HELP Global Report on Water and Disasters
2019

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HELP Global Report on Water and Disasters 2019

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Preface

I, as Chair of HELP, am pleased to launch the first edition of HELP Global Report on Water and Disasters.

Water is life and lies at the heart of the 2030 Agenda. The successful implementation of the SDG6 and water-related targets as well as Sendai Framework for Action are crucial for realizing the whole 2030 Agenda. Water can also threaten life. The toll of water-related disasters in lives and livelihoods has been immense, along with many other damaging short-term and long-term social and economic impacts., The combined effects of extreme water events, changes in climate patterns, growing populations and urbanization are negatively affecting societies and economies in many regions. They can reduce resilience, spur migrations, and potentially spark conflicts. Actions are needed to mitigate their effects and help assist societies to adapt to their new realities.

During the past decade, water-related disasters have not only struck more frequently but have also been more severe. Global annual economic losses from natural disasters are estimated at between 250 billion to 300 billion US dollars. Although death tolls of disasters have been contained due to global efforts and advancement of science and technology, the number of affected people and, particularly, the economic losses due to disasters have been skyrocketing. About 90% of financing for disasters risk reduction worldwide is directed at emergency response and reconstruction/ rehabilitation, and is increasing year by year, while the amount disbursed for disaster prevention and preparedness is limited to about 10%.

Millions of people continue to be affected by droughts. Droughts are slow onset disasters which cause severe impacts. They are deeply rooted in social, economic, environmental and even political conditions of the affected areas. Compartmentalized water use and management often intensify negative impacts of the disasters and call for increased integrated management. Intricate causes of droughts, however, should not be an excuse for non-action.

Changing patterns of climate exacerbating the extremes in hydro-meteorological events. Eighty percent of their impacts are channelled through water. We must share our experiences and lessons learned, strengthen regional coordination and collaboration, and set common goals and targets to lay a foundation for weathering the water-related disasters to come, and to create better-prepared and resilient societies. Social stability and development depend on actions and policies to dramatically reduce water related damages as percent of GDP.

The High-level Experts and Leaders Panel on Water and Disasters, or HELP, was originally established in 2007 upon recommendation by the UN Secretary-General’s Advisory Board on Water and Sanitation (UNSGAB). It was upgraded to a high-level political body by inviting ministers and heads of international organizations in 2013 and has been engaged in raising awareness and promoting actions to address the issue of water and disasters at global and national levels. The group comprises some 20 high level members and 10 advisors with broad knowledge, deep experiences and proven capabilities in raising awareness and galvanizing actions on the issue.

Its achievements include organizing biennial UN Special Thematic Sessions on Water and Disasters at the level of Heads of State and Government since 2013. It also published series of flagship documents, launched numbers of position papers, and advocated in numerous international conferences and key events.

The focus of HELP is to promote concrete actions by governments and stakeholders and to help achieve transformative changes to drastically improve preparedness and readiness for water-related disasters as well as provision of safe water and sanitation at emergency. Learning from experiences, lessons, and good practices of disasters that have already happened will enable the transformation fast and effectively. As large-scale disasters are experienced only occasionally, learning from cases worldwide is a must for us to build safer and more resilient society against natural extremes. That is the very reason why HELP decided to start compiling and sharing lessons and experiences of major disasters on regular basis. This document, Global Report on Water and Disasters, is a major part of HELP's flagship initiatives. The Report will be published on annual basis so that governments and all stakeholders can learn from lessons and good practices of major water-related disasters. HELP Members, Advisors, and partners will engage in field visit, information collection, and in-depth analysis of disasters and risk reduction measures in all parts of the world. It will ask, through its extensive network, resident leaders and experts to contribute what they have learned from dealing with water related disasters in their own countries. I am convinced that the Report will significantly contribute to progressive improvement of global preparedness for water-related disasters through sharing experiences and lessons.

During the past one-year period, the world has witnessed severe water-related disasters in India, Nigeria, Japan, Indonesia, and, most recently, countries in South African Region. Cyclone Idai and Cyclone Kenneth that made landfall on the southern part of African continent were among the most devastating. The consecutive, fierce and deadly cyclones left swaths of ruins and destruction over vast areas. Idai alone caused unprecedented death toll and economic damages throughout Mozambique, Zimbabwe, Malawi, Madagascar, and other affected countries. Nature will not wait for us to catch up with its changes.

We face many uncertainties in changes in climates, economies, societies and politics. But uncertainties are no excuse for inaction. We must take bold decisions and actions to address risks related to water, sanitation and disasters.: We have to turn uncertainty into opportunities for our sustainable future. Let us work together to build a disaster-resilient, water-secure world for the generations to come.

Han Seung Soo

Han Seung-soo

Chair, High-level Experts and Leaders Panel on Water and Disasters (HELP)
Former Prime Minister of the Republic of Korea

Indonesia is one of the countries in the world which continuously fight against multiple disasters. Located in the Pacific Ring of Fire a high degree of tectonic and volcanic activities, Indonesia has to cope with constant risk of eruptions, earthquakes and tsunamis. In addition, Indonesia is also exposed with disasters induced by climate change, such as flood, drought, extreme weather, etc.

According to World Risk Report (2016), Indonesia is categorized as a high-risk level of disaster, which is dominated by hydrometeorological disaster (based on the National Disaster Management Authority of Indonesia). We are all aware, disasters risk increased significantly. It creates tremendous economic, social, and environmental losses, which can be seen from the decreasing numbers of Indonesia capital stock, increasing numbers of casualties and fatalities and environmental degradation (reduced biodiversity).

Hence, it is necessary to perform disaster mitigation and adaptation. We need to focus in prevention rather than rehabilitation. The development of disaster risk resilience and climate change adaptation is the key to realize 2030 sustainable development agenda and Sendai Framework. Some countries perform quick recovery after disaster and improved resilience capacity, which must be share to others.

Disaster management is a joint task at all levels: international, national, regional and local. Global community must unite to raise awareness and take urgent actions to address the issue of water-related risks to ensure countries' sustainable economic and social progress towards achievement of SDGs, Sendai Framework Disaster Risk Reduction and Paris Agreement on Climate Change.

Therefore, we must engage in international Disaster Risk Management framework such as Sendai Framework Disaster Risk Reduction and Paris Agreement on Climate Change, and contribute to the relevant multilateral platform through the High-level Experts and Leaders Panel on Water and Disasters (HELP).

As the Vice Chair of HELP, I fully support the actions of HELP. I also appreciate the launch of some flagship documents and policy briefs, which encourage countries and stakeholders to enhance water supply management and disaster prevention & preparation in global, country and community levels. Those will be beneficial for many countries in adequately coping with water-related disasters, under coordination of international community to accelerate its recovery process. As the Minister of Public Works and Housing of the Republic of Indonesia, I am also really keen to share our experience in finding new ways to cope with fatalistic events in Lombok and Palu. Both cases will certainly serve the good lessons learned for every HELP members and as the ground for further collaborative in Disaster Risk Reduction initiatives.

Basuki Hadimuljono

Vice Chair of HELP
Minister of Public Works and Housing, the Republic of Indonesia

In March and April this year Tropical Cyclones Idai and Kenneth unleashed their destruction on lives and economies in eastern Africa. As with the other disasters highlighted in this HELP Global Report on Water and Disasters 2018-2019 and the many smaller events, which are just as devastating to the communities affected, the effects will last for years if not decades. The victims of this destruction are people, their prosperity and the planet. The people, by and large, are the poor and most vulnerable. Piece-meal and reactive responses are inadequate. Rather, proactive, urgent, and lasting change is required.

The systemic nature of risk and large-scale dynamic risks are becoming better understood thanks to the efforts in part of the Sendai Framework for Disaster Risk Reduction and the Agenda 2030 for Sustainable Development. This underlines that we need not only better prepare and anticipate potential calamities but shift our everyday practices to adapt and find new ways that break the cycle of disaster–respond–rebuild–repeat.

Climate change is a major driver and amplifier of disaster losses and failed development by making extreme events both more extreme and more frequent. Where water is part of the equation, investing in integrated water resources management can avoid some of the worst economic and social consequences. Floods and droughts highlight in a drastic way - also in the case studies presented in this report - where current management systems are weak.

Investments in integrated water management help safeguard socioeconomic growth in the face of increasing vulnerabilities to droughts and floods. It has been shown that the most beneficial water investments have been connected to integrated planning that combines and sequences investments in institutions, information systems and infrastructure. These are investments in preventing impacts - reducing potential damage before disasters occur. Taking such an approach can inspire action on disaster risk reduction even beyond the water community and help us tackle climate change and disaster risk reduction together as a truly sustainable development challenge.

Disasters may not differentiate where they hit – but when they hit, the poor and the vulnerable are the most affected. To protect the vulnerable, we will need an all-of-society engagement – with political leadership, solid science informing policy, an emphasis on the gender dimension, and finance coming together. Multi-stakeholder platforms are crucial here in ensuring that inequality is not exacerbated and that political will can be turned into effective action. The 3,000 partners that form the Global Water Partnership are ready to engage with you, bringing our technical capacity and insights locally and globally to build together a more resilient future.

Howard Bamsey
Chair, Global Water Partnership

1. Overview of Water-related Disasters in 2018

Kenzo Hiroki

Professor, National Graduate Institute for Policy Studies (GRIPS)

Water-related disasters in 2018 resulted in death toll of 6,500, over 57 million people affected, and economic loss of 140 billion US Dollars worldwide

1.1 Human loss and number of affected people by water-related disasters in 2018

The year 2018 was marked by recurrent water-related disasters in all parts of the world. Around 6,500 people lost their lives by water-related disasters (e.g. floods, tsunamis, slides and debris flow, storms, and droughts) out of total yearly death of around 10,400. Over 60% of deaths were caused by water-related disasters including tsunamis. According to EM-DAT (International Disaster Database) of Centre for Research on the Epidemiology of Disasters (CRED), extreme weather events accounted for most of 61.7 million people affected by natural disasters. 57.7 million people were affected by water-related disasters. It is 93.3 % of total disasters. The increasing trend of number of affected people by water-related disasters continue due to, inter alias, climate change, population growth, and urbanization.

Table 1.1 Death Toll by Disaster Type (2018 vs. average 21st Century)

Event	2018	Average (2000-2017)
Drought	0	1,361
Earthquake (death toll by tsunami)	4,321 (Around 1,300)	46,173
Extreme temperature	536	10,414
Flood	2,859	5,424
Land slide	282	929
Mass movement (dry)	17	20
Storm	1,593	12,722
Volcanic activity (death toll by tsunami)	878 (420)	31
Wildfire	247	71
Total (Water-related -disasters)	10,733 (Around 6,500)	77,144

Source: UNDRR using EM-DAT (International Disaster Database)

Note: Figure on tsunami was estimated by HELP

Table 1.2 Top 10 Countries by Number of People Affected (2018)

	Country	Total number of affected people
1	**India**	23,900,348
2	**Philippines**	6,490,216
3	**China**	6,415,024
4	**Nigeria**	3,938,204
5	**Guatemala**	3,291,359
6	**Kenya**	3,211,188
7	**Afghanistan**	2,206,750
8	**U.S.A.**	1,762,103
9	**Japan**	1,599,497
10	**Madagascar**	1,472,190

Source: UNDRR using EM-DAT (International Disaster Database)

Note: **Bold letters** in name of countries indicates that majority of number of disaster-affected people are by water-related disasters including droughts.

Human loss by water-related disasters can be substantially reduced by making effective use of time lag between occurrence of natural catastrophic events (heavy rain, seismic shake, and winds and low pressure of typhoons/ hurricanes) and arrival of natural force (floods, tsunamis, and high tides) to the people and communities. Since such time lags certainly exist for all water-related disasters, timely early warning and facilitating people's quick actions such as evacuation are the keys.

1.2 Economic loss by water-related-disasters

In terms of economic loss, 2018 was recorded as one of the worst economic-loss years mainly due to water-related disasters. According to Munich Re., "The overall economic impact was US$ 160bn, of which US$ 80bn was insured." 140 billion USD or 92% of all economic loss were caused by disasters related to water and climate.

"2018 was the fourth-costliest year since 1980 in terms of insured losses. 2018 was above the inflation-adjusted overall loss average of US$ 140bn. The figure for insured losses – US$ 80bn – was significantly higher than the 30-year average of US$ 41bn. 2018 therefore ranks among the ten costliest disaster years in terms of overall losses, and was the fourth-costliest year since 1980 for the insurance industry."

"In particular, Hurricanes Michael and Florence in the Atlantic, and Typhoons Jebi, Mangkhut and Trami in Asia, all left their mark. Overall losses from tropical cyclones in 2018 came to roughly US$ 57bn, of which US$ 29bn was insured. There was also an extremely high impact from wildfires in California that produced overall losses of US$ 24bn and insured losses of US$ 18bn. Over the course of the year, 29 events each resulted in an overall loss of US$ 1bn or more."

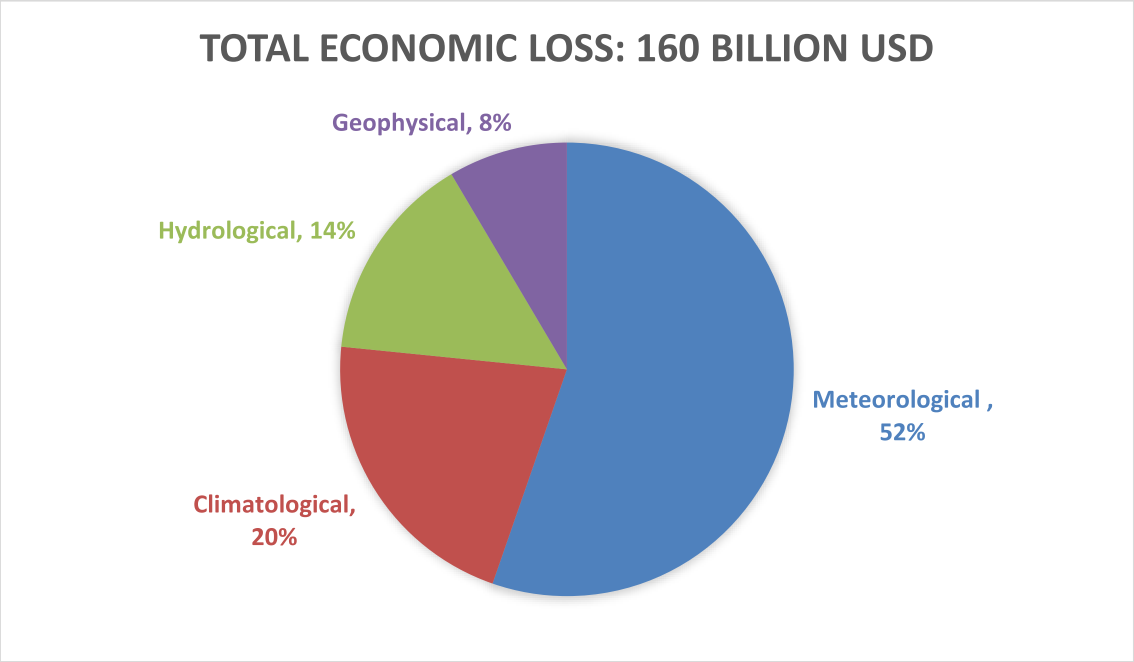

Fig. 1.1 Economic loss by kinds of disasters in 2018

Made from Munich Re. Report 2018

https://www.munichre.com/topics-online/en/climate-change-and-natural-disasters/natural-disasters/the-natural-disasters-of-2018-in-figures.html

1.3 Major disasters in 2018

Severe water-related disasters happened in all continents and many islands. Major water-related disaster events include floods in India (June-August, 2018), heavy rain and flooding in Western Japan (June-July, 2018), floods in Nigeria (August, 2018), Floods in North Korea (August-September, 2018), Floods in Nigeria (September, 20189, Typhoon Mangkhut, in Guam, Marshall islands, the Philippines, and South China (September, 2018), Hurricane Florence in U.S.A. (September, 2018), Hurricane Michael in U.S.A. (October, 2018), tsunami and liquefaction-related slides caused by earthquake in Central Sulawesi, Indonesia, and tsunami caused by volcano-related slides under the sea along Sunda Straight , Indonesia (December, 2018). Countries in which major droughts happened include Afghanistan, Argentina, Australia, El Salvador, Guatemala, Honduras, India, Kenya, Nicaragua, Pakistan, and Uruguay.

Reference

UNDRR (2019). 2018: Extreme weather events affected 60m people (https://www.unisdr.org/archive/63267)
Munich Re (2019). The Natural Disasters in 2018 in Figures (https://www.munichre.com/topics-online/en/climate-change-and-natural-disasters/natural-disasters/the-natural-disasters-of-2018-in-figures.html)

2. Overview of Heavy Rain Disaster in Western Japan in June-July, 2018

Hirotada Matsuki

Director, International Affairs Office, Water and Disaster Management Bureau,

Ministry of Lang, Infrastructure, Transport and Tourism (MLIT), Japan

2.1 Overview of the Disaster

2.1.1 Water-related disasters and risk reduction policy

Water-related disasters hit Japan every year. Disasters struck Izu-Oshima island in 2013, Hiroshima city in 2014, Kanto-Tohoku region in 2015, Hokkaido-Tohoku region in 2016, Northern Kyushu region in 2017 and a widespread area in Western Japan in 2018.

Heavy disasters are annual events in Japan, therefore the central and local governments are most often in a cycle of preparedness, disaster, response and recovery. In the cycle, Japanese society has been urging policy-makers and infrastructure managers to reduce disaster risks and damages and to prevent disasters from events of similar scales in the future. Post-disaster work is preparation in view of the next one. This is the basic concept of "Build Back Better". However, disasters vary in magnitude and frequency, and people living in disaster-prone areas have to face unprecedented events. To solve the problem and develop disaster risk reduction policies, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) relies on its academic think tank called River Council for Social Infrastructure Development. This chapter describes the evidence-based policy-making process by MLIT and the River Council after the heavy rains of July 2018.

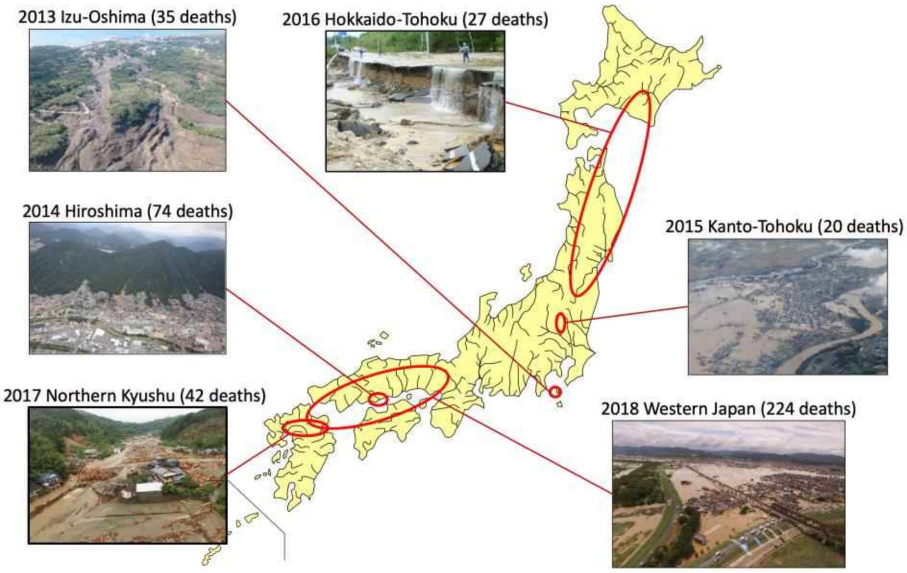

Fig. 2.1 Successive water-related disasters hitting Japan

2.1.2 Outline of the damage and response

In July 2018, Heavy Rain caused simultaneous river floods, waterlogging, debris flow, among others, in a wide area of Western Japan. As a result, 224 people died, 8 people went missing, 21,460 houses collapsed, and 30,439 houses were inundated. Local governments issued evacuation orders for 2,007,489 people (915,849 families), and evacuation advisories for 2,304,296 people (985,555 families). Lifeline infrastructures were also damaged, such as 263,593 households affected with disrupted water supply.

Fig.2.2 Damage of Heavy Rain in July 2018

1) River floods

The number of rivers, in which the water exceeded the hazardous water level, was the largest ever, with 50 rivers in 26 basins under MLIT management and 234 rivers in 138 basins under prefectural management. Levees were breached at 37 points in total. Of these, 2 breaches occurred on the Oda River in Takahashi River basin under MLIT management, and 35 breaches were in rivers under prefectural management; namely, 16 breaches in 10 rivers in Okayama and 16 in 12 rivers in Hiroshima. Especially in the Oda River and its 3 tributaries particularly, levees were breached at 8 points due to the “backwater phenomenon” in which branch river floods synchronized with the major river flood. Among 558 dams managed by MLIT, 213 dams conducted flood control operations. Twenty-two dams used over 60% of flood control capacity. Eight dams almost exhausted their flood control capacity and shifted to emergency discharge operations, under which the outflow was equal to the inflow. Some operations triggered floods in the downstream.

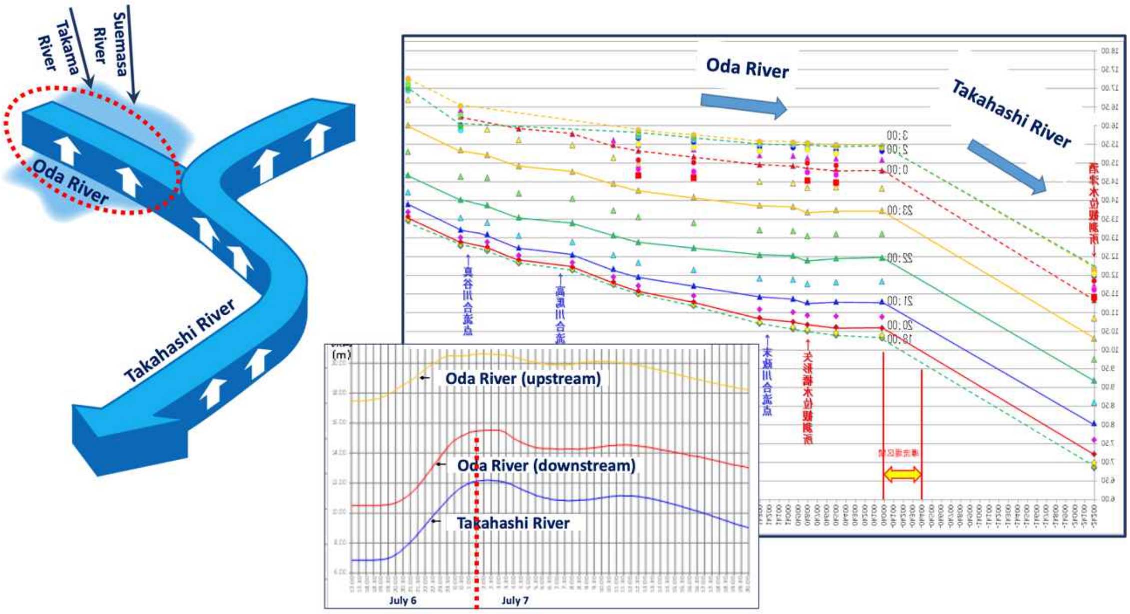

Fig. 2.3 Backwater phenomenon due to synchronized flood peak-time

2) Waterlogging

Inundation, including waterlogging, occurred around 47 rivers in 22 MLIT-managed river basins and 242 rivers in 69 prefecture-managed river basins. Record breaking and long-lasting rainfalls and intensive short-period squalls in widespread areas caused a mixture of river flooding and waterlogging at 88 municipalities in 19 prefectures in Western Japan. Municipalities reported 18,853 houses were affected by waterlogging, and 90% of them were in areas undergoing construction of sewage drainage systems.

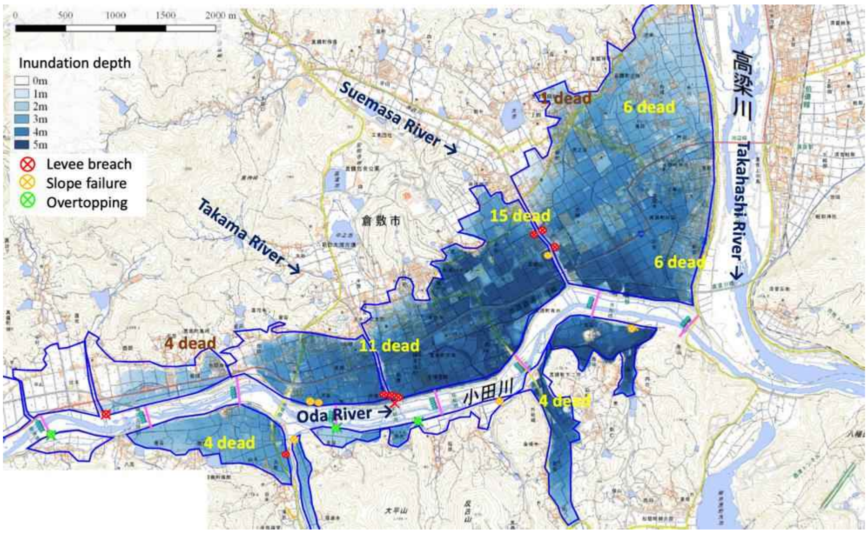

Fig. 2.4 Deep inundation up to over 5 m due to levee breaches

3) Sediment disasters

Sediment disaster warnings were issued to 505 municipalities in 34 prefectures. Sediment disasters occurred in 31 prefectures especially in Hiroshima and Ehime Prefecture. The total number of 2,512 was 2.3 times higher than the annual sediment disaster occurrence of the past 10 years. Sediment-water synergistic floods, wherein preceding sedimentation in the downstream dammed up subsequent sediment and water, hit Oya-ohkawa and Sozu rivers in Hiroshima Prefecture. Many masonry sabo dams in Hiroshima Prefecture, which had passed periodical inspections, collapsed or were flushed away by debris flows.

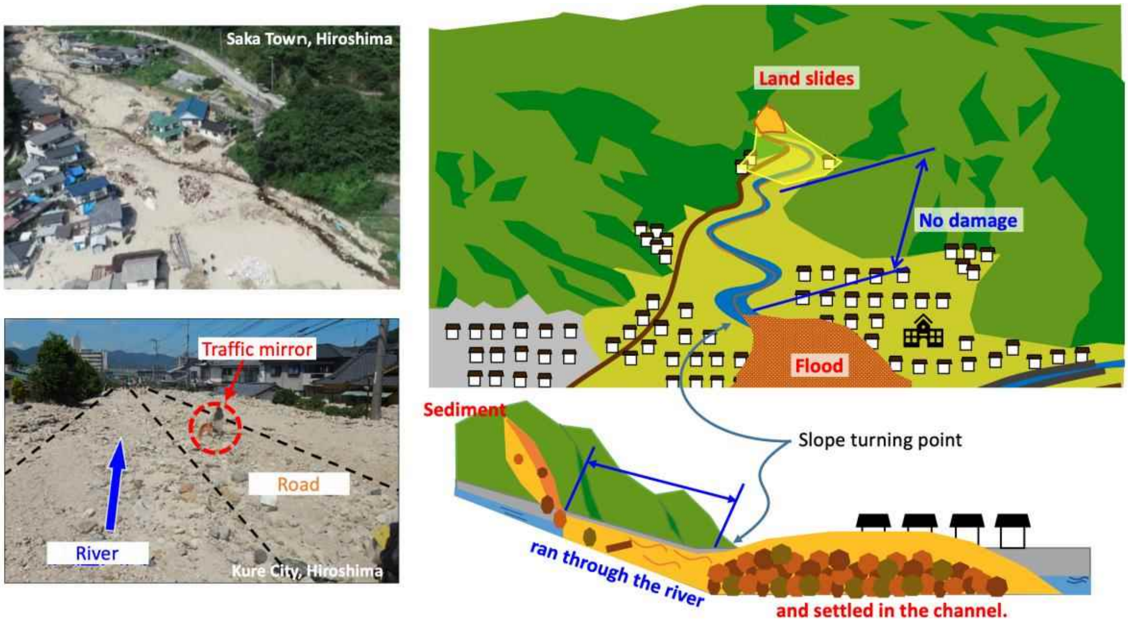

Fig. 2.5 Sediment-water synergistic floods

4) Human loss

Heavy rain in July 2018 affected 232 people who were reported dead or missing. This is the first time a human toll exceeding 200 occurs since 1982. Fatalities and reports of missing people occurred in 14 prefectures, mainly in Okayama, Hiroshima and Ehime Prefectures. Eighty percent of the fatalities (87 of 109 people) in Hiroshima were caught in sediment disasters. Almost all who perished (59 of 61 people) in Okayama from drowning in flood water. Half of the deceased in the Hiroshima sediment disasters and 90% of deaths in the Mabi Town inundation were over 65 years old.

5) Road and rail interruption

Expressways were interrupted by debris flows, bridge collapses and rainfall regulations on 77 sections of 63 routes in numerous areas from Chubu to Kyushu. Railways were stopped by debris flow, rail submersions and bridge collapses on 115 routes of 32 companies. The JR Freight Company suspended 30% of its operations and provided substitute or alternate transportation.

6) Lifeline infrastructure suspension

Lifeline infrastructures of electricity and water-sewage services wes damaged in many areas of Western Japan. Many blackouts occurred in Okayama, Hiroshima and Ehime Prefectures, but electricity was quickly restored in urban areas as of July 13th. Water outages occurred due to debris flows into purification plants and pump stations in Okayama, Hiroshima and Ehime Prefectures. Temporary water purifiers were working for a long time in Kure and Uwajima Cities. Sewage treatment plants were damaged in Okayama and Fukuoka Prefectures. Residents were asked to perform voluntary bans.

7) Stagnation of medical care

Inundations and water outages hit 95 medical centers in Japan. Some of the damage endured until September 13th. Large-scale inundation hit the Mabi Memorial Hospital after 4:00 am on July 7th, and isolated 300 patients and evacuees. Roof leaks and inundations struck 268 nursing homes for the elderly. 657 occupants from 30 homes had to move to alternate facilities or hospitals.

8) Damage on industries

Agricultural damage was estimated to amount to 167.5 billion yen in agriculture, 160.8 billion yen in forestry, 2 billion yen in aquaculture, for a total of 330.3 billion yen. Industrial factories were inundated due to a levee breach in Mihara City, Hiroshima Prefecture and waterlogging occurred in industrial parks in Okayama City, Okayama Prefecture.

9) Disaster garbage

Floods generated a large quantity of disaster garbage. In Okayama, Hiroshima and Ehime Prefectures it amounted to 290 tons in total. Waste treatment plants were damaged directly by floodwaters and also road interruptions and water outages.

10) Search and rescue

The Ministry of Defence performed search and rescue operations with 33,100 self-defense force soldiers, 28 vessels and 38 aircrafts at its peak. The Fire and Disaster Management Agency rescued 397 victims during searches performed by 15,000 firefighters and 271 helicopters in Okayama, Hiroshima, Ehime and Kochi Prefectures.

11) TEC-FORCE

MLIT dispatched the Technical Emergency Control Force (TEC-FORCE) to affected municipalities. The number of MLIT members mobilized amounted to 10,820 man-days in total (as of October 29, 2018) and 607 per a day at a maximum. Pump vehicles conducted 24-hour drainage operations on 1,200 ha of waterlogging over 3 days at Mabi Town in Kurashiuki, Okayama. Road sprinklers and road sweepers performed dust-proofing and water supply to recover primary services for living conditions.Staff members removed sediment, driftwood and garbage on rivers and roads in Kure City, Hiroshima.

2.1.3 Features of the floods

Based on the rainfall background (1) and the damage outline (2) mentioned above, features of the water-related disaster caused by the Heavy Rain of July 2018 can be summarized as follows:

1) Meteorological factors of recent heavy rains

The Heavy Rain that caused water-related disasters in Japan can be sorted into typhoon-type, rainy front-type, rainband-type, among others. The August 2014 Sediment Disaster in Hiroshima and the July 2017 Heavy Rain in Northern Kyushu were caused by linear rainbands settling in relatively narrow areas. The September 2015 Kanto-Tohoku Heavy Rain on Kinu River was induced by linear rainbands boosted by a typhoon and a tropical cyclone. The 2016 Hokkaido-Tohoku Heavy Rain had moving rainbands along the typhoon’s route and intensive rainfall.

The July 2018 Heavy Rain was caused by a lingering rainy front enhanced by rich vapor supply from two high-pressure masses that generated a long-lasting rainfall over a wide-area.Each water-related disaster had different breakout mechanisms due to natural phenomena, with differing impacts on residents. These factors often worked synergistically.

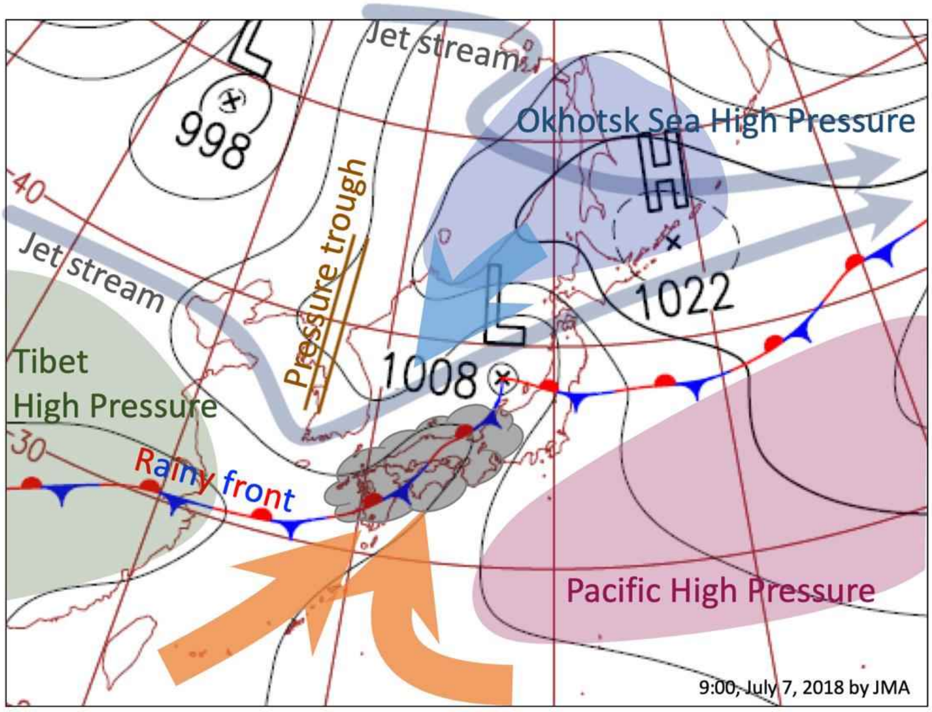

Fig. 2.6 Humid airstream around Western Japan

2) Unprecedented hydrological features in 2018

Average precipitation exceeded the flood discharge simulation scenarios in 8 major river basins of Western Japan, including in Takahashi and Hiji Rivers, however, the peak discharges were less than the discharge estimates. This means the July 2018 Heavy Rain had no intensive peaks as in the case of a typhoon, rather, the record-breaking total precipitation occurred over a long-lasting period. Hence, rainy front-type rainfall occurred in Setouchi region where typhoon-type events were heretofore dominant. This explains why many river floods occurred, not only in small and medium scale river basins but also in major river basins, which had relatively wide catchment areas, and that backwater phenomena caused several levee breaches along the Oda River in Takahashi River basin.

Large amounts of rainfall exceeding sewerage design capacities and long-lasting high-water levels hindered drainage causing waterlogging. Excessive inflows were stored in dam reservoirs, however, 8 dams exhausted the flood control capacity and shifted to emergency discharge operations. Many sediment disasters occurred in the Southern area of Hiroshima Prefecture. With a total 1,242 sediment disasters registered in the prefecture, this is more than their annual occurrences in the whole of Japan. Sediment supply from upstream disasters flowed through the river channel continuously and settled around the slope turning point. The rise in the riverbed downstream caused sediment-water synergistic disasters. Local linear rainbands in long-lasting rainfall episodes created wavy precipitation in each area and produced a couple of water level peak and discharge in each river. Intensive squalls on fully-moistened soil triggered sediment disasters and quick discharge to rivers and dams.

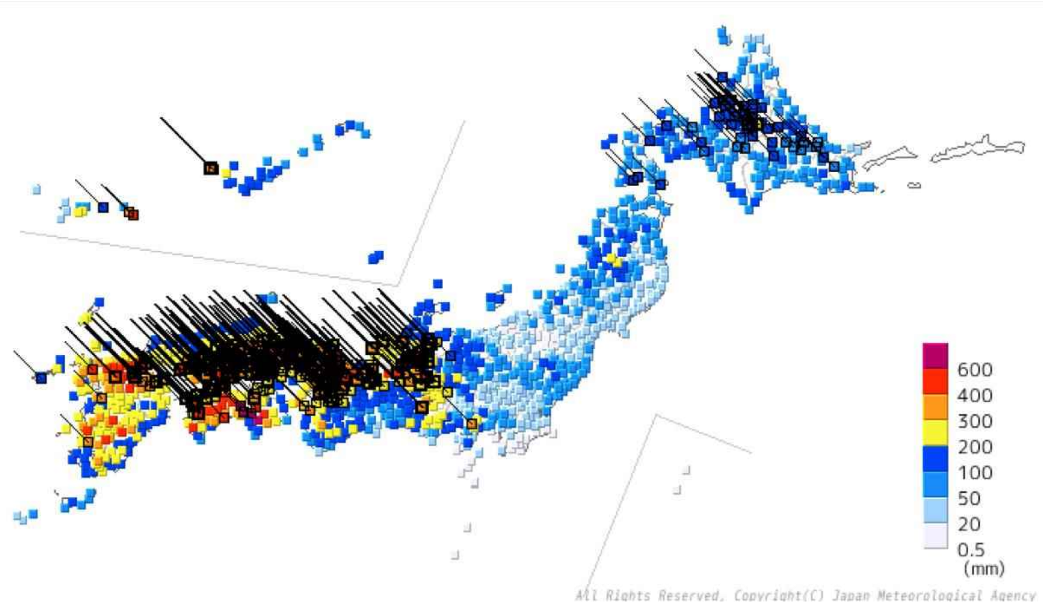

Fig. 2.7 Maximum 48-hour rainfall during June 28 to July 8, 2018

3) Evacuation advisories and resident’s evacuation

Municipalities in MLIT-managed river basins, including the severely affected Oda River, issued evacuation advisories citing maximum probable inundation scenarios, a timeline plans of emergency operations, and hotline to MLIT river offices. However, some municipalities in prefecture-managed river basins hesitated to issue evacuation advisories after acknowledging the dangerous water levels. Also sediment disaster warnings did not help in evacuation advisories.

In the case of Mabi Town of Kurashiuki City, inundation maps and hazard maps almost corresponded to the actual flooding and evacuation advisories that were issued. Some residents testified that they started evacuation just after hearing the advisories at midnight but that roads were so crowded. However, because the rainfall was not so heavy, a number of residents could not decide to evacuate. In the inundation area, due to levee breaching, 44 among the 51 people who drowned were found in their houses. The fact that most of them were on the ground floor suggests that even vertical evacuation was difficult to perform, especially for elderly people.

Ninety percent of human loss due to sediment disasters occurred within sediment disaster warning zones, where early warnings were issued in advance. In the case of Hiroshima City, many people might have decided not to evacuate because they had not received warnings before. Long-lasting but weaker rainfall than the 2014 Sediment Disaster might have enhanced their normalcy bias.

Huge inundations occurred downstream of the dams that had exhausted their flood control capacities. Dam operators delivered operational information to mayors through hotlines and the media, however in many cases, the information without inundation areas did not trigger evacuation of residents. Some victims lost their way to the shelters or got into accidents during the evacuation because evacuation routes were already endangered. In some communities, evacuation routes ran through a sediment disaster-warning zone. In other cases, debris flows hit a housing development from several valleys.

4) Socio-economic losses over wide areas

Damages to emergency operation centers, core medical services, to lifeline infrastructure of electricity and water-sewage services, and to transport infrastructures of rail and roads, disrupted emergency response work and quick recovery. The damages also impacted companies that were not in the affected areas. The impact spread widely to areas that were not themselves inundated, through interrupted supply chain networks and employee absences. Automobile factories in Hiroshima and other enterprises had to stop their manufacturing and service operations. Self-defense force soldiers and fire fighters supported search and rescue operations and the TEC-FORCE members assisted in infrastructure recovery. But widespread damage and interrupted road communications required extended support.

2.1.4 Problems to be solved

The unprecedented disaster left us with unusual problems. These are seeds to build up more resilient societies.

1) Limited capacity of existing infrastructure to cope with large-scale floods

Floods occurred at many sections where channel capacity was limited in both prefecture-managed and MLIT-managed rivers. Dams exceeded the flood control capacity and caused flooding downstream. Some dams, which had limited outflow possibilities due to narrow downstream channels, reached their full capacities earlier. Much rain caused waterlogging and debris flows simultaneously over wide areas.

2) Complex factors of water-related disasters

The backwater phenomena, in which floods in tributary rivers synchronized with the primary river flood caused tributary flooding and waterlogging. Much sediment flowed through rivers from upstream landslides and settled in the downstream channel. The ensuring riverbed rise caused sediment-water synergistic disasters.

3) Climate change impacts relative to water-related disasters

This was a confirmed instance of climate change impact. “Increased water vapor due to global warming” contributed to the July 2018 Heavy Rain episode. Further extreme climate change impacts will make rainfall all the more frequent and violent. Rainy front-type rainfall occurred in the Setouchi region where typhoon-types were heretofore domain. Climate change might alter meteorological factors across regions.

4) Human damage due to overdue evacuations

Even though hazard maps, local risk information and evacuation advisories were provided, many residents could not understand the actual risks nor perceive the immediate threats. They did not decide to evacuate and perished from the water-related disaster, especially so in the case of elderly people. In instances where evacuation routes were dangerous, victims lost their way to the shelters or got into accidents during the evacuation.

5) Miscommunication on infrastructure operational information

Dams, sewerage network, pumping stations and floodgates kept localities safe against heavy rains under a certain threshold. Local residents did not understand the possibility of floods due to heavier rainfall in excess of infrastructure capacity. Lack of information of area-specific risks and of real-time operations made residents unconcerned.

6) Local socio-economic damage

Damage to local emergency operation centers, core medical centers, lifeline infrastructure networks of electricity and water-sewage services, and to rail and road transport infrastructure disturbed the emergency responses and quick recovery process. Long-term business suspensions and population outflows are an ongoing concern.

7) Widely-spread damage

TEC-FORCE members were dispatched from all over Japan but it was insufficient to cope with the overwhelming number of requests due the wide-spread of areas affected. MLIT Regional Bureaus mobilized staff members and materials. But insufficient information hindered resource allocation. Emergency operations faced difficulties in determining the extent of the damage at the initial stage, such as having the appropriate permits to access private properties to clear the garbage.

2.1.5 Key concepts and countermeasures

In order to tackle the problems, structural measures and non-structural measures should be adequately combined to maximize total outcomes. Countermeasures were compiled under 4 key concepts as follows:

- **A) Life-saving measures against hazards that exceed infrastructure capacity**
- **B) Preventive measures to minimize socio-economic losses and launch quick recovery and reconstruction**
- **C) Adaptive measures to more frequent and heavier rains over wider areas, exacerbated by climate change**
- **D) Research and Development**

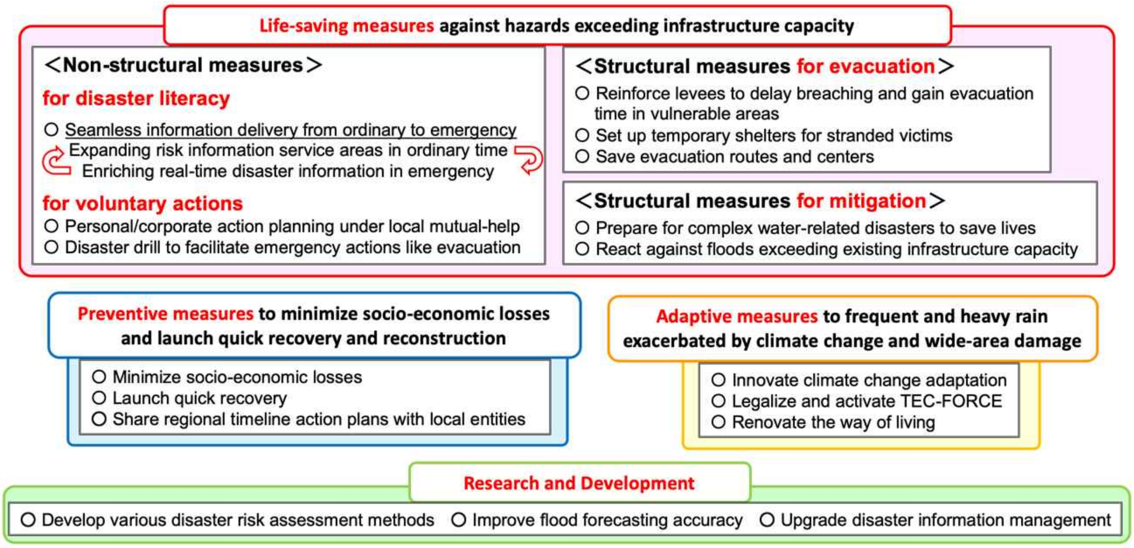

Fig. 2.8 Key concepts and countermeasures

A) Life-saving measures against hazards that exceed infrastructure capacity

1) Seamless information from routine times to emergency

- Emergency warnings with local risk information during routine operations

Disclose area-specific risks such as river water levels to guide evacuations and probable inundated areas on hazard maps during routine time. Deliver real-time river information with local risk information through the media and the internet in times of emergency.

- Visualized information to assist risk perception during emergencies

Deliver water level information with visualized information to assist risk perception through simple and low-cost cameras.

- Timeline plans of disaster operations for evacuation

Enrich timeline plan of disaster operations to clarify time-series disaster operations before and after evacuation advisories to manage locally-specific flash floods, storm surges and sediment disasters, involving dam operators in the Mega-flood Management Committees if necessary. Develop district-level and personal-level timeline plans of operations. Involve the media and ICT companies to enhance emergency communication capacity.

- Risk level indicators standardized and shared among various disasters

Develop a user-oriented website to integrate various types of disaster information of river and slope conditions, weather forecasting and hazard maps. Standardize, summarize and simplify disaster information to facilitate risk comprehension.

- Information delivery through activated media channels

Improve river information delivery systems in active cooperation with the media and ICT companies, and strengthen partnerships with them.

- Capacity disclosure of disaster management infrastructure

Disclose the capacity of reservoirs, sabo weirs and levees and damages due to hazards exceeding infrastructure capacity, to assist in enable risk perception for evacuation. Share dam operation rules with residents in the downstream areas, and deliver operational information during flood control.

2) Risk information sharing without a blind spot

- Probable inundation zoning

Publish probable inundation zones caused by the worst-case rainfall in all legally designated flood-forecasted rivers. Install 3L water level gauges (low-cost, long-life and localized). Boost probable inundation zoning around sewage networks and coastal areas.

- Probable inundation mapping for downstream dams

Simulate and publish probable inundation areas and depth caused by the worst-case rainfall for downstream dams.

- Probable sediment disaster zoning

Prompt prefectures to complete basic surveys and publish probable sediment disaster zones under the Sediment Disaster Management Act.

- Hazard map revision using maximum flood scenario

Enhance professional support to municipalities for revising hazard maps that show the maximum inundation scenario with the worst-case rainfall. Assist public-help for residents with technical and mental challenges for local specific disaster risks. Publish hazard maps revised, probable inundation zones newly estimated and probable sediment disaster zones additionally designated, promptly through the hazard map portal site.

- Hazard map portal site of water-related disasters

Enrich and open data on the hazard map portal site for local residents and companies. For instance, publish probable inundation maps even in small and medium-scale river basins and maps for storm surges and waterlogging. Disclose topographic classification maps to understand disaster risks without inundation maps.

3) Real-time information to encourage evacuation

- Time-series flood risk-line system

Develop and install a system to assess varying flood risks continuously up-down, right-to-left, and hour-by-hour. Improve forecasting accuracy of the peak water level and arrival time to assist risk-based evacuation and advisories.

- Water level monitoring and flood forecasting

Carry out flood forecasting at more rivers, sewage networks and coastal communities for disaster potential. Install 3L water level gauges on small and medium-scale rivers and enrich real-time water level data delivery.

- Flood commentary by river authorities

Explain actual flood management using flood forecasting, water level data and live images from river authorities (MLIT or prefectures) through the local media.

- Dam information delivery for evacuation

Review dam information management, such as releasing discharge and schedule, for local governor's evacuation orders and evacuee's actions. Discuss how to use dam and river information with municipalities, and share it among local communities.

- Supplementary sediment disaster warning

Improve sediment disaster warning to support varying risk perception using time-series risk indicators. Assist in the issuance of evacuation orders by automatic indicators of risk level over criteria.

- Warning system ensured during mega-scale floods

Secure the water-resilience of water level gauges and dam communication systems, even for mega-scale floods to provide essential data for operation and evacuation.

4) Individual disaster response initiatives

- Mutual-help enhancement

Promote neighbourhood-level evacuation planning and foster leaders for local disaster management. Enhance local communications among neighbouring voluntary groups, social welfare councils and flood fighting teams to ensure evacuation of all residents, including the elderly at home and the socially-vulnerable. Promote evacuation planning of nursing homes and keep close ties with the community.

- Personal evacuation planning and risk mapping

Support each community to promote "My Timeline Plans" so individuals can make disaster operation decisions in advance, and "My Evacuation Maps" to reconfirm safe evacuation routes and danger points, keeping adequate exchanges with the district-level disaster management plan.

- Support tools for evacuation planning to support individual proactive evacuation planning, develop area-specific and time-series inundation simulations, which indicate the inundation area and arrival flow times along MLIT-managed rivers and in small and medium-scale river basins, and disseminate it through the internet.

- Human resources development for local resilience

Nominate and dispatch experts in water and sediment disaster management to municipalities to support hazard mapping, disaster operation planning, and participatory evacuation drills.

- Disaster education

Promote disaster education using the numerous lessons learned in recent water-related disasters and through locally-specific disaster histories, using the Mega-flood Management Committees. In particular, transfer basic knowledge to students through natural and social science classes at elementary and junior high schools.

- Evacuation drill with public participation

Conduct evacuation drills with public participation using practical evacuation orders and river/dam information. Share various trials in the Mega-flood Management Committee.

5) Structures for flood risk reduction

- Resistant levee to delay breaching

Develop and build durable levees as infrastructure for crisis management in flood-prone areas to gain a little longer time for vulnerable resident’s evacuation.

- Sabo works to Protect evacuation routes and shelters

Prevent sediment disasters using sabo structures, like weirs, around the one and only route or shelters to enable smooth evacuation. Negotiate to use private buildings as emergency shelters in high inundation risk areas.

6) Life-saving shelters for stranded victims

- Life-saving shelters for emergencies

In areas with no permanent evacuation shelters, reserve life-saving mounds made of disposed soil or private buildings as temporary shelters, through local initiatives.

7) Risk management against complex disasters

- Confluence improvement

Strengthen and heighten levees around confluences where backwater phenomena might breach levees and cause deep inundation. Reinforce levees of tributaries depending on possibility of backwater phenomena.

- Sediment flow management

Build sabo weirs and sediment pools through sound coordinated planning with river improvement, to prevent sediment-water synergistic disasters.

- Channel maintenance

Cut trees and dredge riverbeds to secure channel capacity of narrow sections around probable inundation areas of dense housing and critical institutions.

- Cooperative action against complex disasters

Enhance cooperation among various agencies to implement integrated projects to reduce risks of large-scale water-related disasters, which are caused by simultaneous river flood, debris flow, waterlogging, storm surge and others.

8) Countermeasures against unexpected floods

- Dam upgrading for flood control

To enhance flood control capacity, upgrade existing dams through operational improvement, capacity alteration, discharge capacity enlargement and crest heightening. Adjust spillways and remove sediment from retarding basins. Negotiate with dam users to divert reservoir capacity more for flood control purposes.

- Flood control capacity development

Improve downstream channels to enable increased discharge during flood control operations. Prevent sediment inflow to the reservoir and remove sediments hindering full flood control capacity. Maintain spillways and remove sediment from retarding basins.

- Masonry sabo weirs reinforcement

Reinforce and rehabilitate masonry sabo weirs to secure functions against possible debris flows.

B) Preventive measures to minimize socio-economic losses and launch quick recovery and reconstruction

1) Measures to minimize socio-economic losses

- Resilience of critical infrastructure

Protect lifeline infrastructures for electricity, water-sewer services and transport through sediment control, in cooperation with facility managers. Promote waterproofing of emergency control centers, core medical centers, water supply and sewage networks in cooperation with facility managers who conduct business continuity planning, evacuation drills and facilitation of storage tanks and barrier walls.

- Protection of the urban center and core functions

In urban and rural flood-prone areas, promote basin-wide flood control integrating river improvement, sewage drainage and existing infrastructure maintenance. In coastal areas, build sea levees and storm surge walls through comprehensive planning. In areas below sea level, maintain river and sea levees, and strengthen drainage capacity. In dense asset areas of Tokyo or Osaka, develop life-saving levees in collaboration with private developers. Hasten waterlogging drainage using reserved pumps and pump vehicles from rivers where the water level is not forecasted to rise.

2) Measures to launch quick recovery and reconstruction

- Drainage operation and maintenance

Foster an effective scheme to build and operate drainage facilities to prevent against long-lasting waterlogging around river confluences or in areas below sea level.

- Waterproof drainage facilities

Hold the waterproof function of drainage facilities throughout the inundation, and stock materials for quick recovery from interruption.

- Persistent emergency control centers

Protect the functions and reliability of the emergency control center through power duplication and other measures.

- Preparation for quick recovery and reconstruction

Share damage simulation scenarios from large-scale water-related disasters in the Mega-flood Management Committees and prepare for quick recovery and permanent reconstruction in coordination with all sectors involved.

C) Adaptive measures to more frequent and heavier rains over wider areas, exacerbated by climate change

1) Adaptation to climate change

- Systematic upgrade of safety level

Promote urgently necessary countermeasures against more frequent and violent heavy rain due to climate change, and upgrade safety levels systematically in accordance with aggravating climate change impacts.

- Strategic observation and advanced maintenance

Observe river channel capacity periodically, forecast sedimentation and forestation quantitatively using cross-section surveys and 3-D laser imaging. Refine river management and facility operation with more intensive water level monitoring.

2) Preparation for wide-area and long-lasting heavy rain

- TEC-FORCE legalization and activation

Establish the legal basis for TEC-FORCE in anticipation of wide-area and long-lasting heavy rains, activate it by involving human resources from the private sector and by installing real-time disaster information management.

- Real-time disaster information collection

Install remote measuring instruments, such as unmanned aerial vehicles and laser imaging sensors, to gather information during simultaneous disasters or successive typhoons. Share the information with local governments.

- Timeline plans of emergency operations involving various agencies

To take integrated actions against wide-area water-related disasters, establish a timeline plans of emergency operations to identify time-series countermeasures for each agency involved in the Mega-flood Management Committees. Involve the public transportation sectors, especially in areas below sea level. During disasters, keep mutual communication and information sharing according to the timeline plan.

3) Rethinking the way of living

- On-street disaster risk indicator

Promote on-street hazard signage, such as indication of probable inundation depth, to raise awareness for area-specific risks. Set local risk signboards in sediment disaster risk zones.

- Disaster risk internalization in the societies

Strengthen partnership between disaster management section and urban planning sections to reflect disaster risks to consolidated urbanization and house relocation. Cooperate with the real estate industry and insurance companies to encourage house owners to avoid disaster risks; house renovations can be a good opportunity for this. In sediment disaster risk zones, encourage owners of existing buildings to implement necessary countermeasures such as safety check, reinforcement and relocation.

D) Research and Development

1) Advanced disaster risk assessment

- Changing risk assessment due to climate change

Advance a technical study to reflect on future climate change impacts for infrastructure planning and design, based on past heavy rains and storm surges. For the study, pay close attention on the interactions between flood control, sabo, sewage and coastal management to respond to complex disasters. In particular, estimate rainfall volume quantitatively and accurately in a trend of frequent and violent heavy rain due to climate change, and analyse rainfall patterns in each region according to meteorological factors.

- Breakout mechanism analysis of various water-related disasters

Develop methods of hazard prediction and risk assessment through analysing breakout mechanisms of sediment and flood disasters. Evaluate relative risks in sediment disaster risk zones to save lives.

- Standardized risk assessment method for various disasters

Develop standardized assessment methods of various local disasters in the region for municipalities to promote risk-based town planning, relocation guidance and voluntary disaster preparedness of private companies.

- Socio-economic loss assessment due to heavy rain

Develop quantitative assessment methods of socio-economic losses within and around affected areas to understand total actual damage and prepare for next disasters in coordination with all social sectors.

2) Risk-based disaster prevention and mitigation

- Step-by-step approach to climate change impact

Implement risk management measures one by one to respond to confirmed climate change impacts and adapt to uncertainty in the future.

- Flood forecasting accuracy improvement

Improve flood forecasting accuracy by enriching water level observation and applying radar rainfall forecasting to ensure smooth evacuation and adequate dam operation. Enhance flood forecasting even in small and medium-scale rivers using 3L water level gauges and image analysis technology. For forecasting accuracy improvement, consider required accuracy at the site with a long-term strategy.

- Advanced dam operation using rainfall/inflow forecasting

For further flood control ability, improve accuracy of rainfall/inflow forecasting, and develop forecast-based dam operation methods.

3) Risk information management to support evacuation

- Advanced sediment disaster warning

For accuracy improvement of sediment disaster warning, develop higher-resolution soil-rainfall index, and improve website displays and information delivery methods to assist warning and evacuation. For mayors to issue timely and appropriate evacuation advisories, develop longer-period sediment disaster forecasting and supplementary information such as rainband prediction from radar monitoring data.

- Risk information delivery for evacuation

Develop real-time river information delivery systems to support residents’ voluntary risk perception and mayors’ timely evacuation advisories, using latest CCTV cameras and artificial intelligence technology.

(6) Evidence based policy-making and implementation

Similar to the River Council meetings, MLIT and related ministries conducted emergency inspections of critical infrastructures for disaster risk reduction and public transportation since September. The Cabinet Secretariat finally published the inspection report on November 27. After consideration by the Finance Ministry, the Government of Japan approved a Cabinet Decision on December 14, 2018, named "Three-year Emergency Measures for Disaster Prevention/Mitigation and National Resilience". The decision focused on the maintenance of critical infrastructure to prevent/mitigate natural disasters to sustain the national economy and livelihoods.

+ Critical infrastructure maintenance to prevent/mitigate natural disasters

- Prevent/minimize damage from large-scale flood, sediment, earthquake, tsunami, etc.
- Ensure emergency response capacity for search, rescue and medical care
- Provide disaster information for evacuation

+ Critical infrastructure maintenance to sustain national economy and livelihood

- Preserve energy supply including electricity
- Hold food supply, lifeline infrastructure, supply chain, etc.
- Protect land-sea-and-air transport network
- Provide information and communication services necessary for livelihoods

The Government fixed the period for the emergency measures to 3 years, setting supplemental budget in 2018 and initial budgets for 2019 and 2020. The amount will be 7 Trillion Yen (64 Billion USD), including governmental loans and private financing.

From the heavy rain in the prefectures of Western Japan, MLIT garnered many lessons and solutions, recommended by the River Council. The Government of Japan shared these and established a DRR policy package with a three-year deadline and budget to implement emergency measures throughout Japan. This is a typical "Build Back Better" policy and a systematic scheme of Japan to foster a resilient society.

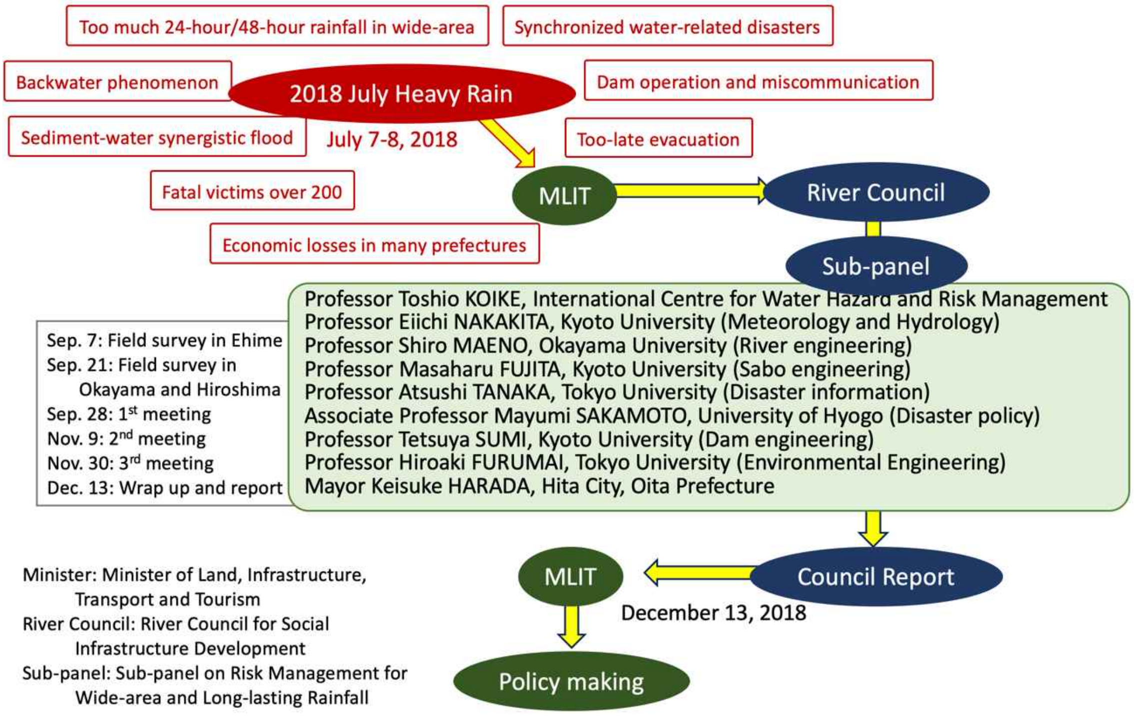

Fig. 2.9 River Council Report and MLIT policy-making

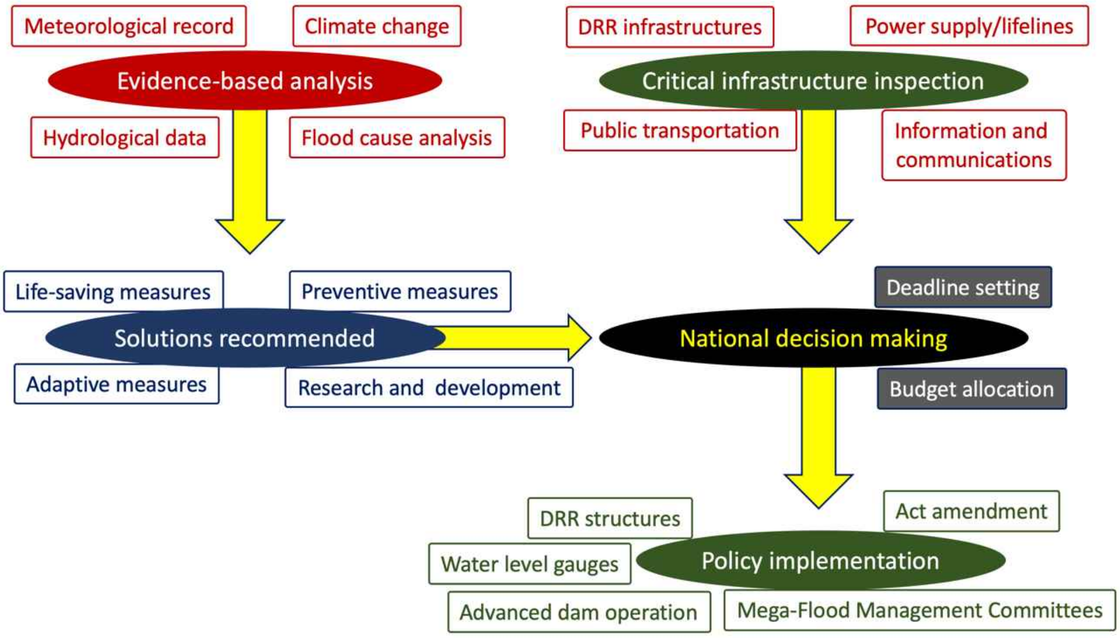

Fig. 2.10 Evidence based policy implementation by the government

3. Mechanism, Trends and DRR Strategy of Heavy Rain Disaster in Western Japan

Toshio Koike

Director, International Centre for Water Hazard and Risk Management (ICHARM),

Public Works Research Institute

3.1 Summary of the heavy rain disaster

Record heavy rainfall hit Hiroshima, Okayama and Ehime prefectures of Japan in July 2018, leaving 232 people either dead or missing. It was the first time since 1982 that a single heavy rain event fatally victimized over 200 people at once. Economic and other activities also sustained severe damage. The Cabinet Office of Japan estimated that the infrastructure damage added up to 0.9 to 1.7 trillion yen (approximately 10 to 20 billion dollars), which is an order of magnitude larger than the amount caused by other recent flood disasters.

The disaster resulted from heavy rainfall that continued for 24 to 72 hours over almost all parts of Western Japan, resulting from the record intense convergence of water vapor that lasted for several days over the region due to the characteristic meandering pattern of the jet stream. Experts pointed out another factor that contributed to the extreme phenomenon: continuous supplies of water vapor into the atmosphere due to higher sea surface temperatures around Japan at that time.

Increased floodwaters induced by the heavy rainfall devastated many parts of Western Japan through various forms of hazards such as, inundation due to levee breaches and overflows, debris flows, mudflows, and urban inundation. Hiroshima, Okayama and Ehime prefectures, where many observation stations recorded 24-to-72 hour rainfall exceeding the 100-year return period, experienced particularly severe damage. In some places, the backwater phenomenon occurred at the confluence of the main and tributary streams; in other places, multiple factors were found to have contributed to unprecedented disasters, in which sediment transported from hills and mountains deposited in rivers, reducing their cross-sectional area and eventually causing floodwaters to overflow. Moreover, with eight dams in the three prefectures filled up to the flood control capacity, the dam operators were forced to trigger the extreme floodwaters procedures to protect the dam structures, which is another aspect of this heavy rain disaster that deserves attention.

3.2 Increasingly intensified water-related disasters

Water-related disasters continue to become more destructive. As the climate continues to change, the frequency and pattern of heavy rainfall changes, which affects the pattern of river-related disasters and create unforeseen disaster incidents. Worse still, as Japan’s population is decreasing and aging rapidly, the society as a whole is losing awareness to risks.

1) **Changing natural hazards**

The Automated Meteorological Data Acquisition System (AMeDAS), a regional meteorological observation system operated by the Meteorological Agency of Japan, started operation in 1974, collecting hourly rainfall data from about 1,300 stations across the country. According to the data collected by AMeDAS, unprecedented heavy rainfall is occurring more frequently throughout the country. The finding stems from an analysis in which a total of 44 observation years were divided into three periods; the yearly number of stations that recorded the highest 24-hour rainfall in history was then counted; and an average number of stations was calculated for each period. As shown in Fig. 3.1, the average was about 20 stations per year in the first two periods, while it is more than 50 in the last period. In the July 2018 heavy rain event, a new record of hourly rainfall was registered at only 14 stations, but 125 stations registered records for 48-hour rainfall, and 123 stations for 72-hour rainfall, which indicates that about 10% of the stations in Japan observed their highest long-term rainfall in history.

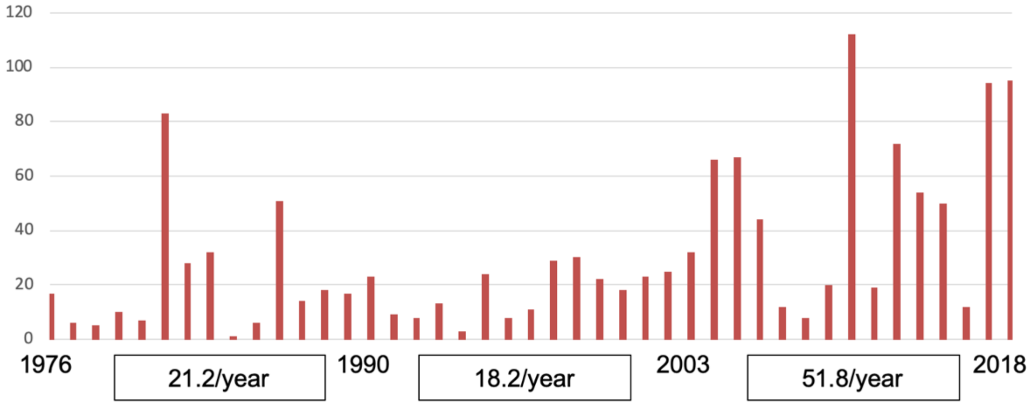

Fig. 3.1 Number of rain gauge stations where the historical maximum 24hrs rainfall were updated per year.

As the pattern (e.g., intensity and frequency) of heavy rain has changed, the patterns of sediment- and water-related disasters have also started changing. In many parts of Hiroshima Prefecture, slope failures and debris flows occurred due to the heavy rainfall. Decomposed granite soil, produced from granodiorite rocks when they are weathered to deep inside of the mountain, played a critical role in this disaster. This type of soil was transported from the mountains to the rivers through slope failures and then in debris flows. After temporarily depositing in and around the river courses, the soil was again transported downstream in floodwaters and filled the narrow, gently-sloped river courses running through the small plains in the valley bottoms. As a result, the flood flow was blocked from running in the river courses and spread over the valley plains, and completely changed the idyllic landscape of the area. This type of disaster became widely recognized by the public as “flooding caused by a combination of sediment and floodwaters”. In fact, a similar disaster had occurred in the Northern Kyushu heavy rain disaster of 2017 and the Pekerebetsu River of Hokkaido when the Hokkaido and Tohoku regions were hit hard by heavy rain in 2016.

Given the same total rainfall, the flood peak is larger when the rainfall duration is shorter and the intensity is greater. Conventionally, short, strong rainfall patterns derived from historical events have been used to define the design flood peak discharge for planning river channels and dam reservoirs. However, the larger rainfall in total led to a larger discharge for a longer period even if the flood peak discharge did not reach the design level, and consequently dams used up the flood control capacity. In addition, consider a case of rivers merging at a confluence. Typically, the flood runoff starts first in tributaries and then moves to the main stream. However, when the discharge in tributaries is still large because of longer heavy rainfall while the flooding is reaching its peak in the main stream, the backwater phenomenon occurs at the confluence. It has been commonly known that a levee breach on one side saves the other, but this conventional wisdom may not necessarily be the case in some cases. Once the backwater phenomenon starts, the water level remains high for a long period even if a levee breaches on one side of the river. Then, the levees weaken as more water permeates into the levee bodies, and eventually the levees breach on both sides of the river. During the July 2018 heavy rain, the area around the Oda River, a tributary of the Takahashi River in Okayama Prefecture, suffered severe damage when this phenomenon occurred concurrently with other factors.

2) An increasingly vulnerable society

In the July 2018 heavy rain disaster, about 60% of the victims were 65 or older. However, in Mabi Town of Kurashiki City, Okayama Prefecture, where the inundation depth reached about five meters, the number for the same age group shot up to nearly 90% as shown in Fig. 3.2. In Japan, demographically speaking, the ratio of the working-age people aged 15 to 64 per one aged 65 and over was 3.9 in 2000 and 2.3 in 2015, and it is estimated to be 1.4 in 2065. Fig. 3.3 shows a downward trend in this ratio and indicates that a smaller percentage of people will be able to help themselves and help others evacuate and take other necessary actions in case of disaster and that a larger percentage of people will need help from others.

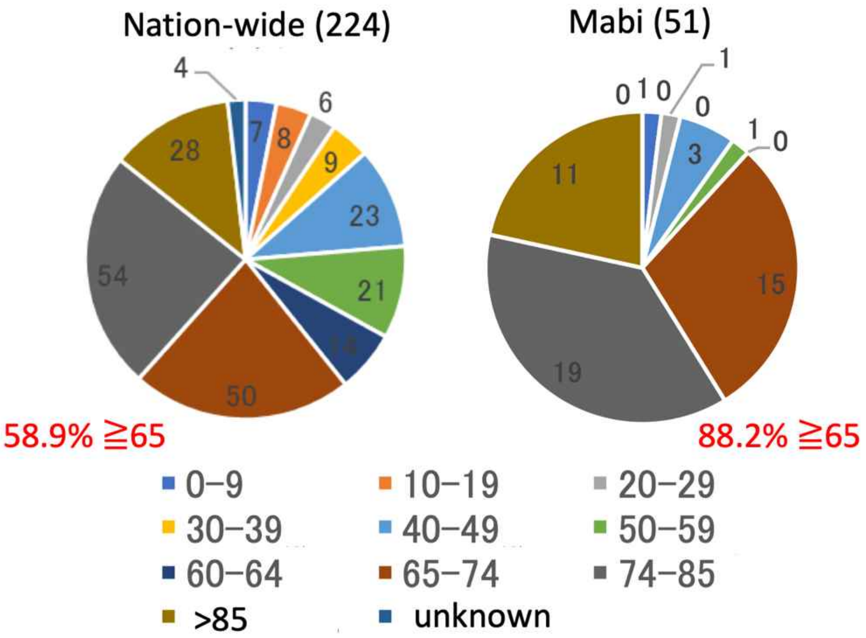

Fig. 3.2 Mortality analysis - the age distribution.

by courtesy Dr. M. Ohara, ICHARM

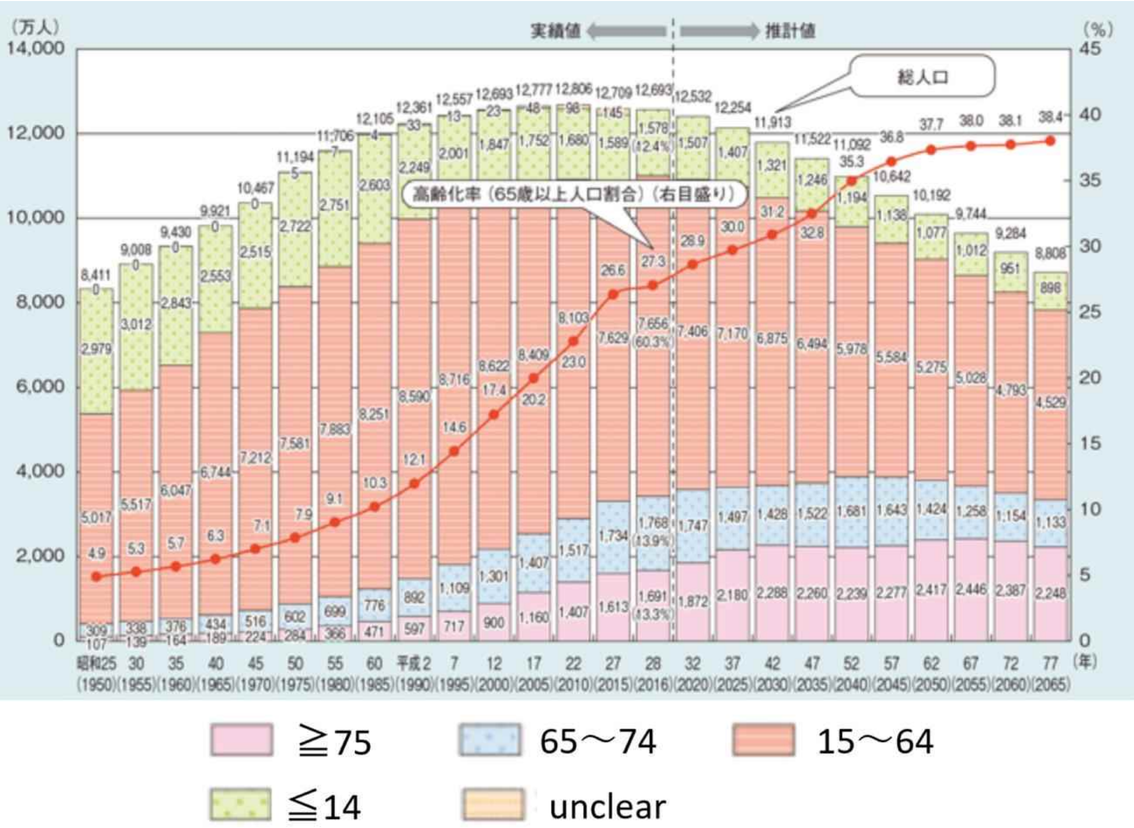

Fig. 3.3 Changing the demographic structure by the Cabinet Office.

Another lesson was learned from the July 2018 heavy rain disaster, which fatally affected the areas around the Takahashi and Oda rivers. The municipal offices in charge of the areas had published a sediment- and flood-hazard map for 100- and 150-year heavy rain events, and the inundation depth during the disaster virtually matched the depth illustrated in the hazard map as shown in Fig. 3.4. Moreover, a questionnaire survey later found that many of the residents in the areas had known about the map before the disaster. However, the survey also revealed that only a quarter of the residents had understood how to utilize the map. These results indicate that being provided with risk information does not necessarily mean that one understands the real purpose of it.

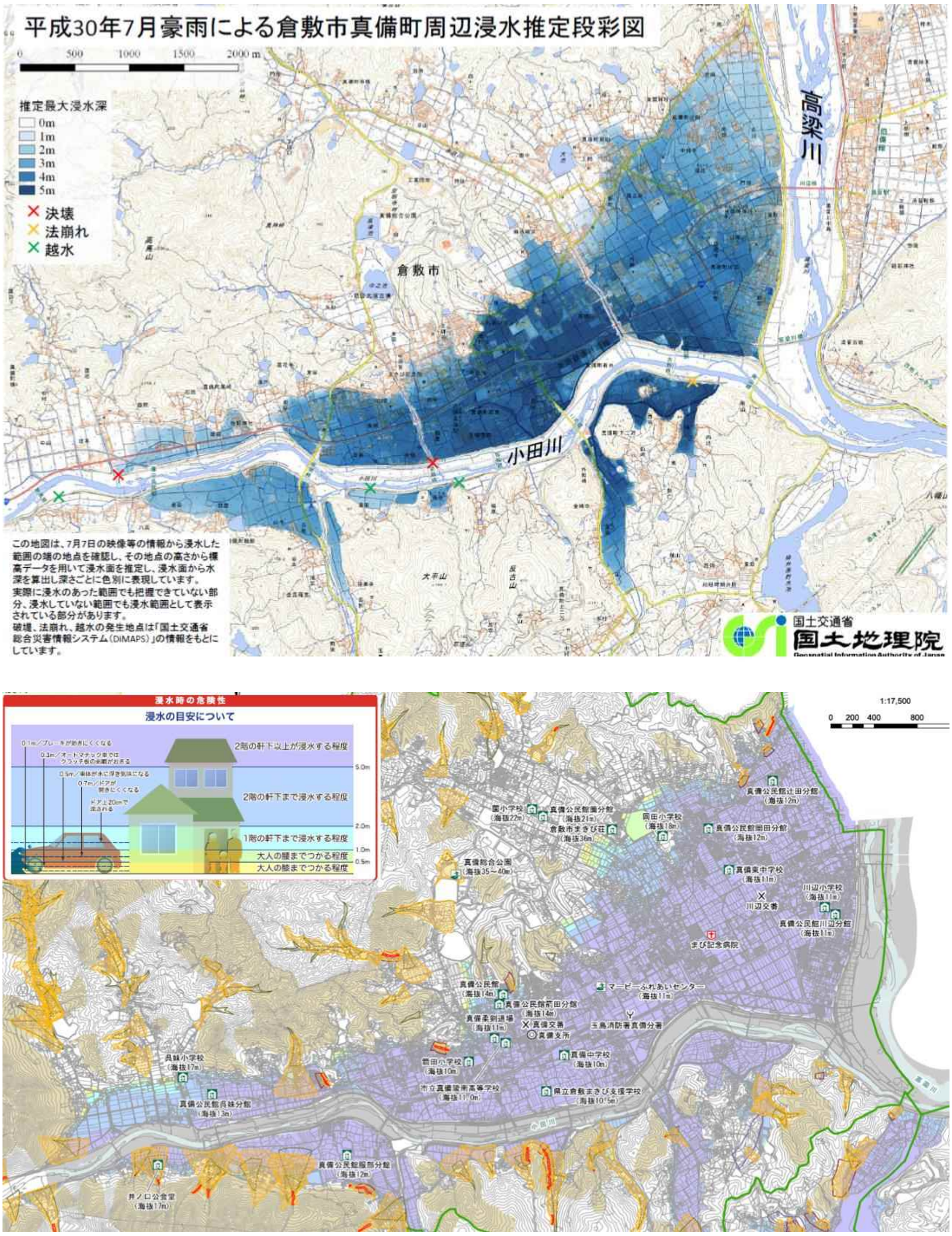

Fig. 3.4 An inundation depth map (Top: Geospatial Information Authority of Japan) and a flood hazard map (Bottom: Kurashiki City Office) of Mabi Town in Okayama Prefecture.

3.3 DRR Strategies

After carefully analysing the characteristics and issues related to the disaster and devising a basic policy for effective disaster management, the Social Infrastructure Development Council submitted a report to the Minister of Land, Infrastructure, Transport and Tourism (MLIT) on December 13, 2018, suggesting a series of actions that should be implemented immediately. The report proposes organizing a system to promote self-help and mutual support in case of disasters, in order to build communities where each member can take appropriate evacuation action independently. To this end, it suggests calling for more cooperation from the private sector such as the mass media and communications companies, increasing the quality and quantity of information on disasters, risks and evacuation, and improving tools and methods for better informing the public. The report also provides advice on social infrastructure planning to prepare for complex disasters and hazards exceeding the design capacity of structures and offers proposals to accelerate post-disaster recovery and reconstruction, and raise public awareness of disaster risks. Overall, it stresses the importance of a “multi-layered” effort in which actions planned from different perspectives are taken for well-defined purposes.

4. Floods in Nigeria in July, 2018

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Summary

This report reflects on critical issues relating to a recent July flood in Nigeria such as causes, impacts and remedies. Flood incidences have become a recurrence decimal, due to a number of possible factors including high frequency and intensity of rainfall, rapid population growth, urbanization, poor urban planning and climate change. Attempts to tackle the hazard in Nigeria appear to be limited by lack of hydrological data and other remote causes which are yet to be identified. In this context, the present report reviews the widespread flood incidences in Nigeria and efforts to tackle them. Continuous extreme rainfall since early in the year reaches its peak in late September, causing severe and extensive floods in 12 out of 36 states in Nigeria. Two major rivers, the Niger River and Benue River overflowed their banks into the surrounding communities resulting in widespread destruction. The Nigerian government had to declare a state of emergencies in nine states. The floods affected about 1.9 million people, destroyed 82,000 houses, displaced 210,000 people and devastated crops and livestock. When the flood waters receded in some communities, many people did not have homes, businesses and farms to return to. Many continue to seek refuge in public schools and other public buildings where living conditions are extremely poor. The fear of public health hazards and outbreak of diseases like malaria, cholera and typhoid was very high as sanitary conditions deteriorated, especially in the temporary shelters provided by Government. It is argued that more robust and scientific approaches to flood risk management such as flood modeling and vulnerability assessment are needed.

Keywords: Flooding; Nigeria; Flood risk; Climate change; Flood modeling; Flood vulnerability assessment

4.1 INTRODUCTION

4.1.1 Background and Context

Flood in Nigeria is considered to be one of the most devastating and frequently occurring natural hazards in the recent times. Impacts of flood disaster on society and its effect on sustainable development have become overwhelming. The increasing climate change, accompanied with excessive rainfalls and its devastating consequences remain indelible in the lives of many people in Nigeria. Over the years and in almost every part of the Country, excessive rainfalls due to climate change have resulted in flooding, which has claimed lives and properties. These unpalatable experiences have placed many Communities, on hold in their struggle for development. As the Country's population increases at an alarming rate with relatively slow infrastructural development. More lives and properties are becoming vulnerable to the risk of flood hazards whenever extreme events occur. These hazard were generally linked to poor urban planning and climate change especially due to increased frequency and intensity of rainfall. The impacts of floods in Nigeria include high mortality, physical injuries, widespread infection and vector-borne diseases, social disorders, homelessness, food insecurity, economic losses (mainly through destruction of farmlands, social and urban infrastructure) and economic disruption (most notably in oil exploration in the Niger delta, traffic congestion in many cities in Nigeria, disruption in telecommunication and power supply)

4.1.2 The Physical Setting

Nigeria is a country in West Africa lying approximately between Latitudes 4° and 14°N and Longitudes 3° and 15°E and bordered by the Republic of Niger to the north, Republics of Benin and Niger to the west, Republic of Cameroon to the east, and the Atlantic Ocean to the south. It has a land mass of 923,769 km^2 that is naturally divided into three regions, the north, west and east, by the valleys of its two principal rivers, the Niger and the Benue. The three regions consist of distinctive relief features including highlands and plateau, uplands and plains, escarpments and valleys, and coastal wetlands and delta (Figure 4.1). Thus, the north has the Jos Plateau located in its eastern central area. It also has the Adamawa Mountains along the eastern border, north of the Benue valley. The west has the uplands and plains studded with inselbergs, while the eastern region has the escarpments and the Eastern Borderlands plateau and highlands (Bamenda Mountains and the Mambilla Plateau). The mountains plateau and highlands are made of igneous and metamorphic rocks. The Eastern Borderlands constitute headwaters for some of the tributaries of River Benue, Lake Chad and River Cross. In western Nigeria, the uplands comprise the Yoruba Hills and Ranges and its extension, the Kukuruku Hills. The ranges and hills constitute a major drainage divide separating the rivers running southwards into the Gulf of Guinea from those running eastwards and northwards into the River Niger. (NIHSA, 2018)

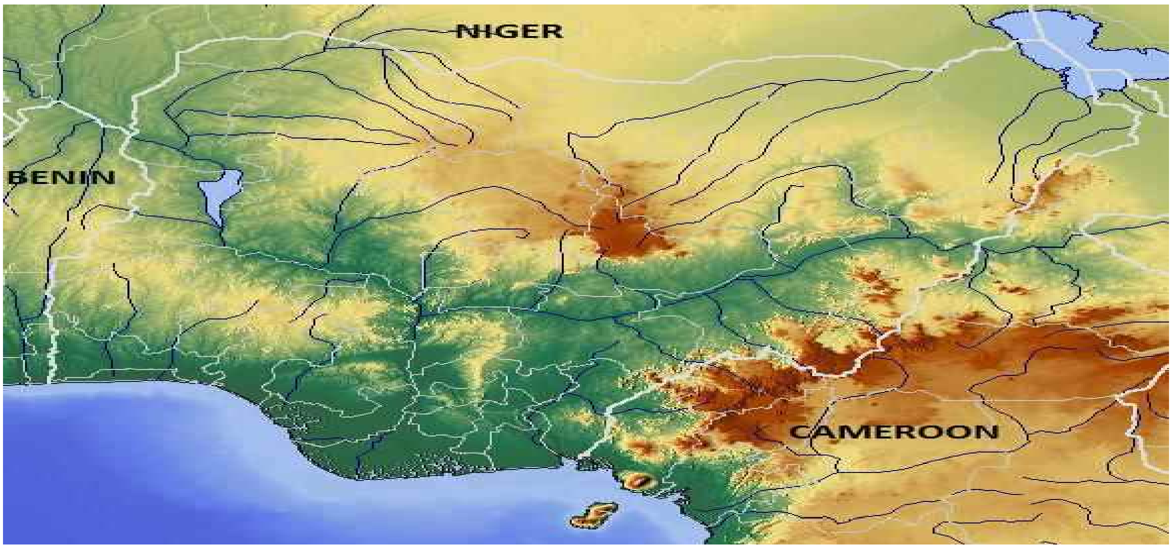


Fig. 4.1 Generalized relief map of Nigeria (Source: Nigeria flood Outlook, 2018)

The coastal zone consists of four contiguous physiographic types, each terminating landward at the southern boundary of the Coastal Plains. These are the Barrier Beach–Lagoon complex, the climate at any location in Nigeria is directly related to the distance from the coast (Figure 4.2), except where coastal upwelling on the one hand, and inland orographic effects on the other, provides counteracting influences. The climate type within 100 km of the coast is the Koppen's A_f humid tropical type with mean rainfall ranging from 1800mm at Lagos in the west, to amounts in excess of 4000 mm in the area proximate to the River Cross estuary (Eket, Akwa Ibom). Landward, at distances exceeding 200 km from the coast in western Nigeria, and 250 km in the east, the Koppen's A_{w1} wet and dry climate type prevails. The rainy season extends from April to October with mean annual rainfall in excess of 1200 mm. Mean annual rainfall in these two climatic zones varies from less than 400 mm in the distal northeast to approximately 1000 mm in the southwest, along the boundary with the Koppen's A_{w1} zone. The length of the rainy season varies from three months in the northeast (July – September) to six months (in the south) (May –October). The dry season lasts variously from October to May, during which, cold and dry Harmattan winds prevail, particularly between November and February. The rainfall and number of rain–days both decrease rapidly northwards.

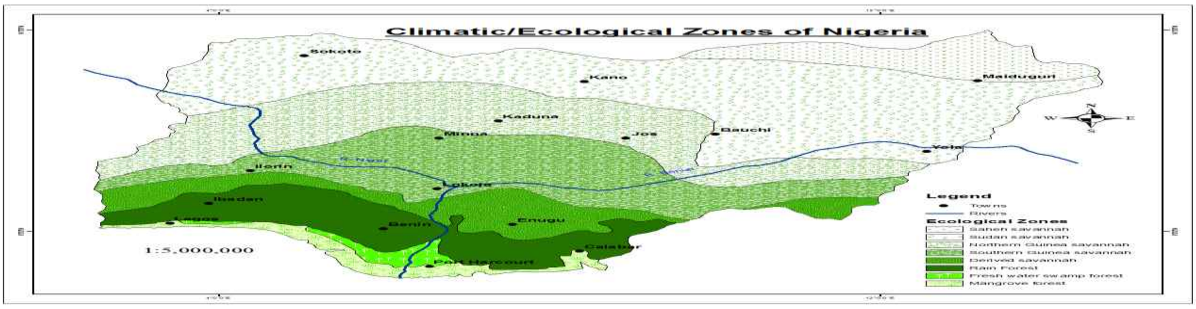
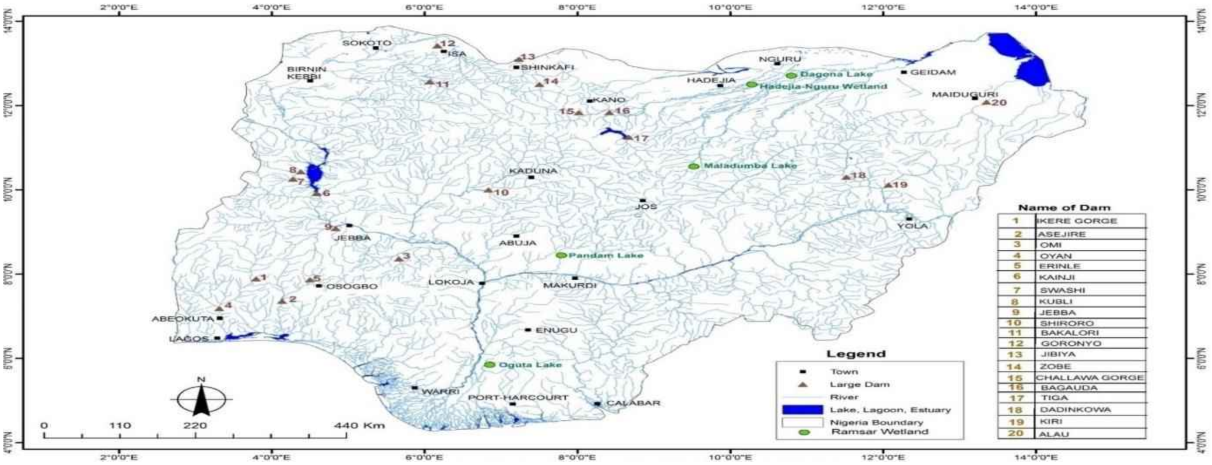


Fig. 4.2 Climatic/Ecological zones of Nigeria (Source: NIHSA, 2018)

4.1.3 The River Systems of Nigeria

The large number of high order rivers and the well–drained nature of the country present a picture of inexhaustible water resources (Figure 4.3). However, the climate over Nigeria imposes a regime on many of the rivers such that there is a rainy season of high water and a dry season of little or no water within the average year. The rivers in Nigeria can be grouped into five drainage systems namely:

- Niger (i.e. the Niger and its tributaries apart from the Benue)
- Benue (the Benue and its tributaries)
- Chad (Lake Chad and all its tributaries)
- Cross River/Imo/Kwa Ibo and all the short rivers draining the eastern littoral zone
- Western littoral rivers (the rivers of western Nigeria that follow more or less regular courses in the N – S direction.



Name of Dam	
1	IKERE GORGE
2	ASEJIRE
3	OMI
4	OYAN
5	ERINLE
6	KAINJI
7	SWASHI
8	KUBLI
9	JEBBA
10	SHIRORO
11	BAKALORI
12	GORONYO
13	JIBIYA
14	ZOBE
15	CHALLAWA GORGE
16	BAGAUDA
17	TIGA
18	DADINKOWA
19	KIRI
20	ALAU

Fig. 4.3 Map of Nigeria Showing Drainage System

The division of these rivers into the five groups is not based on any peculiar characteristic but that of proximity and similarity in the direction of flow. Except for the Chad drainage system, which is an endorheic drainage system, all the other drainage systems ultimately drain into the Gulf of Guinea. The rivers flowing into Lake Chad from Nigeria (mainly River Komadugu–Yobe, River Ngadda and River Yedseram) provide 10% inflows into the lake. The other tributaries of the Lake Chad originate from Cameroon, Chad and Central African Republic (including Chari and Logone), and provide 80% of the inflow, while precipitation provides the remainder 10%.The five river systems have been divided into eight Hydrological or Basin Areas (Figure 4.4 and Table 4.1):

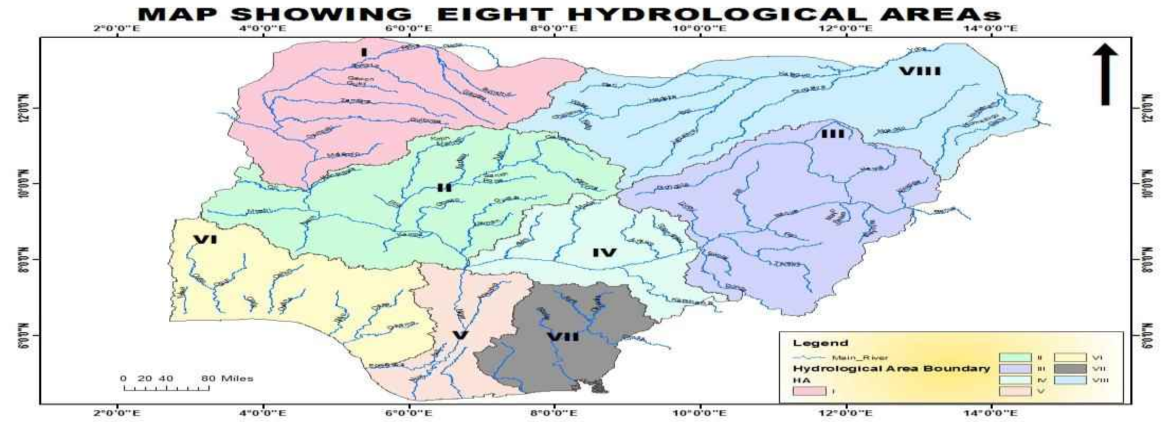


Fig. 4.4 Hydrological or Basin Areas of Nigeria

Table 4.1 The Eight (8) Hydrological Areas

Hydrological Area	Drainage Area (km²)	Description
HA I: Niger North	131600	Consists mainly of the Sokoto–Rima drainage basin and some relatively small drainage basins in the northwestern zone of the country. All the rivers drain directly or otherwise into the River Niger.
HA II: Niger Central	158100	Consists mainly of the Kontagora, Kaduna, Gbako, Gurara, Moshi, Oyi–Kampe and some smaller drainage basins discharging into the middle section of the River Niger (Kainji Dam–Lokoja).
HA III: Upper Benue	158900	Mainly the Gongola, Donga and Taraba drainage basins though it includes numerous but small rivers draining directly into the Benue.
HA IV: Lower Benue	73000	Rivers Mada, Ankwe, Shemankar, Katsina Ala and many others that drain into the Benue from the north and south between the confluence with the Niger and some distance east of Makurdi.
HA V: Niger South	53900	Consists of tributaries such as the Mimi, Orle, and the Anambra discharging into the main trunk of the Niger, and the Ase, Orashi and Sombreiro, which drain into the Upper Niger Delta.
HA VI: West Littoral	100500	All the north–south flowing rivers in the southwestern zone of the country.
HA VII: East Littoral	59800	Consists of the rivers draining eastern Nigeria, including Cross River and River Kwa Ibo, which drain into the Gulf of Guinea.
HA VIII: Lake Chad	188000	Consists of the rivers draining into the Lake Chad. The principal rivers are the Hadejia, Gana-Komadugu–Yobe, Ngadda and Yedseram.

4.1.4 The July 2018 Flood in Nigeria

The widespread flood of July 2018 in Nigeria is widely believed to be due to extreme rainfall event. It affected about, 441,250 people and displaced 141,400 people in Adamawa, Anambra, Bayelsa, Benue, Delta, Edo, Kebbi, Kogi, Kwara, Niger, Rivers, and Taraba states (NEMA 24/09/2018; ERCC; 24/09/2018). By the 24th of September, flood across 12 states and 50 Local Government Areas (LGAs) in central and southern Nigeria had resulted to about 108 deaths and 192 injuries (NEMA 24/09/2018). Across all affected states, there was an urgent need for shelter, with around 13,000 houses damaged (NEMA 24/09/2018). The affected population lost many household and personal belongings. The floods caused considerable damage to agricultural land across Nigeria, with about 122,650 hectares of agricultural land destroyed. In addition to shelter, there was an urgent need for food, non food items (NFIs) and medicine (NEMA 24/09/2018). The flood fatality was widespread and rapidly evolving. Initial assessments indicated that Rivers and Bayelsa States were amongst the most affected states. Water levels continue to rise in Rivers and Bayelsa States. However by the end of October, water levels in the lower Benue River Basin attenuated to about 10m, compared to 11m and 21m in September of the same year. The River Niger at Lokoja city in Kogi State also recorded about 11.05m by 24th of September, but did not recede until the end of October as well. (NEMA 24/09/2018). Light to moderate rainfall however continues until late November of 2018.

4.1.5 Contribution from Transboundary Rivers

The Niger River Basin is a large and highly complex network of rivers, which encompasses nine countries, including Benin, Burkina Faso, Cameroon, Chad, Ivory Coast, Guinea, Mali, Niger, and Nigeria, where the Niger Delta contributes up to 8% of the land area. The flooding was in part attributed to heavy rainfall within neighboring countries of Nigeria, and those that lie within the Niger river basin. '*Niger'* experienced heavy rainfall earlier in the month with several states affected by localized flooding in August and July 2018. Based on the Niamey gauge station (Niger) water levels had increased from 1.47 to 5.38 meters from 28th of June to 15th of August (NBA, 2018). As of mid-August, this rainfall had resulted in 19 deaths and at least 65,000 people affected by the floods. In addition, 7,000 houses, 25,000 livestock and 6,500 hectares of crops were destroyed (NEMA, 2018). The flood coincided with localized rainfall and the antecedent high river discharges of the Niger river.

4.1.6 Impact on Critical Infrastructure

Bridges and roads have been damaged and at least 15 lives lost. Many critical infrastructures have been affected by the flood since the start of the extreme rainy period from July to November 2018. Several township roads of affected States have been flooded and many bridges collapsed (Vanguard, 15/09/2018). Power and telecommunications were affected in some of the flood-affected states. The Okpai Gas Independent Power Plant in Ndokwa East Council of Delta State which supply power to Aso Rock Villa, the seat of Government in Nigeria in Abuja was flooded (The Guardian, 25/09/2018). Also affected by the power cut were Communities in Kdokwa West and Ukwuani councils of Delta States. The Affected infrastructure may be categorized into six as follows:

Shelter: Nigeria Emergency Management Agency (NEMA) reported that the flood displaced around 141,400 people across 12 states, of which 80,600 people are estimated to be living with friends and family (NEMA, 24/09/2018). Over 13,000 houses were partially or totally damaged. Internally displaced persons (IDPs) were relocated to emergency shelters, such as Local Government Area Offices, Schools, Stadiums and Churches. Some other affected population were moved to other IDPs centres that were constructed by the Presidential Committee on Flood Relief and Rehabilitation (NEMA 21/09/2018). The affected population that were in need of urgent shelter and support were provided with relief materials such as blankets, mats, hygiene kits and kitchen sets (IFCR 23/09/2018).

Livelihood: It is estimated that about, 122,650 hectares of agricultural land have been flooded across central and southern Nigeria. Crops were destroyed before the harvesting season begins in October (NYT 17/08/2018). This makes the affected population more vulnerable to food insecurity, and negatively impacts the livelihoods of farmers. Flooding is also likely to affect other livelihoods, such as fishers and petty traders.

Food: Relief materials and food items although in short supply were provided for IDPs across all affected states. Severe flood damage to agricultural crops simply implies fear or significant risk of food security to some communities throughout the harvest season (Daily Trust 20/09/2018). There are still no reports on whether markets that have been flooded have closed. Transportation of food was also severely restricted because; most of the main roads were flooded. Despite the flooded roads most major markets however remain very active for business.

Health: There were reports of an increase in diarrhea cases in four of the flood-affected states (IFCR 23/09/2018). 27,930 cases of suspected cholera were reported between 1st of January and 10th of September nationwide (NCDC 10/09/2018). Between the same period suspected cholera cases were also reported in the flood affected states of Adamawa (2,002), Anambra (23), Kebbi (198), Kogi (102), Niger (547), other affected states without reliable numbers of cholera cases includes, Bayelsa Benue, Delta ,Edo Rivers Kwara and Taraba (NCDC 10/09/2018). In Adamawa, an increase of 119 suspected cholera cases was recorded between 17th -23rd of September, most likely due to sewage leaks into the flood water (Adamawa State Ministry of Health 23/09/2018) The fear of escalation of vector-borne diseases, such as malaria, dengue and-or typhoid fever remains a serious concern even at the end of the flood in December (NEMA, 2018). The Federal Government of Nigeria also confirmed that malaria cases have increased due to the floods (IFCR 23/09/2018).

WASH: Many of the displaced population were moved to emergency shelters, such as LGA offices, stadiums, schools and churches complains of poor or inadequate sanitation facilities. In most of the affected states, water sources have been contaminated by flooding (IFCR, 23/09/2018). There was however insufficient information on the potential amount of broken water points in the affected area.

Education: Many schools that were converted to temporary shelters remain closed after the flood. Primary and secondary schools were closed in Ogbaru, Southern Anambra state as a safety measure, following floods that displaced more than 1,1000 people (OCHA, 24/09/2018).

Insecurity: Whilst there is no reliable information available on the amount of women and girls affected by the floods, it is estimated that the numbers of vulnerable group of Women and Children population are the most affected by insecurity. Women and Girls living in overcrowding IDPs camps were open to violence or abuse. There were lack of privacy and inadequate toilets and washing facilities which further increases their vulnerability to violence, abuse, and sexual exploitation. (UNHCR 12/2017: OCHA 2016).

4.1.7 Historical Flooding and the 2018 July Flood

Historically, flooding in Nigeria dates back to the early 1950’s with coastal and fluvial floods. Such floods which affected mainly coastal environments were influenced by seasonal interruption of major rivers and water overtopping their natural and artificial defences (Akintola, 1994). Fluvial floods account for the majority of the flood threats experienced in locations along the plains adjoining major rivers in the country, including rivers Niger, Benue and Hadejia. The states in Nigeria mostly affected are Adamawa, Kano, Niger, Jigawa, Kaduna, Cross River and Kebbi (NEMA, 2018). The worst fluvial flood in Nigeria was the Kano state flood disaster of 2006 which affected hundreds of thousands of lives with economic loss worth millions of US dollars (Adebayo and Oruonye, 2012). Coastal floods in Nigeria affect the low-lying areas in the southern part.

Devastating flood events was also reported in 1963 in Ibadan city, when Ogunpa River was over-flown causing loss of lives and property; the incidence later reoccurred in 1978, 1980, 2011 and 2012 with estimated damages of worth over ($833 Million) and deaths of over 100 people was recorded,

4.1.8 Comparisons to the July 2012 Flood

The worst but recent of all the flood events that caused a huge devastation across the geopolitical zones in the country was the July, 2012 event. The flood (the worst since 40years), which occurred in at least 34 states out of the 36 states of the country as a result of a heavy rainfalls caused a lot of damages both to lives and properties (UNCHA, 2012). According to EM-DAT: International Disaster Database on Nigeria disaster, in 2012 alone, about 7,000, 867 lives were affected by the widely spread flood while 363 and $500,000 deaths including economic damages respectively were recorded (Okoye, 2015). This was further compounded by heavy rainfall, throughout the month of September causing high volumes of water to be held back in dam reservoirs. At the end of September as these dams were forced to open, the high volume of water could no longer be contained, resulting in extensive floods across floodplains of the Niger and Benue rivers. This resulted in extensive economic losses and damages to properties and infrastructure. For instance, flooding in the Niger Delta disrupted oil production and damaged extensive hectares of crops (NEMA, 2018).

Despite repeated annual occurrence of flood hazards and the huge risks associated with them, it appears not much remediation measures or structures have been put up by various Governments to date to prevent reoccurrence. There is the need to develop effective management and adaptation techniques to flood hazards as well as emergency preparedness for potential future hazards. However, while the current flooding remains very severe, it does not appear as severe as the July 2012 floods in Nigeria, which will continue to linger for long in the memory of many Nigerians for years to come.

4.2 CAUSES OF FLOODING IN NIGERIA

4.2.1 Definition of Flooding

Flooding is the temporary inundation of all or part of the floodplain or temporary localized inundation occurring when surface water runoff moves via surface flow, gutters and sewers (Tokunbo, 2017). It may be referred to as a comparatively high flow of water that overtops the natural or artificial banks in any reach of stream. Flooding is also regarded as an overflow or inundation that comes from a river or other body of water and causes or threatens to damage (Tokunbo, 2017]. Its occurrence is usually due to the increase in volume within a water body which causes it to exceed drainage channel capacity and overflow its bounds. Due to the nature of flood occurrence, full analysis of the effect of a flood requires investigation and correlative research to link physical hazard and socioeconomic impact. The most effective form of evaluating effects of any flood event including most environmental disasters involves the assessment of such impacts within a past, present and future context.

Flood may result from many conditions working singly and in synergy. Natural causes of flooding are generally as a result of heavy rain and downpour. Anthropogenic causes of flooding are enhanced by human activities; that is, flooding in terms of environmental hazard is not totally a physical phenomenon. Floods only become a hazard when they impinge unfavorably upon human activity, mostly due to built-infrastructure along floodplains and coastlines.

Based on this understanding, flood hazards also create socioeconomic phenomena and socio-psychological conditions of stress. Major causes of flooding have been linked to human interaction with the environment (e.g., urbanization and agricultural activity). As urbanization intensifies, natural surfaces are replaced by buildings, paved roads and concrete surfaces, which do not readily allow water to percolate into the ground. The effect is, therefore, a large proportion of rainfall, which normally should infiltrate into soil or be intercepted by vegetation, is immediately converted into surface runoff.

4.2.2 Causes of the July Flood

The encroachment of buildings on floodplains through towns and cities and the depositing of waste materials into the drains were materially responsible for most drains overflow in Nigeria. In combination, poor city planning and management, in addition to natural rain-induced causes, can be detrimental in an urban setting. Six general causes of flooding specific to Nigeria, include: (1) heavy rainfall (i.e., a tropical climate combined with a relating wet season); (2) soil nature (i.e., poor infiltration of rainwater flow and soil percolation); (3) deforestation (i.e., increased forest and vegetation removal, especially within lowlands and valley beds); (4) climate change (i.e., attributed by NEMA, including the worst flood disaster in 2012 and indirect aggravation of flood patterns in flood prone areas; (5) poor waste disposal (i.e., blockage of drainage channels, especially in urban centers); and (6) poor land use policy planning and management (i.e., improper sitting of buildings, structures, road and drainage construction and land use ordering, as well as available control tools to oversee development standards). It is unfortunate Nigerian authorities lack proper planning and coordination when it comes to execution of flood prevention activities.

4.2.3 Impact of Climate Change on Floods

Climate change refers to long term change in climate due to natural variability. A major factor that influences flood is the climatic condition of a particular geographic location manifested in the form of amount, duration and intensity of precipitation (i.e., rainfall). The combination of precipitation and high temperature affect soil moisture content (i.e., percentage saturation), liquid limit and infiltration rates. One of the consequences of climatic variability is when humid environments increase and alter rainfall patterns. There is no doubt the effects of climate change alter the precipitation patterns of distribution, intensity and duration of extreme rainfall events and a higher frequency of strong precipitation. In the case of Nigeria, due to higher temperatures and drought, land has become more susceptible to runoff, intensifying flood events. Changes in rainfall intensity and distribution influence river morphology (i.e., erosion of banks and fast sedimentation in riverbeds) introducing augmented dynamic flood shift patterns.

4.2.4 Urbanization and Floods

A significant numbers of researches over the past two decades have shown a strong relationship between urban areas and local micro-climate. The “urban heat island” (UHI) effect is now well-established, whereby urban areas have higher temperatures than surrounding regions. In many cases, UHI increases rainfall in the vicinity of cities. A number of studies have found an increase in rainfall in regions downwind of urban areas, with some cases recording increases as high as 25%. In urbanized areas, a huge amount of anthropogenic waste heat is emitted due to human activities; the increase of energy consumption may be responsible for environmental problems and temperature rise in the urban atmosphere. Hence even without long term climatic changes, urban extreme rainfall intensities may be increasing with severe impacts on society at large.

In Nigeria, the rehabilitation of drainage system, rivers channels and sewers lags far behind municipal development. Consequently, the existing drainage capacities are insufficient in draining runoff discharge thereby increasing flood risk. Moreover, there is a lack of adequate infrastructural provision, especially within Edo State. Over the last decade, Benin City and other parts of Edo State have witnessed rapid territorial expansion, in which successive administrations until recently have failed to match population growth with infrastructural development, particularly in the expansion of its drainage network. Currently, with an annual urbanization rate of 5.5%, the highest in the world, Nigerian cities face numerous problems, including: deterioration of the environment, urban decay, un-cleared refuse, flooding, erosion and pollution. At present, it is feasible to acknowledge that the primary causes of urban flooding and gully erosion are multifarious and complex.

4.2.5 Frequency of Flood Occurrences

It is on records that at least flooding occurs frequently along the Niger and Benue Rivers every year, the large population situated along the river is at high risk. In addition to the high rainfall, poor urban planning, inadequate drainage systems and the lack of advance technologies to monitor and mitigate flood are common reasons cited for flooding in African cities (World Bank Group). The urbanized cities were developed rapidly, with the loss of natural soils as land areas were replaced by roads and buildings. Unregulated housing in flood prone areas has significantly contributed to the flood risk (World Bank Group).

4.2.6 The Most Critically Affected Area

The torrential rainfall that triggered floods, in western Nigeria started in mid-July. The runoff causes infrastructural damages and several fatalities in the States of Ogun and Katsina. (FEWS NET, 26 Jul 2018) It was also reported that about 622 individuals were displaced from their homes in Sonbon geri ward of Song LGA in Adamawa state due to heavy rains and flooding in the region between 15 and 18 August 2018. Majority of the affected persons were displaced to neighbouring wards in Song LGA, including Song Waje (438 individuals) and Zumo (165 individuals) wards, while 19 individuals were displaced to Manjekin ward of Maiha LGA. (IOM, 27 Aug 2018) At Enugu city (southeast Nigeria), heavy rainfall contributed to flash flooding and casualties over the past week, where 70 mm of rain was recorded over 24 hours between 1st and 2nd of September. According to media reports, about 21death was recorded by 3rd of September and about 15 in Niger State, three in Kano State and three more in Nasarawa State. (ECHO, 3 Sep 2018)

By 17th of September 2018, the Federal Government of Nigeria had to declare the flood a National Disaster in the worst four affected States of Anambra, Delta, Kogi and Niger. About 327,052 people were officially recorded in the worst affected States. The National and Territorial Emergency Operating Centers (EOCs) were later activated to facilitate emergency response in the States and to collect information on critical gaps and needs. (Gov't, 21 Sep 2018)

The authorities in the Southern Anambra state on the 18th of September ordered the closure of all primary and secondary schools in Ogbaru locality as part of safety measures following heavy floods that have displaced more than 1,100 people in the state. The National Emergency Management Agency [(NEMA)] on 17th of September declared national disaster in Anambra and three other states due to extensive floods. Following the declaration of national disaster, the International Humanitarian Agencies brought relief materials to support Government efforts. (OCHA, 24 Sep 2018)

By the end of August, the total number of causalities had risen to about 826,000 people in the 12 states, (NEMA, 26th Sep.2018) of this number, it is on reliable record that about 321 roads and bridges were destroyed, about 176,000 people displaced and 199 lives lost to this flood, with more than 150,000 hectares of farmland inundated.

In a later report the Government of Nigeria further announced that about 200 people have died, and 1,310 injured, with an estimated figures of about two million people directly affected by the flood. The floods also left more than 561,000 people internally displaced and over 350,000 of them were critically in need of temporary shelter, food, safe drinking water, household items and health care. In the most affected areas, children were not able to go to school for weeks. (OCHA, 11 Oct 2018)

By 11th of October NEMA extended the state of national disaster to five more states which includes Adamawa, Taraba, Bayelsa, Kebbi and Rivers. Further account of the floods recorded about 200 lives and more than 600,000 displaced which brought the number of displaced people in the IDPs camps to 210,000 and 391,000 are reported to be scouting within host communities). (OCHA, 22 Oct 2018)

The Governor of Katsina State, Aminu Bello Masari, also confirmed the loss of life of about 48 people from Jibia local government area of Katsina State with about twenty missing people. The Governor was quoted to have said "This is the worst natural disaster I have ever witnessed in my life. I believe this is the worst ever seen in the state," "The devastation caused by the heavy rains at Kukan Danmaciji of Jibia LGA was indeed enormous, overwhelming and heartbreaking. The Governor further prayed for the repose of the departed souls and promised to do its able best to alleviate the sufferings caused by the losses." The governor also visited the affected areas where he directed the State Ministry of Environment to divert the storm water into a wider drainage away from the inundated communities.

4.2.7 National and Local Response Capacity – the Institutional Approach

Institutional approach towards addressing the threats of flooding in Nigeria dates back to the early 1960's with the establishment of Federal and State Ministries of Works. However, the increasing frequency and severity of floods across the country prompted the establishing of the Federal Environmental Protection Agency (FEPA) as a unit in the Federal Ministry of Works and Housing in 1988 and the Federal Ministry of Environment (FME) in 1999. Among other things, the key roles of FME towards flooding risk reduction in Nigeria is to assess the flooding potentials as well as design, determine, develop and/ or authorize the development of appropriate flood reduction measures for the country.

In addition to the establishment of FME, there exist other various Ministries and Agencies created to tackle flooding in Nigeria which includes: Federal Emergency Management Agency (FEMA), National Emergency Management Agency (NEMA), State Emergency Management Agency (SEMA), Local Emergency Management Agency (LEMA), National Orientation Agency (NOA), National Commission for Refugees (NCR), National Environmental Standards and Regulations Enforcement Agency (NESREA). Others are Nigerian Meteorological Agency (NIMET), Nigeria Hydrological Services Agency (NIHSA), NEST (Nigeria Environmental Study/Action Team) and Building Nigeria's Response to Climate Change (BNRCC).

NEMA is basically a coordinating body for disaster management in Nigeria. Actions towards addressing the threats of flooding which the agency coordinates include but not limited to policy formulation, leasing with and assessing the state of preparedness of all other relevant agencies, data collation from relevant agencies, education of the general public on flooding and interaction with SEMA towards the distribution of relief materials to disaster victims within states and local government areas. Recently, a memorandum of understanding was signed with NESREA and NOA to intensify efforts towards flood risk management in Nigeria.

4.2.8 The National Emergency Management Agency (NEMA)

The National Emergency Management Agency (NEMA) is the coordinating agency for emergency management in Nigeria. The agency regularly organizes coordination meetings to oversee initial assessment and response.

4.2.9 The Nigeria Security and Civil Defense Corps (NSCDC)

The Nigeria Security and Civil Defense Corps (NSCDC) responded to July flood by deploying officers in its Disaster Department Management to flood-affected areas, including Kogi, Niger, Delta and Anambra states (Ripples Nigeria 19/09/2018). The Nigerian Army Emergency Response Team also provide necessary support to address the needs of the affected population in flood-affected areas, (Vanguard 19/09/2018). The army also supported the government with technical assistance including the deployment of helicopters. The Nigerian army at IDP camps provided security support (Vanguardngr 19/09/2018). The Vice President of Nigeria, Yemi Osinbajo, stated during his visit to an IDP camp on 24 September in Korton Karfe, Kogi State that the Federal Government intends to provide livelihood assistance to those who lost their farmland and their homes, once the flood recedes. Promises were also made that the Federal and State Government will provide medical support (NaijaNews 25/09/2018).

4.2.10 The International Red Cross Society,

The National Red Crescent Society, in coordination with the ICRC and IFRC provided lifesaving support to 50,000 households in Kogi, Niger, Anambra and Delta states. Local and international humanitarian organizations were all visibly active in their response. (IFRC 23/09/2018; the Nation 20/09/2018). The Copernicus Emergency Management Service (EMSR315) was activated for the Nigeria floods (DG ECHO 21/09/2018). UN agencies, NGOs and the International Federation of Red Cross and Red Crescent Societies (IFRC) supported NEMA, through the provision of technical support and/or assistance to the affected population across the Country.

4.2.11 National Environmental Standards and Regulations Enforcement Agency (NESREA)

NESREA is the agency which enforces all environmental laws, guidelines, policies, standards and regulations in Nigeria, as well as enforcing compliance with provisions of international agreements, protocols, conventions and treaties on the environment to which Nigeria is a signatory, Whilst the provision of humanitarian needs such as shelter, clothing and floods for internally displaced persons is anchored by NEMA, the importance of local communities being aware of flooding and actively participating in discussions and decisions which might increase their resilience and adaptability to the hazard highlights in the roles of NOA, which re-orientates and keeps Nigerians informed about ways of taking part in issue that affects them. The poor perception of flooding in the country should be the concern of this agency.

NIHSA provides reliable and high quality hydrological and hydrogeological data on a continuous basis for the for the purposes of assessing the status and trends of the nation’s water resources including its location in time and space, extent, dependability, quality and the possibilities of its utilization and control. Since 2013, the Agency has been creating awareness of flooding through the “flood outlook” initiative. Other activities of NIHSA include; provision professional advice to various levels of government in Nigeria on all aspects of hydrology, collaborates with NIMET to issue flood forecast and contributes towards creating awareness of flooding among local communities. NIMET furnishes the country with weather report, and other meteorological information, issues alerts and early warning and forecast on impending flood disasters within the country.

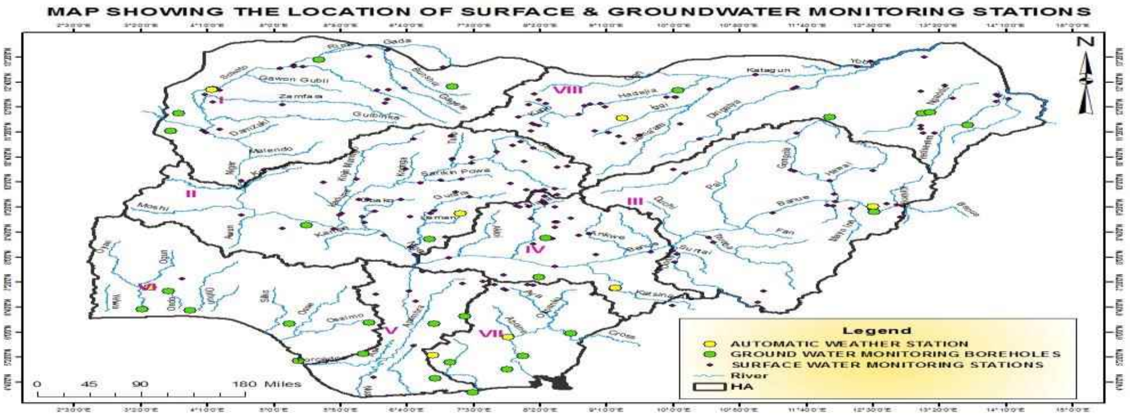


Fig. 4.5 Map showing Network of Groundwater and Weather Stations (NFO,2018)

4.2.12 Federal Emergency Management Agency (FEMA)

Issues relating to flood insurance are coordinated by FEMA, the agency mandates is to makes federally funded insurance protection policy available for property owners in Nigeria. Policies relating to assisting flood victim at state and local government levels are coordinated by SEMA and LEMA. As climate change is complicit with other factors that influence flooding in Nigeria, BNRCC's key role is to collaborate with other agencies to promote the capacities of the generality of human populations within the country to cope with the effects of climate change. NEST is responsible for research development to advance the cause of flood detention and prevention in Nigeria.

4.3 FLOOD DISASTER RESPONSE BY LOCAL COMMUNITIES AND THE PUBLIC

The peculiar attitude of Nigerians towards issues like natural disaster is to find a possible natural means to adapt. Although such attitude has cost many lives and properties, however, it is nevertheless a significant benefit to Nigerians and has severally worked in their favour during emergency situations. Families in Nigeria sometimes co-habit and this offers a comparative advantage in the event of flood disasters. In many flooding incidences in Nigerian cities, the general public often offered assistance to victims, assisted in evacuation of those displaced and in protecting property from further damage. Many IDPs easily find shelter and other humanitarian needs from families and friends while awaiting intervention by authorities. Even though, anti-social behavior, such as looting and sexual harassment of some of the internally displaced victims often occurred.

4.3.1 Humanitarian response to flooding in Nigeria

Almost in all cases of flood incidence in Nigeria, many victims have received humanitarian supports notably from the following humanitarian Agencies such as, the International Federation of Red Cross (IFRC), United Nations, World Bank, Foreign countries including UK, the United States, China, Japan, France as well as religious organizations including the Catholic, Anglican and Pentecostal churches and missionary societies.. Considerable attention has been given to flooding in Nigeria through research and scientific studies. However, the need for science and technology to embrace environmental education in Nigeria has been identified With regards to facilitating the evacuation of victims affected by floods and providing them with urgent humanitarian needs, the level of dissatisfaction and agitations from large numbers of the flood victims, especially the IDPs, queries the effectiveness of these measures.

4.3.2 Action by research and media institutions

Most of what is known about flooding in Nigeria today can be attributed to efforts by research and media institutions. In the literature, undoubtedly, considerable attention has been given to flooding in Nigeria. Presently there are more than five hundred publications indexed in the Google scholar that relates to flooding and means of tackling it in Nigeria. In addition, the country has a number of countrywide research-based groups such as the NEST (Nigeria Environmental Study/Action Team), BNRCC (Building Nigeria's Response to Climate Change) and university-based research groups that focus on flooding within Nigeria. Similarly, the Nigerian media has been given the credit of providing qualitative information regarding the widespread flooding in Nigeria.

4.4. THE 2018 ANNUAL FLOOD OUTLOOK (AFO) REVIEW

4.4.1 Flood Prediction

The Nigeria Hydrological Services Agency (NIHSA), a parastatal of the Federal Ministry of Water Resources, is saddled with the responsibility amongst others to advice the Federal and States Governments on all aspects of hydrology. One of the key mandates of NIHSA is to work with the meteorological services and other relevant stakeholders, to issue flood forecasts for the Country. NIHSA achieves this by the production of the Annual Flood Outlook (AFO). This national forecast was initiated in 2013 after the benchmark 2012 floods and the 2018 edition is the sixth in the series.

NIHSA in fulfillment of its mandate over the past years has steadily improved on the quality and quantity of data as well as the models used in generating the AFO's. This has greatly impacted on the accuracy of the flood forecast and its adoption by the public. Consequently, this has led to a reduction in the harmful effects of flood on the communities that have heeded the warnings and carried out remediation actions contained in the AFO's issued in the past.

The 2018 Annual Flood Outlook was derived from the application of two reliable models, viz;
Geospatial StreamFlow model (GeoSFM) and the Soil and Water Assessment Tool (SWAT). These models utilized hydrological and hydrogeological data, disaggregated Seasonal Rainfall Prediction (SRP), satellite rainfall data, Digital Elevation Models (DEM), topographical and soil/water index balance data amongst others. The Geospatial Stream Flow Model, developed by the United States Geological Survey (USGS) provides an analytical tool for monitoring wide area hydrologic events. The Model is used to identify and map the status of stream flow and soil water condition. On the other hand, the SWAT Model is a river-basin model developed by Texas Water Resources Institute, Texas A&M University System. The Model is developed to quantify the impact of land management practices in large, complex watersheds. It is a physically-based, semi–distributed and continuous simulation model operated with Geographic Information System (GIS) interface.

The 2018 AFO which is similar to earlier edition contains useful information on the areas that are likely to be flooded and the severity of the expected flood. It also issues professional advice on measures to be taken before, during and after flood. The flood Outlook also serves as an important guide in reducing flood risks and vulnerabilities.

In other to accurately predict the 2018 AFO, flows were simulated from 1981 – 2017 period at 0.05° resolution and the predicted 2018 rainfall from NiMet. The GeoSFM model was calibrated at each Hydrological Area (HA) based on discharge record at stations within the respective HAs. The probable flood zones were determined based on statistical analysis of the simulated flows and Digital Elevation Model (DEM) using GIS package. The impact of transboundary inflow to HA I and HA III were assessed based on 50th and 90th percentile of historical inflow. The 50th percentile being the mean inflow while 90th percentile the extreme inflow scenarios.

4.4.2 Highlights of 2018 Annual Flood Outlook (AFO)

The eight hydrological areas and their well–defined hydrogeological features which have been articulated in the flood prediction are discussed below.

Hydrological Area I (Niger North)

Hydrological Area I comprises of Sokoto, Zamfara, Kebbi, and parts of Katsina and Niger States and is drained mainly by the Rivers Niger, Sokoto and Rima. It has two distinct geological features, mainly the Precambrian Crystalline Basement which covers 30% of the area and Sedimentary terrain which covers 70%.

The Highly Probable and Probable flood risk areas in Hydrological Area I are shown in Tables 4.2 and 4.3 as well as Figure 4.6:

Table 4.2 Highly Probable Flood Risk LGAs in HA I

S/N	State	LGAs
1	Niger	Borgu
2	Kebbi	Argungu, Augie, Suru, Bagudo, Ngaski
4	Sokoto	Sabon Birni, Isa, Gudu, Wamakko

Table 4.3 Probable Flood Risk LGAs in HA I

S/N	State	LGAs
1	Niger	Agwara, Borgu, Magama
2	Kebbi	Argungu, Augie, Bagudo, Birnin–Kebbi, Bunza, Dandi, Kalgo, Koko–Besse, Ngaski, Shanga, Suru, Yauri
3	Zamfara	Bakura, Bungudu, Maradun, Shinkafi, Zurmi, Kaura–Namoda
4	Sokoto	Bodinga, Dange–Shuni, Goronyo, Isa, Kware, Rabah, Sabon–Birni, Silame, Tambawal, Wurno, Yabo, Wamakko

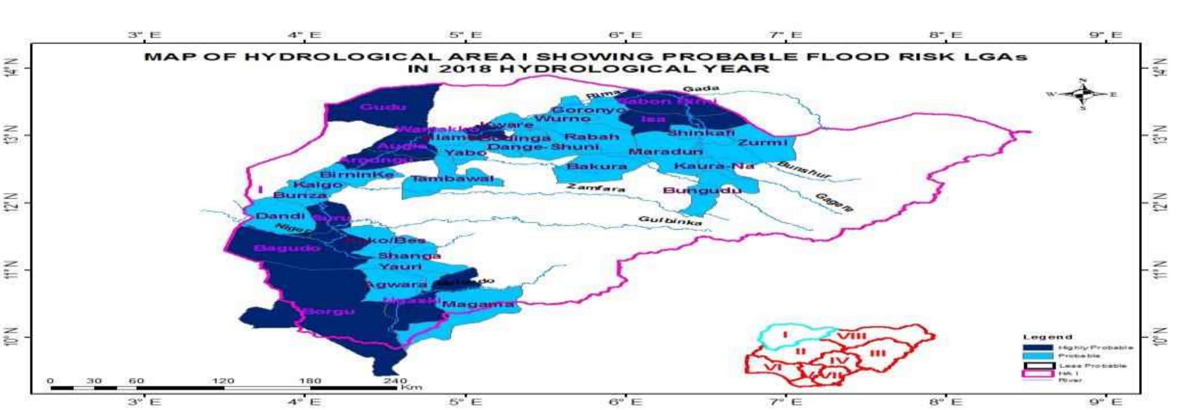


Fig. 4.6 Probable Flood Risk LGAs in HA I

Hydrological Area II (Niger Central)

Hydrological Area II covers Niger, Kwara, Kaduna, Kogi States and the FCT. The geology of the Hydrological area comprises of about 20% Sedimentary rocks and 80% Basement complex rocks. The main rivers in the area are: Niger, Kaduna, Gurara, Usuma, Kampe and Awun.

The Highly Probable and Probable flood risk areas in Hydrological Area II are shown in Tables 4.4 and 4.5 as well as Figure 4.7:

Table 4.4 Highly Probable Flood Risk LGAs in HA II

S/N	State	LGAs
1	Niger	Rafi, Lavun, Wushishi
2	Kaduna	Igabi, Soba, Kaduna South
3	Kwara	Ifelodun, Ilorin East
4	Kogi	Koton–karfe
5	FCT	Kwali

Table 4.5 Probable Flood Risk LGAs in HA II

S/N	State	LGAs
1	Niger	Bosso, Chanchaga, Edati, Gbako, Mashegu, Mokwa, Shiroro, Wushishi
2	Kwara	Asa, Edu, Ilorin West, Oyun, Pategi
3	Kogi	Lokoja
4	FCT	Abaji
5	Kaduna	Kaduna North, Kaduna South
6	Plateau	Jos South

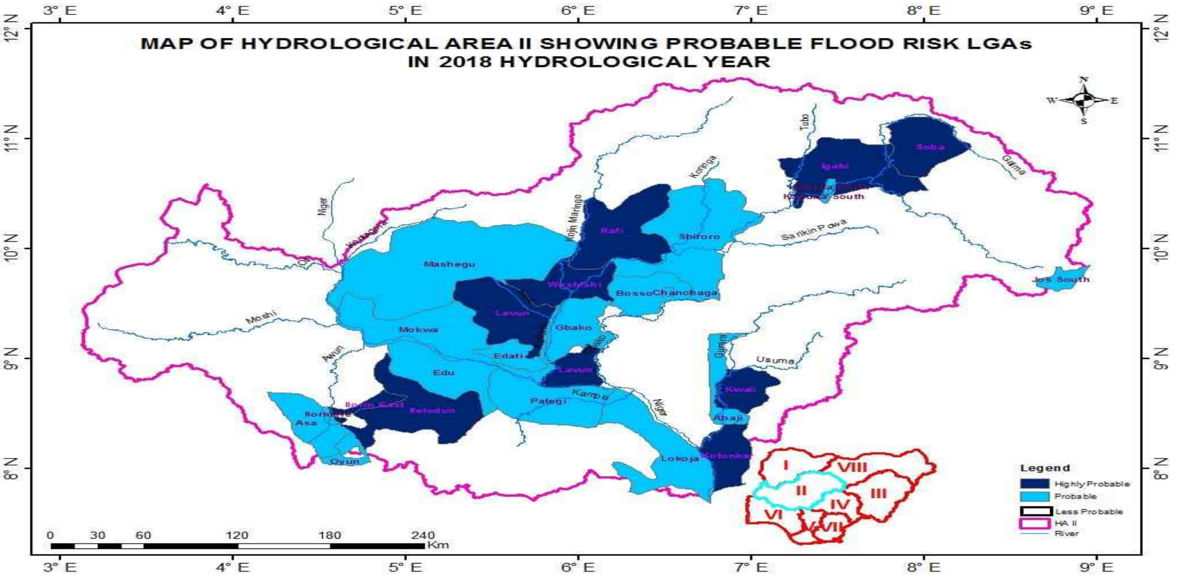


Fig. 4.7 Probable Flood Risk LGAs in HA II

Hydrological Area III (Upper Benue)

Hydrological Area III comprises of Adamawa, Taraba, Gombe, Bauchi and part of Borno State. It is made up of about 70% Sedimentary and 30% basement. The major rivers are Benue, Gongola, Taraba, Donga, Faro, and Mayo-Kebbi.

The Highly Probable and Probable flood risk areas in Hydrological Area III are shown in Tables 4.6 and 4.7 as well as Figure 4.8:

Table 4.6 Highly Probable Flood Risk LGAs in HA III

S/N	State	LGAs
1	Taraba	Gassol, Ibi, Wukari
2	Adamawa	Numan, Guyuk, Yola South
3	Gombe	Balanga
4	Plateau	Barakin Ladi

Table 4.7 Probable Flood Risk LGAs in HA III

S/N	State	LGAs
1	Taraba	Ardo-Kola, Gassol, Jalingo, Lau, Sardauna, Gashaka
2	Adamawa	Demsa, Guyuk, Lamurde, Numan, Yola North, Yola South
3	Bauchi	Kirfi
4	Gombe	Dukku, Funakaye, Kwami, Nafada, Yamaltu

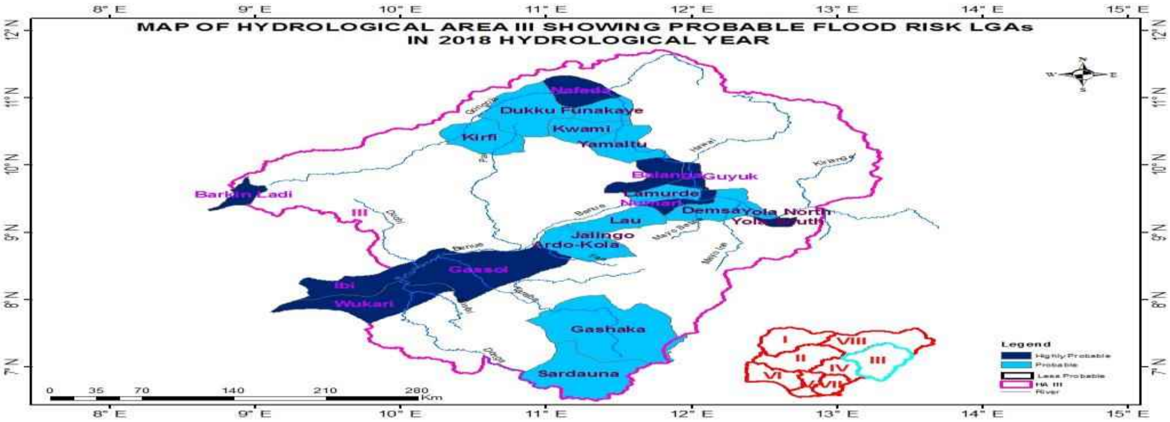


Fig. 4.8 Probable Flood Risk LGAs in HA III

Hydrological Area IV (Lower Benue)

Hydrological Area IV covers Plateau, Nasarawa, Benue and part of Kogi States. The area is covered by 50% Sedimentary and 50% Basement and is drained mainly by Rivers Benue, Katsina–Ala, Dep and Mada. The Highly Probable and Probable flood risk areas in Hydrological Area IV are shown in Tables 4.8 and 4.9 as well as Figure 4.9:

S/N	State	LGAs
1	Benue	Apa, Gboko, Gwer East, Gwer West, Makurdi,Logo, Buruku, Katsina–Ala
2	Nasarawa	Obi
3	Kogi	Bassa, Dekina

4	Taraba	Ibi, Wukari
5	Plateau	Barakin Ladi

Table 4.8

Highly Probable Flood Risk LGAs in HA IV

Table .4.9 Probable Flood Risk LGAs in HA IV

S/N	State	LGAs
1	Benue	Agatu, Buruku, Guma, Tarka
2	Kogi	Omala, Bassa
3	Nasarawa	Awe, Nasarawa, Keffi, Nasarawa–Eggon, Keana, Doma, Toto
4	Taraba	Ibi.
5	Kaduna	Kaura

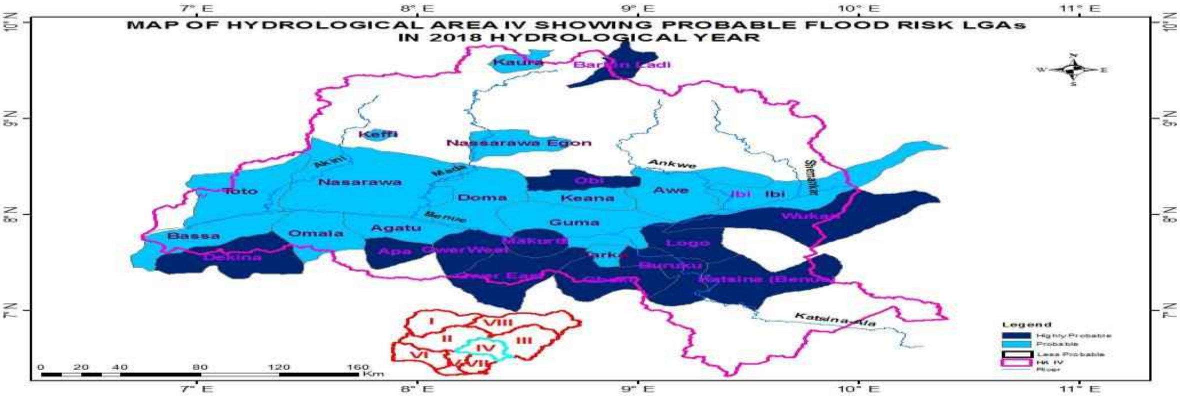


Fig.

Fig. 4.9 Probable Flood Risk LGAs in HA IV

Hydrological Area V (Niger South):

Hydrological Area V includes: Bayelsa, Delta, Edo, Anambra and parts of Kogi, Imo, Enugu and Rivers States. The geology is 90% Sedimentary and 10% Basement. The major Rivers are: Niger, Anambra, Ase, Orashi, Nun and Forcados.

The Highly Probable and Probable flood risk areas in Hydrological Area V are shown in Tables 4.10 and 4.11 as well as Figure 4.10:

Table 4.10 Highly Probable Flood Risk LGAs in HA V

S/N	State	LGAs
1	Delta	Ughelli North, Oshimili South, Oshimili North
2	Bayelsa	Brass, Yenegoa, Ekeremor, Southern Ijaw
3	Anambra	Aguata, Idemili North, Ogbaru
4	Kogi	Dekina, Idah

Table 4,11 Probable Flood Risk LGAs in HA V

S/N	State	LGAs
1	Edo	Esan South, Etsako East
2	Delta	Aniocha North, Bomadi, Ndokwa East, Ndokwa West, Patani, Ughelli South

3	Bayelsa	Kolokuma/Opokuma, Nembe, Ogbia, Sagbama
4	Rivers	Akukutor, Asari–To, Bonny, Degema, Gokana, Khana, Okrika, Opobo/Nkoro, Oyigbo, Tai
5	Anambra	Anambra East, Anambra West, Anaocha, Ayamelum, Dunukofia, Njikoka, Onitsha North, Onitsha South, Orumba North, Oyi
6	Enugu	Oji-River, Udi, Uzo–Uwani
7	Kogi	Adavi, Ajaokuta, Ibaji, Igalamela–Odolu, Ofu

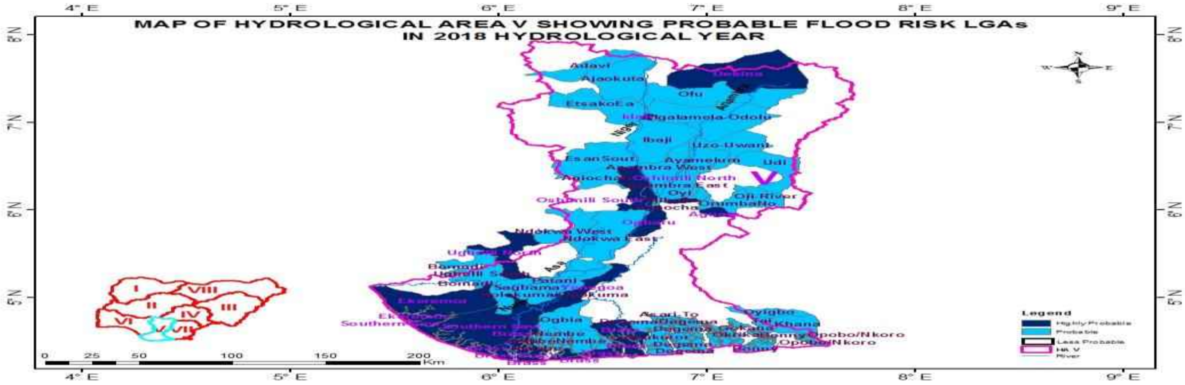


Fig.

Fig. 4.10 Probable Flood Risk LGAs in HA V

Hydrological Area VI (Western Littoral):

Hydrological Area VI comprises of the following States: Lagos, Ogun, Oyo, Osun, Ondo, Edo, Delta and Ekiti. The Area is 60% Basement and 40% Sedimentary and is drained by Rivers: Yewa, Ogun, Osun, Shasha, Omi, Owena, Osse,and Ossiomo

The Highly Probable and Probable flood risk areas in Hydrological Area VI are shown in Tables 4.12 and 4.13 as well as Figure 4.11:

Table 4.12 Highly Probable Flood Risk LGAs in HA VI

S/N	State	LGAs
1	Oyo	Ibarapa North, Ibarapa Central
2	Osun	Irewole
3	Delta	Ethiope West, Ughelli North, Warri North, Warri South
4	Lagos	Epe, Lagos Island, Mainland, Badagary, Eti–Osa
5	Ekiti	Ijero

Table 4.13 Probable Flood Risk LGAs in HA VI

S/N		State	LGAs
1		Ogun	Abeokuta South, Abeokuta North, Ifo, Ijebu North–East, Obafemi–Owode, Ogun Waterside
2		Oyo	Ibadan North–East, Ibadan North–West, Ibadan South–East, Ibadan South–West, Iseyin, Itesiwaju, Kajola, Ogbomosho South, Ona–Ara, Oyo East, Egbeda
3		Osun	Ayedire, Ede North, Ede South, Egbedore, Ifelodun, Ila, Ilesha West, Irepodun, Isokan, Iwo, Obokun, Odo Otin, Ola–Oluwa, Olorunda, Oriade, Osogbo, Orolu
4		Ekiti	Irepodun/Ifelodun
5		Ondo	Ilaje Eseodo
6		Delta	Burutu, Ughelli South, Warri North, Warri South–West

7		Lagos	Agege, Ajeromi/Ifelodun, Amuwo Odofin, Apapa, Epe, Ibeju/Lekki, Ikeja, Ifako/Ijaye, Ikorodu, Kosofe, Mushin, Ojo, Shomolu
8		Kwara	Oyun
9		Edo	Akoko–Edo

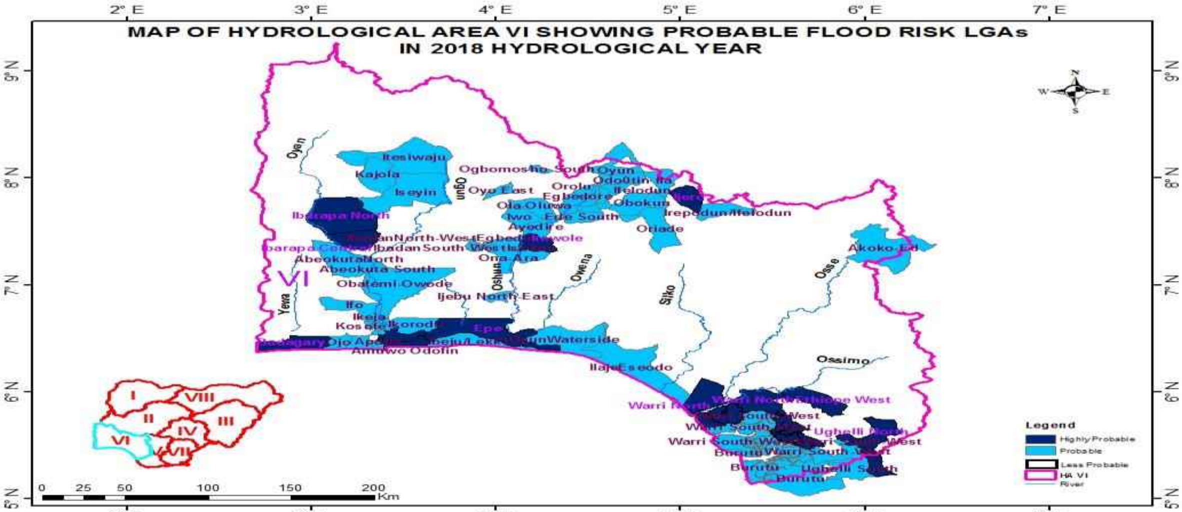


Fig. 4.11 Probable Flood Risk LGAs in HA VI

Hydrological Area VII (Eastern Littoral)

The Hydrological Area VII comprises of Abia, Anambra, Imo, Enugu, Ebonyi, Cross–River, Akwa–Ibom and Rivers States. The area is covered by 90% Sedimentary and 10% Basement and drained by Imo, Kwa-Iboe, Calabar, Ivo, Asu, Cross River and Ebonyi Rivers.

The Highly Probable and Probable flood risk areas in Hydrological Area VII are shown in Tables 4.14 and 4.15 as well as Figure 4.12.

Table 4.14 Highly Probable Flood Risk LGAs in HA VII

S/N	**State**	**LGAs**
1	Abia	Isiala Ngwa North, Umu–Nneochi
2	Akwa Ibom	Ibiono Ibom,
3	Cross River	Bekwarra,Obudu, Calabar South,Bakassi
4	Ebonyi	Afikpo South
5	Enugu	Enugu North
6	Benue	Konshish, Gboko, Gwer East

Table 4.15 Probable Flood Risk LGAs in HA VII

S/N	**State**	**LGAs**
1	Rivers	Etche, Khana, Omumma, Oyigbo
2	Akwa - Ibom	Ibeno, Ikot–Aba, Itu, Mbo, Nsit Atai, Okobo, Oron, Udung Uko, Uruan, UrueOffo
3	Abia	Ukwa East, Ukwa West, Umuahia North, Umuahia South
4	Imo	Ezinihite, Ideato South, Ideato North, Ihitte/Uboma, Mbaitoli, Nkwerre, Nwangele, Obowo, Okigwe, Owerri Municipal, Owerri North, Owerri West, Unuimo, IsialaMbiase

5	Cross River	Odukpani, Boki, Abi, Akpabuyo, Biase, Calabar, Obubra, Yakurr
6	Ebonyi	Abakaliki, Afikpo, Ebonyi, Ezza South, Ikwo, Ohaukwu
7	Enugu	Enugu East, Enugu South

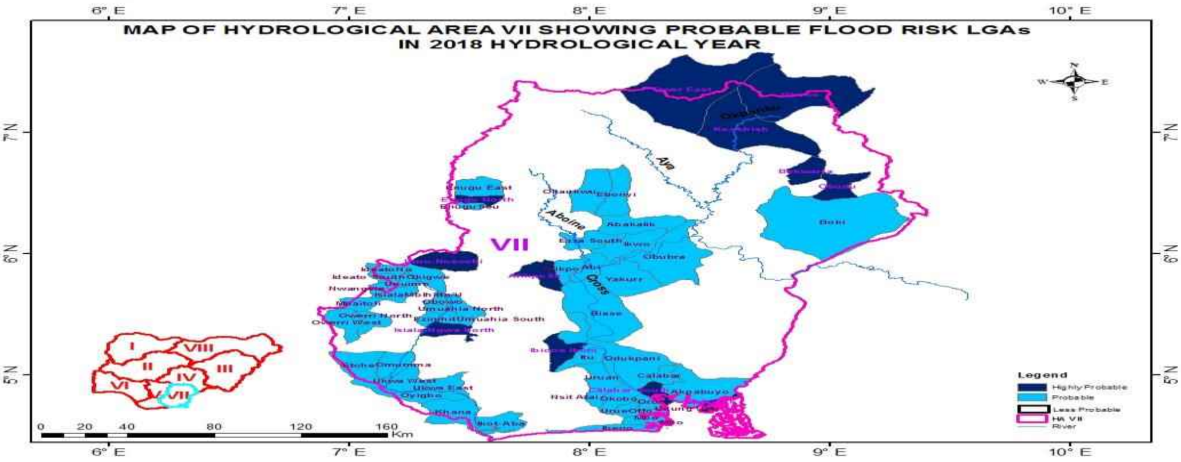


Fig. 4.12 Probable Flood Risk LGAs in HA VII

Hydrological Area VIII (Chad Basin):

The Hydrological Area VIII comprises of Kano, Jigawa, Yobe, Borno States and parts of Bauchi, Plateau and Adamawa States. The geology is made up of 80% Sedimentary and 20% Basement rocks. Major rivers in the area are:Hadejia, Jama’are, Komadugu–Yobe, Yedseram, Ngadda and Dingaiya.

The Highly Probable and Probable flood risk areas in Hydrological Area VIII are shown in Tables 4.16 and 4.17 as well as Figure 4.13:

Table 4.16 Highly Probable Flood Risk LGAs in HA VIII

S/N		State	LGAs
1		Kano	Gabasawa, Gezawa, Wudil
2		Jigawa	Auyo, Biriniwa
3		Borno	Kukawa, Lake chad (Water Body)
4		Yobe	Nangere, Potiskum, Yusufari, Yunusari, Bade

Table 4.17 Probable Flood Risk LGAs in HA VIII

S/N	State	LGAs
1	Kano	Ajingi, Albasu, Bebeji, Dala, Garum Mallam, Gaya, Gwale, Kabo, Karaye, Kumbotso, Kura, Madobi, Nasarawa, RiminGad, Tudun Wada, Dawakin Tofa, Warawa
2	Jigawa	Auyo, Biriniwa, Guri, Gwaram, Jahun, Kafin Hausa, Kaugama, KiriKasa, Kiyawa, Maigatari, MalamMad, Miga, Ringim, Taura
3	Bauchi	Itas/Gad, Jama'are, Shira, Zaki
4	Borno	Kala/Balge, Bama, Ngala
5	Yobe	Bade, Borsari, Geidam, Jakusko, Karasuwa, Nguru, Yunusari

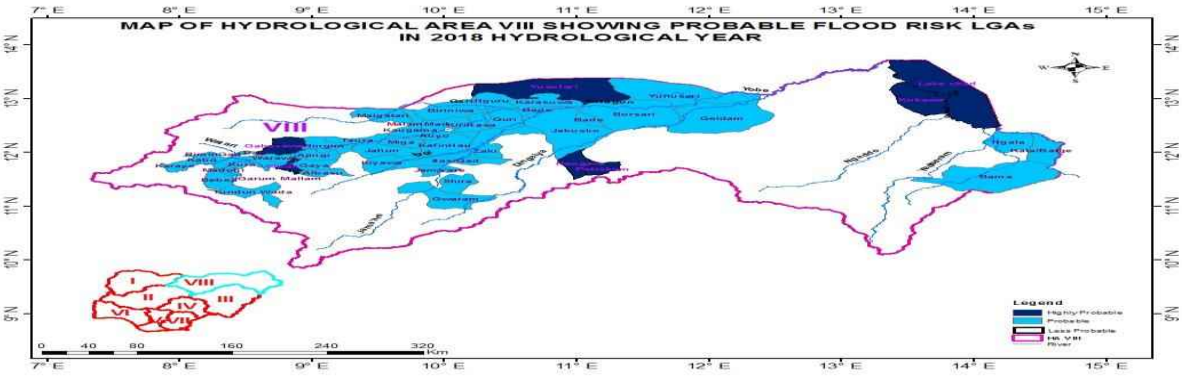


Fig. 4.13 Probable Flood Risk LGAs in HA VIII

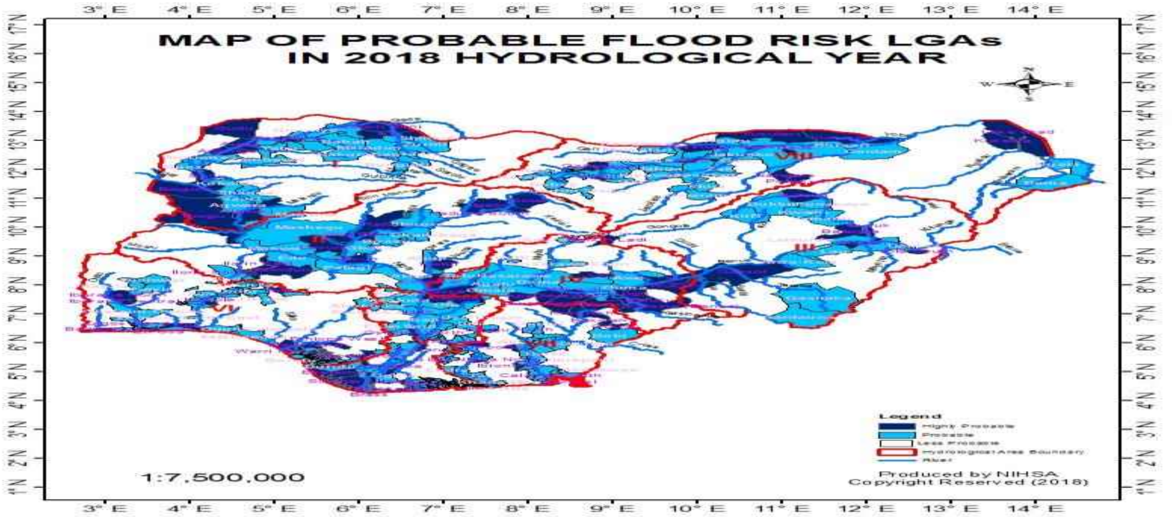
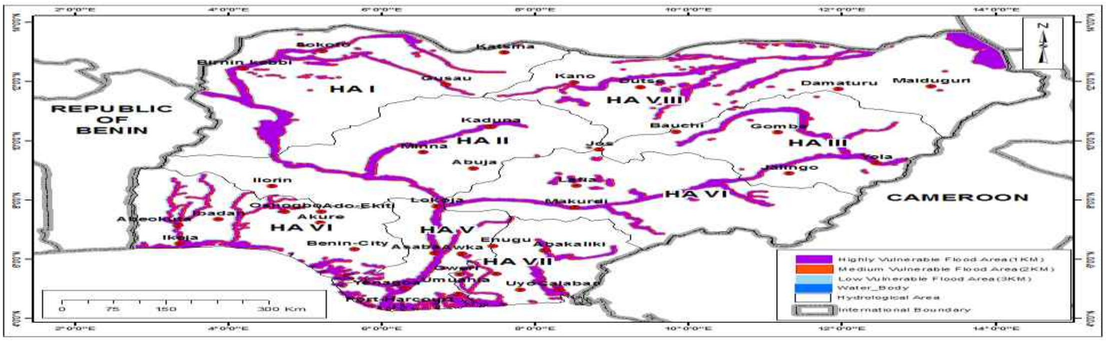


Fig.4.14 Map of Probable Flood risk LGAs in 2018

The expected areas for river flooding in 2018 are located in the following drainage basins: Niger, Benue, Sokoto–Rima, Anambra–Imo, Cross River, Niger Delta, Komadougu–Yobe, Ogun–Osun and several other sub–basins of the country. The predicted probable flood areal coverage in 2018 is expected to be lower than the predicted probable flood and the observed flooded areas in 2016 (Figure 4.14).



4.5 TECHNICAL LESSONS LEARNT

4.5.1 Science and technology

Development, transfer and application into practices of science and technology should be in the center of on disaster risk reduction strategy within the country and at the community levels. Science and technology community in Nigeria should advance inter-disciplinary and trans-disciplinary research and help improve and integrate data collection and dissemination, and work together with the implementation authority to develop tools to enhance governance and decision making for disaster risk reduction. Nigeria Governments should make proactive use of science and technology on water and disasters to enhance their levels of preparedness and response.

Considering the specific situation of Nigeria regarding flooding, the nation's academia should focus attention on more scientific investigations. Flooding and climate change concepts should be integrated into curriculum of studies in Nigerian schools. Current issues in flood research such as flood modelling, vulnerability assessment, uncertainty analyses and early warning systems should be promoted.

It is obvious that perception of flooding in Nigeria has only received little attention. Due to lack of funds and the indifference of political leaders towards research, a number of researches relating to flooding in the country seem to recycle issues that are well known such as causes and impacts of flooding. To tackle this challenge, we recommend that annual budgeting for Nigeria should be specific and more realistic with funds for research.

Nigerians should participate in matters relating to flooding which most largely affects their lives. This can be done by asking relevant questions, seeking to know and willing to adapt to individual actions which can potentially influence flood risk reduction within the country. Individuals in politics should ensure that laws which underlie the enforcement of environmental standards and regulations are made. Equally, the general public and local communities in Nigeria should support research through positive and accurate responses to questionnaire and surveys.

The lack of detailed plan and strategy for disbursing funds and inaccurate information relating to those who have been affected by flooding most probably undermine humanitarian support in Nigeria and account for financial mismanagement. Humanitarian actions in Nigeria are generally for post-disaster and emergency situations suggesting some limitation based on what can be achieved through financial support. Given that most local communities in Nigeria consist of poor human populations, we recommend that the focus and priority of humanitarian supports should be on improving the living condition of the population people whilst not undermining the need for assistance in eventualities. Thus focus will not only ultimately reduce their chances of people being vulnerable to flooding and assist in minimizing financial mismanagement, but also it will boost the credence of humanitarian supports towards natural disasters in general and flooding in particular in Nigeria.

The Federal Government of Nigeria however, seemingly understands the increasing need for improved flood management in Nigeria, as noted during the 2012 floods in Nigeria. There was an indication of improved awareness of the situation by Government Agencies, now more than ever before. It was estimated that about 22,000 volunteers were trained by the Nigerian Red Cross for pre and post-event response. The warehouses were also stocked with necessities in preparation for future emergencies. In addition, dam operators were directed to release water from the dams periodically to reduce the risk of flooding for communities downstream.

4.6 International Best Practices and Lessons

4.6.1 International Flood Management Practices: Sustainable Flood Prevention, Protection and Mitigation

A number of principles and approaches from an international perspective reinforce the connection between flood prevention, protection and mitigation. A brief internationalized state-of-the-art of flood management practices puts into perspective flood strategies that integratively promotes coordinated development and management of actions regarding water, land and related resources. From this viewpoint, such practices consider different kinds of flooding (i.e., hydrological circumstances) and environmentally-focalized conditions that contribute to the problem. Flood management practices from around the world are briefly examined and commented upon from the Nigerian perspectives.

In accordance with the Water Directors of the European Union (EU), the EU Floods Directive 2007/60/EC and the United Nations and Economic Commission for Europe (UN/ECE) Guidelines on Sustainable Flood Prevention eight notable practices are described: (1) integrated river basin approach; (2) public awareness, public participation and insurance; (3) research, education and exchange of knowledge; (4) retention of water and non-structural measures; (5) land use, zoning and risk assessment; (6) structural measures and their impact; (7) flood emergency; and (8) prevention of pollution. There has been a number of European-centric working groups which have expanded upon the Water Framework Directive 2000/60/EC and EU Floods Directive 2007/60/EC that focus on flood risk management information-based systems. Key deliverance has focused on securing basic resource needs for better integration and coherent management approaches for natural water retention methods, improved ecosystem quality and reduced, overall, continent-wide flooding.

At present, authorities throughout Nigeria significantly lack capacity in all eight of these practices. From a European standpoint, the country insufficiently conducts background controls and has limited pathways for extensive implementation.

4.6.2 United States of America

In the USA, flood management practices are predominantly updated by the Federal Emergency Management Agency (FEMA); at present, FEMA has 56 legislative floodplain management publications, with its NFIP Floodplain Management Guidebook 5th Edition stating six practices that make up the management scheme: (1) floodplain management concepts; (2) mapping and map revisions; (3) the National Flood Insurance Program (NFIP); (4) floodplain management at the local level; (5) NFIP floodplain development standards; and (6) flood hazard mitigation]. In addition, ongoing reports included FEMA’s National Flood Insurance Program Community Rating System: A Local Official’s Guide to Saving Lives, Preventing Property Damage, and Reducing the Cost of Flood Insurance FEMA B 573/2018 highlight flood mapping and regulations, damage reduction and preparedness]. Nigeria’s authorities have published a very limited number of government reports and publications, with a very limited amount of conceptual management, mapping and, basically, no proper insurance-oriented program. American management practices within Nigeria would be beneficial however not feasible due to the expensive nature of implementing such a scheme.

4.6.3 Canada

In Canada, recent flood management practices prioritized three flood risk management initiatives: (1) data and shared understanding; (2) homeowner and education awareness; and (3) proactive cross sector collaboration. In Australia, the national publication entitled Managing the Floodplain: A Guide to Best Practices in Flood Risk Management in Australia extensively references 58 manuals and handbooks specific to Australia’s environment. Similarly, New

Zealand has published Meeting the challenges of future flooding in New Zealand stating four fundamental actions: (1) active and engaged risk management by central and local government collaboration; (2) risk reduction embedded within the policy framework; (3) appropriate resources, including sufficient information, guidance and funding, made available to promote good practice in the daily management of flood risk; and (4) central and local government monitoring to understand the levels of flood risk and inform future policy and management practices. Additionally, coastal flooding attention looks at: storm, tides and sea level preparedness; landform characteristics; and flood hazard preparedness. Other countries with noteworthy flood management practices include: the United Kingdom, Japan, Singapore and China. In retrospect of these management practices, Nigeria would benefit from Canadian-style initiatives that prioritize on community and societal level involvement. In both Australia and New Zealand, the pure volume of research and development exemplify the extent of how flood management practices are prioritized and integrated into high level governance interlacing academia and institutions alike with government.

4.6.4 The Imperative of Disaster Risk Reduction (DRR)

Disaster risk reduction is the concept and practice of analyzing and reducing the causal factors of disasters by decreasing exposure to hazards, lessening vulnerability of people and property, improving management of land and the environment, and enhancing preparedness for adverse events. Disaster risk reduction also includes establishing adequate financial protection, including financial planning and investment as well as the sharing of risk through financial mechanisms. Disaster risk reduction activities at local, national, regional and global levels are guided by an international blueprint known as the Hyogo Framework, which was adopted by the United Nations General Assembly in 2005. Its adoption reflects a paradigm shift from disaster management – that is, from coping with impacts – to prevention. The Hyogo Framework's five priorities for action emphasize that reducing disaster risk requires strengthened governmental commitment and investment, risk information and early warning capacity, education and public awareness, understanding the underlying risk factors, and preparedness to respond to impacts that could not be avoided. Disaster risk reduction is primarily concerned with hazards of natural origin – such as earthquakes, floods, droughts and cyclones – and related technological threats. These hazards arise from a variety of geological, meteorological, hydrological, oceanic, biological, and technological sources, sometimes acting in combination (UNDP, 2003).

4.7 TECHNICAL RECOMMENDATIONS

Six Urgent Imperatives steps necessary to avert a repeat of July Flood; these are to:

1) Galvanize and mobilize before disaster strikes
2) Prioritize systems to forecast, inform, alert and evacuate
3) Incorporate disaster risk reduction and climate change adaptation as integral to development planning
4) Improve disaster response
5) Provide safe water and toilets quickly when disaster/conflict strikes
6) Special crosscutting Initiatives

4.8 CONCLUSION

The July Flood in Nigeria was devastating for many Communities with large scale destructions to life and properties including critical infrastructure and economic activities. The hazard which has been generally linked to climate change and poor urban planning has received the attention of government at all levels, local communities, humanitarian agencies and research. However, efforts so far at tackling the hazard seem limited mostly due to lack of data relating to flooding and other factors which are yet to be identified. Although flood hazard is widespread in the country, many poor communities appear very reluctant to relocate in response to early warning information at their disposal.

Water-related disasters pose both direct impacts (e.g. damage to buildings, crops and infrastructure, and loss of life and property) and indirect impacts (e.g. losses in productivity and livelihoods, increased investment risk, indebtedness and human health impacts). The increasing economic cost and toll of disasters should be a significant incentive for governments and humanitarian organizations to focus more attention on preparedness, prevention and addressing the root causes of vulnerability.

Natural hazards are inevitable: high death and destruction tolls are not. Ill-advised human activity can both create and accelerate the impact of water-related disasters. These water threats have been increasing with climate change and human activities, in the North and South of the Country, from East to West. But, with preparedness and planning, fatalities and destruction can be decreased. The Nigerian Government must redouble its efforts and commitment to the principles of coherent disaster prevention and response. The need is now for concrete and significant changes to make this happen.

4.9 Author Contributions:

Funding
This report received support from HELP Secretariat.

Conflicts of Interest
The authors declare no conflict of interest.

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5. Floods in Kerala, India in September, 2018

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Summary

Recently, Kerala, a state of India, has experienced the worst ever floods in its history since 1924. The state received cumulative rainfall that was 42% in excess of the normal average and as a consequence, seven districts namely Alappuzha, Ernakulam, Idukki, Kottayam, Pathanamthitha, Thrissur, and Wayanad, were worst affected. Floods in conjunction with landslides affected as many as 5.4 million people, and displaced 1.4 million people, while 433 people lost their lives (22 May–29 August 2018). The devastating floods and landslides caused extensive damage to houses, roads, railways, bridges, power supplies, communications networks, and other infrastructure; washed away crops and livestock and affected the lives and livelihoods of millions of people in the state. Post Disaster Need Assessment (PDNA) conducted by United Nations Development Programme (UNDP) in collaboration with Government of Kerala estimates the total damages to be around INR 10,557 crore and total losses to be around INR 16,163 crore amounting to a total disaster effects of around INR 26,720 crore (USD 3.8 billion). According to a conservative estimate, close to 2.6% of Kerala's gross state domestic product (GSDP) got washed away by the floods instantly. The Government of India had declared it a Level 3 Calamity, or "calamity of a severe nature".

The Kerala Flood of 2018 highlight issue related to flood risk reduction mainly the failure of structural approach to flood management and institutional challenges. The article discusses the key drivers of Kerala flood and also compares the recent flood with the Great Flood of 99 (as per the calendar of Kerala) in 1924 to highlight the key issues of flood management and institutional dysfunction which remain more or less unresolved. Its an extreme event which has posed a challenge for the future in disaster risk reduction and climate change.

Key words: Kerala Flood, incentivisation, Great Flood of 99, Flood Risk Management

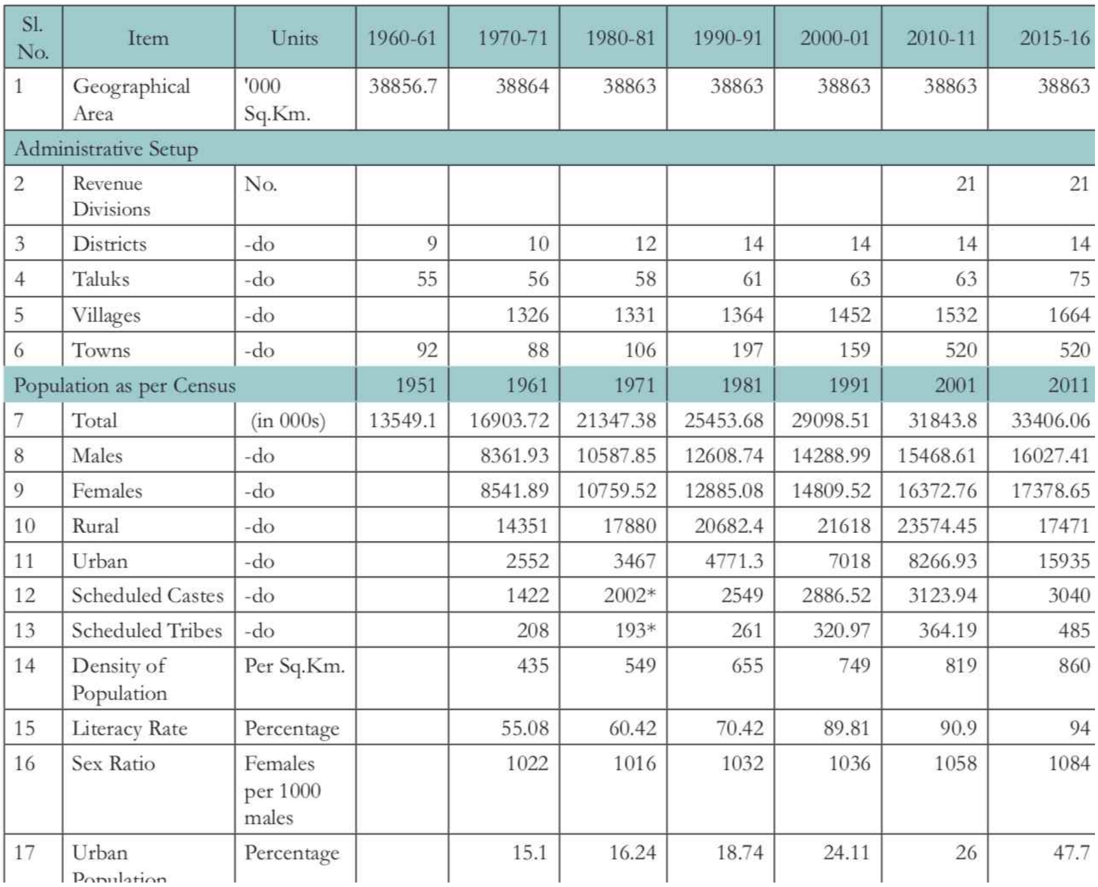
5.1 Overview Kerala Flood

Kerala, (population density of 860/sq.km.) is one of the most progressive states of the country, with high per capita income (Rs.128347- higher than the national average of Rs.82269, high life expectancy (77 years) and high literacy rate (94%). It is a model state for attaining human development index (0.79) , sex ratio (1084 females per 1000 males), and its development story is being emulated by many states of the country. These parameters are also happens to be the parameters of a resilient society. Many of the Sustainable Development Goals have been achieved by the state and striving for higher human happiness index. Kerala also ranks first in India in terms of Human Development Index (HDI), also first among states in inequality adjusted HDI which indicates the least loss of HDI on account of

Inequality. and among top four in terms of growth in per capita income. Kerala is considered a developed state in a developing country.

Kerala, however, is highly vulnerable to natural disasters and the changing climatic dynamics given its location along the sea coast and with a steep gradient along the slopes of the Western Ghats. On the other hand, as per the Kerala State Disaster Management Plan the state is exposed to 39 hazards categorized under two broad heads i.e. Naturally triggered Hazards (Natural Hazards) and anthropogenically –Triggered Hazards (Anthropogenic Hazards). Floods are the most common of natural hazards that affects the state. While 14.52 per cent of the total area of the state is prone to floods, for certain districts, this percentage is as high as 50 per cent. Landslides are also major hazard on the Western Ghats in Wayanad, Kozhikode, Idukki and Kottayam districts. Seasonal drought like conditions are also common during the summer months. Dry rivers and lowering water tables in summer result in water scarcity both in urban and rural areas. Between 1881 to 2000, Kerala experienced 66 drought years. Kerala settlement is largely along the coast side which has high density whereas the hill side is sparsely populated.

Table 5.1 Kerala at a glance , source, socio-economic review , Govt of Kerala



Sl. No.	Item	Units	1960-61	1970-71	1980-81	1990-91	2000-01	2010-11	2015-16
1	Geographical Area	'000 Sq.Km.	38856.7	38864	38863	38863	38863	38863	38863
Administrative Setup									
2	Revenue Divisions	No.						21	21
3	Districts	-do	9	10	12	14	14	14	14
4	Taluks	-do	55	56	58	61	63	63	75
5	Villages	-do		1326	1331	1364	1452	1532	1664
6	Towns	-do	92	88	106	197	159	520	520
Population as per Census			1951	1961	1971	1981	1991	2001	2011
7	Total	(in 000s)	13549.1	16903.72	21347.38	25453.68	29098.51	31843.8	33406.06
8	Males	-do		8361.93	10587.85	12608.74	14288.99	15468.61	16027.41
9	Females	-do		8541.89	10759.52	12885.08	14809.52	16372.76	17378.65
10	Rural	-do		14351	17880	20682.4	21618	23574.45	17471
11	Urban	-do		2552	3467	4771.3	7018	8266.93	15935
12	Scheduled Castes	-do		1422	2002*	2549	2886.52	3123.94	3040
13	Scheduled Tribes	-do		208	193*	261	320.97	364.19	485
14	Density of Population	Per Sq.Km.		435	549	655	749	819	860
15	Literacy Rate	Percentage		55.08	60.42	70.42	89.81	90.9	94
16	Sex Ratio	Females per 1000 males		1022	1016	1032	1036	1058	1084
17	Urban Population	Percentage		15.1	16.24	18.74	24.11	26	47.7

5.1.1 The deluge

Kerala has experienced the worst ever floods in its history since 1924. State has an average annual precipitation of about 3000 mm. About 90% of the rainfall occurs during six monsoon months. Kerala experienced an abnormally high rainfall from 1 June 2018 to 19 August 2018. This resulted in severe flooding in 13 out of 14 districts in the State. As per IMD data, Kerala received 2346.6 mm of rainfall from 1 June 2018 to 19 August 2018 in contrast to an expected 1649.5 mm of rainfall. Further, the rainfall over Kerala during June, July and 1st to 19th of August was 15%, 18% and 164% respectively, above normal. A severe spell of rainfall was experienced at several places on the 8th and 9th of August 2018. As per the govt of Kerala PDNA report, more than 433 people got perished. Out of total deaths, 62% were men, 23 % women and 15 % children which is an unusual case than what is normally happening in other states where percentage of women dying are much more than the men.

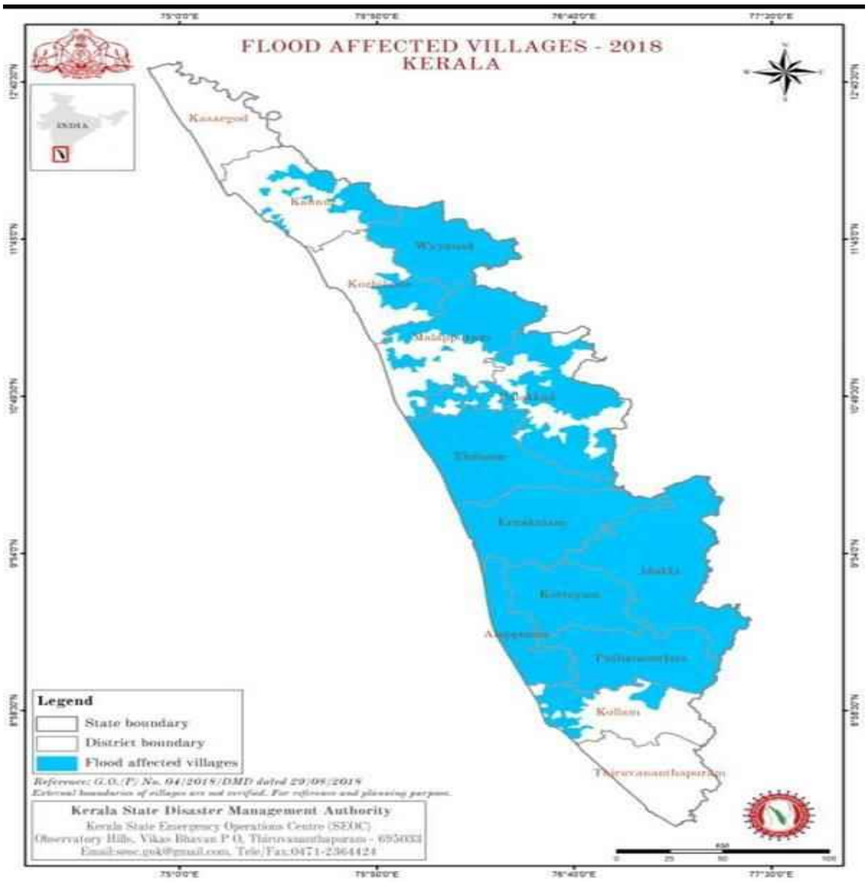
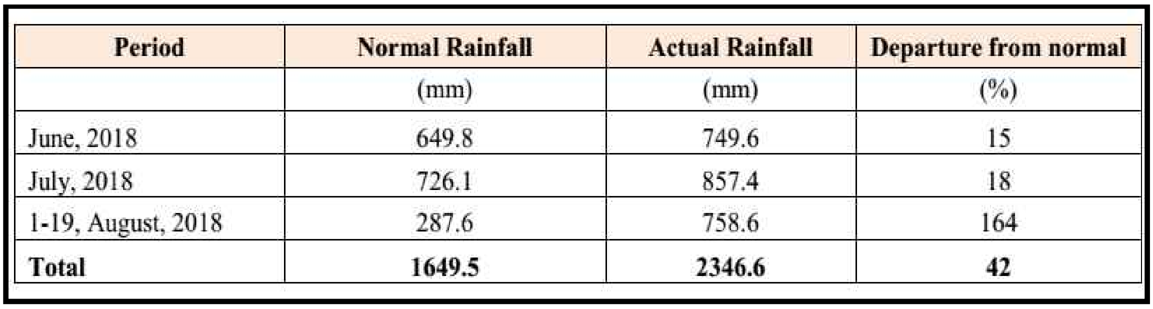


Figure 5.1 Flood inundation map 2018. 12 out of 14 districts got affected by the floods. Affected districts: Trichur, Ernakulam, Idukki, Kottayam, Alappuzha and Kuttanad and also Kundala. Source: PDNA report Govt of Kerala

The 1- day rainfall of 398 mm, 305 mm, 255 mm, 254 mm, 211 mm and 214 mm were recorded at Nilambur in Malappuram district, Mananthavadi in Wayanad district, Peermade, Munnar KSEB and Myladumparain in Idukki district and Pallakad in Pallakad district respectively on 9 August 2018. This led to further flooding at several places in Mananthavadi and Vythiri in Wayanad district during 8-10, August 2018.

Figure 5.2 NASA released Satellite image of Kerala before (left) and during flood (right)

Table 5.2 Month wise actual rainfall, normal rainfall and percentage departure from normal

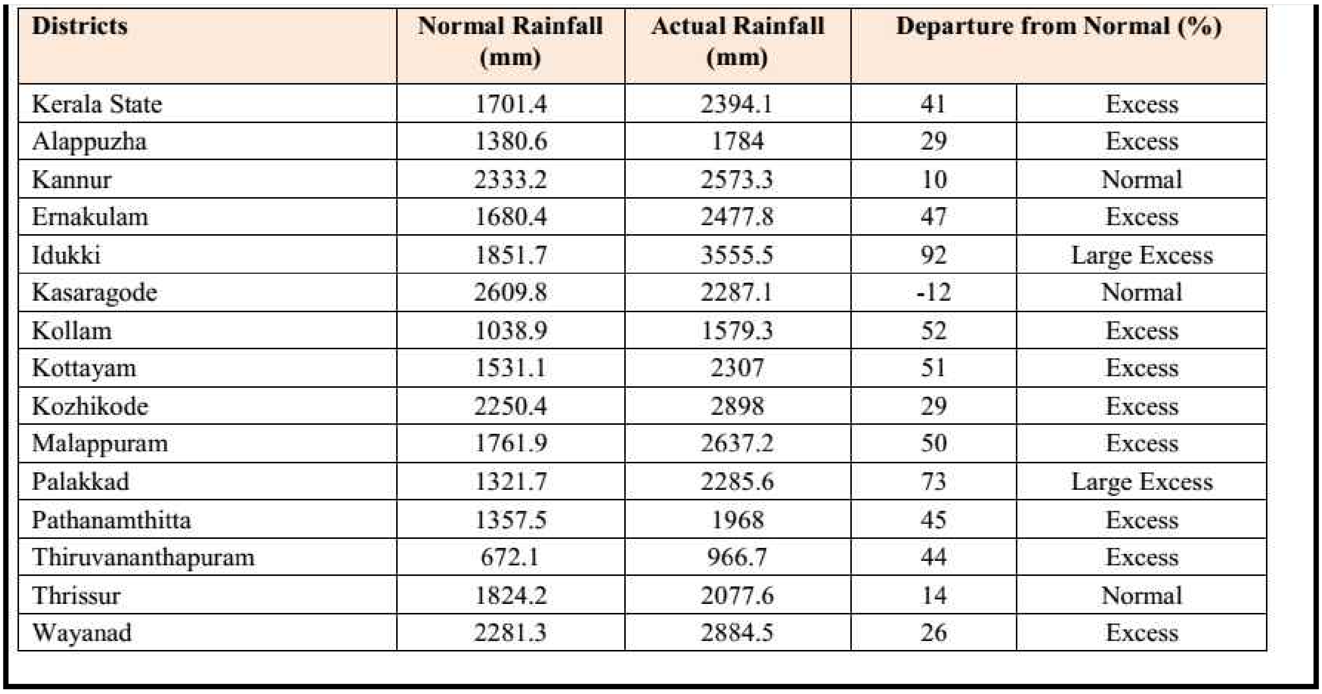


Period	Normal Rainfall	Actual Rainfall	Departure from normal
	(mm)	(mm)	(%)
June, 2018	649.8	749.6	15
July, 2018	726.1	857.4	18
1-19, August, 2018	287.6	758.6	164
Total	**1649.5**	**2346.6**	**42**

Source-CWC report on Kerala Flood 2018

The state received cumulative rainfall that was 42% in excess of the normal average and as a consequence, seven districts namely Alappuzha, Ernakulam, Idukki, Kottayam, Pathanamthitha, Thrissur, and Wayanad, were worst affected Floods in conjunction with landslides affected as many as 5.4 million people, and displaced 1.4 million people, while 433 people lost their lives (22 May–29 August 2018). Around 1,259 out of 1,664 villages spread across its 14 districts were affected.

Table 5.3 District wise Rainfall Record during June 1, 2018 to June 22, 2018

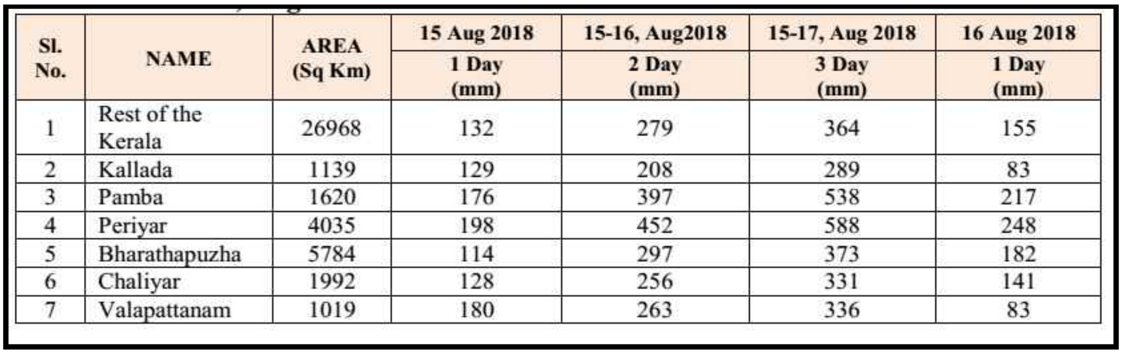


Districts	Normal Rainfall (mm)	Actual Rainfall (mm)	Departure from Normal (%)	
Kerala State	1701.4	2394.1	41	Excess
Alappuzha	1380.6	1784	29	Excess
Kannur	2333.2	2573.3	10	Normal
Ernakulam	1680.4	2477.8	47	Excess
Idukki	1851.7	3555.5	92	Large Excess
Kasaragode	2609.8	2287.1	-12	Normal
Kollam	1038.9	1579.3	52	Excess
Kottayam	1531.1	2307	51	Excess
Kozhikode	2250.4	2898	29	Excess
Malappuram	1761.9	2637.2	50	Excess
Palakkad	1321.7	2285.6	73	Large Excess
Pathanamthitta	1357.5	1968	45	Excess
Thiruvananthapuram	672.1	966.7	44	Excess
Thrissur	1824.2	2077.6	14	Normal
Wayanad	2281.3	2884.5	26	Excess

Source-CWC report on Kerala Flood 2018

The rainfall received between 15-17 August, 2018 was spread over the entire Kerala. The rainfall was so severe that gates of 35 dams were opened for releasing water. Five gates of Idukki reservoir which were opened after 26 years.

Table 5.4 Rainfall Depth realised in different sub-basins and rest of Kerala during 15-17 August, 2018



Sl. No.	NAME	AREA (Sq Km)	15 Aug 2018	15-16, Aug2018	15-17, Aug 2018	16 Aug 2018
			1 Day (mm)	2 Day (mm)	3 Day (mm)	1 Day (mm)
1	Rest of the Kerala	26968	132	279	364	155
2	Kallada	1139	129	208	289	83
3	Pamba	1620	176	397	538	217
4	Periyar	4035	198	452	588	248
5	Bharathapuzha	5784	114	297	373	182
6	Chaliyar	1992	128	256	331	141
7	Valapattanam	1019	180	263	336	83

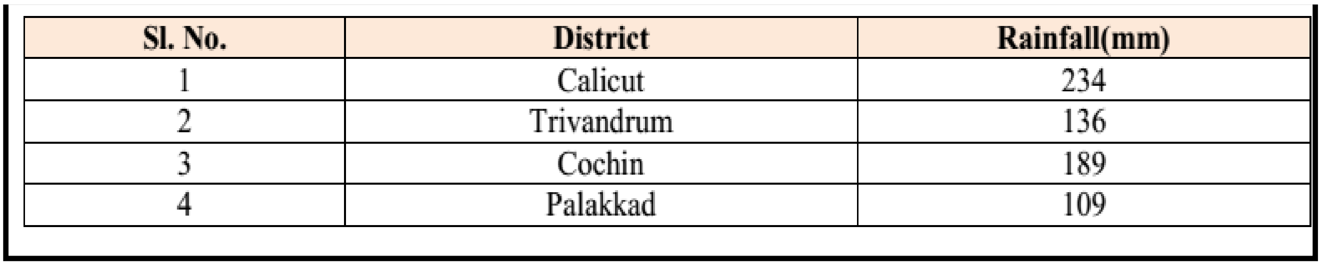
The day1cumulative, day2 cumulative and day3, cumulative rainfall data is given in table 3 to understand the rainfall variability at different places and rainfall depths at different river sub-basins in Kerala.

5.1.2 Historical Analysis of Floods in Kerala

The 1924 too witnessed unprecedented and very heavy floods in almost all rivers of Kerala. The rainstorm of 16-18, July 1924 was caused by the South-west monsoon that extended to the south of peninsula on 15th July and caused rainfall in Malabar. Under its influence, heavy rainfall occurred in almost entire Kerala. The area under the storm recorded 1-day maximum rainfall on 17th of July, 2-day maximum rainfall for 16-17, July 1924 and 3-day maximum rainfall for 16-18, July 1924. The centre of the 1-day and 2-day rainstorm was located at Devikulam in Kerala which recorded 484 mm and 751 mm of rainfall respectively. The centre of 3-day rainstorm was located at Munnar in Kerala which recorded a rainfall of 897 mm in 3 days.

The year 1961 has also witnessed severe floods, the worst affected area was Periyar sub-basin and the average rainfall was 56% above normal. The record of 1-day rainfall is given in table. It was recorded that 115 people have lost their lives, around 50,000 houses were fully and partially damaged and around 115,000 acres of paddy field was affected.

Table 5.5 Day1 Rainfall Record in different district of Kerala, 1961



Sl. No.	District	Rainfall(mm)
1	Calicut	234
2	Trivandrum	136
3	Cochin	189
4	Palakkad	109

Source-CWC report on Kerala Flood 2018

Kerala is having 57 large dams out of which 4 dams are operated by Government of Tamil Nadu. The total live storage capacity under these dams is 5.806 BCM. This is equal to 7.4% of annual average runoff of all 44 rivers in Kerala, which is about 78 BCM (ref: Water Resources of Kerala 1974). Out of the above, only 7 reservoirs are having a live storage capacity of more than 0.20 BCM and they constitute 74% of the total live storage in Kerala.

Table 5.6 Major Reservoirs in Kerala

Sl.No.	Name of Reservoir	Live Storage Capacity (MCM)
1.	Idukki	1460
2.	Idamalayar	1018
3.	Kallada	488
4.	Kakki	447
5.	Parambikulam (for use of TN)	380
6.	Mullaperiyar (for use of TN)	271
7.	Malampuzha	227

The Periyar 244 Km in length is the longest river of Kerala. The total drainage area of the basin is 5389 sq km out of which 98% lies in Kerala. The Periyar originates from Sivagiri peak 80 Km south of Devikulam at an elevation of 2438 m above Mean Sea Level (MSL) and joined by the Mullayar, 16 km downstream and then the river reaches Vandiperiyar and passes through a second narrow gorge below which it is joined by Perumthura. Further down, it is joined by six tributaries after which tributary Edamalar join Periyar. After passing Malayattur, the river reaches Alwaye where it divide itself in two branches, the upper river joins the Chalakudi river at Punthenvelikara and then expands at Munambham and the other branch fall into a Vembanad lake. The dams with significant storage in Periyar sub-basin are Mulla-Periyar, Idukki and Idamalayar. The catchment area of river Mullaperiyar dam is about 637 sq km. The free catchment between Mullaperiyar & Idukki dam is about 605 sq km and the Idamalayar catchment area is about 472 sq km.

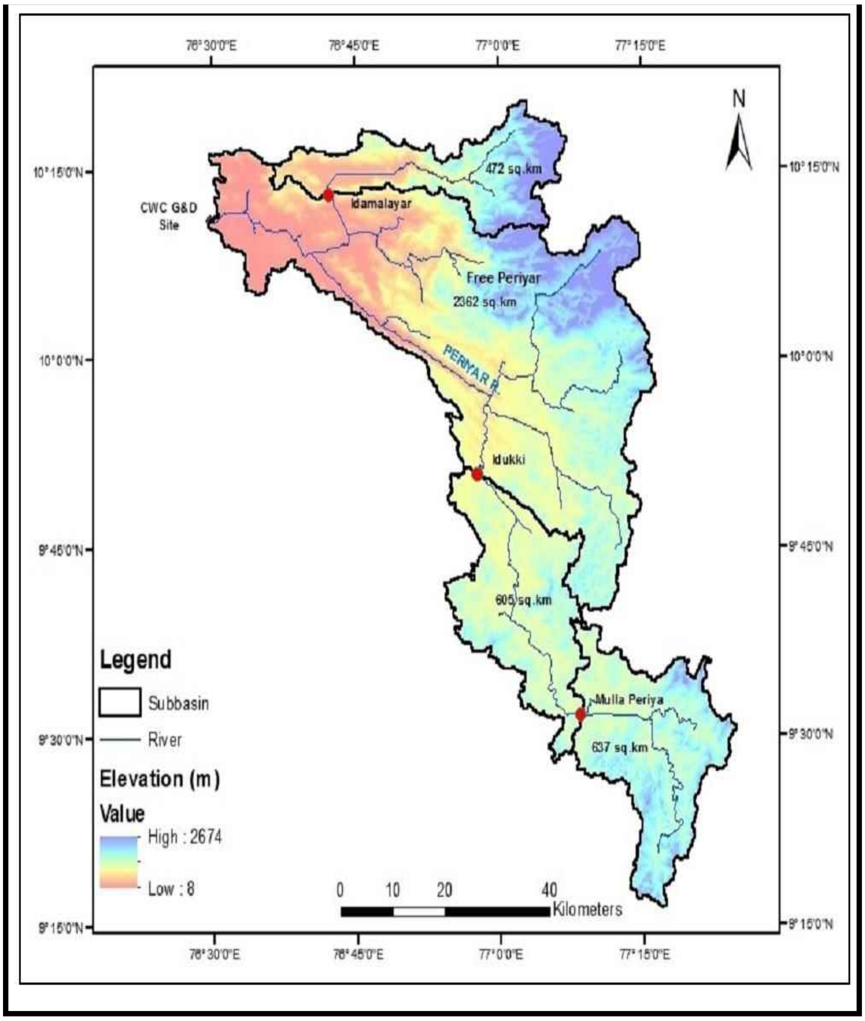
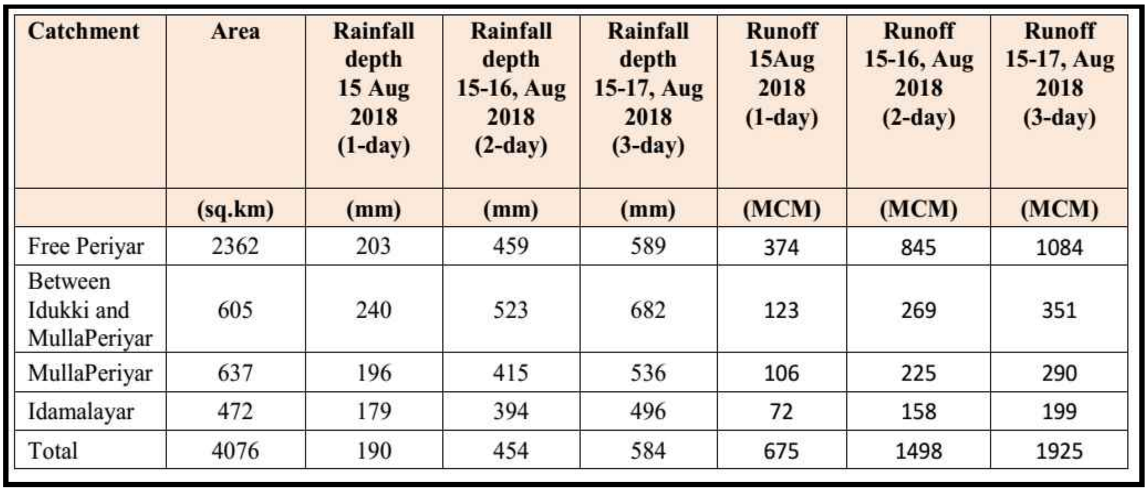


Figure 5.3 Periyar river Drainage area map up to Neeleshwaram

Source- Central Water Commission Report on Kerala Flood 2018

Table 5.7 Periyar river sub basin rainfall and run-off

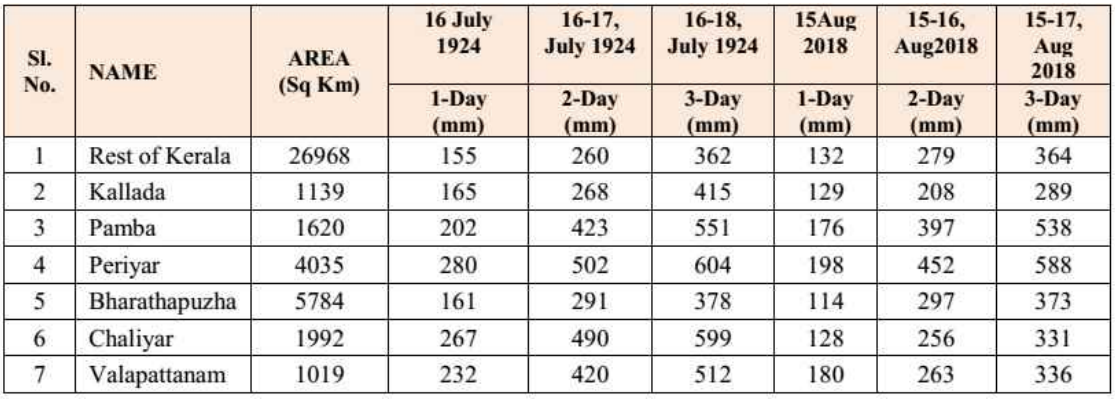


Catchment	Area	Rainfall depth 15 Aug 2018 (1-day)	Rainfall depth 15-16, Aug 2018 (2-day)	Rainfall depth 15-17, Aug 2018 (3-day)	Runoff 15Aug 2018 (1-day)	Runoff 15-16, Aug 2018 (2-day)	Runoff 15-17, Aug 2018 (3-day)
	(sq.km)	(mm)	(mm)	(mm)	(MCM)	(MCM)	(MCM)
Free Periyar	2362	203	459	589	374	845	1084
Between Idukki and MullaPeriyar	605	240	523	682	123	269	351
MullaPeriyar	637	196	415	536	106	225	290
Idamalayar	472	179	394	496	72	158	199
Total	4076	190	454	584	675	1498	1925

In the above table 7, the estimated rainfall of Periyar sub-basin for 1-day, 2-day and 3-day rainfall of 15-17 Aug, 2018 is about 190 mm, 454 mm and 584 mm respectively and runoff volume for 1-day, 2-day and 3-day is estimated at 675 MCM, 1498 MCM and 1925 MCM respectively.

Looking at the history of Kerala flood, The Great flood of 1924 when Periyar river flooded, the rain continued for three weeks and the districts got flooded are more or less the same which got affected in flood 2018 such as Trichur, Ernakulam, Idukki, Kottayam, Alappuzha and Kuttanad and also Kundala Valley Railway which was first the monorail system in India was washed away. The 1924 witnessed unprecedented and very heavy floods in almost all rivers of Kerala. The rainstorm of 16-18, July 1924 was caused by the South-west monsoon that extended to the south of peninsula on 15th July and caused rainfall in Malabar. Under its influence, heavy rainfall occurred in almost entire Kerala. The area under the storm recorded 1-day maximum rainfall on 17th of July, 2-day maximum rainfall for 16-17, July 1924 and 3-day maximum rainfall for 16-18, July 1924. The centre of the 1-day and 2-day rainstorm was located at Devikulam in Kerala which recorded 484 mm and 751 mm of rainfall respectively. The centre of 3-day rainstorm was located at Munnar in Kerala which recorded a rainfall of 897 mm in 3 days. The severity of the storm has been compared with the storm of 16-18, July 1924 centred at Devikulam in Kerala.

Table 5.8 Comparison of rainfall depths realised in different sub-basins and rest of the Kerala during 15-17, August 2018 storm with Devikulam storm of 16-18, July 1924 [Source: Central Water Commission]



Sl. No.	NAME	AREA (Sq Km)	16 July 1924	16-17, July 1924	16-18, July 1924	15Aug 2018	15-16, Aug2018	15-17, Aug 2018
			1-Day (mm)	2-Day (mm)	3-Day (mm)	1-Day (mm)	2-Day (mm)	3-Day (mm)
1	Rest of Kerala	26968	155	260	362	132	279	364
2	Kallada	1139	165	268	415	129	208	289
3	Pamba	1620	202	423	551	176	397	538
4	Periyar	4035	280	502	604	198	452	588
5	Bharathapuzha	5784	161	291	378	114	297	373
6	Chaliyar	1992	267	490	599	128	256	331
7	Valapattanam	1019	232	420	512	180	263	336

From the Table 5.8 analysis, it can be seen that the 2-day and 3-day rainfall depths of 15-17,August 2018 rainfall in Pamba, Periyar and Bharathapuzha sub-basins are almost comparable to the Devikulam storm of 16-18, July 1924. For entire Kerala the depth of rainfall realised during 15-17, August 2018 is 414 mm, while the same during

16-18, July 1924 was 443 mm. In 1924 Kerala received a 3,368 mm of rain in the month of July which was 64 percent higher than normal whereas in Kerala Flood 2018, Kerala received 2346.6 mm rain between 1 June- 19 August, 2018 which was 42 percent above normal (normal rainfall=1649.5 mm).

One or the disasters, due to its high physical exposures what has naturally ordained, affect Indian states. The impact of disasters are also high as development investment and construction practices in the high exposure states do not commensurate with its risks. There have been a capacity gaps too at all levels-community, local level administration, officials capacity who are handling it, technology and education about ex-ante disaster risk reduction are not very popular. Ex-post disaster response has been of high capacity as more focus is on disaster response, relief and immediate recovery. And, hence institutional system, public policy, rules and procedures, people's orientations have been more towards post-disaster-related activities. Pre-disaster risk reduction has got the least attention and hence for addressing ex-ante is a challenge. This is true for most of the states. However, in the last two decades gradually its getting recognized at the policy level, legislation and new institutional system. But the pace is slow against the exposure of risk.

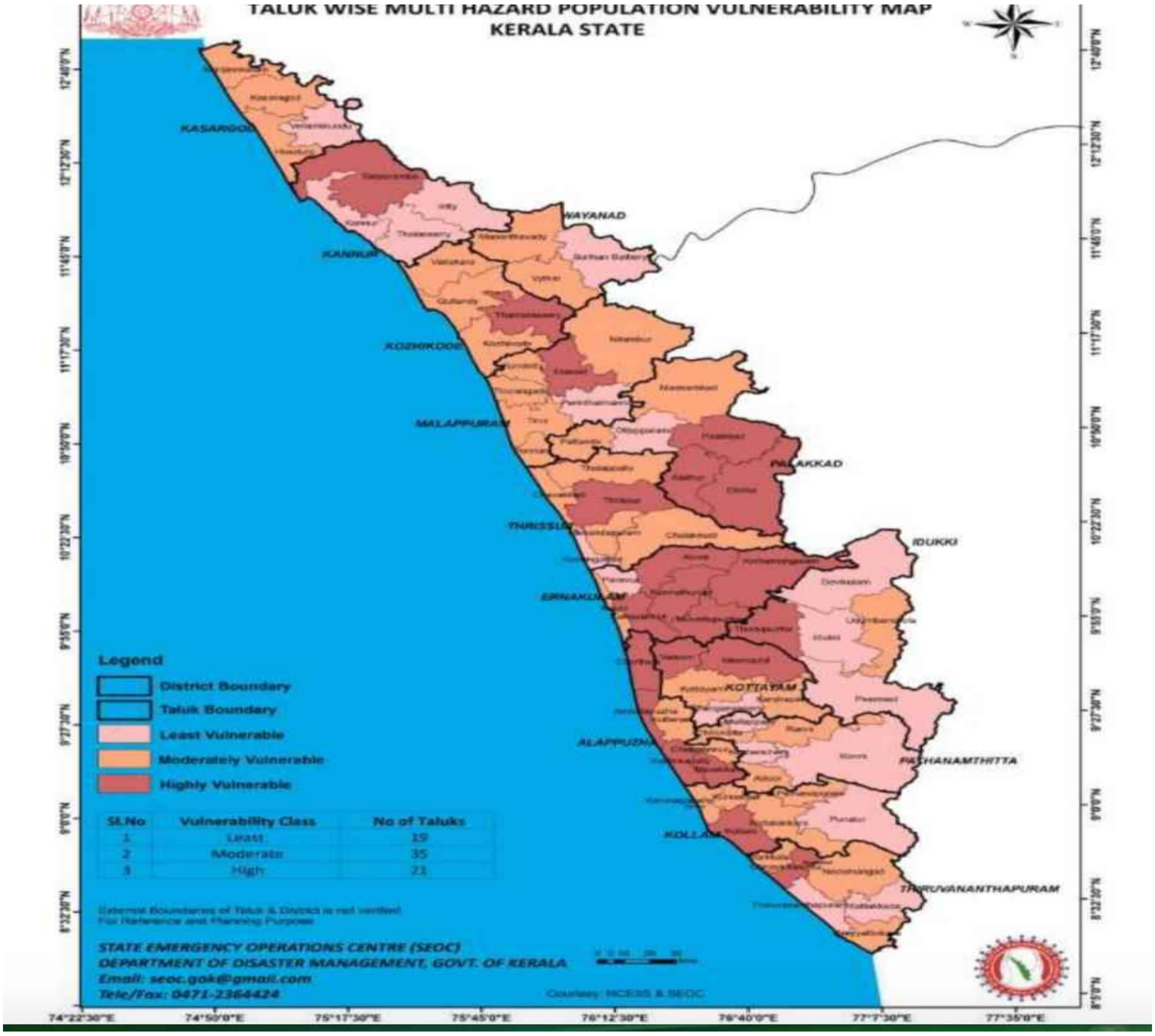


Figure 5.4 Multi Hazard Population Vulnerability Map of Kerala State

As per the flood guidelines of national disaster management Authority (NDMA) 2008, "floods have been a recurrent phenomenon in India and cause huge losses to lives, properties, livelihood systems, infrastructure and public utilities.

India’s high risk and vulnerability are highlighted by the fact that 40 million hectares out of a geographical area of 3290 lakh hectares are prone to floods. On an average every year, 75 lakh hectares of land is affected, 1600 lives are lost and the damage caused to crops, houses and public utilities is Rs. 1805 crores due to floods.” (Figure 4: Source-Vulnerability Atlas map KSDMA).

The Deluge of 2018 cost heavily on the people of Kerala. More than 433 people got perished. Out of total deaths, 62% were men, 23 % women and 15 % children. This figure is not the repeat story of the floods of other states in the country where mostly percentage of women get affected more than the men. Kerala is high on gender equity and also high on human development index than the other flood-affected states of India (Assam, Bihar, Uttar Pradesh, Jammu & Kashmir, Maharastra, Karnataka, Uttarakhand, Himachal Pradesh etc.). Around 14 lakh people had to be evacuated to relief camps, over 1.75 lakh building were damaged either fully or partially, affecting 7.5 lakh people. More than 1700 schools were used as relief camps. A total of 1613 school were affected by floods and schools were closed from 2 to 23 days. However, after opening of school attendance was recorded very low as 20% due to trauma and stress of losing beloved ones. Over 95,000 latrines were damaged affecting 4 lakh people. An estimated 317, 000 shallow wells were contaminated and access to pipe water was disrupted for 20% of the state population. The devastating floods and landslides caused extensive damage to houses, roads, railways, bridges, power supplies, communications networks, and other infrastructure; washed away crops and livestock and affected the lives and livelihoods of millions of people in the state. Early estimates by the government put recovery needs at about USD 3 billion; however, it was felt that a comprehensive assessment of damage, loss, and needs would amount to much more. The total estimated damage does not include damages to private buildings and properties including shops, showrooms, business units, private hospitals/educational institutions and private vehicles. It does not take into account losses incurred by private traders and business units and also damage, and loss suffered by Kochi airport, road transport and waterways. The total damage and loss now estimated at INR 26,720 crore in this report would be much higher, if these were included.

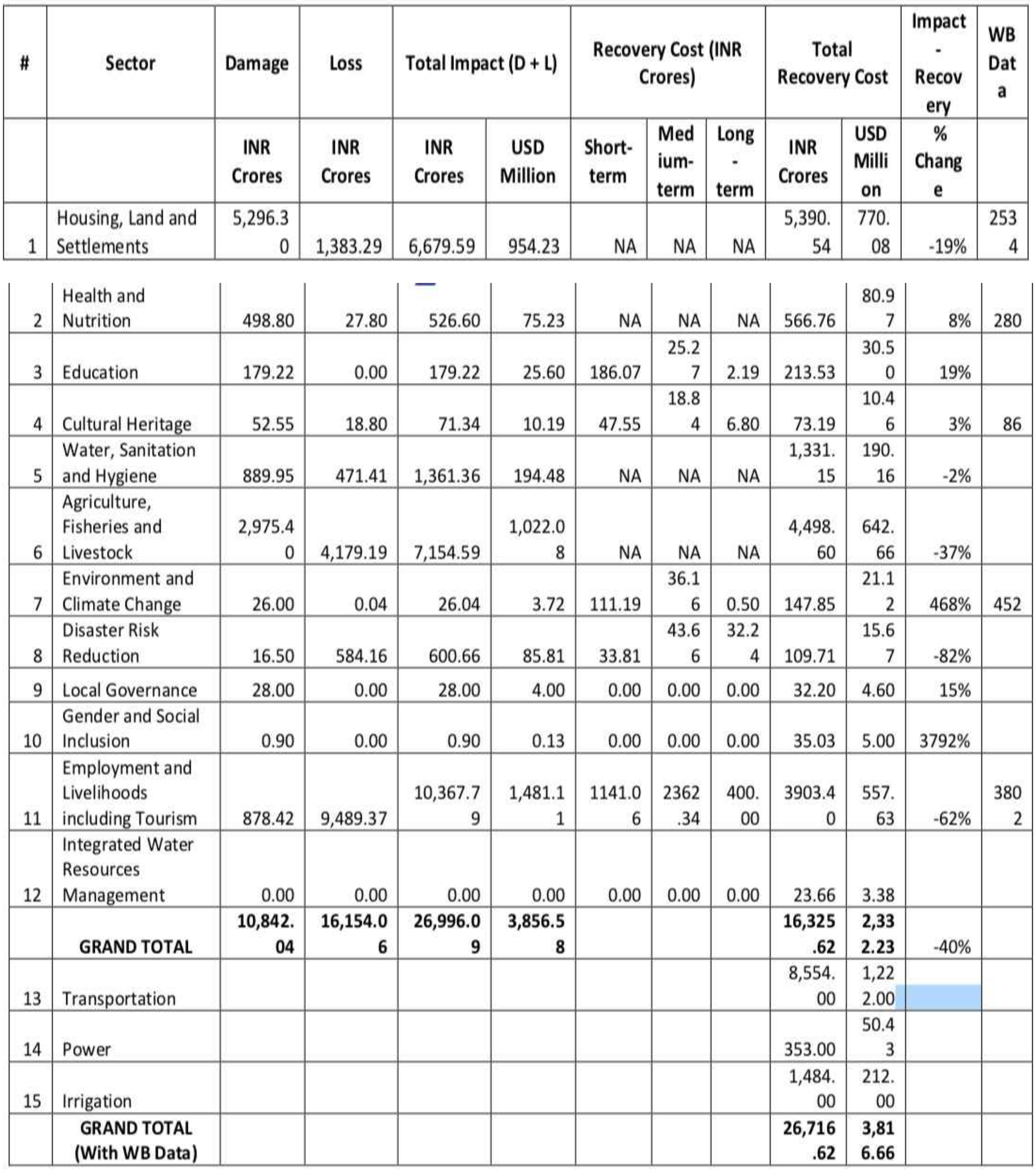
As per the Post Disaster Need Assessment (PDNA) the most affected sectors are infrastructure (38% of the total effects) which includes transportation and water, sanitation and hygiene, power, irrigation and other infrastructure sectors followed by cross cutting sectors (27%), social sectors (18%) and productivity sectors (17%). Over 1.75 lakh buildings have been damaged either fully or partially, potentially affecting 7.5 lakh people. More than 1700 schools in the state were used as relief camps during the floods. Most of the camps closed after 10 days. Floods affected teaching and learning in almost all the districts with institutions being closed from 2 to 23 days. A total of 1613 schools have been affected by the floods. Some schools in Alappuzha were closed for more than a month.

Among the worst affected were workers in the informal sector who constitute more than 90% of Kerala’s workforce. It is estimated that nearly 74.5 lakh workers, 22.8 lakh migrants, 34,800 persons working in micro, small and medium enterprises, and 35,000 plantation workers (majority being women), have been displaced from employment. Thousands of casual workers and daily wage earners such as agriculture labourers, workers in the coir, handloom, and construction sector and in the plantations have experienced wage loss for 45 days or more. Kerala has suffered huge economic losses on account of the floods. According to a conservative estimate, close to 2.6% of Kerala’s gross state domestic product (GSDP) got washed away by the floods instantly. Kerala state has a Scheduled Tribe population of 364,189, mostly concentrated in flood-affected Wayanad district (over 136,000 people). Scheduled Tribes (ST) are among the most disadvantaged socio-economic groups in India. (Census 2011, United Nations in India accessed on 15/08/2018) A lot of tribes live in remote and isolated forest areas, making them more vulnerable to natural hazards. Elderly people are disproportionately affected by natural disasters. Although Kerala has the highest life expectancy at birth in the country (71.8 years), it is also the state with the highest number of elderly people, with 12.6% of its population aged 60 years old or above. It also has the highest old-age dependency ration with almost 20%. (Government of India 2016). Floods disproportionally affect the poor, who generally live in more vulnerable areas in housing that is susceptible to damage by floods. (ACAPS 01/2012).

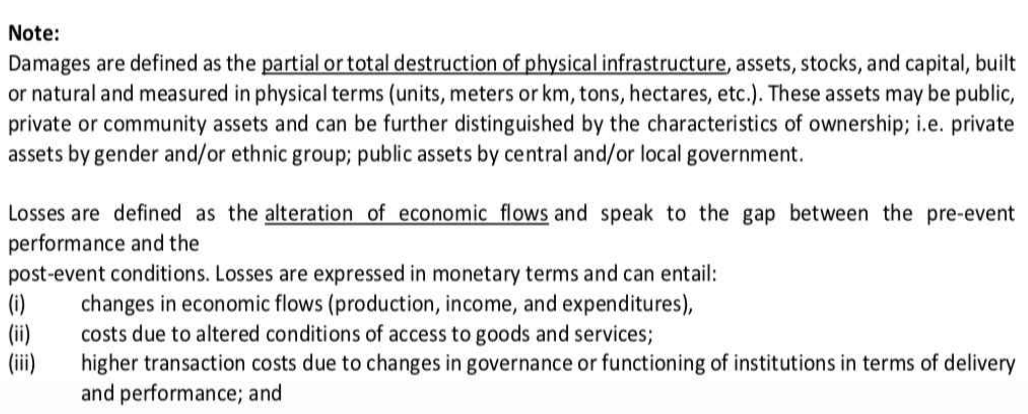
Central and the state governments including local government, people of Kerala, living in or outside Kerala, came forward and took up the challenges and could come out from the deluge to long recovery stage by taking extraordinary efforts collectively. The country has also faced such a problem in the past too but such high level of community response was not seen. Hence, it took time to other states to recover fully, but now they could recover well. Maharashtra(1993, 2005), Andhra Pradesh (1997, 2001) Orissa (1999), Gujarat(2001), TamilNadu (2005, 2015) , Andaman & Nicobar (2005), Jammu & Kashmir (2005, 2015), Bihar (2008, 2017) Uttarakhand(2015), etc. and few more state also got affected by floods and have gone through the process of long term recovery. As per the World Bank damage assessment report, the current flood led to the loss of approximately US$ 3.8 billion and little more nearly US $4 billion is the recovery cost. It is a huge impact on public assets in a smaller state like Kerala. Most of the districts, 12 out of 14, got affected by floods. Refer pic 1 the map of Kerala showing the how it was affected. The devastating floods leading to massive landslides caused extensive damage to houses, roads, railways, bridges, power supplies, communications networks, and other infrastructure. Livelihood got seriously affected, crops and livestock and affected the lives and livelihoods of millions of people in the state. As per the Post Disaster Need Assessment (PDNA) conducted by United Nations Development Programme (UNDP) in collaboration with Government of Kerala estimates the total damages to be around INR 10,557 crore (direct loss on current price) and total losses (loss of flow-revenue) to be around INR 16,163 crore amounting to a total disaster effects of around INR 26,720 crore (USD 3.8 billion). According to a conservative estimate, close to 2.6% of Kerala's Gross State Domestic Product (GSDP) got washed away by the floods instantly.

Kerala needs INR 31,000 approximate crore to rebuild itself from a natural disaster that is probably the worst in a century. The policy of non-acceptance of foreign financial assistance has been the practice in India but if any country is giving on their own , in such situation country accept the aid.

Table 5.9 Sectoral damage loss and need assessment data (UNDP/Govt of Kerala PDNA)



#	Sector	Damage	Loss	Total Impact (D + L)		Recovery Cost (INR Crores)			Total Recovery Cost		Impact - Recovery	WB Data
		INR Crores	INR Crores	INR Crores	USD Million	Short-term	Medium-term	Long-term	INR Crores	USD Million	% Change	
1	Housing, Land and Settlements	5,296.30	1,383.29	6,679.59	954.23	NA	NA	NA	5,390.54	770.08	-19%	2534
2	Health and Nutrition	498.80	27.80	526.60	75.23	NA	NA	NA	566.76	80.97	8%	280
3	Education	179.22	0.00	179.22	25.60	186.07	25.27	2.19	213.53	30.50	19%	
4	Cultural Heritage	52.55	18.80	71.34	10.19	47.55	18.84	6.80	73.19	10.46	3%	86
5	Water, Sanitation and Hygiene	889.95	471.41	1,361.36	194.48	NA	NA	NA	1,331.15	190.16	-2%	
6	Agriculture, Fisheries and Livestock	2,975.40	4,179.19	7,154.59	1,022.08	NA	NA	NA	4,498.60	642.66	-37%	
7	Environment and Climate Change	26.00	0.04	26.04	3.72	111.19	36.16	0.50	147.85	21.12	468%	452
8	Disaster Risk Reduction	16.50	584.16	600.66	85.81	33.81	43.66	32.24	109.71	15.67	-82%	
9	Local Governance	28.00	0.00	28.00	4.00	0.00	0.00	0.00	32.20	4.60	15%	
10	Gender and Social Inclusion	0.90	0.00	0.90	0.13	0.00	0.00	0.00	35.03	5.00	3792%	
11	Employment and Livelihoods including Tourism	878.42	9,489.37	10,367.79	1,481.11	1141.06	2362.34	400.00	3903.40	557.63	-62%	3802
12	Integrated Water Resources Management	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.66	3.38		
	GRAND TOTAL	**10,842.04**	**16,154.06**	**26,996.09**	**3,856.58**				**16,325.62**	**2,332.23**	-40%	
13	Transportation								8,554.00	1,222.00		
14	Power								353.00	50.43		
15	Irrigation								1,484.00	212.00		
	GRAND TOTAL (With WB Data)								**26,716.62**	**3,816.66**		



Note:

Damages are defined as the partial or total destruction of physical infrastructure, assets, stocks, and capital, built or natural and measured in physical terms (units, meters or km, tons, hectares, etc.). These assets may be public, private or community assets and can be further distinguished by the characteristics of ownership; i.e. private assets by gender and/or ethnic group; public assets by central and/or local government.

Losses are defined as the alteration of economic flows and speak to the gap between the pre-event performance and the

post-event conditions. Losses are expressed in monetary terms and can entail:

(i) changes in economic flows (production, income, and expenditures),

(ii) costs due to altered conditions of access to goods and services;

(iii) higher transaction costs due to changes in governance or functioning of institutions in terms of delivery and performance; and

5.1.3 Reasons for the flood:

Many stories are cropping up regarding the present Kerala floods. The most debated was whether the present "disaster" is a natural or man-made. In such scenario, the popular argument is it was excessive rains and we can not do anything about it and hence the disaster. Off-late this argument doesn't hold good as the narratives are that all these extreme events are natural activities and when it interfaces with human and human induced activities it gets converted into disaster. Our development initiatives are not been able to recognize the impending threat and we keep making risk blind investment, land use and building by laws. Or even if the laws are risk sensitive, the implementation is risk blind. Most of the low line areas of Kerala and also the natural water flow runway from the dam, the down stream is chocked. I legal occupation of the land in down stream and construction in the low lying areas converted heavy rains into disaster. The 2018 floods of Kerala is both rural and urban flooding.

As per CWC, India is having more than 600 big dams spread across the country and the larger concentration of dam is in the north west and south west of the country. Some of them have aged and many more are ageing. Biggest dam disaster without the dam breach was seen during Kerala flooding where water released from the dam was enormous rather we can say unmanageable discharge. Leading to an historical disaster killing more than 430 people and consuming more than Rs 26000 crore (World Bank 2018) worth development investment. Recently in Brazil, the dam collapsed on January 25th 2019 killing more than 350 people (The Economist, Feb, 2nd 2019). Management of Dams and reservoirs are going to be a new challenge in the changing climate scenario where large rains come in very short span of time. Down stream development is also taking place simultaneously. Land use pattern changing its vulnerability everyday and making risk more high and dynamic. -

One of the reasons for the havoc is extreme rainfall, between 1 August to 19 August 2018, Kerala had received 758.6 mm rain which is 164 percent above rainfall but we cannot prevent extreme rainfall but the factors which have aggravated the impact of rainfall are by allowing unprecedented illegal stone quarrying, deforestation, sand mining, change in land use (reduction in paddy fields) and changing drainage pattern.

Inadequate management of dams is the second reason for devastation. India is home to 5,000 large dams (greater than 15 m in height) third largest after USA and China. Kerala is home to 57 large dams out of which 4 dams are operated by Government of Tamil Nadu. The water levels in several reservoirs were almost near their Full Reservoir Level (FRL) due to continuous rainfall from 1st of June. Dam can limit the flood damage but to truly tame floods, dams need to be relatively empty before the onset of rains but the Idukki dam was already near full capacity till July end. The river downstream, its flood plain and even the river bed, not used to having regular floods, may have changed, with false sense of security that people are given/they get. The carrying capacity of the downstream river may have changed and is required to be studied. The river immediately downstream of Idukki dam has seen no flows for 26 years, the last time the gates were opened was in 1992.

Third, Dams emergency action plans (EAPs) two largest reservoirs Idukki and Idamalayar in Kerala have been operating for years with inadequate emergency action plans. In January, CWC published guidelines for preparing operating manuals for dams after a 2017 report from India's Comptroller and Auditor General (CAG), criticized the lack of dam operating manuals and emergency action plans (EAPs) for reservoirs. These dams also lack "rule curves'' which means that level of water that can be maintained safely behind a dam. Every dam is supposed to have a dam specific rule curve that tells, among other things, how the dam is supposed to be filled during the monsoon, to optimize flood moderation for the downstream area, while ensuring that the dam is filled up only closer to the end of the monsoon. Almost all the dams in Kerala were almost full by the end of July. The rule curve of the dam may also be studied in the context of the 2018 floods of Kerala, as end of July is just half through the South West Monsoon and large parts of Kerala also gets benefit from the North East Monsoon, that follows SW Monsoon. So to fill up the dams by end of July was sure invitation to disaster.

Fourth, a committee was set up in 2011 under an ecologist Madhav Gadgil which come up with a report called Western Ghats Ecology Expert Panel (WGEEP) and suggested classification of Ghats into three zones: Ecologically highest sensitive zones (ESZ1), where certain types of areas would be "no-go", including water courses, water bodies, special habitats, biodiversity rich areas, and sacred groves; ecologically high sensitive zones (ESZ2), where construction of new railway lines and major roads would not be allowed, except when "highly essential"; and ecologically moderately sensitive zones (ESZ3), where new energy projects and infrastructure such as roads may be allowed but with "strict environmental regulations" suggested prevention of any stone quarrying, construction activities, deforestation, sand mining. Kerala has a 15-year-old law called the Kerala Forest (Vesting & Management of Ecological Fragile Lands) Act 2003, which says people can be evicted from protected areas, such as wildlife sanctuaries and national parks. In the context of new development paradigm this could have been seen as an important tool of planning.

Fifth, as a part of shelter management, The National Cyclone Risk Mitigation Project is a project with the Government of India, the National Disaster Management Authority under the Ministry of Home Affairs, the National Institute for Disaster Management and participating coastal states. As per the World Bank Review Mission Report for Phase II, the project got board approval in 28 May, 2015 with effect from 09 November, 2015. Kerala has committed to building 27 multipurpose floods/cyclone shelters (MPCS) under the project, and as per the report the implementation progress was unsatisfactory and the State Project Implementation Unit (SPIU) needs to expedite the process. Now, the government has planned to complete 17 (MPCS) by March 2020. If proper consideration was given to this in 2015 then the different needs of affected households for safety, privacy, would have been be addressed appropriate to the context and available resources instead of current chaos.

Last but not the least, flood forecasting sites & public warnings, Kerala gets no flood inundation modeling, flood early warning system from Central Water Commission (CWC). It is a matter of concern that CWC has no flood forecasting sites; it only has flood monitoring sites in Kerala. Now, CWC should include some of the major dams of Kerala such as Idukki & Idamalayar as flood forecasting sites. Also, early warning has very less importance if it doesn’t reach to the public in a simplest and quick manner. Evacuation warnings are generally given through microphone announcements about opening of dam gates but in Kerala the warnings may be given but they were inadequate in terms of safer places, amount of water to be released, area to be submerged etc. Generally, it has been seen that people resist in evacuating their homes considering the less impact of floods but when they were aware of the intensity and place to be submerged they will be in a better position to take a decision.

5.1.4 Aggravating factors

a. Prolonged monsoon season

This flooding episode is the second one to have occurred in Kerala since the beginning of the monsoon season in June. Heavy rains that began around 9 July 2019. Kottayam, Alappuzha and Ernakulam districts were the worst affected areas. Although the rainfall is expected to be less heavy over the coming days, the monsoon is expected to continue until September. The monsoon usually lasts between June and September. In India, the rains have had a particularly severe impact in 2018, causing 774 deaths since May.

b. Population density and settlement

Kerala state is 38,852km2, and its population density is around 860 people per square kilometers, which is three times the national average of 324 people per square kilometers, making it one of the most densely populated states in the country. Settlements are taking place in the low lying areas with complete ignorance of building design, building byelaws, land use planning etc. It seems lessons of 1924 could not get translated into the planning and development process of Kerala.

c. Location and type of housing/infrastructure

Roughly, 50 percent population lives in rural and 50 percent in urban areas. Housing in Kerala is for the most part resistant to floods about 87% of the population lives in ‘pucca’ housing (solid and permanent buildings), and 11.4% in ‘semi-pucca’ housing (semi-permanent). An estimated 6,500 people are living in slums or squatter settlements in urban areas in Kerala. (Government of India 20120. However, if we see the damage pattern the housing sector loss is around of Rs. 5500 crores. So, it seems that the quality of the housing and design suited the flood prone areas have to be improved substantially.

d. Agriculture & Livelihoods

Flooding can have a long-term negative impact on agriculture and rural livelihoods. Each year vast areas of agricultural land are lost or damaged during the monsoon. In Kerala state, during the 2017 monsoon, coffee crops already suffered a drop of 40% compared to 2016. Rubber plantations in the central part of the state have been negatively impacted by continuous rain over the last five months. This significantly affects the livelihoods of the population dependent on agriculture for their income. (The Times of India 14/08/2018)

e. Other factors of vulnerability

Local authorities were forced to open 27 reservoirs to absorb excess water caused by flooding. One of the reservoirs had not been opened for 26 years. (Le Monde 12/08/2018) The release of water from the dams exacerbated the flooding, especially in Idukki and Ernakulam districts. (Act Alliance 11/08/2018) As of 14 August, the cumulative water released was 237,872 million cubic meters. (The Times of India 14/08/2018). There are concerns in Kerala state that a dam in Mullaperiyar located further upstream could break due to the pressure of the high water level. Overflowing of the Mullaperiyar dam would affect the Idukki dam area, further aggravating the damages caused by floods (The Times of India 14/08/2018).

f. Complacency about the disaster

Since Kerala did not face big disaster after 1924, the people administration and other stakeholders did not prioritize disaster management in their day to governance. People also did not take it in that perspective it seems. Govt of India brought legislation on disaster management called DM Act 2005 , after that it also brought national policy on disaster management in 2009 which focuses on strengthening disaster management system and building capacity of the local level of governance. Under the policy both national and state levels institutions are to be strengthened for taking actions for pre disaster risk reduction and post disaster response. Immediate recovery and response system have approved but ex-ante disaster risk reduction system is still weak. The lessons of 1924 could be translated into the habit of the people for taking pre disaster actions.

5.1.5 Immediate Response and Recovery

Disaster management and governance is generally viewed and practiced from the mitigation, planning, management, response and recovery sequence (Waugh 2000; Hy & Waugh, 1990). During a disaster it is necessary to reduce the uncertainty by anticipating problems and solutions (Hy & Waugh, 1990, p23). What theories influence or should influence the disaster administration? A number of theories which are relevant with reference to disaster administration includes chaos theory, communitarian, critical, cultural, Marxist, populist, pragmatist, rational and social constructivist. Also analysing the theory will better help us to identify the theory and practice gap. Frederickson and Smith (2003) classify theories as political control of bureaucracy, public institutional theory, postmodern theory, theory of bureaucratic politics, decision theory, rational choice theory and theories of governance.

Incident Response System (IRS) is generally available in all the disaster management plans which is centralised but the number of theories have a direct impact on planning and management of disasters such as chaos theory (Kirschenbaum, 2004).Communitarian theory provides the flexibility to shift the responsibilities during disaster planning and response from communities to government and back to communities if government fails. Etizoni (1996), also includes responsiveness as a definite characteristics of community that addresses the need of its citizens. Critical theory provides the framework to analyse the inequality and exploitation that are built into the structure (Gotham, 2005, p.95). Disaster administration can benefit from multitude of theories and like the same way theory can benefit from the practices. Administration theories may not be able to predict the realities of next disaster because no two disasters are alike but learnings and experiences help to manage it better.

With growing importance and increased attention it is necessary to have a new theoretical perspective is required in disaster management. Also public administration should develop theory and ideals for disaster administration. For formulating theory there is a need to reduce the uncertainty and provide concrete solutions, communication success and failures need to be ascertained, events need to be described and predicted, response and coordination mechanism needs to be documented, human behaviours need to be anticipated.

During the planning/ mitigation phase hierarchical ideals are based on structuration (Giddens, 1986) and bottom up approach (Schneider, 1992, p.136). When disaster strikes, management and response hierarchies become more bureaucratic with top-down approaches. The hierarchy becomes centralised and stakeholders involved in disaster response need tactful action and decisions which leaves less time for reflexivity which is critical thinking which will lead to critical, responsible and ethical actions (Cunliffe & Jun , 2005, p. 225).

While the disaster administration is the quintessential role of the government (Waugh, 2000) and the increased number of disasters and extreme events have certainly encouraged greater attention towards disaster administration and the number of researchers involved in disaster administration is relatively small as compared to researcher in other social science disciplines.

Collaborative decision making has been widely recognised by scholars (Hills, 2004; Raiffa, et al, 2002; Turoff, et al, 2008). Collaborative decision making can be defined as combination and utilisation of resources and management tools by several entities to achieve a common goal. One of the important reason for failure has been insufficient organisational resources and unpreparedness of the organisation involved in emergency management. (Kapucu & Van Wart, 2006). Collaboration occurs when people from different organisations produce something together through joint resources, decision making and ownership.

The state government responded swiftly with rescue and relief operations and saved many lives by rapidly mobilising the following national forces, around 4, 100 Kerala Fire and Rescue Services individuals along with the entire rescue equipment deployed; National Disaster Response Force (NDRF) 58 teams with 207 boats and other equipments; Indian Army: 23 columns with 104 boats; Navy with 94 rescue teams, one medical team, nine helicopters, two fixed wing aircrafts and 94 boats; Coast Guard with 36 teams, 49 boats, two helicopters, two fixed wing and 27 hired boats; Air Force with 22 helicopters from Air Force and 23 fixed wing aircrafts; Central Reserve Police Force with 10 teams and Border Security Force with two companies and one water vehicle team.

In addition, the fishing community of the state rendered phenomenal voluntary assistance towards search and rescue in the flood affected areas. Nearly 669 boats that went out with 4,537 fishermen are estimated to have saved at least 65,000 lives.

The Government of India announced an additional assistance of INR 600 crore (USD 85 million)10 which included ex-gratia payment of INR 2 lakh (USD 2,800) per person to the next kin of the deceased and INR 50,000 (USD 700) per head to those seriously injured. The Ministry of Rural Development sanctioned an additional INR 1,800 crore (approximately USD 260 million) under the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) for 2018–19 for 5.5 crore person days of work. Relief assistance was provided to people in camps including immediate food supplies (rice, wheat, and pulses), drinking water, kerosene and other life-saving items. Food packets and assistance of INR 10,000 per family to clean inundated houses were also disbursed.

5.2 Good practices and lessons learned

5.2.1 Community Resilience during Kerala Floods-2018

Social capital and community cohesion are critical in supporting resilience to flood events. These aspects are currently underemphasised in emergency response and policy strategies when compared to material and infrastructural components of flood resilience. Importance of community cohesion and social networks in mitigating negative impacts to well-being during and after flood events is significant. The Kerala Floods 2018, have exemplified the tool of community resilience in the best possible way. These include formal and informal modes of support, for example fishermen offering their services to rescue people and donating to relief efforts, telecom giants Jio, Vodafone providing free services in the flood affected areas, huge contributions made to the CM’s relief fund, faith based volunteers offering free food to the victims. The presence of support workers and volunteers have also formed an important part of the social infrastructures relevant to community resilience. Community workers provide localised support measures but also offer a link to more formal institutional mechanisms. Kerala flood 2018 saw a strong connect of social capital and its attributes, it’s technical expertise present all over state enabled in better response, researchers of Amrita Vishwa Vidyapeetham University designed an app called AmritaKripa designed for disaster management which helped locate, rescue and provide relief to over 12,000 people stranded in floods all over Kerala which enabled better information sharing with response agencies for effective response, a Kozikhode-based social networking app, Qkopy, helped spread traffic related information regarding the floods which gave the updates of traffic shared by traffic department These updates are one-way communication alerts that inform about the condition of different areas, so that people know whether to avoid or visit them.

Stress and anxiety as a result of flooding are likely to not be reported yet they impact on the personal and work lives of those affected. Well-being impacts are seen in those with professional roles such as engineers and front-line workers, and are related to working with people in extreme distress, and the emotionally charged nature of political and public debate creating highly stressful working environments. Within the stories of flooded individuals in Kerela, there were many examples of how the negative impacts of flooding could be mitigated by support from the community, through the networks and relationships that exist for example through schools, the Church, or friends and neighbours. Community resilience is particularly important in cases where infrastructural resistance and resilience is not possible. Community help and cohesion plays a particularly important role in mitigating the mental health and well-being impacts from flooding, which are long lasting and complex, and rarely resolved when the flood waters have receded

5.2.2 Fishermen: The Unsung Heroes

Noteworthy courage and strength has been exhibited by the Fishermen community in Kerala. Hundreds of fishermen reached out to the worst-affected areas from far-flung places, spending their own money to transport their mechanised boats and fuel in trucks.

In absolutely difficult circumstances, fishermen helped rescue thousands of people across the affected areas.Their familiaritywith the local topology and experience in turbulent waters helped facilitate the rescue operations carried out by security forces and NDRF in areas where air lifting was not even feasible or just not available. Incidentally, just a few months ago these same fishermen were reeling from the aftershocks of the Ockhi cyclone and are still themselves recovering. Venturing into the remote corners with their vessels, they played a decisive role in rescuing people from critical areas like Chengannur and Kuttanad and provided relief materials, essential food items and drinking water to rescue camps. Most of the fishermen involved in the herculean task hail from districts such as Malappuram, Kollam, Kannur, Thrissur, Ernakulam and Thiruvananthapuram. They live in dire conditions, working day and night to make their ends meet, but still took the risk of saving people.Despite the offer of the payment from the government for their lossess occureedduring response, the fisherment denied of taking any assistance in this regard. In fact they mentioned that “ they are our own people and it our duty to save their lives a community.”

Source: Santosh kumar NIDM

Use of indigenous knowledge and their personal experience led to a better understanding of the helplessness of those trapped in coastal areas. The ‘sons of the sea’ truly deserved to be called bravehearts of the rescue mission. According to experts, the design of their wood and fibre twin-engine country boat is adept at navigating strong undercurrents and withstanding damage by underwater objects. And particularly heartwarming is the fact that instead of waiting for government aid to come along, the fishermen pooled money from their own pockets to hire trucks that would transport their boats to flood-hit areas. As many as 952 fishing boats and more than 4,500 fishermen from coastal areas of Kerala rescued at least 65,000 people between August 15 and August19.

According to a rough estimate by Pathanamthitta collector Nooh, out of all the people rescued in the district, 70% were saved by fishermen, 15% by NDRF and forces, and 15% by the locals. There were cables and electricity lines that boatmen had to cut to make way, submerged walls and fences that they ran into every now and then, furniture pieces and dead animals floating on the water, and snakes hanging on to tree branches, walls and gates The good part was on that they could access those areas which were not possible for navy and coast guard and National Disaster response Force because of the non familiarity of local terrain and their equipment's. Secondly the commitment towards the affected communities was so high that they did not charge a single penny to any one for the services rendered. "Its our people, It our own brother and sisters, how can we charge them." Said one of the fishermen during the interaction.

5.2.3 One God one Religion

Kerala has a large diversity of religious groups within the state with the majority of Hindus, Muslims comprise of 26.5% and Christians 18.38% of the population.Kerala flood also buried religious differencesDisaster destroy economic –social and religious differences. People from religions opened their hearts to extend their support irrespective of religious identity. All the places of worships/offering prayer were left open for providing shelters to the affected peole. Faith based organisations came forward to serve the people. Compassion with passion was the key principle which emerged foor disaster response. Local communities, organisations and governments have the greatest capacity to offer assistance. These bodies are embedded in the local community, speak the local language and understand the local culture. They know who in the community is most vulnerable and what people and infrastructure is available to assist.

5.2.4 Women Leadership

Women empowerment have been a very old and popular debate. Despite of many public policy intervention it has not changed much. Kerala is a different state as explained earlier in terms of gender sensitiveness and empowerment. The pivotal component of any community is the women population. The role of women in the aftermath of Kerala Floods requires special attention. Women workers broke the conventional chains of restraint and emerged as superheroes by contributing significantly in the relief and rehabiltation process. The support rendered by women groups is the gesture of a fine model of community service by the self-help group in post-disaster reconstruction.

Workers of the Kudumbashree(a women led civil society group) poverty eradication and women empowerment programme were involved in the cleanliness and sanitation of public spaces.Kerala was facing labour problem in the post disaster immediate recovery stage. Migratory workers from different states who were working in Kerala, most of them had gone back to their respective places. It is the women of the state of Kerala which took the challenge and over 1.13 lakh residential premises across 10 districts were cleaned up and made habitable by them . They had also cleaned over 3,100 public spaces while our community counsellors, 320 in all, offered psychological support to over 11,000 affected people.

Kudumbashree workers were active since initial days of the flood in cooking food, packageing and distributing meals to the affected people. A total of 6,757 women from the Kudumbashree neighbourhood groups at Kalanjoor, Nedumbram, Enadimangalam, Kadambanad, Ezhamkulam, Peringara, Koduman, Adoor, Pallikkal, Kadapra, Enath, Niranam, Panthalam, Kuttoor and Konni panchayats and Thiruvalla municipality were mobilised to clean living premises at Peringara, Niranam, Nedumbram, Kuttoor and Kadapra panchayats and within the Thiruvalla municipality. Each cleaning team had about 20 to 25 women equipped with bleaching and cleaning lotions. They were supported by the respective panchayats, Health Department and Accredited Social Health Activists (ASHA workers).

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In India, in many instances, women have played significant role in recovering from disasters both in pre and post disaster scenario. women members have been able to demonstrate their roles compared to male in disaster preparedness ,risk reduction post disasters rehabilitation, reconstruction, restoration etc. This is an example of breaking the stereotypes- a departure from the traditional thinking about women only as just home-makers but they are risk managers too.

5.2.5 Role of Digital Media

Technology could play a pivotal role for communities in times of a disaster. Twitter, Facebook, whats'app and other social media networks provided an opportunity be transparent and also fast and beyond any glitch. Social media could help in i) sharing information and spreading awareness for relief operations ii) in mobilizing funds iii) monitoring and iv) in providing insights to the whole situation.

During Floods, various Facebook groups like 'Trivandrum Indian', 'Where In Trivandrum' and Eat-At Trivandrum were in the forefront of flood relief activities. The social media groups had changed into a control room of sorts, aiding tremendously with the relief measures. Distressed messages were posted by people facing acute shortage of food water and mediciene. By the time information went viral on social media, people poured in with their need.

Residents all over the state could make appeals on social media for help, The families trapped in high rise flats, students stranded in hostels and devotees in churches used social media platforms to seek help and pass on information about their location using Google maps.

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Keralarescue.in is another initiative by the state government which allowed people to seek or offer relief. By visiting the website, one can request for help, make a donation, find a relief centre, get important contact information, and/or volunteer for their services.

Along with the state government, common people too were relying on digital solutions to help the flood-hit state. A group of freelancers across Twitter had designed a platform on Google Maps that compiles and provides verified locations for shelter, rescue, food and water, volunteers, helpline, relief collection, transportation, medicines and more across Kerala.

Google's Person Finder is an ideal tool in disasters like floods, where there are numerous people on the lookout for any scrap of information about their family and friends. The option allows to either find, or provide information about someone. Navy and air force also used social media platforms to coordinate with people and initiate rescue operations. It was estimated that around 1.5 lakh individuals have been rescued through these channels, though exact figures are not yet known.Using Google location and tracking, they had been able to gain proximity to even remote locations

5.2.6 Disaster Long Term Recovery

Nava Keralam is the government's vision of converting the crisis into an opportunity by more explicitly embedding the idea of building a green and resilient Kerala into the Approach Paper to the Thirteenth Five-Year Plan, the Disaster Management Policy, the State Water Policy, and the Gender Equity and Women's Empowerment Policies of Kerala. The recovery policy framework for building a Green Kerala committed to: (i) the Chief Minister's vision of a Nava Kerala (New Kerala), and (ii) the concept of 'build back better and faster' rests on four pillars.

Pillar 1: Integrated water resources management (IWRM)

CWC in its report vetted that "continuous heavy rains and topographical factors were the inclining factor of the flooding in the state. Even though the dams would have been opened earlier, it would had a lesser impact on the current status of flooding. But it was noticed that Kerala received the heavy rainfall in three in-stints It has been vetted that the dams were already near toFRL level by the end of the July. If the dam operation authorities would have released 25 percent of its water between 1st to 9th august, it would have different impact than that of releasing the water from 14 August, 2018. The figure 5.5 & 5.6 below shows the inflow and outflow of the Idduki and Idamalayar Reservoir. This shows there is a need to develop comprehensive dam operation manual with scientific predication with probable area of submergence and mapped data.

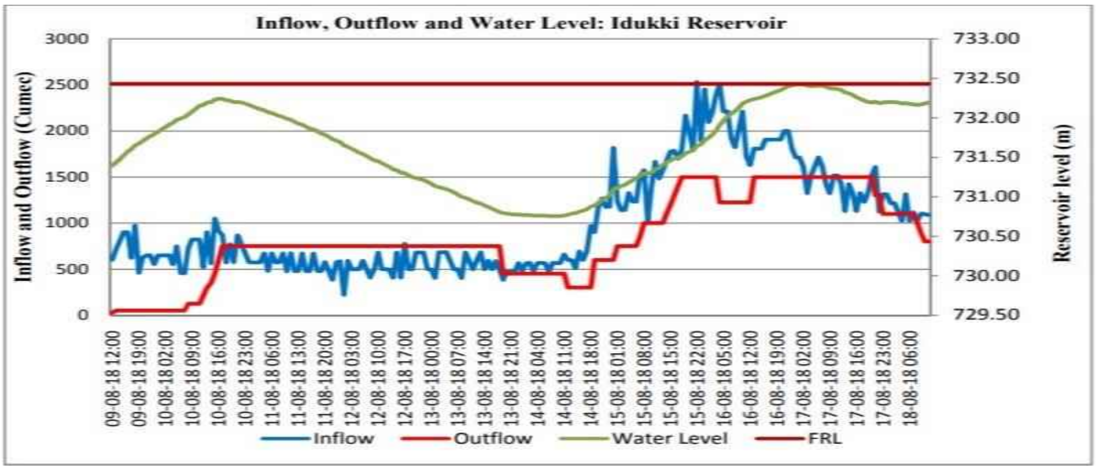


Figure 5.5 Inflow Outflow and Water level at Idukki reservoir

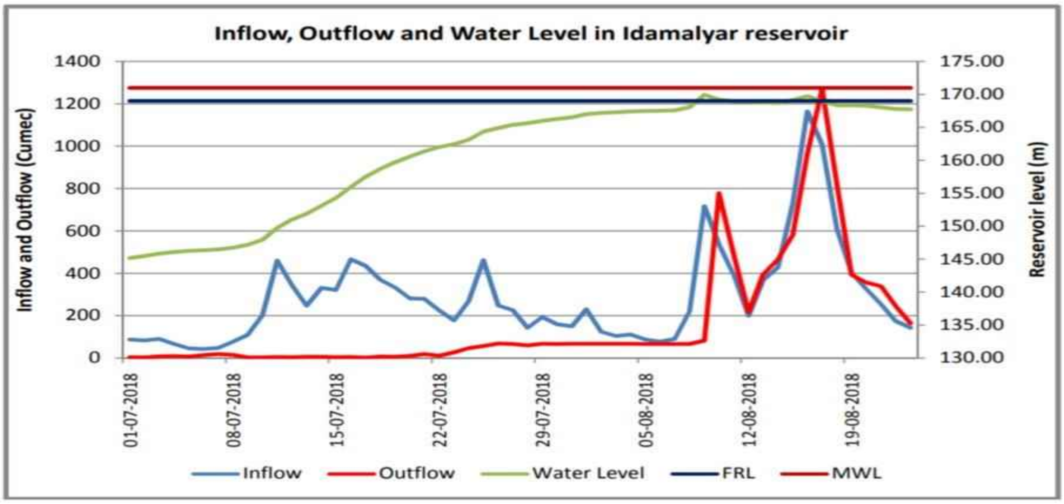


Figure 5.6 Inflow Outflow and Water level at Idamalyar reservoir

Pillar 2: Eco-sensitive and risk-informed approaches to land use and settlements

It has become inevitable for the people of Kerala to follow the lessons learnt and the exposure of risks of their state in changing climate situations where hydro –meteorological disaster is going to be intensified further. entire recovery has to be planned in all the investment to be made in building navkeralam.

Pillar 3: Inclusive and people centred approach

Disaster recovery and disaster risk reduction both have to be made inclusive. The aged population, differently abled people, children , poorest of the poor all have to go through different experiences at the time of disaster and hence different interventions have to be designed suited to different set of people depending upon their exposure. One size fit to all will not work. Different interventions should be designed to different set of people depending upon their vulnerabilities.

Pillar 4: Knowledge, innovation, and technology

An assessment of flow forecast at key points along the drain networks, It should include following recommendations-

1) Points Identification

All the key points along the drainage network in the selected sub basins which are likely to be impacted during extreme weather events should be identified for estimation of flows in the drainage network. These points may include, but not limited, river system, canal system , MI Tanks, crossing points like road and rail crossings and point close to habitation etc.,

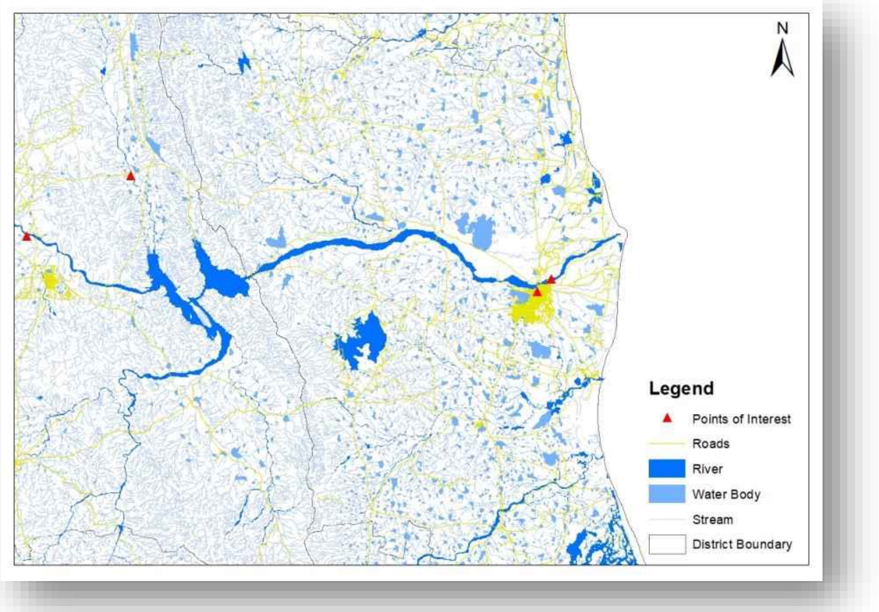


Figure 5.7 Points of Interest

2) Catchment Area Generation:

Catchment area delineation tool should be used through which both independent as well as full catchment areas can be delineated for any given point.

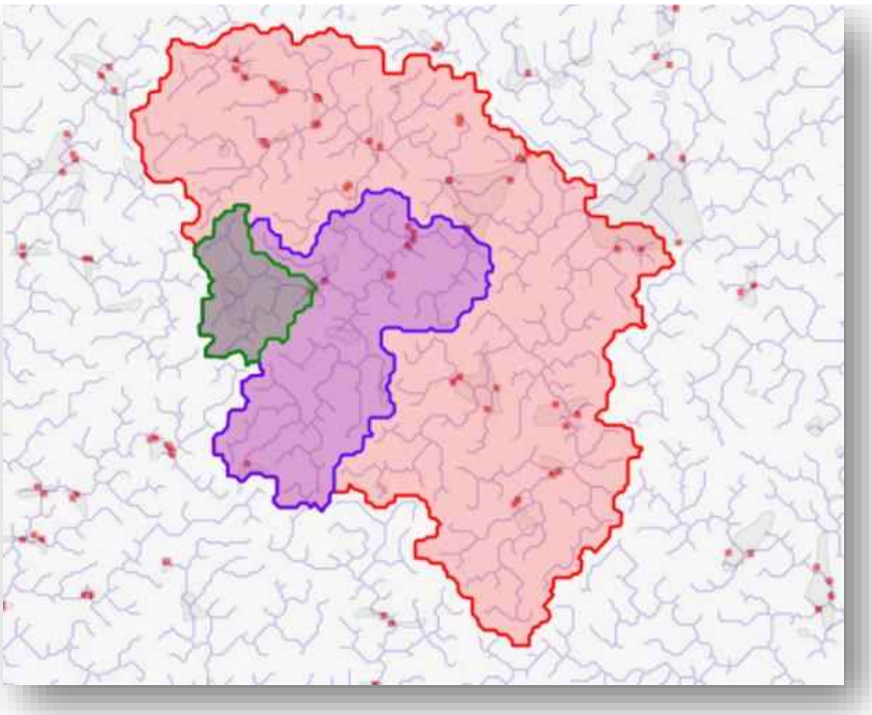


Figure 5.8 Catchment Area Delineation

3) Hydrology Model:

Hydrology Model should be implemented, which uses high resolution Digital Elevation Model, Land use Land Cover and Current and Forecast weather parameters like Rainfall, Temperature, Humidity and Wind-speed to compute runoff generated in each individual grid of the catchment area for the key point of interest.

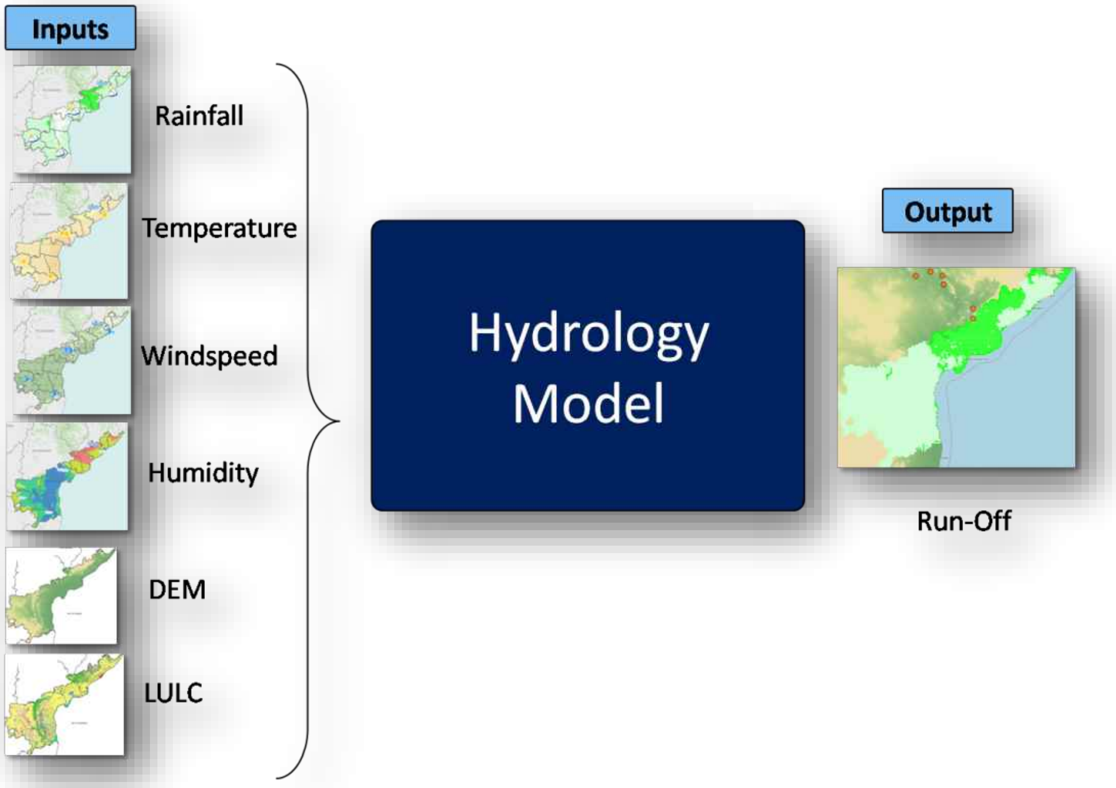


Figure 5.9 Hydrology Model

4) Flow Routing Model:

Flow routing model will be implemented to measure the time delay required to collect runoff generated in each grid of the catchment area at the point of interest.

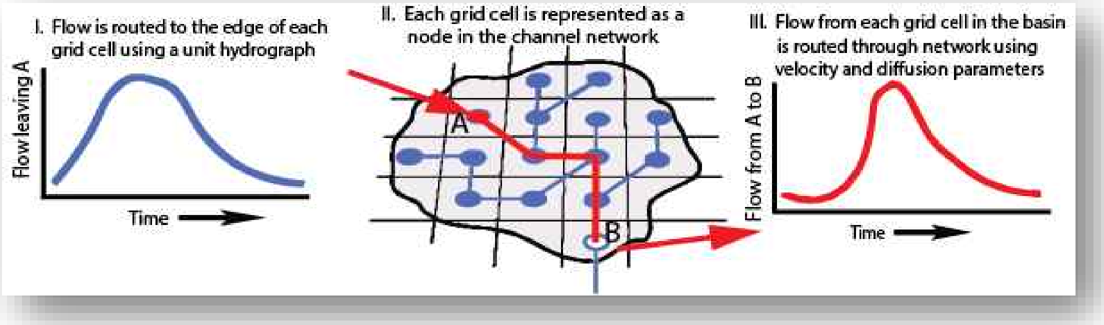


Figure 5.10 Flow Routing Model

5) Estimation of Drain Capacity at key points along the drain network

Using the high-resolution DEM derived from the drone-based survey, the system will compute the drainage profile (Cross section, Slope, bed level, and full supply level) and carrying capacity of drainage network for the identified key points of interest. This information will be used during the extreme events to compute whether flows in the drainage within the capacity level of the drain or not, if not system will raise an alert and communication will be sent to officials using existing alert system followed by the disaster management team.

6) Estimation of Inundation area and its Impact

The flood inundation model will use the hydrology model derived flood forecast data at key points of interest to assess the extent of area which is likely to inundate and heat map will be generated to identify the extent of area for which there is probability of damage to infrastructure and property.

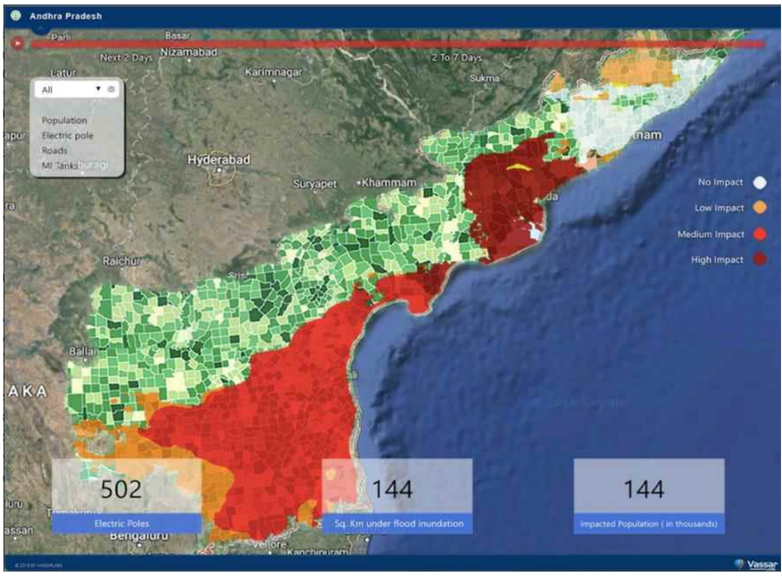


Figure 5.11 Inundation Heat Map

The Government should make annual audits of all the dams taking into account of structural capability, probable flood impact zone with the help of simulator for flood management for every dams and should make probable mitigation and preparedness measures.

7) Volunteer groups/ community response teams

One of the often quoted “good things” which came from Kerala’s response to the floods was the active participation of the local people themselves in relief and rescue operations. The fishing community with their specialised knowledge and skills provided crucial assistance to the state machinery in the rescue operations. In the past also, people and local communities have taken centre-stage in environmental movements, just as they continue to do so, in Kerala. “Save the Silent Valley” movement in the 1970s, various “Save the River” campaigns, the Coca-Cola Virudha Samara Samiti’s movement against groundwater exploitation by the Coca Cola company in Plachimada are some such notable movements in Kerala. Volunteer team from community members and training them can help build sustainability into the structural mitigation and relief process. The teams would facilitate maintenance and repair work, and pass on their knowledge to other community members and neighbouring communities through formal training and informal communication. Thus, it is important that such participation is encouraged with meaningful inclusion in decision making. This can be ensured through institutionalising these uncertain community responses through proper mechanism.

8) Incentivisation Risk Reduction

Disaster risk reduction is not an easy process with high scale. People needs to be informed about their risks and for seeking their participation in risk reduction has to be incentivized. The support for risk reduction could be of any form such as monetary benefits, tax relaxation, low interest rate loan, award, tax holiday etc .These wuld help in engaging community in risk reduction. This would also help in scaling up with speed.

9) River Basin Approach

With the South–West monsoon still active and the North–East monsoon to follow, immediate measures should have been taken to ensure that the reservoirs have sufficient storage space to absorb possible inflows in the event of high to very heavy rainfall, for the remaining period of this monsoon. No matter how many dams you have, all of the water comes to the river, so what we need is a river basin-based approach, rather than individual dams, with a cumulative impact assessment and flood mapping.

10) Strengthening Flood warning system

The Central Water Commission (CWC) — responsible for flood forecasting — has no flood forecasting stations in Kerala's river basins or in 14 other states. This is despite announcing in December 2015 that two would be set up in Kerala. With the impact of climate change most deeply felt in the South Asia region, a 1/1000 event can no longer be ruled out, but should be the new norm. India,not just Kerala, needs more accurate and real-time flood forecasting, weather forecasts and climate models.

11) Decentralised governance in Rebuilding Kerala

In fact, Kerala, in keeping with the structure of the Act, the State Disaster Management Authority and the District Disaster Management Authority are already in place, but no such authority existed at the level of local government. Kerala’s Disaster Management Policy, 2010, mentions “local bodies” as important stakeholders in disaster management. However, again, their role seems to be to function purely within the ambit of the framework “mandated by and in coordination with” the state and district level government departments and agencies.

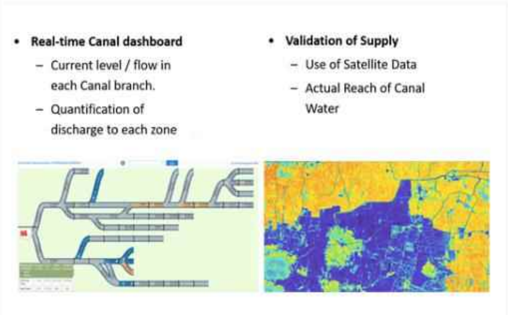
12) Dam Management policy and way forward

The National Disaster Management Authority in its flood management guidelines 2008 had mandated all the state /SDMAs to draw up an action plan for completing the review/modification of rule curves and operation manuals within a period of three years and but the same has not been done so far.

The Government of Andhra Pradesh has been investing in building its water resources information systems that provide visibility to water availability at the administrative and hydrological levels. The State wanted one authoritative system that contains all water related information such as supply, demand, environmental factors etc. to provide decision support to policymakers.

Water Resource Information System from Vassar Labs provides a solution to bring sensor data, mobile input data, mathematical model derived data, satellite data, web-based data and all other data relevant to water to one platform to bring near real time visibility to all the water related assets for a large state,, district or block such as Rainfall, Ground Water, Reservoirs – Major, Medium and Minor, Rivers and Streams,Irrigation Canals, Environmental factors like temperature, humidity, sunshine, wind speed etc.

The sensor data is augmented with the data from Hydrology models, Satellite data and data derived from Satellite data like Evapotranspiration, Soil Moisture, Water Spread area to volume estimations for the reservoirs.This data not only helps in assessing water balance and water audits and also enables supports in decision support system that optimizes the outflows based on inflows - both predicted and current from all major reservoir and canals across the states.



- Real-time Canal dashboard
  - Current level / flow in each Canal branch.
  - Quantification of discharge to each zone
- Validation of Supply
  - Use of Satellite Data
  - Actual Reach of Canal Water

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5.3 Conclusion

Post Disaster activities are visible and pre disaster risk reduction is invisible. For reducing impact of disaster the need of the hour is for making invisible visible. There is a need to strengthen risk governance which may take up ex-ante measures for both climate change induced disaster and sustaible development goal. The colossal loss of lives and damage to the property creates development gap. Protecting new investment by making it resilient are the key force behin resilient recovery. The Intergovernmental Panel on Climate Change, in its fifth Assessment report, observed that there has been an overall decrease in seasonal mean rainfall in the monsoon, with more break days, but an increase in extreme rainfall events.

Given that more dams are being planned and cleared by the Indian environment ministry, lessons from the floods are pertinent for all states, from Maharashtra, with the most number of dams, as well as the North-East and dams in Central India that see cyclonic rainfall. What India — not just Kerala — needs right now is more accurate and real-time flood forecasting, weather forecasts and climate models that look ahead, protection of natural flood buffers, better communication and investment in science and technology that can save lives.

Financial resilience through risk financing would be innovative steps as many people did not get what they had lost. Government of the states are worried on the fiscal health of the states. They do not have enough resources to complement state response to disasters. People do not get what they are loosing and there always have been the gap between actual loss and what have been given to them as an humanitarian response support. The Kerala floods have served as an important reminder of the impact of water management programmes and flood mitigation measures.

Social Capital is an essential component which networks communities with each other and plays an prominent role in providing access to the information, increasing social cohesion, better response engagement, enhanced political involvement, government responsiveness, enhanced economic assistance which reduces initial transaction cost of government for the effective response. The state also witnessed a enhance economic assistance where in its first day of disaster Rs 134.29 cr and 1027.27 cr in 15 days IN CMRDF as financial support from its communities living abroad as a token of support which reduced initial transaction cost of government for the effective response and relief of the government. This was the first time in any disaster which witnessed such a social cohesion between the communities, technical expertise with government for effective response in Kerala

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6. Overview of Earthquake and Tsunami in Central Sulawesi, Indonesia in September, 2018

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6.1 Outline of the disasters and damage

The Republic of Indonesia (hereinafter referred to as “Indonesia”) was struck by a major earthquake at 18:02 on September 28, 2018, (Central Indonesian Time) with the moment magnitude (M_w) of 7.5 in the middle of Sulawesi Island. The epicentre was located at 0.178°S, 119.840°E, or around 80km north from Palu City, the capital of Central Sulawesi Province. The Yellow Bridge, a symbol of Pal City, and several high-rise buildings collapsed (Figure 6.1). Soon after the earthquake struck the region, tsunamis as high as a few meters hit the coastal area of the Palu Bay. Landslides in association with liquefaction due to the seismic shake, an unusual disaster phenomenon, occurred. The phenomenon has been called “Nalodo” by local people in their language. Nalodo destroyed numbers of buildings and houses, which led to a large number of casualties. According to National Disaster Management Authority (BNPB) (Figure 6.2), as of February 5th, 2019, the number of death and missing amounted to 4,340, and evacuees 172,635. Direct damage and economic loss reached 2.89 trillion IDR (204 million USD) and 15.58 trillion IDR (1.1 billion USD), respectively.

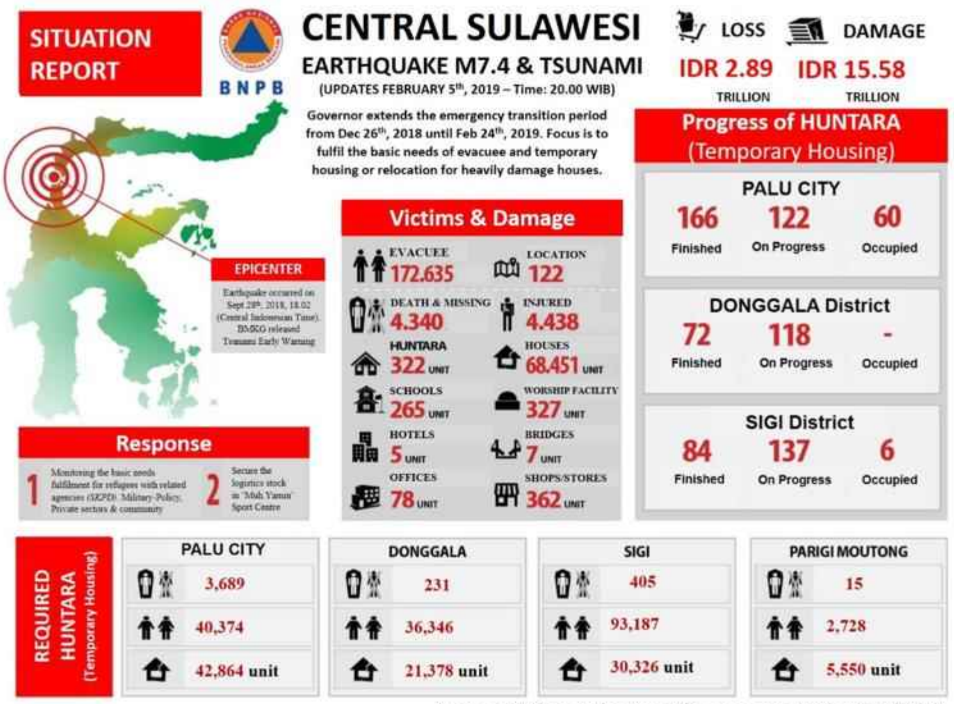
High-rise building

Liquefaction-landslide affected area

Palu IV bridge

Tsunami affected coastal area

Fig. 6.1 Damaged buildings and facilities



SITUATION REPORT

BNPB

CENTRAL SULAWESI

EARTHQUAKE M7.4 & TSUNAMI

(UPDATES FEBRUARY 5th, 2019 – Time: 20.00 WIB)

Governor extends the emergency transition period from Dec 26th, 2018 until Feb 24th, 2019. Focus is to fulfil the basic needs of evacuee and temporary housing or relocation for heavily damage houses.

LOSS	DAMAGE
IDR 2.89 TRILLION	IDR 15.58 TRILLION

EPICENTER

Earthquake occurred on Sept 28th, 2018, 18.02 (Central Indonesian Time). BMKG released Tsunami Early Warning

Victims & Damage

EVACUEE 172.635	LOCATION 122
DEATH & MISSING 4.340	INJURED 4.438
HUNTARA 322 UNIT	HOUSES 68.451 UNIT
SCHOOLS 265 UNIT	WORSHIP FACILITY 327 UNIT
HOTELS 5 UNIT	BRIDGES 7 UNIT
OFFICES 78 UNIT	SHOPS/STORES 362 UNIT

Response

1 Monitoring the basic needs fulfilment for refugees with related agencies (SKPD), Military-Policy, Private sectors & community

2 Secure the logistics stock in 'Mah Yamin' Sport Centre

Progress of HUNTARA (Temporary Housing)

	Finished	On Progress	Occupied
PALU CITY	166	122	60
DONGGALA District	72	118	-
SIGI District	84	137	6

REQUIRED HUNTARA (Temporary Housing)

	PALU CITY	DONGGALA	SIGI	PARIGI MOUTONG
	3,689	231	405	15
	40,374	36,346	93,187	2,728
	42,864 unit	21,378 unit	30,326 unit	5,550 unit

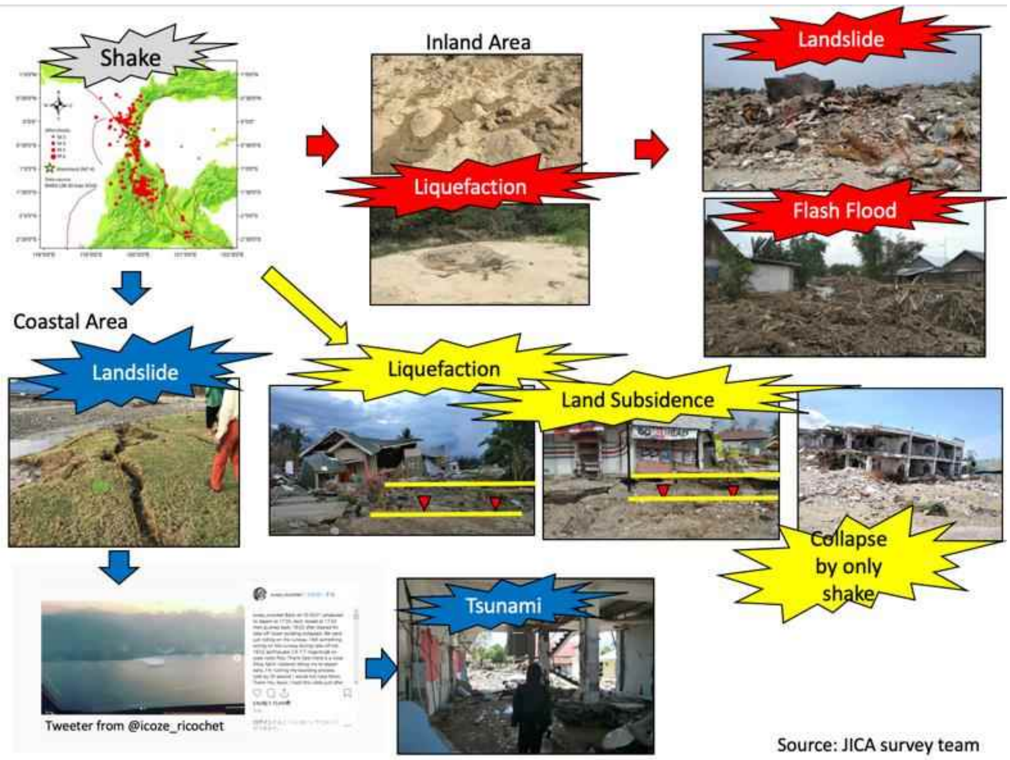
Source: National Disaster Management Authority (BNPB)

Fig. 6.2 Damage and Loss

6.2 Features of disasters

6.2.1 Cascaded disasters

M_w7.5 Earthquake occurred due to Palu-Koro fault movement on September 28th, 2018. Tsunamis caused by the earthquake quickly assaulted the coastal area in and around Palu. Nalodo happened in several places in Palu and killed more than a thousand of people. This earthquake is unique because it induced other types of severe disasters such as tsunami and Nalodo in the vicinity: Firstly, earthquake occurred in Donggala region (Northern part of Palu city). The earthquake shook large areas and destroyed tall buildings. Secondly, right after earthquake, the shake triggered landslides in not only inland areas but also coastal areas. Coastal landslides generated several tsunamis in the Palu Bay. Thirdly, Nalodo occurred in many places. It brought enormous damage in various areas. These disasters that claimed many victims can be called “Cascaded Disasters”. The earthquake disaster was not simple but complicated in terms of mechanism and damage (Figure 6.3).



Source: JICA survey team

Fig. 6.3 Cascaded disasters

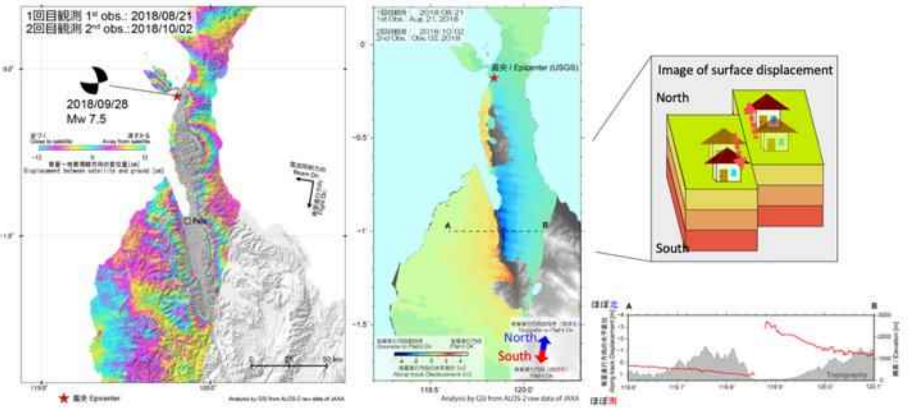
6.2.2 Earthquake

1) Surface displacement

The M_w 7.5 earthquake was caused by Palu-Koro fault movement. GSI Japan conducted interferometric analysis using ALOS-2/PALSAR-2 data to measure the crustal deformation caused by this movement. The analysis result shows that the crustal deformation occurred in the part of the island. According to the analysis, the fluctuation range extends to as far as 160 km south from the epicenter. Also, a large crustal movement is seen in the south of Palu, and a displacement of about 5 m has occurred. It is in accordance with the left lateral movement of the fault with a north-south strike (Figure 6.4).

JICA conducted observational survey tracing displacement evidence by satellite. Figure 6.5 shows survey points of field observation. The point-by-point survey revealed a unique characteristic of the disaster. Complete collapse of one or two buildings was observed in each point, but the buildings beside them were not destroyed. In short, the houses on the surface rupture zone were destroyed, but the houses outside the surface rupture zone escaped collapse as shown in Figure 6.6.

The surface rupture with left lateral slip appeared over at least 7 km around the terminal part of alluvial fan in the western side of the flood plain. Maximum left lateral displacement was 4.6 m with east side-up vertical offset of about 0.5 m. As a result, this fault can be called a strike-slip fault.

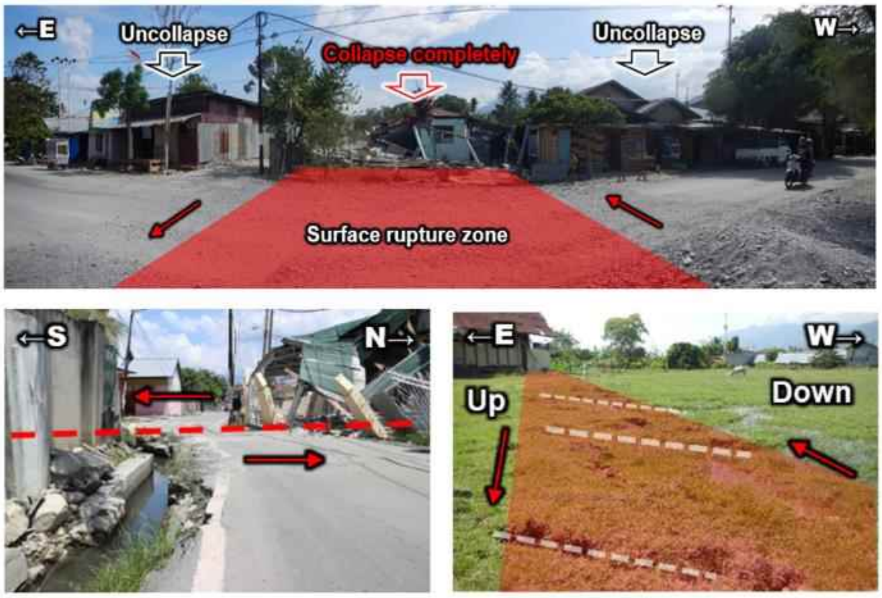


Source: Geospatial Information Authority of Japan (GSI)

Fig. 6.4 Crustal deformation

Source: JICA survey team

Figure 6.5 Points of observational field survey

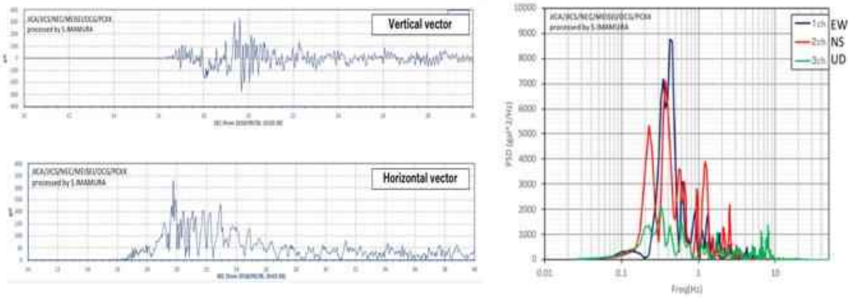


Source: JICA survey team

Fig. 6.6 Damages around surface rapture zone

2) Acceleration

A strong motion accelerometer was installed in Palu City. It is located about 80km from the epicenter. The record shows the horizontal acceleration was 333 Gal and vertical acceleration was 335 Gal. Dominant frequency was 0.2 to 0.6 Hz. That means dominant period of seismic wave was 1.7 to 5 seconds (Middle-Long Period). That would cause damages to not low-rise buildings but high-rise buildings due to resonance (Figure 6.7).



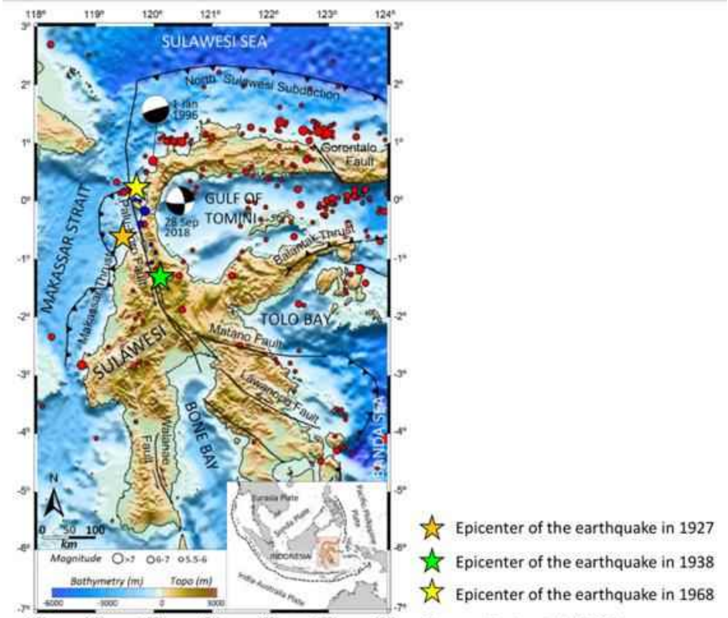
Source: JICA survey team

Figure 6.7 Accelerators and dominant frequency

6.2.3 Tsunami

1) Record of tsunamis

As pointed out by Omira et al. (2019) (Figure 6.8), Sulawesi has a long history of earthquake-induced tsunamis. In the period between 1820 and 1982, 14 tsunamis have been reported around the Sulawesi Island (Prasetya et al. 2001). Palu-Koro Fault was responsible for causing at least two tsunamigenic earthquakes, on December 1st, 1927 and on August 14th, 1968 at the Bay of Palu (Prasetya et al. 2001). The most recent tsunami in the region, one as high as 2–4 meters, occurred on January 1st, 1996 after an Mw 7.8 normal faulting earthquake (Pelinovsky et al. 1997; Gomez et al. 2000).



Source: Omira et al. (2019)

Figure 6.8 Historical tsunami records

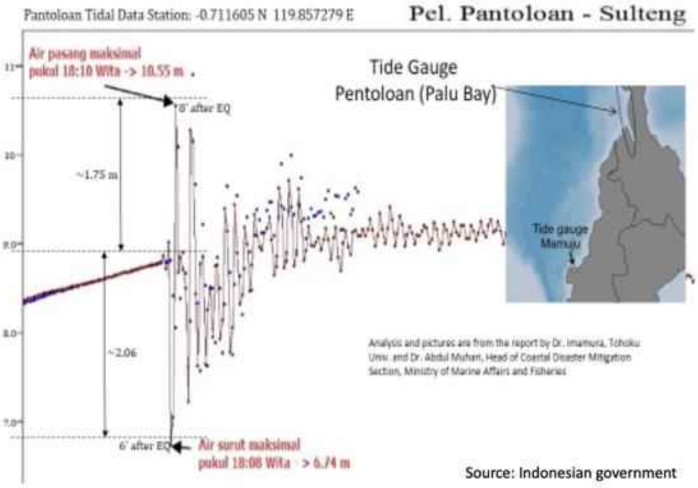
2) Feature of the tsunami

The nearest tide gauge at Pantoloan observed the tsunami. Tsunami is preceded by deep receding wave and its maximum height was about 1.75 m at Pantoloan. Only two peaks of tsunami were observed with very short period of wave. The first peak came in 8 minutes after the earthquake. This indicates that the tsunami source should be very local. The source area should not be too wide as it is represented from the observed wave period. After the second peak, tsunami wave heights were no longer significant (less than 30cm) (Figure 6.9).

Video capturing the tsunami and immediate tsunami simulation based on the fault model by USGS indicates the devastating tsunami was caused by landslides (Figure 6.10).

Satellite image shows the change of coastal line of the Palu Bay after the earthquake. The lands of estuary of the Palu River and other small rivers were lost. It was assumed that the lost land had slipped into the sea and caused tsunamis. Mechanism of the tsunami can be as follows (Figure 6.11):

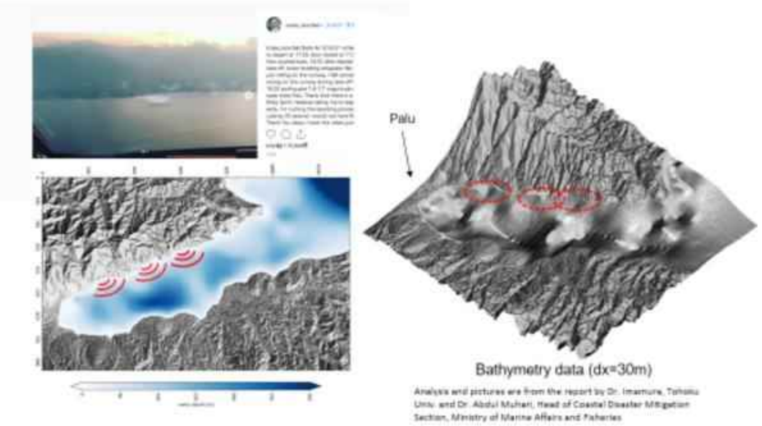
1. Landslides into the sea happened.
2. The slipped lands in the sea pushed out water. It generated strong pressure towards the opposite coast direction. Landslide was also accompanied by backwash.
3. Resultant huge tsunami ran towards the opposite coast. Smaller tsunami went towards the coast where landslides occurred.



Analysis and pictures are from the report by Dr. Imamura, Tohoku Univ. and Dr. Abdul Muhari, Head of Coastal Disaster Mitigation Section, Ministry of Marine Affairs and Fisheries

Source: Indonesian government

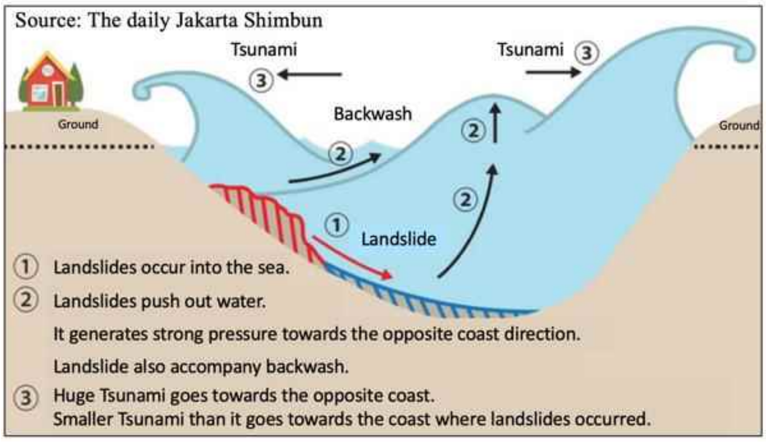
Figure 6.9 Record of Tide gauge at Pantoloan



Analysis and pictures are from the report by Dr. Imamura, Tohoku Univ. and Dr. Abdul Muhari, Head of Coastal Disaster Mitigation Section, Ministry of Marine Affairs and Fisheries

Source: Indonesian government

Figure 6.10 Coastal landslides



Source: The daily Jakarta Shimbun

① Landslides occur into the sea.
② Landslides push out water.
It generates strong pressure towards the opposite coast direction.
Landslide also accompany backwash.
③ Huge Tsunami goes towards the opposite coast.
Smaller Tsunami than it goes towards the coast where landslides occurred.

Figure 6.11 Tsunami mechanism

3) Inundation

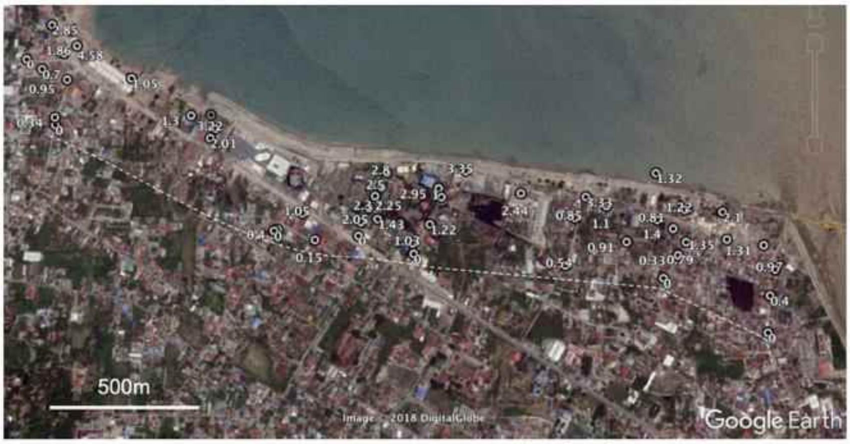
Figure 6.12 shows the inundation area identified by satellite image. The tsunami reached inland about 400m from the coastline in central area of Palu City.

Many stalls along the coast were washed away, and the walls of the one-story building collapsed. However, the damage to the multi-story concrete building along the coast was minor.

The field survey by Koshimura (2018) shows that most parts of inundation depth from the ground level were less than 3 m in central area of Palu City (Figure 6.13).

Source: JICA survey team

Fig. 6.12 Tsunami inundation and heights



Source: Shunichi Koshimura, Tohoku University, Japan

Figure 6.13 Tsunami inundation depths

6.2.4 Nalodo (Liquefaction-landslide)

1) Record of Nalodo

"Liquefaction rarely kills people." This phrase has been often mentioned. However, more than a thousand people were killed in this liquefaction. Lateral flow by liquefaction is usually limited up to around 10 m. However, liquefaction of this disaster caused movement of land as long as around 400m at maximum. This kind of liquefaction is very rare through history. It is possibly the first time that more than a thousand people were lost due to liquefaction. The historical record of this phenomena has not been found in Central Sulawesi. However, the Kaili tribes, the indigenous inhabitants around Palu, called the phenomena "Nalodo", that means "Getting buried in mud" or "Subsiding land". That means the Kaili tribes had experienced this liquefaction-landslide phenomenon in the past.

2) Impact of Nalodo

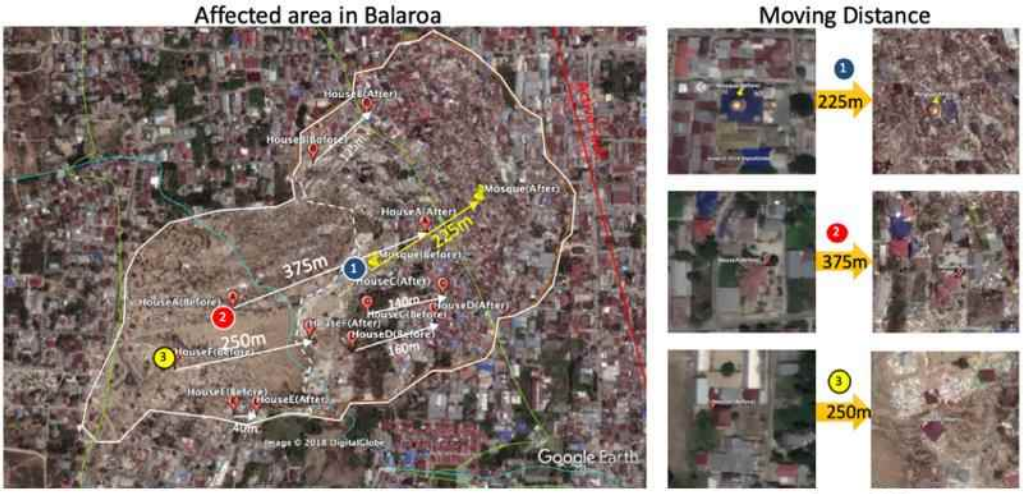
There are 3 major Nalodo damaged area, namely Balaroa, Petobo and Jono Oge (Figure 6.14).

Balaroa is located in the western side of Palu City. The affected area is about 0.4km^2 (1km in length and 0.4km in width) with slope angle of 1.6 degree. This area is mainly used for residential area. 930 buildings were damaged by Nalodo. Petobo is located in the eastern side of Palu City. The affected area is about 1.6km^2 (2.6km in length and 1.1km in width) with slope angle of 0.9 degree. The higher area is used for paddy field and the lower area as residential area. 1,255 buildings were damaged by Nalodo. Jono Oge is located in the northern side of Sigi regency. The affected area is about 1.75km^2 (3.5km in length and 1.5km in width) with slope angle of 0.7 degree. This area is mainly used for paddy field, palm plantation, or housing. In this area, 238 buildings were damaged by Nalodo.

By comparison of satellite images, it was confirmed that a building roof did not collapse and moved about 400 m (Figure 6.15), which led to the assumption that the ground on which the building stood slipped.

Source: Shinichiro Mori, Ehime University, Japan

Fig. 6.14 Main Nalodo damage area



Source: JICA survey team

Figure 6.15 Movement of buildings in Balaroa

3) Features of the Nalodo area

Land in the upper side of Jono Oge is very dry. Many cactuses grow on the land. There is no water in the river channel. On the contrast, land in the lower side of Jono oge is wet. Palm trees grow on the land. There is enough water running in the river channel. The ground water level is very high in the Nalodo affected area.

These affected areas have common aspects (Figure 6.16);

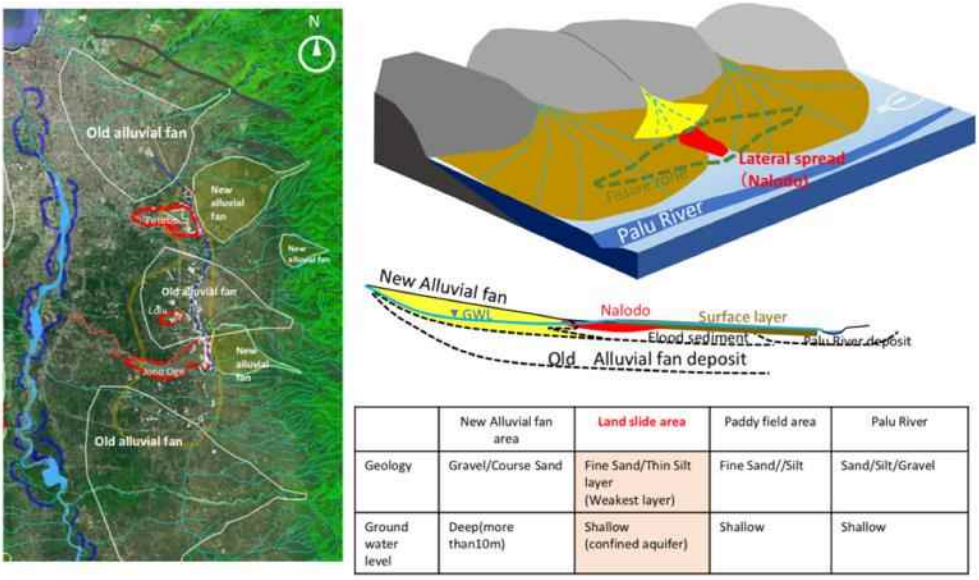
(1) They are gentle slope areas around the toe part of an alluvial fan.

(2) They are areas of shallow groundwater (Some people say that groundwater naturally spouts to the ground when they stick pipes into the ground. Plants that prefer wet soil flourish.)

(3) Landslide have occurred

(4) Most of houses were much more severely damaged than those in non-Nalodo affected areas

Based on the topography and geological survey, the Nalodo area can be a depression engulfed by two large old alluvial fans. A small new alluvial fan (debris flow deposit) exists on the mountain side of the depression. The area of the depression is a river sediment deposition site which is Nalodo-prone.



	New Alluvial fan area	Land slide area	Paddy field area	Palu River
Geology	Gravel/Course Sand	Fine Sand/Thin Silt layer (Weakest layer)	Fine Sand//Silt	Sand/Silt/Gravel
Ground water level	Deep(more than10m)	Shallow (confined aquifer)	Shallow	Shallow

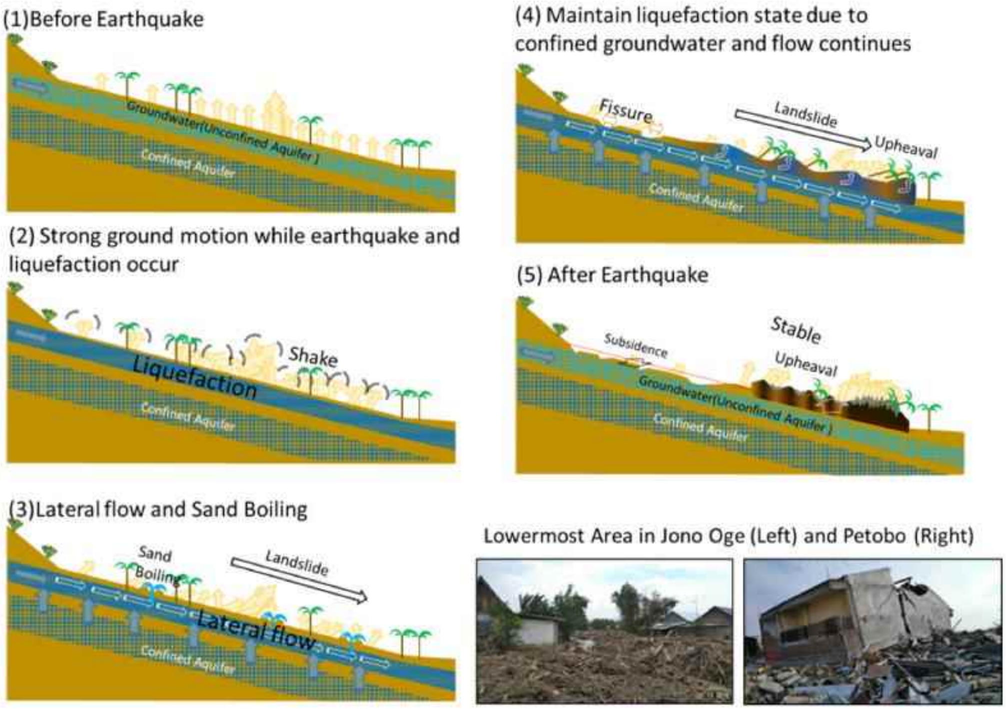
Source: JICA survey team

Fig. 6.16 Features of the Nalodo potential area

4) Mechanism of the Nalodo

The liquefaction was supposed to have continued for a long time due to plentiful groundwater, especially confined one. The mechanism of the phenomena should be clarified by further research. As of now, the areas were supposed to be affected by a common mechanism as below (Figure 6.17):

1. The liquefaction occurred because of strong shake and confined aquifer
2. The landslide occurred because of slope and large-scale liquefaction
3. Those phenomena brought about upheaval or flash flood in downstream areas because a lot of moist soil surged from upstream
4. They also brought about mudflow with fissure in upstream areas because a lot of soil were lost towards downstream



Source: JICA survey team

Figure 6.17 Nalodo mechanism

7. Post Disaster Infrastructure Improvement in Central Sulawesi

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Abstract

Most assessments of losses due to natural disasters focus on damages to assets, including buildings, infrastructures, equipments, and production. Recent data indicate that ignorance of the risk causes significant losses, socially, economically and financially. Therefore, a comprehensive measure of this risk is required to avoid more societal losses. This report highlights the implementation of Build Back Better concept, which may encourage to authorities in Indonesia.

The objective of this report is to present recent conditions, approaches, and immediate as well as prospective measures to perform Post-Earthquake, Tsunami and liquefaction Disaster Management. We propose a comprehensive measure, which shows Build Back Better as a solution to accelerate recovery and reconstruction in Central Sulawesi. Build Back Better approach should be supported by improved resettlement plan, disasters management, early warning system, as well as capacities of institutions which is required skilled personnel, and cooperation between authorities at all administrative levels.

Keywords: Build Back Better, Disaster Risk Management, Central Sulawesi Disaster

CHAPTER 1:

7.1 BACKGROUND

Build Back Better (BBB) concept signifies an ideal reconstruction and recovery process that delivers resilient, sustainable, and efficient recovery solutions to disaster-affected communities (Encyclopedia of Earthquake Engineering, Springer-Verlag Berlin Heidelberg, 2014). The motivation behind the Build Back Better concept is to make communities stronger and more resilient following a disaster event.

Relationship among Disaster Risks, Infrastructure, Livelihood and Spatial Planning is required to perform “Build Back Better”. The Spatial Planning from BBB perspective is to enhance disaster-resilient city, to achieve Sustainable socio-economic development, and to enable livelihood recovery and community empowerment, which need of strategic zoning. In order to achieve BBB, it is require establishing Disaster Prone-Zone (ZRB) map, detailed hazard assessment, land use and building regulation.

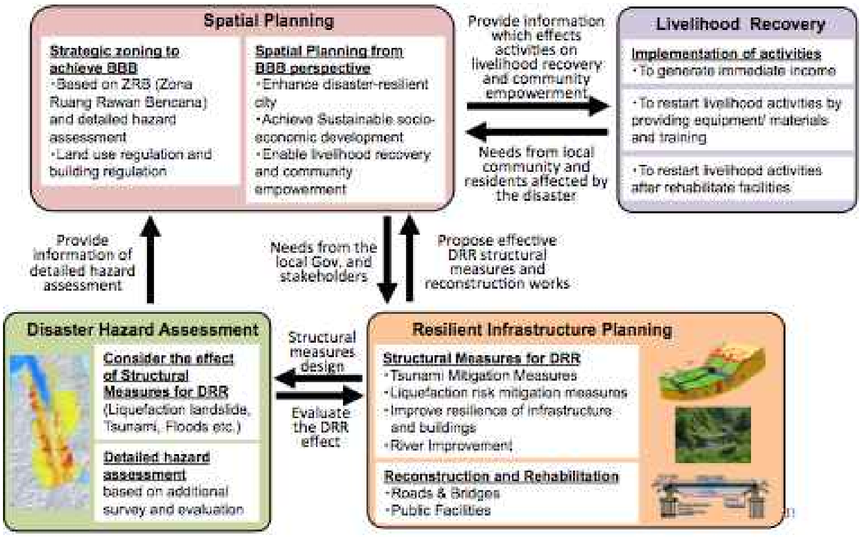


Figure 7.1 Build Back Better (BBB) Concept

There are 3 (three) point of view of Build Back Better for Infrastructure (UNISDR, 2017): a. Infrastructure recovery, b. Constraints on cost, time and social acceptance; c. Disaster risk reduction-driven regulations including land use planning, building codes, and critical infrastructure assessment. The risk analysis play significant role to determine the disaster risk reduction on tsunami, sliding liquefaction and seismic shake will be explained in the following section.

The tsunami in Palu Bay shares these characteristics (JICA, 2018):

1. Multiple tsunami sources;
2. Coastal Land Subsidence
   - There were several places where the ground subsided about 2 m over the width of 100 m.
   - The subsidence is due to liquefaction and related gravity flows caused multiple
3. Rapid Inundation (4 min.)

   Highly destructive tsunami inundation was occurred within 4 min. at Wani.

4. High inundation (ave. 3-4m / max. 6.5m)

   The inundation height is locally high up to 6.5 m (splash is excluded).

Tsunami is preceded by deep receding wave and is followed by maximum tsunami height of about 1.75 m. Only two peaks of tsunami are observed with very short period of wave. This indicates that the source should be very local and the generation source area should not be too wide as it is represented from the observed wave period. After the second peak, tsunami wave heights are no longer significant (less than ~30 cm).

Source: JICA Yellow colored zone: Tsunami inundated area

Figure 7.2 Tsunami Inundated Area in Palu Bay

The sliding liquefaction occured in Palu is very large and rare in the history of the world, while the Kaili tribes are the original inhabitants, who have lived around Palu, called these phenomena “Nalodo”, which means “Getting buried in mud” or “Subsiding land”. Hence we propose to use technical term of “Nalodo” for sliding liquefaction. There were 6 sites of such a devastated and huge ground flow induced by liquefaction in central Sulawesi. The biggest events are in Balaroa, Petobo and Jono Oge.

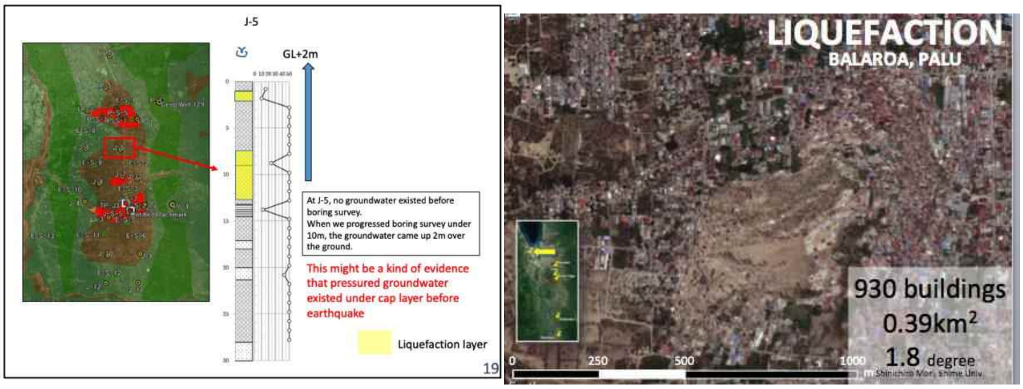
Based on drilling and analysis data, the incidence of Nalodo in Palu is showed by 5 (five) conditions (JICA, 2018):

1. The groundwater level is shallow;
2. Confined aquifer exists;
3. Slope exists (not horizontally perfect);
4. A loose sandy soil layer is deposited;
5. Low Permeable Cap Layer exists.

Why did such a large area liquefy at the same time? One reason is the existence of a thin "low permeable cap layer" among a loose sandy soil layer that is distributed in a broad area. The "low permeable cap layers" consists of soft clay or silt. While under the layer, there is a liquefaction-prone soil, which is mainly loose sand deposit.

In addition, the area has shallow underground water levels, which generally moves, however it will be restrained and remains below low permeable cap layer due to existence of aquifer layer and forms water film. As frictions disappear on the water film, the surface layer can move downward freely.

Huge lateral flow occurred toward lower by gravity and consequently, during a big earthquake its pressure increase significantly and brought fissure in the upper area, and upheaval in the lower area (JICA, 2018). Evidence of great pressure is shown in the drilling data at point J-5 (Figure 7.3) , where it was not found in a groundwater layer, but when drilling continued to more than 10 m, the underground water layer rose up to 2m and above. This indicates after the earthquake, pressure on the groundwater layer is still present.



At J-5, no groundwater existed before boring survey.
When we progressed boring survey under 10m, the groundwater came up 2m over the ground.

This might be a kind of evidence that pressured groundwater existed under cap layer before earthquake

Figure 7.3 Drilling Data at Point J-5

7.2 IMPACT

Earthquake in Palu have impacts on casualties, material and immaterial losses, hence, resulting in physical damage to infrastructure. Those appear during disasters and bring very fatal consequences, as it leads to interruption of the evacuation route, in turn, delays in humanitarian assistance. In addition to that, disconnection of roads and bridges due to natural disasters brings about the obstruction of the distribution of goods and services, leading to a decrease of regional economic growth.

The current phenomenon has resulted in vulnerability infrastructure affecting potential disaster and direct impact on its structures. The impact of earthquake disaster on infrastructure include severe damage of settlement, water resources and road infrastructure in Palu (Directorate General of Highways, Ministry of Public Works and Housing, 2018):

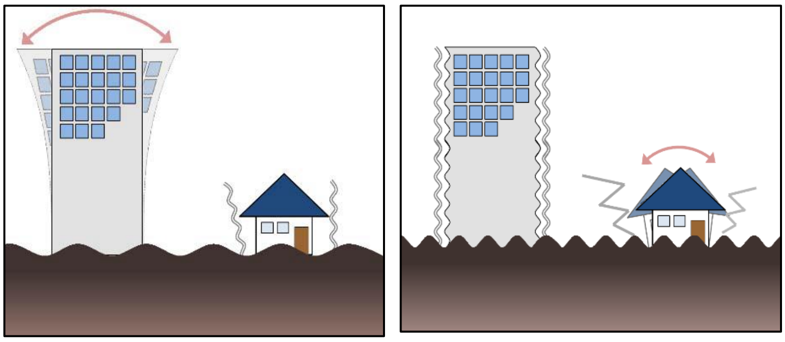
Figure 7.4 Palu IV Bridge Was Collapsed

Figure 7.5 Superstructure of Palu I Bridge was Moved to 20 cm

Figure 7.6 Surface Rupture and Collapse Houses in Palu

Surface rupture with left lateral slip appeared over at least 30-km around the terminal part of alluvial fan in the western side of the flood plain. In the vicinity of the surface rupture, the houses on the surface rupture zone collapsed completely, but the houses outside the surface rupture zone escaped collapse (Fig. 7.6).

The damage buildings by Seismic Shake is measured by its dominant frequency is 0.2 to 0.6 Hz (JICA, 2018), the seismic wave period is 1.7 to 5 seconds and that would not cause damages of low-rise buildings, but cause damages of high-rise buildings and ground damage (Figure 7.7).



Long Short

Figure 7.7 Illustration of Damage Building caused by Seismic Shake

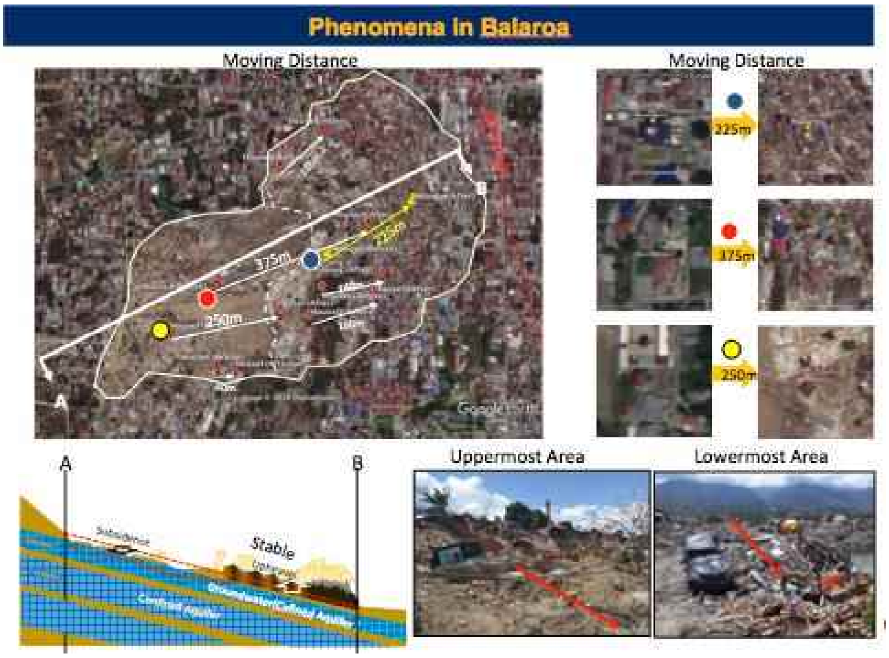


Figure 7.8 Phenomena in Balaroa

Figure 8 shows the impact of liquefaction phenomena in Balaroa, which caused the longest distance of building movement is around 400 meter. There were 6 sites of such a devastated and huge ground flow induced by liquefaction in central Sulawesi, especially, flow in Balaroa, Petobo and Jono Oge. Most of houses were collapsed from ground movement caused by liquefaction as shown in Figure 7.9.

Figure 7.9 Collapsed House in Balaroa

7.3 IMPLEMENTATION OF BUILD BACK BETTER

7.3.1 CHOOSING LOCATION FOR NEW RESETTLEMENT

Basic Concept

Lessons from planned relocation implemented as a disaster risk management strategy indicate that it provides opportunities to save lives and assets and improve the standard of living in high-risk areas, if articulated into a comprehensive risk management strategy and planned and implemented properly (UNHCR, 2014). It is important that efforts to protect the lives and assets of those exposed to disasters do not make communities more vulnerable to other social, economic, or cultural risks associated with planned relocation.

Planned relocation should be a process of rebuilding and integration, enabling people to settle sustainably in a new location. In order to be sustainable, planned relocation should provide affected populations with suitable land and/or housing; access to public services like water, sanitation, electricity, and transportation; and access to social services like education and health and sources of income, livelihood and/ or employment opportunities (UN Sustainable Development Challenges, 2013).

Implementation

Relocation areas for settlements must meet the land suitability criteria as follows (JICA, 2018):

4. Relatively safe from disasters-(active faults, volcanoes, landslides, tsunamis, floods) based on below hazzard map (Figure 7.10);

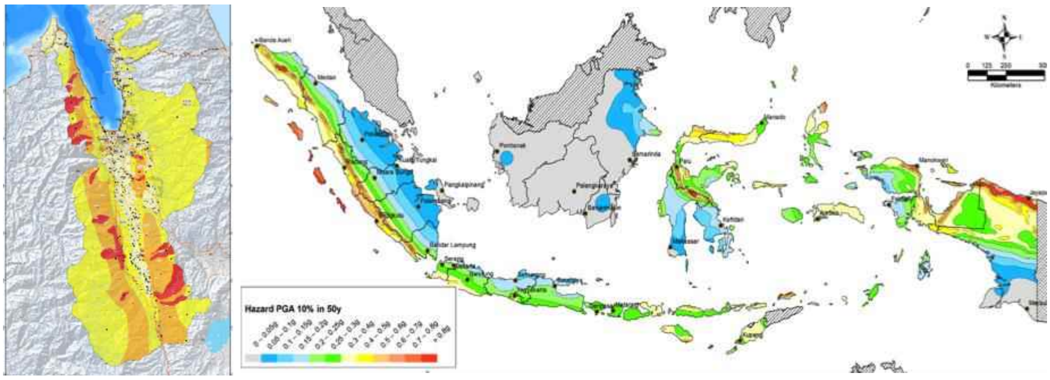


Figure 7.10 Hazard Map

5. Being in the planned spatial pattern of cultivation areas in the Spatial Plan for community livelihood (relatively good land capability/carrying capacity);
6. Slope is below 15%;
7. Existing land use has not been built;
8. Accessible to both water sources and utilities.;
9. Place attachment point of view in building settlement that relatively close to the original location.

The Central Sulawesi local government formulated a Master Plan of Post Disaster Recovery and Development on Central Sulawesi Province in 2018 in regard to:

a. Planning for the reconstruction of affected areas after disaster risk-based disasters;

b. Preparing plans for recovery and development of regional infrastructure, economy, and socio- cultural communities in affected areas;
c. Coordinating financing plans, cooperation and institutions to implement recovery programs.

Referring to the level of impact caused by the earthquake, tsunami and liquefaction disasters in Palu City, in residential areas in particular, a proposed relocation plan is located in four locations, namely Duyu Village in Tatanga District, Palu City; Talise and Tondo Villages in Mantikulore District, Palu City; Ngatabaru Village, the border of Palu City and Sigi Regency; and Pombewe Vilage, Sigi Biromaru District, Sigi Regency.

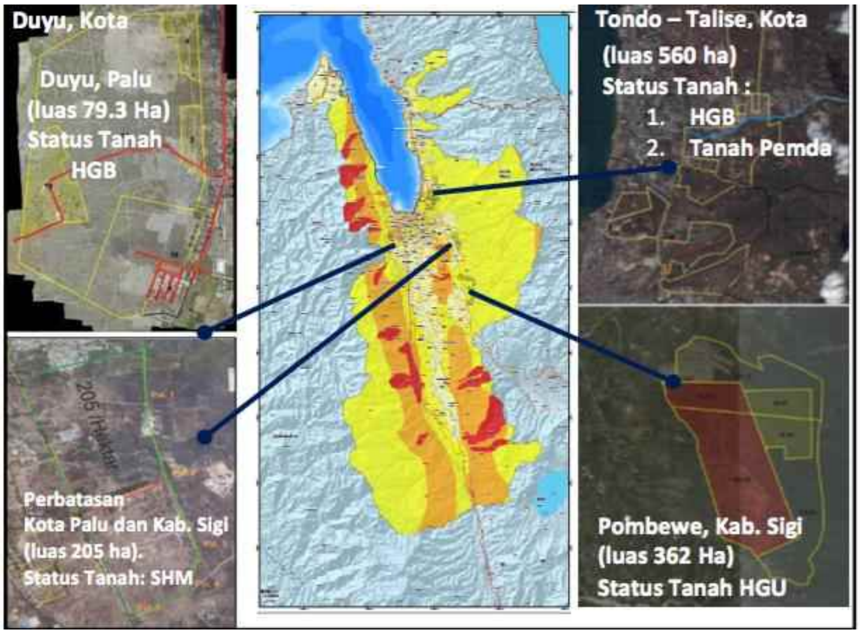


Fig. 7.11 Proposed Relocation Plan

7.3.2 MANAGING POSSIBLE LIQUEFACTION

The approach and future plan that can be done is to implement efficiently in assessing risks and planning the built back better (UN Sendai Framework to Disaster Risk Reduction 2015-2030) that is associated with risks, geological conditions and identification of the Nalodo mechanism, starting with assumptions, surveys and analysis and modifying those assumptions. Following are recommendations for improvements for Nalodo prevention:

1. Lowering ground watertable, by controlling possible intercept or percolation of surface water into ground water. For this purpose, all irrigation canals must be lined;

2. Providing surface and underground drainage system vertically and horizontally in order to drain the underground water to a lower river system downstream;

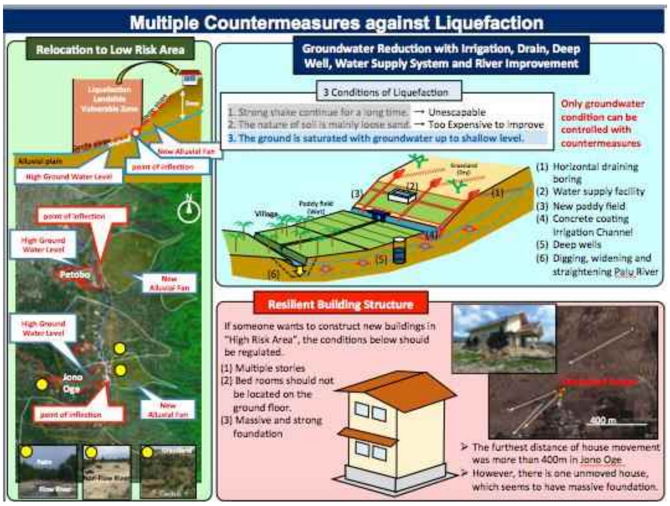
3. Lowering underground water by developing Deep wells construction;

4. Adjusting morphology of the river in Palu, by dredging and deepening the river bed to make drainage of ground water is possible.

In regard to liquefaction resistant design code, there are approaches need to be managed:

1. Mitigating Target Hazard
   Construction of irrigation, drain, deep well, water supply system and river improvement in order to achieve ground water level reduction.

2. Accepting Target Hazard
   Design of Resilient Facilities against Liquefaction, Disaster education, evacuation drill.



Multiple Countermeasures against Liquefaction

Relocation to Low Risk Area

Groundwater Reduction with Irrigation, Drain, Deep Well, Water Supply System and River Improvement

3 Conditions of Liquefaction

1. Strong shake continue for a long time. → Unescapable
2. The nature of soil is mainly loose sand. → Too Expensive to improve
3. The ground is saturated with groundwater up to shallow level.

Only groundwater condition can be controlled with countermeasures

(1) Horizontal draining boring
(2) Water supply facility
(3) New paddy field
(4) Concrete coating Irrigation Channel
(5) Deep wells
(6) Digging, widening and straightening Palu River

Resilient Building Structure

If someone wants to construct new buildings in "High Risk Area", the conditions below should be regulated.

(1) Multiple stories
(2) Bed rooms should not be located on the ground floor.
(3) Massive and strong foundation

- The furthest distance of house movement was more than 400m in Jono Oge
- However, there is one unmoved house, which seems to have massive foundation.

Figure 7.12 Multiple Countermeasures against Liquefaction

7.3.3 MANAGING TSUNAMI

Multiple integrated countermeasures for Tsunami Evacuation Re-inforcement are following:

1. Tsunami Prevention with Zoning includes Beach conservation, Mangrove plantation, Setback from the coastal landslide, No building / no infrastructure;
2. Green Tsunami dike with Tsunami wave force reduction and Inundation area reduction (integration between structural and non-structural);
3. Buildings structure which involve Tsunami resistance and vertical evacuation;
4. Road with Horizontal evacuation.

- "Spatial Plan" should be set based on "Disaster Risk Assessment."
- However, there would remain "Uncertainty" in disaster risk even after assessment.
- In accordance with the situation transition and additional data availability, "Reconstruction Plan" should be prepared step by step, like "Basic Plan", "Master Plan" and "Action Plan."

Figure 7.13 Managing Tsunami through Planning

Multiple source of triggering the tsunami and rapid inundation time are very important parameter in designing infrastructure to minimize risk of tsunami.

7.3.4 MANAGING DEBRIS FLOW

Geological condition of Palu Areas predominantly consists of alluvium deposits and Celebes Molasse Sarasin in a weakly consolidated layer. The previous serials of earthquakes have even made the condition worse, ie. the celebes molasse layer became loose and had easily eroded and slided during a heavy raining event, resulted in a very destructive debris flow and endanger settlement and other productive areas downstream.

With the purpose of reducing the potential destructive energy and to control the spreading of debris flow, we are working on construction of Sabo-works consist of series of check-dam, channel works and sand-pockets.

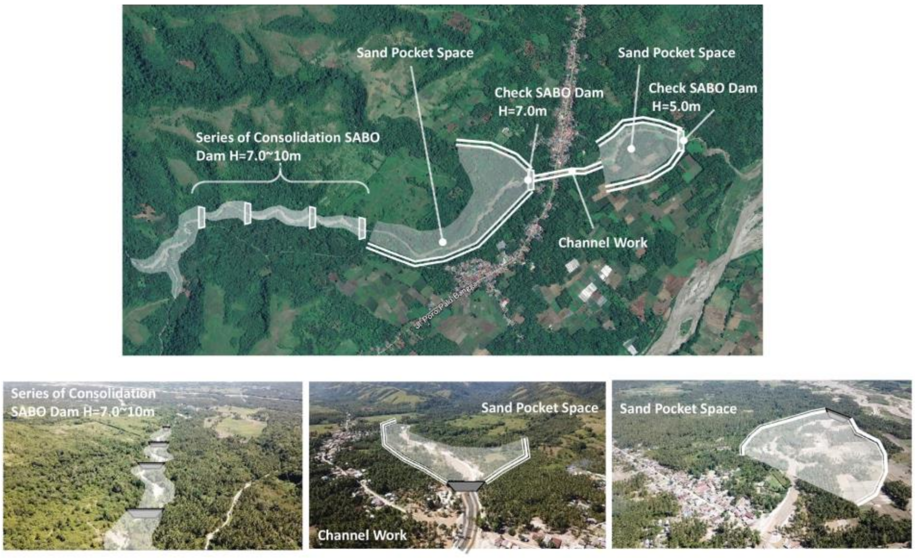


Figure 7.14 Managing Debris Flow in Bangga River

7.3.5 RE-EVALUATING BUILDING CODE

Earthquake is not deadly, however the poor designed buildings killed people, and the resulting devastation came as no surprise, either, because Palu is filled with buildings not made to stand up to a earthquake. Effects of liquefaction have to be considered in building foundation design, considering the reduction of lateral and axial capacity and stiffness of deep foundation, lateral spreading, settlement and possiblity of down drag effect. According to tectonic Conditions of Palu and Central Sulawesi, Maximum Considered Earthquake Geometric mean (MCE_G) in Building Code SNI-1726-2012 is 0,8-0,9 g.

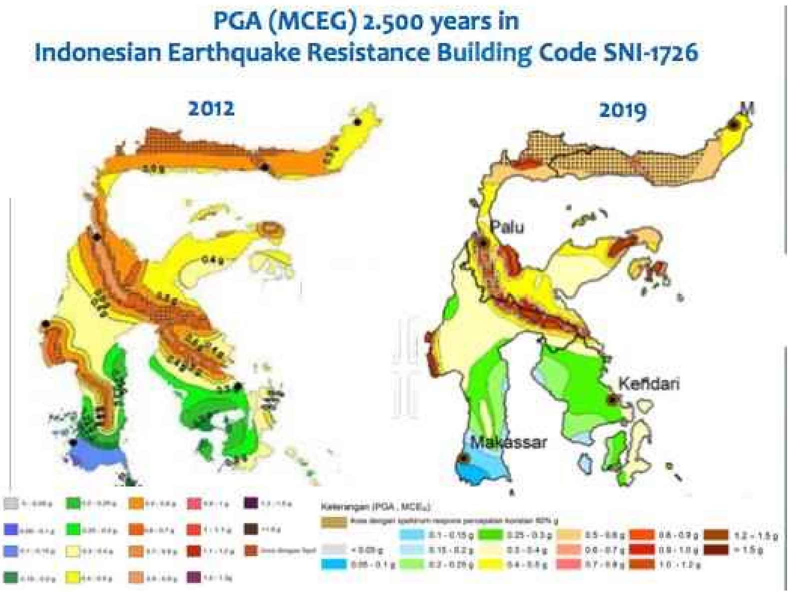


Figure 7.15 Maximum Considered Earthquake Geometric

The Ministry of Public Works and Housing is preparing the new National Standard for Earthquke Resilience Planning (R-SNI 1726) and Structural Concrete Requirements for Buildings (R-SNI 2847) which are used to to assist and provide advice to regional authorities in the framework of granting permits for infrastructure development.

The Ministry of Public Works and Housing is working together with experts in the fields of: architecture, civil, structural, geotechnical, mechanical, electrical, and environmental set up experts panel on building. The team members is formed to provide advice and recommendations on the new design of buildings, - particularly buildings whose design has a level of difficulty that is not able to be handled by the local government -, recommendations on existing buildings retrofitting that vulnerable due to disasters.

The recommendations are used as an input to the permit authority in order to make binding decisions to the building owner and to the consultant Team who remains responsible for the building design, with the advice from the Team (if any), which are based on the design standards. Their works consist of:

- Building design: architectural drawings, modeling, assumptions, calculations, working drawings, technical specifications, construction methods;
- Compliance checking in applying the provisions of the design standards;
- The technical logic checking used in the design based on the accumulated experience stored in the Team archive;
- During the inspection process, interaction between the Team and the planning consultant is significant to provide design inputs as well as recommendations on the quality of the consultants which is later be used to assess the extension of the consultant's practice permit in Jakarta.

7.3.6 EARLY WARNING SYSTEM

The way forward for enhanced early warning and hazard monitoring requires methods be defined and communicated that increase the efficiency and effectiveness of early warning systems and multi-hazard monitoring networks, as well as promotes their use for risk management and ensure that these networks are themselves highly resilient. Early warning systems are also defined to detect initial tsunami; intensity of rainfall, run-off and ground water level; possibility of liquefaction, inundation, debris flow and landslide.

In order to improve effective warning and hazard monitoring, the Central Sulawesi local government in their Master Plan of Post Disaster Recovery and Development on Central Sulawesi Province in 2018 included the action plan:

- Training of local human resources especially those working in the construction sector to be able to understand the techniques of building construction that are resistant to potential disasters;
- Preparing organizations and providing / HR training to carry out spatial planning tasks;
- Training or assistance for disaster risk reduction, and preparedness, and disaster response;
- Training for the local government to provide understanding and awareness of the community about disaster hazards and risks, especially handling vulnerable groups such as persons with disabilities, the elderly and children; and establish community-based disaster alert networks and strengthen social interaction among community member.

7.4 CLOSURE

We understand that lesson learned by Tohoku Earthquake and Tsunami in 2011, there would be no upper-limit of disaster hazard, unavoidable intensive hazard as long as we live in disaster-prone country, the victims, damage and loss cannot be perfectly prevented from the intensive hazard.

However, this report recommends concepts to reduce intensive & extensive risks are as follows:

- Mobilizing the best mix of Structure and Non-Structure measures Risk Sensitive Reconstruction Plan and avoid re-producing same vulnerability again through reconstruction process, aiming at minimizing victims and economic losses;
- Identifying the disaster risk of each area;
- Delivering possible countermeasures;
- Taking into account of constraints i.e. cost, time, and social acceptance;

- Optimizing the countermeasures in the entire region.

It is required obtaining consistent regulations and a strong legal framework with the purpose of assisting the authorities at administrative levels to be aware of disaster risks in order to achieve better reconstruction.

8. Cyclones Idai and Kenneth in South African Region in 2019

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Tropical cyclones are weather systems that develops over warm tropical oceans (temperature greater than 26° C) and are characterised by thunderstorm activity and low level cyclonic wind circulation. When the maximum sustained wind speed is less than 63 km/h, the weather phenomenon is referred to as a tropical depression, tropical storm for wind speed from 63 to 119 km/h, and tropical cyclone when the speed exceeds 119 km/h. Globally, each year about 80 – 90 tropical storms and cyclones are formed in the Pacific, Atlantic and Indian Oceans (Frank, 2009). Southern Africa is affected by storms that form in the South-West Indian Ocean (SWIO) between the 5° – 10° and 30° S latitude, and from the east African coast to 90° E longitude. Beyond the 30° S latitude, the ocean tends to be colder than 26° C which inhibits cyclogenesis (Leroux, et. al. 2018; Frank, 2019). Each year about 9 – 10 tropical storms and cyclones are formed over the SWIO and about 4 – 5 of these develop into tropical cyclones. The cyclone season in the SWIO is from November to April, and 74% of the tropical systems occur during the December – March period.

Tropical storms and cyclones formed in the SWIO mostly move towards the southwest, due to the influence of the easterly trade winds and may later recurve to the south and southeast (Leroux, et. al. 2018). Consequently, the eastern coasts of Madagascar and Mozambique are frequented by tropical storms and cyclones. On average Mozambique is affected by a tropical storm every year, and a tropical cyclone once in three years. Tropical storms and cyclones tend to have an average lifetime of 7 – 9 days. When tropical storms and cyclones move overland, they weaken mainly, due to wind shear. In the open and warm ocean, evaporation of water that is enhanced by wind is the major contributor to the energy for sustaining a cyclone. Overland this source of energy is no longer present (Ramsay, 2016). Although a cyclone weakens overland, the system may cause heavy rainfall leading to flooding and landslides particularly in Mozambique, Malawi, Zimbabwe and Botswana as was the case for Cyclone Dineo in 2017.

There is a major concern regarding the potential effects of climate change on the frequency and intensity of tropical cyclones since global climate models predict an increase in the frequency of extreme weather events, such as intense rainfall and droughts (Dosio & Panitz 2016). Muthige *et. al.* (2018) examined climate change effects on tropical cyclones in the SWIO and concluded that the frequency of occurrence of tropical cyclones is likely to decrease. What is however interesting for southern Africa is that the first category 5 tropical cyclone to be formed over the SWIO was observed in 1994. Since then there have been 12 category 5 cyclones (Fitchett, 2018). Fitchett (2018) concluded that the evidence available was not adequate to support the existence of an upward trend in the occurrence of category 5 tropical cyclones. Mavume *et. al*. (2009) noted that the frequency of cyclones during the 1952-2007 period had decreased despite an increase in sea surface temperatures in the SWIO. The current research results do raise doubts about the possible increase in the frequency of tropical cyclones arising from climate change effects. The Intergovernmental Panel on Climate Change concluded that climate change is likely to lead to a decrease or no change in the frequency of occurrence of tropical cyclones at the global level. The effects of climate change will vary among the ocean basins (Christensen, et. al. 2013). There is a potential that while the frequency of occurrences of cyclones will not change, their intensity may increase which will increase the damage caused.

8.1 Cyclones Idai and Kenneth

During the 2018/2019 cyclone season, there have been 14 tropical systems formed over the SWIO, and Cyclones Idai and Kenneth are the most recent severe cyclones to make landfall over Mozambique (Figure 8.1).

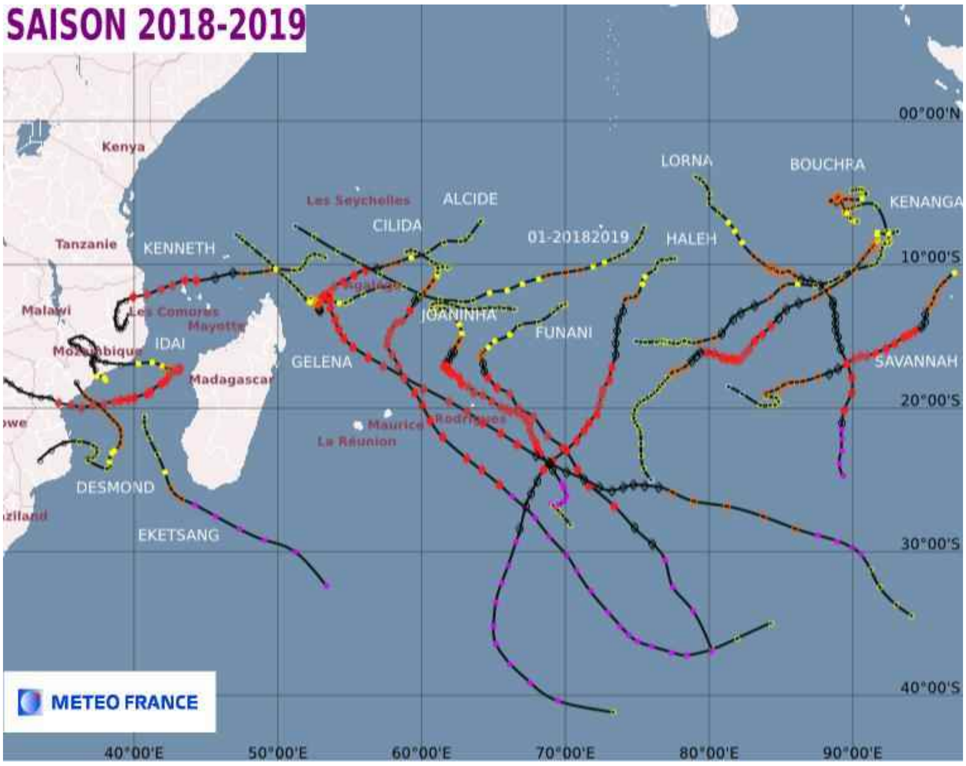

Fig. 8.1 Tropical storms and cyclones that formed over the South-West Indian Ocean during the 2018-2019 cyclone season (Source: http://www.meteofrance.re/cyclone/saison-en-cours).

Cyclone Idai was a catastrophic tropical cyclone that originated from a tropical depression formed over the Mozambican Channel on 4 March 2019[1]. This storm moved initially over land in Mozambique and Malawi during the 4-9 March 2019 period, and then returned to the Mozambican Channel where it made a rapid intensification to become a tropical cyclone. On 11 March 2019 at 06.00 UTC the system had become an intense tropical cyclone with wind speed up to 165 km/h and heading towards the mainland Mozambique[1]. The cyclone which was now a category 4 made landfall immediately north of Beira during the early hours of 15 March 2019. This system weakened on the same day into at tropical depression as it moved overland. By the evening of the same day this tropical depression had moved some 230 km from the coast into eastern Zimbabwe affecting the Chimanimani and Chipinge districts.

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[1] http://www.meteofrance.re/cyclone/trajectoire

The system further moved as far as the central part of Zimbabwe and started dissipating on 16 March 2019 having moved overland for 470 km from Beira. From being a tropical depression to dissipation, Cyclone Idai lasted 12 days (4-16 March 2017).

Cyclone Kenneth was a surprise as it occurred towards the end of the cyclone season during late April 2019, and was formed over the northern limits of cyclone formation at 9.5° S latitude and 53.3° E[1]. The northern part of Mozambique, Cape Delgado Province, had not experienced cyclones during the last 30+ years. The meteorological centre in La Reunion, which serves as the Regional Specialised Centre (RMSC La Reunion), coordinating monitoring of tropical cyclones in the South-West Indian Ocean, issued an advisory statement about a zone of tropical disturbance over the ocean on 21 April 2019. This system started moving westward and by 23 April 2019 was classified as a tropical depression, and a tropical cyclone on 24 April 2019 that was affecting the Comoros Island. The central part of the cyclone was located north of the Comoros Islands. Cyclone Kenneth which had wind speed of about 205 km/h made landfall on 25 April 2019 over Pemba a north coastal town in the Cape Delgado Province of Mozambique. Once the cyclone moved overland, it started to weaken and by 00.00 UTC on 26 April 2019, the RMSC La Reunion downgraded the system to a tropical depression. The system dissipated on 28 April 2019 after moving 540 km overland. Thunderstorm activity developed off the coast of Mozambique on 27 April as the system began drifting northward. During the Cyclone Kenneth period, Pemba received 570 mm of rainfall by 29 April 2019 and other parts of Cape Delgado and Nampula Provinces received 100 – 200 mm of rainfall.

8.2 IMPACTS OF CYCLONE IDAI AND CYCLONE KENNETH

Cyclone Idai caused a disaster with the highest fatalities in comparison to previous cyclones. Over 1000 people in Malawi, Mozambique and Zimbabwe died due to houses collapsing or being flooded while they were inside, drowning crossing flooded areas, landslides, injuries inflicted by objects moved by wind or water (Table 8.1). Wind associated with the cyclone caused considerable damage to infrastructure and uprooting of trees in both Mozambique and Zimbabwe.

Table 8.1 Effects of Cyclones Idai and Kenneth[2]

	Cyclone Idai			Cyclone Kenneth
Effects	Malawi	Mozambique	Zimbabwe	Mozambique
Number of human deaths	59	603	344	45
Number of persons displaced	60,880	400,000	4,500	3,214
People in need	868,900	1.2 M	279,000	374,000
Cultivated areas damaged	Not available	715,378 hectares	Not available	Not available
Schools damaged	104	540	139	193

Most parts of Beira, which has a population of 530,000 people with the majority living in poorly developed residential areas, such as slums that succumbed to high wind speeds and water levels. Cyclone Idai caused storm surges that reached heights of up to 4.5 m along the Mozambican coastline. Most areas in Mozambique and Zimbabwe affected by Cyclone Idai received 200 – 600 mm of rainfall during this period which contributed to flooding. High resolution satellite image analysis by the European Space Agency and NASA showed that most of the low-lying areas with an elevation of less than 20 m stretching from the coast to about 100 km along both the Pungwe River and the Buzi River, were inundated creating a lake of with water depths of up to 6 m in some parts (Figure 8.2). Flooding occurred on about 3000 sq km in the Manica and Sofala Provinces of Mozambique[3]. An estimated 715,378 hectares of

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[2] https://reliefweb.int/sites/reliefweb.int/files/resources/joint_national_sitrep_1_mozambique_10_may_2019_final_whoinsdps_for_trans.pdf

https://reliefweb.int/report/mozambique/unicef-cyclone-idai-and-kenneth-post-impact-situation-may-2019

[3] https://reliefweb.int/sites/reliefweb.int/files/resources/joint_research_centre_analysis_of_wind_rainfall_and_storm_surge_impact_09_april_2019.pdf

http://unosat-maps.web.cern.ch/unosat-maps/MZ/TC20190312MOZ/UNOSAT_A3_TC20190312MOZ_FloodExtent_Dombe.pdf

http://unosat-maps.web.cern.ch/unosat-maps/MZ/TC20190312MOZ/UNOSAT_A3_Natural_Portrait_TC20190312MOZ_cumulative.pdf cultivated lands with crops ready for harvesting were inundated in these two provinces. In addition, fisheries infrastructure, which was a main source of livelihood along the coast and Pungwe River was damaged. Most households in both Mozambique and Zimbabwe depend on agriculture for livelihoods. The damage to agricultural lands just before the harvesting period has caused severe food insecurity. Estimates by humanitarian organizations are that about 1.1 million people were made food insecure.

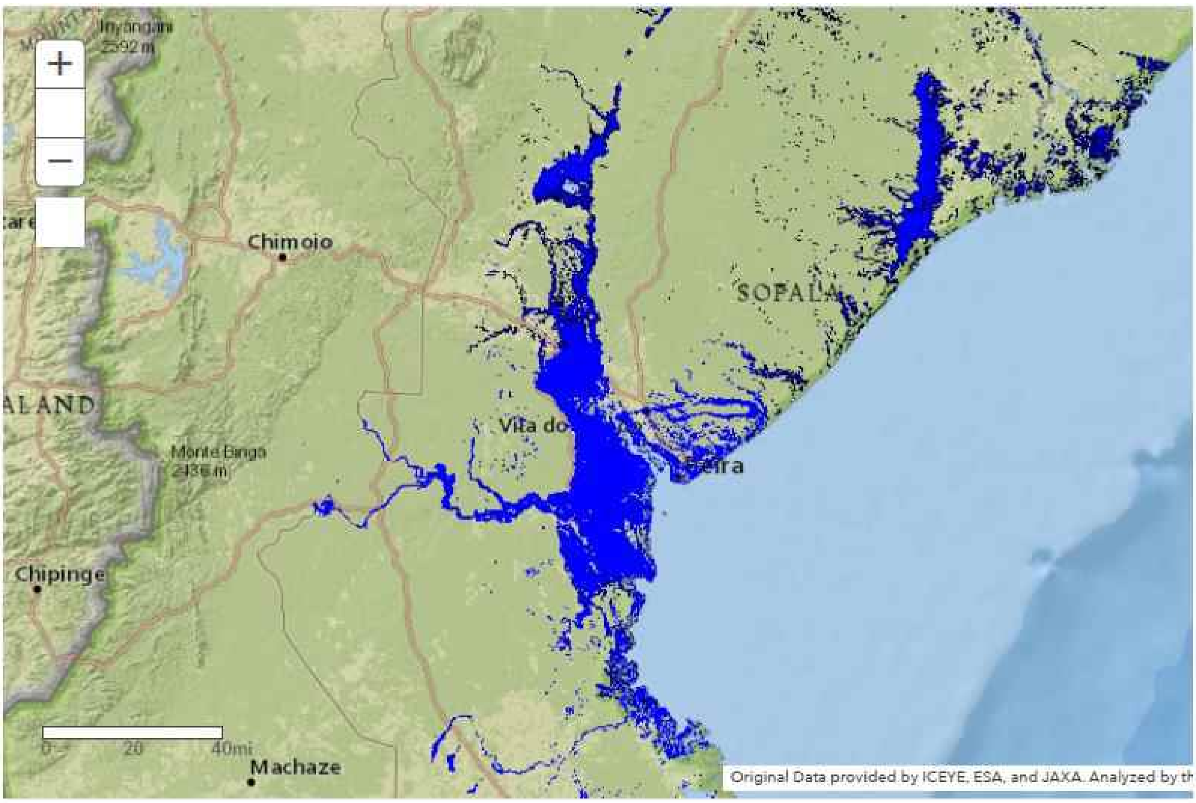

Figure 8.2 Flood extent in Mozambique mapped using from 18 – 23 March 2019 images by the Advanced Rapid Imaging and Analysis (ARIA) team at NASA's Jet Propulsion Laboratory using modified JAXA ALOS-2 data (2019), Copernicus Sentinel data (2019), ICEYE data (2019) (https://maps.disasters.nasa.gov/)

The Mozambique-Zimbabwe border region has a mountain range aligned in an east-west direction with an altitude of 1000 – 2000 m above sea level. Cyclone Idai which was moving from east to west was forced to ascent these mountains which enhanced rainfall formation. Parts of Chimanimani and Chipinge Districts in Zimbabwe, which are located on the mountain range, received 200 – 400 mm of rainfall during the passage of the cyclone. This region has very steep slopes and high rainfall in a short period caused flash floods, landslides and rockfalls (Figure 8.3 and 8.4). Since the tropical storm arrived during the late evening on 15 March 2019, most of the heavy rainfall and wind occurred overnight and the resulting landslides and rockfalls buried houses while the occupants were asleep without

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any warning or rescue mechanisms in place. At the Dzingire Centre 26 km south of Chimanimani in Zimbabwe, over 80 houses located within the then floodplain of the Rusitu River were washed with most of the occupants asleep (Figure 8.4).

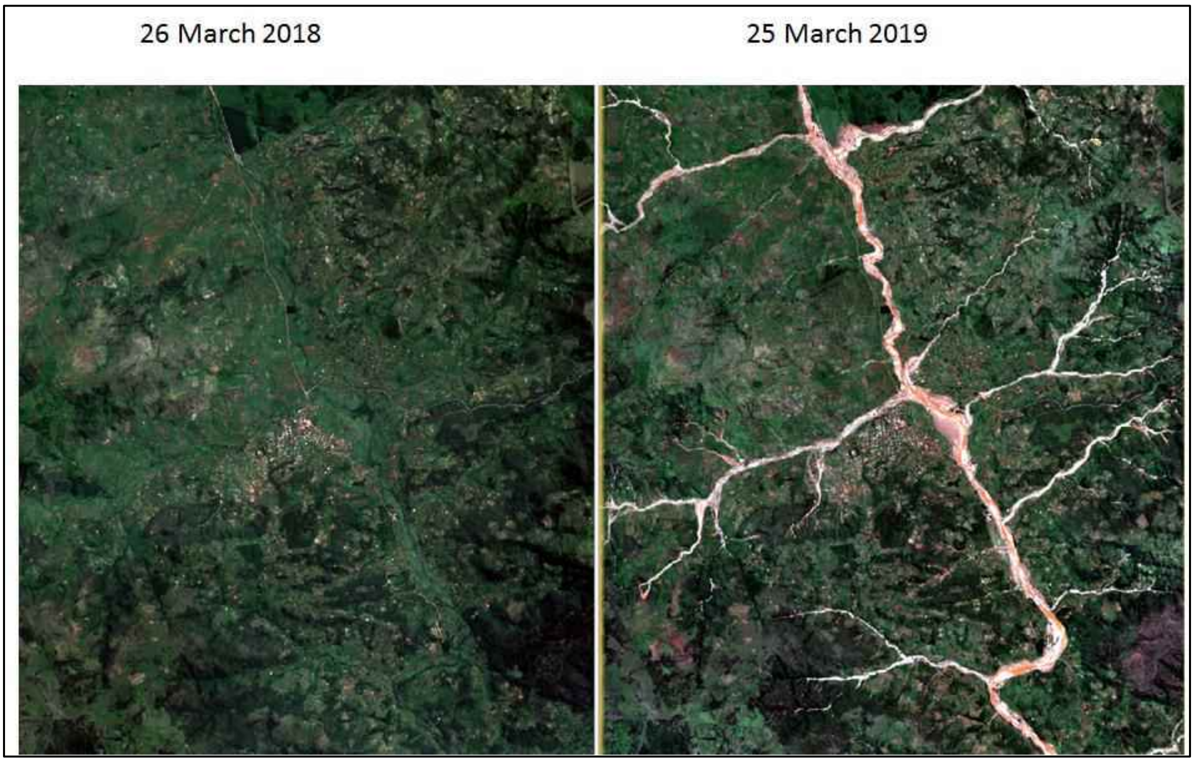

Figure 8.3 Landslides and widening of the Nyahode River 13 km south of Chimanimani due to rainfall and floods during the Cyclone Idai period (Source: Sentinel 2 images from the European Space Agency).

Figure 8.4 A comparison of satellite images before (24/6/2018) and after (20/3/2019) Cyclone Idai at Dzingire Centre in Zimbabwe located at the confluence of three rivers, Nyahode River from the north joining Rusitu River which

flows from west to east, which is joined by the Chipita River from the south. About 65 buildings disappeared while 39 were damaged. (Source: Images processed and obtained from SERTIT, http://sertit.u-strasbg.fr/index_en.htm)

The damage to roads, bridges, and closure of roads by uprooted trees made most areas affected by Cyclone Idai inaccessible in both Mozambique and Zimbabwe. Power lines and mobile phone bases were also destroyed contributing to the inaccessibility of affected areas. During the cyclone and 2-4 days later, continuous rainfall and misty weather created problems for helicopter flights to the affected areas. This hampered search and rescue efforts in both countries. Destruction to water supply systems and contamination of water sources resulted in the spread of cholera (Table 1). This has been particularly problematic in those parts of Mozambique that already had low levels of access to safe water and sanitation facilities. Post Cyclone Idai assessments undertaken have revealed that 72% of the sampled locations in Manica and Sofala Provinces were food insecure, 59% had problems accessing health services, 54% considered lack of shelter as problem[4].

8.3 RESPONSE TO THE DISASTER

According to the World Meteorological Organization, RMSC La Reunion is required to issue and share with members of the WMO Regional Association I (RA I) a daily cyclonic information bulletin about tropical weather activity and possible formation of tropical cyclones in the near future[5]. When a tropical disturbance has been detected, RMSC La Reunion informs members of RA I about the location, intensity, dimensions and future track. This information is shared every 6 hours and incorporated into national cyclone warning strategies. Members of RA I cooperate in providing national cyclone warnings to avoid confusion. When Cyclones Idai and Kenneth occurred, RMSC La Reunion and all the relevant national meteorological centres provided warnings to their governments. The first alerts were issues on 4 March 2019 and 21 April 2019, respectively. Regional and international television stations included warnings about these cyclones in their news and weather bulletins.

In both Mozambique, and Zimbabwe the national meteorological centres issued warnings about Cyclone Idai warning of high wind speed, heavy rainfall and flooding. In Mozambique, the government issued alerts three days before the landfall of Cyclone Idai. Some people responded to the warnings in Beira and moved out of flood prone areas. The National Institute for Disaster Management (INGC) identified evacuation routes for affected persons and possible areas for shelter. In Zimbabwe, most of the warnings about a cyclone were circulated informally through social media. The Department of Civil Protection advised people to move to high ground in order to avoid flooding. The possibility of landslides occurring on high ground and contributing to the disaster had not been foreseen. Both governments and the affected communities did not foresee that a disaster of the magnitude caused by Cyclone Idai will occur.

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[4] https://reliefweb.int/report/mozambique/multi-sectoral-rapid-assessment-post-cyclone-idai-14-districts-sofala-and-manica

[5] https://library.wmo.int/doc_num.php?explnum_id=4031

Once the effects of Cyclone Idai became apparent, the National Institute for Disaster Management in Mozambique coordinated all the responses of government agencies and humanitarian partners. INGC established provincial hubs to coordinate responses in Beira for the Sofala Province, Chimoio for Manica Province, and Quelimane for Zambezia Province. By the end of March 2019, there were several UN agencies, international and national NGOs, participating in providing assistance on health, water and sanitation, shelter, food security, education, and logistics. The UN Office for the Coordination of Humanitarian Affairs (OCHA) estimated that in Mozambique 1.1 million people, were getting food assistance, 907,00 safe water, and shelter for 29,000 households. Aerial assessments were being undertaken. Due to damage to roads, there were still communities located in hard to access areas with limited assistance.

The Department of Civil Protection in Zimbabwe coordinated the relief work. However, due to most of the roads having been damaged, the most severely affected Chimanimani District was not accessible during the first 3 days of the cyclone. Continuous rainfall and misty weather made access by helicopters problematic during the first 3-5 days after the cyclone. The Department of Civil Protection had never planned for a disaster at the scale of Cyclone Idai. In affected communities, there was no suitable equipment for retrieving persons buried in damaged houses or heavy boulders.

The large voluntary support by individuals in all the major centres in Zimbabwe and the diaspora in the form of donation of food, clothing and other items to help those severely affected was highly remarkable. Collection and transportation of donated materials were done by volunteers, including private organisations. The medical fraternity deployed teams on a voluntary basis to the affected areas. By the beginning of April 2019, international and national humanitarian organizations were assisting in the management of the disaster.

8.4 LESSONS LEARNT FROM CYCLONE IDAI AND KENNETH

Cyclone Idai amplified pre-existing development challenges

The major lesson is that Cyclone Idai amplified pre-existing human development challenges and high vulnerability of large sections of the society in Malawi, Mozambique and Zimbabwe arising from weak national and local governance, communities largely depending on near subsistence livelihoods, lack of access to basic services, inequalities at national and international levels. The affected communities have very low resilience to any form of disaster, and Cyclone Idai unfortunately demonstrated this. A large proportion of the population in Beira reside in slums, which could not withstand the impact of heavy rains, winds and flooding.

Need for more localized early warning systems

RMSC La Union and the national meteorological organizations were able to track Cyclones Idai and Kenneth from formation, intensifying intense tropical cyclones, heading towards mainland, and finally dissipation. Thus, information was available about an impending disaster in both cases. In Mozambique evacuation plans and measures for protecting some buildings were put in place. In Zimbabwe cyclone alerts were provided as part of the usual weather bulletins. The early warnings provided were not effectively acted upon by district and local authorities including those to be affected. With ready availability of satellite some effort should have been made to provide location specific warnings to community leaders, schools, local police stations, and clinics.

Need for capacity building and clearly defined roles of local authorities in disaster management

During the period Cyclone Idai was affecting parts of Mozambique and Zimbabwe, local authorities who are close to affected communities were not prominent in leading search and rescue operations. There seems to be very little investment in disaster management and dissemination of early warnings at the local authority level. Even within communities, the roles of representatives in coordinating disaster management does not seem to be well defined, except to act as lead persons when external humanitarian organizations arrive. Investment in disaster management at the local authority level should be made a priority in both Mozambique and Zimbabwe. National governments should allocate adequate resources for disaster management to local authorities. There is a desperate need to establish disaster management teams at district levels.

Unavailability of disaster response options due to poverty

In Mozambique due to the frequent occurrences of tropical storms, there is some level of awareness about the possible effects of these weather systems. However, due to poverty that affects the majority of the population, they often do not have any options for responding to these events. The same is true for rural communities that were affected in Zimbabwe. Even if they had ample information about the impending disaster, they may not have resources to move out of harm’s way.

Public unawareness about the nature of impending disasters and appropriate responses

In Zimbabwe, a cyclonic activity is mainly associated with windy weather. Thus when cyclone warnings are provided, they are not considered to cause disasters. Cyclone Idai demonstrated the low level of public awareness about disasters such as landslides, rockfalls, uprooting of large trees, and flooding arising from cyclones. Almost all the affected were not expecting major problems. In addition, there had never been any information disseminated about the appropriate response as part of disaster preparedness management plan.

Integration of disaster reduction in land use planning

A considerable proportion of the communities affected by Cyclone Idai resided in unplanned settlements, or settlements planned in marginal areas vulnerable to flooding and landslides in both rural and urban areas. The rapid expansion of settlements and cultivated lands onto steep highland areas accompanied by deforestation exacerbating flooding and landslides. Settlements and cultivation in floodplains and other wetlands in Beira and other locations worsened the flooding problem. There is a need to integrate management of flooding and landslides in land use planning in order to reduce the impacts of these disasters. Demarcating areas prone to flooding and prohibiting settlements in them in both rural and urban areas will minimize future problems of properties being destroyed by floods.

Need for improved coordination of voluntary and disaster management efforts by the public

During the aftermath of Cyclone Idai, Zimbabwe witnessed a huge effort by citizens in and outside the country who voluntarily offered assistance in various ways. Private sector organizations in the major centres also participated in providing assistance, e.g. transporting goods donated. Medical personnel and other experts also moved in rapidly on a voluntary basis to provide assistance. Local humanitarian NGOs based in Zimbabwe were also actively involved. This demonstrates that there is a potential for citizens and the local NGOs contributing to significant disaster management. However, these efforts were not coordinated at national and local levels. In some cases, there seemed to be a contestation between citizens and the government in providing relief with some government officers insisting that they should coordinate distribution of donations, while some private groups were of the opposite view.

The government should develop a mechanism for acknowledging and effectively coordinating voluntary efforts by citizens, NGOs and private sector in disaster preparedness and management. With proper coordination these efforts will provide immediate relief, and international organisations will only be called in to fill gaps.

Need for systematic use of satellite data and lack of in-situ monitoring

Satellite data for monitoring weather events and monitoring their effects such as flooding and landslides are now readily available. The European Space Agency and NASA made some of the information available. There seems to be an no effective institutional framework for coordinated and systematic utilization of satellite data and products for timeously managing disasters.

Management of weather and hydrological disasters requires in-situ data. However, there is inadequate coverage by stations for weather and flooding monitoring in both Mozambique and Zimbabwe. Without in-situ data, it becomes difficult to validate the scale of the disaster. Funding for the collection of in-situ weather and hydrological data needs to be prioritized for routine management, assessing level of risk from disasters and their management.

Reliance on international humanitarian assistance

Disaster management systems in Mozambique and Zimbabwe have tended to rely significantly on external input. There is a need to improve the capacity to manage disasters at the national and local levels without relying greatly on external organizations. Policies and priorities of international organizations providing disaster management assistance are always changing. Heavy reliance on these international organizations exposes countries in disaster prone areas to negative consequences of such policy changes. Disaster management at national and local levels should be made part and parcel of the development effort in Mozambique and Zimbabwe as is reflected in the Sendai Framework for Disaster Reduction.

8.5 The Conversation

1) Anecdotes and specific cases

“*A Family’s Story of Surviving Cyclone Idai*

As Cyclone Idai was barreling down on Mozambique Carolina and her children, including four-year-old Ana*, ran for their lives. The family sought shelter in a nearby building as their home crumpled under the force of Cyclone Idai’s powerful wind and deadly flash flooding. When the roof of the building they were taking refuge in collapsed around them, Carolina and her children were left with absolutely nothing.*

Eventually, the family found space in a school where they felt safe. Carolina’s family, including her young children, spent two days without food before receiving aid.

"I haven't seen anything like this in my life, Carolina said. "We've lost everything but thank God I'm alive. Because if I'd stay in our house that collapsed, I wouldn't be alive.", https://www.savethechildren.org/us/about-us/why-save-the-children/story/cyclone-idai-survivor-story

Cyclone Idai disaster: Survivors speak out

"There were nine of us in the house, only four of us managed to survive the cyclone and the other five died. We were struck by rocks that fell from the mountains and they destroyed the house and all the structures at the homestead.

"My uncle helped me out of the rubble which had trapped me and we managed to help others although l was too weak to continue. I know my wife survived, unfortunately, my brother, his wife and children and my own son did not survive," https://www.herald.co.zw/cyclone-idai-disaster-survivors-speak-out/

After Cyclone Idai, *'Beira Has Found Itself in the Dark'*
Daviz Simango, Mayor of Beira City: "*The cyclone was marked by extremely strong winds. They destroyed our city. Public and private infrastructure, schools, hospitals and houses were all destroyed. Our economy has been hit hard -- warehouses, shops and stalls have been ruined. The telecommunications systems have failed, and there's a very severe water shortage. ...*
Beira has found itself in the dark and has become a ghost town at night". https://allafrica.com/stories/201903220008.html

Marthe Frieden, medical team leader of for the emergency response of* Doctors Without Borders (MSF) Southern Africa *to Cyclone Idai in Zimbabwe

"The cyclone has intensified an existing socio-economic crisis in the region, and in the aftermath we are witnessing a multi-layered calamity: A drought, a crippling economic crisis, an underlying HIV epidemic, growing rates of diabetes, hypertension and other non-communicable diseases, and now the devastation caused by arguably the worst cyclone to hit the region in recorded history. If progress is to be made in the medium and long-term, multi-faceted support is needed. In the short term our MSF teams will remain alongside the health ministry and other actors, building bridges where we can.", https://www.msf.org.za/stories-news/staff-patient-stories/cyclone-idai-zimbabwe-first-six-days

8.6 RECOVERY AND RECONSTRUCTION

After the Cyclones Idai and Kenneth, many essential services such as hospitals and schools are not working, roads are damaged, food and potable water are in short supply. It is necessary to focus on the affected areas and rebuild the communities back. The affected people have to receive counselling due to the traumatic experience during the cyclones.

Disaster risk management should be based on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment. Such knowledge is useful for risk prevention, mitigation, preparedness and response. The immediate recovery plan has to provide:

i. Primary health care
ii. Food security and nutrition
iii. Water, sanitation and hygiene
iv. Shelter, clothing, education and communication lines
v. Responding to water borne diseases such as cholera, bilharzia and dysentery
vi. Protection and psycho-social support.

The reconstruction phase should aim at reducing vulnerability and increasing resilience to future cyclone induced disasters and other risks. The reconstruction phase has to focus on contributing to the achievement of all the Sustainable Development Goals (end poverty, achieve food insecurity, ensure healthy lifestyles, education, gender equality, access to water, etc) as a way of building communities that in future will be resilient to disasters.

The reconstruction phase should also incorporate disaster risk reduction measures. The Sendai Framework for Disaster Risk Reduction 2015-2030 provide very clear guidelines and actions required at national and local levels in both Mozambique and Zimbabwe, i.e. understanding disaster risk, strengthening disaster risk governance, investing in disaster risk reduction and building back better.

The experiences and lessons from both Cyclones Idai and Kenneth should be taken into account in planning a future in which weather and hydrological-related disasters are timely and effectively managed and risks reduced.

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9. Learning from Hurricane Harvey through economic, ecological and social perspectives

9.1 Outlook of the Disaster

The 2015–2030 Sendai Framework for Disaster Risk Reduction (United Nations, 2015) identifies the urgent need for learning about disasters. Unfortunately, it is well established in the literature that learning about disasters is not easily achieved (Meyer, 2010; Birkland, 2009; Donahue and Tuohy, 2006). This section reports on the application of the post-event review capability (PERC), a consistent, practice-based and transdisciplinary disaster forensic analysis methodology, as applied to Hurricane Harvey in the Houston metropolitan area in 2017. Hurricane Harvey dropped more than 1 m of rain over eastern Texas where it caused devastating flooding, displaced more than 30,000 people and prompted more than 17,000 rescues. Total damage from the hurricane is estimated by the National Oceanic and Atmospheric Administration (NOAA) at USD 125 billion (Blake and Zelinsky, 2018) - the second-costliest tropical cyclone on record after Hurricane Katrina. The PERC approach looks beyond engineering grey infrastructure-type questions to incorporate social and ecological considerations as well. It provides lessons learned and recommendations to enhance flood resilience that can be applied not only in Houston, but globally. We know that: while hazards are natural, disasters are not; that while resilience-building is cost-effective, few incentives currently exist to invest early, incorporate resilience approaches and build back better; and that the neediest in society are often neglected both before and after disasters. By applying PERC, we provide a consistent and practical approach to understand these issues as they pertain to each event, and identify actionable recommendations.

9.2 The Post-Event Review Capability (PERC)

Developed as part of Zurich Insurance Group’s flood resilience alliance[6], the PERC provides a methodology for undertaking forensic analysis and independent reviews of large disaster events, while providing accessible, consistent, and generalizable insights. There is a need to build and enhance resilience in infrastructure, services, and agents’ capacity and livelihood systems if risk is to be proactively reduced, given the global growth of hazard, exposure and vulnerability (e.g., Simonovic and Peck, 2013; Keating et al., 2014; Keating et al., 2016; UNISDR, 2015). A disaster forensic analysis methodology like PERC helps to capture new insights and review lessons of the past, both within and across disciplinary boundaries, especially in the dynamic contexts of urbanization and climate change. Its focus on lessons and recommendations relevant for building disaster resilience distinguishes it from disaster impact assessment approaches such as Damage and Loss Assessments (DaLA) (Worldbank, 2010) and Post Disaster Needs Assessments (PDNA) (GFDRR, 2013). PERC is open source and a manual on its use has been published by Venkateswaran et al (2015).

PERC seeks to answer questions related to disaster resilience, disaster risk management, and catastrophe intervention. It looks at what worked well (identifying best practice) and opportunities for improvements (providing actionable recommendations). It highlights that, while hazards are natural, disasters are not; there is a choice to act early to prevent the creation of new risk and reduce existing risk, and that the choice very often is not only the right one from

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[6] https://www.zurich.com/flood-resilience

a humanitarian perspective but is also cost-effective. Building disaster resilience building goes beyond engineering grey infrastructure-type solutions to fight hazards such as flood waters, to incorporating social and ecological approaches as well.

From the 13 PERC reports published so far, a lot of commonality both across geographies as well as across cultural and development contexts has emerged. This enables analysts to identify important lessons that are generalizable. A first report on these general lessons was published by Keating et al (2016) and turned into a policy paper by Zurich (2018-01). The PERC analyses of global disasters leave no doubt that disaster risk management professionals are faced with universal truths when it comes to attitudes and actions around resilience building to natural hazards. The research has shown that:

- Disaster risk management is playing catch-up to increasing exposure to natural hazards (Miller et al., 2008; UNISDR, 2011; Zurich Insurance Group, 2013a)
- Globally, spending on response is still much greater than investment in pre-event risk reduction (87 and 13 percent, respectively). Where money is invested in prevention, it typically goes to physical infrastructure rather than more cost-effective integrated risk management options such as environmental planning and awareness building for risk avoidance. Our research has shown that on average 1 USD invested in pre-event resilience building saves 5 USD in future losses (Zurich Flood Resilience Alliance, 2014).
- Protection infrastructure already in place (e.g. levees) often produces a false sense of security.
- Few incentives exist to encourage resilience approaches and building back better.
- The most vulnerable groups in society are often excluded both before and after disasters.

9.3 Hurricane Harvey event overview

Hurricane Harvey made landfall along the Texas coast near Port Aransas on Friday August 25, 2017 as a Category 4 hurricane. Wind damage along the coast near the landfall was extreme. However, Harvey quickly weakened and its forward motion slowed; the hurricane shifted from a wind threat to a flood threat. By Saturday flash flooding developed across Houston and Harris County, with peak intensity rainfall reaching 13-15 cm per hour in places. On Sunday the United States Army Corps of Engineers (USACE) deployed emergency releases at two key flood reservoirs: Addicks and Barker. Despite the releases, Addicks began spilling by Tuesday morning. Similar spills and emergency releases occurred at Lakes Houston and Conroe as they rapidly rose and overflowed. The Addicks and Barker releases contributed to catastrophic flooding along the Buffalo Bayou. All bayous (swamps) and creeks in Harris County experienced record flooding.

Harvey exceeded all previous rainfall records back to the late 1800s. The majority of Hurricane Harvey's rainfall in Harris County occurred during four days, with total rainfall estimates ranging from 66 to 119 cm (Figure 9.1). Record flooding occurred at every bridge crossing along Buffalo Bayou. In downtown Houston, water levels exceeded the record set by storm Allison by 1.5 to 2.1 m. Rainfall statistics were 1 percent annual occurrence probability (100-year return period) or less frequent (>500y) for all watersheds in the county in this period. Flooding was unusually deep in some areas, due in part to the intense short duration rainfall and the record flood levels along several creeks and bayous. In a few areas, water levels rose to the second story of structures. The extent of impacted areas was also extreme: at peak flooding, ca. 25–30 percent of Harris County—roughly 1,150 km^2 of land—was submerged. 60 counties across southeast Texas were impacted, with heavy rain extending into Louisiana. Storm impacts were also recorded in Arkansas, Alabama, Tennessee, Kentucky and North Carolina.

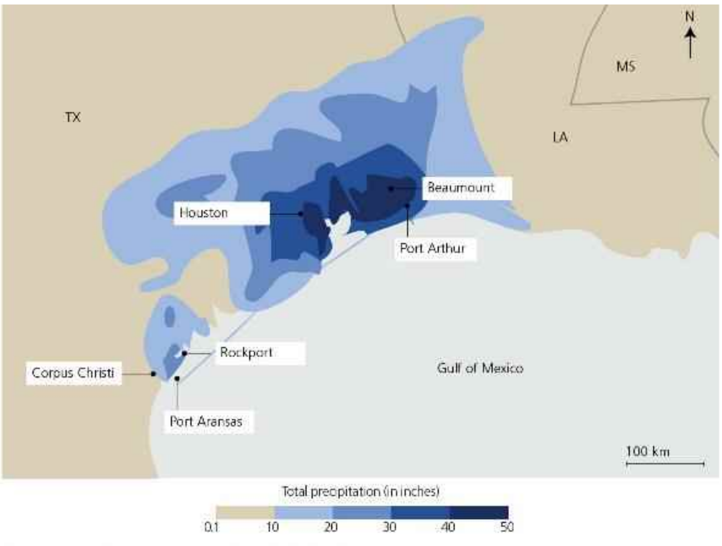

Figure 9.1 Hurricane Harvey's total precipitation between August 25 and 30, 2017 in Texas and Louisiana, based on data from NOAA Climate.gov. Reproduced from Zurich (2018-02).

Throughout Texas, 103 people died in storm-related incidents, 36 of them in Harris County (Blake and Zelinsky, 2018). Unlike with other recent Harris County flood events, the majority of the fatalities associated with Harvey were not from drowning in vehicles, but from high water levels and fast-moving water. Notably, Harvey was one of the only flood events where people drowned in their home or work place, and one of the few times where authorities urged residents to climb on to their roofs to escape flood waters. Official rescues exceeded 13,000 people, while a flotilla of private boats rescued an unaccounted number of additional people. Over 37,000 Texans took refuge in shelters.

Approximately 203,000 homes were damaged, 12,700 were destroyed, and more than 700 businesses were impacted. Over 100 roads (Schaper, 2017) were closed in the immediate aftermath, 800 wastewater treatment plants were impacted, and the school district reported USD 700 million in damages (Kamath, 2017). Energy production in the Gulf of Mexico declined by approximately 21 percent in the wake of Harvey. Many energy-related ports and terminals temporarily closed. About 12 percent of total U.S. refining capacity was offline for several days. Two refineries had to be shut down following related storm damage and releases of hazardous pollutants, while a chemical plant in Crosby exploded on August 31 due to power failures and flooding.

The U.S. government estimated damages from Harvey at USD 125 billion, primarily from damage to homes and commercial property. In addition to direct physical losses, the loss of revenue by retailers and restaurants alone is estimated to be approximately USD 1 billion (Planalytics, 2017). Many homes, even within the 100-year floodplain, lack flood insurance. Insurers estimate the total insured losses from Hurricane Harvey at USD 19.4 billion (Texas Department of Insurance, 2018). In addition, 738,000 people registered for assistance with FEMA, with payouts reaching USD 378 million (Moravec, 2017). Harris County Flood Control District (HCFCD) estimates that 83 percent of the 1.4 million buildings in Harris County lacked flood insurance when the storm hit (Zaveri, 2017).

While this event was extreme, the intensity of rainfall associated with Harvey is not without precedent along the coastline of the Gulf of Mexico. The typography of the Houston area means it has been prone to flooding since its founding, although every single one of the major historic floods in Houston has manifested differently. Flooding is likely to become more frequent and perhaps more severe in the future, as rainfall intensity is increasing. We see this because NOAA periodically updates precipitation intensity return periods using additional data: prior to the December 2017 release of new calculations for public comment and review, the 24-hour 1 percent annual probability storm event (the "100-year" storm, calculated in 1961) for Harris County was 33.5 to 34.3 cm of rain. The new value, using an additional 50 years of data, is 41 to 43 cm. The old "100-year" event is now estimated to have a 4 percent annual probability – the "25-year" event.

9.4 Response and recovery

The Emergency Operations Center of Harris County (EOC) was operational days before Hurricane Harvey made landfall, preparing assets and monitoring the situation. However, as Harvey made landfall and caused widespread flooding, they were overwhelmed with the number of calls requesting assistance. The initial round of flooding occurred as bayous flowed out of bank and local drainage systems were overwhelmed. The second round of flooding, which occurred approximately 48 hours later due to the Addicks and Baker reservoirs being opened, took many residents and businesses by surprise. In total, the Harris County EOC remained open 24 hours a day, 7 days a week for 26 days, with initial response activities gradually shifting to early recovery ones.

In the recovery phase new grant mechanisms emerged to support the many organizations in Houston working with low-income neighborhoods. The "2-1-1 program" - which connects residents with social service resources - received over 366,000 calls, many from flood-impacted residents. The Harris County Long Term Recovery Committee coordinated a number of organizations, who collectively worked on a wide variety of recovery issues. Additional support came from the Texas OneStar Foundation and prominent community members who established a number of relief funds. Emergent grassroots groups also helped rebuild flood damaged homes.

In transitioning from response and short-term recovery to long-term recovery, Houston is faced with the challenge of navigating a complex governmental context in order to make decisions about what recovery will look like and how actions can be leveraged to build future flood resilience. The city has prioritized flood recovery and resilience actions, including strengthening floodplain regulations. In response to this event, regulations in Harris County and Houston now require homes within the 100-year and 500-year floodplain to be elevated 61 cm above the 500-year flood level, some of the most stringent criteria in the USA. While this does not address the nearly 50 percent of impacted structures that lie outside mapped floodplains, it is nonetheless a strong start.

Buyouts of particularly high-risk locations and repeat loss properties are a second focal point. HCFCD projects clearly demonstrated that leaving space for water by widening bayous and creating retention ponds that double as parks and recreation spaces can successfully mitigate flood risk in Houston (Figure 9.2). However, in built up urban areas this approach requires buying out and removing existing structures. While there is interest in this approach, existing funding streams are not designed to take advantage of the post-flood environment and decisions for buyouts take a long time. Not knowing if they might eventually be eligible for a buyout incentivizes the rebuilding of damaged homes and/or selling to builders, perpetuating the stock of at-risk housing.

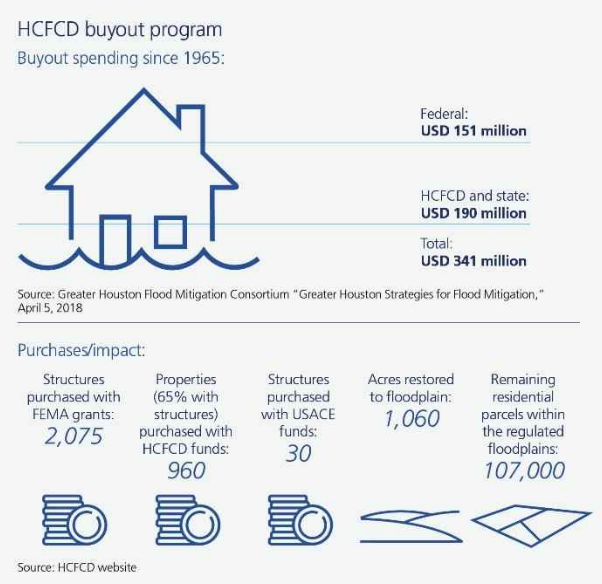

Figure 9.2 Spending on flood buyouts in Harris County since 1965. Reproduced from Zurich (2018-02).

The next key priority emerging in the recovery phase is large infrastructure projects. Interestingly, many in Houston are looking for opportunities to leverage the recovery processes not just to address flooding but to build resilience more broadly. As a result, two of the largest infrastructure projects under discussion — the Ike Dike and the Mid-Bay Solution — would have provided relatively little benefit during Harvey. Instead, these solutions recognize that, as destructive as Hurricane Harvey was, the greatest threat to the city is a major hurricane that comes directly up the ship channel. The resulting storm surge has the potential to inundate the refineries and petrochemical plants along the channel and far surpass the damages caused by Harvey.

The leading infrastructure solution being proposed to address flooding is the construction of a third reservoir to address overflow issues from the Cypress Creek basin into Addicks Reservoir. While a year after Harvey the Harris County voters passed a USD 2.5 billion bond measure for flood mitigation, funds for the estimated USD 500 million third reservoir have not been allocated, nor have other funds been identified. There has been little discussion of the regulatory framework that gave rise to the flooding at Addicks and Barker Reservoirs – the lack of regulation and risk landscape awareness within and below the reservoirs and the construction upstream that is increasing runoff volume. Unless these issues are addressed, a third reservoir is likely to have only a limited period of successful operations before it too fails.

While certain recovery initiatives have been prioritized, significant gaps remain. The most visible of these are funding for recovery, inequitable distribution of relief funds and a broad need for drainage improvement and maintenance. The funding required for rapid recovery was slow to materialize in Houston and Harris County. A year after the event the state had spent USD 2.7 billion, primarily on response and immediate recovery such as health and human services. Payouts from private insurance and through the National Flood Insurance Program (NFIP) amount to only a fraction of the estimated damages. Federal assistance had been about 2 billion dollars, primarily for schools and reimbursing public safety costs, though eventually the Federal Emergency Management Agency will reimburse municipalities for up to 70% of recovery expenses to rebuild as was.

Lack of action or rebuilding as was, however, leaves the same vulnerabilities in place, with the potential for long-term economic impacts that far exceed what it would cost to support action today. What funding is available has been inequitably distributed; while Harvey impacted homes in both high- and low-income neighborhoods, homes in higher-income communities are receiving more of the attention. Many lower income and vulnerable communities have yet to receive much-needed support and assistance, even though their needs are greater, their coping capacity is lower, and they are typically under-insured.

9.5 Lessons learned

Built environment: Engineering has a critical role in flood risk reduction, but it must be complemented by softer solutions and be part of an integrated approach to flood risk management. This also means that various actors need to come together to work on flood risk reduction. Hurricane Harvey highlighted the limits of engineering solutions to flooding. Particularly in a low-regulation, changing landscape where storm intensity and frequency is increasing, we cannot rely on the built environment alone to control flooding.

This is particularly evident when we look at the location of the flood impacts during Harvey, where nearly three-quarters of damaged homes and apartment buildings lay outside the 100-year floodplain, and more than half outside all floodplain designations in Harvey. Even with the far more restrictive regulations just passed by the city of Houston – requiring all homes in the 100- and 500-year floodplains to be elevated – such regulations would still have fallen short of protecting more than 100,000 Harris County homes that flooded in Harvey. There is a need for broader solutions than widening and straightening bayous and building reservoirs, such as leaving more space for water, restoring wetlands to retain and slow runoff, and changing residential construction. The pace of development in the region provides opportunity to dramatically reduce flood risk with minimal cost to today’s taxpayers.

Regulatory landscape: In order for drainage, reservoirs and bayou projects to perform as designed, the regulatory landscape needs to create and maintain the surrounding environment required for successful performance. The lack of a consistent, regionally coordinated regulatory environment is leading to shortcomings in the built environment that exacerbate flood damages. For instance, when the Addicks and Baker reservoirs were released, over 9,000 homes and many businesses downstream were heavily impacted. Despite the slow onset of the event even moveable assets were lost. There were numerous points at which these impacts could have been mitigated, including when the land was initially purchased and homes constructed, when areas upstream were permitted for development, and when flood maps were developed and disseminated. Critically, the potential for in-reservoir and downstream flooding should have been immediately communicated to a pre-informed populace.

This list is not exhaustive, yet it points to just how broad responsibility often is. Indeed, it is often because responsibility crosses sectors, jurisdictions and scales that needed action is not taken. Action needs to be taken by all jurisdictions across all scales in an integrated way. If the regulatory gaps highlighted in the Addicks and Barker Reservoir story and similar events that occurred across Harris County during Harvey are not addressed, new reservoirs, bayou projects and other large-scale efforts could eventually suffer a similar fate. The physical structures for flood risk mitigation are only as good as the regulatory environment that supports, enables and maintains them.

Culture of awareness: With better risk awareness coupled with enhanced risk communication, many of the damages suffered by individual homeowners and businesses can be at least partially mitigated. In some cities, historic watermark signs memorializing past floods assure that everyone in the city—resident, business and tourist alike—

are aware that floods happen regularly. Similar signs on homes and businesses impacted by Harvey would be a strong first step, both celebrating Houston’s strength in recovery while also highlighting the need to stay prepared. In addition, signs are needed within and around the edges of Barker and Addicks reservoirs highlighting that these are more than parks and making clear to people when they are entering the flood pool boundaries.

The discussion of whether flood-impacted houses should disclose prior flooding when they are sold presents a regulatory opportunity to further support a culture of awareness. Ideally, Houston and Harris County will make such disclosure mandatory. This awareness then needs to be translated into action. Too many businesses and homeowners in Houston failed to take even simple actions that could have significantly decreased their losses. In addition to carrying flood insurance and knowing the risk environment in which they are located, all businesses and homeowners can and should practice simple flood protective actions.

Flood insurance: Flood risk is far more widespread than flood insurance uptake. Many people still think of flood risk as rare and limited to the 100-year floodplain. As Harvey and past flooding events in the area have demonstrated, neither are true. This illustrates that owners and renters should be more proactive about assessing their need for flood insurance. Insurance brokers, as the main interface between property owners and the insurance world, could take the lead on this type of messaging. Such messaging could be coupled with multi-hazard policies that include flood insurance, making the perceived cost-benefit more appealing and simplifying decision-making by not requiring a separate line of coverage for flooding.

Coordination and collaboration: In Houston, limited governance and regulation at all levels has led to a highly fragmented governance landscape with not enough coordination. The resulting fragmentation creates significant challenges for building flood resilience in Houston and Harris County. However, perhaps because there are gaps in leadership and coordination, collaboration among organizations in some sectors is very high and one of the few avenues to get bigger picture issues and efforts accomplished. This exemplifies the “culture of assistance” that exists in Houston and Texas and which was highlighted in the days and weeks following the hurricane. The informal mutual support and philanthropic contributions seen during and following Harvey represent a broad social mobilization that saved lives and contributed substantially to recovery. It is part of the fabric of Texas culture and one that should be emulated elsewhere.

9.6 Recommendations

9.6.1 Preparedness and risk reduction

Use forward-looking scenarios to plan for the future. As a society, we continue to use historical data, statistical analysis and current conditions to design infrastructure that will still be in use 50 years into the future, and then wonder why it is inadequate. We know the world is changing, both naturally and by our actions — land subsidence from groundwater pumping, increased runoff from development, reduced water storage as we grade and pave wetlands, putting more assets in unprotected, exposed areas; coupled with increasing temperatures and storm intensity are resulting in increased flood damages. Rather than rely on past conditions, we must begin to use regional worst-case historical information coupled with projections of future climate and development scenarios in our planning.

Assess and address places where government- or nationally-backed insurance programs are incentivizing rather than minimizing risk. In the United States, the NFIP is currently available to any home or business in participating communities. However, though pricing is risk-informed — communities can reduce the cost of insurance for their residents by adopting various best-practices — it is not risk-based. This gap allows new homes built in floodways and the floodplain to obtain government subsidized flood insurance, thus increasing the high-risk flood insurance pool nationally. Growing debt from the resulting payouts puts the program as a whole in jeopardy. This type of challenge is not unique to the United States. Government- or nationally-backed programs should be regularly reviewed to assure they are not creating perverse incentives.

Make flood insurance more universally appealing for homeowners and businesses. On the supply side, both the federal government and private insurers should explore options to bundle flood insurance as part of a multi-hazard policy. This could make flood insurance more appealing and more affordable, resulting in increased uptake. On the demand side, education campaigns are needed for both property owners and insurance brokers regarding a) flood risk, which is far more widespread than just the 100-year floodplain; b) flood damage costs, which are generally far more severe than homeowners and businesses realize; and c) how carrying flood insurance increases options and speeds recovery.

Build a culture of awareness around risk. Creating a culture of awareness around risk can support the public in making informed decisions about risk mitigation, including evacuation. Installing floodwater markers, disclosing previous flooding of homes to potential buyers, adding signs to the Houston park-reservoirs indicating when entering a flood-control reservoir, and integrating disaster preparedness into day-to-day routines are all steps that contribute to creating a culture of awareness around risk. This in turn can incentivize incremental, small decisions by residents and businesses that collectively can dramatically reduce exposure and risk, such as elevating mechanical assets, locating critical materials above ground level, and incorporating risk awareness and preparedness in people's day-to-day lives.

Address household preparedness as part of business preparedness. Several of the businesses interviewed as part this study incorporate employee awareness of, and preparedness to address potential risk in their business preparedness plans. This supports staff to be better able to continue working through hazard event and/or return to work more quickly following a disaster.

9.6.2 Response

Improve messaging around disaster events to more accurately reflect real risk. The current language we use to describe extreme floods such as "100-year event", "unprecedented," "biblical" or "black swan" does little to help people understand their risk. If anything, it minimizes the issue, making people believe such an event will not occur again in their lifetime. Instead, more careful use of language and comparisons to similar events that have occurred elsewhere in the region can highlight the ways an event is rare but not anomalous — for example, hurricane seasons as intense as the 2017 season have a probability of about a 10 percent in any given year.[7] "Black swan" events are

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[7] NOAA hurricane data, accumulated cyclone energy

not events with very low probability, but rather events that have not been seen in the historical record. This, in turn, will support an ongoing awareness of risk and incentivize risk reduction behaviors.

Trust the public with information that helps them manage their safety and preservation of assets. During a disaster, timely dissemination of information gives people more opportunity to protect themselves and their assets. In Harvey, critical information, particularly about reservoirs filling and releasing, was not communicated effectively. As a result, households and businesses were unable to accurately explore their options and make informed decisions regarding personal and property safety. Key to successful communication is to plan in advance how and what to communicate, know who will provide the messaging, and identify who this information is being communicated to and how materials need to be presented to reach that audience.

Partnerships and relationships are fundamental to resilient response and recovery. The people and organizations that had pre-established relationships that they could call on for preparedness, response, recovery and business continuity were able to react more quickly and, for those impacted, immediately begin recovery. This type of relationship building needs to be an intentional focus during non-disaster periods.

9.6.3 Recovery

Adapt policy and funding mechanisms to increase resilience for poor and vulnerable households. Deferred maintenance is a key resilience gap for vulnerable households — households fail to qualify for recovery aid due to pre-existing household structural issues such as unaddressed roof damage. However, those structural issues are often the result of poverty, not negligence, and they frequently exacerbate the impacts residents suffer in disaster events. In turn, increased impacts push the same residents further into poverty and further decrease their ability to make structural repairs. This negative cycle is an issue in Houston, nationally, and globally. Changing policy and funding allocations to address this gap head-on could dramatically increase resilience for some of Houston’s and the world’s most at-risk inhabitants.

Repeat loss properties should not rebuild as-was but instead should be bought out or mitigated. For repeat loss properties, repairs are a temporary patch until the next flood event and for many of these properties the interval between events is becoming smaller as flood events become more intense and frequent. In particular, though the U.S. government has unambiguous data on the location and cost of NFIP-insured repeat loss properties, those properties continue to receive regular NFIP payouts. A second or third NFIP payout to any one property should trigger an automatic option to buy out the property and retire the land and/or require mandatory, meaningful flood mitigation before the property is re-eligible for NFIP. In the long-run, this would save significant taxpayer money. In parallel, owners, governments, insurers and aid organizations alike need to recognize and advocate for the retirement or mitigation of such properties. To rebuild as was traps owners, and the NFIP, in a cycle of loss.

Owners need to know all their options up front. Currently, impacted businesses and homeowners are often forced to make decisions about how or whether to rebuild with incomplete information. Obtaining Small Business Association loans or qualifying for homeowner buyouts often takes months or years in the aftermath of an event, and owners are unable to afford to wait. This can lead to rebuilding as was, or force owners to sell their properties at post-event prices, resulting in a significant financial loss. More timely information up-front would allow for better long-term strategic thinking and better support decisions that increase resilience.

Increase dissemination of flood mitigation options for homeowners and businesses. Insurance covers much of the financial costs of a loss but avoiding flooding and loss altogether through mitigation is always preferable. There are an increasing number of low-cost, relatively simple flood mitigation options that can help prevent or reduce losses up-front. Insurers, insurance brokers, real estate agents, small business associations and chambers, and non-profit organizations could help support dissemination of some of these options through existing channels like newsletters, customer interactions and regular meetings.

Invest in regulation, coordinated floodwater retention and neighborhood drainage. There has been significant discussion about the need for a third reservoir, for more bayou mitigation, for tunnels and pumps to bypass the bayous, and rerouting rainfall and runoff to the bay. However, without land use regulations that limit development in floodways, floodplains and reservoir pools, coupled with more coordinated land development and flood retention efforts, and mandates to improve and maintain neighborhood-level drainage, large-scale projects will rapidly suffer the same challenges currently experienced by existing systems. Regulation, coordinated flood retention, and drainage are not high-visibility projects demanded by the public. However, the collective impact of these efforts could significantly reduce city flooding at a fraction of the cost of large infrastructure projects, while at the same time laying the groundwork needed to maximize the operational flexibility and success of larger efforts. Houston and Harris County need to begin actively discussing, promoting and implementing these smaller actions.

Not acting now to build flood resilience will potentially be very costly in the future. Hesitancy on the part of leadership to take bold and potentially controversial action could leave Houston on a business-as-usual trajectory. Initial strong steps were taken in the policy arena following Harvey, but risk reduction actions are stalled, tied up in discussion over what should be done and who should pay for it. What appears to have been pushed to the side is the reality that lack of action could be very costly for Houston in the future, in ways that could reverberate throughout the entire economy and region. Action, addressing everything from funding sources to drainage to large-scale mitigation, is needed and must occur at, and be coordinated, across scales and jurisdictions.

9.7 Conclusions

In the Houston Harvey flooding, over 9,000 homes and numerous businesses were located both in Houston's flood control reservoirs, and downstream of dam gates and spillways. Not only were structures heavily impacted, moveable assets were lost, in spite of the slow onset of the event. This case highlights an extreme version of how disasters are anything but natural — there is an immense man-made component. However, this also means there is also an enormous amount we can do to mitigate our risk.

Given Houston’s history of flooding and its physical and development landscape, the question is not whether it will flood again, but when and how badly. The city and county have already taken bold policy steps to reduce future risk. The challenge now is to take equally bold funding and implementation steps across all scales: from major infrastructure to street drains, through awareness raising, and for the state of Texas and the federal government to help support those steps. How the city and county decide to mitigate future flood risk, and how aggressively they pursue that mitigation, will determine the extent of the impacts from the next event.

At the same time, residents and businesses cannot sit back and wait for the authorities to fix things for them. They need to become proactive about asking for, expecting and being willing to pay for action. They must also remember that even the best flood mitigation leaves residual risk. Businesses of all types and residents must become far more proactive about understanding and taking action to prepare for and/or mitigate that risk.

These lessons and recommendations are true not just in Houston and Harris County but across scales and even globally. Too often, we look at disasters elsewhere as a curiosity, somehow assuming “that would never happen here.” Yet the stories from Hurricane Harvey make it clear that is exactly what Houstonians thought too — the size of the event and the extent of the risk landscape far exceeded what anyone expected. Analysis of the PERCs conducted to-date shows that the reality is that not only could a disaster happen in your community, at some point it will. We as a global community must begin to look at extreme events not as curiosities but as wake-up calls, and adjust our planning, preparation, regulation and action accordingly.

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10. Lessons of past disasters and preparedness actions to cope with future hydrological extreme events in the Netherlands

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Summary

The Netherlands, being a low-lying delta of the rivers Rhine, Meuse and Scheldt, have grappled for centuries in coping with water-related disasters - floods originating from both storm surges and high river discharges. Projected climate change scenarios learned the country to prepare for even more frequent and more intense extreme events. We realized the need for new solutions: automatically heightening the levees to protect against flooding was no longer a sustainable solution. We had to change the system we worked with for centuries and broaden its goals.

The Netherlands revisited their safety standards for protection against flooding, now incorporating a risk-based approach. We introduced nature-based solutions like “Room for the River” to enable higher river discharges and the “Sand Engine” for beach nourishment to complement traditional engineering for protective disaster resilient infrastructure. The Netherlands embraced system thinking to future proof the country, and we incorporated cultural and ecological values into adaptive decision making.

The Netherlands has proven it can shift the fundamentals of its strategy to prepare for a changing climate. Essentially, we have addressed the synergies between the agendas of water-related disaster risk reduction and climate adaptation in a coherent way, both of which are essential in reaching the integrated goals of the nation’s long-term vision for sustainable development. The narrative behind is being described below.

10.1Historic disasters and near disasters

The Netherlands have a long history of flood disasters, the responses to which have shaped much of the flood management infrastructure as we know it now. Two major disasters in the last century stand out for the way the Dutch handles protection against flooding. The first one, in 1916, caused widespread flooding due to a large number of dike breaches along the inner sea called “de Zuiderzee”. Although there were only 19 fatalities, it led to the closure of this sea by a 30 km long dam: the “Afsluitdijk”. The second disaster happened in 1953, when a storm surge hit the south-western part of the Netherlands and again caused a huge number of dike breaches (more than 150) that led to the inundation of 1650 km^2 of land. Besides 1853 fatalities the damage was estimated at 680 million euro or 10% of GDP at that time. This traumatic event brought about the installation of the first Delta Commission that advised the government to close off most of the delta estuaries with barriers so that the coastline that needed to be protected was significantly shortened. It was the start of a huge undertaking that became known as the Dutch Delta Works.

In more recent years two (near) flooding events acted as a wake-up call realizing that even after the Delta Works the Netherlands was still quite vulnerable to flood disasters. Due to heavy rainfall in 1993 the rivers Rhine and Meuse had to cope with very high discharges. Floods along the Meuse in Limburg caused extensive damage and in some places people needed to be evacuated. In 1995 the waters in these rivers rose again at danger level prompting the authorities to evacuate 250,000 people and around 1 million livestock. Luckily the dikes did not breach, and no casualties or major damage was recorded. These incidents combined with worries about higher peak levels that can be expected due to climate change made the government aware of the need for new safety measures.

Before describing these measures and policies it is important to have a better understanding of the specific nature of the country's flood hazard and vulnerability. The Netherlands is a low-lying delta, where three large rivers, the Rhine, Meuse and Scheldt, discharge into the North Sea. Without the present dikes and other flood protection measures, approximately half of the country would be regularly flooded. Until approximately a millennium ago, land freely accreted and eroded because of the dynamic behaviour of the sea and the rivers. The local population lived on the higher land or on artificial mounds, protected by a simple dyke. Over the centuries the people gradually reclaimed more and more land by building new dikes and creating so-called 'polders': low-lying areas prevented from flooding by a dike constructed around it (Gerritsen, 2005). Due to soil subsidence within these polders most of the land became lower than the sea level.

Basically, flood hazards in the Netherlands primarily originate from the sea and the rivers. Although the temperate climate precludes the occurrence of hurricanes or typhoons, strong gales that come from the Northwest can cause the sea to rise to high levels, especially due to the funnelled shape of the southern part of the North Sea. Because during the 1953 storm the time of the surge peak coincided with the time of spring-tide high water, the total water-level reached heights that, in many locations, exceeded those recorded ever before (Gerritsen, 2005).

The storm surge had a return period of one in hundred years, similar to the danger level river stages in 1995. But in this case heavy rainfall in the river catchments of Rhine and Meuse, in combination with melting snow, were the main causes of the high river discharges. The maximum discharge at Lobith (the place where the river Rhine enters the Netherlands) measured approx. 12,060 m3/s, only 5% less than the highest ever recorded discharge from 1926 (TAW, 1995). A big difference between the two events is the fact that during the 1953 disaster, people were completely surprised by the rising waters, which had its peak between 03.00 and 04.00 on Sunday morning. At that time the radio had been off the air for hours and would remain so for several more. Private telephones were not yet widespread, and the islands were isolated during the night, after the ferry boats had stopped. Moreover, all but a few people were in bed (Gerritsen, 2005). In contrast, the 1995 high water levels were predicted 2 days in advance and early warnings were given with high frequency to local waterboards and rapidly installed regional crisis centres (TAW, 1995).

10.2Responses

The people in the Netherlands have a long history of fighting against the water. For a long time, the primary response after a flood would be to heighten the dike to the height of the highest recorded high water plus a safety level of approx. half a metre (Battjes & Gerritsen, 2003). Only 17 days after the 1953 disaster took place the Delta Committee was installed. Its task was 'to develop measures, in order that such a disaster could not happen again'. Besides advising the government on taking up the Delta Plan, involving huge investments in closing off all estuaries but one, this Commission also introduced the first version of 'risk informed decision making'. It calculated through a cost-benefit analysis the optimal safety levels for different parts of the country, based on a combination of probability of occurrence and potential impact. Areas that are highly populated and having huge economic importance, such as North- and South Holland (with cities such as Amsterdam, Rotterdam and the Hague) would need to have a safety level of 1:10,000 years. Whereas other coastal areas with lower population densities would get a safety level of 1:4,000 years against storm surges. Areas liable to river floods could do with even lower safety level of 1:3,000 years (later adjusted to 1:1250 years), because of the longer lead time for early warning and the fact that freshwater does less damage than seawater.

The decades that followed were characterized by an optimism that coastal and geotechnical engineers would once and for all solve the flood risk. Based on the safety standards large flood protection projects were carried out. In 1996 the Flood Protection Act marked a conclusion of this period: the technical safety standards became statutory and all flood protection structures were to be tested against these standards every 6 years. Strict safety standards, dedicated forms of governance (including taxation), regular safety assessments and sound engineering have yielded a well-protected country. The flood prone areas are safeguarded from flooding by approximately 3800 kilometres of primary flood protection structures of which about 90% are managed by regional water authorities, whereas the remaining structures are managed by the national water authority (Rijkswaterstaat, part of the Ministry of Infrastructure and Water Management) (Jorissen et al., 2016). The primary flood protection structures are found along the major rivers, large lakes, estuaries and the coast. Most primary flood protection structures are dikes. In addition to this, also structures such as locks, gates and (storm surge) barriers are used. Along the coast the dunes provide a natural protection against flooding.

Especially after the near-flooding in 1995 people started to realize that the flood risk can never completely be reduced. Rising concerns of climate change and sea level rise, combined with the Katrina disaster in the USA in 2005 made people aware that, despite having the highest flood safety standards in the world, there always remains a risk and – more importantly – that strengthening dikes is perhaps not the only or best solution. Besides, also the ecological consequences of higher dikes and damming estuaries became a factor that could no longer be denied. Presently, decades after finalization of the Delta Works, each enclosed former estuary has specific environmental problems, which mainly result from lack of connectivity, reduced tidal flows and disrupted sediment balance (Van Wesenbeeck et al., 2014). Although the most important water related value is still safety, the ecological quality is currently deemed much more important than during the engineering era (Van der Brugge, 2009).

One of the most conspicuous examples of this paradigm shift is the “Room for the River” project. Projections of a plausible increase of 30% in flood discharges in the Rhine River due to climate change triggered new studies on how to cope with this increased flood risk. Instead of raising the levees it was decided to give more room to the river. This would substantially lower flood levels and sustain a more attractive environment, both urban and natural. More space for rivers was officially adopted by the Netherlands government to achieve the required safety level for the river systems. It became the guiding principle for climate change adaptation along the major rivers.

The “Room for the River” program had a budget of more than 2 billion Euro and consisted of 39 different projects, located along all the main branches of the river Rhine. The first machines started digging in 2007 and the whole program was finished in 2015, within anticipated budget and time limits. The overarching idea is to give the rivers back the space that was taken during the past centuries when floodplains became occupied by industries and residential areas. At many locations along the rivers cities expanded and reduced the floodplain area. Bottlenecks were thus created and resulted in increasing water levels during high river discharges. Besides the main goal of flood protection, the program also explicitly considered co-benefits: the spatial quality, amenity and nature values of the river landscape. Especially, the program focused on:

- Increasing the landscape diversity between river branches,
- Strengthening the openness of the river with its characteristic waterfronts,
- Conserving and developing the scenic, ecological, geological, cultural and historic values,
- Improving the environmental quality, and
- Promoting the use of the main navigable waterways.

Meanwhile, people became aware that climate change could have far reaching consequences for the flood safety as well as for the fresh water supply of the entire country instead of only for the main rivers. Sea level rise and salinity intrusion, combined with an autonomous land subsidence (on average 1 mm/y, with a maximum of about 5 mm/y at certain locations) and socioeconomic development would on the long run pose great challenges to the entire water infrastructure. This prompted the Government to embark on an ambitious Delta Programme in which national, regional and local authorities prepared key decisions, developed strategies and implemented measures, in close cooperation with the public, stakeholders and knowledge institutions.

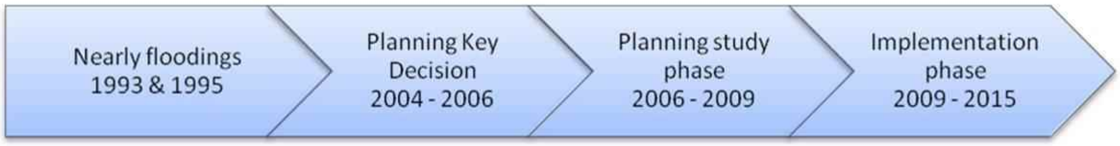
One of the novelties of the Delta Programme is that key decisions and regional strategies have been developed with a long-term perspective, i.e. a time horizon up to 2100. This long-term perspective stimulates the combination of investment agendas of different policy fields or authorities. In addition, it helps to anticipate on climate change gradually by making future-proof decisions on capital investments in infrastructure, flood defences and the built environment. On the other hand, this long- term perspective introduces uncertainty about the future conditions for which these measures must be designed.

Hence, the idea of climate change adaptation was introduced by using scenarios, models and adaptation pathways. To tackle uncertainty, four so-called Delta Scenarios presented the “corner flags of the playing field of plausible futures”. Each scenario combined climate change (rapid or moderate) with socio-economic development (growth or decline). The climate change parameters were downscaled from the IPCC AR5 and elaborated for the Netherlands (KNMI, 2014). Socio-economic parameters described the future size and spatial distribution of population and land use and constituted basic data for flood risk potential and fresh water demand. The Delta Scenarios presented a framework for checking the performance of the strategies under different future conditions.

10.3 Anecdotes and specific cases

Stakeholder participation in the “Room for the River” program

Not surprisingly it took several years of studies, planning and deliberations before measures were implemented. It first started with a number of studies and research activities, which concluded that the traditional way of flood protection (larger dikes) would take up much space and would affect the beautiful river landscape, that the urban squeeze would require more fundamental solutions and that due to climate change the rivers will have to convey more and more river discharge. Studies pointed out several locations where extra room could be created and in the year 2007 the Dutch government approved the Room for the River program that included 39 locations were measures would be taken.



Since such a large-scale program has a national interest, it was the central government that decided on the policy to give more room to the rivers. A Planning Key Decision (PKB) was formulated, that outlined the locations and types of measures. However, for the overall implementation of each of the 39 projects, local governments (municipalities) and stakeholders had to become involved as well. Many parties have interests because they own land along the river, have a house there or use the floodplain as recreational area. These people live in the area every day, so it is important that they are content with the new situation. Therefore, much attention was given to information and consultation meetings with local administration and stakeholders, which was a relatively unique and new approach.

Figure 10.1 Local inhabitants discussing a Room for the River project

The local government worked closely with the inhabitants of each project location. All the stakeholders tried to find a solution for the main question: “how do you want to achieve the required reduction of the water level?” From the beginning it was clear for everyone that the general objective of the program, i.e. reducing water levels at high discharges, was not negotiable. But the type of measures, their exact location and implementation was open for discussion. In this participative planning process solutions were found where all parties were satisfied with.

During this process the role of information and knowledge is crucial. Both national and regional authorities, municipalities and individual citizens proposed around 700 local measures that could help reducing the water levels. Each of these measures would have secondary impacts and different costs. A Decision Support System, called the *Planning Kit* was especially developed to handle such a huge amount of information and proved to be successful in supporting joint planning with stakeholders (Van der Most et al., 2017). Underlying the tool are advanced scientific, cause-effect models. These remain hidden to the users of the tool. Users can add measures to the existing situation of a river area in an intuitive manner, directly relating to their normal perception. They can for instance lower a dam or remove an obstacle. The tool visualizes the results of such interventions, again, in an intuitive way, e.g. showing the effects on natural quality and water levels. In this way, stakeholders – ranging from authorities to citizens – can jointly evaluate different strategies for adaptation in a river area, without being burdened with interpreting the results of the underlying models.

From flood exceedance chances to flood risk

Up till recently, Dutch flood protection policy was based on a flood exceedance approach. After the disastrous coastal flooding in 1953, flood defences were designed and maintained on an exceedance frequency of extreme flood levels. It was assumed that failure results from overtopping and that a flood covers the entire land behind the dike. Based on this approach a flood protection system of dikes, dams and dunes was realized up to a design frequency of 1/10,000 for the coastal area and 1/1250 for the rivers. Despite this high level of protection, a small probability of flooding always remains, the so-called residual risk. Flooding in Central Europe in 2002 and in New Orleans in 2005 illustrated the large scale of damage and disruption of modern society when flooding does occur. Therefore, and also prompted by the European Floods Directive (EU, 2007) that prescribed all European countries to develop flood policies based on a risk-based approach, Dutch policy started to change to a real risk-based approach, explicitly including the consequences of flooding in policies and preparing measures to reduce these consequences by spatial planning, building codes and disaster management (Van Alphen, 2014).

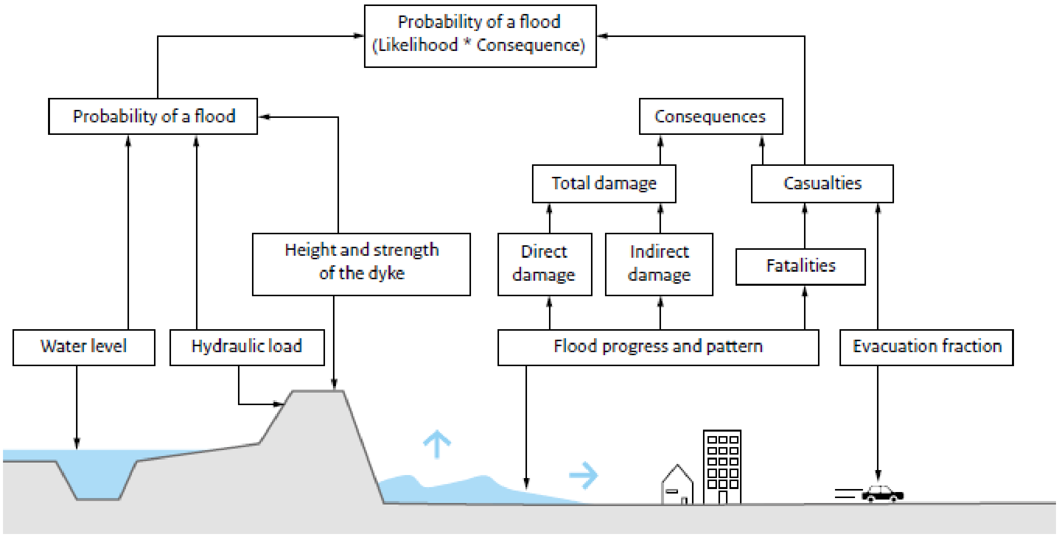


Figure 10.2 Elements of the Netherlands' integrated flood risk management approach: Risk as a result of flood probability (determined by hydraulic load and defence strength/height) and flood consequences (damage and casualties, determined by flood characteristics, buildings and evacuation success) (Source: Van Alphen, 2014).

The new risk-based approach, which was announced in the new National Water Plan 2009-2015, (MinIenW, 2009) involved a fundamental change in the type and level of flood protection standards. New knowledge on failure mechanisms of flood defences, inundation patterns, damage and casualty functions and powerful computer simulations enabled analyses with detailed information on the probability and consequences of floods. Besides including several dike failure mechanisms (such as macro-stability and piping) which could lead to flooding, also a cost-benefit approach (CBA) was used that provided insight in both the potential damage of a flood and the cost of raising the dikes. To this end two studies were carried out: a cost-benefit analysis, to determine the economically most efficient flood protection standards (Kind, 2011) and a study on the location specific casualty risk for individuals and societal groups (Beckers and De Bruijn, 2011). In the CBA study the costs of protection were compared to damages of infrastructure and loss of production from businesses in order to derive economically optimal flood protection standards. The damage calculations included intangible damages like damages to nature, landscape and cultural heritage and the impact on humans from loss of life. The study on casualties was based on the ambition to provide a basic safety level for each person from the risk to perish in a flood event. Eventually the Parliament decided that this safety level should be 1:100,000 per year for each individual.

Based on these studies location specific flood risk standards were proposed in which the legal flood risk standard was set to be the lowest probability between the two results, i.e. every individual is protected to the local individual casualty risk, which can be increased when economic damages warrant a higher protection. The resulting current legal standards for flood risks in The Netherlands are presented in figure 3. The innovative approach taken has been awarded with the Franz Edelman award.

Figure 10.3 Flood standards in The Netherlands (https://waterveiligheidsportaal.nl/#/nss/nss/norm)

Furthermore, the concept of multi-layered protection has been applied in deriving the safety standard. In this concept the flood control infrastructure forms the first layer, followed by a second layer that would reduce the damage through spatial planning. The third layer consists of efficient contingency plans in case of emergencies, including eventual evacuation.

These concepts and approaches resulted in economically efficient flood protection standards for different parts of the Netherlands that significantly differed from the previous standards, now ranging from 1/300 per year to 1/1,000,000 per year. It is expected that through these new standards an additional 1152 km of dike length needs to be strengthened, on top of the 748 km that was already needed based on the old standards. In order to complete the task of improving these 1900 km by 2050 it would require upgrading more than 50 km per year and an annual budget of €360 million (Jorissen et al., 2016). On the benefit site, these new standards would reduce the potential economic damage with a factor of 20 whereas the probability of 1000 fatalities due to a flood will be reduced by a factor 45 (Van Alphen, 2014).

Risk perception

Although the scientific formulation of a risk as probability times consequence seems very logical and rational, this is not the same as how people perceive risk. It is generally acknowledged that there is a discrepancy between how risks are formally quantified and how people perceive risk and whether they accept risk. Firstly, people distinguish between risks from natural hazards and hazards caused by human activities. Natural hazards are accepted more easily. Secondly, in the common perception, the consequences of events are not only easier to grasp but are also more important than their probability. The consequences are therefore given more weight in the judgement of risk. This means that people judge one hundred fatalities with a 1/100 per year probability as being worse than 1 fatality every year. Furthermore, in their actual behaviour, people take into account the personal advantages of running a certain risk. This also explains why people accept comparatively high risks in traffic, and in smoking cigarettes. In the context of flood risk management, personal gains are seldom obvious.

A research project a couple of years ago in the Netherlands showed that only a minority of respondents among the 3000 households and 200 business enterprises that were interviewed regard flooding as a likely event. The public has a great trust in the current flood defence system and in the authorities' ability to maintain this system. However, when it comes to assigning regionally differentiated standards for flood protection, a different picture emerged: there were strong adversaries of differentiation, whereas for others differentiation was viewed as a logical consequence of differences in the values to be protected. One way out of this dilemma is to base the new safety standard on the principle that every inhabitant should have a maximum allowable probability of drowning due to a flood (Local Individual Risk, LIR) of no more than 10^{-5} per year (i.e. once in 100,000 years), which is comparable with norms for other external risks such as safety against industrial calamities (which lies in the range between 10^{-5} and 10^{-6}). This is what the Delta Commission advised the Government.

Evacuation in 1995

It would turn out to be the largest evacuation in the Netherlands since the second World War. More than 250,00 people and 1 million of livestock were evacuated from areas behind the river dikes to higher places. After all, if the dikes had actually been breached, many places in the protected floodplain would have been submerged to about five meters and with a tremendous speed. At least the first two floors of many houses would have been flooded. It requires little imagination that such a decision was a hard one to take by the authorities. Evacuating such large number of people requires a lot of logistics and creates a disruption of normal life and economic activities. The decision was compounded by the uncertainty of the strength of many dike sections. The civil authorities had to rely on the expert judgement of waterboards and the national water management agency ("Rijkswaterstaat") who in many instances could not give a pertinent answer. Clearly, there were signs of potential failures, such as piping (the development of erosion channels under a dike) and seepage of water behind the dike. Although the waterboards could not guarantee the stability of the dikes, it didn't mean that these would breach. Based on previous experience of the waterboards and external advice from geotechnical experts the responsible dike manager had to make a judgement. It was evident that in such cases the boundaries of science and societal acceptance were reached and dealing with such uncertainties was extremely difficult (TAW, 1995).

It also proved to be a stress-test for crisis communication and organisation. All waterboards had to work with regional and provincial crisis coordination centres, that consisted of municipalities, provincial authorities, the police and fire brigade. Such centres had to rely completely on the technical judgements of the waterboards, but sometimes it proved difficult for them to accept these because of the earlier mentioned high level of uncertainty of the dike strength. Furthermore, the public opinion was sometimes biased by the media (television and newspapers) the information of which was sometimes misinterpreted. For instance, pictures of overtopping summer levees created alarm, whereas such is a normal phenomenon that occurs every winter (TAW, 1995). Eventually a combination of emergency measures to strengthen the weakest sections (Figure 4) and bold decisions by the authorities for preventive evacuation turned out for the best.

Figure 10.4 Emergency repair during high water at Ochten, The Netherlands in 1995

10.4 Good practices and lessons

The near-disaster in 1995 provided many a lesson for Dutch flood management. First, it proved risky to fully depend on dikes as the main measure for disaster risk reduction. Disaster preparedness, crisis communication and evacuation plans are also badly needed. Therefore, the Ministry of Security and Justice (responsible for disaster management policy and frameworks) has drafted safety region specific agreements to improve disaster management planning and response, especially on the supra-regional scale. These arrangements will be monitored, in parallel to the six-year evaluation of the flood defences (Van Alphen, 2014).

Secondly, more knowledge to assess dike strength and failure mechanisms is indispensable for a better risk assessment, also in emergency situations. Recent research includes piping experiments at laboratory scale, but also full-scale experiments using the “Smart Dike”, a unique international test facility with the aim of conducting systematic experiments and integrating and validating dike and sensor technology. Also, a Wave Overtopping Simulator has been used to perform destructive tests on inner slopes of real dikes in order to measure the erosion resistance against overtopping waves from severe storms. The results of these experiments already revealed a wide range of erosion processes, thus deepening our understanding and guiding the improvement of current models. Based on the knowledge gained, handbooks for design of dikes and guidelines for stability assessment for existing dikes have been rewritten.

Furthermore, working with nature instead of against it by giving the river the space it needs would provide a sensible addition to building stronger dikes. Although the direct response to the 1995 high waters was a “Delta plan” for the river dikes to immediately strengthen the most critical dike sections, already the Technical Advice Commission for Flood Control mentioned in its evaluation report in the same year that “levees alone are not enough” (TAW, 1995). By constricting the river in a narrow space waters will rise higher and the remaining floodplain will continue to accumulate sediment, whereas the land behind the dikes gradually subsides. Heightening the dikes is only a temporary solution. “Room for the River” would prove a much more resilient climate change adaptation strategy.

Since 1995 our knowledge on the climate change impacts on the Dutch water infrastructure has significantly increased and indicates that flood risk management will be a never-ending effort. Rising sea levels and increasing high river discharges, fiercer downpours and possibly increasing storminess will challenge the safety of the low-lying lands in which the great majority of the population lives. This necessitates a recurrent assessment whether the existing flood management strategies are still sufficient. A long-term perspective with ex-ante risk analyses, using climate scenarios and adaptive delta management, as the Delta Programme showed, seems the best strategy to cope with these challenges. With the end of the technical lifetime of many post-war structures approaching in the coming decades, reconstruction of aging infrastructure becomes an important driver for adaptation. The Delta Programme tries to frame these short-term investment agendas within a future perspective, seeking an optimum between “too much too early” and “too little too late”. Adaptation paths identify where a change of strategy is still possible, and how to avoid “lock in” situations (Haasnoot, 2013).

At the same time the Delta Programme took a pragmatic approach by including institutional, financial and legal components: there is a Delta Act that formed the legal basis of the programme, a Delta Commissioner who is an independent high-level government official supervising the programme and a Delta Fund of around 1 billion Euro per year that provides stability in financial resources. This budget covers the costs for operation, maintenance and reconstruction in (primary) flood protection, national water management and fresh water supply but excludes the regional water management tasks, the costs of which are primarily paid through local taxation (Jorissen, 2016). This latter budget is several times larger than the Delta Fund and is partly spent by the waterboards, the role of which cannot be overestimated.

Indeed, the waterboards have proven to be of paramount importance in disaster risk reduction since more than 8 centuries. Their mission is “*Dry feet and clean water*” and forms an indispensable link between the national/regional government and civil society. Because of their local presence they play a pivotal role in water governance. In fact, they are among the oldest forms of local government in the Netherlands, some of them having been founded in the

13th century. As of 2019 there are 21 water boards in the Netherlands. From time to time their existence is challenged as some say that the work can also be done by the provincial government. However, their unique focus on water management and the fact that taxes are paid by the inhabitants solely for that purpose make them highly valuable, and it shows that flood risk reduction is a matter of the utmost importance for Dutch society that does not require political debate.

With more than 65% of its Gross National Product being produced below sea level, the Netherlands has a unique position in the world. This explains the high safety standards against flooding that no other country has. With all the risk reduction measures in place the Dutch are well prepared for the upcoming challenges that climate change will bring, at least for the next 50 to 100 years. However, idleness would be misplaced, as recent history has shown. Given the uncertainty around sea level rise, for instance, a tipping point at which present safety measures would not be sufficient, could arise earlier than anticipated. Therefore, studies into the consequences of more extreme sea levels than currently used in the Delta scenarios are being conducted, as the Dutch do not want to be taken by surprise again.

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