Chapter 4

ENVIRONMENTAL IMPACT ASSESSMENT

4.1 Introduction

The methodology used for environmental impact assessment follows the sequence summarized in Figure 4.1, with consultations incorporated into every phase:

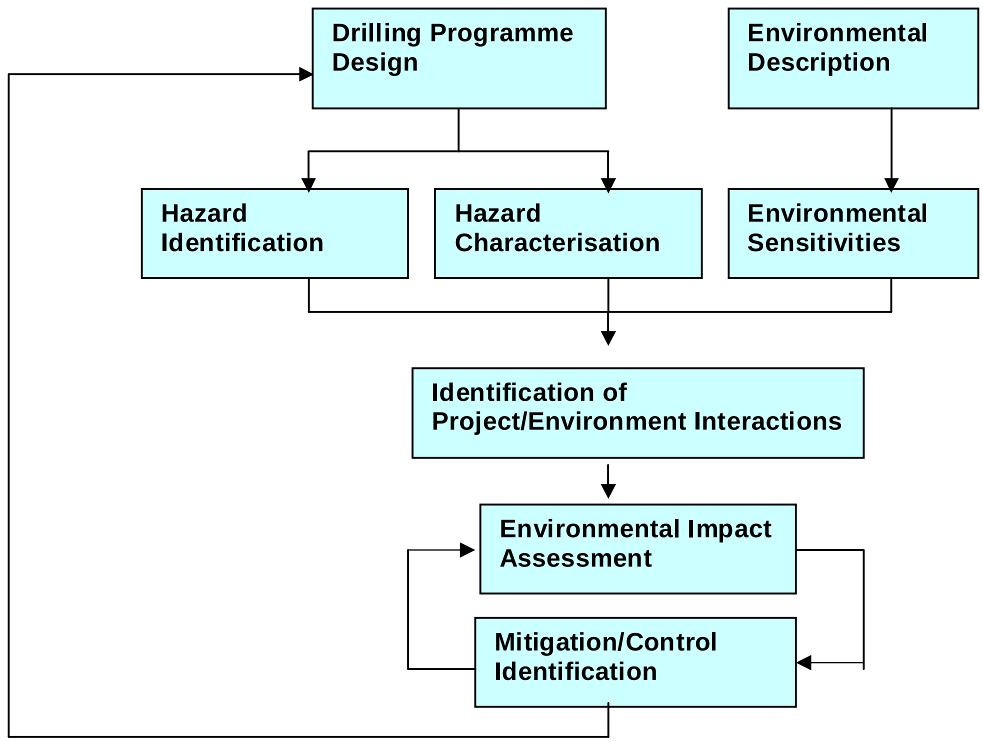

Fig. 4.1. Methodology for Environmental Impact Assessment

The main supporting information required for an assessment includes a description of both the project (Chapter 2) and the environment in which it will take place (Chapter 3). The information presented in these two chapters (2 and 3) helps in identification of the interactions between the planned activities and the environment.

In this section, the interactions between the project and the environment are identified for both routine and non-routine (unplanned) events and the total environmental impact assessment has been established from a matrix of hazards against environmental sensitivity.

4.2 Identification of Interactions

The basis of Environmental Impact Assessment (EIA) study for a proposed project consists of

i) Identification of the factors likely to have impact on the environment,

ii) Prediction of the likely scenario due to these impacts following the implementation of the project, and

iii) Suggesting ways aimed at mitigation of the impacts.

The environmental interactions of the present project are summarized in Table 4.1. This analysis would be used later to prepare an Environmental Management Plan (EMP).

The EIA of the drilling operations are evaluated with the Matrix method. The method essentially consists of a list of different activities during the project implementation and their likely impacts on the environmental indices, presented in a matrix format. The matrix allows the identification of cause-effect relationships between specific activities and their impacts. In preparing the matrix, the mitigation measures that are in operation presently or are likely to be taken up, are also taken into consideration. The Matrix includes:

- All major activities of the drilling project likely to have impact on the environment,
- The qualitative estimates of the impact of each activity on the environment,
- The mitigation measures already in place to reduce impacts on the environment,
- Additional mitigation measures suggested, wherever feasible,
- The qualitative estimates of the impact of each activity on the environment after implementation of the additional mitigation measures.

The qualitative evaluation of the impacts based on the above matrix is done on the basis of a few indicators presented below:

No Impact (0). This indicates that the project activity is unlikely to have any impact on a particular environmental index.

Table 4.1. Interactions between Project Activities and Environmental Sensitivities

Hazard	Environmental Sensitivities													
	Physical			Biological			Socio-Economic							
	Soil and sediment	Water Quality	Air Quality	Flora	Fauna	Protected Areas/Sensitive Habitats	Living conditions	Economy	Existing oil and gas activities	Pipelines/Cables	Personnel/support crews	Archaeology	Tourism/Leisure	Land Use
Physical Presence														
Noise and Vibration														
Atmospheric Emission														
Solid waste disposal														
Well Kick														

(The possible interactions with different elements of the environment are shown in the shaded boxes)

Negligible Adverse Impact (NA)/Negligible Beneficial Impact (NB). It indicates that the proposed activities will have only minor effect, adverse or beneficial, on the environmental parameters concerned. Generally these impacts are of temporary duration (occur intermittently) or are in insignificant quantities. Impacts are not likely to exceed stipulated limits.

Significant Adverse Impact (SA)/Significant Beneficial Impact (SB). In this case, the activities and their environmental impacts are considered to be significantly adverse if they create, or have the potential to generate environmental impacts, which are readily identifiable, tangible, and harmful. Significant beneficial impacts create reasonable positive impact on the environment.

High Adverse Impact (HA)/High Beneficial Impact (HB). The activities that create or have a potential to create considerable damage to the environmental parameters belong to this class. They may be, at times, irreversible and long-term. Likewise high beneficial impacts are those impacts that radically improve the environment.

Any new stress added to the environment has adverse consequences for the biota. Oil exploration, drilling and extraction activities are inherently invasive and affect ecosystems, human health and local cultures (O'Rourke and Connolly, 2003). The environmental concerns usually associated with these 'upstream phase' activities in the life cycle of oil, emanate from the physical disturbance caused by the location and operation of the project facilities and the pollution caused by the waste that is generated.

Physical Disturbance. The physical disturbance of the environment resulting from oil exploration activities can have a negative impact on the fauna, especially if it causes changes in factors on which the recruitment and survival of wildlife populations in the area are dependent.

In the context of the proposed exploratory drilling for hydrocarbons by OIL in Jonai, a major source of physical disturbance will be the work undertaken to strengthen the existing roads and to build new stretches of road to facilitate the movement of heavy equipment, including mobile rigs up to the drilling sites. On site, platforms will have to be erected, camps for crew set up and other project facilities implemented, with all of these activities having the potential to cause physical disturbance of the area. Another factor capable of causing physical disturbance will be the increased deployment of personnel and vehicles in the area, which will accompany implementation of the project.

The physical disturbance associated with the proposed exploratory drilling activities will, in a large part, be due to the loss of natural vegetation as land is cleared for roads, platforms and other project facilities. It has already been mentioned in Chapter 3 that most of the natural forest cover within the surveyed area has been converted to human use. In fact the LU/LC classification carried out as a part of this REIA has found only 4.3 % of the surveyed area to possess any form of forest cover. Any further decline in this natural vegetation cover can lead to critical changes in feeding, nesting and breeding areas of wildlife, resulting in loss of wildlife habitat. Here it is important to note that the relationship between the extent of physical disturbance in an area and the extent of habitat loss is usually nonlinear: small changes in critical areas can render large areas unsuitable for animals (Lohani et al., 1997).

Soil erosion, which accompanies the loss of vegetation cover, is another area of concern, especially given the heavy rainfall and flood prone zone in which the exploratory drilling project is proposed to be implemented. Loss of topsoil will not only result in a degradation of terrestrial habitats but will also increase sediment supply to streams in the area, leading to changes in their hydrology and geomorphology. This can cause alteration of ecological processes in these aquatic ecosystems with effects ranging from impacts on filter feeding organisms (Hart and Finelli, 1999) to alterations in carbon processing and nutrient cycling (Jones and Mulholland, 2000).

Finally the ecological costs of an increase in vehicular traffic in the area cannot be ignored. The increased traffic has the potential to disrupt wildlife and cause more road kills.

Waste Release associated with Exploratory Drilling. The large majority of the waste generated by the oil industry is during drilling and pumping operations. Releases into the environment from drilling operations result in chemical contamination of land, water and air, and are a source of ecotoxicological concern.

Large quantities of ‘drilling wastes’ in the form of drilling mud and drill cuttings are produced during oil well drilling. Drilling mud is used to aid the drilling process. On a drilling rig, the mud is pumped through the drill string and sprays out on to the drill bit cleaning, cooling and lubricating it. It then circulates to carry the crushed rock cuttings to the surface. Drilling mud serves a variety of other functions like control of formation pressures, sealing permeable formations, maintaining well bore stability, minimizing formation damage and controlling the corrosion of drill string and casing. It is therefore not surprising that a variety of mud is used to provide specific drilling solutions. Drilling mud is broadly categorized as Water-based mud, Oil-based mud including Synthetic mud and Pneumatic mud. Onshore drilling generally employs water-based or oil-based mud with various chemical additives to deal with particular drilling situations. Irrespective of its category, all drilling mud possesses varying degrees of toxicity. The drilling waste generated at the well site contains not only drilling mud but also drill cuttings of the subsurface material and contaminants like hydrocarbons, lubricants and chemicals used to liquefy the cuttings. On the surface, the mud and cuttings are separated by mechanical means and the mud returned to the mud pits for recirculation. The drill cuttings, consisting of drilling mud, hydrocarbons, water, chemical additives and subsurface material containing minerals, are disposed off in waste pits or through land-farming. The same disposal method is also applied to the spent mud.

Oil well exploration and development also generates ‘associated wastes’ – a term, which encompasses a wide range of small volume waste streams, associated with oil exploration and production. Although associated wastes constitute a relatively small proportion of the total wastes produced by the oil industry, they are most likely to contain a range of chemicals and naturally occurring materials that are of concern to health and safety. The waste streams included under associated wastes include workover, treatment and completion fluids, drainage from the drilling site containing oil from leaking equipment, waste from equipment cleaning and chemicals from spills, and domestic and sanitary wastes. These wastes are also usually disposed off in on-site waste pits.

Oil well drilling can also create significant air pollution with emissions from drilling equipment, emission from support vehicles and hydrocarbons escaping from wells. This has the potential to degrade local air quality

Ecotoxicological concerns originate from the probability of humans, animals and plants exposed to the toxic releases being adversely affected. It needs to be emphasized however that a release does not always lead to exposure. Exposure is defined as contact of an organism with a toxic agent, and the effect of the exposure on the organism is determined by the toxic dose it receives. Dose is a function of the concentration of the chemical in the environment and the duration of the exposure at that concentration.

Animals and man are exposed to toxic agents through three routes: inhalation, ingestion and dermal absorption. Inhalation exposure occurs when volatile compounds and fine particulates are respired. Oral exposure occurs through consumption of contaminated food, water or soil. Dermal exposure occurs when the contaminants are absorbed directly through the skin. The total exposure experienced by an individual is the sum exposure from all three routes.

There is a paucity of toxicological data on wildlife. The toxicological data from laboratory animal studies can be used to understand the potential risk the contaminants pose for wildlife but not directly extrapolated. Terrestrial wild fauna are significantly exposed to contaminants in multiple media. They may drink or swim in contaminated water, ingest contaminated food or soil and breathe contaminated air. Because most wild fauna are mobile, moving among and within habitats exposure is not restricted to a single location and wild fauna tend to integrate contamination from several spatially discrete sources.

The inhalation exposure of wildlife to toxic concentrations of contaminants in the air is an area of concern. There is a potential risk of exposure if releases result in an increase in the ambient concentration of the contaminants in the air. Because contaminants in the air tend to be diluted, dispersed and settled out, the risk of inhalation exposure is higher near the site of release.

Oral exposure of wildlife to contaminants may be from consumption of contaminated food, drinking contaminated water, or ingesting soil. Soil ingestion may be incidental while foraging or purposeful to meet nutrient needs. Oral exposure is modified by dietary diversity, age, sex, season and behaviour patterns.

For terrestrial wildlife species, dermal exposure is usually not significant for birds or mammals as the feathers and fur in these animals reduce the likelihood of significant dermal exposure by limiting the contact with the skin of the contaminated media. However with contaminants which have a high affinity for dermal uptake and in an exposure scenario that results in significant dermal exposure (e.g. burrowing and swimming amphibians), this can be an important route for uptake.

For aquatic species, any contamination of the medium they live in will usually have serious effects.

In the context of the proposed exploratory drilling of oil wells sought to be undertaken by OIL in Jonai, if there is a discharge of drilling wastes and associated wastes from the oil well drilling operations into the environment and if appropriate measures are not taken to contain them, it will constitute a serious threat to both terrestrial and aquatic ecosystems in the area. The risk to wildlife is likely to emanate from naturally occurring radioactive material brought to the surface during drilling (Epstein and Selber, 2002), contamination of soil and surface waters by recalcitrant hydrocarbons in drill cuttings and in associated waste streams, contamination of aquifers by leaching from onsite waste pits; these pits can, if exposed, also be potential traps for animals that mistake them for water holes (Doyle, 1994), and the contamination of surface waters by sanitary wastes.

Noise is also going to be a factor that can be expected to adversely impact the wildlife in the proposed project area. This noise is likely to be contributed largely by the equipment that will be deployed for the drilling operations.

Against the background of the information available on the environmental impact of exploratory drilling activities, it can be concluded that the physical disturbance associated with the proposed project and its polluting potential pose a risk to the wildlife in the study area. Considering the large-scale loss and fragmentation of the wildlife habitat in the proposed project area, it is important to ensure that the implementation of the project causes no further loss to the existing habitat. This will only be possible if there is a minimum of physical disturbance and all releases to the environment from the project are contained within permissible limits.

Mitigation Measures

The mitigation measures to minimize the impact of the proposed exploratory drilling activities on the fauna in the area must address the issues of physical disturbance and pollution. Some of the suggested measures are as follows:

(i) Ensuring minimum removal of natural vegetation and initiation of reforestation over the project area.

(ii) Restricting the movement of vehicles and personnel to the minimum necessary for implementing the project as this will reduce disturbance caused to wildlife, road kills and, also noise and emissions.

(iii) Implementation of a facility-wide waste management plan with pollution prevention as an integral part of the plan. The focus of pollution prevention should be

- Ø Reduction of the impact associated with stormwater runoff by ensuring that materials such as drilling fluids and chemicals stored onsite are not exposed to rain;
- Ø using containment dikes to prevent storm water runoff to waste storage areas;
- Ø operation procedures to prevent spills and to ensure swift containment and clean up of accidental spills.

(iv) Exploring the possibility of implementing a Closed Loop Drilling Fluid System as this will help dispense with the construction of a reserve pit that can leak toxic liquids into surface or groundwater and also release substantial quantities of VOCs to the air.

(v) Implementation of a V- shaped reserve pit instead of the conventional rectangular pit. Industry practice has found this pit to reduce the amount of water needed to maintain the desired fluid characteristics and also to leave a smaller 'footprint' at the site.

(vi) Substitution of toxic drilling fluid additives with low toxicity compounds to reduce the risk associated with drilling fluid disposal.

(vii) Careful removal of drill cuttings and other contaminating solids from the drilling fluid, thereby reducing the need to dilute or replace the fluid. This can be done by adding desanders and desilters to shale shakers in the mud treatment system and by employing mud cleaners to break oil-water emulsions and remove dissolved components.

(viii) Recycling the drilling fluid.

(ix) Preventive maintenance and leak containment of engines, tanks, pumps and all other equipment.

(x) Inventory control to ensure efficient use of materials and reduce waste generation.

(xi) Proper disposal of all domestic and sanitary wastes generated on-site.

It must be mentioned here that in the waste management hierarchy, the first option is source reduction, followed by recycling of wastes with energy recovery as the next alternative, with waste treatment as the last option.

4.3 Routine Operations

For routine (planned) operations, the process of environmental impact assessment considers each interaction qualitatively on the basis of the criteria of expected consequences provided in Table 4.2. This qualitative scale helps to rank hazards on a relative basis and identify areas where additional control measures may be required.

4.4 Non Routine Events

Hazards associated with unplanned events such as accidental fuel spills or gas releases have been assessed with reference to the expected frequency of occurrence as well as the consequence of an adverse impact on the environment allowing an overall risk ranking to be determined (Table 4.3).

This classification assists in identifying the greatest risks to the environment from unplanned events. Those hazards resulting in negligible or minor consequence to the environment, with a negligible to low expected frequency of occurrence are generally acceptable, whereas those resulting in severe consequences which have a high likelihood of occurrence are not. Medium risks need to be reduced as far as reasonably practicable and procedures should be set in place to minimize impacts should an incident occur.

4.5 Routine Hazards

4.5.1 Hazard Identification

Potential hazards to the environment that will occur from routine operations undertaken whilst drilling are illustrated summarized below:

(i) Physical Presence. The rig and support equipments can represent a temporary obstacle to other activities including the movement of wild animals.

Table 4.2. Assessment of Significance of Effect or Hazard

1	**Major** May affect the whole population or species in sufficient magnitude to cause a change in abundance, distribution, or size of genetic pool such that natural recruitment would not return that population or species, or any population or species dependent on it. Has a measurable effect on the livelihood of those using the resource over a period of months/years.
2	**Moderate** May affect a portion of the population or species resulting in a change of abundance and/or distribution, or size of genetic pool but does not change the integrity of any population as a whole. Has a measurable effect on the livelihood of those using the resource over a period of weeks/months.
3	**Minor** May affect a specific group of individuals of a population in a localized area but does not affect other tropic levels or the integrity of the population itself. May be noticed but does not affect the livelihood of those utilizing the resource.
4	**Negligible** May affect a specific group of individuals of a population in a localized area in a way similar in effect to small random changes in the population due to ambient environmental conditions. Has no discernible effect on the environmental resource as a whole and is likely to go unnoticed by those who already use it.

Table 4.3. Assessment of Significance of Hazard – Non-Routine Events

Frequency of Occurrence	Consequence of Impact (see Table 4.2)			
	4	3	2	1
(1 per 100+ unit yrs)	VL	VL	L	M
(1 per 10-100 unit yrs)	VL	L	M	H
(1 per 1-10 unit yrs)	VL	L	M	H
(>1 per unit yr)	L	M	H	H

Risks VL=Very Low, L=Low, M= Medium, H = High

(ii) Soil and Sediment Disturbance. The drilling and subsequent activities may affect soil quality of the area and subsequently sediment quality of the rivers and streams.

(iii) Noise. The drilling and support activities will generate noise. Noise is thought to have the potential to disturb or confuse the birds and animals.

(iv) Atmospheric Emissions. Routine emissions to air result from power generation. Testing of the well will also result in emissions to atmosphere by the way of flaring.

(v) Wastes. Wastes include wash water, sewage, drill fluid/cuttings. These will be collected and treated for disposal or transferred. Any effects from controlled disposal of such wastes should be negligible.

Table 4.4 shows the overall likely impacts.

Table 4.4. Assessment of Impacts Associated with Routine Drilling Operations (1 Major, 2 Moderate, 3 Minor, 4 Negligible impact)

Hazard	Environmental Sensitivities													
	Physical			Biological			Socio-Economic							
	Soil and sediment	Water Quality	Air Quality	Flora	Fauna	Protected Areas/Sensitive Habitats	Living conditions	Economy	Existing oil and gas activities	Pipelines/Cables	Personnel/support crews	Archaeology	Tourism/Leisure	Land Use
Physical Presence				4	2	4	4	4						4
Noise and Vibration					2	4	4				4	4	4	
Atmospheric Emission			4								4			
Drill Cuttings and Cement	3	3												
Drilling Fluids	3	3			4									
Drainage and Wastewater	3	3					4							
Solid waste disposal	3	3			4									3

4.5.2 Effects and Control Measures

(i) Physical Presence

The rig will be located in an area where there is no habitation for a long distance around the drill site, and therefore, the people inhabiting the nearby villages are not likely to be disturbed directly by the drilling activity.

The presence of the drilling rig and support equipments may result in some interference with the movement of wild animals in the area. However, such disturbances during drilling are typically limited to an area of about 500 meters of the rig, a total area of some 0.8 square kilometers for the duration of the drilling programme of about 3 months.

Drilling will be confined to a relatively small area and restrictions on movement of people of the locality will be very short term. Overall, experience shows that interference can be avoided over the short drilling period by introducing good management practices and the impact of the physical presence of men and machines during the drilling programme is anticipated to be negligible.

(ii) Noise and Vibration

Drilling and support activities will generate some amount of noise and vibration. The movement of vehicles and drill crew will also generate some noise. As there is no nearby population, the noise and vibration will have no impact on the inhabitants, but will have some impact on the drilling crew unless preventive measures are taken. Further, the surrounding forest cover will reduce the noise. It may however have some impact on the wild animals and birds having their habitat nearby. Noise is known to affect breathing patterns and it masks the communication between animals. Since the drilling will be completed within a short span of time, and the animals and the birds living near the site are likely to migrate temporarily to the interior of the forest, there is not likely to be any permanent damage due to the noise and vibration generated during drilling which will be confined to a very short distance.

For hemispherical sound wave propagation through homogeneous loss-free medium, the noise levels at various locations from different sources can be estimated by using the relation:

$$Lp2 = Lp1\ 20 \log (r2/rl) – Ae1,2.$$

where Lp1 and Lp2 are sound levels at two points located at distances r1 and r2 from the source. Ae1, 2 is the excess attenuation due to environmental conditions. Combined effect of all the sources then can be determined at various locations by using the principle of logarithmic addition:

$$Lptotal = 10 \log (10(Lp1/10) + 10(Lp2/10) + 10(Lp3/10) + \ldots\ldots\ldots)$$

The noise generated due to the diesel engines operating the rig along with the mud circulation system is considered to be the most significant of the noise generating sources in the drilling operation. Generally, the noise sources in a drilling well are scattered within an area of about 110 m x 110 m and drilling operations will be carried out away from human habitation. Hence, the noise source can be considered to be a point source for the nearest human habitation.

The noise propagation modeling performed for noise generation due to operation of the diesel engines shows the following exposure levels (Table 4.5) in terms of the occupational and human settlement exposure levels.

Table 4.5 Occupational and human exposure levels

Type of exposure	Predicted exposure level (dBA)
1. Occupational exposure	
Leq (8 h) at drilling platform (rig, mud circulation system, Diesel engines)	104
Leq (8 h) at the site boundary (about 40 m from drilling platform)	64
2. Human settlement exposure	
Leq (24 h) at villages 0.5 km away	54 (day) 47 (night)

It is found that the background noise level in the study area is 43 - 64 dBA during day and 28 - 45 dBA during the night (Chapter 3). The damage risk criteria for hearing, as enforced by OSHA, USA, stipulate that noise levels up to 90 dBA are acceptable for 8-hour exposure per day. In this context, it is to be noted that

- At places, excepting the drilling platform, continuous presence of workers is not required. Hence, the workers, other than those working at the drilling platform, will not be exposed to continuously high noise levels.
- The noise level at the drilling platform is of concern from occupational consideration and adequate protective measures aimed at reducing the effect of noise levels will have to be taken for these workers.
- The noise levels predicted for the human settlements are below the levels specified by the CPCB for residential areas.
- The study area serves as a habitat or roaming place of some wild animals. Any uncommon noise is likely to distract the animals from the place of occurrence of such noise. However, there is no likelihood of causing any permanent damage.

(iii) Air environment

For the purposes of impact predictions on air environment, emission sources can be classified into point and area sources. There is no area sources considered for the purposes of predictions. The point sources identified are diesel engines/generator sets at drill sites and flaring of gas subsequent to drilling in the event of striking oil/gas. In this respect, the following have to be taken into consideration:

- The diesel engines and associated generators will be in operation 24 hours a day during the drilling period, for operation of drill rig, and mud circulation system.
- Diesel will be used as a fuel for operation of diesel engines/power generators and will contain negligible sulfur and ash content.
- The gas flaring during testing of wells. The Assam gas normally has very little sulphur and ash content.

The meteorological data recorded during the study (Chapter 3) have been used for the predictions. For predictions of impacts of NOx on air environment, an interactive model that estimates short-term concentrations for a number of arbitrarily located receptor points at ground level due to the point sources are used.

Dispersion modeling is done taking into consideration two possible scenarios:

- Flaring at the rate of 10,000 m3/day of natural gas at the drilling site. Such a scenario may occur in case of an oil well having associated gas. For this scenario, computer modeling indicates that a maximum of about 3.5 µg/m3 of NOx would result as an 8-hour average GLC (Ground level concentration) due to flaring emissions at a height of 9 m and at a distance of about 100 m from the flare.
- Flaring at the rate of 150,000 m3/day of natural gas at the drilling site. Such a scenario may occur in case of gas well only. For this scenario, computer modeling indicates that a maximum of about 50 µg/m3 of NOx would result as an 8-hour average GLC (Ground level concentration) due to flaring emissions at a height of 9 m and at a distance of about 320 m from the flare.

The concentration limit for NOx (as NO2) in the ambient air, as specified by CPCB is 80 µg/m3 for residential, rural and other areas (120 µg/m3 for industrial areas, 30 µg/m3 for sensitive areas) and the average baseline ambient air concentration of NOx in the area was found to lie in the range of BDL – 6.6 µg/m3. Hence, the predicted impact level due to the flaring operation will remain within the prescribed limits of CPCB for the ambient air quality.

The dispersion modeling studies conducted for the flaring of natural gas are based on the following assumptions:

- The NOx emission rate is 2.17 g/m3 of natural gas flared. (Source: Database "FIRE" generated by the U.S. Environmental Protection Agency).
- The heat emission rate due to the flaring of natural gas is 4.91 x 106 Joules/sec. (Source: Robert H. Perry, Don W. Green in Perry's Chemical Engineers' Handbook (7th Edition), McGraw-Hill Publication.)

Emission of gases from power generation on the drill rig is of relatively low volume. Although such power generation emissions will contribute in a small way to the overall pool of greenhouse and acidic gases in the atmosphere, total amounts emitted are relatively small and local environmental effects will be negligible.

Steps to limit atmospheric emissions further will have to be undertaken during all drilling operations. These include:

(i) Advanced planning to ensure efficient operations;
(ii) Well maintained and operated equipment and generators;
(iii) Regular monitoring of fuel consumption.

An alternative way of sampling down-hole liquids and gases and checking their pressures may be used to reduce the amount of exposure of hydrocarbons at surface.

(iv) Water environment

The survey of the water environment in the area reveals that both surface water and ground water sources are free from the usual contaminants (Chapter 3). However, the surface water is bacteriologically contaminated. The water can be used for drinking and other purposes by appropriate disinfection procedure. The drilling operations are unlikely to have much impact on the water sources of the area.

During the drilling operations, the wastewater generated will consist of the drilling fluid waste liquid and water used for washing. This wastewater will be appropriately treated and temporarily contained in specially designed pits during the drilling process. The composition of the drilling fluid is largely water and bentonite with additives like potassium chloride and glycol. None of these chemicals are hazardous. As the liquid levels rise, the water will be appropriately diluted and discharged to the adjacent drainage channels. The water from these channels is not used for human consumption.

Separate drainage facilities are to be provided for storm water and other non-harmful effluents. This runoff will be channeled to a drilling mud source water pit. These measures will ensure minimum infiltration of the contaminants into ground water resources of the area.

Other possible contaminants are chemicals associated with the cementing process. However the volumes of these that are likely to be discharged are small. It is suggested that only PLONOR Grade Chemicals, which are considered as having little or no risk to the environment (OSPAR, May 1999) are to be used. As all the drilling chemicals are water-based and of PLONOR Grade, they have not been assessed for the Chemical Hazard Assessment and Risk Management (CHARM) methodology.

In order to minimize potential environmental impacts on water bodies, the following measures will have to be incorporated into the drilling programme:

(i) Installation of cuttings and fluid cleaning/treatment equipment to reduce the volume of cuttings/ cleanings as far as practicable and also to reduce the amount of fluid that will be discharged with the cuttings. The waste fluid generated will be treated and either reused or diluted and discharged.

(ii) Putting in place management procedures to ensure optimal performance of the cuttings cleaning equipment and shaker screen housekeeping.

(iii) Maintaining a continuous drill fluid mass balance throughout the drilling programme.

(iv) Optimization of hole sizes to minimize the amount of rock to be drilled.

(v) Ensuring that the surface water in the vicinity of the drill rig is monitored during drilling for any possible adverse impact.

Water generated from rig wash down may contain trace amounts of drill fluid, lubricants and residual chemicals resulting from small leaks or spills and rainfall in the areas. The volume of these discharges depends on the frequency of wash down and amount of rainfall. Liquid storage areas and areas that might otherwise be contaminated with oil will have to be segregated from other areas to ensure that any accidental spills are contained.

(v) Land environment

The major waste product of a drilling operation is the generation of rock cuttings, plus small amount of residual fluids adhering to the cuttings. It is estimated that drilling the proposed wells will generate cuttings of the anticipated volume of 1500 cu. m. These cuttings will have to be treated and then stored at site in specially designed pits.

Other waste products likely to be generated include

- garbage,
- food scraps,
- scrap metal,
- waste oil and
- surplus chemicals.

Necessary steps and precautions are to be taken for minimizing the amount of waste generated and controlling its eventual disposal. Where possible, all waste materials are to be segregated by type, garbage is to be processed in a compactor and stored in a designated area or burnt in a special burn pit. Other wastes are to be stored in suitable containers and will be recycled or disposed of in a controlled manner through authorized waste contractors. Materials like scrap metals, waste oil and surplus chemicals are to be sent for recycling or reuse as far as practicable.

The other minor impacts on land environment, due to the drilling operations, could be due to vegetation loss during construction of the access road and preparation of the drilling site. Since forests surround the drilling site, these impacts will be minimum. Clearing of trees is to be kept to a minimum and formal procedures have been undertaken to ensure full compliance with the Government of India/Government of Assam regulations.

(vi) Socio-economic environment

The drilling activities are likely to have the following impacts on the existing socio-economic profile of the area:

(a) The proposed activities will generate indirect employment in the region due to the requirement of workers in road construction, site preparation, supply and transport of raw materials and equipment, auxiliary and ancillary works, etc. These would give temporary relief to the people of the locality and their socio-economic conditions would improve.

(b) The activities would also result in enhancing the local skill levels through exposure to drilling activities and technology, and help in capacity building for future employment opportunities.

(c) Some of the existing roads may have to be upgraded to facilitate the movement of the heavy equipments and vehicles, leading to improvement in transport facilities in the area.

(d) In the event of commercial quantities of hydrocarbon reserves being discovered, more long-term employment opportunities are likely to be created. Besides, the hydrocarbons brought to the surface will help in contributing to the ongoing efforts of the government to meet the national demand of petroleum resources.

(e) There can be occupational hazards such as personal injuries, accidents during installation and operation of drilling rigs, in case safety measures are not adequately implemented. Stringent Health Safety and Environment Policy has to be implemented for all the operations, and this is to be followed by all employees, consultants and contractors working in the drilling activities. The implementation is to be reviewed from time to time.

(f) The spent drilling mud along with the formation cuttings, if not properly treated and discharged, may lead to degradation of soil quality and hence, affect crop production in the nearby agricultural land. Strict procedures are to be implemented to prevent such type of land damage.

4.6 Non Routine Hazards

4.6.1 Hazard Identification and Risk Assessment

On rare occasions, an unplanned event can have the potential to jeopardize the safety of the crew and cause environmental damage. Potential non-routine events that may occur whilst drilling include:

(i) Well kicks- A well kick is defined as a controlled, unplanned influx of reservoir fluids into a well and does not result in an oil spill to the neighboring area. An influx of more than 4.75 cubic meters (30 barrels) represents a serious kick and such kicks occur on less than 1.5 percent of wells drilled (Hinton 1999).

(ii) Small releases of hydrocarbons during operations such as refueling or transportation.

(iii) Well Testing Fallout

The spills with the potential to occur from the proposed drilling programme will be limited by

- Ø Hydrocarbon (Fuel) inventories present at the site or during transportation (Tipping over of a fuel tanker)
- Ø Hydrocarbons present in the sub surface formations during kicks or blow outs.

A Minor Spill is defined as a small spill of < 200 sq m, containable with resources at site while a Major Spill is defined as one, which is uncontainable with resources at site.

4.6.2 Potential Effects and Predicted Fate

Hydrocarbon Spills

There is the potential for a loss of containment of hydrocarbons throughout operations. Spills of all types and sizes are rare events during drilling operations. The potential effects of spilt oil on the environment are shown in Table 4.6.

Well Kick

In the event of a well kick some hydrocarbons may be released to the environment in a controlled manner. If a kick is not correctly controlled, it could escalate into a blowout that could, if improperly managed, escalate to a blow-out and in its worst form, to an unconfined flow of reservoir fluid to the nearby areas

Table 4.6 Hazards Associated with Non-Routine Events

Hazard	Environmental Sensitivities													
	Physical			Biological			Socio-Economic							
	Soil and sediment	Water Quality	Air Quality	Flora	Fauna	Protected Areas/Sensitive Habitats	Living conditions	Economy	Existing oil and gas activities	Pipelines/Cables	Personnel/support crews	Archaeology	Tourism/Leisure	Land Use
Well Kick			VL											
Minor Hydrocarbon Spill	VL	VL		VL	VL	VL								
Major Hydrocarbon Spill	H	M	VL	M	L	M	L						L	L

4.6.3 Control Measures

Well Kick Control

In the event of a kick, the influx will be circulated out of the mud and pressure control established using classical pressure control methods. Great care has to be taken to minimize the probability of a kick occurring whilst drilling.

Specific procedures and training will be carried out to ensure that the correct action would be taken on the rig in the event of a kick occurring. The operating personnel will be trained for such an eventuality and the key responsible people will be required to hold relevant well control certifications. The rig will be equipped with Blow Out Preventers of suitable ratings while drilling different sections to ensure safety of equipment and personnel in case of a blow out.

Blow Out Prevention

Primary control will be achieved by providing sufficient hydrostatic pressure by means of drilling fluid column in the hole to prevent the influx of formation fluid into the well bore. This is called primary well control and it involves the following:

- Drilling fluid (mud) of sufficient gravity to be used.
- Active volume of drilling fluid to be continuously monitored, especially during tripping.
- Changes in density, volume and flow rate of drilling fluid from the well bore to be immediately detected and appropriate action to be taken.

In addition to careful monitoring and control of the fluid system and installation of casing in each section of the well, a blow-out preventer stack (or BOP) consisting of a series of individual preventers will be installed on the wellhead in the Cellar pit after the top hole section has been drilled.

The function of the BOP is to prevent uncontrolled flow from the well by positively closing in the well bore, if flow from the well bore is detected. The BOP is made up of a series of hydraulically operated rams and can be operated in an emergency from the drill rig.

The well is not anticipated to encounter any zones of abnormal pressure and the BOP will be rated for pressures well in excess of those expected to be encountered in the exploration well. During drilling operations small amounts of BOP fluid are typically discharged every two weeks, during testing of the BOP. This discharge will be contained.

Hydrocarbon Spills

The main sources of potential spills (collected from historical oil spill records) and the measures to be taken within the drilling programme to minimize or eliminate the risks are summarized in Table 4.7.

Table 4.7 Sources of Spills and Control Measures Planned

Potential Source of Spill	Control Measures to be taken
All Spills	A specific Oil Spill Contingency Plan (OSCP) will be in place providing guidance on actions to be taken in the event of any type of spill.
Unburnt hydrocarbons during testing	The plan is not to flare the oil produced during test, but to transport it for safe storage. Only the associated gas will be flared after separation.
Fuel base oil or other utility fluids (e.g. diesel, lubricants)	Transportation – Ensure that tankers are fit for purpose. The roads leading to the site will be properly designed, the drivers trained, speed limits will be enforced strictly and no night driving will be allowed. Refueling areas will be separate and lined and bunded. Proper procedures would be followed and proper equipment will be used. Storage will be in specially bunded and lined areas, designed to hold full volume of the spilt oil. In case of tripping of a fuel tanker, specific instructions in the Oil Spill Contingency Plan will be followed.
Loss of well control	This is to be minimized through detailed mud programme, detailed study of the known geological conditions of the area, BOP design and use of good drilling practice.

4.7 Cumulative Effects

A simple evaluation of the potential for cumulative impacts from an operation should look at the operation per se and the operation in relation to the other similar activities that are or have been carried out in the same area. Quantifying the predicted emissions from the planned well, combined with knowledge of previous similar activities within the general area, allows a simple assessment of the additional or cumulative 'loading' of discharged material into the nearby environment caused by the proposed activity. Further examination of the spatial and temporal extent of emissions and discharges and associated impacts can give a better understanding of the potential for cumulative impacts from different sources.

The discharges associated with the drilling will include atmospheric emissions from power generation, drainage water and sewage, cuttings and associated mud discharges and solid wastes. Cumulative impacts resulting from the emissions to atmosphere during drilling are highly unlikely – combustion for power generation and during well testing gives rise to minor emissions of carbon dioxide (CO_2), oxides of nitrogen (NO_x), oxides of sulphur (SO_x) and unburned hydrocarbons. Dispersion of these types of low volume emissions is generally rapid and cumulative effects with the nearest existing sources will be below levels of detection. Thus, although such emissions will contribute in a small way to the overall pool of greenhouse and acidic gases in the atmosphere, local environmental and trans-boundary effects will be negligible.

Emissions of low volume discharges such as drainage water and grey water are likely to be undetectable within a short distance from the sites and a short time after discharge and therefore no cumulative impacts are likely.