RAPID ENVIRONMENTAL IMPACT ASSESSMENT STUDY
BRAHMAPUTRA RIVER BED SEISMIC SURVEY

NEF PROJECT
OIL INDIA LIMITED
DULIAJAN 786602, ASSAM

Conducted by

EIA PROJECT, GAUHATI UNIVERSITY
DEPARTMENT OF CHEMISTRY
GUWAHATI 781014, ASSAM

Chapter 4
ENVIRONMENTAL IMPACT ASSESSMENT

4.1 Introduction

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

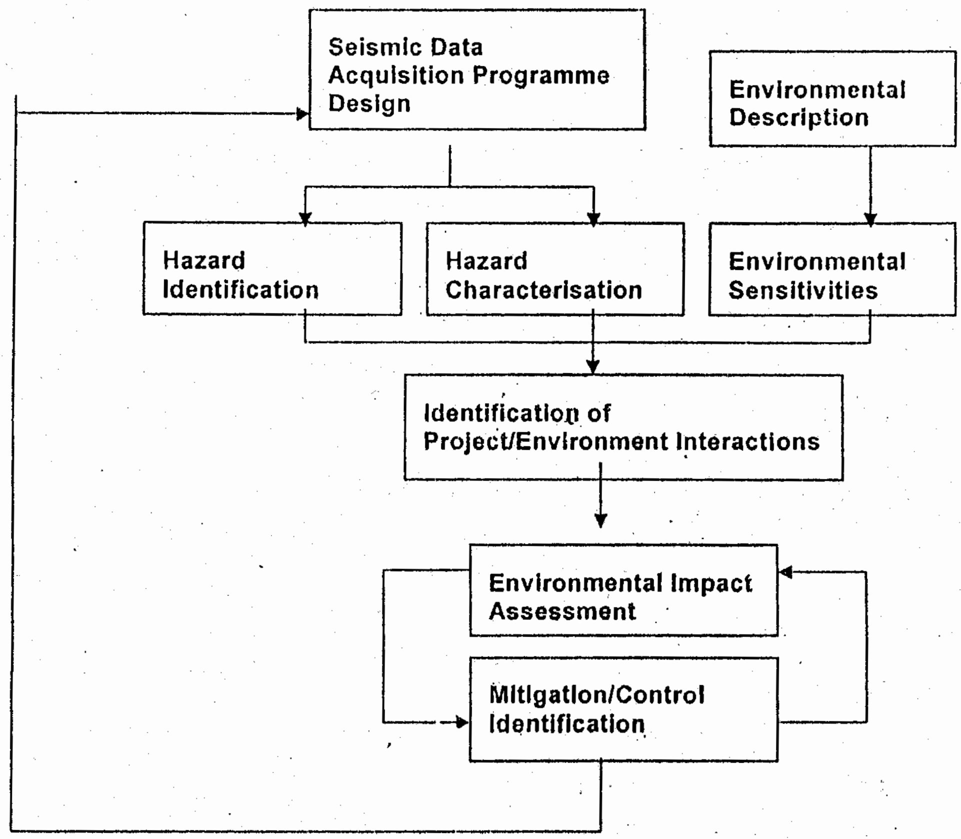

Fig. 4.1: Environmental Impact Assessment

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, allows identification of the interactions between the planned well and the environment.

In this Chapter, the interactions between the project and the environment are identified for both routine and non-routine (unplanned) events and an environmental impact assessment has been undertaken by establishing a matrix of hazards against environmental sensitivity.

Seismic Data Acquisition

Seismic methods are successful almost at all stages from petroleum prospecting, discovery, and characterization to exploitation monitoring. Attractiveness of seismic methods is their universality, flexibility and feasibility in diverse areas and conditions. Operating with vibrators, explosives, air guns geophones and hydrophones, seismic delivers a consistent data volume within one survey programme. Sophisticated algorithms like pre-stack time and depth migration, wave processing ensure a high quality of subsurface imaging. High performance machines and visualization algorithms used in seismic data interpretation combined with simultaneous analysis of multiple seismic attributes provide good decisions in well location and discovery success. Their openness to new technologies makes them a major tool for hydrocarbon discoveries.

In the present seismic data acquisition, air guns will be used to generate the pressure pulse on the river surface which will be transmitted down from water column to the earth and this in turn after reflection from the different layers of the earth will be recorded by the suitable sensors placed along the profile.

On the land surface near the River banks on both sides and on very shallow water, where air gun operation is not possible, class II explosive charge in plastic containers will be used in shot holes 20 m deep and about 90 mm in diameter. The holes will be drilled using portable drilling equipment. While working in inaccessible areas, like forests, the drilling crew will use the footpath clearance already made by the survey crew. The coverage may be 1-2 km per day along the line depending upon logistics in the area.

Air Gun Specifications

The specifications of the air gun to be used are as follows:

a) Air gun type: Input/Output make sleeve gun

b) Volume : 450-600 Cubic. Inches

c) Gun Pressure : 1600 to 2000 PSI

Explosive composition

Specification of explosive
Length: 75 cm
Diameter: 63 mm

Composition
Ammonium Nitrate: 80-81 %
Ca/Na Nitrate: 10-11 %
Paraffin Oil: 2.5 -3.5 %
Wax: 0.5 to 1.0 %
Emulsifier: 2.0 – 2.5 %
Sensitizer: 1.5 – 2.5 %

Volume = 2338 cm³

Plastic container composition: High density polyethylene

4.2 Identification of Interactions

Table 4.1 summarizes the interactions between the proposed project and the sensitivities of the local and regional environment. At this stage, the interactions are not quantified but simply identified for further consideration in the environmental impact assessment.

The components of the seismic survey that could result in significant environmental effects have been determined through an evaluation of the proposed activity, the surrounding environment and the legislative requirements. The activities with potential to cause significant environmental effect include:

- Operation of the seismic vessel and towing of the acoustic energy source and streamer (hydrophone) arrays through the survey area.
- Discharge or 'firing' of the acoustic energy source (air gun) arrays.
- Discharge from explosive charge on land.
- Emissions from vehicles, diesel generators, etc.
- Routine waste discharges from the survey vessel.
- Accidental fuel and oil spills from the survey vessel.
- Accidental loss of streamers and associated equipment.
- Introduction of invasive species.

Each of these activities has the potential to result in detrimental impacts on the physical, biological and socio-economic environment of the area. The key potential environmental aspects associated with the proposed seismic survey, their effects and mitigation measures are discussed in the following sections.

Table 4.1. Interactions between Project Operations 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					■		■				■			■
Emissions to atmosphere			■								■			
Solid waste disposal														■

4.3 Environmental Impact Assessment Methodology

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

- Identification of the factors likely to have impact on the environment,
- Prediction of the likely scenario due to these impacts following the implementation of the project,
- Suggesting ways aimed at mitigation of the impacts.

The inferences drawn for the current project on the above lines are given below. This analysis is used to prepare an Environmental Management Plan (EMP) document.

The environmental impact of the seismic data acquisition 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, mitigation measures presently in operation, if any, or are likely to be taken up, are also taken into consideration.

The Matrix includes:

- All major activities of the 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 the indicators presented below:

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

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.

4.6. Impacts of Physical Presence

The project area is located over the Brahmaputra River and the wet and forest lands which are mostly free from human habitation. Therefore the physical presence of men and equipments as well as the actual operation is not likely to disturb any human settlements.

The presence of men, equipments and support vehicles, etc. may result in some interference with the movement of wild animals in the area as well as fish and other aquatic species in the water. However, such disturbances will be temporary in nature and are not likely to leave any permanent impact.

The above kind of interference can be minimized or avoided by careful planning in moving men and equipments and by introducing good management practices for reducing the impact of the physical presence. This requirement is outlined in the **Environmental Monitoring Plan**

To safeguard the indigenous aquatic fauna of the Brahmaputra river ecosystem from inadvertent importation of harmful alien species, quarantine procedures will have to be adhered to with respect to boats and other equipment that are Imported into the Brahmaputra river system from other aquatic bodies.

4.7 Impacts of Noise and Vibration

4.7.1 Noise Propagation

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:

$$Lp_2 = Lp_1\ 20 \log (r_2/r_1) - Ae_{1,2}.$$

where Lp_1 and Lp_2 are sound levels at two points located at distances r_1 and r_2 from the source. $Ae_{1,2}$ 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:

$$Lp_{total} = 10 \log (10^{(Lp1/10)} + 10^{(Lp2/10)} + 10^{(Lp3/10)} + \cdots\cdots)$$

The noise generated due to shot gun/air gun operation will not be very significant after a little distance from the source and the noise source can be almost considered as a point source without giving rise to much environmental noise.

The impulses created by the release of air from arrays of up to 24 air guns create low frequency sound waves powerful enough to penetrate up to 40 km below the river bed. The "source level" of these sound waves is over 200 dB, roughly comparable to a sound of at least 140 dB in air (Table 4.5). These sound waves become less intense as they travel away from the air gun array, due to both scattering off of the river bed and "acoustic spreading", by which the total sound energy is spread out into a larger and larger area as it spreads in a spherical or cylindrical fashion.

Table 4.5 Occupational and human exposure levels to noise

Type of exposure	Predicted exposure level (dBA)
Occupational exposure	
L_{eq} (8 h) at air gun operation point	200
L_{eq} (8 h) at about 40 m away	128
Environmental noise (ambient)	
L_{eq} (24 h) Mean	39.8 – 64.2 (day time), 30.6 – 53.6 (night time)

4.7.2 Principal issues

The major environmental issues relating to seismic surveys have largely focused on the potential effects to fish stocks and aquatic mammals from the sound waves associated with the seismic energy source. Concerns have included:

- Pathological effects (lethal and sub-lethal injuries) – immediate and delayed mortality and physiological effects to nearby organisms,
- Behavioural change to populations of riverine organisms,
- Disruptions to feeding, mating, breeding or nursery activities of organisms in such a way as to affect the vitality or abundance of populations
- Disruptions to the abundance and behaviour of prey species for aquatic mammals, water birds and fish
- Changed behaviour or breeding patterns of commercially targeted aquatic species, either directly, or indirectly, in such a way that commercial or recreational fishing activities are compromised.

The central concerns about seismic air guns include physiological damage they may cause (ranging from catastrophic tissue damage to long-term hearing loss), behavioral responses such as causing fish and other aquatic fauna to move away from the survey area, and the added noise, the air guns contribute to the general din of the silent river.

4.7.3 Measurement uncertainties

It is important to note that there are several acoustics measurement issues to take into account when considering the dB level of any waterborne sound.

i) First, due to the higher density of water, sounds of similar perceived volume have a higher pressure in water; the standard correction is about 60dB.

ii) Second, there are several measurement systems used by acoustics researchers; each is useful for considering different sorts of biological effects. Peak-to-peak measurements are several dB higher than Mean-squared measurements, which in turn are a few dB higher than Equivalent Energy measurements. The total variation in the standard measurement systems can account to up to a 26dB difference, so when we are considering the effects of a given sound level, it is important to recognize which scale is being used.

iii) Finally, each species preferentially hears a certain range of frequencies more easily (for example, large whales hear and vocalize best in lower frequencies, while dolphins hear and vocalize at significantly higher frequencies).

It is generally assumed that human-made noise in frequency ranges outside the primary range for a given animal will be either imperceptible, or will be heard relatively faintly, and therefore have relatively milder effects on behavior. However, high-power sound waves may also have physical effects beyond the effects on auditory perception. The actual hearing ranges of many aquatic creatures are not known (it is often inferred from the range in which a given species vocalizes, but as we know from our own hearing, the range of perception is much wider than the range of vocalization). These two factors, acoustic measurement variation and a large degree of uncertainty about the physiological and perceptual hearing systems of the creatures, both suggest that reliance on any specific dB measurement is problematic.

Therefore it is very difficult to make any definitive claims about how the aquatic creatures may respond to a given dB level. At best, an underwater dB rating is a decent estimate of the sound's physical power, and a somewhat useful benchmark by which to make informed guesses about its possible effects. This is why scientists tend to rely on behavioral responses and observed physiological damage caused by water-based sound, and to avoid making direct comparisons with human hearing, and especially human safety thresholds, in the air.

That being said, it is especially important to base our decisions about operational safety, mitigation, and regulation on careful observation of the actual responses of many species at a range of distances from seismic survey vessels, rather than to over-rely on ideas about the danger of specific dB levels or on models of how we think that the dB level will change as the sound moves out into the river environment. Nevertheless, researchers and regulatory agencies have tended to rely as best they can on the concrete numbers that have emerged from various studies of the impact of anthropogenic (human-made) sound on creatures living on water bodies especially seas.

4.7.4 Impacts Reported

The reports that emanate from the studies of the impacts of seismic survey air guns are fairly consistent, and tend to show that whales, dolphins, fish, sea turtles, and squid are all clearly impacted by seismic activity. The danger of gross physiological damage is relatively low, apparently an issue only at very close range (and possibly in unusual topographic situations). There are clear avoidance responses in all species at ranges of one to several kilometers; it is likely that the sounds are audible and may mask important communication or perceptual cues at much greater ranges. It is to be noted that there is much local variability in how far sound travels in water. Acoustic propagation is relatively well understood yet highly variable, with water depth, water and river bed composition, temperature, and salinity all playing roles. Powerful sounds can travel extremely long distances while remaining significantly louder than the ambient background noise.

Seismic air gun arrays output a rather broadband low-frequency sound (i.e., not a single "tone" or "chord", but rather a noise composed of an undifferentiated range of tones). Peak output is generally in the range of 50Hz, with a secondary peak appearing in the 150-200Hz range, and continuing decreasing peaks up to almost 1kHz. There is often a "ghost notch", or reduction of output intensity in the 100-125Hz range, due to "destructive interference" from sound reflecting off the surface. The primary frequency range used to analyze the sub-surface geology is 3-100Hz; this is the most dominant and usable frequency band that bounce back up toward the surface. There is considerable transmission of sound in somewhat higher frequencies, as well.

Most creatures respond more dramatically to sustained sounds than to transient ones. This is partly because our perceptual systems take some time to process and react to sound. Studies with marine mammals tend to bear this out; whales may (depending on habituation) show avoidance to sustained sounds at around 120 dB, while avoidance to short-duration sounds (like air guns) begins at 140-150dB. However, this tendency is perhaps somewhat countered by the relatively "unnatural" waveforms of some human-generated sounds. Impulse noises, such as caused by explosions and air guns, have faster rise-times than most natural sounds, far faster than vocalizations, and somewhat faster than even seaquakes. This faster rise time can trigger a reaction that would more likely be expected to a louder noise; this may account for initial startle or early avoidance maneuvers at sound levels as low as 125 dB. It is to be noted that most of the studies are so far centered on creatures in sea.

4.7.5 Evidences from marine seismic operations

The following general conclusions have been derived from the Statement of Canadian Practice (from "*Review of Scientific Information on Impacts of Seismic Sound on Fish, Invertebrates, Marine Turtles and Marine Mammals" (Habitat Status Report 2004/002,* http://www.dfo-mpo.gc.ca/csas/Csas/status /2004/HSR2004_002_E.pdf) :

a. For fish, the biological and ecological effects of marine seismic sound are expected to be low or are unknown or not fully understood, except if the seismic sound were to have behavioural consequences that could cause a lasting dispersion of spawning aggregations or cause a lasting deflection from migration paths;

b. For invertebrates, the biological and ecological effects of marine seismic sound are expected to be low or are unknown or not fully understood, except if the seismic sound were to influence reproductive growth activities, or lead to a lasting dispersion of spawning aggregations or a lasting deflection from migration paths;

c. For zooplankton, eggs and larvae of fish and invertebrates, data are generally insufficient to evaluate the potential damage to eggs and larvae of fish or shellfish that might be caused by seismic sound under field operating conditions; however, the magnitude of mortality of eggs or larvae that models predict from exposure to seismic sound are far below that which would be expected to affect populations;

d. For turtles, it is considered unlikely that marine turtles are more sensitive to seismic sound than cetaceans or some fish;

e. For marine mammals, the biological and ecological effects of marine seismic sound are expected to be low or are unknown or not fully understood, but may be higher if there were to be behavioural consequences that would:

(i) displace feeding marine mammals from areas where there are no alternate areas;
(ii) displace marine mammals from breeding or nursery areas; or
(iii) divert migrating marine mammals from routes or corridors for which alternate routes or corridors either do not exist or would incur substantially greater physical costs to traverse.

4.7.6 Long-range sound transmission

Air gun noise is over 200dB (often 230dB) at the source, drops quickly to under 180dB (usually within 50-500m, depending on source level and local conditions), and continues to drop more gradually over the next few kilometers, until leveling off at somewhere near 100dB. At this level, the sound can travel for hundreds or thousands of kilometers; in many or most locations, 100dB is significantly louder than the existing ambient background noise, so the air guns raise the background noise to this level, potentially masking local biological calls and signals. Such effects have been noted at ranges from 1300-3000 km from active surveys. These sounds are primarily low frequency, so at long distances, the effects are most pronounced for larger species such as the great whales and some fish that use low frequency sounds; many fish and the toothed marine mammals such as dolphins, seals, and sperm whales, use higher frequencies in their communication.

Most seismic surveys begin with a "ramp up" period, typically 30 minutes, during which the air guns are turned on a few at a time, so that any creature or large fish in the area will be forewarned and have time to move away (smaller fish and turtles may need more time, and of course slow-moving bottom creatures are unlikely to flee). Similarly, as the ships move along their survey lines, their slow approach allows time for animals to move away. In the US, Europe, and Australia, safety zones are routinely established around operating seismic survey vessels, with on-board observers watching for animals entering this zone, which ranges from 150 m to 3 km, depending on the intensity of the airgun arrays and local sound propagation properties. Most commonly, the safety radius is 500 m to 1km; outside of this zone, sounds are generally considered to be less than 180dB, the threshold where physical damage is considered likely.

4.7.7 Physiological Effects

There is much concern among environmental activists about the possibility of loud human sound, especially low frequency noise, causing severe tissue damage such as that seen in conjunction with some low-frequency and mid-frequency military sonars that operate at intensities similar to airguns (source levels over 200dB). However, in contrast to several strandings (often with clear physiological effects such as bleeding from the ears) that have coincided with sonar tests, there has not been any particular increase in strandings in areas exposed to extended airgun operations. One such event, involving two beaked whales (the family that seems most susceptible to sonar) occurred in 2002 in the Gulf of California, although the bodies were too decomposed when found to allow testing that could determine whether the auditory system seemed damaged. (A series of mass strandings coincidental to a seismic survey in southeastern Australia during late 2003 has further fueled concern.) Still, given the many years of airgun operations worldwide, the current evidence is far less troubling than that which is accumulating regarding military sonars, especially the mid-frequency active sonar.

That being said, recent research on fish has identified the physiological mechanism by which loud sound (In the 180dB range) can cause long-term hearing damage. Tiny hairs in the ears of fish can be damaged, and holes left in the sensitive tissues within the auditory system.

In addition, evidence is beginning to accumulate that suggests that some populations of sea creatures may be experiencing long-term hearing loss. It is not possible to pinpoint exposure to loud noise as the source of this damage to the auditory systems, but it bears further scrutiny.

The mildest (and likely the most common) physiological effect that is associated with exposure to excessive sound is acoustic masking. The more ambient sound there is in an environment, the harder it will be for the creatures to communicate, perceive prey or predators, and navigate. While by far the dominant source of anthropogenic noise in a river or sea is shipping, accounting by some reports for over 90% of noise, the noise of ships ranges from 150-190dB at the source. Both naval sonar and airgun noise are significantly more intense than even the loudest ships, so that they can be heard above the shipping noise at close range (up to 10-30 km), and become a significant factor in the distant ambient noise at greater ranges. Thus these louder sounds, though more transient (and pulsed, rather than continuous) are likely to cause additional masking of auditory information of biological importance, especially in the near to mid distance.

4.7.8 Behavioural Effects

Much more prevalent than clear physiological damage are changes in behavior in response to airgun noise. It is not certain to what degree these changes lead to biologically significant effects; in many or most cases, forcing aquatic creatures to move-up to several kilometers to get away from excessive noise is considered by researchers and regulatory agencies to be a "negligible" impact.

Nevertheless, it is clear that whales, fish, and sea turtles all exhibit "avoidance" behavior when encountering sounds above around 155 dB (equivalent energy, 170 dB RMS, 183dB peak). There is some variation in this threshold, but it is surprisingly consistent across species. While it seems clear that movement on the scale of 1-30 km, as has been seen in various species, does not cause any immediate survival impacts on individual animals, the long-term effects on reproduction or species-level survival, as may be caused by stress, use of limited energy reserves, or temporary exclusion from preferred feeding grounds, is very difficult to know. In addition, as we become more aware of the extent of these modest but relatively consistent behavioral responses, the ethical question of whether it is right to impose human-created sounds on other creatures may also be raised.

When dealing with species that are either declining (e.g., many fish species) or in the process of a gradual return from the brink of extinction (e.g., many cetacean species), there is some concern that small and cumulative impacts from many sources, including noise, may be significant in affecting long-term population trends. For this reason, many environmental activists, and some regulatory agencies, are beginning to apply precautionary approaches to regulation and management of such stocks. The precautionary approach is more likely to consider the uncertainty in our knowledge as an important factor in making management or mitigation decisions, rather than waiting for conclusive causative evidence before limiting human activity such as noise-making.

4.8 Impact on Terrestrial and Aquatic Fauna

The potential sources of disturbance for fauna within the survey area, from the proposed seismic exploration have been identified earlier in this report. An assessment, based on the observations during the bio-survey and available information of the possible impact of these disturbances on the fauna in the area is given below.

4.8.1 Impact of seismic line laying

It is assumed that path clearing and the laying of seismic lines during the proposed seismic survey will avoid the felling of any large trees and thus not create any fragmentation of the riparian forest habitat. It is however likely that riparian vegetation like shrubs, grass and reeds will have to be cleared. If extensive, this clearing can have an adverse impact on the fauna of the river corridor. Riparian vegetation moderates a myriad of ecological processes in river corridors among which is the providing of a substrate for biological activity and habitat/cover for aquatic, amphibious and terrestrial animals (Ward et al., 2002). Birds like the purple moorhen, chestnut bittern and the pheasant-tailed jacana nest among grass and reeds in the riverine floodplain. Other birds use the riparian vegetation to forage for food. This vegetation also provides a habitat for different species of herpetofauna and terrestrial and aerial macroinvertebrates. Again, the riparian vegetation is important for the integrity of the instream habitat. Clearing it can deny the adults of many aquatic insects a suitable habitat within which to mate and oviposit (Petersen et al., 1999) and also remove a major energy source, of the aquatic ecosystem, in the form of allochthonous detritus (e.g. Dobson and Hildrew, 1992; Hall et al., 2000).

In addition, terrestrial and aerial macroinvertebrates that fall from the riparian vegetation and enter the water help sustain fish populations in the stream (Waters 1988, 1993). Extensive clearing of riparian vegetation during the seismic survey operations therefore has the potential of adversely affecting the faunal composition of the riverine ecosystem.

4.8.2 Impact of seismic noise and vibrations

The major cause for concern, of an adverse impact on the fauna from a seismic exploration, however is the noise from seismic pulse generation and other activities that are associated with the entire operation. The effects of noise on wildlife are not well documented. Individual and species differences in the tolerance levels to noise and noise parameters (e.g., frequency, intensity, etc.) make the assessment of noise impact on wildlife difficult. Researchers however agree that noise is a potential threat to the health and long term survival of animals. There are four major ways in which noise affects animals:

(i) Hearing loss,

(ii) Acoustic masking, i.e. interference with the ability to perceive important environmental cues and animal signals,

(iii) Non – auditory physiological effects, and

(iv) Behavioral effects.

In the context of the proposed seismic exploration, it is important to note that off-road vehicles (ORVs) can produce noise in the intensity range of 85 – 95 dB SPL re: 20 μPa. Detonation of explosives for the generation of seismic pulses produce noise in the intensity range of 100 – 140 dB SPL re: 20 μ Pa. A boat with a large outboard motor generates sound intensities of around 175 dB SPL re: 1μPa and air gun arrays deployed at a pressure of 1600 psi are expected to produce sound intensities of 234.83 dB SPL re: 1μPa. Along with intensity, the frequency component of sound is also important in considering the impact of anthropogenic sound on animals. The noise generated from various sources during a seismic survey is likely to be broadband with low frequency components dominating.

4.8.3 Physiological Stress generation

Unexpected bursts of sound of intensities higher than 85 dB SPL causes physiological stress in almost all animals. Studies involving different species have shown that this stress is reflected in increased heart rate and respiratory activity (Ames and Arehart, 1972), elevations of blood pressure (Petersen et al., 1981) and alterations in hormonal balance and metabolism (Anthony et al., 1959; Ogle and Lockett, 1966). Sound-stressed animals also exhibit a range of behavioral responses to the noise stimulus. These include a startled response, head raising, body shifting, trotting short distances, freezing, wing flapping and panic and escape behavior. When the physiological and behavioral effects are coupled, the consequences are bodily injury, energy loss, decrease in food intake, habitat avoidance and abandonment and reproductive loss (Busnel, 1978).In lactating mammals, especially in the immediate postpartum period, sudden fright has caused a cessation of milk secretion. Sound stressed mice in the laboratory have shown a resorption of embryos and 66 % reduction in fetal weight. Deer in the wild have abandoned their home range in response to low intensity intrusion into their habitat by humans and vehicles. Noise has also caused mother birds to panic and fly from nests, ejecting eggs from the nest in the process. This also breaks the incubation rhythm, and there is often nest desertion with the mother bird failing to return.

4.8.4 Impact on auditory capabilities

Noise also has deleterious effects on the auditory capabilities of animals. Noise from ORV movement and seismic pulse generation can cause impairment and even loss of hearing in animals. Hearing loss caused by noise from ORVs has been documented in mammals (Luckenbach and Bury, 1983), birds (Marler et al., 1973) and reptiles and amphibian (Bondello et al., 1979; Brattstrom and Bondello, 1983). Hearing loss can have serious consequences for animals dependent on their sense of hearing for finding prey, avoiding predators and interacting with individuals of the same species. Sounds in the natural environment which have survival value are usually low intensity sounds. The hearing capabilities of different species of animals are adapted to this natural acoustic environment. Species of owls, for example, have extremely sensitive hearing and are able to hear sounds in the 0.4 – 7 kHz range with a threshold of -4 dB SPL (van Dijk, 1973). This auditory sensitivity is used by owls for predation. Prey animals also have fine auditory sensitivity which allows them to detect the crawl of a snake or the swoop of an owl to avoid predators. Immel (1995) has documented the disabling of a reflexive response of the kangaroo rat against the rattle snake, its primary predator, upon exposure to ORV noise. Under normal circumstances, the rat can hear the snake at a distance of 30 inches and it responds by kicking sand into the eyes of the snake and escaping. ORV noise eliminates this defensive hearing and it returns only several days later; in the intervening period the rat remains highly vulnerable to predation. At noise levels of 95 dB SPL re: 20 μ Pa, there is considerable loss of auditory sensitivity in lizards and amphibians with an increased vulnerability to predation.

4.8.5 Impacts on behaviour

Noise has also been found to interfere with critical life history behaviors like hibernation. It often forces animals to emerge prematurely from hibernation causing stress and endangering survival. It has been observed that burrowing amphibians which use early summer thunderstorms as the cue to emerge from their burrows, mistake high intensity noise for the environmental cue and emerge in the wrong season (Brattstrom and Bondello, 1983).

4.8.6 Acoustic Masking

With the high intensity noise generated during seismic operations having a dominant low frequency component, along with hearing impairment and loss, ~~there is also acoustic~~ masking. This occurs because the environmental cues and communication signals that most animals use are low frequency sounds and there is considerable overlap with the frequencies of sound from ORVs and seismic pulse generation. This leads to loss of important acoustic signals.

Acoustic masking by the noise produced by boat engines can also affect fish. Masking occurs when anthropogenic sounds in the same frequency range, blots out sounds that are of biological importance for fish. This affects communication, prey/predator detection and generally the sensing of an environment which is predominantly acoustic. While the most dramatic masking is caused by sounds within 0.1 to 0.2 octaves of the sound of interest, masking can also take place in frequencies further from the source of interference, with increasing interference as the intensity of the interfering sound increases.

While there is no baseline data available for the impact of noise on individual species in the proposed seismic survey area, it can generally be stated that these animals too will be susceptible to both the auditory and non auditory effects of noise. Members of the mammalian, avian and herpetofauna assemblage in the survey area will all be exposed to the risks that accompany the introduction of broadband low frequency noise of high intensity into the natural environment.

4.8.7 Impacts of boat noise

The proposed seismic survey will involve the deployment of motor boats and air gun arrays in the Brahmaputra river channel. These will contribute significantly to noise in the underwater environment and the possible impact of this noise on the fauna in the river cannot be ignored.

Due to the scarcity of light underwater and the efficiency with which sound transmits through this medium, the underwater environment is predominantly an acoustic environment. Aquatic animals rely on sound for intra-specific communication, navigation, location of prey and avoiding predation. Anthropogenic noise in the underwater environment affects all these auditory functions to a lesser or greater degree. An aquatic animal also exhibits non-auditory physiological and behavioral effects when exposed to noise stress. But because its very survival hinges on its ability to perceive and accurately interpret its acoustic environment, research done on the impact of anthropogenic noise on aquatic fauna has focused primarily on auditory effects.

Most human activities associated with the underwater environment produce noise of varying intensity but with frequency components less than 1.0 kHz (Richardson and Wursig, 1997). This is also true of boat engines and seismic gun arrays. A boat with a 70 hp outboard engine, running at medium speed, produced sound in a frequency spectrum range from 0.4 Hz to 4.0 Hz having an intensity of 142 dB SPL at 50 meters from the engine and 176 dB SPL at 1 meter (Stewart et al., 1982). Seismic air gun arrays output a rather broadband low frequency sound. Peak output is generally in the range of 50 Hz, with a secondary peak appearing in the 150 Hz – 200 Hz range and continuing decreasing peaks up to 1 kHz. Air gun arrays have extreme source levels (at 1 meter from source), usually more than 200 dB SPL. The air gun arrays in the proposed seismic survey, deployed at 1600 psi, will have source levels of 235 dB SPL.

In recent years, the effect of boat engine noise on fish hearing has received close attention. Based on auditory sensitivity fish are broadly categorized as hearing specialists and hearing generalists. Hearing specialists have a broad hearing frequency range with low auditory thresholds while hearing generalists have a narrower frequency range with higher auditory thresholds. Most fish are known to have their best sensitivity to sound energy in the frequency range of 100 – 1000 Hz (Fay, 1988) although many fish also display high sensitivity at lower frequencies (Sand and Karlsen, 1986). From the audiograms of about 50 fish species, it was found that the maximal acoustic sensitivity of species with swim bladder (hearing specialists) is at a *best frequency* of 412 ± 301 Hz (mean ± SD, N=40), and the mean threshold at the best frequency for all species is 80 ± 18 dB SPL (Schellart and Popper, 1992).

Some fish communicate by using their swim bladder for vocalization. The frequency content of this vocalization, generated by the swim bladder, has an upper frequency limit of 800 Hz with fundamental frequencies between 25 and 250 Hz. When both vocalization and hearing are considered, the frequency range of interest for most fish is between 50 and 1000 Hz.

Boat engine noise has been found to not only significantly raise the auditory threshold in many fish species but also cause acoustic masking. The cyprinid, *Pimephales promelas* is a hearing specialist with its most sensitive hearing range from 0.8 to 2.0 kHz. Exposing this fish to noise from a 55 hp outboard engine idling in neutral position (142 dB SPL) for two hours raises the threshold in its most sensitive hearing range by 8 to 14 dB SPL (Scholik and Yan, 2002a). In an earlier experiment on the same species, where they used white noise at 142 dB SPL (frequency band 0.3 to 4.0 kHz), Scholik and Yan (2001) demonstrated that auditory sensitivity lost after two hours of exposure to this noise took 6 days to recover. There was no recovery from the threshold elevation resulting from a 24 hour exposure even after 14 days. Hearing generalists appear to be less susceptible to loss of auditory sensitivity and exposure of the bluegill sunfish (*Lepomis machrochirus*) to white noise (0.3–2.0 kHz, 142 dB) caused a less than 5 dB threshold shift at all the frequencies examined (Scholik and Yan, 2002b).

4.8.8 Impact of air gun noise

There is a surprising paucity of references reporting effects of air gun noise on fish. With sound produced by discharging air guns being of high intensity and having a frequency spectrum within the hearing range of most fish, this lack of evidence is probably due not to a lack of seismic effects on fish but to a lack of appropriate research. The limited studies that are available however point to behavioral, physiological and auditory effects on fish, of the repetitive high energy noise that seismic surveys produce in the water column.

The behavioral effects that have been observed include a startle response, change in swimming patterns and a change in vertical distribution. While these behavioral effects have not been observed to persist for very long, they could be ecologically significant if they lead to dispersion of spawning aggregates or deflection from migration paths. Seismic shots at close range have the potential to cause physical damage to the fish auditory system. Cage experiments have shown that the ears of fish (*Pagrus auratus*) exposed to an operating air gun, towed towards and away from the underwater cage to mimic the signal from a passing seismic vessel, sustained extensive damage to their sensory epithelium (McCauley et al. 2003). The possibility of the high intensity noise produced by air guns damaging other organs also cannot be discounted. The acoustic impedance of fish tissue matches that of the water and most of the sound energy enters their bodies. If the frequencies of this sound match the resonance frequency of the fish's body, the sympathetic vibration that is generated may be strong enough to shear vital organs.

Considering its intensity and frequency, the output from seismic guns also has the potential to disrupt communication, detection of predators and prey, navigation and other functional uses of sound by fish. This aspect of seismic noise has not been investigated but some workers have speculated that the discontinuous nature of seismic signals may allow these functions to occur between the pulses. It has however been observed that a behavioral response to seismic noise is often a cessation of vocalization, and this disrupts communication.

Seismic activity has been shown to affect fish abundance and catchability at different distances from active air gun arrays. Lokkeborg and Soldal (1993) have reported that catch rates for cod (*Gadus morhua*) were reduced during seismic shooting, by 55 – 85 % for long line and trawl fisheries at distances of 5 – 10 nautical miles. Engas et al. (1995) also found cod and haddock (*Melanogrammus aeglefinus*) abundance and catch rates to be reduced during a seismic operation by 50 – 70 % at distances up to 18 nautical miles. Regarding larval mortality from seismic activity, a worst case risk analysis was carried out by Saetre and Ona (1996) on fish larval mortality from a 3D seismic survey. This study concluded that it is difficult to differentiate larval mortality rates due to seismic survey from natural mortality rates.

The evidence that is available for the impact of boat engine noise and noise from air gun arrays on fish fauna cannot be directly extrapolated for assessing the effects of the proposed seismic survey on the fish fauna of the Brahmaputra River. The biological impacts of seismic surveys vary with the local conditions of the environment (topography, bed character, channel dimensions) and also the condition of organisms (breeding state, nutritive condition).

The freshwater environment is acoustically very distinct from the marine environment where most studies on the effects of seismic activity have been undertaken; it is a relatively quiet environment. Due to the sediment load that the Brahmaputra carries, conditions of light underwater are also very poor. It is therefore not surprising that the large majority of fish in this river are hearing specialists with a well developed sense of hearing and some of these fish also vocalize. Any damage to their auditory system and loss of acoustic sensitivity consequent to exposure to noise generated during the seismic survey can have far-reaching consequences on the survival of these fish. Even if there are no auditory effects, behavioral effects expressed as avoidance, alteration of feeding and resting and of swimming patterns can affect fish populations. Behavioral effects have also been shown to affect fish catch in the sea and this could also be true of fish in the river.

4.8.9 Specific Concerns: (i) Gangetic River Dolphin

The Brahmaputra River system is home to the Gangetic River Dolphin. The stretch of the river that falls within the proposed seismic survey area is known to have a population of around 50 of these endangered aquatic mammals. Their presence was confirmed by sightings made at the various sites in the river during the biosurvey that was conducted, and it is very important that this population not be adversely impacted by the proposed seismic survey.

The River Dolphin is nearly blind and its pinhole eyes can detect only dark and light. For this animal its acoustic capabilities are critical for its survival. To assess the effect that noise generated by the seismic survey could have on the dolphin, it is necessary to know the hearing and vocalization characteristics of this animal. Although there is not much research that has been done on the acoustic capabilities of the Ganges River Dolphin, this has been studied in other dolphin species. Dolphins hear sound at a wide range of frequencies from 75 – 125 Hz up to 5 – 150 kHz. Long trains of echo-locating clicks that dolphins emit help them to hunt fish. Dolphins in fact use both their active and passive sonar abilities to hunt for prey and perceive their environment. Apart from the broadband sonar clicks, dolphins also emit narrow band frequency modulated tonal whistles. The frequency range of dolphin vocalizations, range from 0.25 to 150 kHz. The lower frequency vocalizations (0.25 to 50 kHz are used in social communication while the higher frequency vocalizations in the range from 40 – 150 kHz are used in echolocation.

Since there is little overlap between the predominant frequencies produced by boat engines and seismic shots, and the best frequencies at which dolphins hear, the disruption of the river dolphin's echo-locating abilities by acoustic masking is not a major threat. Lower frequency social communication, starting at 250 Hz may however be affected by the high intensity low frequencies of seismic sound. There could however be shifts in the dolphin's hearing thresholds on exposure to the noise of seismic survey. Individuals whose acoustic abilities have been affected would be unable to avoid threats in their environment like fishing gear which they normally avoid by acoustic means. There could also be behavioral effects caused by the seismic survey which includes displacement from feeding areas, breeding or nursery areas, changes in dive and respiratory patterns and changes in vocalization. The ecological consequences of these effects are unknown.

A major threat to the dolphin population, in the stretch of the river being considered for the seismic survey, would however come from reduced prey availability if the seismic survey affects fish population in the area.

4.8.10 Specific Concerns: (ii) Freshwater Turtles

The implementation of the seismic survey must also take into account the presence of freshwater turtles in the Brahmaputra river channel. Studies have shown that the most sensitive hearing in turtles is in the frequency range of 100 – 700 Hz. This frequency band has overlaps with the frequency output of boat engines and seismic guns and turtles are therefore able to hear these sounds. There is however limited information on the effects that anthropogenic noise has on turtles. McCauley (2000) has reported that sea turtles in caged trials show increased swimming behavior on exposure to sound at 155 dB and erratic swimming at 164 dB.

The effects that need to be considered in this context are increased swimming activity, changes in swimming direction, avoidance, loss of hearing sensitivity and stress.

4.8.11 Aquatic Invertebrates

Regarding the aquatic invertebrates, information on the impact of seismic surveys on this assemblage is scanty. In crustaceans, physiological effects like reduced growth and reproduction, and also behavioral changes have been recorded on exposure to continuous sound. Gastropods are also known to be sensitive to noise in their environment. But any presumption of effects of the proposed seismic survey on the macro invertebrates assemblage of the survey area will be speculative.

4.17 Major Mitigation Measures

4.17.1 General Introduction

From various evidences available in literature, it can be concluded that seismic sounds in the riverine environment are neither completely without consequences nor are they certain to result in serious and irreversible harm to the environment. In the huge range of effects between those extremes, however there are many *potential* detrimental consequences. In general risks of these consequences are poorly quantified, often unknown, and likely to be variable with both conditions of the environment and of the organisms exposed to the sounds. The long and widespread history of seismic surveys globally in marine environments with no documented fish or invertebrate kills, and only circumstantial evidence of associations with infrequent strandings of marine mammals and giant squid, suggest that seismic surveys with fairly routine mitigation measures in place are unlikely to pose high risk of mortality of the organisms. This line of conclusion can be extended to seismic surveys on river bed. However, this suggestion must be qualified, because sub-lethal or longer-term effects could have occurred and not have been detected by the monitoring programs typically in place.

Immediate behavioral reactions to exposure to seismic sound have been widely documented in marine organisms, especially marine mammals; particularly behaviors which would result in avoiding the immediate area where the sounds are being produced, or reducing vocalisations. The possible longer-term consequences of these short-term behavioral changes are debated among experts. The debate is largely speculative and there is little empirical basis to determine the likelihood of the full chain of events which would lead to serious longer-term consequences of the short-term behavioral reactions. However, the risk to be managed would be the combined probability of all the events in the chain occurring.

Whatever be the absolute level of risk posed by seismic sounds, there are mitigation measures available which the evidence available suggests can reduce the risk by varying, but sometimes substantial, amounts. The effectiveness of specific mitigation measures is likely to depend on the effect of concern and how the measures are implemented. The impact on the seismic operations of application of some mitigation methods, such as not conducting surveys in critical times and places, will also vary with many factors, but sometimes also could be large. Clearly much more research and monitoring are needed to better clarify and quantify the unknown risks and uncertain effects, if they occur, and the effectiveness of mitigation measures to a wider range of potential effects.

4.17.2 Effects of seismic sound on river ecosystem

The issue of concern was the effects of sound, particularly seismic sound, on riverine organisms and the river ecosystem in general. Attempts have been made to formulate a scientific basis for developing a regulatory framework for use of sound in aquatic environments, at least in the frequencies used for seismic surveys. In this respect, the following considerations are important:

1) When considering the possible impacts of seismic sounds on the river ecosystem, it makes sense to embed these considerations within the larger framework of the impact of all anthropogenic noise on the ecosystem. The major anthropogenic sources of noise that might be appropriate to consider in a holistic view would include seismic sounds, shipping, explosives, construction, and low-frequency SONAR. Moreover, the significance of impacts of sound in the environment, if any, should be evaluated in the context of other uses of ecosystem.

2) The dearth of scientific information, especially concerning field experiments on fish, invertebrates, and the larger aquatic mammals, makes it extremely difficult to evaluate the impact of a particular type of seismic sound, or more generally noise, on a particular species. Restricting the considerations to only seismic sound impacts would have reduced the already-sparse information base to one that would not have supported any conclusions with an acceptable level of confidence.

3) Given the scarcity of hard information on so many facets of this multi-dimensional problem, it is likely that a meaningful appreciation of risk can only be obtained by taking an integrated view of all the sources of information available.

4) Many conclusions refer to the likelihood of various biological effects, if animals were exposed to seismic sound. Likelihood is used in a relative sense, and not as the product of quantitative risk assessments, which are not possible with the information available. Saying that an event has a "high likelihood" does not mean we necessarily expect to see it in nine out of every ten animals exposed to the sound, or even in nine out of ten replicates of the same experiment. Rather, it means that compared to the expectation of the event in the absence of seismic sound, the likelihood of the event has increased substantially, and it would be observed if sought with due diligence. However, it still may not be the typical event.

5) The conclusions that follow often refer to "seismic sound" and "field operating conditions". These terms are used colloquially and are not defined prescriptively. In this document "seismic sound" refers generally to that produced by the types of air guns and arrays normally used at present. "Field operating conditions" refers to 2-D and 3-D seismic surveys using measures such as ramp-up of sound level at onset, and ceasing sound emissions when cetaceans are known to be in the proximity of the operations.

6) Both the likelihood and severity of biological effects that may result from seismic surveys are likely to vary with local conditions of the environment (bottom topography, depth and width of water body, etc.) and conditions of the organisms (breeding state, nutritive condition, etc.). These conditions should not be ignored when evaluating risks and the potential for mitigation.

7) It was agreed that the biologically meaningful aspect of seismic sound is the "received sound" by the organism(s) potentially being affected. However, "received sound" is multi-dimensional. Seismic sound (or noise in general) can be characterized by its frequency spectrum (acoustic energy or pressure as a function of acoustic frequencies), peak pressure (a time domain concept, referring to the maximum instantaneous amplitude of the pressure signal), rms pressure (mean pressure averages over a time interval), Sound Exposure Level (a measure of the "dosage" of sound energy received over a time interval), and in other ways.

8) The mechanisms by which exposure to seismic sound could result in biological impacts are sufficiently varied that no one metric may be sufficient to describe the risk of impact from a particular type of seismic sound. Some mechanisms may be well characterized by one or two of these metrics; others may not be well characterized by any of them. For example, peak pressure may be the most relevant parameter for risk of trauma, whereas rms pressure may be the most relevant parameter for non-trauma effects such as Temporary Threshold Shifts [TTS]. The frequency band, intensity, and duration of exposure all contribute to auditory effects, because although the impact must occur within the frequency band of exposure, it is anticipated that auditory impact is greater within the hearing range of a species, and will decline towards the margins of its hearing threshold.

9) Although careful experimentation ought to be able to determine which feature(s) of the sound stimulus caused the observed reactions (when they occurred), the existing literature on experiments with marine fish and invertebrates rarely describes completely enough the characteristics of the sounds used to allow biological observations to be interpreted with confidence.

10) The literature on experiments and field observations of marine mammals exposed to sound stimuli is more extensive than the literature on effects on other types of marine organisms, and more so on riverine fish and other organisms. Therefore, a more complete (but still partial) basis for setting thresholds is absent. It was conjectured that sedentary species that cannot leave an area may experience higher levels of exposure to seismic sound than mobile animals, and this factor may be taken into account in management as well.

11) A number of studies reported sub-lethal effects on marine organisms, such as elevated stress-related chemicals, and damage to ears or other morphological structures. The dearth of long-term studies of marine organisms exposed to seismic sounds means that the long-term consequences of these effects, when they occur, are unknown. This applies also to riverine organisms.

12) The severity of impact at the population level may be higher for an effect like auditory masking, if it occurs, because masking has the potential to affect a very large geographical area for low frequency sounds. Masking also may have few immediately observable signs that impacts are occurring, so mitigation may be less likely to be triggered than with individual mortalities due to trauma (which have limited geographical extent and are more easily observable).

4.17.3 Effects of seismic sound on fish: General Issues

The following general conclusions can be made, on the basis of available reports, for effects of seismic sound on fish:

a) Physical Effects

(i) There are no documented cases of fish mortality upon exposure to seismic sound under field operating conditions.

(ii) Under experimental conditions, some fish species show lethal effects from low-frequency (<500 Hz) tonal sounds, under exposure levels of 24 h at >170 dB. This experimental regime is however greatly different from field operating conditions of seismic surveys, so extrapolation of the results to seismic surveys is not properly warranted.

(iii) Exposure to seismic sound from an air gun even at close distances is considered unlikely to result in direct fish mortality.

(iv) Under experimental conditions, sub-lethal and/or physiological effects, including effects on hearing, have sometimes been observed in fish exposed to an airgun. The experimental design made it impossible to determine to the satisfaction of all experts what intensity of sound was responsible for the observed damage to ear structures, nor the biological significance of the damage that was observed. Simulated field experiments attempting to study such effects have been inconclusive. Currently, information is inadequate to evaluate the likelihood of sub-lethal or physiological effects under field operating conditions. The ecological significance of sub-lethal or physiological effects, were they to occur, could range from trivial to important depending on their nature.

b) Behavioural Effects

(i) There is high likelihood of obtaining the following effects in some fish exposed to seismic sound:

- startle response,
- change in swimming patterns (potentially including change in swimming speed, and directional orientation), and
- change in vertical distribution.

These effects are expected to be short-term, with duration of effect less than or equal to the duration of exposure, are expected to vary between species and individuals, and be dependant on properties of received sound. The ecological significance of such effects is expected to be low, except where they influence reproductive activity.

(ii) Several scientific studies have investigated other behavioral effects on fish during seismic surveys. Some have found the effects listed below and some have not:

- Change in horizontal distribution of fish not closely associated with habitat structures,
- Change in catchability of fish possibly related to changes in behavior. Differences in experimental regimes and lack of adequate controls in some of the experiments means that the published results are an insufficient basis to predict the nature of any change that may occur, or even if a change will occur.

The duration of these effects may or may not extend beyond the duration of exposure, are expected to vary between species and individuals, and be dependant on the properties of received sound. The ecological significance of such effects is expected to be low, except when they may lead to a dispersion of spawning aggregations or deflection from migration paths. The magnitude of effect in these cases will depend on the biology of the species and the extent of the dispersion or deflection.

c) Other effects

The potential for seismic sound to disrupt communication, detection of predators/prey, navigation and other functional uses of sound by fish has not been studied. There is speculation that the discontinuous nature of seismic signals may allow these functions to occur between sound "pulses". There is also speculation that behavioral responses may include cessation of sound production by fish. If it were to occur, hearing damage would also be expected to impact these functions. Ecological significance of such effects is unknown.

4.17.4 Effects of seismic sound on invertebrates: General Issues

The following general conclusions can be made, on the basis of available reports, for effects of seismic sound on invertebrates:

a) Physical Effects

(i) There are no documented cases of invertebrate mortality upon exposure to seismic sound under field operating conditions.

(ii) Under experimental conditions, lethal and/or sub-lethal effects, including effects on external structure, have sometimes been observed in invertebrates exposed close to (less than 5 m) an air gun.

(iii) Therefore, exposure to seismic sound is considered *unlikely* to result in direct invertebrate mortality.

b) Physiological Effects

(i) There is a series of publications showing effects of extended exposure to non-seismic sounds on the physiology of crustacean under experimental conditions. Effects include reduced growth and reproduction rates and behavioral changes, which indicate the sensitivity of some invertebrates to noise. In a gastropod (mollusc), the physiological effects (sign of stress) were reported under field seismic operating conditions. In other species such effects were rarely present, except for some sign of excitation of in some species of crabs.

(ii) Currently, information is lacking to evaluate the likelihood of sub-lethal or physiological effects on crustaceans during pre-molt, molting and post-molt periods.

(iii) The ecological significance of sub-lethal or physiological effects, were they to occur, could range from trivial to important depending on their nature.

c) Behavioral Effects

(i) There is high likelihood of obtaining the following effects in some invertebrates exposed to seismic sound:

- startle response,
- change in swimming/movement patterns (potentially including change in swimming /movement speed, and directional orientation).

(ii) Both increases and decreases in catch rates of commercially exploited species have been documented, but changes do not occur consistently.

(iii) These effects are expected to be short-term, with duration of effect often less than the duration of exposure, are expected to vary between species and individuals, and be dependent on properties of received sound.

(iii) Some invertebrates are sedentary or have limited locomotive capacity. Therefore their capacity to avoid seismic sound is extremely limited compared to many fish and riverine mammals. This may increase their exposure to seismic sounds, but there is no basis on which to assume that increased exposure makes such species inherently more or less sensitive to those sounds.

(iv) The ecological significance of the effects is expected to be low, except if effects of exposure to seismic sounds were to influence reproductive or growth (molting) activities, or lead to a dispersion of spawning aggregations or deflection from migration paths. The magnitude of effect in these cases will depend on the biology of the species and the extent of the dispersion or deflection.

d) Other effects

(i) The potential for seismic sound to disrupt communication, orientation, detection of predators/prey, locomotion and other functional uses of sound by invertebrates has not been studied. Loud sounds will reduce the efficiency of communication and other functional uses of sounds, but the severity and conditions under which this occurs with invertebrates are unknown. It is not known if invertebrates can communicate acoustically during the inter-pulse intervals that occur between seismic transmissions. Ecological significance of such effects, if they occur, is unknown.

4.17.5 Effects of seismic sound on Zooplankton, eggs and larvae of fish

The following general conclusions can be made, on the basis of available reports, for effects of seismic sound on Zooplankton, Eggs and Larvae of Fish and Invertebrates:

1) Few studies of the effects of seismic sound on eggs and larvae or on zooplankton have been found. A number of these provided inadequate description of experiment design, properties of the sound applied as treatments, or had methodological shortcomings.

2) Data are generally insufficient to evaluate the potential damage to eggs and larvae of fish (or other planktonic organisms) that might be caused by seismic sound under field operating conditions.

3) From the experiments reported to date, results do show that exposure to sound may arrest development of eggs, and cause developmental anomalies in a small proportion of exposed eggs and/or larvae; however these results occurred at numbers of exposures much higher than are likely to occur during field operation conditions, and at sound intensities that only occur within a few meters of the sound source.

4) Effects of seismic sounds on behavioral functions and sensory perception of fish and invertebrate eggs and larvae are unknown;

5) In general, the magnitude of mortality of eggs or larvae that models predict could result from exposure to seismic sound would be far below that which would be expected to affect populations. However, special life history characteristics such as extreme patchiness in distribution and timing of key life history events in relation to the duration and coverage of seismic surveys may require case by case assessment.

4.17.6 Effects of seismic sound on turtles

The following general conclusions can be made, on the basis of available reports, for effects of seismic sound on Turtles:

Studies on sea turtle behaviour to seismic sound have found the following. Such studies have not been reported for freshwater turtles. However, the same considerations are likely.

1) Auditory studies suggest that sea turtles, specifically loggerhead and green turtles, are able to hear and respond to low frequency sound, but their hearing threshold appears to be high.
2) In three studies, the following behavioral responses of sea turtles in enclosures exposed to air gun sounds were sometimes observed:
   - increased swimming speed,
   - increased activity,
   - change in swimming direction, and
   - avoidance.
3) Sea turtles may become accustomed to seismic sound over time, although the results of the studies done were inconclusive on this matter.
4) Loss of hearing sensitivity and physiological stress response has also been considered as a possible consequence of exposure of sea turtles to seismic sound.
5) The response, if any, of free-ranging sea turtles to seismic sound conducted under field operating conditions is unknown.
6) Based on studies that have been conducted to date, it is considered *unlikely* that sea turtles are more sensitive to seismic operations than cetaceans or some fish.

4.17.7 Effects of seismic sound on riverine mammals

The following general conclusions made, on the basis of available reports, for effects of seismic sound on marine mammals, may also be applicable to riverine mammals:

a) Mortality and Physical Effects

1) There are no documented cases of marine mammal mortality upon exposure to oil and gas exploration seismic surveys. The role of the different sound sources in the stranding events could not be resolved. Therefore, although whale strandings have been linked to exposure to anthropogenic sound, exposure to seismic sound is considered unlikely to cause direct marine mammal mortality.
2) Under experimental conditions, sub-lethal, temporary elevations in hearing thresholds (TTS) have sometimes been observed in captive marine mammals exposed to pulsed sounds.

Currently, the likelihood of these effects has not been evaluated under field operating conditions. The significance of such TTS effects, were they to occur, are likely to be unimportant, unless:

a. the threshold was elevated repeatedly or for an extended period of time, which could result in a Permanent Threshold Shift [PTS]; or
b. other threats were present at the same time as the temporary elevations in hearing thresholds, and the threats were ones normally avoided by acoustic means, such as predators or entanglements in fishing gear.

3) There are no documented cases of a marine mammal experiencing damage to non-auditory body tissues upon exposure to seismic surveys under field operating conditions. Therefore, exposure to seismic sound under field operating conditions is considered unlikely to result in such types of tissue damage to marine mammals, but the presence of other sound sources operating simultaneously with seismic operations should be taken into account when proposals are evaluated.

b) Direct Behavioral Effects

1) There is documented displacement and migratory diversion in some marine mammal species exposed to seismic sound. The duration of these effects may or may not extend beyond the duration of exposure. The effects are expected to vary between contexts, species, gender and age class, and individuals, and be dependant on the properties of received sound. The ecological significance of such effects is expected to be low, but may be higher if they:

   - displace feeding marine mammals from areas where there are no alternates,
   - displace marine mammals from resting areas where there are no alternates,
   - displace marine mammals from breeding or nursery areas, or
   - divert migrating animals from routes for which their alternate routes either do not exist or would incur substantially greater costs to traverse.

2) The magnitude of effect in these cases will depend on the biology of the species and the extent and duration of the dispersion or deflection. Also, there is a risk that a seismic project occurring in another area could cause incursion of displaced competitors into the critical habitat or area of high biological productivity occupied by other species.

3) In summary, exposure to seismic sound can result in displacement and/or migratory diversion in some marine mammals, but this effect is species, individual, and contextually-related. The ecological significance of such effects is unknown, but there are conditions under which the worst-case scenarios could be high.

4) There are documented changes in dive and respiratory patterns in some marine mammal species (e.g., bowhead whales, harbour and grey seals) exposed to seismic sound. There are records of the duration of these effects extending beyond the duration of exposure. The effects are expected to vary between contexts, species and individuals, and be dependant on the properties of received sound. The ecological significance of such effects is expected to be low, except if such effects:

   - interfere with feeding, or
   - incur substantial energetic costs;

The magnitude of effect in these cases will depend on the biology of the species and the extent and duration of the dispersion or deflection.

5) In summary, exposure to seismic sound can result in changes in dive and respiratory patterns in some marine mammals, but this effect is expected to vary with species, individual, and context. The ecological significance of such effects is unknown, but there are conditions under which the worst-case scenarios could be high.

6) Social behavior can include a wide variety of activities such as mating, cooperative feeding, play, aggressive interactions, and communication. There have been no directed studies of the effects of seismic sounds on mating, cooperative feeding, play, or aggressive interactions.

7) There have been direct studies of the potential for anthropogenic sound to cause changes in the vocalization patterns of marine mammals. For most cetacean species studied, there were measurable changes in vocalization patterns, but these studies were not conducted during seismic operations. In the UK, Norway, and the Sable Gully, sperm whales did not stop calling when exposed to seismic sounds.

8) There is evidence that exposure specifically to seismic sounds has sometimes caused changes in vocalization patterns in marine mammals. However, it has not been possible to measure the functional consequences of these changes (such as loss of contact between individuals or reduced ability to coordinate social behaviors), if any, nor the percent of time which they would occur.

9) Many species of marine mammals both produce and respond to sounds. Studies have shown these vocalizations to sometimes communicate information that is functionally important for feeding, breeding, parental care, predator avoidance, or maintenance of social groupings. Studies have also found vocalizations can occur when there are no observable functional consequences, although in such cases it is unclear if the vocalizations had no consequences, or if the effects were longer term or farther afield than the studies.

10) There have been no published studies of the potential for seismic sound to reduce the efficiency of communication in marine mammals. Loud sounds will reduce the efficiency of communication but the severity and conditions under which this occurs with marine mammals are poorly known. When seismic sounds are produced there are inter-pulse intervals which present the opportunity for cetaceans to place vocal communication signals, but cetaceans have not been shown to use this mechanism in the field. Moreover, there is unpublished information that when multi-path echoes occur, such as in areas of complex bathymetry, the pulses of the seismic sound may smear over distance and time, such that the quieter inter-pulse intervals may be reduced or eliminated. This creates the potential for calls of cetaceans such as blue whales to be masked by seismic sounds although the distances over which the masking would be effective, if it were to occur, are unknown. It is unknown if whales could reduce the effects of masking through processes such as changes in their calling patterns, and the consequences of these changes (if they occur) are unknown. This facultative response has been documented in some other marine mammal species exposed to loud manmade sounds. Therefore, it is unknown if exposure to seismic sound can result in such reduced communication efficiency in marine mammals.

11) There have been no direct studies of the potential for seismic sound to reduce the efficiency of echolocation in marine mammals. Therefore, it is unknown if exposure to seismic sound can result in reduced echolocation efficiency in marine mammals.

12) There have been no direct studies of the potential for seismic sound to hamper the passive acoustic detection of prey by marine mammals. In a published study on the effects of whale watching vessels on killer whale behavior, it was postulated that sounds from these vessels could reduce the ability of killer whales to detect their prey. It is not known if such an effect could result during exposure to seismic sounds, or even which species of marine mammals use passive acoustic detection of prey as an important feeding strategy.

13) There have been no direct studies of the potential for seismic sound to hamper the passive acoustic detection of predators by marine mammals.

14) There have been no direct studies of the potential for seismic sound to reduce the ability of marine mammals to avoid anthropogenic threats. There are published reports of other types of sounds interfering with the ability of individual whales to avoid anthropogenic threats such as ship strikes and net entanglements, but it is not known how widespread this response is. It is also not known if such an effect could result from exposure to seismic sounds. Therefore, it is a concern that exposure to seismic sound could reduce the ability of marine mammals to avoid anthropogenic threats, but the risk has not been demonstrated.

15) There have been no direct studies of the potential for seismic sound to hamper parental care or bonding in marine mammals. Therefore, it is unknown if exposure to seismic sound can hamper parental care or bonding in marine mammals.

16) There have been no studies of the potential for seismic sound to induce chronic effects, such as immunosuppression or reduced fecundity, in marine mammals. Therefore, it is unknown if exposure to seismic sound can result in such chronic effects on marine mammals.

17) There have been no studies of the potential for seismic sound to reduce prey availability, through displacement or reduced catchability, for marine mammals. Therefore, it is unknown if exposure to seismic sound can result in such indirect effects on marine mammals.

4.17.8 Impact Mitigation

Considering the above points of general nature, the following control measures will help in further minimizing the impacts and in maintaining the existing conditions of the environment:

(a) Training of workers

Utmost importance should be given to specific and detailed training of all personnel to be engaged in the work before any activity commences. The salient points for such training should be

(a) A complete understanding of the delicate and fragile nature of the pristine environment in which the work has been proposed to be carried out.

(b) Knowledge of all the likely effects, the activities are likely to have on the environment with particular reference to the possible impacts on aquatic fauna.

(c) The physical work situation in the field.

(d) Measures to be taken to prevent accidents, including occurrence of fire.

(e) Careful handling of all wastes in the work areas as well as in the camping sites.

(f) Protection to be taken against attacks by animals, insects, reptiles, etc.

(g) Protection to be taken against infection of diseases, particularly malaria and enteric infections.

(h) Precautions to be taken in case of unforeseen events.

(b) Environmental Monitoring

Details of Environmental Monitoring Plan are given in the next chapter. It is essential that the impacts, if any, on the environmental elements with particular reference to effects on wild life, fish and other aquatic fauna, are carefully monitored during the progress of the work and also after the completion of the work.

(c) Events reporting and action

A mechanism should be established before commencement of the work for prompt collection and reporting of information on all accidents and other impacts, immediately noticed during the work. All these should be carefully documented and prompt action to be initiated for mitigation.

(d) Interactions with the public

Very often, the public may be misinformed about the possible effects of the activities. A mechanism should be worked out for properly informing the people and for frequent consultation.

4.17.9 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 impacts from the planned activities, combined with knowledge of previous similar activities in the same or other areas, allows a simple assessment of the additional or cumulative 'loading' of the impacts into the nearby environment caused by the proposed activity. As emissions to atmosphere and discharge of effluents and solid wastes to water and land are expected to be negligible in the proposed activities and mostly will be undetectable, further examination of the spatial and temporal extent of emissions and discharges and associated impacts is not considered necessary.

4.17.10 Specific Measures for protection of the Fauna

Although 3D seismic surveys have been conducted for almost 15 years now (2D surveys have a slightly earlier history and 4D surveys have now been used more and more), conclusive proof of the safety of seismic operations is absent. This has led to the adoption of a **'precautionary principle'** in seismic operations, and to decisions tending towards **caution and protection**. All over the world, this has been recognized as making ecological and biological sense. For the proposed seismic survey on the Brahmaputra River Basin, the implementation of the following measures will help in reducing the impact of the seismic exploration on the fauna in the area:

1. In the area of the Brahmaputra river landscape under consideration, except for a considerable number of avian species, most of the other fauna are resident or migrate locally. It is therefore difficult to work out a schedule of least impact for the seismic operations when the larger number of species will be absent from the operational area. In both terrestrial and underwater operations however, the schedule should be planned to avoid the known breeding periods of the more sensitive fauna in the area. It has been conclusively proved that the breeding state is when all animals are most vulnerable to stress in their environment.

2. Land operations should ensure that only a minimum of the riparian vegetation is removed for laying seismic lines. Once the survey is over, the regeneration of this vegetation must be monitored. Care must also be taken to properly fill up all the shot holes that are drilled in course of the survey.

3. The movement of vehicles and personnel should be kept to the minimum necessary for implementing the survey as this will help reduce both noise and waste.

4. There is negligible information on the environmental impact of seismic exploration in river basins. It would help in the decision making, regarding adoption of operational parameters with minimum impact, if the acoustic propagation loss for both boat engine noise and air gun arrays is modeled by incorporating the determining variable in the river channel.

5. Given the potential of boat engine noise to adversely impact aquatic fauna, the movement of motorboats over water, must be regulated. Acquisition of boats for use in the survey should consider the noise generating potential of the engine and propellers of these boats.

6. In the choice of the air gun array to be deployed it is desirable that the lowest possible power array, needed to obtain the information sought, be used. This is because in the relatively shallow water of the river channel, air gun activity can significantly damage fish hearing and affect communication (Richardson 1995).

7. In marine seismic operations, 180 dB SPL is the threshold for acceptable levels of exposure for marine creatures. However for the relatively quieter freshwater environment of the river channel, and the fact that behavioral effects have been evident in marine creatures at 161 dB SPL of received sound (Pearson and Skalski, 1992), this threshold should be lowered. Hastings (1991) has suggested a 150 dB SPL threshold of exposure for teleostean fishes.

8. Again the standard exclusion zone of 1km that the industry adopts for seismic operations at sea should be modified to avoid causing behavioral disruption in the fauna in the river corridor.

9. In deploying air guns, a 'soft start' is standard practice. This serves to forewarn animals in the area and allows them to move away from the immediate vicinity. While it is assumed that a 'soft start' procedure will be adopted, the 'ramp – up' period should be long enough to allow smaller fish, turtles and slow moving bottom dwellers enough time to move away.

10. Survey operations should include both visual and passive acoustic monitoring to confirm the absence of any aquatic fauna, including the river dolphin, in the exclusion zone adopted.

11. Waste disposal procedures should follow established norms.

12. There should be continuous monitoring of the ecological health of the survey area during all phases of the seismic operation and after.

In planning the operations, the following breeding seasons of the important faunal species are to be kept in consideration:

Birds

a) Spotted Bill Pelican : September-April
b) Oriental Dart : Round the year (Simalu tree)
c) Greater Adjutant Stork : November – January
d) Lesser Adjutant Stork : November-March
e) White Winged Wood Duck : January – May

Mammals

a) Capped Langur : No evidence of confirmed breeding season. Gestation period : 85 – 105 days
b) Gangetic Dolphin : Peak breeding season December to January, Lean breeding season March-June, Age of maturation : male 10 years, female 6-10 years, Gestation period 1 year.

Amphibia and Reptiles : Breeding season March to May

Fish : Breeding season March to May (Monsoon breeder), June to August (Summer breeded), November to January (Winter breeder)

4.17.11 Specific measures for reducing impact on Flora

The adverse impact on vegetation in general is expected to be of low order and temporary both in aquatic and land vegetation. Such adverse impact may further be minimized and managed properly if the following norms are followed during the seismic data acquisition:

a) Minimum clearing should be done during shot-hole preparation, specially in forestland. Holes should be filled up immediately after completion of the test.

b) Felling of trees should be avoided.

c) Waste of any kind produced during the survey should be disposed of properly and as per established norms.

d) Activity should be minimum along the erosion-prone areas, especially near the riverbank.

4.17.12 General Mitigation Measures and Best Practices

Mitigation measures should include shutting down air guns when cetaceans are seen at very close range (100m to 1km, depending on the size of the air gun array and species of concern in the area), gradually ramping up the power of the air guns over a 15 minute period (to allow fish and whales to move away), and employing on-board observers to watch for dolphins, freshwater turtles, etc., at the surface. If any sighting is made, the operation should be delayed till the creatures move away. No air gun should be fires at close proximity of any type of aquatic organism.

Many innovative approaches to mitigation and monitoring are emerging from researchers and regulatory agencies worldwide. A "best practices" approach to mitigation would include:

(i) **Case by case analysis and modeling.** Because of the great variability in transmission loss across different sorts of river floor profiles, and the small but significant variation in the output levels of individual air gun arrays, modeling of likely propagation patterns of predicting the horizontal sound propagation from any specified air-gun array source needs to be done on a case by case basis.

(ii) **Consider establishment of a larger exclusion zone** to reduce behavioral effects, especially on species with tenuous populations. It may be that observed behavioral disruptions will be better addressed by a 2 – 5 km radius, rather than the current 1 km radius. In the same way, the current 180 dB standard for acceptable received levels of sound (based on avoiding physiological damage) may need to be adjusted downward to avoid behavioral disruption.

(iii) **Require passive acoustic monitoring** (Passive Acoustic Monitoring utilizes listening devices to eavesdrop on vocalizations beneath the surface; systems have been developed that can identify a large number of species based on such acoustic data): such monitoring can complement visual observations by identifying animals vocalizing beneath the surface, down to the bottom. Passive acoustic monitoring can also extend the zone of effective observation.

(iv) **Incorporate Environmental Effects Monitoring** into all active seismic surveys. EEM should include measurement of received sound levels at ranges of 1 to 25 km, as well as both visual and passive acoustics monitoring of the responses of riverine mammals, fish, and other species present in the area. One area that needs more observation is the effects of exposure to air gun noise experienced by bottom-dwelling creatures directly beneath the guns.

(v) **Consider cumulative impacts over time** in permitting and effects modeling; include consideration of seasonal and historical impacts from other activities (shipping, military, industrial, and other seismic) in the specific survey area and nearby region.

(vi) **Use of the lowest possible power array** to meet local conditions and obtain information being sought.

(vii) **Extend ramp-up times** where turtles are present; 30 minute ramp-ups are minimal and 60 minutes preferable, to accommodate turtles' relatively slow swimming speeds. Evidence from fishery studies also suggests that smaller fish would benefit from slower ramp-ups.

(viii) **Adapt the sequencing of seismic lines** to account for any predictable movements of fish across the survey area.

(ix) **Quarantine boats and other equipments** to safeguard the indigenous aquatic fauna of the Brahmaputra river ecosystem from inadvertent importation of harmful alien species. Quarantine procedures should be adhered to with respect to boats and other equipment that are imported into the Brahmaputra river system for the seismic data acquisition from other aquatic bodies.

These "best practices" may require a greater investment in time and money for conducting seismic surveys, but they will be immensely environment-friendly.

4.18 CONCLUSIONS from EIA

The overall Impact Matrix for the project and the results of the mitigation measures upon proper implementation is given in Table 4.7

The seismic data acquisition is not likely to introduce any significant stress factor into the natural or social environment of the project area. The work will not involve any displacement or eviction of population, and will not discharge any chemical and other contaminants to air, water and soil. It will not put any additional demand on the water resources of the area. The ambient air quality will remain undisturbed, as the seismic data acquisition will not involve any major emissions to the atmosphere. The sound pressure level in the whole of the area is uniformly low, and although there may be some additional SPL generation during the actual days of operation of seismic data acquisition and also due to movement of machinery, vehicles and manpower, this will be relatively transient in nature and will have little impact on the background sound levels. In any case, the surrounding forest cover of the area will quickly absorb any additional noise generated.

With the mitigation measures strictly implemented, the biodiversity of the plant and animal kingdoms (both aquatic and terrestrial) is not likely to have any short-term or long-term impact from the work envisaged and the habitats of the birds and animals, as well as the aquatic fauna will not be affected. The seismic data acquisition will not have any adverse impact on the existing demographic distribution, nor will it affect the present socioeconomic conditions of the people. The work is not likely to interfere with the existing agricultural practices and the production levels. Similarly, the work will not have any adverse impact on health and general well being of the people.

The strict implementation of the measures outlined above along with the mitigation measures and the Environmental Management Plan will ensure little damage to the overall environmental scenario of the survey area. Instead the survey may bring about some minor positive impacts as discussed above.

Chapter 6
CONCLUSIONS

This Rapid Environmental Impact Assessment (REIA) carries out a study of the baseline environmental status and assesses the potential impacts of the proposed seismic survey on the Brahmaputra River Basin to be carried out by Oil India Limited.

The baseline study includes all environmental elements such as the geological status of the study area, land use pattern, past and present meteorological and climatic status, existing air, water, soil and sediment quality, terrestrial and aquatic flora and fauna, socioeconomic and health status of the people, etc.

Based on the project elements, the REIA examines and predicts possible impacts of the proposed seismic survey on various sectors of the environment and suggests a series of mitigatory measures for eliminating or minimizing the negative impacts. A detailed analysis of the impacts show that most of the adverse impacts are likely to be on the fish and other forms of aquatic organisms, and therefore, the REIA suggests detailed guidelines on preventing any damage to the aquatic fauna by taking necessary precautionary steps during the seismic activities.

From the results of the baseline survey and the prediction of the likely impacts, the REIA draws up an Environmental Management Plan (EMP) where the different elements of management including OIL's Health, Safety and Environmental Management Plan (HSEMP) have been highlighted with appropriate guidelines for strengthening the same in order to ensure minimum damage to the environment during the proposed activities. The Impact Assessment assigns a *no impact* or *negligible impact* category when potential effects are not distinguishable from natural variation or when no effects are expected. A number of potential impacts of the project are judged to have no impact or negligible impact. These included impacts due to solid waste disposal, air emissions, and effluents (oily water, domestic and sanitary waste, cooling water, industrial wastewater, etc.) during both preparation phase and operation phase of the proposed activities.

The REIA has taken into account the following key environmental sensitivities while considering the impacts and while formulating the EMP:

Key environmental sensitivities

- The Brahmaputra River, one of the major rivers of the world, is the lifeline of Assam and the northeastern region of India. The people of Assam are sentimentally linked with the River from ancient time and many people worship the River while others consider a dip in the River as a sacred duty.
- The island, Majuli, the largest river island in the world is the seat of Vaishnava religion, culture and tradition as propounded by the great saint, Sri Shankaradeva and has been now considered as a World Heritage Site.
- The Brahmaputra is the home of the famous Gangetic dolphin and also the freshwater turtles. Besides, it is very rich in fish and other aquatic organisms.

Summary of Impacts

The proposed project has the potential to affect a number of different receptors/resources during the operation of the project. However, most impacts could be reduced to *minor* significance after effective mitigation measures.

For some of the impacts judged to be moderate (disruption of habitat, increased turbidity), no mitigation measures are recommended or necessary because the same are not possible or practical given the low magnitude of the predicted effect, or the environmental management measures built into the project.

Impacts of some project activities are judged to be major, and mitigation measures are developed to reduce the predicted impacts to moderate or negligible extent. The major impacts are predicted as follows:

- During the preparation and operation phases of the project, a large number of boats and other vessels, including hovercrafts will be in the project area. Collision with bigger aquatic animals could affect the survival of the entire population.

- Noise and vibration from the boats and vessels in general and air guns in particular could have various physiological, behavioural and other effects on the aquatic organisms, may affect the feeding areas and may result in disruption of feeding. If feeding is disrupted for sufficiently long, the condition of many individuals could be adversely affected, leading to population-level impacts.

Mitigation measures have been developed for each of the major predicted impacts. In all cases, the mitigation measures are judged to be effective in reducing major impacts to moderate impacts. The suggested measures include

- various procedures to reduce noise levels and control vessel movements to avoid collisions,
- a ramp-up procedure to allow the species to temporarily migrate from the actual operating zone,
- the use of shipboard observations by experienced Qualified Wildlife Observers to ensure that precautions are taken if the River Dolphin or Turtles are sighted in the vicinity of the actual operating area of air guns,
- immediate stoppage of activities if migration appears to be blocked or feeding appears to be interrupted, and any fish-kill, abnormal behaviour, etc. are noticed.

Monitoring programmes as part of the Environmental Effects Monitoring have been suggested to be undertaken both during the actual operation phase and after the activities cease completely. These, in particular, will include

- surveys of species distribution,
- behavioural studies,
- photo-identification of individuals,
- studies of the distribution and composition of the prey species, and
- acoustic measurements of ambient noise.

These monitoring plans will allow assessment of the extent to which mitigation measures have been effective, with a view to making adjustments if necessary.

The effectiveness of all the above measures will depend on the strict implementation of the EMP. A detailed mechanism for a functioning EMP with various responsibilities being well defined and a structure being installed for reporting of any accident, etc., and quick redressal has been suggested as part of the EMP. Public consultation has been an important feature of the EMP and at all stages of the project, a detailed mechanism for informing and consulting the people and Government and non-government organizations has been suggested.