सत्यमेव जयते

Ministry of Housing and Urban Affairs
Government of India

Flood and Water Stagnation Risk Management

TRAINING MANUAL

Climate Centre for Cities

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Supported by:
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
based on a decision of the German Bundestag

difu Deutsches Institut für Urbanistik

ClimateSmart Cities Assessment Framework

Water Management

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Flood and Water Stagnation Risk Management
Training manual

Developed by:
Climate Centre for Cities, NIUA in association with Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and The Deutsches Institut für Urbanistik (DIFU) (English: German Institute of Urban Affairs).

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Executive Summary

On one hand, cities are a significant contributor of carbon emissions aggravating climate change and on the other, cities are considerably impacted by climate disasters. The recently released Global Climate Risk Index 2021 ranks India as the 7th most affected country from climate related extreme weather events (storms, floods, heatwaves etc.). Further, studies indicate that poor planning and urban management are expected to cost Indian cities somewhere between $2.6 and $13 billion annually.[1] Cities are increasingly at the forefront of addressing both urbanization and climate change and to strengthen climate-sensitive urban development, a holistic understanding of the urban development from a climate lens is crucial. The climatesmart Cities Assessment Framework (CSCAF) launched in 2019 by the Ministry of Housing and Urban Affairs (mohua), Government of India aimed to address this gap. This first-of-its-kind assessment with 28 progressive indicators across 5 thematic areas helps cities to benchmark their development, understand the gaps and further prioritize climate relevant development.

With a focus on building local capacities to develop and adopt climate measures, the Climate Centre for Cities (C-Cube) at the National Institute of Urban Affairs (NIUA) initiated a series of training aligned to the thematic areas of CSCAF - Energy and Green Buildings, Urban Planning, Green Cover & Biodiversity, Mobility and Air Quality, Water Management, Waste Management. The focus of the training is to provide a step-by-step approach of conducting studies, assessments and stakeholder consultations, establishing committees, developing action plans and implementing relevant measures that not only makes the cities climate resilient but also helps them progress across the assessment of CSCAF. The focus of this training is on the 'Flood/ Water Stagnation Risk Management' indicator under the thematic areas of water management in the CSCAF.

India experienced the highest monsoon rainfall in 2019 when compared to previous 25 years.[2] Every year, around 75 lakhs hectares of land is impacted by floods resulting in loss of more than 1,600 lives and damages to houses and public utilities exceeding over Rs.1,800 crores.[3]

With increasing floods in cities, the need for city level flood management plan is becoming significant. Conducting assessments, identifying vulnerable hotspots, ensuring sops can be followed during a flood and establishing end-to-end Early Warning Systems (EWS) are important for the cities that experience flooding and water stagnation.

In this context and the emerging need, This module on 'flood and water stagnation risk management' focuses on the initiatives required for becoming flood resilient. The objective of this module is to build capacities of smart cities to understand and improve their performance with respect to the CSCAF indicator by enabling them to undertake informed measures. The module developed by the National Institute of Urban Affairs (NIUA) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) along with the Ministry of Housing and Urban Affairs (mohua), Government of India.

The module elaborates on the current urban flooding scenario in urban India, the components of flood risk assessment, possible strategies for flood risk assessment, objectives of standard operating procedures (SOP), variations of sops based on short term/medium term/ long term strategies, stages of alerts and warnings, exercises based on urban flood management SOP, institutional framework & arrangements and policies & guidelines. The learnings from this module will enable cities to conduct flood risk assessments and formulate flood management plan to include strategies to be implemented on ground to address the shocks and stresses climate change poses to cities.

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[1] *Mani, M. et al., 2018. South Asia's Hotspots: The Impact of Temperature and Precipitation Changes on Living Standards, Washington D.C.: World Bank Group.*

[2] *Mallapur. C, 2019. 2019 Monsoon Heaviest In A Quarter Century. Indiaspend. [Online] Available at: https://www.indiaspend.com/2019-monsoon-heaviest-in-a-quarter-century/ [accessed 7 Feb, 2022]*

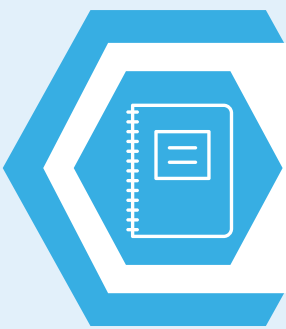
[3] *NDMA. 2022. Floods. [Online]. Available at: https://ndma.gov.in/Natural-Hazards/Floods [accessed on 23 March 2021*

Who is the training manual designed for?

What is the focus of the training manual?

How to make use of this manual?

What are the Learning outcomes of the training?



Scope and limitations of the training

The training module on the indicator 'Flood/ Water Stagnation Risk Management' is intended for Urban Local Bodies (ulbs), specifically the water utility department, flood & irrigation department and other water service providers along with other development authority or parastatal officials involved in flood and water management in urban areas. A basic understanding of flood and water stagnation in urban areas is a prerequisite for various the stakeholders.

This training manual focuses on understanding the impacts of storm water management and urban flooding scenario in urban areas. It highlights the principles around flood risk management which influences the making of flood management strategies. It outlines the components of flood risk assessment, possible strategies for flood risk assessment, objectives of standard operating procedures (SOP), variations of sops based on short term/medium term/ long term strategies, stages of alerts and warnings, exercises based on urban flood management SOP, institutional framework & arrangements and policies & guidelines.. Based on the assessment strategies need to be formulated for effective implementation.

This manual can be used as a technical reference material which delves into details touched upon in the presentation with references to additional reading material to aid participants in following the training sessions.

The learning outcomes of this training for cities is to develop a better understanding of flood risk assessment and introduce effective ways for implementing actions to mitigate flood related risks. This training module would also equip cities in conducting flood risk assessments to establish current and future demand and availability based on which strategies can be formulated and implemented.

As the training module is designed and developed as a 2 – hour online training session with interactive exercises for city officials its scope is limited to establish a basic understanding of flood management strategies and actions aligning to CSCAF indicator and outlines flood management plans and assessments.

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Abbreviations

AACCCRN	Asian Cities Climate Change Resilience Network
Args	Automatic Rainfall Gauges
CWC	Central Water Commission
DDMA	District Disaster Management Authority
DEOC	District Emergency Operation Centre
Dept.	Department
DIFU	Deutsches Institut für Urbanistik (German)
DRWM	Decentralized Rainwater/ Storm water Management
EMS	Emergency Management Service
EOC	Emergency Operation Centre
ESF	Emergency Support Function
GI	Green Infrastructure
GIS	Geographical Information System
GIZ	German Agency for International Cooperation
HFL	High Flood Level
IDRN	India Disaster Resource Network
IIT	Indian Institute of Technology
IRS	Incident Response System
KML	Keyhole markup language (file type used for digital maps)
LID	Low Impact Development
LIUDD	Low Impact Urban Design and Development
MHA	Ministry of Home Affairs
MOHUA	Ministry of Housing and Urban Affairs
NDMA	National Disaster Management Authority
NDRF	National Disaster Response Force
NEC	National Executive Committee
NGO	Non-Governmental Organisation
NIDM	National Institute of Disaster Management
NMSH	National Mission on Sustainable Habitat
NIUA	National Institute of Urban Affairs
RWA	Resident Welfare Association
SCAF	Smartcity Assessment Framework
SDMA	State Disaster Management Authority
SDRF	State Disaster Response Force
SOI	Survey of India
SOP	Standard Operating Procedure
Sqmt	Square metre
Srsacs	State Remote Sensing Application Centres
Suds	Sustainable Urban Drainage Systems
SWC	Smart Water City
SWCNP	Sound Water Cycle on National Planning
UDA	Urban Development Authority
UFDM	Urban Flood Disaster Management
ULB	Urban Local Body
UT	Union Territory
WSUD	Water Sensitive Urban Design

Photo Credit: Water Stagnation by Francis on Unsplash

1

Introduction

Urban flood is defined as 'the submergence of usually dry area by a large amount of water that comes from sudden excessive rainfall, an overflowing river or lake, melting snow or an exceptionally high tide[4].

For this training purpose and also under CSCAF, water stagnation is defines as inundation of a particular area for more than four hours of a depth more than six inches. For urban authorities, both flood and water stagnation may be considered as hazard and need to reduce adverse impact of these phenomenon on citizens, infrastructure and services.

Table 1 List of Urban Flooding incidences in India[5]

Cities	Flooding Years
Ahmedabad	2001
Bangalore	2005, 2009, and 2013
Chennai	2004 and 2015
Delhi	2002, 2003, 2009, 2010, 2013, 2016
Guwahati	2010 and 2011
Hyderabad	2000, 2001,2002, 2006 and 2008
Jamshedpur	2008
Kolkata	2007 and 2013
Mumbai	2005, 2007, and 2015
Srinagar	1992, 2014 and 2015
Surat	2006 and 2013

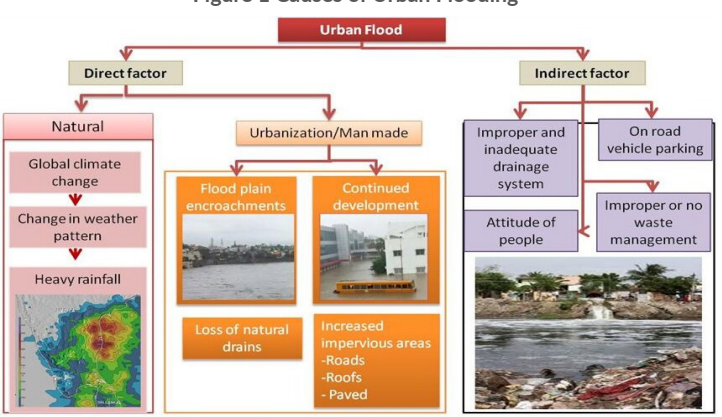
[4] *NDMA. 2010. Guideline for Urban Flood Management. New Delhi*

[5] *NIUA, 2016. India Urban Climate Change Fact Sheets. (online) Available at: https://smartnet.niua.org/sites/default/files/resources/FS%203_Urban%20Flooding.pdf [accessed on 04/12/2021]*

[6] *FPRG India. 2021.Urban flooding in India : Challenges and Solutions. (online) Available at: https://fprgindia.in/urban-flooding-in-india-challenges-and-solutions/ [accessed on 04/12/2021]*

In last two decades, India has witnessed major flooding events in urban areas. During 1980-2017, India experienced 278 floods that affected more than 750 million people and caused loss of about $58.7 billions.[6] Flooding and inundation are caused because of various direct and indirect factors attributed to natural phenomenon and human activities. The impacts and reoccurrence of Urban flooding are further intensified by rapid urbanization, increase in population, shrinkage in open land and green spaces, illegal encroachments, inadequate drainage infrastructure capacity, unplanned reservoir regulation and lack of flood control structures. Further, construction of buildings on reclaimed wetlands, flood plains, low-lying areas and improper disposal of Garbage have aggravated the situation. Above all, climate change and increase in the rainfall pattern or precipitation have significantly increased the risk of flooding in India.

Figure 1 Causes of Urban Flooding[7]



[7]*Drishti. 2022. Urban flooding. (online) Available at: https://www.drishtiias.com/daily-updates/daily-news-editorials/urban-flooding [accessed on 04/12/2021]*

Pluvial flooding which is rain-driven flooding is becoming a critical issue. Many cities are vulnerable to pluvial flooding and associated risks. In addition to flooding, many cities also experience water stagnation due to various urban development patterns such as increasing impervious surfaces deterring ground water absorption, inefficient storm water network, growing development activities in flood plains and decreasing green cover that has the potential to slow down stagnation. Further, lack of adequate flood management makes cities vulnerable to floods. Often sewerage lines carry rain water and alternative measures like storage, infiltration and delayed surface runoff are not widely adopted in cities. With the projections of increasing frequency and severity of these events, it is pertinent for cities to develop a comprehensive strategy for building flood resilience.

1.1. Aligning to ClimateSmart Cities Assessment Framework

The indicator 'flood and water stagnation risk assessment' in CSCAF assesses the preparedness of the city to address the risk of flooding and water stagnation. Main components of this indicator include

a. Rapid and Comprehensive Risk Assessment,
b. Developing Stand Operating Procedures (sop) for flood management at city level,
c. Implementation of structural and non-structural mitigation measures for flood mitigation.

Figure 2 Components of the indicator

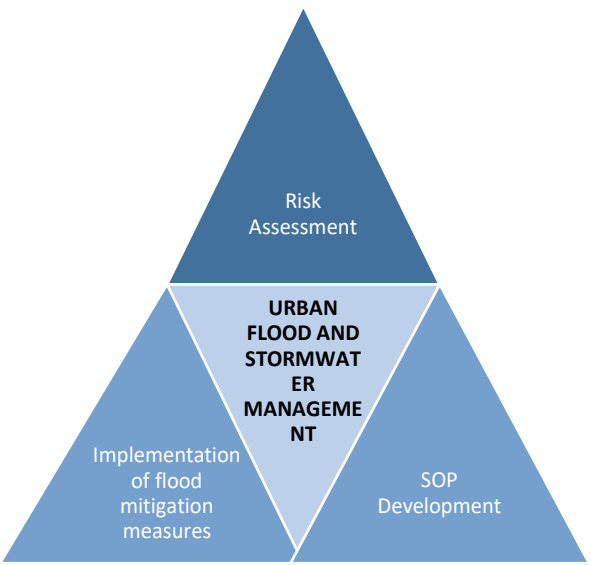


Table 2 Components of assessment framework

	1	2	3	4/5
Progression levels	Flood/water stagnation risk assessment not conducted	Rapid flood/ water stagnation risk assessment	Detailed flood risk assessment and preparation of management plan	Implementation of actions for flood/ water stagnation management
Evidence/ Data sources		1. **Rapid flood risk assessment** report prepared which shall include: Reasons of flooding/ water stagnation; Flooding/ water stagnation Hotspots in city (including the number of incidences); Flood/ water stagnation Levels and frequency 2. **Map of flooding/ stagnation hotspots** in the city as a .kml file (additional evidence)	1. Detailed flood risk assessment for various return period (5 years, 10 years and 50 years) 2. Flood management plans including structural and non -structural strategies (as per NDMA guidelines for urban flood management, 2010) 3. Mechanisms for implementing sops (as per mohua/state guidelines) in place. 4. Map of detailed flood risk assessment (scale 1:5000) as a .kml file (additional evidence)	1. Implementation of measures recommended in the flood management plan 2. Implementation of urban flood management SOP (as per mohua/ state guidelines) (20 points) 3. Urban flood alert and early warning systems established 4. Map of drainage and storm water networks in the city as a .kml file (additional evidence)
Score	0	25	50	100

2

Flood Management: Institutional framework and guidelines

Disaster management in India is addressed by the respective state governments. The central government's role is to provide technical and financial aid to lower governmental units. Central agencies provide general guidance, financial support, technical assistance, and coordination across governmental units.

The National Government issues policies and guidelines from time to time for streamlining and strengthening disaster preparedness at all levels. A partial list of guidelines issued by the Union Government on flood management includes:

- *National Disaster Management Act, 2005*
- *National Guidelines on Flood Management, 2008*
- *National Policy on Disaster Management, 2009*
- *National Guidelines on Urban Flood Management, 2010*
- *National Water Policy (1987, 2002, 2012)*
- *National Disaster Management Plan, 2016 (Revised 2019)*

The Guideline on Flood issued by the National Disaster Management Authority (NDMA) in the year 2008 were the first comprehensive document to provide direction for planning and developing flood mitigation capacities at various levels. This included recommendations on structural and non-structural measures, including strengthening/ revising flood forecasting and early warning systems, flood proofing of new developmental projects, building knowledge-skill-abilities (KSA) through awareness, education and training, improving compliance regime and flood emergency response capabilities at various levels (NDMA, 2008).

NDMA delinked urban flooding from the subject of (riverine) floods and channelized its efforts to come up with separate guidelines for it, as they understood that strategies

on flood disaster management largely focused on riverine floods, which were specific to rural areas. The National Guidelines on Urban Flood Management, issued in 2010, provides a comprehensive elaboration on the steps to be taken by various stakeholders for enhancing national urban flood resilience. The national guidelines precisely define the respective roles of key players including Ministry of Housing and Urban Affairs (mohua), the national guidelines precisely define the respective roles of key players including Ministry of Housing and Urban Affairs, the Indian Meteorological Department (IMD) and the Central Water Commission (CWC).

CWC and mohua are responsible with flood management in general and urban flood in particular. CWC holds the general responsibility of initiating, coordinating and furthering consultation with state governments and initiating schemes for the control, conservation and mutilation of water resources in the respective state for the purpose of flood risk management, irrigation, drinking water supply and water power generation (CGWB, 2016).

In addition to its other responsibilities, mohua is also mandated to be the nodal agency for flood management, tasked with establishing the urban flood cell I the ministry; state nodal departments and ULBs and facilitate urban flood risk assessment, forecasting and warning both at the national level and state/UT levels through the required mechanisms.[8]

The primary responsibility for flood management is with the States. A number of States have already enacted laws with provisions to deal with matters connected with flood control works. The schemes for flood control are planned, investigated and implemented by the States as per priorities within their own resources.

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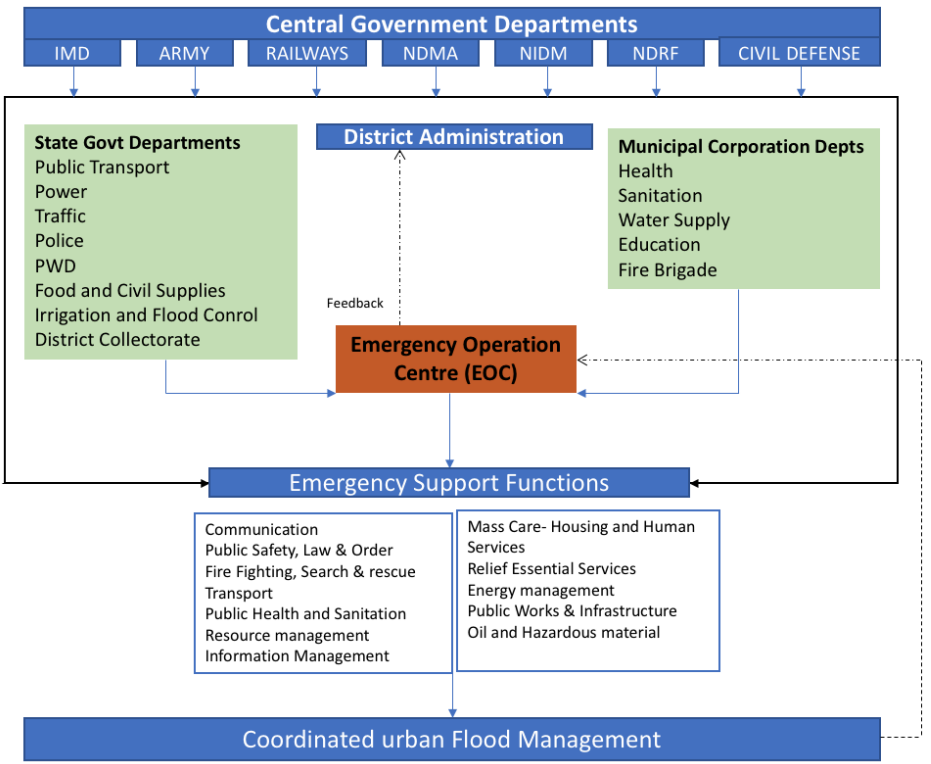
[8]*NDMA, 2010. National Guidelines on Urban Flood Management. New Delhi.*

2.1. Institutional Mechanism for Urban Flooding Management in India

An overview of intuitional mechanism for urban flooding, including agencies at National, State and Local level is depicted in the figure.

Figure 3 Institutional Mechanism for coordination of Urban Floods, NDMA



2.2. Key action points from NDMA guideline on urban flood management

According to the guideline, a standing mechanism to build and establish an integrated town/city-specific Urban Flood Disaster Management (UFDM) Framework should be in place.

At national level following agencies are involved at different phases

- National Disaster Management Authority (NDMA)
- Ministry of Housing and Urban Affairs (mohua)
- National Remote Sensing Centre (NRSC)
- Central Water Commission (CWC)
- Survey of India (SoI)

- Related Ministries/ Departments /Agencies,
- States, and
- Experts from Indian Institute of Technology (IIT), other Institutes of national importance and service/ professional bodies

Figure 4 Phase wise roles of agencies in flood management

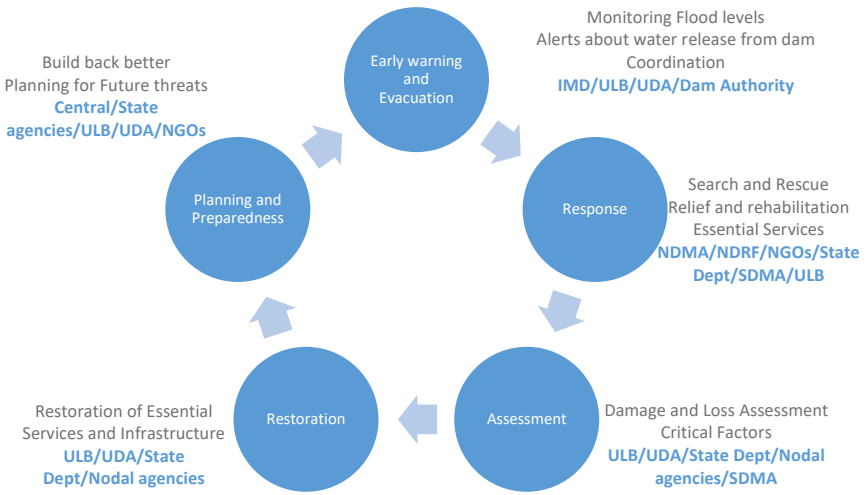


Figure 5 Key Components of NDMA guideline on urban flood management 2010

Agencies and mechanisms	Provisions	Out Reach
· Ministry of Urban Development · Urban Flooding Cell · 'Local Network Cell · Automatic Rainfall Gauges (ARGs) · Protocol for Sub-Division of Urban Areas · Urban Flood Early Warning System · Establish Incident Responsec System (IRS)	· Catchment as basis for Design of Stormwater Drainage System · Watershed as basis for all Urban Flood Disaster Management Actions · GIS Mapping for all 2325 Class I, II and III cities · Contour Mapping at 0.2 - 0.5 m interval · GIS Based Inventory · Stormwater Drainage designed with Runoff Coefficient upto 0.95 · Desilting of drains before monsoon · Rainwater Harvesting in buildings	· Involve Resident Welfare Associations (RWA), Community Based organisations (CBOs) in monitoring · Removing encroachment and facilitating resettlement · Capacity development of stakeholders · Public awareness campaigns · Involvement of public representatives in awareness generation

At State level, a State Level Guidance, Monitoring and Approval Mechanism for Urban Flood Disaster Management (UFDM) should involve Consortium of Local Level Technical Institutions, along with agencies such as

- Ministry of Housing and Urban Affairs (mohua)
- States and Union Territories (UTS)
- State Remote Sensing Application Centres (SRSACS)
- Urban Local Bodies (ULBs)

Each city /ULB to establish Emergency Operations Centre (EOC) under Control of District Commissioner/ District Magistrate / Municipal Commissioner should be established.

Key functions of EOC in managing urban flooding would be

- Coordination with line agencies
- Policy Making and plan preparation including action plans as per SOP
- Direction and Monitoring of Operations Management
- Information gathering and record keeping
- Preparation of web enabled resource inventory under India Disaster Resource Network (IDRN)
- Public Information and Citizen Updation
- Resource Management
- Reporting

Photo Credit: Milind Ruparel on Unsplash

3

SOP for Flood Management

This chapter focuses on the urban flooding Standard Operating Procedure (SOP) developed by mohua, GoI. SOP is "a set of directives, covering those features of operations that lend themselves to a definite or standardized procedure". Objectives of SOP are:

- To minimize the loss of life and damages to property and to ensure restoration and rehabilitation.
- To illustrate a concise chart, listing major executive actions required in response to urban flooding
- To list necessary tasks for preparedness, response relief and restoration required to be undertaken by the line agencies and departments involved.
- To ensure effective integration of tasks/events of each department at every stage of the disaster management process and enable continuous coordination of all actions.
- To enable reporting of actions taken by each agency / department for further review and updating of the existing SOP from past learnings.

The following points need to be followed for adopting the SOP.

- To be executed without deviation / modification to guarantee the expected outcome.
- Modifications or deviation to be thoroughly investigated
- All quality impacting processes and procedures should be laid out in sops.
- Sops should be the adopted in routine training program of employees.
- Sops should be regularly updated with a minimum review schedule of 3 years.
- Sops should be in place for all Quality Systems including specific operations. (Procedures are applicable unless prescribed otherwise in a particular case. Flexibility necessary in special situations is retained without the loss of its effectiveness)

The management of urban flooding is an emerging subject, and as such it has to be treated holistically in a multi-disciplinary manner. Three phases of disaster management for effective and efficient response to urban flooding:

Pre-Monsoon phase:

- Preparedness: Planning for Disaster Reduction

During Monsoon phase:

- Early Warning
- Effective Response and Management Relief planning and execution

Post-Monsoon phase:

- Restoration and Rehabilitation

3.1. Variations of sops

However, these sops need to be customised according to type of cities, its location, terrain and risks. Broad categories and relevant strategies are given in Table 3.

Table 3 Variation in SOP

Location/ terrain	General	Short term	Medium Term	Long term
Coastal cities	Floods in coastal cities are compounded by high tides depending on the time of the event.	Clearing of natural and engineered drainage system from silt and municipal solid waste.		Plans to include emphasis on rain water harvesting at household & neighbourhood level.
Inland cities	Immediate water discharge and prevention of water logging is a challenge in inland cities.	Clearing of natural and engineered drainage system from silt and municipal solid waste	Catchment areas with natural gradient towards a nearby lake / river to be restricted from development.	Afforestation for reduction of rainwater runoff. Rejuvenation and conservation of ponds, tanks and lakes with interconnections
Hill towns	Challenged with very high runoff, short flow duration and high scouring on account of slope, floods may also trigger mud flow and land slide	Clearing of natural drains from municipal solid waste and other dumping.	Flood plains to be kept construction free by notifying "Conservation zones" along the river channels, suitably demarcated and with strict compliance/ enforcement. Natural drain channels to be kept obstruction free at all times. Digital Flood modelling to be attempted for different scenarios of precipitation.	Afforestation is highly desirable along the hill slopes to reduce impact of flood and prevent landslides.

Location/ terrain	General	Short term	Medium Term	Long term
Cities along rivers	Challenged with shifting water course in the middle and lower Gangetic plains or unexpected high water discharge in-course	To undertake dredging and de-silting to keep the bed clear for volume flow	Building byelaws may incorporate provisions for construction on higher plinth or stilts as traditionally practiced. Vulnerable areas be demarcated and be kept construction free	Natural and manmade water bodies should be well conserved, rejuvenated and interconnections be established for efficient flood control.
Cities near dams and reservoirs	Requires selective actions from the measures mentioned above along with coordination with the reservoir management agencies			

Photo Credit: Kelly Sikkema on Unsplash

3.2. Alerts and Warnings

For the purpose of dissemination of alerts, a uniform system has been devised by MHA categorizing alerts in stages – Yellow, Orange and Red.

While generating and transmitting alerts to stakeholders and line departments, the concerned agency has to indicate the category of alert as well as its corresponding stage (Red/Orange/Yellow).

The communication stages are:

- Yellow: to be communicated to EOC through EMS
- Orange: to be communicated to EOC and SDMA@ 12 hourly updates
- Red: to be communicated to EOC, DEOC/SDMA, NEOC@ 3 hourly updates or more frequent.

Central Water Commission (CWC) has developed a network of flood forecasting stations to issue daily flood bulletins to all designated authorities/ agencies of the Central Government and State Government/ District Administration for all major river basins as following

Table 4 Flood categories and alert stages as per CWC

Category	Description	Stage
IV	Low Flood (Water level between warning level and danger level)	Yellow
III	Moderate Flood (Water Level below 0.50 m less than HFL and above Danger Level)	Yellow
II	High Flood (Water Level less than HFL but still within 0.50 m of HFL)	Orange
I	Unprecedented Flood (Water Level equal and above HFL)	Red

However, typically flood warnings in local area may be categorised as per the following:

Table 5 Flood categories and alert stage (typical)

Category	Description	Stage
IV	Sudden flash flood due to sporadic heavy downpour	Yellow
III	Water logging in arterial and sub-arterial roads and intersections	Yellow
II	Breach of river embankment /flooding of river plains	Red
I	Water logging/ flooding in residential and other buildings	Red

Photo Credit: Juan Manuel Sanchez on Unsplash

4

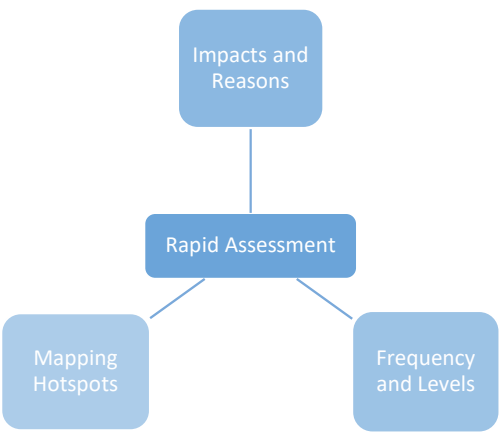
Flood Risk Assessment

In our context, Flood Risk Assessment is a systemic study of hazard, vulnerability and risks posed by fluvial and pluvial floods in urban areas. It is based on probability of flooding event and consequences (damage and loss) by this event.

A city can take up Rapid Risk Assessment as the first step toward managing and reducing flood risks. Rapid risk assessment may include:

- Likely Impacts of flood/ stagnation
- Assessing Reasons of flooding/ water stagnation Flooding/ water
- Identifying stagnation Hotspots in the city (including the number of incidences)
- Flood/ water stagnation Levels and frequency
- Map of flooding/ stagnation hotspots in the city

Figure 6 Rapid Assessment of Flood Risk



The actual risk can be analysed by identifying a chain of causes and effects: rainfall or storms causing high water levels; high water levels causing either a load on flood defences or the immediate flooding of floodplains; the load on the defences causing failure of an embankment; the failure causing breach growth and inundation the inundation drowning people or devastating property.

How to analyse flood hazard?

An analysis of flood hazard should focus on characteristics and frequency of the floods. This means one needs to establish the probability and magnitude of all floods by investigating following:

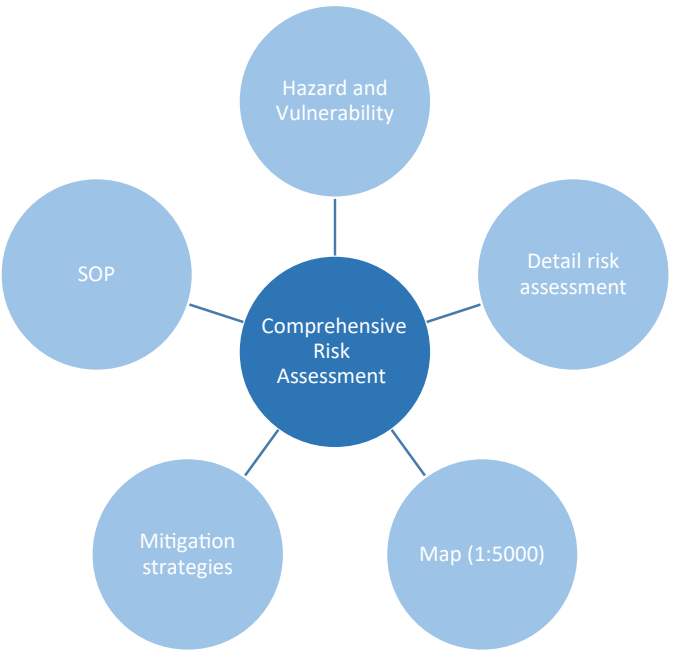
1. The probability distribution of floods of different magnitudes at a particular location;
2. The geographical extent of all these floods;
3. The depth and duration of these floods;
4. The velocity of the flood water's flow

The above mentioned hazard characteristics may differ with every flood type:

Flash floods	Lowland Floods	Coastal Floods	Floods along or in Estuaries
· Velocity and debris concentrations are higher · The analysis of flash flood hazard focuses on probability and prediction	· This tend to cover larger areas than floods in upland areas and may last long. · This may result from prolonged rainfall over large areas.	· Coastal floods are a function of tides, storm surges and wave conditions.	· This is the result from a coincidence of river floods meeting high water levels in the sea generated by storm surges or high tides.

We can estimate the probability of floods by examining records of flood events in past, using essentially statistical interpolation techniques.

Figure 7 Comprehensive Assessment of Flood Risk



To chalk out comprehensive strategy to prevent, prepare and respond to floods, we need to go for Comprehensive Risk Assessment, which may include:

1. Hazard: To understand the geography of flood hazard, need to consider the areal extent and other characteristics (Depth, Velocity, time to peak etc). Historical records, maps, photographs, remote sensing and other relevant data of past occurrence can be referred.
   - ✓ To understand the degree of exposure is to produce an overlay of the hazard map with demographic, socio-economic and environmental characteristics of the area. The overlayed maps can be used to help delimit areas where flood warnings are needed, spatial planning for flood risk mitigation and risk reduction measures.
2. Vulnerability assessment: this includes studying frequency and severity of hazard and impact of hazard on different social groups to identify most vulnerable groups. This also entails study of effect of hazard on infrastructure and economic systems.
   Risk Assessment: This includes determining the risks to people, assets and infrastructure and services by flood hazard and mapping detailed flood risk assessment for various return period (5 years, 10 years and 50 years). This analysis could be used to assess the flood risk and exposures probability.

Table 6 Information needed about the receptors

Demography		Source
Number of people live in the area	Number & types of residents	National Census
Influx population – work	Industrial and commercial enterprises located in site.	Field surveys or secondary sources of data
Influx population – travel in the area liable to flooding		
Property		
Number or area of different types of property (houses; factories; etc)	Their value and susceptibility to flooding	Field surveys (primary data) and existing land use fata (secondary)

3. Flood Consequences are quantified as the monetary losses and the intangible effects; and can be in several different forms.
   - ✓ Direct Consequences: this covers all harm which results from immediate physical contact of flood water with humans, property and the environment. Example, damage to building, economic assets, loss of human life, immediate health impacts, and loss of ecological a d cultural goods.
   - ✓ Indirect Consequences: Damages caused by disruption of physical and economic linkages. Example, the loss of production, costs of traffic disruption and the cost of emergency services.

Structural Measures	Non Structural Measures
Physical measures/ Augmenting Infrastructure	Non Physical measures including capacity building, policy directives and regulations
Reservoirs	Early warnings
Detention Basins (natural depressions)	Flood Plain Zoning
Embankments	Flood Proofing
Channelisation of Rivers	Mock drills
Channel Improvement	Capacity Building
Drainage Improvement	
Diversion of Flood Waters	
Watershed Management	

4. Flood management plans: After determining risks, flood risk management plan should be developed, which includes various structural and non -structural strategies to prevent, prepare and mitigate flood risks. Examples of structural and non-structural measures are given in above table.

5. Mechanisms for implementing Standard Operating Procedures (sops) - *https://www.niua.org/sites/default/files/SOP_Urban_flooding.pdf*

Table 7 Structural and Non Structural Mitigation Measures

Structural Measures	Non Structural Measures
Physical measures/ Augmenting Infrastructure	Non Physical measures including capacity building, policy directives and regulations
Reservoirs	Early warnings
Detention Basins (natural depressions)	Flood Plain Zoning
Embankments	Flood Proofing
Channelisation of Rivers	Mock drills
Channel Improvement	Capacity Building
Drainage Improvement	
Diversion of Flood Waters	
Watershed Management	

Photo Credit: Ezra on Unsplash

5

Strategies for flood risk management

Broadly the measures for flood mitigation can be divided into four categories :

1. Resilient Infrastructure: refers to assets and services which are minimally affected in any hazard and can be restored quickly. For example in Surat floods of 2006, the piped gas services in most of the areas were not affected despite flooding in the supply management units.
2. Urban design Innovations: Innovative approaches and designs that lead to flood mitigation is discussed in detail in this section. This includes approach like water sensitive urban design and innovative practices like Slow-Spread-Sink-Spread assets to prevent and mitigate flooding
3. Community Participation: Most of the governmental efforts to tackle urban flooding does not bear fruit because of low cooperation of communities. For example, sensitising communities to avoid throwing garbage in sewers, drains and water percolating structures play important role to curb flooding incidents.
4. Planning and regulations: it forms most important and effective means to systematically mitigate urban flooding. It involves, bylaws, zonal regulations, development guidelines which contribute to reduce urban flooding. Innovative designs may form part of guidelines and compliance regime. For example bye-laws that mandates providing water recharging structure for projects more than 5000 sqm area.

Urban Design and Innovation approaches cover wide variety of initiatives as listed below. Though different terms are used in different countries, the basic tenets of the approach remains the same, i.e. To minimise the disturbance to natural ecosystem, promoting conservation and integrating natural assets/ systems (like water bodies) etc in developmental planning. Here are some examples from across the globe.

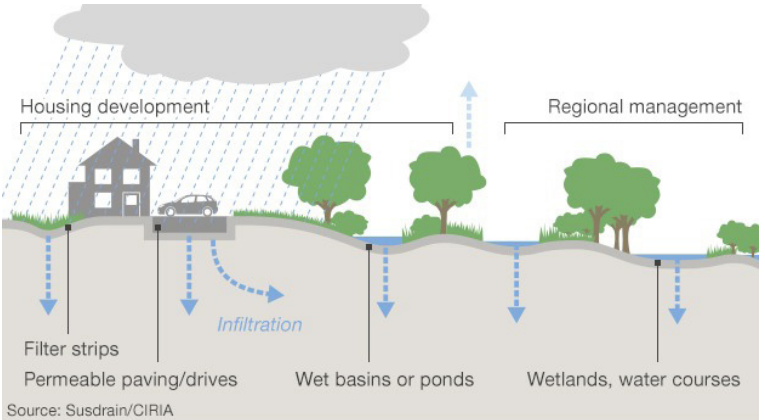
Figure 8 Components of Flood Management

Sustainable Urban Drainage Systems (suds) in the United Kingdom

Drainage systems can contribute to sustainable development and improve the places and spaces where we live, work and play by balancing the different opportunities and challenges that influence urban design and the development of communities. Approaches to manage surface water that take account of water quantity (flooding), water quality (pollution) biodiversity (wildlife

And plants) and amenity are collectively referred to as Sustainable Drainage Systems (suds). Suds mimic nature and typically manage rainfall close to where it falls. Suds can be designed to transport (convey) surface water, slow runoff down (attenuate) before it enters watercourses, they provide areas to store water in natural contours and can be used to allow water to soak (infiltrate) into the ground or evaporated from surface water and lost or transpired from vegetation (known as evapotranspiration).

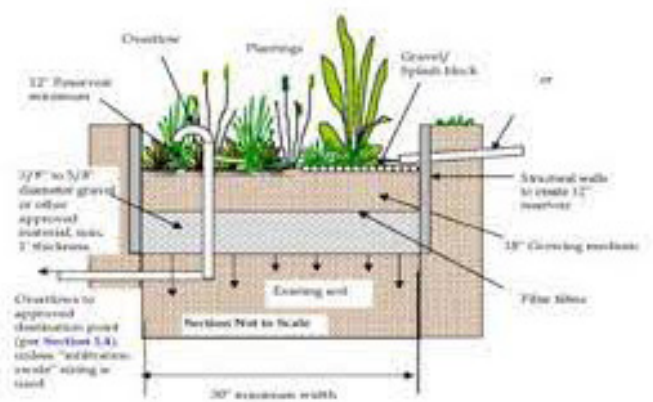
Figure 9 Sustainable Urban Drainage Systems (Schematic)[9]



Decentralized Rainwater/ Storm water Management (DRWM) in Germany

Describes a concept for different approaches to rainfall in urban areas. Rainwater is not drained primarily through channel and pipe networks but retained locally, used, evaporated, infiltrated or throttled if needed. Decentralised rainwater infiltration and decentralized stormwater treatment are partial aspects of stormwater management.[10]

Figure 10 Decentralised Rainwater/Stormwater Management[11]



[9]*BBC News. 2022.What's the best way to prevent flooding?. (online) Available at: https://www.bbc.com/news/uk-25929644 [accessed on 04/12/2021]*

[10]*Susdrain. 2022.Sustainable Drainage. (online) Available at: https://www.susdrain.org/delivering-suds/using-suds/background/sustainable-drainage.html [accessed on 04/12/2021]*

Sound Water Cycle on National Planning (SWCNP) in Japan

This new policy in Japan is seen as a holistic approach toward realizing integrated water resource management. It emphasises on properly conserved water cycle valued for human activities and environment. Policy includes directives for

- Sound water cycle by rain water management
- Reduction of stormwater runoff
- Detention and infiltration in watershed

Smart Water City, South Korea

A SWC integrates Information and Communication Technology (ICT) throughout the entire tap water supply process, from treatment to faucet, so that people can directly check for themselves in real-time the status of the tap water supply process and water quality. By implementing ICT into a city's water management in this way, a SWC can effectively reduce the general public's distrust in tap water, thereby increasing the drinking rate of tap water.

Figure 11 Smart water city (SWC)[12]

[11]*Commission on Water Resource Management. 2008. A Handbook for Stormwater Reclamation and Reuse Best Management Practices in Hawaii. (online) Available at: https://files.hawaii.gov/dlnr/cwrm/planning/hsrar_handbook.pdf*

[12]*International Water Resources Association. 2022. Case Studies for IWRA's Smart Water Cities Project. (online) Available at: https://www.iwra.org/smartwatercities_proposals/ [accessed on 04/12/2021]*

Low Impact Urban Design and Development (LIUDD) in New Zealand

LIUDD is an integrated urban design and development process using nested scales within catchments in urban and peri-urban environments. LIUDD aims to protect aquatic and terrestrial ecological integrity while allowing urbanisation at all densities. LIUDD is focused on avoiding, a wide range of adverse effects of a physiochemical, biodiversity, social, economic and amenity nature resulting from conventional development at little or no extra cost.[13]

Figure 12 Low Impact Urban Design[14]

Sponge Cities in China

Figure 13 Sponge City[15]

[13]*The University of Aukland. 2009. Low Impact Urban Design and Development: The Big Picture. (online) Available at: https://www.landcareresearch.co.nz/uploads/public/researchpubs/Science_Rep_LIUDD_optimised.pdf [accessed on 04/12/2021]*

[14]*UACDC. 2022. Low Impact Development. (online) Available at: http://uacdc.uark.edu/models/low-impact-development [accessed on 04/12/2021]*

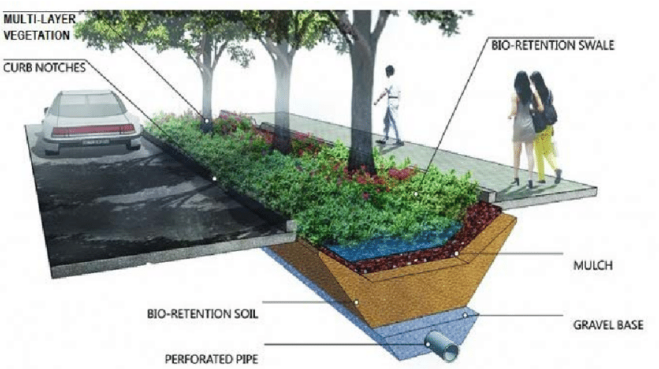
'Sponge City' manages stormwater through increased infiltration, detention, storage, treatment, and drainage. By implementing this concept, the impact of urban development on water-related problems and natural ecosystems is diminished.

Urban design innovations for stormwater management include components of a) Slowing down runoff, b) Spreading the water in the larger area, c) Sinking in the excess water and d) Storing rainwater.

Figure 14 Strategies of Flood Management

Slowing down runoff

Figure 15 Bioswales



[15]*Business Insider India. 2022. China is building 30 'sponge cities' that aim to soak up floodwater and prevent disaster. (online) Available at: https://www.businessinsider.in/science/china-is-building-30-sponge-cities-that-aim-to-soak-up-floodwater-and-prevent-disaster/articleshow/61594618.cms [accessed on 04/12/2021]*

With pavements, roads and roofs, most rainwater in urban areas is diverted causing two key impacts, a) non-replenishment of groundwater and b) excessive runoff causing flash floods and deluge in low lying areas. These problems can be addressed by simple design improvisation in roadside drainages and pavements. For example, Bioswales are improvised drainage systems running parallel to the road, allowing water percolation to the ground by creating permeable green spaces longitudinally. Similarly, permeable pavements allow rainwater to trickle down and reduce the runoff.

Figure 16 Permeable Pavements

Spreading the water in larger area

The decrease in water bodies due to urbanization can be addressed by creating artificial lagoons, ponds and lakes, particularly in low lying areas. This will help in increasing the capacity of water bodies within urban areas can reduce waterlogging and flooding as they spread rainwater in larger areas.

Figure 17 Urban Ponds

Sinking in the excess water

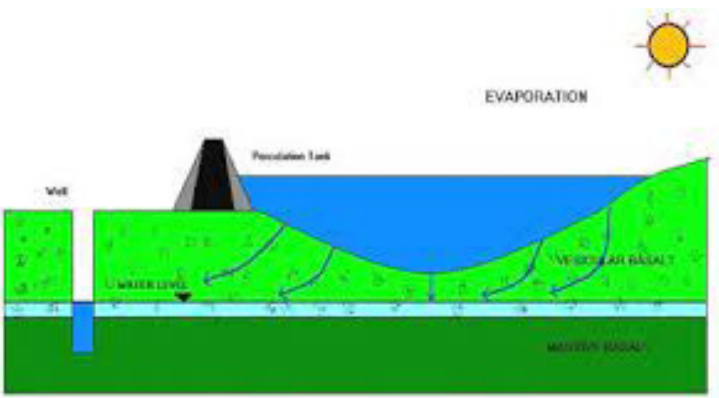
One of the best ways to mitigate flash floods and deluges in urban areas is to recharge groundwater, especially where groundwater withdrawal is more. This has the dual advantage of mitigating floods and replenishing safe sub-terrain water sources. To achieve these objectives, many cities have mandated water recharging and percolation structures within their development area.

Storing rain water

It is difficult to store all the rainwater for further use. However, at individual households or society or institutional levels, we can accumulate rainwater and use it for drinking and other purposes when needed. If adopted on a mass scale, this may significantly reduce flood risks in urban areas. The rooftop rainwater harvesting system has been widely adopted in many areas for this purpose. A combined storage tank system and groundwater recharge may also be helpful to harvest maximum rainwater.

Figure 18 Water harvesting and recharging

Figure 19 Rooftop Rainwater Harvesting



The strategies developed by cities should be

- Holistic- considering inter-sectoral linkages and implications of specific actions on other sectors
- More attention to urban planning- the exercise of planning should address the risks due to various hazards and consider people's participation in the development process.
- Ecological quality- the ecological impact of development processes should be considered for sustainability
- Considering local conditions- one solution may not fit all situations. Considering the socio-economy, terrain, geoclimatic conditions and other factors, the solutions should be tailor-made for different neighbourhoods even within the city.

Photo Credit: Ankit Srivastava on Unsplash

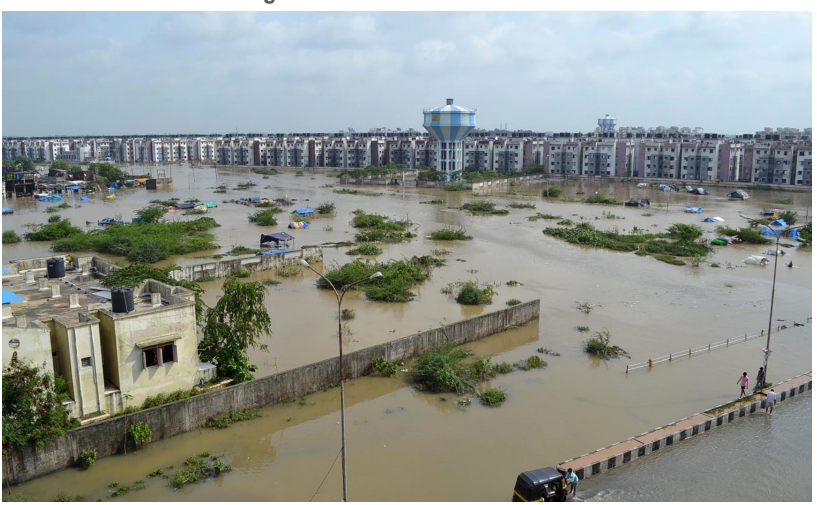
6

Case study

6.1. Surat early warning system

Surat has been known for experiencing floods even after building the Ukai dam, Due to the rapid growth and expansion of the city, the impact of floods are increasing, especially over the last two decades, with floods occurring at least once in four years. The floods in 2006 inundated 75% area of the city.[1]

Figure 20 Surat flood simulation



[1]*WeAdapt. 2013. End-to-End Early Warning System for Ukai and Local Flood in Surat City. (online). Available at: https://www.weadapt.org/placemarks/maps/view/932*

Surat being a part of the Asian Cities Climate Change Network (ACCCRN) developed hydrological models and conducted flood risk studies. These studies illustrated that emergency release due to the increasing frequency and intensity for river discharges was a major cause for flooding. City-wide vulnerability analysis showed the high vulnerability of households (especially slum dwellers and poor residing in riverine areas) and industries and other economic activities.

Based on the observed trends of floods in the past and the water management practice-related issues at Ukai Dam, a simplified decision system using state of the art technology was developed to better manage water release (minimize risks of flooding and risk of lack of irrigation water in summer). Thus the project of "End-to-End Early Warning System for Ukai and Local Floods in Surat City" was initiated by Surat Climate Change Trust (SCCT), which was established under the supervision of Surat Municipal Corporation. The key achievements under the project are:

- Development of reservoir inflow and outflow prediction models
- Installation of ten automatic weather stations and two water level measurement units across the city, to provide detailed weather, tide and flow information
- Development of city-level spatial data (in GIS) for flood management
- Development of Flood preparedness, response and mitigation plans

The hydrological model provided key decision-makers with advanced information (5-day inflow forecasts). During the 2013 monsoon, SCCT used this system to predict floods caused by extreme precipitation in the middle and lower Tapi basin and Khadi (tidal creeks) floods. Spatial maps to aid in flood preparedness and management were also developed and Surat has been able to enhance their flood management.

6.2. Water squares, Rotterdam

The Benthemplein area in Rotterdam was in a high-flood risk zone. However, the water square is helping to prevent floods. It is one among many smart solutions applied in Rotterdam, such as green rooftops, water storage facilities, and the Bellamyplein, a smaller version of the Benthemplein[2].

The water square can be understood as a twofold strategy. It makes money invested in water storage facilities visible and enjoyable. It also generates opportunities to create environmental quality and identity to central spaces in neighbourhoods. The water square will be dry and in use as a recreational space most of the time[3].

Now refurbished, Benthemplein is known as "Waterplein" (Water Square) because of the installation of three pools that fill up when it rains. However, the pools are dry for a good part of the year and can be used as recreational public space. The largest and deepest pool occupies the centre of the square and is only filled when there is a lot of heavy rain, which turns a "water wall" on one of its four sides into a spectacular, abundant cascade. The square can retain nearly 2 million liters of water.4

When it is empty it is used as a playing area for football, basketball or volleyball, and it has two rows of tiered seating so that members of the public can watch the matches5. The water square combines water storage with the improvement of the quality of urban public space.

Watch how water square work thorough given link:

Https://www.youtube.com/watch?Time_continue=218&v=kujf4btl3pe&feature=emb_logo

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[2]*De Urbanisten. 2022.Water Square Benthemplein. (online) Available at: http://www.urbanisten.nl/wp/?portfolio=waterplein-benthemplein [accessed at 04.12.2021]*

[3]*De Urbanisten. 2022.Water Square Benthemplein. (online) Available at: http://www.urbanisten.nl/wp/?portfolio=waterplein-benthemplein [accessed at 04.12.2021]*

[4]*Stormwater Report. 2022.First Full Scale Water Square Opens in Rotterdam.(online) Available at: https://stormwater.wef.org/2014/03/first-full-scale-water-square-opens-rotterdam/ [accessed on 04.12.2021]*

[5]*Public Space. 2022. "Water Square" in Benthemplein (online) Available at: https://www.publicspace.org/works/-/project/h034-water-square-in-benthemplein [accessed on 04.12.2021]*

Figure 21 Rotterdam water squares[6]

[6]*Public Space. 2022. "Water Square" in Benthemplein. (online) Available at: https://www.publicspace.org/works/-/project/h034-water-square-in-benthemplein [accessed at 04.12.2021]*

7

Interactive Exercise

Urban flood management involves various stakeholders with different functions, both in normal time (to build capacity and prepare for flooding) and in emergency time (to respond). Understanding and application of Standard Operating Procedure (SOP) for flood management helps ulbs to prepare and respond effective in flooding events. The focus of this exercise is to

1. Identify Stakeholders, their roles in various sectors and prioritise activities for capacity building and preparedness in normal times.
2. Identify sector wise Emergency Support Functions (esfs) during response, relief and recovery phases of flood management
3. Corelate emergency support functions in accordance to alert levels

The activity is divided into two parts:

1. 1) Normal time, where focus is on preparedness and capacity building activities in normal time, and
2. 2) Emergency phase, where focus is on response, relief and recovery activities.

Exercise 1 : Agencies and their roles in normal time.

This exercise is aimed to identify roles and responsibilities for various departments and agency in normal time, for preparedness and capacity building for flood management, and prioritise the actions.

The matrix consist of thematic sectors on left column and processes of flood management related to normal times, in top row. These thematic sectors have further segments denoted by yellow notes. For e.g. The first sector of “admin and Logistics’ have two segments admin and logistics, and planning and coordination. There are three columns- Mitigation and Adaptation, Data collection and Mapping, and Coordination.

There are several 'activity notes' with different activities/tasks on right side of matrix. These notes are also available on bottom left corner for easy access. Below the activity notes on right side, are the circles marked with names of different agencies involved in urban flood management, as given in SOP for Urban Flooding by Ministry of Housing and Urban Affairs (mohua), earlier called Ministry of Urban Development (moud). We will call these circles as 'Agency tags'. Below agency tags are small green circle dots with number 1 or 2. These are the 'priority dots' for activities.

So the exercise is sub divided in three parts:

1. Participants need to drag and drop activity notes in relevant row/column matrix, which they think is appropriate. These notes are meant for first two columns of Mitigation and Adaptation, and Data Collection and Mapping processes. (The third column of Coordination should only be used for "agency tags') They can use blank notes to come up with additional activities. For example note of Pre Monsoon Plan can be parked in first box of matrix which denotes sector of 'Admin and Logistics' and process of 'Mitigation and Adaptation'. Likewise all the activity notes can be placed in appropriate cell of the matrix.
2. Once the activities are arranged in first two columns, participants can move 'Agency Tags' in third column of Coordination. Here, agencies which will be involved in various activities of that sector should be placed in one cell of the column. Likewise all the sectors will be assigned different agencies.
3. Once we have activities and agencies arranged in the matrix, participants can move green dots to prioritise the activities in each sector. Dot with number 1 is for the highest priority and dot with number 2 is for second or low priority.

After all three activities, we get clear picture of roles and responsibilities of various agencies in different processes of flood management in normal time. These are basically preparedness and capacity building activities to done before the onset of monsoon. Then we move to second part of the exercise which is focused on emergency support functions for flood management.

Table 8 Exercise 1A: Agencies, stakeholders and activities during normal time

Exercise 1A: Agencies and their roles in normal time

This exercise is aimed to identify roles and responsibilities for various departments and agency in normal time, for preparedness
And capacity building for flood management, and prioritise the actions
Step 1: *Drag and drop activity notes into matrix selecting appropriate processes and sectors*
Step 2: *Drag and drop Agency labels in the row of coordination according to their lead roles*
Step 3: *Drag and drop Priority Ranking red dots on the activities of top priority across all columns of matrix*

Activites During the Normal Times	Admin and Coordination activities	Health, Housing, Water, Sewerage Related Activities	Stormwater, Power Supply, Road, Transport related activities	Early Warning and Evacuation, Fire, Safety, Security Related Activities
Activities	Admin and Logistics	Essential Services	Infrastructure	Safety & Security
Mitigation and Adaptation				
Data Collection and Mapping				
Coordination Lead				

Stakeholders :			
Municipal Sanitation Department	District Collectorate	NGOs	Fire Brigade
Traffic Police	PWD	Health Department	Stormwater Department
Home Guards	Urban Development Authority	Police	Food & Civil Supply
IMD	Telecom Department	Railways	PHED
Irrigation Department			

List of Activities	
1. Buses on Standby for evacuation	23. NDRF called-in
2. Prepare Health Directory	24. Evacuation, Search and Rescue
3. Temporary Sanitation Facilities	25. High Rainfall Alerts
4. Water Purification Kits Distribution	26. Water Supply and Sewerage
5. Pre Monsoon Plan	27. Cleaning up of Debris
6. Activate Emergency Alarms and Systems	28. Health and Hygiene
7. Evacuation in Low Lying Areas	29. Rehabilitation Plan
8.Evacuation in low lying areas	30. Conduct Mock Drills
9. Dewatering from low lying areas	31. Medical Support
10. Deployment at low lying areas	32. Prepared Disaster Management Plan
11. Temporary Shelters with Food and Water Supply	33. Training Needs Assessment
12. New Bridge Plan	34. Equip Communication Devices
13. Repair of Damaged Roads and Bridges	35. Temporary Sanitation Facilities
14. Arranging for Dumpers and Earth Movers	36. Demarcate Flood Plan Data
15. GO NGO Coordination for Relief	37. Respond
16. Canal Beach Repair	38. Fogging and Disinfection
17. Health Surveillance	39. Restoration of Water Supply
18. Prepositioning of food and relief items	40. Clearing Carcasses
19. Advisory to citizen to move to safe place	41. Update data on Flooding spots and landslide prone area
20. Prepositioning of food and relief items	42. Security and Fire Safety
21. Early Warning	43. Pre Monsoon Plan
22. Boats Ready	

Figure 22 Layout of first part of exercise

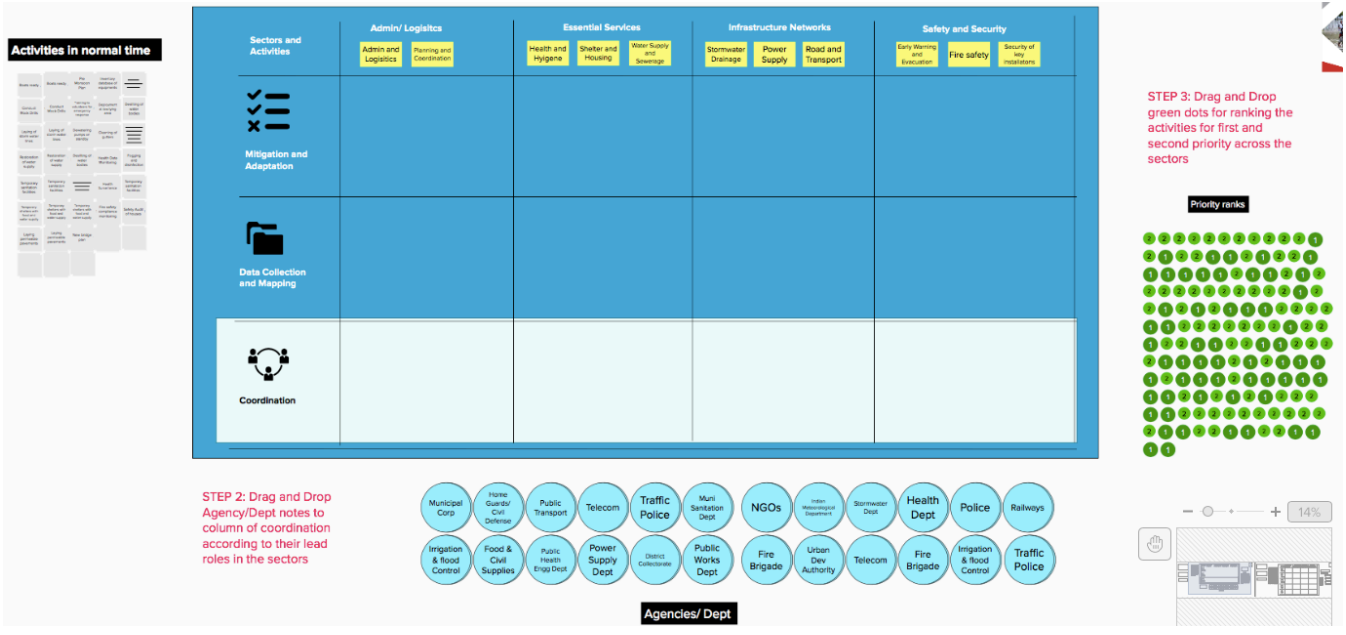
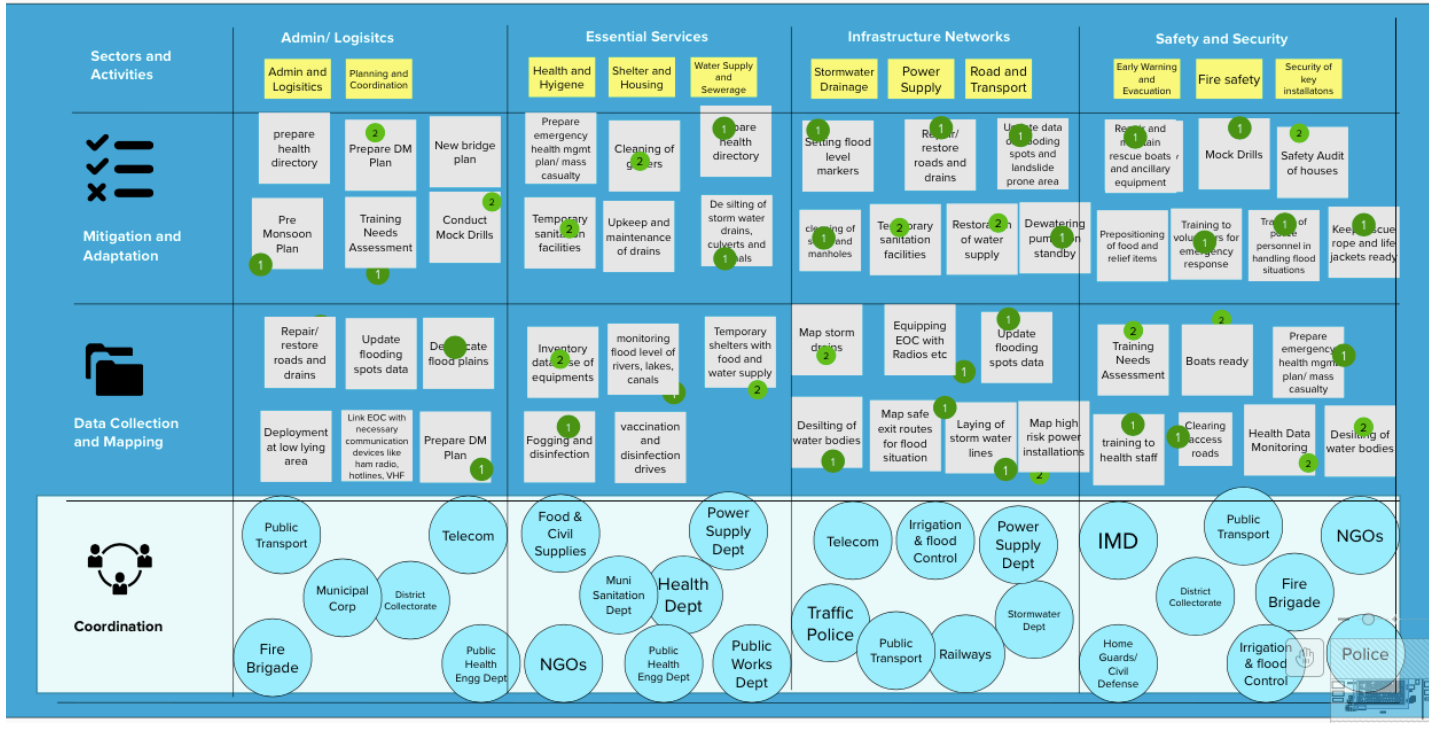


Figure 23 On completion of first part of exercise



Exercise 2: Emergency Support Functions and Colour Coded Alerts

This exercise is aimed to identify phase wise emergency support functions in different sectors for flood management, and prioritise the actions according to colour coded alerts issues by administration/ government.

In this exercise, the matrix consists of sectors in the rows similar to Exercise 1, however, the columns indicates five phases of emergency response, i.e. Prepare, warn, respond, relief and restore. On right side there are notes of 'Emergency Support Functions' or ESFs. And below these notes are the colour coded dots of yellow, orange and red. These dots represent alert stages, which is described further below in the canvas.

This exercise has two sub parts.

a. Participants have to move these ESF notes to appropriate matrix. For example, the function of temporary sanitation facility can be moved to column of 'relief' phase and row of essential services. Once all the ESFs are arranged in matrix, we can move to second part of exercise. Before that, facilitator will explain the colour coded alert indicators in detail.
b. Participants can now put colour coded dots, representing the alert level on each ESF note. For Example, deployment of NDRF may be on the highest alert stage- Red, while pre-positioning of food items may be started at orange alert stage.

However, these allocation of alert stage will need discretion from the authorities in real case scenario, as there are no watertight compartments either in phases of flood management or alert warning mechanism. These functions may overlap in one or more phases or one or more alert indicators.

Lastly, summarizing the learnings from both the exercises, participants will get more clarity on activities and functions of different agencies in different phases and prioritizing the same. This leads to development of effective SOP where all the actors are clear about their roles and responsibilities and also how to coordinate with others.

Table 9 Exercise 1B: Agencies, stakeholders, activities during Emergency time

Exercise 1B: Agencies and their roles in emergency time

Exercise 1B : *Phase-wise Emergency Support Functions in Flood Management (Response)*
This exercise is aimed to identify emergency support functions in different sectors for flood management and prioritise the functions in different phases according to colour coded alerts issued by administration and other agencies.
Step 1: Drag and drop Emergency Support Function notes into matrix selecting appropriate phases and sectors
Step 2: Drag and drop colour code dots on activities which needs priority in respective alert level.

ACTIVITES DURING THE NORMAL TIMES	Admin and Coordination activities	Health, Housing, Water, Sewerage Related Activities	Stormwater, Power Supply, Road, Transport related activities	Early Warning and Evacuation, Fire, Safety, Security Related Activites
Activities	Admin and Logistics	Essential Services	Infrastructure	Safety & Security
Prepare				
Warn				
Respond				
Relief				
Restore				

List of Activities	
Pre Monsoon Plan	**Conduct Mock Drills**
Temporary shelters with food and water supply	Evacuation in low lying areas
Food packet distribution	Canal Breach Repair
Cleaning of gutters	Joint Damage Assessment
Restoration of water supply	Deployment at low lying area
Medicinal support	Fogging and disinfection
Temporary sanitation facilities	New bridge plan
Advisory to citizens to move to safe place	Health surveillance
Dewatering from low lying areas	Clearing carcasses
Buses on standby for evacuation	Rehabilitation plan
Update data on flooding spots	Food packet Distribution
Prepositioning of flood and relief items	Desilting of water bodies
Water purification kits distribution	Clearing access roads
Repair of damaged roads and bridges	Cleaning up of Debris
GO NGO Coordination for Relief	Arranging for dumpers and earth movers
Activate emergency alarms and systems	Reconstruction of houses
Boats Ready	NDRF Deployed

Figure 24 Layout of second part of exercise

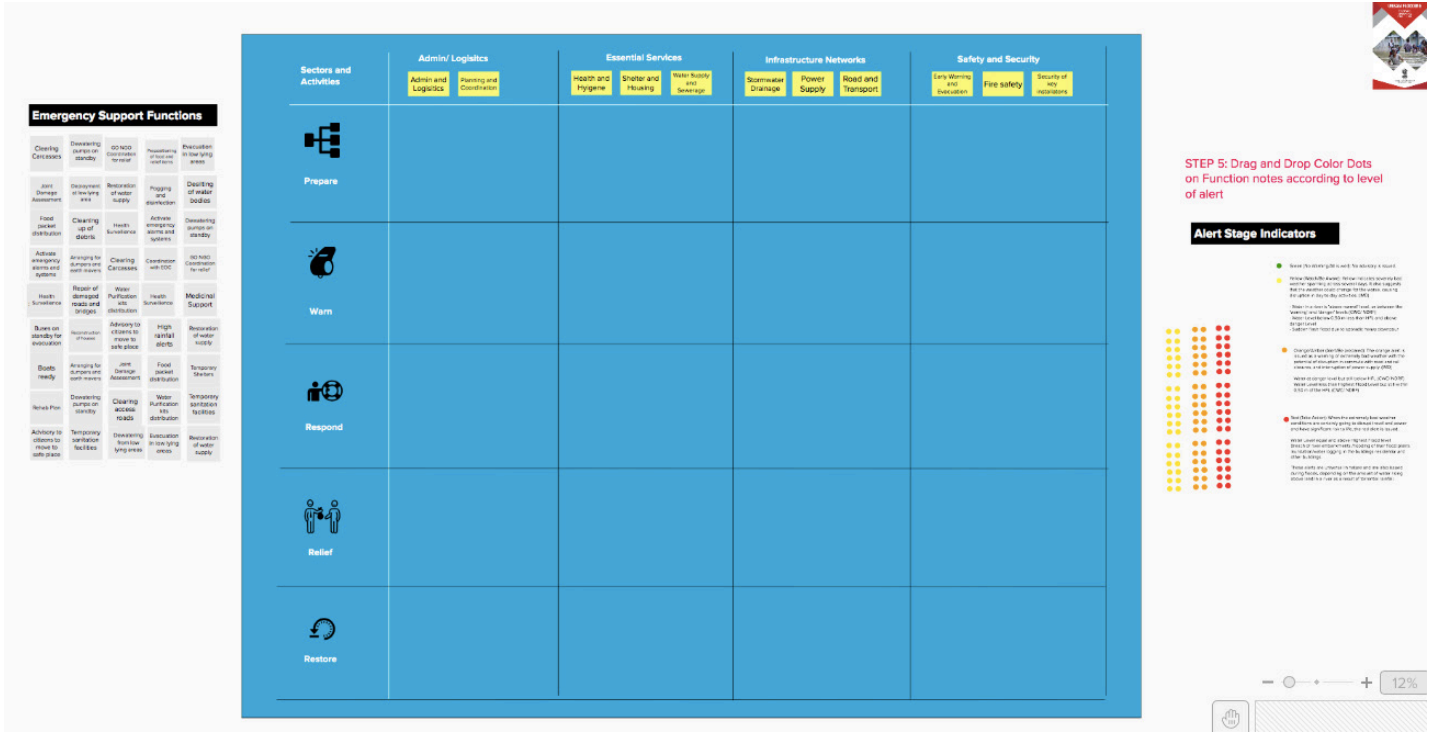
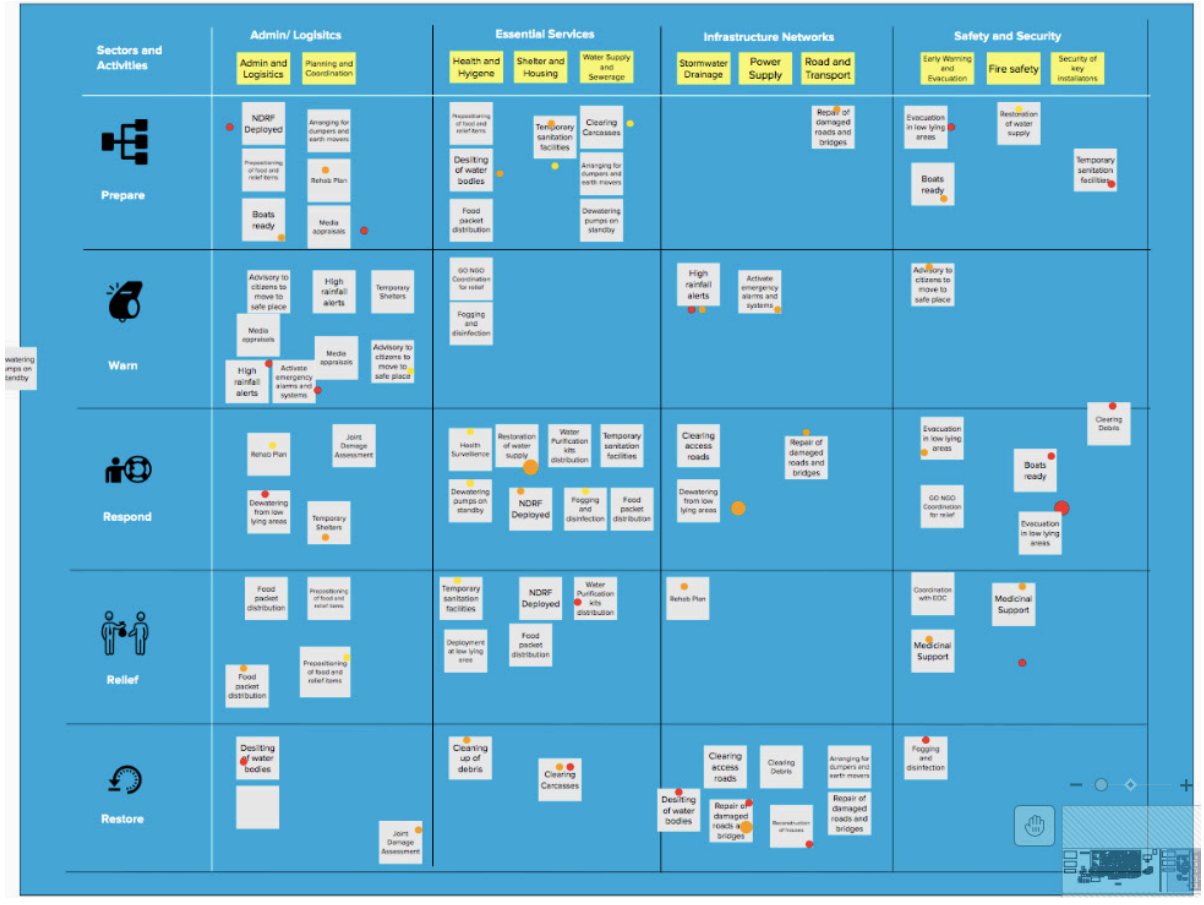


Figure 25 On completion of second part of exercise



8

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