of Pollution) Act, 1974; Forest Conservation Act, 1980 (amended in 1988); Environment (Protection) Act, 1986; Hazardous Wastes (Management and Handling) Rules, 1989; Coastal Regulation Zone Notification 1991; Biological Diversity Act 2002.

2.2.1 Indian Ports Act, 1908

The Indian Ports Act provides enactment relating to ports and port fees and rules for safety of shipping and conservation of ports.

2.2.2 Coastguard Act, 1978

The Coast Guard Act 1978 deals mainly with constitution of the Coast Guard, service conditions, offences, and punishment. Chapter III - 14.2 (c) under the title of duties of the Indian Coast Guard, however, mentions the preservation of the marine environment and prevention and control of marine pollution. The said provision lists, "Taking such measures as are necessary to preserve and protect the maritime environment and to prevent and control marine pollution". Similarly Chapter III - 14.3 states, "The Indian Coast Guard shall perform under this section in accordance with, and subject to, such rules as may be prescribed and such rules may, in particular, make provisions for ensuring that the Indian Coast Guard functions in close liaison with Union Agencies, institutions and authorities so as to avoid duplication of effort".

In order to implement the above provision, a National Oil Spill Disaster Contingency Plan (NOS-DCP), to combat oil spill disaster was formulated and the Indian Coast Guard was made coordinating agency in view of its operational capability. To facilitate the above process D. G. Shipping and the Ministry of Surface Transport delegated limited powers under Section 69, 356 G and 356 K (i) of the Merchant Shipping Act to the Indian Coast Guard.

2.2.3 Merchant Shipping Act, 1958

The Merchant Shipping Act 1958 of the Government of India is made to foster the development and ensure the efficient maintenance of Divisions Indian Mercantile Marine, in a manner best suited to serve the national interests, to provide for the registration of Indian ships and generally to amend and consolidate the laws relating to merchant shipping. The Directorate General of Shipping, on behalf of the Central Government (Ministry of Shipping), enacts the provisions under the Merchant Shipping Act. The said act governs all aspects of merchant shipping, including prevention and containment of pollution of the sea by oil, in Part XI A of the act.

By a Gazette notification, all aspects concerning marine pollution and control, under the provisions of Section 69, 356 G and K (i) have been delegated to the Indian Coast

Guard. So far as other powers with regard to oil pollution matters, it is for the Directorate General of Shipping to ensure compliance.

2.2.4 Major Port Trust Act, 1963

The Major Port Trusts Act is one under which major ports carry out their functions within their port limits. The above act enforces the responsibility for taking all necessary action, including pollution prevention within the conservancy limit of the port, on the conservator of the port.

2.2.5 The Indian Wild Life (Protection) Act, 1972, amended in 2002 and in 2006, provides for "the protection of wild animals, birds and plants, and for matters connected therewith or ancillary or incidental thereto, with a view to ensuring the ecological and environmental security of the country". Under the Act, animals include "mammals, birds, reptiles, amphibians, fish, other chordates and invertebrates, and also includes their young and eggs". Wildlife is defined to include "any animal, aquatic or land vegetation which forms part of any habitat", which has been interpreted to imply that the destruction of habitat amounts to destruction of wildlife itself.

2.2.6 Water (Prevention & Control of Pollution) Act, 1974, Amended in 1988

The objectives of the Water (Prevention and Control of Pollution) Act are to provide for the Prevention and Control of Water Pollution and the maintenance or restoration of the wholesomeness of water for the establishment, with a view to carrying out the purposes aforesaid, of Boards for the prevention and control of water pollution, for conferring on and assigning to such Boards powers and functions relating thereto and for matters connected therewith.

2.2.7 Environmental Protection Act, 1986 (Amended 1991)

The Environment Protection Act (EP Act) 1986 is umbrella legislation on environment protection. The act has vested substantial powers in the Central Government with wide ranging aspects of environment protection including protection of the marine environment. Under the act, notifications and rules have been issued to regulate and control the pollution aspects of all industrial activities including offshore exploration and production activities. The Ministry of Environment and Forests (MoEF) however, while according clearance for industrial activities including offshore E&P activities in the country including the EEZ, makes stipulations on Environment Impact Assessment (EIA), Risk Analysis, Hazop Analysis, and Disaster Management Plan (DMP) for adherence, and monitors them for compliance.

2.2.8 Coastal Regulation Zones Notification –1991

MOEF has declared the coastal stretches of seas, bays, backwaters etc that are influenced by tidal action (in the landward side) up to 500 meters from the High Tide Line (HTL) and the land between the Low Tide Line (LTL) and the HTL as Coastal Regulation Zone (CRZ)

CRZ is classified into four categories i.e. CRZ-I, CRZ-II, CRZ-III, CRZ-IV
CRZ-I:

i. Areas that are ecologically sensitive and important, such as, national parks/marine parks, sanctuaries, reserved forests, wildlife habitats, mangroves,

corals/ coral reefs, areas close to breeding and spawning grounds of fish and other marine life, areas of outstanding natural beauty/ historical/ heritage areas, areas rich in genetic diversity, areas likely to be inundated due to rise in sea level consequent upon global warming and such other areas as may be declared by the Central Government or the concerned authorities at the State/ Union Territory level from time to time.

ii. Area between the Low Tide Line and the High Tide Line.

CRZ-II: the area that has already been developed up to or close to the shoreline. For this purpose, "developed are" is referred to as that area within the municipal limits or in other legally designated urban area which is already substantially built up and which has been provided with drainage approach roads and other infrastructure facilities. Such as water supply and sewage mains.

CRZ-III: areas that are relatively undisturbed and those, which do not belong to either category or II. Theses will include coastal zone in the rural area (developed and underdeveloped) and also areas within Municipal limits or other legally designated urban areas, which are not substantially built.

CRZ-IV: Coastal stretches in the Andaman and Nicobar, Lakshadweep and small inlands except those designated as CRZ-I, CRZ-II OR CRZ-III.

The following statutory regulations have been also referred in this task: -

i. The Factories Act, 1948 (amendment 1987) and rules.
ii. Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989 (MSIHC)
iii. The Chemical Accidents (Emergency, Planning, Preparedness and Response), Rules, 1996.
iv. The Petroleum Act, 1934 along with the Petroleum Rules, 1976.
v. Explosive Act 1884 and explosive Rules 2008.
vi. Dock workers Safety, Health and Welfare Act, 1986 along with Regulations, 1990.
vii. Petroleum and Natural Gas Regulatory Board (PNGRB) Act, 2006.
viii. ERDMP Regulations 2010.
ix. Disaster Management Act 2005.
x. The Motor Vehicles (Central) Rules, 1989 under the Motor Vehicles Act - 1988.
xi. The Manufacture Storage, Import and trans-boundary movement of Hazardous Chemicals Rules (2008 amended in 2009).
xii. Central Electricity Authority (CEA) Regulations, 2010 made under Indian Electricity Act.
xiii. Public Liability Insurance Act, 1991.
xiv. National disaster management authority guidelines – Chemical (industrial) disasters.
xv. OISD-STANDARD-114: Safe handling of hazardous chemicals.
xvi. OISD-STANDARD-117: Fire protection facilities for Petroleum depots, Terminals, Pipeline installations and Lube oil installations.
xvii. OISD-STANDARD-138: Inspection of Cross Country Pipelines – Onshore.

xviii. OISD-STANDARD-156: Fire protection facilities for ports handling hydrocarbons.

xix. OISD-STANDARD-244: Storage and handling of petroleum products at depots and terminals including standalone crude oil storage facilities.

2.2.9 Factories Act, 1948 and Rules, the Major provisions are: -

i. Constitution of Site Appraisal Committee by the State Governments.

ii. Preparation of On-Site Emergency plans by the Occupier, detailing Disaster Control Measures.

iii. Detailed Health and Safety policy to be laid down by the occupier.

iv. Occupier to constitute a Safety Committee comprising of workers and management.

v. Occupier to provide necessary training within the organization or at specialized institutions.

vi. Occupier to disclose all relevant information to general public also.

2.2.10 Manufacture, Storage and Import of Hazardous Chemicals, Rules, 1989 as amended in 1994 – Excerpts of some salient points are given as below:

Rule 13 (1): An occupier shall prepare and keep up-to-date [an on-site emergency plan containing details specified in Schedule II and detailing] how major accidents will be dealt with on the site on which the industrial activity is carried on and that plan shall include the name of the person who is responsible for safety on the site and the names of those who are authorized to take action in accordance with the plan in case of an emergency.

Rule 13 (4): The occupier shall ensure that a mock drill of the on-site emergency plan is conducted every six months.

Rule 14 (1): It shall be the duty of the concerned authority as identified in Column 2 of Schedule 5 to prepare and keep up-to-date an adequate off-site emergency plan containing particulars specified in Schedule 12 and detailing how emergencies relating to a possible major accident on that site will be dealt with and in preparing that plan the concerned authority shall consult the occupier and such other persons as it may deem necessary.

Column 2 of Schedule 5; Sl. No. 9:

Concerned authority: District Collector or District Emergency Authority designated by the State Government (for preparation of off-site emergency plans as per rule 14).

Rule 14 (4): The concerned authority shall ensure that a rehearsal of the off-site emergency plan is concluded at least once in a calendar year.

2.2.11 Petroleum Rules, 2002

Rule 16 (3): Ports into which petroleum may be imported:

Adequate fire-fighting facilities as per OISD standard – 156 shall be provided at the ports handling petroleum.

Rule 32 (1): Restriction on loading and unloading by night:

Petroleum shall not be loaded into, or unloaded from, any ship, vessel or vehicle between the hours of sunset and sunrise, unless –

a) Adequate electric lighting is provided at the place of loading or unloading.

b) Adequate fire-fighting facilities with personnel are kept ready at the place of loading for immediate use in the event of fire.

3. BRIEF DESCRIPTION OF PORT FACILITIES AND OPERATIONS AT JNPT

3.1 AREA OF OPERATION

Jawaharlal Nehru Port (also known as Nhava Sheva) is a port at Navi Mumbai (formerly known as the Nhava Sheva Port) within the Mumbai harbour on the west coast of Maharashtra, India. The port was commissioned on 26th May 1989.The port lies on the main land opposite to the city of Mumbai across the Thane creek. It is well connected to the major highways and rail networks in India.

The port encompasses an area of 3000+ hectares. The port handles 56% (JNPT website) of India's container traffic.

The port has 5 container terminals, one shallow water berth, one liquid cargo jetty (BPCL jetty), one shallow water berth and an anchorage area (ONGC). The various operations related to different container berths/jetty at JNPT are as follows:

- Gateway Terminal India (GTI- APM)
  - Loading and unloading of containers

- Jawaharlal Nehru Port Container Terminal (JNPCT)
  - Loading and unloading of containers

- Nhava Sheva International Container Terminal (NSICT – DP World)
  - Loading and unloading of containers

- Nhava Sheva (India) Gateway Terminal Pvt. Ltd.
  - Loading and unloading of containers

- Bharat Mumbai Container Terminal Pvt. Ltd Phase-I (BMCTPL)
  - Loading and unloading of containers

- Shallow Water Berth
  - Loading and unloading of spares related to offshore supply vessel for oil exploration,
  - Loading and unloading of containers,
  - Unloading of cement,
  - Loading/unloading of various bulk liquid cargoes.

- Liquid Cargo berth – BPCL Jetty
  - Loading/unloading of various bulk liquid cargoes.

- Anchorage area
  - Bunkering of HSD for ONGC vessels.

It is an all weather port. The nearest airport to JNPT is Mumbai (Chhatrapati Shivaji International) airport is about 57 km via NH348A.

3.2Location

Latitude: 18°56'43'' N
Longitude: 72°56'24''E

3.3 Port Layout Port Layout with HTL, LTL and CRZ mapping

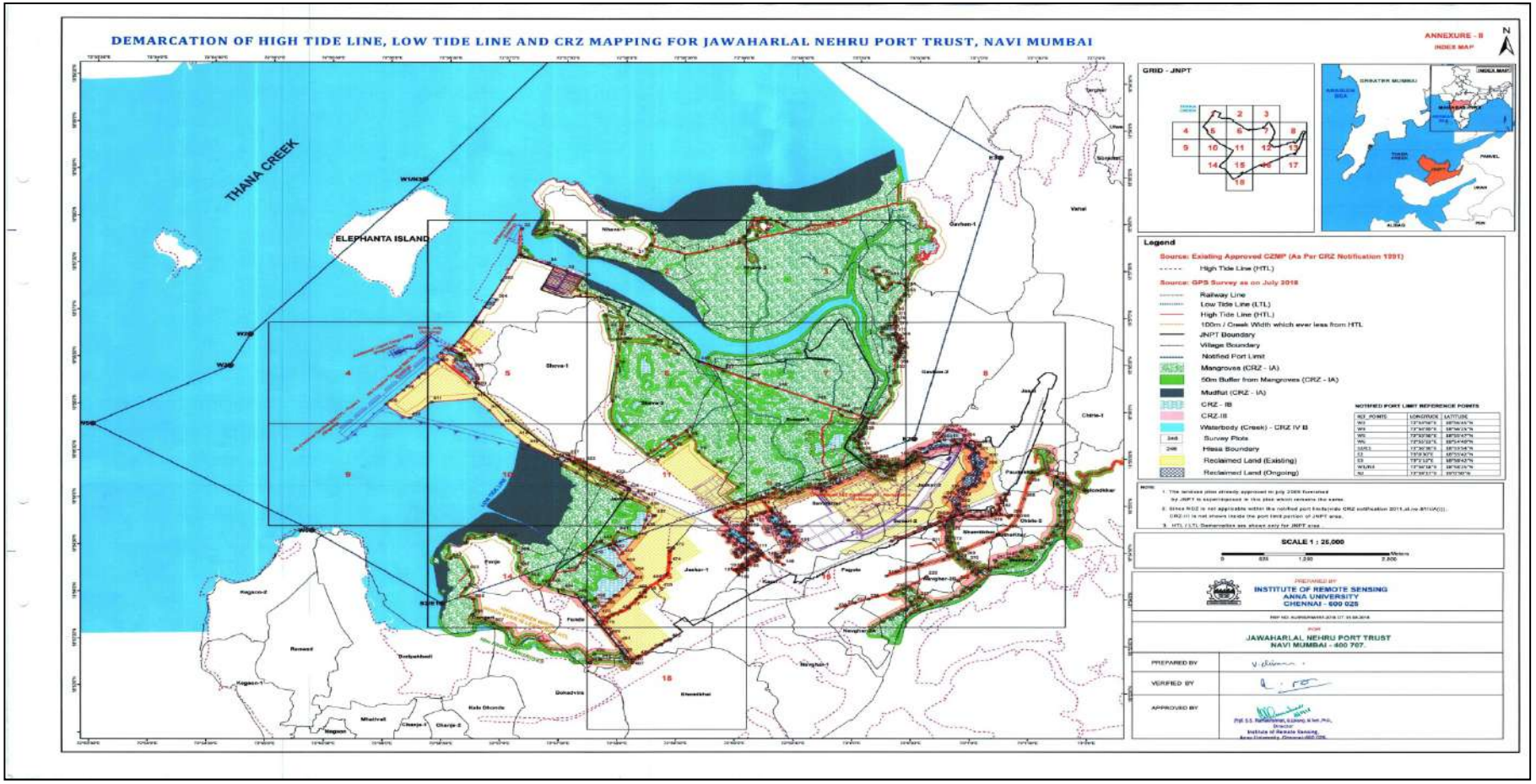


Figure 3.1: Demarcation of HTL, LTL and CRZ mapping

3.4 Port Layout

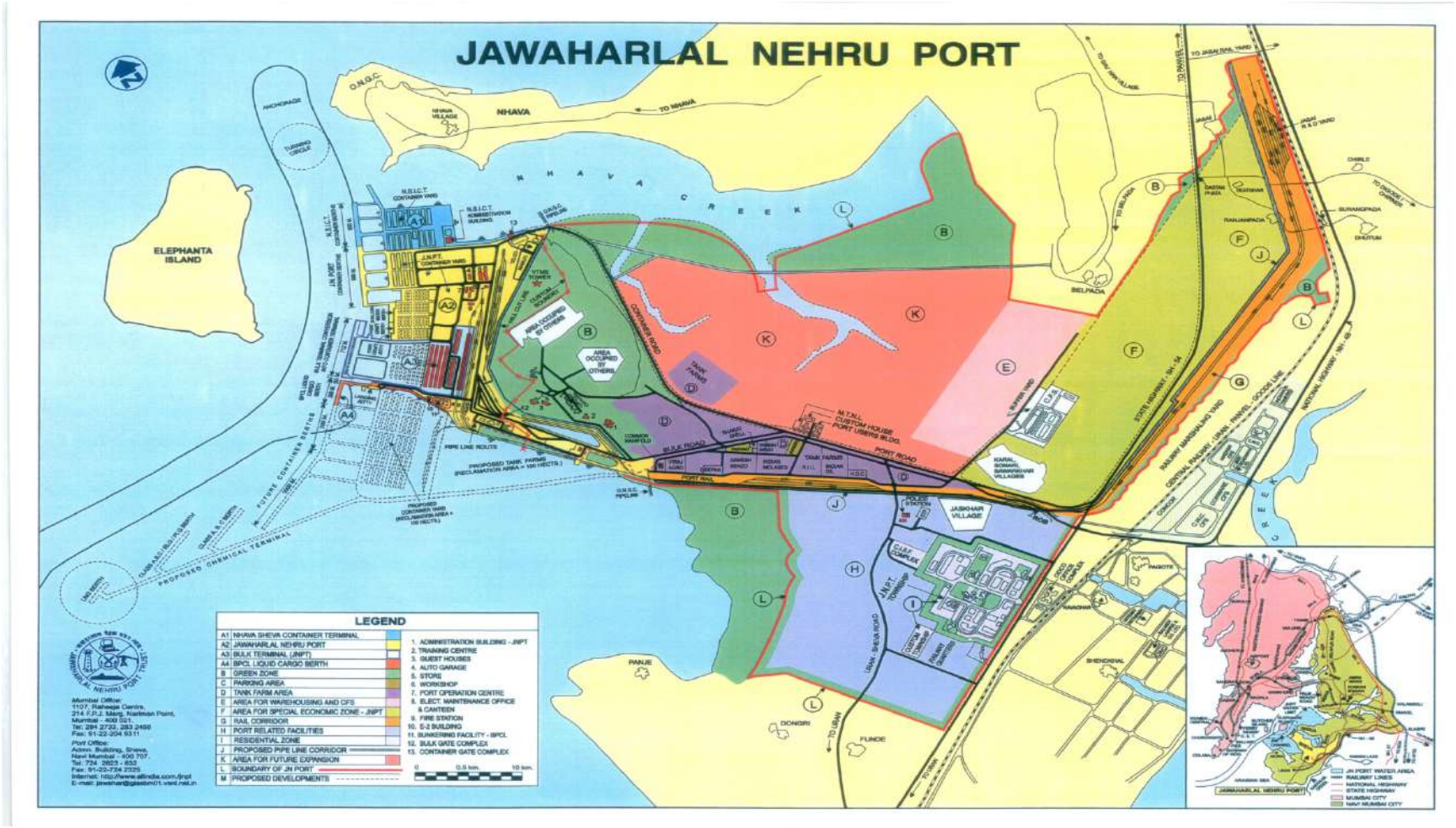


Figure 3.2: Layout of JNPT

3.5 Port Limit

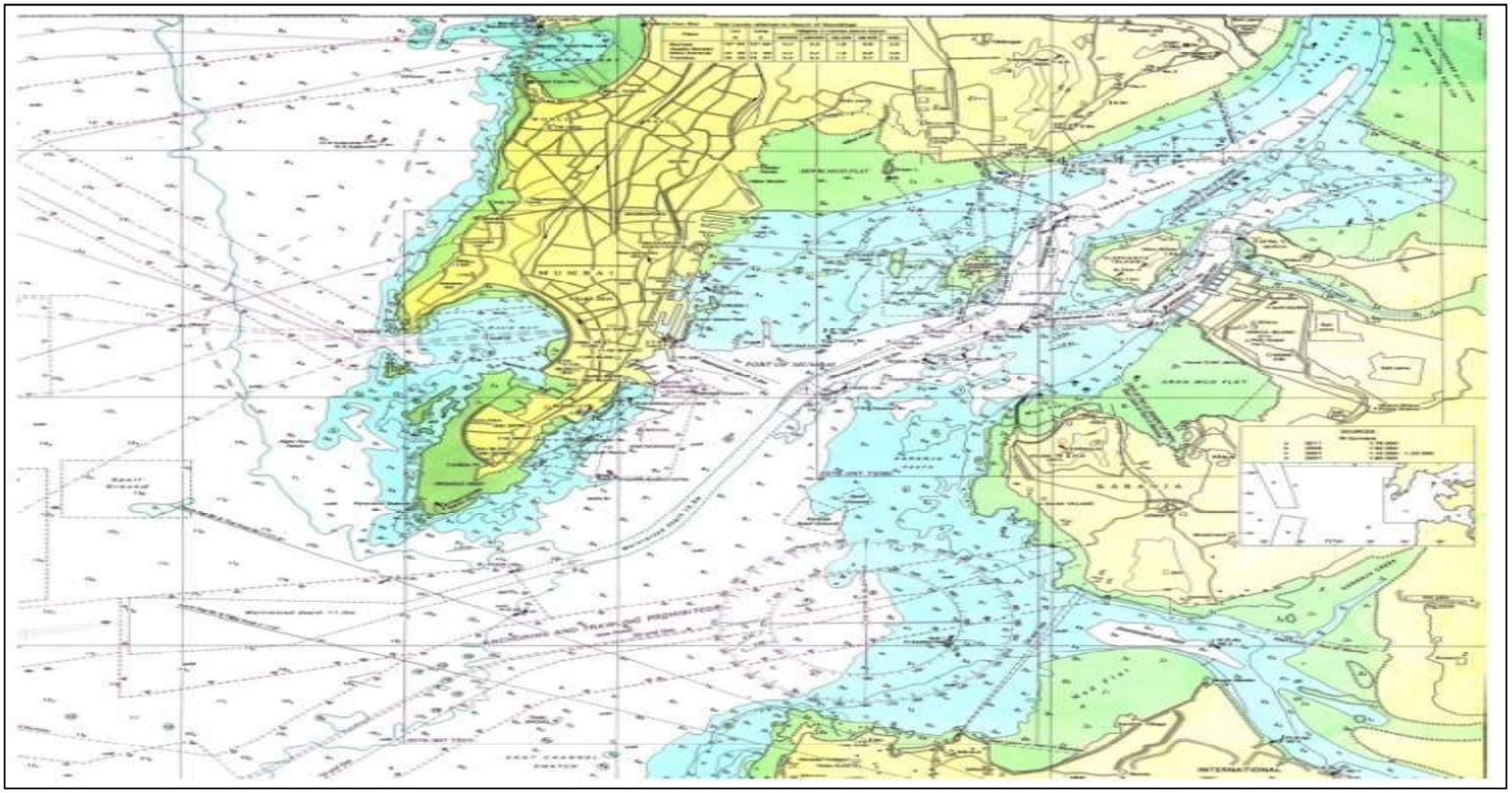


Figure 3.3: Port Limit

3.6 Port Area

The details of which are as follows

Table 3.1: Port Area

Water Spread	50 sq. Km.
Land Area	7414+ acres (3000+ hectares)

3.7 Entrance Channel (Navigational Channel)

- Common Harbour channel for JNPT and Mumbai Port, up to No. 4 berth of Jawahar Dweep Terminal.
- Designed Channel depth is 13.1 meter in JNP channel & 14.2 meters in outer harbour channel. (Below Chart Datum)
- Channel width 370 meters at straight reach, 460 meters at the berths.
- Depth at berth: 16.5 meters (Below Chart Datum)
- Anchorage of 600 meters diameter

Table 3.2: Entrance Channel

Length	:	22 km channel share with MbPT upto Jawahar Dweep + 7.2 km from Jawahar Dweep to JNPT
Width	:	370 m at straight reach, 460 m at the berths

3.8 Berth Particulars

Table 3.3: Berth Particulars

Sr. No	Berth	Type	Maximum permissible draft/m	Quay length (m)	Maximum size of the vessel that can be accommodated length (m)
1.	JNPCT + SWB	Alongside	15	680+445	370 + 183
2.	NSICT	Alongside	15	600	370
3.	GTICT	Alongside	15	712	370
4.	NSIGT	Alongside	15	330	370
5.	BMCT (Phase-I)	Alongside	16.5	1000	370
6.	Liquid Cargo Terminal	Alongside (twin berth)	16.5 (outer berth), 12.5 (inner berth)	300	370 + 185

3.9 Meteorological Parameters

3.9.1 Temperature and Rainfall

The temperature starts rising from March and May is generally the hottest month of the year with mean daily max temperature of 32.9°C. With the onset of monsoon by about first week of June

there is an appreciable drop in temperature. The month of January is the coolest month of the year with mean daily maximum and minimum temperatures of 29.1°C and 19.3°C.
The region is subject to a regular seasonal climatic variation determined by the occurrence of two annual monsoons. The South-West monsoon period extends from June to September. Most of the annual rainfall occurs during South-West monsoon, the average monthly rainfall being about 45 cm. Rain during the North-East monsoon is slight.

The average rainfall in the area is about 2422 mm and annual mean number of rainy days is about 77.8. The period between June to September receives nearly 95% of the seasonal rain. The monthly variation in temperature and rainfall is as per table 3.4.

Table 3.4: Temperature and Rainfall

Month	Temperature		Rainfall (mm)	No of rainy days average
	Maximum °C	Minimum °C		
January	30.6	16.4	0.6	0.3
February	31.3	17.3	1.5	0.1
March	32.7	20.6	0.1	0.1
April	33.1	23.7	0.6	0.3
May	33.3	26.1	13.2	1.2
June	31.9	25.8	514.1	15.4
July	29.8	24.8	868.3	23.5
August	29.3	24.5	553	19.1
September	30.1	24	306.4	12.8
October	32.9	23.1	62.9	3.7
November	33.4	20.5	14.9	1
December	32	18.2	5.6	0.3

3.9.2 Wind

General direction of wind is from the North to the West quarter, with seasonal variations are as per table 3.5.

Table 3.5: Wind directions and Speeds

Months	Directions	Speeds
February to May	Mainly from N.W	Max 8 to 10 Beaufort Substantial 4-6 Beaufort
June to September	Mainly from W.N.W	Max 8 to 10 Beaufort Substantial 6-8 Beaufort
October to January	Mainly from N.NW	Max 6 to 8 Beaufort Substantial 2-6 Beaufort.

Winds are generally light to moderate with some increase in force in the summer and monsoon

seasons. During January to May wind strengthens in the afternoon. In the southwest monsoon season winds are mainly from west or north east. During rest of the years, winds are north easterly to easterly in the mornings and blow from directions between south west and northwest in the afternoons. Summary is as per table 3.6.

Table 3.6: Wind speeds

Month	Wind Speed (knots/hr)
January	9.1
February	9.3
March	10.4
April	10.5
May	10
June	12.8
July	14.8
August	13.4
September	10
October	8.5
November	8.2
December	8.5
Total/average	10.5

3.9.3 Waves

The predominant waves are the swell waves generated by deep sea storms.
These mainly arise just before and during the South West monsoon. The statistical analysis indicates that most wave periods fall between 6 seconds and 10 seconds.

During the continuance of the North-East monsoon, North-Easterly winds known as "Elephantas" blow for short durations during the months of October-November. As the fetch and duration of these winds are limited, the "Significant height" of the resulting waves is not likely to exceed 1 meter with period ranging from 3 to 5 seconds.

The predominant wave direction during monsoon is from south west to west. During this period, waves of 4 to 5 m height normally occur, however, waves of 8.0 m height and period of 14 seconds have also been reported. October and November are transition periods during which the predominant wave direction changes to north and north east. During December and January the waves mainly occur from north to north east and from February to May waves predominantly come from the north-west quadrant. The summary of wave data is as per table 3.7.

Table 3.7: Wave height

Parameter	Value	
	1 year	100 year

Significant wave height (m)	0.6	1.6
Significant wave period (year)	10	10
Max. wave height (m)	1	3

3.9.4 Currents

The currents in Mumbai harbour and the near shore zone are tide induced with reversal at high and low waters. The current strength ranges from 1.5 to 3 knots. Current speeds and directions within the Bay and associated tributaries are largely due to the tidal movements and show little variation from non monsoon to monsoon. The maximum current speed in the outer Bay exceeds 1 m/s and the variation in the water column at any given time is not significant. Lateral variations in the speed however occur with current in the eastern area being somewhat stronger. The maximum current speeds decrease in the inner creek and are typically around 0.8 m/s, decreasing markedly during neap tide.

As characterized for a tide dominated system, the alongshore components are fairly strong with the dominance of seaward component while cross-shore components are relatively weak. Their relative magnitude and directions are indicative of net seaward movement over a tidal cycle though shoreward drift can be significant around the change of tide.

Excursion lengths and average current speeds observed for the Bay based on the available drogue trajectories are as per table 3.8.

Table 3.8: Tide excursion at Mumbai Harbour

Tide	**Excursion length (km)**		**Avg. Current speed (m/s)**	
	Flood	Ebb	Flood	Ebb
Spring	11.5	11.5	0.5	0.55
Neap	5.5	6.0	0.25	0.3

Excursion lengths during flood and ebb are more or less of a similar magnitude as expected for tidal creeks devoid of large volumes of external water inputs. The overall circulation pattern suggests that the pollutants entering the creek upstream of the bridge at Vashi tend to oscillate within the creek system and flushing to the sea is a delayed process. These pollutants would however be considerably diluted under the influence of tide induced turbulence and advection.

During monsoon however, the creek receives voluminous land run-off and the discharge of near freshwater through the Ulhas estuary, which flushes the inner creek to a large extent. Current and tidal streams being of importance to study movement of spilled oils, the details thereof are mentioned here under.

3.9.5 Tides

The quality of water-spread area of the Bay is mainly influenced by tides which induce flushing and dispersion of pollutants entering the system. The tides in Mumbai harbour are characterized by occurrence of two high and two low waters with marked diurnal variation in the levels.

The monsoon freshwater flow, though important in flushing the inner zone, is not high enough to cause significant changes in the hydrography of the outer Bay. Tides (1.2 - 5 m) in the region are semi-diurnal type with an appreciable diurnal inequality. The flood tidal front advances in north-easterly direction and ebbs to south-west.
The dominant tide in the *Mumbai Harbour* is the semi-diurnal tide with a period of 12 hours and 40 minutes. Table 3.9 gives the particulars of tidal levels related to Chart Datum.

Table 3.9: Tidal Levels

Tide	Above (+) or Below (-) datum
Highest High Water recorded	+5.39 m
Mean High Water Spring Tides	+4.42 m
Mean High Water Neap Tides	+3.30 m
Mean Sea Level	+2.50 m
Mean Low Water Neap Tides	+1.86 m
Mean Low Water Spring Tides	+0.76 m
Lowest Low Water recorded	-0.46 m
Highest Low Water	+2.74 m

Statistical studies indicate that all high tides exceed + 2.70 m. and about 5% of all high tides would be less than + 3.20 m.

Variations in tides in Mumbai estuary are as per table 3.10.
Table 3.10: Tide Variations

Location	Range (m)		Time lag from Apollo Bunder (min)
	Spring	Neap	
Apollo Bunder	5.0	1.6	-
Pir Pau	4.3	1.4	10-15
Vashi	4.2	1.2	10-30
Airoli	4.9	1.6	12-45
Thane	4.9	1.5	15-60

The tidal range decreases markedly up to Vashi as compared to that at the Apollo Bunder but increases in the inner creek, the range at Thane is only marginally lower than that at Apollo Bunder. This increase appears to be due to the funnel shape geometry of the Bay that is conducive for accumulation of seawater with the advance of tidal front in the lower creek. The tide at Thane lags by 30 to 45 min with respect to the tide at Apollo Bunder with the lag more pronounced for neap tide.

Spring tides are important for spill response as oil beached during this time is likely to remain stranded on the upper portion of the shoreline until the next spring tide (about 14 days) or storm

event. If there is a storm surge during a spring tide, the oil can remain stranded for a much longer period.

3.9.6 Sea Conditions

3.9.6.1 Cyclones

The location of the port is such that it rarely encounters cyclone.

3.9.7 Visibility

In general, on the west coast, above latitude 16°N sometimes mist develops during sunrise but disperses thereafter. From November to March, this area is prone to occurrence of smog clouds over land thus obscuring visibility. This happens only for short periods most often shortly after sunrise but also occasionally in the evenings. Visibility is generally good for most part of the year.

3.9.8 Meteorological Observatory

Meteorological Observatory receive forecast for Rainfall, Cyclone, and Wind warnings from Regional Meteorological Centre (RMC) - Mumbai.

Meteorological Observatory provides data on Pressure, Temperature, Humidity, Rainfall, Wind Speed and Direction and Tide level.

3.10 ESTABLISHMENTS WITHIN THE PORT AREA

- Jawaharlal Nehru Port Container Terminal (JNPCT)
- Nhava Sheva International Container Terminal (NSICT - DP world)
- Nhava Sheva (India) Gateway Terminal Pvt. Ltd.
- Gateway Terminals India (GTI-APM terminal)
- Bharat Mumbai Container Terminal Pvt. Ltd. (BMCTPL)
- Bharat Petroleum Corporation Limited (BPCL terminal)
- Indian Oil Corporation Ltd. tank farm (IOCL)
- RIL tank farm
- IMC tank farm
- GBL tank farm
- Bharat Shell tank farm
- Suraj Agro tank farm
- Deepak Fertilizer tank farm
- Jawahar Custom House
- Speedy CFS

3.11 Storage Facilities

Table 3.11: Storage facilities at JNPT

Tank Farm	Product	Storage Tank (nos.)	Total capacity (KL)
RIL	Naphtha, Motor Spirit (MS), Kerosene, N-Paraffin, Paraxylene, Mixed Xylene, HSD, Aviation Turbine Fuel (ATF), Light Diesel	10	71,025

	Oil (LDO), Aromatic Feed Stock (AFS), Aromatic Heavy Ends, Linear Alkyl Benzene		
IMC	CBFS, CPO, CDSBO, BUTYL ACRYLATE, STYRENE, MDC, 2EH, ULTRA-6, EHC-110, HSD, MS,CSFO, CRUDE GLYCOL, 500 N, SN-600, 150N, SN150, AP/E CORE2500, PALMOLEIN, R600, J150	46	170,000
GBL	Acetic Acid, Acetone, Aniline, Butyl Acrylate, Butyl Acetate, CG, Chloroform, Crude Glycol, Cumene, EDC, IPA, LAB, MDC, MEG, MIBK, Mix Xylene, N Butanol, Phenol, Styrene Monomer, Tolune, VAM, Edible Oil, Base Oil, Bitumen	Phase I-41 Phase II-22	150,000 --
IOCL	MS, BS-III HSD, BS-IV HSD, ATF, LSHF HSD	11	108,000
Deepak Fertilizer	Ammonia, Phosphoric Acid	03	29,000
Bharat Shell	Base Oil	04	15,000
Suraj Agro	Edible Oil	15	65,100

3.12 Stakeholders

- Port Authority,
- Ship owners and operators,
- Terminal Operators,
- Tank Farms,
- Container freight Station (CFS),
- Stevedoring companies,
- Rail carriers/operators,
- Truck and Shipping companies,
- Contractors to support the day- to day activities of the port.

3.13 Population data - JNPT Terminals

Table 3.12: Population at JNPT terminals

Sr. No.	Description	Population	
		Day	Night
1.	Jawaharlal Nehru Port Container Terminal (JNPCT)	3600	1500
2.	Nhava Sheva International Container Terminal (NSICT - DP world)	1453	-

3.	Nhava Sheva (India) Gateway Terminal Pvt. Ltd.		
4.	Gateway Terminals India (GTI-APM terminal)	1685	-
5.	Bharat Mumbai Container Terminal Pvt. Ltd.	399	100
6.	BPCL Liquid Cargo Jetty	50	-

3.14 Population data - JNPT Tank Farms

Table 3.13: Population at JNPT tank farms

Sr. No	Description	Population	
		Day	Night
1.	RIL	37	8
2.	IMC	210	22
3.	GBL	100	25
4.	IOCL	25	8
5.	Deepak Fertilizer	40	12
6.	Bharat Shell	10	04
7.	Suraj Agro	23	10

3.15 Population Data (Approximate) for Other Areas

Table 3.14: Population data

Sr. No.	Location	Population	
		Day	Night
1	JNPT Township (Port quarters)	4500	4000
2	Administration Building Port EMP. Contract Staff	260	05
3	Customs House EMP Agency	2000	-
4	PUB	2000	10
5	Guest House	50	30
6	Training centre	40	01
7	JNPT Hospital	50	10
8	South Gate Complex	150	50
9	Centre Gate Complex	300	200
10	North Gate Complex	300	200
11	CISF (G.G + R.G +B.G)	55	45

12	MTNL Office	-	-
13	Police Station	50	10
14	Custom Township	-	-
15	CISF Complex	300	300
16	Railway Quarters	-	-
17	Port Fire Station	26	18
18	Port Operation Centre	50	10
19	Ships at all berths @20 Crew/Ship	280	280
20	Jaskhar Village	2500	2500
21	Karal Village	3500	3000
22	Sonari Village	1000	1000
23	Sawarkhar Village		
24	Ranjanpada Village		
25	Belpada Village	2000	2000
26	JNPT CFS	300	200
27	Air Force Station	-	-

4. RISK ASSESSMENT PRINCIPLES

4.1 Methodology

The present Risk Assessment (RA) exercise has been done in the following stages:

- Gathering of relevant information and Data
- Hazard Identification
- Frequency Estimation
- Consequence Estimation
- Risk Estimation
- Recommendations.

4.2 Gathering of relevant information and Data

Following data are collected and used for risk assessment study:

- Facility description
- Population data
- Meteorological data
- Generic failure rate data from published literature
- MSDS of Hazardous chemicals.

4.2.1 Meteorological data:

The consequences of releases of flammable and toxic materials into the atmosphere are strongly dependent upon the rate at which the released material is diluted and dispersed to safe concentrations.

Variation in wind direction defines the apparent orientation of consequences. SAFETI accounts for the different wind directions from the wind distribution probability input and combine the values into the risk calculation. Atmospheric conditions, which include temperature and humidity, are also addressed. Two sets of weather data were considered: One set for day-time and one set for night-time. Stability classes were finalized as per Pasquill-Gifford stability classes as mentioned in CPQRA.

Wind speed and stability class considered for this study: 5-D and 2-F.

The representative weather data used in present analysis are as follows:

Table 4.1: Weather conditions

Description	**Weather Categories**	
	Day	**Night**
Temperature (^{o}C)	35	25
Relative humidity (%)	60	70
Atmospheric stability	D	F
Wind speed (m/s)	5	2

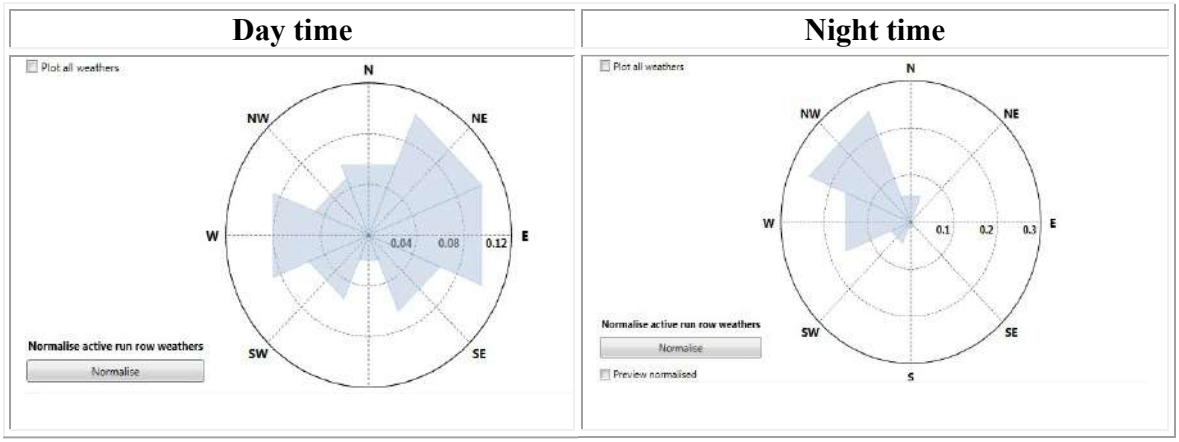


Figure 4.1: Wind rose for the Day & Night time

4.3 Hazard Identification

The first step in risk assessment is to identify hazards. Thereafter evaluate it in terms of the risk it imposes.

In order to rate the fire and explosion hazards for the chemicals handled and storage, the Dow's Fire & Explosion Index (F&EI) is used.

F&EI analysis is a step-by-step evaluation of the realistic fire, explosion and reactivity potential of processes, equipment and its contents. The F&EI is used for any operation in which flammable, combustible or reactive material is stored, handled or processed. It is a product of three attributes i.e. Material Factor (MF), General Process Hazards (GPH) and Special Process Hazards (SPH).

The MF is the starting value in computation of F & EI. MF is a measure of intrinsic rate of potential energy released from fire or explosion produced by combustion or other chemical reaction. The MF is obtained from Flammability factor and Reactivity factor i.e. N_F and N_R respectively given for various chemicals by National Fire Protection Association (NFPA).

Process hazards that contribute to the magnitude of losses have been quantified as penalties, which provide factors for computation. Every penalty may not be applicable to a specific situation and the same may have to be modified. The GPH and SPH are taken into account as penalties, which are applied, to MF.

The F & EI is defined as:

F & EI = MF x (GPH) (SPH)

Wherein, the product of GPH and SPH is termed as the Unit Hazard Factor (UHF).

The degree of hazard is identified based on F & EI range as per the criteria given Table 4.2:

Table 4.2: F&EI

F & EI Range	Degree of Hazard
0 – 60	Light

61 – 96	Moderate
97 – 127	Intermediate
128 –158	Heavy
> 158	Severe

4.4 Frequency Estimation

There are various methodologies to derive the frequency or probability of occurrence of an incident such as historical incident data on failure frequencies, or from failure sequence models, such as fault trees and event trees.

Such an event tree analysis has been depicted in Fig 4.2 to determine failure frequency of *incident – outcomes*. The probability factors used in event tree analysis have been derived based on failure rate data available from published literature and application of judgment.

Event tree:

An event tree is used to develop the consequences of an event. An event tree is constructed by defining an initial event and the possible consequences that flow from this. The initial event is usually placed on the left and the branches are drawn to the right, each branch representing a different sequence of events and terminating in an outcome.

Following Event Trees will be considered for the Risk assessment study:

Event Tree for a Continuous & Instantaneous Release:

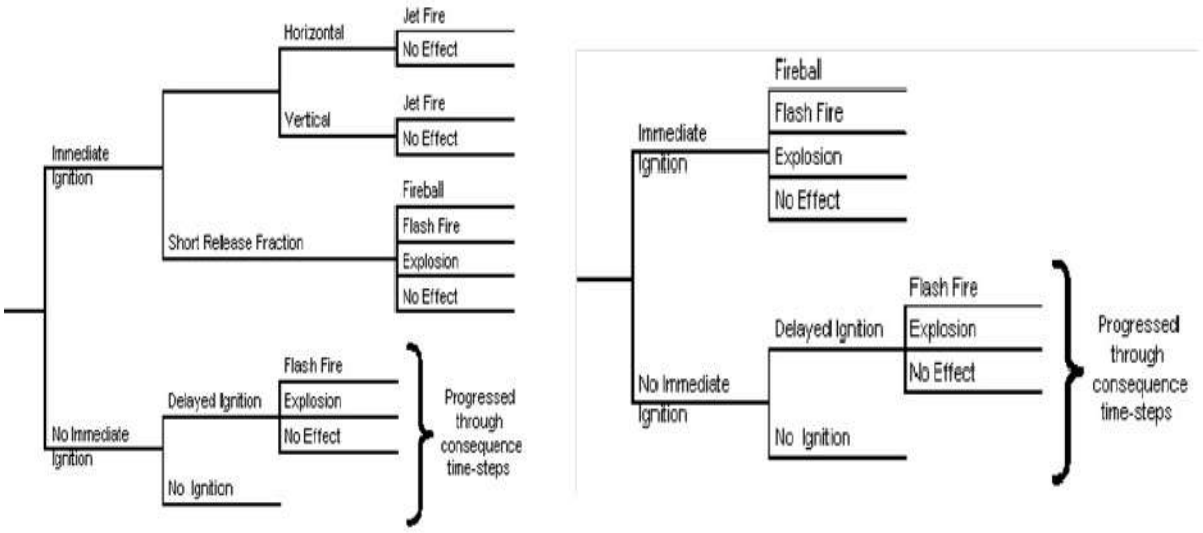


Figure 4.2 Event tree for Continuous & Instantaneous Release:

4.5 Consequence Estimation

Potential for damage of property, loss of lives and injury to health due to possibility of accidents has been estimated for various credible scenarios as mentioned in para 4.5.2.

4.5.1 Consequence modeling generally involves three distinct steps:

i. Estimation of the source term, i.e., how much material in what form (gas/liquid/two-phase) is being released from containment as a function of time, and development of the release scenarios or possible hazard outcomes (cloud dispersion, fire, explosion, etc.) following the release.

ii. Estimation of the hazard level (hazard modeling) as a function of time and at selected receptor locations, i.e., estimation of:
   - Ambient concentrations for a toxic or flammable gas release (for modeling the effects of a toxic cloud or flash fire),
   - Thermal radiation flux for fires (for a jet fire, pool fire, or fireball),
   - Overpressure for explosions (for a confined explosion, boiling liquid expanding vapour explosion [BLEVE], or vapour cloud explosion [VCE]).

iii. Estimation of damage level on the selected receptor, based on the hazard level at the receptor location (vulnerability modeling).

4.5.2 Incident Outcomes - Definitions

4.5.2.1 Fireball

One of significant fire hazard related to liquefied gas. The fireball either results from the bursting of pressure vessel or from vapor cloud explosion. In the first case bursting may occur under fire conditions and be part of a BLEVE or it may occur in the absence of fire. Momentum forces predominate, if fireball is formed from the bursting of vessel, while buoyancy forces predominate, if it is formed from a vapor cloud.

4.5.2.2 Pool Fire

A pool fire occurs when a flammable liquid spills onto the ground and is ignited. A fire in a liquid storage tank is also a form of pool fire, as is a trench fire. A pool fire may also occur on the surface of flammable liquid spilled onto water.

4.5.2.3 Jet Fire

Normally on high-pressure release of pressurized vessel or pipelines on ignition, burn likes a jet flames in open space. Any equipment can come in heavy thermal load if the flame jet impinges on it. The consequent radiation hazard is very small.

4.5.2.4 Unconfined Vapor Cloud Explosions (UVCE) and Flash Fire

When gaseous flammable material is released a vapor cloud forms and if it is ignited before it is diluted below its lower explosive limit, a vapor cloud explosion or a flash fire will occur. Insignificant level of confinement will result in flash fire. The vapor cloud explosion will result in overpressure.

4.5.2.5 Boiling Liquid Expanding Vapor Explosion (BLEVE)

A BLEVE occurs when there is a sudden loss of containment of a pressure vessel containing a superheated liquid or liquefied gas. It is sudden release of large mass of pressurized superheated liquid to atmosphere. The primary cause may be external flame impinging on the shell above liquid level weakening the vessel and leading to shell rupture.

4.5.2.6 Toxic Effect

The critical toxicity values which should be considered for evaluating effect on humans in the event of release of chemicals are:

a) Permissible exposure limits
b) Emergency response planning guidelines
c) Lethal dose levels.

4.5.3 Damage Severity Criteria

The quantitative estimation of effects of Thermal radiations and overpressure on human population, process and equipment is given in following three tables.

Table 4.3: Exposure at different incident levels of Thermal radiation (Ref. 9, 20)

RADIANT HEAT (kW/m^2)	HUMAN EXPOSURE LIMITS*
35 to 37.5	100% lethality in 1 min; 1% lethality in 10 seconds
25	100% lethality in 1 min; significant injury in 10 seconds
12.5 to 15.0	1% lethality in 1 min; first degree burns in 10 seconds
9.5	Pain threshold reached after 8 seconds; second-degree burns after 20 seconds
4.0 to 5.0	Sufficient to cause pain to personnel if unable to reach cover within 20 seconds; However, blistering of the skin (second-degree burns) is likely; 0% lethality
1.6	Will cause no discomfort for long exposure

Table 4.4: Thermal radiation damage levels (Ref. 9, 20)

INCIDENT HEAT FLUX (Kw/m^2)	DAMAGE TO EQUIPMENT	REMARKS
35.0 to 37.5	Damage to process equipment	Generally includes steel tanks, chemical process equipment, industrial

		machinery
25.0	Minimum energy to ignite wood at indefinitely long exposure without a flame	
18.0 to 20.0	Plastic cable insulation degrades	
12.5 to 15.0	Minimum energy to ignite wood with a flame; melts plastic tubing	
* Based on an average 10 min exposure time		

Table 4.5: Explosion overpressure damage impacts (Ref. 9, 20)

Overpressure (bar)	Mechanical Damage to equipment	Damage to people
0.3	Heavy damage to plant & structure	Fatality probability = 1 for humans indoor as well as outdoor >50% eardrum damage >50% serious wounds from flying objects
0.1	Repairable damage	1% death >1% eardrum damage >1% serious wounds from flying objects
0.03	Major glass damage/10% glass damage	Slight injury from flying glass

4.5.4 Software used for consequence assessment

Analysis of liquid/gaseous release events are made by analytical methods, like computer dispersion models PHAST which will predict real time scenario of the situations. The values of downwind concentration of vapor clouds are determined by the physical properties of the dangerous substances, meteorological data, leakage rate, etc. PHAST & SAFETI software is developed by DNV and is used for both consequence and risk calculations. It contains a series of up to date models that allow detailed modeling and quantitative assessment of release rate pool evaporation, atmospheric dispersion, Vapour Cloud Explosion, Combustion, heat radiation effects from fires etc.,

4.6 Risk Estimation

Risk Estimation combines the severity and likelihood of all incident outcomes from all considered incidents to derive quantity of risk in terms of Individual Risk and Societal risk. **These estimated risks are shown in para 4.6.1 and 4.6.2.**

4.6.1 Individual Risk

The individual risk is as risk to the person located in the vicinity of a hazard. Individual Risk Criteria (IRC) is used to ensure that individuals living or working near a hazardous activity do not bear an excessive risk. Individual risk can be estimated for the most exposed individual, for groups of individuals at particular places or for an average individual in an effect zone.

4.6.1.1 Individual Risk Criteria

The most comprehensive and widely – used criteria for Individual Risks are the ones proposed by the UK-HSE as follows.

Table 4.6: Individual Risk Criteria

Maximum tolerable risk for workers	:	10^{-3} per year
Maximum tolerable risk for members of the public	:	10^{-4} per year
Broadly acceptable risk	:	10^{-6} per year

In between the maximum tolerable and broadly acceptable levels, the risk should be reduced to a level which is as low as reasonably practicable (ALARP), taking account of the cost and benefits of any further risk reduction.

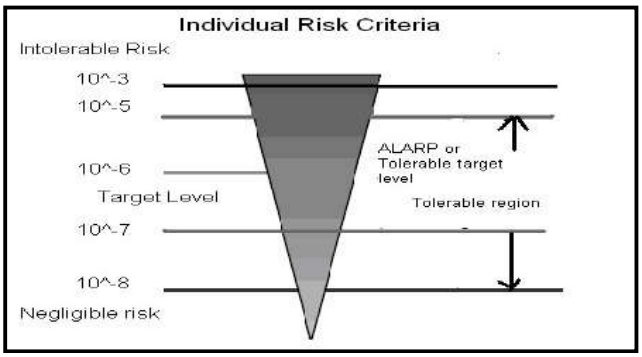


Figure 4.3: Individual Risk Criteria

Figure 4.3 show the zone between the unacceptable and broadly acceptable regions is called the tolerable region. Risks in that region are typical of the risks from activities that people are prepared to tolerate in order to secure benefits in the expectation that the nature and level of the risks are properly assessed and the results used properly to determine control measures; the residual risks are not unduly high and kept as low as reasonable practicable (the ALARP principle); and the risks are periodically reviewed to ensure that they still meet the ALARP criteria.

4.6.2 Societal Risk

Some major incidents have the potential to affect many people. Societal risk is a measure of risk to a group of people. It is most often expressed in terms of the frequency distribution of multiple casualty events (F-N curve) as shown in figure 4.4. However, societal risk can also be expressed in terms similar to individual risk. For example, the likelihood of 10 fatalities at a specific location x, y is a type of societal risk measure. The calculation of societal risk requires the same frequency and consequence information as individual risk. Additionally, societal risk estimation requires a definition of the population at risk around the facility (e.g. residential, industrial, school).

4.6.2.1 FN Curve

An F-N curve is a plot *of cumulative* frequency versus consequences (expressed as number of fatalities). A logarithmic plot is usually used because the frequency and number of fatalities

range over several orders of magnitude. It is also common to show contributions of selected incidents to the total F-N curve as this is helpful for identification of major risk contributors.

4.6.2.2 Societal Risk Criteria

The criteria shown in Figure 4.4 are used here for calculation of Societal Risk. The acceptance criteria for F-N curve based on HSE UK Guideline are presented below:

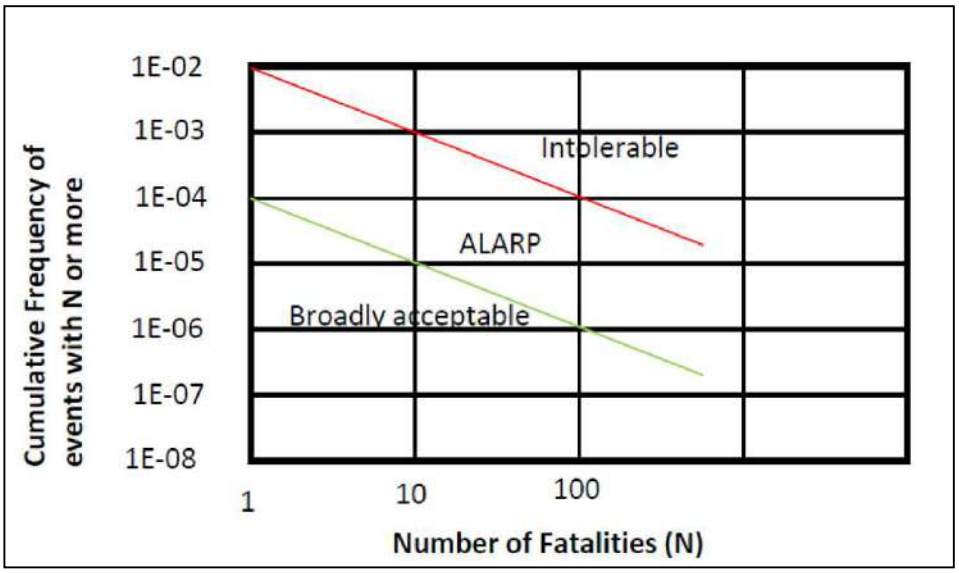


Figure 4.4: Societal Risk Criteria

5.0 RISK ASSESSMENT OF IMDG CARGO HANDLED AT CONTAINER TERMINALS

5.1 Facility Description of Container Terminals

5.1.1 Facility Description of JNPCT

JNP handled around 55% of the country's containerized cargo. Backup infrastructures like 34 CFSs, connectivity with 46 ICDs, Full fledge Custom House.

Recently modernization of container terminal was undertaken by adding three new post-Panamax sizes Rail Mounted Quay Crane (RMQCs) at main berth totaling 9 RMQCs supported by 27 nos. RTGCs and 5 nos. RMGCs and installed old three cranes at shallow water berth which also became mechanized berth, in addition also developed other infrastructure facilities which helps JNPT's cargo handling capacity gone up by around 12%.

The Port handled 5.13 million TEUs of container traffic during the financial year 2018-19, which is highest ever container traffic since the inception of the Port and 55%of the total container throughput of the country's major ports. Out of the total traffic of 5.13 million TEUs, the share of the JNPCT was 1.056 million TEUs (21%), the share of NSICT was 0.56 million TEUs (11%), the share of NSIGT was 0.94 million TEUs (18%), the share of APMT 2.04 million TEUs (40%) and the remaining 0.52 million TEUs (10%) were contributed by BMCTPL Terminal.

Table 5.1: JNPCT terminal details

Quay length (m)	680
Maximum Draft (m)	15
Capacity (In million TEUs)	1.35
Reefer Points (Nos.)	576
RMQCs (Nos.)	09
RTGCs (Nos.)	27
RMGCs (Nos.)	05
Tractor Trailers	100 (Hired)
Backup Area in Hectares (Container Yard)	61.49 (Including Shallow Birth area)
Reach Stackers	11 (Hired)
Railway Siding Tracks for ICD	04
Maximum Permissible LOA of The Vessel (m)	370

5.1.2 Facility Description of GTI-APM Terminal

Gateway Terminals India (GTI) is a joint venture between APM Terminals and the Container Corporation of India Ltd (CONCOR). Incorporated in July 2004, GTI operates the third container terminal at Jawaharlal Nehru Port on a build, operate and transfer (BOT) basis for a

period of 30 years. It commenced partial operations in March 2006 and became fully operational from October 2006.

Table 5.2: GTI-APM terminal details

Quay length (m)	712
Maximum Draft (m)	15
Reefer Points (Nos.)	880
RMQCs (Nos.)	10
RTGCs (Nos.)	40
RMGCs (Nos.)	03
Yard Area (In Hectares)	47.24
Maximum Permissible LOA of The Vessel (m)	370
Empty Handlers	02
Twin Lift Spreaders	61 m rated load

Fig 5.1: Terminal Layout

5.1.3 Facility Description of NSICT and NSIGT-DP WORLD TERMINAL

JN Port entered into a license agreement in July 1997 with M/s. Nhava Sheva International Container Terminal (NSICT) a consortium led by M/s. P & O Ports, Australia, for construction, operation and management of a new 2-berth container terminal on BOT basis for period of 30 years. The same was commissioned in April 1999. The project comprises construction of 600 meters quay length; reclamation of 25.84 hectares of area backup for container yards and

requisite container handling equipment along with other related facilities. The present capacity of the terminal is currently assessed as 15.00 million tonnes per year.

Table 5.3: NSICT and NSIGT-DP world terminal details

	NSICT	NSIGT
Quay length (m)	600	330
Maximum Draft (m)	15	15
Reefer Points (Nos.)	772	320
RMQCs (Nos.)	08	04
RTGCs (Nos.)	29	16
RMGCs (Nos.)	03	03
Yard Area (In Hectares)	25.84	27
Maximum Permissible LOA of The Vessel (m)	370	370

5.1.4 Facility Description of BMCT TERMINAL

BMCT - Fourth Container Terminal is developed on Design, Built, Fund, Operate and Transfer (DBFOT) basis for the concession period of 30 years. The work was awarded to M/s Bharat Mumbai Container Terminals Pvt. Ltd. (the subsidiary of Port of Singapore Authority) at the Revenue Share of 35.790%. The Concession Agreement was signed on 6th May 2014 and the Concession was awarded on 22nd December 2014.

The project is implemented in two Phases. i.e. Phase –I and Phase –II. The total capacity addition would be 4.8 Million TEUs, 2.4 Million TEUs in each phase.

Table 5.4: BMCT terminal (Phase-I) details

Quay length (m)	1000
Maximum Draft (m)	16.5
Reefer Points (Nos.)	1620
RMQCs (Nos.)	04
RTGCs (Nos.)	36
RMGCs (Nos.)	04
Yard Area (In Hectares)	90
Maximum Permissible LOA of The Vessel (m)	370
Designed Capacity	2.4 million TEUs

Table 5.5: Cargo classes as per IMDG Code

IMO Class	Description
Class 1	Explosives
1.1	Substances and articles which have a mass explosion hazard
1.2	Substances and articles which have a projection hazard but not a mass explosion hazard
1.3	Substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard
1.4	Substances and articles which present no significant hazard
1.5	Very insensitive substances which have a mass explosion hazard
1.6	Extremely insensitive articles which do not have a mass explosion hazard
Class 2	Gases: Compressed, Liquefied or Dissolved under pressure
2.1	Flammable gases
2.2	Non-flammable gases
2.3	Toxic gases
Class 3	Flammable Liquids
Class 4	Flammable Solids or Substances
4.1	Flammable solids
4.2	Substances liable to spontaneous combustion
4.3	Substances which, in contact with water, emit flammable gases
Class 5	Oxidizing Substances (agents) and Organic Peroxides
5.1	Oxidizing Substances (agents) by yielding oxygen increase the risk and intensity of fire
5.2	Organic peroxides – most will burn rapidly and are sensitive to impact or friction
Class 6	Toxic and infectious Substances
6.1	Toxic substances
6.2	Infectious substances
Class 7	Radioactive Substances
Class 8	Corrosives
Class 9	Miscellaneous dangerous substances and articles*
MHB	Materials hazardous only in bulk **
*Marine pollutants which are not of an otherwise dangerous nature are listed in class 9 **The regulations for materials hazardous only in bulk are not applicable to these materials when they are carried in closed freight containers, however, many precautions may have to be observed	

5.2 QRA study methodology

5.2.1 The study consists of the following steps

- Collection of data/documents
- Hazard identification
- Failure frequency estimation
- Consequence estimation
- Risk assessment
- Recommendations

5.2.2 Collection of data/documents

5.2.2.1 Collection of data/documents from JNPCT Container terminal

The data/documents collected for the study as follows:

- Emergency Action Plan
- Oil Spill Response Contingency Plan – Mumbai & JNPT Harbour
- JNPT Local Oil Spill contingency Plan
- Fire Safety Audit Report
- Safety Audit Report
- Population data
- Fire fighting system/arrangements with details
- MSDS for Chemicals handled at SWB
- SoP for handling of hazardous chemicals/substances through flexible hoses from vessels/ships berthed at SWB
- SoP for ensuring statutory compliance related to Safety and Environment at JNPT-Tank farm area

5.2.2.2 Collection of data/documents from GTI-APM Container terminal

The data/documents collected for the study as follows:

- Emergency Response Plan
- Hazardous cargo handled
- Population data
- Fire fighting system/arrangements with details
- Risk Assessment worksheets
- SoP for handling of hazardous containers

5.2.2.3 Collection of data/documents from NSICT & NSIGT-DP WORLD TERMINAL

The data/documents collected for the study as follows:

- Emergency Response Manual
- Hazardous cargo handled
- Population data
- Fire fighting system/arrangements with details
- Incident data of
- Risk Assessment worksheets
- SoP for handling of hazardous containers

The generic failure rate data are taken from the available published literature.

5.2.2.4 Collection of data/documents from BMCT

The data/documents collected for the study as follows:

- Emergency Response Manual
- Layout of Hazardous containers (DG) storage yard
- Population data
- Emergency Evacuation Escape route in building
- Fire Fighting layout
- Fire fighting system/arrangements with details

5.2.3 Hazard identification

At JNPCT, APMT, BMCT, NSICT & NSIGT dangerous cargoes contained in drums and other forms of packing such as gas bottles are being transported in box type containers. Alternatively, ISO (International Standards Organization) container tanks are used for transporting bulk liquids and gases in containers. Drums and other forms of packaging are considered more vulnerable to damage during container handling. However, IMDG code requires the construction standards of drum be commensurate with the degree of hazard posed by the material being contained. Notably, the drum, used, being smaller in size (~200 litre), the possibility of large spillage is significantly reduced for this option.

A variety of hazardous and non-hazardous materials are being handled at these container terminals. A list of hazardous chemicals handled by these container terminals is shown in table 5.8.

The following are the identified hazardous activities including their interfaces relevant to the study, which give rise to element of risk:

- Temporary storage (intermediate keeping) of containers within the Terminal
- Unloading/loading of containers from the vessel moored to jetty from/to the container transport positioned alongside the vessel.
- Internal transfer of containers within the terminal by road-vehicles.
- Loading/Unloading of containers from/to road-vehicles at the temporary storage area.

The loss of containment would be the worst scenario, which has been identified for hazardous tank container. The incident outcome is pool formation and evaporation. This causes formation of toxic cloud, which moves in the wind direction and can potentially cause harm to the people exposed to it as well as fire and explosion hazards.

Loss of containment might occur as a result of a number of undesirable events. These includes as below:

- A cargo damaging accident during a crane lift;
- Loss of containment of contents due to leakage;
- Vehicle Collision within the port area;
- Vehicle fires within the port area; and
- Fire on a ship at the berth.

Following credible release scenarios are considered for tank container:

1. Loss of containment – Major failure, a puncture or major loss of containment through 2.5 inch or more diameters.

2. Loss of containment – Medium leakage, loss of containment through 1.0 inch or more diameters.
3. Loss of containment – Minor leakage, a small 0.2 inch or lesser diameter hole in the tank near the base.

Note: The probability of release from box type containers is likely to be much less as described above.

5.2.4 Frequency estimation

An event tree analysis has been depicted in Fig 4.2 to determine failure frequency of incident – outcomes. The probability factors used in event tree analysis have been derived based on failure rate data available from published literature.

The initial incident frequency per year for Leakage/Rupture, for the considered scenarios have been taken from failure rate data (*Ref: Failure Rate and Event Data for use within Risk Assessments, HSE-UK (page 63)*) as shown in the following Table 5.6.

Table 5.6: Frequency of Initial Incident Outcomes per year

Type of Release	Failure Frequency (per vessel per year)
Catastrophic rupture	3.0×10^{-6}
Major (2.5 inch) leak	3.0×10^{-5}
Medium (1.0 inch) leak	3.0×10^{-5}
Minor (0.2 inch) leak	3.0×10^{-4}

5.2.5 Consequence Estimation

Potential for damage of property, loss of lives and injury to health due to possibility of accidents has been estimated. One severe incident (e.g., rupture of a pressurized flammable liquid tank) can lead to many distinct physical outcomes [e.g., unconfined vapor cloud explosion (UVCE), boiling liquid expanding vapor explosion (BLEVE), flash fire].

The dimensions for the tank containers considered are as below:

Table 5.7: Dimensions for the tank containers

20' Tank container					
External Dimensions			Weights		
Length External Dimension to ISO [mm]	Width External Dimension to ISO [mm]	Height External Dimension to ISO [mm]	Max. Gross wt. [kg]	Tare Weight [kg]	Max. Payload [kg]
6058	2438	2438	30480	4190	26290
6058	2438	2591	30480	4190	26290

Ref: http://www.tis-gdv.de/tis_e/containe/arten/tank/tank.htm#beschreibung

Table 5.8: List of Chemicals considered for the consequence analysis in PHAST

Sr. No.	IMDG ID	UN No.	Cargo Description
01	3	1092	Acrolein
02	3	1093	Acrylonitrile
03	3	1114	Benzene
04	3	1131	Carbon Disulphide
05	2.3	1040	Ethylene Oxide
06	3	1235	Methylamine
07	2.1	1206	Heptanes
08	3	1208	Hexanes
09	3	1280	Propylene oxide
10	3	1294	Toluene
11	3	1307	Xylenes

5.2.5.1 Consequence analysis results

The diagrammatic results of PHAST analysis are presented in **Appendix G.**

Table 5.9: Consequence results for the Jet fire

Chemical handled	Leak scenarios	Weather conditions	Jet fire radiation distances (m)		
			37.5 kW/m^2	12.5 kW/m^2	4.0 kW/m^2
Acrolein	Minor Leak	2-F	14	17	21
		5-D	12	14	18
	Medium Leak	2-F	60	71	88
		5-D	50	61	78
	Major Leak	2-F	133	159	199
		5-D	111	136	175
Acrylonitrile	Minor Leak	2-F	15	18	22
		5-D	13	15	20
	Medium Leak	2-F	64	76	95
		5-D	54	65	84
	Major Leak	2-F	124	147	184
		5-D	120	146	189
Benzene	Minor Leak	2-F	14	17	21
		5-D	12	14	19
	Medium Leak	2-F	56	68	87
		5-D	49	61	80

	Major Leak	2-F	102	124	160
		5-D	96	120	160
Carbon disulphide	Minor Leak	2-F	---	14	17
		5-D	10	12	15
	Medium Leak	2-F	42	51	63
		5-D	37	45	57
	Major Leak	2-F	85	103	127
		5-D	75	91	115
Ethylene Oxide	Minor Leak	2-F	17	20	13
		5-D	14	18	10
	Medium Leak	2-F	70	86	52
		5-D	59	75	41
	Major Leak	2-F	131	155	192
		5-D	110	133	170
Methylamine	Minor Leak	2-F	---	16	19
		5-D	11	13	16
	Medium Leak	2-F	56	66	79
		5-D	47	56	69
	Major Leak	2-F	127	147	178
		5-D	105	125	156
Heptane	Minor Leak	2-F	12	15	19
		5-D	10	13.00	17
	Medium Leak	2-F	52	64	83
		5-D	44	56	75
	Major Leak	2-F	110	135	178
		5-D	99	126	171
N-Hexane	Minor Leak	2-F	12	15	19
		5-D	10	13	17
	Medium Leak	2-F	52	64	83
		5-D	45	56	75
	Major Leak	2-F	117	144	189
		5-D	100	126	171
Propylene Oxide	Minor Leak	2-F	14	17	21
		5-D	12	14	18
	Medium Leak	2-F	58	70	88
		5-D	49	60	78
	Major Leak	2-F	130	156	200

		5-D	109	134	175
Toluene	Minor Leak	2-F	13	16	21
		5-D	11	14	18
	Medium Leak	2-F	44	54	69
		5-D	44	54	72
	Major Leak	2-F	77	94	122
		5-D	75	94	125
Xylene	Minor Leak	2-F	10	12	15
		5-D	11	13	18
	Medium Leak	2-F	31	37	48
		5-D	31	38	51
	Major Leak	2-F	53	65	84
		5-D	52	65	86

Table 5.10: Consequence results for the Pool fire

Chemical handled	**Leak scenarios**	**Weather conditions**	**Pool fire radiation distances (m)**		
			37.5 kW/m^2	**12.5 kW/m^2**	**4.0 kW/m^2**
Acrolein	Minor Leak	2-F	---	---	---
		5-D	---	---	---
	Medium Leak	2-F	29	41	54
		5-D	30	39	46
	Major Leak	2-F	61	91	128
		5-D	67	94	126
Acrylonitrile	Minor Leak	2-F	13	14	16
		5-D	---	---	---
	Medium Leak	2-F	35	50	67
		5-D	39	52	64
	Major Leak	2-F	74	106	149
		5-D	83	110	148
Benzene	Minor Leak	2-F	10	15	19
		5-D	13	17	21
	Medium Leak	2-F	23	33	49
		5-D	24	39	52
	Major Leak	2-F	---	42	73
		5-D	---	45	82
Carbon	Minor Leak	2-F	---	9	14

disulphide		5-D	---	10	16
	Medium Leak	2-F	20	31	48
		5-D	20	36	51
	Major Leak	2-F	36	67	103
		5-D	37	75	106
Ethylene Oxide	Minor Leak	2-F	16	12	16
		5-D	18	15	18
	Medium Leak	2-F	56	40	56
		5-D	58	43	58
	Major Leak	2-F	53	83	121
		5-D	58	88	122
Methylamine	Minor Leak	2-F	13	13	15
		5-D	---	---	---
	Medium Leak	2-F	30	38	46
		5-D	34	38	42
	Major Leak	2-F	58	79	102
		5-D	61	78	95
Heptane	Minor Leak	2-F	---	---	---
		5-D	---	---	---
	Medium Leak	2-F	27	39	52
		5-D	34	42	47
	Major Leak	2-F	---	49	78
		5-D	---	58	90
N-Hexane	Minor Leak	2-F	---	---	---
		5-D	---	---	---
	Medium Leak	2-F	25	28	31
		5-D	---	---	---
	Major Leak	2-F	---	50	76
		5-D	48	62	80
Propylene oxide	Minor Leak	2-F	---	---	---
		5-D	---	---	---
	Medium Leak	2-F	26	35	44
		5-D	---	---	---
	Major Leak	2-F	59	86	121
		5-D	62	85	112
Toluene	Minor Leak	2-F	11	16	21
		5-D	14	19	22

	Medium Leak	2-F	24	34	51
		5-D	25	40	55
	Major Leak	2-F	---	43	75
		5-D	---	47	86
Xylene	Minor Leak	2-F	11	17	22
		5-D	15	20	24
	Medium Leak	2-F	25	34	51
		5-D	26	40	56
	Major Leak	2-F	---	45	77
		5-D	---	48	88

Table 5.11: Consequence results for the Flash Fire

Chemical handled	**Leak scenarios**	**Weather conditions**	**Flash Fire (m)**
			LFL (ppm)
Acrolein	Minor Leak	2-F	9
		5-D	7
	Medium Leak	2-F	61
		5-D	74
	Major Leak	2-F	97
		5-D	139
Acrylonitrile	Minor Leak	2-F	11
		5-D	8
	Medium Leak	2-F	58
		5-D	79
	Major Leak	2-F	80
		5-D	118
Benzene	Minor Leak	2-F	15
		5-D	9
	Medium Leak	2-F	89
		5-D	95
	Major Leak	2-F	112
		5-D	167
Carbon disulphide	Minor Leak	2-F	22
		5-D	11
	Medium Leak	2-F	138
		5-D	98

	Major Leak	2-F	179
		5-D	185
Ethylene Oxide	Minor Leak	2-F	9
		5-D	7
	Medium Leak	2-F	74
		5-D	66
	Major Leak	2-F	138
		5-D	143
Methylamine	Minor Leak	2-F	6
		5-D	5
	Medium Leak	2-F	34
		5-D	34
	Major Leak	2-F	88
		5-D	98
Heptane	Minor Leak	2-F	13
		5-D	8
	Medium Leak	2-F	79
		5-D	99
	Major Leak	2-F	105
		5-D	176
N-Hexane	Minor Leak	2-F	14
		5-D	8
	Medium Leak	2-F	114
		5-D	106
	Major Leak	2-F	186
		5-D	256
Propylene Oxide	Minor Leak	2-F	13
		5-D	8
	Medium Leak	2-F	98
		5-D	101
	Major Leak	2-F	169
		5-D	231
Toluene	Minor Leak	2-F	9
		5-D	8
	Medium Leak	2-F	46
		5-D	67
	Major Leak	2-F	55

		5-D	84
Xylene	Minor Leak	2-F	8
		5-D	8
	Medium Leak	2-F	21
		5-D	32
	Major Leak	2-F	25
		5-D	33

Table 5.12: Consequence results for the Toxic impact

Chemical handled	**Leak scenarios**	**Weather conditions**	**Toxic impact distance (m)**
			IDLH (ppm)
Acrolein	Minor Leak	2-F	8850
		5-D	1768
	Medium Leak	2-F	> 10,000
		5-D	> 10,000
	Major Leak	2-F	> 10,000
		5-D	> 10,000
Acrylonitrile	Minor Leak	2-F	667
		5-D	236
	Medium Leak	2-F	2078
		5-D	1037
	Major Leak	2-F	2281
		5-D	1794
Benzene	Minor Leak	2-F	804
		5-D	525
	Medium Leak	2-F	474
		5-D	281
	Major Leak	2-F	126
		5-D	71
Carbon disulphide	Minor Leak	2-F	129
		5-D	66
	Medium Leak	2-F	489
		5-D	298
	Major Leak	2-F	1055
		5-D	562
Ethylene	Minor Leak	2-F	152

Oxide		5-D	81
	Medium Leak	2-F	632
		5-D	152
	Major Leak	2-F	1377
		5-D	763
Methylamine	Minor Leak	2-F	816
		5-D	258
	Medium Leak	2-F	3227
		5-D	1307
	Major Leak	2-F	2916
		5-D	3163
Heptane	Minor Leak	2-F	----
		5-D	----
	Medium Leak	2-F	----
		5-D	----
	Major Leak	2-F	----
		5-D	----
N-Hexane	Minor Leak	2-F	----
		5-D	----
	Medium Leak	2-F	----
		5-D	----
	Major Leak	2-F	----
		5-D	----
Propylene oxide	Minor Leak	2-F	188
		5-D	100
	Medium Leak	2-F	692
		5-D	465
	Major Leak	2-F	1620
		5-D	1003
Toluene	Minor Leak	2-F	----
		5-D	----
	Medium Leak	2-F	----
		5-D	----
	Major Leak	2-F	----
		5-D	----
Xylene	Minor Leak	2-F	----
		5-D	----

	Medium Leak	2-F	----
		5-D	----
	Major Leak	2-F	----
		5-D	----

Table 5.13: Consequence results for the Explosion

Chemical handled	Leak scenarios	Weather conditions	Explosion distances (m)		
			0.3 bar	0.1 bar	0.03 bar
Acrolein	Minor Leak	2-F	23	24	43
		5-D	13	13	28
	Medium Leak	2-F	171	178	292
		5-D	138	144	241
	Major Leak	2-F	213	223	403
		5-D	285	297	492
Acrylonitrile	Minor Leak	2-F	24	25	46
		5-D	13	14	29
	Medium Leak	2-F	138	144	245
		5-D	148	154	255
	Major Leak	2-F	173	181	309
		5-D	259	268	427
Benzene	Minor Leak	2-F	34	36	60
		5-D	23	24	43
	Medium Leak	2-F	218	227	382
		5-D	164	172	305
	Major Leak	2-F	271	281	452
		5-D	286	299	500
Carbon disulphide	Minor Leak	2-F	45	46	73
		5-D	22	23	37
	Medium Leak	2-F	241	252	424
		5-D	160	167	278
	Major Leak	2-F	441	458	759
		5-D	307	320	525
Ethylene Oxide	Minor Leak	2-F	23	24	42
		5-D	13	13	27
	Medium Leak	2-F	160	166	276
		5-D	137	143	236
	Major Leak	2-F	256	268	467

		5-D	295	307	501
Methylamine	Minor Leak	2-F	---	---	---
		5-D	---	---	---
	Medium Leak	2-F	82	86	153
		5-D	91	95	157
	Major Leak	2-F	188	197	350
		5-D	238	248	403
Heptane	Minor Leak	2-F	35	36	63
		5-D	13	14	32
	Medium Leak	2-F	205	214	355
		5-D	164	172	307
	Major Leak	2-F	227	236	410
		5-D	310	324	547
N-Hexane	Minor Leak	2-F	35	37	66
		5-D	13	15	34
	Medium Leak	2-F	266	278	477
		5-D	176	185	330
	Major Leak	2-F	482	489	808
		5-D	421	442	781
Propylene Oxide	Minor Leak	2-F	35	36	61
		5-D	13	14	32
	Medium Leak	2-F	250	260	425
		5-D	173	181	311
	Major Leak	2-F	448	457	723
		5-D	393	411	703
Toluene	Minor Leak	2-F	24	25	45
		5-D	13	14	29
	Medium Leak	2-F	115	120	201
		5-D	127	133	228
	Major Leak	2-F	125	130	213
		5-D	179	184	285
Xylene	Minor Leak	2-F	---	---	---
		5-D	12	13	24
	Medium Leak	2-F	46	48	83
		5-D	80	83	136
	Major Leak	2-F	36	38	70
		5-D	67	69	107

5.2.6 Risk estimation: Calculated Individual and Societal Risk

5.2.6.1 Individual Risk of JNPCT:

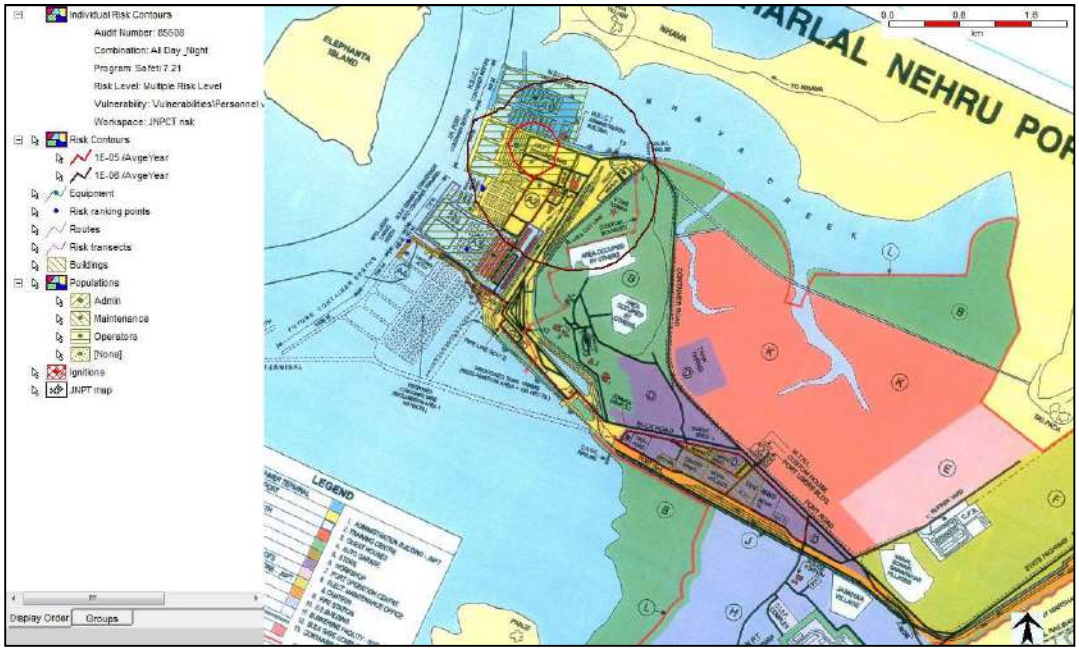


Fig 5.2 Individual risk for the hazardous tank containers (JNPCT)

5.2.6.2 Societal Risk (F-N Curve):

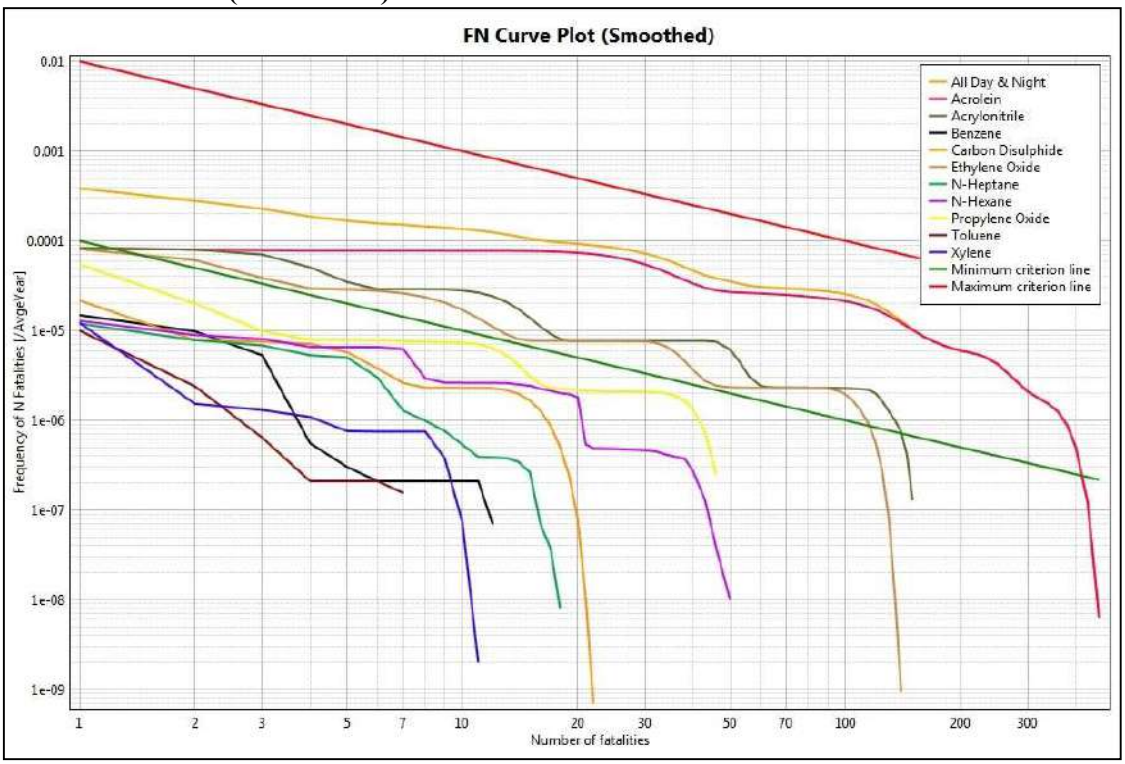


Fig 5.3 Societal risk for the hazardous tank containers (JNPCT) and overall total societal risk

5.2.6.3 Individual Risk of APM Terminal:

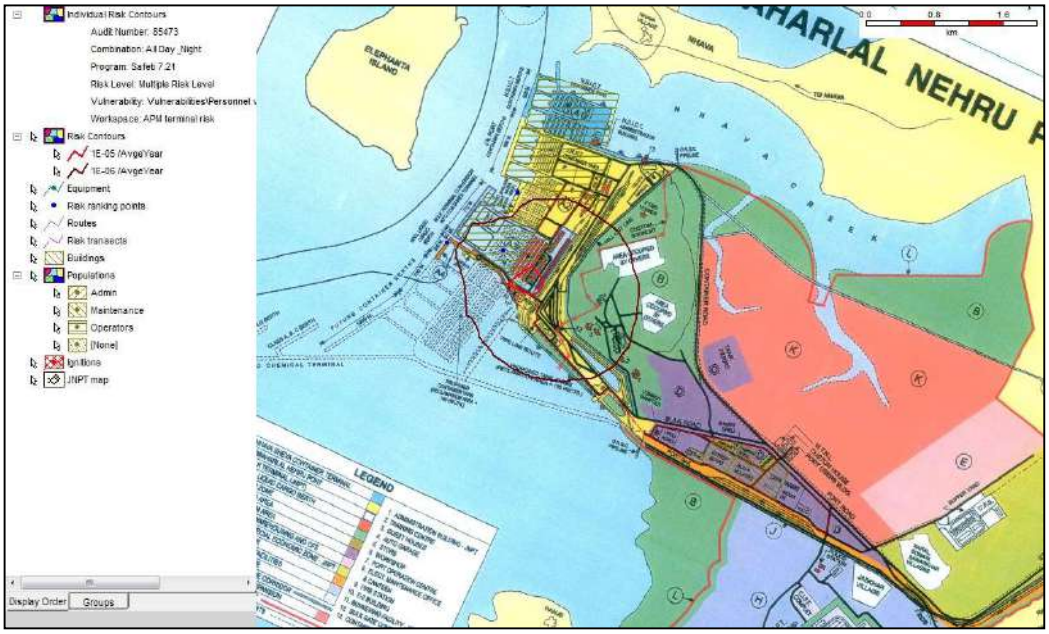


Fig 5.4 Individual risk for the hazardous tank containers (APM terminal)

5.2.6.4 Societal Risk (F-N Curve):

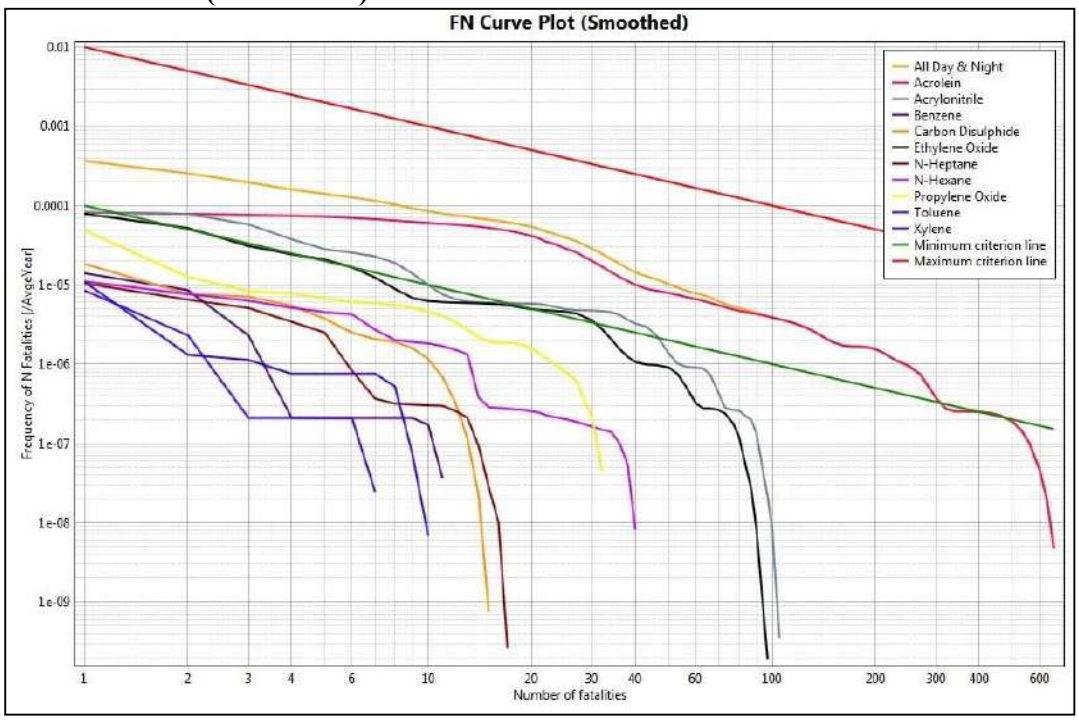


Fig 5.5 Societal risk for the hazardous tank containers (APM terminal) and overall total societal risk

5.2.6.5 Individual Risk of DP world terminal:

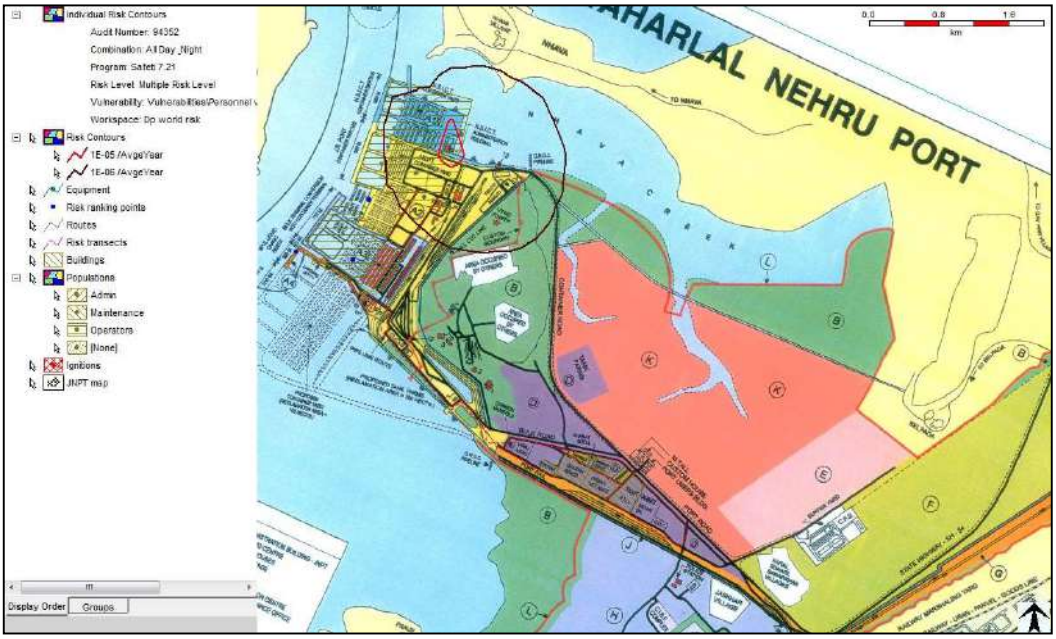


Fig 5.6 Individual risk for the hazardous tank containers (DP world terminal)

5.2.6.6 Societal Risk (F-N Curve):

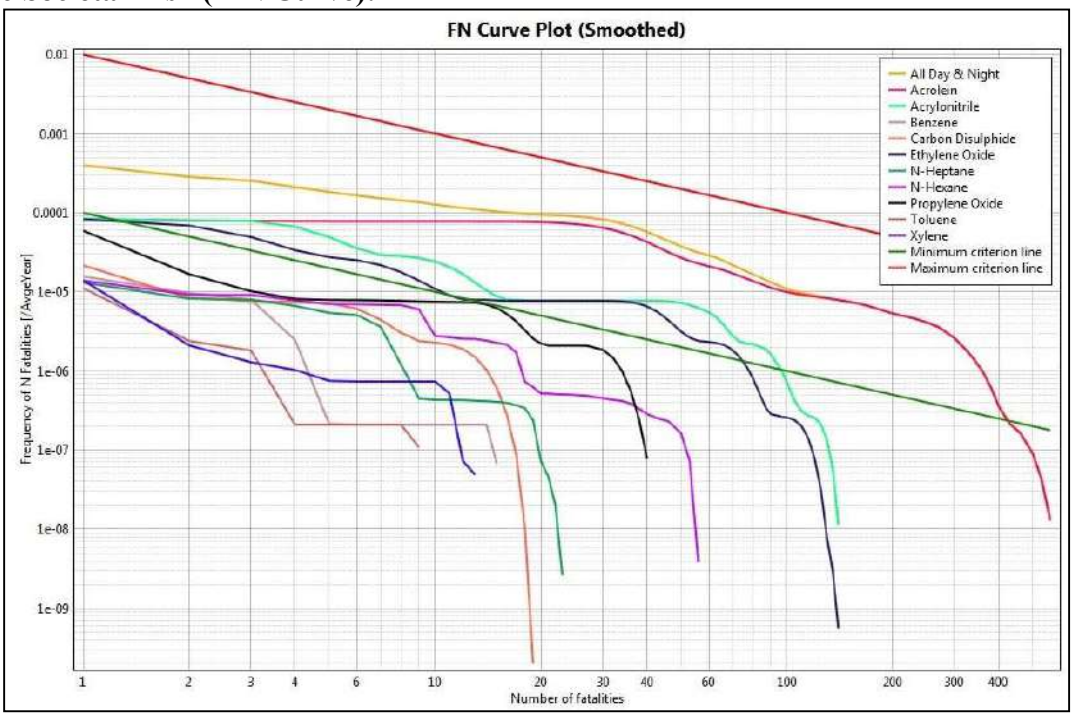


Fig 5.7 Societal risk for the hazardous tank containers (DP world terminal) and overall total societal risk

5.2.6.7 Individual Risk of BMCT terminal:

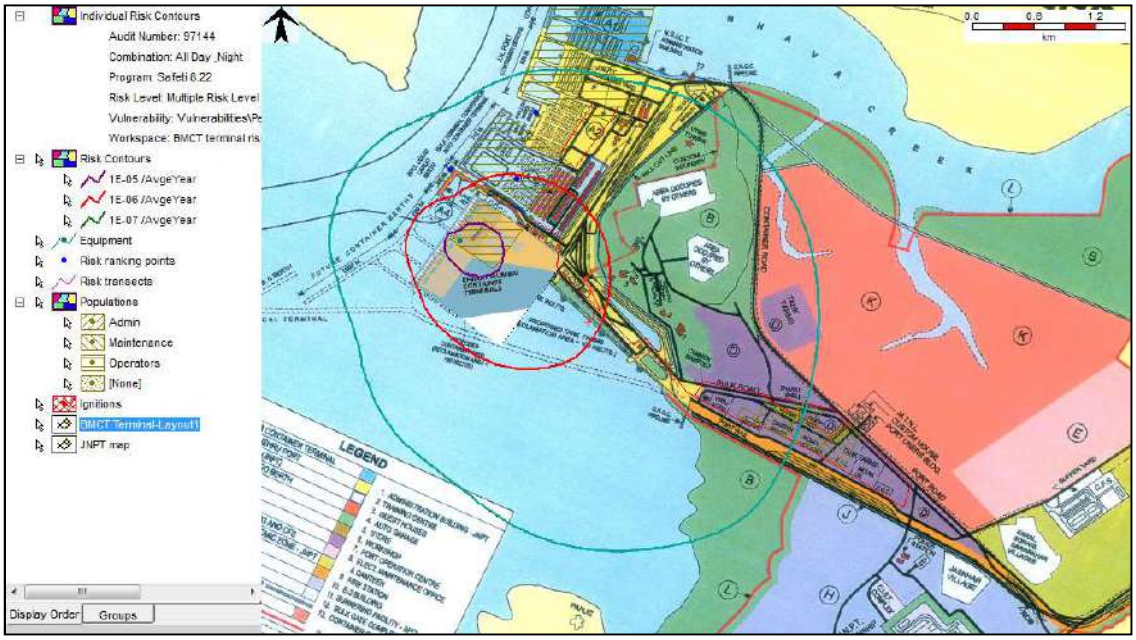


Fig 5.8 Individual risk for the hazardous tank containers (BMCT terminal)

5.2.6.8 Societal Risk (F-N Curve):

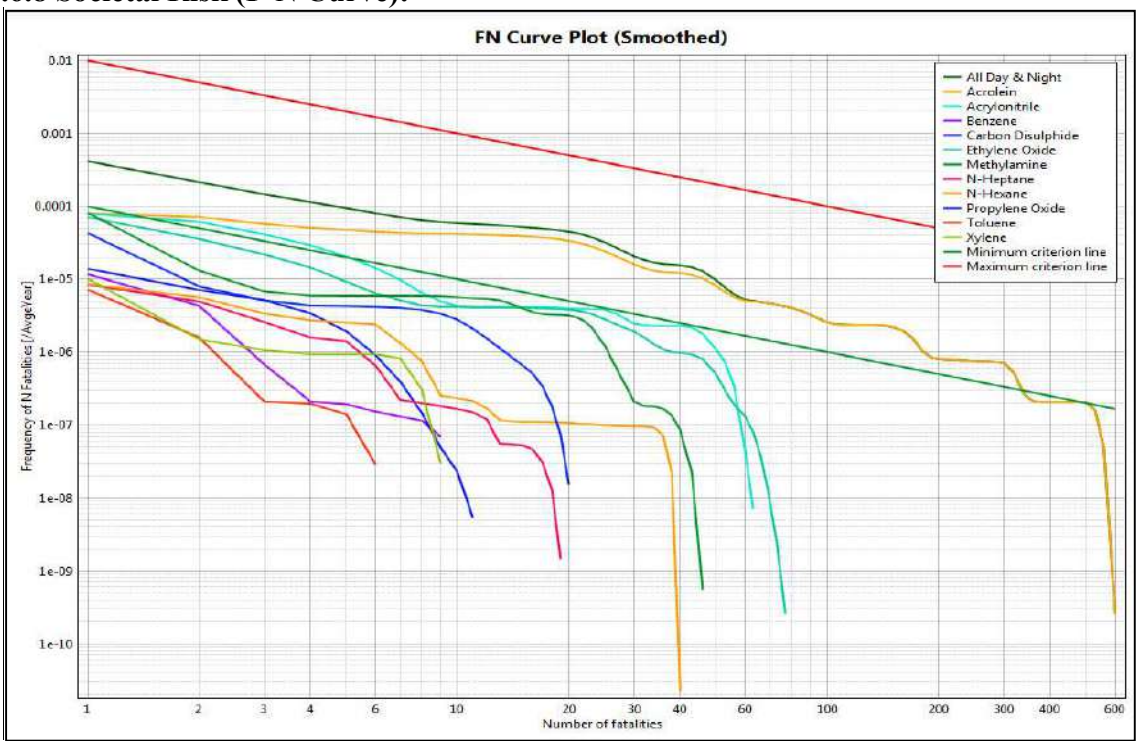


Fig 5.9 Societal risk for the hazardous tank containers (BMCT terminal) and overall total societal risk

Note: Total societal risk as presented above is for the case when the all hazardous tank containers stowed at one place and at a given time. However, in reality this situation is a remote possibility as such the actual credible risk is much lower than as projected here.

5.3 Recommendations for Container Terminals

i. Provision to be made for use of portable smoke, hydrocarbon and toxic gas detectors during the safety round by the operational personnel.

ii. Though the construction of the RTG and RMG cranes and its hooks, spreaders and locks appear to be robust and of standard make, however, intensive preventive maintenance and upgrades should be carried out in consistent manner in order to assure the reliability of the capability of material handling.

iii. Though, the possibility of containment failure of ISO containers is very low, however, in order to deal with unlikely possibility of small leakage, Spill kits with absorbents should be provided. Also, a close external inspection should be made periodically for identification of small leakages, corrosion and any abnormalities on the surfaces of the ISO containers.
In the event of finding some badly corroded surface and/or leakage during the inspection, the concerned container/tank-container should be immediately taken out of the keeping area of the yard and be shifted to bund area. Further appropriate action should be taken such as emptying out, deactivation etc.

iv. EAP should include the action plan for the natural disasters (Earthquake, Flood, Cyclone, Tsunami etc.).

v. Assessment of critical buildings and structure to withstand damage due to natural calamities such as earthquake, cyclone and flooding should be carried out periodically.

vi. Comprehensive disaster loss insurance policy should include natural disaster earthquake, cyclone, flooding, tsunami, etc.

vii. Training on using of HAZMAT should be given to the concerned operational personnel to deal with the spillage if any.

viii. Information on MSDS of the DG containers handled at the terminal should be collated and stored at the terminal.

ix. Emergency contact checklist should be updated.

x. Proper signage board for speed limit of vehicles should be provided at JNPCT.

xi. Fire water system shall be kept pressurized for a minimum residual pressure of 7 kg/cm^2 even at hydraulically remotest point in the installation.

xii. Good housekeeping to be maintained at the Fire water pump house.

xiii. Best practices of stacking containers to be followed at DG stack yard area as per relevant standard.

xiv. Speed limit signage to be provided at JNPCT yard area.

xv. The hot work system and other permit system are to be monitored on case by case basis for JNPCT.

xvi. Combined fire mock drill (with DP world, GTI-APM terminal, BMCT) from JN PORT to be conducted periodically on regular basis.

6.0 RISK ASSESSMENT FOR HAZARDOUS CARGOES HANDLED AT BPCL LIQUID CARGO JETTY

6.1 Facility description of BPCL Liquid Cargo Jetty

BPCL's Liquid Cargo Jetty (LCJ) is situated at Jawaharlal Nehru (JN) Port, Navi Mumbai inside Jawaharlal Nehru Port Trust (JNPT), Sheva, Navi Mumbai. M/s Bharat Petroleum Corporation Limited (BPCL) is the owner and Jetty operator of the LCJ. The Jetty handles various liquid cargos viz. petroleum (Class A, Class B and Class C), non-petroleum, chemicals, etc. from ship to shore and vice-versa through close conduit system of pipeline network, using marine loading arms for POL products and hoses for non-POL products. The Jetty has two parking berths, one on sea side and the other on shore side to facilitate various marine ships/vessels. LCJ is developed with large network of pipelines, intermediate lines, pig launchers, marine loading arms and loading hoses.

The total quay length is 300 m. The vessels can be handled at creek side as well as shore side. Vessels with a capacity of 85,000 DWT tankers (Creek side) and 35,000 DWT tankers (Shore side) respectively have been handled at the Jetty. The berths are in operation since February 2002. Water depth in front of berth is maintained at 12.3m during Monsoon 13.0m during fair weather for Creek side and 10.2m for Shore Side with respect to chart data. Three ships can be unloaded simultaneously, one at the shore side and two at the creek side.

LPG unloading facility is also present at this jetty, which receives at BPCL, Uran LPG Plant. Products such as Crude Oil, Naphtha, Motor Spirit, High speed Diesel (HSD), Phosphoric Acid, Ammonia etc. are handled by private tank farm owners respectively through unloading arm, flexible hoses and transferred through dedicated cross-country pipelines.

There are unloading arms installed on each side of the jetty. BPCL handles the chemicals using SS braided hoses. The hoses are flanged to the unloading pump installed in the ship and then laid across the jetty up to the fixed pipeline.

6 numbers of Marine unloading arms are installed on Creek Side & 4 numbers Marine unloading arms are installed on Shore Side. There is also a provision for future installation of a Marine unloading arm on shore side and a Marine unloading arm on sea side.

The jetty operations are carried out round the clock. There is a BPCL office on the Jetty which takes care of the day to day operations. **List of hazardous chemicals handled at Liquid cargo Jetty is given in Table 6.3.**

The details of the unloading arm and hoses given in table below:

Table 6.1: Marine unloading arm/Hose details:

MLA/Hose details		Material	Pressure in bar (g)	Temperature (^{0}C)
Dia.	Company			
16"	ONGC	Crude oil	3	Atm.
12"	IOCL	Black oil	3	Atm.

12”	IOCL	White oil	3	Atm.
12”	RIL	White oil	7	Atm.
12”	IMC	White oil	7	Atm.
12”	BPCL	LPG	7	-4
12”	BPCL	Fuel Oil	3	Atm.
8”	BPCL	LDO	3	Atm.
16”	Dipak fertilizers	Ammonia	6	-18
10”	IMC	Chemicals	7	Atm.
8”	GBL	Chemicals	7	Atm.
12” & 8”	IMC/Suraj	Base oil	7	Atm.
12”	IMC/Suraj	Edible oil	7	Atm.
12”	GBL	Edible oil	7	Atm.
12”	GBL	Edible oil	7	Atm.

Table 6.2: Process parameters for pipelines:

Pipeline details		**Material**	**Unloading/loading flow rate (m^3/hr)**	**Pressure in bar (g)**	**Temperature (^{0}C)**
Dia.	**Company**				
30”	ONGC	Crude oil	3000	3	Atm.
24”	IOTL	Black oil	1250	3	Atm.
24”	IOTL	White oil	1250	3	Atm.
16”	RIL	White oil	750	7	Atm.
10”	IMC	White oil	250	7	Atm.
12”	BPCL	LPG	185 MT/hr	7	-4
12”	BPCL	Fuel Oil	60	3	Atm.
8”	BPCL	LDO	25	3	Atm.
16”	Dipak	Ammonia	500	6	-18
10”	IMC	Chemicals	250	7	Atm.
8”	GBL	Chemicals	250	7	Atm.
8”	IMC/Suraj	Base oil	100	7	Atm.
12”	IMC/Suraj	Edible oil	300	7	Atm.
18”	GBL	Edible oil	400	7	Atm.
12”	GBL	Edible oil	300	7	Atm.

6.2 Pipelines within the Liquid Cargo Jetty includes

- Two numbers of 24” White Oil Pipeline connecting LCJ and IOC Terminal
- 24” Black Oil Pipeline connecting LCJ and IOC Terminal

- 12” & 8” Furnace Oil Pipelines connecting LCJ and BPCL Bunk Depot
- Two numbers of 12” LPG Pipeline connecting LCJ and Uran LPG Plant
- 24” White Oil Pipeline connecting LCJ and IOT Navghar Terminal
- 24” Black Oil Pipeline connecting LCJ and IOT Navghar Terminal
- 16” White Oil Pipeline connecting LCJ and RIL Terminal
- 12” Base Oil Pipeline connecting LCJ and Shell Terminal
- 16” Phosphoric Acid Pipeline connecting LCJ and Deepak Terminal
- 16” Ammonia Pipeline connecting LCJ and Deepak Terminal
- 16” Black Oil Pipeline connecting LCJ and IMC Terminal
- 12” Edible Oil Pipeline connecting LCJ and IMC Terminal
- 10” Chemicals Pipeline connecting LCJ and IMC Terminal
- 8” Base Oil Pipeline connecting LCJ and IMC Terminal
- 18” & 12” Edible Oil Pipelines connecting LCJ and Suraj Agro Terminal
- 8” Base Oil Pipeline connecting LCJ and Suraj Agro Terminal
- 18” Edible Oil/ Molasses Pipeline connecting LCJ and GBL Terminal
- 12” Edible Oil Pipeline connecting LCJ and GBL Terminal
- 8” Chemicals Pipeline connecting LCJ and GBL Terminal
- 30” Crude Oil Pipeline connecting LCJ and ONGC Uran

Fig 6.1 Liquid Cargo Jetty of JNPT

6.3 Fire fighting facility of Liquid Cargo Jetty

The fire fighting facility of the BPCL liquid cargo jetty has been provided in line with OISD 156.

Table 6.3: Fire fighting facility of LCJ

Sr. No.	Fire fighting details	
1	Fire water pumps	3 nos. main + 2 nos. as standby (880 m^3/hr each)

2	Jockey pump	1 no. main + 1 no. as standby (72 m^3/hr each)
3	Tower Monitors	06 nos. (2×12 m : 3000 LPM, 2×20 m : 6000 LPM and 2×20 m : 7570 LPM)
4	Water curtain nozzles	10 nos. (2 nos. 6000 LPM each, 8 nos. 4000 LPM each)
5	No. of Double Hydrant Points	19 nos.
6	Foam tank (SS)	3 nos. (15 m^3 each)
7	Foam pumps	4 nos. (15 m^3/hr each)
8	Oil Combat System:	Slop tank: 1 no. (11 KL) Oil dispersant spray units: 2 nos. Oil sorbents: pillows (50 nos.) Oil containment boom: 240 meters
9	Manual Call Points (MCP)	18 nos.
10	Gas detectors	07 nos.
11	Fire extinguishers DCP/CO_2	34 nos.
12	Hose boxes	18 nos.

6.4 QRA study methodology

6.4.1 The study consists of the following steps

- Hazard identification
- Failure frequency estimation
- Consequence estimation
- Risk assessment
- Recommendations

6.4.2 Collection of data/documents

The data/documents collected for the study as follows:

- HAZOP study report
- QRA study report
- Emergency Response and Disaster Management Plan
- BPCL Oil Spill Contingency Plan
- Population data
- Fire drill report
- Fire fighting system/arrangement with detail
- SoP for unloading arms
- MSDS

The generic failure rate data are taken from the available published literature.

6.4.3 Hazard Identification

A number of hazardous POL/Chemicals are handled at BPCL LCJ as shown in below table.

Table 6.4: List of hazardous chemicals handled at Liquid Cargo Jetty

No.	Chemicals	Class	Flash Point (^{O}C)	NFPA rating		
				N_F	N_H	N_R
1	1,4-Butanediol	C	134	1	1	0
2	1-Butanol	B	26	3	1	0
3	2-Ethyl Hexanol	C	85	-	-	-
4	2-Propyltheptan-1	C	100	-	-	-
5	Acetic Acid	B	43	2	3	0
6	Acetic Anhydride	B	51	2	3	1
7	Acetone	A	-20	3	1	0
8	Acrylonitrile	A	-1	3	4	2
9	AHE-70	C	--	-	-	-
10	Allyl Alcohol	A	> 23	3	3	0
11	Ammonia	NPP	--	1	3	0
12	Aniline Oil	C	70	2	3	0
13	Aromatic Feed Stocks (AFS)	NPP	110	-	-	-
14	Aromex	NPP	150	-	-	-
15	Base Oil	C	> 200	-	-	-
16	Benzene	A	-10	3	2	0
17	Biodiesel	NPP	130	-	-	-
18	Butadiene	C	76	4	3	2
19	Butyl Acetate	B	24	3	2	0
20	Butyl Acrylate	B	40	3	2	0
21	Carbon Tetrachloride	non flammable	--	0	3	0
22	Castor oil	NPP	> 200	-	-	-
23	Caustic Soda	NPP	--	-	-	-
24	Chloroform	C	--	0	2	0
25	Cyclohexane	A	-20	3	1	0
26	Diethylene Glycol	NPP	124	1	1	0
27	Edible Oil	NPP	> 200	-	-	-
28	Ethanol's	A	13	3	2	0
29	Ethyl Acetate	A	-4	3	1	0
30	Ethylene	A	-136	4	2	2
31	Ethylene Diamine	B	33	3	3	0

32	Ethylene Dichloride	A	13	3	3	0
33	Glycerine	NPP	160	-	-	-
34	Iso Butanol	B	28	3	1	0
35	Iso Nonyl Alcohol	C	NA	-	-	-
36	Iso-Butyl alcohol	B	28	3	1	0
37	Isopropyl alcohol	A	12	3	1	0
38	Lauryl Mirystl Alcohol	C	121-145	-	-	-
39	Linear Alkyl Benzene (LAB)	NPP	145	1	1	0
40	LPG/Propane/Butane	A	-40	4	2	0
41	Lube Oil	C	> 200	-	-	-
42	Luprant	C	> 204	-	-	-
43	M.E.G/Crude Glycol	NPP	111	1	2	0
44	Meta Methyl Acrylate	NPP	--	-	-	-
45	Meta Xylene	B	30	3	1	0
46	Methanol	A	12	3	1	0
47	Methyl Ethyl Ketone	A	-9	3	1	0
48	Methyl Iso Butyl Ketone	A	23	3	2	0
49	Molasses	NPP	--	-	-	-
50	MTBE	A	10	3	1	0
51	N Paraffin	B	40	-	-	-
52	N-Hexane	A	-23	3	2	0
53	Ortho Toluidine	C	85	2	3	0
54	O-Xylene	B	30	3	2	0
55	Palm Fatty Oil/Acid	NPP	120	-	-	-
56	Palm oil	NPP	130	-	-	-
57	Para Xylene/mixed Xylene	B	25	3	2	0
58	Paraffin oil	NPP	190	-	-	-
59	Phenol	C	79	2	3	0
60	Phosphoric Acid	NPP	--	0	3	0
61	Polypropylene	NPP	113	-	-	-
62	Propylene	A	-108	4	1	1
63	Propylene Glycol	NPP	132	1	0	0
64	Styrene Monomer	B	31	3	2	2

65	Sulphuric Acid	NPP	--	0	3	2
66	Toluene	A	4	3	2	0
67	Triethylene Glycol	NPP	111	-	-	-
68	Vegetable Oil	NPP	200	-	-	-
69	Vinyl Acetate	A	-8	3	2	2

6.4.4 Hazards of LPG

LPG is mixture of propane and butane. LPG is colorless and odorless. An odorizing agent is added before distribution to give its characteristic smell. LPG is easily liquefied under pressure, it expands by volume 1:250 when converted from liquefied to gaseous.

LPG is approximately twice as heavy as air when in gas form. LPG in liquid form can cause severe cold burns to the skin owing to its rapid vaporization. LPG forms a flammable mixture with air in concentrations of between 1.9% and 10%, it can be a fire and explosion hazard. Vapor/air mixtures arising from leakages may be ignited some distance from the point of escape and the flame can travel back to the source of the leak. At very high concentrations when mixed with air, vapor is an anesthetic and subsequently an asphyxiant by diluting the available oxygen. LPG is having the flammability (N_F) classification as 4, Health hazard (N_H) classification as 1 and reactivity (N_R) classification as 0.

6.4.4.1 Dow's Fire & Explosion index of LPG

In order to rate Fire and Explosion hazards of handling of LPG at BPCL Jetty, the Dow's Fire & Explosion Index (F&EI) is used.

Table 6.5: NFPA hazard ranking of LPG

Chemical	N_H	N_F	N_R
LPG	1	4	0

6.4.4.2 Summary of DOW's Index

For the LPG handling and storage, F&EI have been worked with conservative estimation as given in table below:

Table 6.6: Summary of DOW's F&EI for LPG

Chemical	MF	GPH	SPH	UHF	F&EI	Rating
LPG	24	2.45	2.4	5.88	141.1	HEAVY

Location	Plant	PROCESS UNIT
BPCL LCJ	**-**	**LPG Handling**
STATE OF OPERATION **LPG Handling**		BASIC MATERIAL(S) FOR MATERIAL FACTOR **Liquefied Petroleum Gas**

MATERIAL FACTOR	**24**

1. General Process Hazards		**Penalty Factor Range**	**Penalty Factor Used**
Base Factor		1.00	1.00
A. Exothermic Chemical Reactions		0.30 to 1.25	-----
B. Endothermic Processes		0.20 to 0.40	-----
C. Material Handling and Transfer		0.25 to 1.05	0.85
D. Enclosed or Indoor Process Units		0.25 to 0.90	-----
E. Access		0.20 to 0.35	0.35
F. Drainage and Spill Control	.	0.25 to 0.50	0.25
General Process Hazards Factor (F_1)			**2.45**
2. Special Process Hazards			
Base Factor		1.00	1.00
A. Toxic Material(s)		0.20 to 0.80	0.20
B. Sub-Atmospheric Pressure (< 500 mm Hg)		0.50	-----
C. Operation In or Near Flammable Range			-----
1. Tank Farms Storage Flammable Liquids		0.50	-----
2. Process Upset or Purge Failure		0.30	-----
3. Always in Flammable Range		0.80	0.50
D. Dust Explosion		0.25 to 2.00	-----
E. Pressure	Operating Pressure 7 bar Relief Setting --- bar	From Figure	0.5
F. Low Temperature		0.20 to 0.30	-----
G. Quantity of Flammable/Unstable Material:	Quantity = ---- lb H_C = ---- BTU/lb	100×10^6	-----
1. Liquids or Gases in Process		From Figure	0.10
2. Liquids or Gases in Storage		From Figure	-----
3. Combustible Solids in Storage, Dust in Process		From Figure	-----
H. Corrosion and Erosion		0.10 to 0.75	-----
I. Leakage – Joints and Packing		0.10 to 1.50	0.10
J. Use of Fired Equipment		From Figure	-----
K. Hot Oil Heat Exchange System		0.15 to 1.15	-----
L. Rotating Equipment		0.50	-----
Special Process Hazards Factor (F_2)			**2.40**
Process Unit Hazards Factor (F_1 x F_2) = F_3			**5.88**
Fire and Explosion Index (F_3 x MF = F&EI)			**141.1**
FIRE & EXPLOSION INDEX (RATINGS)			***HEAVY***

6.4.5 Failure leak scenarios

Failure cases for jetty pipelines, unloading arm and hoses will include two leak sizes, one is a small leak and the other is a large or a full-bore release. The same is tabulated below:

Table 6.7: failure leak scenarios

Leak category	Representative hole size
Small leak	20% of nominal diameter
Rupture	Nominal diameter (FBR)

6.4.5.1 Failure frequency estimation

The failure frequency for loading/unloading and transfer activities is as follows:

Double wall refrigerated storage vessel:

- Catastrophic failure rate : 5.0×10^{-7}(per vessel per year)
- Major failure : 1.0×10^{-5}(per vessel per year)
- Minor failure : 3.0×10^{-5}(per vessel per year)
- Failure with a release of vapor only : 4.0×10^{-4}(per vessel per year)

Vessel connection failure:

- 25 mm dia. leak : 3.0×10^{-5}/yr
- 50 mm dia. leak : 7.5×10^{-6}/yr
- 100 mm dia. leak : 4.0×10^{-6}/yr
- 150 mm dia. leak : 3.0×10^{-6}/yr

Above ground pipeline failure:

- Rupture (> 110 mm dia.) : 6.5×10^{-9}/(m.yr)
- Large hole (>75 - < 110mm) : 3.3×10^{-8}/(m.yr)
- Small hole (>25 - < 75mm) : 6.7×10^{-8}/(m.yr)
- Pin hole (<25 mm) : 1.6×10^{-7}/(m.yr)

Flexible hose failure:

- Full Bore Rupture : 4.0×10^{-6}/(hr)
- Hose leak : 4.0×10^{-5}/(hr)

Loading/unloading arm failure:

- Full Bore Rupture : 6.0×10^{-5} per operation
- Hose leak : 6.0×10^{-4} per operation

6.4.6 Consequence analysis

Based on a review of the plant details, the above leak scenarios have been considered for consequence analysis for the chemicals handled at BPCL jetty to assess the impact of fire, vapour cloud explosion and toxic dispersion.

Table 6.8: Consequence results for the Jet fire

Chemical handled	Leak scenarios	Weather conditions	Jet fire radiation distances (m)		
			37.5 kW/m^2	12.5 kW/m^2	4.0 kW/m^2
LPG	Leak from Marine unloading arm	2-F	94	111	140
		5-D	79	96	125
	FBR of MLA	2-F	115	139	178
		5-D	97	121	159
	Leak from Pipeline	2-F	123	147	188
		5-D	104	128	170
	FBR of Pipeline	2-F	122	146	187
		5-D	103	127	168
Ammonia	Leak from Marine unloading arm	2-F	---	159	187
		5-D	---	132	158
	FBR of MLA	2-F	---	157	194
		5-D	---	138	168
	Leak from Pipeline	2-F	---	160	193
		5-D	---	138	168
	FBR of Pipeline	2-F	---	221	264
		5-D	---	194	235
Crude Oil	Leak from Marine unloading arm	2-F	18	21	27
		5-D	22	26	34
	FBR of MLA	2-F	39	47	62
		5-D	38	48	64
	Leak from Pipeline	2-F	63	77	101
		5-D	69	87	118
	FBR of Pipeline	2-F	134	166	220
		5-D	115	146	199
Naphtha	Leak from Marine unloading arm	2-F	94	115	150
		5-D	80	101	136
	FBR of MLA	2-F	326	404	535

		5-D	283	358	483
	Leak from Pipeline	2-F	94	115	150
		5-D	80	101	136
	FBR of Pipeline	2-F	78	94	121
		5-D	90	110	143
MS	Leak from Marine unloading arm	2-F	95	117	152
		5-D	81	102	137
	FBR of MLA	2-F	357	442	582
		5-D	311	393	530
	Leak from Pipeline	2-F	95	117	152
		5-D	81	102	137
	FBR of Pipeline	2-F	98	118	151
		5-D	104	127	165
Acetone	Leak from Marine unloading Hose	2-F	105	126	158
		5-D	88	108	139
	FBR of Hose	2-F	161	194	244
		5-D	141	172	222
	Leak from Pipeline	2-F	105	126	158
		5-D	88	108	139
	FBR of Pipeline	2-F	32	38	46
		5-D	34	39	48
Acrylonitrile	Leak from Marine unloading Hose	2-F	102	121	151
		5-D	97	118	152
	FBR of Hose	2-F	120	144	181
		5-D	105	127	164
	Leak from Pipeline	2-F	102	121	151
		5-D	97	118	152
	FBR of Pipeline	2-F	22	26	31
		5-D	24	28	35
Allyl Alcohol	Leak from Marine unloading Hose	2-F	57	68	84
		5-D	57	69	89
	FBR of Hose	2-F	65	79	98
		5-D	58	70	89
	Leak from	2-F	57	68	84

	Pipeline	5-D	57	69	89
	FBR of Pipeline	2-F	---	13	15
		5-D	13	15	18
Benzene	Leak from Marine unloading Hose	2-F	85	103	133
		5-D	82	102	136
	FBR of Hose	2-F	116	142	184
		5-D	103	128	169
	Leak from Pipeline	2-F	85	103	133
		5-D	82	102	136
	FBR of Pipeline	2-F	22	26	32
		5-D	25	29	36
Cyclohexane	Leak from Marine unloading Hose	2-F	97	118	153
		5-D	84	106	143
	FBR of Hose	2-F	133	163	213
		5-D	118	148	198
	Leak from Pipeline	2-F	97	118	153
		5-D	84	106	143
	FBR of Pipeline	2-F	23	27	34
		5-D	25	30	38
Ethylene	Leak from Marine unloading Hose	2-F	19	24	30
		5-D	20	25	30
	FBR of Hose	2-F	66	87	116
		5-D	71	90	115
	Leak from Pipeline	2-F	19	24	30
		5-D	20	25	30
	FBR of Pipeline	2-F	25	33	44
		5-D	34	36	39
MTBE	Leak from Marine unloading Hose	2-F	92	112	144
		5-D	78	97	130
	FBR of Hose	2-F	191	234	305
		5-D	169	212	283
	Leak from Pipeline	2-F	92	112	144
		5-D	78	97	130
	FBR of Pipeline	2-F	37	44	55

		5-D	37	44	56
Propylene	Leak from Marine unloading Hose	2-F	21	27	34
		5-D	24	29	35
	FBR of Hose	2-F	70	93	128
		5-D	75	97	126
	Leak from Pipeline	2-F	21	27	34
		5-D	24	29	35
	FBR of Pipeline	2-F	27	35	46
		5-D	40	42	46
Toluene	Leak from Marine unloading Hose	2-F	65	79	102
		5-D	65	81	108
	FBR of Hose	2-F	76	93	120
		5-D	67	83	111
	Leak from Pipeline	2-F	65	79	102
		5-D	65	81	108
	FBR of Pipeline	2-F	13	15	19
		5-D	15	18	22
Vinyl Acetate	Leak from Marine unloading Hose	2-F	88	106	133
		5-D	80	98	127
	FBR of Hose	2-F	114	138	174
		5-D	100	122	159
	Leak from Pipeline	2-F	88	106	133
		5-D	80	98	127
	FBR of Pipeline	2-F	22	26	31
		5-D	25	29	36
Xylene	Leak from Marine unloading Hose	2-F	45	54	70
		5-D	45	56	74
	FBR of Hose	2-F	47	58	75
		5-D	42	52	69
	Leak from Pipeline	2-F	45	54	70
		5-D	45	46	75
	FBR of Pipeline	2-F	8	9	11
		5-D	9	11	14

Table 6.9: Consequence results for the Pool fire

Chemical handled	Leak scenarios	Weather conditions	Pool fire radiation distances (m)		
			37.5 kW/m^2	12.5 kW/m^2	4.0 kW/m^2
LPG	Leak from Marine unloading arm	2-F	---	---	---
		5-D	---	---	---
	FBR of MLA	2-F	---	---	---
		5-D	---	---	---
	Leak from Pipeline	2-F	57	88	127
		5-D	---	35	36
	FBR of Pipeline	2-F	57	88	127
		5-D	35	39	42
Ammonia	Leak from Marine unloading arm	2-F	---	50	55
		5-D	---	47	53
	FBR of MLA	2-F	---	29	38
		5-D	---	30	39
	Leak from Pipeline	2-F	---	68	92
		5-D	---	70	89
	FBR of Pipeline	2-F	77	100	135
		5-D	79	103	132
Crude Oil	Leak from Marine unloading arm	2-F	---	43	70
		5-D	---	51	81
	FBR of MLA	2-F	---	55	92
		5-D	---	58	106
	Leak from Pipeline	2-F	---	31	56
		5-D	---	35	62
	FBR of Pipeline	2-F	---	75	156
		5-D	---	74	179
Naphtha	Leak from Marine unloading arm	2-F	32	43	57
		5-D	---	---	---
	FBR of MLA	2-F	---	49	87
		5-D	---	52	103
	Leak from Pipeline	2-F	32	43	57
		5-D	---	---	---

	FBR of Pipeline	2-F	---	34	84
		5-D	---	34	101
MS	Leak from Marine unloading arm	2-F	32	42	54
		5-D	---	---	---
	FBR of MLA	2-F	---	50	88
		5-D	---	53	104
	Leak from Pipeline	2-F	32	42	54
		5-D	---	---	---
	FBR of Pipeline	2-F	---	34	83
		5-D	---	34	100
Acetone	Leak from Marine unloading Hose	2-F	44	74	109
		5-D	50	80	107
	FBR of Hose	2-F	56	104	164
		5-D	66	117	171
	Leak from Pipeline	2-F	44	74	109
		5-D	50	80	107
	FBR of Pipeline	2-F	32	73	124
		5-D	39	85	130
Acrylonitrile	Leak from Marine unloading Hose	2-F	41	56	73
		5-D	46	61	76
	FBR of Hose	2-F	33	50	69
		5-D	36	53	71
	Leak from Pipeline	2-F	58	85	119
		5-D	65	88	118
	FBR of Pipeline	2-F	43	76	121
		5-D	51	80	122
Allyl Alcohol	Leak from Marine unloading Hose	2-F	34	49	64
		5-D	38	53	67
	FBR of Hose	2-F	29	44	60
		5-D	31	47	62
	Leak from Pipeline	2-F	53	81	115
		5-D	60	86	117
	FBR of Pipeline	2-F	42	75	117
		5-D	48	79	119

Benzene	Leak from Marine unloading Hose	2-F	29	36	60
		5-D	30	43	63
	FBR of Hose	2-F	---	32	55
		5-D	---	36	60
	Leak from Pipeline	2-F	---	37	64
		5-D	---	41	71
	FBR of Pipeline	2-F	---	20	52
		5-D	---	21	62
Cyclohexane	Leak from Marine unloading Hose	2-F	---	31	49
		5-D	---	34	56
	FBR of Hose	2-F	---	28	48
		5-D	---	29	56
	Leak from Pipeline	2-F	---	17	46
		5-D	---	18	56
	FBR of Pipeline	2-F	---	33	55
		5-D	---	36	62
Ethylene	Leak from Marine unloading Hose	2-F	---	---	---
		5-D	---	---	---
	FBR of Hose	2-F	---	---	---
		5-D	---	---	---
	Leak from Pipeline	2-F	---	---	---
		5-D	---	---	---
	FBR of Pipeline	2-F	---	---	---
		5-D	---	---	---
MTBE	Leak from Marine unloading Hose	2-F	35	47	60
		5-D	35	42	47
	FBR of Hose	2-F	36	53	72
		5-D	40	55	73
	Leak from Pipeline	2-F	45	64	87
		5-D	40	50	60
	FBR of Pipeline	2-F	45	77	122
		5-D	53	80	122
Propylene	Leak from Marine unloading Hose	2-F	---	---	---
		5-D	---	---	---

	FBR of Hose	2-F	---	---	---
		5-D	---	---	---
	Leak from Pipeline	2-F	---	---	---
		5-D	---	---	---
	FBR of Pipeline	2-F	---	---	---
		5-D	---	---	---
Toluene	Leak from Marine unloading Hose	2-F	---	38	59
		5-D	32	43	65
	FBR of Hose	2-F	---	33	55
		5-D	---	36	60
	Leak from Pipeline	2-F	---	38	66
		5-D	---	42	74
	FBR of Pipeline	2-F	---	20	53
		5-D	---	22	62
Vinyl Acetate	Leak from Marine unloading Hose	2-F	32	47	62
		5-D	34	51	65
	FBR of Hose	2-F	27	44	62
		5-D	28	48	65
	Leak from Pipeline	2-F	43	70	99
		5-D	46	73	99
	FBR of Pipeline	2-F	33	68	109
		5-D	37	74	111
Xylene	Leak from Marine unloading Hose	2-F	---	38	59
		5-D	---	43	65
	FBR of Hose	2-F	---	33	54
		5-D	---	36	59
	Leak from Pipeline	2-F	---	39	67
		5-D	---	42	76
	FBR of Pipeline	2-F	---	21	53
		5-D	---	22	62

Table 6.10: Consequence results for the Flash Fire

Chemical handled	Leak scenarios	Weather conditions	Flash Fire (m)
			LFL (ppm)
LPG	Leak from Marine unloading arm	2-F	114
		5-D	116
	FBR of MLA	2-F	294
		5-D	193
	Leak from Pipeline	2-F	321
		5-D	214
	FBR of Pipeline	2-F	317
		5-D	212
Ammonia	Leak from Marine unloading arm	2-F	44
		5-D	56
	FBR of MLA	2-F	30
		5-D	34
	Leak from Pipeline	2-F	39
		5-D	42
	FBR of Pipeline	2-F	50
		5-D	55
Crude Oil	Leak from Marine unloading arm	2-F	42
		5-D	77
	FBR of MLA	2-F	77
		5-D	81
	Leak from Pipeline	2-F	52
		5-D	22
	FBR of Pipeline	2-F	63
		5-D	104
Naphtha	Leak from Marine unloading arm	2-F	224
		5-D	155
	FBR of MLA	2-F	605
		5-D	378
	Leak from Pipeline	2-F	232
		5-D	155
	FBR of Pipeline	2-F	364

		5-D	172
MS	Leak from Marine unloading arm	2-F	228
		5-D	155
	FBR of MLA	2-F	663
		5-D	414
	Leak from Pipeline	2-F	232
		5-D	155
	FBR of Pipeline	2-F	391
		5-D	189
Acetone	Leak from Marine unloading Hose	2-F	74
		5-D	97
	FBR of Hose	2-F	141
		5-D	129
	Leak from Pipeline	2-F	96
		5-D	107
	FBR of Pipeline	2-F	58
		5-D	29
Acrylonitrile	Leak from Marine unloading Hose	2-F	57
		5-D	84
	FBR of Hose	2-F	84
		5-D	89
	Leak from Pipeline	2-F	70
		5-D	98
	FBR of Pipeline	2-F	39
		5-D	22
Allyl Alcohol	Leak from Marine unloading Hose	2-F	22
		5-D	25
	FBR of Hose	2-F	19
		5-D	20
	Leak from Pipeline	2-F	22
		5-D	28
	FBR of Pipeline	2-F	14
		5-D	10
Benzene	Leak from	2-F	81

	Marine unloading Hose	5-D	91
	FBR of Hose	2-F	157
		5-D	118
	Leak from Pipeline	2-F	122
		5-D	107
	FBR of Pipeline	2-F	53
		5-D	32
Cyclohexane	Leak from Marine unloading Hose	2-F	94
		5-D	102
	FBR of Hose	2-F	154
		5-D	129
	Leak from Pipeline	2-F	132
		5-D	113
	FBR of Pipeline	2-F	56
		5-D	30
Ethylene	Leak from Marine unloading Hose	2-F	19
		5-D	17
	FBR of Hose	2-F	115
		5-D	116
	Leak from Pipeline	2-F	19
		5-D	17
	FBR of Pipeline	2-F	68
		5-D	65
MTBE	Leak from Marine unloading Hose	2-F	118
		5-D	113
	FBR of Hose	2-F	203
		5-D	163
	Leak from Pipeline	2-F	140
		5-D	115
	FBR of Pipeline	2-F	78
		5-D	36
Propylene	Leak from Marine unloading Hose	2-F	18
		5-D	16
	FBR of Hose	2-F	109

		5-D	110
	Leak from Pipeline	2-F	18
		5-D	16
	FBR of Pipeline	2-F	65
		5-D	58
Toluene	Leak from Marine unloading Hose	2-F	33
		5-D	46
	FBR of Hose	2-F	45
		5-D	49
	Leak from Pipeline	2-F	43
		5-D	66
	FBR of Pipeline	2-F	25
		5-D	16
Vinyl Acetate	Leak from Marine unloading Hose	2-F	40
		5-D	53
	FBR of Hose	2-F	69
		5-D	75
	Leak from Pipeline	2-F	50
		5-D	69
	FBR of Pipeline	2-F	41
		5-D	17
Xylene	Leak from Marine unloading Hose	2-F	21
		5-D	23
	FBR of Hose	2-F	16
		5-D	16
	Leak from Pipeline	2-F	21
		5-D	25
	FBR of Pipeline	2-F	11
		5-D	10

Table 6.11: Consequence results for the Toxic impact

Chemical handled	**Leak scenarios**	**Weather conditions**	**Toxic impact distance (m)**
			IDLH (ppm)
LPG	Leak from	2-F	---

	Marine unloading arm	5-D	---
	FBR of MLA	2-F	---
		5-D	---
	Leak from Pipeline	2-F	---
		5-D	---
	FBR of Pipeline	2-F	---
		5-D	---
Ammonia	Leak from Marine unloading arm	2-F	3841
		5-D	812
	FBR of MLA	2-F	4574
		5-D	1472
	Leak from Pipeline	2-F	5489
		5-D	1877
	FBR of Pipeline	2-F	9005
		5-D	2965
Crude Oil	Leak from Marine unloading arm	2-F	---
		5-D	---
	FBR of MLA	2-F	---
		5-D	---
	Leak from Pipeline	2-F	---
		5-D	---
	FBR of Pipeline	2-F	---
		5-D	---
Naphtha	Leak from Marine unloading arm	2-F	---
		5-D	---
	FBR of MLA	2-F	---
		5-D	---
	Leak from Pipeline	2-F	---
		5-D	---
	FBR of Pipeline	2-F	---
		5-D	---
MS	Leak from Marine unloading arm	2-F	---
		5-D	---
	FBR of MLA	2-F	---

		5-D	---
	Leak from Pipeline	2-F	---
		5-D	---
	FBR of Pipeline	2-F	---
		5-D	---
Acetone	Leak from Marine unloading Hose	2-F	---
		5-D	---
	FBR of Hose	2-F	---
		5-D	---
	Leak from Pipeline	2-F	---
		5-D	---
	FBR of Pipeline	2-F	---
		5-D	---
Acrylonitrile	Leak from Marine unloading hose	2-F	2857
		5-D	1195
	FBR of Hose	2-F	5169
		5-D	1326
	Leak from Pipeline	2-F	3300
		5-D	1333
	FBR of Pipeline	2-F	2376
		5-D	761
Allyl Alcohol	Leak from Marine unloading hose	2-F	---
		5-D	---
	FBR of Hose	2-F	---
		5-D	---
	Leak from Pipeline	2-F	---
		5-D	---
	FBR of Pipeline	2-F	---
		5-D	---
Benzene	Leak from Marine unloading hose	2-F	420
		5-D	313
	FBR of Hose	2-F	698
		5-D	388
	Leak from	2-F	483

	Pipeline	5-D	354
	FBR of Pipeline	2-F	367
		5-D	179
Ethylene	Leak from Marine unloading Hose	2-F	---
		5-D	---
	FBR of Hose	2-F	---
		5-D	---
	Leak from Pipeline	2-F	---
		5-D	---
	FBR of Pipeline	2-F	---
		5-D	---
MTBE	Leak from Marine unloading Hose	2-F	---
		5-D	---
	FBR of Hose	2-F	---
		5-D	---
	Leak from Pipeline	2-F	---
		5-D	---
	FBR of Pipeline	2-F	---
		5-D	---
Propylene	Leak from Marine unloading Hose	2-F	---
		5-D	---
	FBR of Hose	2-F	---
		5-D	---
	Leak from Pipeline	2-F	---
		5-D	---
	FBR of Pipeline	2-F	---
		5-D	---
Toluene	Leak from Marine unloading Hose	2-F	318
		5-D	253
	FBR of Hose	2-F	407
		5-D	257
	Leak from Pipeline	2-F	350
		5-D	275
	FBR of Pipeline	2-F	164

		5-D	99
Xylene	Leak from Marine unloading Hose	2-F	---
		5-D	---
	FBR of Hose	2-F	---
		5-D	---
	Leak from Pipeline	2-F	---
		5-D	---
	FBR of Pipeline	2-F	---
		5-D	---

Table 6.12: Consequence results for the Explosion

Chemical handled	Leak scenarios	Weather conditions	Explosion distances (m)		
			0.3 bar	0.1 bar	0.03 bar
LPG	Leak from Marine unloading arm	2-F	265	275	405
		5-D	29	302	420
	FBR of MLA	2-F	487	521	955
		5-D	322	340	570
	Leak from Pipeline	2-F	554	584	967
		5-D	365	384	622
	FBR of Pipeline	2-F	542	572	948
		5-D	354	372	608
Ammonia	Leak from Marine unloading arm	2-F	106	112	202
		5-D	137	143	236
	FBR of MLA	2-F	80	83	135
		5-D	90	93	146
	Leak from Pipeline	2-F	102	106	175
		5-D	123	127	198
	FBR of Pipeline	2-F	136	141	230
		5-D	167	173	268
Crude Oil	Leak from Marine unloading arm	2-F	---	---	---
		5-D	---	---	---
	FBR of MLA	2-F	---	---	---
		5-D	---	---	---
	Leak from Pipeline	2-F	---	---	---
		5-D	---	---	---

	FBR of Pipeline	2-F	---	---	---
		5-D	---	---	---
Naphtha	Leak from Marine unloading arm	2-F	330	344	616
		5-D	253	269	465
	FBR of MLA	2-F	845	849	904
		5-D	458	461	544
	Leak from Pipeline	2-F	393	423	804
		5-D	253	269	465
	FBR of Pipeline	2-F	582	618	1289
		5-D	349	378	743
MS	Leak from Marine unloading arm	2-F	333	349	629
		5-D	259	268	463
	FBR of MLA	2-F	915	920	976
		5-D	474	480	585
	Leak from Pipeline	2-F	392	421	796
		5-D	253	268	463
	FBR of Pipeline	2-F	608	643	1342
		5-D	399	430	832
Acetone	Leak from Marine unloading Hose	2-F	109	114	203
		5-D	166	173	268
	FBR of Hose	2-F	148	150	179
		5-D	147	148	181
	Leak from Pipeline	2-F	216	223	321
		5-D	180	189	299
	FBR of Pipeline	2-F	96	107	240
		5-D	71	77	153
Acrylonitrile	Leak from Marine unloading Hose	2-F	103	106	174
		5-D	154	161	250
	FBR of Hose	2-F	86	88	119
		5-D	104	105	125
	Leak from Pipeline	2-F	182	188	270
		5-D	166	173	269
	FBR of Pipeline	2-F	74	81	170
		5-D	41	44	84

Allyl Alcohol	Leak from Marine unloading Hose	2-F	38	40	68
		5-D	51	54	93
	FBR of Hose	2-F	33	34	47
		5-D	34	35	50
	Leak from Pipeline	2-F	48	50	78
		5-D	71	74	113
	FBR of Pipeline	2-F	31	35	76
		5-D	15	16	35
Benzene	Leak from Marine unloading Hose	2-F	114	116	200
		5-D	154	161	249
	FBR of Hose	2-F	167	169	196
		5-D	128	131	162
	Leak from Pipeline	2-F	199	207	314
		5-D	167	175	277
	FBR of Pipeline	2-F	92	101	219
		5-D	69	74	143
Cyclohexane	Leak from Marine unloading Hose	2-F	126	128	231
		5-D	171	180	294
	FBR of Hose	2-F	167	168	193
		5-D	147	149	185
	Leak from Pipeline	2-F	230	241	389
		5-D	184	193	318
	FBR of Pipeline	2-F	92	101	218
		5-D	72	78	160
Ethylene	Leak from Marine unloading Hose	2-F	47	49	74
		5-D	46	48	70
	FBR of Hose	2-F	248	251	367
		5-D	300	302	402
	Leak from Pipeline	2-F	47	49	74
		5-D	46	48	70
	FBR of Pipeline	2-F	190	195	268
		5-D	146	151	212
MTBE	Leak from Marine unloading Hose	2-F	147	150	279
		5-D	186	197	339

	FBR of Hose	2-F	228	230	257
		5-D	181	185	233
	Leak from Pipeline	2-F	249	264	447
		5-D	201	212	363
	FBR of Pipeline	2-F	135	151	354
		5-D	77	85	183
Propylene	Leak from Marine unloading Hose	2-F	47	49	75
		5-D	46	48	70
	FBR of Hose	2-F	221	224	341
		5-D	267	269	367
	Leak from Pipeline	2-F	47	49	75
		5-D	46	48	70
	FBR of Pipeline	2-F	161	167	243
		5-D	117	122	184
Toluene	Leak from Marine unloading Hose	2-F	79	82	117
		5-D	102	106	151
	FBR of Hose	2-F	53	54	83
		5-D	56	58	89
	Leak from Pipeline	2-F	108	111	148
		5-D	115	119	172
	FBR of Pipeline	2-F	49	54	123
		5-D	28	30	60
Vinyl Acetate	Leak from Marine unloading Hose	2-F	92	96	142
		5-D	117	122	187
	FBR of Hose	2-F	74	75	106
		5-D	84	85	112
	Leak from Pipeline	2-F	126	131	190
		5-D	130	135	206
	FBR of Pipeline	2-F	70	76	165
		5-D	45	49	103
Xylene	Leak from Marine unloading Hose	2-F	25	27	47
		5-D	37	39	64
	FBR of Hose	2-F	22	22	29
		5-D	32	33	40

	Leak from Pipeline	2-F	36	37	59
		5-D	57	59	84
	FBR of Pipeline	2-F	20	23	59
		5-D	15	17	36

6.4.6 Risk Estimation

6.4.6.1 Individual Risk results of the simultaneous handling of LPG & Ammonia at BPCL jetty

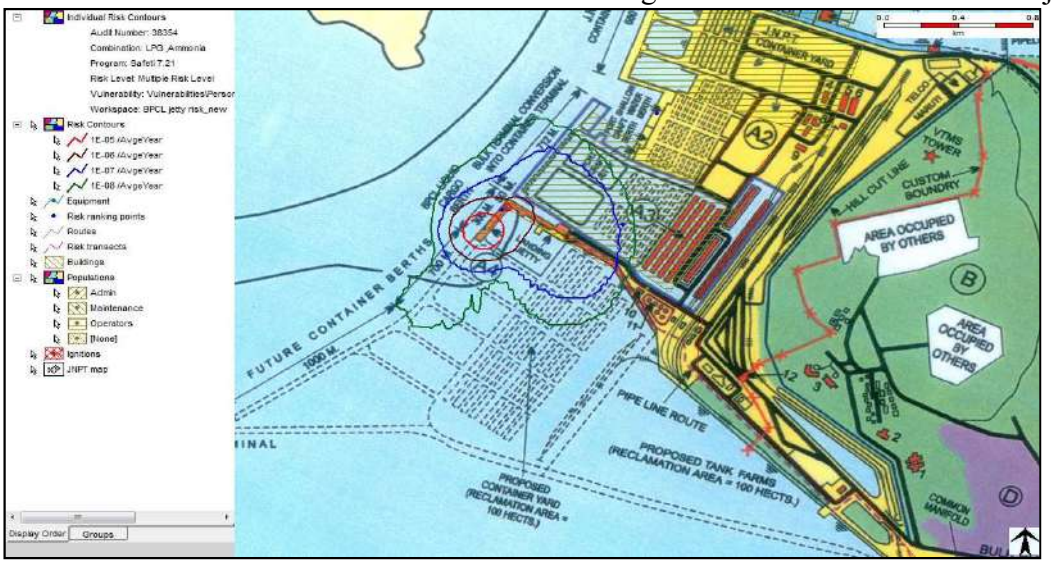


Fig 6.2 Individual Risk of simultaneous handling of LPG & Ammonia

6.4.6.2 Individual Risk results of the simultaneous handling of LPG & Crude oil at BPCL jetty

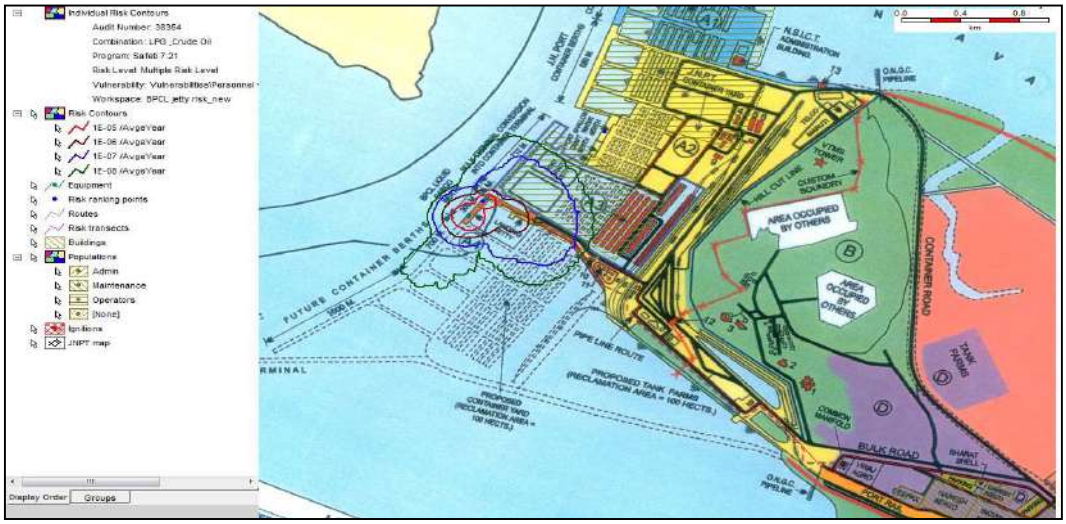


Fig 6.3 Individual Risk of simultaneous handling of LPG & Crude Oil

6.4.6.3 Individual Risk results of the simultaneous handling of Ammonia & Crude oil at BPCL jetty

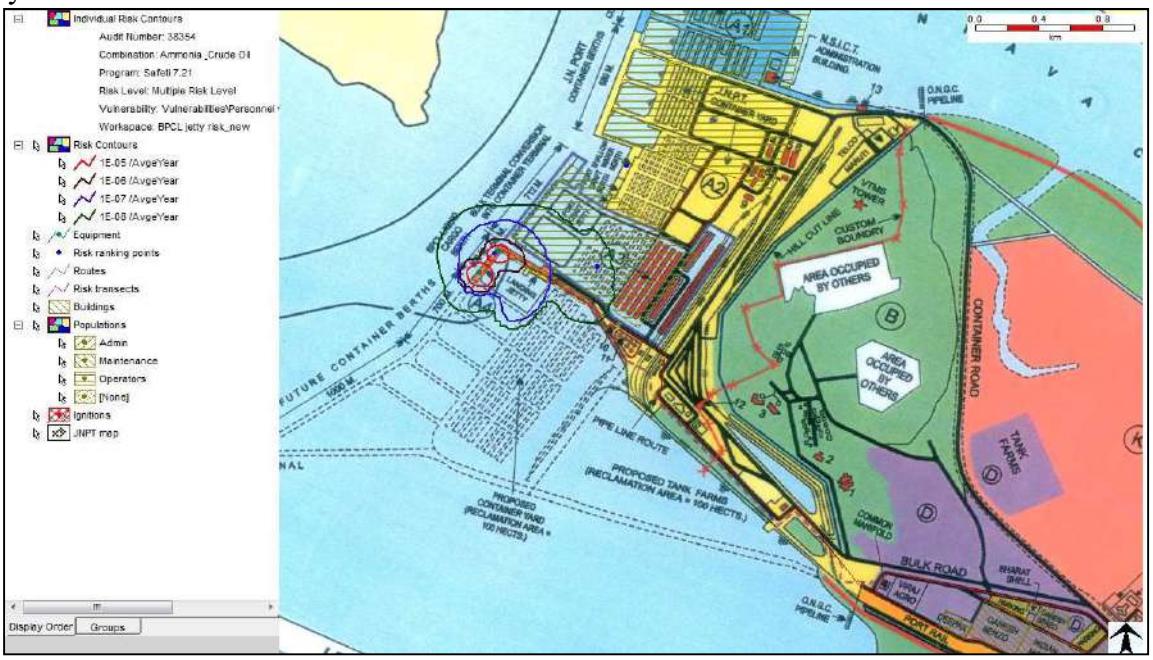


Fig 6.4 Individual Risk of simultaneous handling of Ammonia & Crude Oil

6.4.6.4 Individual Risk results of the simultaneous handling of Ammonia & MS at BPCL jetty

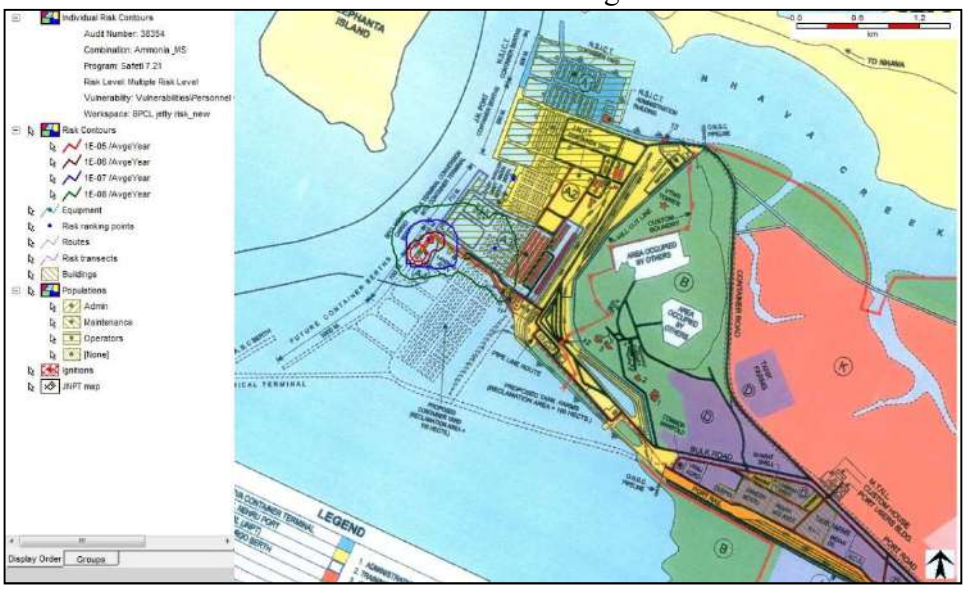


Fig 6.5 Individual Risk of simultaneous handling of Ammonia & MS

6.4.6.5 Individual Risk results of the simultaneous handling of Ammonia & Naphtha at BPCL jetty

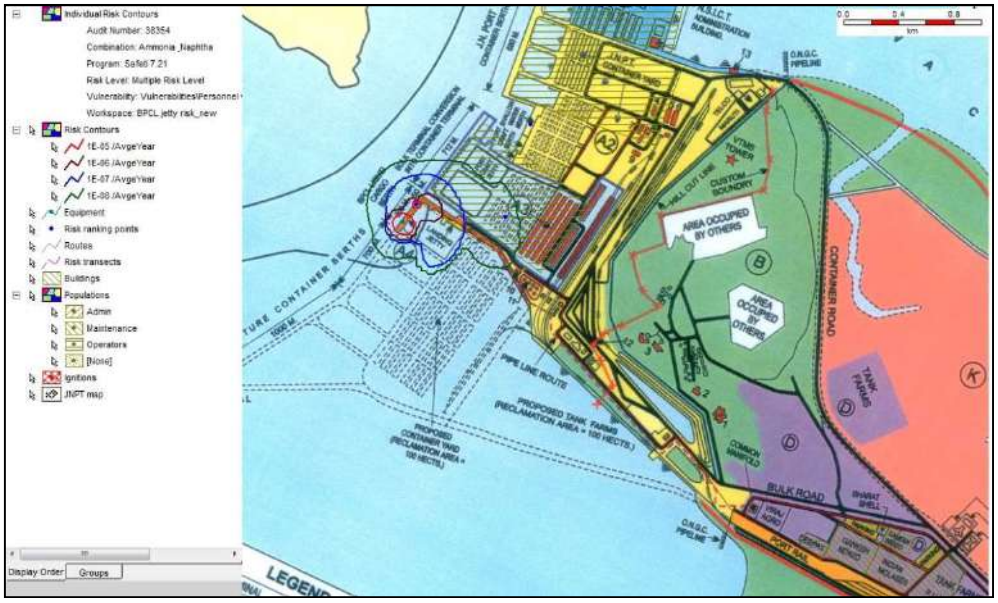


Fig 6.6 Individual Risk of simultaneous handling of Ammonia & Naphtha

6.4.6.6 Individual Risk results of the simultaneous handling of MS & Naphtha at BPCL jetty

Fig 6.7 Individual Risk of simultaneous handling of MS & Naphtha

6.4.6.7 Societal Risk results of the Simultaneous operation at BPCL jetty

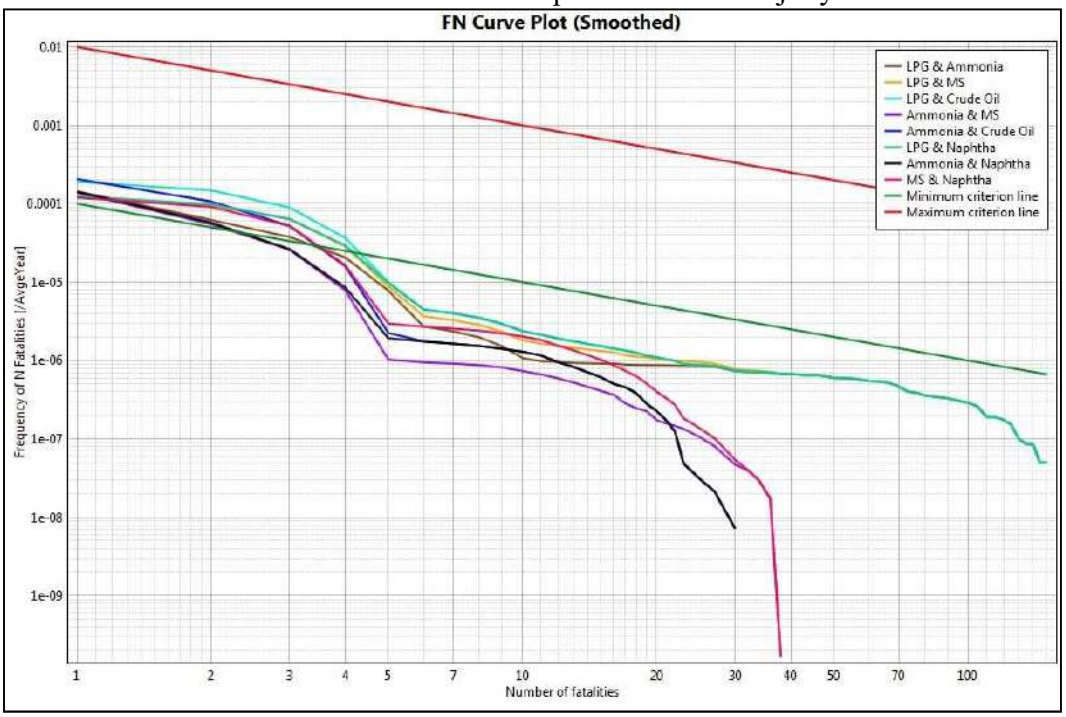


Fig 6.8 Societal Risk

6.5 Recommendations

1. Before any transfer operation is commenced, it is imperative that the intended procedures are thoroughly discussed and a meeting held between the responsible personnel from the tanker and the terminal (berth operator). The purpose of the meeting is primarily to make both sides fully conversant with the characteristics of the tanker and shore handling systems, the envisaged operational and safety procedures and requirements and the parameters to be adhered to during the transfer.

2. Communications: To ensure that effective communication is established between ship and terminal personnel all through the cargo handling operations.

3. Loading arms/flexible hose: The master of a ship and the berth operator, within their respective areas of responsibility, should ensure that:
   a) Adequate procedures and means are available for the operation, supervision, disconnection of loading arms in the event of an emergency, to protect the environment, personnel safety and equipment;
   b) Loading arm/flexible hose is not used for substances other than those for which it is suitable, having regard to the temperature and compatibility of such substances and the working pressure or flow rate for which it is suitable;
   c) Adequate means for draining the inner and outer arms before disconnection;
   d) The operating envelope of the loading arm is suitable for the ship – to be checked before each transfer operation;
   e) The manifold spacing is satisfactory when more than one loading arm is connected simultaneously;
   f) Each loading arm has been periodically maintained and has a valid certificate for its fitness for use; and
   g) There are adequate electrical insulation flanges.

4. Maintenance:
   a) All fire-fighting and safety equipment are to be maintained in ready to fully operational at all times and be checked and tested on a routine basis. The prescribed pressure in the fixed fire line should be maintained and monitored at all time both at port and respective terminals. The fire detection and warning systems should be checked and tested regularly.
   b) The Gas detectors should be periodically calibrated as per the set value.
   c) Pipelines should be periodically inspected and maintained.

5. Training:
   a) All relevant personnel are trained to use the required fire-fighting systems for carrying out fire-fighting operation effectively;
   b) Both ship and shore personnel should be aware of each other's fire-fighting equipment and capabilities;

6. Refrigerated Liquefied Gas (LPG and Ammonia): The master of a ship, the port authority and respective berth operator, within their respective areas of responsibility, should ensure

that the unloading of liquefied gas at low temperatures is only carried out strictly following the SOP and also the following aspects are duly taken care of:

a) All automatic controls, gas detectors and other associated instruments are in working order; and
b) Suitable PPE is available and used as appropriate.

7. Adequate number of firefighting personnel should be available.

8. Ensure good housekeeping around the jetty.

9. BPCL LCJ should make sure that the illumination is adequate during night-time operations.

10. General:
    a) JNPT should conduct drill and exercises jointly with BPCL LCJ.
    b) All the incidents (minor and major) within the BPCL LCJ should be collated and recorded.

7.0 RISK ASSESSMENT OF HANDLING OF HAZARDOUS CHEMICALS AT SWB

7.1 Facility description of SWB

Shallow Draught Berth Commissioned 1st September 2002 of Total Length 445 meters. Vessels up to 183 meters LOA and up to 10 meters draught are being handled. Container Vessels, Cement, General Cargo and Liquid Cargo Vessels are being handled with a Capacity of about 0.15 Million TEUs Container & 0.9 Million Tons Other Cargo. Total 2.77 Million Tons.

Table 7.1 SWB details

Terminal	Shallow Drought Terminal
Quay Length (m)	445
Maximum draft (m)	10-Max (Tidal)
Design capacity (Million TEUs Year) (Million Tonnes/Year)	 0.15 2.77
Max. Permissible LOA of The Vessel	183 Mtrs
RMQCs (Nos.)	3

7.2 Fire-fighting arrangements

The ring main fire hydrant system is available at SWB. In addition to this, a foam tender kept standby at SWB during the entire operation.

7.3 QRA study methodology

7.3.1 The study consists of the following steps:

- Hazard identification
- Failure frequency estimation
- Consequence estimation
- Risk assessment
- Recommendations

7.3.2 Collection of data/documents

The data/documents collected for the study as follows:

- Risk Analysis and HAZOP report
- JNPT Emergency action plan
- Standard operating and maintenance procedure
- Fire fighting system/arrangement with details
- MSDS for Chemicals handled at SWB

The generic failure rate data are taken from the available published literature.

7.3.3 Hazardous Chemicals Handled at SWB

A number of hazardous chemicals are handled at SWB as shown in below table.

Table7.2: List of hazardous chemicals handled at SWB

No.	Chemicals	Class	Flash Point (^oC)	NFPA rating		
				N_F	N_H	N_R
1	Acrylonitrile	A	-1	3	4	2
2	Acetic Acid	B	43	2	3	0
3	Acetonitrile	A	2	3	2	0
4	Acetone	A	-20	3	1	0
5	Aniline Oil	C	70	2	3	0
6	1-Butanol	B	26	3	1	0
7	Butyl Acrylate	B	40	3	2	0
8	Butyl Acetate	B	24	3	2	0
9	Cumene	B	36	3	2	1
10	Chloroform	C	--	0	2	0
11	Di Vinyl Benzene	B	76	2	2	0
12	Ethylene Dichloride	A	13	3	3	0
13	Isopropyl alcohol	A	12	3	1	0
14	Linear Alkyl Benzene (LAB)	NPP	130	1	1	0
15	Methyl Iso Butyl Ketone	A	23	3	2	0
16	Methanol	A	12	3	1	0
17	Methylene Chloride	NPP	NA	1	2	0
18	Mono Ethylene Glycol (MEG)	C	116	3	2	0
19	O-Xylene	B	30	3	2	0
20	Phosphoric Acid	NPP	--	0	3	0
21	Phenol	C	79	2	3	0
22	Para Xylene/mixed Xylene	B	25	3	2	0
23	Sulphuric Acid	NPP	--	0	3	2
24	Styrene Monomer	B	31	3	2	2
25	Toluene	A	4	3	2	0
26	Vinyl Acetate Monomer	A	-8	3	2	2

7.3.4 Failure Leak scenarios:

7.3.4.1 Release sizes for unloading hoses and jetty pipeline:

Failure cases for jetty pipelines, unloading arm and hoses will include two leak sizes, one is a small leak and the other is a large or a full-bore release. The same is tabulated below:

Table7.3: failure leak scenarios

Leak category	Representative hole size
Small leak	20% of nominal diameter
Rupture	Nominal diameter (FBR)

Failure frequencies for loading/unloading and transfer activities:
Typical failure frequency data are given in table below (HSE-UK):

Above ground pipeline failure frequency:

- Rupture (> 110 mm dia.) : 6.5×10^{-9}/(m.yr)
- Large hole (>75 - < 110mm) : 3.3×10^{-8}/(m.yr)
- Small hole (>25 - < 75mm) : 6.7×10^{-8}/(m.yr)
- Pin hole (<25 mm) : 1.6×10^{-7}/(m.yr)

Flexible hose failure frequency:

- Full Bore Rupture : 4.0×10^{-6}/(hr)
- Hose leak : 4.0×10^{-5}/(hr)

7.3.5 Consequence estimation

Based on a review of the plant details, the above leak scenarios have been considered for consequence analysis to assess the impact of fire, vapour cloud explosion and toxic dispersion. Consequence analysis results for the chemicals handled at SWB.

Jet fire results for various scenarios are shown below

Table7.4: Consequence results for the Jet fire

Chemical handled	Leak scenarios	Weather conditions	Jet fire radiation distances (m)		
			37.5 kW/m^2	12.5 kW/m^2	4.0 kW/m^2
Acetone	Leak from Marine unloading Hose	2-F	105	126	158
		5-D	88	108	139
	FBR of Hose	2-F	161	194	244
		5-D	141	172	222
	Leak from Pipeline	2-F	105	126	158
		5-D	88	108	139
	FBR of Pipeline	2-F	32	38	46

		5-D	34	39	48
Acrylonitrile	Leak from Marine unloading Hose	2-F	102	121	151
		5-D	97	118	152
	FBR of Hose	2-F	120	144	181
		5-D	105	127	164
	Leak from Pipeline	2-F	102	121	151
		5-D	97	118	152
	FBR of Pipeline	2-F	22	26	31
		5-D	24	28	35
Allyl Alcohol	Leak from Marine unloading Hose	2-F	57	68	84
		5-D	57	69	89
	FBR of Hose	2-F	65	79	98
		5-D	58	70	89
	Leak from Pipeline	2-F	57	68	84
		5-D	57	69	89
	FBR of Pipeline	2-F	---	13	15
		5-D	13	15	18
Benzene	Leak from Marine unloading Hose	2-F	85	103	133
		5-D	82	102	136
	FBR of Hose	2-F	116	142	184
		5-D	103	128	169
	Leak from Pipeline	2-F	85	103	133
		5-D	82	102	136
	FBR of Pipeline	2-F	22	26	32
		5-D	25	29	36
Cyclohexane	Leak from Marine unloading Hose	2-F	97	118	153
		5-D	84	106	143
	FBR of Hose	2-F	133	163	213
		5-D	118	148	198
	Leak from Pipeline	2-F	97	118	153
		5-D	84	106	143
	FBR of Pipeline	2-F	23	27	34
		5-D	25	30	38
Ethylene	Leak from	2-F	19	24	30

	Marine unloading Hose	5-D	20	25	30
	FBR of Hose	2-F	66	87	116
		5-D	71	90	115
	Leak from Pipeline	2-F	19	24	30
		5-D	20	25	30
	FBR of Pipeline	2-F	25	33	44
		5-D	34	36	39
MTBE	Leak from Marine unloading Hose	2-F	92	112	144
		5-D	78	97	130
	FBR of Hose	2-F	191	234	305
		5-D	169	212	283
	Leak from Pipeline	2-F	92	112	144
		5-D	78	97	130
	FBR of Pipeline	2-F	37	44	55
		5-D	37	44	56
Propylene	Leak from Marine unloading Hose	2-F	21	27	34
		5-D	24	29	35
	FBR of Hose	2-F	70	93	128
		5-D	75	97	126
	Leak from Pipeline	2-F	21	27	34
		5-D	24	29	35
	FBR of Pipeline	2-F	27	35	46
		5-D	40	42	46
Toluene	Leak from Marine unloading Hose	2-F	65	79	102
		5-D	65	81	108
	FBR of Hose	2-F	76	93	120
		5-D	67	83	111
	Leak from Pipeline	2-F	65	79	102
		5-D	65	81	108
	FBR of Pipeline	2-F	13	15	19
		5-D	15	18	22
Vinyl Acetate	Leak from Marine unloading Hose	2-F	88	106	133
		5-D	80	98	127
	FBR of Hose	2-F	114	138	174

		5-D	100	122	159
	Leak from Pipeline	2-F	88	106	133
		5-D	80	98	127
	FBR of Pipeline	2-F	22	26	31
		5-D	25	29	36
Xylene	Leak from Marine unloading Hose	2-F	44	54	70
		5-D	45	56	74
	FBR of Hose	2-F	47	58	75
		5-D	42	52	69
	Leak from Pipeline	2-F	45	54	70
		5-D	45	56	75
	FBR of Pipeline	2-F	8	9	11
		5-D	9	11	13

Table7.5: Consequence results for the Pool fire

Chemical handled	**Leak scenarios**	**Weather conditions**	**Pool fire radiation distances (m)**		
			37.5 kW/m^2	**12.5 kW/m^2**	**4.0 kW/m^2**
Acetone	Leak from Marine unloading Hose	2-F	44	74	109
		5-D	50	80	107
	FBR of Hose	2-F	56	104	164
		5-D	66	117	171
	Leak from Pipeline	2-F	44	74	109
		5-D	50	80	107
	FBR of Pipeline	2-F	32	73	124
		5-D	39	85	130
Acrylonitrile	Leak from Marine unloading Hose	2-F	41	56	73
		5-D	46	61	76
	FBR of Hose	2-F	33	50	69
		5-D	36	53	71
	Leak from Pipeline	2-F	58	85	119
		5-D	65	88	118
	FBR of Pipeline	2-F	43	76	121
		5-D	51	80	122
Allyl Alcohol	Leak from	2-F	34	49	64

	Marine unloading Hose	5-D	38	53	67
	FBR of Hose	2-F	29	44	60
		5-D	31	47	62
	Leak from Pipeline	2-F	53	81	115
		5-D	60	86	117
	FBR of Pipeline	2-F	42	75	117
		5-D	48	79	119
Benzene	Leak from Marine unloading Hose	2-F	29	36	60
		5-D	30	43	63
	FBR of Hose	2-F	---	32	55
		5-D	---	36	60
	Leak from Pipeline	2-F	---	37	64
		5-D	---	41	71
	FBR of Pipeline	2-F	---	20	52
		5-D	---	21	62
Cyclohexane	Leak from Marine unloading Hose	2-F	---	31	49
		5-D	---	34	56
	FBR of Hose	2-F	---	28	48
		5-D	---	29	56
	Leak from Pipeline	2-F	---	17	46
		5-D	---	18	56
	FBR of Pipeline	2-F	---	33	55
		5-D	---	36	62
Ethylene	Leak from Marine unloading Hose	2-F	---	---	---
		5-D	---	---	---
	FBR of Hose	2-F	---	---	---
		5-D	---	---	---
	Leak from Pipeline	2-F	---	---	---
		5-D	---	---	---
	FBR of Pipeline	2-F	---	---	---
		5-D	---	---	---
MTBE	Leak from Marine unloading Hose	2-F	35	47	60
		5-D	35	42	47
	FBR of Hose	2-F	36	53	72

		5-D	40	55	73
	Leak from Pipeline	2-F	45	64	87
		5-D	40	50	60
	FBR of Pipeline	2-F	45	77	122
		5-D	53	80	122
Propylene	Leak from Marine unloading Hose	2-F	---	---	---
		5-D	---	---	---
	FBR of Hose	2-F	---	---	---
		5-D	---	---	---
	Leak from Pipeline	2-F	---	---	---
		5-D	---	---	---
	FBR of Pipeline	2-F	---	---	---
		5-D	---	---	---
Toluene	Leak from Marine unloading Hose	2-F	---	38	59
		5-D	32	43	65
	FBR of Hose	2-F	---	33	55
		5-D	---	36	60
	Leak from Pipeline	2-F	---	38	66
		5-D	---	42	74
	FBR of Pipeline	2-F	---	20	53
		5-D	---	22	62
Vinyl Acetate	Leak from Marine unloading Hose	2-F	31	47	62
		5-D	34	51	65
	FBR of Hose	2-F	27	44	62
		5-D	28	48	65
	Leak from Pipeline	2-F	43	70	99
		5-D	46	73	99
	FBR of Pipeline	2-F	33	68	109
		5-D	37	74	111
Xylene	Leak from Marine unloading Hose	2-F	---	38	59
		5-D	---	43	65
	FBR of Hose	2-F	---	33	54
		5-D	---	36	59
	Leak from	2-F	---	39	67

	Pipeline	5-D	---	42	76
	FBR of Pipeline	2-F	---	21	53
		5-D	---	22	62

Table7.6: Consequence results for the Flash Fire

Chemical handled	**Leak scenarios**	**Weather conditions**	**Flash Fire (m)**
			LFL (ppm)
Acetone	Leak from Marine unloading Hose	2-F	74
		5-D	97
	FBR of Hose	2-F	141
		5-D	129
	Leak from Pipeline	2-F	96
		5-D	107
	FBR of Pipeline	2-F	58
		5-D	29
Acrylonitrile	Leak from Marine unloading Hose	2-F	57
		5-D	84
	FBR of Hose	2-F	84
		5-D	88
	Leak from Pipeline	2-F	70
		5-D	98
	FBR of Pipeline	2-F	39
		5-D	22
Allyl Alcohol	Leak from Marine unloading Hose	2-F	22
		5-D	25
	FBR of Hose	2-F	19
		5-D	20
	Leak from Pipeline	2-F	22
		5-D	28
	FBR of Pipeline	2-F	14
		5-D	10
Benzene	Leak from Marine unloading Hose	2-F	81
		5-D	91
	FBR of Hose	2-F	157

		5-D	118
	Leak from Pipeline	2-F	122
		5-D	107
	FBR of Pipeline	2-F	53
		5-D	32
Cyclohexane	Leak from Marine unloading Hose	2-F	94
		5-D	102
	FBR of Hose	2-F	154
		5-D	129
	Leak from Pipeline	2-F	132
		5-D	113
	FBR of Pipeline	2-F	56
		5-D	30
Ethylene	Leak from Marine unloading Hose	2-F	19
		5-D	17
	FBR of Hose	2-F	115
		5-D	116
	Leak from Pipeline	2-F	19
		5-D	17
	FBR of Pipeline	2-F	68
		5-D	65
MTBE	Leak from Marine unloading Hose	2-F	118
		5-D	113
	FBR of Hose	2-F	203
		5-D	163
	Leak from Pipeline	2-F	140
		5-D	115
	FBR of Pipeline	2-F	78
		5-D	36
Propylene	Leak from Marine unloading Hose	2-F	18
		5-D	16
	FBR of Hose	2-F	109
		5-D	110
	Leak from	2-F	18

	Pipeline	5-D	16
	FBR of Pipeline	2-F	65
		5-D	58
Toluene	Leak from Marine unloading Hose	2-F	33
		5-D	46
	FBR of Hose	2-F	45
		5-D	49
	Leak from Pipeline	2-F	43
		5-D	66
	FBR of Pipeline	2-F	25
		5-D	16
Vinyl Acetate	Leak from Marine unloading Hose	2-F	40
		5-D	53
	FBR of Hose	2-F	69
		5-D	75
	Leak from Pipeline	2-F	50
		5-D	69
	FBR of Pipeline	2-F	41
		5-D	17
Xylene	Leak from Marine unloading Hose	2-F	21
		5-D	23
	FBR of Hose	2-F	16
		5-D	16
	Leak from Pipeline	2-F	21
		5-D	25
	FBR of Pipeline	2-F	11
		5-D	10

Table7.7: Consequence results for the Toxic impact

Chemical handled	**Leak scenarios**	**Weather conditions**	**Toxic impact distance (m)**
			IDLH (ppm)
Acetone	Leak from Marine unloading Hose	2-F	---
		5-D	---

	FBR of Hose	2-F	---
		5-D	---
	Leak from Pipeline	2-F	---
		5-D	---
	FBR of Pipeline	2-F	---
		5-D	---
Acrylonitrile	Leak from Marine unloading hose	2-F	2857
		5-D	1195
	FBR of Hose	2-F	5169
		5-D	1326
	Leak from Pipeline	2-F	3300
		5-D	1333
	FBR of Pipeline	2-F	2376
		5-D	761
Allyl Alcohol	Leak from Marine unloading hose	2-F	---
		5-D	---
	FBR of Hose	2-F	---
		5-D	---
	Leak from Pipeline	2-F	---
		5-D	---
	FBR of Pipeline	2-F	---
		5-D	---
Benzene	Leak from Marine unloading hose	2-F	420
		5-D	313
	FBR of Hose	2-F	698
		5-D	388
	Leak from Pipeline	2-F	483
		5-D	354
	FBR of Pipeline	2-F	367
		5-D	179
Ethylene	Leak from Marine unloading	2-F	---
		5-D	---

	Hose		
	FBR of Hose	2-F	---
		5-D	---
	Leak from Pipeline	2-F	---
		5-D	---
	FBR of Pipeline	2-F	---
		5-D	---
MTBE	Leak from Marine unloading Hose	2-F	---
		5-D	---
	FBR of Hose	2-F	---
		5-D	---
	Leak from Pipeline	2-F	---
		5-D	---
	FBR of Pipeline	2-F	---
		5-D	---
Propylene	Leak from Marine unloading Hose	2-F	---
		5-D	---
	FBR of Hose	2-F	---
		5-D	---
	Leak from Pipeline	2-F	---
		5-D	---
	FBR of Pipeline	2-F	---
		5-D	---
Toluene	Leak from Marine unloading Hose	2-F	318
		5-D	253
	FBR of Hose	2-F	407
		5-D	257
	Leak from Pipeline	2-F	350
		5-D	275
	FBR of Pipeline	2-F	164
		5-D	99
Xylene	Leak from Marine	2-F	---
		5-D	---

	unloading Hose		
	FBR of Hose	2-F	---
		5-D	---
	Leak from Pipeline	2-F	---
		5-D	---
	FBR of Pipeline	2-F	---
		5-D	---

Table7.8: Consequence results for the Explosion

Chemical handled	Leak scenarios	Weather conditions	Explosion distances (m)		
			0.3 bar	0.1 bar	0.03 bar
Acetone	Leak from Marine unloading Hose	2-F	109	114	203
		5-D	166	173	268
	FBR of Hose	2-F	148	150	180
		5-D	147	148	181
	Leak from Pipeline	2-F	216	223	321
		5-D	180	189	299
	FBR of Pipeline	2-F	96	107	240
		5-D	71	77	153
Acrylonitrile	Leak from Marine unloading Hose	2-F	103	106	174
		5-D	154	161	250
	FBR of Hose	2-F	86	88	119
		5-D	104	105	125
	Leak from Pipeline	2-F	182	188	270
		5-D	166	174	269
	FBR of Pipeline	2-F	74	81	170
		5-D	41	44	84
Allyl Alcohol	Leak from Marine unloading Hose	2-F	38	40	68
		5-D	51	54	93
	FBR of Hose	2-F	33	34	47
		5-D	34	35	50
	Leak from Pipeline	2-F	48	50	78
		5-D	71	74	113
	FBR of Pipeline	2-F	31	35	76

		5-D	15	16	35
Benzene	Leak from Marine unloading Hose	2-F	114	116	200
		5-D	154	161	250
	FBR of Hose	2-F	167	169	196
		5-D	128	131	162
	Leak from Pipeline	2-F	199	207	314
		5-D	167	175	277
	FBR of Pipeline	2-F	92	101	219
		5-D	69	74	143
Cyclohexane	Leak from Marine unloading Hose	2-F	126	128	231
		5-D	171	180	294
	FBR of Hose	2-F	167	168	193
		5-D	147	149	185
	Leak from Pipeline	2-F	230	241	389
		5-D	184	193	318
	FBR of Pipeline	2-F	92	101	218
		5-D	72	78	160
Ethylene	Leak from Marine unloading Hose	2-F	47	49	74
		5-D	46	48	70
	FBR of Hose	2-F	248	251	367
		5-D	300	302	402
	Leak from Pipeline	2-F	47	49	74
		5-D	46	48	70
	FBR of Pipeline	2-F	190	195	268
		5-D	146	151	212
MTBE	Leak from Marine unloading Hose	2-F	147	150	279
		5-D	186	197	339
	FBR of Hose	2-F	228	230	257
		5-D	181	185	233
	Leak from Pipeline	2-F	249	264	447
		5-D	201	212	363
	FBR of Pipeline	2-F	135	151	354
		5-D	77	85	183
Propylene	Leak from	2-F	47	49	75

	Marine unloading Hose	5-D	46	48	70
	FBR of Hose	2-F	221	224	341
		5-D	267	269	367
	Leak from Pipeline	2-F	47	49	75
		5-D	46	48	70
	FBR of Pipeline	2-F	161	167	243
		5-D	117	122	184
Toluene	Leak from Marine unloading Hose	2-F	79	82	117
		5-D	102	106	151
	FBR of Hose	2-F	53	54	83
		5-D	56	58	89
	Leak from Pipeline	2-F	108	111	148
		5-D	115	119	172
	FBR of Pipeline	2-F	49	54	123
		5-D	28	30	60
Vinyl Acetate	Leak from Marine unloading Hose	2-F	92	96	142
		5-D	117	122	187
	FBR of Hose	2-F	74	75	106
		5-D	84	85	112
	Leak from Pipeline	2-F	126	131	190
		5-D	129	135	206
	FBR of Pipeline	2-F	70	76	165
		5-D	45	49	103
Xylene	Leak from Marine unloading Hose	2-F	25	27	47
		5-D	37	39	64
	FBR of Hose	2-F	22	22	29
		5-D	32	33	40
	Leak from Pipeline	2-F	36	37	59
		5-D	57	59	84
	FBR of Pipeline	2-F	20	23	58
		5-D	15	17	36

7.3.6 Risk Estimation:

7.3.6.1 Individual Risk at SWB:

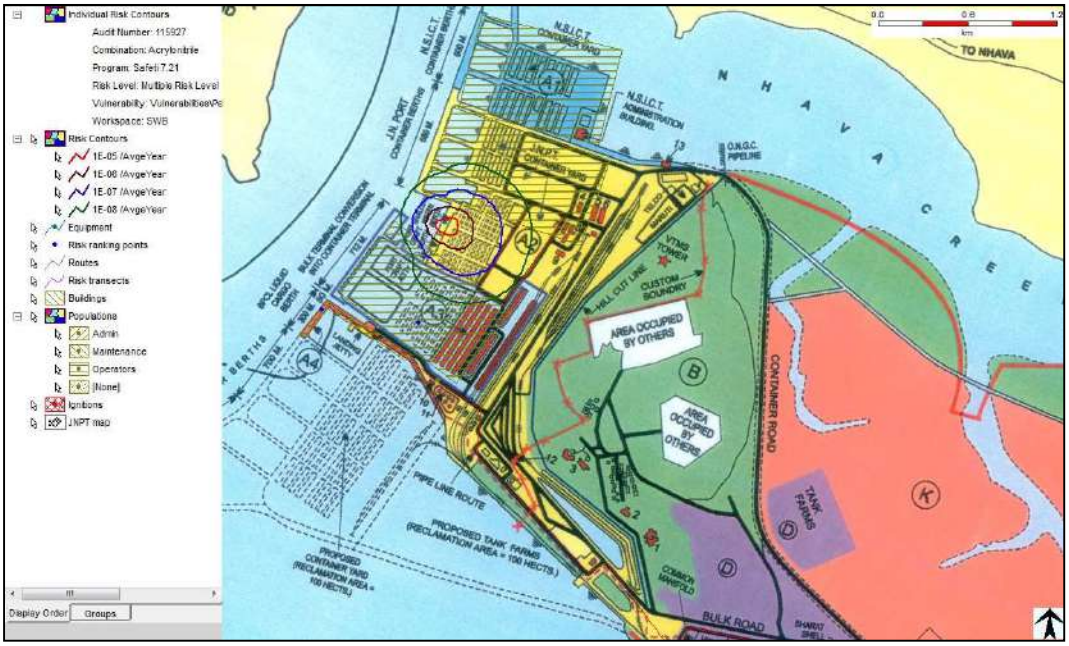


Fig. 7.1 Individual Risk of Acrylonitrile

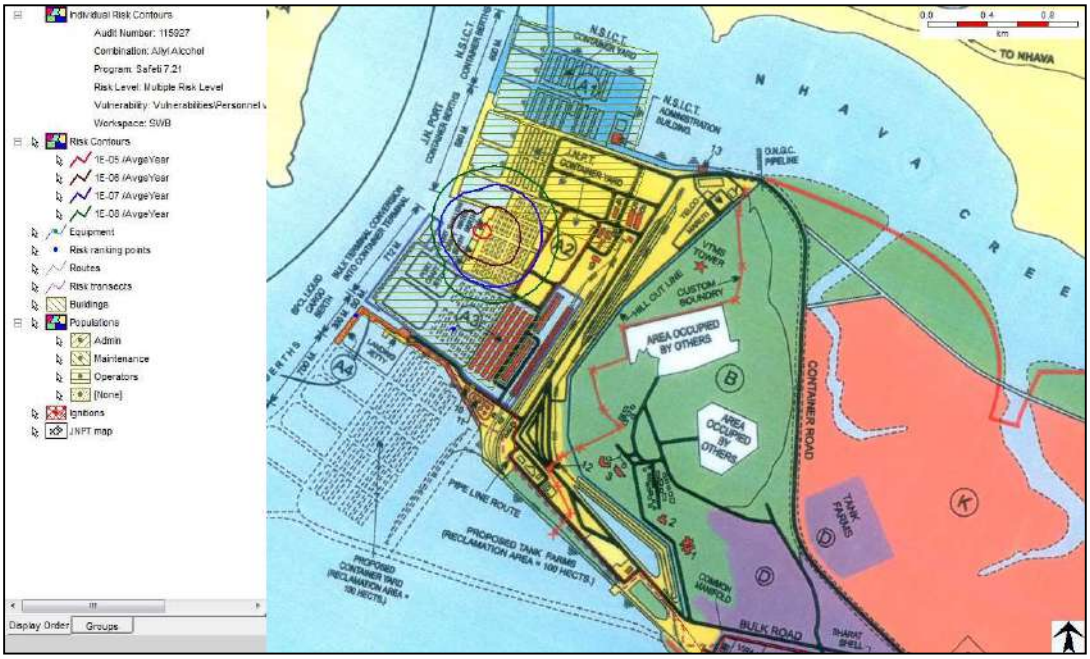


Fig. 7.2 Individual Risk of Allyl Alcohol

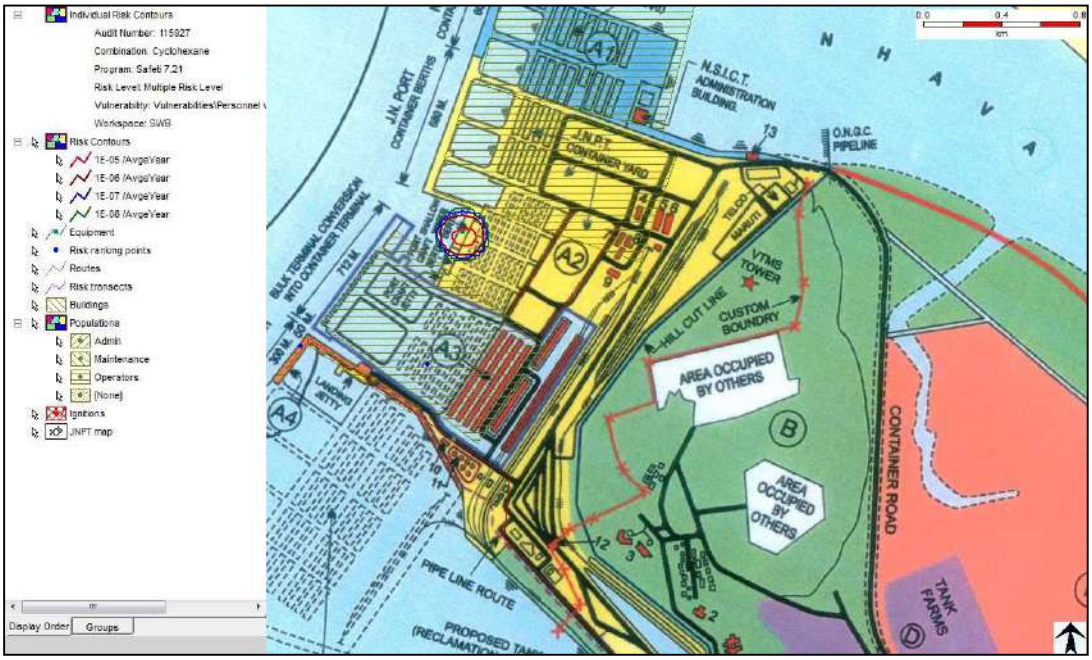


Fig 7.3 Individual Risk of Cyclohexane

7.3.6.2 Societal Risk of chemicals handled at SWB:

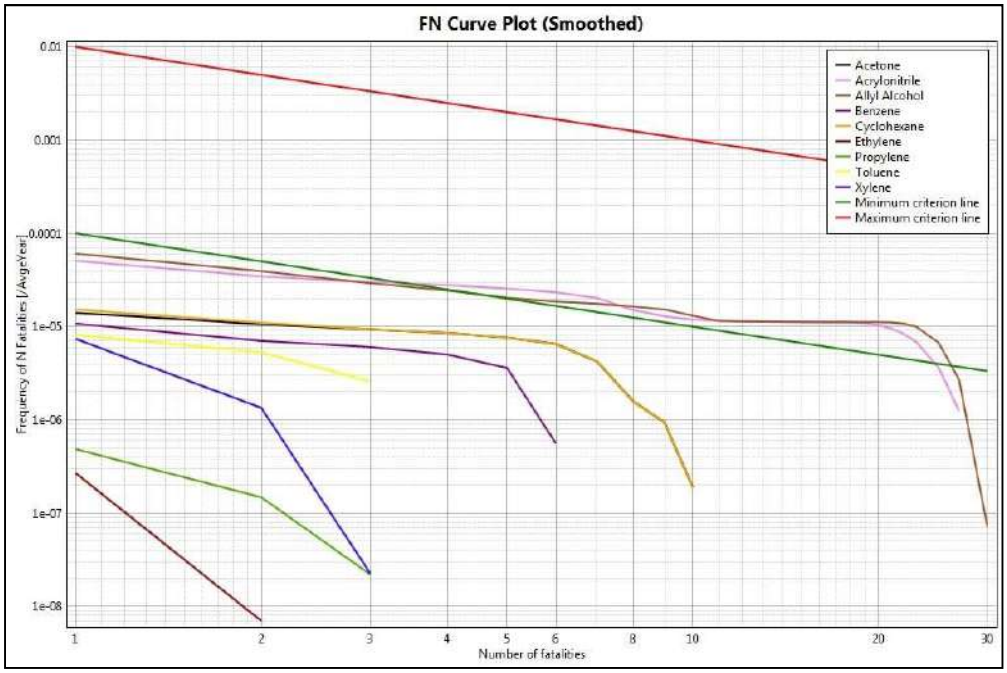


Fig 7.4 Societal Risk

7.4 Recommendations

1. Before any transfer operation is commenced, it is imperative that the intended procedures are thoroughly discussed and a meeting held between the responsible personnel from the tanker and the terminal. The purpose of the meeting is primarily to make both sides fully conversant with the characteristics of the tanker and shore handling systems, the envisaged operational and safety procedures and requirements and the parameters to be adhered to during the transfer.

2. Fixed fire fighting facility shall be available as per OISD 156.

3. To ensure that effective communication is established between ship and shore personnel all through the cargo handling operations.

4. Flexible hose: The master of a ship and the berth operator, within their respective areas of responsibility, should ensure that:
   a) Adequate procedures and means are available for the operation, supervision, disconnection of hoses in the event of an emergency, to protect the environment, personnel safety and equipment;
   b) Flexible hose is not used for substances other than those for which it is suitable, having regard to the temperature and compatibility of such substances and the working pressure or flow rate for which it is suitable;
   c) Each hose has been periodically maintained and has a valid certificate for its fitness for use; and
   d) There are adequate electrical insulation flanges.

5. Suitable PPE should be available and used as appropriate.

6. Maintenance:
   a) All fire-fighting and safety equipment are to be maintained in ready to fully operational at all times and be checked and tested on a routine basis. The prescribed pressure in the fixed fire line should be maintained and monitored at all time both at port and respective terminals. The fire detection and warning systems should be checked and tested regularly.
   b) Fire hydrant Pipeline should be periodically tested, inspected and maintained.

7. The area should be cordoned off with appropriate signage board. No vehicles should be allowed in the vicinity without spark arrestor.

8. Periodic Inspection, testing and maintenance of hoses and pipelines are required to be carried out.

9. Training:
   a) All relevant personnel are trained to use the required fire-fighting systems for carrying out fire-fighting operation effectively;
   b) Both ship and shore personnel should be aware of each other's fire-fighting equipment and capabilities;

10. JNPT should make sure that the illumination is adequate during night-time operations.

11. As there are no fixed type gas detectors installed at the SWB, the operation should be monitored for any kind of leakage with the help of portable multi gas detectors.

12. Adequate number of firefighting personnel should be available at any point of time.

13. All the incidents (minor and major) within the port should be collated and recorded.

8.0 HAZARD ANALYSIS OF HAZARDOUS CARGOES HANDLED AT TANK FARMS IN JNPT

8.1 Reliance Terminal

8.1.1 Facility Description

Reliance Terminal at JNPT is commissioned in September 1995 for storage and distribution of Petroleum Class A and Class B products. Total storage capacity available at Terminal is 71025 KL. In 1996 approvals from statutory authorities was obtained for storage and handling of Petroleum class "A" product and Petroleum class "B" product. Now Terminal has all the statutory approval for storage & handling of petroleum product with total capacity of 71025 KL and petroleum Class A, B & C products.

RIL storage Terminal at JNPT Sheva is suitable for the handling, storing and distribution of petroleum products & petrochemicals. For import and dispatch of products in Vessel, there is one 16" dia. pipeline connecting the Terminal to the BPCL Liquid Cargo jetty at JNPT. At BPCL Jetty, RIL use loading arms provided by JNPT for loading and unloading operations. RIL has also laid 8 Inch dia. cross-country underground Twin Pipelines for transfer of products from the Terminal to their manufacturing plant at Patalganga. The pipeline from the Terminal connects the pipeline from BPCL Refinery to RIL at Patalganga at Kalamboli junction. The Terminal, Pipelines and other facilities are suitable for handling Petroleum Class A (liquids having a flash point below 23 ^{0}C), B (liquids having a flash point 23^{0}C. and above but below 65^{0}C) and C liquids having flash point 65 ^{0}C and above but below 93 ^{0}C.).

Reliance has established Pipeline Management System (PMS) in accordance with PNGRB guidelines to guarantee a high level of protection of human health and the environment. The following issues are addressed by the management system.

(a) Inspection & maintenance of the pipelines as per standard requirements

(b) Only reliable trained staff or qualified contractors carry out maintenance work on a pipeline.

(c) Confirmatory assessment by Third party competent bodies as per PNGRB guidelines – to ensure proper condition of the pipeline and the functioning of the equipment ensuring pipeline safety.

(d) Organization ability, roles and responsibilities, identification and evaluation of hazards, operational control, and management of change, planning for emergencies, monitoring performance, audit and review systems are addressed in the Pipeline Management System.

Terminal has a following product handling facilities and statutory approvals:

a) Naphtha, MS
b) Kerosene, N- Paraffin
c) Para-xylene, Mixed Xylene
d) High Speed Diesel (HSD), Aviation Turbine Fuel (ATF),
e) Light Diesel Oil (LDO), Aromatic Feed Stock (AFS),
f) Aromatic Heavy Ends – 70 (AHE – 70), Linear Alkyl Benzene (LAB)

Table 8.1.1: Pipeline details

Pipeline Details	**JKPL-JNPT Kalamboli Pipelines**
Dia. of pipeline (NB)	08" twin Pipelines (Forward and return stream) of 22.414 KM length
Product handled	Kerosene / Naphtha / AFS (Petroleum class A & B liquid Products)
Pipeline Details	**Dock Pipeline**
Dia. of pipeline (NB)	16" Dia. above ground Pipeline of 5.4 KM length
Product handled	Petroleum Class A, B & C
Storage Terminal	**Petrochemicals & Petroleum Products of**
	Class A – 43025 KL
	Class B – 23000 KL
	Class C – 5000 KL

Table 8.1.2: Storage Tank Details

Tank No.	**Petroleum Class**	**Roof Type**	**Nominal Height (cm)**	**Tank Dia. (cm)**	**Tank Capacity (KL)**	**Operating Conditions**	
						Pressure	**Temp.**
101	A	FLR	2000	2798.6	9500	Atm.	Ambient
102	A	FLR	2000	2799.5	9500	Atm.	Ambient
107	A	FLR	2000	2798.8	9500	Atm.	Ambient
106	A	FLR	2000	2799.5	9500	Atm.	Ambient
116	B	CNR	2000	2797.5	11000	Atm.	Ambient
108	B	CNR	2000	2799.9	11000	Atm.	Ambient
109	A	FLR	1800	2099.7	5000	Atm.	Ambient
110	C	CNR	1600	2098.9	5000	Atm.	Ambient
114	B	CNR	1000	1199.3	1000	Atm.	Ambient
115	A	UG			25	Atm.	Ambient

8.1.2 Pumping Facility (At RIL JNP Terminal)

Cross Country Pipeline – Pumping Facility
Booster pumps: 243 m^3/hr × 02 nos.
Main line pumps: 220 m^3/hr × 02 nos.

Ship loading Pumps
Vessel loading pump: 500 m^3/hr × 02 nos.

Tanker Loading Operation Pump
Tanker loading pump: 100 m^3/hr × 06 nos.

8.1.3 Fire Protection

Fire protection system of existing Terminal comprises of fire hydrant system, foam system and fire extinguishers with sand buckets are kept at suitable locations. Fire detection system at the storage tanks T/L bays with its alarm is also provided. This system is provided along with medium velocity water spray for the storage tanks, T/L bays, etc. The Fire Protection System has been designed in accordance with Tariff Advisory Committee (TAC) regulation. Periodic maintenance and mock drill are continuing from date of commissioning.

8.1.3.1 Fire Water Pumps and Pump House

Existing Terminal has firewater pump house equipped with Fire, Hydrant and Jockey pumps and foam system. These pumps have flooded suction from firewater storage tanks. Since the interconnecting valve between the hydrant and the foam systems are always be kept open, the set points and sequence of starting of pumps are given below.

Jockey Pump

Starts at 7.5 kg/ cm^2 and stops at 9.0 kg/cm^2 or upon starting of any of the main electric motor driven pumps.

Electric motor driven Hydrant Pump: Starts at 6.5 kg/cm^2 and stops manually.
Electric motor driven Foam pump: Starts at 5.5 kg/cm^2 and stops manually.
Diesel Engine driven stand – by pump: Starts at 4.0 kg/cm^2 and stops manually.

Table 8.1.3: The pumping system consists of following pumps:

Pump Detail	Flow Rate	Quantity	Pressure
Main Pumps	273 m^3/ hr	2 nos. working	10.5 kg/cm^2
Jockey Pump	20 m^3/ hr	1 no. Working	10.5 kg/cm^2

8.1.3.2 Fire Water Ring Main

Existing fire hydrant system comprises of double outlet hydrants and water monitors at different locations along the periphery of the dyke-walls and single outlet hydrants on the upper floor of sub-station and Administration Building. Two hoses of 15 Meters length each and a branch pipe with nozzle have been installed in a hose box near every hydrant.

Table 8.1.4: Water Monitors

Sr. No.	Monitor No.	Location	Sr. No.	Foam MOVs
1	WM1	Bet.T102/T109	1	T 101
2	WM2	Bet.T101/T102	2	T 102
3	WM3	Bet.T101/T106	3	T 106
4	WM4	Bet.T106/T116	4	T 107
5	WM5	Near BPH	5	T 108
6	WM6	Near TLPH	6	T 109
7	WM7	Near T110	7	T 110

8.1.3.3 Fixed Foam System
Existing Terminal has a fully automatic foam system has been designed and installed extinguish the fires inside any of the tanks. The foam system comprises of a foam concentrate tank, quick opening motor-operated valves, individual in-line foam inductors catering to each tank, foam markers for pouring the foam inside the tanks, interconnecting pipeline etc.

8.1.3.4 Fire Alarm System/ Smoke Detection
Existing Terminal has been divided into various zones for the purpose of fire-detection and a sophisticated fire-detection and alarm system has been installed for quick detection of fire. Fire – detectors have been provided in 'critical' buildings within the Terminal. Also break-glass units (manual call points) have been provided at strategic locations within the Terminal. As soon as any outbreak of fire is observed, the manual call-point corresponding to the zone where the fire has started operated by the observer and the signal is sent to the Fire-Alarm Panel in security Room.

Fixed Roof Tanks - Flameproof heat detectors have been installed underneath the roof of the tanks. They are distributed in two zones containing 2 Nos. detectors each. The heat detectors operate at 87.7 ^{0}C.

Floating Roof Tanks - For the floating roof tanks, a linear heat sensing detector cable has been fixed inside the foam seals. In the event of fire, this linear heat sensing cable detector will fuse and pass on the fire signal to the Fire Alarm Panel. This cable detector operates at 790C. This cable is replaced after every alarm.

8.1.4 Dock Pipeline Patrolling
Pipeline common corridor section is jointly patrolled by Security guards of JNPT LCBU Association. They are controlled from RIL Tank farm Security Control Room and monitored by RGSS Executives of RIL.

8.1.4.1 Deployment of security rounder – Two rounder's on day round and four rounder's in night time have been deployed for patrolling. These rounder's carry out the patrolling of Dock pipeline common corridor section up to JNPT south gate 'twice in a shift'. Rounder's are equipped with walkie - talkie set for continuous communication with RIL JNP Terminal Security office. Rounder's are checked by a Supervisor on motorcycle and by Officer in each shift. On completion of each round, a report is given to the Security Control Room by the rounder's on the status of pipeline corridor.

8.1.5 Legal Clearances for tank farm

- Factories License - Directorate of Industrial Safety & Health
- Consent to Operate - Maharashtra Pollution Control Board
- Explosive License - Chief Controller of Explosives
- Environmental Clearance - Ministry of Environment & Forests, GoI
- Certificate of Registration - Assistant Labor Commissioner – Under Labour Act

8.1.6 Collection of data/documents
The data/documents collected for the study as follows:

- Risk Analysis (Mond Index) report
- Safety Audit report
- Emergency Response and Disaster Management Plan
- Population data
- Fire fighting system/arrangement with details
- MSDS of Petroleum/Chemicals

8.1.7 Hazard identification

8.1.7.1 Hazards of Naphtha, MS and Xylene:

Naphtha is having the flammability (N_F) classification as 3, Health hazard (N_H) classification as 1 and reactivity (N_R) classification as 0.

MS is having the flammability (N_F) classification as 3, Health hazard (N_H) classification as 1 and reactivity (N_R) classification as 0.

Xylene is having the flammability (N_F) classification as 3, Health hazard (N_H) classification as 2 and reactivity (N_R) classification as 0.

8.1.7.2 Dow's Fire & Explosion index of Naphtha, MS and Xylene.

In order to rate Fire and Explosion hazards of handling and storage of Naphtha, MS and Xylene at terminal, the Dow's Fire & Explosion Index (F&EI) is used.

Table 8.1.5: The NFPA hazard ranking:

Chemical	N_H	N_F	N_R
Naphtha	1	3	0
MS	1	3	0
Xylene	2	3	0

8.1.7.3 Summary of DOW's Index

For the Naphtha, MS and Xylene handling and storage, F&EI have been worked with conservative estimation as given in table below:

Table 8.1.6: Summary of DOW's F&EI

Chemical	MF	GPH	SPH	UHF	F&EI	Rating
Naphtha	16	2.45	1.95	4.78	76.48	MODERATE
MS	16	2.45	1.95	4.78	76.48	MODERATE
Xylene	16	2.45	2.15	5.26	84.16	MODERATE

Location **Storage**	Plant **Storage Terminal**	PROCESS UNIT **NAPHTHA Handling & Storage**
STATE OF OPERATION **NAPHTHA Handling & Storage**		BASIC MATERIAL(S) FOR MATERIAL FACTOR **NAPHTHA**

MATERIAL FACTOR	**16**

1. General Process Hazards		**Penalty Factor Range**	**Penalty Factor Used**
Base Factor		1.00	1.00
A. Exothermic Chemical Reactions		0.30 to 1.25	-----
B. Endothermic Processes		0.20 to 0.40	-----
C. Material Handling and Transfer		0.25 to 1.05	0.85
D. Enclosed or Indoor Process Units		0.25 to 0.90	-----
E. Access		0.20 to 0.35	0.35
F. Drainage and Spill Control		0.25 to 0.50	0.25
General Process Hazards Factor (F_1)			**2.45**
2. Special Process Hazards			
Base Factor		1.00	1.00
A. Toxic Material(s)		0.20 to 0.80	0.20
B. Sub-Atmospheric Pressure (< 500 mm Hg)		0.50	-----
C. Operation In or Near Flammable Range			-----
1. Tank Farms Storage Flammable Liquids		0.50	0.50
2. Process Upset or Purge Failure		0.30	-----
3. Always in Flammable Range		0.80	-----
D. Dust Explosion		0.25 to 2.00	-----
E. Pressure	Operating Pressure 1.2 bar Relief Setting -- bar	From Figure	-----
F. Low Temperature		0.20 to 0.30	-----
G. Quantity of Flammable/Unstable Material:	Quantity = --- lb H_C = ---- BTU/lb	198 x 10^6	-----
1. Liquids or Gases in Process		From Figure	-----
2. Liquids or Gases in Storage		From Figure	0.15
3. Combustible Solids in Storage, Dust in Process		From Figure	-----
H. Corrosion and Erosion		0.10 to 0.75	-----
I. Leakage – Joints and Packing		0.10 to 1.50	0.10
J. Use of Fired Equipment		From Figure	-----
K. Hot Oil Heat Exchange System		0.15 to 1.15	-----
L. Rotating Equipment		0.50	-----
Special Process Hazards Factor (F_2)			**1.95**
Process Unit Hazards Factor (F_1 x F_2) = F_3			**4.78**
Fire and Explosion Index (F_3 x MF = F&EI)			**76.48**
FIRE & EXPLOSION INDEX (RATINGS)			***MODERATE***

Location **Storage**	Plant **Storage Terminal**	PROCESS UNIT **MS Handling & Storage**
STATE OF OPERATION **MS Handling & Storage**		BASIC MATERIAL(S) FOR MATERIAL FACTOR **MS**

MATERIAL FACTOR	**16**

1. General Process Hazards		**Penalty Factor Range**	**Penalty Factor Used**
Base Factor		1.00	1.00
A. Exothermic Chemical Reactions		0.30 to 1.25	-----
B. Endothermic Processes		0.20 to 0.40	-----
C. Material Handling and Transfer		0.25 to 1.05	0.85
D. Enclosed or Indoor Process Units		0.25 to 0.90	-----
E. Access		0.20 to 0.35	0.35
F. Drainage and Spill Control	.	0.25 to 0.50	0.25
General Process Hazards Factor (F_1)			**2.45**
2. Special Process Hazards			
Base Factor		1.00	1.00
A. Toxic Material(s)		0.20 to 0.80	0.20
B. Sub-Atmospheric Pressure (< 500 mm Hg)		0.50	-----
C. Operation In or Near Flammable Range			-----
1. Tank Farms Storage Flammable Liquids		0.50	0.50
2. Process Upset or Purge Failure		0.30	-----
3. Always in Flammable Range		0.80	-----
D. Dust Explosion		0.25 to 2.00	-----
E. Pressure	Operating Pressure 1.2 bar Relief Setting -- bar	From Figure	-----
F. Low Temperature		0.20 to 0.30	-----
G. Quantity of Flammable/Unstable Material:	Quantity = --- lb H_C = ---- BTU/lb	198 x 10^6	-----
1. Liquids or Gases in Process		From Figure	-----
2. Liquids or Gases in Storage		From Figure	0.15
3. Combustible Solids in Storage, Dust in Process		From Figure	-----
H. Corrosion and Erosion		0.10 to 0.75	-----
I. Leakage – Joints and Packing		0.10 to 1.50	0.10
J. Use of Fired Equipment		From Figure	-----
K. Hot Oil Heat Exchange System		0.15 to 1.15	-----
L. Rotating Equipment		0.50	-----
Special Process Hazards Factor (F_2)			**1.95**
Process Unit Hazards Factor (F_1 x F_2) = F_3			**4.78**
Fire and Explosion Index (F_3 x MF = F&EI)			**76.48**
FIRE & EXPLOSION INDEX (RATINGS)			***MODERATE***

Location **Storage**	Plant **Storage Terminal**	PROCESS UNIT **Xylene Handling & Storage**
STATE OF OPERATION **Xylene Handling & Storage**		BASIC MATERIAL(S) FOR MATERIAL FACTOR **Xylene**

MATERIAL FACTOR	**16**

1. General Process Hazards		**Penalty Factor Range**	**Penalty Factor Used**
Base Factor		1.00	1.00
A. Exothermic Chemical Reactions		0.30 to 1.25	-----
B. Endothermic Processes		0.20 to 0.40	-----
C. Material Handling and Transfer		0.25 to 1.05	0.85
D. Enclosed or Indoor Process Units		0.25 to 0.90	-----
E. Access		0.20 to 0.35	0.35
F. Drainage and Spill Control	.	0.25 to 0.50	0.25
General Process Hazards Factor (F_1)			**2.45**
2. Special Process Hazards			
Base Factor		1.00	1.00
A. Toxic Material(s)		0.20 to 0.80	0.40
B. Sub-Atmospheric Pressure (< 500 mm Hg)		0.50	-----
C. Operation In or Near Flammable Range			-----
1. Tank Farms Storage Flammable Liquids		0.50	0.50
2. Process Upset or Purge Failure		0.30	-----
3. Always in Flammable Range		0.80	-----
D. Dust Explosion		0.25 to 2.00	-----
E. Pressure	Operating Pressure 1.2 bar Relief Setting -- bar	From Figure	-----
F. Low Temperature		0.20 to 0.30	-----
G. Quantity of Flammable/Unstable Material:	Quantity = --- lb H_C = --- BTU/lb	198×10^6	-----
1. Liquids or Gases in Process		From Figure	-----
2. Liquids or Gases in Storage		From Figure	0.15
3. Combustible Solids in Storage, Dust in Process		From Figure	-----
H. Corrosion and Erosion		0.10 to 0.75	-----
I. Leakage – Joints and Packing		0.10 to 1.50	0.10
J. Use of Fired Equipment		From Figure	-----
K. Hot Oil Heat Exchange System		0.15 to 1.15	-----
L. Rotating Equipment		0.50	-----
Special Process Hazards Factor (F_2)			**2.15**
Process Unit Hazards Factor (F_1 x F_2) = F_3			**5.26**
Fire and Explosion Index (F_3 x MF = F&EI)			**84.16**
FIRE & EXPLOSION INDEX (RATINGS)			***MODERATE***

8.1.8 Failure Leak scenarios:

8.1.8.1 Release sizes considered for the consequence assessment:

Table 8.1.7: failure leak scenarios

Leak category	Representative hole size
Small leak	20% of nominal diameter
Fixed duration release	600 sec. release duration
Short Pipe Rupture	Full Bore Rupture

8.1.9 Consequence analysis

Based on a review of the plant details, the above leak scenarios have been considered for consequence analysis to assess the impact of fire, vapour cloud explosion and toxic dispersion.

Consequence results for the Jet fire

Table 8.1.8: Jet fire results for various scenarios are shown below

Chemical handled	Leak scenarios	Weather conditions	Jet fire radiation distances (m)		
			37.5 kW/m^2	12.5 kW/m^2	4.0 kW/m^2
MS	Leak	2-F	105	129	168
		5-D	92	116	155
	Fixed duration release	2-F	488	605	799
		5-D	402	506	679
	Short pipe leak	2-F	148	181	235
		5-D	131	163	217
Naphtha	Leak	2-F	84	103	134
		5-D	75	93	124
	Fixed duration release	2-F	306	378	498
		5-D	260	328	443
	Short pipe leak	2-F	93	113	146
		5-D	85	105	140
Xylene	Leak	2-F	29	36	46
		5-D	26	32	43
	Fixed duration release	2-F	91	112	146
		5-D	77	96	128
	Short pipe leak	2-F	26	32	41
		5-D	24	29	38

Table 8.1.9: Consequence results for the Pool fire

Chemical handled	Leak scenarios	Weather conditions	Pool fire radiation distances (m)		
			37.5 kW/m^2	12.5 kW/m^2	4.0 kW/m^2
MS	Leak	2-F	---	27	57
		5-D	---	30	67
	Fixed duration release	2-F	---	181	329
		5-D	---	180	382
	Short pipe leak	2-F	---	40	90
		5-D	---	40	109
Naphtha	Leak	2-F	---	27	58
		5-D	---	30	68
	Fixed duration release	2-F	---	192	344
		5-D	---	191	397
	Short pipe leak	2-F	---	42	94
		5-D	---	43	113
Xylene	Leak	2-F	---	31	66
		5-D	---	33	76
	Fixed duration release	2-F	---	292	479
		5-D	---	291	534
	Short pipe leak	2-F	---	59	122
		5-D	---	59	141

Table 8.1.10: Consequence results for the Flash Fire

Chemical handled	Leak scenarios	Weather conditions	Flash Fire (m)
			LFL (ppm)
MS	Leak	2-F	351
		5-D	184
	Fixed duration release	2-F	3909
		5-D	1944
	Short pipe leak	2-F	955
		5-D	378
Naphtha	Leak	2-F	341
		5-D	155
	Fixed duration release	2-F	3231
		5-D	1328
	Short pipe leak	2-F	948

		5-D	313
Xylene	Leak	2-F	107
		5-D	39
	Fixed duration release	2-F	179
		5-D	136
	Short pipe leak	2-F	135
		5-D	34

Table 8.1.11: Consequence results for the Explosion

Chemical handled	Leak scenarios	Weather conditions	Explosion distances (m)		
			0.3 bar	0.1 bar	0.03 bar
MS	Leak	2-F	611	661	1495
		5-D	328	351	728
	Fixed duration release	2-F	5533	5642	10312
		5-D	3105	3250	6057
	Short pipe leak	2-F	1627	1757	3898
		5-D	720	773	1658
Naphtha	Leak	2-F	599	649	1475
		5-D	293	314	664
	Fixed duration release	2-F	4238	4354	8809
		5-D	2102	2187	3624
	Short pipe leak	2-F	1583	1704	3711
		5-D	637	686	1497
Xylene	Leak	2-F	257	272	530
		5-D	97	107	258
	Fixed duration release	2-F	763	794	1308
		5-D	333	361	822
	Short pipe leak	2-F	279	303	686
		5-D	89	99	258

8.2 IMC Terminal

8.2.1 Facility Description

M/s IMC Limited situated at plot no 6 on a site of 15.73 acres at JNPT area. Terminal consist of storage tanks with supporting facilities such as doc lines & internal pipelines, dedicated pumps, tanker filling shades, weigh bridges, store, fire fighting system ,Chilling Plant, Scrap yard , ETP , DG Sets , Electricity supply tank farm with transformer. Premises are being monitored by CCTV.

The terminal is surrounded by existing M/s Ganesh Benzoplast Ltd., on Northern side; 40 ft. road connecting to state highway No 41 which ultimately connects JNPT to NH No 4 Mumbai –Pune road on Eastern side, 40 ft road on Southern side and 60 ft road on Western side.

The immediate surrounding within 2 km region of the terminal site is thinly populated. Sonari, Dongri, Panje, Dastan, Navgarh, Dhutum, Chirale, Kunda and Uran are some of the villages in easterly, north easterly, south easterly and southern direction. The western direction of site is entirely covered by Arabian Sea.

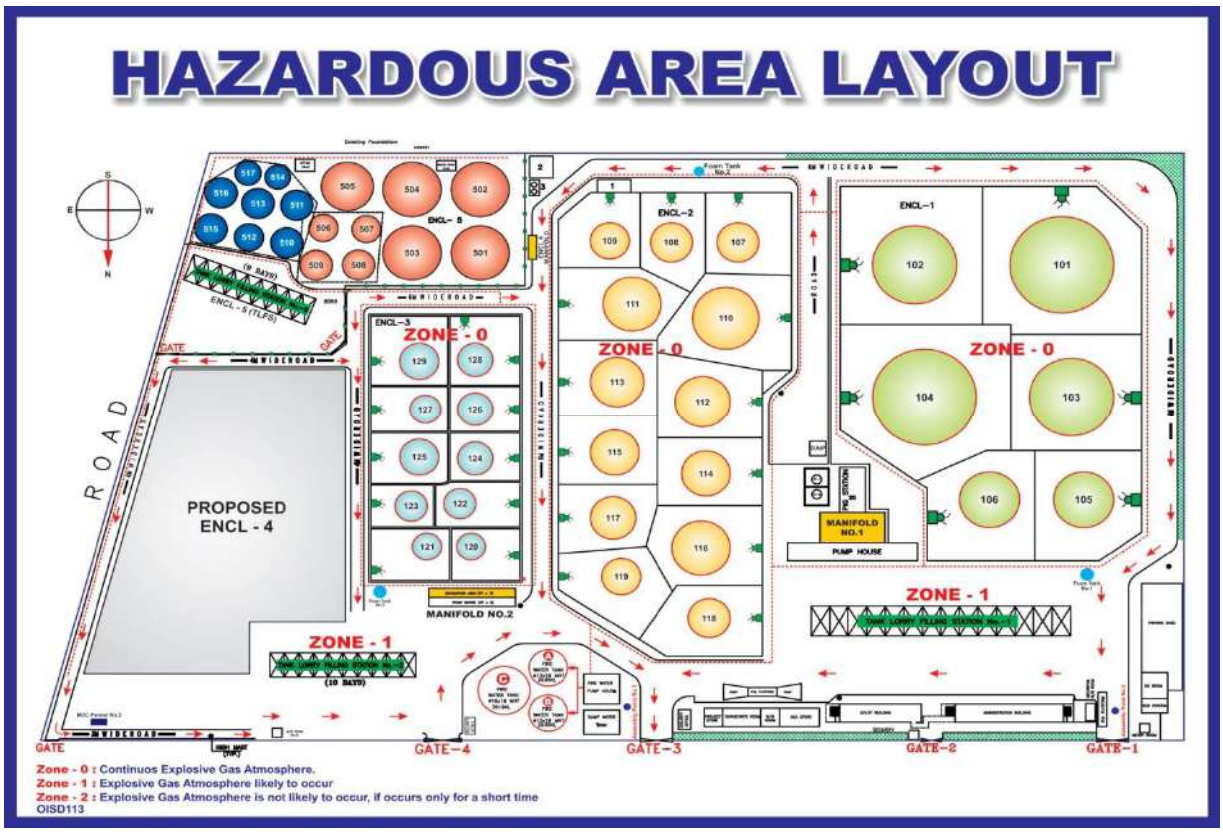


Fig. 8.2.1 IMC Hazardous area layout

Table 8.2.1: Details of Storage Tanks

Tank No.	Diameter (m)	Height (m)	Capacity (KL)	Product Stored	Licensed	Product Class
101	32.00	19.95	15695.622	CBFS	B	EXCLUDED
102	26.00	20.00	10631.985	EDIBLE OIL	B	NA
103	26.00	20.00	10405.990	EDIBLE OIL	B	NA
104	32.00	20.00	16096.260	CRUDE GLYCOL	C	NA
105	18.5	20.00	5256.448	BA	B	B
106	18.5	20.00	5237.743	HSD	A	EXCLUDED
107	13.0	19.45	2577.612	STYRENE MONOMER	B/C	B
108	13.0	19.45	2589.516	STYRENE MONOMER	B/C	B
109	12.0	17.95	2027.168	STYRENE MONOMER	B/C	B
110	20.5	20.00	6589.045	CBFS	B/C	EXCLUDED
111	18.0	20.00	4652.609	DIESEL	A	EXCLUDED
112	17.0	20.00	4531.382	HSD	A	EXCLUDED
113	16.5	20.00	4169.232	HSD	A	EXCLUDED
114	15.0	20.00	3520.100	LUBE OIL	B/C	EXCLUDED
115	15.0	20.00	3538.491	LUBE OIL	B/C	EXCLUDED
116	18.0	20.00	5073.522	HF-HSD	A	EXCLUDED
117	14.0	20.00	3073.988	ETHANOL	A	A
118	13.0	19.50	2589.046	EDIBLE OIL	B/C	NA
119	12.0	18.00	1967.395	MS	A	EXCLUDED
120	9.0	13.50	859.317	LUBE OIL	A/B	EXCLUDED
121	9.0	13.50	858.577	LUBE OIL	A/B	EXCLUDED
122	10.0	15.04	1179.761	MDC	A/B	B
123	10.0	15.05	1181.490	ETHANOL	A	A
124	11.0	16.50	1565.821	BA	A/B	B
125	12.0	14.23	1935.125	LUBE OIL	A	EXCLUDED
126	10.97	16.50	1568.917	LUBE OIL	A	EXCLUDED
127	9.498	14.23	1011.675	ETHANOL	A	A
128	11.0	16.50	1492.692	MS	A	EXCLUDED
129	12.0	18.00	1492.692	MS	NA	EXCLUDED
501	18.0	23.00	5842.310	EDIBLE OIL	NA	NA

502	18.0	23.00	5846.875	EDIBLE OIL	NA	NA
503	18.0	23.00	5856.560	EDIBLE OIL	NA	NA
504	18.0	23.00	5843.458	EDIBLE OIL	NA	NA
505	16.0	23.00	4612.252	EDIBLE OIL	NA	NA
506	8.99	17.99	1145.660	EDIBLE OIL	NA	EXCLUDED
507	8.99	17.99	1147.285	LUBE OIL	NA	EXCLUDED
508	10.0	19.47	1538.050	LUBE OIL	NA	EXCLUDED
509	10.0	19.51	1539.450	LUBE OIL	NA	EXCLUDED
510	10.0	22.06	1710.504	LUBE OIL	NA	EXCLUDED
511	10.0	22.06	1724.852	LUBE OIL	NA	EXCLUDED
512	9.0	20.04	1269.364	LUBE OIL	NA	EXCLUDED
513	10.0	22.06	1709.559	LUBE OIL	NA	EXCLUDED
514	8.0	18.00	892.171	EDIBLE OIL	NA	NA
515	10.0	22.06	1720.823	LUBE OIL	NA	EXCLUDED
516	10.0	22.06	1710.597	LUBE OIL	NA	EXCLUDED
517	8.0	18.00	899.026	EDIBLE OIL	NA	EXCLUDED

Table 8.2.2: Storage Product Details

Product	Boiling point (^{O}C)	Flash Point (^{O}C)	Fire Risk	Specific Gravity	Soluble in	Product category
Edible oil	NA	Above 169	Slight	0.91	Organic solvents	unclassified
Lube oil	230-600	Above 210	NIL	0.8770	Organic solvents	excluded
Carbon black feed stock	230-600	NA	Slight	1.14	Organic solvents	excluded
Styrene Monomer	145.2	31.1	Highly Flammable	0.9045	Alcohol ether	Class B
Vinyl Acetate monomer	72	-8	Flammable	0.9317	Alcohol ester	Class A
Crude glycol	105	170	NIL	1.2	Organic solvents	Non class
Butyl acrylate	147.9	38.9	Highly Flammable	0.8900	Organic solvents	Class B
MDC (Methylene dichloride)	39.75	NA	Slight	1.3266	Water solvents	Non class
MS	225	< -40	Flammable	N/P	Negligible	Class A

HSD	160-371	52	Flammable	0.812-0.88	Negligible	Class B
Ethanol	-78	-12	Flammable	0.79-0.81	---	Class A

Table 8.2.3: Details of Dock Pipe Line

Dock Line Dia. In inches	Dock Line Length In Mtrs.	Connected Berth	Product Handled
8	4800	LB-1,LB-2	Lube Oils
12	4800	LB-1,LB-2	Edible Oils
16	4800	LB-1,LB-2	Black Oils
10	4800	LB-1,LB-2	Chemicals

Table 8.2.4: Details of Fire Fighting System

1. Fire Fighting systems installed	a. Fire hydrant system b. Medium velocity cooling system c. Fixed foam system d. Fire extinguishers
2. Details of Fire pumps a. Fire main pump b. Jockey pump	 Q=171 lit/sec, No. = 04 Q=8.33 It/sec. No. = 02
3. Starting sequence in auto mode a. Fire main pump b. Standby pump **c.** Jockey pump	**Starts at** **Stop at** 6.0 Kg/cm^2 Manual mode only 5.5 Kg/cm^2 Manual mode only 7.0 Kg/cm^2 8.8 Kg/cm^2
4. Water Storage Capacities a. Fire water tanks-3Nos. b. Type	 Capacity: 2000KL x 2 nos. + 3600 KL x 1no. each tank Above ground mild steel storage tanks.
5. Hydrant Accessories a. Single Hydrant b. Double Hydrant Points c. Water Monitors (38 mm Bore) d. Hose boxes containing hoses and nozzle	 03 Nos. 33 Nos. 22 Nos. 14 Nos.
6. Ring Main Details a. Ring main size b. Position of ring main c. Furthest point pressure d. Length of ring main 200 mm Nb 150 mm Nb	 400 mm/200mm/ NB. Above ground 7 Kg / cm^2 665 m 185 m

7. Medium velocity Cooling System Details a. Application rate b. Water source	 5 LPM / m^2 of the shell Tapped from Ring main with quick opening type isolation valve for each tank.
8. Fixed Foam System Details a. Application rate b. Foam type c. Foam storage tanks d. Foam available	 5 LPM / m^2 of the liquid surface area of the chemical. AFFF 3 % Concentration No. = 03 6255Ltrs.

8.2.2 Collection of data/documents

The data/documents collected for the study as follows:

- Risk Analysis report
- HAZOP study report
- Onsite Emergency Control Plan
- Safety Audit report
- Population data
- Fire fighting system/arrangements with details
- MSDS of Chemicals
- Emergency Response Disaster Management Plan (ERDMP) - 2017

The generic failure rate data are taken from the available published literature.

8.2.3 Hazard Identification

8.2.3.1 Hazards of MS, Ethanol & Styrene:

MS is having the flammability (N_F) classification as 3, Health hazard (N_H) classification as 1 and reactivity (N_R) classification as 0.

Ethanol is having the flammability (N_F) classification as 3, Health hazard (N_H) classification as 0 and reactivity (N_R) classification as 0.

Styrene is having the flammability (N_F) classification as 3, Health hazard (N_H) classification as 2 and reactivity (N_R) classification as 2.

8.2.3.2 Dow's Fire & Explosion index of MS, Ethanol & Styrene.

In order to rate Fire and Explosion hazards of handling and storage of MS, Ethanol & Styrene at terminal, the Dow's Fire & Explosion Index (F&EI) is used.

Table 8.2.5: The NFPA hazard ranking of Naphtha:

Chemical	N_H	N_F	N_R
MS	1	3	0
Ethanol	0	3	0

Styrene	2	3	2

8.2.3.3 Summary of DOW's Index

For the MS, Ethanol and Styrene handling and storage, F&EI have been worked with conservative estimation as given in table below:

Table 8.2.6: Summary of DOW's F&EI

Chemical	MF	GPH	SPH	UHF	F&EI	Rating
MS	16	2.45	1.95	4.78	76.48	MODERATE
Ethanol	16	2.45	1.60	3.92	62.72	MODERATE
Styrene	24	2.45	2.10	5.14	123.5	INTERMEDIATE

Location **Storage**	Plant **Storage Terminal**	PROCESS UNIT **MS Handling & Storage**
STATE OF OPERATION **MS Handling & Storage**		BASIC MATERIAL(S) FOR MATERIAL FACTOR **MS**

MATERIAL FACTOR	**16**

1. General Process Hazards		**Penalty Factor Range**	**Penalty Factor Used**
Base Factor		1.00	1.00
A. Exothermic Chemical Reactions		0.30 to 1.25	-----
B. Endothermic Processes		0.20 to 0.40	-----
C. Material Handling and Transfer		0.25 to 1.05	0.85
D. Enclosed or Indoor Process Units		0.25 to 0.90	-----
E. Access		0.20 to 0.35	0.35
F. Drainage and Spill Control	.	0.25 to 0.50	0.25
General Process Hazards Factor (F_1)			**2.45**
2. Special Process Hazards			
Base Factor		1.00	1.00
A. Toxic Material(s)		0.20 to 0.80	0.20
B. Sub-Atmospheric Pressure (< 500 mm Hg)		0.50	-----
C. Operation In or Near Flammable Range			-----
1. Tank Farms Storage Flammable Liquids		0.50	0.50
2. Process Upset or Purge Failure		0.30	-----
3. Always in Flammable Range		0.80	-----
D. Dust Explosion		0.25 to 2.00	-----
E. Pressure	Operating Pressure 1.2 bar Relief Setting -- bar	From Figure	-----
F. Low Temperature		0.20 to 0.30	-----
G. Quantity of Flammable/Unstable Material:	Quantity = ---- lb H_C = ---- BTU/lb	198×10^6	-----
1. Liquids or Gases in Process		From Figure	-----
2. Liquids or Gases in Storage		From Figure	0.15
3. Combustible Solids in Storage, Dust in Process		From Figure	-----
H. Corrosion and Erosion		0.10 to 0.75	-----
I. Leakage – Joints and Packing		0.10 to 1.50	0.10
J. Use of Fired Equipment		From Figure	-----
K. Hot Oil Heat Exchange System		0.15 to 1.15	-----
L. Rotating Equipment		0.50	-----
Special Process Hazards Factor (F_2)			**1.95**
Process Unit Hazards Factor (F_1 x F_2) = F_3			**4.78**
Fire and Explosion Index (F_3 x MF = F&EI)			**76.48**
FIRE & EXPLOSION INDEX (RATINGS)			***MODERATE***

Location **Storage**	Plant **Storage Terminal**	PROCESS UNIT **Ethanol Handling & Storage**
STATE OF OPERATION **Ethanol Handling & Storage**		BASIC MATERIAL(S) FOR MATERIAL FACTOR **Ethanol**

MATERIAL FACTOR	**16**

1. General Process Hazards		**Penalty Factor Range**	**Penalty Factor Used**
Base Factor		1.00	1.00
A. Exothermic Chemical Reactions		0.30 to 1.25	-----
B. Endothermic Processes		0.20 to 0.40	-----
C. Material Handling and Transfer		0.25 to 1.05	0.85
D. Enclosed or Indoor Process Units		0.25 to 0.90	-----
E. Access		0.20 to 0.35	0.35
F. Drainage and Spill Control		0.25 to 0.50	0.25
General Process Hazards Factor (F_1)			**2.45**
2. Special Process Hazards			
Base Factor		1.00	1.00
A. Toxic Material(s)		0.20 to 0.80	-----
B. Sub-Atmospheric Pressure (< 500 mm Hg)		0.50	-----
C. Operation In or Near Flammable Range			-----
1. Tank Farms Storage Flammable Liquids		0.50	0.50
2. Process Upset or Purge Failure		0.30	-----
3. Always in Flammable Range		0.80	-----
D. Dust Explosion		0.25 to 2.00	-----
E. Pressure	Operating Pressure 1.2 bar Relief Setting -- bar	From Figure	-----
F. Low Temperature		0.20 to 0.30	-----
G. Quantity of Flammable/Unstable Material:	Quantity = ---- lb H_C = ---- BTU/lb	198 x 10^6	-----
1. Liquids or Gases in Process		From Figure	-----
2. Liquids or Gases in Storage		From Figure	-----
3. Combustible Solids in Storage, Dust in Process		From Figure	-----
H. Corrosion and Erosion		0.10 to 0.75	-----
I. Leakage – Joints and Packing		0.10 to 1.50	0.10
J. Use of Fired Equipment		From Figure	-----
K. Hot Oil Heat Exchange System		0.15 to 1.15	-----
L. Rotating Equipment		0.50	-----
Special Process Hazards Factor (F_2)			**1.60**
Process Unit Hazards Factor (F_1 x F_2) = F_3			**3.92**
Fire and Explosion Index (F_3 x MF = F&EI)			**62.72**
FIRE & EXPLOSION INDEX (RATINGS)			***MODERATE***

Location **Storage**	Plant **Storage Terminal**	PROCESS UNIT **Styrene Handling & Storage**
STATE OF OPERATION **Styrene Handling & Storage**		BASIC MATERIAL(S) FOR MATERIAL FACTOR **Styrene**

MATERIAL FACTOR	**24**

1. General Process Hazards		**Penalty Factor Range**	**Penalty Factor Used**
Base Factor		1.00	1.00
A. Exothermic Chemical Reactions		0.30 to 1.25	-----
B. Endothermic Processes		0.20 to 0.40	-----
C. Material Handling and Transfer		0.25 to 1.05	0.85
D. Enclosed or Indoor Process Units		0.25 to 0.90	-----
E. Access		0.20 to 0.35	0.35
F. Drainage and Spill Control	.	0.25 to 0.50	0.25
General Process Hazards Factor (F_1)			**2.45**
2. Special Process Hazards			
Base Factor		1.00	1.00
A. Toxic Material(s)		0.20 to 0.80	0.40
B. Sub-Atmospheric Pressure (< 500 mm Hg)		0.50	-----
C. Operation In or Near Flammable Range			-----
1. Tank Farms Storage Flammable Liquids		0.50	0.50
2. Process Upset or Purge Failure		0.30	-----
3. Always in Flammable Range		0.80	-----
D. Dust Explosion		0.25 to 2.00	-----
E. Pressure	Operating Pressure 1.2 bar Relief Setting -- bar	From Figure	-----
F. Low Temperature		0.20 to 0.30	-----
G. Quantity of Flammable/Unstable Material:	Quantity = ---- lb H_C = ---- BTU/lb	198 x 10^6	-----
1. Liquids or Gases in Process		From Figure	-----
2. Liquids or Gases in Storage		From Figure	-----
3. Combustible Solids in Storage, Dust in Process		From Figure	-----
H. Corrosion and Erosion		0.10 to 0.75	-----
I. Leakage – Joints and Packing		0.10 to 1.50	0.10
J. Use of Fired Equipment		From Figure	-----
K. Hot Oil Heat Exchange System		0.15 to 1.15	-----
L. Rotating Equipment		0.50	-----
Special Process Hazards Factor (F_2)			**2.10**
Process Unit Hazards Factor (F_1 x F_2) = F_3			**5.14**
Fire and Explosion Index (F_3 x MF = F&EI)			**123.5**
FIRE & EXPLOSION INDEX (RATINGS)			***INTERMEDIATE***

8.2.4 Consequence Analysis

Based on a review of the plant details, the above leak scenarios have been considered for consequence analysis to assess the impact of fire, vapour cloud explosion and toxic dispersion.

Table 8.2.7: Jet fire results for various scenarios considered above are shown below.

Chemical handled	Leak scenarios	Weather conditions	Jet fire radiation distances (m)		
			37.5 kW/m^2	12.5 kW/m^2	4.0 kW/m^2
Butyl Acrylate	Leak	2-F	25	30	38
		5-D	22	27	35
	Fixed duration release	2-F	57	69	88
		5-D	48	59	78
	Short pipe leak	2-F	22	26	33
		5-D	20	24	31
Ethanol	Leak	2-F	---	62	76
		5-D	46	55	69
	Fixed duration release	2-F	129	158	195
		5-D	112	134	169
	Short pipe leak	2-F	---	61	75
		5-D	47	56	69
HSD	Leak	2-F	38	46	60
		5-D	34	42	57
	Fixed duration release	2-F	99	123	161
		5-D	85	107	145
	Short pipe leak	2-F	34	41	53
		5-D	31	38	51
MDC	Leak	2-F	---	90	109
		5-D	62	78	95
	Fixed duration release	2-F	---	224	273
		5-D	158	191	234
	Short pipe leak	2-F	---	119	145
		5-D	89	108	131
MS	Leak	2-F	52	53	82
		5-D	46	58	77
	Fixed duration release	2-F	108	134	175
		5-D	93	117	158
	Short pipe leak	2-F	45	55	71
		5-D	42	52	69

Styrene Monomer	Leak	2-F	20	24	30
		5-D	18	22	28
	Fixed duration release	2-F	42	51	65
		5-D	36	44	58
	Short pipe leak	2-F	17	20	26
		5-D	15	19	24
Vinyl Acetate Monomer	Leak	2-F	67	81	102
		5-D	59	72	93
	Fixed duration release	2-F	150	181	229
		5-D	128	156	203
	Short pipe leak	2-F	73	88	110
		5-D	66	80	102

Table 8.2.8: Consequence results for the Pool fire

Chemical handled	**Leak scenarios**	**Weather conditions**	**Pool fire radiation distances (m)**		
			37.5 kW/m^2	**12.5 kW/m^2**	**4.0 kW/m^2**
Butyl Acrylate	Leak	2-F	---	35	71
		5-D	---	37	80
	Fixed duration release	2-F	---	189	319
		5-D	---	188	353
	Short pipe leak	2-F	---	70	136
		5-D	---	70	153
Ethanol	Leak	2-F	51	86	128
		5-D	56	91	130
	Fixed duration release	2-F	308	464	687
		5-D	338	480	692
	Short pipe leak	2-F	114	185	281
		5-D	130	193	284
HSD	Leak	2-F	---	30	62
		5-D	---	31	72
	Fixed duration release	2-F	---	176	312
		5-D	---	176	354
	Short pipe leak	2-F	---	52	110
		5-D	---	52	128
MDC	Leak	2-F	---	47	88
		5-D	---	48	95

	Fixed duration release	2-F	---	194	330
		5-D	---	210	349
	Short pipe leak	2-F	---	101	184
		5-D	---	108	196
MS	Leak	2-F	---	29	60
		5-D	---	31	70
	Fixed duration release	2-F	---	106	203
		5-D	---	107	235
	Short pipe leak	2-F	---	47	102
		5-D	---	48	121
Styrene Monomer	Leak	2-F	---	32	68
		5-D	---	34	78
	Fixed duration release	2-F	---	154	275
		5-D	---	154	310
	Short pipe leak	2-F	---	126	61
		5-D	---	145	62
Vinyl Acetate Monomer	Leak	2-F	46	84	130
		5-D	52	91	133
	Fixed duration release	2-F	186	307	475
		5-D	213	323	483
	Short pipe leak	2-F	106	184	290
		5-D	124	196	295

Table 8.2.9: Consequence results for the Flash Fire

Chemical handled	**Leak scenarios**	**Weather conditions**	**Flash Fire (m)**
			LFL (ppm)
Butyl Acrylate	Leak	2-F	20
		5-D	22
	Fixed duration release	2-F	30
		5-D	39
	Short pipe leak	2-F	54
		5-D	20
Ethanol	Leak	2-F	98
		5-D	36
	Fixed duration release	2-F	139
		5-D	109

	Short pipe leak	2-F	187
		5-D	40
HSD	Leak	2-F	213
		5-D	68
	Fixed duration release	2-F	485
		5-D	198
	Short pipe leak	2-F	230
		5-D	65
MDC	Leak	2-F	16
		5-D	18
	Fixed duration release	2-F	251
		5-D	171
	Short pipe leak	2-F	300
		5-D	61
MS	Leak	2-F	285
		5-D	101
	Fixed duration release	2-F	787
		5-D	229
	Short pipe leak	2-F	668
		5-D	116
Styrene Monomer	Leak	2-F	58
		5-D	30
	Fixed duration release	2-F	53
		5-D	55
	Short pipe leak	2-F	7
		5-D	7
Vinyl Acetate Monomer	Leak	2-F	223
		5-D	78
	Fixed duration release	2-F	677
		5-D	259
	Short pipe leak	2-F	639
		5-D	157

Table 8.2.10: Consequence results for the Explosion

Chemical handled	Leak scenarios	Weather conditions	Explosion distances (m)		
			0.3 bar	0.1 bar	0.03 bar
Butyl Acrylate	Leak	2-F	114	118	195
		5-D	56	61	149
	Fixed duration release	2-F	107	113	210
		5-D	100	107	219
	Short pipe leak	2-F	151	161	333
		5-D	48	54	154
Ethanol	Leak	2-F	256	271	526
		5-D	73	77	147
	Fixed duration release	2-F	574	598	1005
		5-D	262	283	626
	Short pipe leak	2-F	367	400	936
		5-D	104	116	306
HSD	Leak	2-F	377	405	884
		5-D	144	155	340
	Fixed duration release	2-F	1419	1475	2410
		5-D	429	462	1009
	Short pipe leak	2-F	591	592	1068
		5-D	154	169	414
MDC	Leak	2-F	48	51	98
		5-D	47	50	89
	Fixed duration release	2-F	471	494	1009
		5-D	348	368	691
	Short pipe leak	2-F	587	619	1153
		5-D	154	166	355
MS	Leak	2-F	521	565	1291
		5-D	223	241	534
	Fixed duration release	2-F	1470	1573	3285
		5-D	466	501	1085
	Short pipe leak	2-F	1241	1322	2800
		5-D	258	281	657
Styrene Monomer	Leak	2-F	200	210	376
		5-D	58	60	102
	Fixed duration release	2-F	240	250	415
		5-D	137	146	295

	Short pipe leak	2-F	---	---	---
		5-D	---	---	---
Vinyl Acetate Monomer	Leak	2-F	434	466	988
		5-D	170	183	401
	Fixed duration release	2-F	1203	1275	2455
		5-D	528	570	1276
	Short pipe leak	2-F	1032	1114	2542
		5-D	359	392	937

8.3 DFPCL (Deepak Fertilizers) Terminal

8.3.1 Facility Description

The Tank farm Terminal of M/s. Deepak Fertilizers & Petrochemicals Corporation Ltd., situated at JNPT in their premises at Plot no. 01, Navi Mumbai, established in 1995, is basically an intermediate storage facility, primarily constructed to cater to the needs of the Fertilizers & Petrochemical Complex of M/s Deepak Fertilizers, at Taloja.

There are three above-ground Storage Tanks. Out of these, two tanks, each of 7000 KL capacity, are of fixed roof type for storage of Phosphoric Acid (54% solution) and the remaining one of Double wall Double Integrity (Cup in Cup design) type of 15000 MT capacity for storage of liquid Ammonia at - 32 ^{0}C (Refrigerated Atmospheric pressure storage tank).

The products are received from the nearby Jetty which is 4.5 km away from terminal by (a) 16" NB, Low Temperature Carbon Steel (LTCS) insulated pipeline for Ammonia and (b) 16" NB SS piggable pipeline for Phosphoric acid. These are then stored in the tanks and transported to Taloja works, as per requirement, by road tankers. There is also a 4" NB, Low Temperature Carbon Steel (LTCS) insulated pipeline from tank farm to jetty carrying liquid ammonia (at -32^{0}C) for pre-cooling of 16" NB ammonia pipeline prior to start of unloading of Ammonia from ships at jetty.

The ammonia storage tank is provided with instruments for measurement, monitoring and control of pressure, temperature and level.

A refrigeration system is provided to maintain the pressure of ammonia storage tank. The system is sized to ensure there is no increase in tank pressure at any time. Apart from taking care of heat ingress, the refrigeration system takes care of vapors generated during flushing of liquid ammonia into ammonia storage tank during unloading operation. It consists of 4 number refrigeration compressors to maintain pressure and temperature of the ammonia storage tanks in normal case, loading of ammonia road tankers and ammonia shipment unloading.

A self supporting flare with LPG pilot burners is also provided for flaring ammonia vapour in case of emergency. This flare is normally in use.

Other facilities at Storage Tank installation includes:

- Tanker loading system in which 3 nos. road tankers are filled at a time from ammonia storage tank through a ammonia transfer pump. The operator at the control room has option to shut down the loading operation.
- 06 nos. of gas detectors for ammonia leak detection in the tanker loading area, ammonia pumps area and refrigeration area are provided

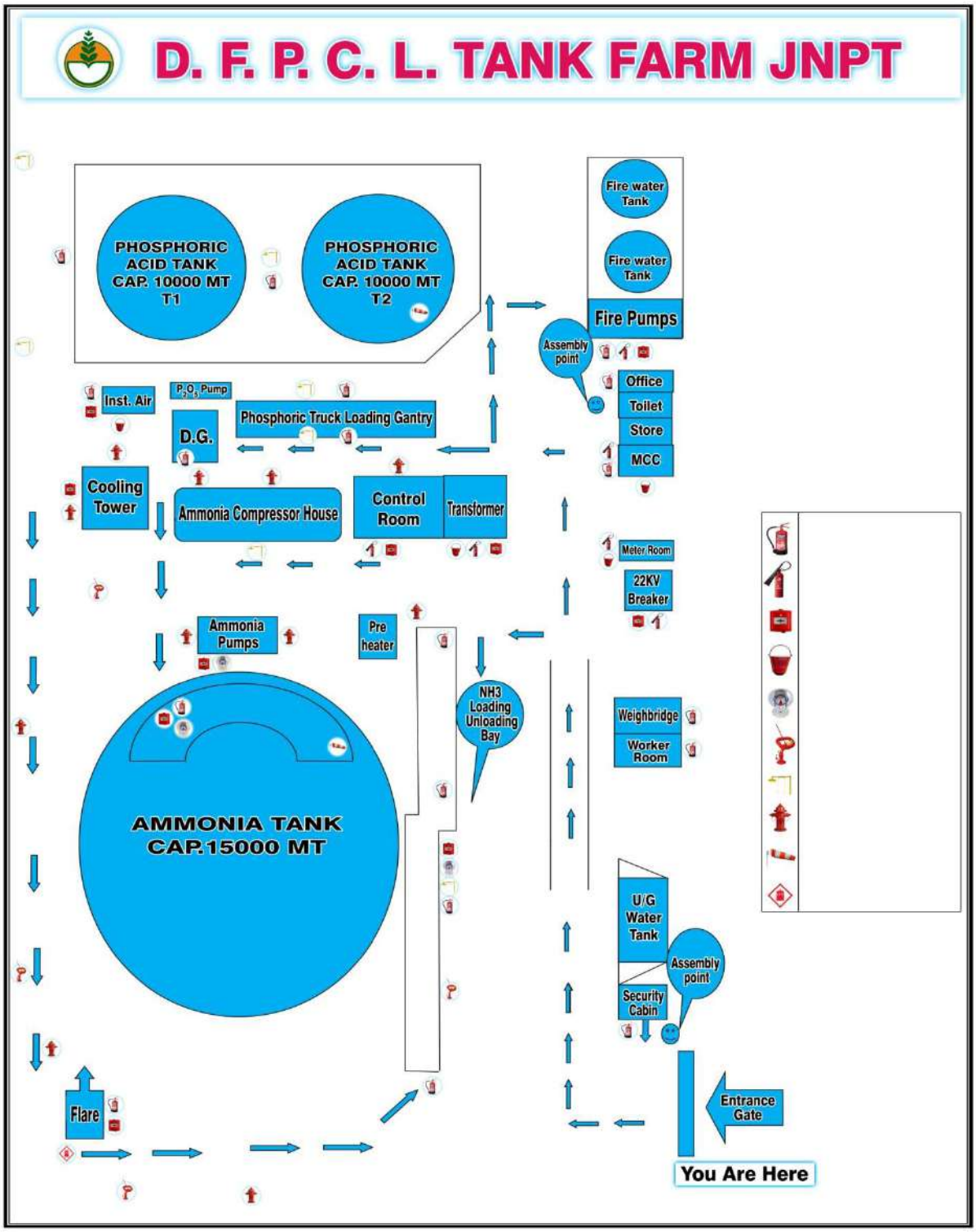


Fig 8.3.1: Layout of DFPCL Terminal

8.3.2 Pipeline length and diameter

- Liquid Ammonia : Length : 4.5 km and diameter : 16" and 4" for pre-cooling
- Phosphoric acid : 4.5 Km and 16" diameter

Table 8.3.1: Details of Fire Fighting

1. Fire Fighting systems installed	a. Fire hydrant system b. Manual open water sprinkler system for ➢ Ammonia loading bay – Old ➢ Ammonia tank top portion c. Manual water curtain system for ➢ Ammonia loading bay – New ➢ Ammonia transfer pump ➢ Ammonia compressor room ➢ Ammonia receiver d. Automatic smoke detection and alarm system ➢ Terminal control room ➢ MCC
2. Details of Fire pumps	
a. Electrical driven Fire main pump	Q=171 m^3/hr, H=70m
b. Diesel engine driven stand-by pump	As above
c. Electrical driven Jockey pump	Q=11 m^3/hr, H=70m
3. Water Storage Capacities	
a. Fire water tanks-2Nos.	Capacity: 300 m^3 each. Common suction header is provided from the two tanks to the fire pumps housed in the adjacent pump house.
b. Type	Above ground mild steel storage tanks.
4. Hydrant Accessories	
a. Single Hydrant	9 Nos.
b. Double Hydrant Points	33 Nos.
c. Water Monitors	3 Nos.
d. Hose boxes containing hoses and nozzle	9 Nos.
5. Other Details	
a. Fire Jeep	1 No.
b. Manual call points (MCP)	15 Nos.
c. Smoke detectors	12 Nos.
d. Heat detectors	5 Nos.
e. Ammonia detectors	8 Nos.
f. DCP Fire Extinguishers	27 Nos.
g. Foam type Fire Extinguishers capacity	1 No.

9 L. h. CO_2 type Fire Extinguishers i. Fire Brigade inlet j. Fire Bucket k. SCBA	 16 Nos. 1 No. 17 Nos. 05 Nos.

Table 8.3.2: Location of Ammonia Detectors

Sr. No.	Location of Detector	No. of Detector Provided
1	Near Marine unloading arm	02
2	Near Ammonia transfer Pump area	01
3	In ammonia compressor house	01
4	At ammonia unloading bay 1 to 4	01
5	At ammonia unloading bay 5 to 7	01
6	Near ammonia tank outlet nozzles area	01
7	At ammonia tank top	01

Table 8.3.3: Details regarding Interlocks for Ammonia system

Interlock	Interlock Details	Interlock Description
1	Tank pressure and tank level high-high close HV 10201 and HV10202	If pressure is high-high (high-high pressure set at 800 mm WC) while ammonia unloading from vessel, it will close HV 10201 and HV 10202 (This interlock by pass while unloading shipment)
2	Tank pressure and tank level low-low close HV 10401 A,B,C,D and trip 10P01A,B	Tanker loading valve close and ammonia transfer pump trip (Low-low pressure set at 300 mmWC)
3	If valve XV 10203 is not fully open trip 10P0A,B	Ammonia transfer pump suction valve not open fully transfer pump trip (This interlock provided to avoid dry run of pump)
4A, 4B	10P0A,B fail to develop head in 1 min trip 10P01A,B	If discharge pressure of the pump not develop 16 kg/cm^2 then ammonia transfer pump trip
5	Tank pressure high-high HV 10205 open fully to vent	Ammonia tank vent open to flare when tank pressure raise to 900 mm WC
6	If any one of the level indication in anulus is higher than that in cup XV 10203 closes	If annulus (outer tank) level is high, inner tank outlet close
8A, 8B, 8C, 8D	Individual compressor trip on suction pressure low/low/ discharge temp/pressure high-high lube oil temp. High-high /primary oil separator oil level/low temp. of oil	Individual compressor trip if compressor section pressure low /low/discharge temp / pressure high high lube oil temp high-high / primary oil separator oil level / low temp of oil

10	XV 10201 closed when the last running compressor trips	Parallel to interlock no.01
11	Starts the selected compressor when pressure is high and selection is in auto mode through a selector switch and load to 100%	As compressor is running in manual mode and this interlock is applicable for auto mode of compressor
12	On pressure low stop any running compressor irrespective of the selector switch is auto/manual mode	If ammonia tank pressure is low-low that is 300 mm WC running compressor trip
17	Emergency stop for tripping all running compressor	For emergency stop of ammonia compressor
17A, 17B, 17C, 17D	Emergency stop for tripping all running compressor	For emergency stop of the individual compressor
18A, 18B, 18C, 18D	XV 10303A,B,C,D closed when corresponding compressor stop/trip and open when compressor starts	individual compressor stop when compressor stop and open when compressor start
19	Opening of PV 10313 initiates opening of XV 10301 and closing of PV 10313 result to closing of XV 10301 after a time delay of 0.1 min	To maintain ammonia level in the economiser
20	LV 10301 and PV 10313 closes when last compressor trips and open when first compressor start on 10V02 high pressure	Ammonia vapour going to tank and flare closed when compressor stop and start when compressor start
21	Trip any running transfer pump	For trip any running ammonia transfer pump
22	High-high level in vapour separator of economiser give alarm in control room and close XV 10302 and thereafter trip all running compressor	If ammonia level in the economiser high-high that is 90% then stop running compressor
23	Low level in ammonia receiver 10V02 close LV 10301 with alarm in control room	If ammonia level in ammonia receiver low then ammonia not go in the tank
32	On high and low level raw water, alarm appear on PC and trip the pump 105A/B on low-low level	Raw water pump stop when raw water tank level low
34	High and low level alarm in control room. On high level LV	When water level in cooling tower basin high LV 10501 closed and when water level in

	10501 closes and low level LV 10501 open	cooling tower basin low then open LV 10501

8.3.3 Collection of data/documents

The data/documents collected for the study as follows:

- HAZOP study report for Ammonia storage and associated facilities
- Risk Analysis and DMP report for Liquid Ammonia pipeline
- Onsite Emergency Control Plan
- Safety Audit report
- Population data
- Fire fighting system/arrangement with details
- MSDS of Ammonia and Phosphoric Acid

The generic failure rate data are taken from the available published literature.

8.3.4 Hazards of Ammonia

Ammonia is a colorless gas with a characteristic pungent smell. It is lighter than air, its density being 0.589 times that of air. It is easily liquefied due to strong hydrogen bonding between molecules. The liquid ammonia boils at -33^{0}C and freezes at -77.7 ^{0}C.

Ammonia is widely used as a refrigerant gas, as well as in the fertilizer industry. Ammonia is not considered as flammable gas. However, a large and intense energy source may cause ignition and/or explosion.

Ammonia gas can decompose at a high temperature forming very flammable hydrogen and toxic nitrogen dioxide. Ammonia gas is toxic gas and may be fatal if inhaled. Ammonia gas may cause lung injury, and the liquefied gas can cause frostbite and injury to eyes and skin. A 10-minute exposure to 30 ppm may be faintly irritating to some, while 50 ppm may be found to be moderately irritating by most.

Ammonia is having the flammability (N_F) classification as 1, Health hazard (N_H) classification as 3 and reactivity (N_R) classification as 0.

8.3.4.1 Dow's Fire & Explosion index of Ammonia

In order to rate Fire and Explosion hazards of handling and storage of Ammonia at JNPT, the Dow's Fire & Explosion Index (F&EI) is used.

Table 8.3.4: The NFPA hazard ranking of Ammonia:

Chemical	N_H	N_F	N_R
Ammonia	3	1	0

8.3.4.2 Summary of DOW's Fire and Explosion Index (F&EI):
For the Ammonia handling and storage, F&EI have been worked with conservative estimation as given in table below:

Table 8.3.5: Summery of DOW's F&EI

Chemical	MF	GPH	SPH	UHF	F&EI	Rating
Ammonia	04	1.70	2.92	4.96	19.86	LIGHT

Location **Storage**	Plant **Storage terminal**	PROCESS UNIT **Ammonia Handling & Storage**
STATE OF OPERATION **Ammonia Terminal**		BASIC MATERIAL(S) FOR MATERIAL FACTOR **Ammonia**

MATERIAL FACTOR	**04**

1. General Process Hazards		**Penalty Factor Range**	**Penalty Factor Used**
Base Factor		1.00	1.00
A. Exothermic Chemical Reactions		0.30 to 1.25	-----
B. Endothermic Processes		0.20 to 0.40	-----
C. Material Handling and Transfer		0.25 to 1.05	0.25
D. Enclosed or Indoor Process Units		0.25 to 0.90	-----
E. Access		0.20 to 0.35	0.20
F. Drainage and Spill Control	.	0.25 to 0.50	0.25
General Process Hazards Factor (F_1)			**1.70**
2. Special Process Hazards			
Base Factor		1.00	1.00
A. Toxic Material(s)		0.20 to 0.80	0.60
B. Sub-Atmospheric Pressure (< 500 mm Hg)		0.50	-----
C. Operation In or Near Flammable Range			-----
1. Tank Farms Storage Flammable Liquids		0.50	-----
2. Process Upset or Purge Failure		0.30	0.30
3. Always in Flammable Range		0.80	-----
D. Dust Explosion		0.25 to 2.00	-----
E. Pressure	Operating Pressure --- bar	From Figure	0.02
F. Low Temperature		0.20 to 0.30	0.30
G. Quantity of Flammable/Unstable Material:	Quantity = --- lb H_C = --- BTU/lb	16×10^{10}	-----
1. Liquids or Gases in Process		From Figure	-----
2. Liquids or Gases in Storage		From Figure	0.40
3. Combustible Solids in Storage, Dust in Process		From Figure	-----
H. Corrosion and Erosion		0.10 to 0.75	-----
I. Leakage – Joints and Packing		0.10 to 1.50	0.30
J. Use of Fired Equipment		From Figure	-----
K. Hot Oil Heat Exchange System		0.15 to 1.15	-----
L. Rotating Equipment		0.50	-----
Special Process Hazards Factor (F_2)			**2.92**
Process Unit Hazards Factor (F_1 x F_2) = F_3			**4.96**
Fire and Explosion Index (F_3 x MF = F&EI)			**19.86**
FIRE & EXPLOSION INDEX (RATINGS)			***LIGHT***

8.3.5 Consequence analysis

Based on a review of the plant details, the above leak scenarios have been considered for consequence analysis to assess the impact of fire, vapor cloud explosion and toxic dispersion.

Table 8.3.6: Consequence results for the Jet fire

Chemical handled	Leak scenarios	Weather conditions	Jet fire radiation distances (m)		
			37.5 kW/m^2	12.5 kW/m^2	4.0 kW/m^2
Ammonia	Leak	2-F	---	---	128
		5-D	---	91	111
	Fixed duration release	2-F	---	637	773
		5-D	438	533	645
	Short pipe leak	2-F	---	162	203
		5-D	---	147	177

Table 8.3.7: Consequence results for the Pool fire

Chemical handled	Leak scenarios	Weather conditions	Pool fire radiation distances (m)		
			37.5 kW/m^2	12.5 kW/m^2	4.0 kW/m^2
Ammonia	Leak	2-F	53	71	103
		5-D	---	77	105
	Fixed duration release	2-F	531	667	902
		5-D	529	691	907
	Short pipe leak	2-F	118	159	227
		5-D	118	169	230

Table 8.3.8: Consequence results for the Flash Fire

Chemical handled	Leak scenarios	Weather conditions	Flash Fire (m)
			LFL (ppm)
Ammonia	Leak	2-F	38
		5-D	50
	Fixed duration release	2-F	59
		5-D	63
	Short pipe leak	2-F	25
		5-D	29

Table 8.3.9: Consequence results for the Toxic impact

Chemical handled	Leak scenarios	Weather conditions	Toxic impact distance (m)
			IDLH (300 ppm)
Ammonia	Leak	2-F	> 10,000
		5-D	2210
	Fixed duration release	2-F	---
		5-D	
	Short pipe leak	2-F	> 10,000
		5-D	2162

Table 8.3.10: Consequence results for the Explosion

Chemical handled	Leak scenarios	Weather conditions	Explosion distances (m)		
			0.3 bar	0.1 bar	0.03 bar
Ammonia	Leak	2-F	84	89	166
		5-D	144	148	225
	Fixed duration release	2-F	152	173	516
		5-D	160	180	510
	Short pipe leak	2-F	51	58	175
		5-D	60	66	175

8.4 IOCL Terminal

MS, HSD, ATF, LSHFD handled and transferred from BPCL LCJ to IOCL Terminal

8.4.1 Facility description

IOCL is a public sector organization, located on Plot no. 8, Jaskhar Village, Opp. Port Users Building, JNPT Road, Tal-Uran, Dist- Raigad, Navi Mumbai-400 707. This Terminal is functional since April 2000, is operated in accordance with the provisions of licenses/consents granted by the Chief Controller of Explosive, Government of India, Chief Inspector of Factories, Maharashtra and Maharashtra Pollution Control Board, as per the relevant statutory Acts and Rules of Government of India and Government of Maharashtra. The Terminal has been designed, operated and maintained in accordance with the statutory provisions and industry standards to ensure its safe and smooth functioning**.**

Table 8.4.1: Neighboring facilities from IOCL JNPT Terminal

Sr. No.	Direction	Location	Approximate distance from IOCL Terminal (meters)
01	North	Neighboring facility	100
02	East	Uran Village road	50
03	South	Open Space	50
04	West	Open Space	50

IOCL is a marketing Division of MS, HSD, ATF and LSHF HSD. The terminal receives diesel from Pipeline, stores these in tanks and distributes these products by road tankers as well as through pipeline to different consumers.

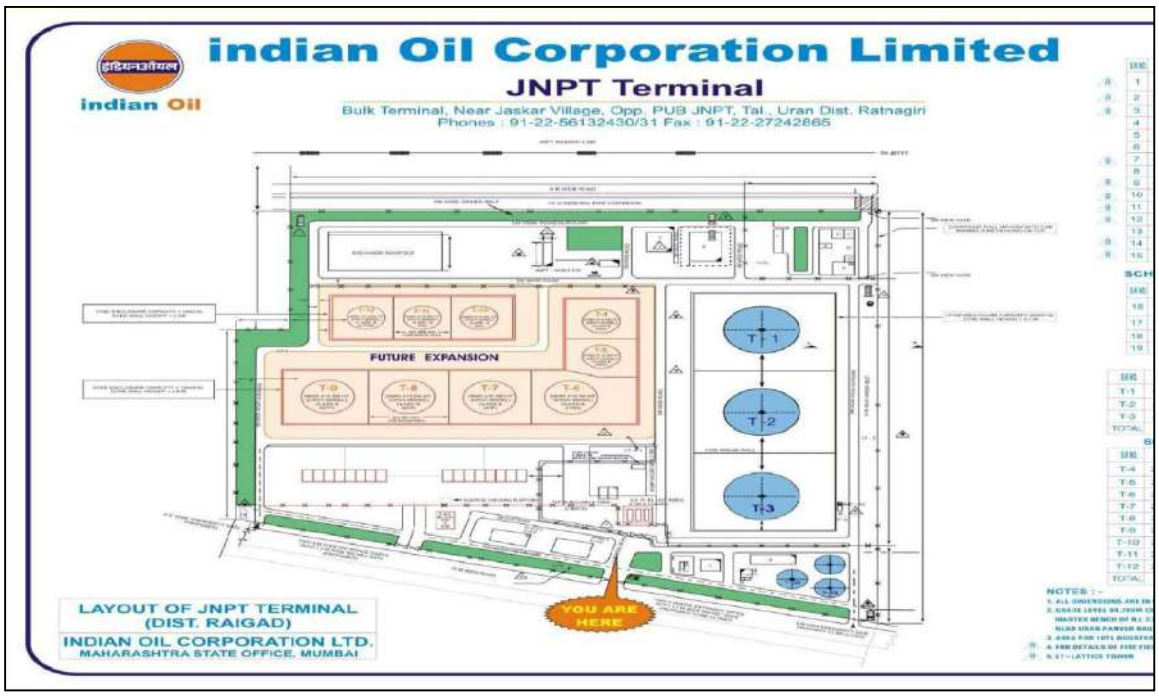


Fig 8.4.1: Layout of IOCL Terminal

8.4.2 Details of Storage Tanks

Table 8.4.2: Storage tank details

Sr. No.	Tank No.	Product	Height (m)	Diameter (m)	Capacity (KL)
1	T1	LSHF HSD	16.5	40	20000
2	T2	HSD	16.5	40	20000
3	T3	HSD	16.5	40	20000
4	T4	HSD	17	20	5000
5	T5	HSD	17	20	5000
6	T6	SKO	17	20	5000
7	T7	ATF	17	20	5000
8	T8	ATF	17.25	28	10000
9	T9	ATF	17.25	28	10000
10	T11	MS	14.5	20	4000
11	T12	MS	16.75	18	4000

There are 2 bays in TLF which are used for dispatch of for LSHF HSD, and HSD. Currently, the Terminal has a total of 6 nos. pumps. All pumps are dedicated to a particular service. The pump details at the Terminal are as given below.

Table 8.4.3: Pump Details

Pump No.	Product	Flow Rate (LPM)	Head	RPM	Use
01	JVPL MP1	220	110	1482	PLT
02	JVPL MP2	220	110	1482	PLT
03	JVPL MP3	220	110	1482	PLT
04	TLF P2A	144	39	2930	Delivery
05	TLF P2B	144	39	2930	Delivery
06	TLF P3C	60	25	1470	Delivery

Table 8.4.4: Fire Fighting Facilities

The IOCL-JNPT Terminal has fire extinguishers installed at strategic locations in the Terminal.				
Water Tank				
Tank No	**Dia. (m)**	**Height (m)**	**Capacity(KL)**	**Total Pumpable Water Storage**
18	16	15	2854	
19	16	15	2854	**11300 KL**
20	24	15	5600	

No of F/E	Pump		Engine	
	kl/hr	Head	HP	RPM
1	616	105	355	2100
2	616	105	355	2100
3	616	105	355	2100
4	616	105	355	2100
5	616	105	355	2100
6	616	105	355	2100

No of Jockey	Pump		Motor	
	kl/hr	Head(M)	KW	RPM
1	171	125	90	2900
2	171	125	90	2975

FIRE PUMP SEQUENCE		
FIRE PUMP NO.	**STARTS AT**	**STOPS AT**
Jockey Pump on AUTO	7.0 kg/cm2	8.0 kg/cm2
Second Jockey Pump	STAND BY	
First Fire Pump	6.5 kg/cm2	Manual STOP
Second Fire Pump	6.0 kg/cm2	Manual STOP
Third Fire pump	5.5 kg/cm2	Manual STOP
2 nos. of fire pumps	STAND BY	

Table 8.4.5: Fixed Fire Fighting Equipments covering all activities /operating areas:

Water Monitor	17 nos.
Water cum Foam Monitors	8 nos.
Double head hydrants	39 nos.
HVLR	2 nos.
Portable HVLR	3 nos.
MEFG	3 nos.

8.4.3 Fire Alarm System

8.4.3.1 Hydrocarbon Detection System

Hydrocarbon detection system is provided to detect vapors at area of potential leakages of class 'A' petroleum product within location like tank dyke, pump house drains & OWS. These detectors are placed in such a way that all possible sources of leaks and collection of products are continuously detected and alarm is set at 20% of lower explosive limit of class A.

Working of HCD

- On leakage of any hydrocarbon material, HCD will raise an audio alarm in TAS, control panel and in field.
- On hearing the sound, acknowledge alarm from TAS, filed or control panel.
- Physically check in field about source of leakage and quantity to assess the situation.
- In case of any leakage, attend the leak; collect the spilled product and clear contaminated oil from filed.
- Physically check in field about source of leakage and quantity to assess the situation.
- In case of any leakage, attend the leak ; collect the spilled product and clear
- Contaminated oil from filed.
- Reset the HCD

8.4.3.2 Dyke Valve Position Indicator

Dyke valve position indicator is provided to detect position of dyke valve storing hydrocarbon product. These detectors are placed in such a way that on opening valve (even crack opened) it will give an audio alarm in control room.

8.4.3.3 Rim Seal Protection System

Highlights of the Detection System

- Class A1 Heat Detection with UL / VdS approval.
- Sensitivity configurable through a wide range.
- High mechanical strength of the sensor tube.
- Continuous detection at every point of the sensor tube network.
- Self diagnostic & debugging for monitoring the system's healthiness.

8.4.4 Control Room Philosophy & Interlocks

Control room is the Data acquisition, processing, display, recording & controlling equipment for the Product pumps, ROSOVs, DBBVs, TLF equipment, Radar Tank gauging systems and Dyke Wall Valve position indicator System.

All the activities come under the domain of TAS (Terminal Automation System) which is categorized as:

1. Tank Truck Loading system
2. Tank Farm Management System

8.4.4.1 Tank Truck Loading System

- Comprises of Load Rack Computer system (LRCS) that controls the Tank Truck filling at TLF with accuracy of + 0.05% of the Batch.
- LRCS is integrated with SAP for Data communication & control required for filling of TTs at TLF.
- LRCS works on Supervisory Control & data Acquisition (SCADA) with main hardware components as Batch Controllers, Card readers, Remote Interaction Terminal, Digital control valve (DCV), Positive Displacement Flow metering system with strainer & air eliminator, Diff pressure gauge, pulse transmitter.
- Automatic Flow rate control from 0-2200 LPM.
- Multi product bays – separate flow meter for each product and one card reader irrespective of no. of products.
- Loading point with RIT (Remote Interaction Terminal)with 3 push button and lamps
- TT loading interlock with checks for earthing.
- Loading Arm: Self supported spring loaded pantograph type for only SKO TT loading temporary arrangement for top loading TTs for MS & HSD is also made which will be removed once bottom loading is started
- Bottom Loading Arm:
- Process shutdown switch at TLF, Product Pump House, Control room & Location In-charge's Cabin for ESD Philosophy.
- TT Entry & exit with card reader.

8.4.4.2 Tank Farm Management System (TFMS)

- Two nos. Radar Level Gauging with Temperature sensors for each tank.
- Accuracy of auto gauging equipments
  - Product Level : + 1 mm
  - Water Level : + 2 mm
  - Temperature : + 0.2 ^{0}C
- TFMS Computer gives Product level and Product quantity, Product temperature, High level alarm, High-High level alarm and triple High level alarm if product reaches Safe filling height, low level alarm & low-low level alarm if product reaches the minimum pumpable level.
- TFMS is integrated with LRCS.

8.4.5 Terminal Security System

- Closed Circuit Camera Television System (CCTV) comprising of 33 Cameras
- 24 Fixed Type Zoom (FTZ) Cameras provided each at in gate, out gate, Product Pump house, TT parking area and boundary walls.
- 4 Pan Tilt Zoom (PTZ) Cameras provided to cover TLF, Tank Farm.
- 5 HD Type Zoom (FTZ) Cameras provided each at

- LCD display is provided at Security cabin & LIC's cabin, Control room and Camera Control is provided at LIC's cabin
- 12 TB Hard disks are provided for Data storage capacity that can store the Data for 15 days.

Table 8.4.6: Population Details around IOCL

Sr. No.	Direction	Location	Distance from IOCL Terminal (meter)	Population Approx.
01	North	Open Space	5000	-
02	South	Open Space	5000	-
03	East	Zaskar Village	4000	1500
04	West	Neighbouring Facility	100	150
05	South-East	JNPT Township	4000	500

8.4.6 Collection of data/documents

The data/documents collected for the study as follows:

- Risk analysis report
- Emergency Response and Disaster Management Plan
- Population data
- MSDS of Petroleum products
- Fire fighting system/arrangement with details
- Storage tank details

8.4.7 Hazards of HSD and MS

HSD is having moderate fire hazard when exposed to heat and flame. HSD is stable under normal temperature and pressure in a closed container. HSD is having the flammability (N_F) classification as 2, Health hazard (N_H) classification as 0 and reactivity (N_R) classification as 0.

HSD is not considered to be particularly toxic and accidental poisoning is very rare. However, if diesel is swallowed, medical advice should be obtained immediately as there is a risk of short-term lung damage if vomiting occurs or if droplets of diesel are inhaled. Long term skin exposure to diesel may result in eczema (dermatitis) and should be avoided.

MS is having moderate fire hazard when exposed to heat and flame. MS is stable under normal temperature and pressure in a closed container. MS is having the flammability (N_F) classification as 3, Health hazard (N_H) classification as 1 and reactivity (N_R) classification as 0.

8.4.7.1 Dow's Fire & Explosion index of HSD and MS

In order to rate Fire and Explosion hazards of handling and storage of HSD and MS at JNPT, the Dow's Fire & Explosion Index (F&EI) is used.

Table 8.4.7: The NFPA hazard ranking of HSD and MS

Chemical	N_H	N_F	N_R
HSD	0	2	0
MS	1	3	0

8.4.7.2 Summary of DOW's Index

For the HSD and MS handling and storage, F&EI have been worked with conservative estimation as given in table below:

Table 8.4.8: Summary of DOW's F&EI

Chemical	MF	GPH	SPH	UHF	F&EI	Rating
HSD	10	2.45	1.70	4.165	41.65	LIGHT
MS	16	2.45	1.95	4.78	76.48	MODERATE

Location **Storage**	Plant **Storage Terminal**	PROCESS UNIT **HSD handling & Storage**
STATE OF OPERATION **HSD handling & Storage**		BASIC MATERIAL(S) FOR MATERIAL FACTOR **HSD**

MATERIAL FACTOR	**10**

1. General Process Hazards		**Penalty Factor Range**	**Penalty Factor Used**
Base Factor		1.00	1.00
A. Exothermic Chemical Reactions		0.30 to 1.25	-----
B. Endothermic Processes		0.20 to 0.40	-----
C. Material Handling and Transfer		0.25 to 1.05	0.85
D. Enclosed or Indoor Process Units		0.25 to 0.90	-----
E. Access		0.20 to 0.35	0.35
F. Drainage and Spill Control	.	0.25 to 0.50	0.25
General Process Hazards Factor (F_1)			**2.45**
2. Special Process Hazards			
Base Factor		1.00	1.00
A. Toxic Material(s)		0.20 to 0.80	-----
B. Sub-Atmospheric Pressure (< 500 mm Hg)		0.50	-----
C. Operation In or Near Flammable Range			-----
1. Tank Farms Storage Flammable Liquids		0.50	0.50
2. Process Upset or Purge Failure		0.30	-----
3. Always in Flammable Range		0.80	-----
D. Dust Explosion		0.25 to 2.00	-----
E. Pressure	Operating Pressure 1.2 bar Relief Setting -- bar	From Figure	-----
F. Low Temperature		0.20 to 0.30	-----
G. Quantity of Flammable/Unstable Material:	Quantity = --- lb H_C = --- BTU/lb	93.5×10^6	-----
1. Liquids or Gases in Process		From Figure	-----
2. Liquids or Gases in Storage		From Figure	0.10
3. Combustible Solids in Storage, Dust in Process		From Figure	-----
H. Corrosion and Erosion		0.10 to 0.75	-----
I. Leakage – Joints and Packing		0.10 to 1.50	0.10
J. Use of Fired Equipment		From Figure	-----
K. Hot Oil Heat Exchange System		0.15 to 1.15	-----
L. Rotating Equipment		0.50	-----
Special Process Hazards Factor (F_2)			**1.7**
Process Unit Hazards Factor (F_1 x F_2) = F_3			**4.165**
Fire and Explosion Index (F_3 x MF = F&EI)			**41.65**
FIRE & EXPLOSION INDEX (RATINGS)			***LIGHT***

Location **Storage**	Plant **Storage Terminal**	PROCESS UNIT **MS Handling & Storage**
STATE OF OPERATION **MS Handling & Storage**		BASIC MATERIAL(S) FOR MATERIAL FACTOR **MS**

MATERIAL FACTOR	**16**

1. General Process Hazards		**Penalty Factor Range**	**Penalty Factor Used**
Base Factor		1.00	1.00
A. Exothermic Chemical Reactions		0.30 to 1.25	-----
B. Endothermic Processes		0.20 to 0.40	-----
C. Material Handling and Transfer		0.25 to 1.05	0.85
D. Enclosed or Indoor Process Units		0.25 to 0.90	-----
E. Access		0.20 to 0.35	0.35
F. Drainage and Spill Control	.	0.25 to 0.50	0.25
General Process Hazards Factor (F_1)			**2.45**
2. Special Process Hazards			
Base Factor		1.00	1.00
A. Toxic Material(s)		0.20 to 0.80	0.20
B. Sub-Atmospheric Pressure (< 500 mm Hg)		0.50	-----
C. Operation In or Near Flammable Range			-----
1. Tank Farms Storage Flammable Liquids		0.50	0.50
2. Process Upset or Purge Failure		0.30	-----
3. Always in Flammable Range		0.80	-----
D. Dust Explosion		0.25 to 2.00	-----
E. Pressure	Operating Pressure 1.2 bar Relief Setting -- bar	From Figure	-----
F. Low Temperature		0.20 to 0.30	-----
G. Quantity of Flammable/Unstable Material:	Quantity = --- lb H_C = --- BTU/lb	198×10^6	-----
1. Liquids or Gases in Process		From Figure	-----
2. Liquids or Gases in Storage		From Figure	0.15
3. Combustible Solids in Storage, Dust in Process		From Figure	-----
H. Corrosion and Erosion		0.10 to 0.75	-----
I. Leakage – Joints and Packing		0.10 to 1.50	0.10
J. Use of Fired Equipment		From Figure	-----
K. Hot Oil Heat Exchange System		0.15 to 1.15	-----
L. Rotating Equipment		0.50	-----
Special Process Hazards Factor (F_2)			**1.95**
Process Unit Hazards Factor (F_1 x F_2) = F_3			**4.78**
Fire and Explosion Index (F_3 x MF = F&EI)			**76.48**
FIRE & EXPLOSION INDEX (RATINGS)			***MODERATE***

8.4.8 Consequence analysis

Based on a review of the plant details, the above leak scenarios have been considered for consequence analysis to assess the impact of fire, vapour cloud explosion and toxic dispersion. No hazard distances for VCE and jet fire scenarios.

Consequence analysis results for the chemicals handled at IOCL tank Farm.

Table 8.4.9: Consequence results for the Jet fire

Chemical handled	Leak scenarios	Weather conditions	Jet fire radiation distances (m)		
			37.5 kW/m^2	12.5 kW/m^2	4.0 kW/m^2
MS	Leak	2-F	95	117	152
		5-D	84	105	140
	Fixed duration release	2-F	366	452	595
		5-D	309	389	524
	Short pipe leak	2-F	135	165	214
		5-D	121	151	200
HSD	Leak	2-F	30	36	47
		5-D	27	34	45
	Fixed duration release	2-F	100	124	163
		5-D	86	108	146
	Short pipe leak	2-F	26	32	41
		5-D	25	30	40
ATF	Leak	2-F	68	83	108
		5-D	60	75	100
	Fixed duration release	2-F	211	261	343
		5-D	180	228	307
	Short pipe leak	2-F	72	88	113
		5-D	67	83	110

Table 8.4.10: Consequence results for the Pool fire

Chemical handled	Leak scenarios	Weather conditions	Pool fire radiation distances (m)		
			37.5 kW/m^2	12.5 kW/m^2	4.0 kW/m^2
MS	Leak	2-F	---	25	54
		5-D	---	28	64
	Fixed duration release	2-F	---	120	232
		5-D	---	120	273
	Short pipe leak	2-F	---	37	86

		5-D	---	38	104
HSD	Leak	2-F	---	28	59
		5-D	---	29	68
	Fixed duration release	2-F	---	316	518
		5-D	---	313	579
	Short pipe leak	2-F	---	48	105
		5-D	---	49	123
ATF	Leak	2-F	---	26	56
		5-D	---	28	66
	Fixed duration release	2-F	---	149	277
		5-D	---	149	321
	Short pipe leak	2-F	---	41	93
		5-D	---	42	112

Table 8.4.11: Consequence results for the Flash Fire

Chemical handled	**Leak scenarios**	**Weather conditions**	**Flash Fire (m)**
			LFL (ppm)
MS	Leak	2-F	328
		5-D	167
	Fixed duration release	2-F	2827
		5-D	1300
	Short pipe leak	2-F	897
		5-D	349
HSD	Leak	2-F	202
		5-D	58
	Fixed duration release	2-F	1621
		5-D	271
	Short pipe leak	2-F	213
		5-D	7
ATF	Leak	2-F	327
		5-D	136
	Fixed duration release	2-F	2243
		5-D	897
	Short pipe leak	2-F	843
		5-D	294

Table 8.4.12: Consequence results for the Explosion

Chemical handled	Leak scenarios	Weather conditions	Explosion distances (m)		
			0.3 bar	0.1 bar	0.03 bar
MS	Leak	2-F	576	625	1433
		5-D	304	325	679
	Fixed duration release	2-F	3654	3686	7212
		5-D	2022	2143	4559
	Short pipe leak	2-F	1531	1652	3652
		5-D	670	721	1552
HSD	Leak	2-F	357	386	864
		5-D	137	149	351
	Fixed duration release	2-F	3154	3232	5629
		5-D	613	664	1509
	Short pipe leak	2-F	521	521	1006
		5-D	---	---	---
ATF	Leak	2-F	579	628	1449
		5-D	270	290	621
	Fixed duration release	2-F	3308	3410	6756
		5-D	1267	1285	2417
	Short pipe leak	2-F	1518	1647	3790
		5-D	1451	653	604

8.5 Ganesh Benzoplast Ltd. Terminal

8.5.1 Facility Description

M/s Ganesh Benzoplast Limited is located in the Liquid chemical corridor of JNPT. The company has started its operation in 1994. It is engaged in storage of storage of imported edible oil, lube oil, Molasses, Acetic Acid, Mono Ethylene Glycol, Kerosene, etc.

There are two terminals of GBL.
Terminal A – 41 Tanks
Terminal B – 22 Tanks

The company has started its Unit B operation in 2014. The company is running its activities in three shifts. Total 100 employees including contract workers are engaged for running the activities at site.

The ships bringing imported chemicals are parked at JNPT jetty (BPCL Jetty/SWB) and the chemicals are transferred to storage tanks at GBL terminal. All tanks are above ground tanks. The cargoes are transferred to site from distance of 5 Km through pipeline.

Table 8.5.1: Pipeline details

Sr. No.	Nature of Pipeline	Diameter (inches)	Material of Construction
1	Pipeline from Port to terminal	18	M.S.
2	Pipeline from Port to terminal	12	M.S.
3	Pipeline from Port to terminal	12	S.S.
4	Pipeline from Port to terminal	8	S.S.

Table 8.5.2: Storage Tank Details

Tank No.	Diameter (cm)	Height (cm)	Ref. Height (cm)	Capacity (KL)
101	2800	1800	1823.6	10000
102	2800	1800	1828.3	8500
103	2800	1800	1812.5	8500
104	2100	1850	1876.5	5200
105	2100	1650	1697	5200
106	2100	1650	1665.5	5600
107	2100	1650	1673	5500
108	1598	1400	1436.9	2750
109	1600	1400	1441.9	2800
110	1600	1400	1446.2	2750
111	1600	1190	1219.5	2419
112	1200	1050	1082.3	1120
113	1200	1050	1089	1100

114	1200	1050	1084.8	1100
115	1200	1047.6	1073.5	1100
116	1200	1050	1089	1100
117	1200	1000	1087	1100
118	1200	1050	1088.2	1100
119	1200	1050	1089.7	1100
120	1000	800	831.4	600
121	1000	800	826	600
122	1000	800	834.5	600
123	1000	800	838	600
128	1600	1400	1444	2800
129	1600	1400	1411.9	2850
130	1600	1380	1412	2650
131	1600	1400	1408	2700
132	2100	1650	1675	5550
133	2100	1650	1696.4	5200
134	2100	1650	1668.5	5200
135	2100	1622	1645.5	5200
136	2100	1635	1666	5500
137	2100	1635	1680.7	5500
138	2100	1650	1671.1	5500
139	2800	2150	2185.1	12000
141	2800	2150	2188.4	15000
140A	2350	2250	2270	6000
140B	2150	2250	2268	6000
140C	2100	2250	2264.5	6500
140D	2100	1200	2070	5000
140E	1850	2250	2268	6050

8.5.2 Fire Fighting Facility

Terminal fire fighting system comprises of fixed and portable fire fighting equipments as following:

a) Fire Hydrant Network – All around the terminal boundary and hazardous operating area consisting of fire hydrant valves & monitors, Medium Velocity Water Sprinkler System are available.

b) Diesel Generators: presently a hired Diesel generator set is available.

Sr. No.	Fire fighting details	
1	Water storage capacity	2000 KL
2	Fire fighting pump	2 nos. (1 electrical driven, 1 diesel driven), 410 m^3/hr
3	Jockey pump	1 no., 25 m^3/hr
4	No. of Double Hydrant Points	35 nos.
5	Water cum foam Monitor	1 no.
6	No. of Fire Hose Boxes	35 nos.

8.5.3 Collection of data/documents

The data/documents collected for the study as follows:

- Risk analysis report
- Onsite Emergency Plan
- Safety Audit report
- Maximum credible loss analysis
- Storage tank details
- Population data
- Fire fighting system/arrangement with details

8.5.4 Hazards of Chemicals handled and stored at terminal:

The various hazardous chemicals handled and stored by GBL are given in table 7.2.
Acetone is having the flammability (N_F) classification as 3, Health hazard (N_H) classification as 1 and reactivity (N_R) classification as 0.

Toluene is having the flammability (N_F) classification as 3, Health hazard (N_H) classification as 2 and reactivity (N_R) classification as 0.

Vinyl acetate is having the flammability (N_F) classification as 3, Health hazard (N_H) classification as 2 and reactivity (N_R) classification as 2.

8.5.4.1 Dow's Fire & Explosion index

In order to rate Fire and Explosion hazards of handling and storage of chemicals, the Dow's Fire & Explosion Index (F&EI) is used.

Table 8.5.3: The NFPA hazard ranking of:

Chemical	N_H	N_F	N_R
Acetone	1	3	0
Toluene	2	3	0
Vinyl Acetate	2	3	2

8.5.4.2 Summary of DOW's Fire and Explosion Index (F&EI):
For the chemicals handling and storage, F&EI have been worked with conservative estimation as given in table below:

Table 8.5.4: Summery of DOW's F&EI

Chemical	MF	GPH	SPH	UHF	F&EI	Rating
Acetone	16	2.45	1.80	4.41	70.56	MODERATE
Toluene	16	2.45	2.00	4.90	78.4	MODERATE
Vinyl Acetate	24	2.45	2.10	5.15	123.5	INTERMEDIATE

Location **Storage**	Plant **Storage Terminal**	PROCESS UNIT **Acetone Handling & Storage**
STATE OF OPERATION **Acetone Handling & Storage**		BASIC MATERIAL(S) FOR MATERIAL FACTOR **Acetone**

MATERIAL FACTOR	**16**

1. General Process Hazards		**Penalty Factor Range**	**Penalty Factor Used**
Base Factor		1.00	1.00
A. Exothermic Chemical Reactions		0.30 to 1.25	-----
B. Endothermic Processes		0.20 to 0.40	-----
C. Material Handling and Transfer		0.25 to 1.05	0.85
D. Enclosed or Indoor Process Units		0.25 to 0.90	-----
E. Access		0.20 to 0.35	0.35
F. Drainage and Spill Control	.	0.25 to 0.50	0.25
General Process Hazards Factor (F_1)			**2.45**
2. Special Process Hazards			
Base Factor		1.00	1.00
A. Toxic Material(s)		0.20 to 0.80	0.20
B. Sub-Atmospheric Pressure (< 500 mm Hg)		0.50	-----
C. Operation In or Near Flammable Range			-----
1. Tank Farms Storage Flammable Liquids		0.50	0.50
2. Process Upset or Purge Failure		0.30	-----
3. Always in Flammable Range		0.80	-----
D. Dust Explosion		0.25 to 2.00	-----
E. Pressure	Operating Pressure --- bar Relief Setting -- bar	From Figure	-----
F. Low Temperature		0.20 to 0.30	-----
G. Quantity of Flammable/Unstable Material:	Quantity = ---- lb H_C = ---- BTU/lb	198 x 10^6	-----
1. Liquids or Gases in Process		From Figure	-----
2. Liquids or Gases in Storage		From Figure	-----
3. Combustible Solids in Storage, Dust in Process		From Figure	-----
H. Corrosion and Erosion		0.10 to 0.75	-----
I. Leakage – Joints and Packing		0.10 to 1.50	0.10
J. Use of Fired Equipment		From Figure	-----
K. Hot Oil Heat Exchange System		0.15 to 1.15	-----
L. Rotating Equipment		0.50	-----
Special Process Hazards Factor (F_2)			**1.80**
Process Unit Hazards Factor (F_1 x F_2) = F_3			**4.41**
Fire and Explosion Index (F_3 x MF = F&EI)			**70.56**
FIRE & EXPLOSION INDEX (RATINGS)			***MODERATE***

Location **Storage**	Plant **Storage Terminal**	PROCESS UNIT **Toluene Handling & Storage**
STATE OF OPERATION **Toluene Handling & Storage**		BASIC MATERIAL(S) FOR MATERIAL FACTOR **Toluene**

MATERIAL FACTOR	**16**

1. General Process Hazards		**Penalty Factor Range**	**Penalty Factor Used**
Base Factor		1.00	1.00
A. Exothermic Chemical Reactions		0.30 to 1.25	-----
B. Endothermic Processes		0.20 to 0.40	-----
C. Material Handling and Transfer		0.25 to 1.05	0.85
D. Enclosed or Indoor Process Units		0.25 to 0.90	-----
E. Access		0.20 to 0.35	0.35
F. Drainage and Spill Control		0.25 to 0.50	0.25
General Process Hazards Factor (F_1)			**2.45**
2. Special Process Hazards			
Base Factor		1.00	1.00
A. Toxic Material(s)		0.20 to 0.80	0.40
B. Sub-Atmospheric Pressure (< 500 mm Hg)		0.50	-----
C. Operation In or Near Flammable Range			-----
1. Tank Farms Storage Flammable Liquids		0.50	0.50
2. Process Upset or Purge Failure		0.30	-----
3. Always in Flammable Range		0.80	-----
D. Dust Explosion		0.25 to 2.00	-----
E. Pressure	Operating Pressure --- bar Relief Setting -- bar	From Figure	-----
F. Low Temperature		0.20 to 0.30	-----
G. Quantity of Flammable/Unstable Material:	Quantity = ---- lb H_C = ---- BTU/lb	198 x 10^6	-----
1. Liquids or Gases in Process		From Figure	-----
2. Liquids or Gases in Storage		From Figure	-----
3. Combustible Solids in Storage, Dust in Process		From Figure	-----
H. Corrosion and Erosion		0.10 to 0.75	-----
I. Leakage – Joints and Packing		0.10 to 1.50	0.10
J. Use of Fired Equipment		From Figure	-----
K. Hot Oil Heat Exchange System		0.15 to 1.15	-----
L. Rotating Equipment		0.50	-----
Special Process Hazards Factor (F_2)			**2.00**
Process Unit Hazards Factor (F_1 x F_2) = F_3			**4.90**
Fire and Explosion Index (F_3 x MF = F&EI)			**78.40**
FIRE & EXPLOSION INDEX (RATINGS)			***MODERATE***

Location **Storage**	Plant **Storage Terminal**	PROCESS UNIT **Vinyl Acetate Handling & Storage**
STATE OF OPERATION **Vinyl Acetate Handling & Storage**		BASIC MATERIAL(S) FOR MATERIAL FACTOR **Vinyl Acetate**

MATERIAL FACTOR	**24**

1. General Process Hazards		**Penalty Factor Range**	**Penalty Factor Used**
Base Factor		1.00	1.00
A. Exothermic Chemical Reactions		0.30 to 1.25	-----
B. Endothermic Processes		0.20 to 0.40	-----
C. Material Handling and Transfer		0.25 to 1.05	0.85
D. Enclosed or Indoor Process Units		0.25 to 0.90	-----
E. Access		0.20 to 0.35	0.35
F. Drainage and Spill Control	.	0.25 to 0.50	0.25
General Process Hazards Factor (F_1)			**2.45**
2. Special Process Hazards			
Base Factor		1.00	1.00
A. Toxic Material(s)		0.20 to 0.80	0.40
B. Sub-Atmospheric Pressure (< 500 mm Hg)		0.50	-----
C. Operation In or Near Flammable Range			-----
1. Tank Farms Storage Flammable Liquids		0.50	0.50
2. Process Upset or Purge Failure		0.30	-----
3. Always in Flammable Range		0.80	-----
D. Dust Explosion		0.25 to 2.00	-----
E. Pressure	Operating Pressure --- bar Relief Setting -- bar	From Figure	-----
F. Low Temperature		0.20 to 0.30	-----
G. Quantity of Flammable/Unstable Material:	Quantity = ---- lb H_C = ---- BTU/lb	198 x 10^6	-----
1. Liquids or Gases in Process		From Figure	-----
2. Liquids or Gases in Storage		From Figure	-----
3. Combustible Solids in Storage, Dust in Process		From Figure	-----
H. Corrosion and Erosion		0.10 to 0.75	-----
I. Leakage – Joints and Packing		0.10 to 1.50	0.10
J. Use of Fired Equipment		From Figure	-----
K. Hot Oil Heat Exchange System		0.15 to 1.15	-----
L. Rotating Equipment		0.50	-----
Special Process Hazards Factor (F_2)			**2.10**
Process Unit Hazards Factor (F_1 x F_2) = F_3			**5.15**
Fire and Explosion Index (F_3 x MF = F&EI)			**123.5**
FIRE & EXPLOSION INDEX (RATINGS)			***INTERMEDIATE***

8.5.5 Consequence analysis

Based on a review of the plant details, the above leak scenarios have been considered for consequence analysis to assess the impact of fire, vapour cloud explosion and toxic dispersion. No hazard distances for VCE and jet fire scenarios.

Table 8.5.5: Jet Fire results for various scenarios are shown below

Chemical handled	Leak scenarios	Weather conditions	Jet fire radiation distances (m)		
			37.5 kW/m^2	12.5 kW/m^2	4.0 kW/m^2
Acetic Acid	Leak	2-F	---	30	37
		5-D	---	27	33
	Fixed duration release	2-F	---	115	140
		5-D	80	97	120
	Short pipe leak	2-F	---	33	40
		5-D	---	30	36
Acetone	Leak	2-F	67	82	102
		5-D	60	72	92
	Fixed duration release	2-F	205	247	312
		5-D	175	213	276
	Short pipe leak	2-F	80	97	120
		5-D	76	91	115
Aniline	Leak	2-F	---	8	10
		5-D	6	7	9
	Fixed duration release	2-F	13	16	20
		5-D	11	14	18
	Short pipe leak	2-F	---	8	10
		5-D	7	8	10
Dichlorom ethane	Leak	2-F	---	75	91
		5-D	54	66	80
	Fixed duration release	2-F	248	306	372
		5-D	214	258	319
	Short pipe leak	2-F	---	135	165
		5-D	98	119	145
Styrene	Leak	2-F	19	23	29
		5-D	17	21	27
	Fixed duration release	2-F	53	65	84
		5-D	46	57	75
	Short pipe leak	2-F	24	29	37

		5-D	21	26	34
Toluene	Leak	2-F	34	41	53
		5-D	31	38	49
	Fixed duration release	2-F	115	140	182
		5-D	98	122	163
	Short pipe leak	2-F	43	53	67
		5-D	39	48	63
Vinyl Acetate Monomer	Leak	2-F	54	65	81
		5-D	48	58	74
	Fixed duration release	2-F	192	232	295
		5-D	163	200	260
	Short pipe leak	2-F	75	90	113
		5-D	68	82	105
Xylene	Leak	2-F	22	26	34
		5-D	20	24	32
	Fixed duration release	2-F	72	88	114
		5-D	61	76	102
	Short pipe leak	2-F	27	33	42
		5-D	24	30	39

Table 8.5.6: Consequence results for the Pool fire

Chemical handled	**Leak scenarios**	**Weather conditions**	**Pool fire radiation distances (m)**		
			37.5 kW/m^2	**12.5 kW/m^2**	**4.0 kW/m^2**
Acetic Acid	Leak	2-F	---	41	77
		5-D	---	42	84
	Fixed duration release	2-F	---	406	593
		5-D	---	407	635
	Short pipe leak	2-F	---	95	168
		5-D	---	96	183
Acetone	Leak	2-F	44	76	117
		5-D	51	81	119
	Fixed duration release	2-F	288	452	698
		5-D	319	468	705
	Short pipe leak	2-F	99	166	260
		5-D	115	174	264
Aniline	Leak	2-F	64	101	156

		5-D	73	105	157
	Fixed duration release	2-F	213	335	517
		5-D	237	345	521
	Short pipe leak	2-F	127	203	317
		5-D	143	210	320
Dichloromethane	Leak	2-F	---	41	77
		5-D	---	41	84
	Fixed duration release	2-F	---	281	460
		5-D	---	304	483
	Short pipe leak	2-F	---	110	199
		5-D	---	119	212
Styrene	Leak	2-F	---	28	61
		5-D	---	29	70
	Fixed duration release	2-F	---	126	229
		5-D	---	126	260
	Short pipe leak	2-F	---	63	128
		5-D	---	63	147
Toluene	Leak	2-F	---	26	58
		5-D	---	28	68
	Fixed duration release	2-F	---	162	289
		5-D	---	161	328
	Short pipe leak	2-F	---	57	120
		5-D	---	58	140
Vinyl Acetate Monomer	Leak	2-F	39	74	115
		5-D	44	80	118
	Fixed duration release	2-F	289	465	718
		5-D	325	487	728
	Short pipe leak	2-F	107	186	293
		5-D	126	198	298
Xylene	Leak	2-F	---	27	59
		5-D	---	29	68
	Fixed duration release	2-F	---	168	297
		5-D	---	168	335
	Short pipe leak	2-F	---	60	124
		5-D	---	60	143

Table 8.5.7: Consequence results for the Flash Fire

Chemical handled	Leak scenarios	Weather conditions	Flash Fire (m) LFL (ppm)
Acetic Acid	Leak	2-F	10
		5-D	11
	Fixed duration release	2-F	33
		5-D	46
	Short pipe leak	2-F	25
		5-D	17
Acetone	Leak	2-F	160
		5-D	78
	Fixed duration release	2-F	1174
		5-D	466
	Short pipe leak	2-F	466
		5-D	146
Aniline	Leak	2-F	8
		5-D	8
	Fixed duration release	2-F	12
		5-D	14
	Short pipe leak	2-F	7
		5-D	8
Dichloromethane	Leak	2-F	13
		5-D	16
	Fixed duration release	2-F	79
		5-D	277
	Short pipe leak	2-F	103
		5-D	74
Styrene	Leak	2-F	15
		5-D	21
	Fixed duration release	2-F	52
		5-D	57
	Short pipe leak	2-F	84
		5-D	27
Toluene	Leak	2-F	88
		5-D	44
	Fixed duration release	2-F	635
		5-D	226

	Short pipe leak	2-F	283
		5-D	80
Vinyl Acetate Monomer	Leak	2-F	113
		5-D	54
	Fixed duration release	2-F	900
		5-D	401
	Short pipe leak	2-F	410
		5-D	130
Xylene	Leak	2-F	19
		5-D	24
	Fixed duration release	2-F	102
		5-D	88
	Short pipe leak	2-F	120
		5-D	32

Table 8.5.8: Consequence results for the Toxic impact

Chemical handled	**Leak scenarios**	**Weather conditions**	**Toxic impact distance (m)**
			IDLH (ppm)
Acetic Acid	Leak	2-F	3682
		5-D	1078
	Fixed duration release	2-F	19703
		5-D	7326
	Short pipe leak	2-F	6665
		5-D	2205
Acetone	Leak	2-F	----
		5-D	----
	Fixed duration release	2-F	----
		5-D	----
	Short pipe leak	2-F	----
		5-D	----
Aniline	Leak	2-F	387
		5-D	221
	Fixed duration release	2-F	772
		5-D	375
	Short pipe leak	2-F	563
		5-D	175

Dichloromethane	Leak	2-F	----
		5-D	----
	Fixed duration release	2-F	----
		5-D	----
	Short pipe leak	2-F	----
		5-D	----
Styrene	Leak	2-F	----
		5-D	----
	Fixed duration release	2-F	----
		5-D	----
	Short pipe leak	2-F	----
		5-D	----
Toluene	Leak	2-F	----
		5-D	----
	Fixed duration release	2-F	----
		5-D	----
	Short pipe leak	2-F	----
		5-D	----
Vinyl Acetate Monomer	Leak	2-F	----
		5-D	----
	Fixed duration release	2-F	----
		5-D	----
	Short pipe leak	2-F	----
		5-D	----
Xylene	Leak	2-F	----
		5-D	----
	Fixed duration release	2-F	----
		5-D	----
	Short pipe leak	2-F	----
		5-D	----

Table 8.5.9: Consequence results for the Explosion

Chemical handled	**Leak scenarios**	**Weather conditions**	**Explosion distances (m)**		
			0.3 bar	**0.1 bar**	**0.03 bar**
Acetic Acid	Leak	2-F	11	11	16
		5-D	11	11	17
	Fixed duration	2-F	96	101	190

	release	5-D	113	121	249
	Short pipe leak	2-F	95	100	180
		5-D	24	25	46
Acetone	Leak	2-F	272	292	633
		5-D	149	159	318
	Fixed duration release	2-F	1457	1489	2762
		5-D	874	942	2071
	Short pipe leak	2-F	617	638	1410
		5-D	320	346	787
Aniline	Leak	2-F	11	11	15
		5-D	23	25	44
	Fixed duration release	2-F	12	13	24
		5-D	12	13	25
	Short pipe leak	2-F	---	---	---
		5-D	---	---	---
Dichloromethane	Leak	2-F	36	39	74
		5-D	35	37	63
	Fixed duration release	2-F	259	279	608
		5-D	527	552	975
	Short pipe leak	2-F	316	334	641
		5-D	162	172	346
Styrene	Leak	2-F	45	47	77
		5-D	46	48	79
	Fixed duration release	2-F	200	209	372
		5-D	142	153	330
	Short pipe leak	2-F	178	191	414
		5-D	50	53	105
Toluene	Leak	2-F	164	175	361
		5-D	86	91	177
	Fixed duration release	2-F	873	888	1613
		5-D	480	520	1184
	Short pipe leak	2-F	399	420	1036
		5-D	195	214	520
Vinyl Acetate Monomer	Leak	2-F	204	215	443
		5-D	116	124	266
	Fixed duration release	2-F	1164	1191	2015
		5-D	725	783	1748

	Short pipe leak	2-F	558	577	1356
		5-D	274	299	709
Xylene	Leak	2-F	68	70	113
		5-D	47	49	85
	Fixed duration release	2-F	313	331	624
		5-D	208	224	490
	Short pipe leak	2-F	217	236	550
		5-D	62	66	131

8.6 Shell terminal

8.6.1 Facility Description

M/s Shell India Markets Pvt. Ltd. (SIMPL) formally known as Bharat Shell Ltd. (BSL) is a Shell Overseas Investments B.V. - Netherlands (An affiliate of the Royal Dutch Shell Group) company setup in 1993 is located Opposite to I.M.C. Limited, Sheva, JNPT, Navi Mumbai-400707. SIMPL commissioned its first state of the art Lubricant Oil Blending Plant (LOBP) in Taloja, near Mumbai in January 1997 to manufacture a range of Shell branded lubricants.

SIMPL is approximately 25 Km away from LOBP and is set up on approx. 5000 m^2 area allocated to SIMPL by Port Authorities in their Liquid Cargo User Terminal. The storage capacity of the Terminal is approx. 15000 KL. All tanks are atmospheric tanks. Base Oils are received at the JNPT Terminal from Shell approved refineries by marine vessel. The Base Oils are unloaded and transferred from the port to the Terminal by approximately 4.5 Km long Tanker Discharge Line (TDL). These oils are then transferred in road tanker to the LOBP.

8.6.2 Fire protection

- Portable Extinguishers
- Fire hydrant system with water monitors
- Fire Pump House – 1 no.
- 2 fresh water tanks 200 m^3 of each

8.6.3 Collection of data/documents

The data/documents collected for the study as follows:

- Emergency Response Plan
- Safety Audit report
- Population data
- Mock Drill report
- Pipeline hydrostatic test report
- Terminal Information Booklet

The hazard of Terminal is Low due to properties of base oils; further consequence assessment study has not been carried out.

8.7 Suraj Agro Terminal

8.7.1 Facility Description

M/s Suraj Agro Infrastructure (India) Pvt. Ltd. is located in the Plot No. 4, Liquid Chemical Corridor of JNPT from 1998. It is engaged in storage of imported Edible oil, Molasses, etc. There are 14 storage tanks of different capacities. All tanks are above ground tanks. The product are transferred from BPCL LCJ to Suraj Agro site from the distance of 4 km, through pipeline of 18", 12" (M.S.) and 8" (S.S.) and it is being stored in storage tank.

Material stored at site then dispatched to the importers through tankers. About 80 to 90 tankers are loaded and dispatched every day through this facility.

Table 8.7.1: Storage Tank Details

Tank No.	Product	Capacity (KL)	Ref. Heights (cm)	Diameter/ Height (m)	Safe Filling Capacity (KL)
01	Edible Oil	10000	2050.9	25/20	9696
02	Edible Oil	10000	2044.0	25/20	9780.4
03	Edible Oil	10000	2051.5	25/20	9695
04	Edible Oil	10000	2049.7	25/20	9783.35
05	Edible Oil	3500	2035.7	15/20	3453.49
06	Edible Oil	3500	2032.5	15/20	3455.72
07	Edible Oil	3500	2032.5	15/20	3452.924
08	Edible Oil	3500	2033.8	15/20	3475.913
09	Edible Oil	3500	2044.0	15/20	3456.28
10	Edible Oil	3500	2035.9	15/20	3515.916
11	Edible Oil	3500	2029.7	15/20	3451.16
12	Edible Oil	600	1253.7	8/12	587
13	Slop Tank	20			
14	Water Tank	500			
15	Edible Oil	50	500	8/10	500

Table 8.7.2: Fire Protection

Sr. No.	Tank No.	Hydrant/Monitor
01	01	DH-4, WM-1
02	02	WM-1, DH-1
03	03	WM-2, DH-4
04	04	WM-6, DH-1
05	05	SH-11, SH-10
06	06	WM-6, DH-2
07	07	WM-3, SH-10
08	08	WM-5, DH-2

09	09	WM-3, SH-9
10	10	WM-5, DH-3
11	11	WM-4, DH-3
12	12	WM-4, SH-9
13	13	SH-8

8.7.2 Collection of data/documents

The data/documents collected for the study as follows:

- Emergency Response Plan
- Safety Audit report
- Safety Report
- Population data
- Summary sheet of Storage Tanks

The hazard of Terminal is Low due to handling of edible oils particularly low hazard properties; further consequence assessment study has not been carried out.

8.8 Recommendations

1. Before any transfer operation is commenced, it is imperative that the intended procedures are thoroughly discussed and a meeting held between the responsible personnel from the vessel and the terminal (berth operator). The purpose of the meeting is primarily to make both sides fully conversant with the characteristics of the vessel and shore handling systems, the envisaged operational and safety procedures and requirements and the parameters to be adhered to during the transfer.

2. Communications: To ensure that effective communication is established between ship and terminal personnel all through the cargo handling operations.

3. Fire fighting arrangements and water storage capacity shall be as per OISD 117, as applicable.

4. Maintenance:
   a) All fire-fighting and safety equipment are to be maintained fully operational at all times and be checked and tested on a routine basis. The prescribed pressure in the fixed fire line should be maintained and monitored both at port and respective terminals. The fire detection and warning systems should be checked and tested regularly.
   b) The Gas detectors should be periodically calibrated as per the set value.
   c) Pipelines should be periodically inspected and maintained for material corrosion and system integrity.

5. Training: All relevant personnel are trained to use the required fire-fighting systems for carrying out fire-fighting operation effectively. Also drill to be conducted periodically.

6. It is concluded that Risk analysis and EAP for the individual facilities/terminal (IMC, DFPCL, RIL, IOCL, GBL, Shell & Suraj Agro) have been carried out by the respective facilities on their own. The recommendations derived there from are duly implemented.

7. ERDMP/DMP/EAP should include the action plan for the natural disasters (Earthquake, Flood, Cyclone, Tsunami etc.).

8. Adequate number of firefighting personnel should be available.

9. The firewater network shall be kept pressurized at minimum 7.0 kg/cm^2 g by use of suitable jockey pumps.

10. Good housekeeping to be maintained in the Fire pump house, Control room and terminal area.

11. It is understood that mutual aid agreement among all tank farms and agencies are continued to be maintained effectively.

12. RCC structure for the cross country pipelines corridor alongside the road to be repaired at the earliest opportunity.

13. Assessment of critical buildings and structure to withstand damage due to natural calamities such as earthquake, cyclone and flooding should be carried out periodically.

14. Comprehensive disaster loss insurance policy should include natural disasters (earthquake, cyclone, flooding, tsunami etc.).

15. Approval for ERDMP of the individual tank farm to be obtained from PNGRB at the earliest.

16. Road leading to tank farm boundary on south side should have better access control at both ends and vehicular speed limits displayed.

17. General:
    a) JNPT should conduct drill and exercises jointly with the all the tank farms.
    b) All the incidents (minor and major) within the tank farm should be collated and recorded.

Additional Recommendations as per OISD 244 (as applicable):

14 Quantitative Risk Assessment (QRA) shall be done whenever major addition(s) in facilities or major changes in the surrounding areas, operating parameters, product grade takes place or once in every five years whichever is earlier.

15 Alternative access shall be provided for each facility so that it can be approached for fire fighting in the event of blockage on one route. For existing locations, wherever it is difficult or not practicable to implement due to severe space constraint, QRA shall be conducted and mitigation measures shall be implemented.

16 Physical segregation of hazardous and non hazardous areas shall be provided. Layout drawing indicating hazardous and non hazardous area segregation /demarcation shall be available.

17 Tank farm area shall be covered through CCTV surveillance system and same shall be continuously monitored.

18 The dyke and the enclosures will be inspected for cracks, visible damage etc. every six months (pre and post monsoons) and after every major repair in the tanks / dykes etc. so as to keep it impervious.

19 The boundary wall shall be constructed as per the directives of the Ministry of Home Affairs or any other Government directive. In any case the boundary wall shall be of minimum 3 M height from either side of boundary wall with V/U shaped barbed wire fencing on the wall with 600 mm diameter concertina coil on top.

20 Vehicles with spark ignition engine shall not be allowed inside hazardous area. Vehicles with internal combustion engine (compression ignition) such as tank truck (fuelled by HSD) required to be permitted for business shall have Petroleum and Explosives Safety Organization (PESO) approved spark arrestor fitted on the vehicle.

21 Hydrocarbon (HC) detectors shall be installed near all potential leak sources of class "A" petroleum products i.e. tank dykes, tank manifolds and pump house manifold. These detectors shall be placed in a way that entire possible source of leaks and collection of products is continuously detected and alarm is set at 20% of lower explosive limit of class A.

22 Tank body valves on process lines (inlet, outlet & recirculation) of all storage tanks storing class – A & B products shall be **Remote Operated Shut Off Valve (ROSOV)**.

23 Settlement of tanks takes place over a period of time and a depression is formed on tank pad along the circumference. The same should be effectively made up with proper slope to avoid rain water accumulation and subsequent corrosion of the bottom plate. Where large settlement is anticipated, supporting arrangement for the connected piping shall be suitably designed to take care of the settlement.

24 Sufficient lighting shall be provided so as to enable terminal operators to move safely within the accessible areas of installation and to perform routine operations. In the event of normal power failure, emergency lighting shall be provided in critical areas.

25 The Illumination in the operational areas including inside the dyke and manifold shall be such that adequate visibility is there at all times for emergency and normal operations.

26 Hoses used for TT Loading/Unloading shall be handled with care and inspected periodically as per OISD-STD-135.

27 Personnel working at TT Loading/Unloading shall wear applicable Personal Protective equipment.

28 The tank farm must be kept clean and free from vegetation.

29 The fire water pumps shall be provided with auto start facility with pressure drop in fire water network.

30 Fire water system shall be kept pressurized for a minimum residual pressure of 7 kg/cm^2 at hydraulically remotest point in the installation.

31 Jockey pump shall be provided for keeping the hydrant system /line pressurized at all times.

32 Fire water mains, hydrant & monitor stand posts, risers of water spray system shall be painted with “Fire Red” paint as per of IS: 5. Hose boxes, water monitors and hydrant outlets shall be painted with “Luminous Yellow” paint as per IS: 5.

33 Security staff should be trained as first responders for fire fighting and rescue operation along with plant operating personnel through oil industry approved reputed institute.

34 Whenever changes are envisaged at the installation, MOC document in the prescribed format shall be initiated. Depending upon the critical nature of impact the document shall be routed to the appropriate authority for approval. No changes shall be permitted without approved MOC. In order to handle any emergency situations suitable MOC mechanism shall be developed and records maintained.

9. RISK ASSESSMENT DUE TO COLLISION AND GROUNDING

9.1 Methodology

IMO guidelines define a hazard as "something with the potential to cause harm, loss or injury" the realisation of which results in an accident. The potential for a hazard to be realised can be combined with an estimated (or known) consequence of outcome. This combination is termed "Risk". Risk is therefore a measure of the frequency and consequence of a particular hazard.

This Risk Assessment exercise is primarily for the concern of environmental pollution caused by accidental spillage of oil at or around the JNPT. As such, the factors which may influence the risk, includes the following:

- Frequency of ship movement;
- Exposure time of the port due to transit of ship;
- Physical and mechanical condition of the ship and its equipment;
- Performance of ship's crew, including pilot;
- Traffic density;
- Hydrographic and meteorological conditions;
- Type and quantity of oil carried by the ships.

The present Risk Assessment exercise has been done in the stages as follows:

- **Gathering of relevant information and Data (para 9.2)**
- **Hazard Identification (para 9.3)**
- **Frequency Estimation (para 9.4)**
- **Consequence Estimation (para 9.5)**
- **Risk Estimation (para 9.6)**
- **Recommendations (para 9.7)**

9.2 Gathering of Relevant Information and Data

In this stage following aspects which are available or in place at JNPT, were studied.

1 The general information and data of JNPT,
2 The general historical incident data,
3 Vessel traffic management,
4 Procedures and requirements for vessel navigation.

All the above activities were carried out in consultation with JNPT personnel (including Dy. Conservator, harbour master, dock master, marine officer, pilots and Safety Inspector) and studying relevant documents.

9.2.1 The General Information and Data of JNPT - this includes:

- Geographical location of the port
- A detailed map of the port
- Sizes and types of vessels calling the port
- Traffic data for last three year
- The tidal variation, wave height and periodicity

- Navigational channel width, depth and the required heading;
- Operational limitations due to weather
- Types of berths, securing and fendering arrangements
- Types of cargoes being handled (Oil products; IMDG; chemicals in bulk; gasses; etc.)
- Details of navigational aids
- Communication, radar coverage, vessel monitoring system
- Pilotage system and pilotage criteria; training systems and competence assurance systems in place
- Physical and chemical data for the hydrocarbon products
- Review of previous OSCP and EAP reports.

Entire JNPT port area has been divided into following three areas for the purpose of Risk Assessment:

- ❖ Area 1: Inner harbor (inner basin)
- ❖ Area 2: Navigational Channel
- ❖ Area 3: Anchorage area.

9.3 Hazard Identification

The techniques used for identification of the hazards are described as below:

9.3.1 Interviews and Familiarisation Trips

Initially Study Team of IRS undertook familiarisation trips to various berths within port.

The Study Team held a series of interviews/meetings with JNPT personnel, including Deputy Conservator, Harbour Master, Dock Master, Duty Officers, VTS Officers, Sr. Traffic Manager and Pilots.

9.3.2 Document Study and Incident Data

Various internal documents connected with port operations were provided to the Study Team; these were reviewed and hazards relating to navigation were identified.

9.3.3 HAZID Meetings and Workshops

Structured HAZID (Hazard Identification) meeting was carried out at the premises of JNPT.

The Study Team was provided with incident data's. This information was used to assist in the initial compilation of the hazard lists (and also later in assigning frequency and consequence to the respective hazards).

The purpose of this workshop was to explore and identify further hazards associated with particular areas (e.g. inside basin including turning circle, navigational channel, port limit, etc).

Using the data obtained from the interactions, familiarisation trips, document studies, checklist, HAZID meetings and workshops, a preliminary list of significant hazardous scenarios with regards to oil spill accidents have been identified as follows:

Scenario 1: Collision with small craft - Tanker / Container/ Bulk Carrier in harbour
Scenario 2: Collision between two vessels in channel (Regulated traffic)

Scenario 3: Tanker /Container/ Bulk Carrier tug assisted berthing - Contact with jetty
Scenario 4: Grounding- Tanker/Container/ Bulk Carrier transiting in channel
Scenario 5: Grounding- during pilotage of deep draft vessel
Scenario 6: Collision with dredger within navigational channel
Scenario 7: Collision – passing vessel in port waters (unregulated traffic)
Scenario 8: Dragging anchor
Scenario 9: Contact - during operations in turning circle (large vessels)
Scenario 10: Collision with channel marking buoys
Scenario 11: Fire on vessel in the Navigational channel/Anchorage

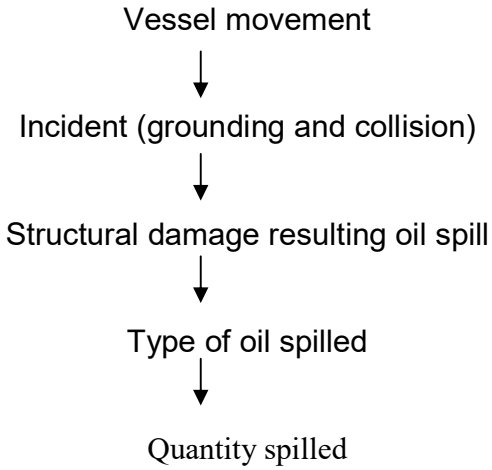
In summary there are two categories of accidents having potential for causing major oil spills have been identified:

- Collision
- Grounding

The collision accidents are dependent on maritime traffic situation (channel layout, traffic intensity, level of VTS management), weather conditions (wind, currents, and visibility), vessel characteristics (vessel type, vessel age, maneuverability, and available bridge equipment), human factors (experience and capability of the captain and the crew, working conditions).

Grounding often occurs where there is inadequate water depth as compared to vessel draft and do not always result in releases. This is due to the fact that the riverbeds of the most frequently traveled waterways are mostly soft mud or silts. However, there is still the potential for significant damage from rocks or debris.

An event sequence analysis as described below is used for estimating the frequency of spillage due to collision and grounding:



9.3.4 Historical analysis, databases, statistics

Our risk analysis primarily considers spillage from fuel oil tank of ship calling to JNPT. Table 9.1 shows representative fuel oil capacity of different type of vessels.

Table 9.1: Fuel oil capacity of Vessels [Ref. No. 13]

ID	Ship Type	Deadweight (M. Tons)	No. of bunker tanks >100 m^3 in volume	Fuel oil capacity at 98% Filling (M. Tons)
T1	Tanker (Panamax)**	48000	2	1070
T2	Tanker (Aframax)**	82000	5	2312
T3	Tanker (Suezmax)**	121000	6	4528
T4	Tanker (Suezmax)	151000	6	4074
T5	Tanker (VLCC)	300000	7	8759
T6	Tanker (VLCC)**	306000	8	7896
T7	Tanker (Panamax)	40000	3	1892
T8	Tanker (Panamax)	37000	3	2211
T9	Tanker (Aframax)	85000	5	2849
T10	Tanker (Suezmax)	136000	5	4659
C1	Containership (Post Panamax)	55000	16	7801
C2	Containership (Panamax)	36000	12	5253
C3	Containership (Panamax)	29000	8	2838
C4	Containership (Feedership)	11000	4	933
C5	Containership (Feedership)	25000	12	4043
C6	Containership (Feedership)	15000	8	2293
O1	LNG Carrier	72000	9	7020
O2	Livestcok Carrier	23000	13	3229
O3	Ro-Ro Vessel	28000	9	8314
B1	Bulk carrier (Capesize)	161000	4	4728
B2	Bulk carrier (Handysize)	28000	5	1633
B3	Bulk carrier (Handysize)	25000	3	1379
B4	Bulk carrier (Panamax)	45000	8	2437
B5	Bulk carrier (Handysize)	31000	3	338

** Indicates vessels with double-hull in way of all bunker tanks

Information provided by ITOPF indicates (as shown in Table 9.2):

- A significant number of accidental tankers spill less than 7 tonnes (50 barrels) occur during loading and discharging operations (35%);
- For spills between 7 and 700 tonnes (50-5000 barrels), loading and discharging operations still remain a significant cause (29%), in addition to collision (25%) and grounding (20%);
- However, for spills greater than 700 tonnes (5000 barrels) the major causes are collision (29%) and grounding (35%).

Table 9.2: Incidence of spills by cause (1974-2010) [Ref. no. 18]

	<7 Tonnes	7-700 Tonnes	>700 Tonnes	TOTAL
OPERATIONS				
Loading/Discharging	3157	385	37	3579
Bunkering	562	33	1	596
Other Operations	1250	61	15	1326
ACCIDENTS				
Collisions	180	337	132	649
Groundings	237	269	160	666
Hull Failures	198	57	55	310
Equipment Failures	202	39	4	245
Fires & Explosions	84	33	34	151
Other/Unknown	1975	121	22	2118
TOTAL	7845	1335	460	9640

9.4 Frequency Estimation

9.4.1 Frequency Assessment Criteria

The probability of collision and grounding depends on the factors including the following:

- maritime traffic situation (channel layout, traffic intensity, level of VTS management)
- weather conditions (wind, currents, visibility)
- vessel characteristics (vessel type, vessel age, maneuverability, available bridge equipment)
- human factors (experience and capability of the captain and the crew, working conditions).

Frequencies are derived for 'most credible' and 'worst credible' hazardous events, using the following frequency criteria:

Table 9.3: Frequency Matrix [Ref. no. 27, 28]

Category	Descriptive term	Definition
F1	Frequent	An event occurring once a week to once an operating year
F2	Likely	An event occurring once a year to once every 10

		operating years
F3	Remote	An event occurring once every 10 operating years to once in 100 operating years
F4	Unlikely	An event occurring once every 100 operating years to once in 1000 operating years
F5	Rare	An event occurring once in more than 1000 operating years

9.5 Consequence Estimation

Marine oil spills have the potential to cause serious impacts to natural resources and the livelihoods that depend on them. The extent of impact however is influenced by a number of factors such as the type and amount of oil spilled, the physical characteristics of the affected area, and the weather conditions at the time of the spill and the type and effectiveness of the response methods employed. **Probable fate of spilled oil is described in Appendix C.**

9.5.1 Impacts of Oil Spills

When the oil spills in large quantity, it temporarily affects the air-sea interaction, thus preventing the entry of oxygen from the atmosphere. The first set of organisms affected is the primary producers like phytoplankton, which are the basis of the marine food chain. The other free-swimming organisms such as fish larvae and fish also get affected. Further, when the oil sinks during the course of time, it affects the benthic organisms. The other amenities that are affected include mangrove forests, coral reefs and several marine resources. Oil spills can also have a serious economic impact on coastal activities and resources of the sea.

Spills close to the shoreline tend to have the greatest immediate impact because more diverse forms of life may come into contact with the oil. In addition to ecological concerns, shoreline spills can affect the air quality, due to the hydrocarbon gases and sulphur compounds present in the oil, and are also a potential fire hazard. They will also depress recreational areas, harbours, industries, commercial fishing grounds and tourist attractions. Table 9.4 gives briefly the impacts of oil spills on coastal resources.

Table 9.4: Impacts of oil spills on coastal resources [Ref. no. 11]

Receptor	Potential damage
Mammals	It has been rare for whales, dolphins, seals and sea lions to be affected following a spill. Sea otters are more vulnerable due to their way of life and their fur structure.
Birds	Birds using the water/air interface are at risk, particularly auks and divers. Oiled birds usually die. Recovery of local populations depends either on the existence of a reservoir of young non-breeding adults from which breeding colonies can be replenished (e.g. guillemots) or a high reproductive rate (e.g. ducks). There is no evidence to date that any oil spill has permanently damaged a seabird population, but the populations of species with every local distributions could be at risk.

Fish	Eggs and larvae in shallow bays may suffer heavy mortalities under slicks, particularly if dispersants are used. It is believed that adult fish tend to swim away from oil. There is no evidence so far that any oil spill has significantly affected adult fish populations in the open sea.
Invertebrates	Invertebrates include shellfish (both molluscs and crustaceans), worms of various kinds, sea urchins and corals. All these groups may suffer heavy causalities if directly exposed to fresh oil.
Endangered species	Rare animals or plants, or those with limited geographic distribution may be particularly vulnerable to oil impacts and raise specific concerns.
Planktonic organisms	Serious effects on plankton have not been observed in the open sea. This is probably because high reproductive rates and immigration from outside the affected area counteract short-term reductions in numbers caused by the oil.
Larger algae	Oil does not always stick to the larger algae because of their mucilaginous coating. Intertidal areas denuded of algae are usually readily re-populated once the oil has been substantially removed. Many algae are of economic importance either directly as food or for products such as agar. Algae cultured for this purpose lose their commercial value if tainted.
Mangroves	The term "mangrove" applies to several species of trees and bushes. They have a form of aerial 'breathing root', which enables them to live in fine, poorly oxygenated mud. They are very sensitive to oil, partly because oil films on the breathing roots inhibit the supply of oxygen to the underground root system.
Harbours and marinas	The functioning of commercial ports and harbours can be disrupted by oil slicks or clean-up activities. Boats in marinas may be at risk of oiling and subsequently need to be cleaned.
Industrial sea-water intakes	Seawater intakes may be at risk from floating and/or dispersed oil, leading to a need for protection or for shutting down operations.
Fishing industry	Fishing may not be feasible due to oil slicks or the imposition of fishing bans. Aquaculture facilities may be severely affected by direct oiling or loss of market confidence.
Recreational and tourism	Use of beaches and the coast for amenity and water sport purposes can be severely curtailed or disrupted by shoreline oiling.

9.5.2 Vulnerability Analysis

All coastal habitats are vulnerable to oil/chemical disaster and natural disaster. The vulnerability analysis provides information about resources and communities that could be harmed in the event of any kind of disaster. **Table 9.5** is used to determine vulnerability level of JNPT surrounding coast in the case of an accidental or due to natural calamity or manmade oil/chemical spillage or due to fire/explosion/toxic dispersion.

9.5.2.1Vulnerability areas in and around JNPT are as follows:
Sensitive areas around JNPT

Fig 9.1 Sensitive area around JNPT

Mora Jetty to Juna Sheva Road (JNPT)

This stretch comprises of a small estuary and inlet running south from Mora Jetty or land head to Funde village and then north up to Panje Land Head and is named Boripkhadi, the stretch continues from Panje Koliwada further East up to starting of Juna Sheva road. The area consists of mud flats prone to flooding during high tide and is not accessible. The area has some of the thickest vegetation of mangroves in India and varied bird life. The Uran mangroves, about 60 km from Mumbai, are a vast stretch beginning from the northern end of Palm Beach Road in Navi Mumbai, up to Funde village in Boripkhadi. The mangrove area is considerably large, dominated by two species i.e. *Avicennia marina* and *Sonneratia alba*.

The small bay from Panje Koliwada to beginning of JNPT road leading to BPCL jetty has thick mangrove vegetations. Reliance tank farm is situated on the western portion of this bay along the road.

Figure 9.2: Coastal Zone Management Plan (Mora to Juna Sheva Road - JNPT)

JNPT – Nhava to South Entrance to Panvel Creek

The stretch from Juna Sheva to JNPT Nhava consists of the port and large number of associated manmade structures with metal approach roads and connections.

The geographic position of the port is 18°56′56.00”N, 72°56′57.32”E. The port comprises of alongside berths and Sheva POL terminal being operated by BPCL and IOC.

The port is the 6th largest port and largest container port in India.

The geographical position of Nhava Island is 18°57’28.5”N and 72°59’11.45”E and Sheva is 18°56’05.34”N and 72°57’39.98”E.

The stretch extending from Nhava - where the facilities for ONGC vessel berthing and store supplies for Bombay high are created a tank farm is situated, is approximately 8 kms in length with mudflats and mangroves. The small water stream running south between JNPT and Nhava forms extensive JNPT backwaters that are thick in vegetation and mudflats. The internal areas of this small back water are not accessible either from Nhava or JNPT.

The complete stretch has thick mangrove vegetation and sea life. The stretch from Shivaji Nagar to Sector 3 on the south entrance to Panvel creek though well developed in terms of public utilities and manmade structures, the shoreline is muddy and has thick mangrove vegetation. Sector 51 forms the north entry point to Panvel creek. The shoreline is low lying mudflats with thick mangrove forests. Mangroves stretch inland along the Panvel creek on both banks to a considerable distance.

Figure 9.3: Coastal Zone Management Plan (JNPT- Nhava to South Entrance to Panvel Creek)

Table 9.5: Assessing vulnerability data for JNPT coastal area

		Very low (0)	Low (1)	Moderate (5)	Unknown or high (20)	Extreme (50)
Environment	Shoreline character			X		
	Plants and animals			X		
	Protected sites			X		
Human	Economic				X	
	Cultural			X		

	Social, amenity and recreation			**X**		

Overall vulnerability ratings of JNPT coastal area = 45 (HIGH) (Using Table 9.6)

Table 9.6: Conversion of consequence score into qualitative vulnerability rating [Ref. no. 10]

Sum of combined scores	Vulnerability rating
0	Very low
1-3	Low
4-18	Moderate
19-79	High
80+	Extreme

Table 9.7: Categories to determine vulnerability level [Ref. no. 10]

Resource category		Consequence level description				
		Very low (0)	**Low (1)**	**Moderate (5)**	**Unknown or High (20)**	**Extreme (50)**
Environment	**Shoreline character**	Negligible sensitivity	Low sensitivity (e.g. exposed rocky headlands, eroding wave cut platforms)	Moderate sensitivity (e.g. fine grained sand beaches, exposed compacted tidal flats, mudstone, coarse grained beaches)	High sensitivity (e.g. mixed sand and gravel beaches, gravel beaches, shelter rocky coasts)	Extremely high sensitivity (e.g. sheltered tidal flats, salt marshes, mangroves)
	Plants and animals	None or very few vulnerable species	Minor short-term impacts	Vulnerable species are generally of local value only	Limited but medium term effects	Vulnerable species are of local and regional importance
	Protected sites	No protected sites present	Scenic or wildlife management reserve	Scenic/nature reserve, wildlife refuge	Marine park, marine reserve, wildlife/marine mammal sanctuary	International protected sites
Human	**Economic**	No resources or activities of economic significance	Low economic significance for the region and nation	Some economic significance of the region, none nationally	High regional economic significance, some national significance	High national economic significance
	Cultural	No cultural importance	Some importance for local community, low regional significance	Importance to local and regional community but low national significance	Importance to local and regional community, some national significance	High national cultural significance
	Social, amenity and recreation	No community significance	Low community significance for the region and nation	Some community significance for the region, none nationally	High regional community significance, some national significance	High national community significance

9.5.3 Consequence (Impact) Assessment

The collision or grounding accidents at JNPT have the potential to cause severe damage to significantly large areas and habitats.

Assessment of consequence has been done considering the effect of potential accidents on -

- Life (e.g. personal injury, fatality, etc.)
- Property damage (e.g. damage to ship)
- Environment (oil pollution, etc.)
- Port Business (reputation, financial loss, etc.)

Table 9.8: Impact Categorization (I0 – I4) [Ref. no. 27, 28]

Scale	People	Property	Environment	Port Business
I0	No injury	No damage	Negligible environmental impact	Negligible
I1	Minor (Single slight injury)	Minor damage	Minor Tier 1 oil spill, Minimal environmental harm	Minor
I2	Slight (multiple minor or single major injury)	Local damage	Moderate Tier 2 (limited outside assistance) oil spill or environmental amenity impaired, Moderate environmental impact	Moderate Bad local publicity or short term loss of dues, revenue, etc.
I3	Serious (multiple major injuries or single fatality)	Major damage	Serious Tier 2 (regional assistance) oil spill, localized flooding or multiple amenities impaired, Long term or serious environmental damage	Serious Bad widespread publicity, temporary port closure or prolonged restriction of navigation
I4	Major (More than one fatality)	Total loss	Major Tier 3 (national assistance) oil spill, widespread flooding or extensive damage to amenities, Major environmental harm. e.g. major pollution incident causing significant damage or potential to health or the environment	Major Port closes, navigation seriously disrupted for more than 1-2 days. Long term loss of trade

9.5.4 Oil Spill Scenarios

In the event of collision or grounding accidents the approx. potential oil spillage for different types of vessels calling to JNPT (as shown in the following table 9.9) is calculated using Table 9.1 and ADIOS2 software and assuming one tank rupture/leakage for worst credible case.

Table 9.9: Potential Oil Spill Volumes for Various Spill Scenarios in Port limit of JNPT

Source	Incident	Location(s)	Oil Type	Approx. Potential Volume (1)
Containership	Grounding (1 tank)	Channel	Fuel oil	Up to 400 T
	Collision (1 tank)	Wharf / Channel	Fuel oil	400 T
Bulk carrier	Grounding (1 tank)	Channel	Fuel oil	Up to 400 T
	Collision with wharf or other vessel (1 wing type)	Wharf / Channel	Fuel oil	400 T
Oil Tanker	Grounding (1 tank)	Channel	Fuel oil	Up to 400 T
	Collision (1 tank)	Wharf / Channel	Fuel oil	400 T
Fishing Vessel	Grounding (Total Loss)	Channel	Diesel	50 T
	Collision (Total Loss)	Wharf / Channel	Diesel	50 T
Tug/Pilot vessel	Grounding (Total loss)	Channel	Diesel	25 T (Est. total fuel held)
	Collision with wharf or other vessel (Total loss)	Wharf / Channel	Diesel	25 T (Est. total fuel held)

(1) Indicative worst credible scenario. Actual volumes will vary according to vessel configuration and incident character.

N.B.: As regards incidents involving spillage of cargo oils from oil tanker the OSCP needs to be referred to.

9.5.5 Oil Spill Weathering Modeling

The most credible worst-case scenarios for oil spill have been simulated as below:

- **Scenario:** A 400 T spill of fuel oil over 10 hours, representing a loss from a ruptured fuel tank due to collision/grounding.

The analysis for weathering of oil has been done by computation using the software 'Automated Data Inquiry for Oil Spills **(ADIOS2)**'. The results are shown in **Appendix D**.

9.5.6 Oil Spill Trajectory Modeling

The analysis for spreading of 400 MT Fuel oil over 6 and 12 hrs in the month of February, May and June has been simulated using trajectory modeling software 'General NOAA Operational Modeling Environment **(GNOME)**' developed by National Oceanic and Atmospheric Administration (NOAA) and the results are shown in **Appendix E**.

9.6 Risk Estimation

The risk analysis is based on the outcomes of Hazard identification, Frequency Analysis and Consequence Assessment.

9.6.1 Risk Assessment Matrix

For each identified hazard, risk quantification is done based on a scale of 1 (low risk) to 10 (high risk) as described in the Table 9.10 as below:

Table 9.10: Risk Assessment Matrix [Ref. no. 27, 28]

Impact	I4	5	6	7	8	10
	I3	4	5	6	7	9
	I2	3	3	4	6	8
	I1	1	2	2	3	6
	I0	0	0	0	0	0
Frequency		F5	F4	F3	F2	F1

Where: -

0 & 1 - Negligible Risk
2 & 3 - Low Risk
4, & 5 – Assessed to be in ALARP region
6 – Heightened Risk
7, 8 & 9 - Significant Risk
10- High Risk

Based on the values of frequency and consequence as assessed, Risk Ranking have been done in Table 9.11 for each of the four consequence entities as described in Table 9.10 both for the 'most likely' and the 'worst credible' scenarios as mentioned in **Appendix B-Hazard Analysis Worksheet**.

Spill risk = probability of spill x impacts of spill

9.6.2 Risk Ranking:

The risk score of each of the four categories (People, Property, Environment and Business) is analyzed to obtain four indices for each hazardous scenario as follows:

a) The average risk value of the four categories in the 'most likely' set.

b) The average risk value of the four categories in the 'worst credible' set.
c) The maximum risk value of the four categories in the 'most likely' set.
d) The maximum risk value of the four categories in the 'worst credible' set.

The hazardous scenarios list is then sorted in order of the aggregate of the four indices to produce an Assessed Risk Ranking List, in descending order, with the highest risk scenario prioritized at the top.

Table 9.11: Risk ranking for JNPT port for grounding, collision & oil pollution

Scenario No.	Rank No.	Area	Category	Hazard Detail	Assessed Risk							
					Most Credible				Worst Credible			
					People	Property	Environment	Business	People	Property	Environment	Business
2	1	2	**Collision**	Collision between two vessels in channel (Regulated)	**8**	**8**	**0**	**8**	**7**	**7**	**6**	**7**
7	2	2	**Collision**	Collision – passing vessel in port waters (un-regulated traffic)	**3**	**6**	**0**	**3**	**6**	**6**	**4**	**7**
11	3	2	**Fire**	Fire on vessel in navigational channel	**6**	**3**	**0**	**6**	**6**	**6**	**5**	**6**
4	4	2	**Grounding**	Grounding– Tanker/Container/ BC transiting in channel	**2**	**4**	**0**	**6**	**5**	**5**	**5**	**6**
1	5	2	**Collision**	Collision with small craft - Tanker /Container/BC in channel	**3**	**6**	**0**	**3**	**6**	**6**	**2**	**6**
5	6	2	**Grounding**	Grounding – During pilotage of deep draft vessel	**2**	**2**	**0**	**6**	**3**	**6**	**3**	**6**
3	7	1	**Contact**	Tanker/Container/B C tug assisted berthing – Contact with jetty	**3**	**3**	**0**	**3**	**6**	**6**	**2**	**6**
9	8	1	**Contact**	Contact – During operations in turning circle (large vessels)	**0**	**3**	**0**	**3**	**5**	**6**	**5**	**6**
10	9	2	**Collision**	Collision with channel marking buoys	**0**	**3**	**0**	**3**	**5**	**6**	**5**	**6**

8	10	3	**Collision**	Collision – Anchor dragging	**2**	**2**	**0**	**2**	**5**	**6**	**5**	**6**
6	11	2	**Collision**	Collision with dredger within navigational channel	**0**	**2**	**0**	**2**	**6**	**6**	**3**	**6**

9.7 Recommendations

1. The VTS system being vital for monitoring vessel traffic in the area should be fully functional round the clock.

2. Training on execution and management of DMP for the concerned personnel of JNPT should be conducted regularly.

3. Weather limit for safe operation (the existing procedure) to be followed and updated periodically based on actual experience gained.

4. Weather forecast to be followed regularly and the port operation to be planned accordingly.

5. Tug masters should undergo induction and refresher training relevant to their roles and responsibility.

10. CONCLUSIONS

1. As per the agreed scope of work, we have completed the following tasks:
    a. Risk Assessment, and
    b. Disaster Management Plan.

2. The DMP have been developed based on the Information/Data received from JNPT authority, review of pertinent literature including relevant guidelines, and our experience and knowledge. As per our evaluation based on IMO guidelines (para 9.5.2), the JNPT area falls under high consequential vulnerability zone resulting from an accidental oil spill.

3. The successful implementation of the Risk Control measures and DMP depend on the active and effective coordination between JNPT, Berth operators and the support organizations, so this is emphasized.

4. It is concluded that the best practices of ship handling operations will be followed and all the requirements towards applicable rules and regulations will be complied with.

5. We conclude that the existing control measures will be maintained in effective manner. The additional measures as given in recommendations will be implemented.

6. Risk Assessment for handling of HSD, Ammonia, Naphtha, LPG and other chemicals have been carried out with regards to Fire, Explosion and toxic dispersion and the analysis results can be seen in chapter 5, 6, 7 and 8.

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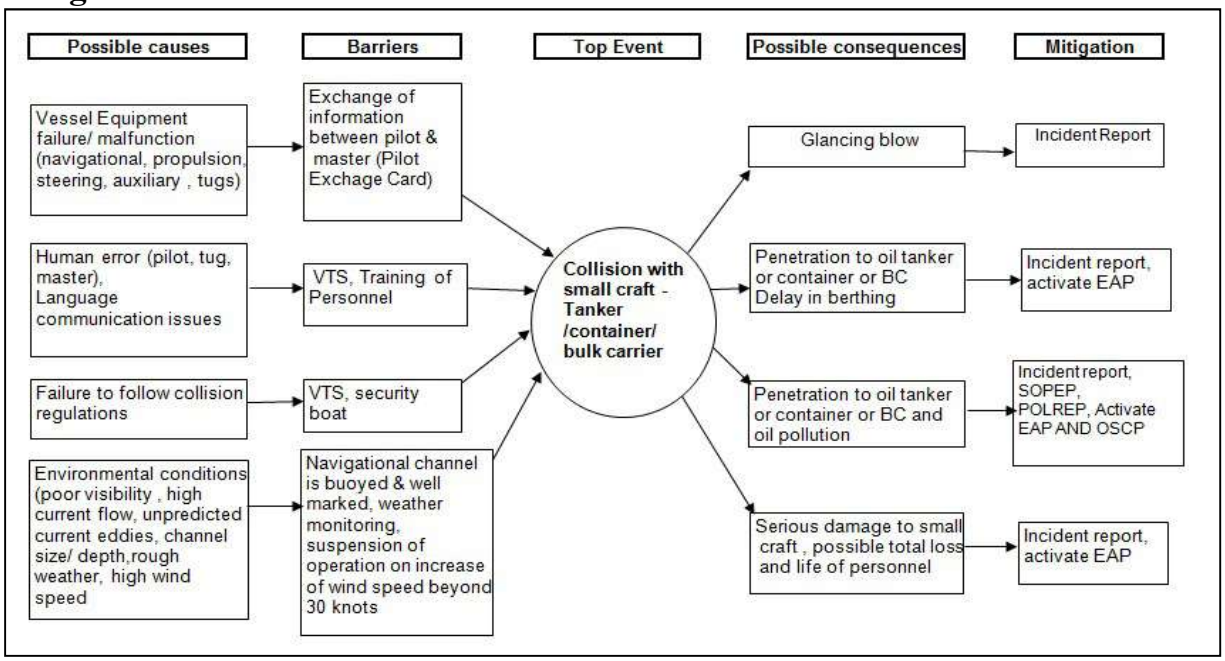
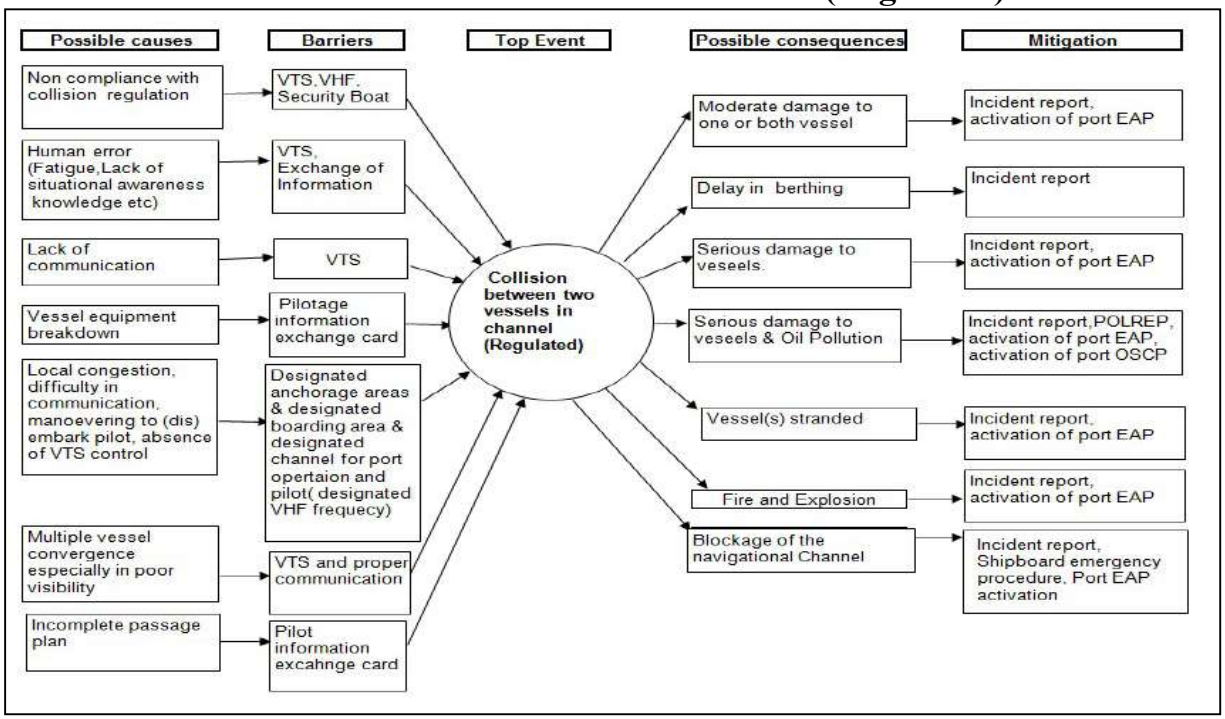
APPENDIX A
BOW-TIE DIAGRAMS USED FOR HAZARD ANALYSIS

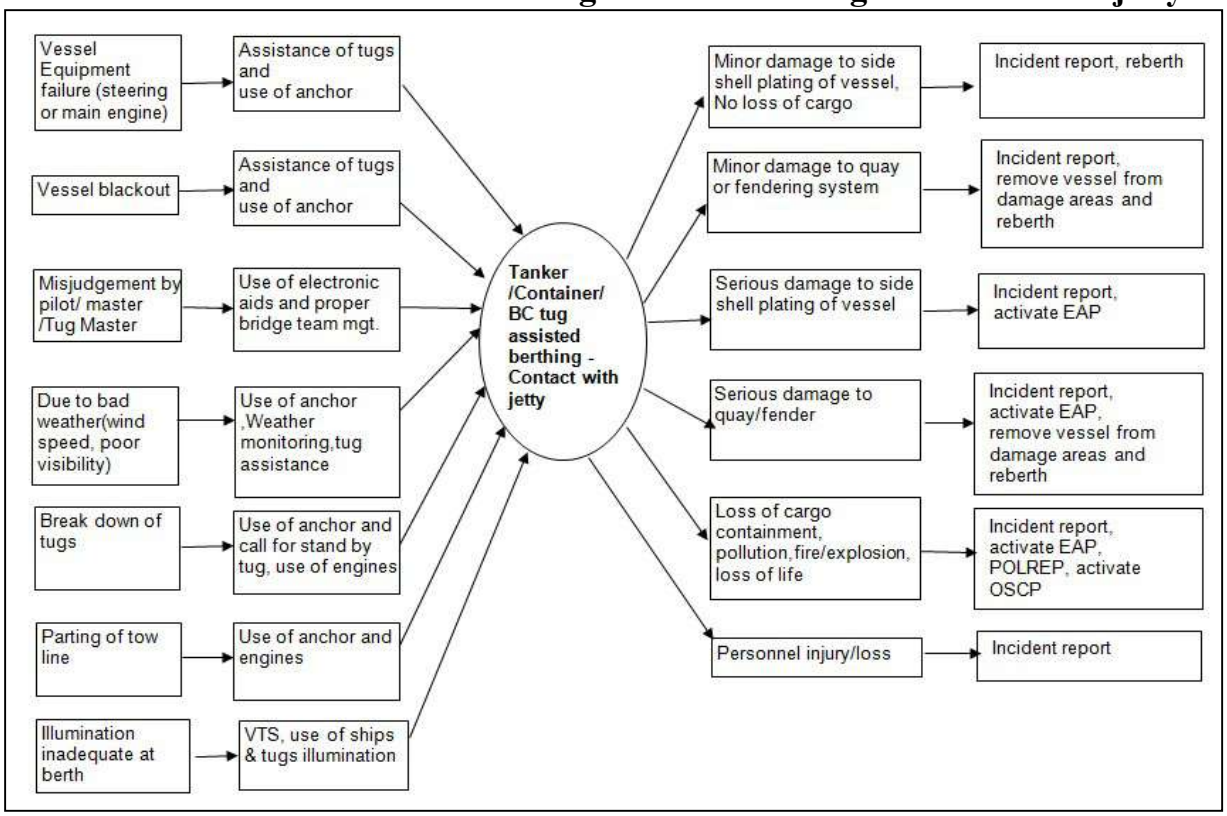
Scenario 1: Collision with small craft – Tanker/Container/bulk carrier in navigational channel



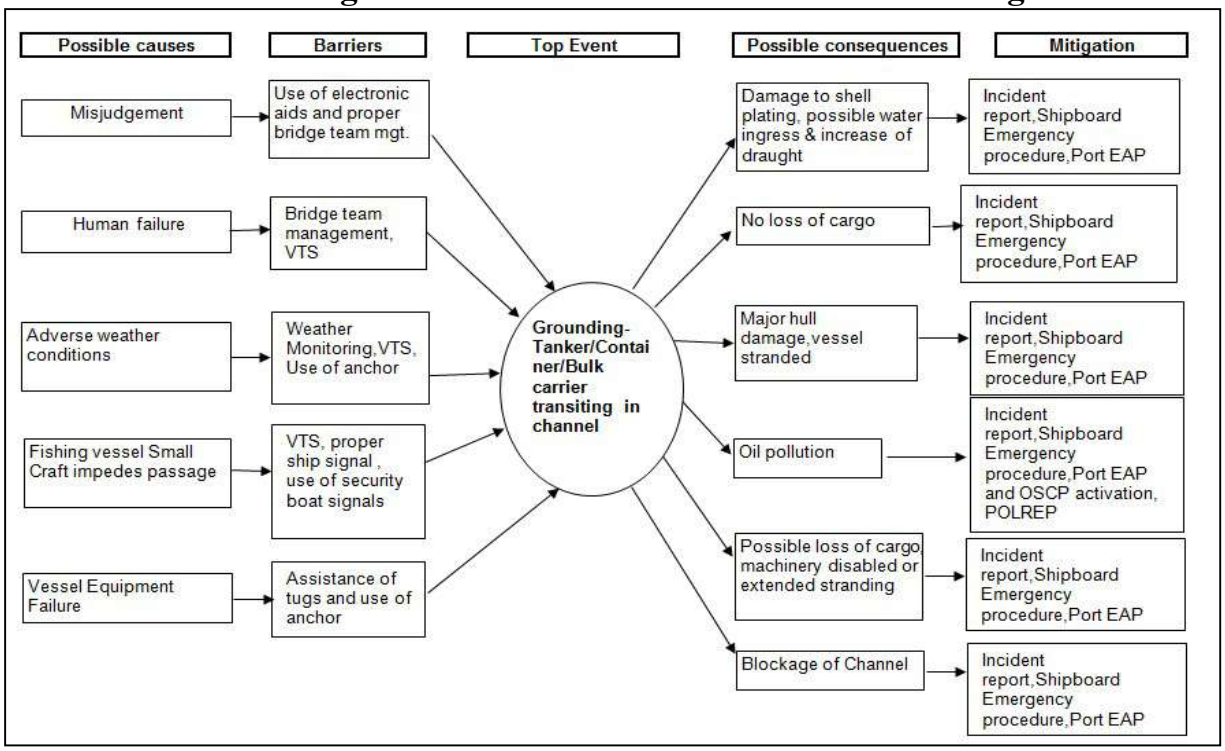
Scenario 2: Collision between two vessels in channel (Regulated)



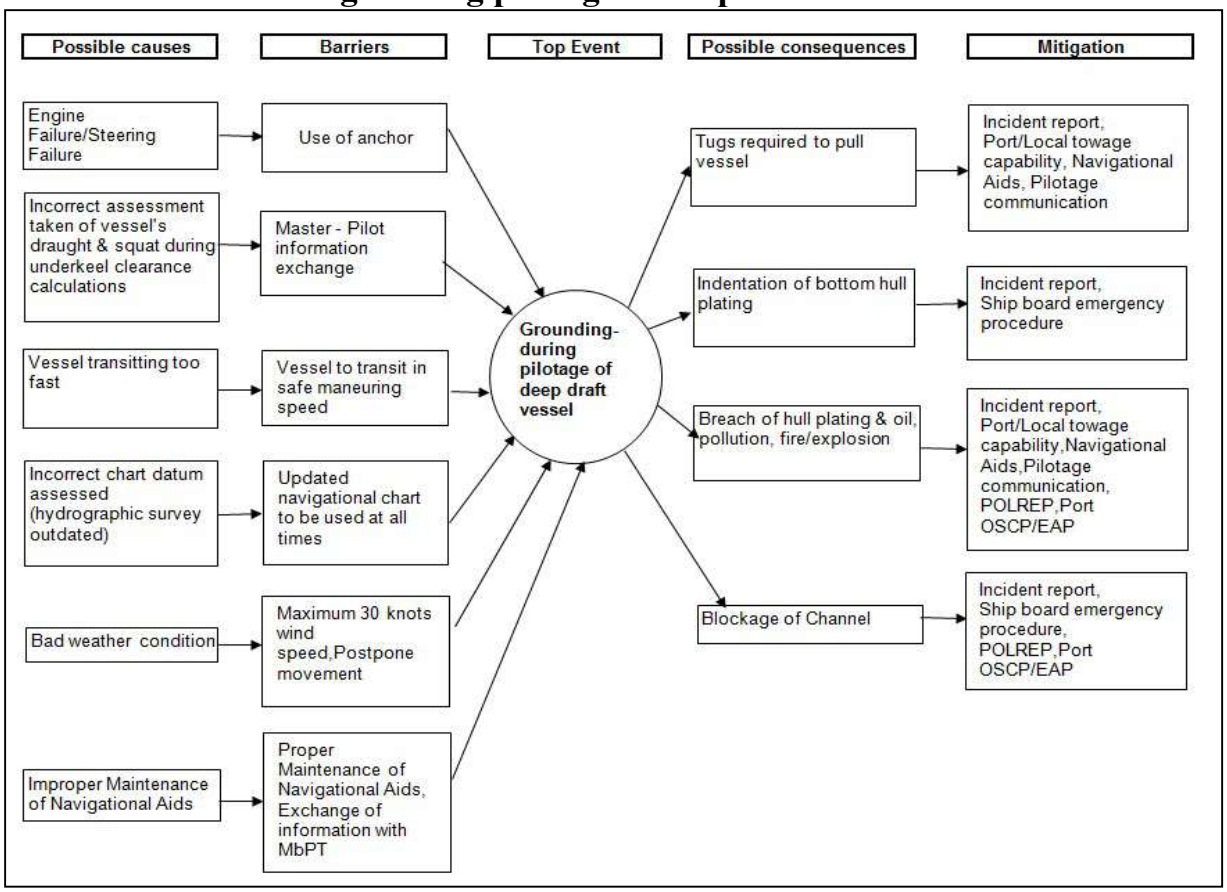
Scenario 3: Tanker/Container/BC tug assisted berthing – Contact with jetty



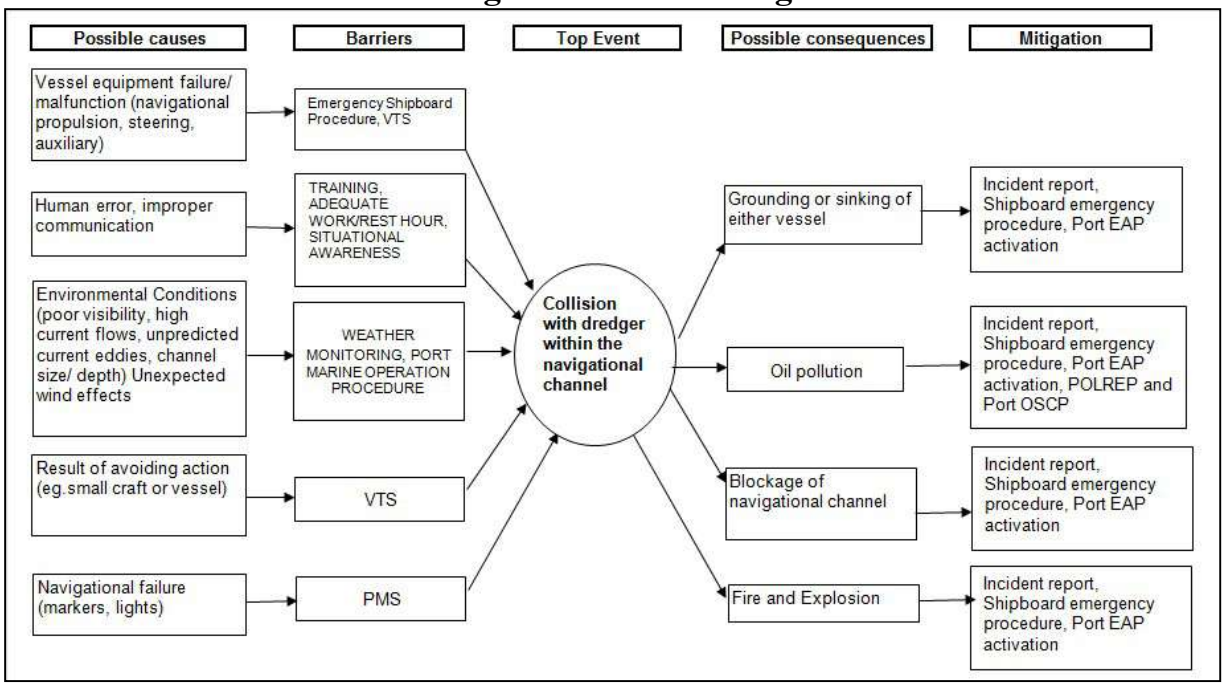
Scenario 4: Grounding- Tanker/Container/Bulk carrier transiting in Channel



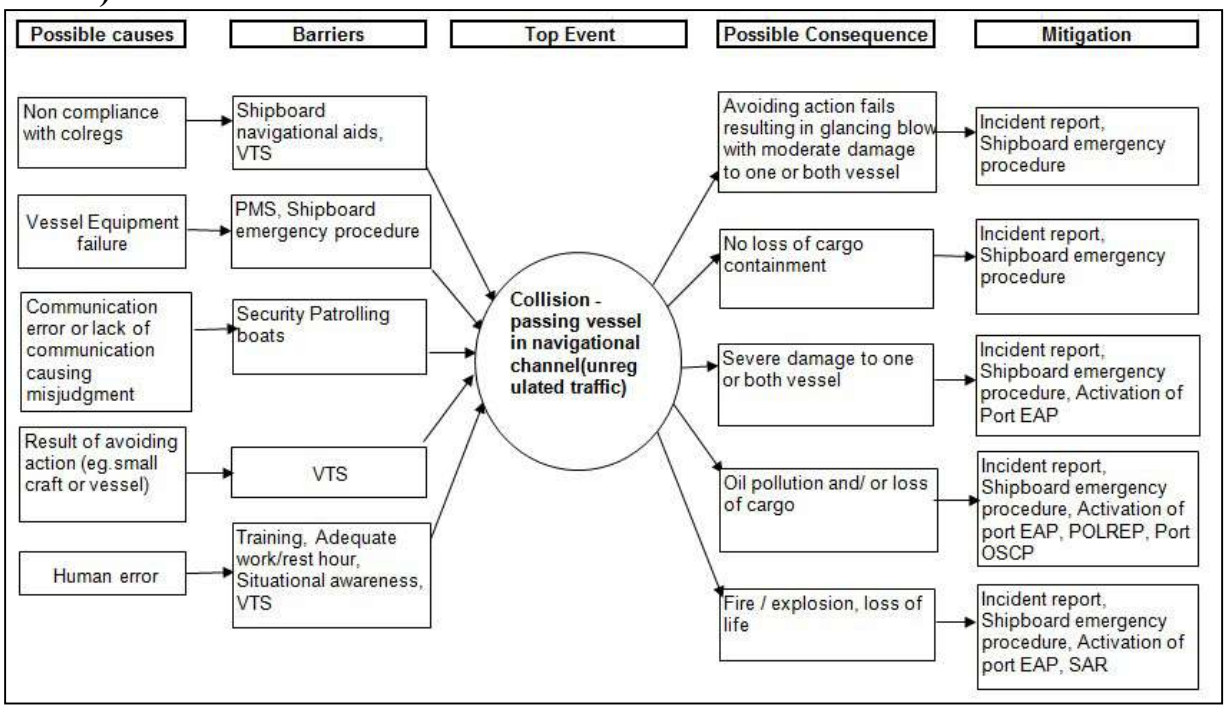
Scenario 5: Grounding- during pilotage of deep draft vessel



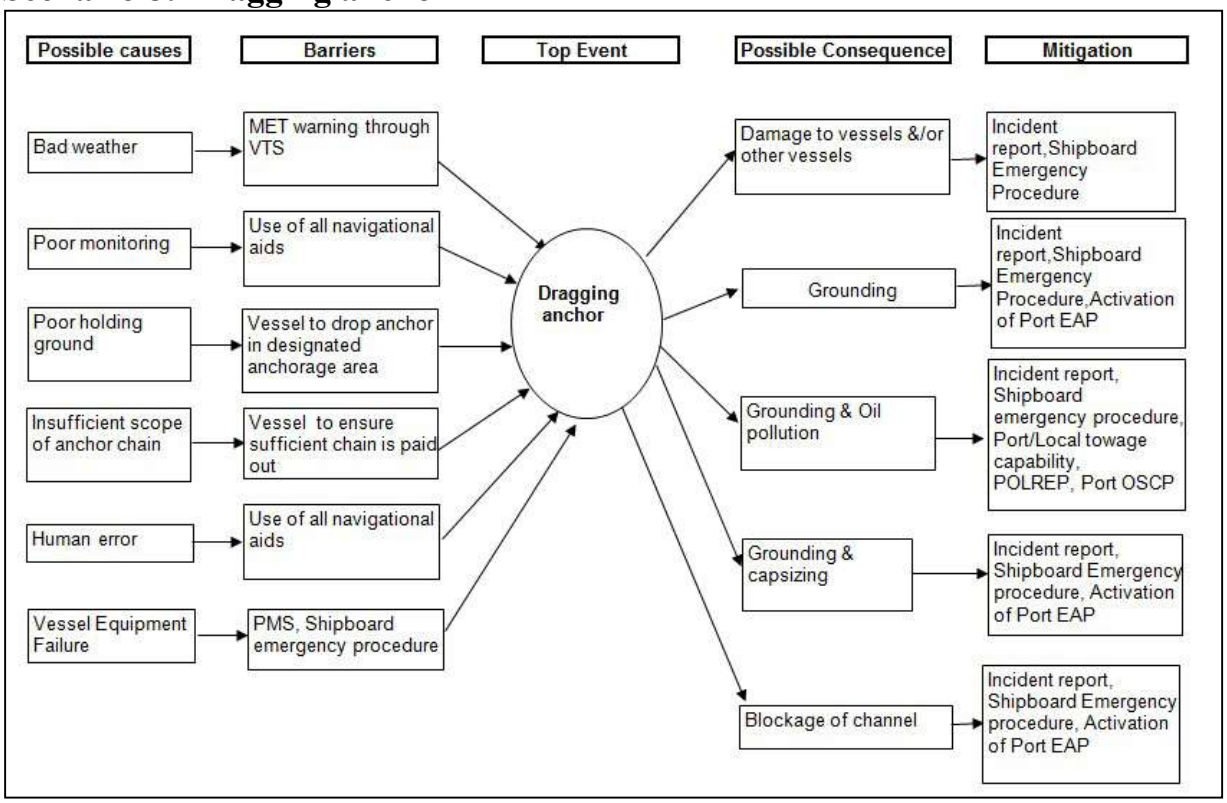
Scenario 6: Collision with dredger within the navigational channel



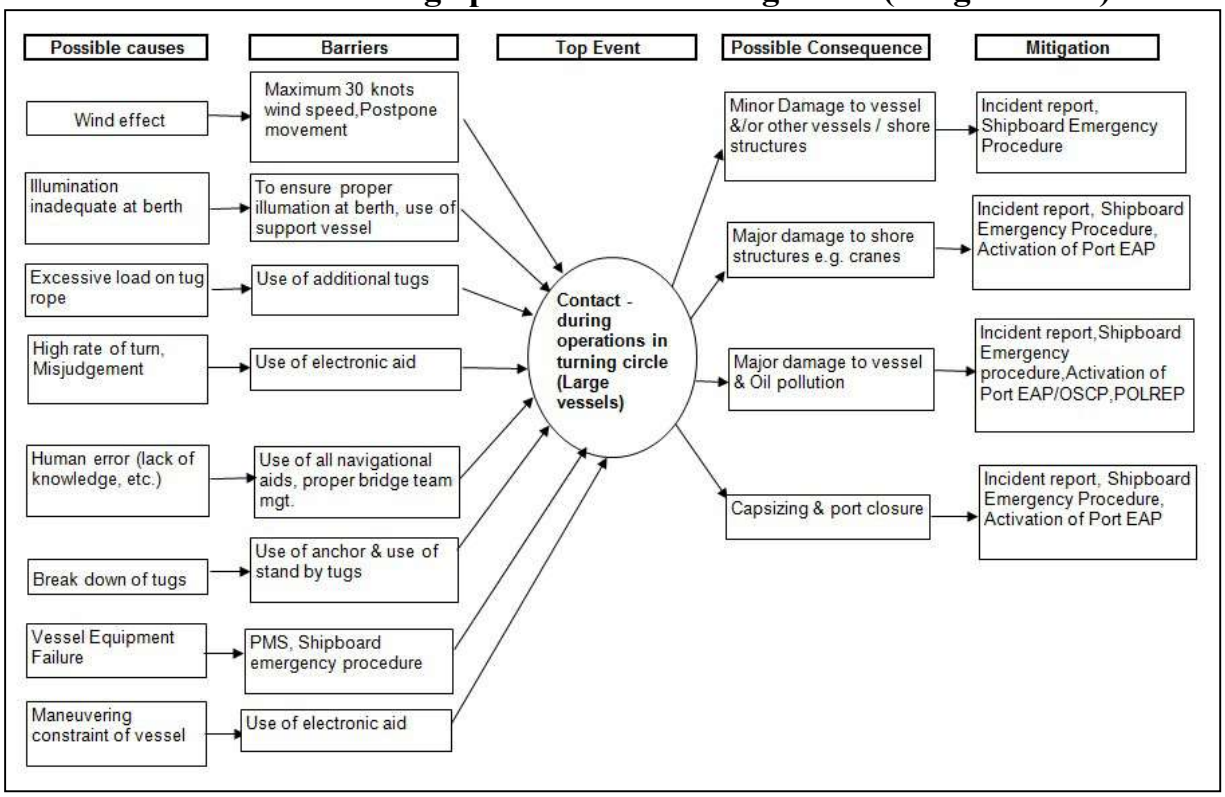
Scenario 7: Contact- passing vessel in navigational channel (Unregulated traffic)



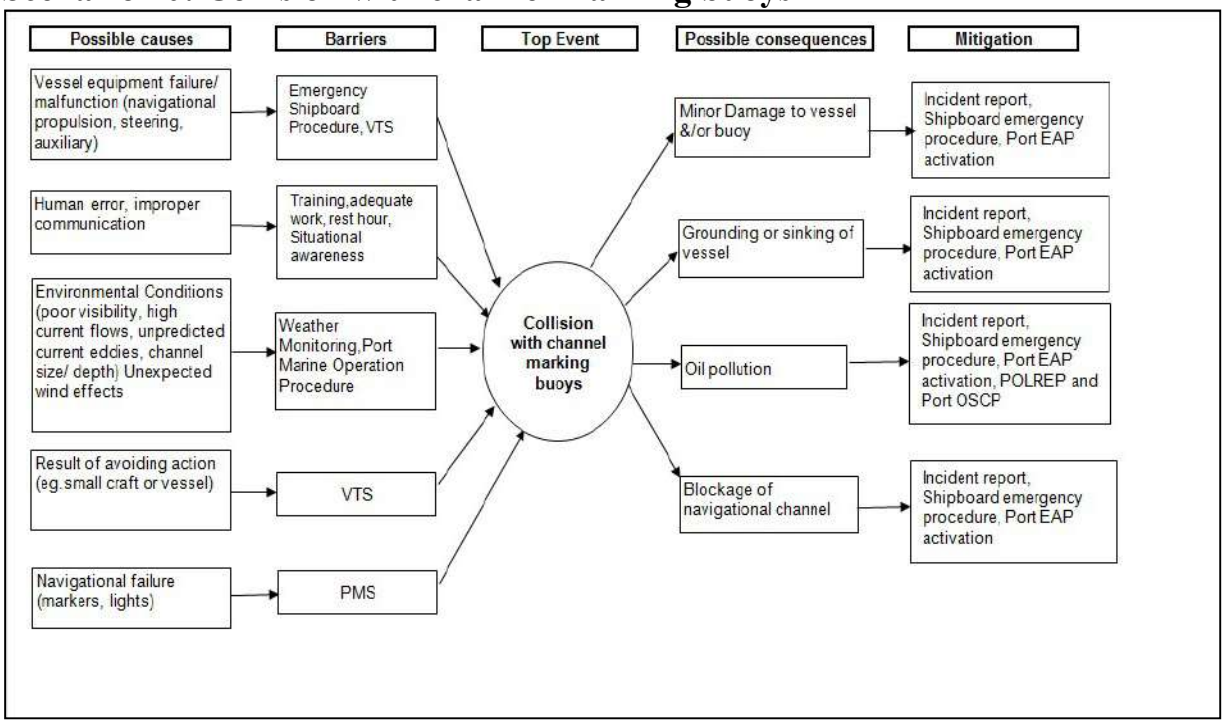
Scenario 8: Dragging anchor



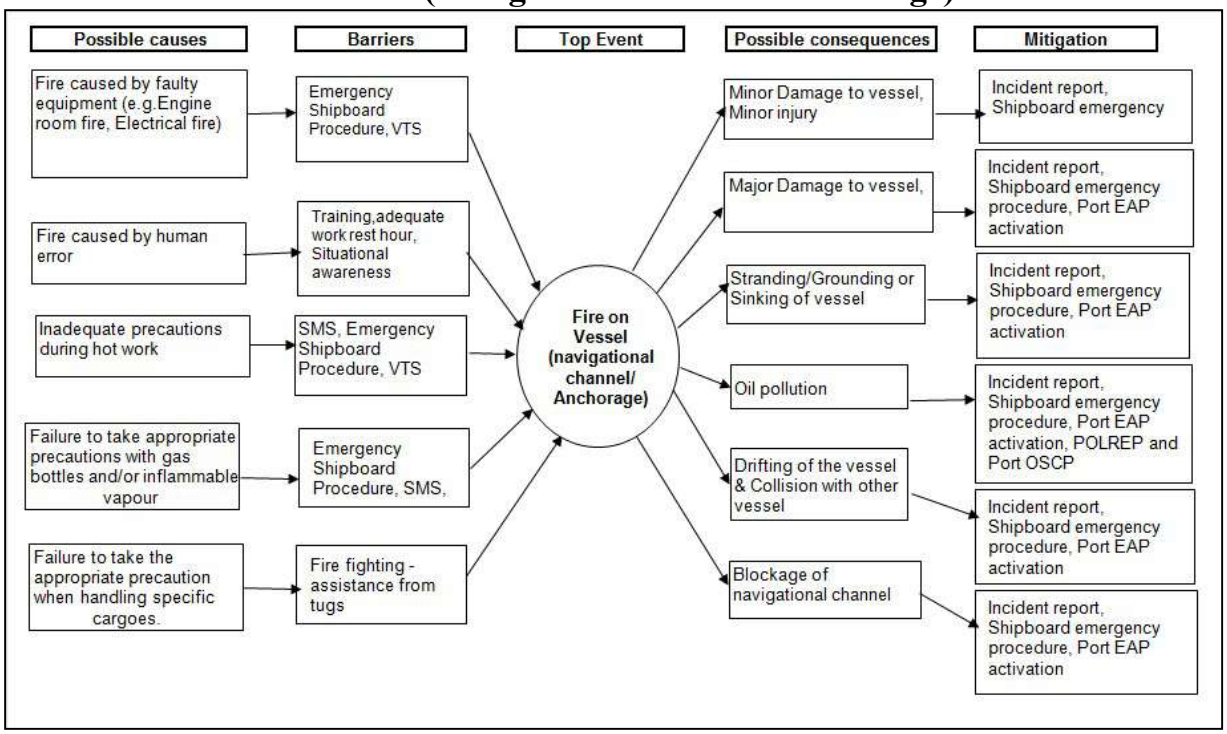
Scenario 9: Contact –during operations in turning circle (Large vessels)



Scenario 10: Collision with channel marking buoys



Scenario 11: Fire on vessel (Navigational channel/Anchorage)



APPENDIX B: HAZARD ANALYSIS WORKSHEET

Scenario No.	Area	Category	Hazard Detail	Possible Causes	Hazard Reduction Barriers	MCS	WCS	Hazard Assessed										Mitigation
								Most Credible					Worst Credible					
								Impact					Impact					
								People	Property	Environment	Business	Frequency	People	Property	Environment	Business	Frequency	
1	2	Collision	Collision with small craft – Tanker/ Container /BC in channel	Vessel equipment failure/ malfunction (navigational, propulsion, steering, auxiliary, tugs), Human error (pilot, master, tug), Language communication issues, Failure to follow Collision Regulations, Environmental conditions (poor visibility, high current flow, unpredicted current eddies, channel size/depth, rough weather, high wind speed)	Exchange of information between Pilot & Master (Pilot exchange card), VTS, Training of personnel, Security boat, Navigational channel is buoyed & well marked, weather monitoring, suspension of operation on increase of wind speed beyond 30 knots.	Avoiding action fails resulting in glancing blow with moderate damage to one or both vessel, Delay to berthing	Penetration to oil tanker/Container/BC, Oil pollution, serious damage to small craft, possible total loss and life of personnel	1	2	0	1	2	3	3	1	3	3	Incident report, Activate port DMP, SOPEP, POLREP, Activate port OSCP

Scenario No.	Area	Category	Hazard Detail	Possible Causes	Hazard Reduction Barriers	MCS	WCS	Hazard Assessed										Mitigation
								Most Credible					Worst Credible					
								Impact					Impact					
								People	Property	Environment	Business	Frequency	People	Property	Environment	Business	Frequency	
2	2	**Collision**	Collision between two vessels in Channel (Regulated)	Non-compliance with collision regulation, Human error, Lack of communication, Ship's equipment breakdown, Local congestion, difficulty in communication, maneuvering to (dis)embark pilot, absence of VTS control, Multiple vessel convergence especially in poor visibility, Incomplete passage plan	VTS, VHF, proper communication, Security boat, Pilot information exchange card, Designated anchorage area & designated boarding area & designated channel for port operation & pilot (designated VHF frequency)	Moderate damage to one or both vessel, Delay to berthing	Serious damage to vessels and oil pollution, Vessel(s) stranded, Fire and Explosion, Blockage of the navigational Channel	**2**	**2**	**0**	**2**	**1**	**4**	**4**	**3**	**4**	**3**	Incident report, Activation of port DMP, PLOREP, Activation of port OSCP

Scenario No.	Area	Category	Hazard Detail	Possible Causes	Hazard Reduction Barriers	MCS	WCS	Hazard Assessed										Mitigation
								Most Credible					Worst Credible					
								Impact					Impact					
								People	Property	Environment	Business	Frequency	People	Property	Environment	Business	Frequency	
3	1	Contact	Tanker/ Container/BC tug assisted berthing – Contact with jetty	Mechanical failure (steering or main engine), Vessel blackout, Misjudgment by pilot/master/tug master, Bad weather (wind speed, poor visibility), Break down of tugs, Parting of tow line, Inadequate illumination at berth	Assistance of tugs and use of anchor, Use of electronic aids and proper bridge team management, VTS, Pilot information card, Use of anchor and engines, Weather monitoring, tug assistance, Use of ship's and tugs illumination for night berthing	Minor damage to side shell plating of vessel, No loss of cargo, Minor damage to quay or fendering system	Serious damage to side shell plating of vessel, Serious damage to quay/fender, Loss of cargo containment, pollution, fire/explosion, personnel injury or loss of life	1	1	0	1	2	3	3	1	3	3	Incident report, Remove vessel from damage areas and reberth, Activate port DMP, POLREP, Activate port OSCP.

Scenario No.	Area	Category	Hazard Detail	Possible Causes	Hazard Reduction Barriers	MCS	WCS	Hazard Assessed										Mitigation
								Most Credible					Worst Credible					
								Impact					Impact					
								People	Property	Environment	Business	Frequency	People	Property	Environment	Business	Frequency	
4	2	Grounding	Grounding – Tanker/ Container/ BC transiting in channel	Vessel equipment failure, Misjudgment, Human failure, Adverse weather conditions, Fishing vessel small craft impedes passage	Use of electronic aids and proper bridge team management, Weather monitoring VTS, Use of Anchor, Proper ship signal, Use of security boat signals, Assistance of tugs	Damage to shell plating – possible water ingress & increase in draught, No loss of cargo	Major hull damage, Vessel stranded, Oil pollution, Possible loss of cargo if machinery disabled or extended stranding, Blockage of Channel	1	2	0	3	3	3	3	3	4	4	Incident report, Shipboard emergency procedure, Activate port DMP, POLREP, Activate port OSCP

Scenario No.	Area	Category	Hazard Detail	Possible Causes	Hazard Reduction Barriers	MCS	WCS	Hazard Assessed										Mitigation
								Most Credible					Worst Credible					
								Impact					Impact					
								People	Property	Environment	Business	Frequency	People	Property	Environment	Business	Frequency	
5	2	**Grounding**	Grounding – During pilotage of deep draft vessel	Engine Failure/Steering Failure, Incorrect assessment taken of vessel's draught & squat during under keel clearance calculations, Vessel transiting too fast, Incorrect chart datum assessed (hydrographic survey outdated), Bad weather condition, Improper maintenance of navigational aids.	Use of Anchor, Master-Pilot info exchange card, Vessel to transit in safe maneuvering speed, Updated navigational chart to be used at all times, Maximum 30 knots wind speed operational limit, Postpone movement, proper maintenance of navigational aids, exchange of information with MbPT.	Tugs required to pull vessel clear, Indentation of bottom hull plating	Breach of hull plating & oil pollution, fire/explosion, Blockage of Channel	**1**	**1**	**0**	**3**	**3**	**2**	**4**	**2**	**4**	**4**	Incident report, Port/Local towage capability, Navigational aids, Pilotage communication, Shipboard emergency procedure, Activate port DMP, POLREP, Activate port OSCP

Scenario No.	Area	Category	Hazard Detail	Possible Causes	Hazard Reduction Barriers	MCS	WCS	Hazard Assessed										Mitigation
								Most Credible					Worst Credible					
								Impact					Impact					
								People	Property	Environment	Business	Frequency	People	Property	Environment	Business	Frequency	
6	2	**Collision**	Collision with dredger within the navigational channel	Vessel equipment failure/ malfunction (navigational propulsion, steering, auxiliary), Human error, improper communication, Environmental conditions (poor visibility, high current flows, unpredicted current eddies, channel size/ depth), results of avoiding action (eg. Small craft or vessel), navigation failure (markers, lights)	Emergency shipboard procedure, VTS, training, adequate work/rest hour, situational awareness, weather monitoring, port marine operation procedure, PMS	Temporary grounding without hull damage	Grounding or sinking of either vessel, Oil/chemical pollution, Fire and Explosion, Blockage of navigational channel	**0**	**1**	**0**	**1**	**3**	**4**	**4**	**2**	**4**	**4**	Incident report, Shipboard emergency procedure, Port DMP activation, POLREP, Port OSCP activation

Scenario No.	Area	Category	Hazard Detail	Possible Causes	Hazard Reduction Barriers	MCS	WCS	Hazard Assessed										Mitigation
								Most Credible					Worst Credible					
								Impact					Impact					
								People	Property	Environment	Business	Frequency	People	Property	Environment	Business	Frequency	
7	2	Collision	Collision - passing vessel in navigation channel (unregulated traffic)	Non-compliance with COLREGS, vessel equipment failure, communication error or lack of communication causing misjudgment, result of avoiding action (eg. Small craft or vessel), Human error.	Shipboard navigational aids, VTS, PMS, shipboard emergency procedure, security patrolling boats, training, adequate work/hour, situational awareness.	Avoiding action fails resulting in glancing blow with moderate damage to one or both vessel, No loss of cargo, No serious injury	Severe damage to one or both vessel, Oil pollution and/ or loss of cargo, Fire / explosion, loss of life	1	2	0	1	2	3	3	2	4	3	Incident report, Shipboard emergency procedure, Activation of port DMP, POLREP, Activation of port OSCP

Scenario No.	Area	Category	Hazard Detail	Possible Causes	Hazard Reduction Barriers	MCS	WCS	Hazard Assessed										Mitigation
								Most Credible					Worst Credible					
								Impact					Impact					
								People	Property	Environment	Business	Frequency	People	Property	Environment	Business	Frequency	
8	3	**Collision**	Collision – Anchor dragging	Bad weather, Poor monitoring, Poor holding ground, Insufficient scope of anchor chain, Human error, vessel equipment failure	Met. warning through VTS, Use of all Navigational aids, Vessel to drop anchor in designated anchorage area, Vessel to ensure that sufficient chain is paid out, use of all navigational aids, PMS, shipboard emergency procedure	Minor Damage to vessels and/or other vessels	Grounding and oil pollution, Grounding and capsizing, Blockage of channel	**1**	**1**	**0**	**1**	**3**	**3**	**4**	**3**	**4**	**4**	Incident report, Shipboard emergency procedure, Port/Local towage capability, Activation of port DMP, POLREP, Activation of port OSCP

Scenario No.	Area	Category	Hazard Detail	Possible Causes	Hazard Reduction Barriers	MCS	WCS	Hazard Assessed										Mitigation
								Most Credible					Worst Credible					
								Impact					Impact					
								People	Property	Environment	Business	Frequency	People	Property	Environment	Business	Frequency	
9	1	**Contact**	Contact – During operations in turning circle (large vessels)	Wind effect, Illumination inadequate at berth, Excessive load on tug rope, High rate of turn, Misjudgment, Human error (fatigue, lack of knowledge, etc.), Break down of tugs, vessel equipment failure, maneuvering constraint of vessel	Suspend operation at Max-30 knots wind speed, postpone movement, ensure proper illumination at berth, Use of support vessel illumination, Use of additional tugs, Use of electronic aid, proper bridge team management, use of all navigational aids, PMS, Shipboard emergency procedure	Minor Damage to vessel &/or other vessels/ Shore structures	Major damage to shore structures e.g. cranes, Major damage to vessel & pollution, Capsizing & port closure	**0**	**1**	**0**	**1**	**2**	**3**	**4**	**3**	**4**	**4**	Incident report, Shipboard emergency procedure, Activation of port DMP, POLREP, Activation of port OSCP

Scenario No.	Area	Category	Hazard Detail	Possible Causes	Hazard Reduction Barriers	MCS	WCS	Hazard Assessed										Mitigation
								Most Credible					Worst Credible					
								Impact					Impact					
								People	Property	Environment	Business	Frequency	People	Property	Environment	Business	Frequency	
10	2	**Collision**	Collision with channel marking buoys	Vessel equipment failure/ malfunction (navigational propulsion, steering, auxiliary), human error, improper communication, environmental conditions (poor visibility, high current flows, unpredicted current eddies, channel size/ depth),results of avoiding action (eg. small craft or vessel), navigational failure (markers, lights)	Emergency shipboard procedure, VTS, training, adequate work/rest hour, situational awareness, weather monitoring, port marine operation procedure, PMS	Minor Damage to vessel &/or buoy	Grounding or sinking of vessel, Oil pollution, Blockage of navigational channel	**0**	**1**	**0**	**1**	**2**	**3**	**4**	**3**	**4**	**4**	Incident report, Shipboard emergency procedure, Port DMP activation, POLREP and Port OSCP

Scenario No.	Area	Category	Hazard Detail	Possible Causes	Hazard Reduction Barriers	MCS	WCS	Hazard Assessed										Mitigation
								Most Credible					Worst Credible					
								Impact					Impact					
								People	Property	Environment	Business	Frequency	People	Property	Environment	Business	Frequency	
11	2	Fire	Fire on vessel in the navigational channel	Fire caused by faulty equipment, fire caused by human error, inadequate precautions during hot work, failure to take appropriate precautions with gas bottles and/or inflammable vapour, failure to take the appropriate precaution when handling specific cargoes.	Emergency shipboard procedure, VTS, training, adequate work/rest hour, situational awareness, SMS, PMS, fire fighting assistance from tugs.	Minor damage to vessel, Injury to personnel, Loss of power	Major damage to vessel, Multiple injury and/or fatality to personnel, Loss of cargo, Loss of vessel control.	2	1	0	2	2	4	4	3	4	4	Incident report, Shipboard emergency procedure, Port DMP activation, POLREP and Port OSCP

Area 1: Inner harbour (inner basin)
Area 2: Navigational Channel
Area 3: Anchorage area

APPENDIX C
PROBABLE FATE OF SPILLED OIL

C.1: Introduction

When oil is spilled into the sea it undergoes a number of physical and chemical changes, some of which lead to its removal from the sea surface, whilst others cause it to persist. Although spilled oil is eventually assimilated by the marine environment, the time involved depends upon factors such as the amount of oil spilled, its initial physical and chemical characteristics, the prevailing climatic and sea conditions and whether the oil remains at sea or is washed ashore.

C.2: Physical properties of Oil

The rate at which oil spill spreads will determine its effect on the environment. Most of the oils tend to spread horizontally into a smooth and slippery surface, called a slick, on top of the water. Factors, which affect the ability of oil spill to spread, include surface tension, specific gravity and viscosity.

- **Surface tension** is the measure of attraction between the surface molecules of a liquid. The higher the oil's surface tension, the more likely a spill will remain in place. If the surface tension of the oil is low, the oil will spread even without help from wind and water currents. Because increased temperatures can reduce a liquid's surface tension, oil is more likely to spread in warmer waters than in very cold waters.
- **Specific gravity** is the density of a substance compared to the density of water. Since most oils are lighter than water, they lie flat on top of it. However, the specific gravity of an oil spill can increase if the lighter substances within the oil evaporate.
- **Viscosity** is the measure of a liquid's resistance to flow. The higher the viscosity of the oil, the greater the tendency for it to stay in one place

C.3: Types of Oils

Oil Types, as grouped by the International Tanker Owners Pollution Federation (ITOPF) consist of:

- **Group 1**: Rapidly evaporating and fast spreading oils with low persistence (one day) in the sea. **High toxicity levels**.

  This group includes products such as motor gasoline's and aviation fuels all of which have high evaporation rates. Primary concerns surrounding a release of these products are the potential for fire and explosion; and the pollution risk, although significant due to the toxicity of components, is secondary in terms of the threat to human safety. Most of these products have high aquatic toxicity and a release can have a serious impact on marine life in the intertidal zone and seabirds in offshore waters.

- **Group 2:** Rapidly spreading oil with moderate evaporation and emulsification and relatively low persistence (2-3 days) in the sea. **Generally highly toxic.**

  Fuels such as automotive distillate and marine diesel oils, which are moderate evaporation rates. A release of these products creates a risk of fire and explosion; the pollution risk, although very significant due to toxicity of components, is secondary in

terms of the threat to human safety. A release can have a serious impact on marine life in the intertidal zone as well as seabirds in offshore waters.

- **Group 3:** Light fuels oils, waste oils and lubricating oils. **Medium to low toxicity.**

  These have slower spreading rates and form thick emulsions that may persist in the sea for about a week.

- **Group 4**: Some crude oils and heavy fuel oils. Viscous, residual oils that spread slowly and form persistent emulsions in the sea. **Low toxicity but significant smothering action.**

  Heavy fuel oils (HFO) are supplied as bunker fuels in the ports. Most vessels using the port carry HFO as bunker fuel. Crude oils when shipped contain all four groups initially. When spilled the lighter ends evaporate and the residue consists of groups 3 & 4.

C.4: Oil Weathering Processes

Oil spilled on the sea undergoes a series of processes collectively known as "weathering" which will change its characteristics and behaviour. Although, the individual processes, which bring about these changes act simultaneously, their relative importance during the lifetime of an oil slick varies. The main processes are as follows:

- Spreading
- Evaporation
- Dispersion
- Emulsification
- Dissolution
- Oxidation
- Sedimentation
- Biodegradation

The main factors affecting the behaviour of oil are:

- physical characteristics of the oil, in particular, specific gravity, viscosity and boiling range;
- composition and chemical characteristics of the oil;
- meteorological conditions (sea state, sunlight and air temperatures); and
- Characteristics of the seawater (specific gravity, currents, temperature, presence of bacteria, nutrients and dissolved oxygen and suspended solids).

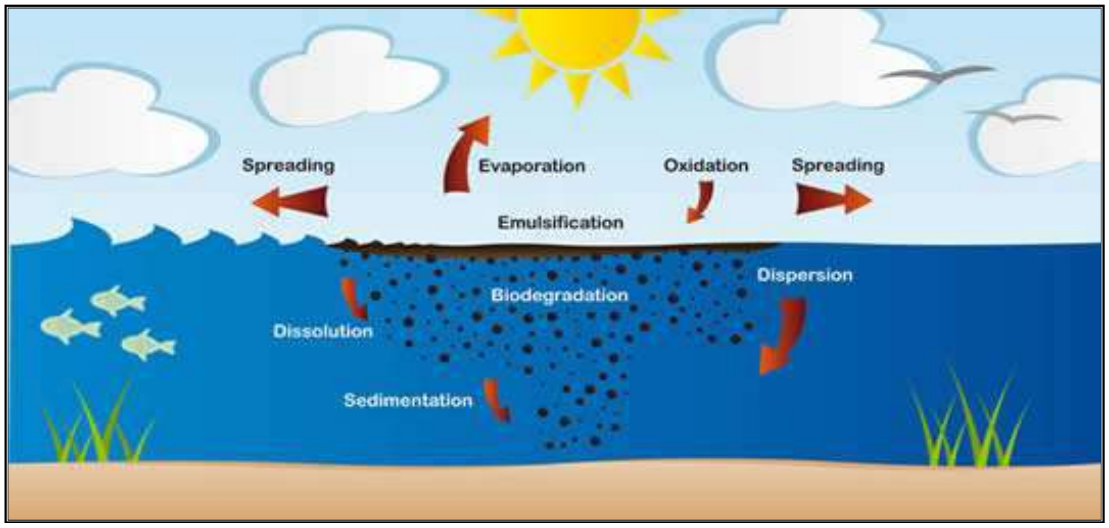


Figure C-1: Processes taking place after an oil spill

The processes of spreading, evaporation, dispersion, emulsification and dissolution are most important during the early stages of a spill, whilst oxidation, sedimentation and biodegradation are long-term processes, which determine the ultimate fate of oil. It should be appreciated that throughout the lifetime of an oil slick, it continues to drift on the sea surface, independent of these processes. The actual mechanism governing movement is complex but experience shows that oil drift can be predicted by taking into account wind-induced effects and surface water currents. These can be calculated using mathematical modeling to determine the oil spill trajectory. The wind-induced effect is normally taken as 1-3% of the wind velocity, and the current effect as 110% of the current velocity. Reliable prediction of slick movement is clearly dependent upon the availability of good wind, tide and current data.

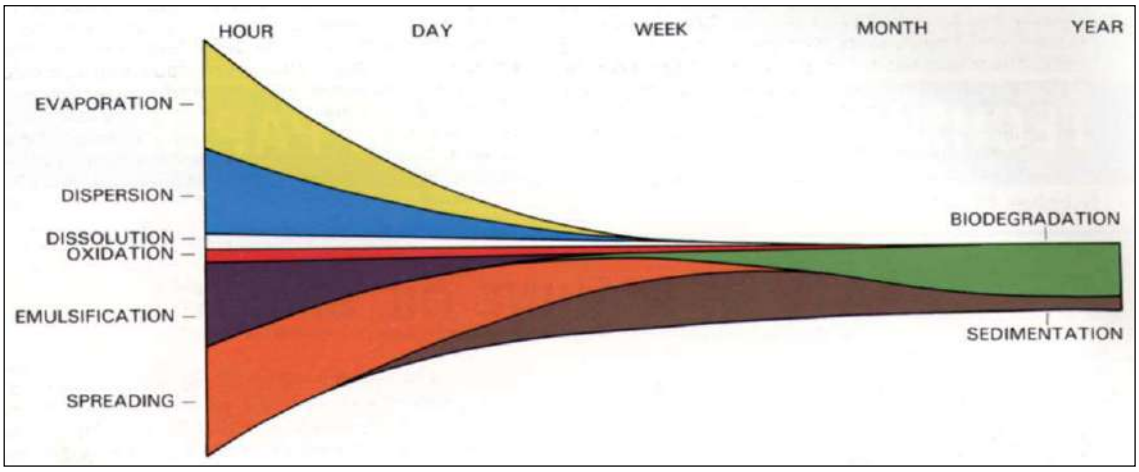


Figure C-2: Schematic diagram of weathering processes with time

C.5: Oil Slick Movement

Movement of an oil slick is dependent on the physical characteristics of the oil, the predominant surface currents, wind direction and velocity. Surface currents will dominate spill movement unless winds are strong. However, wind will cause an oil slick to move at approximately 3% of the wind speed. Slick spreading will dictate spill movement only when very close to the point of release.

Prediction of oil slick movement in an actual spill situation may also be accomplished by vector analysis of the two main forces that influence open water oil slick movement, surface currents and winds is shown below in figure C-3.

STEPS: Steps to use SLICK PREDICTION BY VECTOR ANALYSIS.

1. Ascertain the direction and speed of both surface water currents and the wind.
2. Next, draw ocean current and wind component vectors showing their relative directions and lengths. The velocity of the current and wind is represented by the length of the vector.
3. Draw a line parallel to the wind vector starting from the tip of the current vector and measuring the exact length of the wind vector.
4. Draw a line from the point of origin to the tip of the parallel wind vector line. The final line is the resultant vector that gives the direction and speed of the slick movement. The direction can be measured with a protractor. The speed is determined by measuring the length of the resultant vector relative to the scale in use.

This can be represented by the following simplified formula:

$$\mathbf{V_{oil} = V_{current} + (V_{wind} \times Q)}$$

In which:

V_{oil} = velocity of the oil

$V_{current}$ = velocity of seawater

V_{wind} = velocity of wind at a height of 10 m

Q = empirically established wind speed factor (usually about 3%)

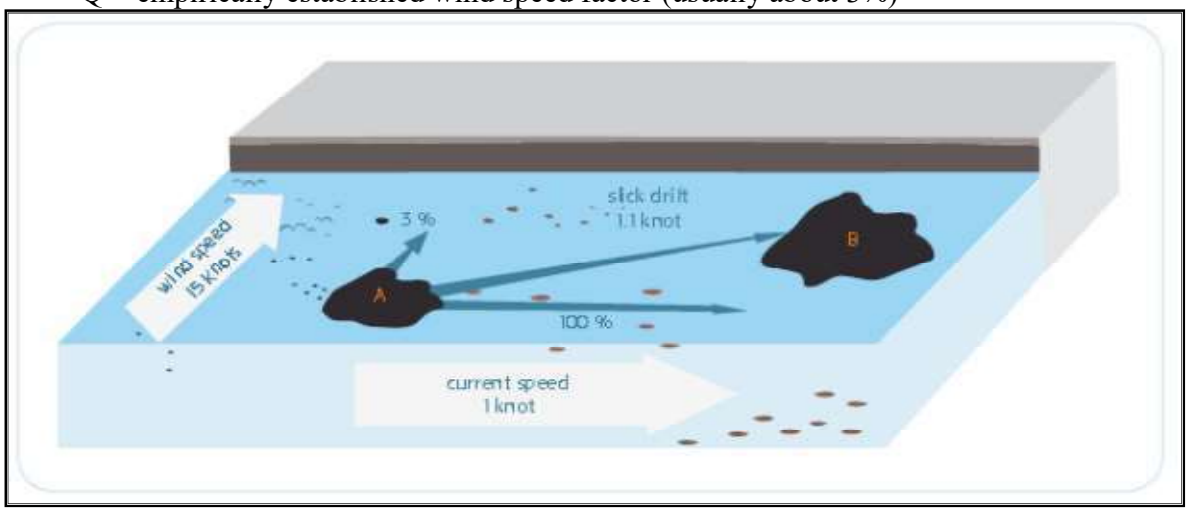


Figure C-3: Slick Prediction by Vector Analysis

APPENDIX D
OIL SPILL WEATHERING MODELING BY USING ADIOS2

The National Oceanic and Atmospheric Administration's (NOAA's) Automated Data Inquiry for Oil Spills (ADIOS2) model was used to simulate detailed evaporation, dispersion and emulsification of the spill. Input data for ADIOS2 includes:

- Oil properties (API, viscosity, distillation curves);
- Spill details (volume and duration of the spill); and
- Environmental data (wind and sea surface temperature).

Scenario 1A: Continuous spill of 400 T Fuel oil over 10 hrs, representing the spread from a ruptured fuel tank due to collision/grounding for the month of January.

Figure D-1 and Figure D-2 shows results from the ADIOS2 modeling for predicted weathering and oil budget table for 9 knots wind. Approximately 6% of the oil is predicted to evaporate within 24 hrs, 48% is predicted to become entrained into the water column leaving 46% on the sea surface.

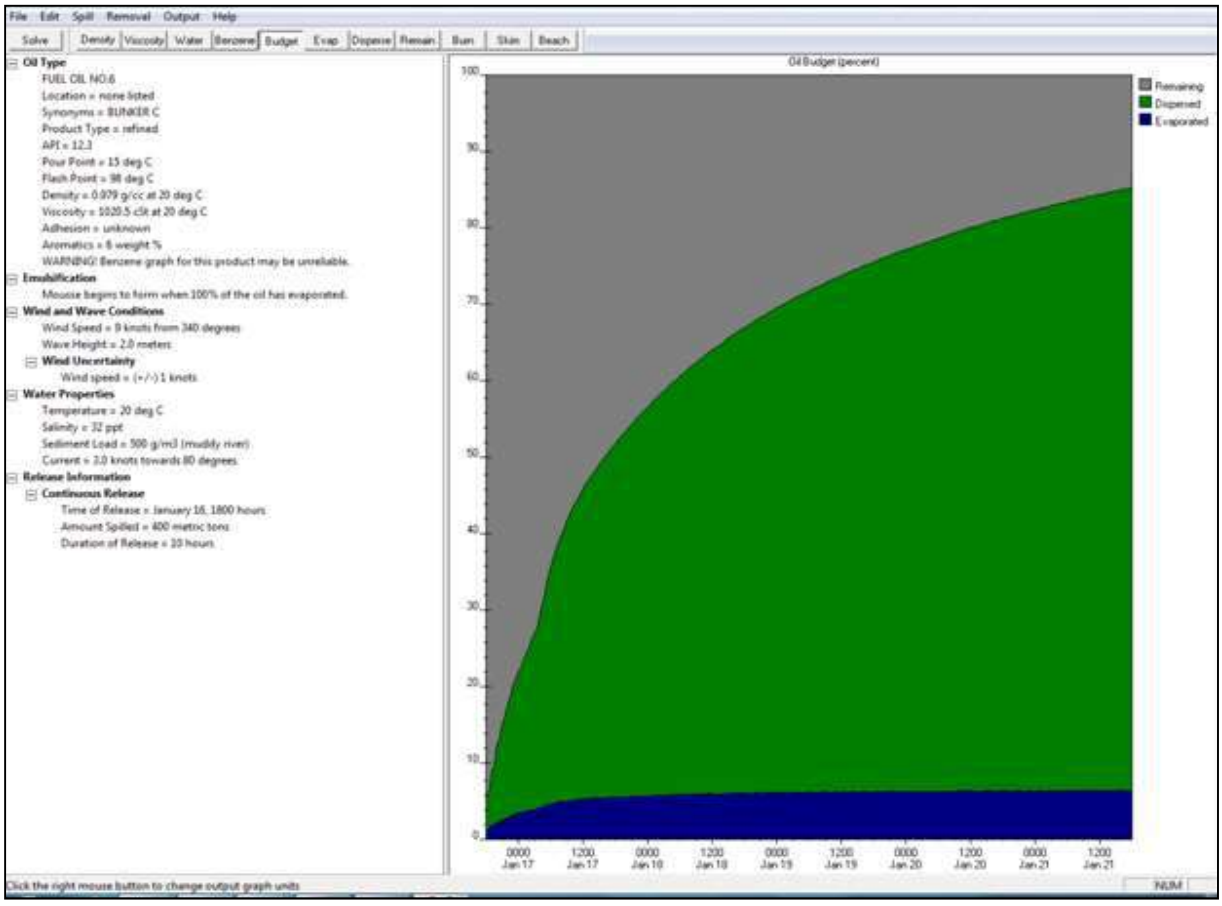


Figure D-1: Predicted weathering of Fuel oil for a continuous release of 400 tons in January.

Spill Scenario - Oil Budget Table ADIOS® 2.0

Oil Name = FUEL OIL NO.6
API = 12.3 Pour Point = 15 deg C
Wind Speed = constant at 9 knots Wave Height = 2 meters
Water temperature = 20 deg C
Time of Initial Release = January 16, 1800 hours
Total amount of Oil Released = 400 metric tons

Hours Into Spill	Released metric ton	Evaporated percent	Dispersed percent	Remaining percent
1	40	1	4	95
2	80	2	8	91
4	160	3	13	84
6	240	3	18	79
8	320	4	21	75
10	400	4	24	72
12	400	4	30	66
14	400	5	34	61
16	400	5	38	57
18	400	5	40	54
20	400	5	43	52
26	400	6	48	46
32	400	6	52	42
38	400	6	56	38
44	400	6	59	35
50	400	6	62	32
56	400	6	64	30
62	400	6	66	27
68	400	6	68	25
74	400	6	70	24
80	400	6	72	22
86	400	6	73	21
92	400	6	74	19
98	400	6	75	18
104	400	6	77	17
110	400	6	78	16
116	400	6	78	15

Figure D-2: Predicted oil budget table for a continuous release of 400 tons in January.

Scenario 1B: Continuous spill of 400 T Fuel oil over 10 hrs, representing a spread from a ruptured fuel tank due to collision/grounding for the month of April.

Figure D-3 and Figure D-4 shows results from the ADIOS2 modeling for predicted weathering and oil budget table for 11 knots wind. Approximately 6% of the oil is predicted to evaporate within 24 hrs, leaving 48% on the sea surface.

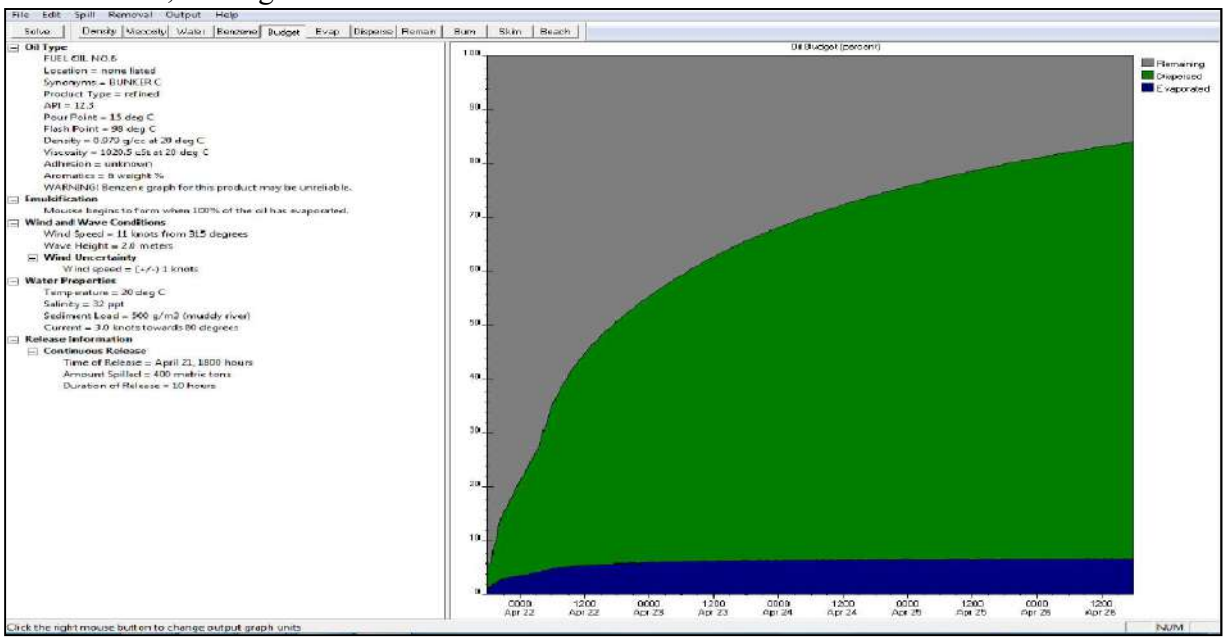


Figure D-3: Predicted weathering of fuel oil for a continuous release of 400 tons in April

Spill Scenario - Oil Budget Table ADIOS® 2.0

Oil Name = FUEL OIL NO.6
API = 12.3 Pour Point = 15 deg C
Wind Speed = constant at 11 knots Wave Height = 2 meters
Water temperature = 20 deg C
Time of Initial Release = April 21, 1800 hours
Total amount of Oil Released = 400 metric tons

Hours Into Spill	Released metric ton		Evaporated percent		Dispersed percent		Remaining percent
1	40	-	1	-	4	-	94
2	80		2		8		90
4	160	-	3	-	13	-	84
6	240		4		17		80
8	320	-	4	-	20	-	76
10	400		4		23		73
12	400	-	5	-	29	-	66
14	400		5		34		61
16	400	-	5	-	37	-	58
18	400		5		39		55
20	400	-	6	-	41	-	53
26	400		6		47		48
32	400	-	6	-	51	-	43
38	400		6		55		39
44	400	-	6	-	58	-	36
50	400		6		60		33
56	400	-	6	-	63	-	31
62	400		6		65		29
68	400	-	6	-	67	-	27
74	400		6		68		25
80	400	-	7	-	70	-	24
86	400		7		71		22
92	400	-	7	-	73	-	21
98	400		7		74		20
104	400	-	7	-	75	-	18
110	400		7		76		17
116	400	-	7	-	77	-	16

Figure D-4: Predicted oil budget table for a continuous release of 400 tons in April

Scenario 1C: Continuous spill of 400 T Fuel oil over 10 hrs, representing a spread from a ruptured fuel tank due to collision/grounding for the month of July.

Figure D-5 and Figure D-6 shows results from the ADIOS2 modeling for predicted weathering and oil budget table for 15 knots wind. Approximately 6% of the oil is predicted to evaporate within 24 hrs, 45% is predicted to become entrained into the water column leaving 49% on the sea surface.

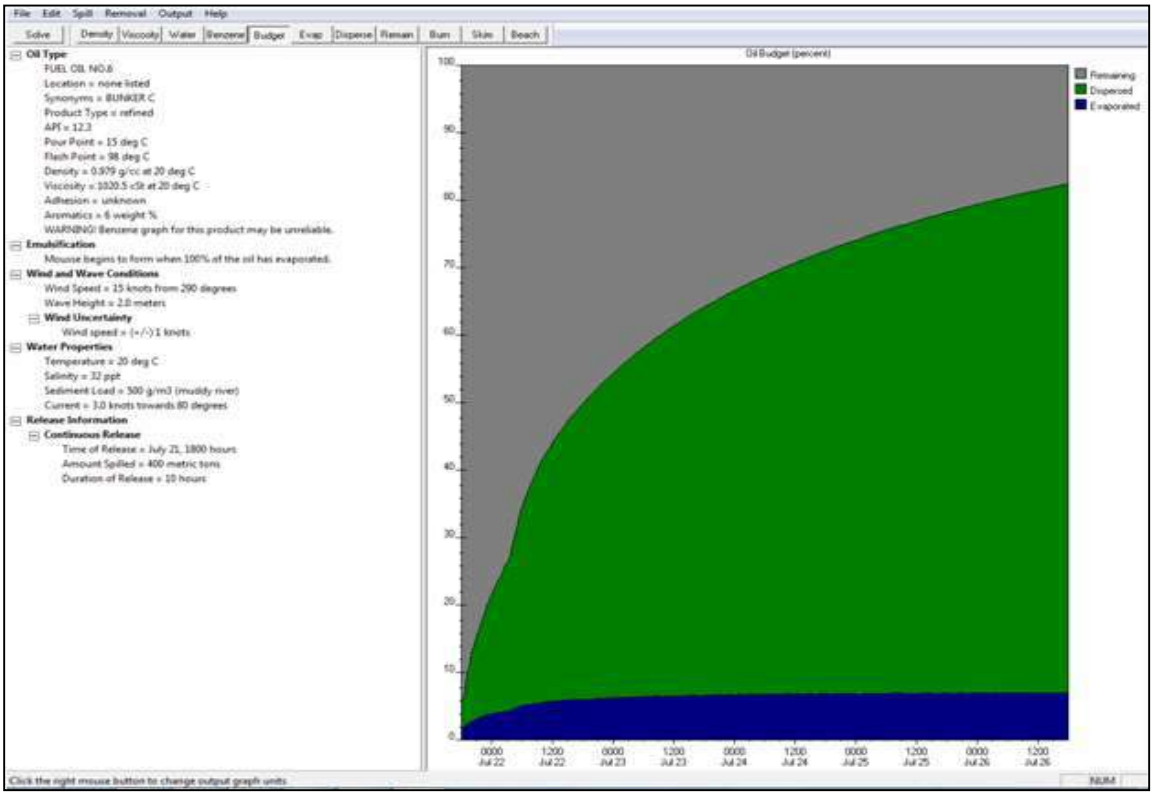


Figure D-5: Predicted weathering of fuel oil for a continuous release of 400 tons in July

Spill Scenario - Oil Budget Table ADIOS® 2.0

Oil Name = FUEL OIL NO.6
API = 12.3 Pour Point = 15 deg C
Wind Speed = constant at 15 knots Wave Height = 2 meters
Water temperature = 20 deg C
Time of Initial Release = July 21, 1800 hours
Total amount of Oil Released = 400 metric tons

Hours Into Spill	Released metric ton	Evaporated percent	Dispersed percent	Remaining percent
1	40	2	5	93
2	80	2	8	89
4	160	3	13	84
6	240	4	17	80
8	320	4	20	76
10	400	4	22	73
12	400	5	28	67
14	400	5	32	62
16	400	6	35	59
18	400	6	38	57
20	400	6	40	54
26	400	6	45	49
32	400	6	49	45
38	400	6	52	41
44	400	7	55	38
50	400	7	58	35
56	400	7	60	33
62	400	7	62	31
68	400	7	64	29
74	400	7	66	27
80	400	7	68	26
86	400	7	69	24
92	400	7	70	23
98	400	7	71	22
104	400	7	73	20
110	400	7	74	19
116	400	7	75	18

Figure D-6: Predicted oil budget table for a continuous release of 400 tons in July

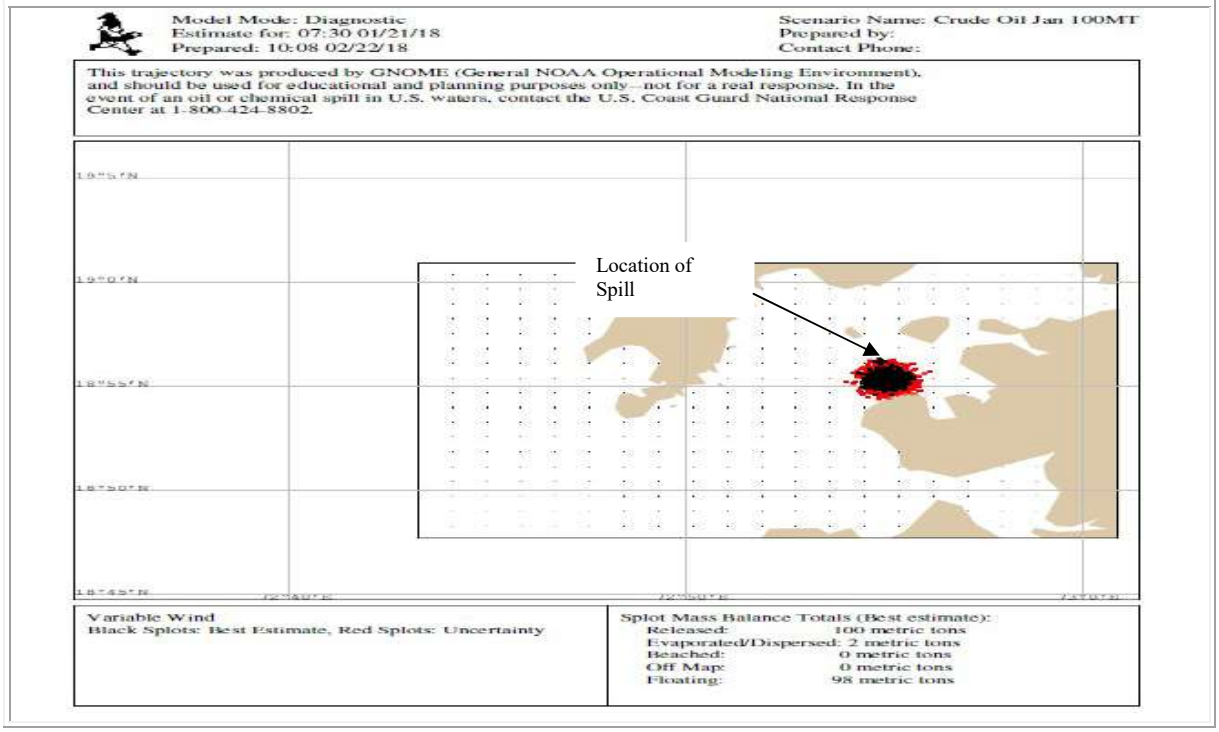
APPENDIX E
OIL SPILL TRAJECTORY MODELING BY USING GNOME

The National Oceanic and Atmospheric Administration's (NOAA's) GNOME model is used to simulate trajectory of Oil Spill. Input data for GNOME includes:

- Map file generated from GNOME Global custom map generator.
- Avg. wind speed of 9.1 knots – North-North West for January, 10.5 knots – North-West for April and 14.8 knots – West North West for July and as per data provided by the JNPT.
- Current file is taken from HYCOM.
- Location of Spill:
  1. Near Y-Junction
  2. Near Elephanta Island
  3. Near Nhava –ONGC Base
- Trajectory Modeling is carried out for spillage of Oils – 2 hr trajectory and 6 hr trajectory for 100 T and 6hr, 12hr and 24 hr trajectory for 10 T spill.
- Trajectory Modeling has been done for Crude Oil, Bunker Oil, Diesel Oil and Kerosene (refer table below).

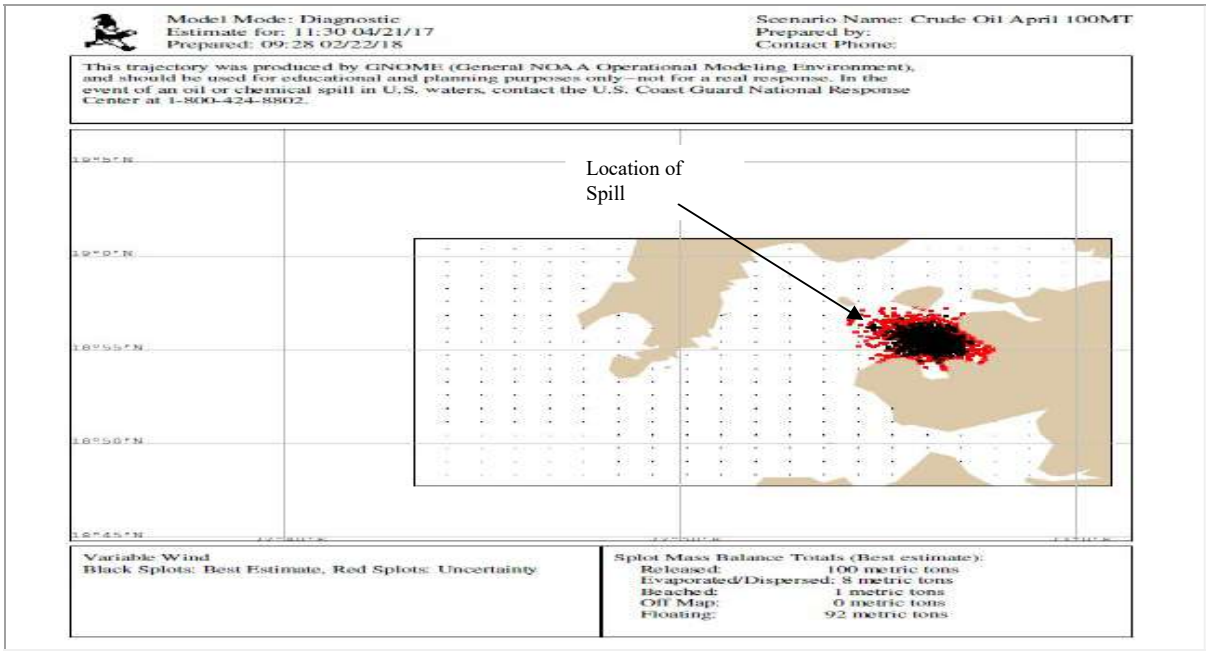
Crude Oil – January – Y Junction

1. Trajectory of spillage of Crude oil of 100mT in JNPT Port limit (Y Junction) for the month of January is as shown in below figure. After 2 hrs the position of the slick is shown in the figure.



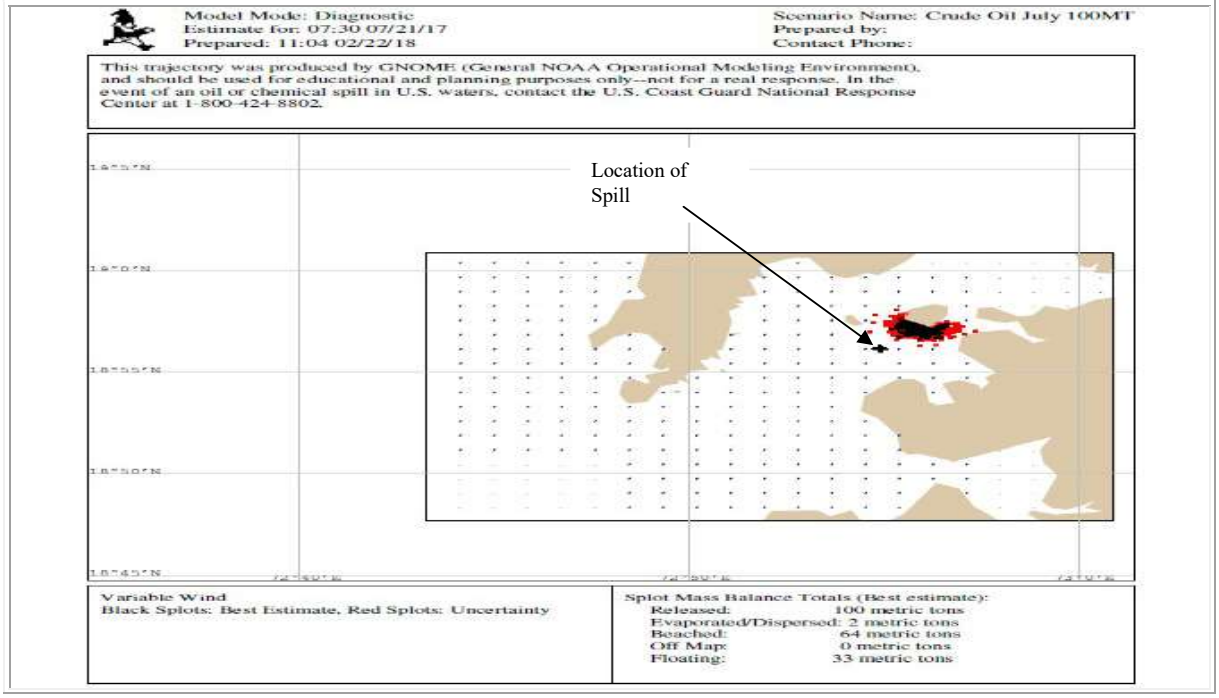
Crude Oil – April– Y Junction

2. Trajectory of spillage of Crude oil of 100mT in JNPT Port limit (Y Junction) for the month of April is as shown in below figure. After 6 hrs the position of the slick is shown in the figure.



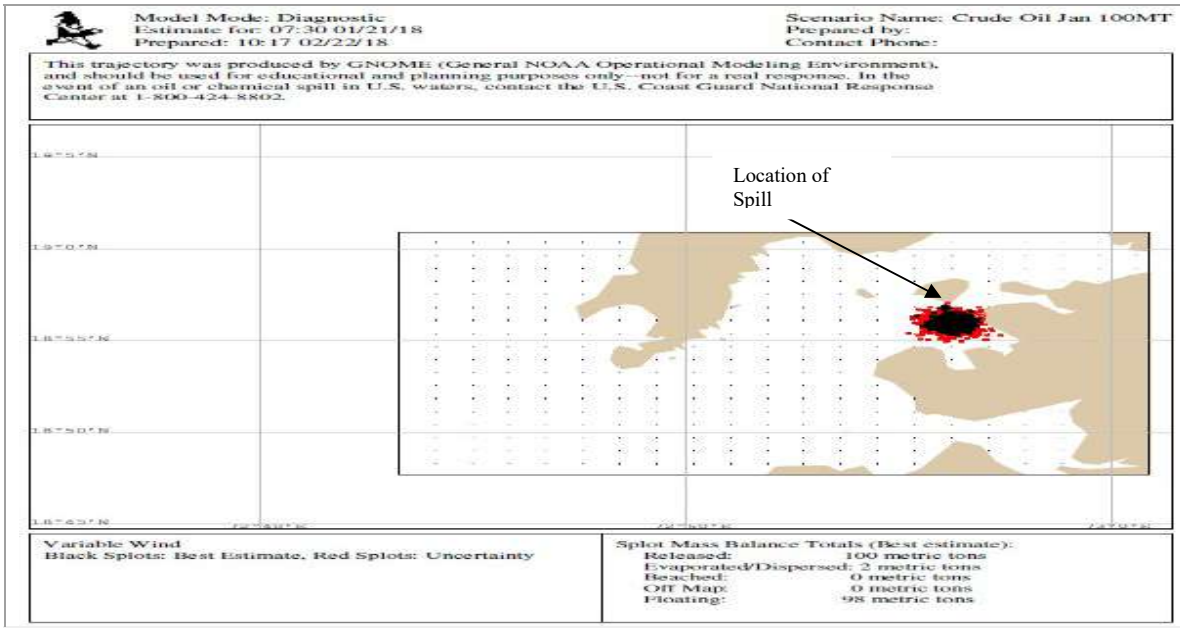
Crude Oil – July– Y Junction

3. Trajectory of spillage of Crude oil of 100mT in JNPT Port limit (Y Junction) for the month of July is as shown in below figure. After 2 hrs the position of the slick is shown in the figure.



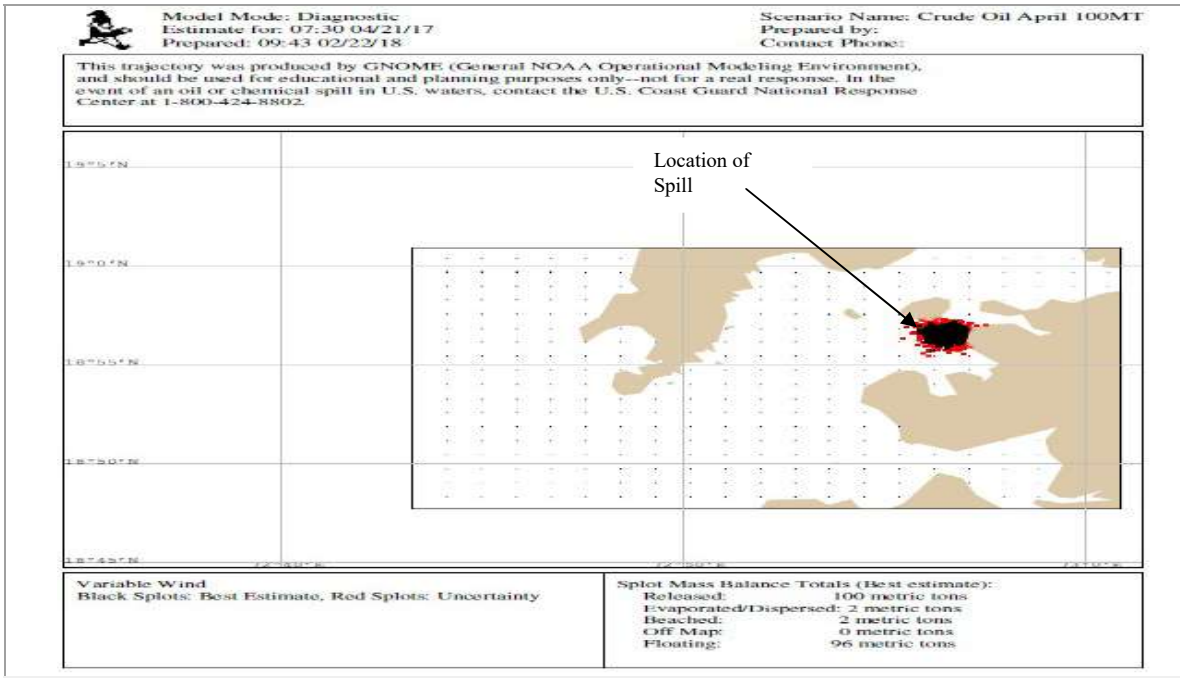
Crude Oil – January – Elephanta Island

4. Trajectory of spillage of Crude oil of 100mT in JNPT Port limit (Near Elephanta Island) for the month of January is as shown in below figure. After 2 hrs the position of the slick is shown in the figure.



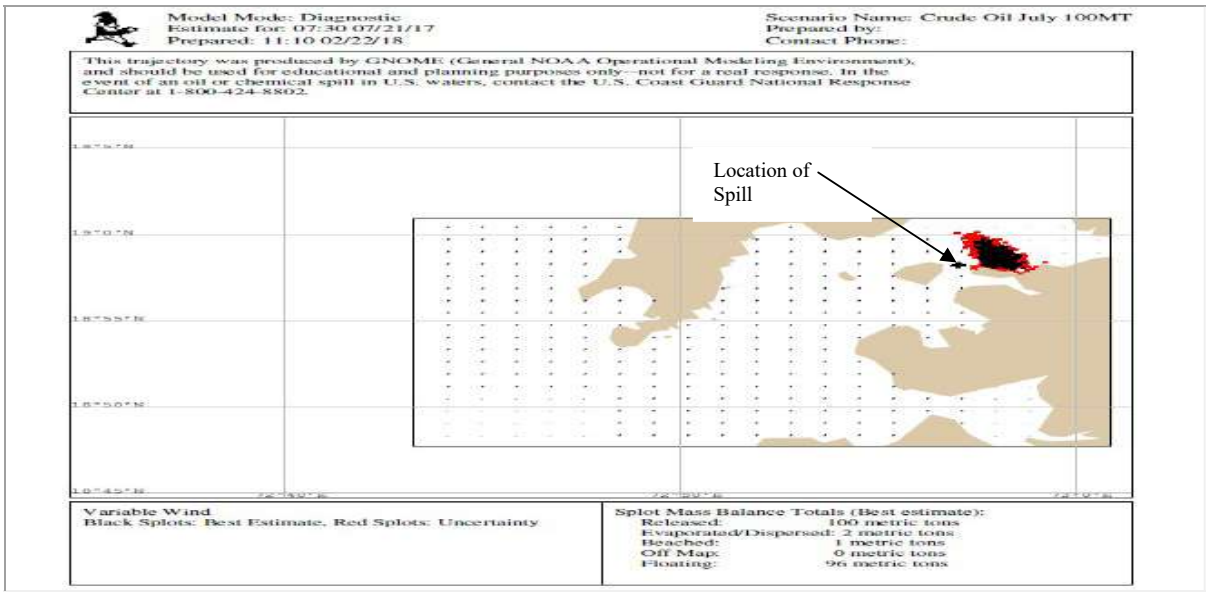
Crude Oil – April– Elephanta Island

5. Trajectory of spillage of Crude oil of 100mT in JNPT Port limit (Near Elephanta Island) for the month of April is as shown in below figure. After 2 hrs the position of the slick is shown in the figure.



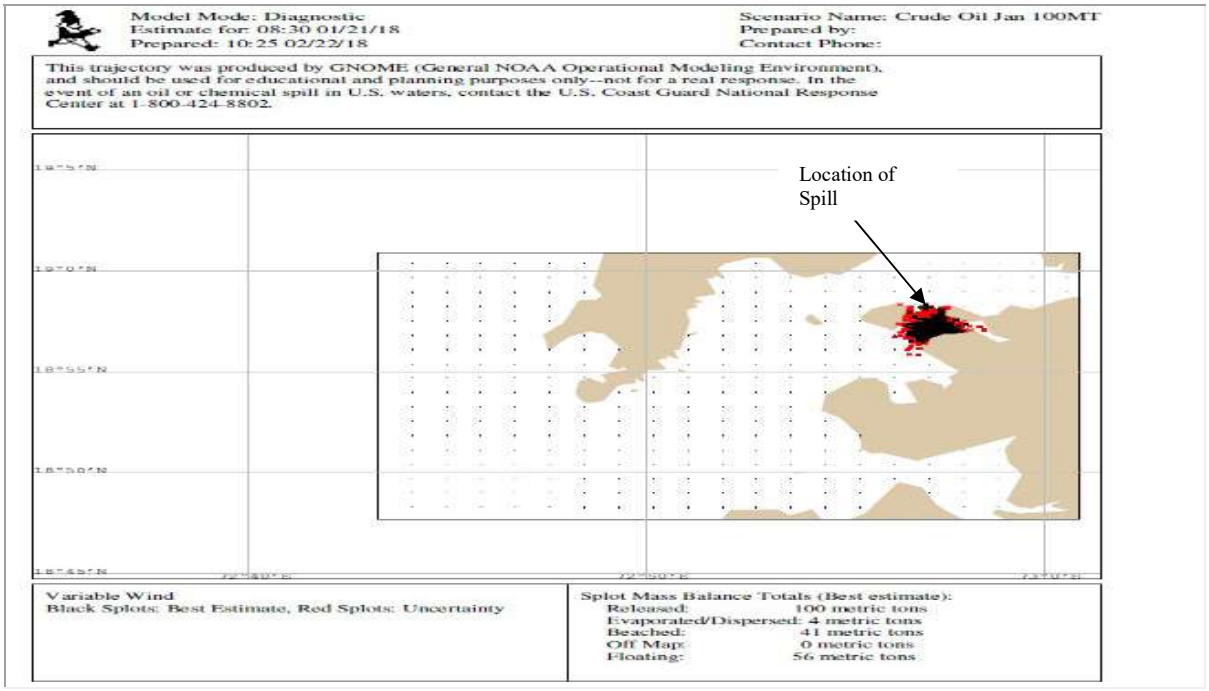
Crude Oil – July-Near Nhava Base-ONGC

6. Trajectory of spillage of Crude oil of 100mT in JNPT Port limit (Near Nhava Base-ONGC) for the month of July is as shown in below figure. After 2 hrs the position of the slick is shown in the figure.



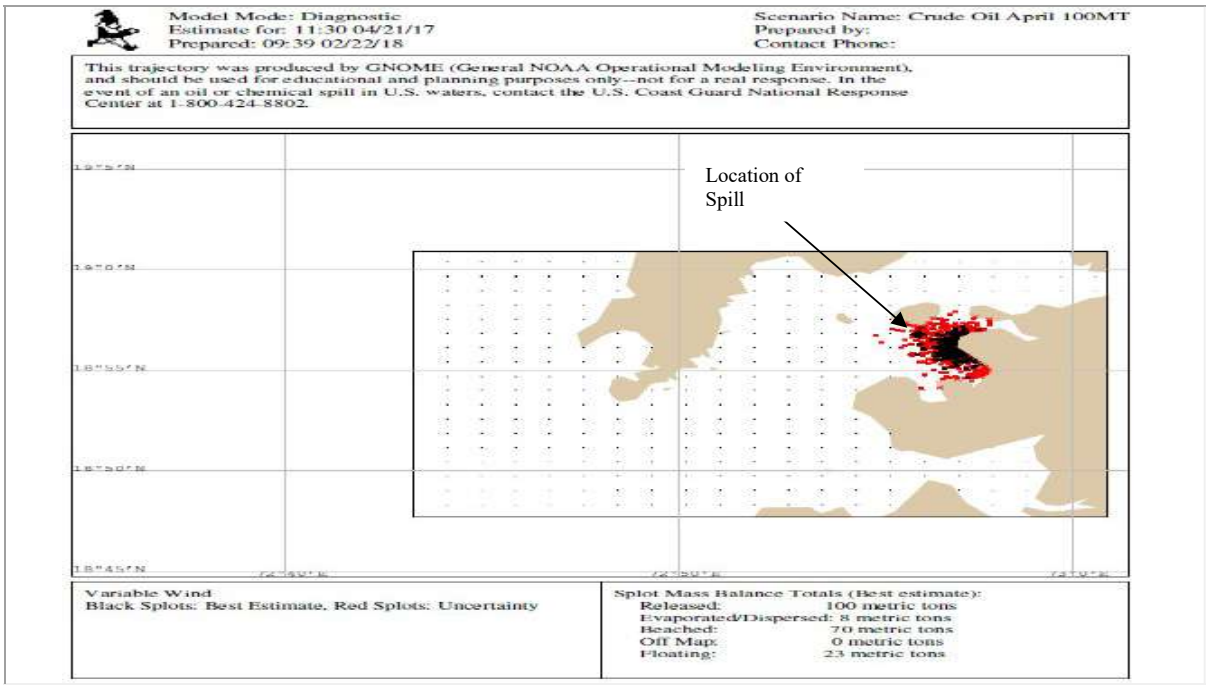
Crude Oil – January – Near Nhava Base-ONGC

7. Trajectory of spillage of Crude oil of 100mT in JNPT Port limit (Near Nhava Base-ONGC) for the month of January is as shown in below figure. After 2 hrs the position of the slick is shown in the figure.



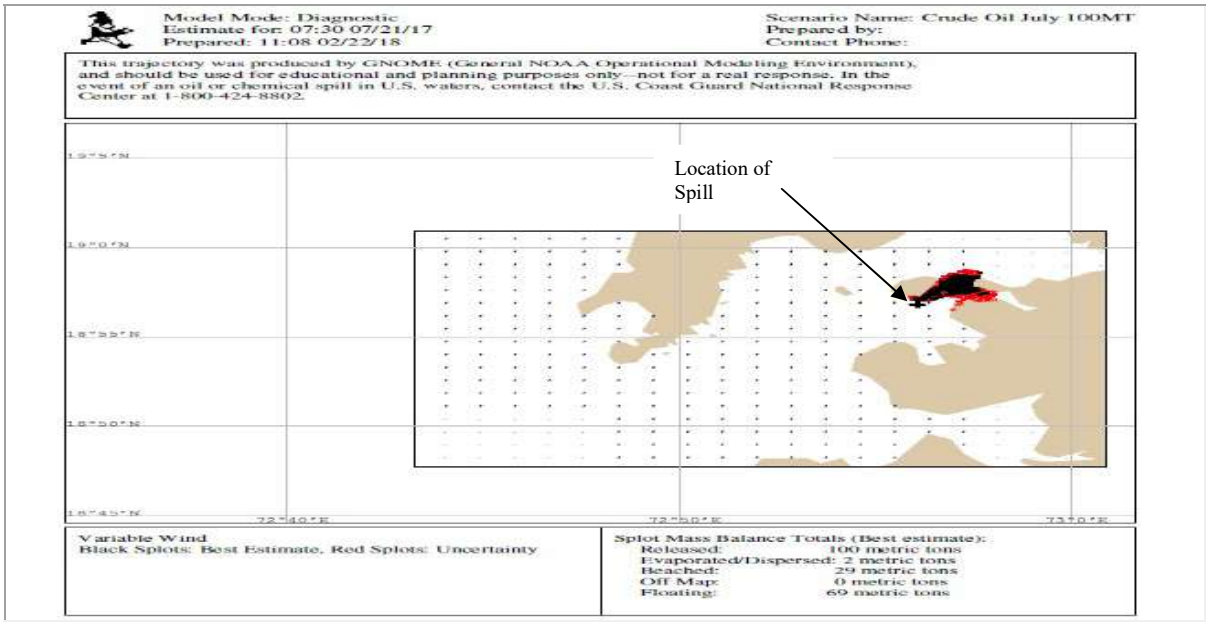
Crude Oil – April– Elephanta Island

8. Trajectory of spillage of Crude oil of 100mT in JNPT Port limit (Near Elephanta Island) for the month of April is as shown in below figure. After 6 hrs the position of the slick is shown in the figure.



Crude Oil – July– Elephanta Island

9. Trajectory of spillage of Crude oil of 100mT in JNPT Port limit (Near Elephanta Island) for the month of July is as shown in below figure. After 2 hrs the position of the slick is shown in the figure.



10 Ton Spill

Table E.1: Summary for 6 hr trajectory
Location : Y Junction
Release: 10MT

Oil type	January			April			July		
	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating
Crude Oil	0.8	8.7	0.6	0.8	0.1	9.2	0.8	8.9	0.4
Kerosene	3.2	6.3	0.5	3.2	0.1	6.7	3.2	6.5	0.3
Diesel	1.1	8.3	0.6	1.1	0.1	8.8	1.1	8.3	0.5
Bunker Oil	0.6	8.8	0.6	0.6	0.1	9.3	0.6	8.8	0.5

Table E.2: Summary for 12 hr trajectory
Location : Y Junction
Release: 10MT

Oil type	January			April			July		
	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating
Crude Oil	1.3	8.2	0.5	1.3	5.3	3.4	1.3	8.5	0.2
Kerosene	5	4.8	0.2	5	3	2	5	4.8	0.1
Diesel	2	7.6	0.5	2	4.9	3.1	2	7.8	0.2
Bunker Oil	1	8.6	0.4	1	5.5	3.5	1.1	8.7	0.3

Table E.3: Summary for 24 hr trajectory
Location : Y Junction
Release: 10MT

Oil type	January			April			July		
	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating
Crude Oil	2.3	7.2	0.6	2.2	6.9	0.9	2.3	7.5	0.2
Kerosene	7.3	2.5	0.2	7.2	2.5	0.4	7.3	2.6	0.1
Diesel	3.6	5.9	0.5	3.5	6	0.5	3.6	6.2	0.2
Bunker Oil	1.8	7.8	0.5	1.8	7.5	0.7	1.9	7.8	0.3

Table E.4: Summary for 6 hr trajectory
Location : Near Elephanta Island
Release: 10MT

Oil type	January			April			July		
	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating
Crude Oil	0.8	4.8	4.5	0.8	7	2.3	0.8	5.5	3.7
Kerosene	3.2	3.3	3.5	3.2	5.2	1.6	3.2	4	2.8
Diesel	1.1	4.3	4.6	1.1	6.7	2.1	1.1	5.3	3.6
Bunker Oil	0.6	4.6	4.8	0.6	7.1	2.3	0.6	5.4	4

Table E.5: Summary for 12 hr trajectory
Location : Near Elephanta Island
Release: 10MT

Oil type	January			April			July		
	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating
Crude Oil	1.3	8.1	0.7	1.3	7.7	1	1.3	7.5	1.2
Kerosene	5	4.6	0.4	5	4.3	0.7	5.1	4.2	0.7
Diesel	2	7.5	0.5	2	6.9	1.2	1.9	7	1.1
Bunker Oil	1	8.4	0.6	1	8	0.9	1	7.5	1.4

Table E.6: Summary for 24 hr trajectory
Location : Near Elephanta Island
Release: 10MT

Oil type	January			April			July		
	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating
Crude Oil	2.2	7.3	0.4	2.2	6.9	0.9	2.3	6.9	0.8
Kerosene	7.2	2.7	0.1	7.2	2.6	0.3	7	2.7	0.3
Diesel	3.5	6.2	0.3	3.5	5.6	0.9	3.4	6.2	0.4
Bunker Oil	1.8	7.8	0.4	1.8	7.1	1.1	1.8	7.4	0.7

Table E.7: Summary for 6 hr trajectory
Location : Near NHAVA –ONGC base
Release: 10MT

Oil type	January			April			July		
	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating
Crude Oil	0.8	8.2	1.1	0.8	7.6	1.7	0.8	4.5	4.7
Kerosene	3.2	6.1	0.7	3.2	5.7	1.1	3.2	3.1	3.7
Diesel	1.1	8.1	0.8	1.1	7.3	1.6	1.1	4.4	4.5
Bunker Oil	0.6	8.4	1	0.6	7.8	1.6	0.6	4.9	4.5

Table E.8: Summary for 12 hr trajectory
Location : Near NHAVA –ONGC base
Release: 10MT

Oil type	January			April			July		
	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating
Crude Oil	1.3	7.9	0.9	1.3	7.3	1.4	1.4	7.8	0.7
Kerosene	5	4.5	0.4	5	4.2	0.8	4.9	4.5	0.4
Diesel	2	7.3	0.8	2	6.9	1.2	2.1	7.1	0.7
Bunker Oil	1	8.1	0.9	1	7.6	1.4	1.1	8	0.8

Table E.9: Summary for 24 hr trajectory
Location : Near NHAVA –ONGC base
Release: 10MT

Oil type	January			April			July		
	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating
Crude Oil	2.2	7	0.8	2.3	6.7	1.1	2.4	6.8	0.4
Kerosene	7.2	2.5	0.4	7.2	2.5	0.4	7	2.5	0.2
Diesel	3.5	5.9	0.6	3.5	5.5	1	3.4	5.8	0.3
Bunker Oil	1.8	7.2	1	1.8	6.9	1.3	1.9	7.1	0.6

100 Ton Spill

Table E.10: Summary for 2 hr trajectory
Location : Y Junction
Release: 100MT

Oil type	January			April			July		
	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating
Crude Oil	2	0	98	2	0	98	2	64	33
Kerosene	11	0	89	11	0	89	11	60	29
Diesel	4	0	97	4	0	97	4	62	35
Bunker Oil	2	0	98	2	0	98	2	64	34

Table E.11: Summary for 6 hr trajectory
Location : Y Junction
Release: 100MT

Oil type	January			April			July		
	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating
Crude Oil	8	87	6	8	1	92	8	89	4
Kerosene	32	63	5	32	1	67	32	65	3
Diesel	11	83	6	11	1	88	11	83	5
Bunker Oil	6	88	6	6	1	93	6	88	5

Table E.12: Summary for 2 hr trajectory
Location : Near Elephanta Island
Release: 100MT

Oil type	January			April			July		
	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating
Crude Oil	2	0	98	2	2	96	2	29	69
Kerosene	11	0	89	11	2	87	11	26	62
Diesel	4	0	97	4	1	95	4	28	69
Bunker Oil	2	0	98	2	2	96	2	30	68

Table E.13: Summary for 6 hr trajectory
Location : Near Elephanta Island
Release: 100MT

Oil type	January			April			July		
	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating
Crude Oil	8	48	45	8	70	22	8	55	37
Kerosene	32	33	35	32	52	16	32	40	28
Diesel	11	43	46	11	67	21	11	53	36
Bunker Oil	6	46	48	6	71	23	6	54	40

Table E.14: Summary for 2 hr trajectory
Location : Near NHAVA –ONGC base
Release: 100MT

Oil type	January			April			July		
	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating
Crude Oil	4	41	56	2	56	42	2	1	96
Kerosene	11	9	80	11	47	42	11	1	88
Diesel	4	9	87	4	56	40	4	1	96
Bunker Oil	2	8	90	2	54	44	2	1	97

Table E.15: Summary for 6 hr trajectory
Location : Near NHAVA –ONGC base
Release: 100MT

Oil type	January			April			July		
	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating	Evaporated /Dispersed	Beached	Floating
Crude Oil	8	82	11	8	76	17	8	45	47
Kerosene	32	61	7	32	57	11	32	31	37
Diesel	11	81	8	11	73	16	11	44	45
Bunker Oil	6	84	10	6	78	16	6	49	45

APPENDIX F
POTENTIAL IMPACTS FROM HNS SPILL

F.1 Introduction

In general terms, HNS material comprise of inorganic or organic chemical compounds, minerals, etc for use within or derived from industries like manufacturing, petrochemical, textile, pharmaceutical, food and agrichemical.

HNS material broadly comprised of the following:

- Refined products derived from oil,
- Other noxious or dangerous liquid substances,
- Liquefied gases,
- Gases,
- Solid bulk materials with chemical hazards,
- Liquids with flash points not exceeding 60°C, and
- Packaged dangerous, harmful and hazardous material.

From a response perspective, this list can be simplified to gas, liquid or solid released in bulk and/or released as packaged goods.

F.2 Fate of released HNS

Whether solid, liquid or gaseous in form, when chemicals are spilled they can behave in a number of different ways. Properties of HNS e.g. flammability, reactivity, toxicity, explosiveness, corrosiveness which can impact on safety, environment, property and socioeconomic activity once it is released into the environment. The fate also determines if it is possible to deploy counter-pollution response techniques, and which options should be chosen.

HNS can be grouped based on its post release behaviour. Grouping of HNS substances as shown in Table F.1 below has the advantage of focusing attention on those aspects of the release that relate to potential impact and problems of response, as follows:

- **Evaporators**: Comprises all volatile liquids which are less dense than sea water;
- **Floaters**: Comprises all non-volatile liquids which are less dense than sea water;
- **Sinkers**: Comprises all products which are more dense than sea water, and;
- **Dissolvers**: Comprises all products which are soluble in sea water.

Table F.1: Grouping of HNS substances by its behaviour

	Group	Properties	Chemicals handled at JNPT
Evaporate immediately(gases)	G Gas	Evaporate immediately	Propane, Butane, LPG
	GD gas/dissolver	Evaporate immediately, dissolve	Ammonia
Evaporate rapidly	E evaporator	Float, evaporate rapidly	Chlorobenzene, Cyclohexane, Pentane, Toluene, N-Hexane
	ED evaporator/ dissolver	Evaporate rapidly, dissolve	Methyl-t-butyl ether, vinyl acetate
Float	FE floater /evaporator	Float, evaporate	Xylene, Toluene
	FED floater/ evaporator /dissolver	Float, evaporate, dissolve	Butyl acetate
	F Floater	Float	Palm Oil, Diesel Oil,
	FD floater/dissolver	Float, dissolve	Butyl acrylate, Butanol
Dissolve	DE dissolver/ evaporator	Dissolve rapidly, evaporate	Ethyl methyl ketone, Acetone, Acetonitrile, phenol,
	D dissolver	Dissolve rapidly	Phosphoric acid, Butanol, Ethanol, Acrylic acid, Ethyl alcohol, Acetic acid, Potassium hydroxide, Potassium hydroxide, Ester
Sink	SD sinker/dissolver	Sink, dissolve	Dichloromethane, Chloroform
	S sinker	Sink	Sulphur, Trichloroethylene

F.3 Factors determining the safety, environmental and socioeconomic impact of HNS incidents

When dealing with an HNS incident one of the priority requirements is the identification of the hazards and assessment of the risk posed by HNS cargo to public and responder safety, the environment and socioeconomic assets. The risk is the product of hazards, probability and consequences or in a mathematical formula:

Risk = Probability x Consequences

Probability can be derived from statistics/incidents reports which show the frequency of incidents.

Consequences are depending on the vulnerability of the incident site or the vessel. It differs from location/vessel to location/ vessel as well as the means of technical equipment and response resources available.

The HNS risks during an accidental release event could be minimised by initially preparing a suitable risk assessment, and then by following the response options:

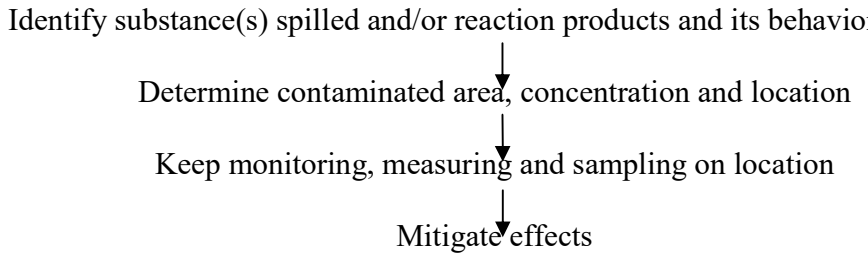
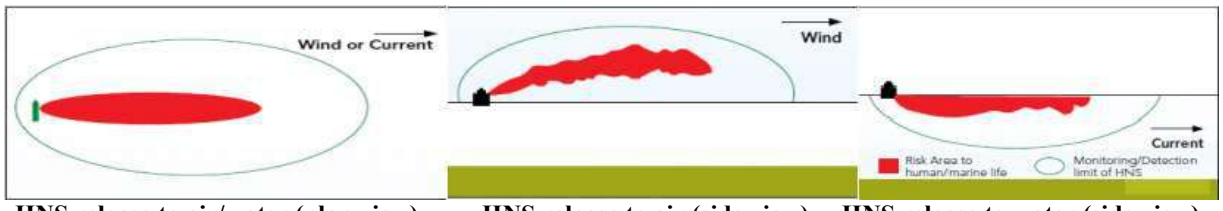


Figure F.1: Flow diagram of general approach to spills involving HNS

In risk assessment it is important to know the geographical scale or "risk area" that could be affected if a risk is not successfully responded to; for example the area around a vessel where explosion damage could extend to. It should be noted that in some cases the risk area will move either with the vessel or, in the case of a release to air or water, with the direction and extent of a toxic HNS plume. Wind, current and tide changes should be considered accordingly.



HNS release to air/water (plan view) **HNS release to air (side view)** **HNS release to water (side view)**

Figure F.2: HNS release to air/water, air and water

F.3.1 Safety impact

The physical fate can therefore determine the hazards posed by an HNS release. In the example of gases/evaporators with toxic (inhalation), flammable or explosive characteristics, the rate of evaporation combined with the total quantity evaporated and atmospheric dilution provides the resultant atmospheric concentration. This concentration relates to the potential toxicity of the

substance, the concentration where there is an explosion hazard and/or flash point for flammability.

Similarly with those substances that act as dissolvers in sea water and have toxic properties (aquatic), hazards will be determined by the rate of dissolution, the total quantity dissolved and dilution by seawater with the resulting concentration determining the level of toxicity a substance has.
Response organizations should also consider the potential for 'domino effects' i.e. where an HNS release could initiate another incident, such as a ship fire or explosion could damage and ignite a neighboring vessel, port facility, storage depot, etc.

F.3.2 Environmental impact
In addition to the toxicity hazards to humans, HNS substances can have lethal effects on marine organisms. Incidents involving releases to marine waters have the benefit of sea and air dilution, to reduce the concentration of a substance to below a lethal dose. However, it should be remembered that lower doses can produce sub-lethal effects to marine organisms over a wider area. Sub-lethal effects may produce some form of impairment which may be detrimental to individual organisms, species, populations or marine communities over a longer term, depending upon the persistence of the released HNS in the marine environment.

Where not directly toxic some forms of HNS material can damage the marine ecosystems by causing changes in the environment. Such changes include variation in salinity and pH, together with de-oxygenation when material is broken down or used biologically in the marine environment (e.g. palm oil, fertilisers, etc). Changes in environmental conditions can induce lethal effects in marine ecosystems.

F.3.3 Socioeconomic impact
Sub-lethal effects can reduce the commercial value of marine resources, e.g. fin erosion, skeletal deformities, growths, etc. on marketed fish.

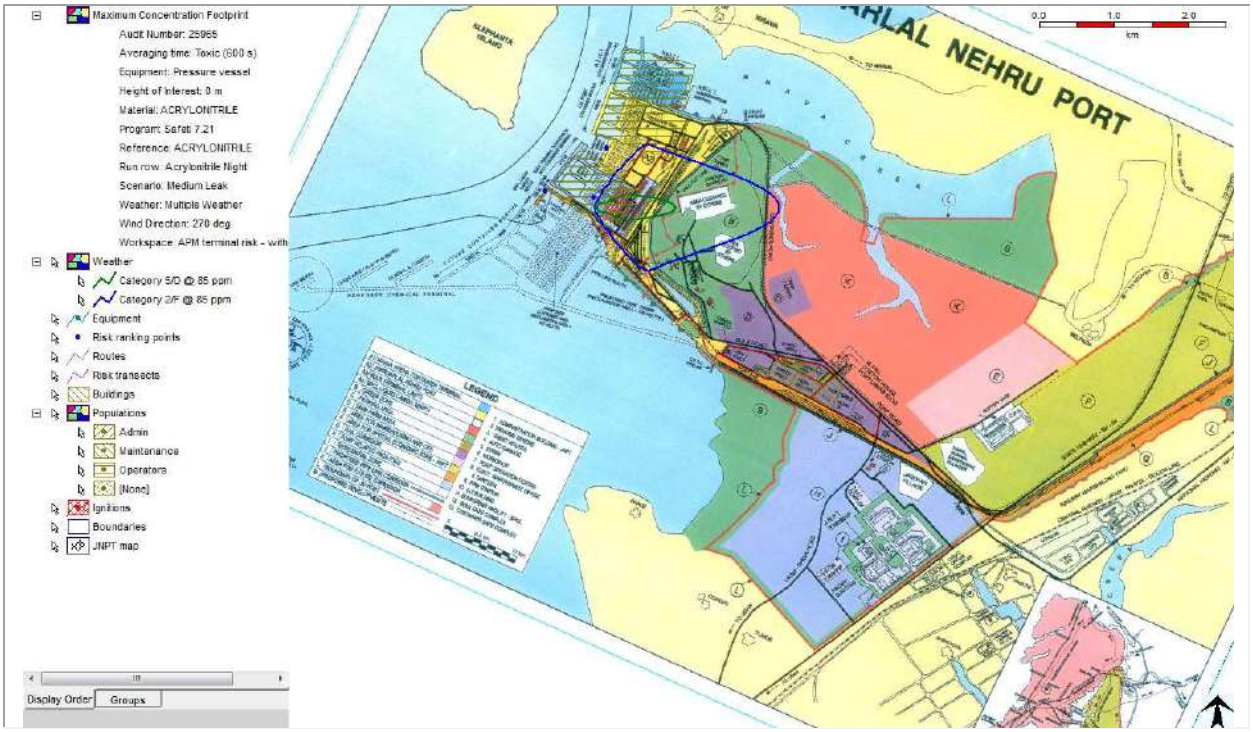
Contamination of an area may reduce its amenity value for economic drivers such as tourism, for example through the pollution of amenity beaches and bathing/recreation waters.

Toxicity, particularly with respect to contamination of commercial fish and shellfish by a bio-accumulating substance may lead to the closure of fishing and aquaculture areas.

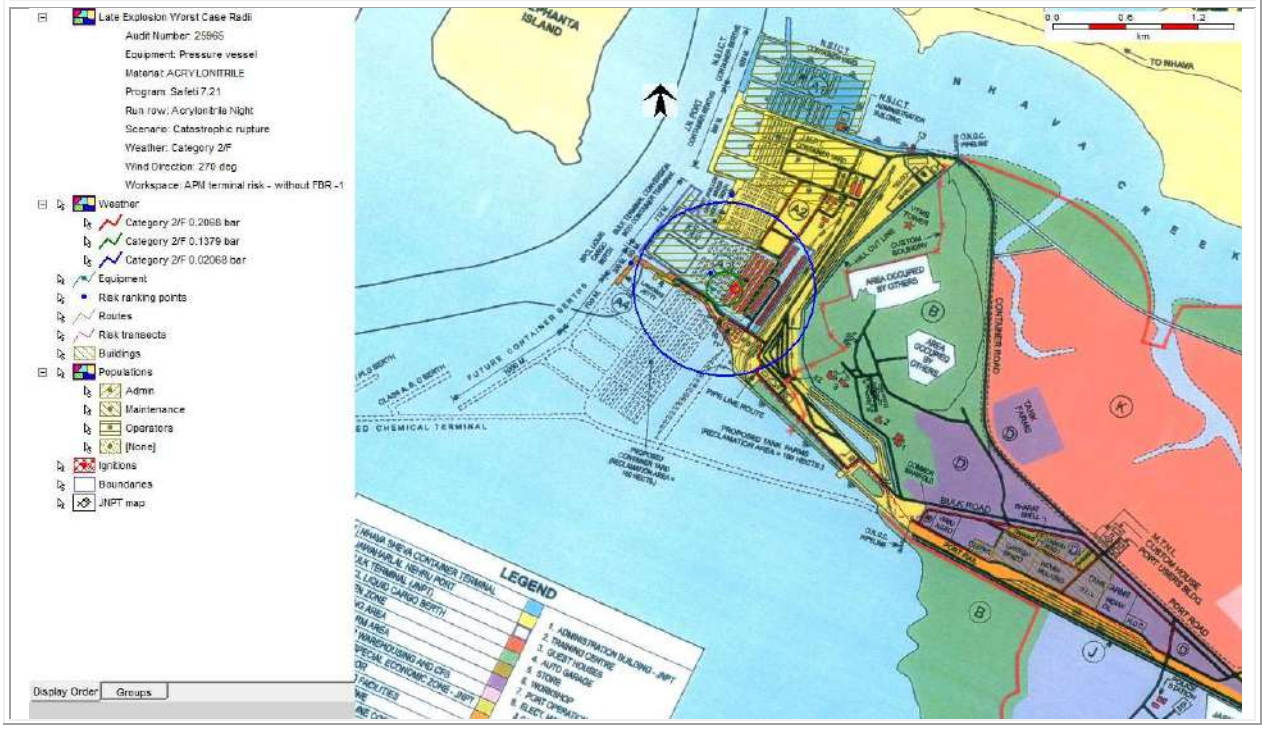
There is also the impact of 'public perception', whereby the impact of an incident can be magnified if public opinion considers the area is not safe to visit or consumer products (e.g. fish, shellfish, etc) from the location are polluted.

APPENDIX G: CONSEQUENCE ANALYSIS RESULTS

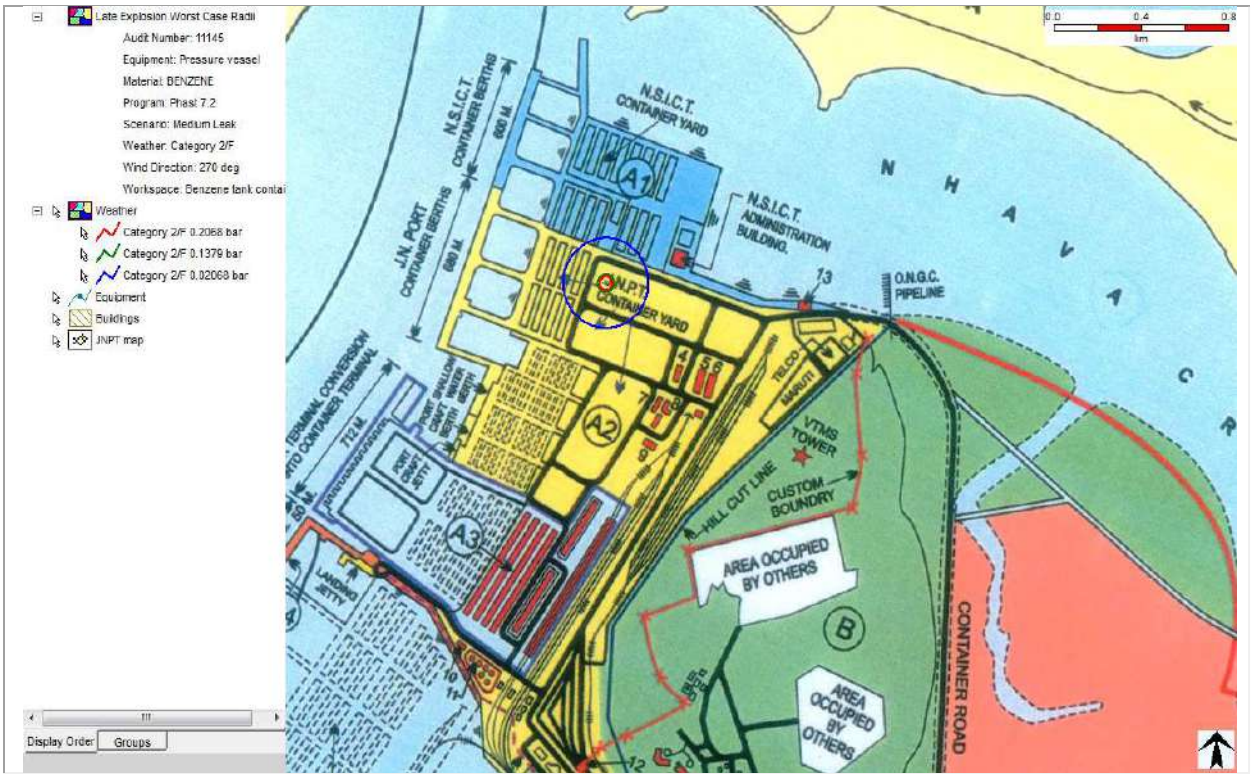
1. Toxic dispersion from Leakage of Acrylonitrile tank container at APM terminal with wind speed **2 m/s, F** stability class and **5 m/s**, **D** stability class.



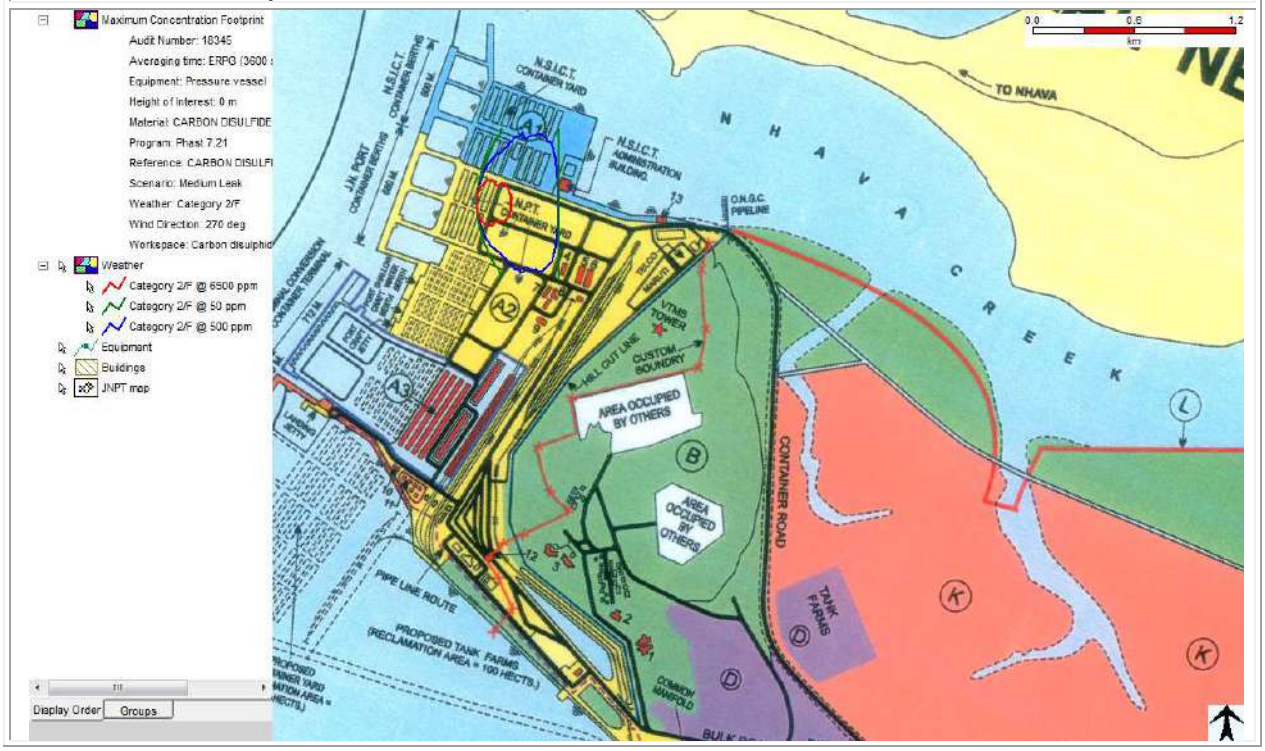
2. Vapor cloud explosion from Rupture of Acrylonitrile tank container at APM terminal with wind speed **2 m/s** and **F** stability class.



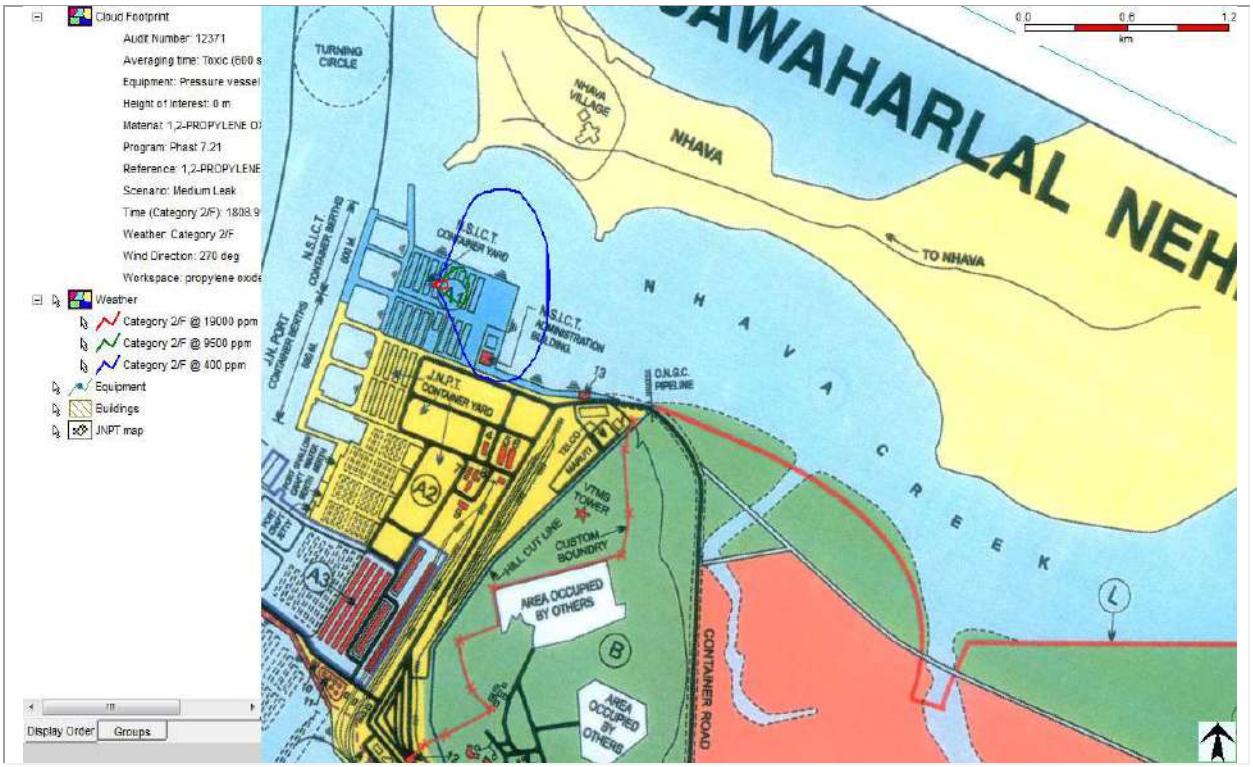
3. Vapor cloud explosion from leakage of Benzene tank container at JNPCT with wind speed **2 m/s** and **F** stability class.



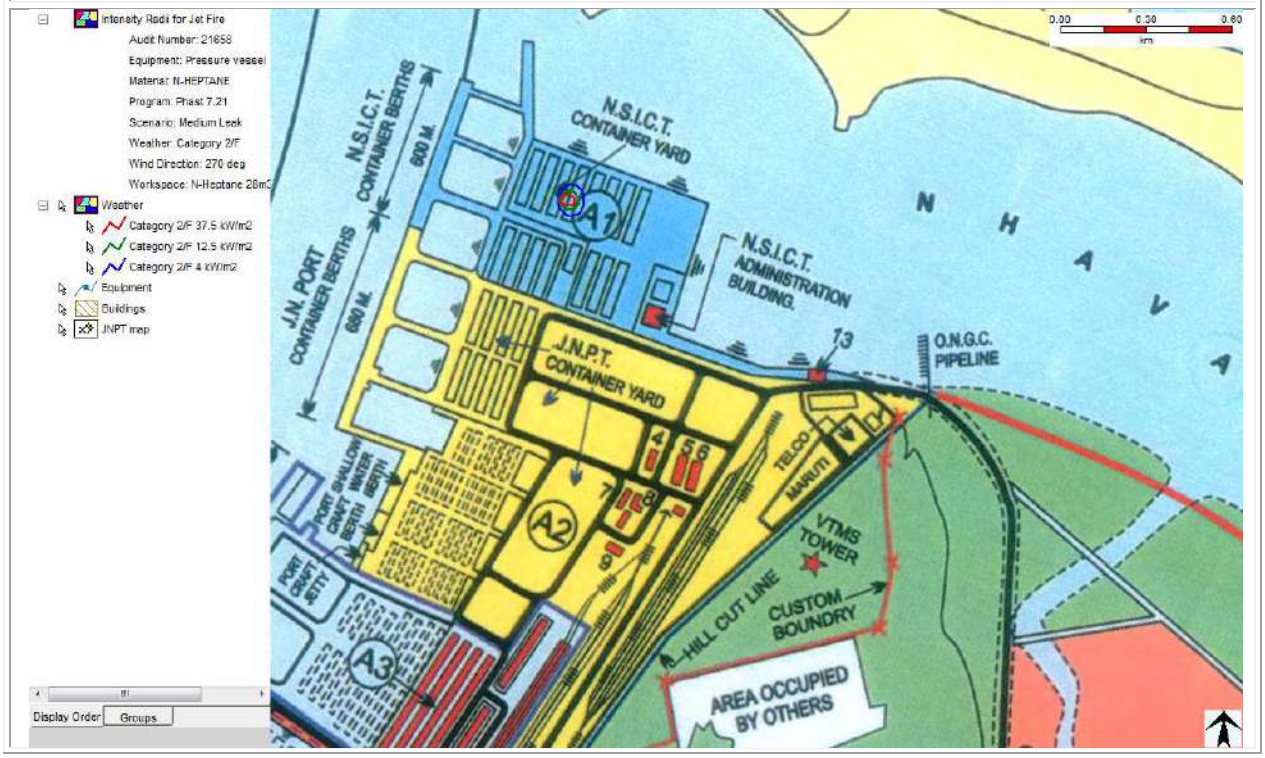
4. Toxic dispersion from leakage of Carbon disulphide tank container at JNPCT with wind speed **2 m/s** and **F** stability class.



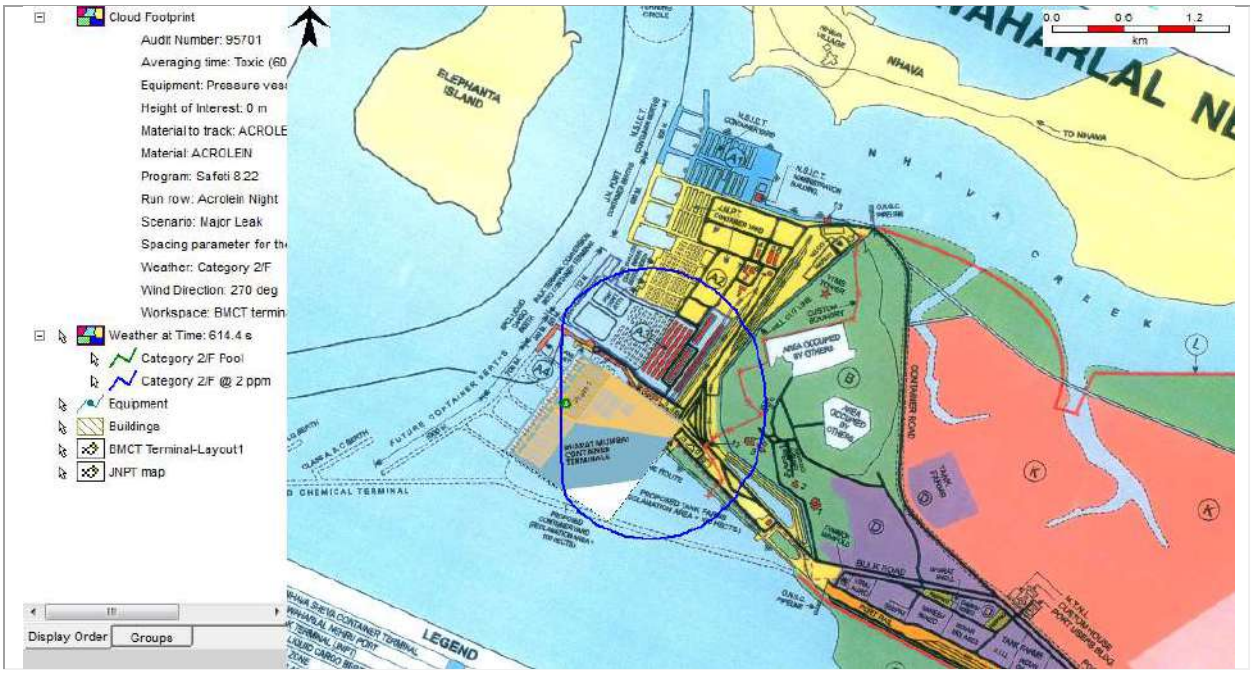
5. Toxic dispersion from leakage of Propylene oxide tank container at DP world terminal with wind speed **2 m/s** and **F** stability class.



6. Jet fire from leakage of N-Heptane tank container at DP world terminal with wind speed **2 m/s** and **F** stability class.

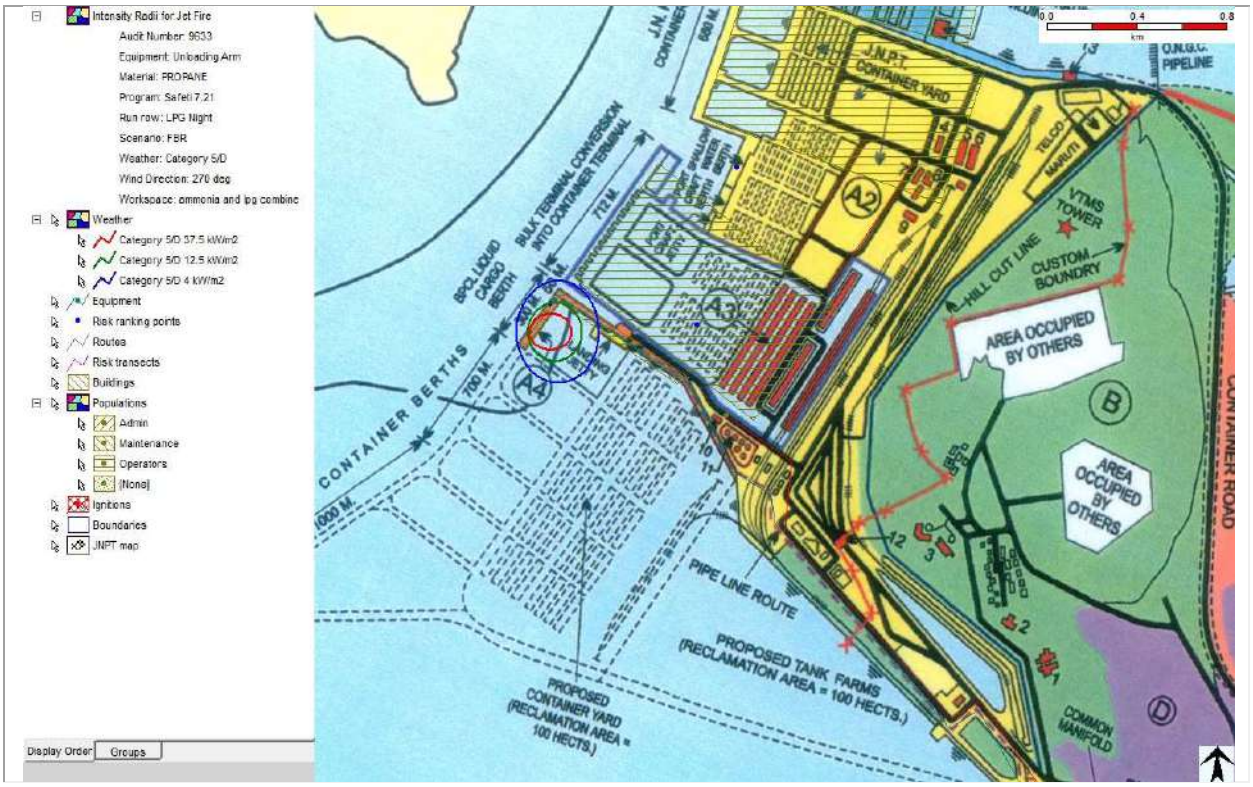


7. Toxic dispersion from leakage of Acrolein tank container at BMCT terminal with wind speed **2 m/s** and **F** stability class.

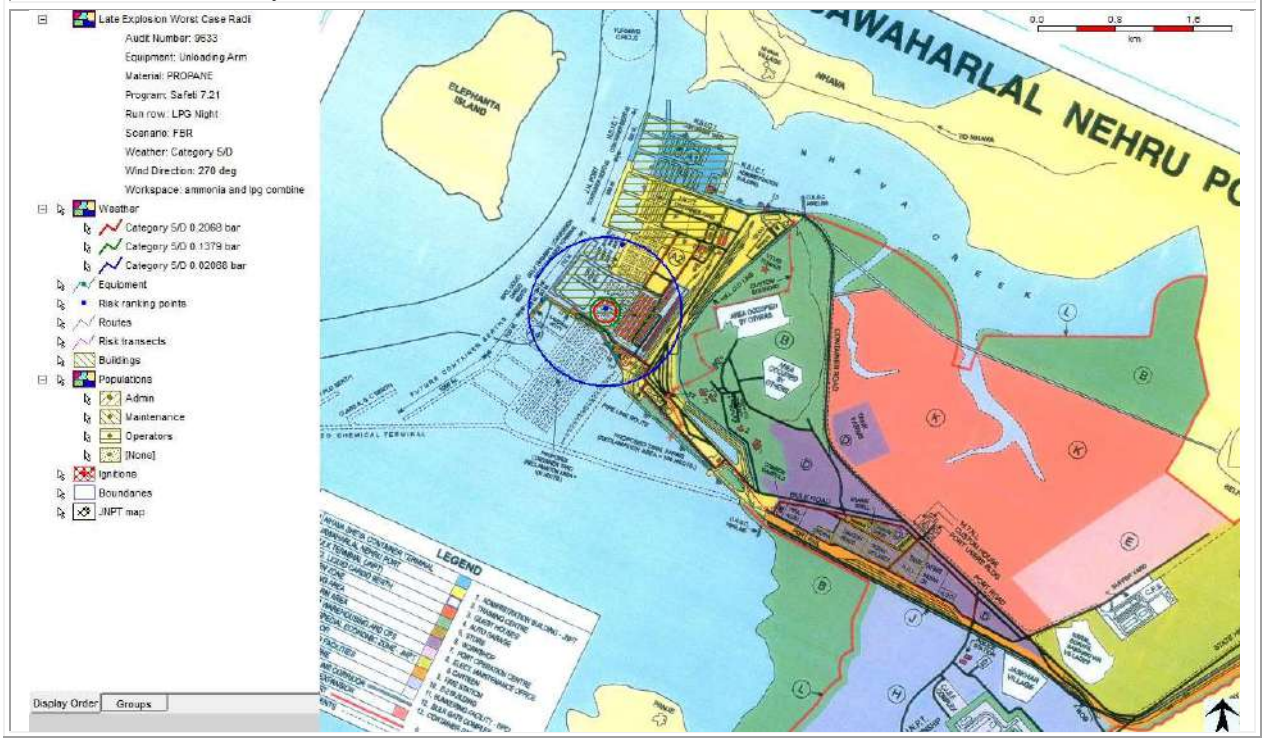


8. Toxic dispersion from leakage of Acrylonitrile tank container at BMCT terminal with wind speed **2 m/s** and **F** stability class.

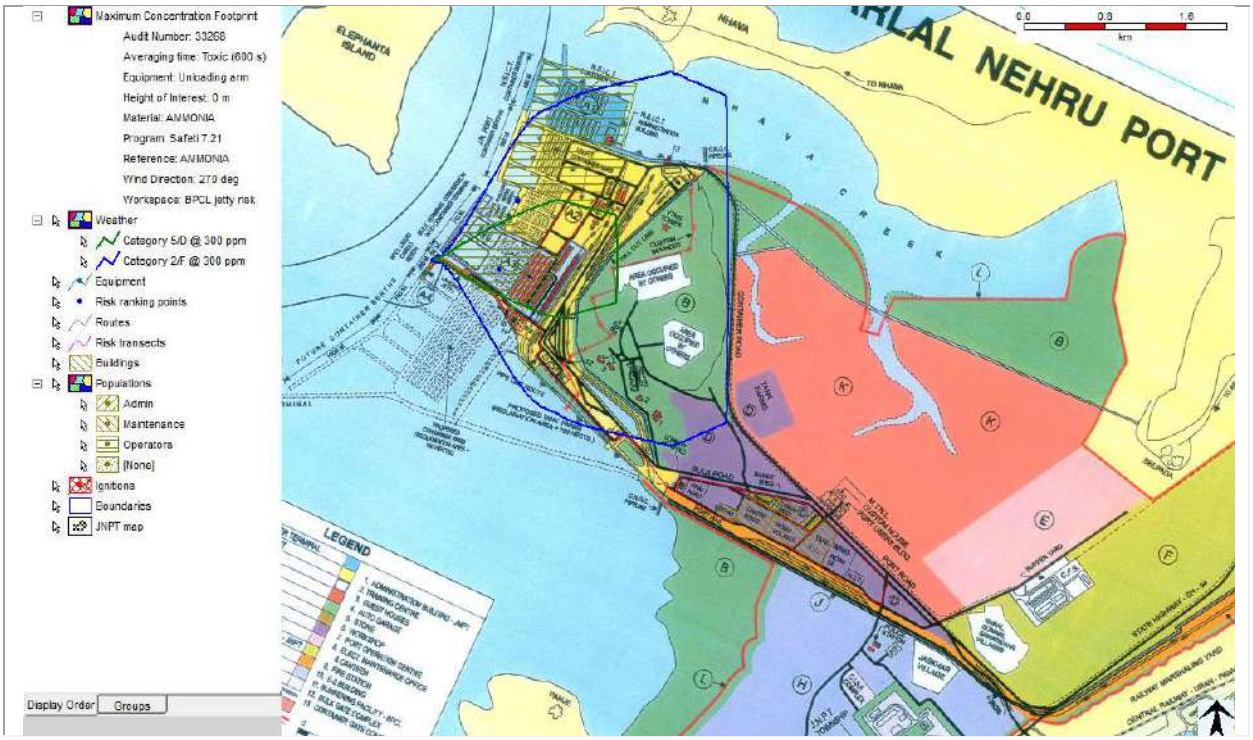
9. Jet fire from Full Bore Rupture of LPG unloading arm with wind speed **5 m/s** and **D** stability class at BPCL LCJ.



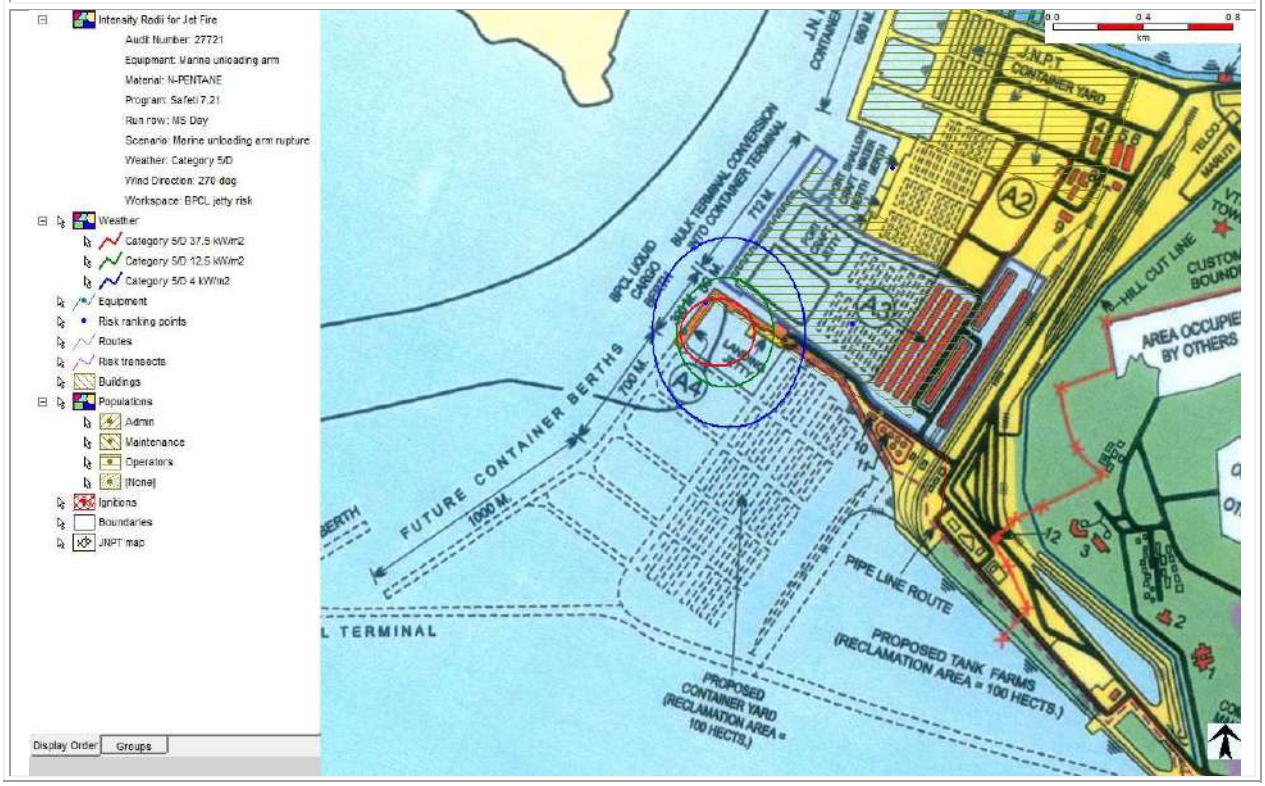
10. Late Vapor Cloud Explosion from Full Bore Rupture of LPG unloading arm with wind speed **5 m/s** and **D** stability class at BPCL LCJ.



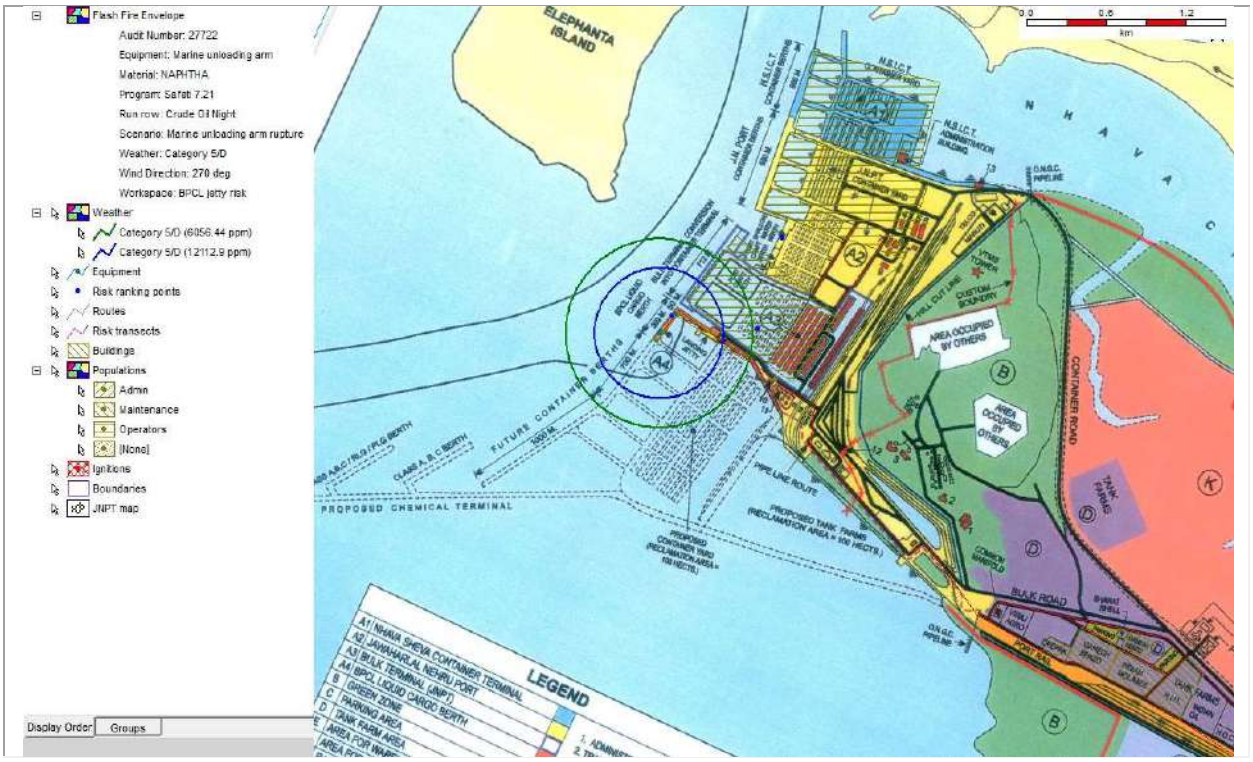
11. Toxic Dispersion from Small leak of Ammonia unloading arm with wind speed 2 **m/s** and **F** stability class at BPCL LCJ.



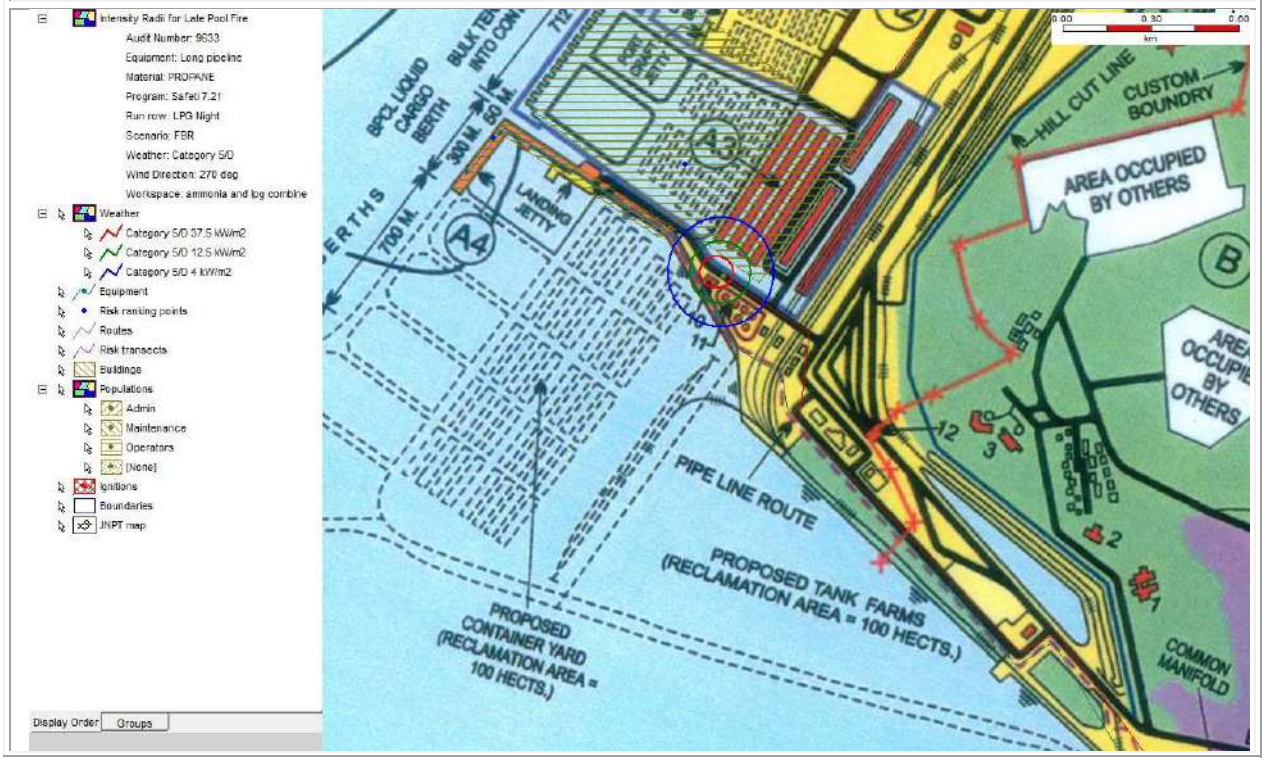
12. Jet fire from Full bore rupture of MS unloading arm with wind speed **5 m/s** and **D** stability class at BPCL LCJ.



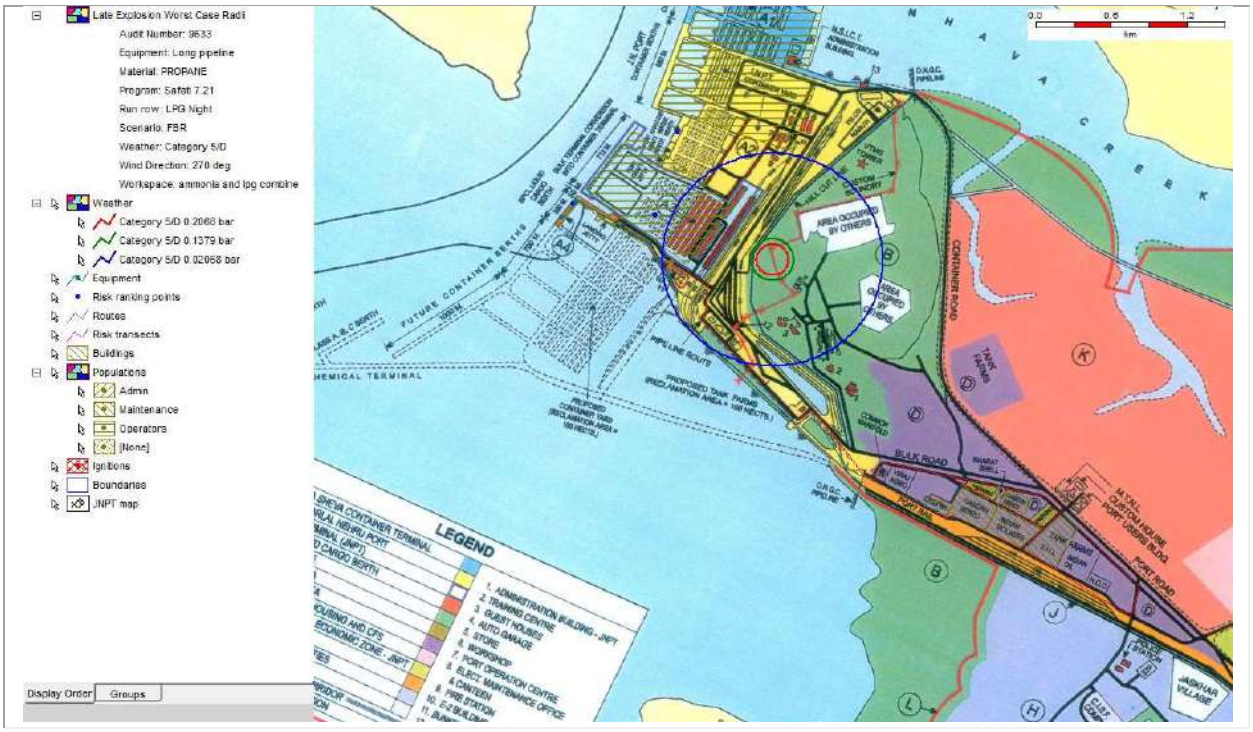
13. Flash fire from Full bore rupture of Naphtha unloading arm with wind speed **5 m/s** and **D** stability class at BPCL LCJ.



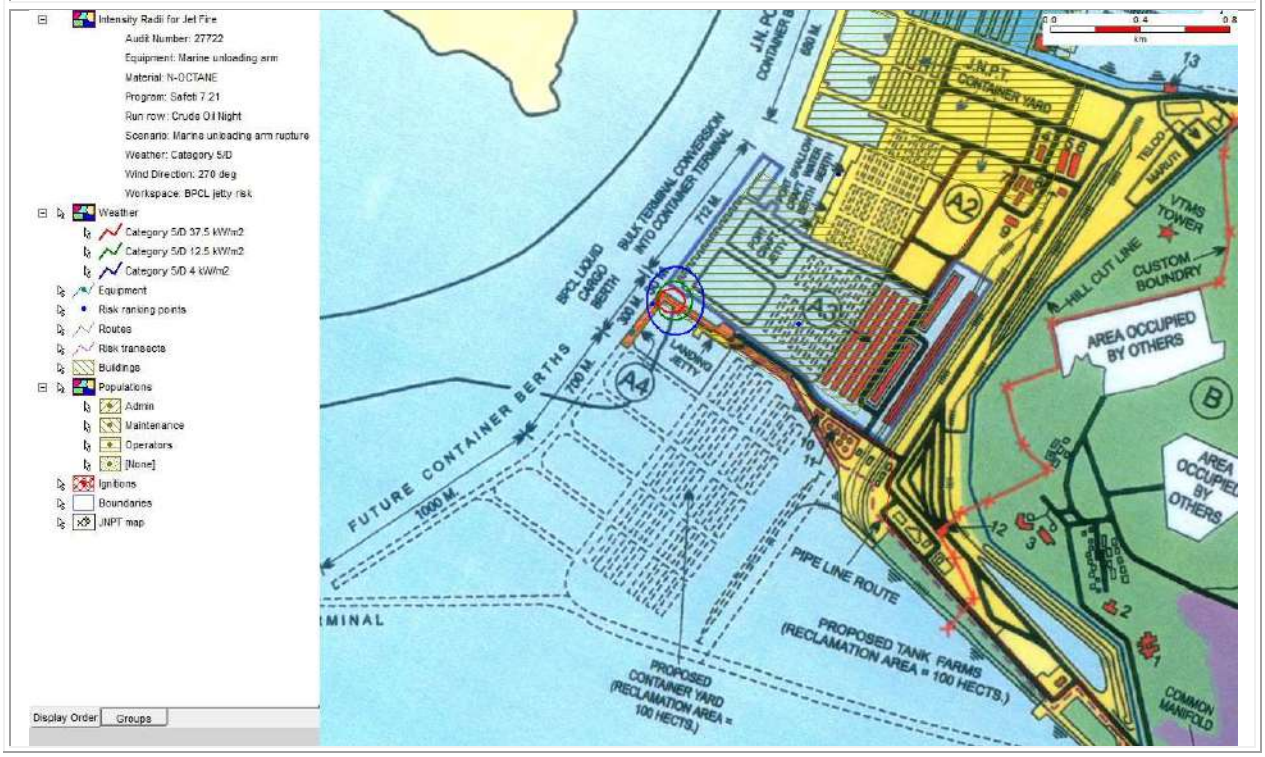
14. Pool fire from Full Bore Rupture of 12"LPG pipeline from jetty to storage terminal with wind speed **5 m/s** and **D** stability class at pipeline corridor (1000 m from BPCL LCJ).



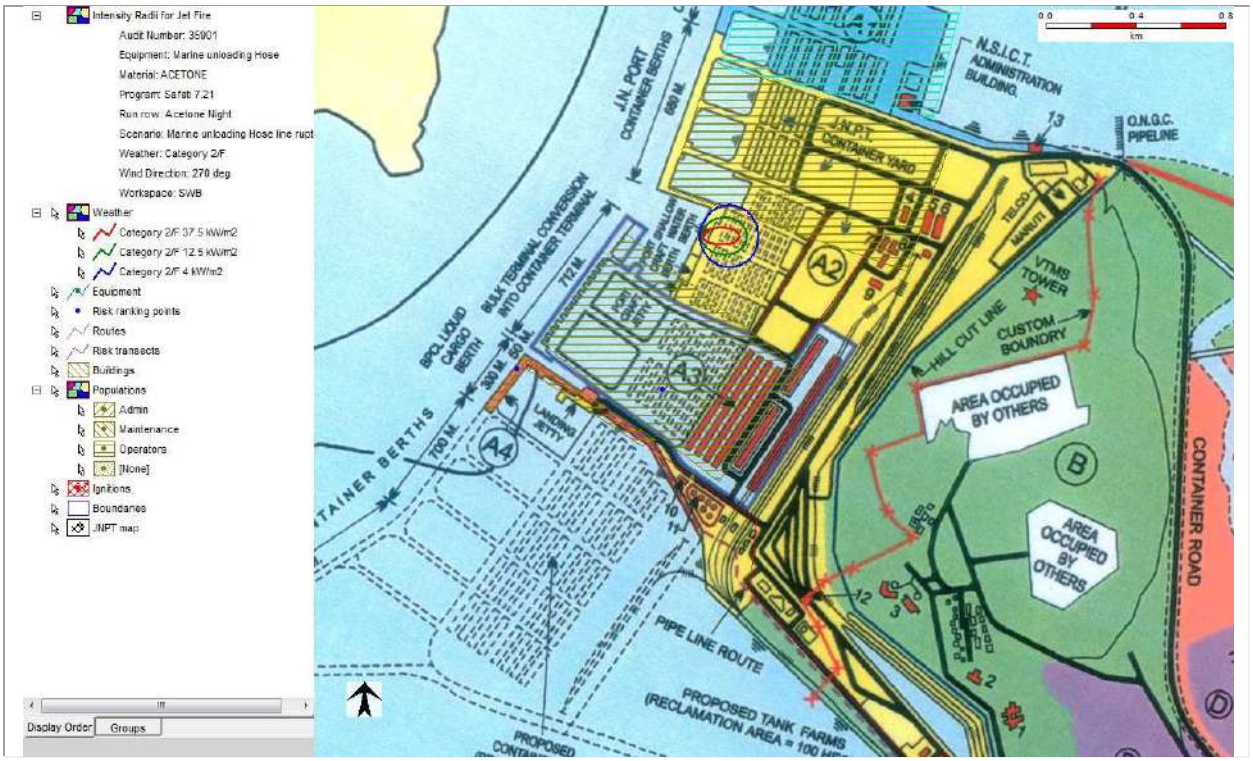
15. Vapor Cloud Explosion from Full Bore Rupture of 12”LPG pipeline from jetty to storage terminal with wind speed **5 m/s** and **D** stability class at pipeline corridor (1000 m from BPCL LCJ).



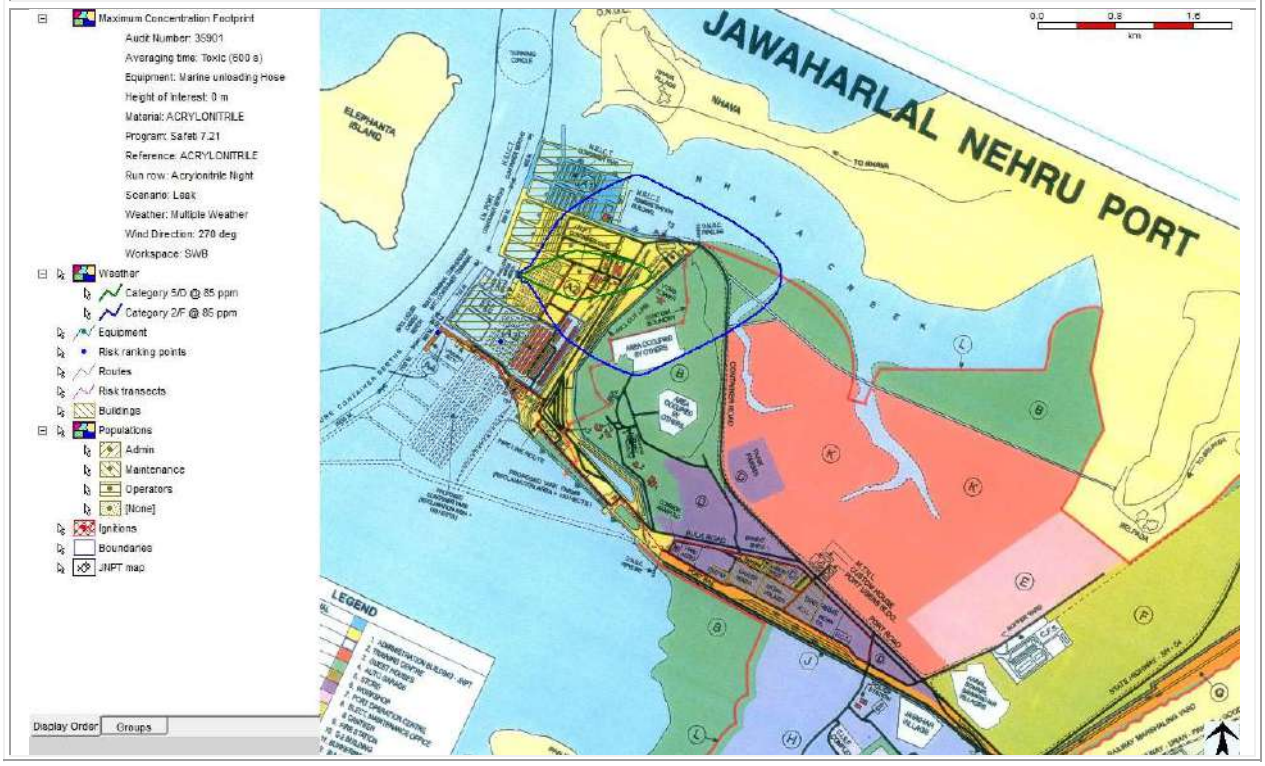
16. Jet fire from Full bore rupture of Crude oil unloading arm with wind speed **5 m/s** and **D** stability class at BPCL LCJ.



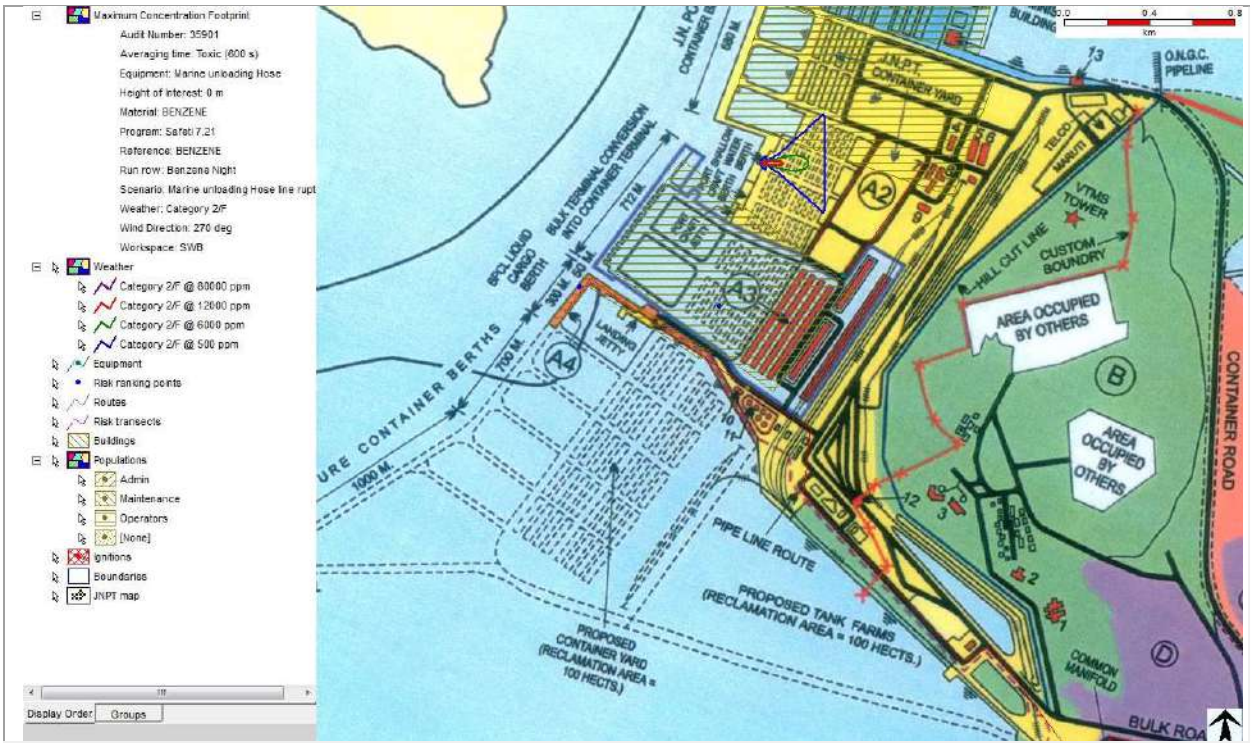
17. Jet fire from Full bore rupture of Acetone flexible hose at SWB with wind speed **2 m/s** and **F** stability class.



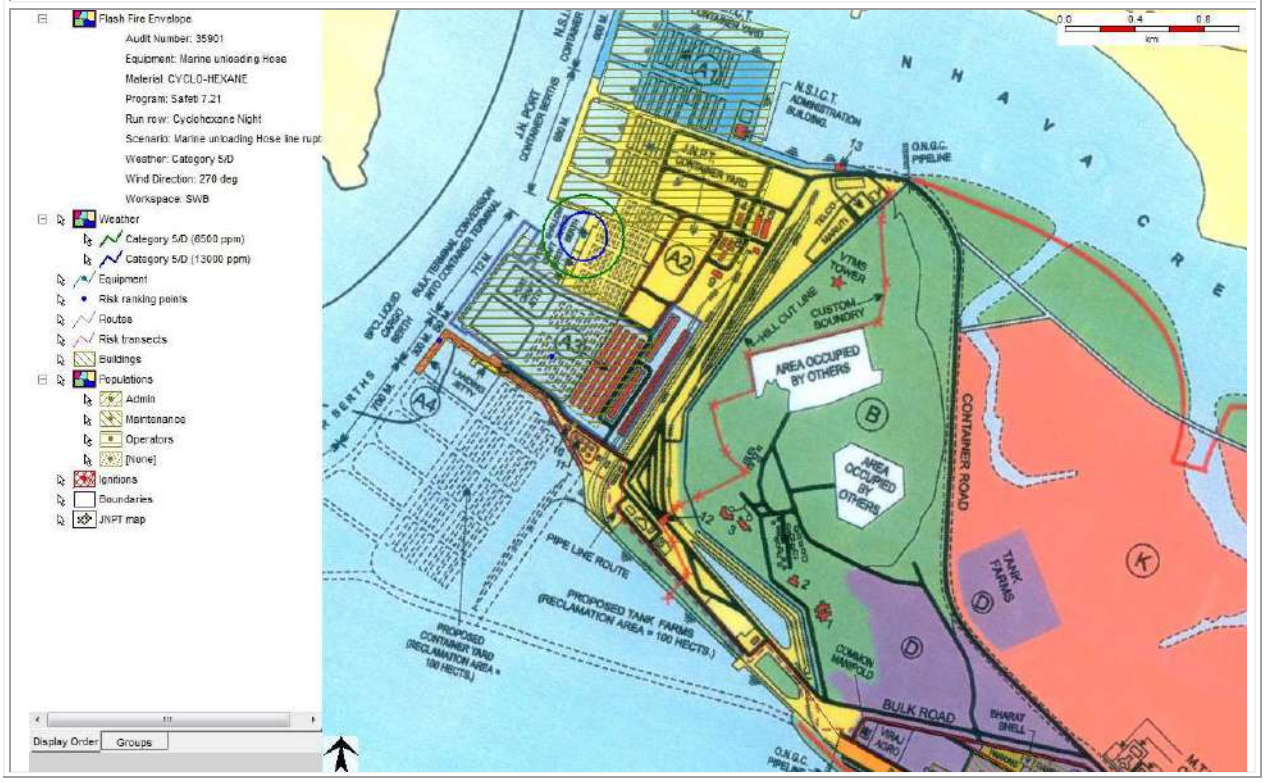
18. Toxic dispersion from Leakage of Acrylonitrile flexible hose at SWB with wind speed **2 m/s** and **F** stability class.



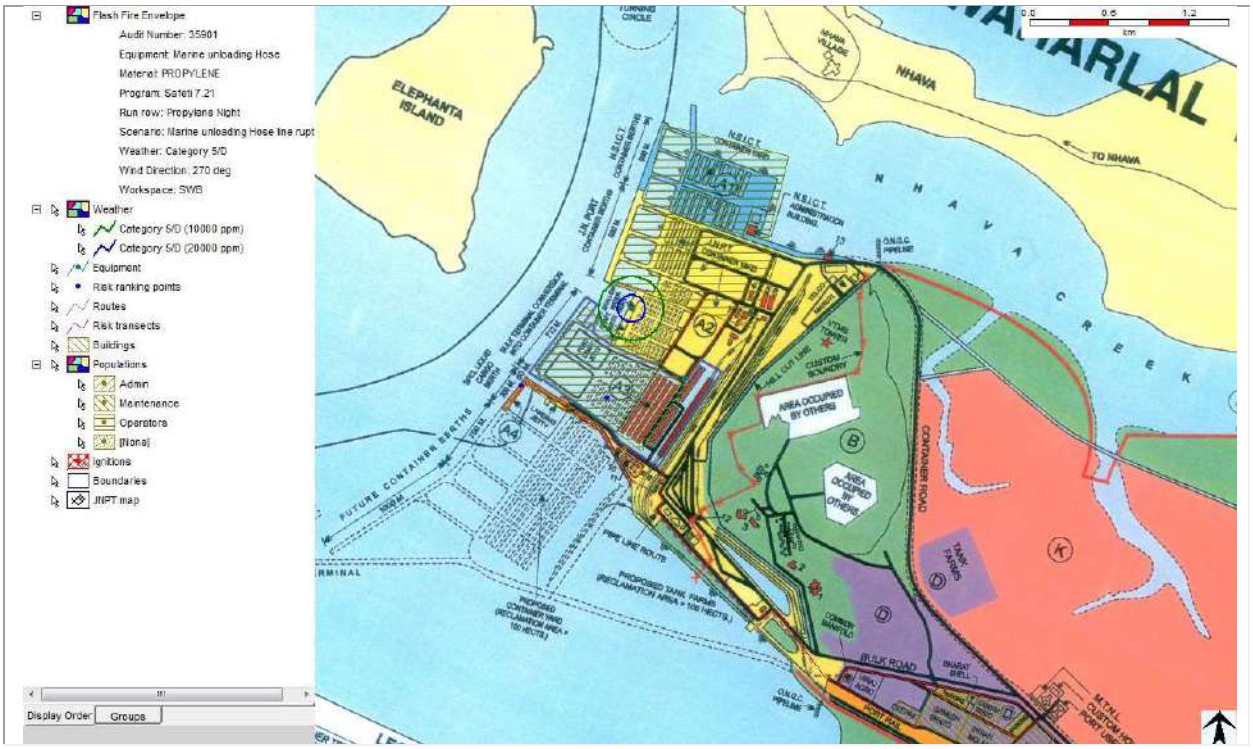
19. Toxic dispersion from Full bore rupture of Benzene flexible hose at SWB with wind speed **2 m/s** and **F** stability class.



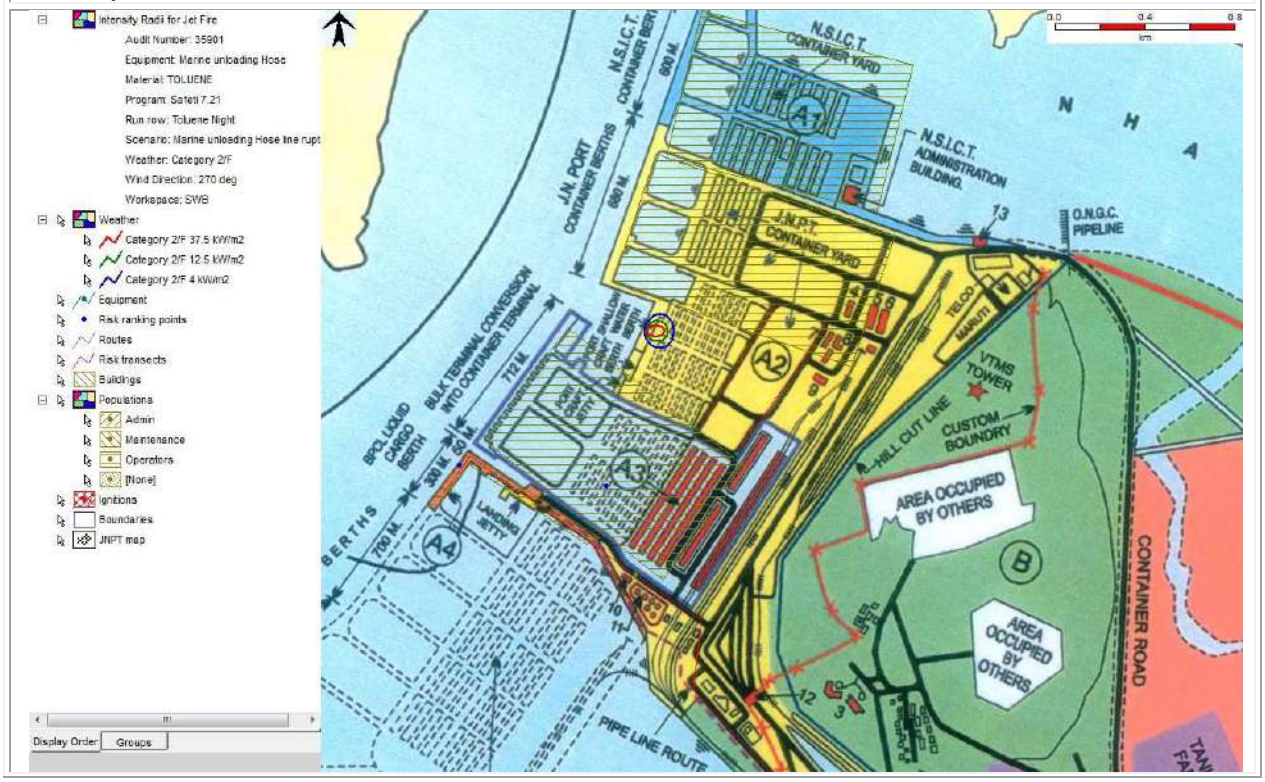
20. Flash fire from Full bore rupture of Cyclohexane flexible hose at SWB with wind speed **5 m/s** and **D** stability class.



21. Flash fire from Full bore rupture of Propylene flexible hose at SWB with wind speed **5 m/s** and **D** stability class.

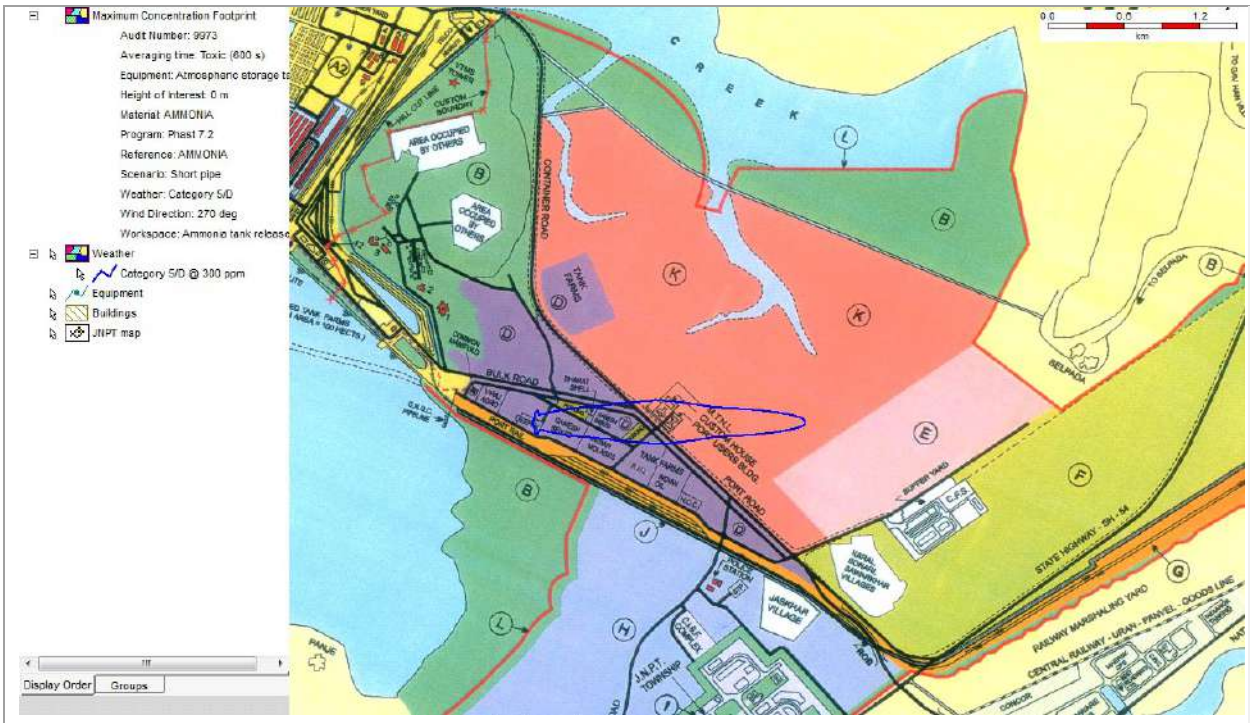


22. Jet fire from Full bore rupture of Toluene flexible hose at SWB with wind speed **2 m/s** and **F** stability class.



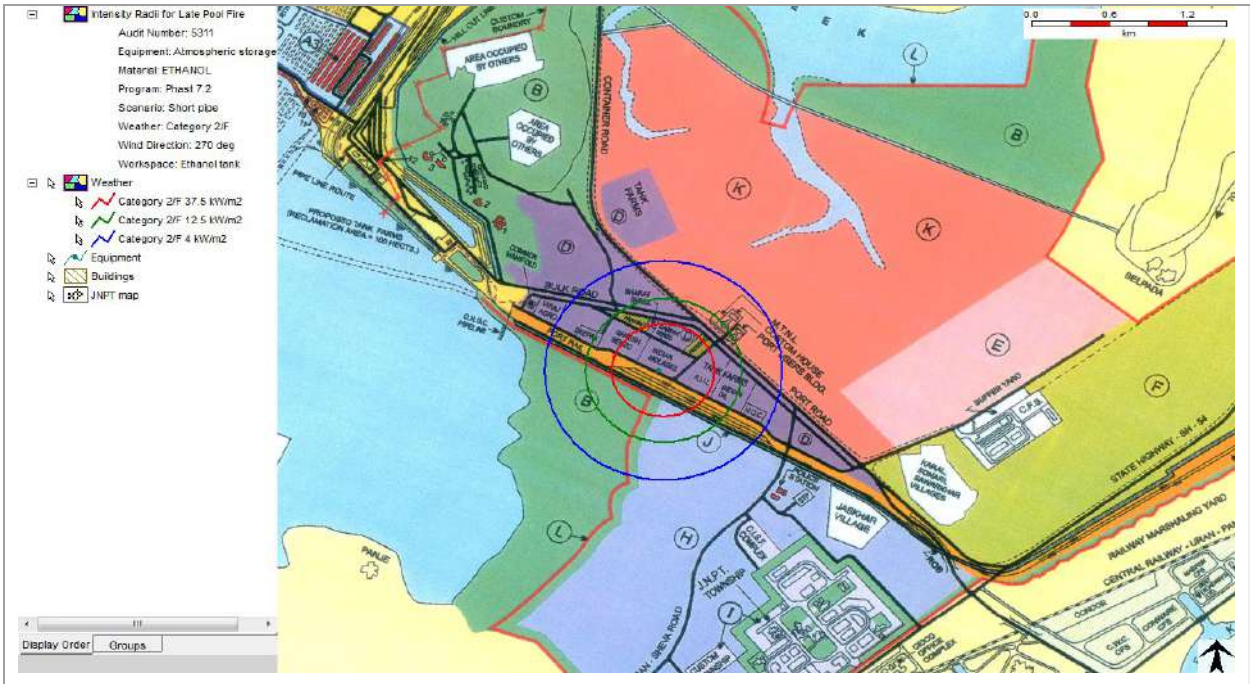
23. Pool fire from Leakage of Ammonia tank at Dipak fertilizer terminal with wind speed **2 m/s** and **F** stability class.

24. Toxic dispersion from Leakage of Ammonia tank at Dipak fertilizer terminal with wind speed **5 m/s** and **D** stability class.

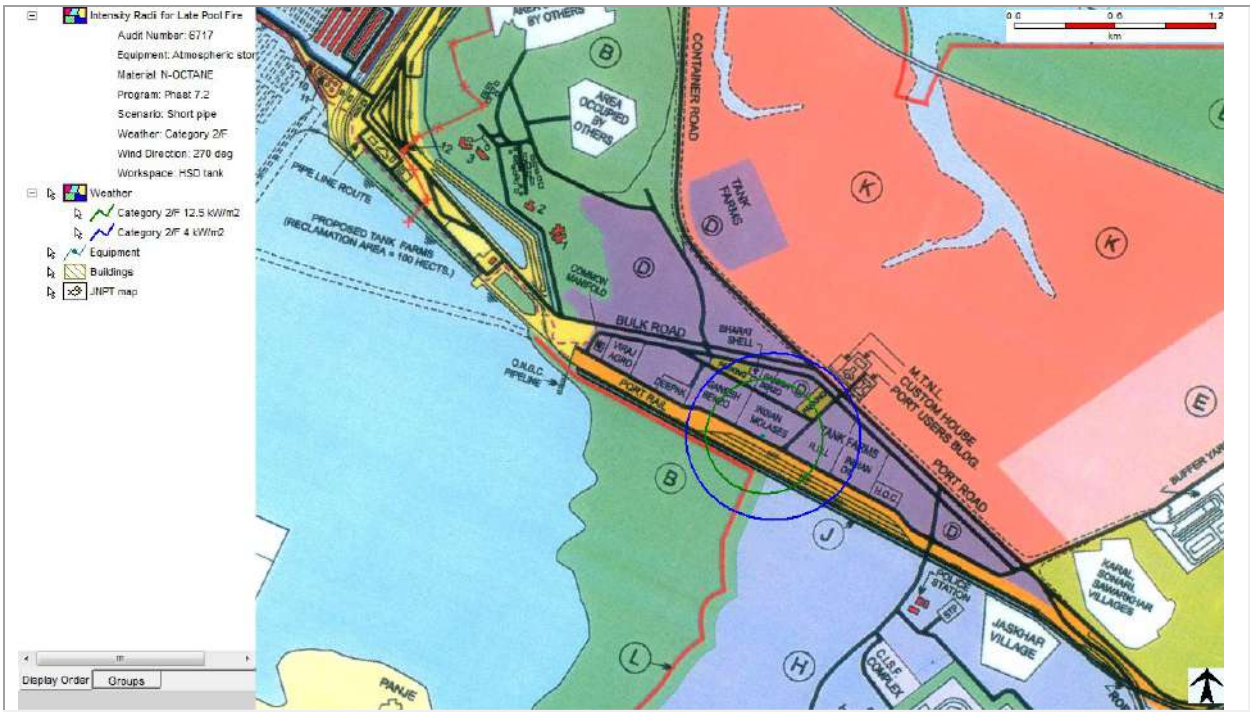


25. Jet fire Leakage of Butyl acrylate tank at IMC terminal with wind speed **2 m/s** and **F** stability class.

26. Pool fire Leakage of Ethanol tank at IMC terminal with wind speed **2 m/s** and **F** stability class.

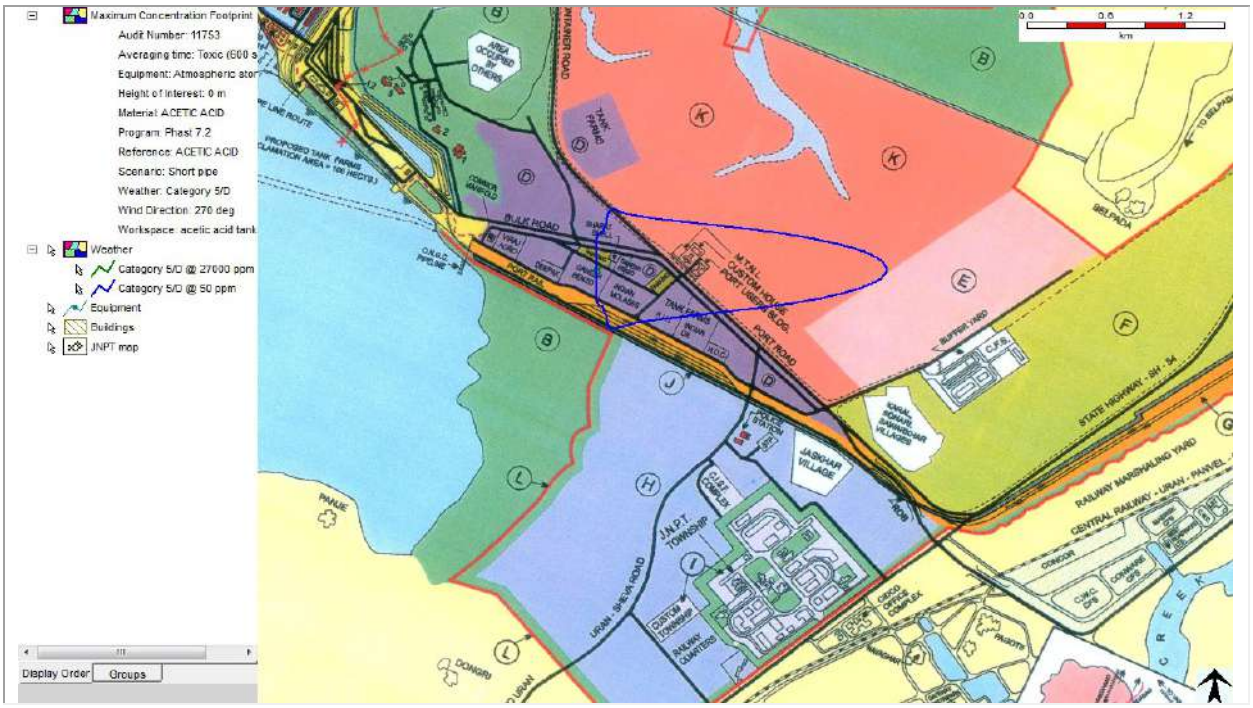


27. Pool fire Leakage of HSD tank at IMC terminal with wind speed **2 m/s** and **F** stability class.

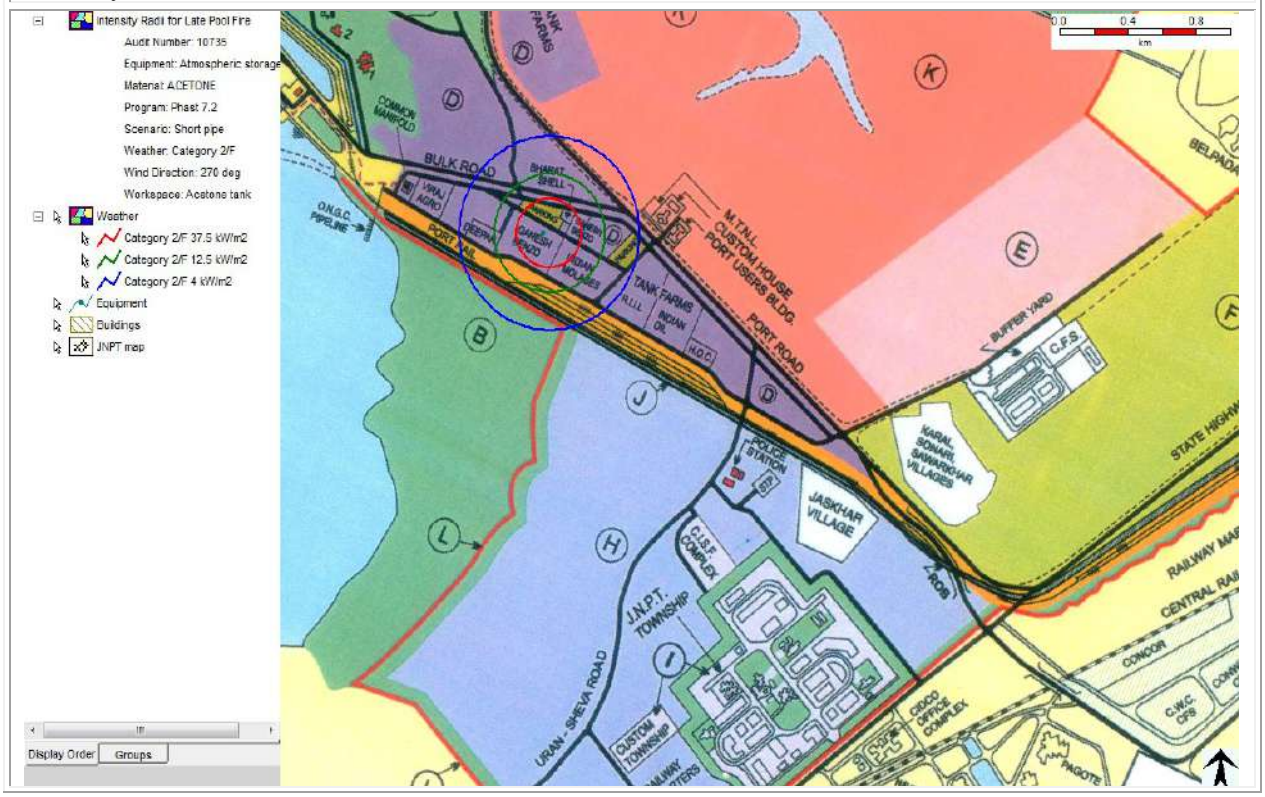


28. Pool fire Leakage of Styrene monomer tank at IMC terminal with wind speed **2 m/s** and **F** stability class.

29. Toxic dispersion from Leakage of Acetic acid tank at GBL terminal with wind speed **5 m/s** and **D** stability class.

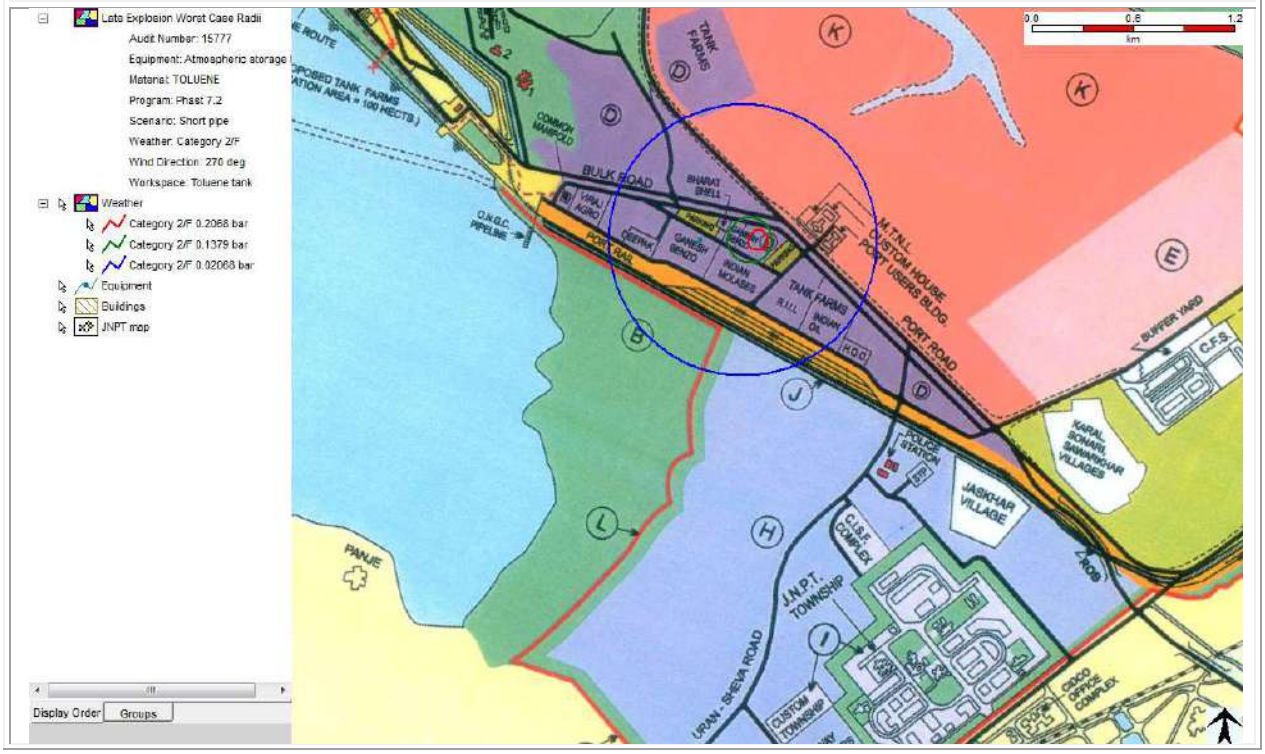


30. Pool fire from Leakage of Acetone tank at GBL terminal with wind speed **2 m/s** and **F** stability class.

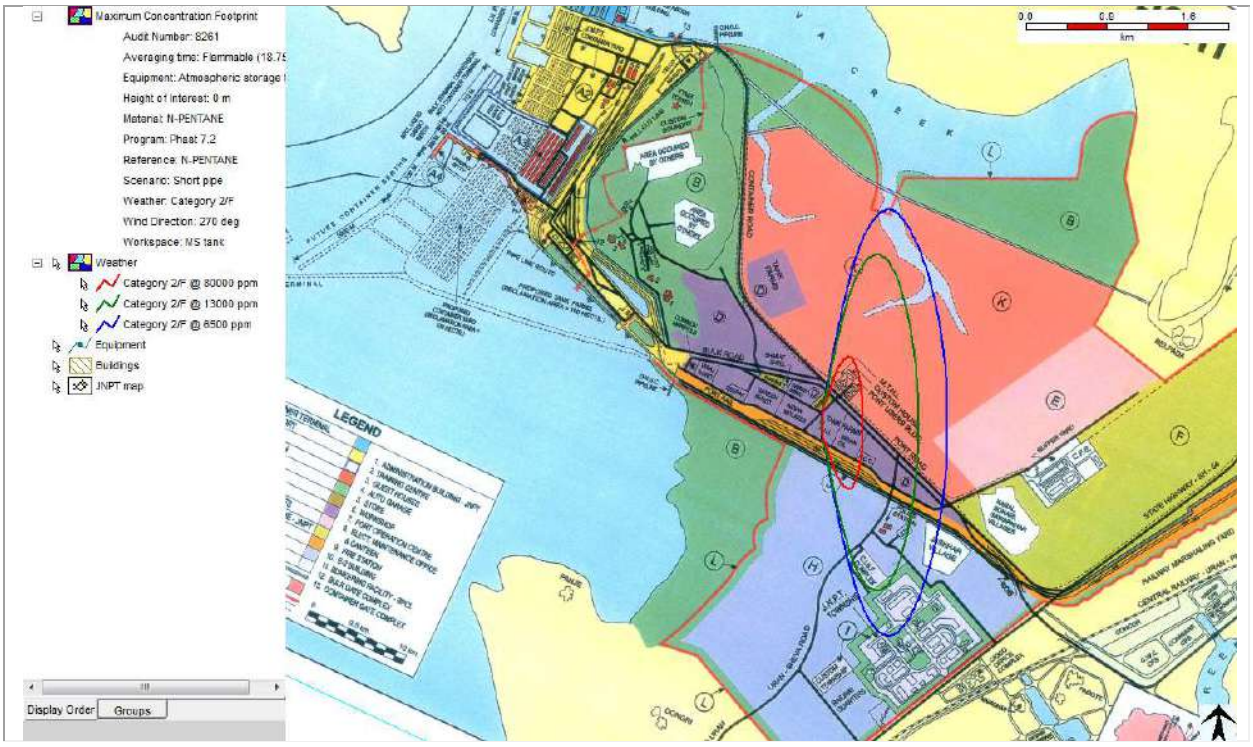


31. Pool fire from Leakage of Aniline tank at GBL terminal with wind speed **2 m/s** and **F** stability class.

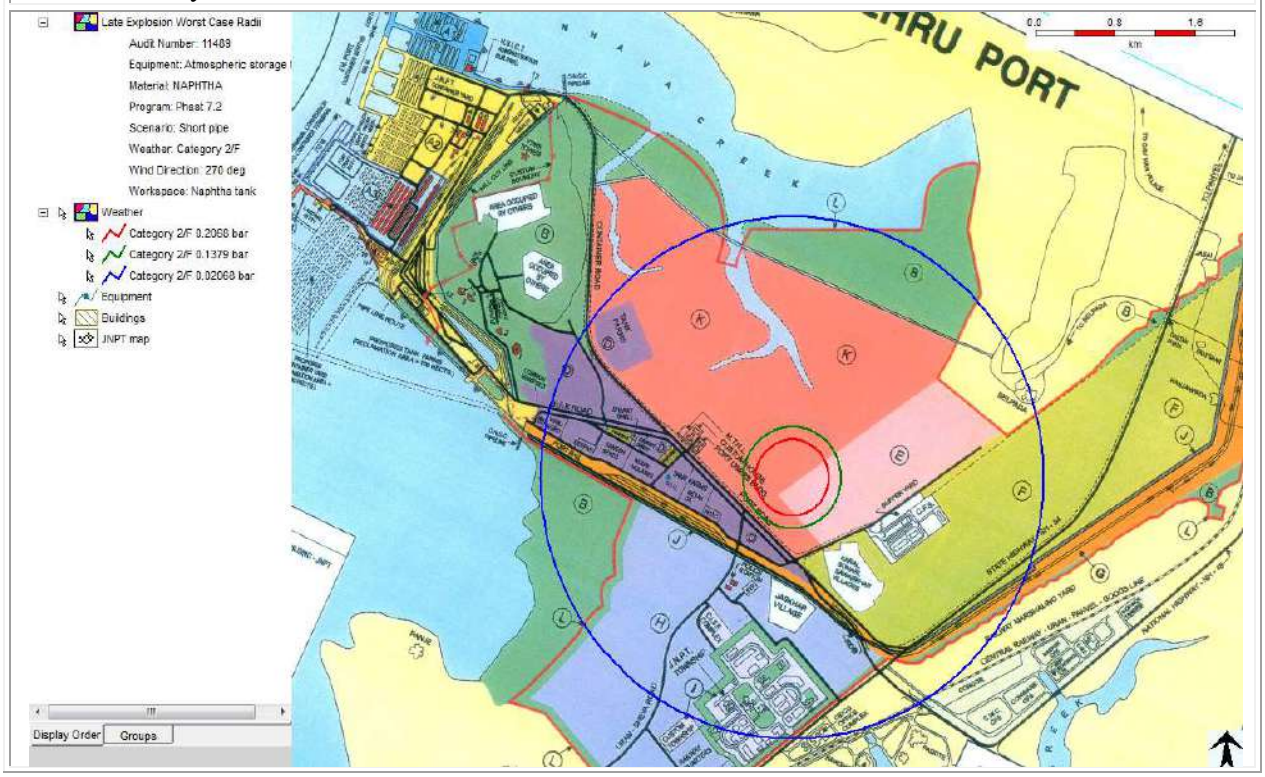
32. Vapor cloud explosion from Leakage of Toluene tank at GBL terminal with wind speed **2 m/s** and **F** stability class.



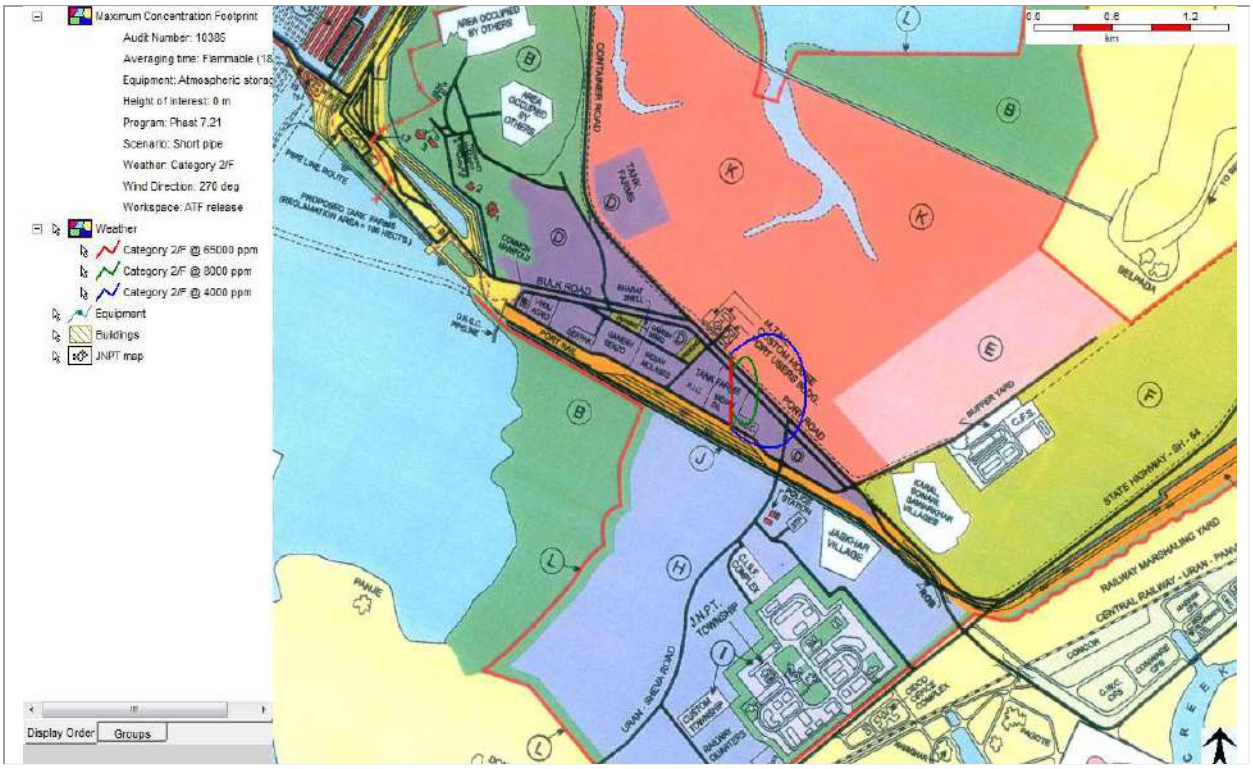
33. Flash fire from Leakage of MS tank at RIL terminal with wind speed **2 m/s** and **F** stability class.



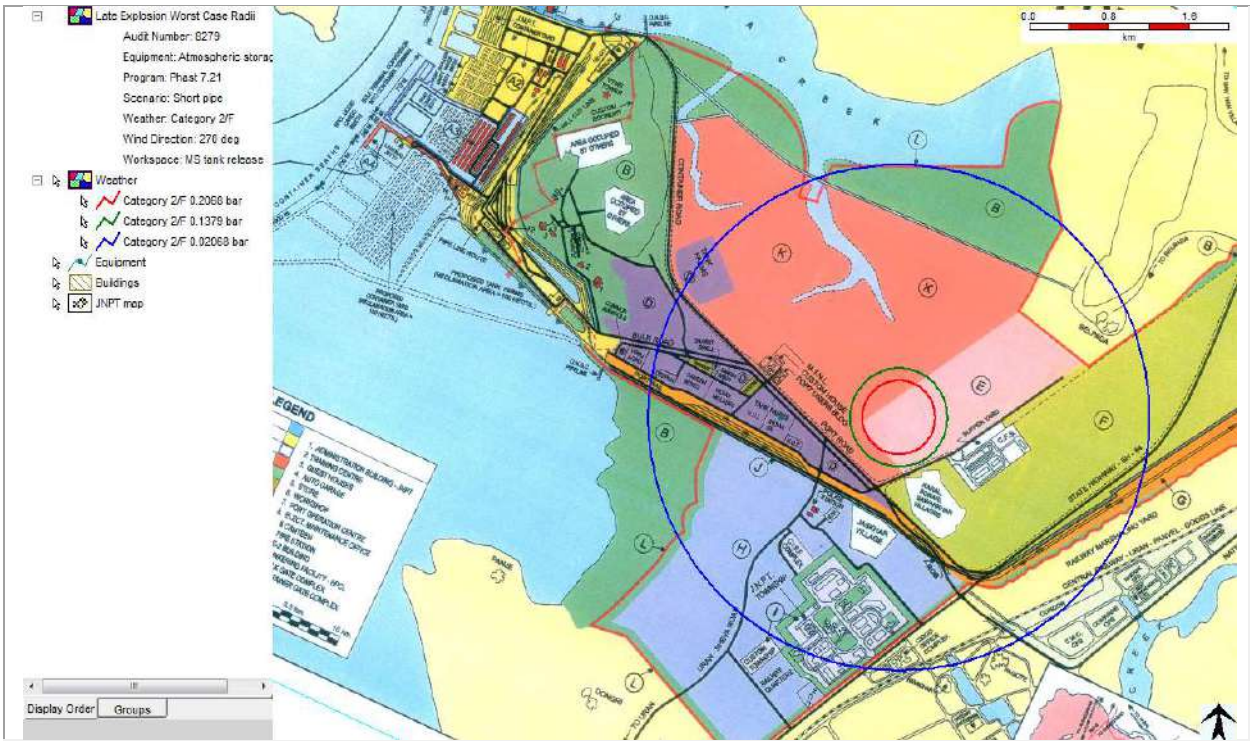
34. Vapor cloud explosion from Leakage of Naphtha tank at RIL terminal with wind speed **2 m/s** and **F** stability class.



35. Flash fire from Leakage of ATF tank at IOCL terminal with wind speed **2 m/s** and **F** stability class.



36. Vapor cloud explosion from Leakage of MS tank at IOCL terminal with wind speed **2 m/s** and **F** stability class.



APPENDIX H
COMMODITY-WISE TRAFFIC HANDLED BY JN PORT

(Traffic in Tonnes)

Commodity	2011-12	2012-13	2013-14	2014-15	2015-16
Liquid Bulk & Shallow Berth (JNPT)					
Diesel (Bunker) at anchorage	80,444	0	0		49,936
H.S. Diesel (Bunker)				26	
Total POL - JNPT	**80,444**	**0**	**0**	**26**	**49,936**
A. Acid (I)			28,053	105,469	104,719
Acetone				11,899	5,937
Aniline Oil				3,449	2,759
Base Oil			4,486	12,652	6,320
Bitumen				1,740	
Butyl Acetate				524	2,952
Butyl Acrylate					1,630
Chloroform				1,784	790
Crude Glycol			2,577	4,294	11,052
Cumene					1,051
EDC					3,107
Edible Oil				85,311	
IPA					1,644
MDC					12,535
MEG (E)					
MEG (I)			76,647	150,411	70,156
MIBK					1,047
Molasses				9,240	
Mix Xylene				1,026	
N Butanol				2,788	3,130
Pegasol					
Phenol				4,872	7,139
Ph. Acid					23,461
SM				19,601	28,993
Toluene				12,686	6,692
Vinyl Acetate Monomer			3,499	14,078	10,269
Xylene (E)					
Total Chemicals - JNPT	**0**	**0**	**115,262**	**441,824**	**305,383**

Edible Oil (I)				8	130,144
Molasses (E)					52,450
Total other Liquid - JNPT	**0**	**0**	**0**	**8**	**182,594**
Total Liquid JNPT	**80,844**	**0**	**115,262**	**441,858**	**537,913**
Liquid Bulk (BPCL)					
AF stock	153,248	147,684	134,182	146,190	113,976
Aniline Oil			2,891	1,647	
ATF	7,032				1,698
Base Oil			112,941	106,509	121,217
C.B.F.S.	100,165	104,449	128,791	86,296	76,766
Crude Oil (E)	3,041,093	2,121,235	1,734,847	1,568,333	1,515,002
Diesel (E)	2,500	9,937	14,799	7,571	
Diesel (I)	500,794	375,664	557,240	362,146	703,950
Furnace Oil (E)	134,193	43,947	384,782	168,450	37,988
Furnace Oil (I)	26,773	13,630	33,917		
LPG	10,248	291,151	311,674	699,017	675,249
Lube Oil	173,508	141,282			
Naphtha (E)	637,421	831,309	964,182	649,806	556,232
Naphtha (I)	58,528	45,207	34,197	216,278	195,598
Total POL - BPCL	**4,845,503**	**4,125,495**	**4,414,443**	**4,012,243**	**3,997,596**
A. Acid (I)	100,932	182,027	139,029	63,597	57,836
Acetone	1,004		1,001	8,011	4,611
Ammonia		7,000	129,713	111,408	67,073
Aniline Oil					1,069
Butyl Acetate					859
Butyl Acrylate	14,013	17,199	16,113	16,888	18,964
Caustic Soda		30,447			
Chloroform			525	1,002	
Crude Glycol	15,756	19,502	19,784	10,143	3,356
DEG		1,197	512		
Ethyl Acetate (E)		951			
E G				429	
Ethanol				9,063	9,095
Ethanol Alcohol					5,094
Ethanol Hexanol				2,574	
LAB (E)	26,030	18,875	10,844	4,146	
LAB (I)		6,123	3,705		

MEG (E)		1,500			
MEG (I)	340,787	340,625	225,671	182,347	27,569
Methanol	3,701				
Meta Xylene	2,954	985			
Methyl Dichloride	5,508	6,969	9,127	6,122	4,624
MTBE		1,978			
N Butanol				1,003	2,785
Ortho Xylene					880
Para Xylene (E)					72,019
Para Xylene (I)	7,396			4,196	
Ph. Acid	73,797	73,759	108,987	26,519	59,054
Phenol			1,000	13,166	9,438
Styrene	35,324	32,523	26,952	24,156	16,748
Toluene	2,006		2,000	12,605	14,563
Vinyl Acetate Monomer	9,057	7,105	5,389	9,663	9,151
Total Chemicals - BPCL	**638,265**	**748,765**	**700,352**	**506,978**	**384,788**
Edible Oil (I)	1,010,607	946,926	987,515	1,191,267	1,453,506
Molasses (E)	82,194	58,168	64,084	31,153	90,577
Total Other Liquid - BPCL	1,092,801	1,005,094	1,051,599	1,222,420	1,544,083
Total Liquid (BPCL)	6,576,569	5,879,354	6,166,394	5,741,641	5,926,467
Total Liquid (JNPT + BPCL)	**6,657,413**	**5,879,354**	**6,281,656**	**6,183,499**	**6,464,380**

APPENDIX I: CHEMICAL SAFETY SHEETS

Sr. No. ↓	C.A.S. No.	CHEMICAL NAME	HAZARD CLASSIFICATION		
I.1	-	LIQUIFIED PETROLEUM GAS	FLAMMABLE – Y	TOXIC – Y	CORROSIVE - N
SAFETY RELATED PROPERTIES					
FLASH POINT °c	**U.E.L. (% V/V)**	**L.E.L. (% V/V)**	**SPECIFIC GRAVITY**	**WATER SOLUBILITY**	**PHYSICAL STATE AT STORAGE CONDITION**
Propanes= -104.4, Butane= -60	Propane= 9.5, Butane= 8.4	Propane=2.2 , Butane= 1.6	Liquid 0.51-0.58 / Vapour 1.5	NO	LIQUID
$N_h = 1$	$N_f = 4$	$N_r = 0$	IDLH = 19,000 ppm	TLV = 1000 ppm	REACTIVITY WITH WATER NO
HEALTH HAZARD DATA					
	INHALATION	**INGESTION**	**SKIN**	**EYES**	
EFFECTS	Concentration in air greater than 10%, cause dizziness in a few minutes. 1% concentrations give the same symptom in 10 min. High concentrations cause asphyxiation.				
EMER-GENCY MEASURES	Remove victim from exposure and apply artificial respiration. Guard against self-injury if confused.				
P.P.E.s	Self contained breathing apparatus for high vapour concentration.				
EMERGENCY / FIRST AID MEASURES					
COMBUS-TION PRODUCTS					
FIRE FIGHTING	Allow to burn while cooling adjacent equipment with water spray. Extinguish small fires with dry chemical powder. Water not to be used.				
FIRST AID/ ANTIDOTES	Seek immediate medical help.				
SPILL CONTROL MEASURES	Stop discharge if possible. Keep people away. Shut-off ignition sources and call fire department. Stay upwind and use water spray to 'knock down' vapour. Evacuate area if large discharge. Avoid contact with LIQUID.				

Sr. No. ↓	C.A.S. No.	CHEMICAL NAME	HAZARD CLASSIFICATION		
I.2	-(Mixture)	MOTOR SPIRIT	FLAMMABLE – Y	TOXIC – N	CORROSIVE - N
SAFETY RELATED PROPERTIES					
FLASH POINT °C	**U.E.L. (% V/V)**	**L.E.L. (% V/V)**	**SPECIFIC GRAVITY**	**WATER SOLUBILITY**	**PHYSICAL STATE AT STORAGE CONDITION**
-40	7.6	1.4	Liquid ---- / Vapour >1	NO	LIQUID
$N_h = 1$	$N_f = 3$	$N_r = 0$	IDLH = N.A.	TLV = N.A.	REACTIVITY WITH WATER **NO**

HEALTH HAZARD DATA				
	INHALATION	**INGESTION**	**SKIN**	**EYES**
EFFECTS	Irritation to upper respiratory tract	Harmful	Irritation. Repeated contact may cause dermatitis	Irritation
EMER-GENCY MEASURES	Move victim to fresh air. Give artificial respiration, if breathing has stopped.	Have victim drink water or milk. Do not induce vomiting	Remove conta-minated clothing. Wash affected skin with soap and water.	Flush eyes with plenty of water for at least 10 min.
P.P.E.s	Breathing apparatus if required.		Use PVC or rubber gloves	Goggles

EMERGENCY / FIRST AID MEASURES	
COMBUS-TION PRODUCTS	-
FIRE FIGHTING	Fire extinguishing by water fog, alcohol resistant foam or dry agent such as with dry chemical powder and CO_2
FIRST AID/ ANTIDOTES	Seek immediate medical help. No specific antidote. Treat symptomatically
SPILL CONTROL MEASURES	Remove all sources of ignition. Increase ventilation. Evacuate all personnel. Wear full protective equipment and clothing to minimise exposure. Place inert, non combustible, absorbent material onto spillage. Use clean non-sparking tools to collect the material and place into a suitable labelled container

Sr. No. ↓	C.A.S. No.	CHEMICAL NAME	HAZARD CLASSIFICATION		
I.3	7664-41-7	AMMONIA	FLAMMA-BLE – Y	TOXIC – Y	CORROSIVE – N
SAFETY RELATED PROPERTIES					
FLASH POINT °C	**U.E.L. (% V/V)**	**L.E.L. (% V/V)**	**SPECIFIC GRAVITY**	**WATER SOLUBILITY**	**PHYSICAL STATE AT STORAGE CONDITION**
N.A.	25.0	16.0	Liquid 0.771 / Vapour 0.60	YES	LIQUID
$N_h = 2$	$N_f = 1$	$N_r = 0$	IDLH = 300 ppm	TLV-STEL = 35 ppm	REACTIVITY WITH WATER
HEALTH HAZARD DATA					
	INHALATION	**INGESTION**		**SKIN**	**EYES**
EFFECTS	5000 PPM may call death from inflammation, edema of larynx.			Contact of the liquid with skin freezes the tissues and causes caustic burns.	700 ppm cau-ses eye irri-tation and permanent injury will result.
EMER-GENCY MEASURES	Remove the victim to fresh air and provide artificial respiration or oxygen.			Wash the affected area with plenty of water	Wash the affected area with plenty of water and seek medical health.
P.P.E.s	Provide gas mask and self contained breathing apparatus			Provide rubber boots and protective clothing.	Use safety goggels.
EMERGENCY / FIRST AID MEASURES					
COMBUS-TION PRODUCTS	-				
FIRE FIGHTING	Stop flow of gas water spray of fog.				
FIRST AID/ ANTIDOTES	Seek immediate medical help.				
SPILL CONTROL MEASURES	Contained leaking liquid on sand or earth, allow to evaporate dilute the vapours with plenty of water.				

Sr. No. ↓	C.A.S. No.	CHEMICAL NAME	HAZARD CLASSIFICATION		
I.4	8030-31-7	NAPHTHA	FLAMMA-BLE – Y	TOXIC – Y	CORROSIVE – N
SAFETY RELATED PROPERTIES					
FLASH POINT °C	**U.E.L. (% V/V)**	**L.E.L. (% V/V)**	**SPECIFIC GRAVITY**	**WATER SOLUBILITY**	**PHYSICAL STATE AT STORAGE CONDITION**
41.6	5	0.8	Liquid 0.88 / Vapour N.A.	NO	LIQUID
$N_h = 0$	$N_f = 3$	$N_r = 0$	IDLH = 10000 ppm	TLV = N.A. (Skin) ppm	REACTIVITY WITH WATER
HEALTH HAZARD DATA					
	INHALATION	**INGESTION**	**SKIN**	**EYES**	
EFFECTS	Primary narcotic, causing unconsciousness in high concentrations. The symptoms of acute benzene poisoning are not likely, since the compound has components other than benzene.	If Swallowed causes nausea or vomiting	Irritation	Irritation.	
EMER-GENCY MEASURES	Remove the victim from exposed area. Support respiration.	Do not induce vomiting	Wash with the plenty of water for 15 mins. Remove contaminated clothes and shoes.	Wash with the plenty of water for 15 mins. Seek medical aid immediately.	
P.P.E.s	Provide Hydrocarbon. Vapour Canister.		Plastic Gloves	Face Shield	
EMERGENCY / FIRST AID MEASURES					
COMBUSTION PRODUCTS	N.A.				
FIRE FIGHTING	Foam, Carbon Dioxide, D.C.P				
FIRST AID/ ANTIDOTES	Antidotes not available.				
SPILL CONTROL MEASURES	For Small Sprilling absorb on earth and sand.				

Sr. No. ↓	C.A.S. No.	CHEMICAL NAME	HAZARD CLASSIFICATION		
I.5	7664-38-2	PHOSPHORIC ACID	FLAMMA-BLE – N	TOXIC – Y	CORROSIVE – Y
SAFETY RELATED PROPERTIES					
FLASH POINT °C	**U.E.L. (% V/V)**	**L.E.L. (% V/V)**	**SPECIFIC GRAVITY**	**WATER SOLUBILITY**	**PHYSICAL STATE AT STORAGE CONDITION**
N.A.	N.A.	N.A.	Liquid 1.892 / Vapour N.A.	YES	LIQUID
$N_h = 2$	$N_f = 0$	$N_r = 0$	IDLH = 10000 ppm	TLV = 0.75 (Skin) ppm	REACTIVITY WITH WATER
HEALTH HAZARD DATA					
	INHALATION	**INGESTION**	**SKIN**	**EYES**	
EFFECTS	Burns on mouth and lips. Produce sour acrid taste, severe, gastrointestinal irritation, nausea, vomiting, bloody, diarrhea, difficult in swallowing, severe abdominal pains, thirst, acidemia, difficult breathing, convulsions, collapse, shock and death.				
EMER-GENCY MEASURES		Do not induce vomiting. Give water, milk or vegetable oil.	Flush with water for at least 15 mins. Seek medical aid.	Flush with water for at least 15 mins. Seek medical aid.	
P.P.E.s			Rubber hand gloves protective overclosing and shoes	Face Shield.	
EMERGENCY / FIRST AID MEASURES					
COMBUSTION PRODUCTS	-				
FIRE FIGHTING	Non Combustible				
FIRST AID/ ANTIDOTES	Antidotes not available.				
SPILL CONTROL MEASURES	Neutralise with alkali and dilute and drench with water.				

Sr. No. ↓	C.A.S. No.	CHEMICAL NAME	HAZARD CLASSIFICATION		
I.6		DIESEL OIL	FLAMMABLE – Y	TOXIC – N	CORROSIVE - N
SAFETY RELATED PROPERTIES					
FLASH POINT °C	**U.E.L. (% V/V)**	**L.E.L. (% V/V)**	**SPECIFIC GRAVITY**	**WATER SOLUBILITY**	**PHYSICAL STATE AT STORAGE CONDITION**
>66	5	0.7	Liquid 0.81 – 0.91 / Vapour >1	NO	LIQUID
$N_h = 0$	$N_f = 2$	$N_r = 0$	IDLH = N.A.	TLV = 5 mg/m^3	REACTIVITY WITH WATER **NO**
HEALTH HAZARD DATA					
	INHALATION	**INGESTION**	**SKIN**	**EYES**	
EFFECTS	Dizziness, Headache	Nausea, vomiting	Irritation. Repeated contact may cause dermatitis	Irritation	
EMER-GENCY MEASURES	Move victim to fresh air. Give artificial respiration, if breathing has stopped.	Do not induce vomiting	Remove conta-minated clothing. Wash affected skin with water.	Flush eyes with plenty of water for atleast 10 min.	
P.P.E.s	Breathing apparatus if required.		Use PVC or rubber gloves	Goggles	
EMERGENCY / FIRST AID MEASURES					
COMBUS-TION PRODUCTS	-				
FIRE FIGHTING	Fire extinguishing by water fog, alcohol resistant foam or dry agent such as with dry chemical powder and CO_2				
FIRST AID/ ANTIDOTES	Seek immediate medical help. No specific antidote. Treat symptomatically				
SPILL CONTROL MEASURES	Stop leak, if safe to do so. Contain spillage. Absorb in sand or earth for disposal. Eliminate all sources of ignition. Use personal protective equipment. Cordon off the area. Stay upwind.				

Sr. No. ↓	C.A.S. No.	CHEMICAL NAME	HAZARD CLASSIFICATION		
I.7	108-05-4	VINYL ACETATE	FLAMMABLE – Y	TOXIC – Y	CORROSIVE - N
SAFETY RELATED PROPERTIES					
FLASH POINT °C	**U.E.L. (% V/V)**	**L.E.L. (% V/V)**	**SPECIFIC GRAVITY**	**WATER SOLUBILITY**	**PHYSICAL STATE AT STORAGE CONDITION**
-7.8	13.4	2.6	Liquid 0.9317 / Vapour 3	YES	LIQUID
$N_h = 2$	$N_f = 3$	$N_r = 2$	IDLH = N.A.	TLV = 5 ppm	REACTIVITY WITH WATER **NO**
HEALTH HAZARD DATA					
	INHALATION	**INGESTION**	**SKIN**	**EYES**	
EFFECTS	Irritation, Headache, anesthesia, lung irritation and affect nervous system.		Slightly hazardous in case of skin contact	Irritation	
EMER-GENCY MEASURES	Move victim to fresh air. Give artificial respiration, if breathing has stopped.		Wash affected skin with plenty of water.	Flush eyes with plenty of water for atleast 10 min.	
P.P.E.s	Organic vapor canister or self contained breathing		Use rubber gloves, shoes	Gas-tight Goggles	
EMERGENCY / FIRST AID MEASURES					
COMBUS-TION PRODUCTS	Corrosive and noxious gases				
FIRE FIGHTING	Foam, dry agent such as with dry chemical powder and CO_2				
FIRST AID/ ANTIDOTES	Seek immediate medical help. Take off immediately all contaminated clothing. Move to fresh air, oxygen or artificial respiration.				
SPILL CONTROL MEASURES	Stop leak, if safe to do so. Wear a self-contained breathing apparatus. Contain spillage. Eliminate all sources of sparks & ignition. Use personal protective equipment. Cordon off the area. Stay upwind.				

Sr. No. ↓	C.A.S. No.	CHEMICAL NAME	HAZARD CLASSIFICATION		
I.8	108-88-3	TOLUENE	FLAMMA-BLE – Y	TOXIC – Y	CORROSIVE – N
SAFETY RELATED PROPERTIES					
FLASH POINT °C	**U.E.L. (% V/V)**	**L.E.L. (% V/V)**	**SPECIFIC GRAVITY**	**WATER SOLUBILITY**	**PHYSICAL STATE AT STORAGE CONDITION**
4.4	7.1	1.1	Liquid 0.8636 / Vapour 3.1	NO	LIQUID
$N_h = 2$	$N_f = 3$	$N_r = 0$	IDLH = --- mg/m^3	TLV = --- mg/m^3	REACTIVITY WITH WATER **YES**
HEALTH HAZARD DATA					
	INHALATION	**INGESTION**	**SKIN**	**EYES**	
EFFECTS	Prolonged or repeated exposure via inhalation may cause central nervous system and cardiovascular symptoms similar to that of acute inhalation		Irritation, tissue damage, may produce burns	Irritation, redness, watering and etching.	
EMER-GENCY MEASURES	Remove the affected into fresh air. Give artificial respiration to affected patient. Move patient to hospital immediately.	Do not induce vomiting. Never give water to an unconscious person.	Flush with water for at least 15 mins. Seek medical aid. Don't remove clothing if it sticks to the skin	Flush with water for at least 15 mins. Seek medical aid. Hole the eyelids apart.	
P.P.E.s			Rubber hand gloves protective over closing and shoes	Face Shield.	
EMERGENCY / FIRST AID MEASURES					
COMBUSTION PRODUCTS	-				
FIRE FIGHTING	Alcohol resistant Foam, Dry chemical, Carbon dioxide				
FIRST AID/ ANTIDOTES					
SPILL CONTROL MEASURES	Absorb in absorbent material for minor spill. Dam up the liquid spill. Absorb liquid into dry sand, earth or similar material.				