Quantitative Risk Assessment for Jaigarh – Dabhol Natural Gas Pipeline

Risk Assessment Report

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1 Quantitative Risk Assessment - Introduction

Quantitative Risk Assessment (QRA) involves the systematic analysis and evaluation of risks related to the proposed natural gas pipeline Jaigarh – Dabhol project. The QRA is an integrated risk management process outlining rational evaluations of the identified risks based on their significance and recommending appropriate preventive and risk mitigation measures. The results of the QRA provides valuable inputs into the overall project planning to ensure that the project risks stay As Low As Reasonably Practicable (ALARP) levels at all times during project implementation.

Box 1.1: QRA – Integrated Risk Management Process

QRA as a part of integrated risk management process for the proposed project consists of the following iterative steps:

- *Identification of hazards*
- *Setting Acceptance Standards for the defined risks*
- *Evaluation of likelihood and consequences and risks of possible events.*
- *Confirmation of arrangements to mitigate the events and respond to the same on occurrence.*
- *Establishment of performance standards*
- *Establishment of continuous monitoring, review and auditing of arrangements*

1.1 SYSTEM REQUIREMENT & FACILITIES PROPOSED

This proposal of laying proposed pipeline system broadly involves laying of 30" OD, 56 km pipeline from Jaigarh-Dabhol

1.2 OBJECTIVE OF THE QRA STUDY

The overall objective of this QRA with respect to the proposed project involves the identification and evaluation of major risks, prioritizing the risks identified based on their hazard consequences and formulating suitable risk reduction/mitigation measures in line with the ALARP principle. Hence in order to ensure effective management of any emergency situations (with potential individual and societal risks) that may arise with respect proposed pipeline the following specific objectives need to be achieved.

- Identify potential risk scenarios that may arise from the operation of the natural gas pipeline
- Analyze the possible likelihood and frequency of such risk scenarios by reviewing historical accident related data for natural gas pipelines.

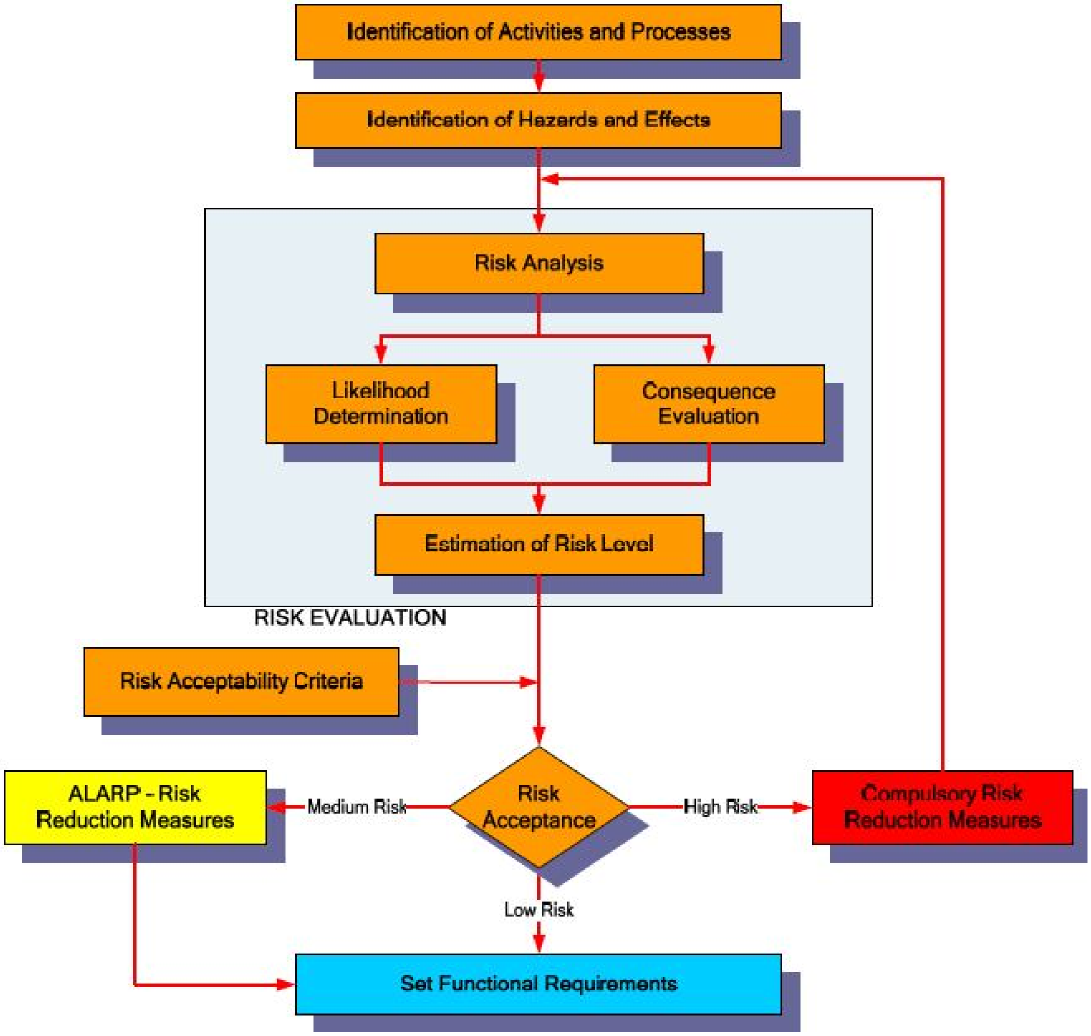
- Predict the consequences of such potential risk scenario's and if consequences are high, establish the same by through application of quantitative simulations.
- Recommend feasible preventive and risk mitigation measures as well as provide inputs for drawing up of Disaster Management Plan (DMP) for the project.

2 Risk Assessment Methodology

The risk assessment process is primarily based on likelihood of occurrence of the risks identified and their possible hazard consequences particularly being evaluated through hypothetical accident scenarios. With respect to the proposed project, the major risks viz. jet fire resulting from natural gas pipeline failure have been assessed and evaluated through a risk matrix generated to combine the risk severity and likelihood factor. Risk associated with the natural gas distribution network have been determined semi- quantitatively as the product of likelihood/probability and severity/consequence by using order of magnitude data (risk ranking = severity/consequence factor X likelihood/probability factor). Significance of such project related risks was then established through their classification as high, medium, low, very low depending upon risk ranking.

The risk matrix is a widely accepted and standardized method of quantitative risk assessment and is preferred over purely quantitative methods, given its inherent limitations to define a risk event with certainty. The application of this tool has resulted in the prioritization of the potential risks events resulting from failure of proposed project pipeline thus providing the basis for drawing up risk mitigation measures and leading to formulation of plans for risk and emergency management. The overall approach is summarized in the **Figure 2.1**

FIGURE 2.1: RISK ASSESSMENT METHODOLOGY



2.1 HAZARD IDENTIFICATION

Hazard identification for the purposes of this QRA involves the qualitative review of the project design and operations including relevant information provided by HEGPL. Available literature related to pipeline risk assessment worldwide, pipeline route and configuration, work procedures were reviewed for the NATURAL GAS pipeline. Information (including historical data) related to possible hazards associated with pipeline transportation of hydrocarbons were also sourced from veritable secondary sources of the upstream oil and gas industry viz. OSHA, UNEP, API, OGP, EGIF etc.

Based on the result of this exercise, potential hazards that may arise due to pipeline transportation of natural gas were identified and a qualitative understanding of their probability and significance were obtained. It is to be noted here that many of these potential hazards could be triggered by natural events like earthquakes, floods and such factors have been considered in arriving at probable frequency of occurrence of such hazards.

Taking into account the applicability of different risk aspects in context of the pipeline and tank operations, the following hazards have been associated with proposed project which has been dealt in detail in the subsequent sections.

- Release of natural gas from pipeline failure viz. leakage, ruptures etc. resulting in jet fires

2.2 FREQUENCY ANALYSIS

The frequency analysis of the hazards identified with respect to the proposed project was undertaken to estimate the likelihood of their occurrences during the project life cycle. Hazard frequencies in relation to the proposed project were estimated based on the analysis of historical accident frequency data and professional judgment. Based on the range of probabilities arrived at for different potential hazards that may be encountered during pipeline operations with respect to the propsoed project, the following frequency categories and criteria have been defined (**Table 2.1**)

TABLE 2.1: FREQUENCY CATEGORIES AND CRITERIA

Likelihood Ranking	Criteria Ranking (cases / year)	Frequency Class
5	>1.0	Frequent
4	$>10^{-1}$ to <1.0	Probable
3	$>10^{-3}$ to $<10^{-1}$	Occasional/Rare
2	$>10^{-5}$ to $<10^{-3}$	Not Likely
1	$>10^{-6}$ to $<10^{-5}$	Improbable

2.3 CONSEQUENCE ANALYSIS

In parallel with the frequency analysis, hazard prediction / consequence analysis exercises were undertaken to assess the likely impact of project related risks on onsite personnel, infrastructure and environment. In relation to the proposed project, the estimation of the consequences for each possible event has been based either on accident frequency, consequence modeling or professional judgment, as appropriate. Overall, the consequence analysis takes into account the following aspects:

- Nature of impact on environment and community;
- Occupational health and safety;
- Asset and property damage;
- Corporate image
- Timeline for restoration of environmental and property damage
- Restoration cost for environmental and property damage

The following criteria for consequence rankings (**Table 2.2**) have been drawn up in context of the possible consequences of the risk events that may occur during the operation of the natural gas pipeline:

TABLE 2.2: SEVERITY CATEGORIES AND CRITERIA

Consequence	Ranking	Criteria Definition
Catastrophic	5	• Multiple fatalities/Permanent total disability to more than 50 persons • More than 5 years for natural recovery • Net negative financial impact of >10 crores • Long term impact on ecologically sensitive areas • International media coverage • Loss of corporate image and reputation
Major	4	• Single fatality/permanent total disability to one or more persons • 2-5 years for natural recovery • Net negative financial impact of 5 -10 crores • Significant impact on endangered and threatened floral and faunal species • National stakeholder concern and media coverage.
Moderate	3	• Short term hospitalization & rehabilitation leading to recovery • 1-2 years for natural recovery • Net negative financial impact of 1-5 crores • Short term impact on protected natural habitats • State wide media coverage
Minor	2	• Medical treatment injuries • 1 year for natural recovery • Net negative financial impact of 0.5 – 1 crore • Temporary and mitigable environmental impacts • Local stakeholder concern and public attention
Insignificant	1	• First Aid treatment • Natural recovery < 1year • Net negative financial impact of <0.5 crores. • No significant impact on environmental components • No media coverage

2.4 RISK EVALUATION

Based on ranking of likelihood and frequencies, each identified hazard has been evaluated based on the likelihood of occurrence and the magnitude of consequences. The significance of the risk is expressed as the product of likelihood and the consequence of the risk event, expressed as follows:

Significance = Likelihood X Consequence

The **Table 2.3** below illustrates all possible product results for the five likelihood and consequence categories while the **Table2.4** assigns risk significance criteria in three regions that identify the limit of risk acceptability. Depending on the position of the intersection of a column with a row in the risk matrix, hazard prone activities have been classified as low, medium and high thereby qualifying for a set of risk reduction / mitigation strategies.

TABLE 2.3: RISK MATRIX

Consequence ↑		Likelihood → Frequent 5	Probable 4	Remote 3	Not Likely 2	Improbable 1
Catastrophic	**5**	25	20	15	10	5
Major	**4**	20	16	12	8	4
Moderate	**3**	15	12	9	6	3
Minor	**2**	10	8	6	4	2
Insignificant	**1**	5	4	3	2	1

TABLE 2.4: RISK CRITERIA AND ACTION REQUIREMENTS

Risk Significance	Criteria Definition & Action Requirements
High (16 - 25)	**"Risk requires attention"** – Project HSE Management need to ensure that necessary mitigation are adopted to ensure that possible risk remains within acceptable limits
Medium (10 – 15)	**"Risk is tolerable"** – Project HSE Management needs to adopt necessary measures to prevent any change/modification of existing risk controls and ensure implementation of all practicable controls.
Low (5 – 9)	**"Risk is acceptable" –** Project related risks are managed by well established controls and routine processes/procedures. Implementation of additional controls can be considered.
Very Low (1 – 4)	**"Risk is acceptable" –** All risks are managed by well established controls and routine processes/procedures. Additional risk controls need not to be considered

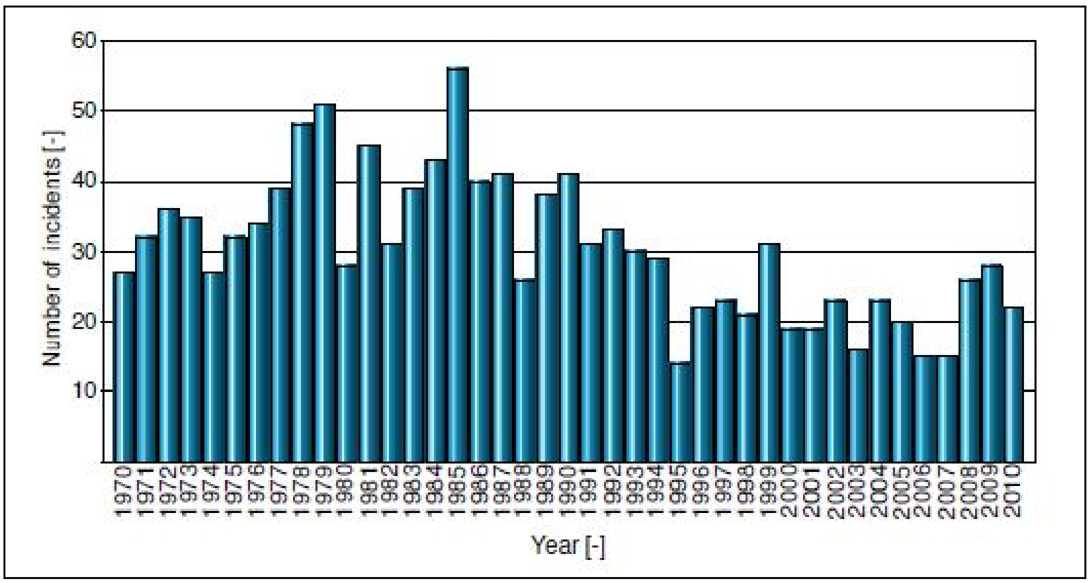
3 Risk Assessment of Identified Project Hazards

As already discussed in the previous section, two major categories of risk have identified in relation to the proposed natural gas pipeline system. A comprehensive risk assessment study has been undertaken for these risks to evaluate their significance in terms of severity of consequences and likelihood of occurrence. The risk assessment study details have been summarized in the subsequent sections below:

3.1 PIPELINE FAILURE CAUSES

Pipeline failure causes and their frequency of occurrence with respect to the proposed pipeline project have been discussed based on the review of the database of the European Gas Pipeline Incident Data Group (EGIG). The EGIG is a cooperation of 15 major gas transmission systems in Europe with the objective of providing a broad basis for the calculation of safety performance of the pipeline systems thus providing a more realistic picture of the frequencies and probabilities of incidents. The 8th EGIG report recorded a total of 1249 nos. incidents for the period 1970-2010, with 76 nos. incidents being reported for the last three years (2007-2010). The number of pipeline failure incidents per year for the period 1970-2010 has been presented in the **Figure 3.1** below.

Figure 3.1: Natural Gas Pipeline Failure Incidents (1970-2010)



Source: 8th EGIG Report

Pipeline failure leading to release of hydrocarbons may occur under the following circumstances –

- Internal corrosion
- External corrosion – from defects in protective system, in cased crossings beneath roads and railway lines

- External interference – due to construction machinery, unauthorized excavations, missing ground markers;
- Structural failure/mechanical defects
- Ground movement resulting from natural hazards viz. seismic events, subsidence, landslides, floods etc.

External interference and construction defects are also potential cause of pipeline accidents and may also occur at valve and pump stations and have been discussed in detail in **Section 3.1.1** of this report. Based on the aforesaid factors, accidental releases from pipelines are classified as either leaks or ruptures (*Pluss, Niederbaumer & Sagesser, 2000*). Similar failure cases have been considered for the proposed pipeline project.

3.1.1 Pipeline Failure – Potential Hazards

Natural gas is flammable when mixed in air at concentrations from 5 to 15% (volume basis). Its fire-related properties are comparable to other light hydrocarbon fuels. Natural gas is buoyant at ambient conditions because of the difference in density between methane and air. Pipeline leaks or rupture may possibly result in various fire hazards depending upon whether the ignition is immediate or delayed. The IGEM/TD/2[1] (Institution of Gas Engineers & Managers) standard recognizes the following possible fire hazards as being applicable following a natural gas pipeline release that ignites:

Ignition of a Leak (Immediate or Delayed) to give a Jet Fire

In case of leaks from buried pipelines, the transient flow will be channelized through the voids from the overlaying soil. If the leak is sufficiently large then soil will be ejected above the pipeline. The jet will entrain air as it moves upward and will get disperse depending on the prevailing wind direction and other meteorological conditions. The concentration of gas till its Lower Flammability Limit (LFL) is hazardous, as it can catch fire on availability of ignition source. The total duration of release and its impact/consequence will depend on how quickly the release is identified and the sectionalizing valve isolates the pipeline section. If the material encounters an ignition source while it is in the flammable concentration range, a jet fire may occur. The momentum of released material from a buried pipeline generally results in vertically oriented fires. Such fires have smaller hazard ranges than horizontally orientated fires.

1 IGEM/TD/2 provides a framework for carrying out an assessment of the acute safety risks associated with major accident hazard pipelines (MAHPs) containing high pressure Natural Gas. It provides guidance on the selection of pipeline failure frequencies and on the modelling of failure consequences for the prediction of individual and societal risks.

Immediate Ignition of a Rupture to give a Fireball & Crater Fire

Following a rupture, or large puncture, there will be rapid depressurization in the vicinity of the failure. For the buried pipelines as in this case, the overlying soil will be ejected with the formation of a crater of a size and shape, which influences the behavior of the released gas. At the start of the release, a highly turbulent mushroom shaped cap is formed which increases in height above the release point due to the source momentum and buoyancy, and is fed by the gas jet and entrained air from the plume which follows. In addition to entrained air the release can also result in entrainment of ejected soil into the cap and plume. Eventually, the cap will disperse due to progressive entrainment and a quasi-steady plume will remain. (*Acton, Gosse & McCollum, 2002*).

If the large scale quasi-instantaneous flammable gas release is under pressure is ignited almost immediately a fireball will result. In order for a fireball to occur, the cloud must be ignited before it has time to disperse hence there must be an ignition source close to the release point at the time of release. The energy released by the rupture of the pipeline typically results in the formation of a crater around the rupture point. Gas enters the crater from each end of the ruptured pipeline. Once the fireball has dissipated, this gas continues to burn as a crater (or trench) fire. Crater fire generally occurs when the ignition of the gas released by rupture is delayed. However the review of historical data indicates that

The concentration of gas in the vapour clouds formed will therefore generally be low and the probability of vapour cloud fires to be produced is relatively lean. Ignition of the cloud is likely to occur at concentrations below the Lower Flammability Limit (LFL) of 2.2 vol.%. In some cases, the cloud if ignited, the flame will not propagate through the cloud and will lead only to the formation of isolated pockets of ignition making any potential cause of fireballs unlikely. Further the probability of ignition of a natural gas release is remote as natural gas is a considerably light gas whose molecular weight is lower than air and also taking into account low ignition probability (2%-4%) of gas pipeline failure as reported by EGIG. Also the surrounding area through which the pipeline traverses is open and there is no area within which the released gas could be confined (Refer Hazardous Chemical Databook, G Weiss, Noyes Data Corporation). In view of the above discussion the occurrence of fireball is remote and hence is not considered for qualitative analysis.

Flash Fires

The buoyancy of natural gas and momentum of the high pressure release tend to propel the gas away from ground level within a relatively short distance from the source. This means that it is highly unlikely that flammable concentrations of gas will be produced at ground level beyond a short distance from the source. For this reason, flash fires are not included within the QRA.

3.1.2 Pipeline Failure – Frequency Analysis

An effort has also been made to understand the primary failure frequencies of natural gas pipeline which is the result of the number of incidents within a period divided by the corresponding total system exposure. Based on the EGIG database the evolution of the primary failure frequencies over the entire period and for the last five years has been provided in **Table 3.1** below.

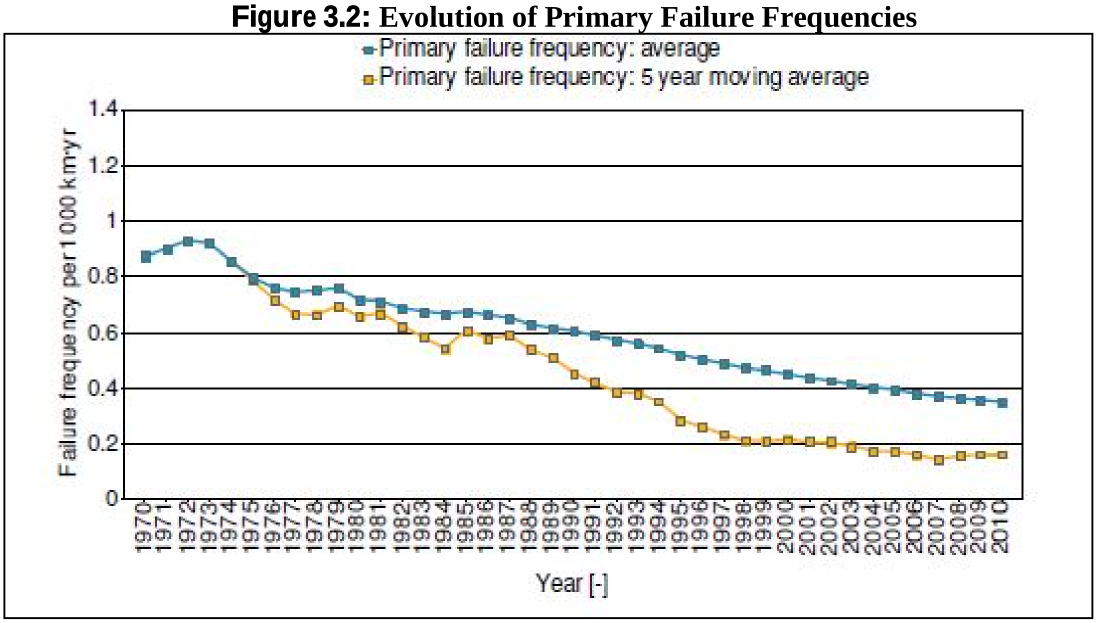
Table 3.1: Primary Gas Pipeline Failure Frequency

Period	No. of Incidents	Total System Exposure (km.yr)	Primary failure frequency (1000 km.yr)
1970-2007	1173	$3.15.10^6$	0.372
1970-2010	1249	$3.55.10^6$	0.351
1981-2010	860	$3.01.10^6$	0.286
1991-2010	460	$2.25.\ 10^6$	0.204
2001-2010	207	$1.24.\ 10^6$	0.167
2006-2010	106	$0.654.10^6$	0.162

Source: 8h EGIG Report

As referred in the above table the primary failure frequency for the period 2006-2010 (0.16) is nearly half the failure frequency recorded for the entire period 1970-2010 (0.351) indicating an improvement in pipeline safety performance over the recent years. The overall failure frequency of 1970-2010 (0.11) was also computed to be slightly lower than the failure frequency of 0.372 reported for the period 1970-2007. The evolution of primary failure frequencies over the entire period including the 5 year period of 1970-2010 has been presented in the **Figure 3.2** below.

Figure 3.2: Evolution of Primary Failure Frequencies



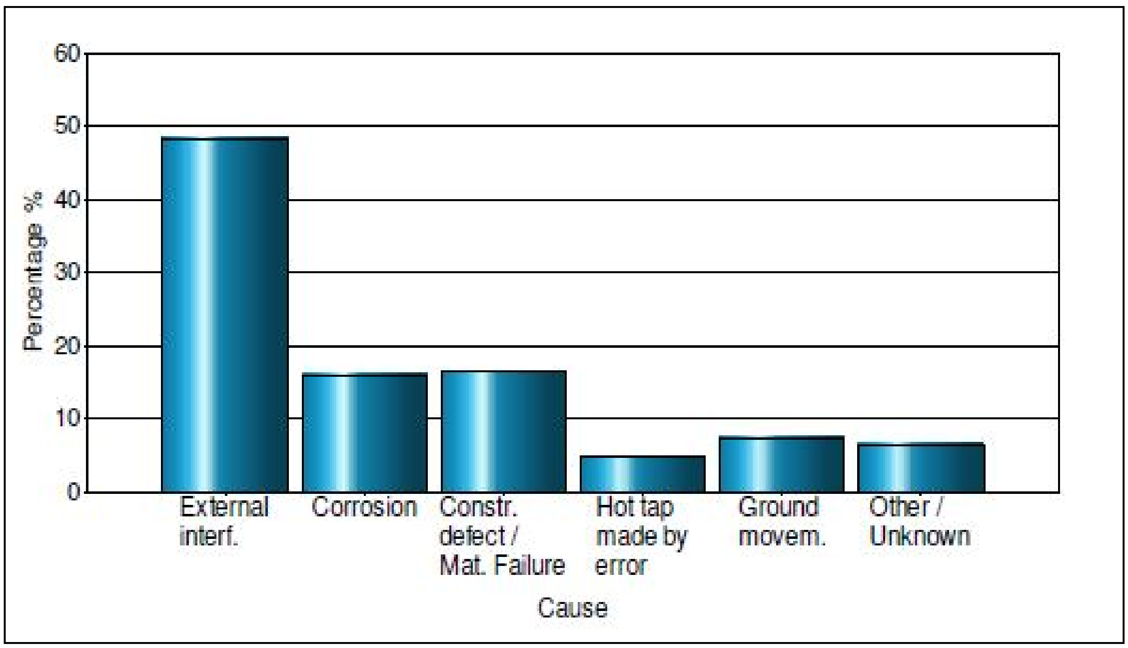
Source: 8th EGIG Report

The above figure depicts a steady drop of the primary failure frequencies and the failure frequencies of the 5 years moving average. The primary failure frequency over the entire period declined from 0.87 per 1000 km.yr in 1970 to 0.35 per 1000 km.yr in 2010. The moving average primary failure frequency over five years decreased by a factor 6 (0.86 to 0.16 per 1000 km.yr). Data published by the UK Onshore Pipeline Operators Association (UKOPA) show a similar trend, with the frequency of accidental releases in the period 2002-2006 being over 25 times lower than the frequency for the period 1967-1971 (0.028 as opposed to 0.706 releases per 1000 km of pipe per year).

Pipeline Failure Frequency Analysis – Incident Causes

As discussed in **Section 3.1.1** natural gas pipeline failure incidents can be attributed to the following major causes viz. external interference, construction defects, corrosion (internal & external), ground movement and hot tap. The distribution of incidents with cause has been presented in the **Figure 3.3** below.

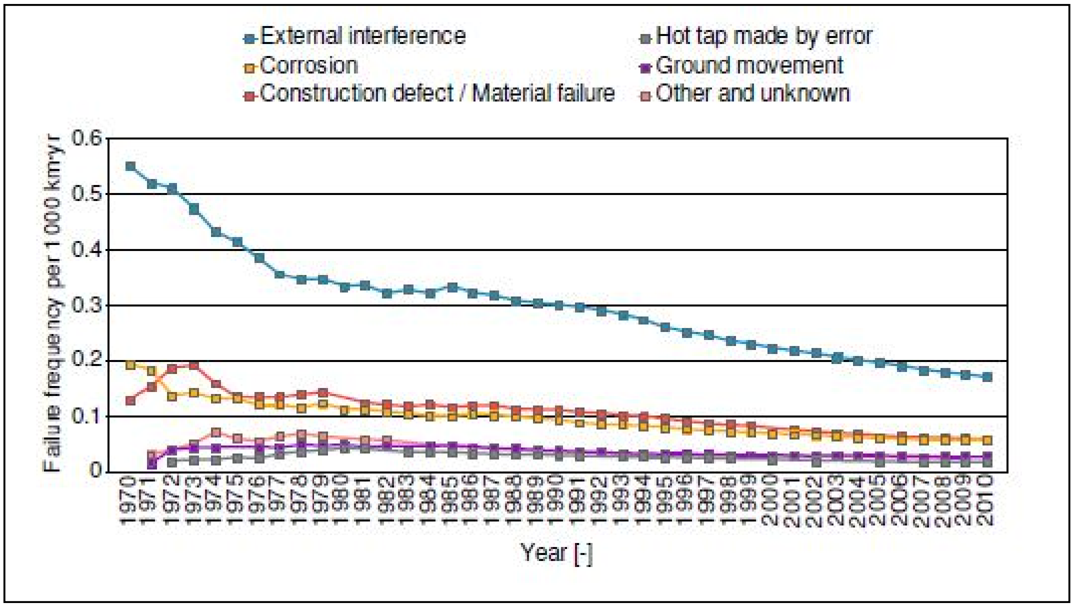
Figure 3.3: Natural Gas Pipeline Failure – Distribution of Incident & Causes



Source: 8th EGIG Report

The interpretation of the aforesaid figure indicated external interference as the major cause of pipeline failure contributing to about 48.4% of the total failure incidents followed by construction defects (16.7%) and corrosion related problems (16.1%). Ground movement resulting from seismic disturbance, landslides, flood etc contributed to only 7.4% of pipeline failure incident causes. The primary failure frequencies per cause for the period 1970-2010 have been presented in **Figure 3.4** below.

Figure 3.4: Natural Gas Pipeline Primary Failure Frequencies Per Cause



Source: 7th EGIG Report

The **Figure 1.5** illustrate the reducing failure frequency over the years which has been achieved primarily due to technological developments viz. welding, inspection, condition monitoring using in-line inspection and improved procedures for damage prevention and detection. As far as the cause of external interference is concerned, its associated primary failure frequency over the period 1970-2010 decreased to 0.17 per 1000 km.yr while the 5-years moving average has leveled off at around 0.10 per 1000 km.yr since 1997. However external interference to this date remains the main cause of pipeline failure incidents, with nearly 50% of the incidents being attributed to the former over the period 2006-2010.

The pipeline failure frequency viz. leaks or rupture for the proposed pipeline project is established based on the interpretation of the database of European Gas Pipeline Incident Data Group (EGIG) representing almost 2 million kilometer year of pipeline operations. The failure rate reported by EGIG for on-shore gas pipeline with design pressure greater than 15 bar is **4.76×10^{-4} km/year.** Full Bore Rupture (FBR) represents 13% of the cases (**6.188×10^{-5} failure /km/yr**) and 87% of the cases represents Leaks (**4.14×10^{-4} failure /km/yr**).

The frequency of pipeline failure during transportation of natural gas as recorded by EGIG is presented in the **Table 3.2** below.

Table 3.2: Gas Pipeline Failure Frequency & Class

Sl. No	Pipeline Failure Case	Failure Frequency (per km.year)	Frequency Class
1	Natural Gas Pipeline Rupture	**6.188×10^{-5}**	**Not Likely**
2	Natural Gas Pipeline Leak	**4.14×10^{-4}**	**Not Likely**

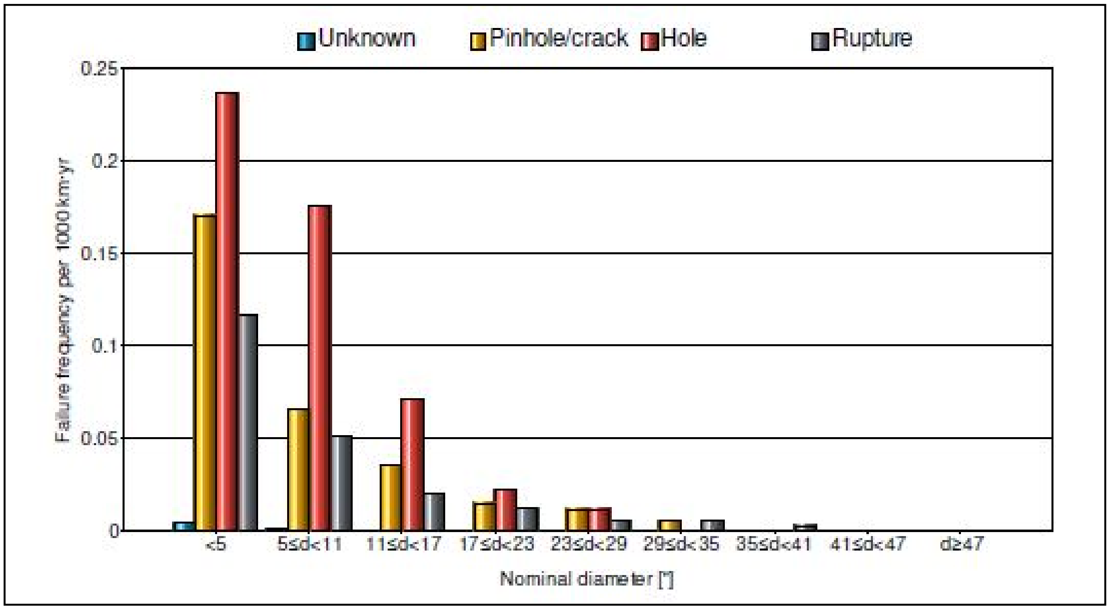
Hence based on the above table and frequency categories defined (Refer **Table 3.1**) it can be concluded that the failure frequency (leaks and/or rupture) for the proposed natural Gas Pipeline Project is "**Not Likely**". Further considering that the following preventive measures are likely to be adopted by HEGPL for addressing any potential pipeline related safety risks/hazards viz. jet fire etc the failure frequencies for the proposed pipeline project are likely to be minimal.

- Pipeline shall be protected from external corrosion by impressed current cathodic protection and suitable external coating.
- Corrosion coupons & corrosion sensing probes will be provided as required for monitoring internal and external corrosion.
- Provision of SCADA and Leak Detection System.

Pipeline Failure Frequency Analysis – Damage Type

As discussed in the earlier section potential hazards from pipeline failure primarily results from pin-hole cracks, holes and/or ruptures caused due to external disturbances, construction defects, corrosion etc. As external disturbance has been identified as one of the major cause for pipeline incidents (EGIG database) the same has been considered in evaluating the failure frequency with respect to the nature of damage and pipeline design parameters viz. diameter. The pipeline failure frequency in relation with external interference, damage type and diameter class have been presented in the **Figure 3.5** below.

Figure 3.5: External Failure Frequency – Relation with Damage Type & Diamter Class



Source: 8th EGIG Report

The above figure reveals that pipeline with smaller diameter are more susceptible to damage by external disturbance as compared to larger diameter pipes. Thinner wall thickness of pipelines with smaller diameter also contributes to the increased failure frequency for such pipelines. Hence based on the aforesaid findings it can be therefore concluded that the failure frequency of the 30" dia proposed pipeline project is likely to be low.

3.1.3 Pipeline Failure – Ignition Probability

Fortunately not every gas release ignites, which seriously limits the consequences of the incidents. In the period 1970-2010, only 4.5% of the gas releases recorded as incidents in the EGIG database ignited. Ignition depends on the existence of random ignition sources. The EGIG database gives the opportunity to evaluate the link between ignition and leak size. The **Table 3.3** presents the ignition probabilities per leak type for gas pipelines.

Table 3.3: Ignition Probabilities Per Leak Type

Sl.No	Size of Leaks	Ignition Probabilities (%)
1	Pin Hole Crack	**4**
2	Hole	**2**
3	Rupture	**13**

Source: EGIG Report

The above table indicates that ignition probability of a gas pipeline failure event (pin hole crack and holes) is negligible contributing to only 2% - 4% depending upon leak type.

The ignition probability of pipeline failure (rupture & leaks) with respect to the proposed project is derived based on the following equations as provided in the IGEM/TD/2 standard

$$\left.\begin{aligned} &\mathbf{P_{ign} = 0.0555 + 0.0137pd2;\ for\ 0 \leq pd^2 \leq 57} \\ &\mathbf{P_{ign} = 0.81;\ for\ pd^2 > 57} \end{aligned}\right\} \textbf{(Ignition Probability for pipeline ruptures)}$$

$$\left.\begin{aligned} &\mathbf{P_{ign} = 0.0555 + 0.0137(0.5pd2);\ for\ 0 \leq 0.5pd^2 \leq 57} \\ &\mathbf{P_{ign} = 0.81;\ for\ 0.5pd^2 > 57} \end{aligned}\right\} \textbf{(Ignition Probability for pipeline leaks)}$$

Where:

P_{ign} = Probability of ignition

p = Pipeline operating pressure (bar)

d = Pipeline diameter (m)

Pipeline Failure – Ignition Probability

The ignition probability of natural gas release from 30" dia of the proposed pipeline project is calculated based on the above equations utilizing the following input parameters as discussed below.

Pipeline Pressure (bar) = p= 115 kg/cm^2 or 112.77 bar

Pipeline diameter = d = 30 inches or 0.762 m

For pipeline rupture pd^2 = (112.77) X (0.762)^2 = 65.47

For pipeline leak 0.5 pd^2 = 0.5 X (112.77) X (0.762)^2 = 32.73

Since **pd^2 > 57** and **$0 \leq 0.5pd^2 \leq 57$,** the following equation has been utilized for deriving the ignition probability for feeder pipeline failure.

$P_{\text{ign for pipeline rupture}} = 0.81$

$P_{\text{ign for pipeline leak}} = 0.0555 + 0.0137(0.5pd^2) = 0.0555 + 0.0137\ (32.73) = 0.503 \times 10^{-2}$ or 0.5%

The ignition probability of natural gas from a gas pipeline failure viz. leak and rupture for the proposed project is computed to be ≤2% and is therefore considered to be negligible. This also supported by the ignition probabilities recorded by EGIG (Refer Table **3.3**) for gas pipelines based on leak types.

3.1.4 Pipeline Failure – Consequence Analysis

Pipeline generally contains large inventories of oil or gas under high pressure; although accidental releases from them are remote they have the potential of catastrophic or major consequences if related risks are not adequately analyzed or controlled. The consequences of possible pipeline failure is generally predicted based on the hypothetical failure scenario considered and defining parameters such as meteorological conditions (stability class), leak hole & rupture size and orientation, pipeline pressure & temperature, physicochemical properties of chemicals released etc.

As discussed in **Section 3.1.1,** jet fire have been identified as the possible consequences resulting from the natural gas pipeline failure and is dependent on the ignition time. Jet fires are generally burning jet of gas or spray of atomized liquid released from high pressure equipment. This may be very damaging to equipment within the fire, and lethal to personnel and local communities at some distance. Fireballs may arise from a rupture in the pipeline followed instantaneous ignition of the cloud of flammable gas released under high pressure. However as discussed earlier occurrence of such an event is considered to be remote and is not considered as part of this exercise.

Taking into account the above pipeline failure consequences and frequency analysis as discussed in **Section 3.1.2** the following hypothetical risk scenarios (**Table 3.4**) have been considered for failure consequence modeling with respect to proposed pipeline project:

Table 3.4: Hypothetical Failure Cases for Modeling the Risks

Case No	Pipeline Failure Case	Hole Size (inch)	Design pressure (bar)	Pipeline temperature (°C)	Scenario Description
I	30” pipeline leak	0.50	112.77	38	Formation of jet fire
II		1.00			Formation of jet fire
III	30” pipeline rupture	-			Formation of jet fire

The above risk scenarios for pipeline failure are modeled using ALOHA[2] and interpreted in terms of Thermal Radiation Level of Concern (LOC). Predominant local meteorological conditions as specified in the baseline chapter have been considered in modeling the pipeline risks using ALOHA. Natural gas is primarily composed of methane and the same has been considered in modeling the threats resulting from the proposed pipeline failure.

Thermal Radiation Level of Concern (LOC) is a threshold level of thermal radiation, usually the level above which a hazard may exist. For each LOC chosen, ALOHA estimates a threat zone where the thermal radiation is predicted to exceed that LOC at some time after a release begins. These zones are displayed on a single Threat Zone plot displayed as red, orange and yellow with red representing the worst hazard. The threat zone displayed by ALOHA represent thermal radiation levels and also indicates the effects on people who are exposed to those thermal radiation levels but are able to seek shelter within one minute. ALOHA uses three threshold values (measured in kilowatts per square meter) to create the default threat zones:

- *Red: 10 kW/ (sq m) -- potentially lethal within 60 sec;*
- *Orange: 5 kW/ (sq m) -- second-degree burns within 60 sec; and*
- *Yellow: 2 kW/ (sq m) -- pain within 60 sec*

[2] **ALOHA** is a public domain computer code that is part of a system of software that is known as the Computer-Aided Management of Emergency Operations (CAMEO) that was developed by the **United States Environmental Protection Agency (EPA)**, through its Chemical Emergency Preparedness and Prevention Office (CEPPO) to plan for and respond to chemical emergencies

Case I: Release and ignition of natural gas from 30" dia pipeline leak – hole size (0.5"dia)

The jet fire threat zone plot for release and ignition of natural gas from pipeline leak of size - diameter 0.5 inch is described as:

THREAT ZONE:

Threat Modeled: Thermal radiation from pool fire

Red : <10 meters --- (10.0 kW/ (sq m) = potentially lethal within 60 sec)

Orange: <10 meters --- (5.0 kW/ (sq m) = 2nd degree burns within 60 sec)

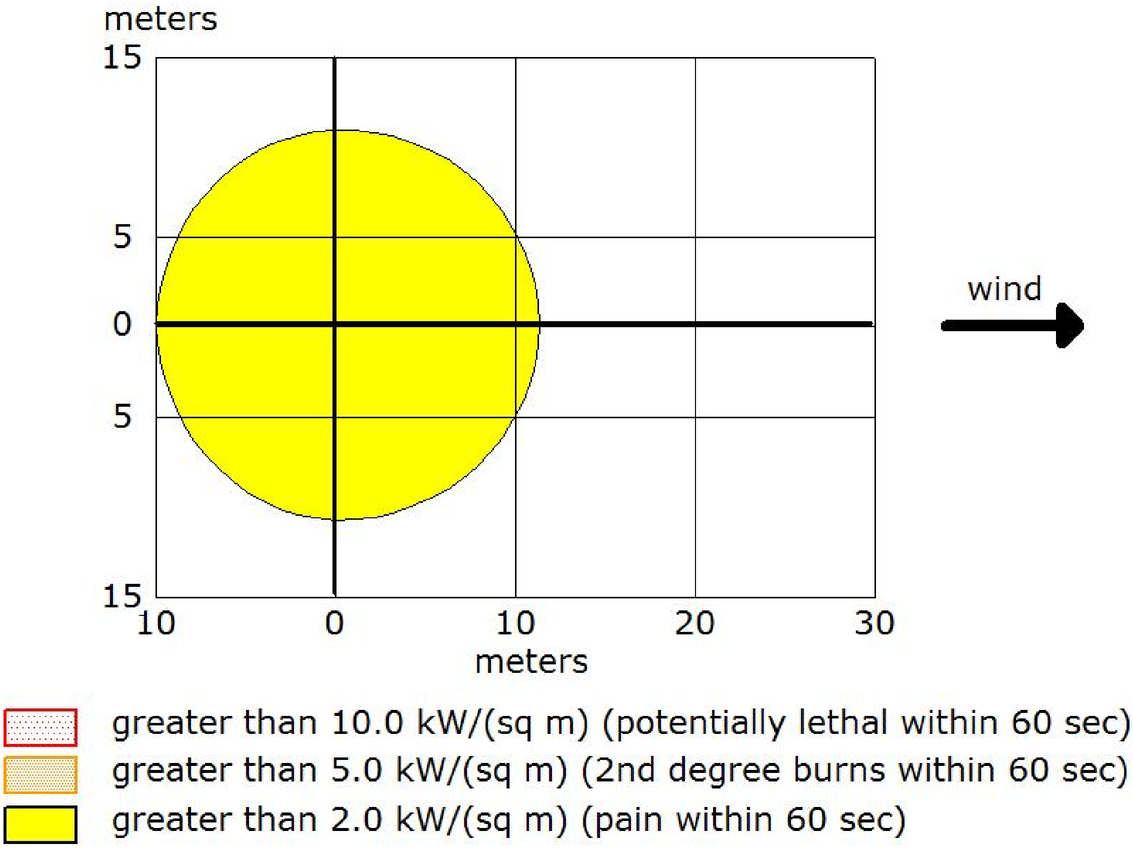
Yellow: <10 meters --- (2.0 kW/ (sq m) = pain within 60 sec)

The worst hazard for release and ignition of natural gas from pipeline leak (hole size – 0.5" dia) will be experienced to a maximum radial distance of <10 m from the source with potential lethal effects within 1 minute.

Case II: Release and ignition of natural gas from 30" dia pipeline leak – hole size (1"dia)

The jet fire threat zone plot for release and ignition of natural gas from pipeline leak of size - diameter 1.0 inch is represented in **Figure 3.7** below.

FIGURE 3.6: THREAT ZONE PLOT FOR JET FIRE (30" DIA PIPELINE) – 1" DIA LEAK



THREAT ZONE:

Threat Modeled: Thermal radiation from pool fire

Red : <10 meters --- (10.0 kW/ (sq m) = potentially lethal within 60 sec)

Orange: <10 meters --- (5.0 kW/ (sq m) = 2nd degree burns within 60 sec)

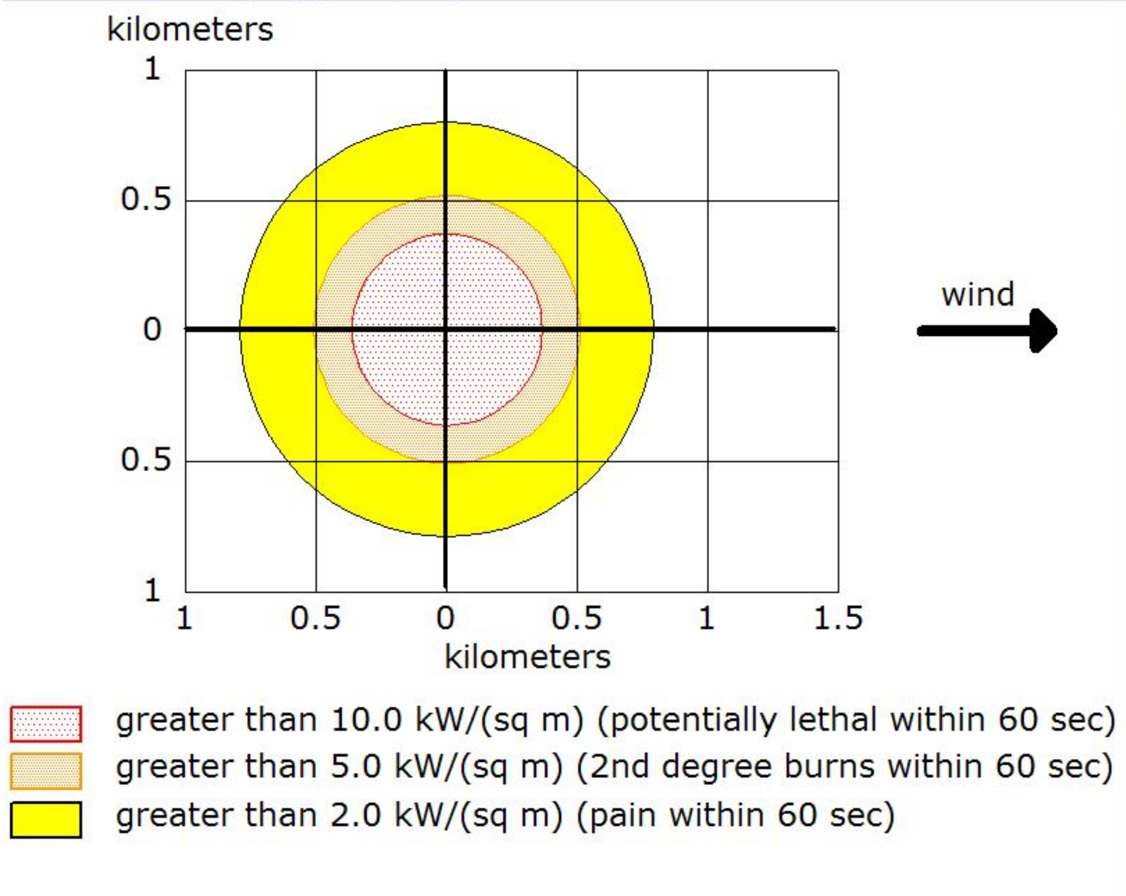
Yellow: 11 meters --- (2.0 kW/ (sq m) = pain within 60 sec)

The worst hazard for release and ignition of natural gas from pipeline leak (hole size – 1" dia) will be experienced to a maximum radial distance of 10 m from the source with potential lethal effects within 1 minute.

Case III: Release and ignition of natural gas from 30" dia pipeline rupture

The jet fire threat zone plot for release and ignition of natural gas from 30" dia pipeline rupture **-** is represented in **Figure 3.8** below.

FIGURE 3.7: THREAT ZONE PLOT FOR JET FIRE - 30" DIA PIPELINE RUPTURE



THREAT ZONE:

Threat Modeled: Thermal radiation from pool fire

Red   : 369 meters --- (10.0 kW/ (sq m) = potentially lethal within 60 sec)

Orange: 514 meters --- (5.0 kW/ (sq m) = 2nd degree burns within 60 sec)

Yellow: 793 meters --- (2.0 kW/ (sq m) = pain within 60 sec)

The worst hazard for release and ignition of natural gas from 30" dia pipeline rupture will be experienced to a maximum radial distance of 369 m from the source with potential lethal effects within 1 minute.

4 Findings & Conclusion

For various hypothetical scenarios considered with respect to pipeline leaks and ruptures, the threat zones calculated using ALOHA for defined thermal radiation intensities have been presented in the **Table 4.1** below.

TABLE 4.1: THREAT ZONE DISTANCE - PROPOSED NATURAL GAS PIPELINE FAILURE SCENARIOS

Case No	Pipeline Failure Case	Hole Size (inch)	Distance to 10.0 kW/m² (m)	Distance to 5.0 kW/m² (m)	Distance to 2.0 kW/m² (m)
I	30" pipeline leak	0.50	<10	<10	<10
II	30" pipeline leak	1.00	<10	<10	11
III	30" pipeline rupture	30	369	514	793

Thus the risk ranking and significance of the proposed natural gas pipeline failure is rated as "**Medium**" with a risk score of "**12**" as presented below.

Likelihood ranking	**3**	**Consequence ranking**	**4**
Risk Ranking & Significance = 12 i.e. "Medium"			

Based on the above findings it can be concluded that risk falls in ALARP zone and also given that adequate safety and emergency response measures will be implemented by HEGPL in adherence to OISD standards during the operation and maintenance of natural gas pipeline any potential risk to this regard can be effectively managed or safely handled.

5 Disaster Management Plan

5.1 OBJECTIVE

The primary objective of the DMP is to provide a safe, timely, effective and coordinated response by the onsite Emergency Response Team (ERT), along with the other local and government agencies/departments to prevent or minimize any major emergencies that may arise from possible failures of pipeline during operation of the Jaigarh Dabhol Tie-in line project.

The main objectives of this plan are:

- *Minimize the risk for human life, environment and common property resources, by means of an effective and efficient intervention;*
- *Protection of the environment;*
- *Protection of public safety;*
- *Initiate the early and efficient response throughout the utilization of all available resources.*

5.2 PURPOSE

The purpose of the DMP is to effectively manage and control the emergencies occurring during project operations. This DMP ensures,

- emergency response group is effective & adequate;
- clear roles and responsibilities of key personnel & support groups;
- availability and adequacy of emergency infrastructure & resources; and
- efficient emergency communication

5.3 HEGPL EMERGENCY/CRISIS MANAGEMENT TEAM

HEGPL pipeline division will develop a emergency/crisis management team to respond to fire, accidents and technical emergencies. The team will be made up from operations personnel, who can be called upon 24 hours a day, supported by senior management field personnel as and when required. The role and responsibilities of specific Emergency Coordinators at Pipelines Division is discussed below:

Chief Incident Controller (CIC)

The Chief Incident Controller (CIC) shall have overall responsibility to protect personnel, site facility and the public before, during and after an emergency or disaster. The CIC shall be present at the Head Office (Mumbai). Responsibilities of the Chief Incident Controller shall include the following:-

a) Review and updation of the ERDMP as and when requried;
b) Assessment of situation and declaration of emergency;

c) Activation of Emergency Control Centre;
d) Taking decision on seeking assistance from mutual aid members and external agencies like Police, Fire Brigade, Hospitals etc.;
e) Continuous review of situation and decide on appropriate response strategy;
f) Taking stock of casualties and ensure timely medical attention;
g) Ensuring correct accounting and position of personnel after the emergency;
h) Ordering evacuation of personnel as and when necessary;
i) Taking decision in consultation with District Authorities when an off-site emergency to be declared.
j) Direct Site Incident Controller (SIC) to take appropriate actions and depute Crisis Coordinators to control the situation

Site Incident Coordinator (SIC)

The Site Incident Controller shall report to the Chief Incident Controller. The SIC shall be available at the main emergency control center (proposed to be setup at Jaigarh) for counsel and overall guidance. SIC should be nominated by the entity in each shift 12 hrs. Responsibilities of the Site Incident Controller shall include the following:-

a) The SIC shall maintain a workable emergency control plan, organize and equip the organization with ERDMP and train the personnel;
b) The SIC shall be capable of making quick decisions and taking full charge;
c) The SIC shall communicate from the Emergency Control Centre to coordinate activities among groups;
d) The SIC shall be responsible for ensuring that appropriate local and national government authorities are notified, preparation of media statements obtaining approval from the CIC and releasing such statements once approval received;
e) The SIC shall also ensure the response to the incidents or the emergencies, as the case may be, is in line with entity procedures, coordinating business continuity or recovery plan from the incident. He must ensure next of kin are notified in a timely manner;
f) The SIC shall, also co-ordinate if any specialist support is required for the above purpose; and
g) The SIC shall decide in consultation with CIC on seeking assistance of mutual aid members and external agencies like Police, Fire Brigades, hospitals, etc.

Crisis Coordinators

(A) ***Administration and Communication Coordinator***

Responsibilities of the administration and communication controller shall include the following:-

a) To coordinate with mutual aid members and other external agencies;
b) To direct them on arrival of external agencies to respective coordinators at desired locations;

c) To activate the medical center and render first aid to the injured. Arrange ambulance and coordination with hospitals for prompt medical attention to casualties;
d) To ensure head counts at assembly points;
e) To arrange procurement of sparse for firefighting and additional medicines and drugs;
f) To mobilize transport to various teams for facilitating the response measure;
g) To monitor entry and exit of personnel onto and out of incident area;
h) To ensure only authorized personnel enter into the incident area;
i) To regulate the flow of traffic into and out of incident site and control the mob outside, if any, with the assistance of the police.
j) To provide administrative and logistics assistance to various teams; and
k) To arrange evacuation as directed by the chief incident controller and in coordination with the civil authorities like police, panchayat / municipal authorities, etc.

Fire Safety Coordinator and Fire Team

Responsibilities of fire and safety coordinator shall include the following:-

a) To activate emergency sirens as per the practices codes;
b) To take charge of all firefighting and rescue operations and safety matters;
c) To ensure that key personnel are called in and to release crew of firefighting operations as per emergency procedures;
d) Assess functioning of his team and communicate with the SIC and or administrative controller for any replenishment or, replacement of manpower or firefighting equipment;
e) Direct the fire brigade personnel and mutual aid members to their desired roles as also proper positioning of the manpower and equipment;
f) To decide the requirement of mutual aid and instruct fire station, who in turn will contact mutual aid members;
g) To coordinate with outside fire brigades for properly coordinating firefighting operation;
h) To arrange requirement of additional firefighting resources including help from mutual aid partners;
i) Continually liaise with the SIC implement the emergency combat strategies as communicated by him; and

Note: Fire chief shall wear identification jackets at the site of disaster so that he is clearly distinguished among firefighting personnel and is visible from a distance.

Search Party Leader

He will, depending on the situation

a) Immediately rush to the situation along with the Telecom instrumentation, and specified manpower

b) After locating the site ensure the closing of the up –stream and down-stream valves to contain leak.
c) Assess the situation and give feedback to the SIC for further assistance/mobilization
d) Identify nearby water sources for the fighting.
e) Ensure security at site by posting chowkidar, patrolman, local police or home guard.
f) Mobilize labour and raise earthen dams to contain oil spillage, if necessary.

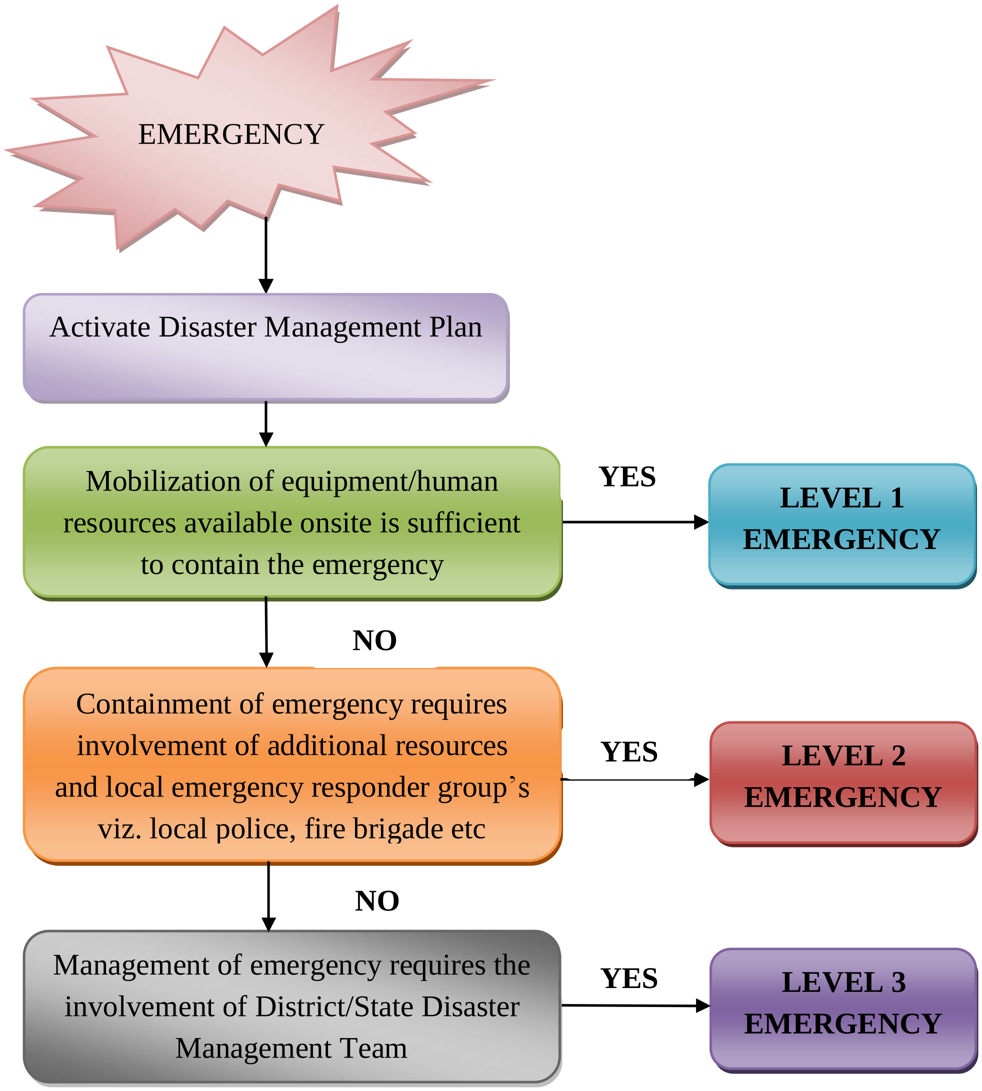
Maintenance of ERDMP Records

1) There shall be maintenance of ERDMP records for all kind of emergencies covering near miss, Level-I, Level-II and Level-III. Organization shall maintain an Incident Record Register for the above purpose and post-disaster documentation like resources deployed, relief, rehabilitation measures and lesson lead to avoid re-occurrence of any such emergency. Head of HSE or any other designated personnel by the CIC/SIC shall be responsible for maintenance of such records.
2) A good public relations program is extremely important in an emergency situation. Inquiries will normally be received from the media, government agencies, local organizations and the general public.
3) This section of the Response plan shall include a public relations or media plan. It should identify an Information Officer that is well-equipped and trained in media relations.

5.4 EMERGENCY CLASSIFICATION

Due consideration is given to the severity of potential emergency situation that may arise as a result of pipeline accident events as discussed in the **Quantitative Risk Analysis (QRA**) study. Not all emergency situations call for mobilization of same resources or emergency actions and therefore, the emergencies are classified into three levels depending on their severity and potential impact, so that appropriate emergency response procedures can be effectively implemented by the HEGPL Emergency/Crisis Management Team. The emergency levels/tiers defined with respect to this project based on their severity have been discussed in the subsequent sections with 'decision tree' for emergency classification being depicted in **Figure 6.1**

FIGURE 5.1: EMERGENCY CLASSIFICATION "DECISION TREE"



5.4.1 Level 1 – Emergency

This is an emergency or an incident which

(i) Can be effectively and safely managed and contained within the site, location or installation by the available resources;
(ii) Has no impact outside the site, location or installation.

5.4.2 Level 2 – Emergency

This is an emergency or an incident which-

(i) Cannot be effectively and safely managed or contained at the location or installation by available resource and additional support is alerted or required;

(ii) Is having or has the potential to have an effect beyond the site, location or installation and where external support of mutual aid partner may be involved;

(iii) Is likely to be danger to life, environment or to industrial assets or reputation.

5.4.3 Level 3 – Emergency

This is an emergency or an incident with off-site impact which could be catastrophic and is likely to affect the population, property and environment inside and outside the installation, and management and control is done by district administration. Although the Level-III emergency falls under the purview of district authority but till they step in, it should be the responsibility of the unit to manage the emergency.

Note: Level-I and Level-II shall normally be considered as onsite emergency and Level-III as off-site emergency. In case of any emergency in ROW, it will be considered as offsite.

5.5 EMERGENCY RESPONSE MEASURES

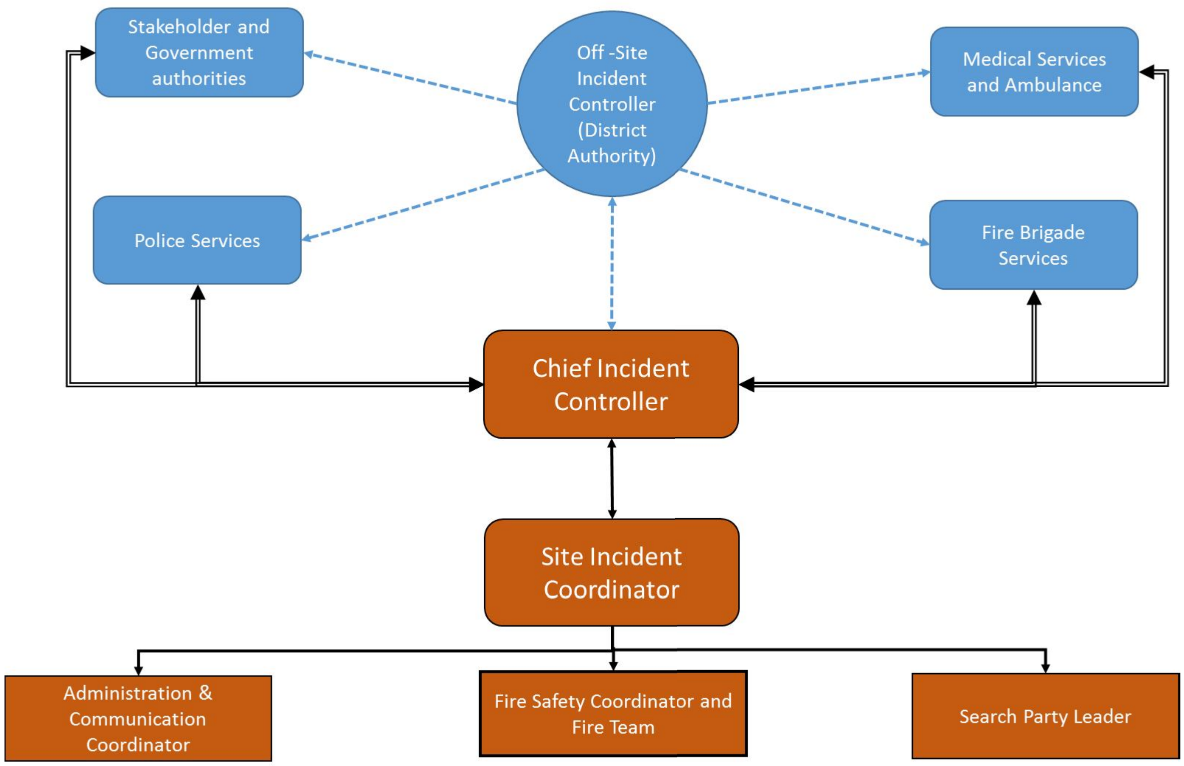
(i) **Declaration of Emergency**

Level-I and Level-II Emergency- The emergency has to be declared by the Chief Incident Controller.

Level-III Emergency- The emergency has to be declared by District Authority.

An emergency starts as a small incident which may become a major incident with passage of time. At the initial stages, the emergency organization chart shall be put into action. If the incident goes beyond control (inside the station or in main line) the on-site emergency plan will be activated by the chief incident controller at the appropriate stage as considered necessary. During idle shift or holidays, the security personnel will combat the incident as per the ERDMP organization chart and at the same time inform various emergency controllers for guidance and control the situation. In the mainline the line patrol men and GDR guards have been deployed who pass on the information to the management for controlling emergency. The people around the ROW are also made aware of the hazards of the pipeline and whom to inform in case of any emergency. When emergency becomes catastrophic and evacuation is considered necessary by the site incident controller, the situation will be handed over to district authority for implementing the off-site emergency plan. In the mainline ROW also, the site is handed over to the district authorities for implementing the off-site emergency plan. The management of emergency (inside the station or in main line) henceforth has to be controlled by the district crisis management group under the supervision of the District Collector/DDMA. In addition to preparation of on-site emergency plan, furnishing relevant information to the district authorities for the preparation of off-site emergency plan is a statutory responsibility of the occupier of every industry handling hazardous substance. Person reporting the fire / emergency should state the location at a prominent place to guide the firefighting crew arriving on the scene. The man should try to attempt to mitigate the emergency, extinguish the fire with the equipment available nearby till arrival of the firefighting crew.

Figure 6.1: Emergency Response Action and Communication



(ii) Information To Public

It is important to provide accurate information to the general public in order to prevent panic. Some citizen simply want to know what is happening while other citizens need to know as to what they could do immediately to protect themselves as well as others. In less urgent cases, however, newspaper articles to provide detailed information to enhance public understanding of gas leakage & procedures so adopted to shut the leakage. One person should be identified to serve as spokesperson. It is strongly recommended that the individual identified have experience in public information, community relations, and or media relations. The spokesperson can identify for the media, the appropriate individuals who have specialized knowledge about the event and its consequences. The chain of command should, therefore include this spokesperson. Other members of response team should be instructed to direct all communications and public relations issues to this one person (Chief Incident Controller).

Source of information to the public are pamphlets containing do's and don'ts and by organizing meeting in small groups in the villages near ROW. One or two engineers from the station are visiting the villages and organize the meeting with the help of village officials like Gram Pradhan on quarterly basis.

- In case of any emergency inside the station only employee and other connected persons like firefighting, security, ambulance crew are to be allowed to enter area and outside unknown persons and laborers should not be allowed to enter the pump station.

- In case of any emergency in the mainline burst, the area has to be cordoned off. Villagers and other unauthorized person should not be allowed to enter the area and smoking should be strictly prohibited in this area. It will be useful to educate the people working or living near the ROW about the hazards and Do's and Don'ts about the gas leakage for this purpose meetings should be organized in small groups of 10 to 15 person in the village near ROW.

General advice on the action as to what members of the public should take on hearing the warning.

- No consideration should be carried out on the right of way (ROW)

- If gas leakage is found on/or near R.O.W. It should be informed to the nearest police station/ IOC station.

- If any gas leakage found, public should stay away at a minimum distance of 400 meters from the leakage point, should not light matches, smoke bidi or cigarettes. Should not carry ordinary torches, lamps near the leakage point.

- In case of leakage in the fields, all the agriculture operation, use of tractors. Irrigation of the fields, running of the pump should be stopped till HEGPL personnel give clearance.

Usually the information to the local public is given in their local language so that they can easily understand the situation. As the pipeline is located in Marathi and Konkan speaking region most of the information is given to the public in Marathi and Konkan.

(iii) Termination of Emergency

Termination of emergency should begin as soon as the emergency phase of the operation is completed. It should concentrate on giving accurate information to the employees, neighboring units and district authorities involved in offsite emergency etc.

Level I & level II: The Chief Incident Controller after assessing the situation declares the termination of the emergency. The Level-III termination of emergency shall be declared by district authorities through appropriate mode of information transfer so as to reach each and every one.

5.6 EMERGENCY MANAGEMENT MEASURES

(A) Infrastructure Requirements

(i) Emergency Control Center

All communication related to emergency shall be routed to crisis control room at Jaigarh. The Crisis Control Room will be equipped with SCADA, communication systems (Telephones, walki-Talkies), operating manuals, Disaster Management Plans (On-Site/off-Site), Layout Plan of the pipeline, Display of names and Telephone numbers of all coordinators and heads of the organization etc. i.e. DMP Organogram of On-Site Disaster Management Plan will also be displayed. In case the scenario becomes Off-Site the names, address and telephone numbers of all off-Site groups and organization that might have to be contacted will also made available in the control room of the station. .

(ii) Medical Facilities

First Aid:

The control room will be provided with a first aid box to use in case of any minor injury takes place during operation or in case of any emergency. The first aid box is regularly monitored for any sort of shortfall in the equipment used.

If injury is major, person will be sent to the nearby hospitals. The hospital will be identified along the pipeline route at Jaigarh, Khandala, Shrungartali and Dabhol locations. The contact details of the hospital at above mentioned locations will be made available at the control room in following format:

Details of the nominated hospitals - Template

Locations	Nominated hospitals	Address	Phone No.
Jaigarh			
Khandala			
Shrungartali			
Dabhol			

(B) Resources for controlling emergency

(i) Fire and Gas Detection system

Hand held Multi Gas Detector are provided at all stations to check presence of methane concentration at area of work. Leakage place will be identified through SCADA system.

(ii) Ambulance Facility

The facilities of ambulance at incident area will be from nearby hospitals. The list of medical facilities including hospitals and other necessary equipment for combating initial injuries will be provided in the control room.