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Component-I (B) Description of Module

Items	Description of Module
Subject Name	**Geography**
Paper Name	**Disaster management**
Module Name/Title	Disaster Management for Cyclones
Module Id	**26**
Pre-requisites	
Objectives	• To understand the phenomenon of tropical cyclone • To understand early warning system for tropical cyclone • To acquaint with the disaster management of tropical cyclone
Keywords	

Module 30 Disaster Management for Cyclones

Rationale

Cyclone or tropical cyclone is one of the meteorological hazards which are highly devastating. Having extensive coastlines in the peninsular area, India is vulnerable to tropical cyclones to a great extent. In the past, India has faced several devastating tropical cyclones. Learning from these experiences the country has reduced the impacts due to cyclone significantly by improving disaster management processes. This module will provide a brief overview of disaster management for cyclones in India

Unit 1 - Cyclone & Tropical Cyclone

The Word Cyclone is derived from the Greek Word "Cyclos" meaning coils of a snake. In meteorology, a C**yclone** is an area of low atmospheric pressure characterized by inward spiraling winds that rotate anti clockwise in the northern hemisphere and clockwise in the southern hemisphere of the Earth. The wind speed are in excess of 119km /hour. These are considered as the most violent, most awesome and most feared of all the atmospheric disturbances. There are two main types of cyclone – Tropical and Temperate. While the former is having thermal origin , the later is characterized by dynamic origin due to Coriolis force and movement of air masses. Out of the two cyclones, the tropical cyclone is the most devastating causing disasters wherever they strike the continental land masses .

Tropical cyclone is a globally occurring meteorological hazard. It is a localised low pressure weather system which develops over the warm water of the tropical oceans with wind speeds surpassing 74 miles/hour (118 km/ hour). It can be defined as "a large-scale closed circulation system in the atmosphere with low barometric pressure and strong winds that rotate counter clockwise in the northern hemisphere and clockwise in the southern hemisphere" (UNDHA, 1992). The calm centre of the tropical cyclone is termed as 'eye' of the cyclone .

Tropical Cyclone forms over the following oceans:

- North Atlantic Ocean
- Eastern and western parts of northern Pacific Ocean
- South-western Pacific Ocean

- South-western and south-eastern India Ocean
- Northern Indian Ocean which includes Arabian sea and Bay of Bengal

The terminology of cyclone is having spatial variation based on the location where they are originated .The term "Cyclone" is typically used for low pressure areas forming over the Indian Ocean. A tropical cyclone is termed as hurricane if it originates in Northern Hemisphere east of the International Dateline to the Greenwich Meridian, which is North Atlantic, the Caribbean, the gulf and west coast of Mexico and the Eastern North Pacific. It is termed as typhoon for tropical cyclones originating over the Pacific, north of the Equator and west of the International Dateline." (NHC,2007)

The magnitude of the tropical cyclone differs from region to region. Despite being predictable, high speed cyclonic winds can wreak havoc in regions with intrinsic vulnerabilities. Strong winds associated with cyclone damage structures, disrupt power/communication lines and other infrastructures. Heavy Rainfall associated with cyclones lead to flooding of inland area, land subsidence, land and mudslides which has further impacts on humans, infrastructure, crops, vegetation, livestock etc. Cyclones coupled with tides and local coastal configurations lead to storm surges and allied secondary hazards. Storm Surge leads to flooding of coastal areas, beach erosion and saline water intrusion in localities and agricultural fields leading to the loss of soil fertility. Thus the cascading effects of cyclone make it a complex hazard to respond to. Most notable tropical cyclones in the past are Hurricane Andrew (1992), Hurricane Katrina (2005), Cyclone Nargis (2008), Orissa Super Cyclone (1999) and in recent Cyclone Vardah (2016).

The phenomenon of tropical cyclone occurs periodically. It forms between 30° N and 30° S latitudes. By analysing EM-DAT data for 1989-20004, it is discovered that 4 developed countries (USA, Japan, Australia and New Zealand) and 29 developing nations have significant exposure to tropical cyclones. The average number of cyclone impacts on individual nations was recorded as 46 per year, with many cyclones affecting multiple nations (James M. Shultz 2005).

For a tropical cyclone to develop, the following weather conditions must be fulfilled:

1. Warm ocean waters of at least 26.5°C to a minimum depth of 50 m (165 feet)
2. An atmosphere that cools rapidly with vertical heights, transforming stored heat energy from warm Ocean waters into thunderstorm activity that fuels the development of tropical system.
3. Moist layer at mid- troposphere elevations (5km/3 miles) to enhance thunderstorm formation
4. The presence of near-surface, organized, rotating system characterized by spin (vorticity) and low-level inflow (convergence)
5. Significant Coriolis forces to rotate the cyclone.

6. Minimal vertical wind shear (strong crosswinds at varying altitudes that can slice apart the towering vortex of cloud mass)

The magnitude or intensity of cyclone is measured by Saffir-Simpson Hurricane Scale which classifies cyclone on the basis of wind speed between Category 1 to Category 5 . On this scale, category 1 is least destructive while category 5 is most destructive cyclone. However, in India a different classification is used to categorise the cyclone. This classification is given in the Figure 1.

Types of disturbances	**Associated maximum sustained wind(MSW)**
Low Pressure Area	Not exceeding 17 knots (Less than 31 kmph)
Depression	17 to 27 knots (31-49 kmph)
Deep Depression	28 to 33 knots (50-61 kmph)
Cyclonic Storm	34 to 47 knots (6-88 kmph)
Severe Cyclonic Storm	48 to 69 knots (89-117 kmph)
Very Severe Cyclonic Storm	64 to 119 knots (118-221 kmph)
Super Cyclonic Storm	120 knots and over (more than 222 kmph)

Figure 1: IMD Scheme of Classification of Tropical Cyclone , Source: (NDMA 2008)

Cyclones in India

On account of being located on three sides of sea, India experiences tropical cyclones during pre- (April-May) and post-monsoon (October-November) seasons. The frequency of cyclones also differ in these two seasons. The country is flanked by the Bay of Bengal in the east, the Arabian Sea in the west and the Indian Ocean in the south. Presence of about 7156 kms coastline of which 5400 km is along the mainland makes India highly vulnerable to cyclonic storms (NDMA 2008). Vulnerable districts of the India to Cyclone are depicted in Figure 2.

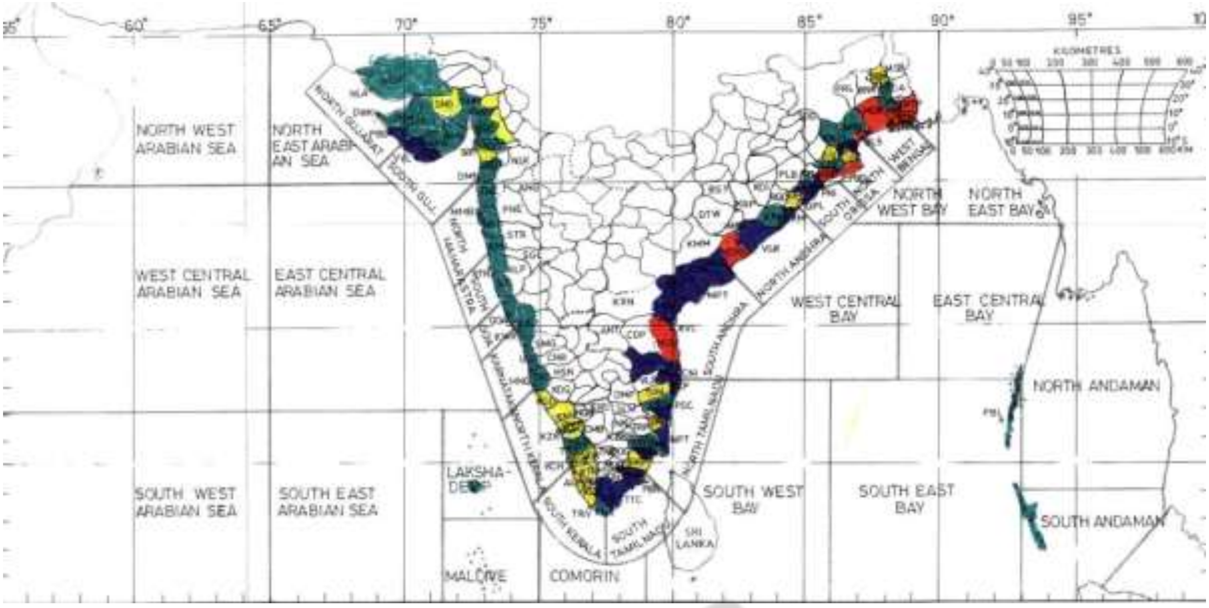

Figure 2: District identified as Vulnerable to tropical cyclone in India, Source: (NDMA 2008)

Very highly prone areas are marked with red colour on the map. These areas are primarily located on the East Coast of India. The highly prone zone which is marked in purple colour, are also mostly confined to the east coast. The state of Gujarat on the west coast is also marked as highly cyclone prone areas. The entire West coast is marked as Moderately prone with green colour. Some interior places in Gujarat and Kerala marked as less prone zone are depicted by yellow colour.

Between 1981 and 2002, the states located in the eastern coast i.e. West Bengal, Odisha, Andhra Pradesh, Tamil Nadu have faced 69, 98, 79 and 54 cyclones respectively (NDMA 2008). Highly prone Orissa faced 98 cyclones which were distributed across the districts of Balasore (32), Cuttak (32), Puri (19) and Ganjam (15). On the other hand, West coastal states have faced much lesser number of cyclones than their Eastern counterparts - Maharashtra (13), Gujarat (28), Kerala (3), Karnataka and Goa 2 each. Therefore, the eastern coast is more prone to Cyclone than the western coast.

Naming of cyclones

It is seen that the cyclones affecting in the Indian subcontinent as well as other parts of the world are known by specific names for easy identification and to eliminate confusion. These names are basically obtained from the list prepared for different regions and are selected a few years earlier to the actual event. The list is decided by committees of the World Meteorological Organisation (WMO) or by national weather offices (like IMD in India) involved in cyclone forecasting. Each year, the names of highly destructive cyclones are 'retired' and replaced by new ones. The below mentioned list contains the names of past as well as prospective cyclones in India and neighbouring countries. These names have been contributed by countries like India, Bangladesh, Myanmar, Maldives, Oman, Pakistan, Sri Lanka and Thailand .

Contributing Nations	List 1	List 2	List 3	List 4	List 5	List 6	List 7	List 8
Bangladesh	Onil	Ogni	Nisha	Giri	Helen	Chapala	Ockhi	Fani
India	Agni	Akash	Bijli	Jal	Leher	Megh	Sagar	Vayu
Maldives	Hibaru	Gonu	Aila	Keila	Madi	Roanu	Makunu	Hikaa
Myanmar	Pyarr	Yemyin	Phyan	Thane	Na-nauk	Kyant	Daye	Kyarr
Oman	Baaz	Sidr	Ward	Mujan	Hudhud	Nada	Luban	Maha
Pakistan	Fanoos	Nargis	Laila	Nilam	Nilofar	Vardah	Titli	Bulbul
Sri Lanka	Mala	Rashmi	Bandu	Mahasen	Priya	Asiri	Gigum	Soba
Thailand	Mukda	Khai-Muk	Phet	Phailin	Komen	Mora	Phethai	Amphan

Names updated 2008 IMD List

Unit 2 –Management of Tropical Cyclones

Early Warning System- As growing of depression into cyclone takes considerable time, it is feasible to forecast and monitor the paths of cyclone through various technological inputs. The cyclone early warning system in India has been evolved over a period of time. The great Bengal cyclone of 1737 was the first cyclone to be recorded with mass casualties. There are other three major cyclones worth to be mentioned are Buckerganj (1876), Haiphong (1881) and Bangladesh (1970) in all of which the estimated loss of life was about 300000 (A.K.Sensarma 1995). After the establishment of India Meteorological Department (IMD) in 1875,cyclone warning started to be issued to various stakeholders .In October 1864, a cyclone warning system was also established by the then government for the Calcutta port. Gradually Cyclone Warning Systems started functioning through Area Cyclone Warning Centre (ACWC) at Mumbai, Calcutta and Madras and Cyclone Warning Centres (CWC) at Ahmedabad, Bhubaneswar and Vishakhapattnam.

With the advancement of INSAT Satellite System and Cyclone Detection Radar (CDR), timely detection of cyclone and tracking of its path became easier. After the Orissa Super Cyclone of 1999, an additional ‘watch period’ of around 72 hours was introduced with the regular 48 hours and 24 hours watch before landfall to improve the early warning system(Dash 2002). Now a days the warnings being issued by IMD through their Area Cyclone Warning Centres (ACWC) and Cyclone Warning Centres (CWCs) to the respective coastal states. This work is supervised and coordinated on real time basis by the forecasting division located at Pune. To coordinate and supervise the cyclone warning programme at the country level, Cyclone Warning Division (CWD) was established at New Delhi. This division also serves as Regional Specialised Meteorological Centre of the World Weather Watch (WWW) programme under the World Meteorological Organization.

Now the tracking and forecasting of cyclone is carried out through data obtained using Radar, Satellite and Conventional Network. Cyclone Detection Radar with a range of 400 km can detect formation of cyclones. The INSAT system provides satellite imagery to be used in the cyclone and warning forecast dissemination. The Conventional Network consists of 559 surface observatories, 65 Pilot Balloon Observatories, 34 radio sonde /Radio-Wind Observatories and Buoys. Utilising all these and using analogue, persistence, climatology and clipper models, the movement of tropical storms is predicted. To predict storm surge, nomograms are used to compute surge at different places along east and west coasts of India.

The cyclone warning system in India is divided in four stages:

Pre Cyclone Watch is issued when a depression forms over Ocean and is likely to affect the Indian Coast in future. This bulletin is issued at least 72 hours in advance.

Second stage is "**Cyclone Alert**" which is also referred to as "Yellow message". This warning is given in initial days or development phase of the cyclone 48 hours prior to expected landfall.

Third stage is "**Cyclone Warning**" which is also referred to as "Orange message" issued at least 24 hours in advance when the cyclone is located within 500km of the coast.

Post-landfall outlook is issued before the cyclone landfall, when cyclone is located within 200 km from the coast. The "**landfall**" warning is issued and referred as "Red Message". This nomenclature is used in all warnings issued by the Indian Meteorological Department.

Cyclone Risk Reduction

The development of cyclone early warning system addresses the component of cyclone risk management, which includes preparedness and mitigation of cyclone risk. few of the important measures for cyclone risk mitigation is 'Ecosystem based Cyclone Risk Reduction', building and maintenance of cyclone shelters, establishment and implementation of building codes considering heavy winds etc.

Ecosystem based Cyclone Disaster Risk Reduction (Eco-CRR) – This aims at integrating disaster risk reduction and climate change adaptation to reduce the impact of cyclone. Cyclone Disaster Risk Reduction means "the concept and practice of reducing disaster risk through systematic efforts to analyse and manage the causative factors of disasters." It includes "reduced exposure to cyclone hazards, reduced vulnerability of people and property, wise management of land and environment, and improved preparedness for adverse events" (UNISDR 2009) . On the other hand Ecosystem means "an unit which includes all organisms(the biotic community) in a given area interacting with the physical environment so that a flow of energy leads to clearly defined biotic structures and cycling of materials between living and non-living components" (Odum and Barrett 2005). It is a functional system unit, with inputs, outputs and boundaries drawn naturally or arbitrarily.

Ecosystem-based approaches to DRR offer a good alternative and/or complement because they are often already part of livelihood strategies and hazard mitigation strategies of local communities (Estrella and Saalismaa 2013). Eco-DRR is the sustainable management, conservation and restoration of ecosystems to reduce disaster risk, with the aim of achieving sustainable and resilient development. As stated earlier Ecosystem is a unit, there are different ecosystems are present in the world.

Coastal ecosystems which consists of Mangroves, salt-marshes, Coral reefs, barrier islands and sand dunes, form natural barriers against hurricane/ tropical cyclones (Estrella and Saalismaa 2013). In the context of India, National Disaster Management Authority (NDMA) identifies Mangrove forests as a suitable mechanism for the ecological security of coastal areas while being beneficial for the livelihood of coastal population. (NDMA 2008) Mangroves in India account for roughly 5% of the world's mangrove vegetation spreading over an area of about 4445 km sq. along the coastal states/UTs (NDMA 2008). Studies have indicated with robust statistical evidence that Mangrove protection has helped in the reduction of death toll during super cyclone of 1999 for the villages taken as sample for study. (Das and R.Vincent 2009).At the global level, many studies stress the importance of Mangroves and Eco-DRR to reduce the impact of the tropical cyclone. (Granek & Ruttenberg, 2007; Batker, et al., 2010) Other Eco Drr measures include developing bio shields, shelter belt plantations, coastal flood plain management measures etc. Thus Eco-DRR is an extremmely important measure in mitigating cyclone impacts.

Cyclone Shelters

As a part of preparedness against cyclone, cyclone shelters are integral. They are necessary to relocate population from villages during evacuation once the cyclone warning is received. The government had started building cyclone shelters after the 1977 Andhra Pradesh cyclone. With the extensive support from Red Cross, over 200 new shelters were built in the period from 1978 to 1982 (Deville, Guggenheim and Hrdlickova 2014). This process continued throughout late 1990 and early 2000s. The first generation cyclone shelters were of circular designs. Figure 4 illustrates design for the circular cyclone shelter.

FRONT ELEVATION

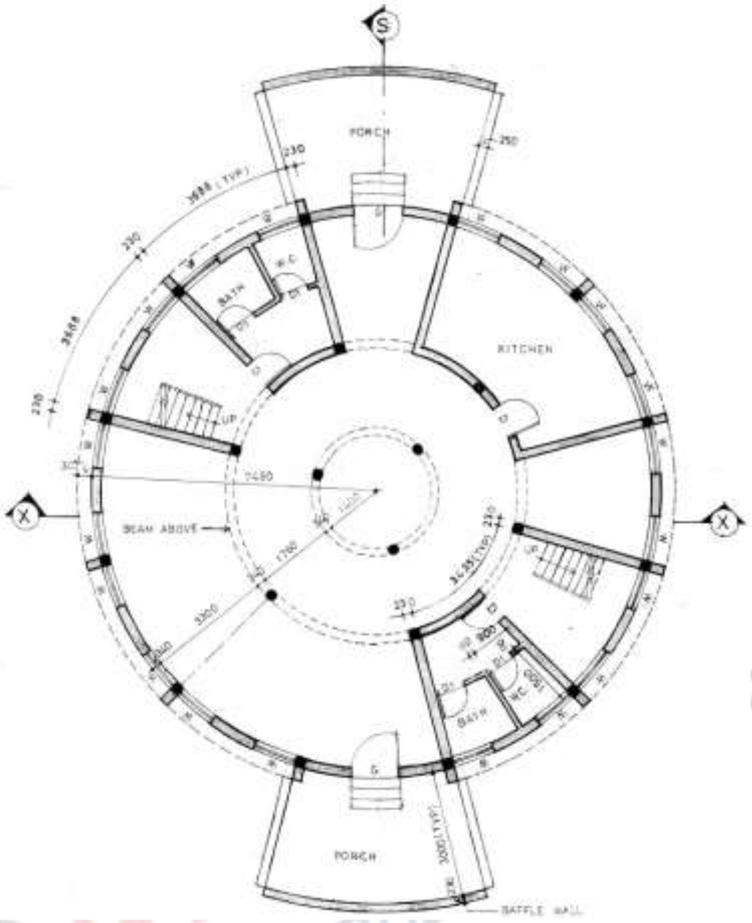

Figure 4: Design of circular cyclone shelter, Source: (Deville, Guggenheim and Hrdlickova 2014)

Later it was observed that due to lack of maintenance and usage, there was significant deterioration in the condition of these cyclone shelter. Often they became dilapidated and unfit for use (NDMA 2008).To address this, in recent years the concept of the multi-purpose cyclone shelters gained prominence. The architectural design of these multi- purpose cyclone shelters are done with the consultation of the community (Deville, Guggenheim and Hrdlickova 2014). Figure 5 illustrates the design of multi-purpose cyclone shelter.

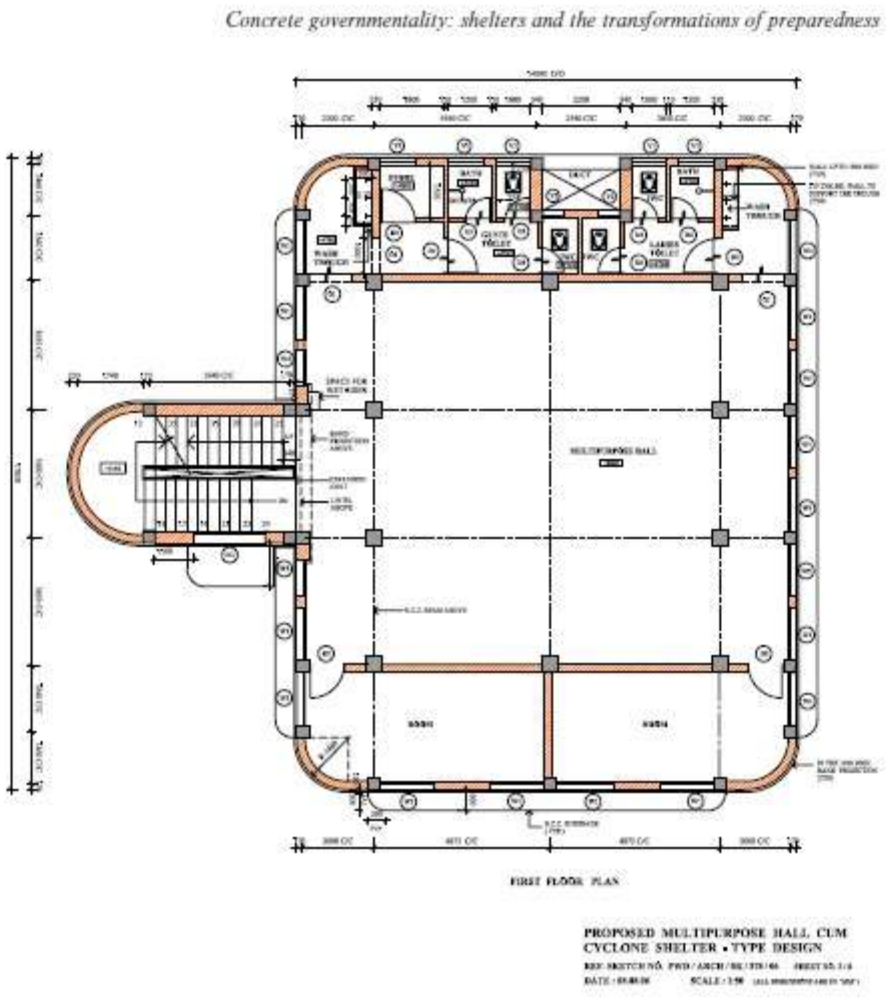

Figure 5: Design of multi-purpose cyclone shelters, Source: (Deville, Guggenheim and Hrdlickova 2014)

Multi-purpose cyclone shelters are built to accommodate different tasks during the normal period so that they can be maintained throughout the year and can be used as shelter during the cyclone. For instance, the following criteria can be identified to determine the location of cyclone shelters in the state of Odisha (Dalal, et al. 2007):

- Easy accessibility of the villagers to the shelter – Considered as most important factor
- Travel distance for an individual to be restricted to 2.25 km
- Coverage of the entire population in the region under consideration
- Suitability of the shelters for other community purpose, like school, health center, community center and building for other public utility at normal times.

To determine the location, 10-kilometre-wide belt was divided into square grids, each having 10 square kilometre area. The ideal location would be at the centroid of the square. Thus the length of diagonal of each square was 4.47 kilometres and distance between a corner and the centroid of the square grid approximately 2.25 kilometres (which is one of the criteria mentioned above). The total population of all the villages included in a grid and the total available plinth area of the double-

storied private and public buildings were calculated. Using a thumb rule that one square foot plinth area is required to accommodate a person in a shelter, estimates were made for the required number of persons to be accommodated in a cyclone shelter and the size of the shelter in a grid. Considering the cost factor, the cyclone shelters were constructed only with discrete pre-determined capacities like 500, 1,000, 2,000, and 3,000 square feet. Availability of road network, drinking water, medical facilities, and presence of natural barriers like creeks and rivers were also considered while deciding the location of cyclone shelters (Dalal, et al. 2007).
Apart from developing cyclones shelters, other mitigation measures are also suggested which include strengthening of road links, culverts etc., proper maintenance of canals, surface drains, development of saline embankments etc.

National Cyclone Risk Mitigation Project (NCRMP)

The government of India has introduced the National Cyclone Risk Mitigation Project (NCRMP) to address the issues of cyclone risk in the country. It aims at taking suitable structural and non-structural measures to mitigate the effects of cyclones in the coastal states and UTs of India. Based on the frequency of occurrence of cyclones, population and the existing institutional mechanism for disaster management, cyclone vulnerable states are divided into two categories.

- **Category I:** Higher vulnerability States- Andhra Pradesh, Gujarat, Odisha, Tamil Nadu and West Bengal
- **Category II**: Lower vulnerability States- Maharashtra, Goa, Karnataka, Kerala, Daman & Diu, Puducherry, Lakshadweep and Andaman & Nicobar Islands

Phase I began with Andhra Pradesh and Odisha in 2011. Other States/UTs will be covered progressively. National Cyclone Risk Mitigation Project has following objectives (Project 2010)

i) To improve Early Warning Dissemination Systems
ii) Enhanced capacity of local communities to respond to disasters
iii) To improve access to emergency shelter, evacuation and protection against wind storms, flooding and storm surge in high risk areas
iv) To strengthen Disaster Risk Management (DRM) capacity at central, state and local levels in order to enable mainstreaming of risk mitigation measures into the overall development agenda.

There are four components of NCRMP as under -

- Component A: Early Warning Dissemination System(EWDS)
- Component B: Cyclone Risk Mitigation Infrastructure
- Component C: Technical Assistant for national and state level capacity building and knowledge creation
- Component D: Project Management and Implementation Support

The project is ongoing in many states and currently in the developmental phase-

Institutional Guidelines on Cyclone Management

In India, the nodal authority for cyclone management is the Ministries of Home Affairs. The other line departments are Ministry of Agriculture, Civil Aviation, Environment and Forests, Health, Atomic Energy, Space, Earth Sciences, Water Resources, Mines, Railways etc. Organizations like NDMA, SDMAs are also coordinating activities at the national and state level respectively . The NDMA guidelines on Cyclone management provide significant insights on the management of cyclones.

In the next section a case study is presented to illustrate the integration of the different systems together during a cyclone situation.

Case study - Cyclone Phailin

On 12 October 2013 evening, very severe tropical cyclone, Phailin brought torrential downpours and damaging winds of more than 220 kilometres per hour and storm surges up to 3.5 metres to the states of Odisha and Andhra Pradesh (Harriman 2013). But improvements in preparedness, forecasting capabilities, early warning systems and disaster management significantly helped in mitigating the impacts of cyclone Phailin.

As the cyclonic system (i.e. depression) formed, the first warning "Cyclone Watch" was given 72-96 hours prior to the landfall in Odisha. A close watch was kept on the movement, speed and direction of Phailin. The second warning that is "Cyclone Alert" was given 36-48 hours before the landfall. Third warning "Cyclone Warning" was given 24 hours prior to the landfall. After receiving this warning, evacuation order were issued by district collectors. Early warning was issued accordingly through the following means.

- Continuous news coverage before and during event, providing location, intensity and timing of the cyclone.
- Use of email, fax, telephone and print media to disseminate warning and alert.
- Use of Public Announcement System in various district to warn the residents of imminent danger and to warn fishermen not to venture into sea
- Distribution of satellite phones to representatives in the 14 most vulnerable districts to ensure that warning communications continued during the cyclone.

A massive evacuation drive was undertaken prior to landfall in the states of Odisha and Andhra Pradesh. In Odisha almost 700,000 people were evacuated from coastal districts to various cyclone shelters. As many as 102,000 residents of Puri district and 180,000 residents of Ganjam district were evacuated (Harriman 2013). The evacuated people were transferred to some 20,000 cyclone shelters, schools, colleges and other safe places. In the state of Andhra Pradesh close to 80,000 people were evacuated.

In Odisha control rooms were set up in Ganjam and nine other districts. Mobile numbers were updated and verified and all government staffs were put to stand-by. State government maintained stock of rations, water and medicine in each shelter for 36 hrs. Central government also kept stock of the rations ready to be moved for response as and when required. The Indian Army, Indian Navy and Indian Air-Force as well as National Disaster Response Force (NDRF) were deployed for emergency and relief efforts, helicopters distributed food rations and Red Cross assumed responsibility of providing safe drinking water to those who were involved in relief efforts.

56 teams of National Disaster Response Force (NDRF) were deployed at vulnerable places with protective measures, with the reserves for each of the two states (Odisha & Andhra Pradesh), and for West Bengal kept as stand-by in interior regions. Almost 2,000 personnel of National Disaster Response Force (NDRF) were deployed in Odisha, Andhra Pradesh and West Bengal. These teams were equipped with rescue equipments in case of any need and satellite phones for smooth and unhindered communication. The role of national cyclone risk mitigation project was significant in developing preparedness in the region prior to the disaster through the construction of shelters, evacuation planning, conducting of mock drills and strengthening of embankments.

This case study highlights how *disaster management for cyclone* works in full swing during an actual event. The involvement of community supported the development of a sound early warning system and active volunteer organizations. Swift response by the government at local, state and central level was exemplary in this case and needs to be replicated in other disasters.

Summary

Tropical cyclone is a localised low pressure weather system that develops over warm water of the tropical oceans with wind speeds surpassing 74 miles/hour (118 km/ hour). The strong winds associated with cyclone damages structure, disrupts power/communication lines and other infrastructures. The cascading effects of cyclones due to winds, associated storm surges and sometimes heavy rainfall, make cyclones a complex hazard to respond to.

As cyclone takes sufficient time to form, one can forecast and predict its path by monitoring the atmosphere. Development of Early Warning system addresses one component of Cyclone risk Management. Preparedness and mitigation of cyclone risk is also of equal importance. Few measures for cyclone risk mitigation are Ecosystem based Cyclone Risk Reduction, building and maintenance of cyclone shelters, establishment and implementation of building codes considering heavy winds etc.