

REVIEW OF EARLY WARNING SYSTEM
NAVI MUMBAI



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ACKNOWLEDGEMENTS

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The review process involved a number of consultation meetings and workshops in the cities. The support of the city government and State Government departments/institutions is highly appreciated.

Specifically we would like to highlight the support and in-depth engagement of the City Project Coordinators from all the seven cities.

A word of special thanks to United Nations Development Programme (India) for their fruitful partnership throughout the implementation of the review process, for their valuable support in coordinating the activities as well as in organizing city missions, and for stakeholder consultations and city workshops.

The findings of the review have been shared and reviewed by the key stakeholders, including the Local Government and their valuable inputs have been incorporated in the final report.

The report takes into account the End-to-End Early Warning System approach of the Regional Integrated Multi-Hazard Early Warning System. This report has been prepared by a six member team with experience in areas of disaster risk management, the hazard risk assessment, early warning system design and climate risk management.



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EXECUTIVE SUMMARY

Advancements in observation and monitoring, mathematical modelling, computing capabilities, communication technology and conduct of scientific risk assessment have allowed technical and disaster management agencies to disseminate timely and accurate warnings and move people and assets from the harm's way. One example of this is the case of Cyclone Phailin, where accurate forecast was made by the Indian Meteorological Department (Cyclone Warning Division) and timely dissemination of warnings to at-risk communities was done by the Orissa State and the District Agencies. Another example is the case of public health. Systemic collection of registered cases and observation of diseases in the city of Surat have led to the provision of timely information on potential outbreaks. Advance information on potential outbreaks leads to identification of additional measures to be stepped up by the local government to reduce the risk of diseases such as malaria, dengue, cholera, filariasis, among others.

India is highly diverse in terms of geography and climate and so are its cities. Cities are exposed to earthquakes, tsunamis, landslides, heavy precipitation, floods, heat waves, cyclone and severe winds, public health risks among others. Past disasters have shown significant impact on city economy and on key sectors (such as transport, energy, water and sanitation, trade and commerce). It is expected that due to climate variability and climate change, the frequency and intensity of the hydro-meteorological hazards will see an increase in future. This, combined with poor reservoir management practices, especially in cities located downstream the reservoirs, may put the lives of citizens and city assets at risk.

Adoption of the Hyogo Framework for Action (HFA) during the World Conference on Disaster Risk Reduction (2005, Japan) has led to a paradigm shift in disaster risk management from a post-disaster response to a comprehensive and strategic approach in disaster risk management encompassing preparedness and prevention strategies. The second high priority area of the HFA stresses the need for identifying, assessing and monitoring disaster risks and enhancing early warning.

This review is commissioned by UNDP under Contract (2013/067), and is an initiative under the programme titled, "GoI-UNDP Climate Risk Management in Urban Areas through Disaster Preparedness and Mitigation Project". The review investigates the condition of EWS governance, requirements of EWS users, core services provided by technical and disaster management agencies, coordination mechanism between technical and disaster management agencies and finally the issues centred on service delivery and feedback in seven cities (Bhubaneswar, Gangtok, Madurai, Navi Mumbai, Shimla, Trivandrum and Vishakapatnam). The report provides firsthand guidance as well as the steps for development of EWS from the city level to the urban local body (ULB), disaster management institutions, technical agencies involved in design and implementation of early warning systems for geological hazards, hydro-meteorological hazards and public health risks.

Methodology of Review

The assessment involved a systematic flow of understanding the EWS governance at the national, state, district and city levels; institutional mechanism and their roles within the elements of EWS; delivery of products and services by technical and disaster management agencies, as well as their coordination mechanism/operational cooperation; reviewing the existing EWS mechanism in cities; role of agencies in EWS and their integration in the disaster management institutional framework (City Disaster Management Plan); discussing with stakeholders the needs in EWS and gaps thereof, capacities of institutions (technical agencies) engaged in EWS, the operational cooperation of technical agencies with the emergency departments/functionaries at the district and city levels (emergency management structure and response capabilities), current status and future needs of observation and monitoring capabilities, data management systems; seeking information on pre-computed assessment of risks for various intensity of hazards (risk assessment), hazard analysis and prediction capabilities (threat assessment/potential impact assessment), warning formulation/issuing of guidance and potential outlook/provision of actionable early warning information/warning products, decision making, generation of tailored risk information and dissemination of risk information to at-risk communities or hot-spot locations (risk communication), information technology and telecommunication capabilities, preparation of response options, institution/emergency responders and community response.

The assessment was based on the information obtained through a set of processes.

- Design of the review framework by the Review Team

- A checklist and questionnaire prepared by the Review Team for obtaining information from technical and disaster management agencies
- Mission to select cities to understand the EWS environment
- Development of Criteria Development Matrix taking into consideration all the key elements of end-to-end EWS
- Information collected through stakeholder consultations/meetings, workshops in respective cities, discussions with programme focal point in cities, meeting with key experts
- Exchange and mid-term feedback from UNDP programme team
- Development of policy brief, where key recommendations cited are discussed for endorsement at the policy level
- Workshop with city stakeholders, sharing of results
- Final report and presentation

Key Observations and Recommendations

Based on the development stage indicators for all the six components (1. EWS governance – national, state and city level institutional framework, 2. User needs, 3. Operational components of EWS, 4. Products and services across the warning chain, 5. Coordination mechanism, 6. Service delivery and feedback loops), the report provides the summary for each city highlighting the current status. The Criteria Development Matrix also outlines the reason for selecting the development stage indicators. Specific recommendations are presented together and this will lead to the development of policy brief.

The overall analysis of this review revealed that in

cities:

- EWS development is crucial for sustainable development and building resilience of the cities. It is therefore important to develop an EWS framework and strengthen strategies across all levels to ensure better coordination efforts for functional EWS at the city level. This must be seen as opportunity to strengthen network among institutions, foster partnerships and build the capacities of all key stakeholders.
- EWS framework must be made as a functional component of the DM Plan process (national/state/district/city). The framework must foster areas of cooperation in data sharing and impact forecasting.
- It is widely realized that city institutions are being rather response-centric instead of being the ones that take preventive measures. The technical capacity in understanding DRR, risk assessment and EWS needs to be strengthened at the ULB level. City level hazard and vulnerability mapping capabilities need to be enhanced on priority basis. A long-term perspective on capacity development should be envisaged.
- There is a common challenge in the interpretation of the forecast products. Technical agencies involved in providing warning have to evolve in providing information that can either be used by a wide pool of users or create products based on user needs.
- Technical agencies/scientific institutions must also enhance the capability to deliver timely warnings with sufficient respite time so that they support DRR functions at the city level.
- The role of technical agencies in warning formulation is increasingly being recognized. It is therefore important to strengthen institutional coordination mechanism between technical and disaster management agencies at all levels.
- City government/ULB has to make significant

investments towards development of EWS and associated mechanisms such as a functional EOC. The current level of preparedness and resource allocation is not sufficient to kick-start any activity around EWS.

ACKNOWLEDGEMENTS	i
EXECUTIVE SUMMARY	ii
CONTENTS	
LIST OF FIGURES	1
LIST OF TABLES	2
ABBREVIATIONS	3
GLOSSARY	4
LIST OF ICONS	6
1. INTRODUCTION	7
2. METHODOLOGY OF REVIEW	11
3. CRITERIA DEVELOPMENT MATRIX AND DEVELOPMENT STAGE INDICATORS	14
4. UNDERSTANDING EWS & KEY FRAMEWORKS FOR GEIOLOGICAL HAZARDS, HYDRO- METEOROLOGICAL HAZARDS AND PUBLIC HEALTH RISKS	22
4.1 EWS framework for Earthquake hazard	23
4.2 EWS framework for Tsunami hazard	24
4.3 EWS framework for Landslide hazard	26
4.4 EWS framework for Tropical Cyclone	27
4.5 EWS framework for Floods	30
4.6 EWS framework for Heat wave condition	32
4.7 EWS framework for Public health risks	34
5. REVIEW OF EWS IN NAVI MUMBAI	36
5.1 General city information	36
5.2 Background on hazard risk	36
5.3 Brief Vulnerability profile	37
5.4 Institutional Framework	37
5.5 Indicators of existing condition of EWS	38
5.6 Summary	43
6. RECOMMENDATIONS AND OUTLOOK	46

CASE STUDIES

Case Study 1: Qinglong County EWS for M 7.8 Earthquake	49
Case Study 2: Community based Earthquake Monitoring System in Xinjiang	50
Case Study 3: Landslide Early Warning Network	51
Case Study 4: Flood Control Centre	52
Case Study 5: End-to-End EWS for Ukai and Local Floods	53
Case Study 6: Urban Services Monitoring System	54

REFERENCES	55
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ANNEXURE

List of Agencies and Key Informants consulted in the Review Process	57
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List of Figures

Figure 1: 7 Cities selected for Review of EWS	8
Figure 2: Highlighting overlay of decision points over standard emergency phase and the weather event decision phase	9
Figure 3: Key Elements in End-to-End EWS	10
Figure 4: Study Framework Schematic showing links of Stakeholders across the Development Model of EWS	13
Figure 5: Evolution of a Hazard Event in four stages	22
Figure 6: Global Earthquake Hazard map showing the regions operating active earthquake EWS	23
Figure 7: SOP diagram of Tsunami Early Warning Centre	26
Figure 8: Cyclone Warning Organization Structure	29
Figure 9: Flood Forecasting Stations in India	31
Figure 10: Heat Index °F(°C)	33
Figure 11: Satellite Image and Basic Information: Navi Mumbai	35
Figure 12: Preparedness of EWS Indicators for Navi Mumbai	45

List of Tables

Table 1: Criteria Development Matrix: Criteria and Indicators of the condition of EWS in cities	14
Table 2: Bulletin types, Threat status & Action points for Tsunami warning alert and watch	25
Table 3: Damage expected and Actions for Low Pressure area to Super Cyclonic Storm	28
Table 4: Criteria Development Matrix: Indicators of existing condition of EWS in Navi Mumbai	38

ABBREVIATIONS

ACWC	Area Cyclone Warning Centre
ADM	Additional District Magistrate
BMC	Bhubaneswar Municipal Corporation
BSNL	Bhartiya Sanchar Nigam Limited
BUDA	Bhubaneswar Urban Development Authority
CBO	Community Based Organization
CDM	Criteria Development Matrix
CDMO	Chief District Medical Officer
CDP	City Development Plan
CDPO	Child Development Project Officer
CESU	Central Electricity Supply Utility
CFO	Chief Fire Officer
CMO	Chief Municipal Officer
CWC	Central Water Commission
DCP	Deputy Commissioner of Police
DDMA	District Disaster Management Authority
DM	Disaster Management
DRR	Disaster Risk Reduction
EOC	Emergency Operation Centre
ESF	Emergency Support Function
EWS	Early Warning System
GIS	Geographical Information Systems
GOI	Government of India
HFA	Hyogo Framework for Action
IC	Incident Commander
IDSP	Integrated Disease Surveillance Programme
IMD	India Meteorological Department
INCOIS	Indian National Center for Ocean Information Services
IRS	Incident Response System
IT	Information Technology
M&E	Monitoring and Evaluation
MHA	Ministry of Home Affairs
MHRVA	Multi Hazard Risk and Vulnerability Assessment
MSK	Medvedev-Sponheuer-Karnik Intensity Scale
NDMA	National Disaster Management Authority
NGO	Non-Governmental Organization
OSDMA	Odisha State Disaster Management Authority
PAS	Public Addressal System

PHD	Public Health Department
RFP	Request for Proposal
RIMES	Regional Integrated Multi-Hazard Early Warning System for Africa and Asia
RSMC	Regional Specialized Meteorological Centre
RTSMN	Real Time Seismic Monitoring Network
SDMA	State Disaster Management Authority
SEOC	State Emergency Operations System
SMS	Short Messaging Service
SOP	Standard Operating Procedures
SRC	State Resource Center
ULB	Urban Local Body
UNDP	United Nations Development Programme
WRD	Water Resource Department

GLOSSARY

Capacity

The combination of all the strengths, attributes and resources available within a community, society or organization that can be used to achieve agreed goals

Climate change

The Inter-governmental Panel on Climate Change (IPCC) defines climate change as: “a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use”

Disaster

A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources

Disaster risk reduction

The concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events

Early warning system

The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss

Forecast

Definite statement or statistical estimate of the likely occurrence of a future event or conditions for a specific area

Geological hazard

Geological process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage

Hazard

A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage

Hydro-meteorological hazard

Process or phenomenon of atmospheric, hydrological or oceanographic nature that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage

Natural hazard

Natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage

Preparedness

The knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions

Prevention

The outright avoidance of adverse impacts of hazards and related disasters

Response

The provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected

Risk

The combination of the probability of an event and its negative consequences

Risk assessment

A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend

Risk management


The systematic approach and practice of managing uncertainty to minimize potential harm and loss


Vulnerability


The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard


Source: 2009, UNISDR Terminology on Disaster Risk Reduction


LIST OF ICONS


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Background information on Review of EWS in 7 cities in India under the ongoing initiative of Climate Risk Management in Urban Areas through Disaster Preparedness and Mitigation project by UNDP.
- 


Methodology/Systematic approach adopted to assess the existing EWS and emergency communication network in 7 cities across India.
- 

The Criteria Development Matrix indicates the possibility of thinking 5 stages of development and helps to review each criterion built around 6 components of the development model of EWS.
- 

General city information like location, climate, demographics, landuse, administration, etc. helps to understand the city and its development of Disaster Management Plan.
- 


Hazard Risk like geo-physical, hydro-meteorological and public health are studied for each city, which would help in reviewing of EWS and later in development of Disaster Management Plan.
- 


The city and its infrastructure are vulnerable to incidences of both geo-physical & hydro-meteorological events. Such event is likely to affect the livelihood of population in addition to economic loss.
- 


Study of Institutional Framework for a city helps to understand the coordination mechanism among various stakeholders, during the time of disaster.
- 


Summary of all the criteria of all 6 components of study framework and discussed in brief.


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Earthquake
- 

Tsunami
- 


Landslide
- 


Cyclone
- 


Flood
- 


Heatwave
- 


Public health risk


- 


Observation and Monitoring
- 


Data Analysis
- 


Prediction
- 

Risk Assessment
- 

Potential Impact Assessment
- 

Warning Formulation
- 

Dissemination to communities at risk
- 

Preparation of Response
- 

Community Response



1. INTRODUCTION

A systematic approach towards managing risk through an established early warning system (EWS) can minimize loss of lives and adverse economic impact. EWS backed with effective institutional arrangements can predict hazards in a timely and effective manner, thereby empowering decision makers and communities at risk.

Adoption of the Hyogo Framework for Action (HFA) during the World Conference on Disaster Risk Reduction (2005, Japan) has led to a paradigm shift in disaster risk management from a post-disaster response to a comprehensive and strategic approach in disaster risk management encompassing preparedness and prevention strategies. The second high priority area of the HFA stresses the need for identifying, assessing and monitoring disaster risks and enhancing early warning.

In recent years hazards of different origin have caused significant loss of lives and economic damages. The damages are showing a growing trend, and increase in climate variability and climate change can tip of many existing mechanisms of managing risk. A closer look into the nature of the hazard events clearly indicates the role of the technical agencies (national/regional/state/city) and the disaster management agencies (at the national/state/district/city/village) in early warning as critical. The increasing factor of risk in today's society underlines the need for enhanced cooperation from a wide spectrum of stakeholders in effective risk reduction and emergency response.

At a national level there is a growing reliance upon EWS as more people and assets are being exposed to the hazards. This calls for functional EWS (most effective for events that take time to normally develop, such as tropical cyclone) or Alert Systems (most effective for events that start immediately, such as earthquake) that have applicability for most hazards. In 2013, Government of Orissa agencies evacuated more than half million people in advance of tropical cyclone (Phailin, Category: Very Severe Cyclonic Storm) thereby reducing fatalities to a fraction (loss of human life - 21) when compared to the fatalities (loss of human life - 9887) from a tropical cyclone (Paradip Cyclone, Category: Super Cyclonic Storm) in the same region 14 years previously.

Advancements in observation and monitoring, mathematical modelling, computing capabilities, communication technology and conduct of scientific risk assessment have allowed technical and disaster management agencies to timely disseminate accurate warnings and move people and assets from the harm's way. In the case of Cyclone Phailin, accurate forecast by the Indian Meteorological Department (Cyclone Warning Division) and timely dissemination of warnings to at-risk communities by the Orissa State and the District Agencies made this possible.

The other example is in the case of Public Health. Systemic collection of registered cases and observations of diseases in the city of Surat has led to the provision of timely information regarding potential outbreaks. Advance information of potential outbreaks leads to identification of additional measures to be stepped up by the local government to reduce the risk of diseases such as malaria, dengue, cholera, filariasis, among others.

Warning dissemination and staging response actions are as important as accurate forecasting and determining potential impact. Any weak link in the elements of EWS (even in case of previous well performing system) will result in under-performance or its failure. Hence evaluation of EWS is important. The evaluation of the system effectiveness can be done during the event, post-event or during the lean period. This review of EWS for all the seven cities is done during the lean period. In most cases the cities haven't formally put in place a functional EWS. While it is important to have technical competence around a range of elements (forecasting, prediction, impact assessment), discussions with stakeholders emphasize that EWS is more organizational and institutional process which works to reduce loss. The methodology adopted in the study has roots to EWS elements defined by RIMES (2008) and the criteria-development concept by Parker (1999).

The review investigates into the condition of EWS governance, requirements of EWS users, core services provided by technical and disaster management agencies, coordination mechanism between technical and disaster management agencies and finally on issues centered around service delivery and feedback.

The purpose of this report is to provide guidance to the city government, disaster management institutions and technical agencies involved in design and implementation of early warning systems for geological hazards, hydro-meteorological hazards & public health risks. This study aims to assess the existing EWS in seven cities (Refer Figure 1) through:

- Review of the technical design/structure and efficacy of existing early warning system, assessment of early warning agencies, communications networks, protocols for issue

of warning, and transmission to the people, assessment of how the residents of the city access the information and how they act upon it.

- Review of the technologies involved in the early warning system network design, technical specifications, up-time performance standards, connectivity and integration with all the important facilities and installations, emergency services, and the disaster management system in the city.
- Review of the mode of collecting information related to hazard events, monitoring, and transmitting it to other agencies, particularly the municipal government and district administration.
- Review of the mode and reach of the warning especially last mile connectivity and dissemination plan through mass media, print and audio-visual.
- Review the messages disseminated through the EWS: on timeliness, appropriateness, accuracy, and simplicity parameters.
- Review of the service support for maintaining the EWS on a regular basis and ensuring hundred percent uptime.

This report reviews the institutional mechanism and the decision making across the development model of EWS and its components. This report considers the use of Criteria Development Matrix (tool for review) to assess the level of development and present the findings for seven urban centres. Specifically, it focuses on the geological hazard, hydro-meteorological hazard and public health risk warning system, their current status, and capabilities and supporting disaster risk reduction.

Case studies of best practices and warning system for individual hazards are presented at the end of the city review sections for ready reference.



Figure 1: **Seven cities selected for review of EWS**

Background

Early warning in the usual context means some form of, either written or verbal indication of, an impending hazard. Early warning in the disaster context implies the means by which a potential danger is detected or forecast and an alert issued. In this report, the following definition has been taken into consideration: 'The provision of timely and effective information, through identifying institutions, that allows individuals exposed to the hazard to take action to avoid or reduce their risk and prepare for an effective response.' ISDR 2004

Over the last decade, India has incorporated disaster-reduction policies in its national, social and economic development plans to establish effective preparedness measures and improve the response capacities. The value of timely and effective warnings in averting losses and protecting resources/development assets becomes apparent. Urban centres are exposed to greater risk due to severe exposure of elements at risk (Mumbai Floods 2005, Surat Floods 2006). Some of the recent events show the rising trend in the number of people being affected by disasters, especially in the urban areas.

Warning represents an added value and function in the overall disaster risk management/disaster risk reduction framework. There are three main abilities that constitute the basis of early warning.

- The first is technical capability to identify a potential risk or the likelihood of occurrence of a hazardous phenomenon, which threatens a vulnerable population.
- The second ability is that of identifying accurately the vulnerability of a population to whom a warning has to be directed,

- The third ability, which requires considerable social and cultural awareness, is the communication of information to specific recipients about the threat in sufficient time and with sufficient clarity so that they can take action to avert negative consequences.

Warning systems are only as good as their weakest link. They can, and frequently do, fail in both developing and developed countries for a range of reasons. There are significant decision points for the scientific/technical agencies and the disaster management agencies. These decision points coincide with the phases of the disaster management/emergency management decision stages as shown in Figure 2 (say, for hydro-meteorological event with sufficient lead time).

A range of factors influence the hazard event phase and the emergency phase. They include:

- Lack of standardized EWS framework, which is understood by both technical and disaster management agencies.
- Non-availability of warning information products and services at different temporal and spatial scales, and provision of same information content for various sectors/stakeholders.
- Warning message not being aligned in terms of societal impacts, risk assessment not being undertaken and potential impact assessment being based on either individual understanding or on past experience and being non-scientific.
- Lack of systemization steps for emergency response based on event severity.
- Warning content unable to facilitate appropriate

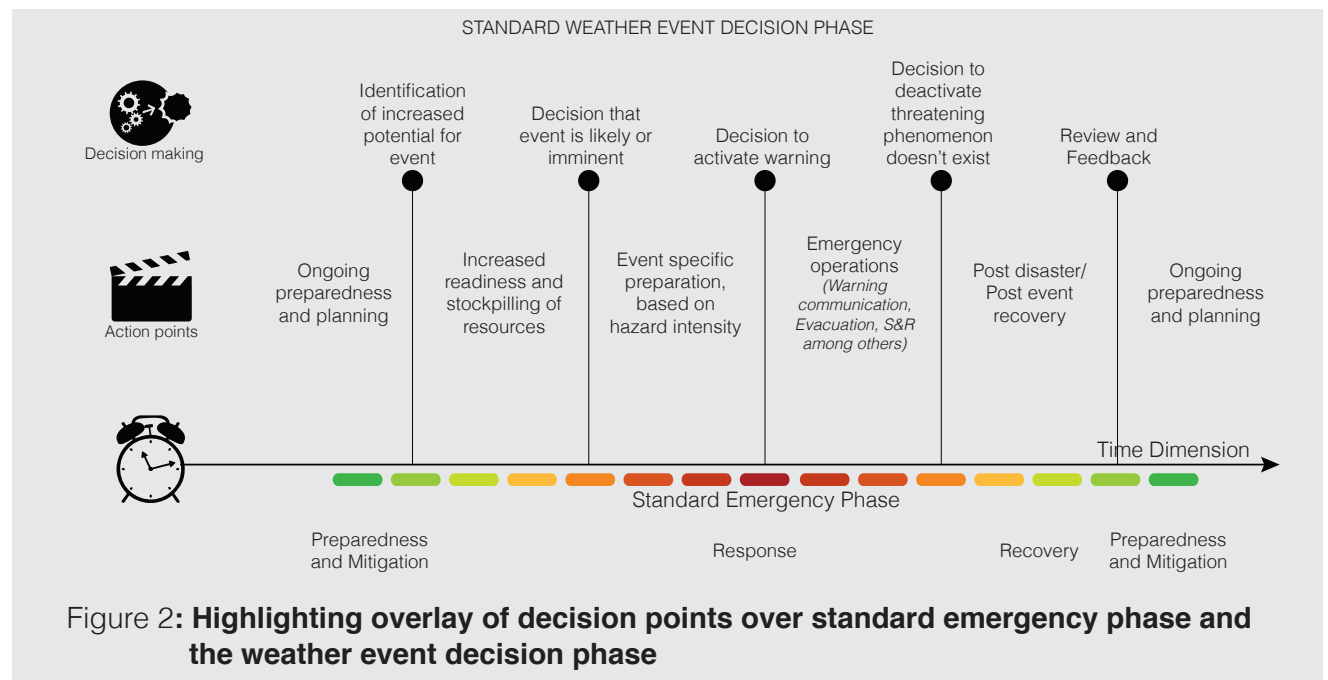


Figure 2: Highlighting overlay of decision points over standard emergency phase and the weather event decision phase

and timely decision actions at least to those people who are most immediately at risk or are under the influence of the hazard.

An effective early warning system links technical agencies that generate warning information with disaster management/emergency management institutions and finally with communities/people at risk. The end-to-end early warning system (RIMES, 2008) involves the following elements (Figure 3 shows the link between these elements):

1. Observation and monitoring
2. Data processing and analysis
3. Prediction and forecasting
4. Risk assessment
5. Potential impact assessment
6. Warning formulation
7. Dissemination to communities at risk (until the last mile)
8. Preparation of response options
9. Community response, which is shaped by:
 - a. Resourced and practiced emergency response plans
 - b. Risk awareness
 - c. Mitigation programmes
10. Receiving user feedback
11. System adjustment/improvement

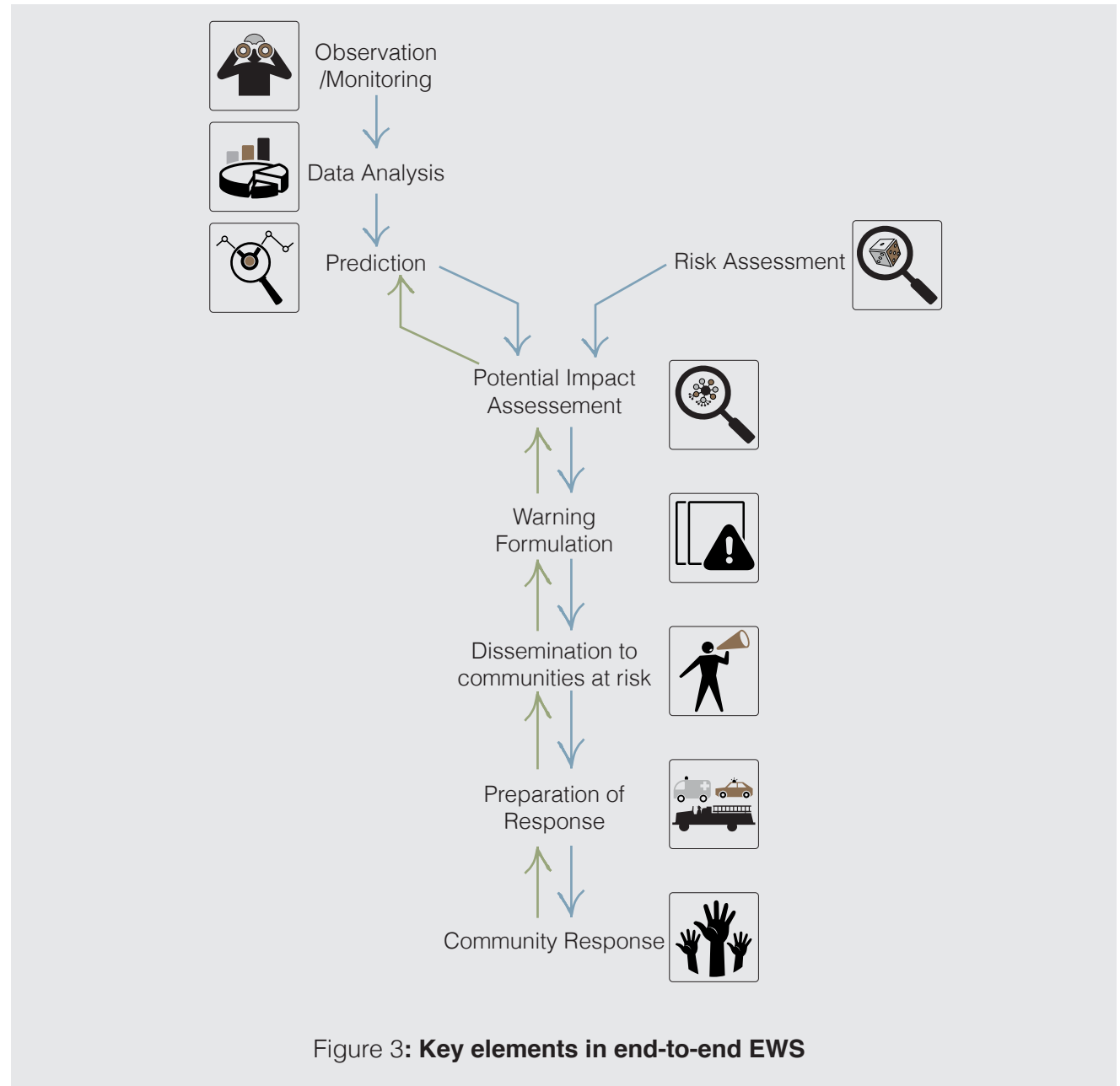


Figure 3: Key elements in end-to-end EWS



2. METHODOLOGY OF REVIEW

A systematic process was adopted by the Review Team to assess the EWS, particularly with respect to the systems for geological, hydro-meteorological and public health risks in all the seven cities.

The assessment involved a systematic flow of understanding the EWS governance at the national, state, district and city levels; institutional mechanism and their roles within the elements of EWS, delivery of products and services by technical and disaster management agencies, as well as their coordination mechanism/operational cooperation; reviewing of existing mechanism of EWS in cities; role of agencies in EWS and their integration in the disaster management institutional framework (City Disaster Management Plan); discussing with stakeholders the gaps and needs in the EWS, capacities of institutions (technical agencies) engaged in EWS, operational cooperation of technical agencies with the emergency departments/functionaries at the district and city levels (emergency management structure and response capabilities), current status and future needs of observation and monitoring capabilities, data management systems; seeking information on pre-computed assessment of risks for various intensity of hazards (risk assessment), hazard analysis and prediction capabilities (threat assessment/potential impact assessment), warning formulation/issuing of guidance and potential outlook/provision of actionable early warning information/warning products, decision making, generation of tailored risk information and dissemination of risk information to at-risk communities or hot-spot locations (risk communication), information technology and telecommunication capabilities, preparation

of response options, institution/emergency responders and community response.

The assessment was based on the information obtained through a set of processes. They are as follows:

- Design of the review framework by the Review Team
- A checklist and questionnaire prepared by the Review Team for obtaining information from technical and disaster management agencies
- Mission to select cities to understand the EWS environment
- Development of Criteria Development Matrix taking into consideration all the key elements of end-to-end EWS (Figure 3)
- Information collected through stakeholder consultations/meetings, workshops in respective cities, discussions with programme focal point in cities, meeting with key experts
- Exchange and mid-term feedback from UNDP programme team
- Development of Policy Brief, where key recommendations cited are discussed for endorsement at the policy level
- Workshop with city stakeholders, sharing of results
- Final report and presentation

The review includes key criteria as indicated in RFP for following key components:

1. TECHNICAL DESIGN / STRUCTURE AND EFFICACY OF EXISTING EWS: Assessment of early warning agencies, communication networks, protocols for issue of warning and transmission to the people. The review should also assess how the residents of the city access the information and how they act upon it.

2. TECHNOLOGIES INVOLVED IN EWS: Review the network design, technical specifications, up-time performance standards, connectivity and integration with all the important facilities and installations, emergency services, and the DM system in the city.

3. MODE OF COLLECTING HAZARD RELATED INFORMATION (Geological hazards, hydrometeorological hazards and disease risks): Review the mode of collecting information related to hazard events, monitoring, and transmitting it to other agencies, particularly the municipal government and district administration.

4. WARNING OUTREACH AND LAST MILE CONNECTIVITY: Review the mode and reach of the warning especially last mile connectivity and dissemination plan through mass media, print and audio-visual medium.

5. MESSAGE CONTENT AND APPROPRIATENESS: Review the messages disseminated through the EWS: on timeliness, appropriateness, accuracy, and simplicity parameters.

6. SERVICE SUPPORT AND SYSTEM MAINTENANCE: Review the service support for maintaining the EWS on a regular basis and ensuring 100 percent uptime.

The schematic diagram (Figure 4) is an illustration of institutional mechanism and decision making around the key warning chain elements. Numbers 1 to 6 in the schematic highlight the core components for evaluating the warning system provided by the technical agencies (national/state/city) to the DM agencies and other DRR stakeholders. The description of the core components and the evaluation principles are summarized below:

1. **EWS GOVERNANCE:** National, State and City Level Institutional Framework: EWS is underpinned by ministry/department/technical institutions providing operational nowcast/forecasts, products and services to a wide range of users/community. EWS in India is underpinned by legislation (DM Act 2005, State Disaster Management Act, State Disaster Management Policy) and institutional framework that clearly define the roles and responsibilities of various stakeholders among the key warning chain elements. Emphasis under this component was given towards understanding of the organizational coordination and cooperation mechanism (decision making and feedback across key warning elements), and allocation of resources at the city level (functional EOC, risk assessment, human resource capacity).

2. **USER NEEDS:** The users in the city are spread across government agencies (district DM authority, municipal corporation city DM authority/local authority, emergency services, first responders); communities at risk; general public; NGOs/CBOs; urban service providers (government and private: line departments such as water supply, storm water drainage, drainage, sanitation, health, transportation, energy, law and order); various sectors of the economy including business establishments, trade and commerce; and the media. The requirements and needs of EWS products and services vary among different users.

3. **OPERATIONAL COMPONENTS OF EWS:** The tasks of the technical agencies and disaster management agencies include developing products and offering a range of services across the warning chain elements. Observation, monitoring, prediction analysis and operational forecasting are

core capacities to be exhibited by the technical agencies. The technical agencies rely on a range of supporting functions such as data gathering, data analysis, IT and telecommunication services and product development through qualified and trained staff. The prediction/operational forecast of hazard onset and hazard intensity are to be further translated into the potential impact assessment at the city level and the surrounding regions. In case of the city having a reservoir/dam located upstream, regional forecast needs to further take into account the opening of the reservoir gates and subsequent inundation scenarios for emergency release.

Risk assessment, risk communication and preparedness for emergency response/evacuation are the responsibilities of the local government/DM stakeholders (as identified in the City DM Plan). Guidelines and procedures typically follow the Standard Operating Procedure (SOP) as outlined in the City DM Plan. A sufficient number of qualified and trained staff undertakes the response functions through designated Emergency Support Functions (ESF). The nerve centre of operations during emergency is the City Emergency Operation Centre (EOC equipped with tools for decision support), which functions as the main hub for all emergency functions during the onset of hazard and during the impact, and shall remain operational until the threat phenomenon subsides. Organizational coordination and cooperation mechanism between ESFs are essential for effective delivery of early warning produced/generated by technical agencies.

City-level product development includes outputs derived from risk assessment studies, tailored risk information generated for the event, relevant information technology and telecommunication services for outreach and capability to handle emergency response.

4. **PRODUCTS AND SERVICES ACROSS THE WARNING CHAIN:** A wide range of products and services aid in decision making. While technical agencies undertake hazard monitoring, detection, analysis, prediction and forecasting (issue advisories to key stakeholders for initiating decisions), risk information will have to be tailored to the requirements of the city and communities at risk.

5. **COORDINATION MECHANISM:** A large number of institutions are involved in the warning chain elements. Each institution plays an essential role and there is a need for synergy and collaboration between forecasting (warning, data exchange through hydro-meteorological services, climate services, public health etc.) and DM agencies. It is important to analyse if there are any specific provisions of expertise by the technical agencies to the DM stakeholders that could support or enhance decision making.

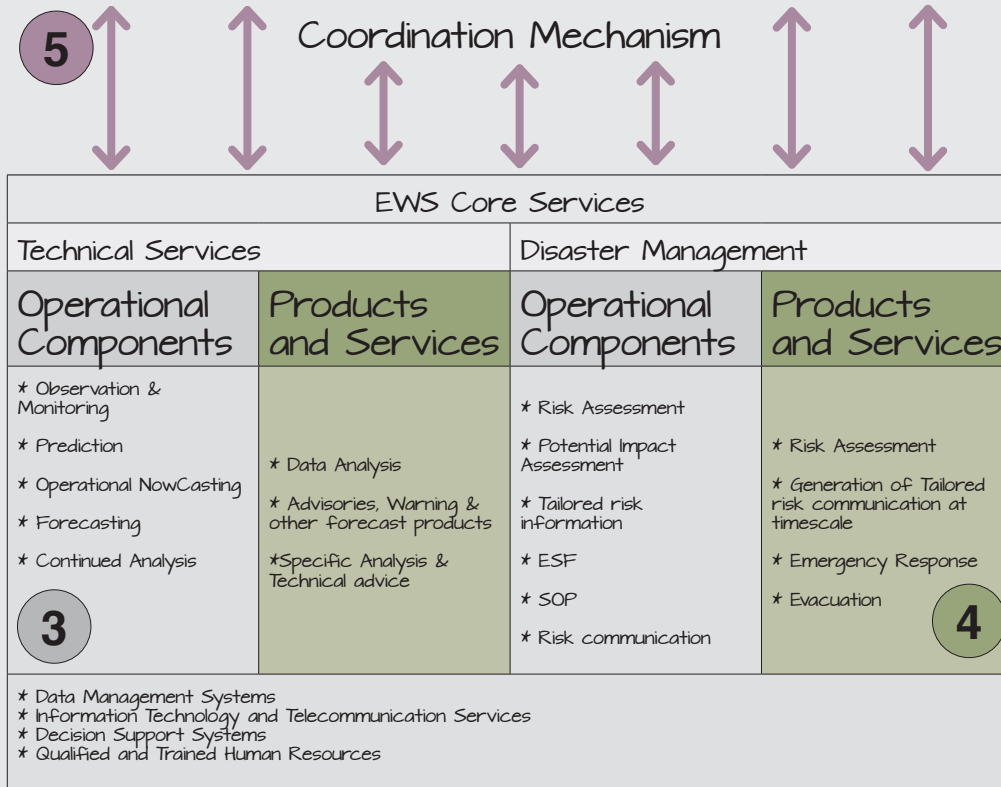
6. **SERVICE DELIVERY AND FEEDBACK LOOPS:** While technical agencies issue the forecast and related warning, DM agencies have to understand the user needs and ensure effective and timely delivery of the services (overarching capacities in quality management system is essential for service delivery across functions). Feedback mechanism across the warning element chain helps in improving delivery/quality of product and services over time.

The elements of EWS and components have been integrated into the development of Criteria Development Matrix (CDM).

1 EWS Governance					
National, Regional & State Technical Agencies			National, State, District & City DM Agencies		
Hydro-meteorological Services	Ocean Services	Public Health	SDMA / State EOC	DDMA / City DM Authority	City EOC / Emergency Responders

2 City EWS users

- District DM Authority
- City DM Authority
- Municipal Corporation
- Emergency Services/ESF
- First Responders
- Communities at risk
- General Public
- NGOs/CBOs
- Business establishment
- Trade and Commerce
- Media
- Urban Service providers
- Water supply & Drainage
- Sanitation
- Public Health
- Transportation
- Energy
- Law and Order



- Component 1
- Component 2
- Component 3
- Component 4
- Component 5
- Component 6

Figure 4: Study framework schematic showing the links of stakeholders across the development model of EWS
 Note: Various components analysed are numbered (as in the text) in the schematic



3. CRITERIA DEVELOPMENT MATRIX AND DEVELOPMENT STAGE INDICATORS FOR EWS

The review of EWS employs a range of criteria across six components and subsequent assessment to arrive at the level of development. Based on the past research and studies, the study has adopted the Criteria Development Matrix to review EWS in seven cities. The Criteria Development Matrix indicates the possibility of considering five stages of development for each criterion built around the six components of the development model of EWS. The Criteria Development Matrix will indicate the progress as basic (Stage 1 development, which is

characterized as rudimentary) to the most advanced (Stage 5 development, which is characterized as current state-of-art and is judged to have reached the fully developed stage containing no major shortcomings). Stages 2, 3 and 4 are characterized as intermediate stages of development. Each of the disaster warnings (hydro-meteorological services, ocean services, climate services and public health services) will be assessed against each criterion and each development stage shall produce a profile indicating the overall stage of development (thereby highlighting gaps and perspective paths for improvement). The level of development stage is based on existing conditions and this can be modified based on the signs of improvement

towards a robust EWS at the city level. Subsequent criteria may be added on in further studies or comprehensive EWS audit exercise.

Criteria Development Matrix has been developed through several rounds of discussions by the review team and is in close alignment to the context of EWS development in India. Table 1 highlights six components identified for the review. It defines 35 criteria and details the development stage for each of the criteria. In the review for each city, specific comments/remarks are highlighted for selection of the development stage for each criterion. An overall score indicates the performance of EWS in the city.

Table 1: **Criteria development matrix: Criteria and indicators of the condition of ews in cities**

S. NO.	COMPONENT 1	EWS GOVERNANCE - CITY LEVEL INSTITUTIONAL FRAMEWORK				
	CRITERIA	DEVELOPMENT STAGE INDICATORS				
		1	2	3	4	5
1.1	State legislation for EWS framework includes local authority (Urban Local Body) as an integral part (document, control to the ULB)	Not envisaged	Need is realized, changes in legislation are in process	In place, but not implemented	In place, partially implemented	In place and implemented
1.2	Institutional mechanism for Local Authority (ULB) is an integral part of EWS framework (document, mandate, implementation)	Not envisaged	Need is realized, changes in institutional mechanism are being brought about	In place, but mandate remains unclear	In place, but partially implemented	In place and implemented
1.3	ULB accorded with the authority to disseminate warnings (mandate, SOP, implementation)	Not envisaged	Mandate does not exist but informal dissemination happens	Mandate exists for dissemination with no SOP in place	Mandate and SOPs in place, implementation not effective	Mandate and SOP in place with effective implementation
1.4	Extent of preparedness and prevention actions evident among state technical and disaster management agencies (relevant department DM Plan at state, SOPs, link from state to city)	Select departments have DM Plan, but it is not implemented	All departments have DM Plan, partially implemented	All departments have DM Plan and SOP in place and implemented, but not integrated across	All departments have DM Plan, SOP in place, implemented and integrated across state departments	All departments have DM Plan, SOP in place, implemented, integrated across state departments and with links to the city

S. NO.	COMPONENT 2	USER NEEDS				
	CRITERIA	DEVELOPMENT STAGE INDICATORS				
		1	2	3	4	5
2.1	Hotspots identified for potential hazard impact (identified, mapped and updated)	Hotspots not identified	Hotspots vaguely identified through past incidence records, not demarcated	Hotspots identified and mapped across city for selected hazards	Hotspots identified and mapped across the city for all hazards, not updated at regular intervals	Hotspots identified and zone of demarcation updated on regular intervals
2.2	Outreach practice (dissemination of warning)	No formal practice for any hazard	Only for select hazards to key government institutions and media	All hazards to key government institutions and media	All government institutions, media, community based organizations	Last mile connectivity established (End-to-End), specific information to select vulnerable communities
2.3	Timely dissemination of warnings to vulnerable groups (residing in slums, high risk prone areas)	No specific warning for vulnerable groups exists in the city	Dissemination of warning exists to some extent	Dissemination of warning exists for select hazards, but with limited respite time	Dissemination of warning exists for all hazards, but with limited respite time	Dissemination of warning exists, with sufficient respite time
2.4	Arrangement for night-time warning (limited to floods, landslides, cyclones, tsunamis)	No specific arrangement for warning in night time	Recognition of the need, planning in progress	Night-time warning is recognized and arrangements reflect this, scope for considerable improvement in dissemination/ outreach	Night-time warning dissemination and outreach established	Warning dissemination tested through conduct of emergency night-time drills/event
2.5	Media engagement in dissemination of warning	Limited coverage, media collects information from respective agencies, shortcomings in communication	Limited coverage of information from respective agencies, technical information presented as received from agencies, shortcomings in communication, problem recognized but not addressed	Media collects and disseminates information, shortcomings are being addressed through collaboration with agencies	Media collects information from technical agencies, timely dissemination of warning to citizens in an understandable format (authenticated value addition)	Standardized content with graphical/iconic representation, near real time updates, citing possible impacts
2.6	Content of warning to general public by local government (ULB) (graphical representation and behavioural content for taking actions at individual/household and community levels)	Limited information	Adequate information for select hazards, but with no behavioural content	Adequate information for relevant hazards, but with no behavioural content	Warning information with graphical, factual representation and general behavioural content at city level	Warning information with graphical, factual representation at ward level and contextual behavioural information provided

S. NO.	COMPONENT 3	OPERATIONAL COMPONENTS OF EWS				
	CRITERIA	DEVELOPMENT STAGE INDICATORS				
		1	2	3	4	5
TECHNICAL AGENCIES						
3.1	Risk assessment and integration with potential impact assessment (identification, mapping, integration)	Risk assessment does not exist	Risk prone areas identified based on historical data, past disasters and other qualitative information in the form of institutional memory and tabular records	Risk assessment undertaken with technical information and demarcates risk prone administrative units, risk assessment products available in the form of maps and quantitative information	Risk assessment (hazard maps, vulnerability and risk maps) available on GIS platform but not updated periodically and not fully integrated with prediction component to derive potential impact assessment and stage response	Risk assessment updated periodically (available on GIS platform) and fully integrated with prediction component to derive potential impact assessment and stage focused response
3.2.1	Warning mechanism for geophysical hazards: Earthquake, Landslide and Tsunami	Warning mechanism does not exist	Warning exists with no consistency in warning message and inadequate respite time	Consistency in warning message with inadequate respite time	Consistency in warning message with adequate respite time	Advanced warning protocol with adequate respite time (with multiple relay and deactivation process)
3.2.2	Warning mechanism for hydrometeorological hazards: Cyclone, Severe Winds, Stormsurge, Heatwave, Coldwave, Snow, Extreme Rainfall, Fluvial Flood and Pluvial Flood	Warning mechanism does not exist	Warning exists with no consistency in warning message and inadequate respite time	Consistency in warning message with inadequate respite time	Consistency in warning message with adequate respite time	Advanced warning protocol with adequate respite time (with multiple relay and deactivation process)
3.2.3	Warning mechanism for public health risks: Vector borne diseases, Water borne diseases and other communicable diseases	Advisory does not exist	General advisory exists with no indication of areas and vulnerable groups	Advisory exists for vulnerable groups with no demarcation of areas	Demarcation of areas based on active and passive surveillance with time delay, no involvement of private stakeholders	Near real time warning, protocol established, active and passive surveillance along with involvement of private stakeholders
3.3.1	Availability of technology to nowcast/forecast of geophysical hazards by technical agencies	High dependency on national agencies for observation, monitoring and forecasting	Has sufficient technology to observe, monitor and nowcast/forecast at regional level, with high dependency on technology available at regional centres	Has sufficient technology to observe, monitor and nowcast/forecast at district level	Has sufficient technology to observe, monitor and nowcast/forecast at city level	Has sufficient technology to observe, monitor and nowcast/forecast at community level/hotspots

S. NO.	COMPONENT 3	OPERATIONAL COMPONENTS OF EWS				
	CRITERIA	DEVELOPMENT STAGE INDICATORS				
		1	2	3	4	5
3.3.2	Availability of technology in nowcast/ forecast of hydro-meteorological hazards by technical agencies	High dependency on national agencies for observation, monitoring and forecasting	Has sufficient technology to observe, monitor and nowcast/forecast at regional level, with high dependency on technology available at regional centres	Has sufficient technology to observe, monitor and nowcast/ forecast at district level	Has sufficient technology to observe, monitor and nowcast/ forecast at city level	Has sufficient technology to observe, monitor and nowcast/ forecast at community level/hotspots
3.3.3	Disease surveillance system (surveillance coverage, collection method, analysis)	Surveillance exists at district level using paper-based forms; analysis undertaken at district level	Surveillance exists at city level within government hospitals using paper-based forms; analysis undertaken at city level	Surveillance exists at city level within government hospitals, private hospitals and all clinics; using paper-based forms; analysis undertaken at city level	Surveillance exists at city level within government hospitals, private hospitals and all clinics; using computerized data collection; analysis and mapping undertaken at community level	Detailed surveillance is carried out on a near real time basis, disease forecast information is made available for decision making
3.4	Uncertainty in forecast and warning: Geophysical hazards, Hydro-meteorological hazards and Public health risks	Forecast/warning does not exist	Forecast exists with high uncertainty, and no warning exists	Forecast exists with high uncertainty, followed by incomprehensible warning	Warning based on forecast exists, with medium degree of uncertainty	Warning based on forecast exists, with low degree of uncertainty
DISASTER MANGEMENT AGENCY / LOCAL AUTHORITY (ULB)						
3.5	Budget allocation by the local authority for EWS	Budget head doesn't exist	Budget head doesn't exist, currently being spent from miscellaneous heads	Need for DM budget head realized, plan to incorporate budget for Disaster Management	Budget exists for DM, no specific budget head exists for EWS	Budget exists for DM, specific sub-head for EWS exists
3.6	Data availability for operations of EWS	Data available with different agencies in multiple formats, not collated or aggregated, qualitative information available	Data is collated from different departments, partial digitization undertaken but not updated regularly; currently not in usable format	Data is collated and updated regularly, limited quality assurance and quality control, temporal data available, spatial data not available, data is of limited use	Data is collated and updated regularly, quality assurance and quality control, temporal and spatial data available, data available in limited usable format	Standardized spatial and temporal data are collated and updated regularly for city EWS, single window system exists for data updation and dissemination, data available in usable format

S. NO.	COMPONENT 3	OPERATIONAL COMPONENTS OF EWS				
	CRITERIA	DEVELOPMENT STAGE INDICATORS				
		1	2	3	4	5
3.7	Staffing and capacity within local authority for operation and maintenance of EWS	No dedicated staff for EWS	Staff deputed on need basis, not specifically trained for operating EWS	Manpower hired on short-term basis, limited training and capacity building provided	Staff assigned for EWS but with multiple responsibility (other than EWS), limited training and capacity building provided	Dedicated specialized staff assigned for city EWS, training and capacity building of staff conducted at regular intervals
3.8	Use of modern technology to disseminate warnings	Generic media – newspapers, local cable channel and radio	In addition to generic media, public addressal system (PAS) in place, but limited to siren	In addition to generic media, PAS in place, but limited to siren and digital display at select locations	Fixed and vehicle mounted PAS, digital/ electronic display screen at select locations, mobile (SMS), web, community radio	State-of-art alert and warning system, dedicated channel, online dissemination system
3.9	Redundancy (multi-mode) in communication networks	None	Recognition of need, no special arrangements made	Recognition of the need and development in process	Warning system reflects the arrangement, partially developed, but scope for considerable improvement	Well-developed redundancy in communication network
3.10	City Emergency Operations Centre (EOC) for housing information related to hazard, vulnerability and risk	EOC does not exist	EOC is activated on a need basis, no information on hazard/ vulnerability and risk	Need for permanent EOC recognized by ULB, and development in progress	EOC established with limited technical and human resource support, and has information on hazard/ vulnerability and risk	EOC established with adequate technical and human resources (manned 24X7), SOP for EOC, systems exist to provide risk information and disseminate it to stakeholders for preparedness and response on near real time basis

S. NO.	COMPONENT 4	PRODUCTS AND SERVICES ACROSS THE WARNING CHAIN				
	CRITERIA	DEVELOPMENT STAGE INDICATORS				
		1	2	3	4	5
4.1	Degree of local details incorporated in warnings	Only generalized warnings from technical agencies	Generalized warnings from technical agencies, need for incorporation of local details is recognized, system under development	City level macro details are incorporated within warnings	Ward details (including hot spots) are incorporated within warnings	Sub-ward/locality/ community details incorporated in warnings (including ward, hotspots); measures cited to take action
4.2	Raising awareness about warnings at city level	No efforts are being made to sensitize citizens	Efforts are made to raise public awareness on frequent hazards, need basis	Awareness programmes on frequent hazards and their risks are conducted on regular/seasonal intervals, special population needs are also not addressed and programme not evaluated	Comprehensive programmes on all hazards and their risks are conducted on regular basis, special population needs addressed, but programme not evaluated	Comprehensive programmes on all hazards and their risks are conducted to raise the level of public awareness, programme regularly evaluated and strengthened
4.3	Ability of technical agencies and disaster management institutions to cater to early warning products and services to user specific requirements	User need assessment not undertaken	User need assessment undertaken, products identified	Products generated for select hazards catering to selected users	Products generated for select hazards catering to selected users, details available to take actions	Products generated for all hazards catering to all users, and details available to take actions
4.4	Risk communication	Risk assessment does not exist, hence no communication	Risk not assessed in local context, information generated by technical agencies are transferred and published/disseminated	Risk is assessed in local context and communicated to select stakeholders	Risk communication including preparedness measures are communicated to stakeholders, dissemination is not robust (last mile connectivity is not ensured)	Well-established risk communication mechanism enables stakeholders to manage risk, dissemination is robust (last mile connectivity is ensured)

S. NO.	COMPONENT 5	COORDINATION MECHANISM				
	CRITERIA	DEVELOPMENT STAGE INDICATORS				
		1	2	3	4	5
5.1	Extent of coordination between technical agencies and disaster management agencies	Communication is limited to select agencies	Communication with all agencies exist, coordination does not exist	Communication with all agencies exist, limited coordination exists	Coordination mechanism ensures agencies respond to specific needs	Coordination ensures collective decision making
5.2	Extent of links between disaster management agencies and service providers	No formal links exist, service providers depend on information hosted on public domain	Formal links do not exist, select service providers are informed during the onset of an event	Formal links become active only prior to/ during an event	Formal links become active periodically in anticipation of an event, one way communication initiated from disaster management agency	Formal links become active periodically in anticipation of an event, two way communication established to ensure business continuity, co-benefit achieved
5.3	Extent of links between media and disaster management agencies	Media depend on information hosted on public domain	Limited information is provided to media	Collaboration and reflection of warning information in the media products are evident	Active collaboration exists, understanding of warnings are reinforced through discussions, no value addition	Well-developed links exist, seamless flow of information, value addition to warning is evident

S. NO.	COMPONENT 6	SERVICE DELIVERY AND FEEDBACK LOOPS				
	CRITERIA	DEVELOPMENT STAGE INDICATORS				
		1	2	3	4	5
6.1	User community's knowledge of early warning system and its effectiveness	ULB does not have clear understanding of existing early warning systems	ULB is aware of early warnings, but does not initiate action	ULB and service providers are aware of warnings, but impacts are not clear to initiate or coordinate action	ULB and service providers are knowledgeable of warnings and are able to take coordinated action	ULB, service providers and citizens are knowledgeable of warnings and are able to take informed actions
6.2	Extent to which the warning mechanism allows for feedback from affected area	No feedback mechanism exists	Problem recognized and mechanism under development	Feedback mechanism exists, but does not include all stakeholders	Feedback mechanism includes all stakeholders, but is not robust	Feedback mechanism functions in near real time
6.3	Level of reflection and learning evident within local authority	Post event reflection is done, but no change is evident	Post event reflection is done and change is evident in mode of communication	Post event reflection is done and change is evident in communication and response mechanism	Assessment undertaken, change evident in monitoring/forecasting/warning and subsequent increase in respite time	Along with increased respite time there is change in guidelines and standard operating procedures
6.4	Monitoring, evaluation and targets for improvement of EWS	No formal procedure to monitor the EWS performance is in place	Need realized, M&E process is under development	Monitoring of select EWS components are in place, improvement needed	M&E process is in place, not undertaken at regular intervals	M&E process is in place and is being carried out regularly, targets for improvements are outlined

4. UNDERSTANDING EWS AND KEY FRAMEWORKS FOR GEOLOGICAL HAZARDS, HYDRO-METEOROLOGICAL HAZARDS AND PUBLIC HEALTH RISKS

Every type of hazard has its own dynamics. The duration of the phenomenon will vary for hazard type and the event type (small or big). There are various stages associated with the development of the event (Figure 5). Broadly, the stages can be categorized as follows:

- Embryonic stage can be linked to the manifestation of those conditions that may give rise to these events or as the events begin to emerge; preliminary phase of the event.
- Growth stage is when the event gradually evolves in terms of its magnitude or area of influence.
- Mature stage would represent the event as being capable of provoking a disaster in a particular geographic location; event triggers impacts and effects on communities and regions near its path.
- Decaying stage that indicates when the event loses its strength and is dissipating.

In the context of early warning, the time lapse between the embryonic and the mature stage is determinant to the capacity of issuing warnings. If this time lapse is large enough, hierarchical phases could be identified allowing for the establishment of several alert or warning levels.

For example, in case of a tropical cyclone in the Indian Ocean, the disturbance that gives rise to the event and subsequent shaping up is considered as embryonic stage. The growth stage would then encompass those processes related to evaporation of water from the ocean and the convective processes within the atmosphere that

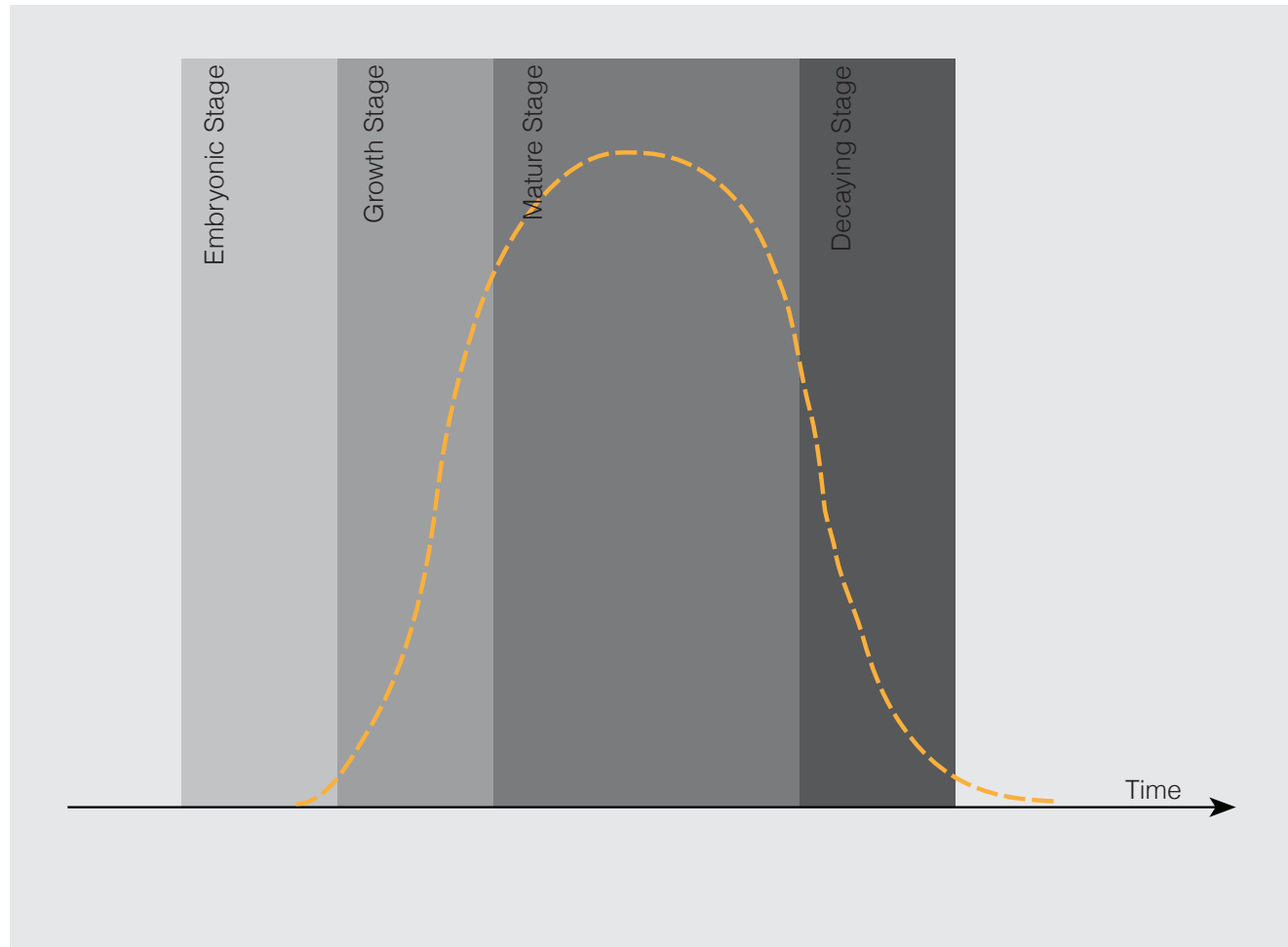


Figure 5: **Evolution of a hazard event in four stages**

Source: Villagrán de León, J. C., Pruessner, I., and H. Breedlove (2013). *Alert and Warning Frameworks in the Context of Early Warning Systems. A Comparative Review. Intersections No. 12.* Bonn: United Nations University Institute for Environment and Human Security.

begin to take shape, such tropical cyclone. In the mature stage, one could see the cyclone as fully manifested in terms of its typical characteristics such as very low barometric pressure, high wind speeds, storm surges and precipitation. Finally, as the cyclone makes landfall, it begins to weaken to the point that it ceases to exist once it is fully inside large landmasses. In this context, meteorologists use a variety of instruments to track the four stages of events. A combination of measurements and computing allows the IMD Cyclone Warning Division to be able to follow the path and the dynamics of such events, leading to forecasts of trajectories and places where such cyclone may make landfall. The disaster management agencies take actions based on the information provided by the technical agencies and follow the Standard Operating Procedure as outlined in the Disaster Management Plan.



4.1 EWS Framework for Earthquake Hazard

Earthquake occurs due to plate tectonic activity. The India sub-continent has a history of devastating earthquakes. Some regions of the country are more risk prone than others. As per the seismic hazard zoning map of India, India is broadly divided into four zones. Zone V is very high damage risk zone (Intensity IX and above on MSK scale); Zone IV is high damage risk zone (Intensity VIII on MSK scale), Zone III is moderate damage risk zone (Intensity VII on MSK scale) and Zone II is low damage risk zone (Intensity VI or less on MSK scale). About 59 per cent of the geographical region of the country falls under Zones III, IV and V.

Studies indicate the possibility of earthquakes of severe intensity in some parts of the country.

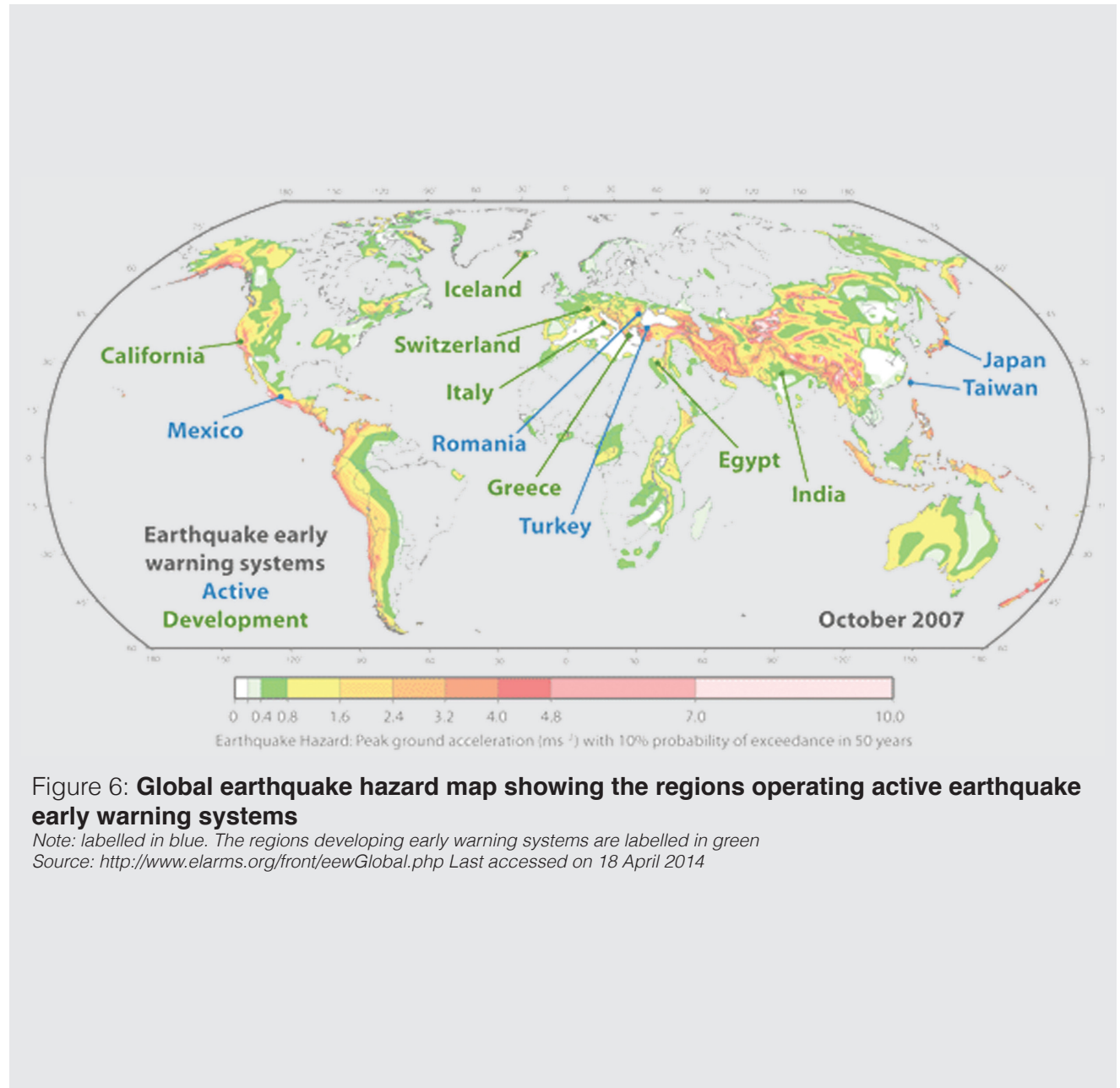


Figure 6: **Global earthquake hazard map showing the regions operating active earthquake early warning systems**

Note: labelled in blue. The regions developing early warning systems are labelled in green
 Source: <http://www.elarms.org/front/eewGlobal.php> Last accessed on 18 April 2014

Given the high vulnerability of the country to damaging earthquakes, there is no functional EWS for earthquake hazard. The growth stage of an earthquake may span across centuries, whereas the phenomenon of ground shaking lasts for seconds to a few minutes. Once the event takes place, the main shock is followed by aftershocks. In some cases, the large earthquake may be preceded by foreshocks. Earthquakes below the ocean bed can trigger tsunami, and on land they can trigger landslides, mudslides, avalanche and rock fall.

Earthquake EWS takes advantage of the rapid availability of earthquake information to quantify the hazard associated with an earthquake and issue a prediction of impending ground motion prior to the arrival of the strong waves in populated areas. Earthquake EWS is a combination of instrumentation, methodology and software designed to analyse and warn the populated areas or sensitive installations. Japan, Taiwan, Mexico, Romania and Turkey currently operate Earthquake EWS, while California (California Integrated Seismic Network, CISEN), Iceland, Switzerland, Italy, Greece, Egypt and India are either in the development or testing phase of Earthquake EWS. Figure 6 shows the status of countries where Earthquake EWS is operational.

India Meteorological Department (IMD) is the nodal agency of Government of India responsible for monitoring seismic activity in and around the country. The operational task of the department is to quickly estimate the earthquake source parameters immediately on occurrence of an earthquake and disseminate the information to all the user agencies including the concerned state and central government agencies responsible for carrying out relief and rehabilitation measures.

Information relating to under-sea earthquakes capable of generating tsunamis on the Indian coastal regions is also disseminated to all concerned user agencies, including the Indian National Centre for Ocean Information Services (INCOIS), Hyderabad, for issue of tsunami related messages and warnings. Earthquake information is transmitted to various user agencies, including public information channels, press, media etc. using different modes of communication, such as SMS, fax, email and is also posted on IMD's website (www.imd.gov.in).

India Meteorological Department also maintains a countrywide National Seismological Network (NSN), consisting of a total of 82 seismological stations, spread over the entire length and breadth of the country. This includes: (a) 16-station VSAT based digital seismic telemetry system around National Capital Territory (NCT) of Delhi, (b) 20-station VSAT based Real Time Seismic Monitoring Network in the north-eastern region of the country and (c) 17-station Real Time Seismic Monitoring Network (RTSMN) to monitor and report large magnitude under-sea earthquakes capable of generating tsunamis on the Indian coastal regions. The remaining stations are of standalone/analogue types. A Control Room is in operation on a 24x7 basis, at IMD Headquarters (Seismology) in New Delhi, with state-of-art facilities for data collection, processing and dissemination of information to the concerned user agencies.



4.2 EWS Framework for Tsunami Hazard

Tsunamis are triggered by undersea earthquakes; landslides which reach seas or oceans and underwater landslides; volcanic eruptions and

dome collapse and meteorites. It is important to note that all earthquakes do not cause tsunamis. The tsunami EWS gathered much attention in India largely because of the consequence of the Indian Ocean tsunami of 26 December 2004. Underwater mass movements get triggered by any of the factors mentioned above. The growth of the phenomenon takes place in the sea and it heads straight to the coastline impacting as tsunami waves. Rise in the sea level and impact of tsunami may last for several hours, and there can be several waves associated with a tsunami event.

In the aftermath of the Great Sumatra earthquake of 26 December 2004, the Ministry of Earth Sciences has set up an Indian Tsunami Early Warning Centre at the Indian National Centre for Ocean Information Services (INCOIS), Hyderabad. The centre is mandated to provide advance warnings on tsunamis that are likely to affect the coastal areas of the country. As a part of this, a 17-station Real Time Seismic Monitoring Network (RTSMN) has been set up by India Meteorological Department.

The network is capable of monitoring and reporting, in least possible time, the occurrence of earthquakes capable of generating tsunamis that are likely to affect the Indian coastal regions. Data from the 17 broadband seismic field stations are transmitted simultaneously in real time through VSAT communication facilities to the Central Receiving Stations (CRSs) located at IMD, New Delhi, and INCOIS, Hyderabad, for processing and interpretation.

The CRSs are equipped with state-of-art computing hardware, communication, data processing, visualization and dissemination facilities. For providing better azimuthal coverage for detecting earthquakes with potential to cause tsunamis, the

RTSMN system has been configured to include about 100 global stations of IRIS (a consortium of Incorporated Research Institutions in Seismology), whose data are available freely through the internet. Information on earthquake is disseminated through various communication channels to all the concerned user agencies in a fully automated mode. Based on the earthquake information provided by the RTSMN and other ocean-related observations/analysis, INCOIS evaluates the potential of the undersea earthquakes to cause tsunami and issues necessary warnings/alerts as per the situation.

The National Tsunami Early Warning Centre at INCOIS is operational since October 2007 and has been issuing accurate tsunami warnings for all undersea earthquakes of ≥ 6.5 M as shown in figure 7. The ITEWS comprises a real time network of seismic stations, Bottom Pressure Recorders (BPR), tide gauges and 24X7 operational tsunami warning centre to detect the potential of earthquakes to cause tsunami, to monitor tsunamis and to provide timely advice to vulnerable community by means of latest communication methods with back-end support of a pre-run scenario database and Decision Support System (DSS). Table 2 presents the bulletin types issued by the ITEWC with the timelines.

However, as local conditions would cause a wide variation in tsunami wave action, the ALL CLEAR determination is made by the local authorities. Actions Based on Threat Status (WARNING/ALERT/WATCH) is given in the table 2.

Bulletin Type	Information	Time of Issue (Earthquake origin time as T_0 minutes)
Type I	Preliminary EQ parameters and LAND/NO THREAT information based on EQ location, magnitude and depth	T_0+20
	Preliminary EQ parameters and qualitative potential of earthquake to cause tsunami, based on EQ location, magnitude and depth	
Type II	Preliminary EQ parameters and NO THREAT information from model scenarios	T_0+30
	Preliminary EQ parameters and quantitative tsunami threat (WARNING/ALERT/WATCH) information from model scenarios	
Type II Supplementary - xx	Revised EQ parameters and quantitative tsunami threat (WARNING/ALERT/WATCH) information from model scenarios – if revised EQ parameters are available much before the real time water level observations are reported	As and when revised earthquake parameters are available or after earthquake lapsed Time + 60 min
Type III	Revised EQ parameters and quantitative tsunami threat (WARNING/ALERT/WATCH) information from model scenarios and real time water level observations indicating tsunami generation	As and when the first real time water level observation is available
Type III Supplementary -xx	Revised EQ parameters and quantitative tsunami threat (WARNING/ALERT/WATCH) information from model scenarios and real time water level observations indicating tsunami generation threat PASSED information for individual zones	Hourly update/as and when the subsequent real time water level observations are available
Final Bulletin	Issued when water levels from multiple gauges confirm that no significant tsunami was generated	
	120 minutes after a significant tsunami passes the last Indian threat zone	

Source: IETWC User Guide Ver. 2, Indian National Centre for Ocean Information Services, June 2011

Threat Status	Actions to be taken	Dissemination to
WARNING	Public should be advised to move inland towards higher grounds. Vessels should move into deep ocean	MoES, MHA, NDMA, NCMC, NDRF battalions, SEOC, DEOC, public, media
ALERT	Public should be advised to avoid visiting beaches and low-lying coastal areas Vessels should move into deep ocean	MoES, MHA, NDMA, NCMC, NDRF battalions, SEOC, DEOC, public, media
WATCH	No immediate action is required	MoES, MHA MoES, MHA, MEDIA, NCMC, NDRF battalions, SEOC, DEOC
THREAT PASSED	All clear determination to be made by the local authorities	MoES, MHA, NDMA, NCMC, NDRF battalions, SEOC, DEOC, public, media

Table 2: **Bulletin types, threat status & action points for tsunami warning alert and watch**



4.3 EWS Framework for Landslide Hazard

The term 'landslide' describes a wide variety of processes that result in the downward and outward movement of slope-forming materials, including rock, soil, artificial fill or a combination of these. The materials may move by falling, toppling, sliding, spreading or flowing (USGS). Landslide causes can be classified into four categories:

- **Geological causes:** These include weak, weathered, sheared or fissured materials, adversely-oriented structural discontinuities (faults, unconformity, etc.), and contrasts in permeability and stiffness.
- **Morphological causes:** These include tectonic or volcanic uplift, glacial rebound, fluvial, glacial or wave erosion of slope toe, or vegetation removal (by forest fire, drought).
- **Physical causes :** These include intense rainfall, rapid snow melt; earthquakes, volcanic eruptions, thawing and weathering (freeze and thaw or shrink and swell).
- **Anthropogenic causes :** These include excavation of the slope or its toe, loading of the slope or its crest, deforestation, irrigation, mining, artificial vibration and water leakage from utilities.

Landslide, a frequently occurring natural hazard in the hilly terrains of India, is a predominant activity during the monsoon period from July to September and after the snowfall from January to March. Strong earthquakes also trigger landslides, particularly in regions marked by critically disposed and unstable slopes. On a rough estimate, nearly 15 per cent of India's landmass or 0.49 million sq km area is prone to landslides. This includes 0.098 million sq km of the north-eastern region, comprising the Arakan Yoma ranges, and 0.392 million sq km of parts of the

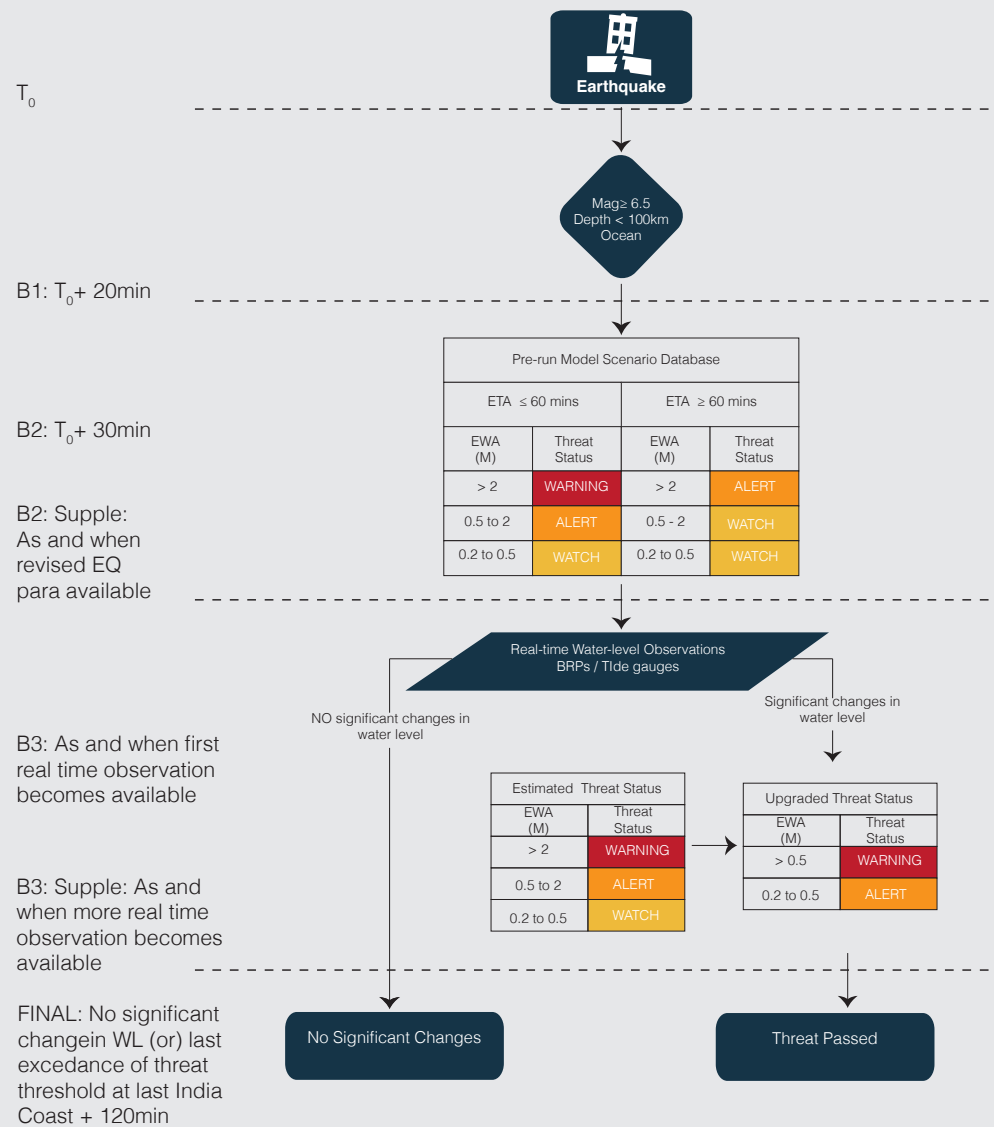


Figure 7: SOP diagram of tsunami early warning centre

Source: http://www.tsunami.incois.gov.in/ITEWS/dss_sop.jsp (Last accessed on 18 April 2014)

Himalayas, Nilgiris, Ranchi Plateau, and Eastern and Western Ghats. As many as 20 states of India are affected by different degrees of landslides. Of these, the states of Sikkim and Mizoram have been assessed to be falling under very high to severe hazard classes. Most of the districts in the states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Arunachal Pradesh, Nagaland and Manipur come under high to very high landslide hazard classes. In the peninsular region, the hilly tracts of states like Karnataka, Andhra Pradesh, Tamil Nadu, Maharashtra, Goa, Madhya Pradesh and Kerala constitute low to moderate hazard prone zones.

Slope saturation by water is the common trigger of landslides, generated through processes such as intense rainfall, snowmelt, changes in groundwater levels, and water level changes along coastlines, earth dams and the banks of lakes, reservoirs, canals and rivers. Landslides and floods are closely allied because both are related to precipitation, runoff and the saturation of ground by water. In addition, debris flows and mudflows usually occur in small, steep stream channels and often are mistaken for floods; in fact, these two events often occur simultaneously in the same area. Building on the fact that some landslides are triggered by intense rainfall, institutions establish the saturation threshold and develop landslide EWS. The presence of extreme weather conditions is used as an indicator to issue warning or to change the levels of warning in the systems, which make use of various threshold levels.

The study of landslide hazard is carried out by the Geological Survey of India (GSI), and can be divided into two broad categories:

1. Pre-disaster Studies: Identification of vulnerable

slopes through landslide hazard zonation (LHZ) mapping on various scales or studying the critical slopes individually and determining their status as far as their stability is concerned.

2. Post-disaster Studies: Detailed analysis of landslides that have occurred, determine the causes responsible for failure and suggest treatment measures required to stabilize the slopes.

Landslide EWS is not undertaken at the moment by GSI or by other agencies in the country.



4.4 EWS Framework for Tropical Cyclone

A tropical cyclone is a rotational low pressure system in the tropics when the central pressure falls by 5 to 6 hPa from the surroundings and the maximum sustained wind speed reaches 34 knots (about 62 kmph). It is a vast violent whirl of 150 to 800 km, spiralling around a centre and progressing along the surface of the sea at a rate of 300 to 500 km a day. The word cyclone has been derived from the Greek word cyclos, which means 'coiling of a snake'. These events are controlled by the interaction between the atmosphere and the oceans in tropical waters. The stages of the cyclone take from a few days to few weeks. During the mature stage, the tropical cyclone may vary its characteristics in terms of wind speed and pressure based on the interaction. On hitting the land, the system weakens and dissipates. Over the last two decades, there has been significant improvement in the capacities of the institutions to monitor, forecast and warn populations in advance of the cyclone hitting the land. World Meteorological Organization has set up five Regional Specialized Meteorological Centres (RSMC) in Miami, Tokyo,

New Delhi, La Réunion and Nadi.

Based on wind speed over the oceanic area, IMD has classified the low pressure systems into the following categories, from low pressure area to super cyclonic storm:

Cyclone Warning Organization Structure in India

RSMC – Tropical Cyclones, New Delhi with effect from 1 July 1988 has been assigned the responsibility of issuing Tropical Weather Outlooks and Tropical Cyclone Advisories for the benefit of the countries in the WMO/ESCAP Panel region bordering the Bay of Bengal and the Arabian Sea, namely, Bangladesh, Maldives, Myanmar, Oman, Pakistan, Sri Lanka and Thailand. The main activities of RSMC, New Delhi, are listed below.

- Round-the-clock watch over the entire North Indian Ocean
- Analysis and processing of global meteorological data for diagnostic and prediction purposes
- Detection, tracking and prediction of cyclonic storms in the Bay of Bengal and the Arabian Sea
- Running of numerical models for tropical cyclone track and intensity prediction
- Issue of Tropical Weather Outlook once daily (at 0600 UTC) and an additional outlook at 1700 UTC in the event of a depression, which is likely to intensify into a cyclonic storm
- Issue of cyclone advisories to the Panel countries eight times a day
- Issue of storm surge advisories
- Implementation of Regional Cyclone Operational Plan of WMO/ESCAP Panel
- Collection, processing and archival of all data pertaining to cyclonic storms, viz., wind, storm surge, pressure, rainfall, satellite information etc.
- Exchange of composite data and bulletins

pertaining to cyclonic storms with Panel countries

- Preparation of comprehensive reports on each cyclonic storm
- Continued research on storm surge, track and intensity prediction techniques

Cyclone Warning Division

Cyclone Warning Directorate – located with RSMC – Tropical Cyclones, New Delhi, was established in 1990 in the Office of the Director General of Meteorology, New Delhi – to co-ordinate and supervise the cyclone warning work in the country in totality. The mission of this division is to improve the cyclone warning activity in the country and to improve links between early warning system of cyclone and disaster management.

The broad functions of the Cyclone Warning Division and RSMC – Tropical Cyclones, New Delhi are as follows:

- Round-the-clock watch over the entire North Indian Ocean
- Analysis and processing of global meteorological data for diagnostic and prediction purposes
- Detection, tracking and prediction of cyclonic storms in the Bay of Bengal and the Arabian Sea
- Issue of numbered Cyclone Warning Bulletins to AIR, Doordarshan and other TV channels and print media for wider coverage
- Interaction with disaster management agencies and providing critical information for emergency support services
- Coordination with government & other agencies at HQ level on all matters relating to cyclonic storms
- Collection, processing and archival of all data pertaining to cyclonic storms, viz., wind, storm surge, pressure, rainfall, satellite information etc.
- Preparation of comprehensive reports on each cyclonic storm

System Intensity	Damage Expected	Suggested Action
Low Pressure Area (Not exceeding 17 kts or less than 31 kmph)	--	--
Depression (17–27 kts or 31–51 kmph)	--	--
Deep Depression (28–33 kts or 52–61 kmph)	Minor damage to loose and unsecured structures	Fishermen advised not to venture into the open seas
Cyclonic Storm (34–47 kts or 62–87 kmph)	Damage to thatched huts. Breaking of tree branches causing minor damage to power and communication lines	Total suspension of fishing operations
Severe Cyclonic Storm (48–63 kts or 88–117 kmph)	Extensive damage to thatched roofs and huts. Minor damage to power and communication lines due to uprooting of large avenue trees. Flooding of escape routes	Total suspension of fishing operations. Coastal hutment dwellers to be moved to safer places. People in the affected areas to remain indoors
Very Severe Cyclonic Storm (64–90 kts or 118–167 kmph)	Extensive damage to kutcha houses. Partial disruption of power and communication lines. Minor disruption of road and rail traffic. Potential threat from flying debris. Flooding of escape routes	Total suspension of fishing operations. Mobilize evacuation from coastal areas. Judicious regulation of rail and road traffic. People in affected areas to remain indoors
Very Severe Cyclonic Storm (91–119 kts or 168–221 kmph)	Extensive damage to kutcha houses. Some damage to old buildings. Large-scale disruption of power and communication lines. Disruption of rail and road traffic due to extensive flooding. Potential threat from flying debris	Total suspension of fishing operations. Extensive evacuation from coastal areas. Diversion or suspension of rail and road traffic. People in affected areas to remain indoors
Super Cyclone (120 kts or more, or 222 kmph or more)	Extensive structural damage to residential and industrial buildings. Total disruption of communication and power supply. Extensive damage to bridges causing large-scale disruption of rail and road traffic. Large-scale flooding and inundation of sea water. Air full of flying debris	Total suspension of fishing operations. Large-scale evacuation of coastal population. Total suspension of rail and road traffic in vulnerable areas. People in the affected areas to remain indoors

Reference/Source: Forecasters Guide, India Meteorological Department, 2008

Table3: **Damage expected & actions from low pressure area to super cyclonic storm**

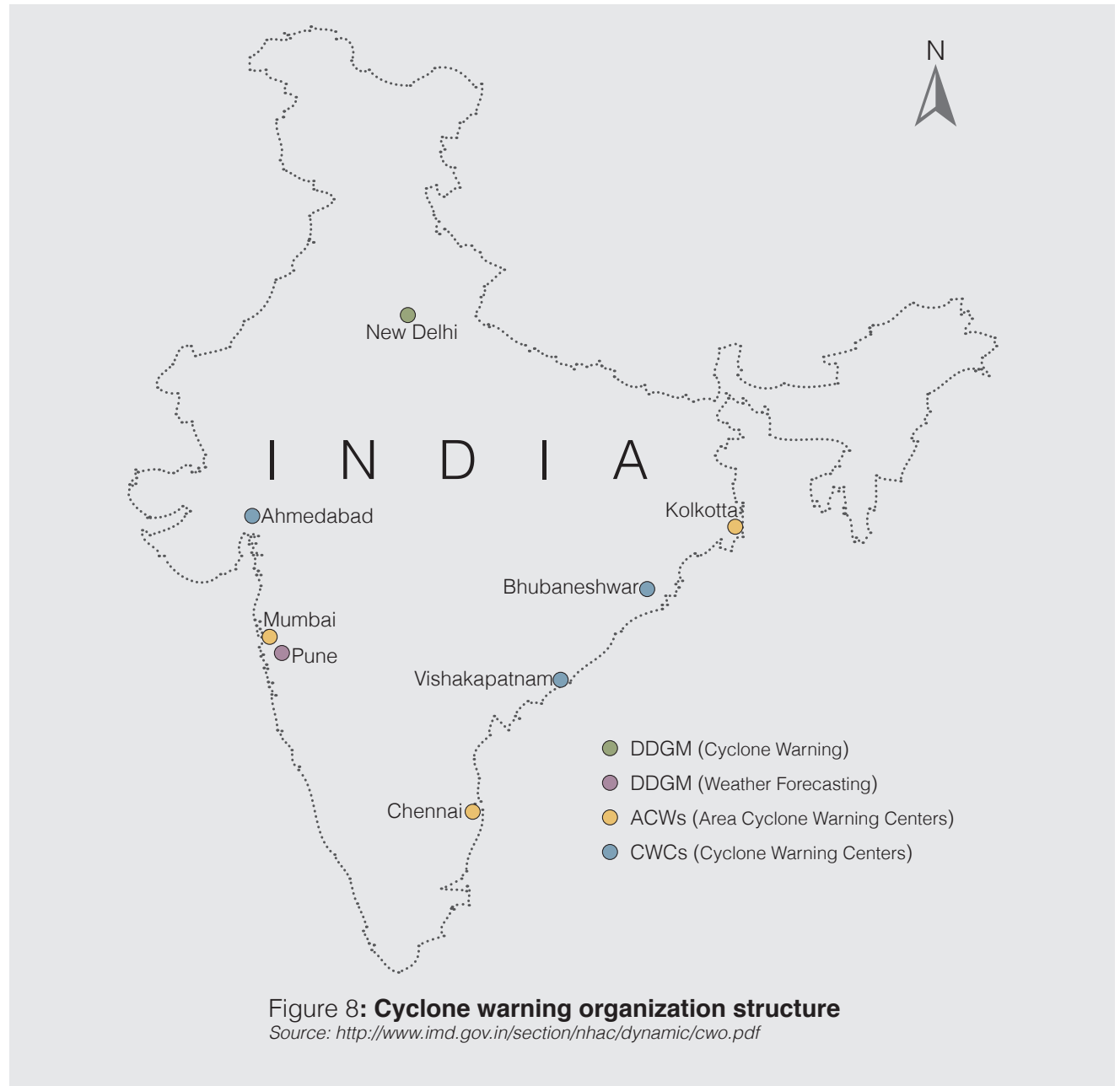
- Collection of all types of information on individual cyclonic storms from State Governments, cyclone warning centres and other agencies.
- Continued research on storm surge, track and intensity prediction techniques.

Area Cyclone Warning Centres (ACWCs)/ Cyclone Warning Centres (CWCs)

With the establishment of additional centres at Bhubaneswar and Visakhapatnam, the Storm Warning Centres at Kolkata, Chennai and Mumbai were named as Area Cyclone Warning Centres (ACWC) and the Storm Warning Centres at Visakhapatnam, Bhubaneswar and Ahmedabad as Cyclone Warning Centres (CWC). CWCs Visakhapatnam, Bhubaneswar and Ahmedabad function under the control of the ACWCs – Chennai, Kolkata and Mumbai respectively.

Meteorological Centre (MC), Hyderabad, liaises between CWC Visakhapatnam and Andhra Pradesh government officials; warnings issued by CWC Visakhapatnam are sent to MC Hyderabad also for briefing the Andhra Pradesh government officials at the state capital.

The present organizational structure for cyclone warnings is a three-tier one, with the ACWCs/CWCs actually performing the operational work of issuing the bulletins and warnings to the various user interests, while the Cyclone Warnings (Directorate) New Delhi and the Deputy Director General of Meteorology (Weather Forecasting), through Weather Central, Pune, coordinate and guide the work of the ACWCs/CWCs, exercise supervision over their work and take necessary measures for continued improvement and efficiency of the storm warning systems of the country as a whole. The ultimate responsibility of carrying on storm warning work, however, rests with the ACWCs and



CWCs. The ACWCs/CWCs maintain round-the-clock watch.

Bulletins and Warnings Issued by ACWCs and CWCs

The following is the list of bulletins and warnings issued by the ACWCs and CWCs for their respective areas of responsibility:

- Weather and sea bulletins
 - for shipping on the high seas and (issued by ACWCs Mumbai and Kolkata only)
 - for ships plying in coastal waters
- Bulletins for Indian Navy (issued by ACWCs Mumbai and Kolkata only)
- Bulletins for departmental exchanges (issued by ACWCs Mumbai, Kolkata and Chennai)
- Port warnings
- Fisheries warnings
- Pre-cyclone watch and post landfall outlook (issued by Cyclone Warning Division)
- Bulletins for the AIR
- CWDS bulletins
- Warnings for registered/designated users
- Bulletins for the press
- Aviation warnings (issued by concerned aviation meteorological offices)



4.5 EWS Framework for Floods

Floods are triggered by heavy rainfall and due to systems such as the cyclone. In some cases, the event can manifest quickly as in flash floods, and in some cases, it can last for days to manifest itself as in very large basins. The fact that most floods are preceded by heavy rainfall, which leads to increasing runoff in the basin and subsequent rise in the level of rivers, the phenomenon allows for EWS to be designed and operated. In addition, if there is a reservoir located upstream, the rule book can incorporate EWS into the operational procedure of the reservoir (flood control).

The EWS for floods can be positioned as a centralized system (managed by agencies like the Central Water Commission) or can be decentralized in the case of a particular city or community-operated EWS.

Flood Forecasting and Warning Organization

In the year 1958, CWC commenced the flood forecasting service in a small way by establishing flood forecasting unit for issuing water level forecasts of the Yamuna for the National Capital, Delhi. On the recommendation of various committees/panels, a Flood Forecast and Warning Organization was set up in CWC in 1969 to establish forecasting sites on inter-state rivers at various flood prone places in the country. The National Flood Forecasting and Warning Network of Central Water Commission, comprises 175 flood forecasting sites, including 28 inflow forecasting sites in flood season (Figure 9).

Central Water Commission, through its 20 flood forecasting divisions, issues forecasts to the various

user agencies, which include civil/engineering agencies of the State/Central Governments such as irrigation/revenue/railways/public undertakings and Dam/Barrage Authorities/District Magistrates/Sub-divisional Officers besides the Defence Authorities involved in the flood loss mitigation work. During the flood season, the Honourable Minister of Water Resources, Government of India, the Chairman and the Member (River Management) of Central Water Commission are apprised of the latest flood situations in the above river basins in the country.

Classification of Various Flood Situations

The Central Water Commission has categorized various flood situations for monitoring the floods in the country through its flood forecasting network, into the following four categories, depending upon the severity of floods, based on flood magnitudes.

Level Forecast

- **LOW FLOOD:** The river is said to be in LOW FLOOD situation at any flood forecasting site when the water level of the river touches or crosses the warning level, but remains below the danger level of the forecasting site.
- **MODERATE FLOOD:** If the water level of the river touches or crosses its danger level, but remains 0.50 m below the highest flood level of the site (commonly known as HFL) then the flood situation is called the MODERATE FLOOD situation.
- **HIGH FLOOD:** If the water level of the river at the forecasting site is below the highest flood level of the forecasting site but is still within 0.50 m of the HFL, then the flood situation is called HIGH FLOOD situation. In this situation, a special Orange Bulletin is issued by the Central Water Commission to the user agencies, which contains the 'special flood message' related to the high flood.
- **UNPRECEDENTED FLOOD:** The flood situation

is said to be UNPRECEDENTED when the water level of the river crosses the HFL recorded at the forecasting site so far. In this situation, a special Red Bulletin is issued by the Central Water Commission to the user agencies, which contains the 'special flood message' related to the unprecedented flood.

Inflow Forecast

- Inflow forecasts are issued for 28 dams/reservoirs/barrages in various river basins in the country. The project authorities have identified the threshold inflow limits for issue of forecast considering various factors such as safety of the dam, status of the reservoir, downstream channel/canal requirements.

Standard Operating Procedure (SOP) for Flood Forecasting and Warning

The basic activity of data collection, its transmission and dissemination of flood forecasts to the local administration is carried out by the field divisions of CWC. The modelling centres and Divisional Flood Control Rooms (DFCR) are located in the premises of the field divisions. The field divisions perform these activities as per the existing Manual on Flood Forecasting, which contains the following critical activities as the general SOPs:

1. Nomination of Nodal Officers of CWC for interaction with the Nodal Officers of the concerned State Governments before monsoon every year
2. Gearing up of flood forecasting network before monsoon every year
3. Operation of Divisional Flood Control Room during monsoon every year
4. Operation of Central Flood Control Room (CFCR) during monsoon every year

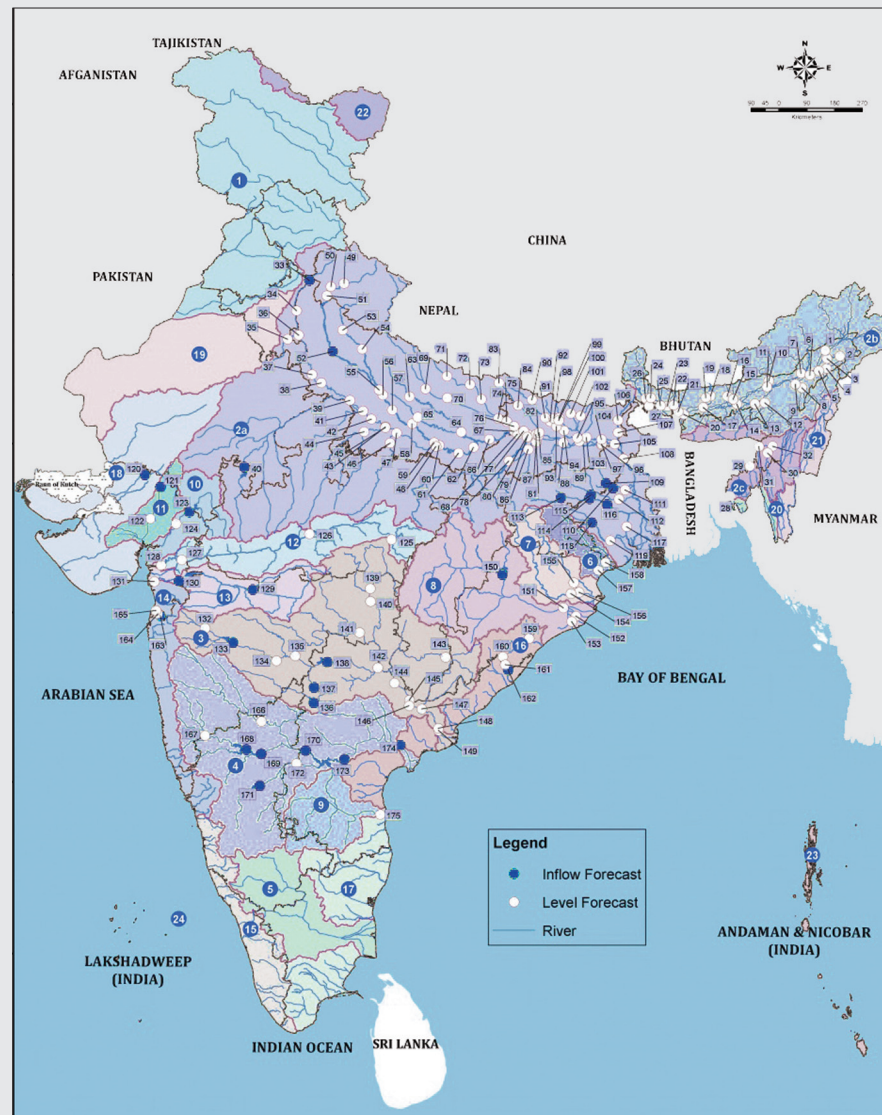


Figure 9: **Flood forecasting stations in India**

Source: http://india-wris.nrsc.gov.in/wrpinfo/index.php?title=CWC_National_Flood_Forecasting_Network. Last accessed on 19 April 2014

5. Issue of flood forecasts to designated officer of the concerned state and transmission thereof through FAX/telephone/email/through special messengers during monsoon every year

6. Sending flood alerts through SMS on mobile phones to the concerned officers of State/Central Government during high and unprecedented flood situations as per Standard Operating procedure (SOP) for issuing alerts and electronic messaging in the event of disaster situations issued by National Disaster Management Division, Ministry of Home Affairs, vide letter No: 31-32/2003-NDM-III/II dated 10 April 2006, made effective from 24 April 2006.

For the purpose of dissemination of alerts to PMO/ Cabinet Secretariat, a uniform system has been devised by categorizing each type of alert in stages – Yellow, Orange and Red.



4.6 EWS Framework for Heat Wave Condition

Heat wave conditions develop over major parts of the country during the mid-season, which often persist until the monsoon advances over the region. Heat wave need not be considered till the maximum temperature of a station reaches at least 40 °C for plains and at least 30 °C for hilly regions. The specifications for declaring the heat/cold wave conditions have been revised three times by IMD so far, viz., in 1978, 1989 and last in 2002. The revised criteria are prevalent with effect from 1 March 2002, along with some additional circulars on comfort index-based temperature forecast, description of 24-hour temperature tendency etc. When the actual maximum temperature remains

45 °C or more, irrespective of normal maximum temperature, heat wave should be declared.

Hot Day – In the northern plains of the country, dust in suspension occurs for several days, bringing the minimum temperature much higher than normal and keeping the maximum temperature around or slightly above normal. Sometimes, increase in humidity also adds to this discomfort. Nights do not get cool and become uncomfortable. To cover this situation, hot day concept has been introduced. Whenever the maximum temperature remains 40°C or more and minimum temperature is 5°C or more above normal, it may be defined as Hot Day, provided it does not satisfy the heat wave criteria given above. Criteria for describing Hot Day for coastal stations are different. When the maximum temperature departure is 5°C or more from normal, Hot Day may be described irrespective of the threshold value of 40°C. If the threshold value of 40°C is reached, Heat Wave may be declared. When a station satisfies both the Heat Wave and Hot Day criteria, then Heat Wave should be given higher priority and be declared.

Hot Wind – Hot wind reduces moisture causing dehydration, and prolonged exposure may prove to be fatal. The phenomenon of Loo (heat wave) over the plains of northwest India is very well-known. It is also described in the weather bulletins and appropriate warnings are issued.

Comfort Index – As per the recommendation of Annual Monsoon Review Meeting, 2004 (Kolkata, January 2004), it has been decided to replace the mere descriptions of maximum and minimum temperatures in weather reports and daily weather summaries by suitable comfort index, based on temperature and humidity as described below with reference to issuance of local forecast at

forecasting centres. The recommendations cited are as follows:

1. Present procedure of issuing local forecast for meteorological parameters, including heat and cold waves, is to continue.

2. In addition to the above forecast, supplementary forecast based on human discomfort utilizing the Heat Index (HI) may be introduced on a trial basis for one year.

3. The HI is to be calculated based on the forecast of maximum temperature and that of relative humidity. Suggested criteria and terminology for issuing human discomfort information are given below. For day time, the criteria will be considered only when the departure of maximum temperature is above 2°C.

4. Regarding discomfort due to low temperatures during winter season, the present criteria using the wind chill index may continue.

5. The use of issuing discomfort forecast will be reviewed after one year based on the feedback from users.

Temp.	Relative Humidity (%)												
	40	45	50	55	60	65	70	75	80	85	90	95	100
110 (43)	136 (58)												
108 (42)	130 (54)	137 (58)											
106 (41)	124 (51)	130 (54)	137 (58)										
104 (40)	119 (48)	124 (51)	134 (55)	137 (58)									
102 (39)	114 (46)	119 (48)	124 (51)	130 (54)	137 (58)								
100 (38)	109 (43)	114 (46)	118 (48)	124 (51)	129 (54)	136 (58)							
98 (37)	105 (41)	109 (43)	113 (45)	117 (47)	123 (51)	128 (53)	134 (57)						
96 (36)	101 (38)	104 (40)	108 (42)	112 (44)	116 (47)	121 (49)	126 (52)	132 (56)					
94 (34)	97 (36)	100 (38)	103 (39)	106 (41)	110 (43)	114 (46)	119 (48)	124 (51)	129 (54)	136 (58)			
92 (33)	94 (34)	96 (36)	99 (37)	101 (38)	106 (41)	108 (42)	112 (44)	116 (47)	121 (49)	126 (52)	131 (55)		
90 (32)	91 (33)	93 (34)	95 (35)	97 (36)	100 (38)	103 (39)	106 (41)	109 (43)	113 (45)	117 (47)	122 (50)	127 (53)	132 (56)
88 (31)	88 (31)	89 (32)	91 (33)	93 (34)	95 (35)	98 (37)	100 (38)	103 (39)	106 (41)	110 (43)	113 (45)	117 (47)	121 (49)
86 (30)	86 (29)	87 (31)	88 (31)	89 (32)	91 (33)	93 (34)	95 (35)	97 (36)	100 (38)	102 (39)	106 (41)	108 (42)	112 (44)
84 (29)	83 (28)	84 (29)	85 (29)	86 (30)	88 (31)	89 (32)	90 (32)	92 (33)	94 (34)	96 (36)	98 (37)	100 (38)	103 (39)
82 (28)	81 (27)	82 (28)	83 (28)	84 (29)	84 (29)	86 (29)	86 (30)	88 (31)	89 (32)	90 (32)	91 (33)	93 (34)	95 (35)
80 (27)	80 (27)	80 (27)	81 (27)	81 (27)	82 (28)	82 (28)	83 (28)	84 (29)	84 (29)	85 (29)	86 (30)	86 (30)	87 (31)

● Uncomfortable hot day/night
 ● Uncomfortable sultry day/night
 ● Highly uncomfortable day/night
 ● Highly uncomfortable sultry day/night

Figure 10: Heat Index °F (°C)

Source: Forecasting Guide, IMD (2008)

Category	Heat Index	Possible Heat disorders for people in high risk groups
Extreme Danger	130°F (54°C) or higher	Heat stroke or sunstroke likely
Danger	105-129°F 41-54°C	Sunstroke, muscle cramps and/or heat exhaustion likely. Heat-stroke possible with prolonged exposure and/or physical activity
Extreme Caution	90-105°F 32-41°C	Sunstroke, muscle cramps and/or heat exhaustion possible with prolonged exposure and/or physical activity
Caution	80-90°F 27-32°C	Fatigue possible with prolonged exposure and/or physical activity



4.7 EWS Framework for Public Health Risks

Integrated Disease Surveillance Project (IDSP) was launched in November 2004 to detect and respond to disease outbreaks quickly. The programme continues in the 12th Plan under NRHM.

Surveillance units have been established in all states/districts (SSU/DSU). Central Surveillance Unit (CSU) has been established and integrated with the National Centre for Disease Control, Delhi.

Training of state/district surveillance teams and Rapid Response Teams (RRT) has been completed for all 35 states/UTs.

IT network connecting 776 sites in States/District HQ and premier institutes has been established with the help of National Informatics Centre (NIC) and Indian Space Research Organization (ISRO) for data entry, training, video conferencing and outbreak discussion.

Under the project, weekly disease surveillance data on epidemic prone disease are being collected from reporting units such as sub-centres, primary health centres, community health centres, hospitals, including government and private sector hospitals, and medical colleges. The data are being collected on 'S' syndromic, 'P' probable and 'L' laboratory formats using standard case definitions. Presently, more than 90 per cent districts report such weekly data through email/portal (www.idsp.nic.in). The weekly data are analysed by SSU/DSU for disease trends. Whenever there is rising trend of illnesses, it is investigated by the RRT to diagnose and control the outbreak.

States/districts have been asked to notify the outbreaks immediately to the system. On an average, 30 to 40 outbreaks are reported every week by the states. About 553 outbreaks were reported and responded to by the states in 2008, 799 outbreaks in 2009, 990 in 2010, 1675 outbreaks in 2011, 1584 outbreaks in 2012, 1964 outbreaks in 2013 and 67 outbreaks in 2014 have been reported till 26 January 2014.

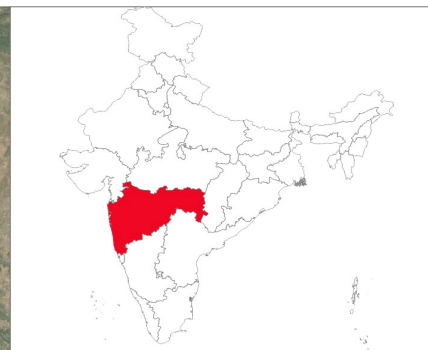
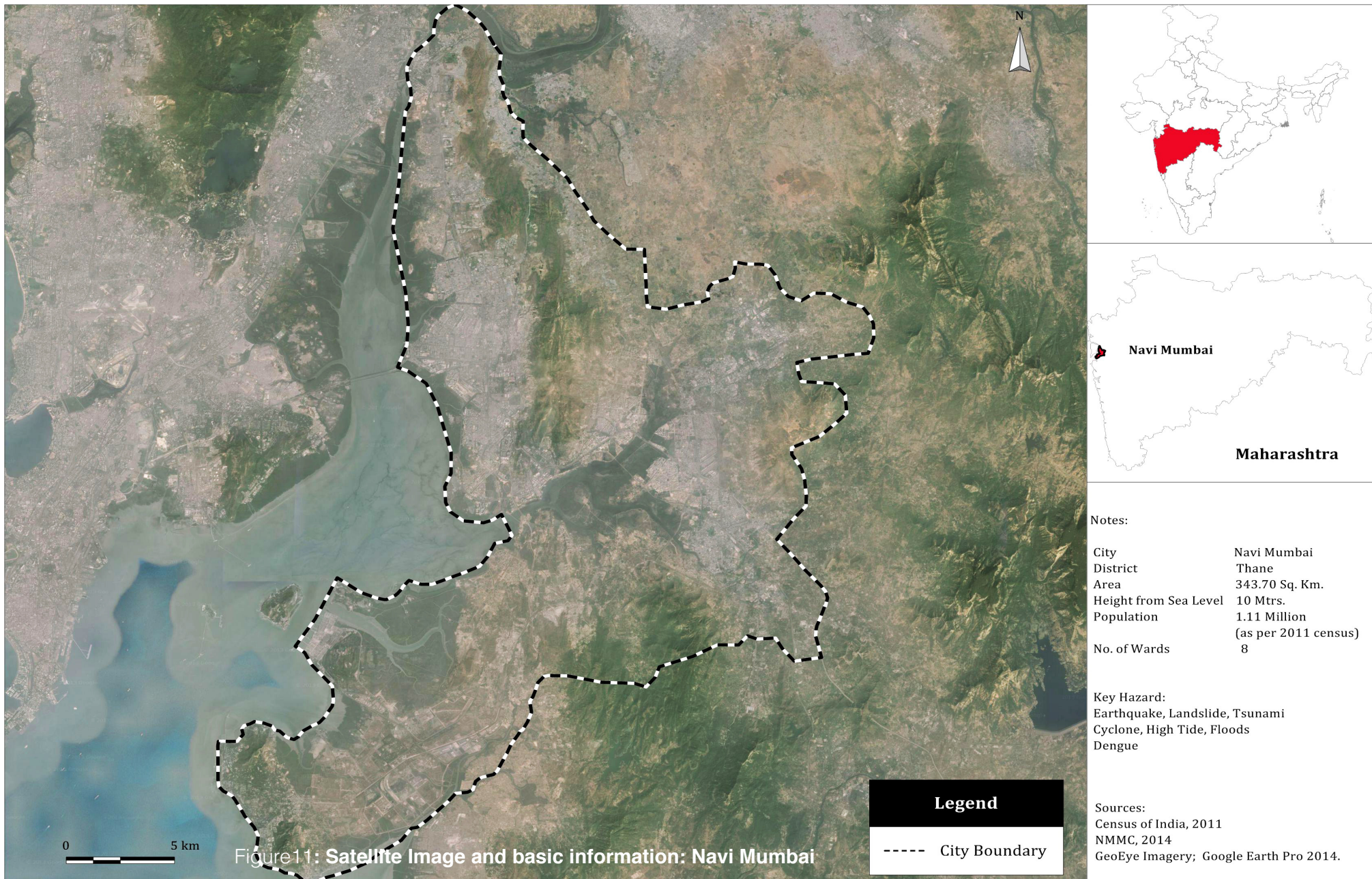
Media scanning and verification cell was established under IDSP in July 2008. It detects and shares media alerts with the concerned states/districts for verification and response. A total of 2595 media alerts were reported from July 2008 to January 2014. Majority of alerts were related to diarrhoeal diseases, food poisoning and vector-borne diseases.

A 24X7 call centre was established in February 2008 to receive disease alerts on a toll free telephone number (1075). The information received is provided to the states/districts surveillance units for investigation and response. The call centre was extensively used during H1N1 influenza pandemic in 2009 and dengue outbreak in Delhi in 2010. About 2,77,395 lakh calls have been received from the beginning till 30 June 2012, out of which 35,866 calls were related to influenza A H1N1. From November 2012, a total of 57,855 calls were received till January 2014, out of which 1605 calls were related to H1N1.

About 50 district laboratories are being identified and strengthened for diagnosis of epidemic-prone diseases. These labs are being supported by a contractual microbiologist to manage the laboratory. About 29 states (42 labs) have completed the procurement. In addition, a network

of 12 laboratories has been developed for influenza surveillance in the country. In nine states, a referral lab network has been established by utilizing the existing 65 functional labs in medical colleges and various other major centres in the states and linking them with adjoining districts for providing diagnostic services for epidemic-prone diseases during outbreaks. Based on the experience gained, the plan will be implemented in the remaining 26 states/UTs. A total of 23 medical college labs, identified in Bihar, Assam, Odisha, Tripura, Kerala, Haryana, Jammu & Kashmir and Manipur, have been added to the network during 2012–13 to provide support in the adjoining districts.

Considering the non-availability of health professionals in the field of epidemiology, microbiology and entomology at district and state levels, MOHFW has approved the recruitment of trained professionals under NRHM to strengthen the disease surveillance and response system by placing one epidemiologist each at state/district headquarters, and one microbiologist and entomologist each at the state headquarters.



Notes:

City	Navi Mumbai
District	Thane
Area	343.70 Sq. Km.
Height from Sea Level	10 Mtrs.
Population	1.11 Million (as per 2011 census)
No. of Wards	8

Key Hazard:
 Earthquake, Landslide, Tsunami
 Cyclone, High Tide, Floods
 Dengue

Sources:
 Census of India, 2011
 NMMC, 2014
 GeoEye Imagery; Google Earth Pro 2014.

Legend

----- City Boundary

Figure 11: Satellite Image and basic information: Navi Mumbai

5. REVIEW OF EWS IN NAVI MUMBAI



5.1 GENERAL CITY INFORMATION

Navi Mumbai is a part of South Konkan coastline. This coastline joins Sahyadri mountain ranges in the south and 50 to 100 m high hills in the east. Navi Mumbai lies between mountain ranges and coastline. The city is bounded by Parsik Hill Range and Thane Creek.

Navi Mumbai is located at the centre of Mumbai Metropolitan Region (MMR), surrounded in the west by Arabian Sea while to the north is Thane, to the east is Kalyan and to the south is Panvel town. Navi Mumbai city has been developed by The City and Industrial Corporation of Maharashtra Ltd. (CIDCO) with the objective of reducing the growth rate of population in Greater Mumbai. Therefore, a wholesome planning approach was laid to provide physical and social services to different sections of the population keeping in view the future population growth. Subsequently, developed area within the jurisdiction of Navi Mumbai Municipal Corporation (NMMC) was transferred to NMMC by CIDCO for maintenance, although CIDCO continues to own and develop vacant land within these nodes as the development authority.

Navi Mumbai is a planned city with an area of 162 sq km. Its jurisdiction starts at Digha in the north and ends at Belapur in the south. NMMC area has been divided into eight zones. Sprawling in 108.5 sq km, these zones are Belapur, Nerul, Turbhe, Vashi, Koparkhairance, Ghansoli, Airoli and Digha.



5.2 BACKGROUND ON HAZARD RISK

Geophysical Hazard

Navi Mumbai is located in seismic zone III as per IS:1893-2002 (BIS, 2002) signifying that the city may be subjected to intensity VII damage as per MSK64 intensity scale. A review of the historical as well as recent earthquake activity in coastal Maharashtra indicates that different parts of the region are characterized by low to moderate level of seismic activity (Jaiswal and Sinha, 2006, 2007). As per Seismotectonic Atlas of India (GSI), the West Coast fault is an active fault and runs along the eastern shore of the Thane Creek in the Mumbai area, along the flanks of the Parsik Hills (Belapur–Vashi region). The Chiplun fault runs from the mouth of Bombay Harbour to the Sangammeshwar area in Ratnagiri district.

Landslides in Navi Mumbai occur mainly due to vertical cutting of hills, for construction of houses, roads, railway lines, etc. in Kharghar hills area. The Kharghar hills are part of the Sahyadri hill ranges of the Western Ghats. In absence of proper embankment material, heavy rains lead to falling of earth material and debris. Most cases of landslides occur during heavy rains. Many areas in Navi Mumbai face the risk of landslides due to increased pressure on land. Many vacant sites on hill slopes or bottoms of hills have turned into inhabited area and thereby become vulnerable to landslides.

The western coast of India has not recorded many tsunamis in the past. However, historical events indicate that the coastal region of Navi Mumbai is vulnerable to tsunamis from historical earthquakes which took place along the Makran coast. Navi

Mumbai has 25 km long coast and the funnelling effect of Thane creek can increase the risk. In the Persian Gulf, the 1945 Mekran earthquake (magnitude 8.1) generated tsunami of 12 to 15 m height. The estimated height of waves witnessed in Mumbai from the same event was about 2 m, with damages to human lives and boats (Jaiswal and Rastogi, 2007).

Hydro-Meteorological Hazard

Navi Mumbai is around 10 m to 15 m above the mean sea level and parts of the city are on reclaimed land on Arabian Sea coast. The city is bounded by Parsik Hill Range and Thane Creek. Nearly 10 per cent (34.20 sq km of 343.70 sq km) of Navi Mumbai is low lying area unsuitable for development as per development plan of CIDCO. According to Survey of India (Sol) tide table, high tide level with respect to mean sea level is 4.5 m in Navi Mumbai. Due to its geographical location, it experiences inundation and water logging in the low lying areas, during high tides.

Settlements located near Thane creek are in the low lying area and are exposed to high tide, heavy rains (up to 3000 mm) and cyclonic storms leading to flooding. NMMC area experienced 806 mm of rainfall on 26 July 2005, which was the highest. This extreme rainfall resulted in floods causing damage to properties and affecting normal life for a few days. The cyclonic storm, Phyan which crossed Maharashtra coast between Alibag and Mumbai on 11 November 2009 resulted in waves over 2 m high and caused loss of seven human lives and about 44 fishermen went missing.

Public Health Risks

The city is prone to both water-borne and vector-borne diseases. Some of the common outbreaks are of malaria, dengue, hepatitis B and leptospirosis. Being close to the coast, the city experiences high humidity and during summers this, combined with high temperatures during the day, leads to heat-related illness.



5.3 BRIEF VULNERABILITY PROFILE

Navi Mumbai is a planned city. The city is bounded by Parsik Hill Range and Thane Creek. Around 10 per cent (34.20 sq km of 343.70 sq km) area of Navi Mumbai has been declared as low lying area (which is marshy land under tidal creeks). As per disaster management plan of Navi Mumbai, nearly 90 locations have recurring water logging problem during monsoon and 41 slum pockets at various locations get affected. About 181 flooding spots have been identified.

The most important factor that increases the social vulnerability of the city to natural hazards is the city's growing population. To cater to the employment needs of the construction industry, domestic help, trade and commerce, there is evidence of workers migrating to Navi Mumbai. During the last two decades, the population of the city increased from 397,000 to 1,111,320 in 2011 (Census of India). Nevertheless, due to its planned development, the percentage of slum population within the city is relatively lower than in Mumbai.

Navi Mumbai has a pre-eminent position in the state as the commercial and trading base. Also, the Maharashtra Government industrial promotion

policy leads to the development of industrial belt in Navi Mumbai. Many government and corporate offices have been shifted from Mumbai to Navi Mumbai. According to CIDCO, there are about 2300 industrial units with an employment of over one lakh with an annual turnover of more than 10,000 crore. Navi Mumbai industrial belt, which is in the jurisdiction of NMMC, has industries such as chemical, pharmaceutical, engineering, textile processing, petrochemical, electronics, oil and processing, paper, plastic, steel and food industries. The exposure of the city to natural hazard may have an impact on the local economy.



5.4 INSTITUTIONAL FRAMEWORK

Navi Mumbai Municipal Corporation

The Navi Mumbai Municipal Corporation (NMMC) manages the disaster situation without intervention from the state authorities, with an EOC and two control rooms. Micro-level plans at zonal level have been prepared for all the eight zones incorporating specific responsibilities of zone officer who will act as Zone Disaster Manager. However, in cases of disasters of exceptionally large magnitude that require coordination with wide range of lateral agencies, including central government agencies, the Additional Chief Secretary (Home) can play a vital role in providing help from various government organizations to the Municipal Corporation to handle the disaster in Navi Mumbai.

NMMC has established Disaster Management Cell at two locations in NMMC area. The functions of the Navi Mumbai Disaster Management Committee are as follows:

- Ensure effective inter-departmental co-ordination between all departments
- Provide policy decisions when required
- Inform government about disaster situation
- Review disaster-related activity reports received from NMMC control room, police control room and army control room, and provide appropriate directions
- Co-ordinate the activities of lateral and central government agencies like Defence Services, SRP, RPF, Coast Guards, Home Guards, CISF, MTNL, Port Trust, FCI, Meteorology Department, MPCB, BARC

NMMC has four AWS and 19 manual rainfall collection spots, which are used in conjunction with the satellite images to add local level information. Hotlines are established between BMC, district collector – Thane and Mantralaya. Three community-based NGOs are connected to the EOC. Local TV and radio channels are used for dissemination of warnings.

IMD Regional Centre, Mumbai

IMD Regional Centre at Mumbai is the principal agency responsible for meteorological observations, weather forecasting, warning and seismology in Maharashtra region. IMD Regional Centre undertakes observations, communications, forecasting, warning and weather services. The centre is also responsible for monitoring tropical cyclone formation in Arabian Sea and carrying out cyclone warning work.

Early warning information (related to heavy rain, high tide, extreme weather including cyclonic events) is regularly being provided by IMD to Disaster Management Unit (BMC), DDMO (Thane) and NMMC by SMS. During monsoon, this information is sent to decision makers such as

District Collector and Municipal Commissioner to take precautionary measures. SMS blasters are used for warning dissemination.

Outreach programmes are conducted by IMD for media to sensitize them on public dissemination of weather-related warnings.

IDSP, Mumbai

IDSP is implemented only in rural areas in the state of Maharashtra. ULBs or cities are not part of this programme. Hence flow of early information from the state to the ULB is not well-established. However, IDSP collects information from Municipal Corporations under Disease Outbreaks/Alerts Reports as per IDSP format.

Revenue Department and State Disaster Management Agency

State Disaster Cell is established under the Relief and Rehabilitation Department of the Government of Maharashtra. State and District Disaster Management Plans are in place. The Emergency Operations Centre (EOC), which was set up in Mantralaya, is being re-established now, post the recent fire accident.

Divisional Control Rooms were set up in divisional headquarters and District Control Rooms in district headquarters. A state-wide communication network was set up, which consisted of VSAT and VHF network. Navi Mumbai city comes in Thane district, Konkan division.

Revenue Department (District Collector)

Regional Disaster Management Centres (RDMC) have been established to set up a first response capacity at the regional level, which can provide support to the urban centres as well as to a number of districts. The RDMC have been established in

cities such as Navi Mumbai, Thane, Pune, Nagpur, Aurangabad, Nashik, Sangli, Nanded, Amravati and Solapur. The RDMCs have sufficient capacity to respond to all kinds of disasters and help citizens in saving their lives and property.

District Disaster Management Authority is headed by the District Collector. Thane district collector's office has EOC, which operates 24X7 for natural (heavy rain, floods, cyclone etc.) as well as manmade disasters (fire). Dedicated emergency telephone line, 1077, is in place. Tehsildars, BDOs and all corporations are connected through hotlines.

Vashi Fishermen's Co-Op Soc. Ltd.

No dedicated legislation exists in the state that describes the inclusion of non-governmental organizations or community-based groups in the formal disaster management coordination structure. Informal mechanisms are in place to interact and coordinate for disaster preparedness, response and mitigation. Vashi Fishermen's Co-Op Society is once such community-based organisation working for the welfare of fishermen. Vashi fishermen community receive regular information from the Fisheries Department, Port Authorities, Customs Department and Indian Coast Guards.

In Navi Mumbai, all fishing boats are equipped with wireless stations, GPS and also with Distress Alert Transmitter (DAT). It is a satellite-based emergency warning system, which transmits emergency signal on manual activation. In Navi Mumbai, DAT instruments were provided by the Indian Coast Guards to fishermen to use during any emergency. It receives audio alarm at Maritime Rescue Coordination Centre (MRCC) of Indian Coast Guard with the time of activation, type of emergency, vessel ID and position in sea.

Warnings are disseminated to each boat/vessel that is well-equipped with wireless stations, GPS and also with satellite-based emergency warning system: Distress Alert Transmitter (DAT).

IIT Mumbai

IIT Mumbai provides technical support for disseminating daily information on local rain, temperature and other related weather information. MCGM has established a network of 65 AWS across Mumbai. Weather information from these AWS is updated on their website every 15 min.

5.5 INDICATORS OF THE EXISTING CONDITION OF EWS

Table 4: **Criteria development matrix: Indicators of existing condition of EWS in Navi Mumbai**

S. NO.	COMPONENT 1	EWS GOVERNANCE - CITY LEVEL INSTITUTIONAL FRAMEWORK					REMARKS
	CRITERIA	DEVELOPMENT STAGE INDICATORS					
		1	2	3	4	5	
1.1	State legislation for EWS framework includes local authority (urban local body) as an integral part (document, control ULB)	●	○	○	○	○	The State Disaster Management (DM) Plan has no mention of role/mandate for NMMC as part of the EWS framework. State DMP focus is on District Disaster Management
1.2	Institutional mechanism for local authority (ULB) is an integral part of EWS framework (document, mandate, implementation)	●	○	○	○	○	Navi Mumbai City DM Plan has no mention of EWS
1.3	ULB accorded with the authority to disseminate warnings (mandate, SOP, implementation)	●	●	●	○	○	The dissemination of warnings happens for heavy rains, high tide and disease outbreaks. The information is provided by the Regional Meteorological Department, IMD through SMS (regular interval pre-/during disaster including hotline connectivity). Such warning mechanism from Municipal Corporation is not evident for other hazards
1.4	Extent of preparedness and prevention actions evident among state technical and disaster management agencies (relevant department DM Plan at state, SOPs, link from state to city)	●	●	●	○	○	Preparedness actions are evident for heavy rainfall and high tide

S. NO.	COMPONENT 2	USER NEEDS					
	CRITERIA	DEVELOPMENT STAGE INDICATORS					REMARKS
		1	2	3	4	5	
2.1	Hotspots identified for potential hazard impact (identified, mapped and updated)	●	●	●	○	○	Institutional memory of hotspots exists based on historical events, further supported by limited field checks during heavy rainfall (for landslide hazard)
2.2	Outreach practice (dissemination of warning)	●	●	●	○	○	Forecast exists for weather events and high tide, information is provided by IMD and SOI Tide Prediction Table to government institutions and media
2.3	Timely dissemination of warnings to vulnerable groups (residing in slums, high risk prone areas)	●	●	●	○	○	Warning is disseminated for select hazards and arrangements are made for availability of food and clean water
2.4	Arrangement for night time warning (limited to floods, landslides, cyclones, tsunamis)	●	●	●	○	○	Arrangements are in place for dissemination of warning, 24 h, round-the-clock
2.5	Media engagement in dissemination of warning	●	●	●	●	○	Media add value through display of visual aids, which include location and severity of the event. Local TV/cable channels are involved in warning dissemination
2.6	Content of warning to general public by local government (ULB) (graphic representation and behavioural content for taking actions at individual/household and community levels)	●	●	●	○	○	Health department of Navi Mumbai Municipal Corporation currently provides health recommendations during monsoon months

S. NO.	COMPONENT 3	OPERATIONAL COMPONENTS OF EWS					
	CRITERIA	DEVELOPMENT STAGE INDICATORS					REMARKS
		1	2	3	4	5	
TECHNICAL AGENCIES							
3.1	Risk assessment and integration with potential impact assessment (identification, mapping, integration)	●	●	●	○	○	City level risk assessment is not undertaken, qualitative ward level hazard indication is provided within the City DM Plan in tabular form (ward-wise number of hotspots for flood/high tide/landslide)
3.2.1	Warning mechanism for geophysical hazards (earthquake)	●	○	○	○	○	No warning and dissemination mechanism currently exists for landslide and earthquakes. The city depends on INCOIS for providing tsunami warnings
3.2.2	Warning mechanism for hydro-meteorological hazards (cyclone, severe winds, heat wave, cold wave, extreme rainfall, fluvial flooding, pluvial flooding)	●	●	●	○	○	IMD Regional Centre at Mumbai is well-equipped. Forecasts and warning are provided by this centre to NMMC
3.2.3	Advisory mechanism for public health risks (vector-borne and water-borne diseases)	●	●	●	○	○	Health department of NMMC currently issues health recommendations during monsoon months
3.3.1	Availability of technology to nowcast/forecast geophysical hazards by technical agencies	●	○	○	○	○	No warning mechanism established
3.3.2	Availability of technology in nowcast/forecast of hydro-meteorological hazards by technical agencies	●	●	○	○	○	IMD Regional Centre at Mumbai is well-equipped with state-of-art instruments, and is able to provide forecast and warning
3.3.3	Disease surveillance system (surveillance coverage, collection method, analysis)	●	●	●	●	○	Monitoring of health information at city level is being carried out by Health Department, NMMC
3.4	Uncertainty in forecast and warning (hydro-met, public health)	●	●	●	●	○	Warning based on forecast exists, with medium degree of uncertainty for hydro-meteorological hazards. None exists for earthquake. Forecast mechanism not in place. Warning information is provided upon realization of first outbreak

S. NO.	COMPONENT 3	OPERATIONAL COMPONENTS OF EWS					
	CRITERIA	DEVELOPMENT STAGE INDICATORS					REMARKS
		1	2	3	4	5	
DISASTER MANAGEMENT AGENCY / LOCAL AUTHORITY (ULB)							
3.5	Budget allocation by the local authority for EWS	●	●	○	○	○	There is no resource allocation in the municipal budget for EWS
3.6	Data availability for operations of EWS	●	●	●	○	○	NMMC has identified low lying areas (water logging areas), flood prone settlements and landslide prone areas
3.7	Staffing and capacity within local authority for operation and maintenance of EWS	●	●	●	○	○	Overseen by staff deputed on need basis, but not specifically trained around EWS operational framework
3.8	Use of modern technology to disseminate warning (hydro-met, public health)	●	●	○	○	○	No technology is used for identification and dissemination of geophysical hazard warning information. Fixed and vehicle mounted PAS with sirens are positioned at various locations for providing hydro-meteorological warning. Health advisory is provided to public at large through local newspapers and local cable TV operators
3.9	Redundancy (multi-mode) in communication networks	●	●	●	○	○	NMMC will shift to a new premises with well-equipped communication system (communicated during the interview in October 2013)
3.10	City Emergency Operations Centre (EOC) for housing data of hazard, vulnerability and risk	●	●	●	○	○	The current set-up is operational throughout the year and is manned with additional human resources during monsoon period

S. NO.	COMPONENT 4	PRODUCTS AND SERVICES ACROSS THE WARNING CHAIN					
	CRITERIA	DEVELOPMENT STAGE INDICATORS					REMARKS
		1	2	3	4	5	
4.1	Degree of local details incorporated in warnings	●	●	○	○	○	Partially operational for heavy rainfall (19 manual rain gauges are installed to monitor local rainfall variability)
4.2	Raising awareness about warnings at city level	●	●	●	○	○	Awareness is spread through distribution of IEC materials in local languages (pamphlet, booklets), cable TV, radio, programmes in schools/colleges/NGOs/general public functions)
4.3	Ability of technical agencies and disaster management institutions to cater their early warning products and services to user-specific requirements	●	○	○	○	○	Products generated for select hazards (hydro-meteorology) catering to selected users (fishermen community), details are provided to undertake actions
4.4	Risk communication	●	●	○	○	○	Risk is not assessed at the city level. Information communicated by technical agency is hazard-specific during the onset of the event and this information is provided to government agencies and media. Except for Vashi fishermen community, there is need for improvement of risk communication within the city

S. NO.	COMPONENT 5	COORDINATION MECHANISM					
	CRITERIA	DEVELOPMENT STAGE INDICATORS					REMARKS
		1	2	3	4	5	
5.1	Extent of coordination between technical agencies and disaster management agencies	●	●				IMD has expressed willingness to coordinate with the ULB to upgrade the hydro-meteorological network
5.2	Extent of links between disaster management agencies and service providers	●	●				Informal link is evident in some line departments like traffic/engineering (road, sewerage) etc. There is scope to formalize this process
5.3	Extent of links between media and disaster management agencies	●	●	●			Reflection of warning information in media products (such as local cable news, FM radio, local newspapers) is evident (daily during the monsoon period)

S. NO.	COMPONENT 6	SERVICE DELIVERY AND FEEDBACK LOOPS					
	CRITERIA	DEVELOPMENT STAGE INDICATORS					REMARKS
		1	2	3	4	5	
6.1	The knowledge of user community of early warning system and its effectiveness	●	●	●	○	○	Exists for only hydro-meteorological hazards and by few selected service providers (traffic police, engineering (road, sewerage))
6.2	Extent to which the warning mechanism allows for feedback from the affected area	●	○	○	○	○	Formal feedback mechanism does not exist. Discussion is held in the monsoon preparation meetings. Feedback is not established with technical agency (such as IMD) and other departments at regional or national levels
6.3	Level of reflection and learning evident within local authority	●	●	○	○	○	City is well-planned (by past learning from Mumbai City). This is evident from the design and development of city infrastructure such as high tide control mechanism by installing holding ponds. However, EWS as a priority area for the city and disaster management function is not in place
6.4	Monitoring, evaluation and targets for improvement of EWS	●	○	○	○	○	Performance monitoring mechanism is not established



5.6 SUMMARY

Navi Mumbai is a newly planned city and much of the city development needs are designed taking into consideration of possible impact of hydro-meteorological disasters. Regulatory mechanisms, like restriction on activities, which can probably trigger an event such as landslide, are in place.

The Maharashtra State Disaster Management Plan addresses planning arrangements only at the district level. Navi Mumbai City Disaster Management plan mainly focuses on the roles and responsibilities during or post disaster. Currently NMMC manages the disaster situation through an EOC and two control rooms. There is no institutional mechanism within the NMMC (ULB) to establish and operationalize EWS.

City is dependent on technical agencies like Regional Meteorological Centre (IMD), INCOIS and Coast Guards for forecast/ information. Currently, the onus of dissemination of warning and response lies with the NMMC (DM Cell) through media and other protocols, which restricts the outreach (time, space and communities at risk). Value addition to the warning received by technical agencies is restricted to visual display (readability). Information sources including satellite cloud cover and locally installed rain gauge stations were evident in NMMC.

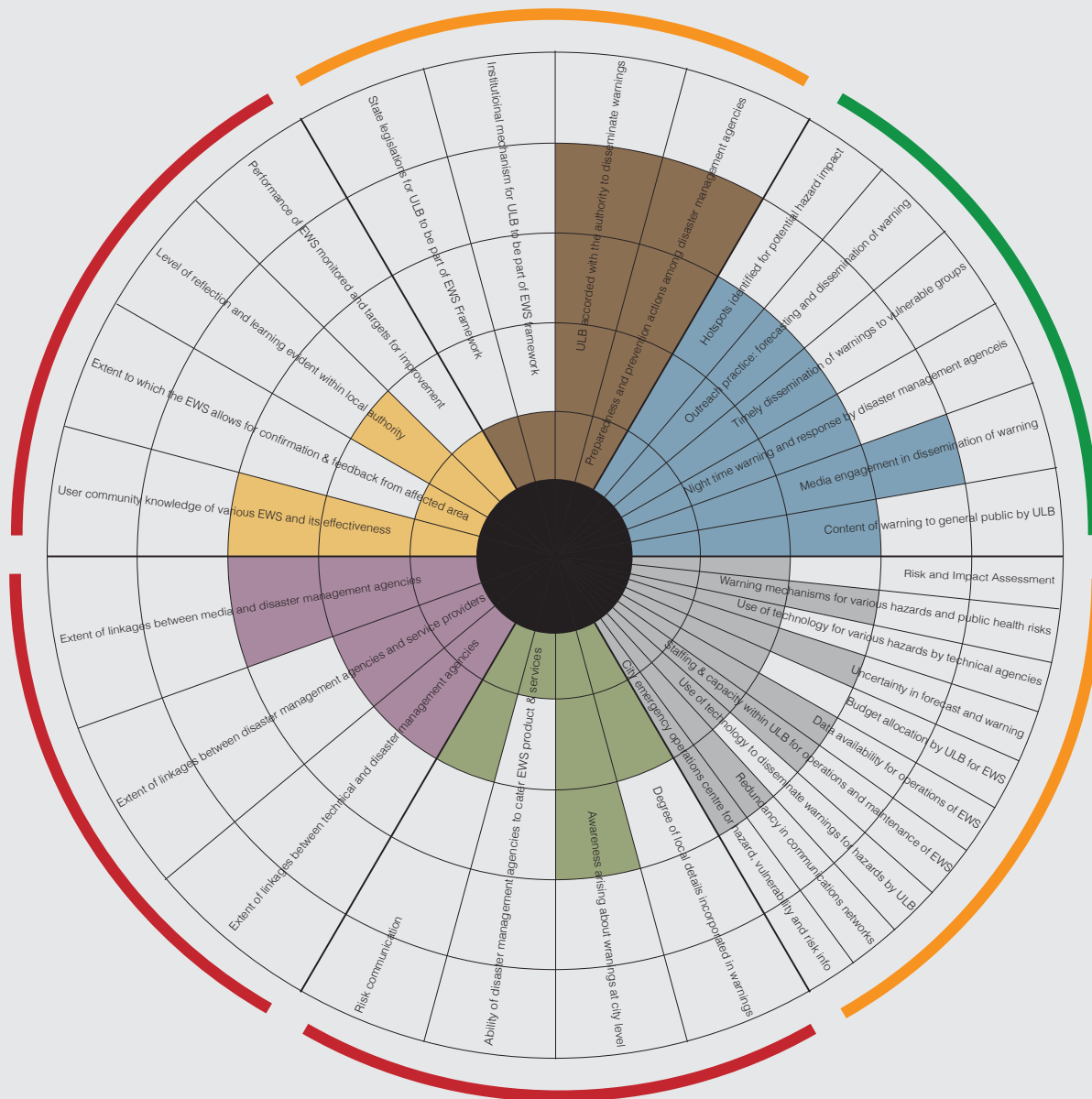
City-level risk assessment is yet to be undertaken to enable/enhance the preparedness and response delivery mechanism. Without detailed hazard, vulnerability and risk assessment may limit response actions to target locations and groups/ communities. Systematic collection, collation, maintenance and updating of relevant data are

required to strengthen the warning mechanism.

There is no separate budget allocation for creating and operationalizing EWS. However, the ULB is proactive in warning dissemination using the locally available communication modes (sirens and vehicle mounted PAS). Initiative to collect information from the local level is attempted (evident through installation of 19 rain gauge stations). City has an EOC with two control rooms and eight Zonal Officers with specific responsibilities to manage the facilities. The EOC and control rooms are mainly geared for relief operations. EOC is manned by government officials on deputation with the help of supporting temporarily hired staff, which is functional round the year. Capacity (human resources as well as infrastructure) to add value or to improve the delivery mechanism of forecast/ potential impact is yet to be developed.

Active awareness building measures are undertaken for frequent hazards. Local institutions have helped develop customized warning products for fishermen community. The warnings include action points in case of an event and are targeted at hydro-meteorological hazards.

Lack of formal links and feedback mechanism exists between different institutions within the city. Links between local agencies, such as PWD/ engineering – health/traffic, if established, can stage better response and reduce the overhead costs substantially.



LEGEND:

- Component 1: Governance
- Component 2: User Needs
- Component 3: Operational Components
- Component 4: Products and Services
- Component 5: Coordination Mechanism
- Component 6: Service Delivery & Feedback loop

Preparedness Level

- Little Progress/ Major concerns
- Partial Progress/ Minor concerns
- Good Progress/ On track

Development Stage Indicators

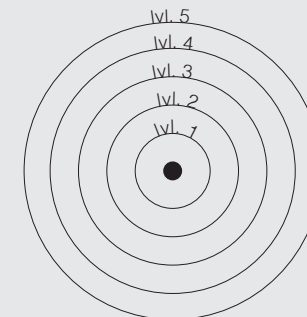


Figure 12: Preparedness of EWS indicators for Navi Mumbai

6. RECOMMENDATIONS & OUTLOOK

Initial results of the review have been shared with the cities during discussion meeting with city stakeholders. Stakeholders from the cities have endorsed the results emanating from the review process. The following set of recommendations have been developed and presented for further action:

Recommendations for improving the EWS for Urban Areas

National / State Institutions

1. State DM Plan should entrust ULB with the responsibility of developing city EWS for specific hazards.

2. For an integrated approach, SDMA should provide an enabling platform to debate, increase coordination and strengthen EWS links across all levels of the government, technical agencies (geological, hydro-meteorological, public health risks), private sector, city level institutions and non-government organizations.

3. IMD's Doppler radar system at city level or within the range of the city has proven to be quite beneficial during cyclone. While the plan to have a radar network is underway, fast-tracking of the same is the need of the hour.

4. IDSP's Health surveillances across cities are found to be relatively useful in detecting outbreaks, since they are directly linked to the state department. Currently, the paper-based approach has a turnaround time of 10 to 15 days for actions. Tools for real time monitoring should be considered.

5. Cities (not the state capital) have limited interactions with state agencies. There is need for enhanced coordination mechanism amongst DM Agencies and ULB.

6. There is a need to create discussion platform for deliberation and discussion between technical agencies (IMD, CWC, GSI, CESS, and INCOIS among others), State Departments and the ULB. In addition, there is a need to create an appropriate framework with due legal process to ensure that roles and responsibilities of the agencies are defined and executed.

Urban Local Bodies

7. The ULB/city government should earmark annual budget for development and maintenance of EWS (Capex & Opex).

8. ULB's DRR agenda should encompass EWS as a critical component. The city government should establish and provide operational services and guide the local development agenda/safeguard infrastructure – assets – communities at risk.

9. Institutionalization of EWS within ULB must ensure integration between line departments and technical agencies. Line departments, in turn, must focus on development of appropriate SOPs for EWS.

10. Cities should invest in a fully operation EOC (24X7) to support risk assessment and EWS. Trained manpower must run the centre's operations.

11. Capacity building of ULB/City Government on EWS (technical and management) is crucial for system development and implementation. The ULB should earmark funds for training so as to assist the process of strengthening the EOC, City

DM Plan, communities at risk, media, emergency responders and key stakeholders.

12. Awareness programme should aim at strengthening the level of preparedness. The programmes should be contextualized and scenario-based.

13. Networking and involvement with state, regional and national level institutions will strengthen EWS at city level. Networking brings in exchange of observation data, expertise, joint validation of modelling results, improved decision making, sharing of lessons learnt and best practices.

14. The ULB/city government should identify and link technical and resource institutions within the city for EWS operations.

15. A functional EWS puts forth the requirement to harmonize SOPs that determine response. Standardization of departmental plans and terminology ensures effective response actions. SOPs have to be evaluated and modified through conduct of drills.

16. ULB/City Government should develop hazard analysis, vulnerability assessment and risk assessment (on GIS platform). Climate variability and climate change should be an integral part of the risk assessment.

17. To strengthen disaster preparedness and emergency response, it is important to ensure that emergency response actions are guided through scientific and observed data. The city EOC should harmonize flow of information from all agencies and determine potential impact locations within the city

18. ULB/City Government requires real time data for a range of services (traffic, health, services monitoring – water/sanitation/solid waste management). There is a need to design and develop integrated hydro-meteorological, public health and environmental (say, air quality) monitoring systems in close cooperation with technical agencies, disaster risk management agencies and the ULB. Such an integrated system will be cost-effective and will ensure operations at all times.

19. Event preparedness meetings should be regularized: before winter (for snow/cold wave), summer (heat wave) and monsoon season (tropical cyclone). Pre-Monsoon Preparedness Forum has helped several cities minimize the risk (discussions around monsoon outlook, calibration of model results, preparedness plan).

20. Night time warning has to be an integral part of EWS. If need for evacuation arises, additional measures should be stepped in to stage emergency response. The city DM Plan should make a clear provision for night time warning.

21. Relay of warning information should use a wide variety of options. Select hot spot locations should be equipped with sirens. To maximize outreach of warnings to general public places (railway stations, bus stations/stops, important city junctions, city market places, parks etc.), display screens must be positioned with real time information.

22. Engagement of the media is important to build a culture of safety and resilience. An exclusive weather channel is recommended.

23. It is critical for City Government/ULB to invest in city-level climate scoping studies, promote

adaptation and resilience measures across key sectors and integrate with DRR and development planning.

Technical Agencies

24. The ULB and allied institutions require support from technical agencies to build the current understanding of hazard risks, DRR options, and expand the understanding to incorporate future threats of climate change and other hazards in decision making for new development and public safety.

25. Development of EWS (monitoring, impact forecasting, warning formulation) has to be hazard specific. EWS development should take into consideration predominant hazards and more frequent/less frequent events (but with a potential for severe damage).

26. Despite technical breakthroughs in earthquake EWS (alerts), efforts should be made by technical agencies to implement EWS in high seismic prone cities. Landslide EWS can be successful in conjunction with appropriate selection of land use criteria for landslide prone region, further combined with environmental monitoring of the risk prone areas.

27. Community-based monitoring has proved to be beneficial for management of geological hazards. A combination of technical and community-focused approach should be adopted for implementation.

28. User understanding of the forecast in technical terms is limited. This is evident from the current set of common information products shared with the user community. Therefore, translation of forecast to warning action has to be backed with action-based information in easy understandable language.

29. Warning mechanism should keep focus on communities at risk. A generic city-level warning may not be appropriate, given the diversity of the built environment in urban areas. In addition, customized local warnings have to be provided to hotspot locations.

30. Warning products should clearly indicate threats to the population/stakeholders. Efforts have to be made by the technical and disaster management agencies to tailor the warning that allows not only understanding the potential event but also determining the potent impact. The warning at the city level should highlight societal impacts and not be broad-based. Stakeholders should be able to distinguish between low impact and high impact events. At the city level, there has to be minimum ambiguity in information when shared with the general public. Communities at risk should be able to perceive risk and react appropriately.

31. Simple and easy to use visualization tools should be made available by technical and disaster management agencies to the citizens. This will ensure participation and effective decision-making.

Summary

It is important at this stage to note that EWS in the seven cities needs to be upgraded significantly to meet the larger objective of reducing fatalities and protecting infrastructure/assets from future events. It is recognized globally that an operational EWS has the potential of minimizing loss and contributing to sustainable development and building resilience. While technology is available for establishing the robust communication system for EWS, it is the institutional foundation and the networking arrangements which have to be deep rooted for meeting the desired objectives of the system. All the key elements of the system have to be functional and it is important to review them annually by targeting for different scenarios and measuring performance.

This report provides insights to issues that need to be addressed for an operational EWS, defines the criteria and measures the development stage indicators for the present situation. The results of this review provide a status and the need to be aware of key design considerations for improvement of existing EWS, as well as for design and implementation of new EWS. It is envisaged that city landscape will have to tailor solutions for public safety, and EWS will be designed and developed on various platforms. It is important to keep these systems people-centric and subsequently build risk knowledge among the stakeholders for success of this system. Criteria Development Matrix can be used as a tool for further review. As EWS systems develop in the city, robust EWS audit mechanism can be rolled in the future to measure system efficiency.

CASE STUDIES FOR ESTABLISHED EWS

Case Study 1: Qinglong County Early Warning Success for M7.8 Earthquake



Photograph: Students in Qinglong County had classes outdoors as the Great Tangshan Earthquake (GTE)

Project title: Community Monitoring and Preparedness for Earthquakes

Location & Country: Northeast China

Hazard type: Earthquakes

Stakeholders: Local communities in China

Period of Implementation: 1966–1980

Contact:

Professor Jean J. Chu
Institute of Geology and Geophysics
Chinese Academy of Sciences (CAS)
Beijing, China
+86-136-9306-7556
E: jeanjchu@gmail.com

Description:

When a strong earthquake killed over 2,40,000 people in Tangshan in 1976, an adjacent county escaped unscathed. All 4,70,000 residents of Qinglong County in the northeast corner of Tangshan survived the magnitude 7.8 quake except for one, who died of a heart attack. Even in Beijing, farther away from Tangshan than Qinglong, hundreds of people were killed by the Great Tangshan Earthquake (GTE). Qinglong, or blue dragon in Chinese, was not invincible to the tremendous power unleashed by this quake, as more than 1,80,000 of its buildings were destroyed, including 7000 which totally collapsed. What saved the day for these rural dwellers was a unique combination of environmental monitoring of nature's signals prior to the quake, and accessing scientific information on precursory changes in electrical resistivity and crustal stress. Local officials and county residents, including schoolchildren, were educated to make sense of all these data, and took effective preparatory measures in time.

Case Study contributed by Prof. Jean Chu

Case Study 2: Community-based Earthquake Monitoring System in Xinjiang



Photograph: Workshops, trains and local communities use computer software to analyse their recorded data

Project title: Community-based Earthquake Monitoring System in Xinjiang (UNDP Project No. CPR/03/612)

Location & Country: Xinjiang Uygur Autonomous Region, China

Hazard type: Earthquake

Stakeholders: Local communities in Xinjiang Uygur Autonomous Region, China

Period of Implementation: April–November 2003

Contact:

Professor Jean J. Chu
Institute of Geology and Geophysics
Chinese Academy of Sciences (CAS)
Beijing, China
+86-136-9306-7556
E: jeanjchu@gmail.com

Description:

On 24 February 2003, a strong earthquake of M 6.8 struck Jiashi County in southwest Xinjiang Uygur Autonomous Region, China. In response, UNDP located funds and worked with China International Centre for Economic & Technical Exchanges (CICETE) and Chinese Academy of Sciences (CAS) to complete a nine-station community-based earthquake monitoring system. This system is presently in full operation and during its first four months was able to see ahead of the M 6.1 earthquake on 1 December 2003, which struck near Bole monitoring station in northwest Xinjiang. Nearly one-third of the staff involved in this nine-station system is women. Public disaster education drives, conducted during the project, involved 50 local government officials and over 700 schoolchildren. The total time taken, from conception to completion of this community-based earthquake monitoring system, was five months (April–September 2003). The project established CSCAN, the Crustal Stress Community Awareness Network, thus improving the capacity of local communities to monitor and prepare for earthquakes.

Case Study contributed by Prof. Jean Chu

Case Study 3: Landslide Early Warning Network



Photograph (L): Installation of the rain gauge by DMR team. Also seen is the local community volunteer as part of the landslide watch network

Photograph (R): Rain gauge with warning thresholds determined for a particular location.

(Location: Mae Phun Sub-district, Lablae District, Uttaradit Province)

Project title: Landslide Early Warning Network

Location & Country: High risk prone areas across Thailand

Hazard type: Landslide

Stakeholders: Department of Mineral Resources, Local communities at risk

Period of Implementation: Ongoing

Contact:

Department of Mineral Resources
 Ministry of Natural Resources and Environment
 75/10 Rama VI Road, Ratchatewi, Bangkok 10400
www.dmr.go.th

Description:

Department of Mineral Resources has carried out study programmes to gain better understanding of such events and has set up activities for the prevention and mitigation of them via engineering. Most of the works undertaken by DMRs are based not only on scientific approach but also on people’s participation. DMR tried to make the best out of limited resources to sustain the geo-hazard management system of the local communities distributed throughout the country. A new concept has been developed under certain key concepts, which are: geological knowledge as a strong foundation, best engineering geological practice, HM King Bhumibhol’s sufficient economy, and living in harmony with nature. DMR promotes the role of people and local communities in warning and preparedness of the geo-hazard risk areas. DMR has set up landslide warning networks for both local and regional areas in the high risk areas throughout the country. The network has been set through a series of seminar meetings for capacity building of the local community with the supply of efficient equipment for the network group to be able to monitor rainfall and landslide in their areas. This activity is especially focussed during the rainy season of the year. This work has created awareness among people who have been or potentially been affected by such hazards to be well-prepared for the event that is yet to come.

Case study contributed by Anup Karanth (Field Study undertaken in 2008)

Additional reading reference: Adichat SURINKUM Worawut Tantiwanit Jarin TULYATID, Prevention, Mitigation and Engineering Response for Geohazard in Thailand, Paper in the 6th International Conference in Geotechnical Engineering, Arlington, VA, 11–16 August 2008.

Case Study 4: Flood Control Centre



Photograph: Monitoring Street Flooding

Source: Screen Print of FMS, Last accessed on 20April2014

Facility: Flood Control Centre

Location & Country: Bangkok, Thailand

Hazard type: Flood

Stakeholders: Department of Drainage and Sewerage, Bangkok Metropolitan Administration, Thai Meteorological Department, Department of Disaster Prevention and Mitigation, Traffic Control Centre, Royal Irrigation Department

Period of Implementation: Since 2000

Contact: BMA City Hall, Dindaeng, Bangkok, Thailand 10400
<http://dds.bangkok.go.th>; <http://www.bangkok.go.th>

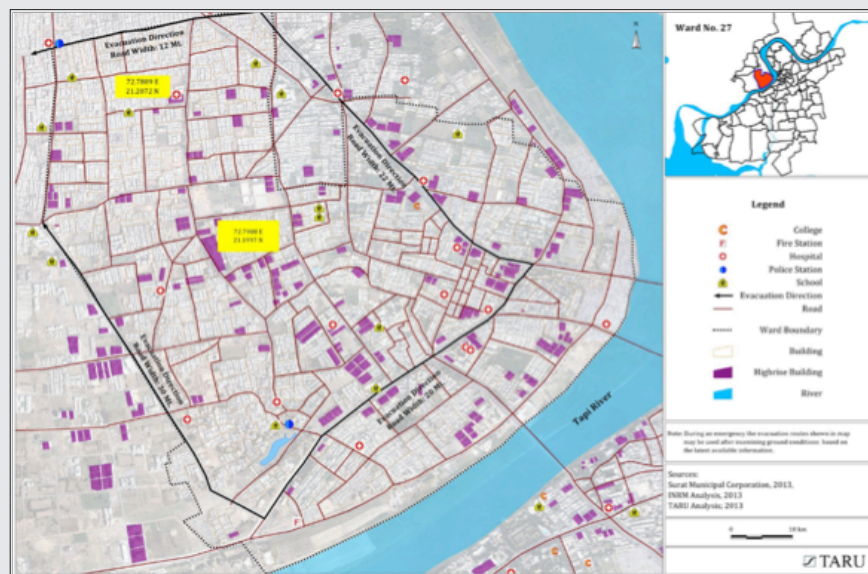
Description:

Bangkok Metropolitan Administration has set up Flood Control Centre (FCC). FCC supervises the hydrological conditions linking directly with the radar of Meteorology Department and of BMA. FCC has been serving as a decision-making tool for the Department of Drainage and Sewerage (DDS) flood protection teams for accurate and immediate directive to solve flood problems effectively. Monitoring stations monitor real time data of rainfall, water levels, pumps operation, water gates operation and water quality that are installed. In addition, the department is implementing a flood forecasting programme aiming at forecasting rainfall intensity and flood forecasting in 650 km² of the east bank area, which will enable BMA staffs to forecast flood condition three to six hours in advance. FCC serves people with flood forecasting news and flood protection and solution. Several communication channels are used to inform people and communities (radio broadcasting, traffic billboards and BMA's website). DDS has weather monitoring system (<http://dds.bangkok.go.th/wms/>); surveillance radar rain images (<http://dds.bangkok.go.th/Radar/radar.htm>); flood monitoring system (<http://dds.bangkok.go.th/Floodmon/>); water measurement system/canal overflow (<http://dds.bangkok.go.th/Canal/>); SCADA system (<http://dds.bangkok.go.th/scada/>); and plan to prevent and resolve flooding, among others.

Case study contributed by Anup Karanth (Institutional Landscaping Exercise for EWS, 2008)

Reference: <http://www.unisdr.org/campaign/resilientcities/cities/view/28>

Case Study 5: End-to-End Early Warning System for Ukai and Local Floods



Evacuation mapping for Ward 27 in Surat City

Project title: End-to-End Early Warning System for Ukai and Local Floods

Location & Country: Surat, India

Hazard type: Floods

Stakeholders: Surat Municipal Corporation, Surat Climate Change Trust, India Meteorological Department, TARU Leading Edge

Period of Implementation: 2011–2015

Contact:

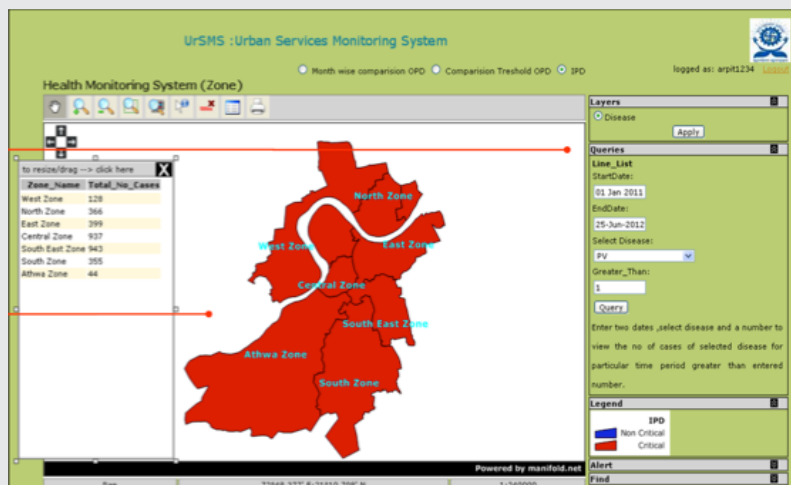
Surat Climate Change Trust,
Muglisara, Main Road,
Surat – 395003 Gujarat, India
www.sccctrust.in

Description:

Over the past two decades, the flood frequency is increasing due to increased variability of rainfall (extreme events), especially within the Tapi river catchment. An End-to-End Early Warning System (an initiative under the Asian Cities Climate Change Resilience Network) has been established in the city of Surat to manage floods caused by extreme precipitation events in the Upper and Middle Tapi basin as well as khadi (tidal creeks) floods. The main objective of this project is to reduce the intensity of floods and resultant flood damage to Surat through improved reservoir operation to minimize peak floods and systems to enable institutions and society to handle flood emergencies. Key project components include: developing management framework for EWS; establishment of Surat Climate Change Trust and Technical Committee, climate change informed hydrological and hydraulic modelling, early warning and disaster management system, integration with City Disaster Management Plan, information and support for the poor and sustainability arrangements. The establishment of the warning system includes the installation of weather systems, data transfer mechanism from catchment to reservoir to city, development of weather and flow prediction models, improvement of existing flood preparedness and action plans.

Reference: Asian Cities Climate Change Resilience Network, www.acccrn.org

Case Study 6: Urban Services Monitoring System



Photograph: Screen Print of Urban Services Monitoring System

Project title: Urban Services Monitoring System (Health Component)

Location & Country: Surat, India

Hazard type: Diseases

Stakeholders: Health Department (Surat Municipal Corporation), TARU Leading Edge

Period of Implementation: 2009–2013

Contact:

Surat Municipal Corporation
Muglisara, Main Road,
Surat – 395003 Gujarat, India
www.suratmunicipal.gov.in; <http://surat.ursms.net/cms/home.aspx>

Description:

High density, lack of safe water supply and its location on a river side, combined with high temperatures and humidity, changing rainfall patterns, rapid urban growth and industrial development make Surat highly conducive to vector-borne and water-borne diseases. Real time structured data collection from different health institutions, including Urban Health Centres (UHCs), government and private hospitals, laboratories and private practitioners and its efficient analysis were the key challenges faced by Health Department, Surat Municipal Corporation. To overcome the above challenge, short message service (SMS)-enabled integrated Urban Services Monitoring System (UrSMS) was conceptualized and developed for the Surat Municipal Corporation. This system brings resilience to disease monitoring framework by providing timely information on the quality of water supplied from distribution stations and occurrence including outbreak of diseases within Surat. The near real time data collection and analysis is currently helping the health department predict disease outbreaks based on number/distribution of cases across the city and enables them take prompt action to prevent further spreading. The system provides better visualisation of data and integration with ongoing government programmes/schemes. So far, the system has been able to significantly reduce the number of patients affected by malaria, dengue and leptospirosis.

Reference: Asian Cities Climate Change Resilience Network, www.aaccrn.org

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ANNEXURE

List of Agencies and Key Informants Consulted in the Review Process

Navi Mumbai

Key Informant	Position	Department/ Organization
Shreedutt Kamat	Consultant	DM Cell/NCRMP
I A Kundan, IAS	Secretary, Disaster Management	Disaster Management Unit
Dr P Awate	SSO	IDSP Mumbai
Prof Kapil Gupta	Professor	IIT Bombay
V K Rajeev	Director, IMD, Mumbai	IMD Mumbai
N Y Apte	Deputy Director General, IMD, Mumbai (Retd.)	
K S Hosalikar	Deputy Director General	IMD Mumbai
Dr Jaideep Vishave	DDMO, Thane District	District Collectorate, Thane
Ashok Ghule	Consultant, DM, Thane District	District Collectorate, Thane District
P Velrasu, IAS	District Collector, Thane	District Collectorate, Thane
S C Mohanty	Disaster Management Expert	
Chetan Patil	Head	RDMC, NMMC
J N Sinnarkar	Deputy Commissioner	NMMC
R D Nikam	Chief Health Officer	NMMC
Dr Ratnesh Mahate	Health Officer (Epidemic Control)	NMMC
Dr Vaibhav Zunjare	Veterinary Health Officer (Leptospirosis)	NMMC
H R Suthar	Chairman	Vashi Fishermen's Co-Op Soc. Ltd.

