3 DISASTER MANAGEMENT – RECENT TRENDS

Structure

3.1 INTRODUCTION

Disasters have been increasing in frequency and intensity over the past few decades. This has been directly linked to the nature and extent of human activities taking place in erstwhile natural surroundings. Human populations are settling in areas hitherto left untouched due to those being declared hazard prone. This trend of increasing disasters has necessitated changes in the disaster management systems too. The trends in disaster management can be studied with reference to vulnerabilities of specific regions in India and the requirements of disaster management in those areas, viz. the Himalayan regions, the Riverine regions and the Coastal regions. The chief emerging requirement in disaster management is sustainable development practices, factoring vulnerabilities of each specific geographic region in development policy. In this Unit, an attempt is made to apprise the learners with the recent general trends in disaster management, which pertain to all disasters- natural and man made- affecting us today.

3.2 DEVELOPMENT PERSPECTIVE TO DISASTER MANAGEMENT

Member States of the United Nations and other States met at the World Conference on Natural Disaster Reduction, in the city of Yokohama, Japan, from 23 May to 27 May 1994, in partnership with non-governmental organisations, international organisations, the scientific community, business, industry and the

media to deliberate within the framework of the International Decade for Natural Disaster Reduction, on immense human suffering that has been incident over the past years, globally, owing/due to natural disasters. It acknowledged increasing human vulnerability to disasters, especially of the poor and disadvantaged groups that are least equipped to cope with crises of such serious magnitude. The *correlation* between disaster prevention, mitigation, preparedness and relief with sustainable development policy in general is only too evident to be any longer overlooked. Hence, the three interrelated concerns of disaster management, (encompassing mitigation, prevention and preparedness), environmental protection and sustainable development need to be *simultaneously addressed* through 'all- encompassing' policy in this regard, for protection of life and preservation of development in the short run and more importantly, for future generations over the long run. Therefore, nations have to rework development strategy to some extent to incorporate these concerns in mainstream development planning, since these have hitherto been addressed as contingent measures, not mainstream measures that are treated consistently through adequate policy responses in this regard on the part of governments. There is another significant ramification to disaster management, which needs to be taken cognisance of. The need for international cooperation for integrated action to combat the threat could not be understated. Since natural disasters are not limited by natural boundaries, regional and international cooperation is imperative to build capacity of governments at regional/global scale(s) to combat the threat concertedly. Particularly, technology transfer to developing countries by the developed to build capacity to fight disasters was emphasised as an imperative in the conference. To that end, bilateral and multilateral assistance and financial resources need to be mobilised by developed countries to support the efforts of developing countries towards disaster preparedness and mitigation. Hence, technology transfer to developing countries along with corresponding training should be attempted as a necessary requirement in concerted disaster management.

Experience with natural disasters over the past few years has led to the realisation that disasters are not one off events, rather a result of concretised vulnerabilities, which need to be addressed/treated over time through sustained public policy in this regard. *Positive correlation* has been unearthed through empirical researches between disaster vulnerability and socio-economic disadvantages stemming from adverse social positioning due to poverty, unemployment, lack of access to basic facilities like education, health and hygiene, as has been experienced in recent experiences with disasters.

While disaster response is limited to short- term relief, long-term strategy is imperative to curb disaster losses over time, by way of reducing vulnerabilities of disadvantaged sections; women, children and the disabled in particular. The same is achieved through building community resilience by way of targeted offensive at particular debilitating factors such as poverty, unemployment and other forms of social and economic deprivation, which create/increase susceptibility to losses. *Prevention* aims at nipping disaster potential in the bud, hence is essential for safeguarding development. Hence, disaster vulnerability can be reduced overtime through planned interventions towards building resilience through public policy. This necessitates *consistent* attempts at vulnerability reduction through plan budget allocations for disaster mitigation with a view to integrating disaster management with mainstream development planning.

In its tenth year of publication, The World Disasters Report, 2003, brought out by the International Red Cross and Red Crescent Societies, called for disaster risk reduction targets to be added to the international development goals for 2015 and beyond. These targets could include reducing by half, the number of people killed and affected by disasters and increasing the number of governments with dedicated plans and resources for risk reduction programs.

The World Disasters Report, 2003 contains criticism of over-reliance on high-profile aid operations, to save lives when long-term investment in disaster mitigation at the local level have proven to be much more effective. No international aid effort was necessary when the worst hurricane since 1944 hit Cuba in 2002, but only five people died. Local mechanisms were in place to evacuate 700,000 people from Havana and other threatened areas. Of the 53,000 people rescued from the floodwaters in Mozambique's two great floods, local people saved 34,000.

Building Community Resilience: Stress on Social Capital

The follow up report, that is, the World Disasters Report, 2004, published by the International Federation of Red Cross and Red Crescent Societies has 'community resilience' as its central theme. Community involvement and active participation in vulnerability reduction efforts are being emphasised as essential strategy for effective policy towards vulnerability reduction. The Report notes that, building community resilience for coping with disasters is the right strategy to adopt, instead of misdirected international aid, most of which does not reach the needy. It has been seen that people have been able to survive most adverse conditions on the strength of their capacities. Therefore, the aid community is advised to concentrate on the *capacities* of the vulnerable communities rather than their *vulnerabilities* and aim at building/reinforcing the same as part of practical strategy to counter- effect vulnerabilities and help people successfully combat disasters. In the same vein, the Report calls for dispelling the myth of *helpless* victims; hence, the requirement of study of the resources and resilience of vulnerable communities to discover ways to augment them to further facilitate/strengthen self- help on the part of *at risk* communities. In Swaziland, HIV/AIDS and drought are endemic. But Chief Masilela informed Red Cross that his community would prefer irrigation and seeds, not food aid, to grow crops, craft their own recovery and retain their dignity. A woman in Mumbai, to quote another instance, has chosen to reside in a low cost dwelling in a flood prone area because that would leave her money to finance her daughter' education (World Disasters Report, 2004).

This is following realisation of the fact that active cooperation of communities is vital for achieving real gains in both policy formulation and implementation. Synergetic partnership between the government and people is essential to have a clear understanding, for instance, of the cultural characteristics and organisational requirements in different societies/situations, respectively and accordingly, specific policy requirements, as per assessed particularities/peculiarities, following insights into a society's behaviour and its interactions with the physical and natural environment, for example, shifting cultivation among tribes in North-East or burning firewood for cooking among tribal communities and poorer segments generally, which were recently indicted as major causes of global warming. This is envisaged as a practical strategy to target vulnerabilities through 'relevant' policy, based on articulate concerns by people themselves, in keeping with the particular requirements of that place. The same is crucial for the success

of any policy measure, particularly planned strategies for environment protection, where community involvement has proven to be a necessary requirement.

There is need for awareness of the fact that unplanned urbanisation is creating newer risks. It creates a case for general upgrading of administrative services as a long-term mitigation strategy, particularly building capacities at the local level with active participation of the people, since, as borne out by experience, national, or even international interventions are likely to be less effective in tackling persistent problems like poor schools, poor quality housing, sanitation, drainage, etc. The same has been realised in successive experiences with disasters around the world, particularly, during the Bam (Afghanistan) Earthquake, when 34 search-and-rescue teams from 27 countries flew to the city and saved 22 lives but, meanwhile, local Red Crescent teams pulled 157 people alive from the rubble, using far fewer 'sniffer' dogs. *Investing in local response capacities therefore saves lives and money;* which is the main inference (Ibid).

Post- Modern Trends

Post-modern cultural values premised on *democratic pluralism* and *quality of life* is gaining credence in the post-industrial society facing the ills of development. It is a political science concept that marks a sharp breakaway from earlier approaches towards governance and towards life in general, so much so, that it could be termed revolutionary. Precisely, the trend is towards people-centered governance, which is *participatory* and accountable, public policy oriented towards sustainable development, in that *pluralism* and *decentralisation* are especially espoused virtues; in fact, preconditions for democratic governance, as is 'diversity' in all its forms which should be factored in public policy, as a necessary requirement for/in good governance. The chief divergence in post-modernism from earlier approaches is, that aesthetic and spiritual aspects of life are being emphasised against purely material. In the same vein, protection of ecology is the central theme in sustainable development. Apart from secular policy, post- modern influences can be discerned in religious and cultural spheres as well. It is chiefly manifest in the West's changed attitude towards 'indigenous cultures' which is different from the insistence on 'the one right way', which was presumably Western. In disaster management accordingly, the trend is towards respecting indigenous resilience strategies and even construction methodology, which is in line with post modernism. Merit is being recognised in traditional building knowledge such as in Marathwada, India. Malwad (timber under structure) constructions offer several good examples of stone masonry. Many traditional artisans possess skills in traditional building techniques such as good quality stone masonry construction, which withstands earthquakes reasonably well. Common practice is to discard local knowledge as inferior/unscientific. However, following studies in indigenous practices, there is increasing 'voice' for incorporating the same in modern engineering knowledge to find lasting solution to physical vulnerability of infrastructure in disaster prone areas (Jigyasu, 2002).

For organisational theory, post-modernism implies a shift of emphasis towards teamwork rather than strict stipulations of hierarchy with undesirables like status differentiation, monolithic order *et al;* cooperation rather than compliance, participatory management rather than monocentric order, peoples' participation, especially regarding choice in service provisioning, etc. To reiterate, this applies to both secular and religious organisations. This is partly a result of growing suspicion towards monocentric authority whereby public and private interests are often confused/diffused; former unknowingly acting as a camouflage for the latter

and similar suspicions, not wholly unfounded. Post modernism argues for more 'political space' for articulation of myriad concerns which in practice make up public interest. Post-modernism, in one word, epitomises harmony/balance in the physical, cultural, material and spiritual senses.

Sustainable Development

Akin to the spirit of post- modernism, sustainable development, in simple words, means development that can be sustained over time, implying, benefit to the present as well as future generations. This virtue would obtain only if development has been 'balanced' with respect to *other/related* concerns. For example, a dam would lead to power generation, which is its central purpose. But public policy would demand consideration of ancillary/related issues, or 'other concerns' such as impact on ecology, displacement of population, socio-economic impact of proposed measure, etc., which would ultimately count in/decide its success. The Brundtland Commission (1987) defines sustainable development as "development, which meets the needs of the present without compromising the ability of future generations to meet their own needs".

According to H. Ramchandran (1990), sustainable development is the latest 'end' in a linear continuum of growth concepts. Understanding of development has progressed from the "simple but nebulous notion of *progress* to *growth* (of GNP), to *growth with equity* in vertical and horizontal dimensions, to the *physical quality of life* and currently to *sustainable development* or *eco development*." The latter concepts have added to the former ones, not replaced them and hence have developed as inclusive ideas adding newer dimensions to the understanding of sustainable development. Thus the concept of sustainable development encompasses all previous ideas, viz. growth, equity, etc., with the added dimension of sustainability for *future use*. Sustainable development has both *ethical* and *utilitarian* value in that preservation of environment is as much a duty of the present generations as a right for future generations, to lead disease free and accidents/disaster free lives and touch higher levels of economic development.

Sustainable development is also a *generic* idea/concept in that development *per se* could be appreciated, applying the premise of sustainability. This broad understanding is credited to social science theorists who are increasingly evaluating policy outcomes on the basis of its *viability* in the cultural, political, socio economic senses. To elucidate, globalisation has cultural impact, besides economic and political, which needs to be studied to understand its potential for apocalyptic change to then question its desirability. The question would be; is a particular change sustainable? Context could be given here of welfare economics, where gainers and losers from/in each proposed measure, are identified to compute *net social welfare* derived/proposed from the measure. All ramifications of policy viz. political fallouts, economic impact, pertaining to distributional aspects, impact on ecology etc. is considered/possibly measured to judge the sustainability, hence, desirability of a measure.

Science and Technology for Disaster Management

Currently, the *All Hazards Approach* is being emphasised in America as a holistic strategy to combat disasters. The understanding that underlines this approach is that all disasters, irrespective of type can be dealt with on the basis of common knowledge/expertise based on academic researches and preparedness, based on information derived thus and constant updating of such knowledge. Its chief

reliance is on science and technology for capacity creation. It relies on creating capacity through R&D in science and technology to deal with any and every kind of disaster(s), ranging from earthquake to terrorism, based on and converting R&D to practice readily to attempt new and innovative ways to deal with crises, whether natural and/or man made. For this purpose collation of science and technology expertise scattered across institutions within the aegis of a single agency is necessary that acts as clearing house as well as a coordinating agency with respect to myriad disciplines/ concerns, even within science involved in disaster management.

This approach lends a fresh perspective to disaster management in that policy in this regard, never at any stage, suffers from redundancy. Disaster management requires a multidisciplinary approach, hence, the need for a single coordinating/overseeing agency.

The Sub-Committee on Disaster Reduction (SDR) of the National Science and Technological Council (NSTC) in the United States (2003) has articulated six important areas that require continued energy and appropriate resources to meet the challenges of hazard risk reduction. The same may be pertinent for all countries facing the threat of terrorism, which is the single most horrifying disaster possibility in recent times.

1) Leveraging existing knowledge of natural and technological hazards to address terrorism events
2) Improve hazard information data collection and prediction capability
3) Ensure the development and widespread use of improved hazard and risk assessment models and their incorporation into decision support tools and systems.
4) Speed the transition from hazard research to hazard management application
5) Increase mitigation activities and incentives
6) Expand risk communication capabilities, especially public warning systems and techniques

Kenneth Bloem of the Johns Hopkins University Center for Bio-Defense Studies has identified a number of parallel streams where preparation for terrorist incidents can be enhanced by decades of research in traditional disaster areas:

- Wildfires and Arson
- Accidental explosions and bombs
- Floods and dam sabotage
- Chemical spills and chemical attacks
- Epidemics and biological terrorism

Ultimately, effective public policy for disaster management is a result of deliberation/cooperation between scientists, decision makers and informed citizens. It should also be remembered that limiting disaster management to a technocratic perspective would exclude many pertinent issues that fall within the domain of social sciences, for example, greater relative vulnerability of the poor and the socially marginalised.

3.3 DISASTER MANAGEMENT IN MOUNTAINOUS REGIONS

The Himalayan range is one of the highest mountain chains in the world. Himalayas, also known as the Extra-Peninsula, are one of the three main geological divisions of India. The other two divisions are the Peninsula and the Indo-Gangetic Plains.

Geographically, the Himalayas extend for about 2400 km, from western Syntaxial bend-near Nanga Parbat to eastern Syntaxial bend-near Namcha Barwa, and exhibit a curvilinear disposition.

The Himalayas are classified, from west to east, into four regions:

i) Punjab Himalaya - area between Indus and Sutlej rivers.

ii) Kumaon Himalaya - area between Sutlej and Kali rivers.

iii) Nepal Himalaya- area between Kali and Tista rivers.

iv) Assam Himalaya- area between Tista and Brahamputra rivers.

Presently, Himalayas are divided into three regions: the Western, Central and Eastern Himalaya. Nepal Himalaya constitutes the Central Himalaya and the mountainous area to its west and east are known as Western and Eastern Himalaya respectively. Thus the Western Himalaya includes Punjab and Kumaon Himalaya covering Himachal Pradesh and parts of Jammu and Kashmir, and Uttaranchal.

The Uttaranchal Himalaya extends from Tons river in the west to Kali river in the east and covers an area of about 46,480 sq.km. Garhwal and Kumaon are the two main regions of Uttaranchal Himalaya.

Major landforms of Uttaranchal Himalaya are arranged in three parallel ranges:

i) Great Himalaya (GH) lies south of Tibetan Plateau and contains the highest elevations.

ii) Lesser Himalaya (LH) lies south of GH and has elevations between 10,000 and 15,000 ft.

iii) Outer Himalaya (OH) lies south of LH and borders Gangetic Plain. Altitude varies between 2000 and 3000 ft. and has geomorphologic depression-the Dun.

Himalaya, in Uttaranchal, can also be divided into four broad geological zones, each having distinct geological history. These are:

i) **Tethys Himalaya Zone (THZ)**: exposes mainly fossiliferous rocks of Phanerozoic and lies north of the central axis (line of highest elevation of CH)

ii) **Central Himalaya Zone (CHZ)**: contains crystalline and metamorphic rocks which are thrust over the sedimentary sequences of lesser Himalaya along the Main Central Thrust (MCT)

iii) **Lesser Himalaya Zone (LHZ)**: exposes largely sedimentary, unfossiliferous sequences of Proterozoic period, which are disposed in distinct tectonic belts between the MCT and Main Boundary Fault.

Fossiliferous rocks of Palaeozoic, Mesozoic and Cenozoic periods have very limited extent.

Regionally metamorphosed rock masses occur as Klippe.

iv) **Outer or Sub Himalaya Zone (OHZ):** This is the southern most zone and exposes sedimentary sequence predominantly of Neogene period. The OHZ lies between MBF and Foot Hill Fault (FHF). FHF is the boundary between the outer Himalaya and Gangetic Plain.

Hazards in the Himalayan Eco-System

The Himalayan region, characterised by a wide variation in topography, geology, soil, climate, flora and fauna and various ethnic groups having different socio-cultural traditions, is a unique geographical entity. All major types of disasters, prominently, earthquakes, landslides, avalanches, flash floods and forest fires, and soil erosion hit this region. In high altitude regions (over 3500m), snow avalanches and glacial lake outburst floods (GLOFs) are common threats while flash floods; landslides and mudflows assume disastrous dimensions in the altitude range from 500 to 3500 m. (Bahadur, 1998).

The Himalayan region with soft weathering rocks, covered with a thin layer of soil is becoming increasingly susceptible/ sensitive to landslides. Such landslides cause disruption, create blockades in the road network and river system, which in turn, cause floods. Interference in the environmental system in the form of indiscriminate chopping down of trees has disrupted the ecological balance, thereby resulting in loosening of the soil and consequent soil erosion and frequent landslides. Over a period of time the eroded soil begins to settle down on the riverbed resulting in shifting of the river. This is one of the major reasons for floods.

A very befitting example in support of the above statement is the *slash and burn* cultivation technique called 'JHUM,' which is practiced in the hilly areas. Development of the communication system by means of road construction and mining of rich mineral reserves over a period of time has destroyed the dense natural evergreen forest cover.

Report of 'The Central Team on Landslides in Hill Areas of Uttar Pradesh' during 1998 indicates the damages caused due to hailstorms, heavy rains and the resulting crop damage in the state during the months of May to September 1998. The report observed that the Himalayan ecology is extremely fragile and falls under Seismic Zone V. Another problem is the rapidly growing urban centers within the Himalayan belt being important tourist basins, both nationally and internationally. They have grown rapidly, often with very little attention to building by-laws and planning principles, which are almost non-existent at this point!

Other main causes for the landslide have been unplanned and unscientific development activities in the hilly areas, unchecked organised crime that is involved in illegal felling of trees, poaching, mining, quarrying, construction and urbanisation which have caused ecological imbalances in the Himalayas. Increasing pressure of human and animal needs, rapid denudation, biotic interference etc. have further aggravated the problem of soil erosion, avalanches, flash floods etc.

Every year, landslides in the region kill dozens of people and cause widespread damage to several villages such that they have now become almost unfit for habitation. Landslides have caused havoc and the terraced fields have been destroyed that cannot be easily renovated or made productive again. The road network remains closed for long periods causing indescribable hardship to the villagers who get their basic supplies and provisions from the neighbouring areas. The water source is also disrupted due to landslides as they are breached from several places and are choked by the debris. The sediment load of rivers has also increased considerably, causing problems like irregular courses and frequent breaching of the banks, which create uncertainty regarding the river course and unexpected floods. More so, the water channels are affected from the up hillside due to which the villagers are devoid of water for irrigation purposes. This adversely affects agriculture production in the region.

As explained by Jagdish Bahadur (1998), related problem is that of soil erosion. The large fluctuation in temperature during the annual cycle generates a severe freeze - thaw cycle resulting in greater erosion of soil and rock formations. Another important factor for excessive soil erosion is very intense monsoon rainfall (from a few hundred mm to thousands of mm in 24 hrs.). Measured sediment yields range from less than one ton/ha/year to over 100 tons/ha/yr. It is normally assumed that the sediment yield of Himalayan rivers is about 16.4 ha.m / 100 km^2/yr, which is about three to five times higher than the value assumed by the designers of water resource storage projects. These estimates are not totally representative of the sedimentation regime and represent only the *suspended sediments*. No quantitative estimates are available for *bed load sediments*, which play an important role for high mountain turbulent streams. Hence, we have to develop strategies for sediment harvesting (seclude sediments for other uses) for efficient water resources management for harmonious development of the region.

The region's agriculture and power generation are fully dependent on the freshwater supply fed by the discharges of the Himalayan glaciers. In the Ganga river only, the loss of glacier melt water would reduce July-September flows by two thirds, causing water shortage for 500 million people and 37 percent of India's irrigated land. Perennial rivers could be changed into seasonal streams giving rise to freshwater scarcity in the summer months when melt waters contribute the bulk of the water (around 75%) to the Himalayan Rivers.

Several glacial lakes have been formed as a result of glacier retreat due to raised temperatures, which could lead to catastrophic events like glacial lake outburst floods (GLOF) in valley's downstream, resulting in destruction of valuable resources such as forests, farms, costly mountain infrastructures and even human life. GLOFs can have devastating consequences for civil works, like bridges, dams and powerhouses, and communities living downstream.

In order to manage the impacts of climate change on glaciers, the nature of these impacts with respect to individual glaciers or drainage basins needs to be studied and understood. In the Himalayas, although there has been research at a large scale on glacier retreat there has been no work at the scale of the individual glacier or drainage basin and so current research is too general to drive policy response (WWF, 2005). Adoption of appropriate soil and water conservation practices on a watershed basis is considered to be the only way to control soil erosion and improve the environment in the mountainous regions. The measures are to be adopted in conformity with the concept of integrated land use planning for development and improvement of catchment and command area. Efforts must

be directed towards utilising the maximum amount of rain to meet the human, animal and crop needs and at reducing to the minimum, the damage by floods and soil erosion. Excess water should be stored in the catchments areas, which will reduce the fury of flash floods, recharge the ground water and improve the environment. Runoff collection ponds in the catchments, though they might get silted up in a few years, will be more useful than the measures in the lower reaches. To prevent rapid siltation of tanks, the contributing catchments (even if they are not cultivated but used for grazing or forestry purposes) need to be well managed so that soil erosion is prevented. All common lands should be put under fuel/fodder trees. Planting of barren areas, especially on slopes, with grass cover is an important component of integrated watershed management programme. Grazing should be completely restricted. After the area is completely protected from grazing, better grasses can be planted. The grasses of industrial importance should also be planted so that there is some economic return to the farmers as well. The surface vegetative cover will not only protect the land from the beating action of rain drops and bind the soil particles but would also decrease the velocity of flowing water and cause less of soil erosion (Bahadur, 1998).

Availability of fresh drinking water is another problem in the region. Increasing urbanisation in the area is putting added pressure on water resources, and not much is being done to replenish the depleting resource. There is no detailed scientific evaluation available for Himalayan water resources. According to Jagdish Bahadur (1998), this is partly due to *insufficient network of observations* for both *precipitation* and *stream discharge* measurements.

Both saline and freshwater natural lakes exist in high altitude regions. Saline lakes abound in the arid region while those lakes, which are extremely poor in electrolytes, are abundant in the humid region, being nurtured by the monsoon. These lakes are situated at altitudes varying from 600m to 5600m and are exposed to climatic conditions that vary from cold deserts of Ladakh to wet humid of Manipur. Very few studies are undertaken on the Himalayan lake ecosystems and the water management programmes are either completely lacking or grossly inadequate (Zutshi, 1985). The inflow of high silt load from glaciers is gradually filling these lakes and rendering the lake waters turbid and unfit for biological activity. The other impact is from pollution from agricultural, industrial, and human and cattle wastes. Restoration plans for the lake systems should be undertaken on ecological considerations following their geophysical environment and annual rhythm in chemical and biological compositions.

To achieve these objectives, the following essential elements for action are considered necessary, as per Jagdish Bahadur (1998):

i) All efforts should be made for proper assessment of water resources.

ii) A comprehensive framework for water resource management is considered in preference to sectoral approach.

iii) Interventions in water sector should move from curative to preventive ones.

iv) A broad range of investments should be made on a continuous basis with ability to operate and maintain investments effectively.

v) Infrastructural improvements must be complemented with measures to strengthen institutions, develop human resource and promote public awareness.

vi) Promotion of water user's associations and increasing user participation.

vii) The participation of the private sector in water management should be deliberately pushed forward.

The Fire Menace

Protection of forests is equally important. According to a Forest Survey of India Report, about 50 percent of forest areas in the country are fire prone (ranging from 50 percent in some states to 90 percent in the others). About 6 percent of the forests are prone to severe fire damage). The coniferous forest in the Himalayan region comprising of fir (*Abies* spp.), spruce (*Picea smithiana*), *Cedrus deodara, Pinus roxburgii* and *Pinus wallichiana,* etc., is very prone to fire. Every year there are one or two major incidences of forest fire in this region. Other areas with deciduous varieties have also shown susceptibility to fire.

The ecological and socio-economic consequences of wild land fires in India include loss of timber, loss of bio-diversity, loss of wildlife habitat, global warming, soil erosion, loss of fuel wood and fodder, damage to water and other natural resources, loss of natural regeneration, losses in productivity of the land, impacts on regeneration of species; and deleterious impacts on water shed also result from forest fires. Estimated average tangible annual loss due to forest fires in country is Rs.440 crore (US$ 100 million approximately). In India, there are no comprehensive data to indicate the loss to forests in terms of area burned, values, and volume and regeneration damaged by fire. One reason to account for the same is alleged fear of accountability on the part of the forest department, and hence deliberate understatement of the problem.

According to the Constitution of India, the Central and State governments in the country are enabled to legislate on forestry issues. The implementation part of the forest policy/programmes lies with the state government. Thus, fire prevention, detection, and suppression activities are the responsibility of the state governments' forestry departments. The policy, planning, and financing are the primary responsibility of the Central Government. There is generally no separate department for carrying out forest fire management in the states. The regular staff of the forest department in the states carries out various activities of forest fire management. During forest fire seasons, in some of the divisions, the state governments recruit firewatchers as a special provision. At the central level, the Ministry of Environment and Forests is the ministry responsible for forest conservation and protection. The "Forest Protection Division" of the Ministry, which is headed by a Deputy Inspector General of Forests, administers Forest Fire management. The Ministry is implementing a plan called *"Modern Forest Fire Control Methods"* in India under which state governments are provided financial assistance for fire prevention and control. This assistance is being used by the state governments for procuring hand tools, fire resistant clothes, fire fighting tools, radios, fire watch towers, fire finders, creation of fire lines, research, training, and publicity on fire fighting. This project is carried out in fourteen states and covers more than 70 percent of the forest area of the country.

Community Involvement

In India, Joint Forest Management (JFM) Committees have been established at the village level to involve people in forest protection and conservation. At present, there are 36 165 JFM committees throughout the country, covering an area of more than 10.24 million hectares. These JFM committees also have been given responsibilities to protect the forests from fires. For this purpose, the

Modern Forest Fire Control plan is being revised and JFM is being made an integral component of the forest fire prevention strategy.

The incidence of forest fires in the country is on the increase and more area is burned each year. The major cause of this failure is the piecemeal approach to the problem. Both the national focus and the technical resources required for sustaining a systematic forest fire management programme are lacking in the country. Important forest fire management elements like strategic fire centres, coordination among Ministries, funding, human resource development, fire research, fire management, and extension programmes are missing.

Taking into consideration the serious nature of the problem, it is necessary to make some major improvements in the forest fire management strategy for the country. The Ministry of Environment and Forests, Government of India, has prepared a National Master Plan for Forest Fire Control. The thrust areas in the programme would be (Bahuguna &Singh, 2002):

- Prevention of human-caused fires through education and environmental modification. It will include silvicultural activities, engineering works, people participation, and education and enforcement. It is proposed that more emphasis be given to people participation through Joint Forest Fire Management for fire prevention.
- Prompt detection of fires through a well-coordinated network of observation points, efficient ground patrolling, and communication networks. Remote sensing technology is to be given due importance in fire detection. For successful fire management and administration, a National Fire Danger Rating System (NFDRS) and Fire Forecasting System are to be developed in the country.
- Fast initial attack measures.
- Vigorous follow up action.
- Introducing a forest fuel modification system at strategic points.
- Fire fighting resources.

Non-timber forest products such as medicinal plants and herbs, essential oils, fibres and silks, natural dyes and organic products, off-season vegetables, bamboo and bamboo products, bees and bee products, and enterprise-based pollination services can provide the basis for increasing incomes and improving livelihoods. Likewise, mountain tourism, hydroelectricity and other renewable energy sources, and the potential for obtaining reimbursement for environmental services, including carbon sequestration, have demonstrated the capacity to become drivers of local economic growth if structured in ways that empower local communities and poor households (Campbell, ICIMOD, 2005).

There is need to adopt a combination of traditional and modern control measures adopting bioengineering techniques for sustainable development. Integrated long-term planning is needed with local participation as an essential development strategy for water resource development of the tallest water tower of the world (Bahadur, 1998).

According to R.B. Singh (2005), some portion of money earmarked for relief should be spent in water management practices like creating storages and water harvesting structures in the upper reaches of the stream. Though floods in the region cannot be controlled for hydro-meteorological and topographical realities,

such measures can modify them to a large extent so as to minimise loss of life and property in the region. Drought and flood proofing programmes with satellite data for hazard zoning, survey of past disasters, and damage assessments etc. are important strategy.

3.4 DISASTER MANAGEMENT IN RIVERINE REGIONS

Several areas in the Hindu Kush Himalayan region (HKH) face flood disasters almost regularly. In particular, floods affect the Ganges, Brahmaputra, Meghna, and Indus flood plains every year. This region contains one of the highest concentrations of people in the world, with a high rate of poverty; population growth has increased the vulnerability to flood disasters. Flooding is a part of the growing spiral of poverty. Economically disadvantaged people move to the flood-prone lowlands because of certain advantages like fertile soil, cheap housing and also because they lack other options. At the same time, they lack the resources to respond to and recover from floods. Communities living in the great plains of India that spread across northern, western and central parts of the country, also including inland parts of the larger coastal states, are vulnerable to a host of disasters.

Floods are also a macro concern in that they constrict socio-economic development opportunities by adversely affecting investment in agriculture, infrastructure, and industrial production and also retard development. Hence, flood management is essential both for survival and for long-term growth (SAF, 2005).

As per the *Expert Group Report on Employment submitted to the Ministry of Urban Affairs in 1998*, losses from floods are exacerbated by poor drainage infrastructure, which are choked during heavy rains due to refuse disposal. This creates a situation referred as, local flooding. The India Meteorological Department has worked out the probable maximum precipitation values for different areas, which are worked out on the basis of observation/computation in 24 hrs. Drainages and embankments, which often breach during heavy rainfall, should be designed keeping in view the probable precipitation values. A Vulnerability Atlas has been prepared which shows hazard vulnerability in different areas. Flood prone areas are marked 'protected', where protective measures such as embankments have been provided. The unprotected areas are high-risk areas where no such effort has been undertaken. Even in protected areas, though, engineering attempts are put to the real test only when actual flooding takes place. In Punjab heavy damage was incurred in 1995, when the Sutlej flooded large parts and embankments usually gave way. The crisis gets worse in coastal areas where flooding is coupled with storm surges and heavy wind velocities, which exacerbates the risks manifold. Other vulnerable regions are the depressions or the poorly drained areas, which are subject to back-flow from flooded rivers, catchments of choked drains etc., which have random risks of flooding due to heavy rains. For identification of such areas, contour surveys are required at the micro level.

Regarding flood hazard, there is emerging consensus that structural mitigation measures have limited utility. Hence, the emphasis is now on non-structural mitigation measures, particularly flood monitoring and forecast, besides creating awareness among people regarding their vulnerable status, significance of following warnings, easy modes of information dissemination regarding

impending disasters, institutionalisation of social capital for better preparedness and so on.

It is most important to remember that natural disasters are not limited by/to national boundaries. For effective combating the threat, regional cooperation is needed. As yet, however, there is no regional framework for such multilateral exchange, although there are successful examples of agreements for bilateral exchange of data. Particular concern was voiced during the Second Steering Committee Meeting of the hydrological research network HKH-FRIEND (Flow Regime From International Experimental Network Data, part of UNESCO's International Hydrological Programme) held in April 2000 in Kathmandu. A regional flood information system is being set up for the Hindukush region. A number of agencies are involved, prime among whom are, the World Meteorological Organisation (WMO), supported by the US Department of State (Regional Environmental Office of South Asia), US Office for Foreign Disaster Assistance, and DANIDA. The scheme will benefit Bangladesh, Bhutan, China, India, Nepal, and Pakistan, who have agreed on an initial Action Plan for Regional Co-operation for Flood Information Exchange (SAF, 2005).

Apart from flooding, the other major problem is availability of fresh water. According to R.B Singh (2005), most people in the region do not have access to safe drinking water. Pollution is major concern and there is great biodiversity loss, both on land and in the inland waterways. Because of erratic rainfall and unequal distribution across regions, many districts in Haryana, Uttar Pradesh, West Bengal and Bihar suffer frequent droughts.

Hence, while on the one hand there are floods, increasingly now, because of global warming induced retreat/melting of glaciers in the Himalayan region; there is a situation of water scarcity in cities like Delhi, to an extent where water riots could ensue! Besides, glacial retreat would reach a point glaciers subside and run off decreases. Hence flood control and water conservation, along with concrete steps, through legislation for controlling water pollution and good maintenance of drainage are significant requirements in disaster management in riverine regions.

As per data cited by R.B. Singh (2005), the average run off in the river system in the country is assessed at 1,869Km^3. Of this the utilisable portion by conventional storage and diversion is estimated, as about 690Km^3.In addition there is substantial replenishable groundwater resource in the country, estimated at 432km^3. Presently, there are two strategies being followed; excess water transfer from surplus to deficit regions through schemes like river linking, and water harvesting, which is, storing water at the place where rainfall occurs. This two-pronged strategy is expected to redeem the flood situation and also replenish aquifers, which have fast receded.

Indian River Systems

The major river systems in the country can be broadly classified into two groups, viz. the rivers of the Himalayan region and rivers of peninsular India. The melting snows and glaciers of the great Himalayan range feed the Himalayan Rivers, during spring and summer, as also by rains during monsoons. They are often uncertain and capricious in their behaviour. They carry significant flows during the winter. On the other hand, the peninsular rivers originate at much lower altitude, flow through more stable areas, and are more predictable in their

behaviour. Their flows are characterised by heavy discharges during monsoons followed by very low discharges during the rainless months.

Nature of Flood problem in various river systems: From the point of view of the flood problem, the rivers can be grouped under the four regions as under:

(a) Brahampurtra region drained by the Brahmaputra Ganga river system

(b) Ganga region drained by the Ganga river system

(c) North West drained by Indus & its tributaries

(d) Central India & Deccan region drained by rivers like Narmada, Tapti

Brahmaputra River System

The region drained by the Brahamputra and Barak and its tributaries covers the state of Arunanchal Pradesh, Assam, Meghalaya, Manipur, Tripura, Nagaland, Northern regions of West Bengal and Mizoram. The tributaries have very steep slopes and shallow braided channels, coarse sandy beds and carry heavy silt. They bring flash floods because of short distances between their source in the hills and the confluence. The major problems faced by this system are that of overspills, drainage congestion, bank erosion, landslides, and aggravation and changes in river course.

Ganga Region

Ganga has a large number of tributaries. Ganga basin with a drainage area of nearly 8,61,400 sq. Km. in India covers slightly more than ¼ of the total geographical area. The tributaries of Ganga are by themselves mighty rivers and most of them are highly flood prone. The northern tributaries of Ganga rise in the hills, some in Nepal, causing most of the flood problems on account of heavy flows and sediment they bring down from the Himalayas. Flooding takes place mainly in Uttar Pradesh, Bihar & West Bengal. In Haryana, the marginal areas along the Yamuna get flooded. Even though flood embankments have been constructed on both banks of the Yamuna, in the territory of Delhi, flooding can occur due to breaches as had happened in 1978. The danger of such flooding has increased, with jacketing of river in the upstream reaches, thus denying the benefit of valley storage.

North -West Rivers Region

Compared to the Ganga and the Brahmaputra river basins, the flood problem is relatively less in this region. The major problem is that of inadequate surface drainage, which causes inundation and water logging over vast areas. However floods are sometimes caused by the Ghaggar River, which used to disappear in the sand dunes of Rajasthan after flowing through Punjab and Haryana. In recent years, besides flooding Punjab and Haryana areas, flooding has become active in Rajasthan also. Jhelum, Chenab and their tributaries also cause occasional floods.

Central India and the Deccan Region

The region does not have very serious flooding problem because the rivers mostly have well- defined and stable courses. In Andhra Pradesh it is confined to spilling by the smaller rivers. Tapti and the Narmada are occasionally in high floods affecting areas in the lower reaches in Gujarat. Godavari and Krishna rivers on the East Coast have acute drainage problem and face flood particularly in the wake of cyclonic storms. The small rivers of Kerala when are in spate, cause

considerable damage. However, in Orissa, damage due to floods has been extensive, caused by the Mahanadi, the Brahmani and the Baitarni which have a common delta where the floodwaters intermingle, and when in spate simultaneously, cause considerable havoc. The problem is accentuated when the flood synchronises with high tides.

3.5 DISASTER MANAGEMENT IN COASTAL REGIONS

India has a coastal stretch of 5700 km. Out of this the east coast bordering Bay of Bengal has a length of 2700 km and the west coast bordering the Arabian Sea has a length of 3000 km. Though India has a long coastline, stretching across many states, the states most exposed to cyclone related hazards, including strong winds, floods and storm surges, are West-Bengal, Orissa, Andhra Pradesh, Tamil Nadu and Gujarat. Destructive natural system events that impact coastal areas can be either episodic or chronic. Together, these types of events define what is meant by natural coastal hazards. The destructive potential of such events is often made much worse by the increasing amount of development along the coastline. A variety of natural hazards regularly threaten the nation's coastal inhabitants. Severe meteorological events such as *Tropical Cyclones* are particularly harsh on coastal areas, often resulting in damages from high winds, storm surge, flooding, and shoreline erosion. *Tsunamis,* whose destructive force is characterised by potentially devastating flood inundation, are uniquely coastal events resulting from offshore sea- bed earthquakes, landslides, or volcanic activity. Coastal locations are also subjected to the impacts of long-term hazards such as chronic coastal erosion, potential sea-level rise, and global climate change. Other hazards impacting coastal areas include biological events such as *Red Tides* and *Harmful Algae Blooms*.

Coastal hazard events can significantly affect or even alter the natural environment, but their impacts are generally not considered "disastrous" unless they involve damages to human populations and infrastructure. Many of the coastal ecosystems that are particularly fragile and sensitive to the cumulative impacts of human development are also naturally fluid and generally capable of adapting to hazard impacts over time. When people and property are not present, hazards are merely natural processes that alter the environment. When people and property are present, however, the impacts of hazards on the developed and natural environments are viewed quite differently. The primary focus is no longer on the natural processes associated with a major hazard event, but instead on the *disastrous results* that can be measured by lives lost, property damages, and economic and environmental impacts. Hazard impacts on the natural environment become more devastating because human development has altered the ability of natural systems to recover from such events. Natural hazard events can also spawn secondary hazards such as sewage releases or hazardous materials spills that are particularly damaging to coastal environments.

Among the main reasons for the continuing increase in the loss levels caused by natural disasters is the continuing growth of the population by unchecked migration of people to coastal areas that are generally more exposed to natural disasters. The development of industry in regions that are subject to natural hazards, without appropriate protective measures, is another reason for the growing increase in the loss levels caused by natural disasters. In Asia, natural hazards cause a high number of lives lost, and relatively small property losses in least developed and developing countries. However, in the relatively developed countries where disaster prevention and mitigation measures are adequately

established, the loss of life is relatively small, but the damage to property is high. Losses may vary even within a country itself. The effect of natural hazards on the loss of human lives is directly related to the poverty levels in a country.

Another factor that exacerbates the effects of natural hazards is environmental degradation, which is taking place in many countries of the region. The damage caused by natural hazards is higher in countries where environmental degradation is rampant. Deforestation, erosion, overgrazing, or over-cultivation and incorrect agricultural practices and degradation of natural buffers amplify the effects of natural hazards. Coral reefs and mangroves are natural protection mechanisms against high-speed winds, which are fast eroding. Restoration of the same can restrict damage from disastrous events to a considerable extent (National Institute of Oceanography).

Requirements in Coastal Disaster Management

Disaster requirements would differ in case of each specific hazard the coastal areas are subject to, which have been referred briefly earlier. Major hazards are Cyclones, Tsunamis, Storm Surges, Coastal Pollution, Coastal Erosion, hazards related to climate change, besides Harmful Algae Blooms and Submarine Mudslides.

For curbing the hazard of *Tsunamis* and *Storm Surges*, the tide gauge data that has regularly monitored tides in the Indian Ocean would be studied to trace past tsunami events and storm surges. Tsunamis have escaped detection, perhaps because of their infrequent occurrence, implying, a long gap between two events, or because of their impact having been low, or because the usual practice of digitising these data at one-hour interval is not enough for capturing tsunamis, which have a smaller period. Hence, a closer analysis of tide gauge data would be attempted to track and possibly predict more vigorous events such as storm surges, cyclones and perhaps, Tsunamis.

Mangroves and forests along the coastlines act as natural buffers against strong winds and storms. These are being referred as bio-shields and their importance has been realised post, recent tsunami. It is, however, necessary to quantify the protection such natural buffer zones, now called bio-shields, provide to coastal habitation. For example, it is necessary to determine the thresholds beyond which they cease to be effective and the extent of protection they provide.

Coastal areas are subject to oil spills. Vulnerability mapping would be needed to identify sensitive ecological zones to plan for emergency and quick evacuation.

To control *coastal pollution*, which has increased with increasing industrialisation of these areas, compliance with EIA (Environmental Impact Assessment) would have to be strictly enforced. There is a need to integrate the results of the EIA studies to generate a national database, and to determine the "carrying capacity" of the coastal waters of India. A beginning towards determining the carrying capacity of Indian coastal waters has been made with the ICMAM (Integrated Coastal and Marine Area Management) and COMAPS (Coastal Ocean Monitoring And Prediction System) programmes, but there clearly is much that still needs to be done.

Eutrophication of waters caused by excessive nutrients, especially nitrogen, leads to potentially harmful algal blooms (HAB). They result in rapid growth of an algal species that contains toxins or causes a negative impact on natural resources or human beings. Though these are natural, pollution exacerbates them. Presently,

there is no database for systematic study of algae blooms, their causes, ways to curb them, etc.

With exploration for oil gaining momentum, offshore structural engineering is gaining importance. The potential threat to such structures from submarine mudslides necessitates engineering design solutions to mitigate the impact. Since poor quality of construction has been identified as one of the causes of higher fatalities due to natural hazards in India, quantification of these hazards must also lead to better regulations and viable building codes.

Besides these, considerable parts of India are multi-hazard prone, in that they might be visited by more than one natural hazard at a time, which poses significant challenge to disaster mitigation policy/strategy. For example, floods and droughts have also been affecting these communities on a regular basis. Floods are experienced almost every year in some state or the other. Major floods were experienced in 1990, 1991, 1993, and 1994. A large number of deaths also occur during summer months due to heat waves, particularly in states like Orissa, that had a drought during 1995-98, and a severe heat wave in 1999. This documentation however mainly covers cyclone disasters and accompanying floods and storm surges (*Ibid).*

Controlling the Cyclone Hazard

Over the warm water (sea surface temperature greater than 26°C) in the tropical ocean, little away from the equator within the belt of 30°N and 30°S, the occurrence of tropical cyclones is almost a worldwide phenomenon. However, their characteristics such as frequency, intensity and coastal impact vary from region to region. But these have been the deadliest when crossing the coast bordering the North Bay of Bengal (coastal areas of Andhra Pradesh, Orissa, West Bengal and Bangladesh), mainly because of the serious storm surge problem in this area.

On an average, about 5-6 tropical cyclones form in the Bay of Bengal and the Arabian Sea every year, out of which 2 or 3 may be severe. More cyclones form in the Bay of Bengal than in the Arabian Sea. The ratio is 4:1. There are two definite seasons of tropical cyclones in the North Indian Ocean. One is from May to June and the other from mid-September to mid-December. May, June, October and November are known for severe storms. The entire east coast is vulnerable to cyclones with varying frequency and intensity. Along the west coast, the Gujarat and Maharashtra coasts are more vulnerable compared to the southern part.

Indian scientists are seriously studying the El-Nino effect on weather and the outcomes of these studies will help in better communication of early warnings as well as preparedness planning.

3.6 TRENDS IN DISASTER MANAGEMENT

Preparedness

One of the many lessons learnt by victims of various natural disasters is that the aftermath of the disaster can be worse than the disaster event itself. Thus, there is a need to acknowledge the need for preparedness towards disaster reduction. However, people are often surprised by the concept of *reducing* disasters. How, it is often asked, can a natural disaster such as an earthquake or a cyclone be *reduced* or *prevented?*

Unfortunately, due to rapid population growth and development of human settlements in disaster prone areas, more and more people and their assets are vulnerable to natural hazards. The number of disasters was three times higher worldwide in the past ten years than in the 1960s, economic losses were eight times higher, exceeding US$ 60 billion a year!

Natural occurrences such as floods, earthquakes, cyclones, etc. simply cannot be avoided altogether; they are a part of the environment we live in. What can be done, however, is to take preventive measures at various levels of society in order to minimise the impact of such natural hazards as much as possible for the people. The impact of a natural hazard can be *reduced*; its worst effects can be *prevented*.

A natural hazard turns into a disaster when it hits a community and disrupts its normal functioning and causes economic damage. Natural disasters hit all, rich and poor alike. But it is the poor who will be hurt most. Protecting the poor from disasters also contributes towards the alleviation of poverty.

The communities actively involved in working on prevention of natural disasters before they strike belong to all groups of society: international and regional organisations, national governments or private firms, local administrations or specialised associations and voluntary organisations.

What is important is to introduce a culture of prevention in all communities, at all levels: action to save lives must be taken before the disaster strikes.

Principles of Mitigation and Preparedness

Disaster mitigation and preparedness activities need to be carried out well in advance of any emergency, and are driven by the following principles:

- Risk assessment is a required step for the adoption of adequate and successful disaster reduction policies
- Disaster prevention and preparedness are of primary importance in reducing the need of disaster relief
- Disaster Prevention and preparedness should be considered integral part of the developmental policy and planning at national, regional, bilateral, multilateral and international stage.
- Early warning of impending disasters and their effective dissemination using telecommunication are the key factors to successful prevention and preparedness
- Preventive measures are most effective when they involve participation at all levels, from the local community to national level to the regional and international level.
- Vulnerability can be reduced by the application of proper design and patterns of development focused on target groups through appropriate education and training
- The international community accepts the need to share necessary technology to prevent, reduce and mitigate disasters, which should be made freely available and done in a timely manner as an integral part of technical cooperation.

Each country bears the primary responsibility of protecting its people, infrastructure and other national assets from the impact of natural disasters. The

international community should demonstrate strong political determination required to mobilise adequate and make efficient use of existing resources, including financial, scientific and technological means.

Preventive Planning

Long-term planning and preparedness for disaster mitigation is gradually being made part of the process of development planning in India. Science & technology inputs constitute its basic thrust, manifested in development of forecasting and warning systems, disaster resistant construction technologies and appropriate cropping systems.

A number of special programs are in operation over many years for mitigating the impact of natural disasters. As the country has been facing natural hazards over centuries, the local communities have developed their own indigenous coping mechanisms. The rich storehouse of this knowledge is our country's proud inheritance. In times of emergencies, spontaneous mobilisation of community action supported by non-government organisations adds strength to national capability towards disaster management.

Accepting the fact that the trend of losses is not indicative of any sign of improvement in spite of initiation of various disaster mitigation measures, the country is planning to lay more stress in some vital areas within this field in the coming years. These include linkage of disaster mitigation with development plans, effective communication system/ use of latest information technology, insurance, extensive public awareness and education campaigns particularly in the rural areas, involvement of private sector, and strengthening of institutional mechanism and international co-operation.

In recent years, the role of the community and of the voluntary sector comprising NGOs has gained significance. It is realised that the best and quickest response to disasters comes from the people on the ground, that is the community and the community based organisations. Preparation and mitigation efforts can, for the same reasons, also work best at community levels. It is for this reason that Community Based Disaster Management is emerging as the most appropriate way of responding to disasters and for preparing for and mitigating the same. Mitigation, prevention and preparedness shall be discussed in detail in subsequent Units.

3.7 CONCLUSION

Disasters have been increasing in their frequency and intensity in recent years. The primary reason for this is the fact that human settlements and activities are interfering with natural systems, and populations are being increasingly exposed to hazards. This can be seen clearly in the Himalayan, riverine and coastal regions of the country, where most of the disasters strike. The disaster management system in India is anchored at the Central Government level, with implementation mechanisms at state, district and local levels. Besides the government, the role of non-governmental organisations, community based organisations and the community are increasingly being recognised as very important.

3.8 KEY CONCEPTS

Eutrophication: Eutrophication is a process whereby water bodies, such as lakes, estuaries, or slow-moving streams receive excess nutrients that stimulate excessive plant growth (algae, periphyton attached algae, and nuisance plants weeds). This enhanced plant growth, often called an algal bloom, reduces dissolved oxygen in the water when dead plant material decomposes and can cause other organisms to die. Nutrients can come from many sources, such as fertilizers applied to agricultural fields, golf courses, and suburban lawns; deposition of nitrogen from the atmosphere; erosion of soil containing nutrients; and sewage treatment plant discharges. Water with a low concentration of dissolved oxygen is called hypoxic (United States Gecological Survey).

Storm Surges: Storms form over warm seas (sea surface temperature should exceed 26 ° C in the Indian Ocean. The frequency of storms is highest in the Bay of Bengal. Though storms are tracked better today owing to satellite and radar remote sensing, there is need for improvement in modeling of storm track and intensity because this is today one of the weakest links in storm-surge prediction. The impact of a storm as it crosses a coast is caused by the surge due to strong winds and low atmospheric pressure, and the high waves riding over the surge.

Submarine mudslides: As on land, mudslides can occur on the continental slopes; apart from the obvious risk they pose to offshore platforms, they can also trigger tsunami (National Institute of Oceanography).

Tsunamis: A Tsunami is caused by vertical displacement of the water column owing to seabed earthquakes, volcanic eruptions, and submarine mudslides. Though they are almost undetectable in the open sea owing to their low amplitude, the tsunami waves can reach heights exceeding 10 m in the vicinity of a coast. The high impact they have on a coast is due to high water velocity and wave height. Tsunami is not as frequent as storm surges along the Indian coast.