2020

HELP Global Report

on Water and Disasters

HELP Water & Disasters

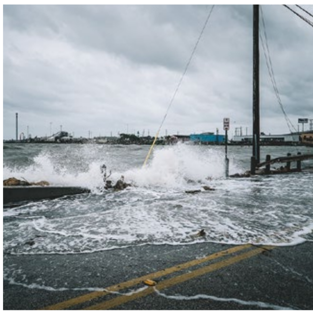
GRIPS

Ministry of Land, Infrastructure, Transport and Tourism

Global Water Partnership

CEGIS

(C)MLIT



(c)UNESCAP/Mari Sawai

Table of Contents

Preface

Dear Readers,

I am pleased to share with you the HELP Global Report on Water and Disasters 2020, the second volume of the annual series that compiles experiences, lessons, and good practices to address the latest large-scale disasters on our planet. I would say that it also serves as a record of the human struggle against the ever-changing elements of nature and progress made therefrom.

The year 2019-2020 was a particularly challenging period for the human race. The unrelenting occurrence of mega-disasters in many parts of the world was followed by the outbreak of COVID-19. The pandemic swept the world with a scale and impact that modern society had not witnessed for decades. As I write this, in December 2020, the third wave of infections is hitting many countries. In addition to 70 million infections and a death toll of 1.5 million (as of December 2020), the total economic loss will reach 28 trillion USD in six years. Countless human relationships and family bonds have been severed, and the political stability of countries and regions has been threatened as well.

However, natural disasters will not wait until the pandemic subsides. The co-occurrence of disasters and the pandemic has already created negative synergy of twin hazards. The High-level Experts and Leaders Panel on Water and Disasters (HELP) has responded to the outbreak instantly. It convened experts and scientists from governments, UN agencies, international organizations, academia, civil society, and the private sector to create a set of principles to help all stakeholders address water-related disaster risk reduction amid the COVID-19 pandemic. The work started in March 2020 when the new coronavirus spread across continents, and was completed by May 2020, before rainy/monsoon season started in many countries. The HELP Principles to Address Water-related Disaster Risk Reduction Under COVID-19 are currently available in nine languages, including all of the UN official languages, and are free to access on the HELP website (https://www.wateranddisaster.org/covid-19/).

This report not only addresses the latest challenges such as COVID-19, but also looks into fundamental questions of how our society can keep living with extreme hydrological events. The experience, lessons, and good practices that were accumulated in the basin of the Mississippi River throughout history were shared in-depth by leading experts of the U.S. Army Corps of Engineers (USACE). I would like to extend my special thanks to LTG Mr. Scott A. Spellmon, Chief of USACE, for his organization's special contributions to this edition. I would also like to thank the authors of the disaster reports from Bangladesh, India, Indonesia, and Japan, as they will help readers to broaden their knowledge and provide new perspectives to better address water-related disasters.

"The night is long that never finds the day." Final tests for vaccines for the new coronavirus have now started. The light of dawn is now faintly visible over the dark horizon of the last year.

However, the war with catastrophes is far from over. If we can learn deeply from the lessons of mega-hazards, including our experiences of 2019-2020, we will have a better chance of winning the next battles with disasters and pandemics more quickly and with fewer casualties and losses.

I sincerely hope that this issue will help readers to be better prepared for disasters that could occur any day, even today.

Han Seung Soo

Dr. Han Seung-soo

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

In early year of 2020 has proved to be a challenge for disaster management system in all around the world to include in Indonesia. In east of Indonesia, the heavy downpour on 1st January 2020 has caused severe flooding in Greater Jakarta and Banten province, causing tremendous loss of life and enormous destruction of infrastructure and property. According to National Disaster Management Agency / Badan Nasional Penanggulangan Bencana (BNPB), more than 1,300 homes have been heavily damaged, and 74 districts across Greater Jakarta flooded. Landslides and flash floods in the wake of the downpour affected 17,200 people across 12 villages in the Lebak district of Banten

The impact of the water-related disaster has led to the development of comprehensive legal framework for Disaster Management. These developments are linked to the key commitments on implementing Disaster Risk Reduction that have been made by adopting the Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR). Overall, Indonesia has made strong and positive steps towards integrating and implementing the key recommendations of the framework to its own National legal framework. I encourage other countries to also implement The Sendai Framework. The Sendai Framework calls upon local government and key stakeholders to review and promote national laws and regulatory frameworks for disaster risk reduction, across all relevant sectors. This includes, among other things, assigning roles and responsibilities, promoting community-level engagement and ensuring compliance with safety enhancing regulations. The legal framework in Indonesia already broadly addresses these priority issues and has a strong institutional structure for disaster management.

In the time of many uncertainties in climate, economies, societies and politics, the nation’s response are solely based on national and regional government policies, community rights and obligations, the role of businesses and international institutions, the different disaster management stages as well as disaster aid financing and management. I Believe Indonesia and many other countries might find issues and difficulties during the implementation of water-related disaster management. In order to manage that, HELP has decided to start a flagship initiative to help countries to overcome such difficulties by investigating and reviewing severe, large-scale, and/or infrequent types of water-related disasters. As the Vice Chair of HELP and representative from Indonesia, I am keen to share our recent best practice experience regarding water-related disaster and I strongly encourage to learn from each other experiences, lessons, and best practice as the key factors to improve preparedness and readiness to properly integrate Disaster Risk Reduction initiatives to each our own disaster management.

M. Basuki Hadimuljono

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

Since the middle of the 19th century the United States Army Corps of Engineers (USACE) has helped the United States mitigate and recover from floods in river systems across the nation. These efforts in Disaster Risk Reduction (DRR) took on new meaning following the great Mississippi River flood of 1927. The Mississippi River and Tributaries (MR&T) project, initiated the following year, charged USACE with mitigating flooding on the lower half of the Mississippi River, from the confluence of the Ohio and Mississippi Rivers to the Gulf of Mexico. In 1936, following disastrous floods in the Midwest and Northeast, the federal and USACE role in flood control was expanded to include mitigation activity across the entire country.

Implementing an innovative approach, USACE treated the lower Mississippi River as a single system and applied principles known today as Integrated Water Resources Management (IWRM). Through the 92-years of the MR&T effort, USACE implemented a range of measures including thousands of miles of levees, four major water diversions, channel stabilization, tributary dams, and backwater storage that have mitigated flood peaks and provide added protection for populated communities and the rich farmlands of the alluvial valley of the Mississippi. The MR&T project continues to evolve today in response to hydraulic and human driven changes to the river system Following the 1936 floods, USACE carried out significant flood mitigation activities in the Missouri, Upper Mississippi, and Ohio River basins.

The Mississippi Basin flood of 2019 was an exceptional event with precipitation amounts greater than the 1927 flood as well as all floods since. While direct damages exceeded $1B, the MR&T together with the risk reduction programs in the other major basins, operated as designed and substantially reduced the losses from what they would have been without this mitigation. This paper describes the evolution of this integrated system and how the USACE, in coordination with local partners, successfully managed this flood event

Each year, throughout the U.S. damages resulting from floods continue to cost billions of dollars in economic losses, which are compounded by individual losses in personal income and property, societal disruption, and environmental losses. As water resources professionals it is our responsibility to continue improvements in flood risk reduction by enhancing the resiliency, reliability and robustness of the Nation's water resources systems. The USACE is committed to this effort,

Building Strong,

Scott A. Spellmon
Lieutenant General, US Army
Chief of Engineers
US Army Corps of Engineers

1. Overview of Water-related Disasters in 2019

Kenzo Hiroki

Professor, National Graduate Institute for Policy Studies (GRIPS) and
Coordinator of High-level Experts and Leaders Panel on Water (HELP)

In 2019, water-related disasters worldwide resulted in over 8,400 deaths, affected more than 93 million people, and caused economic loss in excess

1.1 Human loss and number of people affected by water-related disasters in 2019

The year 2019 was marked by recurrent water-related disasters in all parts of the world. 8,447 people lost their lives in 325 water-related disasters (e.g. floods, tsunamis, slides and debris flows, storms, and droughts) out of a yearly death total of 10,755, meaning that 79% of deaths were caused by water-related disasters. According to the International Disaster Database (EM-DAT) of the Centre for Research on the Epidemiology of Disasters (CRED), of the 94.9 million of people affected by all disasters, 93.2 million people were affected by water-related disasters, meaning that water-related disasters caused 98.2% of the disaster-affected people. The share of water-related deaths (79%) is much higher than the average of the recent ten years (24%). The top nine severest disaster events by death toll are shown in Table 1.2. The trend of the number of people affected by water-related disasters increasing continues due to inter alias, climate change, population growth, and urbanization. In the recent twenty years (2000-2019), the number of people affected by water-related disasters is 3.87 billion, accounting for 94% of the total (4.03 billion). The top ten countries by number of people affected by disasters in the recent ten years (2000-2019) are shown in Table 1.3. Seven of the top ten countries are in Asia, whereas the other three countries are distributed in Americas (U.S.A. and Brazil) and Africa (Ethiopia).

In the recent twenty years (2010-2019), the death toll due to water-related disasters is around 540,000 (including 249,000 by tsunami). This accounts for 45% of total death toll of 1,234,000 due to all disasters (2000-2019).

Table 1.1 Death Toll by Disaster Type (2019 vs. average 2009-2018)

Event	2019	Average (2009-2018)
Drought	85	2,004
Earthquake	262	26,931
Extreme temperature	2,909	7,277
Flood	5,110	4,913
Land slide	727	1,011
Mass movement (dry)	0	14
Storm	2,525	2,835
Volcanic activity	21	134
Wildfire	116	93
Total	11,755	45,212

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

Table 1.2 Top 10 severest disaster events by death toll in 2019

Date	Country	Name of event	Death toll
July 14-September 30	India	Floods	1,900
July 21-27	France	Extreme heat	868
March 14	Zimbabwe	Cyclone	628
March 14-15	Mozambique	Cyclone	603
June 24-July 7	France	Extreme heat	567
July 19-27	Belgium	Extreme heat	400
July 22-27	The Netherlands	Extreme heat	400
September 1-4	Bahamas	Storms	370
June 13- July 1	China	Floods	300
March 16-18	Indonesia	Floods	206

Table 1.3 Top 10 Countries by Number of People Affected for the past twenty years (2000 - 2019)

	Country	Total number of people affected
1	**China**	1,729 million
2	**India**	1,083 million
3	**Philippines**	149 million
4	**Bangladesh**	114 million
5	**U.S.A.**	110 million
6	**Thailand**	77 million
7	**Pakistan**	60 million
9	**Ethiopia**	46 million
8	**Brazil**	41 million
10	**Vietnam**	39 million

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

Note: Country names in **bold letters** indicate that the majority of people affected by disasters were affected by water-related disasters including droughts.

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

1.2 Economic loss due to water-related-disasters

According to statistics from Munich Re., the overall economic impact in 2019 was USD 150 billion, of which USD 52 billion was insured. Tropical cyclones, hurricanes, and typhoons hit and caused severe damage in different parts of the world. This annual loss of USD 150 billion was slightly above the average of the recent twenty years. USD 2.97 trillion was lost due to disasters from 2000 through 2019. Water-related disasters accounted for 74%, or USD 2.169 trillion, of this total. As shown in the figure 1.1, economic loss due to disasters shows an increasing trend.

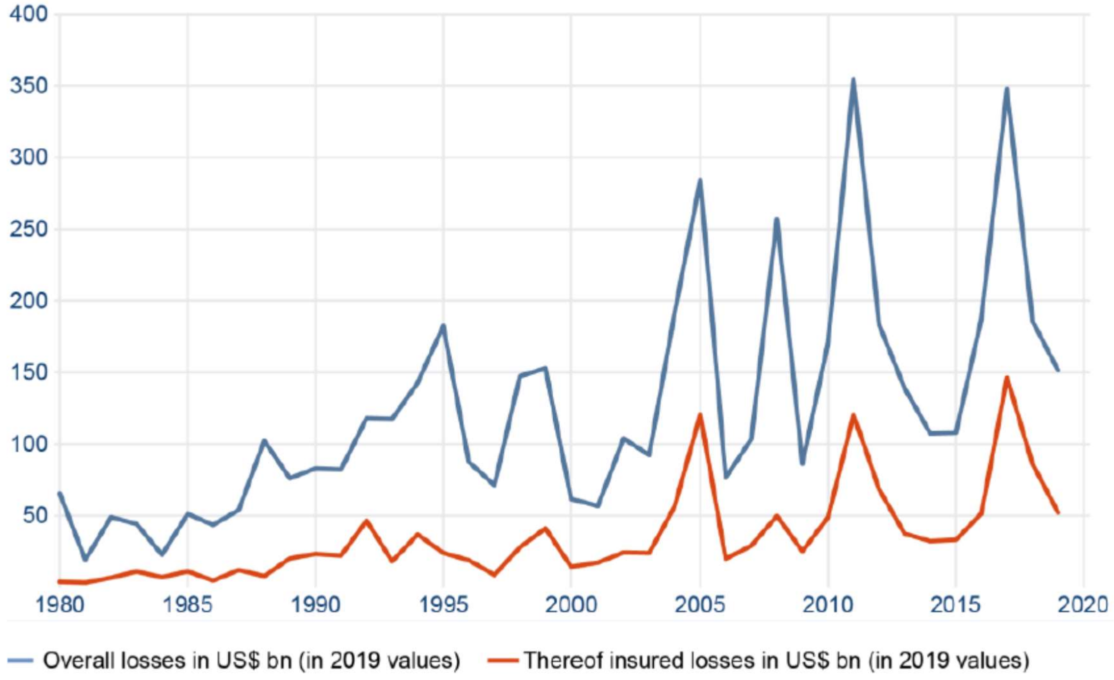


Figure 1.1 Overall and insured losses from natural catastrophes 1980-2019

Source: Munich Re

1.3 Major disasters in 2019

Severe water-related disasters occurred on all continents and many islands. Major water-related disaster events include Cyclone Idai and Kennneth in Mozambique and Zimbabwe (March and April, 2019, respectively) which were reported in detail in the previous version in 2019, floods in China (June-July, 2019), flood in India (August, 2019), Typhoon Lexima in China, Japan, Taiwan, and Malaysia (August, 2019), Hurricane Dorian in Bahama and the United States of America (September, 2019), Typhoon Faxi in Japan (September, 2019), and Typhoon Hagibis in Japan (October, 2019). Countries in which major droughts happened include Australia, Brazil, Chile, India, Spain, the United States of America, and Uruguay.

Table 1.4 Top 5 severest disaster events by economic loss

Date	Country	Name of event	Death toll	Total loss (million USD)	Insured loss (million USD)
Oct. 12-13, 2019	Japan	Typhoon Hagibis	90	17,000	10,000
Sept. 9, 2019	Japan	Typhoon Faxi	5	9,100	7,000
Aug. 6-14, 2019	China, Taiwan, Japan, Malaysia	Typhoon Lexima	65	5,600	840
Aug. 1-26, 2019	India	Flood	9	4,700	Minor
June-July, 2019	China	Flood	4	2,600	Minor

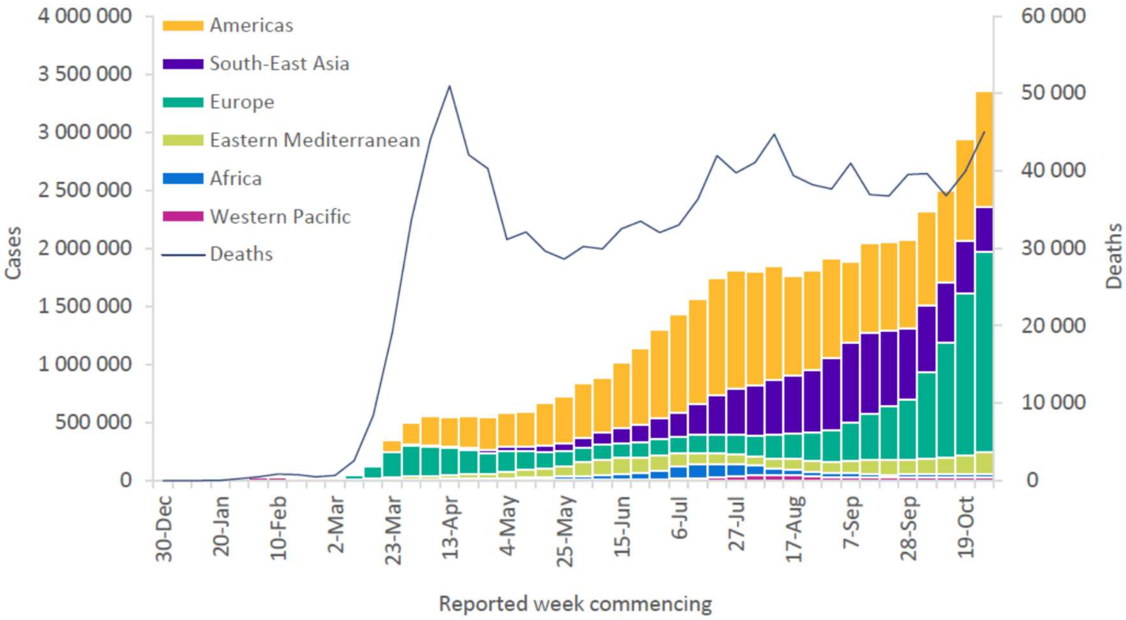
2. Challenges of Disaster Risk Reduction under COVID-19 in 2020

COVID-19 brought drastic changes to the Disaster Risk Reduction landscape in 2020. Holistic management of hazard risks including those due to pandemics is the key to implementing steps to put the SDGs back on track.

2.1 Outbreak of COVID-19 in 2020 that caused new challenges for disaster risk reduction

The year 2020 was marked by the outbreak of COVID-19, which is in itself a major health disaster and in many senses related to water. Initially breaking out in China in late 2019 to early 2020, COVID-19 spread rapidly across borders literally to all continents and islands on earth. It became one of the worst pandemics in history. As seen in Figure 2.1, the number of people infected increased exponentially in all regions.

Figure 2.1 Number of COVID-19 cases reported weekly by WHO Region (until October, 2020)



Source: WHO

2.2 Challenges COVID-19 caused for disaster risk reduction

This novel coronavirus, latent in towns and streets, caused new challenges for disaster risk reduction. It was feared that crowded evacuation places without protection and an aggravated hygiene situation in areas affected by natural disasters would create new epicenters of the COVID-19 explosion.

Cyclone Amphan moved northwards over the Indian Ocean and hit the State of West Bengal, India on May 20th, 2019. It swathed through the eastern part of the Indian sub-continent, passed close to the city of Calcutta, and reached western Bangladesh on May 21st, 2020. The number of people that tested COVID-

19 positive more than doubled within a week from May 20th to May 27th. Several dozen emergency officials were infected by the virus, and over a hundred had to self-quarantine when they were most needed to engage in rescue and relief operations. Although the cyclone is not the only reason for the jump in the number of people affected by the virus, it was feared to be a recurrent cause of the new explosion in COVID-19 infections.

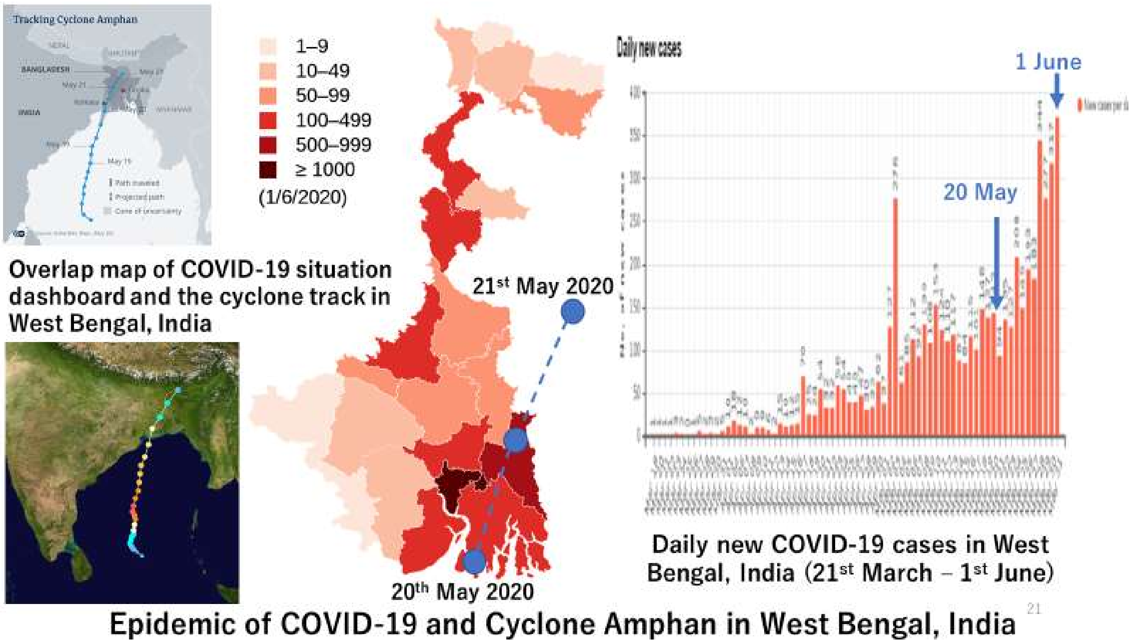
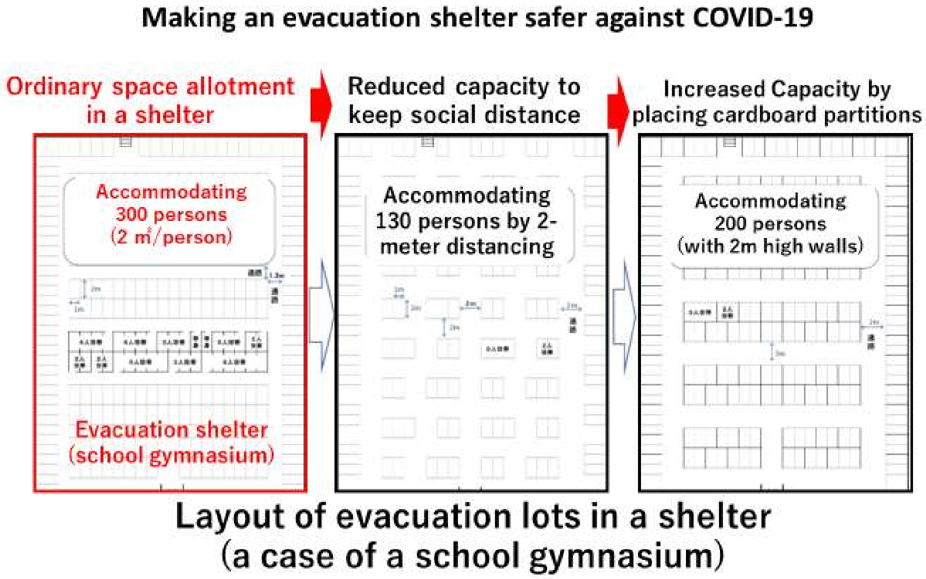


Figure 2.2 Course of Cyclone Amphan (center) and number of COVID-19 cases in West Bengal

Unusual heavy rains caused floods and landslides on Japan's Kyushu Island in June, 2020. Over 90 people lost their lives or went missing. The water-related disasters brought new challenges to disaster evacuations and relief operations for Japanese municipalities. Aware that congested shelters might cause COVID-19 infection clusters, municipalities took special measures to secure larger areas per evacuee and install partitions and beds to avoid the three Cs (closed spaces, crowded places and close-contact settings) and prevent novel coronavirus infections (Figure 2.3). This led to a reduced number of people accommodated by shelters (Figure 2.4). Overflow evacuees had to be diverted to shelters further away under imminent downpours. A few major hospitals and health centers were flooded and temporarily closed, which was a blow to medical activities including preventive and remedial actions for COVID-19 in those areas. The central government had to concurrently manage the two major catastrophes of heavy rain and COVID-19.

Figure 2.3 Measures taken to prevent the breakout of COVID-19 clusters in evacuation shelters (Kumamoto, Japan)



Source: Guideline for Organizing an Evacuation Center under the COVID-19 Pandemic by Gifu Prefecture

Figure 2.4 Change in layout of evacuation lots to prevent COVID-19 clusters

2.3 HELP Principles to Address Water-related Disaster Risk Reduction under COVID-19

The High-level Experts and Leaders panel on Water and Disasters (HELP) took immediate action to help countries and stakeholders to address water-related disaster risk reduction under the COVID-19 pandemic. It convened experts from twenty-three experienced organizations comprising governments, international organizations, academic institutes, the private sector and civil society organizations to create a set of principles to properly and safely manage and address disaster risk reduction under COVID-19. The principles, which are titled Principles to Address Water-related disaster Risk Reduction under COVID-19 and consist of ten chapters, were released on May 30th, 2020, and they call for the awareness of national leaders on the imminent risks of the twin disasters of COVID-19 and natural disasters and urges them to take immediate measures to be prepared for catastrophes. DRR actions with special attention to the current pandemic situation will protect disaster-affected areas from becoming epicenters of the pandemic explosion and help them to swiftly recover from disasters. The Principles are practical advice urgently given to leaders and both managers of DRR and those of COVID-19 to better address water-related disasters that may occur even tomorrow under the pandemic. As shown in the following pages, the Principles address water-related disasters, but most of the items are also applicable to the other types of disasters.

Draft Principles to Address Water-related Disaster Risk Reduction (DRR) under the COVID-19 Pandemic

Leaders, decision makers, and citizens should be aware that water-related disasters continue to be imminent in countries and cities under the COVID-19 pandemic. Disaster Risk Reduction (DRR) strategies and actions specially designed for the current pandemic situation will protect disaster-affected areas from becoming epicenters of pandemic explosion and assist with swift recoveries from disasters. The following Principles offer practical advice to political leaders, managers of DRR and COVID-19 responses, and for all stakeholders to formulate strategies and actions. These initiatives can address water-related disasters that may occur anytime in the future, even under the pandemic. While the Principles address water-related disasters, they are applicable to the other types of disasters as well.

In the current COVID-19 environment, immediate attention has been placed on mitigating COVID-19 infections and treating those who become ill. However, the threats of water-related disasters[1] remain as imminent now as before COVID-19. Competition and complications among DRR emergency responses and COVID-19 health care responses could magnify negative impacts in some countries and cities.

Implementation of DRR strategies and pre-emptive actions that factor in the current pandemic are needed to protect areas impacted by water-related disasters from also becoming new epicenters or clusters of the pandemic. The following Principles offer practical advice to political leaders, managers of DRR and COVID-19, and all stakeholders on how to prepare and respond to avoid magnified impacts due to co-occurring disasters. While these Principles are identified to address water-related disasters, they are equally applicable to other disaster types.

Principle 1: Enhance leaders’ awareness on disaster risk reduction (DRR) in the pandemic
Principle 2: Integrate risk management of disasters and pandemics
Principle 3: Provide clean water, sanitation, and hygiene sustainably during and after disasters
Principle 4: Protect disaster risk management stakeholders from threat of COVID-19
Principle 5: Protect scarce medical resources from disaster impact
Principle 6: Protect disaster evacuees from threat of COVID-19
Principle 7: Protect COVID-19 patients from threat of disasters
Principle 8: Develop Specialized Evacuation Guidance for Cities and Areas under COVID-19 Lock-Down
Principle 9: Finance DRR actions under COVID-19 effectively to avoid economic catastrophe
Principle 10: Strengthen global solidarity and international cooperation to cope with these co-occurring challenges towards building our world back better

Given that, Disaster Response and Recovery from a flood or drought disaster are complicated by mitigation of COVID-19, and vice-versa.

---

[1] Water-related disasters in this document mean all sorts of disasters of which impact is given by water. They include heavy rain, storms, floods, droughts, land slide, debris flow, tsunami, high tides, liquefaction, glacier lake outburst flood (GLOF), and water pollution accidents. Water related disasters comprise over 95% of all disasters in terms of number of affected people. Over 90% of the past 1,000 major disasters are water related.

PRINCIPLE 1: ENHANCE LEADERS' AWARENESS ON DISASTER RISK REDUCTION (DRR) IN THE PANDEMIC

- Be aware that water-related disasters are imminent in countries and cities while they are under COVID-19 pandemic. Although situations in areas affected by both disasters and pandemics can be complicated and confusing, step by step decision making and actions will help. Although tasks may look too immense and complicated, avoid giving up. Making DRR decisions with the pandemic situation in mind, and vice versa, will help avoid later confusion.
- Ensure integrating disaster and pandemic risk management strategies and actions. Bring together joint teams of DRR and COVID-19 experts to provide advice based on their ongoing dialogue and integrated advice. Make critical decisions by consulting them.
- If a water-related disaster happens, maintain or recover as quickly as possible basic services such as power, transport, water and hygiene to prevent spread of disease and cumulative effects of co-occurring disasters, including protecting essential medical and DRR personnel. For this, ask DRR managers to take ex-ante measures such as planning emergency protection of critical infrastructure and arranging contingency supply of recovery material/equipment.
- Effective immediately, request DRR managers to make disaster management plans under the pandemic situation to prepare for its eventuality. Priority should be given to the protection for hospitals, medical facilities and their staff members. From the perspectives of DRR and prevention of COVID-19, the DRR plan under COVID-19 should address the specific needs of men, women, young people and children, the elderly, disabled people, migrants and displaced populations, day workers, slum dwellers, and the homeless.
- Ensure that civil defense authorities and emergency medical services have contingency operational plans to simultaneously address a disaster and COVID-19 in order to rapidly balance their competing responsibilities as they have already been responding to the COVID-19.
- Give the highest priority of human and financial resources allocation to sustainable water supply and sanitation during and after disasters since hygiene, particularly hand washing, is a critical element in containing spread of COVID-19.
- Include items in the Principles of this document in the national and community DRR plans. Ask all DRR stakeholders including private sectors to include items in the Principles in their business continuity plans (BCPs).

Given that the actors in DRR and COVID-19 mitigation need to coordinate for an effective and efficient response.

PRINCIPLE 2: INTEGRATE RISK MANAGEMENT OF DISASTERS AND PANDEMICS

- Fully include the health sector into the integrated risk management system. Use basic approaches of Sendai Framework and other international guidelines for DRR to strengthen DRR governance under COVID-19 such as: risk-based approaches; comprehensive emergency management; all-hazards approach; inclusive, people- and community-centered approach; multisectoral and multidisciplinary collaboration; whole-of-health system-based approach; ethical considerations. DRR collaboration and action protocols need to be reviewed and adjusted to enhance resilience to hazards of all kinds including biological hazards.
- Quickly share and learn from the recent cases of heavy rains, floods, hurricanes and tornados that have occurred under COVID-19 situations. Many of these lessons are reflected in these Principles.

- Create situation-specific guidelines and webinars on DRR approaches in COVID-19 situations that reflect your specific, social, cultural, geographical and economic settings. Consider conducting water-related disaster management drills by DRR managers and stakeholders under the COVID-19 situation.
- Provide hazard maps and DRR advice to hospitals and health facilities before disasters strike. Create overlapping maps of disaster/COVID-19 affected areas and facilities. Risks of both infection and disasters can be reduced by avoiding visits to risk-prone areas. The hazard maps should also include the insecurity due to dual impacts of disaster and pandemic, of water insecurity at the household level.
- Develop concise and clear "early warning" communication messages that relate to evacuation and other response items from the natural disaster in the context of pandemic restrictions and guidance.[i]
- Conduct joint risk awareness campaigns of DRR and COVID-19. Enhance awareness on the value of increasing disaster resilience to the risk drivers, including health pandemics, to be better prepared by implementing prevention actions and advancing knowledge on increasing resilience to disasters. Conduct risk assessment and communication of the co-occuring disasters in high risk zones.
- Ensure that Disaster Management teams maintain transparency of the disaster aftermath and responses, and efforts taken to address Covid-19 issues. The public and those affected by the disasters should be able to obtain valid and updated information. The disaster management team should be a facilitator to harness social collaboration by matching the needs (based on data) and the supply of help (from the public) particularly to raise funds to combat the decease. Create a platform of collaboration where help can quickly be matched to the needs.
- Activate existing youth groups for DRR to call for solidarity and collaboration to contain spread of COVID-19 as behavior of young people are decisive element in controlling the decease. Collaborate with youth groups in disaster management, relief, and recovery activities under the COVID-19 pandemic, making use of their special capability in, e.g., ICT, innovation, and mobilizing their local counterparts.

Given that water, sanitation, and hygiene are critical element in prevention of COVID-19 and swift recovery from disasters.

PRINCIPLE 3: PROVIDE CLEAN WATER, SANITATION, AND HYGIENE SUSTAINABLY DURING AND AFTER DISASTERS

- Be aware that natural disasters often lead to disruptions in water availability which could affect COVID-19 mitigation efforts. In regions with acute water scarcity, disasters may affect the implementation of hand washing, waste management and other practices meant to prevent human-to-human transmission of the COVID-19 virus. Specific attention must be paid to risks caused by droughts since water scarcity may hinder efforts to contain sanitary crises.
- Protect water infrastructure, particularly at water sources, from contamination. Consider using non-contaminated alternative sources including water harvesting, and the reuse of wastewater to prevent collateral hazards of disaster and pandemic.
- The DRR plans of water service providers should include the effects of not only natural hazards but also pandemics. Pandemics will influence the personnel and thus quality of service provision. Hygiene promotion must be included in all stages of the process through different channels such

as medical centers, water/sanitation access points, and emergency personnel.

- Promote research and survey actions to detect COVID-19 traces in wastewater of communities infected with the virus in order to prevent risks, particularly at the time of disasters. New approaches such as, wastewater-based epidemiology (WBE) should be explored. They could be effective and rapid ways to predict potential spreading of COVID-19 from water and sewer system.
- Ask water utilities to enhance the role of digital tools and remote automation/monitoring systems in their business continuity plans. All but essential water and wastewater operational teams, control centers and laboratory staff should be working from a distance if feasible under COVID-19. For workers in the field, teams must be assigned differentiated work shifts that consider quarantine cycles, and must have access to COVID-19 personal protection equipment (PPE).

Given that there are critical infrastructure and human assets needed during response and recovery to floods and droughts under an ongoing pandemic.

PRINCIPLE 4: PROTECT DISASTER MANAGEMENT STAKEHOLDERS FROM THREAT OF COVID-19

- Educate and build the capacity of DRR stakeholders about COVID-19. Provide accessible, concise and clear guidance on how to avoid infection to disaster management officials and volunteers. For example, use advice leaflets, provision of webinar, and more. Include social distancing instructions in DRR activities in manuals and daily check list.
- Make sure that DRR stakeholders including volunteers are equipped with standard COVID-19 protections such as masks, when engaged in disaster preparedness/prevention/recovery activities. If possible, stockpile those as well as COVID-19 personal protection equipment (PPE) for use at highly infectious cases.
- Require daily self-medical checks of disaster management personnel to prevent possible infection in their contact with colleagues and evacuees.
- Balance the need for swift disaster prevention/recovery and for avoiding disease transmission between COVID-19 affected areas and less affected ones through travel of DRR stakeholders, including volunteers.
- Make sure that the quality of monitoring and alerting on disasters is checked and maintained as the quarantine of the officials in charge may affect it.

PRINCIPLE 5: PROTECT SCARCE MEDICAL RESOURCES FROM DISASTER IMPACT

- Avoid designating hospitals and medical facilities as places for evacuation. Remove those buildings and facilities from designated evacuation places in hazard maps and DRR plans.
- Prioritize protection of medical staff, facilities, and equipment from disaster impact by:
    - Moving essential power generation equipment to safe areas from water-related disasters (flooding, etc.) and provision of auxiliary power supply equipment to hospitals, health posts and medical facilities,
    - Early dispatching of disaster management personnel to hospitals, health posts and medical facilities to ensure communication of appropriate DRR advice,
    - Moving essential medical equipment and materials to upper floors at early stage
    - Creating evacuation plans for patients and medical staff, taking infectious zones into consideration,

- Prioritizing provision of water, sanitation and hygiene to hospitals, health posts and medical facilities if water supply and sanitation services are disrupted due to disasters,
- Identifying safe locations of overflow health facilities needed for the pandemics response to avoid building additional short-term COVID-19 hospitals in disaster prone areas such as flood plains
- Educating medical staff responsible for emergency management with basic DRR knowledge before a disaster is imminent.

Given that the combination of risks from natural disasters and COVID-19 can lead to higher loss of life

PRINCIPLE 6: PROTECT DISASTER EVACUEES FROM THREAT OF COVID-19

- Immediately create or revise evacuation plans that include adapted shelters to assure social distancing and good sheltering procedures. Ensure proper ventilation of evacuation buildings/facilities to prevent cluster infection. Identify additional buildings and spaces for shelters that may be needed to meet specific needs for protection of evacuees from COVID-19 such as social distancing and separate spaces for self-quarantine patients. Ideally, specific shelters for COVID-19 patients with medical facilities and separate buildings/facilities/areas of evacuation for self-quarantine patients should be established.
- Promote vertical evacuation as the priority methods of evacuation whenever and wherever possible. This means evacuating to the second or upper floor of evacuees' own or neighborhood building if safe. This is needed to avoid accidents, to manage encounters with disasters during evacuation, and to make evacuation shelters less dense with people thereby reducing risk of infection by the virus in shelters. In areas where vertical evacuation is not possible, such as flat lowlands, discuss with local community on earlier evacuation to increased number of higher buildings, shelters, and spaces to avoid congestion of evacuees.
- Identify and plan early evacuation and care for the most vulnerable from the compound hazards, e.g., seniors, handicapped, pregnant women, and patients with chronic deceases.
- Provide ample clean water, soap, and sanitary goods for evacuees.
- Conduct basic medical checks such as checking evacuee's temperature.
- Prevent any COVID-19 related discrimination to and among evacuees. Keep announcing and distributing accurate information on status and impacts of disasters and COVID-19 in transparent manners as misinformation and fake news tend to spread rapidly and widely under panic situation.
- Advise citizens to include masks, wipes, soaps, towels, and thermometers in evacuation kits prior to disasters.
- Call for cash donation rather than materials which might be contaminated under the pandemic.

PRINCIPLE 7: PROTECT COVID-19 PATIENTS FROM THREAT OF DISASTERS

- Ensure that DRR and COVID-19 are given integrated top priority: avoid risks that directly endanger human life.
- Understand and take concerted actions for COVID-19 mitigations based on medical control principles of infectious diseases. These medical principles include: 1) Eliminate the source of infection; 2) Cut off the transmission route; 3) Protect the vulnerable groups.
- Create protection plans for COVID-19 patients in self-quarantine or designated facilities that include: means of communication and messages; evacuation plans to disaster-safe quarantine

facilities, and medical support after evacuation.

PRINCIPLE 8: DEVELOP SPECIALIZED EVACUATION GUIDANCE FOR CITIES AND AREAS UNDER COVID-19 LOCK-DOWN

- Give special early warning to the locked down areas to ensure effective evacuation and safety assurance against disasters and prevent panic actions.
- Create contingency emergency evacuation plans for lock-down situations to prevent panics and enhanced spread of the infection. Disaster response plans based on a time-line format that includes lifting specific restrictions in specific areas need to be considered.
- Ensure coordination with local authorities to designate safe areas and evacuation routes in case of disasters during lock down.

Given that properly handling disasters under COVID-19 will save trillions of dollars globally

PRINCIPLE 9: FINANCE DRR ACTIONS UNDER COVID-19 EFFECTIVELY TO AVOID ECONOMIC CATASTROPHE

- Fully fund the pandemic finance appeal while at the same time having a contingency budget and funds to address disaster and climate-related risks, keeping in mind that compound hazards may cause irreparable economic catastrophe. Arrange contingency finance agreements with banks and/or insurance companies so they can quickly access funds to respond to disasters.
- Ensure flexible funding and disbursement that enable DRR players to plan and respond to rapidly emerging and changing multiple risks under COVID-19 situation.
- Update disaster risk management capabilities to form a global, digital and data-driven plan, with data on prices, suppliers, lead times and specification for procurement of essential goods and services to address disasters and pandemic. Have plans to face challenges of, for example, lack of manufacturing capacity, long and congested supply chains and competing buyers
- Encourage digital payment mechanism in DRR transactions through telephone-based digital currency payment and digital currencies such as one now distributed by Red Cross for disaster victims in East Africa to prevent spread of COVID-19 through contact infection.

Given that global solidarity rather than isolation is essential to win the battle against co-occurring COVID-19 and disasters.

PRINCIPLE 10: STRENGTHEN GLOBAL SOLIDARITY AND INTERNATIONAL COOPERATION TO COPE WITH THESE CO-OCCURRING CHALLENGES TOWARDS BUILDING OUR WORLD BACK BETTER

- When a mega-disaster occurs, share accurate and timely information on the disaster and its impact with the international community in transparent and accountable manners on a regular basis, to provide global trust to governance and the economy of the affected country.
- Request Weather/Climate Agencies, through involvement of the World Meteorological Organization and UNDRR, around the world to actively coordinate with COVID-19 Taskforces and to provide them forecasts of identifiable climate and weather related risks to alert them of possible water-related disasters in certain areas
- If necessary, prepare to facilitate international DRR and humanitarian assistance personnel and equipment. During entry restriction situations, international DRR and humanitarian aid personnel and equipment may need established protocols to enter affected countries and areas. Countries

should pre-consider and plan facilitation arrangements such as visa issuance, quarantine clearance and customs clearance and protocols for safe assistance during the pandemic. Dispatched teams should be equipped with protection kits. Medical briefings should be given to such international assistance teams before entering COVID-19 affected areas.

- Discuss establishing specific regional bodies of pandemic policies and regulations, following examples of those of DRR. ASEAN countries, for example, have addressed this cross-border issue and regional/ international collaboration for DRR, by establishing a regional center. Such a mechanism is important when discussing re-opening borders and promoting trades of essential goods and people in resilient manners in rapidly changing situations.
- Map risks from many perspectives and work in a collaborative, trans-boundary way since hazards do not respect borders or politics. Explore solutions across sectors such as: water, sanitation and hygiene; energy; education; health and nutrition; livelihoods; child and social protection; shelter and housing; and public open spaces.
- Extend international support to low- and middle-income countries that are struggling to cope with the outbreak recognizing that all need to attend first and foremost to the safety and well-being of their own country’s citizens. A threat to one of us is a threat to all of us. Be aware that we are only as strong as the weakest in coping with COVID-19 and disasters.
- Take a coordinated approach to understanding and reducing risk across borders and within governments. COVID-19 has demonstrated the need for a whole-of-government approach that leverages the capacities of all relevant Ministries, including National Disaster Risk Management Agencies.

Start recovery planning now to build our world back better. National and local governments must factor in biological hazards and risks in their national and local disaster risk reduction strategies (Sendai Framework Target (e)). The challenges presented by this disaster will form the basis for new plans and designs to ensure public and private systems are made resilient in the face of future hazards.

Reference

Centre for Research on the Epidemiology of Disasters (CRED) (2020). Natural Disasters 2019

Munich Re. (2020). Tropical Cyclones Cause highest Losses (2020) Natural Disasters 2019 in Figures https://www.munichre.com/topics-online/en/climate-change-and-natural-disasters/natural-disasters/natural-disasters-of-2019-in-figures-tropical-cyclones-cause-highest-losses.html#:~:text=In%202019%2C%20820%20events%20were,heatwaves%2C%20cold%20spells%20and%20wildfires.

Academy of Disaster Reduction and Emergency Management, Ministry of Emergency Management, China (2020). Global Natural Disaster Assessment Report https://reliefweb.int/sites/reliefweb.int/files/resources/73363_2019globalnaturaldisasterassessment.pdf

World Health Organization (2020). COVID-19 Weekly Epidemiological Update https://reliefweb.int/sites/reliefweb.int/files/resources/weekly-epi-update-12.pdf

3. A SHORT REPORT AND LESSON LEARNED FROM JAKARTA AND LEBAK PROVINCES DISSASTER IN EARLY 2020

M. Basuki Hadimuljono, Ph.D

Minister of Public Works and Housing, Republic of Indonesia

3.1 INTRODUCTION

As an archipelago country, located among equator makes the weather of Indonesia is heavily influenced by Asian or Australian monsoon. Furthermore, bounded by Pacific and Indian Oceans, El-Nino Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) plus a possibility of occurrence of Intertropical Convergence Zone makes the weather in Indonesia is even more complicated and very difficult to be predicted.

National Disaster Management Agency Data for the period of 2005 to 2015 presents that more than 78% (11.648) disasters are related to hydrometeorology and only 22% (3.810) disasters related to geology. The trend is increased, just in 2020, until 18th April 2020, 1.115 disasters are recorded in Indonesia and flood is on top of the list with 409 cases or 37% from the total disasters. Flood is a high risk and threatening disasters in Indonesia, and it has a damaging impact to people's economy.

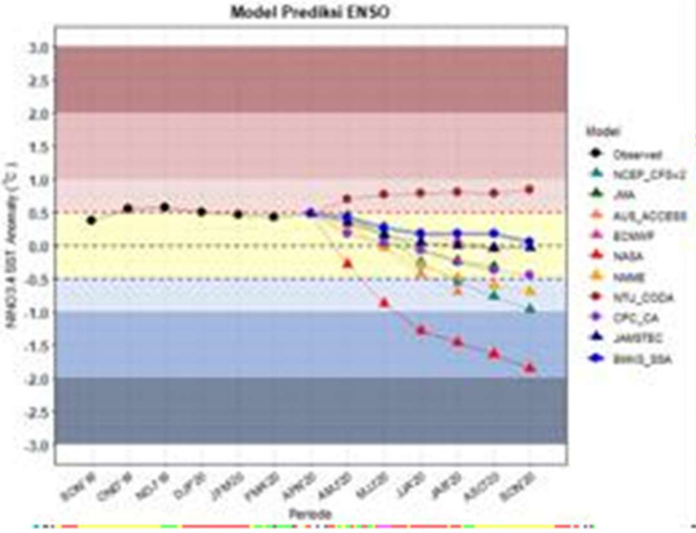
Flood can be caused by changes of environmental conditions, dynamic of natural events and dynamic impact of human activities such as inappropriate land use, un- control settlements along river banks, low maintenance of river morphology, poor design of flood control infrastructures, land subsidence and rising sea levels due to global warming.

This report presents the occurrence of flood and landslides in September 2019 – April 2020 in Jakarta and Lebak Provinces and lesson learned from those disasters.

3.2 DYNAMIC OF NATURAL EVENTS

3.2.1 Atmospheric dynamic conditions of Indonesia in Early January 2020:

- Mass of air flow condition in Indonesia in early January 2020 was generally dominated by Easterly winds. The Australian Monsoon flows over East Nusa Tenggara, West Nusa Tenggara, Bali, Java, Maluku, and Papua Regions. Wind- confluences happened over Western-part of Sumatera, Western and Southern- parts of Borneo, West Sulawesi, North Maluku, and West Papua. These conditions are a typical atmospheric dynamic of Indonesia during December – January period.
- Madden-Julien Oscillation (MJO) was active and Outgoing Longwave Radiation (OLR) anomaly map showed that convective/wet regions were dominating the whole area of Indonesia.
- El Nino Southern Oscillation (ENSO) was on neutral condition and it was predicted to remain neutral until November 2020. Current dipole mode was on neutralcondition and it is predicted to remain until October 2020. However, NASA predicts that ENSO have a tendency to change to Normal-La Nina in November.
- India Ocean Di-pole mode (IOD) condition was normal at that period and it is also predicted to be remain normal until the end of 2020.



Prediksi ENSO BMKG 2020					
AMJ'20	MJJ'20	JJA'20	JAS'20	ASO'20	SON'20
0.42	0.27	0.19	0.18	0.17	0.06

Analisis ENSO April 2020* :
Netral [0.49]

PREDIKSI ENSO

INSTANSI/MODEL	KETERANGAN
NCEP CFSv2	Netral – La Nina Moderat
JMA	Netral
AUS/ACCESS	Netral – La Nina Lemah
ECMWF	Netral
NMME	Netral – La Nina Lemah
NASA	Netral – La Nina Kuat
NTU CODA	El Nino Lemah
CPC CA	Netral
JAMSTEC	Netral
BMKG SSA	Netral

3.2.2 Rainfall Analysis:

- Agency for Meteorology, Climatology and Geophysics (BMKG) predicted on mid of 2019 that the beginning of 2019/2020 Rainy season would be happened on November-December 2019 and it was also predicted that the rainy season would be reaching its peak by January-February 2020.
- In regard to November 2019 - April 2020 rainfall analysis, it was clearly indicated that low rainfall intensity (brown shade: 20-50 mm/monthly) only appeared in November 2019. By December 2019 and January 2020, it was predicted that Indonesia would be dominated by moderate to heavy rainfall intensity (dark-green: 300-500 mm/monthly) and even more on February 2020. Low rainfall intensity was reappeared by April on Nusa Tenggara, but high intensity rainfall still dominating West Sumatera, South Sumatera and Lampung.

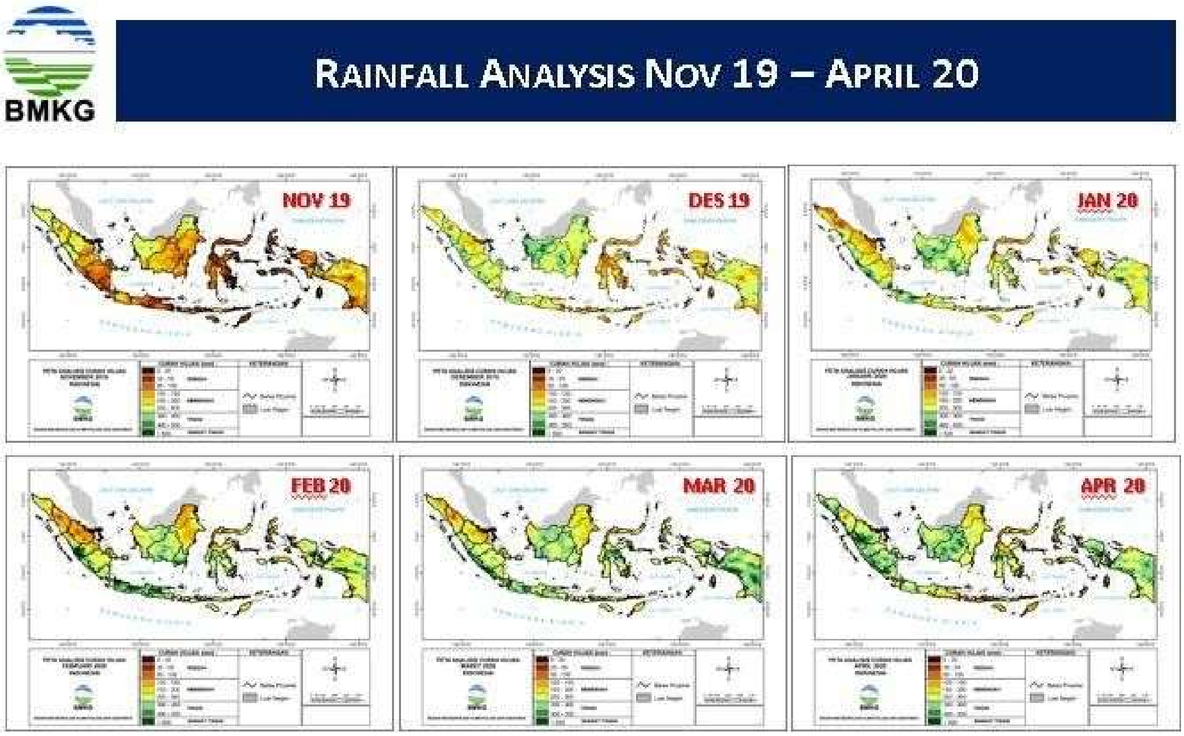


Figure 3.1. Rainfall Analysis on November 2019 – April 2020

- Based on its characteristic, Figure 3.2 indicated that the rainfall in all region in Indonesia was normal by November 2019 - December 2019. However, by January 2020 the rainfall intensity changed to above its normal conditions and continued until April 2020. Rainfall in several regions was predicted to reach an intensity of 150 ~ 200 % above its normal conditions.

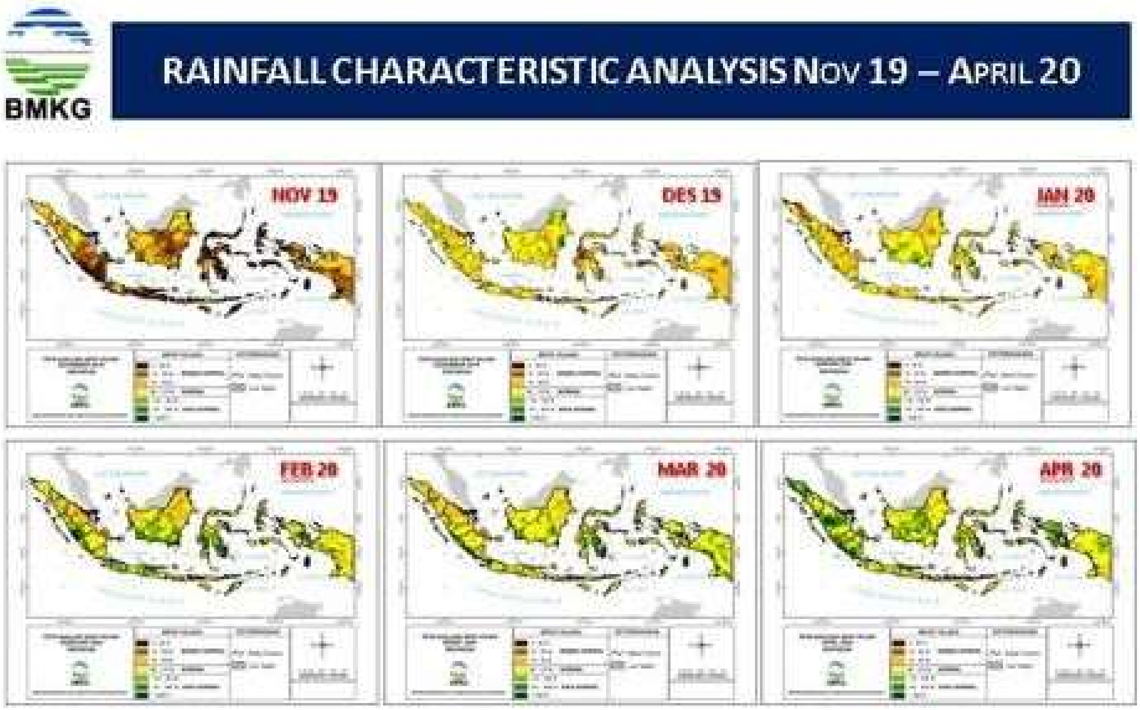


Figure 3.2. Rainfall Characteristic Analysis November 2019 –April 2020

3.3 FLOOD OCCURRENCES IN INDONESIA

3.3.1 Flood Disasters October 2019 – April 2020

- National Disaster Management Agency (BNPB) had recorded that during this period there are 570 cases of flood in 229 Regency/City with 128 fatalities, 10 missing persons, and 2.072.944 people were evacuated.
- A special note must be given that from 570 cases of water related disaster, there were 48 Regency/City flooded over 4 (four) times, as shown on Figure 3.3, 11 (eleven) times for Bogor, Cirebon, Serang, 10 times for Bandung and Sumedang. This ought to be national concern as this 48 Regency/City are the center of economy for its surrounding areas.

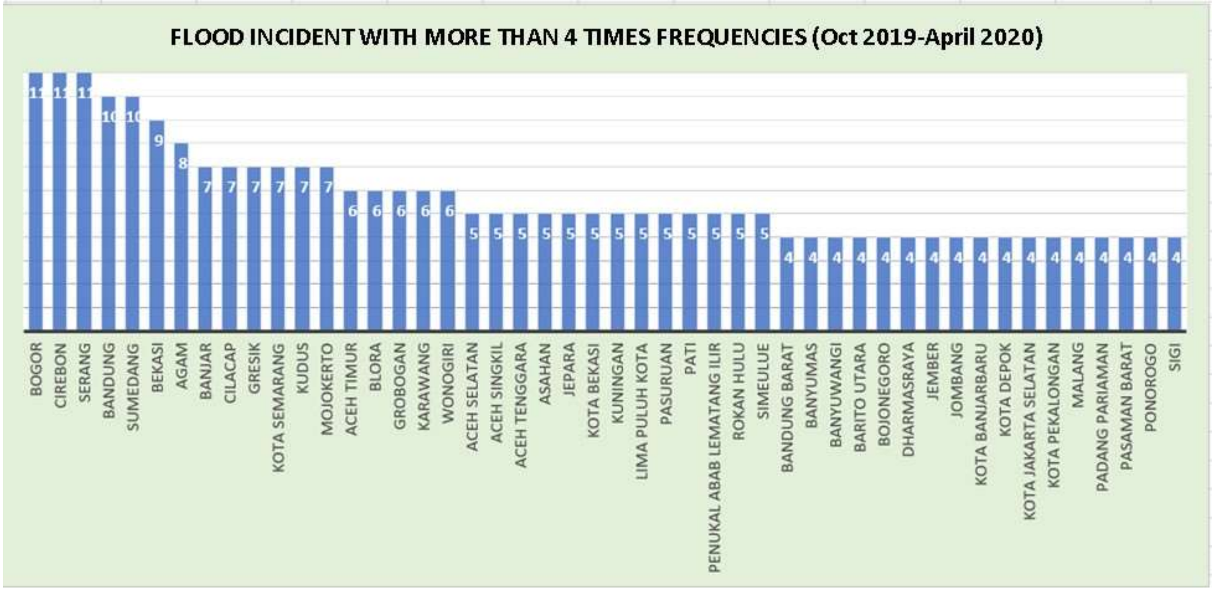


Figure 3.3. Flood Incident with more than 4 times Frequencies

3.3.2 Disaster Events in Jakarta and Its Surrounding Areas:

- One of the flood events that had a severe impact happened in early 2020. It occurred in Jakarta, Bogor, Depok, Tangerang, Bekasi (JABODETABEK). There are 28 villages affected with a total of 27,971 people evacuate. In addition, main roads and toll roads have also been flooded in several sections, resulting in severe congestion and obstruction of logistic distribution around the areas.
- This flood caused by moderate to extreme rainfalls in around Jakarta. The highest daily rainfall recorded at Halim Rainfall Station is of about 377 mm/day. This rainfall intensity has a return period of more than 1000 years. In addition, it is a new record of the highest rainfall measured at Halim with and the record of rainfall in Jakarta since the first measurement carried out in 1866.
- This extreme rainfall is a result of strengthening of the Asian monsoon flow and convergence of air masses or occurrences of Intertropical Convergence Zone (ITCZ) area in northern part of Java. ITCZ triggers the very fast growth of massive and very thick clouds from evaporation of sea around Java which has warmed up and supplied an abundance of water vapor mass to the atmosphere.
- Impact of this disaster is getting worse due to lack of maintenance and obstacles on drainage system, increase of runoff due to land use change andsedimentation on lakes and others water body, under-construction river restoration projects and breaching of dikes.

3.3.3 Detail Data of Disaster Events in Jakarta and Banten October 2019 - April 2020

- Jakarta, Bogor, Bekasi, Depok, Tanggerang:

No.	Date of Events	Type of Disaster	Location	Information	Source of Data
1	01-Jan-20	Flood and landslide	Bogor Regency, Jasinga Subdistrict, Gunung Putri Sub- district, Bojonggede Subdistrict	Flood was triggered by heavy rainfall on 31st December 2019. Jasinga Sub-district inundated by flooding of Cidurian River, while Bojonggede Sub- district influenced by breaching of embankment of Cibeureum Small Lake. Eight villages were affected, including Kalong Sawah, Sipak, Pamegersari, Jasinga, Koleang, Bagiang, Tegal Wangi, Pangaur villages. The dissaster caused 7 fatalities and 1 drifted person by river flow.	https://regional.kompas.com/read/2020/01/02/06394641/5-fakta-bencana-banjir-dan-longsor-di-kabupaten-bogor-7-orang-tewas-1-hilang?page=1
2	01-Jan-20	Flood	Jakarta, Bogor, Tangerang, Depok, and Bekasi	Big flood happens in Jakarta, Bogor, Tangerang, Depok, and Bekasi (Jabodetabek) triggered by extremely heavy rainfall with an intensity of 377 mm/day. The disaster has claimed 16 lives (Jakarta 8 people, Bekasi 1 people, Depok 3 people, Bogor City 1 people, Bogor Regency 1 people, Tangerang 1 people, and South Tangerang 1 people), and more than 31.000 people are evacuated from their houses.	https://tirto.id/penyebab-banjir-jakarta-2020-dan-daftar-jumlah-korban-meninggal-ep9p https://www.bbc.com/indonesia/indonesia-50962493
3	11-Dec-19	Landslide	Lewiliang sub-district, Bogor Regency	Wednesday, 11th December 2019 at 16.02 PM, landslide happened in Cimenteng village, Lewiliang Sub-district triggered by high intensity rainfall. Dimension of landslide: 4,5 m in height, 3 m in height. No fatality was reported.	https://bpbd.bogorkab.go.id/6065-2/
4	11-May-20	Flood	Cibadak-Sukamulih Village, Sukajaya Sub-district, Bogor Regency	On Monday 11th May 2020 at 16.30 PM, flood occurred; caused by a high intensity rainfall. 30 houses were inundated with a height of 75 cm, affected 34 households and 62 lives.	https://bpbd.bogorkab.go.id/banjir-di-kecamatan-sukajaya-kabupaten-bogor-2/
5	18-Apr-20	Flood	Duren Mekar, Sawangan Baru Subdistrict, Depok City	On Saturday 18th April 2020 at 11.00 PM, flood happened in Bukit Sawangan Indah Housing Complex, Sawangan Baru Sub-district, Depok City. Flood was caused by spilling out of Angke river with a height of about 0,5 m., affected approximately 800 houses and 2.676 lives	https://bpbd.bogorkab.go.id/banjir-di-kecamatan-kecamatan-sawangan-baru-kota-depok/

Table 3.1. Data of Disaster in Jakarta, Bogor, Bekasi, Depok, Tanggerang

- Lebak Sub-district, Banten Province

No.	Date of Events	Type of Disaster	Location	Information	Source of Data
1	09-Feb-19	Landslide	Sudamanik Village, Cimarga Subdistrict, Lebak Regency	102 houses suffer a minor to heavy damage and 2 houses collapse	https://www.suara.com/news/2019/02/10/055500/longsor-di- lebak-102-rumah-rusak
2	23-May-19	Flood	Muncang, Cimarga, Sobang, and Sajira Sub-districts, Lebak Regency, Banten Province	29 houses in 4 subdistrict suffer a heavy damage, 27 units minor damage, and 209 units flooded. It also ruin public facilities such as 3 bridges, 3 Islamic boarding schools, **2 Assembly Building,** 1 Elementary School building	https://news.okezone.com/read/2019/05/23/340/2059469/banjir-bandang-terjang-4-kecamatan-di-banten-puluhan-rumah-rusak-berat
3	31-May-19	Flood	Sobang and Leuwidamar Sub- districts, Lebak Regency, Banten Province	Flood hampered Ciparasi and Sukajaya Villages in Sobang Sub-distric, and Lebak Pariang, Leuwidamar and Wantisari Villages in Leuwidamar Sub-distric	https://www.liputan6.com/news/read/3980246/banjir-melanda-2-kecamatan-di-lebak-banten#
4	06-Dec-19	Flood	Cibeber and Bayah Sub-districts, Lebak Regency, Banten Province	Flood caused by Cisantayan River in Cibeber Sub-district and Cimandur river in Bayah Sub- district inundate hundred of houses and ruin 3 bridges.	https://regional.kompas.com/read/2019/12/08/14430911/4-fakta- banjir-bandang-di- lebak-2-kecamatan-terdampak-hingga-3- jembatan
5	06-Dec-19	Landslide	Citorek, Cibeber Sub-district, Lebak Regency, Banten Province	5 villages in Citorek heavily damaged by flood and landslide, 10 of houses are flooded, bridges are damaged, and landslides blocks road in several places.	https://regional.kompas.com/read/2019/12/07/08192711/longsor- dan-banjir-terjang- lebak-akses-ke- negeri-di-atas-awan-tak-bisa
6	27-Jan-20	Flood and landslide	Cipanas Sub-district, Lebak Regency, Banten Province	Flash-flood in Ciberang rive ruin 3 temporary bridges	https://www.liputan6.com/regional/read/4164772/banjir-bandang- dan-tanah-longsor-kembali-melanda- lebak-banten

Table 3.2. Data of Disaster in Lebak Regency

3.4 FLOOD EARLY WARNING SYSTEM

- Flood Early Warning System was built by Research Center for Water Resources in closed cooperation with BMKG since 2015 to support River Basin Authorities all over Indonesia.
- During October 2019 - April 2020, there were 7.226 potential flood incidents caused by heavy rainfall intensity higher than 100 mm/day or in cumulative 200 mm/3 days were reported. Among those warning, there are 21 River Basin reported with more than 100 warnings. Barito-Kapuas River Basin possesses the highest report with 359 times flood warning report, Kapuas River Basin with 331 reports, and River Basins in Papua region such as Einlanden-Digul Bikuma River Basin and Memberamo-Tami River Basin.

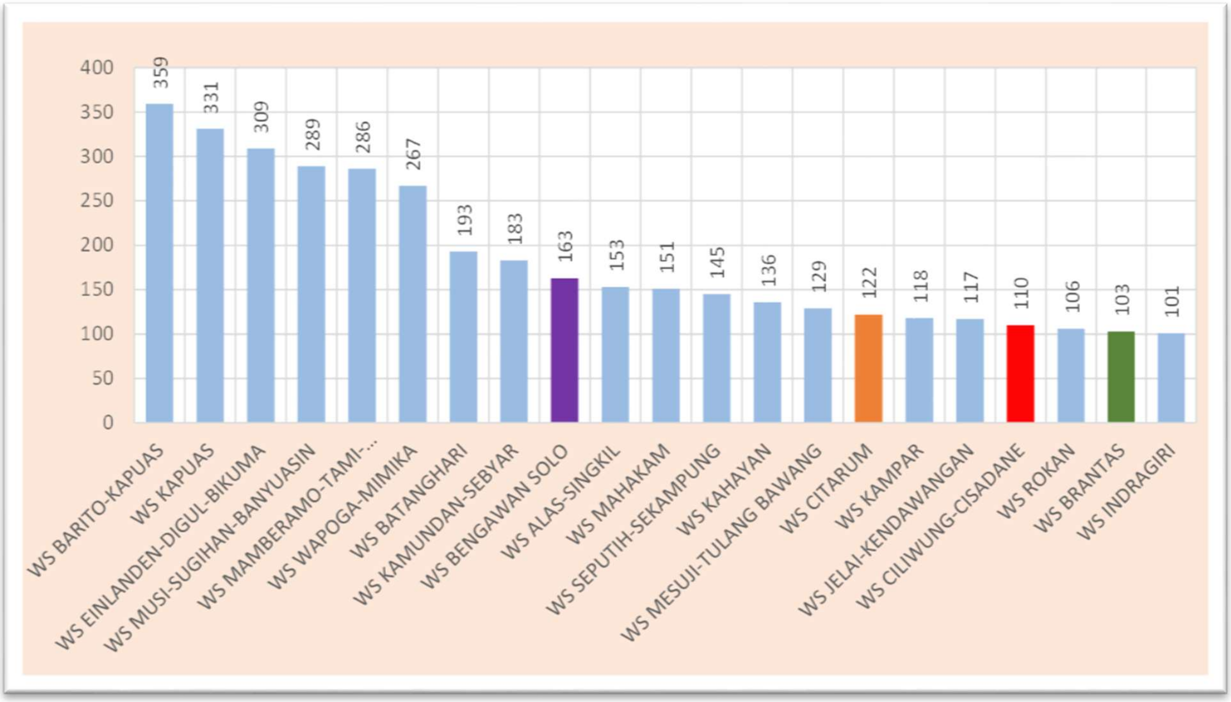


Figure 3.4. River Basin with more than 100 times potential flood warning.

- Jakarta has a more advanced Flood Early Warning System (J-FEWS) which is supported by SOBEK software developed by Deltares. J-FEWS delivers warning and prediction of possible inundated areas in Jakarta. Input and Forecast data used in J-FEWS are presented in Tables 3.3 and 3.4.
- In normal conditions J-FEWS performs quite satisfactory giving forecast, prediction and warning. However, during the 1st January Flood, one day before the flood J- FEWS gave an under-estimated of rainfall intensity prediction ie. only about one- third of the real rainfall intensity. This prediction was regularly updated and present a better prediction 3 hours before the flood occurrence. However, this 3 hours lead time was too short to prepare emergency measures.
- Post disaster evaluation on J-FEWS performance come to a conclusion that Convectional Rainfall happened on 1st January is a bit difficult to be predicted. This phenomenon will be studied in a more detail to improve the J-FEWS performance.

Input Data Management			
Data Type	**Issued by**	**Data Availability**	**Status**
Real time	AWS-BMKG (radar)	Rainfall Intensity	Installed
Ground Station	BBWS Cilicis	Rainfall Intensity and Water Level	Installed
Real time	GPM (Global Precipitation Measurement)	Rainfall Intensity	Installed
Telemetry	PU DKI	Rainfall Intensity and Water surface	Installed
Telemetry	PUSAIR	Rainfall Intensity	Installed
Real time	TRMM	Rainfall Intensity	Installed

Table 3.3. Input Used Data Management of J-FEWS

Forecast Data Management			
Data Type	**Data Name**	**Accessed Data**	**Status and Prediction**
Forecast	ACCESS-R	Rainfall Intensity	Installed (6 days forward, recommended 3 days forward)
Forecast	GFS (Global Forecast System)	Rainfall Intensity	Installed (6 days forward, recommended 3 days forward)
Forecast	ECMWF	Rainfall Intensity	Installed (6 days forward, recommended 3 days forward)

Table 3.4. Forecast Used Data Management J-FEWS

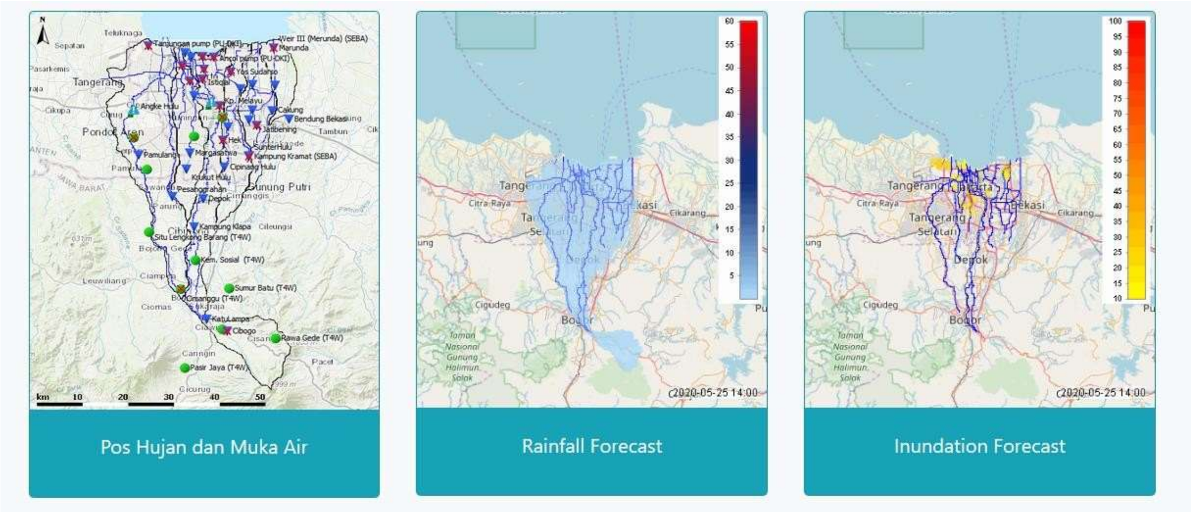


Figure 3.5. Illustration of J-FEWS Display Units.

3.5 CLOSURE

- Even atmospheric dynamic condition of Indonesia in October 2019 – April 2020 was looked normal as typical condition for wet season in Indonesia, but this condition significantly changed in early January 2020.
- The changes were triggered by strengthening of the Asian monsoon flow and convergence of air masses or occurrences of Intertropical Convergence Zone area in northern part of Java.
- The conditions get worse due to lack of maintenance and obstacles on drainage system, increase of runoff due to land use change and sedimentation on water body, under-construction river restoration projects and breaching of dikes.
- Convectional rainfall phenomenon should be studied in a more detail to improve our early warning system performances.

4. Overview of Typhoon Hagibis in Eastern Japan in October, 2019

Kazushi Furumoto

Director for International Coordination of River Engineering, Water and Disaster Management Bureau, Ministry of Lang, Infrastructure, Transport and Tourism (MLIT), Japan

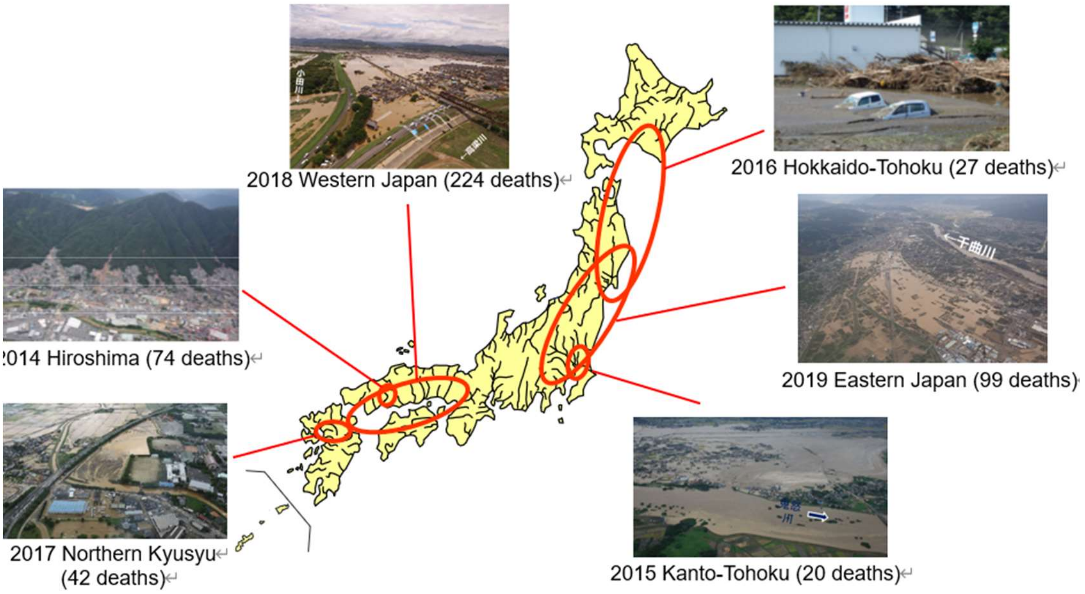
4.1 Overview of the Water-related disaster and risk reduction policy in Japan

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, a widespread area in Western Japan in 2018 and Northern Kyushu region and a widespread area in Eastern Japan in 2019.

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.

This chapter describes the overview of the disaster Typhoon Hagibis in 2019, and the policy-making process by MLIT based on the changes in the climate and social environment.

Fig. 4.1 Successive water-related disasters hitting Japan

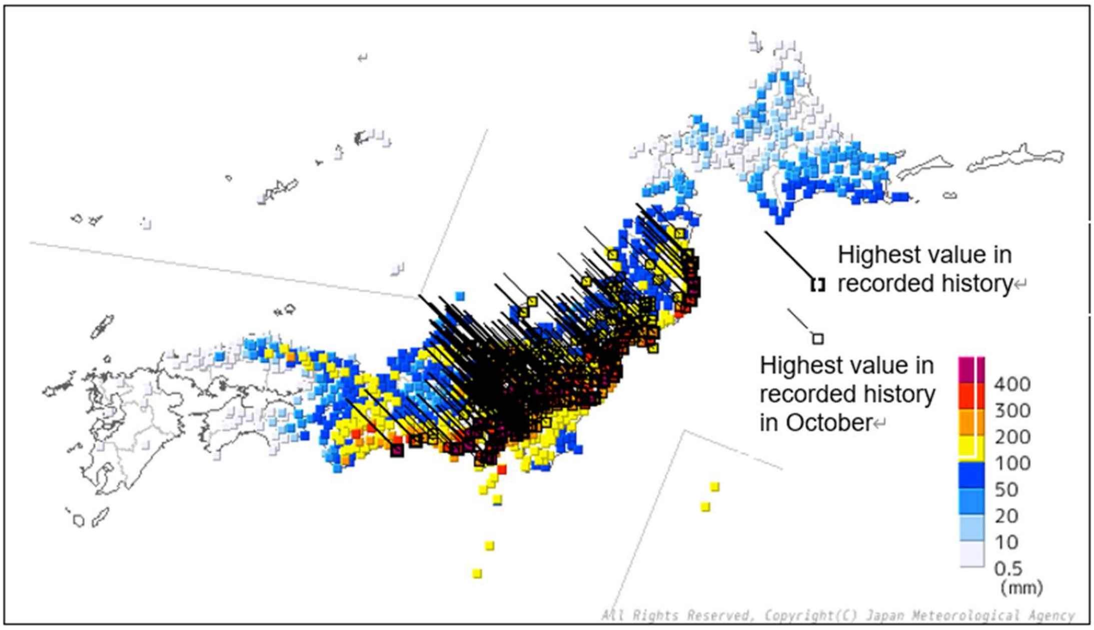


4.2 Overview of the Typhoon Hagibis

4.2.1 Meteorological condition of the typhoon

Typhoon Hagibis, which formed near Minamitori-shima Island on October 6, 2019, made landfall on the Izu Peninsula before 19:00 on October 12. The total precipitation from October 10 to 13 exceeded 500 mm at 17 observatories, mainly in eastern Japan, including 1,000 mm at Hakone, Kanagawa Prefecture. In particular, many points in Shizuoka and Niigata prefectures, the Kanto and Koshin region, and the Tohoku region experienced record heavy rainfall with the highest precipitation levels for 3, 6, 12, and 24 hours in recorded history. In terms of precipitation, the number of 6-hour precipitations at 89, 12-hour precipitations at 120, 24-hour precipitations at 103, and 48-hour precipitations at 72 points reached a new record high.

Fig. 4.2 Maximum values of 24-hour rainfall from October 10 to 13



4.2.2 Summary of the damage and response of MLIT

(1) Damage of river levees and emergency restoration of rivers managed by MLIT

Typhoon Hagibis caused extensive damage to river facilities such as river levees and revetments in rivers managed by MLIT. The number of levee breaches was 14 in 7 rivers, including Chikuma River. In addition, emergency restoration projects were adopted just after the disaster and restoration works were immediately started including 6 sites, where, despite no breaches, but there were heavy damages or scourings in the embankment.

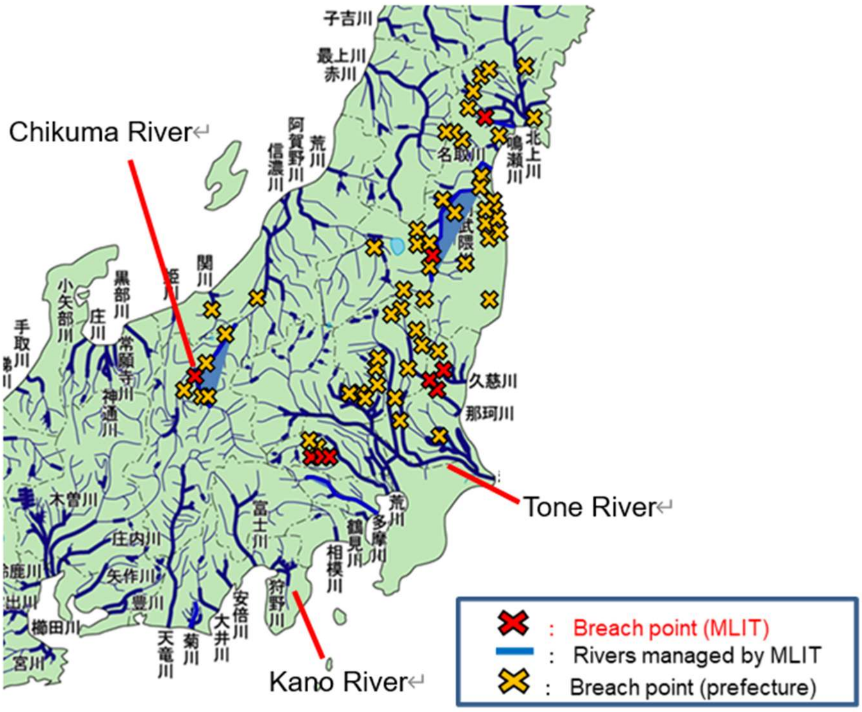
Emergency restoration were carried out 24 hours a day, and on October 20, about a week after the disaster, the temporary embankments were completed, and by November 8, restoration works (double-wall pile sheeting coffer dam and embankment covering with blocks) were completed. In addition, by November 3, emergency restoration works were completed at 6 sites where there were heavy damages or scourings in the embankment.

Furthermore, because the number of damaged infrastructure, managed by local government, was so huge (at least, the number of river levee breache was 128 in total), MLIT received a request from 4 prefectures, to complete temporary embankments for 41 sites of 15 rivers (including 5 river embankments which were scoured) by November 8 on behalf of the national government, based on the River Act.

Fig.4.3 Levee Breach at Chikuma River

Fig.4.4 Emergency restoration work at Chikuma River (Double-wall pile sheeting coffer dam)

Fig.4.5 Location of Levee Breaches



(2) Flood control by dams and retarding basin

The 146 dams managed by MLIT stored the floodwater, thereby lowering the water level of the downstream rivers and preventing or mitigating damages in the downstream areas.

At 6 of these dams, which suffered record-breaking rains, the flood control capacity was expected to be used up, forcing them to implement the emergency flood discharge operation, in which the amount of water discharged is equal to the amount of water flowing into the dams.

Of the 146 dams, 45 dams, mainly in the Kanto region, preliminary dischange operations were implemented with the cooperation of water users in order to increase their capacity to store floodwater before the approach of Typhoon Hagibis.

In Kusaki Dam, which is managed by the Japan Water Agency (JWA), the flood control capacity was increased by about 4.5 million m^3 by preliminary discharge in accordance with the dam operating regulations, and additional preliminary discharge was carried out with the understanding of water users to lower the water level by about 14 m, securing about 15 million m^3 of capacity for flood control. The post-flood simulation confirmed that if the prelliminary charge was not implemented, the emergency discharge was operated and the maximum discharge could have been reached about 1,100 m^3/s, which is about 80% more than the actual maximum discharge of about 600 m^3/s, thereby rising the water level in downstream. The preliminary discharge of the Kusaki dam during Typhoon Hagibis was an example of the effectiveness of preliminary discharge in the face of unusually heavy rainfall.

In addition, at Tsurumi Retarding Basin in Tokyo Metropolitan Area, the flood water over-flowed from the main river to the retarding basin, and water level of the main river was lowered around 0.3m.

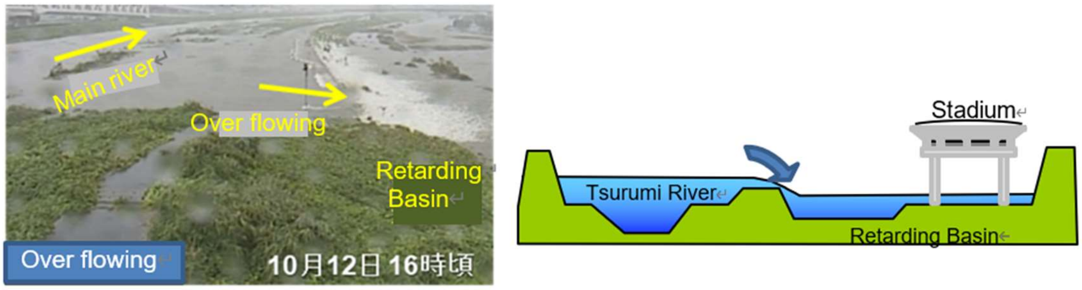


Fig.4.6 Tsurumi Retarding basin

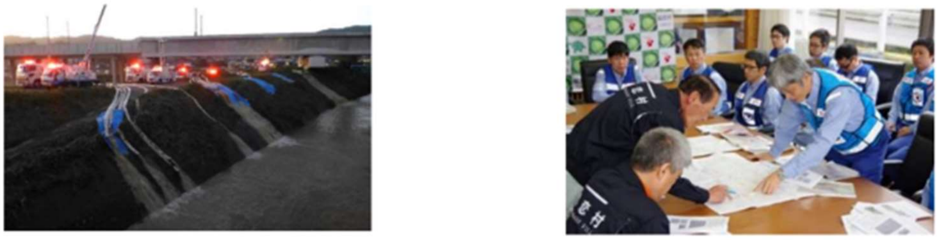
(3) TEC-FORCE

TEC-FORCE (Technical Emergency Control Force) is a specialist group, established in MLIT, which provides fast technical assistance for the affected municipalities to help make fast damage assessment, prevent the occurrence or escalation of disaster, and implement faster restoration and any other temporary disaster responses against large-scale natural disasters, such as earthquakes, flood or landslide disasters, etc.

After passing Typhoon Hagibis, MLIT dispatched TEC-FORCE to affected municipalities. The number of MLIT members mobilized amounted to 30,513 man-days in total (from October 10 to December 27, 2019) and 748 per a day at a maximum from all regional branch office of MLIT. Pump vehicles conducted 24-hour drainage operations on waterlogging. 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.

Field Survey

Road Sweeping



Drainage

Technical advice to local government

Fig.4.7 Activities of TEC-FORCE

4.2.3 Effects of the flood control facilities

In recent years, severe floods have been occurring frequently. In this paragraph, the examples of the effect of flood control facilities, developed before Typhoon Hagibis, in preventing and reducing flood damage, were introduced.

(1) Kano River diversion channel

The construction of the Kano River diversion channel began in 1951 when Typhoon Aion hit the area in 1948, and was completed in 1965 after a review of the plan due to the extensive damage caused by Typhoon Ida in 1958. Although Typhoon Hagibis brought more rain than Typhoon Ida in the Kano River basin, it was able to divide the flood flow of Kano River at the diversion channel and lower the water level of the main river flowing through Numazu City and Mishima City, which are downstream of the main river.

Typhoon Ida in 1958 caused extensive damage in the Kano River basin, with 853 dead or missing and 6,775 houses inundated. In Typhoon Hagibis, the discharge channel prevented the Kano River from overflowing, resulting in zero casualties and about 1,300 inundated houses.

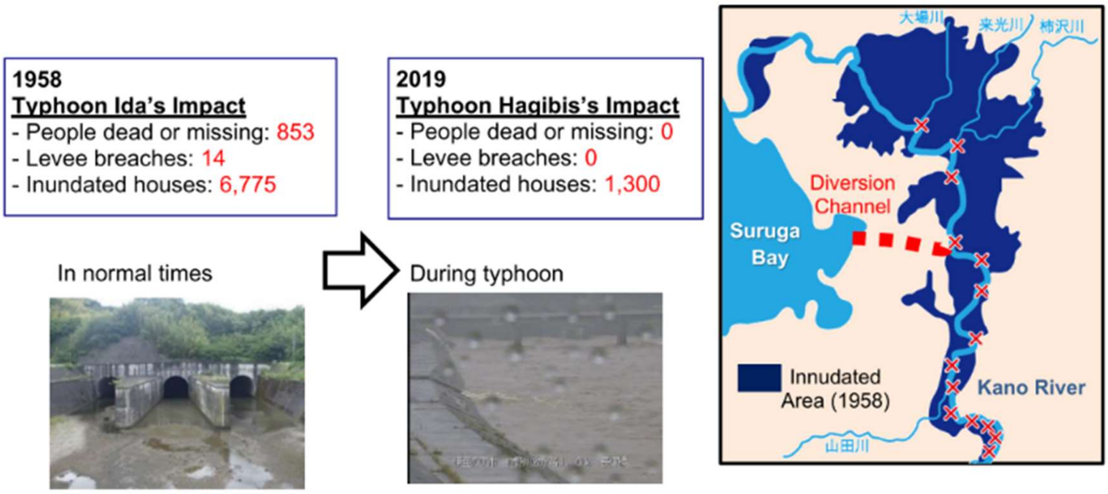


Fig.4.8 The effect of Kano river diversion channel

(2) Dams in upstream of Tone River Basin

During the Typhoon Hagibis, approximately 145 million m^3 of floodwater was stored at the dams located upstream of the Tone River, including the Yagisawa Dam, Naramata Dam, Fujiwara Dam, Aomata Dam, Sonohara Dam, Shimokubo Dam, and the Yamba Dam.

Due to the storage of floodwater by these dams, it is estimated that the water level has been lowered by about 1 m at the Yattajima.

Yamba Dam before & after water storage

Before water storage on Oct.11

After storing 75 million m^3 of water on Oct.15

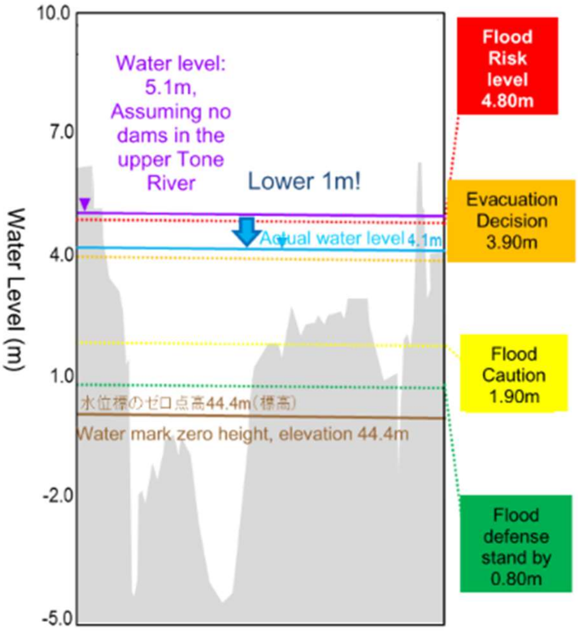


Fig.4.9 The effect of Dams at Yattajima (Tone River Basin)

(3) Effects of comprehensive flood control measures in Kanda River basin, Tokyo Metropolitan Area

Based on the river basin basic plan, flood control measures such as river channel widening, riverbed excavation, retarding basin, storm-water sewerage improvement, rainwater retention and infiltration facilities have been developed in an integrated manner with a target of 75 mm of rain per hour in the Kanda River basin in Tokyo.

Typhoon Hagibis brought record rainfall in Tokyo, and the Yamanote area, mainly in the western part of Tokyo, received 30-40 mm/h of rain for a long period, bringing the total rainfall to about 300 mm. However, flood damage in the downstream section was reduced. For example, the underground regulating reservoir beneath Ring Road No. 7 stored the flood water about 90% of the planned storage volume.

Fig.4.10 The effect of the underground regulating reservoir beneath Ring Road No. 7

4.2.4 Dissemination of information

(1) Collaboration with the media to prevent residents from delaying evacuation

MLIT launched a project in autumn 2018 to “share information on flood and sediment disaster hazards and risks to encourage residents to take action on their own” after the Heavy Rain in July 2018 that killed more than 200 people.

MLIT and the media worked together to discuss measures to prevent residents from falling behind, and in December 2018, the project report consisting of 33 measures was established, and the members began their initiatives.

(2) New Initiative for calling on families to evacuate, “Evacuation Call”

In 2019, each initiative has begun to take concrete steps.

One of the new initiatives is the "Evacuation Call," which uses a smartphone application and short message service (SMS) to obtain disaster management information about the community where a family member lives, and to call directly to a family member to evacuate in the event of disaster when the family members live apart. This initiative started from June 2019 with the collaboration of Japan Broadcasting Corporation (NHK), Yahoo Japan, KDDI (Telecommunications business), and MLIT.

According to a survey conducted by KDDI, 54% of people contacted family members living in the disaster area after receiving disaster and evacuation information of Typhoon Hagibis, and 58% of those received took evacuation action. The results show that this initiative has a certain effect as a trigger for evacuation in heavy rains.

Although the effectiveness of this initiative has been shown, there are still some issues to be addressed in raising awareness of this initiative. Although the campaign was conducted through posters, the Internet and radio, only about 8% of the respondents know the “Emergency Call” initiative according to the Internet survey conducted by MLIT. It is important to improve publicity and expand the number of participating companies.

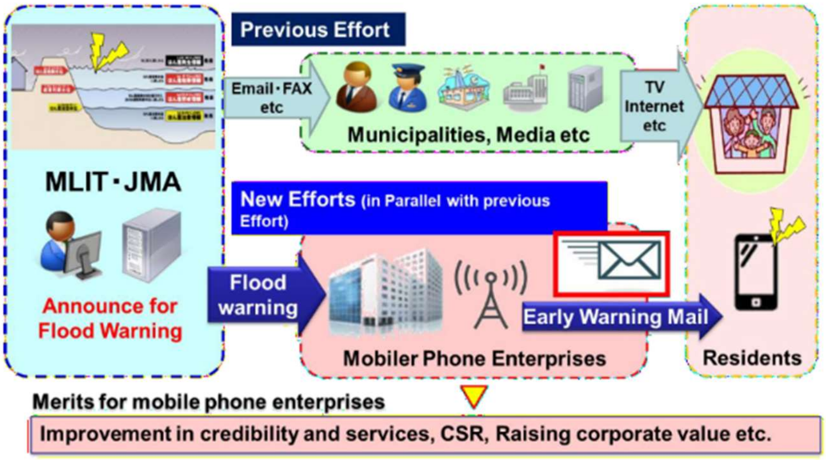


Fig.4.11 Early Flood Warning Mail in corporate with mobile phone companies

(3) The explain of the urgency of the disaster by river expert

MLIT's regional branch offices and local meteorological observatory started new initiative to hold a joint emergency press conference with Japan Meteorological Agency (JMA) to convey the meteorologal and hydorological information to the local residents directly through television and other means. 19 joint emergency press conferences have been held so far including the Tohoku, Kanto, Hokuriku and Chubu regions during Typhoon Hagibis. In addition, MLIT were conveying the urgency of the disaster through TV interviews, and so on.

According to an Internet survey by MLIT, more than 80% of people watched joint emergency conference on TV or other media during heavy rainfall, such as Typhoon Hagibis, and many of them responded that this raised their sense of urgency about floods and made them want to check hazard maps and other disaster prevention information.

NHK	18:10～18:13	Broadcasting times of each TV station
KBC	18:15～18:17	
RKB	18:15～18:16	
FBS	18:15～18:16	
TVQ	17:42～17:43	
TNC	17:45～17:46	

Fig.4.12 Collaboration Annoucement with meteorologal and hydorological information

(4) Issues in the event of widespread and simultaneous flooding

On the other hand, Typhoon Hagibis caused a lot of damages in eastern Japan, and it has become clear that there is a problem of information transmission and dissemination during the case of widespread and simultaneous flooding.

For example, In the Naka and Kuji Rivers, amidst the confusion at the sites of numerous disasters, flood forecasts to inform the danger or occurrence of flooding were not released. In other case, the "Emergency Alert Mail", which provides flood information directly to local residents, was not sent out. In large rivers such as the Shinano, Tone and Abukuma River, as there was a time lag between heavy rainfall in upstream area and peak time of water level in downstream, flood warnings should continue even after the heavy rains have passed. However, it has been pointed out that the canceling of the warning for heavy rains may have been misinterpreted as reassuring information, and that the danger of swelling in the river afterwards may not have been fully communicated to local governments and residents.

In addition, MLIT's "River Disaster Prevention Information" website, which provides information on water levels and rainfall on the Internet, became difficult to connect to due to the concentration of access. On that day, information was provided via a simplified version of the website, and with the cooperation of NHK and Yahoo Japan, members of the information-sharing project, information of water level and rainfall was directed to the members' water level information website. Drastic improvements to the system were needed to prepare for future heavy rains. Furtheremore, strengthening of cooperation with the media and improving of the content and method of disaster information, such as encouraging evacuation, are required.

(5) Result of examination and improvement plan

In November 2019, Bureau of Water Management of MLIT, and the Japan JMA were set up the collaboration team to examine the causes of such problems as the dissemination and transmission of river and meteorological information, and to establish the improvement plan.

Based on the results of the examination, improvement plans were designed such as enhancing the flood monitoring system by installing more cameras and water level gauges on rivers, enhancing communication lines and servers, and creating easy-to-understand disaster prevention terminology.

4.2.5 Summary

During the Typhoon Hagibis, while the flood control facilities have certainly been effective, the frequency and severity of heavy rainfall due to the influence of climate change are becoming more apparent, and river levee breach, water overtopping, and sediment disasters will occur all over the country, especially in low-safety areas. In addition, some dams are anticipated to use up their flood control capacity, resulting in the shift to emergency flood discharge operations. It is necessary to study how to deal with the issues identified by these disasters, and then to develop the future flood damage countermeasures in cooperation with the government, businesses, and residents in response to future increases in rainfall and rising sea levels due to the influence of climate change, and changes in social structures such as declining, aging populations.

4.3 Revised flood management policy based on the impact of climate change on precipitation and the change of social structure

As mentioned above, in light of recent disasters, climate change impact and changes in the social structure, MLIT has been developing the flood management. This section describes the direction of the revised flood management policy in Japan.

4.3.1 Current policies and issues

So far, flood management policy has focused on setting a target of flood scale and taking measures to prevent damage due to that flood scale. However, it has been suggested that ex-ante measures and methods to mitigate damage should be enhanced based on the various scales of flood likely to occur, and that measures should be taken from the point of view of early recovery from damage. It is also suggested that the menu of countermeasures should be enhanced to mitigate the three components of water-related disaster risk, consist of “Hazard”, “Exposure” and “Vulnerability”.

4.3.2 The overall picture of the discussion of the flood management policy in light of recent flood damage, climate change impact and changes in social structures

To summarize these assumptions and background of the discussion so far, the impacts of climate change include the following;

- Severe water-related disasters have become more frequent due to an increase in heavy rainfall caused by climate change.
- Even if we continue to reduce greenhouse gas emissions, the number of water-related disasters caused by heavy rainfall may increase.
- Furthermore, rising sea levels and stronger typhoons are predicted to occur.

In addition, regarding the changes in the social structure, following items are pointed out.

- Declining population and low birthrate and aging population further reduce the power of region's disaster prevention system.
- Vacant houses and open space are increasing not only in mountainous areas but also in urban areas.
- In order to maintain the vitality of the region based on the concept of "Compact + Network," it is necessary to develop safe and secure cities.
- The spread of teleworking has led to major changes in the way individuals work.

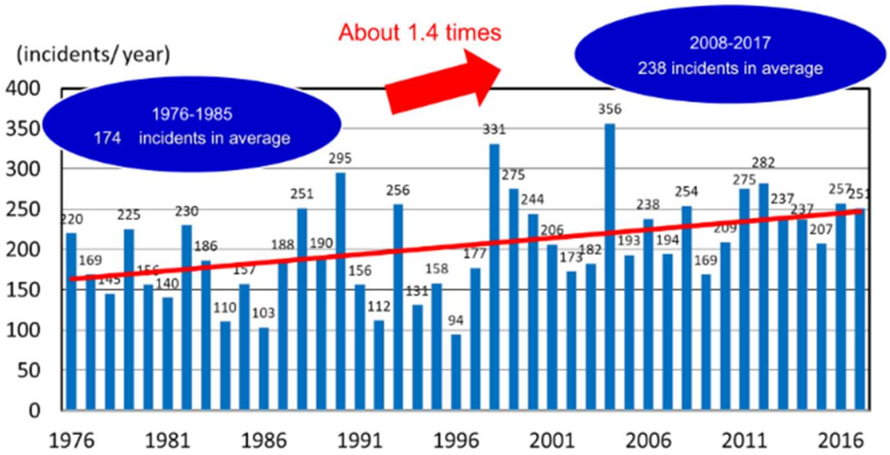


Fig. 4.13 The trend of the frequency of rainfall (50mm /hr or more) in last 30 years in Japan

Furthermore, the transition to a data-driven society with the use of AI technology and big data, should be taken into account, as well as the remarkable progress in information and communication technology (e.g., 5G), observation technology, and computing power.

In addition, the following perspectives should be considered for the revised flood management policy.

A) Resilience

The entire society needs to promote flood disaster countermeasures, including the implementation of flood mitigation by private sectors (such as building owners, factories), and managers of public infrastructure, in order to build a resilient national land. (Mainstreaming of disaster risk reduction)

B) Sustainability

It is necessary to build a strong and sustainable society against water-related disasters through community development and improvement of way of living.

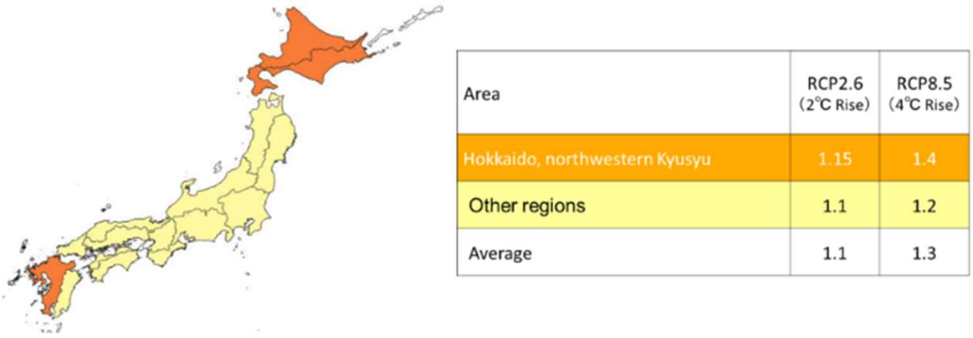
C) Inclusiveness

It is necessary for all actors in all fields to act in order to achieve an inclusive society.

4.3.3 New directions for flood management policy in light of climate and social change

(1) Shifting flood management policy from “past” result to “future” prediction taking into account climate change

The flood management plan should be revised based on from "past rainfall records" to "future prediction of rainfall with climate change".



Area	RCP2.6 (2℃ Rise)	RCP8.5 (4℃ Rise)
Hokkaido, northwestern Kyusyu	1.15	1.4
Other regions	1.1	1.2
Average	1.1	1.3

Fig.4.14 Change rate of future rainfall with climate change

(2) Shift to "Comprehensive watershed flood management

In addition to conventional flood management measures, which are mainly carried out by managers of rivers, sewerage systems, etc., it is necessary to promote a shift to flood management measures ("Comprehensive watershed flood management"), in which not only the catchment area and river area but also the inundation area are considered as “one river basin”, and all parties involved in the entire basin work together to reduce flood damage in the basin.

In other words, with the participation of all actors in the basin, the following measures should be taken according to the characteristics of the each region.

A) Measures to preventing inundation (addressing the “Hazard”)

- Continue to develop flood control facilities to prevent from flooding

B) Measures to reduce the number of subjects damaged by flood (addressing the “Exposure to the risk”)

- Promote community development and improve the way of living to avoid damage even in the event of flooding due to exceeding the capacity of flood control facilities

C) Measures for early recovery and reconstruction (addressing “Vulnerabilities”)

- Improve the evacuation system in order to be more accurate and appropriate in the event of flooding, and the measures for early recovery and reconstruction

The above three elements should be promoted in a multi-layered manner in order to achieve "Comprehensive watershed flood management" in a unified manner.

MLIT plans to expand this policy to all rivers in the country, including those in rural areas, in order to not only prevent from the increase in runoff due to urbanization, but also to promote further measures to control runoff through the cooperation of various entities.

In addition to these measures, MLIT will accelerate the current flood control measures, add a new menu of ex-ante disaster risk reduction, and implement them systematically. It is aimed to create a society where it is common for all government, private sectors and citizens to consider disaster prevention and disaster reduction as part of their awareness and actions.

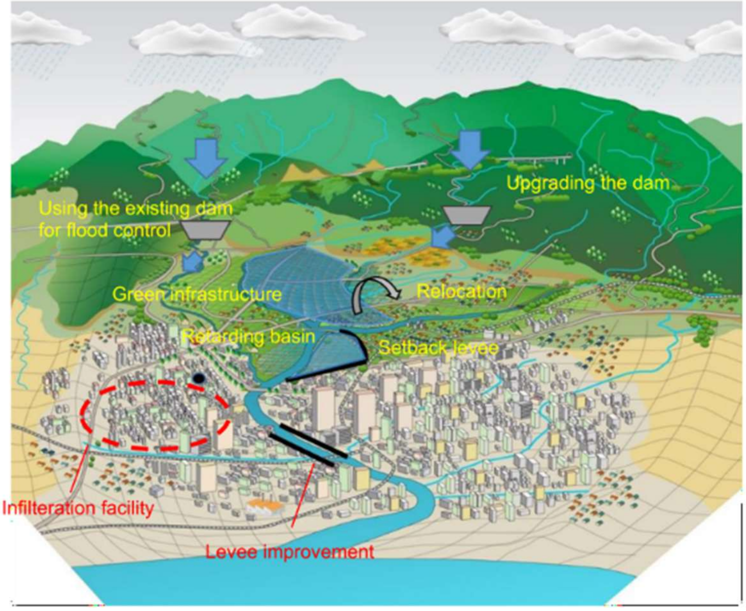


Fig.4.15 Comprehensive Watershed Flood Management

4.3.4 Specific Measures for New Flood Management policy

Based on the new direction of flood management policy as described above, the following measures can be taken.

(1) Revision of flood management plans

- Review of basic high water in the basic policy for river improvement
- Review of the target flow rate in the river improvement plan
- Revision of the Basic Policy for Coastal Management
- Review of design standards to ensure facility functions and safety
- Review of design standards for coastal protection

(2) Conversion to “Comprehensive watershed flood management”

<Measures to prevent from flooding>

A) Reducing the volume of flood waters

- Strengthen the river levees to make them more resilient in the event of overflow
- Continue to study and develop technologies to further strengthen the river levees
- Implement the flood control measures in areas where residences and urban functions are relocated

with low risk of flooding and landslides, as well as in areas that serve as a regional disaster management base

- Utilize new technologies for strengthening the flood management system

B) Storing flood waters

- Strengthen the flood control function of existing dams, including irrigation and water utilization dams (Implementation of preliminary discharge and development of technology and systems for improving prediction accuracy)
- Preserve the retarding and drainage functions through the preservation and development of open levees (Promote of the designation of disaster warning areas to control development.)
- Cooperate with the local community regarding land use

C) Storing rainwater in the watershed

- Develop the rainwater harvesting facilities such as rainwater regulating ponds in the existing sewer network and large-scale storage facilities using underground spaces in urban areas, and develop the cooperation of private sectors, etc.
- Promote runoff control measures in river basins in urban and rural areas to compensate for the decline in rainwater infiltration and storage capacity due to development.
- Effectively use the storage capacity in existing infrastructures and facilities such as reservoirs, rice fields, and abandoned farmland).
- Visualize the effects of cooperation between various actors in the basin

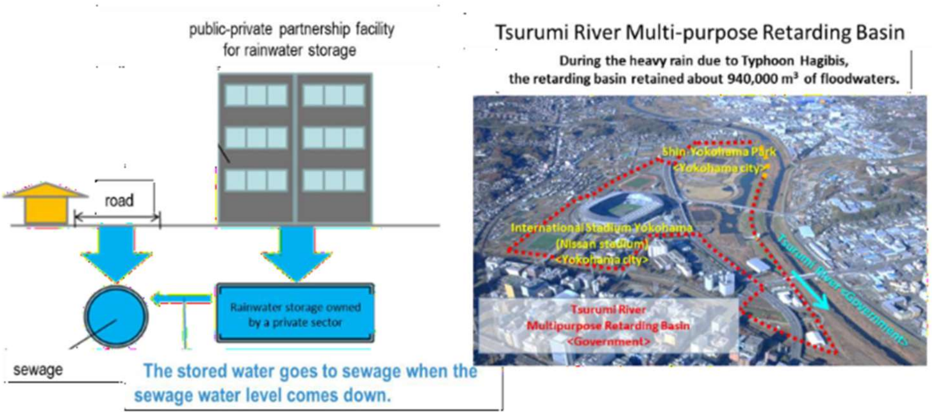


Fig.4.16 Rainwater storage and retarding basin

<Measures to reduce the number of subjects damaged by disaster>

A) Enhancing information on the risk of water-related disasters

- Promptly designate the inundation hazardous areas and announce the flood disaster risks of coasts, sewerage systems
- Publish hazard maps of high frequency flooding in addition to the expected maximum scale
- Promote the designation of landslide warning zones, and improve the accuracy of risk evaluation with more accurate topographical data in future surveys
- Utilize these disaster risk information for risk communication among stakeholders to improve community development and way of living

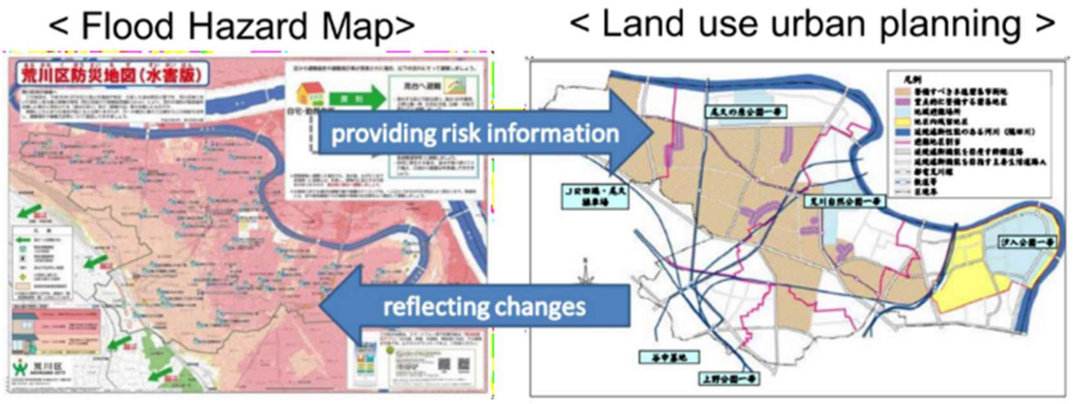


Fig.4.17 Utilization of disaster risk information for urban development and land-use planning

B) Enticing residents to areas with lower disaster risk
- Strengthen development control in high-risk areas
- Provide information on how to live with flood risks in mind
- Provide information on flood risk and initiatives for risk mitigation to the financial and insurance industries
- Promote relocation to the vicinity of local residents in post-disaster recovery, rather than building infrastructure and full-scale recovery in some cases. (Build Back Better)

C) Controlling flood waters and narrowing inundation area
- Promote the construction of secondary levees and the preservation of natural levees

<Measures for Early Recovery and Reconstruction>

A) Facilitating evacuation of residents
- Utilize the power of mutual aid, and information and communication technology in each district
- Improve information and expressions to encourage residents to evacuate
- Implement long-term forecasts by improving the accuracy of forecasts
- Utilize privately owned buildings as evacuation facility

B) Reducing economic damage
- Strengthen the resilience of the social infrastructure that supports the private sector and the local economy

C) Cooperate with stakeholders
- Promptly acquire broad-based disaster information with satellites, sensors and AI
- Strengthen the important facilities against flood to ensure the function even in the event of flooding
- Expand the government's support for emergency disaster response, including TEC-FORECE
- Improve the function of TEC-FORCE through enhanced cooperation between the public and private sectors
- Cooperate with the financial sectors to enhance risk-based flood insurance
- Strengthen flood-fighting activities

<Acceleration of ex-ante disaster risk reduction>

- Compile emergency basin flood management plan for other than the 7 river basins affected by

Typhoon Hagibis, and accelerate ex-ante disaster risk reduction based on the plan

<Improvement of disaster management systems in society as a whole, in order to implement the "Comprehensive watershed flood management">

- Implement evolving information and communication technologies and utilize these technologies to support evacuation activities and disaster risk reduction, including integration of data on water-related disasters, information and communication technologies, and forecasting technologies
- Mainstream disaster management
  Aiming for a society where it is commonplace for every government, private sector, and citizen to consider disaster management in their awareness, actions, and systems
- Promote initiatives while taking into account the effects of "green infrastructure" that makes use of the various functions of the natural environment, including its disaster prevention and disaster reduction functions

For example, of these measures, “Strengthening of the flood control function of existing dams, including irrigation dams” has been implemented as follows.
Relevant ministries and agencies worked together to coordinate with existing dam managers, including irrigation dam, to drastically expand preliminary discharge and secure flood control capacity of existing dams.
As a result of this coordination, "Agreement on flood control", including the specific criteria for preliminary discharge and the amount of flood control volume, has been reached in all rivers managed by MLIT. With this agreement, the flood control capacity has been doubled.
MLIT will operate the dams in an integrated manner, including existing dams in accordance with “Agreement on flood control”, while research and development will be carried out to predict the amount of rainfall, inflow and discharge volume of the dam.

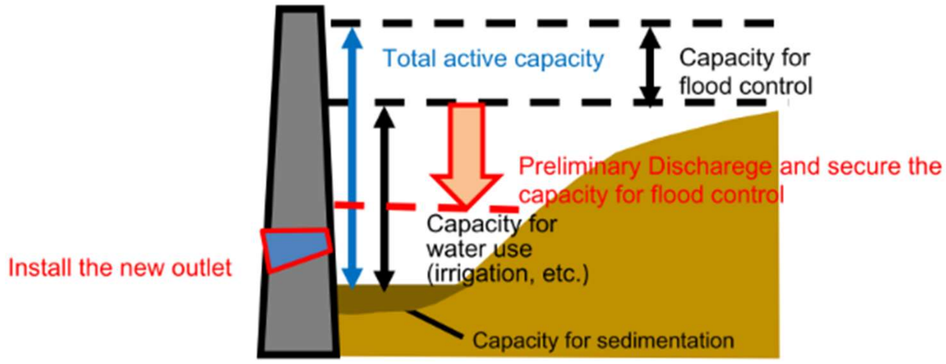


Fig.4.18 Strengthening of the flood control function of existing dams

4.3.5 Summary

As mentioned above, in light of recent disasters and the increase of frequency and severity of flooding due to climate change, MLIT change the flood management policy based on the prediction of rainfall taking in to account of climate change from the historical data. In addition to the development of flood control facilities taken by the managers of rivers, sewerage systems, MLIT will promote “Comprehensive watershed flood management”, basin-wide flood control measures, implemented in cooperation with all parties involved in the entire river basin. This is a typical “Build Back Better” policy and a systematic scheme of Japan to foster a resilient society.

5. The Mississippi R. Flood of 2019: Managing Mega-Flood Disasters

E. Stakhiv, Johns Hopkins University and IWR Visiting Scholar,

J. Manous, Director, U.S. Army Institute for Water Resources (IWR), and

G. Galloway, Glenn L. Martin Institute Professor of Engineering, University of Maryland

5.1 Abstract

The Mississippi R. flood of 2019 belongs in the category of ‘mega-disasters’, though not nearly as destructive, in terms of economic damages or loss of life, as the flood of 1993, or the benchmark flood of 1927. This was mainly because of decades of incremental adjustments and adaptation to population growth and increased flood events that had improved both the robustness of the system to withstand large floods, and increased the resilience of economic sectors like agriculture, to cope with the after-effects, which was enabled through countless new federal and state economic compensation programs for small businesses, and expanded flood and crop insurance programs.

The Mississippi R. basin structural flood control system consists of a layered, hierarchical infrastructure system of main stem and tributary reservoirs, thousands of miles of levees, main stem channel improvements, locks and dams and urban flood protection and associated storm drainage infrastructure. It is a foundational part of the ‘critical infrastructure’ of the basin and the U.S. economy, and serves as the core of a robust system of flood protection. This system evolved incrementally over the past 150 years, having accelerated since the devastating flood of 1927. It serves as the foundation of an integrated network of federal, state and local community measures, both structural and non-structural, that has progressively reduced flood damages.

Each major flood that impacts some region of the U.S. offers a set of interesting, and somewhat unique new characteristics to consider in reconfiguring and designing more robust and resilient flood protection systems for an ever-growing populace. Coupled with the looming but uncertain consequences of climate change, societies have been forced to consider innovative adaptation measures to deal with increased intensity, duration and frequency of floods and associated increased damages due to more densely located populations with greater wealth.

Adding to those complexities, planning future strategies for flood protection must include new sustainability planning objectives along with disaster risk reduction criteria, such as environmental and social justice goals and ‘climate-proofing’ communities and watersheds. Updating infrastructure design and safety criteria to increase the resilience, robustness and reliability of systems and projects is essential, as are new technologies and mitigation measures as part of a new generation of comprehensive risk-reduction strategies tailored for each basin and community. All these changes add institutional, regulatory and public participation and transparency complexities.

5.2 Introduction

Floods and droughts are a permanent feature of human existence, and civilizations have worked for millennia to harness the destructive components of floods in order to benefit man – in the form of providing services such as hydropower, irrigation water, environmental flows or municipal and industrial water supply. However, because of global warming and associated climate changes, both floods and droughts appear to be more intense and more frequent worldwide, at least in the context of data from the past century. It seems nearly each year, a major devastating flood hits some part of the United States, either in the form of an extra-tropical hurricane or a slow-moving weather front that lingers for days. The same holds true for many other parts of the world that have been significantly affected, as in SE Asia and Central Africa.

There is a category of flood disasters that we should term ‘mega-disasters’, because they either affect a large part of a nation, or create such devastation to a region’s infrastructure, that it affects all other critical infrastructure services, in a cascading domino effect, and adversely impacts both regional and national economic productivity for an extended period of time. A major part of a **nation's 'resilience'**, i.e., the ability to bounce back quickly after such devastating disasters, lies in its overall economic and social well-being, as measured, for example by the UNDP's Human Development Index (HDI) http://hdr.undp.org/en/content/human-development-index-hdi.

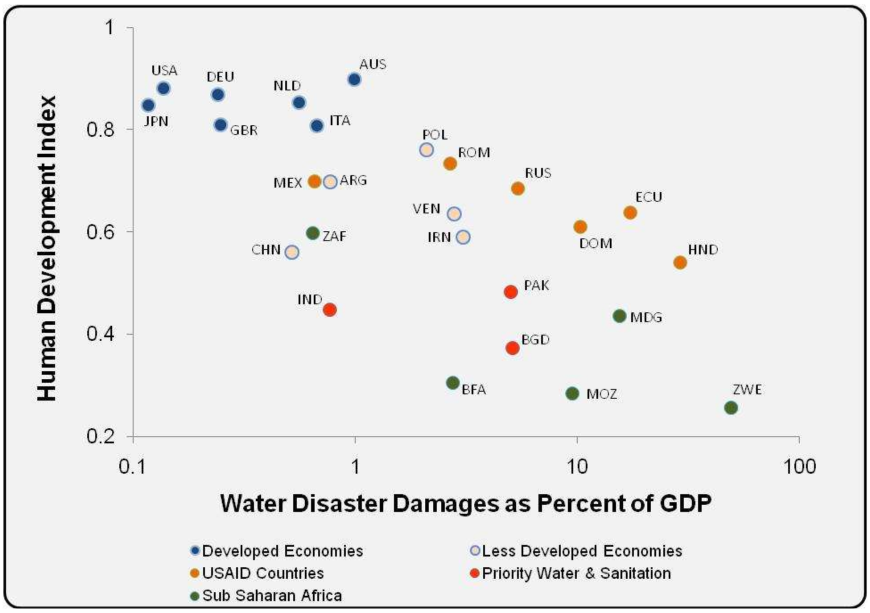


Figure 1 – Human Development Index vs Water Disaster Damages as percent of GDP (Stakhiv, 2010)

It should be obvious developed nations with high HDI's can cope with mega-disasters far better than developing nations with low HDI's. **Figure 1** shows this relationship. For example, floods and droughts have a disproportionately large adverse economic impact on sub-Saharan countries, usually resulting in a 5-10% decrease in annual GDP for each event. These events occur with disastrous regularity on the African continent and SE Asia. When added to the persistent anemic economic growth of many African nations, there is the equivalent of a recession every few years caused by natural calamities.

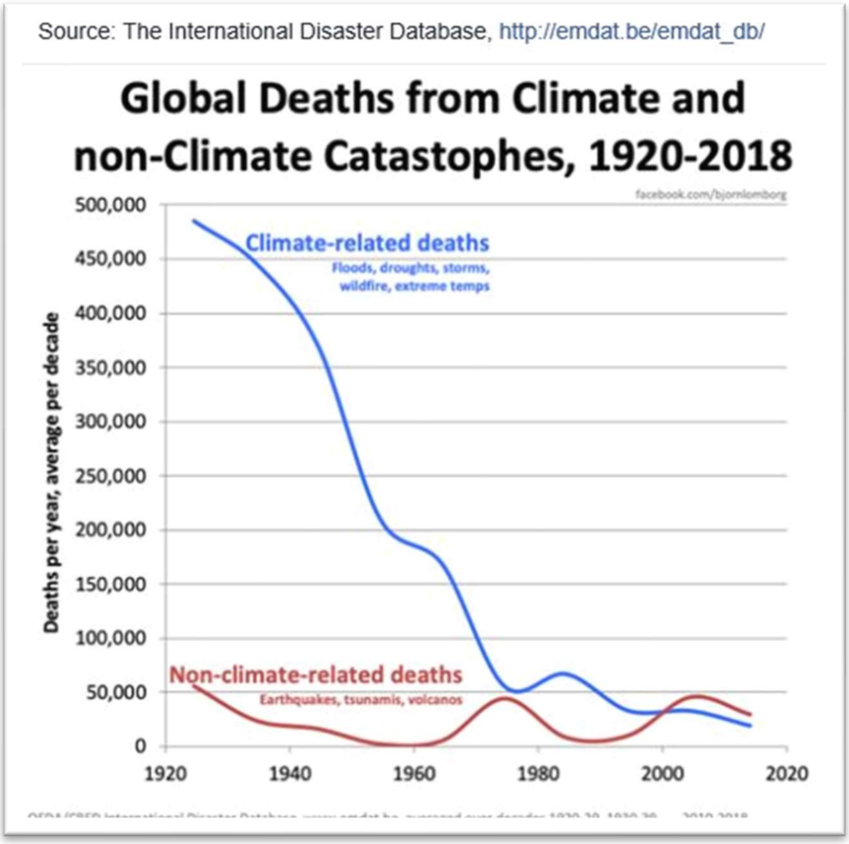


Figure 2 – Global Deaths from Disasters

No nation can prosper, much less reduce poverty, under such recurring catastrophic conditions. A sensible target for ***national resilience*** then, is to reduce major or mega-disaster damages to less than 1 percent of GDP, which is where all the developed world resides. Implementation of infrastructure that mitigates or controls natural disasters is a vital component of **national and community** resilience, for flood control and drought management infrastructure are directly linked to national prosperity.

The only bright spot in information about the ever-increasing economic toll of natural disasters is loss **of life** associated with such disasters has been declining markedly (Rautela, 2015). **Figure 2** shows a steep decline in deaths attributed to natural disasters.

Figure 3 shows the number of deaths has declined dramatically, even as the number of major disasters has increased significantly, along with economic damages (Sandifer and Walker, 2018).

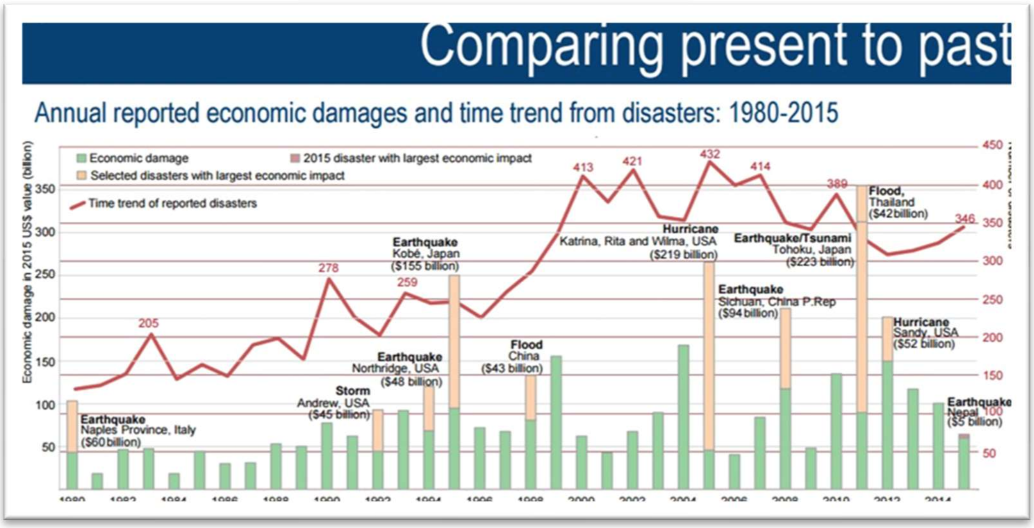


Figure 3 – Sandifer and Walker, 2018

It is important to recognize both the UN Sustainable Development Goals (UN SDG; 2015a) and the contemporaneous UN Sendai Framework for Disaster Risk Reduction (UNISDR; 2015b) advocate many of the principles and targets that are part of any sensible response to flood disaster risk reduction (DRR), which have been espoused since Gilbert White's [1945] path-breaking exposition of feasible solutions. For example, in SDG Goal 13 *("take urgent action to combat climate change and its impacts"*) the first three discrete targets deal with adaptation to natural hazards and mitigation of disasters: https://sustainabledevelopment.un.org/topics/sustainabledevelopmentgoals

> ***13.1*** *Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries*
>
> ***13.2*** *Integrate climate change measures into national policies, strategies and planning*
>
> ***13.3*** *Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning*

The UN SDG 11 *("Make cities and human settlements inclusive, safe, resilient and sustainable"*) targets focus on improving the socioeconomic conditions of the impoverished populace in cities and communities so that they can better withstand natural disasters and recover more quickly while minimizing socioeconomic adverse impacts. In particular, Targets 11.1, 11.2, 11.5 and 11.a,b,c all call for an emphasis on upgrading living conditions, access to transportation and public facilities, and participation in disaster mitigation planning for poor communities:

> ***11.1*** *By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums*
>
> ***11.2*** *By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons*
>
> ***11.3*** *By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries*
>
> ***11.4*** *Strengthen efforts to protect and safeguard the world's cultural and natural heritage*
>
> ***11.5*** *By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations*

> ***11.6*** *By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management*
>
> ***11.7*** *By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities*
>
> ***11.a*** *Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning*
>
> ***11.b*** *By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement**, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels***
>
> ***11.c*** *Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials*

The Sendai Framework (UN, 2015b) reinforces many of the SDG goals, with specific objectives, targets and principles that are more specific to natural disaster risk reduction strategies and policies. In particular, the Sendai Framework laid out an important set of principles for dealing with impoverished and typically under-served communities:

> *"There has to be a broader and a more people-centred preventive approach to disaster risk. Disaster risk reduction practices need to be multi-hazard and multisectoral, inclusive and accessible in order to be efficient and effective. While recognizing their leading, regulatory and coordination role,* ***Governments should engage with relevant stakeholders, including women, children and youth, persons with disabilities, poor people, migrants, indigenous peoples, volunteers, the community of practitioners and older persons in the design and implementation of policies, plans and standards.*** *There is a need for the public and private sectors and civil society organizations, as well as academia and scientific and research institutions, to work more closely together and to create opportunities for collaboration, and for businesses to integrate disaster risk into their management practices.*

Both the SDG's and the Sendai Framework are a collection of management principles and aspirational targets, which require an associated implementation strategy for each nation and river basin. Both UN plans require nations adopt these goals and principles and devise feasible implementation strategies compatible with their respective stages of development. Since 1977, with the publication of Executive Order 11988 and in 1979, when the U.S. Water Resources Council published its report on "A Unified National Program for Floodplain Management" [US WRC; 1979], the U.S. has not only advocated many of these universal goals and principles for sustainable development, coupled with disaster risk reduction, but has put them into practice in all aspects of flood and drought management. Nevertheless, substantial difficulties persist in attaining the goals of social equity and justice, as noted by Galloway (2019) and others, because some of the most vulnerable sectors of society are the poor and underprivileged who live at the margins of America's frequently flooded floodplains, and are most affected by frequent flooding.

Hence, the practice of flood risk management inevitably diverges from principle, because attaining all of the aspirational SDG goals is quite a complex and difficult task, even for a nation with the technological capacity and resources of the U.S., or Japan or Holland, or most of the EU nations. For example, the EU Flood Risk Directive [2007/60/EC] on the assessment and management of flood risks entered into force on 26 November 2007. This Directive requires Member States to assess all water courses and coast lines at risk from flooding, map the flood extent and assets and humans at risk in these areas, and take adequate and coordinated measures to reduce this flood risk**.** The Flood Risk Directive was to be carried out in coordination with the EU Water Framework Directive [2000], notably that flood risk management plans and river basin management plans must be coordinated, and through coordination of public participation procedures in the preparation of these plans. All assessments, maps and plans prepared shall be made available to the public.

A recent report by the European Court of Auditors [2018] found a wide range of impediments in implementing the EU Flood Risk Management Directive, ranging from persistent lack of funding and incompatible land use management plans, to difficulties in explicitly factoring in climate change-related variability in flood frequency, intensity and magnitude.

> *"Member States generally used historical data, which carries the risk of not reflecting future weather conditions or potential changes in the frequency and severity of floods. In relation to non-structural flood-related measures, we found that, where Member States had opted for private flood insurance, coverage remained low. Some land use and spatial planning regulations to mitigate flood risk were in place, but Member States had more to do to improve them."*

Catastrophes and disruptions are inevitable, as there always exist weak links in the best laid plans. The U.S. National Research Council [2013] examined many of the imperfections and defects in America's national floodplain management program, and its management of levees, in a very comprehensive review of the practices of floodplain management and of DRR, by extension. The NRC Committee recognized while many programs existed as part of a federal floodplain management system, they were not 'unified' or harmonized adequately. Each agency had their own rules and procedures, to the extent each agency defined the 100-year floodplain differently. Notwithstanding these deficiencies, the effective, if not altogether efficient response to a series of seven floods in the past decade in the Mississippi River basin has shown some very promising positive outcomes and trends.

For example, given the loss of life, homes, businesses, capital, and infrastructure associated with Hurricane Katrina in 2005, it would be reasonable to expect a decline in economic growth after a disaster. New Orleans experienced severe economic disruption after Hurricane Katrina. Yet, the **gross domestic product (GDP)** of the New Orleans region fell less than 3 percent before fully recovering to pre-Katrina levels in late 2007 (Flowers, 2018), while the GDP of the U.S. fell less than 0.5%. The economic recession of 2007-09 did far more damage to the national and local GDP (-6.3%) than did Hurricane Katrina. This is inherently an indicator, if not measure of the national economic resilience to withstand such large and repeated disasters. The economic costs of natural hazards have increased markedly over the past decade, marked notably by three hurricanes ("Katrina" in New Orleans, 2005, and two back to back hurricanes in 2017: "Maria" in Puerto Rico and "Harvey" in Houston).

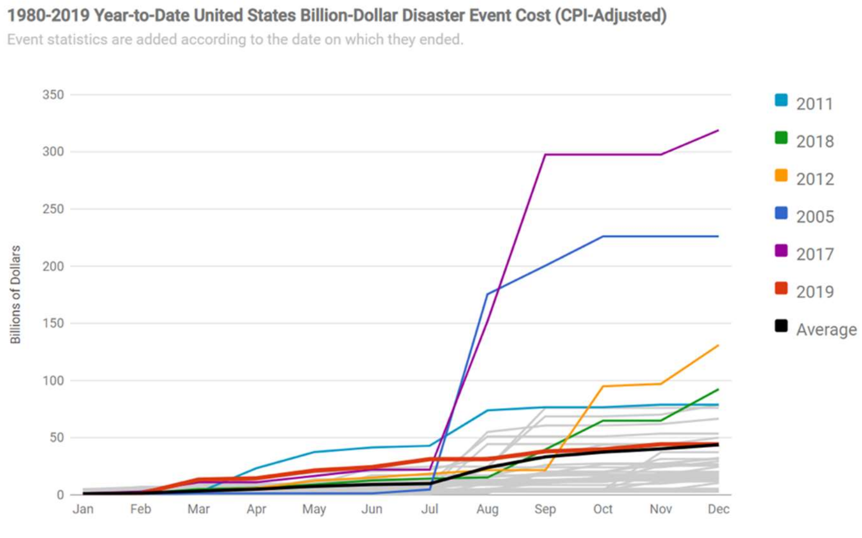


Figure 4 – U.S. Billion Dollar disaster events 1980-2019

In a broader context, the total cost of U.S. billion-dollar disasters over the last 5 years (2015-2019) exceeds **$525 billion**, with a 5-year annual cost average of **$106.3 billion** (inflation -adjusted), both of which are records **(Fig 4).** The U.S. billion-dollar disaster damage costs over the last decade (2010-2019) were also **historically large, exceeding $800 billion** from **119** separate **billion-dollar events**. Moreover, the losses over the most recent **15 years** (2005-2019) are ***$1.16 trillion*** in damages from **156**

separate billion-dollar disaster events (Smith, 2020).

On the other hand, Pielke (2005; 2018) shows quite clearly US flood damages have steadily **decreased as a proportion of U.S. GDP (Figure 5)**. It is important to recognize that even with a steady state system, with no additional flood protection and a stationary climate, flood damages would increase over time as personal and national wealth increases. Property values increase, as does the individual wealth of each household – number of autos, TV sets, electronic equipment and many other items. So the fact US flood damages are decreasing over time as a proportion of GDP, in the face of apparent increased flood frequency and intensity, is an important indicator of the growing effectiveness of both structural and non-structural flood control programs, as well as floodplain management measures.

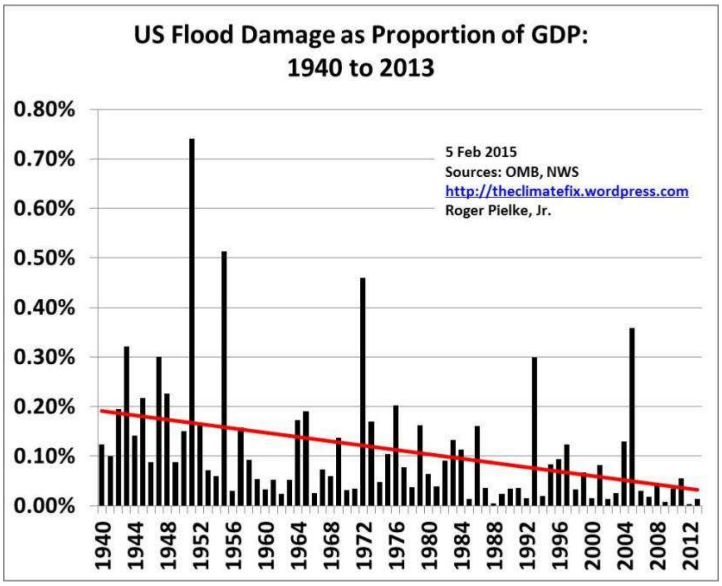


Figure 5 – US Flood Damage as Proportion of GDP

A substantial component of national resilience in dealing with mega-disasters rests in macro-economic policies at the federal level. Policymakers should strive to promote economic resilience by maintaining a vibrant, flexible, and diversified economy able to cope with shocks. There are, however, substantial differences between sectors and impacts are very localized within a country. This means policies need to address the large distributional effects of disasters, particularly on the disadvantaged sectors of society. Financial compensation arrangements (like post disaster relief and public–private insurance systems), societal safety nets, and countercyclical government spending is commonly used to facilitate recovery and mitigate the indirect economic and distributional impacts of disasters.

Benefit–cost analyses of natural disaster risk reduction measures suggest these measures are economically desirable. National and local governments routinely limit disaster impacts through regulations, installing prevention measures such as flood protection, and setting up early warning systems. Local governments, like cities, are well positioned to fine tune disaster risk management policies for local risks, through measures such as zoning and building code policies, evacuation planning, and emergency response. Companies and households can also take action to limit the impacts of disasters, for example, through disaster-resilient building practices (Botzen, Deschenes and Sanders, 2019).

Considering extreme weather events are likely to get worse under a progressively changing climate, a more robust water resources-based development program would contribute two critical elements to maintaining a nation's prosperity. First is mitigation of, and protection from flood and drought damages, while increasing reliability and robustness of water-based services. Second is the provision of the two most important elements of food and energy security – irrigation water and hydropower – not to mention municipal and industrial water supply. Furthermore, if one believes climate change will cause additional stress for each nation, then the answer is more water control infrastructure – not less – so as to increase resilience, economic robustness and reliability of services (Stakhiv, 2011). Consider the development of the western U.S., or any other developed nation for that matter – the key to economic prosperity began with converting the hazardous aspects of floods and droughts into positive engines of economic growth and prosperity.

For developing nations, there are three basic pillars to poverty reduction: stimulating economic growth; increasing social welfare and strengthening governance and institutional capacities to ensure the wide range of public services are provided in a reliable, equitable and cost-effective manner; and the worst aspects of flood and drought disasters do not overwhelm the recovery capacity of a nation (resilience). The same holds true for developed nations, except their actions are more incremental and refined in scope, relying more on technological advances and institutional adjustments at all levels – such as implementing Integrated Water Resources Management [IWRM] principles [GWP; 2000] as well as instituting sustainable development goals. These goals and principles must be advanced against the backdrop of **risk management** – which is the underlying core of the strategies for dealing with flood and drought disasters.

Today, there is an explicit understanding federal, state, and local flood damage reduction policies address some socially acceptable and economically based **risk-bearing threshold – something termed 'tolerable risk'.** Societies – even those who are wealthy, cannot implement absolute **'fail-safe'** strategies. Instead, rational societies advocate **'safe-to-fail'** strategies (Stakhiv, 2010), meaning there exists an array of complementary non-structural measures and compensation programs designed to mitigate expected damages of large floods that **exceed the design capacity of hard infrastructure**. In other words, much of society has come to accept **residual risks** are inevitable, particularly in a future non-stationary and highly uncertain climate regime.

Hence, any flood risk reduction strategy must devise socially accepted risk-tolerance design criteria, and implement measures that effectively mitigate the residual risks of that strategy to constitute the essence of 'resilience' planning. It is these residual risks that require an array of complementary non-structural measures, consisting of flood warning and evacuation systems, floodplain management regulations (zoning and building codes), and compensatory insurance programs that comprise the foundations of community programs that increase their **resilience before, during and after** a damaging flood event.

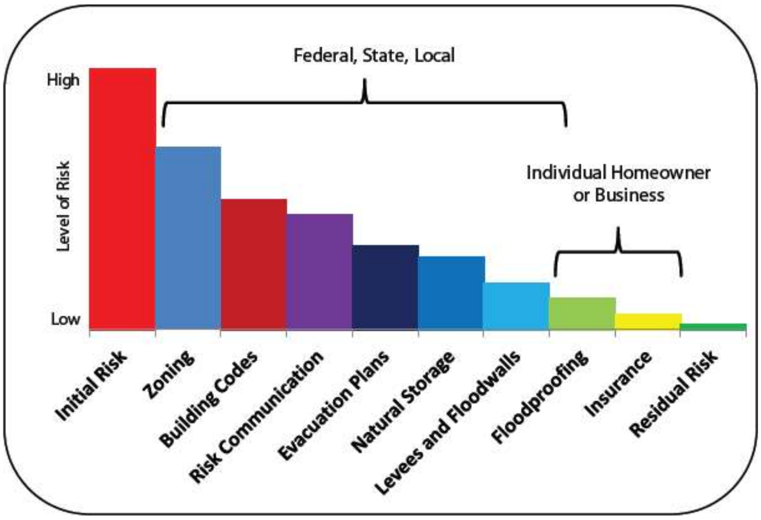


Figure 6 – Administrative responsibilities for implementing flood risk reduction measures

Figure 6 demonstrates the building blocks of such an interdependent system of management measures that combines different elements of robustness, reliability and resilience, while acknowledging residual risks are inevitable, and likely to increase with increasing future climate uncertainties. **In the U.S. system of federalism, different flood prevention and mitigation measures are the responsibility of various levels of government, as well as homeowners and the private sector.**

It should be fairly obvious though, that given the increased uncertainties associated with global warming, residual flood risks will likely increase in the future. Mitigation of this increasing risk will require a comparable improvement in the robustness of current and future flood control systems, as well as the resilience of affected communities.

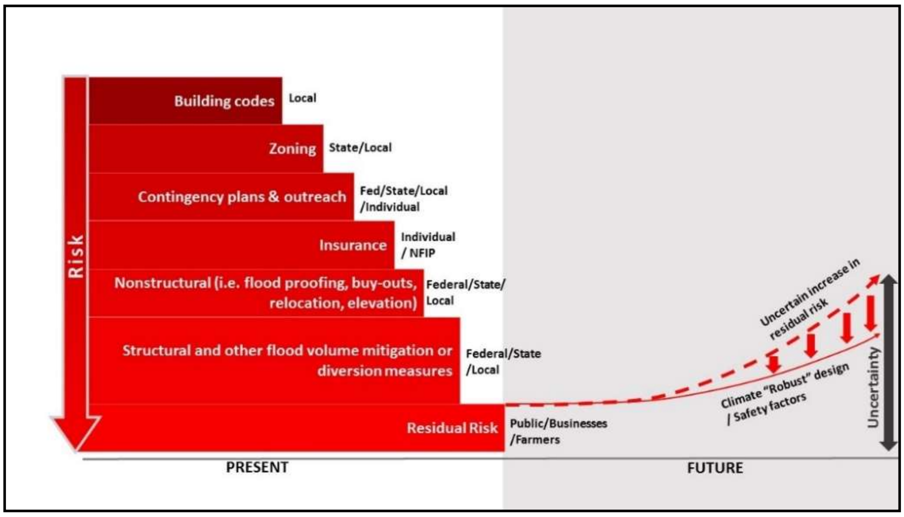


Figure 7 – Hierarchy of Robust and Resilient Flood Damage Reduction Strategies

Every flood in the Mississippi R. basin reminds us of this increased risk, and actions are constantly taken to adapt at all levels of government. Climate-focused 'robust' designs and upgraded engineering design criteria can reduce future risks, somewhat, as shown in Fig 7. However, the uncertainties are so large, that towns and communities will always have to deal with ever-increasing residual risks simply because of the growing uncertainties associated with climate change.

5.3 Overview of the Flood Disaster of 2019

Figure 8 – Mississippi River Basin Drainage Area
http://www.waterencyclopedia.com/Mi-Oc/Mississippi-River-Basin.html

The Mississippi River is North America's longest and largest river in terms of **discharge,** and the fifth largest discharge river worldwide, at an average of 17,330 cubic meters per second (811,530 cubic feet per second). The Mississippi flows 3,763 kilometers (2,333 miles) from Lake Itasca in northern Minnesota to its **delta** in southern Louisiana.

The Mississippi River Basin encompasses more than 40 percent of the U.S. land area. Its diverse features, rich history, and heavy human demands challenge water resource managers who must balance complex issues. The Mississippi River **drainage basin** is the world's second largest, draining 4.76 million square kilometers (1.83 million square miles), including **tributaries** from thirty-two U.S. states and two Canadian provinces. The Mississippi River **basin** encompasses 40 percent of the contiguous United States. Major tributaries include the Missouri, Ohio, Arkansas–Red–White, and Tennessee Rivers.

The flood of 2019 follows a pattern of increasing frequency, magnitude and duration of flooding that has been predicted by the Fifth UN Intergovernmental Panel on Climate Change (IPCC) Assessment Report (IPCC AR5; 2014) and the Fourth US National Climate Assessment report (USGCRP; 2017). From 2000 to 2019, the Mississippi has experienced seven major flood events — in 2002, 2008, 2011, 2014, 2016, 2017 and 2019. The floods of 2011 and 2019 were especially damaging. Four of those were spring floods much like the 2019 flood, fueled by a combination of snowmelt and persistent spring rainfall.

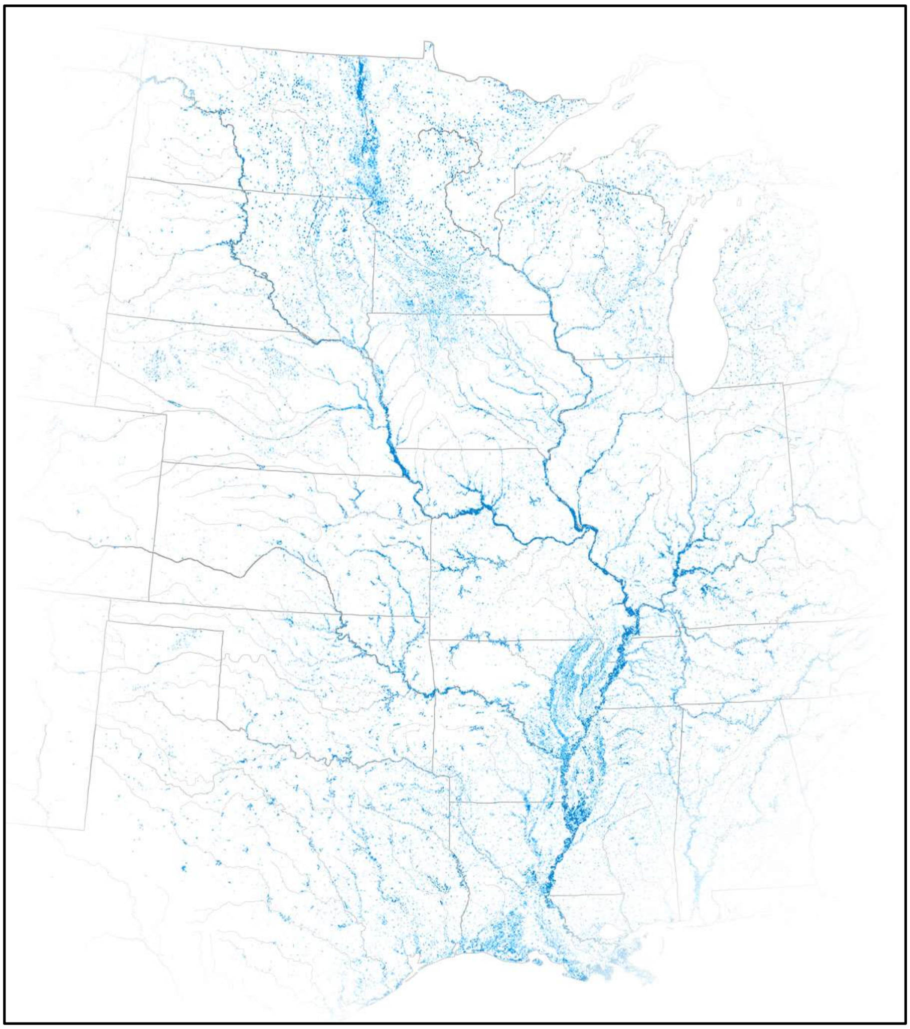


Figure 9 – Flood Damage 2019 Flood (New York Times, Sept 11, 2019. Blue signifies riverine flooding and light green represents rainfall flooded fields

The 2019 flood was a slow-motion disaster that began with high rainfall in the winter of 2018, and continued through the spring of 2019, with rain on frozen fields, and ending with rainfall and snowmelt in late spring (Fig 9).

Nearly 14 million people were affected. By the end of June, the flooding was so intense and widespread that at least 11 states had sought federal disaster funds for more than 400 counties. The year through May 2019 was the wettest 12-month period on record in the United States, according to the National Oceanic and Atmospheric Administration. Nearly 38 inches of water fell, almost eight inches above average.

Nevertheless, the economic, social and environmental impacts of the 2019 flood were far less severe than equivalent large floods of the past – in terms of economic damages, affected households, and loss of life. The reasons stem mainly from an assortment of factors which have been improved over the last few decades:

- *An ever-improving hydraulic flood control system of reservoirs, locks and dams and levees and a series of 'safety relief-valve' emergency water control structures in the Mississippi R. basin that can divert peak floods into floodways with minimal agricultural damages.*
- *Better decision coordination, regarding releases of flood storage among the various components of the main tributaries and inflows into the main stem Mississippi R. (Missouri R system, Ohio R. system, Tennessee R system and Arkansas-Red R. system).*
- *Much improved weather forecasting and modelling systems developed by the USACE and National Weather Service, which provided more detailed and timely information for critical decisions*

In other words, the Mississippi R. basin has been developed and managed in an ever increasingly integrated manner over the past five decades, relying much more on technological innovations, timely and accurate forecasts and a more coherent decision-making infrastructure across the various responsible entities at the federal, state and local levels. Perhaps, most importantly, there was one central coordinator – the US Army Corps of Engineers – which was responsible for planning, constructing and maintaining the complex infrastructure and emergency management system that effectively mitigated the worst damages of the 2019 flood.

5.3.1 Main Physical Characteristics of the 2019 Flood

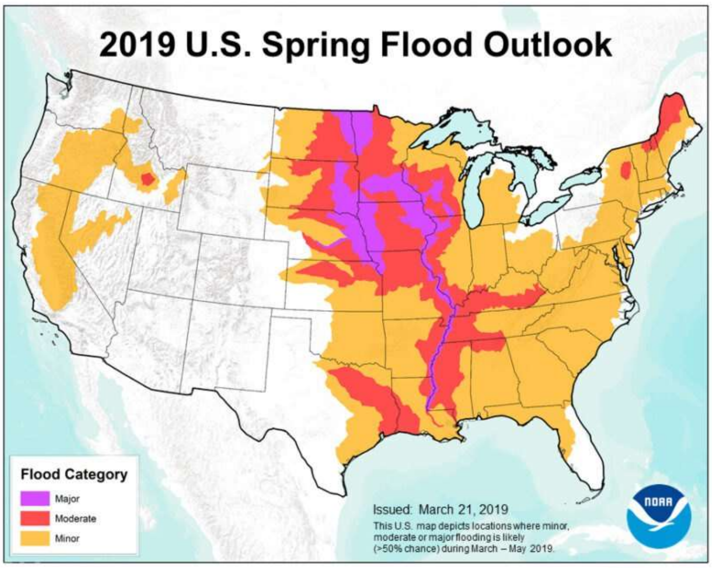


Figure 10 – 2019 U.S. Spring Flood Outlook, NOAA

The 2019 Flood had many unique characteristics, which when combined together placed it in the category of mega-flood disaster. The National Oceanic and Atmospheric Administration [NOAA] 2019 Spring Flood Outlook, a forecast made on March 21, 2019, shows the broad extent of the rainfall and flooding in the Mississippi Basin (Figure 10).

There were five main physical reasons why the 2019 flood was unique and relatively devastating: http://mississippiriverdelta.org/5-reasons-why-2019s-mississippi-river-flood-is-the-most-unprecedented-of-our-time/

1) **Record precipitation occurred in the Mississippi River drainage** basin.

2) **2019 was the longest flood duration recorded.** At >235 days, the Mississippi River was above flood stage for the longest period in recorded history, surpassing the 1927 flood record of 152 days

3) **A record volume of water.** Nearly 210 trillion gallons of water have flowed down the Mississippi River since the start of the year. This volume is 64% greater than the 10-year average (Figures 11 and 12).

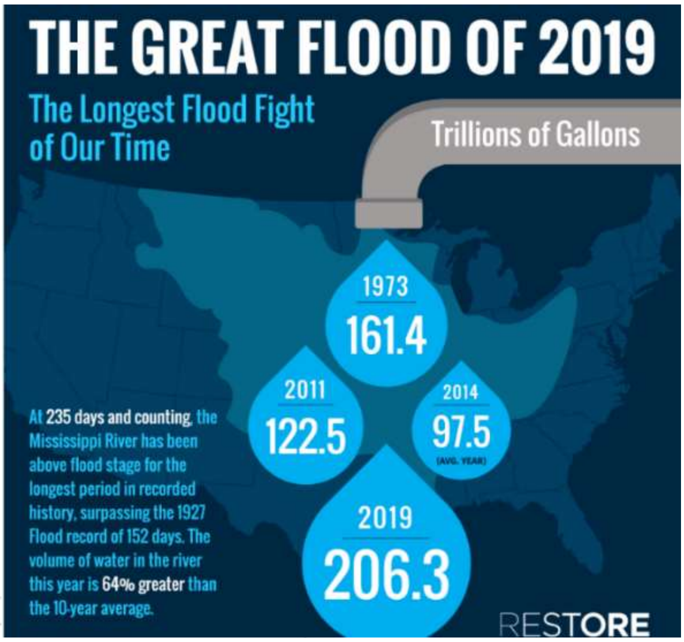


Figure 12 – Record Volume of water

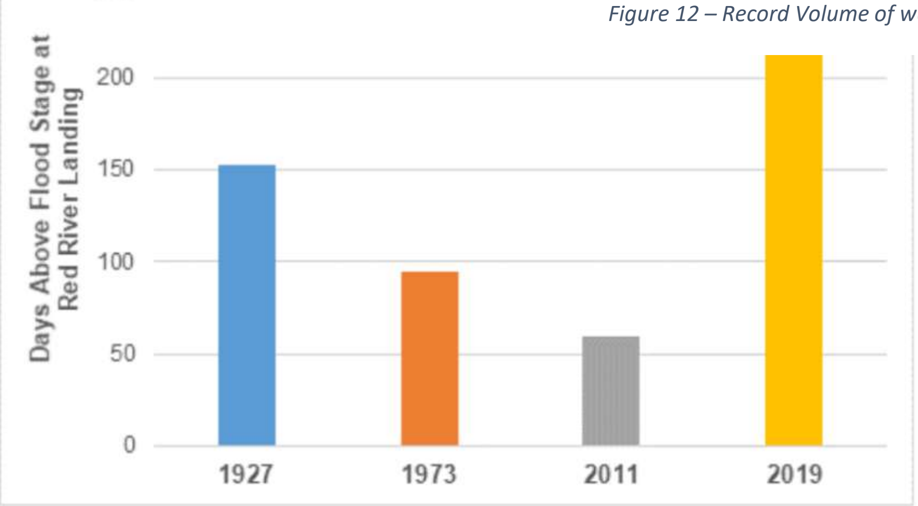


Figure 11 – Flood Duration: Days above flood stage

4) **The Bonnet Carré Spillway's Unprecedented Openings:** The Bonnet Carré Spillway is a 'relief valve' for the city of New Orleans, to prevent the Mississippi R. from overtopping its levees. For the first time in its nearly century-old existence, the Bonnet Carré Spillway was opened twice in back-to-back years. The USACE made history again in May 2019 when they opened the structure for a second time in the same year to relieve pressure on levees and prevent devastating flooding to communities across Jefferson, Orleans, St. Bernard and Plaquemines Parishes in southeast Louisiana. Bonnet Carré Spillway was open for 123 days in 2019.

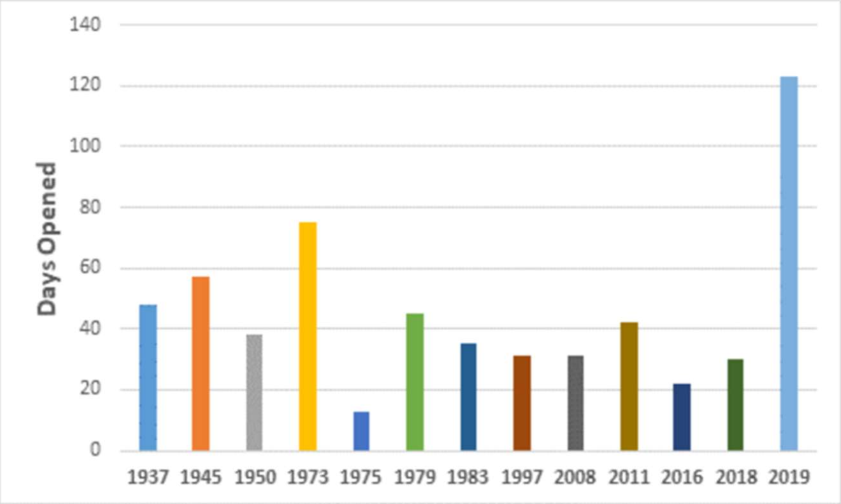
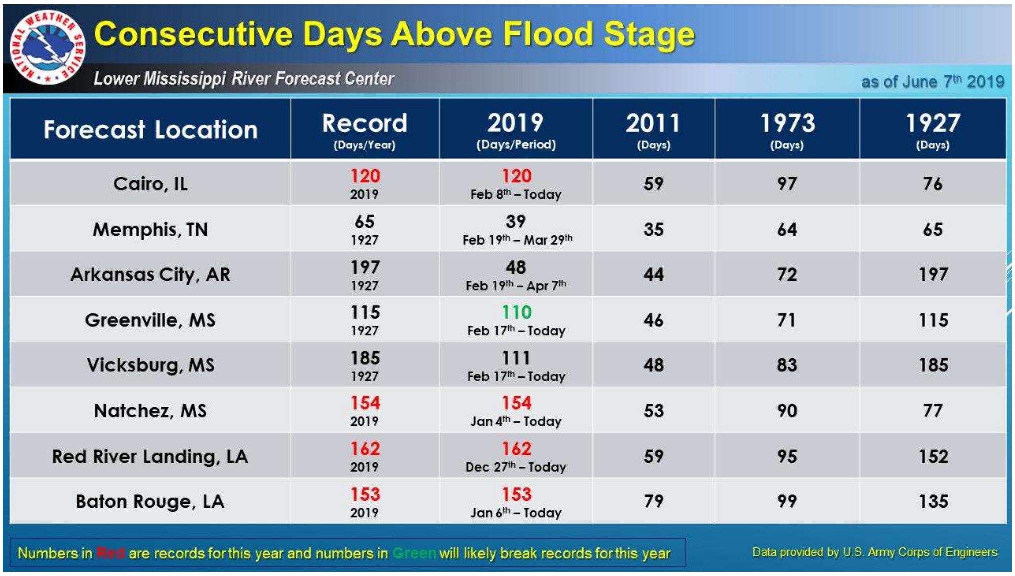


Figure 13 – Bonnet Carre' Spillway Openings

5) **Flooding Occurred for an Unprecedented Length of Time:** Flood duration far exceeded any other large flood in the previous 100 years of record.



Consecutive Days Above Flood Stage

Lower Mississippi River Forecast Center

as of June 7th 2019

Forecast Location	Record (Days/Year)	2019 (Days/Period)	2011 (Days)	1973 (Days)	1927 (Days)
Cairo, IL	120 2019	120 Feb 8th – Today	59	97	76
Memphis, TN	65 1927	39 Feb 19th – Mar 29th	35	64	65
Arkansas City, AR	197 1927	48 Feb 19th – Apr 7th	44	72	197
Greenville, MS	115 1927	110 Feb 17th – Today	46	71	115
Vicksburg, MS	185 1927	111 Feb 17th – Today	48	83	185
Natchez, MS	154 2019	154 Jan 4th – Today	53	90	77
Red River Landing, LA	162 2019	162 Dec 27th – Today	59	95	152
Baton Rouge, LA	153 2019	153 Jan 6th – Today	79	99	135

Numbers in Red are records for this year and numbers in Green will likely break records for this year

Data provided by U.S. Army Corps of Engineers

Figure 14 – Lower Mississippi River 2019 consecutive days above flood stage

5.3.2 Emergency Operations during the Flood

The various federal agencies of the U.S. government do not automatically spring into action to engage in flood fighting and relief efforts during a flood, except for the USACE, which manages the flood control system of the basin. A Presidential **disaster declaration** must be made to trigger the mandated responses by the various federal agencies. President Trump issued a series of such declarations for each damaged state, beginning on March 21, 2019.

On March 21, 2019, President Donald Trump issued a major disaster declaration for the **State of Nebraska** for the severe winter storm, straight-line winds, and flooding that began on March 9, 2019. On March 23, 2019, President Trump issued a major disaster declaration for the **State of Iowa** for the severe storms and flooding that began on March 12, 2019. Other states affected by flooding have declared states of emergency, including **Missouri, Kansas, Wisconsin, Ohio, and South Dakota** as well as **tribal nations in Nebraska, Iowa, and South Dakota**. Additionally, February rainfall and severe storms that resulted in flooding in **Mississippi** and **Tennessee** resulted in their governors' submission of requests for major disaster declarations on March 21 and March 22, 2019, respectively (CRS; 2019(a)). These disaster declarations then, allowed the mobilization of federal agencies to take action, according to their respective mandates and responsibilities.

5.3.2.1 Federal Emergency Management Agency (FEMA)

FEMA is responsible for coordinating a unified federal response to flood-fighting and post flood recovery assistance. FEMA's **Incident Management Assistance Teams (IMAT)** are made up of experienced senior-level emergency management professionals who are able to deploy upon a moment's notice when requested by the state. IMATs generally consist of 10 members, with expertise in operations, logistics, planning, and recovery. They are rapidly deployed anywhere in the region or the country, supporting states and territories with their emergency response efforts.

Teams provide a forward federal presence to facilitate the management of the national response to catastrophic incidents. The primary mission is three-fold:

- Rapidly deploy to an incident or potentially threatened venue
- Identify ways federal assistance could be used to best support the response and recovery efforts, should it become available
- Work with partners across jurisdictions to support the affected State or territory

It is important to recognize, that by law, FEMA's role is to support and take direction from the state government. FEMA's role is to "support citizens and first responders". After a disaster, state and local emergency responders, along with voluntary agencies and faith-based groups, are called on to meet the immediate needs of the affected communities.

FEMA also stockpiles, in warehouses across the nation, various emergency supplies that might be needed for a particular region and event (fires, hurricanes, floods, terrorist attacks, etc.). These include water bottles, building materials, burlap bags for sandbags, etc., and are distributed by State National Guard units, volunteers, Red Cross and other organizations.

5.3.2.2 U.S. Army Corps of Engineers (USACE)

Annually, Congress sets aside funds for disaster response flood work for FEMA and the USACE. This gives USACE an ability to provide preparation, response and recovery measures concerned with flood fighting. Public Law 84-99 authorizes the USACE to engage in flood fighting and rescue operations **if the emergency is beyond local and state capabilities.** During a flood, the USACE has the authority to:

- inspect and, if necessary, strengthen flood control structures
- make temporary levee raises
- provide supplies and 24-hour technical assistance

- assist in the evacuation of people and livestock.

During the 2019 Flood, overflows and levee breaches caused billions of dollars of damage in Iowa, Kansas, Missouri and Nebraska. The federal government declared major disasters in 321 of the 411 counties in those four states — 78% of the counties — making them eligible for emergency federal aid, according to FEMA (Federal Emergency Management Agency) https://www.scientificamerican.com/article/u-s-army-corps-looks-to-avoid-repeat-of-2019-midwest-floods/ .

However, the most important and primary function of the USACE during a flood is managing the existing infrastructure system to prevent or minimize flood damages. In this respect, USACE's vast infrastructure system is the primary line of defense against large floods. The upper Mississippi R. basin is a huge and complex system, which is difficult to manage in a coordinated manner because the needs, and design objectives for each major tributary (Ohio R., Illinois R., Missouri R.) varies based on different legislated priorities of use and action. As such, the system consists of an extensive system of private agricultural levees, municipal flood works and channel projects, with a highly integrated system of federally designed and operated dams, levees and navigation works as the backbone of the sophisticated water management system.

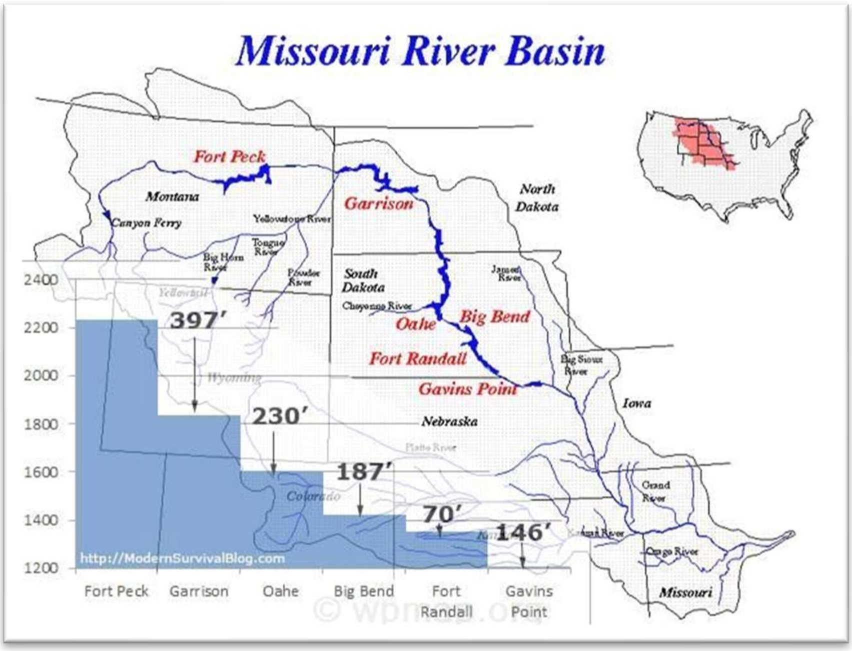


Figure 15 – Missouri River Basin

The Mississippi River drainage basin is home to the largest inland waterway navigation system, within a single drainage basin, with more than 12,000 miles of commercially navigable channels. Though China and Russia have the longest aggregate system of inland navigable waterways throughout their various river basins. From Cairo, Illinois south, the navigation system is organized under a comprehensive programmatic effort called the Mississippi River and Tributaries (MR&T) project and managed by the Mississippi Valley Division, U.S. Army Corps of Engineers. Since 1928, the MR&T has prevented an estimated more than $1.27 trillion in flood damages, or $80 for every dollar invested. The MR&T project consists of six major features: 1) levee system with 3,800 miles of levees and floodwalls; 2) series of locks and dams, 3) four floodways, including Bonnet Carré, Morganza, Birds Point-New Madrid and the Atchafalaya; 4) channel improvement and stabilization projects; 5) reservoirs; and 6) tributary basin improvements.

With such a large and complex system, it is important to have an accurate and integrated basin-wide hydrologic model that assists real-time decision-making. For example, the Missouri R. system has numerous upstream dams, and several large mainstream storage dams (Figure 15), with the capacity to store approximately four years of average annual runoff (~75 million acre-feet MAF).

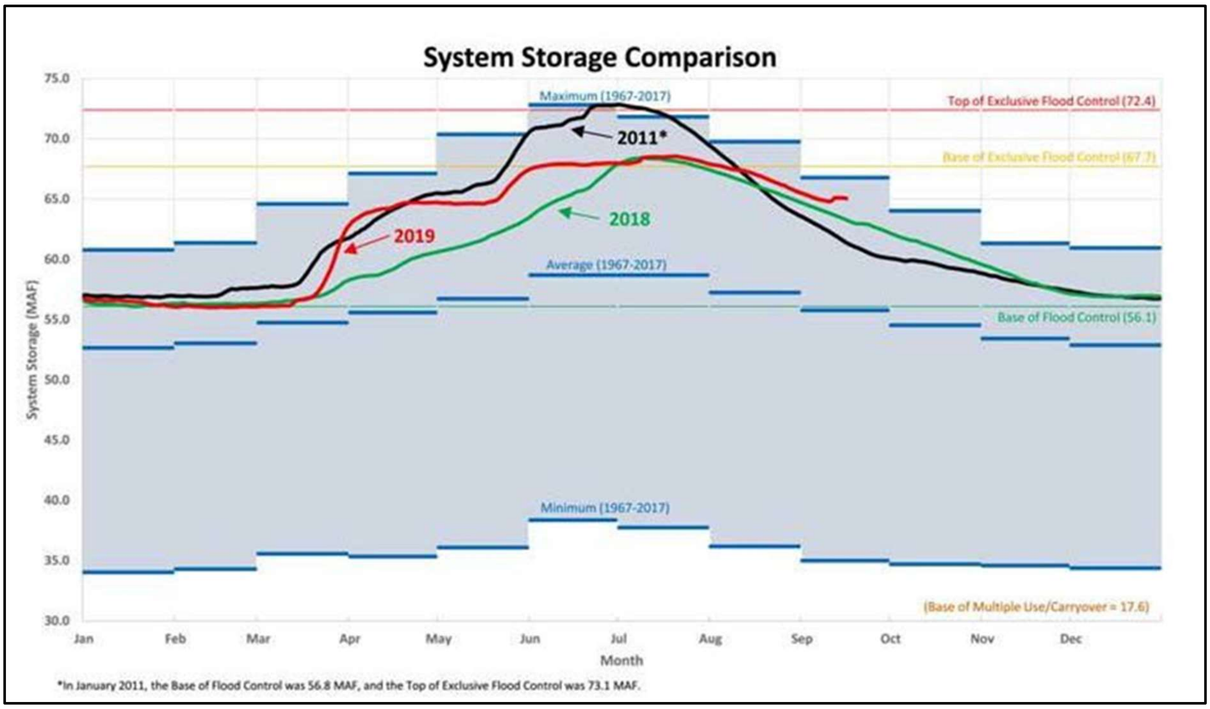


Figure 16 – Missouri River storage

Figure 17 – Illinois River Navigation system

Yet, both the 2011, 2018 and 2019 floods came very close to exceeding that capacity (see Fig 16, USACE, Sept, 2019). The 2011 flood was the largest for the Missouri R. basin, as can be seen in Figure 16.

The upper Mississippi R. basin, the Illinois R. basin and Ohio R. basin, are largely regulated for commercial navigation, with countless upstream dams regulating flood flows (Figure 17 and 18).

One of the fascinating and particularly important technological advances instrumental in managing the complex water infrastructure system during the 2019 flood, was use of the **Corps' Water Management System (CWMS).** Given the varying precipitation and timing of inflows from the great tributaries of the Missouri, Ohio, Illinois and Arkansas Red River systems, it was important for decision makers managing this large and complex system to rely on a single uniformly constructed, accurate, and coordinated modelling system. *Second only to a robust infrastructure system, as the second line of defense and critical component of system robustness and resiliency – is the ability to accurately forecast rainfall, storage, releases and river stages as the basis for a series of coordinated decisions from each of the major tributaries.*

CWMS is the automated information system used by the USACE to support its water control management mission. This mission encompasses the regulation of river flow through more than 700 reservoirs, locks, and other water control structures located throughout the Nation. CWMS is an integrated system of hardware and software that begins with the receipt of hydromet, watershed, and project status data.

Figure 18 – Ohio River Main Stem Locks and Dam

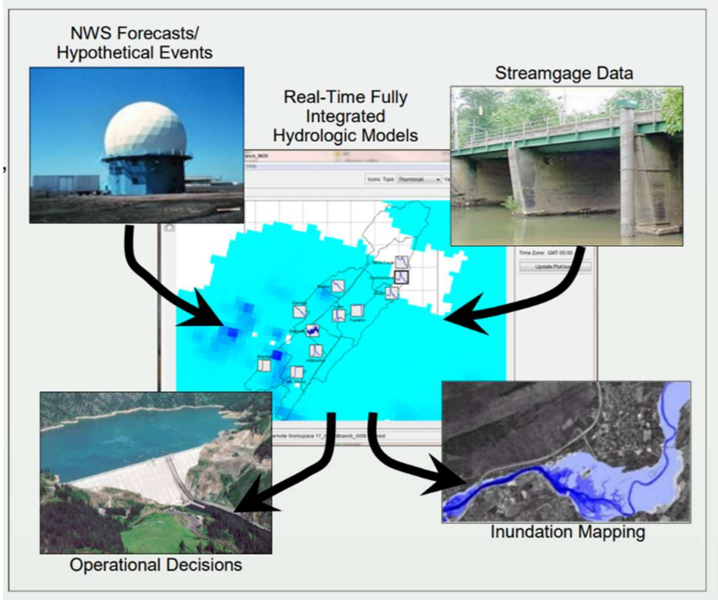


Figure 19 – Corps Water Management System (CWMS)

This data is then processed, stored, and made available through a user friendly interface to the water manager to evaluate and model a watershed. Both modeled and processed data can be displayed and disseminated in tabular, graphical, and/or geo-spatially resulting in an effective decision support system (Figure 19).

Types of incoming real-time data include: river stage; reservoir elevation; gage precipitation; WSR-88D spatial precipitation; quantitative precipitation forecasts (QPF); and other hydro-meteorological parameters. These data are used to derive the hydrologic response throughout a watershed area, including short-term future reservoir inflows and local uncontrolled downstream flows. The reservoir operation model flows are then processed to provide proposed releases to meet reservoir and downstream operational goals. Then, based on the total expected flows in the river system, river profiles are computed, inundated areas mapped, and flood impacts analyzed.

CWMS allows evaluation of any number of operation alternatives before a final forecast scenario and release decision are adopted. For example, various alternative future precipitation amounts may be considered, hydrologic response altered, reservoir release rules investigated, and alternative bridge obstruction, levee integrity, or other river conditions evaluated. When an operational decision is made, the results along with supporting hydromet, watershed, and project status and release data, may be disseminated to others via web technology.

Brown, et al. (2015), among many other researchers, recognized uncertainty of future hydrologic conditions, from days to weeks to seasons and years, is the primary challenge in operations – especially during emergencies. Fortunately, forecasting skill has improved in recent years due to technological and scientific advances including the National Weather Service's Community Hydrologic Prediction System (CHPS) and the U.S. Army Corps of Engineers' Corps Water Management System (CWMS). These systems integrate data and hydrologic models with simulation models to support near-term operations with risk-based approaches such as Monte Carlo and Extended Streamflow Prediction (ESP)

CWMS has been deployed to over 35 USACE District and Division offices with a water management mission – to include the entire Mississippi R. basin. CWMS is currently available only to USACE offices. CWMS is "live" 24/7, continuously providing support during routine high and low flow periods, and during emergencies. CWMS is self-monitoring providing automated status information on components and processes, and alerting to service needs, https://www.hec.usace.army.mil/cwms/.

During the 2019 Flood, USACE's Mississippi Valley Division (MVD), and the six District offices within MVD, relied on CWMS and other models from the USACE's Hydrologic Engineer Center (HEC) to support flood operations in multiple ways. In general, CWMS models supported operations for twenty-one (21) reservoir projects within the MVD region, through forecasting of rainfall-runoff to develop release plans and determining reservoir operations. CWMS model results were closely coordinated with NWS River Forecast Centers to inform and improve forecasted peak stages.

Where CWMS models did not exist along the lower Mississippi River, available HEC-RAS (River Analysis System) models were used to simulate flood flows with results used to collaborate with the National Weather service Lower Mississippi River Forecast Center [NWS-LMRFC] in producing critical river forecasts needed to support USACE floodway operational decisions at Morganza and Bonnet Carré spillways. CWMS and HEC-RAS models produced inundation maps both prior to the event and throughout the event, even on a daily basis, to assist emergency response. The CWMS and HEC-RAS inundation maps were later used to calculate damages and project benefits.

USACE's **Mississippi Valley Division** is made up of six districts, based in St. Paul, Minnesota, Rock Island, Illinois, St. Louis, Missouri, Memphis, Tennessee, Vicksburg, Mississippi, and New Orleans, Louisiana.

St. Paul District CWMS models forecasted snowmelt runoff and reservoir operations at their projects. The models provided data to guide operational decisions based on snowmelt. In addition, National Weather Service (NWS) inflows were used to provide additional guidance with more complex snowmelt modeling. HEC-RAS models were used in the Minnesota and Red River of the North basins for the National Weather Service North Central Forecast Center, greatly assisting with their river forecasting.

Rock Island District used the Coralville Reservoir CWMS model to formulate multiple deviation requests with MVD, and three CWMS HEC-ResSim models informed reservoir operations for constraints on the Mississippi River.

St. Louis District CWMS models provided predicted inundation extents that were used to inform emergency response in the states of Missouri, Illinois and Tennessee. Extended river forecasts on the Mississippi R. supported collaboration with the Coast Guard and River Industry concerning potential river impacts, such as St. Louis Harbor closure.

Memphis District HEC-RAS results helped drive a decision to raise the Mississippi River Farrenburg Levee cofferdam 2-feet. In-progress CWMS models were leveraged to develop models of interior drainage for two pumping stations to evaluate pump failure impacts and address potential inundation impacts to the respective protected areas. Inundation maps were provided to Tennessee Emergency Management.

Vicksburg District CWMS models determined inflows into four Yazoo Project Reservoirs to forecast crest elevations and determine potential spillway flow. With each forecast, downstream emergency managers and local officials were notified of potential risks. The models helped optimize releases to regain flood storage even when downstream control points were at remarkably high water.

New Orleans District used 2D HEC-RAS models of the Mississippi R. to look at various Bonnet Carré Floodway Operation scenarios. A 2D HEC-RAS of the Lower Mississippi R. coupled with a series of Advanced Circulation models [ADCIRC] were used to predict the effects of hurricane storm surge up the Mississippi and Atchafalaya Rivers during unprecedented high river stages.

5.4 Physical flood mitigation actions by the USACE

In addition to the many reservoirs on the main tributaries of the upper Mississippi R basin, the intricate flood control system along the main stem Mississippi R, from Cairo, Illinois down to New Orleans, has several emergency diversion structures – 'safety relief valves' – to reduce the flood stages further downstream and protect main population centers such as St Louis, Memphis, Baton Rouge and New Orleans. *The key decisions on whether to open these floodways rest primarily on the accuracy of the models and an array of risk factors and economic consequences to the farmers and settlements in the floodways.*

To reduce pressure on the levees that protect Baton Rouge, New Orleans, and other southern Louisiana communities, USACE opened a rarely used flood-control structure on the Mississippi River. On June 2, 2019, USACE opened the **Morganza Spillway**, a three quarter mile-long barrier that acts as a pressure-relief valve for the Mississippi. Used only twice since it was completed in 1954, the spillway shunts water into the Atchafalaya River basin and away from the big population centers downstream on the Mississippi.

An issue with use of the Morganza Spillway is the presence of farms, livestock, and even oil wells downstream within the spillway. The USACE does not own the land within the floodway, but has an easement to conduct flood operations. An economic assessment found the 2011 opening caused $56 million in economic damages that could be estimated, largely due to crop losses. The analysis did not look at damage to fisheries or homes and camps. Of note, Morgan City, population 11,000 is located at the end of the floodway. Water released through the Morganza Spillway takes three days to reach the city, which provides local officials notice to close gates in the city's flood wall.

5.4.1 Mississippi R. Flood Control 'Safety Valves'

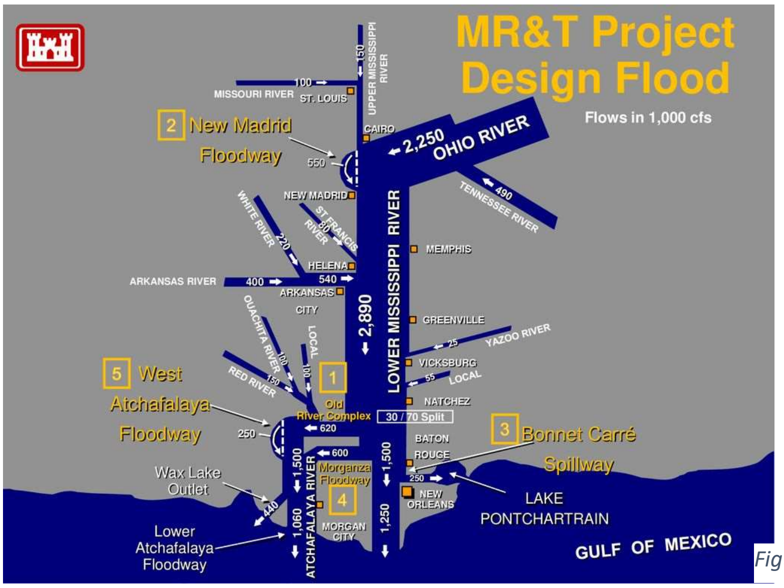


Figure 20 – MR&T Project Design Flood Routing System

An essential feature of any large integrated system, such as the Mississippi R. basin water management system, is to build a series of 'safety valves' to accommodate large floods that exceed the design capacity of individual structures and that of the system, as a whole. Such 'safety valves' are features that play a critical role in increasing the overall system robustness. Just as most large reservoirs in the Mississippi basin are designed with spillways to accommodate a 'probable maximum flood' that would overtop a dam, so the system of dams, levees and locks need a series of such safety valves as part of a ‘safe-to-fail’ strategy in dealing with mega-floods. The Mississippi R. system has four such safety valves along its lower reaches (Figure 20). It should be understood, however, a decision to open the floodgates of the spillways is not taken lightly, and depends on accurate flood and river stage forecasting. This is because a great deal of farming and agriculture takes place on the hundreds of thousands of acres within the floodways, which results in loss of crops and farmers provided millions of dollars in farm or disaster assistance. Hence the decision to “operate a floodway” must be based on an accurate and reliable hydraulic water management system.

No river as big as the Mississippi has been so thoroughly engineered. Built in pieces over decades and still incomplete, the MR&T is designed to hold **the “project design flood.”** This hypothetical flood, based on the science of the 1950’s, represents the largest probable flood based on historical data available at the time, and is roughly equivalent to a once in 200-year event. However, the levees are designed to handle only a portion of this flood, so when a trigger point is met, USACE is authorized to open one of the MR&T’s four floodways (**Birds Point-New Madrid Floodway**, **Old River/Atchafalaya Floodway, Morganza Floodway and Bonnet Carré Spillway**) sending the excess water down a different route to the Gulf of Mexico. As of 2010, USACE expected this would be necessary about once every 10 years.

5.4.1.1 Birds Point-New Madrid Floodway

This floodway is the uppermost flood control component of the Mississippi River and Tributaries Project located on the west bank of the Mississippi River in southeast Missouri just below the confluence of the Ohio and Mississippi Rivers, and below St. Louis, Missouri. The construction of the floodway was authorized by the Flood Control Act of 1928 and later modified by the Flood Control Act of 1965. Its purpose is to divert water from the Mississippi River during major flood events and lower the flood stages upstream, notably at Cairo, Illinois.

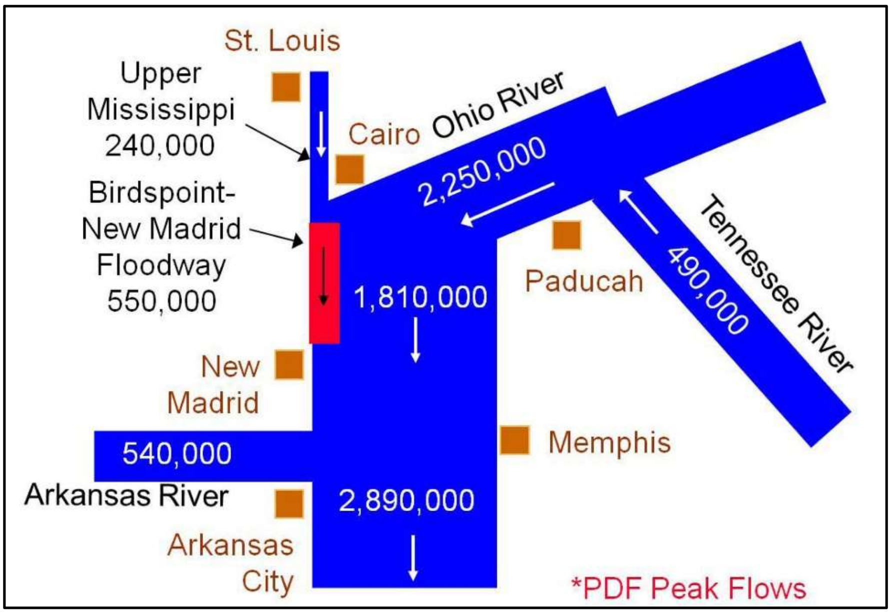


Figure 21 – New Madrid project design diversion flood

The floodway is designed to divert 550,000 cu ft/s (16,000 m^3/s) from the Mississippi River during the "project design flood" hypothetical flood event (Figure 21). At this flow the level of the Mississippi River will drop 7 feet (2.1 m) at Cairo. Unlike the Morganza and Bonnet Carré Spillways in Louisiana, the Birds Point-New Madrid Floodway does not have floodgates. **The floodway is operated by a controlled destruction of the levee, either with explosives or by overtopping.** Being an emergency fuseplug levee, there is an understandable reluctance to use this option, except in extreme emergencies. The frontline levee has an 11 miles (18 km) fuseplug section of the upper levee and a 5 miles (8.0 km) section at the lower levee that are lower than adjacent sections. The operation of the floodway is directed by the president of the Mississippi River Commission after consultation with the Chief of Engineers and has been operated only once, during the 2011 Mississippi R, flood.

5.4.1.2 Morganza Flood Control Structure

New York Times

Figure 22 – Morganza Spillway and Atchafalaya Floodway

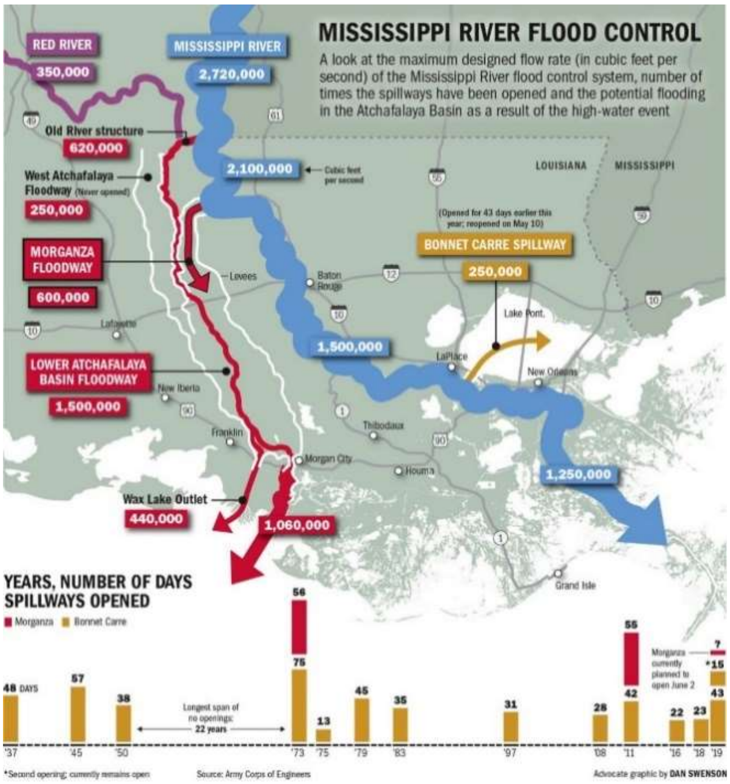
In late May 2019, the U.S. Army Corps of Engineers announced plans to operate the Morganza Flood Control structure in early June to prevent overtopping of the structure and reduce river stages along Mississippi River levees. The proposed operation would have diverted 150,000 cfs from the Mississippi River into the Morganza Floodway. The planned operation was postponed (and eventually cancelled) when subsequent forecasts indicated stages would be lower than originally predicted. The **Morganza Spillway** or **Morganza Control Structure** is a flood-control structure in the U.S. state of Louisiana along the western bank of the Lower Mississippi River at river mile 280, near Morganza in Pointe Coupee Parish (Figure 22).

The spillway stands between the Mississippi and the **Morganza Floodway**, which leads to the Atchafalaya Basin and the Atchafalaya River in south-central Louisiana. Its purpose is to divert water from the Mississippi River during major flood events by flooding the Atchafalaya Basin, including the Atchafalaya River and the Atchafalaya Swamp. The spillway and adjacent levees also help prevent the Mississippi from changing its present course through the major port cities of Baton Rouge and New Orleans to a new course down the Atchafalaya River to the Gulf of Mexico. The Morganza Spillway, operated by the U.S. Army Corps of Engineers, was opened during the 1973 and 2011 Mississippi River floods, (https://en.wikipedia.org/wiki/Morganza_Spillway)

5.4.1.3 Bonnet Carre' Spillway

The Bonnet Carré Spillway was opened on 27 February 2019 for the second consecutive year to divert part of the Mississippi River flow into Lake Pontchartrain (Figure 23). The spillway is operated to limit the Mississippi River passing New Orleans, Louisiana, to the project design flood discharge of 1.25 million cubic feet per second (cfs). The peak diversion discharge through the spillway of 213,000 cfs occurred on 19 March 2019 with an average diversion discharge of approximately 140,000 cfs during this flood period. The spillway was closed on 10 April 2019.

The Bonnet Carré Spillway was reopened on 10 May 2019 marking the first time the spillway has been operated twice in the same year – for two consecutive years. The peak diversion discharge of 161,000 cfs occurred on 21-



Source: Army Corps of Engineers

Advocate graphic by DAN SWENSON

Figure 23 – Bonnet Carre' Spillway

22 May 2019. The Spillway was closed on 27 July 2019. The average diversion discharge was approximately 120,000 cfs.

5.5 Flood Impacts and Consequences

5.5.1 Socioeconomic Consequences of the 2019 Flood

Flooding in the upper Mississippi River basin during the winter, spring, and summer of 2019 caused at least 12 deaths and economic losses in excess of $20 billion. Flooding along the Mississippi R. was not the result of a single weather event, though. Instead, a series of flood events in tributary basins produced Mississippi River flooding of record duration. Flooding along the Tennessee and Ohio Rivers in the winter was followed by catastrophic floods in portions of the Midwestern United States in the early spring and record flooding along the Arkansas River in late May. https://en.wikipedia.org/wiki/Mississippi_River_floods_of_2019

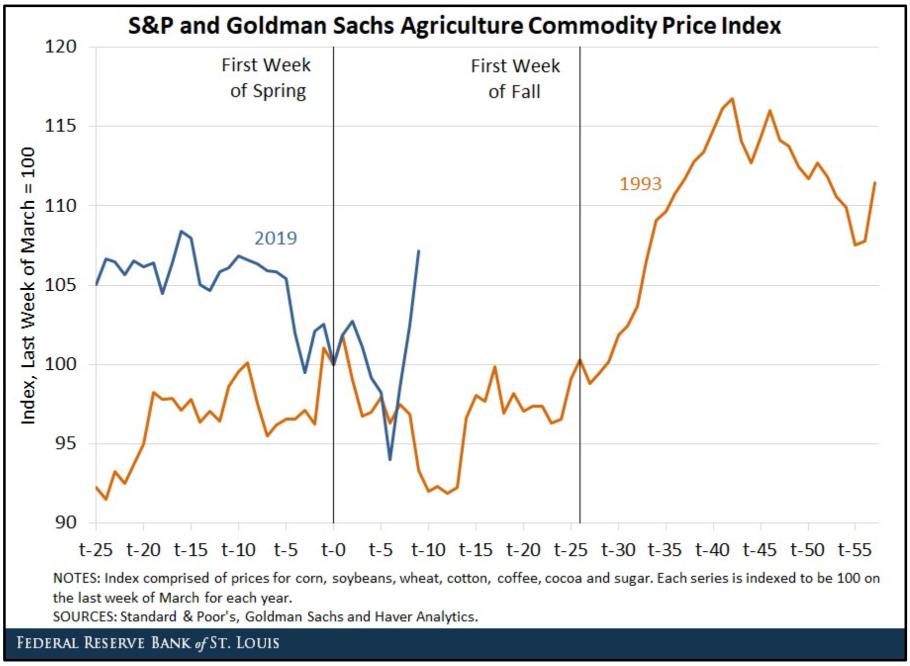
5.5.2 Agriculture

As a consequence of extreme rainfall, more than 200% above normal, corn and soybean planting lagged the five-year average, and grain shipments on the Mississippi, Arkansas and Ohio Rivers dropped well below the previous year and three-year average, according to the U.S. Department of Agriculture. Heavy spring rains across the Nation in 2019 caused nearly 20 million acres of farmland to go unplanted. Farmers incurred, collectively, billions of dollars in losses, disrupting rural economies across the country as well as the communities they support. 2019 was both the second hottest and second wettest year on record, according to the National Oceanic and Atmospheric Administration. The Mississippi River, Arkansas River, and Missouri River all flooded in 2019, and each ranked on NOAA’s all-time list of billion-dollar weather and climate disasters, https://www.popsci.com/story/environment/2019-record-floods-midwest/.

As an example, cotton crops common across much of the Texas panhandle have a narrow planting window, as they need to be planted in late winter or early spring to be ready for harvest before the first freeze that usually occurs in October. With the extremely wet and rainy 2019 spring season, soils were too waterlogged and compacted to start planting — so farmers were not able to plant early enough to avoid the fall freeze.

The Federal Reserve Bank of St. Louis (Kliessen and Bokun, 2019) analyzed the agricultural impacts of this flood as follows:

- Industries will face significant disruptions—most notably the transportation sector, which moves agricultural and non-agricultural manufactured goods across an elaborate network of interstate highways and railroads across the Midwest and Plains states.
- For the U.S. farm sector, according to projections from the Department of Agriculture, real net farm income was forecast to be $66 billion in 2018, less than half its level from five years earlier;
- Waterlogged fields prevented early planting. Only 16% of soybean acres were planted through the week ending May 26, compared to 40% by the same time historically.
- Historically, approximately 70% of corn acres are planted by June. Corn acreage in Illinois, Indiana and Ohio lagged the previous year’s progress by 70, 63 and 49 percentage points, respectively. All else equal, lower production leads to higher prices.



NOTES: Index comprised of prices for corn, soybeans, wheat, cotton, coffee, cocoa and sugar. Each series is indexed to be 100 on the last week of March for each year.
SOURCES: Standard & Poor's, Goldman Sachs and Haver Analytics.

Figure 24 – S&P and Goldman Sachs Agriculture Commodity Price Index

For an historical perspective, Figure 24 shows the index of weekly crop prices from October 1992 to May 1994, the period encompassing the Great Flood of 1993, compared with October 2018 to May 2019. The two vertical lines indicate the last week of March (spring planting preparations) and the last week of September (fall harvest) for each period. The implications of this are that while the direct damages attributed to flooding (flooded homes, businesses, damaged infrastructure such as highways, bridges, roads, and other public services), were estimated at $20B, the far larger costs to society are increased prices of commodities, and loss of revenue to farmers and businesses, estimated at about ten times the direct costs, or approximately $200B. Net farm income for 2019, alone, was estimated to be less than one-half the previous average 5-year level – a loss of over $60B (Kliessen and Bokun, 2019).

On the other hand, the Department of Agriculture projected flooding in the upper Midwest would not affect national yields significantly. In its annual Prospective Plantings Report, produced in April 2019, the USDA stated farmers intend to plant a combined 177 million acres of corn and soybeans this spring (2019). By comparison, estimates of farmland flooding range from 500,000 acres in Iowa and western Nebraska to 1.1 million acres in the Midwest. The overall adverse impact nationally was considered to be small, with corn planted acreage up 4-percent from 2018; soybean acreage down 5-percent; all wheat acreage down 4-percent; all cotton acreage down 2-percent.

5.5.3 Navigation, Transportation and Commerce

During the 2019 floods, hundreds of barges were stalled on the Mississippi River, clogging the main circulatory system for a farm-belt economy battered by a relentless, record-setting string of snow, rainstorms and flooding. Railways and highways closed as well, keeping supplies from farmers and others, and limiting crops sent to market. Almost 200 miles of the Mississippi River navigation system was closed, https://www.bloomberg.com/news/articles/2019-06-08/-punched-in-the-face-by-floods-traffic-snarls-on-u-s-rivers.

Barges, though slower and less conspicuous than trains, planes, and trucks, can be a more economical way to move bulk goods, as they have done around this country for generations. One barge can haul as much as 70 semi-trucks' worth of dry cargo. They are especially useful for farmers, who use them to send harvested grain to export markets and receive fertilizer for their next crop. A majority of the country's exported grain is shipped on the Mississippi and tributaries.

The river closures had a harsh impact on industries, compounding the effects of the lock closures to the north on the Illinois River (Figure 25). St. Louis, at the confluence of the Mississippi, Missouri and Illinois rivers, has evolved into a transportation hub and major loading point for grain and other goods. Groups of barges arriving from the north or south are often reconfigured here for their onward journeys along the different river systems.

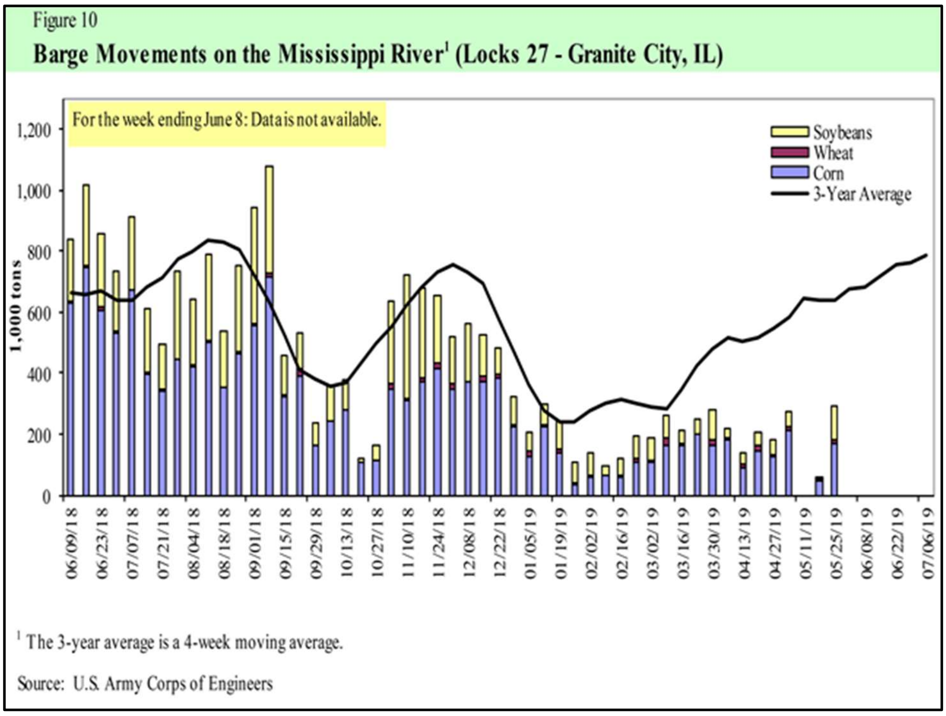


Figure 25 – Barge Movements on the Mississippi River at Lock 27, Granite City, IL

The Arkansas River was closed to commercial traffic, as was the Illinois River, a key connection to Chicago and the Great Lakes. Commercial traffic on the Mississippi R. near St. Louis also closed, where the river crested at its second-highest point on record.

As a result, farmers already grappling with flooded fields and worries about the trade war with China struggled to obtain fertilizer for their crops. Customers saw their deliveries of construction materials and road salt stuck midway to their destinations. In addition, shippers made drastic cuts to operations with work at a standstill, https://www.nytimes.com/2019/06/10/us/flooding-river-shipping.html.

While high waters stop barge traffic, they also carry other dangers. Flood waters closed Interstate highways and overwhelmed farm fields, sewer and septic systems, and industrial plants along rivers. The latter flooded areas can create toxic flows as water moves away from the river beds, https://slate.com/business/2019/06/new-orleans-mississippi-river-high-water-climate-change.html.

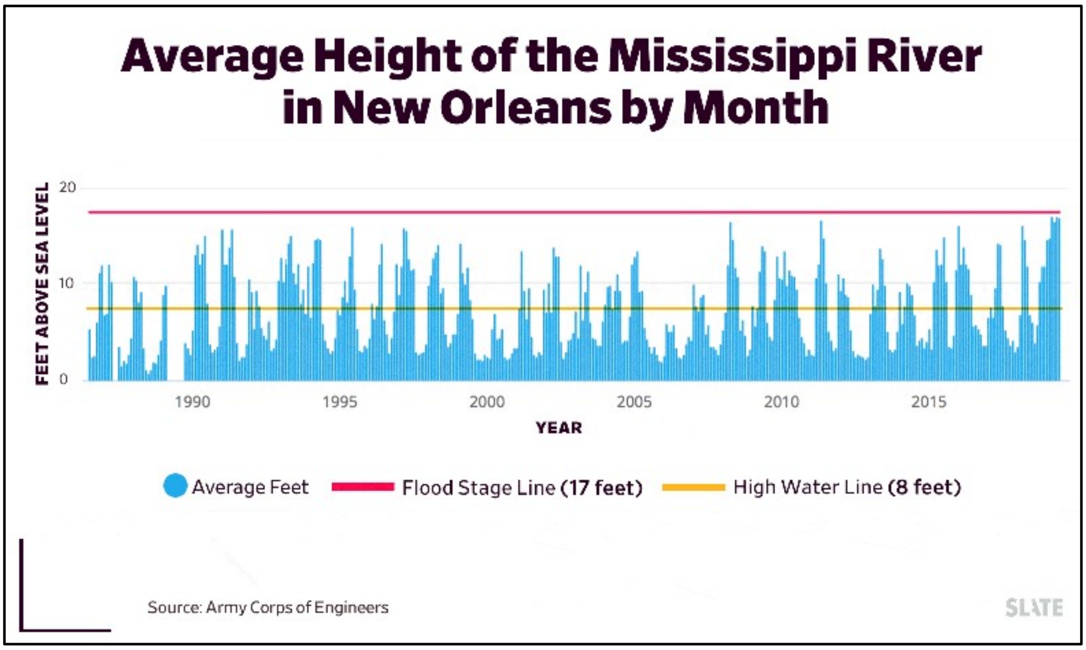


Figure 26 – Average height of the Mississippi River in New Orleans by month

In New Orleans, the Mississippi River is considered at “high water” when it runs through the city at more than 8 feet above sea level (Figure 26). Usually, high water comes in the winter or spring, after snowmelt in the upper basin, and ends by June. Because of rains in the upper basin on frozen ground and snow, the river rose in November (2018) and stayed high until June 2019.

5.6 Recovery Assistance and Post-Recovery Actions

5.6.1 Socio-economic mitigation actions

The U.S. has a wide array of disaster relief programs stand ready to be activated once the President declares a national emergency. In addition, an emergency supplemental appropriations bill was passed by Congress, **the Disaster Relief Act of 2019 (P.L. 116-20**), totaling nearly $20B, in July, 2019, primarily covering several hurricane disasters in 2017-2018, including Hurricane Maria in Puerto Rico. Other federal and state relief programs were already in place to deal with the Mississippi R. flood damages, including grants from the U.S. Department of Agriculture (USDA), low interest loans for businesses from the Small Business Administration (SBA), and flood insurance payments from the Federal Emergency Management Administration (FEMA) run National Flood Insurance Program.

When major disasters strike, USDA has an emergency loan program that provides eligible farmers low-interest loans to help them recover from production and physical losses. USDA also offers additional programs tailored to the needs of specific agricultural sectors to help producers weather the financial impacts of major disasters and rebuild their operations. Livestock owners and contract growers who experience above normal livestock deaths due to specific weather events, as well as to disease or animal attacks, may qualify for assistance under USDA’s *Livestock Indemnity Program*. Producers who suffer losses or are prevented from planting agricultural commodities not covered by federal crop insurance may be eligible for assistance under USDA's *Noninsured Crop Disaster Assistance Program* if the losses were due to natural disasters. USDA's *Emergency Assistance for Livestock, Honeybees and Farm-Raised Fish Program* provides payments to these producers to help compensate for losses due to disease (including cattle tick fever), and adverse weather or other conditions, such as blizzards and wildfires, not covered by other disaster programs.

5.6.2 Flood Resilience and Risk Reduction: Federal Assistance and Programs

The Congressional Research Service, an arm of the US Congress, published a report in 2019, entitled, “Flood Resilience and Risk Reduction: Federal Assistance and Programs”, 2019 (CRS; 2019b) describing the various federal agency programs that were brought to bear during recovery following a series of disasters in the U.S. The report noted “*recent flood disasters have raised congressional and public interest in reducing flood risks and improving flood resilience, which is the ability to adapt to, withstand, and rapidly recover from floods. Federal programs that assist communities in reducing their flood risk and improving their flood resilience include programs funding infrastructure projects (e.g., levees, shore protection) and other flood mitigation activities (e.g., nature-based flood risk reduction) and mitigation incentives for communities that participate in the National Flood Insurance Program (NFIP)”* (CRS, 2019b).

5.6.3 Assistance Programs

Congress established various federal programs to assist state, local, and territorial entities and tribes in reducing community flood risk. Each federal program has its own focus, statutory limitations, and way of operating. For example, the Hazard Mitigation Grant Program (HMGP) is triggered by a major disaster declaration by the President of the United States, in accordance with the terms of the Stafford Act. At that point, the Pre-Disaster Mitigation (PDM) grant program becomes available as the result of a 6% set-aside from the Disaster Relief Fund after every major disaster declaration. The Federal Emergency Management Agency (FEMA) administers the HMGP and PDM. In contrast to how the

HMGP and PDM are triggered, Congress uses annual appropriations and supplemental appropriations to fund other assistance programs.

Eligibility for assistance through some of these programs also may be tied to disaster declarations. These assistance programs include

- FEMA's Flood Mitigation Assistance (FMA) grant program;
- U.S. Army Corps of Engineers (USACE) flood risk reduction projects;
- U.S. Department of Agriculture (USDA) acquisition of floodplain easements and grants for flood risk reduction projects;
- National Oceanic and Atmospheric Administration (NOAA) grants for coastal resilience, restoration, and management (including the Great Lakes);
- U.S. Environmental Protection Agency (EPA) support for state-administered loan programs and direct credit assistance for stormwater management; and
- Department of Housing and Urban Development (HUD) grants through the Community Development Block Grant (CDBG) and Community Development Block Grant−Disaster Recovery (CDBG−DR) programs.

Flood Insurance

Congress established the National Flood Insurance Program (NFIP) in the National Flood Insurance Act of 1968 (NFIA; 42 U.S.C. §§4001 et seq.). For federal flood insurance to be available to homeowners and business owners, the NFIP requires participating communities to develop and adopt flood maps and enact minimum floodplain standards based on those flood maps. The NFIP encourages communities to adopt and enforce floodplain management regulations such as zoning codes, building codes, subdivision ordinances, and rebuilding restrictions. The NFIP also encourages communities to reduce flood risk through three programs: the FMA, Community Rating System, and Increased Cost of Compliance coverage.

The National Flood Insurance Program is now the cornerstone of mitigation and prevention components of the US water DRR Policy. Community measures must meet these minimum FEMA standards. Some of the key rules for NFIP include:

- no development in a defined floodway; no residential living area below 1% flood level;
- no non-residential development subject to damage by 1% flood;
- no rebuilding of flood-damaged property if an event is below 1% flood probability and if damage is 50% or more of structure value.

The Disaster Recovery Reform Act (DRRA, 2018) passed important reforms to federal disaster programs and amended many sections of the *Robert T. Stafford Disaster Relief and Emergency Act* including Section 203, Pre-Disaster Mitigation. These reforms acknowledge the shared responsibility of disaster response and recovery, aim to reduce the complexity of FEMA, and build the Nation's capacity for the next catastrophic event.

FEMA and its partners are working on the development and implementation of DRRA Section 1234: **National Public Infrastructure Pre-Disaster Hazard Mitigation Grant Program.** This program, which FEMA has named Building Resilient Infrastructure and Communities (BRIC), will be funded through the Disaster Relief Fund as a six percent set aside from estimated disaster grant expenditures for the purpose of implementing pre-disaster mitigation measures.

5.6.4 Silver Jackets

The USACE in coordination with other Federal agencies has developed a program called ‘Silver Jackets’, to more closely coordinate the activities of federal, state and local entities as part of the overall federal response to improve community floodplain management planning and disaster recovery. Silver Jackets teams in states across the country bring together multiple state, federal, and sometimes tribal and local agencies to learn from one another, spread the message that flood risk management is a shared responsibility, apply their knowledge to reduce the risk of flooding and other natural disasters, and enhance response and recovery efforts when such events occur. The Silver Jackets program essentially works towards flood risks and increasing community resilience. As of 2020, there are 49 state and 5 U.S. territory Silver Jackets teams, https://silverjackets.nfrmp.us/Home/About-the-Silver-Jackets-Program.

Silver Jackets Program Goals

- Facilitate strategic life-cycle flood risk reduction.
- Create or supplement a continuous mechanism to collaboratively solve state-prioritized issues and implement or recommend those solutions.
- Improve processes, identifying and resolving gaps and counteractive programs.
- Leverage and optimize resources.
- Improve and increase flood risk communication and present a unified interagency message.
- Establish close relationships to facilitate integrated post-disaster recovery solutions.

The Silver Jackets program is part of a larger USACE Flood Risk Management Program (FRMP) that works across the agency to focus the policies, programs and expertise of USACE toward reducing overall flood risk. This includes the appropriate use and resilient design of structures such as levees and floodwalls, as well as promoting alternatives when other approaches (e.g., land acquisition, flood proofing, etc.) reduce the risk of life loss, reduce long-term economic damages to the public and private sector, and improve the natural environment.

Some of the essential goals of the ‘Silver Jackets’ program are to establish a better understanding of the relative risks of various floodplain management measures; establish appropriate risk tolerance thresholds for their communities; implement a broad range of non-structural flood risk management measures; and mobilize the technical and financial resources of federal and state agencies to implement those measures.

5.6.5 Future Adaptation Actions

After every large flood, there are calls from elected officials to understand why the system did not perform as well as could be expected, and where flaws and weak points exist. This is an essential part of an autonomous ‘adaptive management’ process that has been ongoing for the past century, leading to incremental improvements of the system’s three main components: infrastructure; operational management during a crisis; and new institutional, legislative and non-structural floodplain management measures to increase robustness and resiliency.

As an example, immediately after the 2019 flood, the U.S. Army Corps of Engineers was directed by Congress to undertake several studies, among which was a major study of ways to reduce flooding along the lower section of the Missouri River, where record precipitation and failed levees devastated communities during the past year (Frank, 2020). The study will analyze a 735-mile span of the Nation's longest river and its tributaries – a stretch that runs from Nebraska's northeast corner to eastern Missouri, where the Missouri River empties into the Mississippi River.

5.6.6 High Risk Levees along the Upper Mississippi River (identified by the U.S. Army Corps of Engineers).

Levees are almost always damaged or degraded during heavy floods, especially when they are inundated for extensive periods of time – in many cases over 100 days. Levees receive extensive monitoring and maintenance after floods because they serve a vital role in defending riverfront communities and lands from damage. In reviewing USACE records, the Environmental Law & Policy Center (ELPC; 2020) identified a need for more robust monitoring, reinforcement, and repairs. There are levees at risk of breach all along the Mississippi River in Illinois, Iowa, and Missouri, and several others have not received repairs after breaching during the 2019 floods. In Illinois, 41 of 54 levees in the St. Louis District, USACE, have filed damage reports. In Missouri, 30 of 39 levees in the St. Louis District have filed damage reports, http://elpc.org/wp-content/uploads/2019/11/ELPC-High-Risk-Levees-Along-the-Mississippi-River.Nov_.20.19.pdf.

The U.S. Army Corps of Engineers often uses its annual supplemental budget, appropriated by Congress, for these repairs. For example, under its 2018 supplemental budget, USACE received $645 million for short-term flood control and coastal emergency program purposes.

As of September 25, 2019, the USACE short-term 2019 supplemental budget plan allocated:

- $575 million to the Mississippi River and Tributaries short-term repairs account. Some of those funds will be used for levees in Illinois and Missouri along the Mississippi River
- $1 billion to the Flood Control and Coastal Emergencies account. 104 levees were listed to receive assistance in total.
- $908 million to the Operation and Maintenance account. Some of those funds will be used for levees in Illinois and Missouri along the Mississippi River

5.7 Comparing the Consequences of Flood Disasters and other Natural Hazards

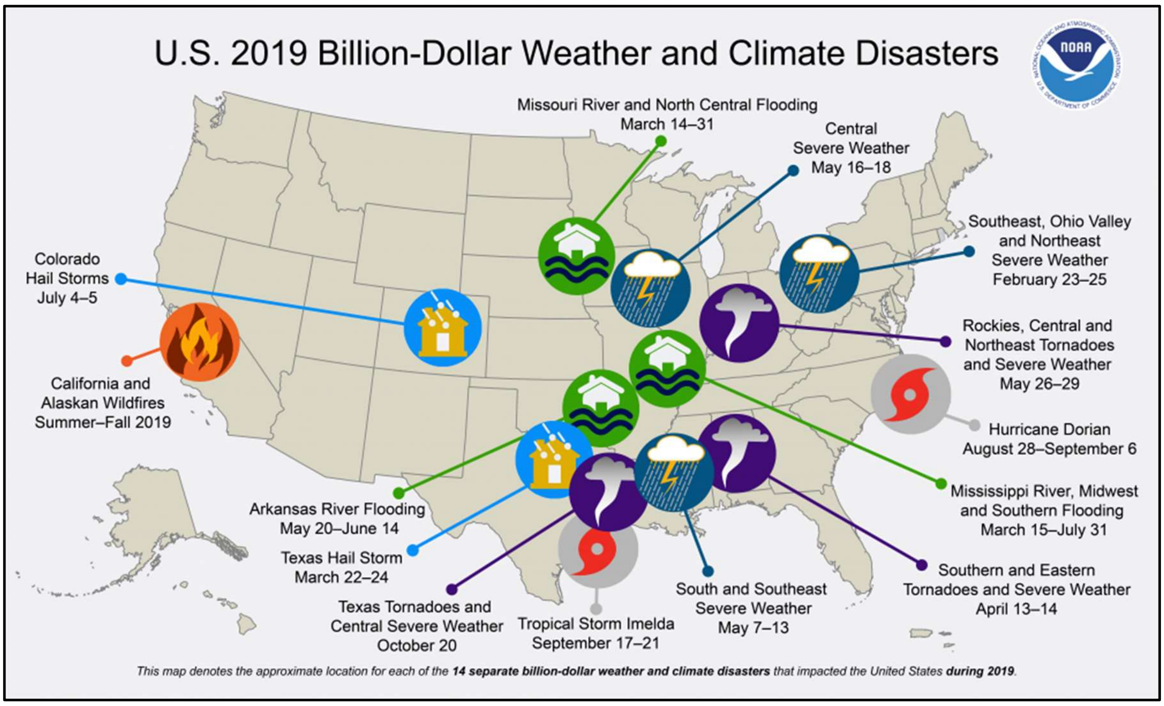
A comparison of the areal extent of the various record floods in the Mississippi River basin (1927, 1993, 2011 and 2019) and nature of economic damages that are thereby entitled to be deemed 'mega-disasters', demonstrates the underlying nature and the relative magnitude of the socioeconomic consequences.

The 2019 Flood should be placed in an overall economic perspective, comparing it with other notable damaging floods, and comparable natural disasters that have afflicted the U.S. over the past few decades. As noted previously, national economic resilience is a cornerstone of national security. Though the *areal extent* of flooding and duration of the 2019 flood were far greater than previous disasters, the damages were proportionately far less, considering the population affected, number of households and economic wealth and production affected – industries, commerce, agriculture and lost work-days.

In particular, it should be noted that, as with the great flood of 1993, most of the agricultural damages, which comprised the majority of total damages, were the result of heavy rainfall and flooded fields, which prevented seeding new crops, rather than riverine-related flood damages caused by rivers overtopping their banks or levees. Nevertheless, the flood did threaten to inundate several large urban areas, since it was the second highest recorded flood crest at St. Louis (46.02 feet), after the flood of 1993 (49.58 feet).

Overall, the period 2017 to 2019 were very bad years for disasters in the U.S. (Figure 27), but the Mississippi R. Flood of 2019, with damages approximating $20 billion, was not the worst among them. Foremost among the disasters are listed below, (https://www.ncdc.noaa.gov/billions/events).

- Hurricane Harvey, Texas, August 2017 - $130B
- Hurricane Maria, Puerto Rico, September 2017 - $94B
- Hurricane Irma, September, 2017 - $52B
- Hurricane Michael, Florida, October, 2018 - $25.5B
- Hurricane Florence, N. Carolina, September 2018 - $24.5B
- **Mississippi R. basin flooding, Spring 2019 - $20B**
- Wildfires, California, Summer, 2017 - $19B



U.S. 2019 Billion-Dollar Weather and Climate Disasters

This map denotes the approximate location for each of the ***14 separate billion-dollar weather and climate disasters*** *that impacted the United States* ***during 2019****.*

Figure 27 – US 2019 Billion dollar weather and climate disasters

While the **direct** economic damages of the 2019 Flood were considerable, estimated at ~ $20 billion, the indirect damages of lost jobs, business revenue and agricultural losses were closer to $100 billion. Even so, the 2019 Flood was far less damaging, in terms of national economic wealth, than the 1927 Flood, as can be seen in Figure 28. The 1927 Flood is ranked third among national disasters in the modern era, the economic losses accounted for less than 0.2% of GDP.

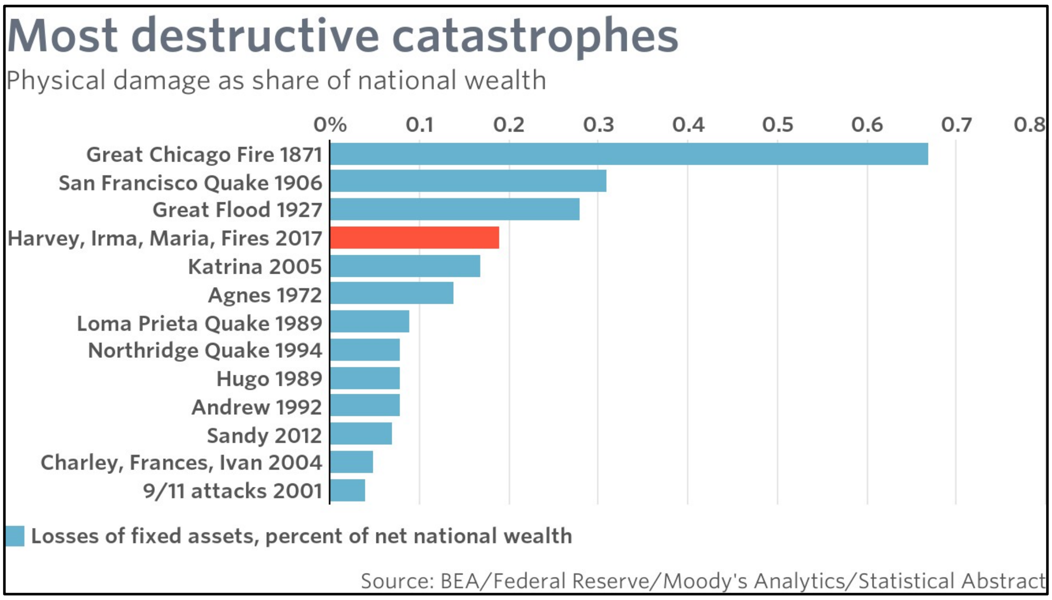


Figure 28 – Most destructive US catastrophes, as a proportion of national wealth

5.7.1 The Benchmark Mega-Flood of 1927.

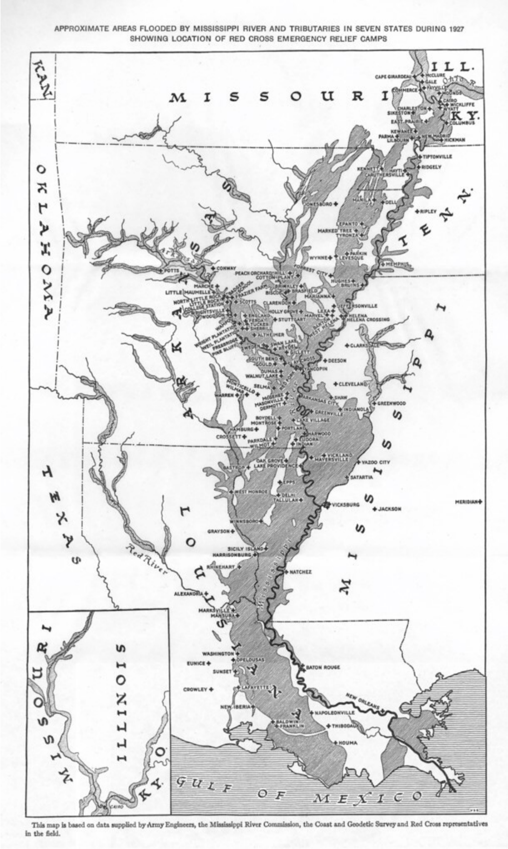


Figure 29– 1927 Mississippi River flood extent

The Great Mississippi Flood of 1927 was the most destructive river flood in the history of the United States (Figure 29), with 27,000 square miles (70,000 km^2) inundated up to a depth of 30 feet (9 m). The 1927 flood, which became the benchmark flood for the next century, inaugurated a new level of federal involvement in flood control and integrated basin management. To prevent future floods, the federal government undertook a vast infrastructure construction program and built the world's longest system of levees and floodways.

Ninety-four percent of more than 630,000 people affected by the flood lived in the states Arkansas, Mississippi and Louisiana. More than 200,000 African Americans were displaced from their homes along the Lower Mississippi River and had to live for lengthy periods in relief camps. As a result of this disruption, many African Americans joined the Great Migration from the south to northern and Midwestern industrial cities rather than return to rural agricultural labor.

On the lower Mississippi River – which begins in Cairo, the southernmost city in Illinois – flood control is far more advanced than in the Midwest. The federal government decided the region should never be flooded again, and the USACE was tasked with the design and construction of the Mississippi River and Tributaries Project to mitigate future flood damages.

The MR&T is so vast that it can be hard to comprehend as a single object. The project includes concrete floodwalls in New Orleans, LA, Cairo, IL, and Caruthersville, Mo.; pumping stations that drain rainwater trapped behind these walls; and nearly 3,500 miles of levees along the river and its tributaries. A fleet of towboats and barges, outfitted with cranes and sleeping quarters for a crew of

200, descends the river each year, paving its bends with concrete to halt erosion. In the 1930s and 1940s, dredge boats straightened the river, shortening it by 150 miles, so floodwaters would speed more quickly downstream.

5.7.2 Lessons of the 1993 Flood

Just as the 1927 Flood inaugurated an era of infrastructure responses to flood hazards, which increased the robustness and safety of the system, the 1993 Flood inaugurated a suite of new measures for mitigating post-disaster damages, which improved the resilience of the various socio-economic sectors dependent on the Mississippi R. system and tributaries.

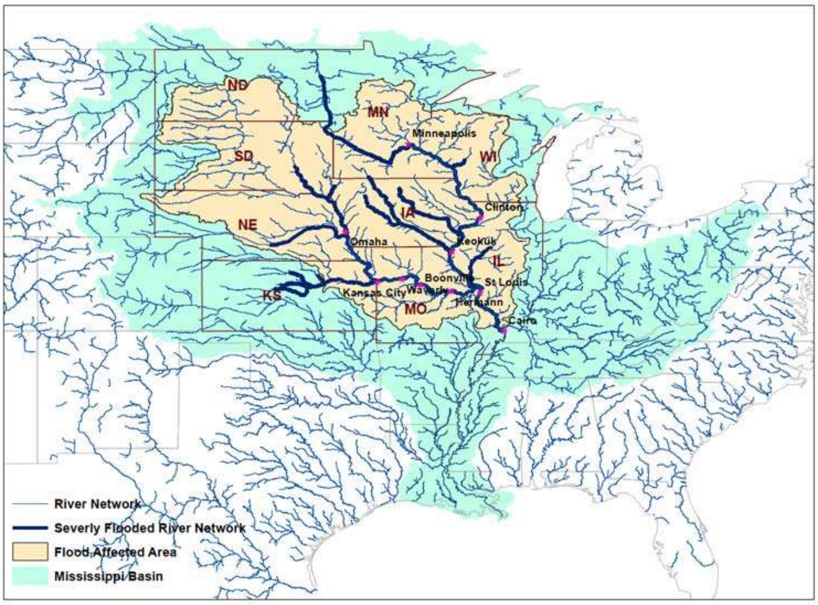


Figure 30 – Mississippi River 1993 flood extent

The Great Flood of 1993 occurred in the Midwestern heart of the U.S., along the upper Mississippi and Missouri rivers and their tributaries, from April to October 1993 (Figure 30). The flood was among the most costly and devastating to ever occur in the United States up until that time, with $22 billion in damages (**approximately $40 billion in 2018 dollars**). The affected hydrographic basin covered approximately 745 miles (1,199 km) in length and 435 miles (700 km) in width, totaling about 320,000 square miles (830,000 km^2). Within this zone, the flooded area totaled around 30,000 mi^2 (78,000 km^2) and was the worst such U.S. disaster since the Great Mississippi R. flood of 1927; as measured by duration, area inundated, persons displaced, crop and property damage, and number of record river levels. In some categories, the 1993 flood even surpassed the 1927 flood, at the time the largest flood ever recorded on the Mississippi. The 1993 flood also eventually threatened downstream communities along the Mississippi R., with a record peak of 49.58 feet at St. Louis, Mo, which nearly overtopped their flood walls. The 2011 Flood was second highest, at 46.02 feet on June 8, 2019.

Previous maximum flows on many streams and rivers were exceeded during the flood of 1993 in the upper Mississippi River Basin. Not only were peak discharges exceeded at many streamflow-gaging stations, but also flood volumes were significantly higher than previous maximums. Rainfall amounts greater than 127 cm (50 in.) were recorded in parts of Kansas, Missouri, and Iowa from April 1 through September 30, 1993. As a result of the excessive rainfall, 53 of the 60 stations discussed had flow volumes greater than twice the mean flow volume for April through September.

The Mississippi River at St. Louis, Missouri, remained above flood stage for 144 days from April 1 to September 30, 1993, compared with 81 days during the spring and summer flood of 1973. Of the 60 stations, 24 recorded new maximum 3-day flood volumes, and 47 recorded new maximum 120-day flood volumes. This indicates the flooding of 1993 is significant with respect to its long duration and flow magnitude. A similar comparison is reflected in the frequency analysis of the 1993 flood.

During the 1993 flood, the 100-year, 3-day flows were exceeded at 22 stations, and the 100-year, 120-day flows were exceeded at 43 stations.

Like the 2019 Flood, the 1993 flood inundated some locations on the Mississippi R. for almost 200 days, while various regions by Missouri neared 100 days of flooding. Approximately 100,000 homes were destroyed, 15 million acres (60,000 km²) of farmland inundated, and the whole towns of Valmeyer, IL, and Rhineland, MO, were subsequently relocated to higher ground. The flood cost 32 lives officially.

What was important about the 1993 flood, was it engendered a 'White House' report (IFMRC, 1994), which recommended major policy changes related to federal and state flood protection policies and programs that basically *focused on measures that improved the resilience of the various communities affected by the flood*. Over 800 recommendations were offered by the Report, addressed to many federal agencies, as well as state and local communities. The key planning and management related issues and recommendations specifically addressed to USACE included in the IFMRC recommendations (Stakhiv, 1995) are the following.

- Changes in the comprehensive evaluation guidelines of federal water resources projects, in order to accommodate environmental quality (EQ) objectives along with national economic development (NED).
- Funding, through existing legislative authorities, programmatic acquisition of needed lands from willing sellers.
- Introducing cost-sharing provisions for state, local, and tribal participation in pre-system, recovery, response, and mitigation activities.
- Increasing environmental attention in federal operation and maintenance and disaster recovery activities.
- Developing a coordination strategy for guiding multiple federal programs dealing with watershed management.
- Giving full consideration to all possible alternative ways of reducing vulnerability to flood damages especially nonstructural solutions.
- Exploiting science and technology to support monitoring, analysis, modeling, and the development of decision support systems and geographic information systems for floodplain activities.

First, some misunderstandings about the Flood of '93 should be addressed, as this is an issue of basic information and interpretation rather than research.

The fact flood damages associated with the large Upper Mississippi River flood were estimated to be $12- 16 billion (1994 dollars) (U.S. IFMRC, 1994) did not mean the flood control measures in place were not effective, nor hydrologically speaking represented the largest recorded flood. Stakhiv (1995) presented additional facts and insights to provide a context for assessing the effectiveness of the performance of the upper Mississippi R. flood management system during the 1993 flood. According to the IFMRC Report:

- Agricultural damage, not related to direct riverine flooding, but directly to extended periods of saturated soils preventing spring planting of crops and subsequent damage to harvest accounted for more than half the damage, i.e., > $ 6-8 billion.

- More than 70-percent of the crop disaster assistance payments were made to counties in upland areas where ground saturation prevented planting or killed the crops. (These agricultural losses would not have been affected by changes in floodplain management policies. Rather, reforms to existing agricultural crop insurance policies appear to be the best solution).
- Nearly half of the approximately 100,000 homes damaged suffered losses due to groundwater or sewer back up as opposed to riverine flooding.
- Flood control projects (reservoirs, levees, and existing floodplain management programs) worked as designed and prevented more than $19 billion in potential damages ($8 billion from levees and $11 billion from reservoirs in the Missouri and Ohio River basins).

Another comprehensive assessment of the Upper Mississippi River 1993 flood disaster was conducted by USACE (1995) under a Congressional authorization (House Resolution 2423, 3 Nov. 1993). In its report to Congress, the USACE addressed the following natural river system impacts on the basis of its modeling and analysis (Stakhiv, 1995).

- USACE reservoirs performed well, reducing floodwater elevation by several feet along most of the main stem Missouri and Mississippi rivers.
- Most USACE levees performed as designed and prevented significant damage.
- The flood affected over 6.6 million acres in 419 counties of the affected area.
- For the 120 counties adjacent to the Upper Mississippi and Lower Missouri Rivers, urban flood damages substantially exceed agricultural losses, including damage due to urban drainage and stormwater runoff.
- Navigation locks and dams did not cause an increase in the stage heights of the 1993 flood.
- The return period of the flood varies widely all over the region ranging from a 20-year flood to over a 500-year event.
- The best estimate for a return period at St. Louis is about a 125-year event.
- Hydraulic model routings of 1993 flood stages through the main stem Mississippi River near St. Louis without the present agricultural levees would have reduced those stages by 2-4 feet under present agricultural practices. The flood stage at St. Louis was 49.8 feet.
- If the agricultural levees along the upper and middle Mississippi River were raised and strengthened to prevent overtopping in the 1993 event, the flood stages near St. Louis would have been about 6 feet higher, on average.
- Reversion to natural forested (non-agricultural) floodplains can cause increases in flood stages, similar to the effects of levee construction.
- Restoration of wetlands may reduce local flooding in the uplands by up to 25 percent, but would have little effect on flood state reduction in the lower floodplain reaches because most depressional reaches were already full during the antecedent period to the 1993 flood event.

Recently, Brigadier General (Ret.) Gerald Galloway, who headed the White House post-1993 Mississippi River Flood Interagency Floodplain Management Review Committee (IFMRC; 1994), reviewed progress of US agencies responsible for flood risk management, against the backdrop of the 2019 flood (Galloway, 2019). He suggested that while a great deal of progress has been made since the 1993 flood to improve the Mississippi R. flood damage reduction system, there is much more left to be accomplished – mainly because public needs and management objectives have changed considerably over the past 25 years. He noted many small changes were made incrementally in place of much-needed comprehensive Congressional legislation and funding in the form of a national Flood Management Act. Galloway also highlighted inadequate federal agency coordination and integration, which has not been able to keep up with the suite of emerging public issues such as environmental justice, environmental protection, and more effective responses to climate change (Galloway, 2019).

Davis (2013) argued similarly, that while much has been accomplished since the 1993 Flood, flood damages and lives lost continue to increase, and hence, the existing flood risk management policies are not sustainable. In particular, he stressed three critical changes need to be made:

- the nexus of Federal programs and local decision making, coupled with legislated project cost-sharing provisions required for USACE projects has skewed federally funded urban development in floodplains and exacerbating flood damages in an unsustainable manner.
- Reform of the NFIP is needed to disconnect the insurance program from the notion of the 100-year base flood as the *de-facto* national flood standard. Base the flood insurance program on actuarial insurance rates for all floodplains whether leveed or not; remove the binary 'in or out' floodplain demarcation now set at the 100-year floodplain and raise level-of-protection required of levee and other works for urban areas from the current 100-year level to the 500-year level for gaining accreditation of protection and levee certification on maps
- Improvement and synchronization of Federal, state, and local government policies and programs in flood risk management continues a key factor to support sustainability. The Silver Jackets program is a good example of improved collaboration initiatives by FEMA, USACE, and state agencies like the California Department of Water Resources (DWR) who are seeking to better synchronize multi-agency activities

5.8 Other Recent Comparable Floods and Disasters

A comprehensive paper on flood disaster risk reduction in the U.S. (Delli-Priscoli and Stakhiv; 2015), reviewed and compared three notable recent mega-disasters in the United States: Hurricane Katrina (2005), which devastated New Orleans; Superstorm Sandy (2011), which severely damaged the New York Metropolitan region; and the Mississippi River Flood of 2011. The review contrasted the ***relative performance*** of existing flood protection systems of three regions, as well as institutional disaster recovery responses. Federal, state, and local responses to these major events have been mixed, as regulatory and management agencies with different evaluation frameworks and decision rules attempted to coordinate their respective responses. The cases revealed new vulnerabilities and weaknesses in the US DRR (Disaster Risk Reduction) responses and planning, while contrasting the relative successes of long-term, strategic DRR planning and investments in the case of the Mississippi River and Tributaries (MR&T) system.

The main 'lessons learned', in comparing the three large recent disasters in the U.S., according to Delli-Priscoli and Stakhiv (2015), are as follows:

1. DRR comprises a special category of flood management, as it connotes extremely large events, with catastrophic human consequences and national level economic impacts. Hence, 'normal' or conventional flood control and floodplain management measures, typically suited for

communities or small watersheds, as necessary precursors for DRR, are not sufficient to deal with catastrophic low probability-high consequence events.

2. Conceptually, federally [or centrally] organized managed systems should be able to deal effectively with such events, but a series of recent disastrous floods and hurricane storm surges in the U.S. have exposed weaknesses in the responses of federally-based disaster management systems that rely on state and local support.

3. Simply put, there are 'too many cooks' involved in disaster planning, response, and execution in the U.S., with mixed lines of authority for execution. A large factor is federal legislation disaggregates and diffuses responsibilities. Even though the U.S. has vast resources and organizational capacities to plan for, and respond to, such large-scale emergencies, the federal system of governance is complex, has multiple layers of authority and responsibility, and contains many veto points. This makes effective and timely coordination before, during, and after such events difficult.

4. As mega-cities grow rapidly in the low-lying coastal areas in the U.S., they will become ever-more vulnerable to large-scale events largely because of inconsistent land use development by state and local authorities. U.S. federal regulations, restrictions and incentives have been inadequate to significantly change existing large urban centers, such as New York, New Orleans, Los Angeles, or Miami. These problems will be magnified by the sprawling growth of such cities as Dhaka, Manila, Lagos, or Jakarta.

5. Centralized, coordinated, financed, and strategically engineered solutions, such as those undertaken by the Dutch for their coastal protection system, are often required for problems on the scale of DRR. The system in the U.S. that comes closest to such coordinated planning and implementation is the MR&T collection of projects built over a century for the Mississippi River basin. This includes the Missouri River, Ohio River, and Illinois River system of reservoirs, navigation locks and flood control levees. This system of flood control storage and levees protects numerous downstream urban areas, such as St. Louis, Memphis, and New Orleans from catastrophic upstream floods.

5.9 Future Considerations and Concerns: Dealing With Climate Uncertainty

Clearly, improvements and changes to the existing flood management system will have to be made continuously, since devising a 'fail-safe' system is unachievable, primarily because of population growth and increasing climate uncertainty, but also because socio-economic conditions change as do objectives for sustainable development. So, the emphasis must be on continually upgrading both system robustness, as the basis for safety and reliability, along with system resilience as the basis for mitigating and ameliorating post-disaster socio-economic damages. At this point, it is necessary to define the terms robustness, resilience, reliability and safety, as these are all essential to understanding the notions associated with disaster risk reduction (DRR) strategies being advocated under anticipated increased uncertainties of a non-stationary climate.

5.9.1 Evaluation of Modern Flood Risk Reduction

Hashimoto *et al.* (1982a, 1982b) introduced a taxonomy to account for risk and uncertainty inherent in water resources system performance evaluation. It is clear the five terms listed below simply represent a set of descriptors that characterize and extend the key components of more traditional engineering reliability analysis, i.e., they focus on the sensitivity of parameters and decision variables to considerations of uncertainty, including some aspects of strategic uncertainty. The terms are:

1) Reliability – a measure of how often a system or its components is likely to fail;
2) Robustness – the economic performance of a system under a range of uncertain conditions;
3) Resiliency – how quickly a system recovers from failure (floods, droughts);
4) Vulnerability – how severe the consequences of failure may be;
5) Brittleness – the inability of optimal solutions to accommodate unforeseen circumstances related to an uncertain future.

The relative vulnerability of a water resources system is, therefore, a function of hydrologic sensitivity of a particular watershed (as input to the managed system) and the relative performance (robustness and resilience) of a water management system devised to control the extremes of hydrologic variability, as it affects the delivery of services required by society – in this case protection from catastrophic floods. On the other hand **societal susceptibility** (related to the current state of economic health, institutional structures and involved public in planning) and **community vulnerability** (related to land use regulations, building codes, flood warning and evacuation systems and flood protection infrastructure) to climate variability and change, depends on numerous factors outside the control of federal and state water managers.

Without an integrated water management capability, society becomes increasingly susceptible both to population-driven increases in water demands, as well as climate change variability. In other words, susceptibility and vulnerability increases not so much because of increased uncertainty in hydrologic variability, but more as a function of an inadequate institutional infrastructure required to manage those resources in times of change, harkening back to the words of Gilbert White (1945): **“Floods are acts of God, but flood losses are acts of man”**. In many cases, upgrading the institutional capacity of states and local communities to implement sound water management practices is the most effective way of reducing vulnerability due to climate variability and anticipated changes, and to increase the resilience to large flood disasters.

To place these relatively abstract concepts of robustness, resilience, safety, and reliability within the context of the Mississippi River flood management system:

- ***Robustness*** *can be represented by the built infrastructure of the existing flood control system of reservoirs, levees, pumping stations, urban flood drainage systems and flood warning and evacuation systems that have been designed and constructed to* ***prevent flooding*** *below a certain level of societal risk tolerance, represented by accepted risk criteria (e.g., 100-year return period). Robustness is dominated by structural solutions.*
- ***resilience*** *is represented largely by the assortment of non-structural flood management measures of the type proposed by Gilbert White (1945), along with a suite of post-flood mitigation measures designed to hasten recovery efforts and ameliorate and compensate for post-flood social and economic damages, and having available resources (supplies, manpower and financing) to respond quickly and effectively both during and after a flood event.*
- ***reliability*** *is represented by the ability of the base flood control infrastructure to perform effectively during a wide range of flood events, and withstand the ‘design flood’ (critical infrastructure, pumps, power plants, wastewater treatment and water supply), and to operationally manage the flood effectively through reliable forecasts and timely decisions*
- ***safety*** *means the flood management system, especially the flood warning and evacuation system, has been designed and developed to minimize loss of life during such large flood events.*

Gilbert White, as part of his doctoral dissertation in 1942 (White, 1945) first expounded a set of ideas and principles that have become the basis of the modern strategy for floodplain management. This coherent strategy essentially became the foundation for a robust and resilient flood damage reduction and disaster risk reduction management system. White's concept of flood management consisted of an *"… integration of engineering, geographic, economic, and related techniques"* and that the *"solutions will not involve a single line of public or private action but will call for a combination of all eight types of adjustments, judiciously selected with a view to the most effective use of floodplains."* The eight types of adjustments that White discussed were:

- elevation of occupied portions of the floodplain above maximum flood levels;
- reducing floods through upstream watershed management measures;
- flood protection by levees and floodwalls, channel improvements, and reservoirs;
- emergency actions, flood warning, and evacuation;
- structural adjustments to current buildings;
- land use controls to curb damage-prone areas;
- public relief and disaster assistance programs; and
- flood insurance.

The eight elements of Gilbert White's (1945) classical floodplain management strategy are the foundations of contemporary resilient floodplain management systems. They are well understood and accepted by virtually every practitioner, federal, state, and local agency planners, and have been reinforced and refined in a 30-year series of prestigious national commission reports that addressed the flood related policies of the United States. Yet, flood losses continue to rise and there is still considerable room for improvement, according to the "Galloway Report" (U.S. Interagency Floodplain Management Review Committee, 1994; and Galloway, 2019) regarding the future of floodplain management policies that were in place prior to the devastating upper Mississippi River flood of 1993.

Today, Disaster Risk Reduction (DRR) is underpinned in the U.S. by risk-based decision making, which is viewed as distinct from traditional water resources multi-objective decision making. The main difference in the two approaches appears to be the reality that the federally dominant ‘top-down’ comprehensive river basin oriented planning and governance structures are dissipating and being replaced by more ‘bottom-up’ local and sub-state level governance decision making. This transforms the traditional water-based national economic development focused paradigm to one of sustainable development at the local level. This new paradigm maximizes social well-being, public safety, and risk-reduction strategies for the local populace, subject to numerous environmental constraints (and preferred solutions) imposed by the regulatory agencies (Stakhiv, 2011).

Risk-based decision making and management has also changed from a normative engineering-standards based approach, which relied substantially on flood event probabilities and engineering design infrastructure failure probabilities, to an ‘analytical-deliberative informed consent’ decision approach (NRC, 1996). In the past, flood risks were explicitly dealt with in terms of engineering based threshold standards, such as the ‘100-year flood’, or ‘standard project flood’ or ‘probable maximum flood or hurricane’, with public safety as the principal concern. The new ‘risk-informed decision making’ paradigm is far more complex, as it is based on risk–cost comparisons and tradeoffs among various options, and it engages the affected public for determining their sense of a set of ‘risk-tolerance’ criteria (U.S. Army Corps of Engineers, 2010).

While these conceptual changes in risk management attitudes are worthy, they introduce far greater complexity and variability to the engineering design and decision making processes, making it more difficult to attain uniformity and consistency of outcomes amongst thousands of communities. However, USACE’s most recent engineering and design guidance (U.S. Army Corps of Engineers; 2019a) attempts to rectify this matter by laying out the following principles:

A risk-informed approach will be used for all dam and levee designs for new projects, modifications, improvements, rehabilitation, or repairs. Risk assessments are the cornerstone for application of a risk-informed decision making approach. The following are the overarching principles to follow:

a) **Hold life safety paramount.** While seeking to manage risk to people, property, and the environment, USACE will consider risk to life safety as priority. Tolerable Risk Guidelines (TRGs) will be used as the risk-informed decision goal for life safety.

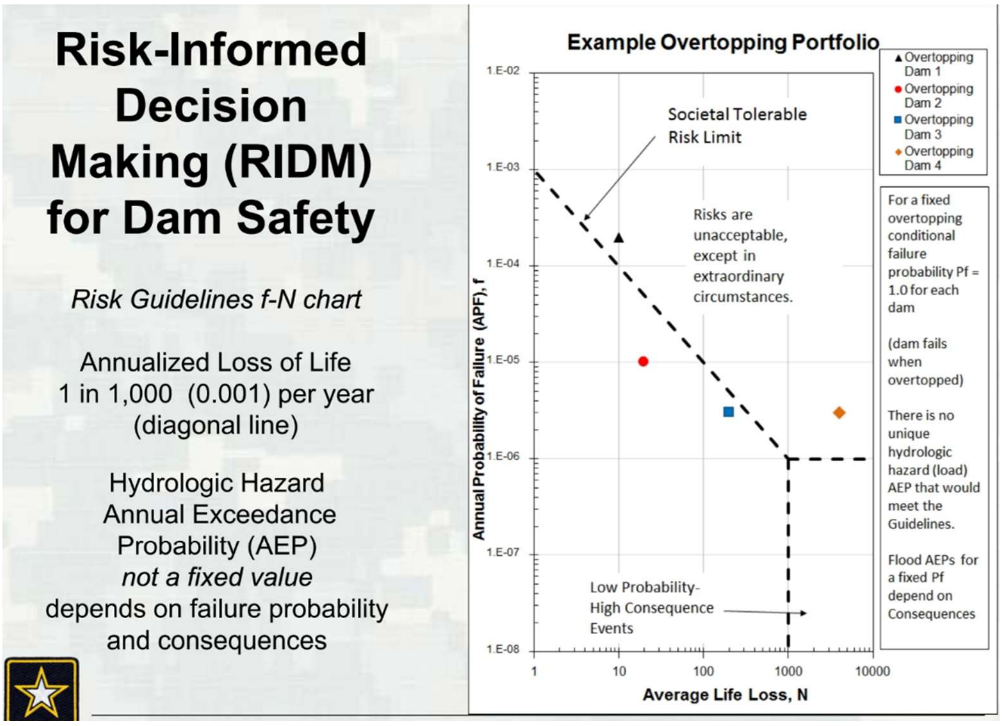
b) Risk-Informed Decision-Making. Decisions for risk management actions will be commensurate with the level of risk that exists when a dam or levee is present to ensure wise federal investments.

c) Ensure open and transparent engagement. USACE will engage project sponsors in all design activities related to their dams and/or levees.

d) Learn and adapt. Risk assessments will be used to evaluate if designs must be up-scaled (i.e., use more stringent design criteria) or downscaled (i.e., use less stringent design criteria) using a risk-informed approach as compared to solely considering traditional standards.

e) Do no harm. Risk-informed designs should not increase the risk to the population and property above the risk the population currently experiences.

Indeed, the USACE most recent guidance on risk analysis and risk tolerance [“Interim Approach for Risk-Informed Designs for Dam and Levee Projects”, 2019a], while advocating risk-informed decision making that balances multiple factors, **still prioritizes life safety as paramount.** The associated planning guidance [ER 1105-2-101] for how to conduct risk assessments for flood risk management studies [in contrast to engineering design guidance] was published in July, 2019 by the USACE [U.S. Army Corps of Engineers, 2019b]. The two complementary guidance documents essentially disaggregate the notion of ‘tolerable risk’ into two distinct components: safety of lives associated with failure of the designed structures and economic damages associated with the causative flood event. The engineering design guidance essentially highlights the risk that analytical procedures address concerning the reliability of the structure to not fail under a range of hydrologic loading conditions.



Risk-Informed Decision Making (RIDM) for Dam Safety

Risk Guidelines f-N chart

Annualized Loss of Life
1 in 1,000 (0.001) per year
(diagonal line)

Hydrologic Hazard
Annual Exceedance
Probability (AEP)
not a fixed value
depends on failure probability
and consequences

Figure 31 – Risk Tolerance for Dam Safety, (U.S. Army Corps of Engineers, 2017)

Quantifying expected loss of life is used to justify safety measures such as adding freeboard to levees, or enhancing spillway design for dams. The planning regulation for conducting flood risk assessments as part of project justification studies, focuses on economic damages used to justify a project's feasibility through benefit-cost analysis. There, the aim is to minimize the 'risk-cost' tradeoff. Clearly, identifying and agreeing on the 'acceptable' or 'tolerable' risk for failure of a levee or dam is the critical aspect of a public risk-informed process. Figure 31 graphically shows what a risk tolerance calculation would look like for dam failure.

5.9.2 Challenges to Implementing Risk Based Flood Risk Management

In 2006, USACE established the National Flood Risk Management Program to advance the goals of flood risk identification, communication, response, and management services across all levels of government to save lives and reduce property damage in the event of floods and coastal storms (USACE; 2017b). All flood risk managers must balance the insights of USACE's professional staff with stakeholder concerns for residual risks, life safety, reliability, resiliency, and cost while acknowledging no single solution will meet all objectives, and trade-offs must always be made.

This public 'risk-informed' evaluation approach requires a great deal more complex and technically sophisticated information and the attention of the public – not just of analysts and decision makers. The public is also asked to bear more of the residual risks and costs, without often fully understanding the consequences.

Quantifying risk and uncertainty is at the center of DRR approaches to increasing resiliency. The core dilemma is previous engineering design standards incorporated a socially determined 'acceptable' level of social risk tolerance, derived through countless failures and repeated improvements. Standards, unlike publicly-derived risk tolerance criteria, have the virtue of being uniformly applied. In contrast, risk-based decision making at the local level is neither replicable nor uniform, requiring loosely connected local solutions, with varying degrees of risk and uncertainty. Achieving consistency in robustness and resilience is the emerging challenge.

One important component of DRR places the onus of understanding the complexities of risk reduction options on the public and local officials. Consequently, for the new paradigm to succeed, the U.S., like other nations, must improve risk communication policies and procedures. Some argue the 100-year flood should be termed the 1% or high risk flood, and the 500-year event as the 0.2% or extreme risk flood, as if that would readily enlighten public attitudes. However, the movement to a risk-based water resources planning and decision-making framework and away from designing to pre-determined engineering design standards does create the possibility of more structures being built in flood hazard zones. Such construction will increase exposure and susceptibility to flooding (Delli-Priscoli and Stakhiv, 2015) as a result of insufficient communication of risk, or more importantly, stakeholder acceptance of risks.

One of the fundamental analytical problems that has emerged is with climate change associated uncertainties, the accepted societal norm of a one-percent tolerable flood risk threshold will likely change. According to Stakhiv (2011), the reason quantifying a risk threshold is important is that it serves as the foundation for several important determinants of various programs:

- National flood insurance program
- Accurate delineation of floodplain areas safe to settle and build
- Economic justification basis (benefit-cost analysis) for structural flood protection projects – size and location
- Engineering design of safe and reliable flood protection infrastructure

Therefore, even with a well-designed and well-executed conventional flood control and damage reduction strategy, based on rationally determined risk thresholds, economic damages, and life loss would be expected to grow because of four primary factors.

1) Technical difficulties in quantifying risk thresholds in an uncertain climate change regime.
2) Growth in population, with greater density in floodplain margins and urban areas susceptible to riverine flooding.
3) Increase in inflation, wealth, and assessed value of land, structures, and contents in flood-prone areas, which automatically increase damages for comparable floods.

Physical alterations of waterways and watersheds which change the characteristics of floods/hydrographs, intensifying peaks of floods and increasing runoff because of expansion of impervious areas in rapidly urbanizing areas.

5.9.3 Challenges in Flood Prediction

One socially defined risk threshold identified by the U.S. National Flood Insurance Program (NFIP), is the one-percent chance flood (1 % chance a given flood will be exceeded), which is also commonly referred to as the 100-year flood. It should be noted engineers and water resources planners use many different flood risk and engineering reliability thresholds, depending on the nature of the hazard and anticipated consequences. Commonly applied thresholds include population at risk; relative vulnerability; potential economic damage; frequency and magnitude of the hazard; and potential for mitigation.

One of the fundamental aspects of flood risk analysis is the ability to quantify a 100-year flood, or its inverse, the 1% chance flood in a stationary climate. Such quantification becomes exceedingly more difficult in a largely unknown, non-stationary climate. A basic issue is the conventional method of fitting a selected probability distribution, such as log-Pearson 3 [LP3], the basis for flood frequency analysis in the U.S. [USGS, 2018], is other probability distributions are equally valid, and various nations use different distributions. European nations lean towards the Generalized Extreme Value [GEV] distribution, as does Japan. Salinas, *et al.* [2014], in a comprehensive survey of over 4,000 European watersheds, found that while the GEV performed better in watersheds where mean annual precipitation was average or above average, LP3 performed better in drier, below average precipitation watersheds.

The selection of an appropriate probability distribution is essential for accurately delineating floodplains and capitalizing national flood insurance funds, as well as selecting the appropriate scale of flood protection infrastructure. Correctly characterizing the flood frequency distribution has the greatest direct influence on the choice of a particular flood management strategy – i.e., deciding whether structural or non-structural flood protection is appropriate for a particular location. Stakhiv [2011] shows how the selection of a probability distribution can dramatically alter the underlying risk analysis and risk tolerance assumptions for any particular location or choice of an alternative project. Figure 32 shows a comparison between the GEV and LP3 probabilities for flood frequency analysis for the same set of data. The graph shows for a given discharge of 25,000 cfs, the LP3 yields a recurrence interval of 100 years, whereas for the same

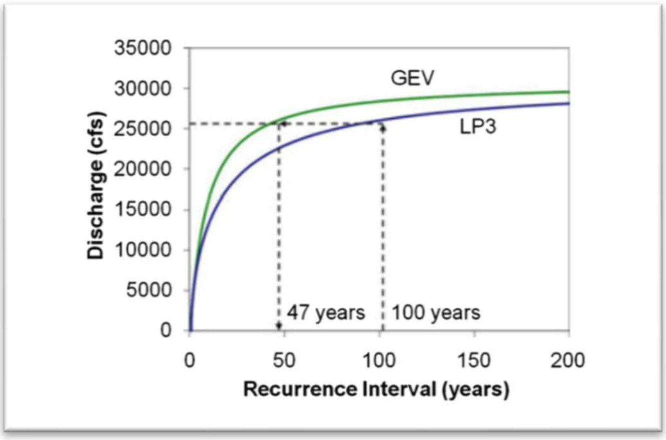


Figure 32 – Comparison of GEV and LP3 flood frequency distributions (Stakhiv, 2011)

discharge, the GEV shows approximates a 47-year interval. Conversely, a 100-year discharge computed by LP3 equates to a 225-year discharge with GEV.

5.9.4 Uncertainty in Flood Risk Design

These large differences in the underlying analytical formulations comprise the basic uncertainties associated with flood frequency analysis. Benefit-cost analysis, which is the primary basis for assessing project feasibility, is based on computations of expected annual damages which, in turn, are based on the selection of a particular probability distribution. The net result is for a given flood discharge, using a GEV distribution would tend to economically justify larger and more robust flood protection structures than the LP3 distribution, by inherently giving more weight to the 'tails' of the distribution – i.e., the large and more rare floods. There are other factors contributing to hydrologic uncertainties – key among them are land use changes and hydraulic alterations of the waterways

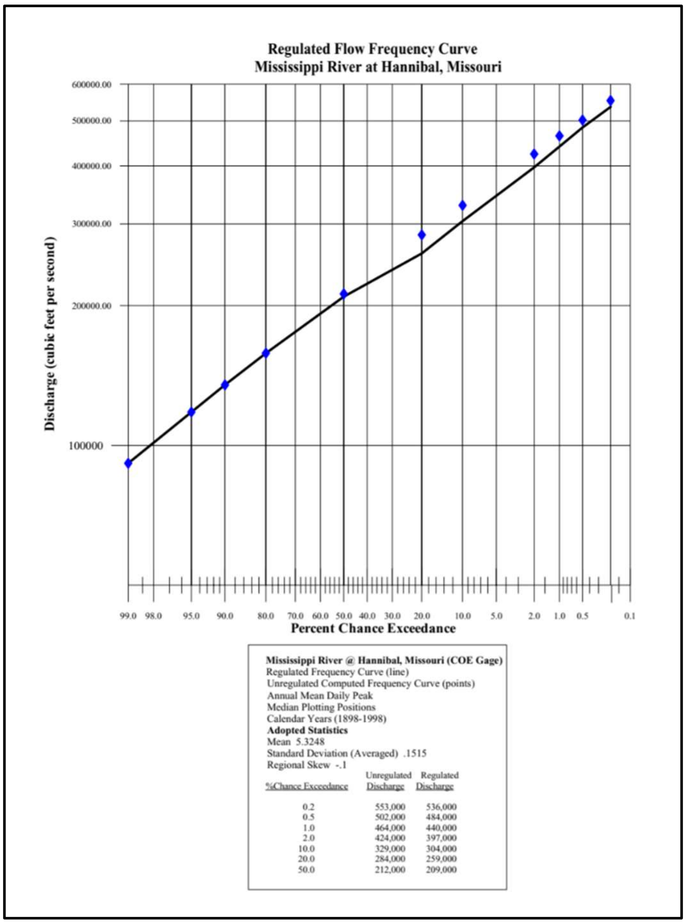
Aside from the basic issue of uncertainties involved with flood frequency analysis is the more complex issue of dealing with climate uncertainty. The core question for planners and engineers is to define an acceptable level of risk tolerance – which will inevitably affect any detailed plans for maximizing resilience, without precisely knowing the frequency of future flood events in a given watershed. What are the risks associated with such unique events, and how to translate this information into infrastructure design and public policy? This is an exceedingly complicated issue and there is considerable discussion and debate amongst academicians and policymakers as to how to characterize and quantify such events (Salas, Obeysekera and Vogel, 2018; Salinas, et al, 2014). Two recent publications, one by the World Bank (Ray and Brown, 2015), and the other by UNESCO (Mendoza *et al.*, 2018) address climate uncertainty and infrastructure design quite effectively through application of a pragmatic 'bottom-up' analysis focused on 'stress tests' of existing infrastructure systems.

Previously, the USACE and most public engineering organizations, resorted to empirical design criteria, such as 'the **flood (or drought) of record'**. Later, this was extended to encompass a concept known as **'the design flood' [or drought]** for levee and embankment structures, which implicitly acknowledged there could be larger floods in the future, where the **'flood of record'** was effectively increased by some incremental percentage. In effect, this became the engineering profession's derived 'tolerable risk threshold' – a risk-cost optimum derived through decades of experience. Next, the concept of the **'probable maximum flood'** was introduced to deal with the possibility of dam failure, as the basis for spillway design. The spillway served as the 'safety valve' feature to accommodate unforeseen, disastrously large floods that could overtop a dam and lead to dam failure. Such catastrophic dam failures can cause even larger uncontrolled disasters than the natural flood itself.

To compensate for these differences and uncertainties, engineers have employed **'safety factors'** and other redundancies in the design of large water infrastructure to increase the safety of the structure and the reliability of the services provided (Yen, 1987; Yen and Tung, 1993). These redundancies account for increased project and system **robustness** to prevent a major catastrophe. On the other hand, resilience – i.e., which is exemplified most through effective response and recovery of damaged systems after a flood disaster – is mainly introduced through adjusting the human habitat in the floodplain with effective resource management technologies.

5.9.5 Impact of Human Intervention on the Mississippi R.

A study conducted by the US Army Corps of Engineers to quantify the flood frequency of the 1993 flood (USACE, 2003), essentially corroborated previous findings that the flood magnitude, based on stream discharge and flood stages, was approximately a 500-year event (Figure 33). However, many man-made factors contributed to increasing and intensifying the peak discharge over a century of growth and development. Waterway constrictions in the form of channelization, levees, bridges,



Mississippi River @ Hannibal, Missouri (COE Gage)
Regulated Frequency Curve (line)
Unregulated Computed Frequency Curve (points)
Annual Mean Daily Peak
Median Plotting Positions
Calendar Years (1898-1998)
Adopted Statistics
Mean 5.3248
Standard Deviation (Averaged) .1515
Regional Skew -.1

%Chance Exceedance	Unregulated Discharge	Regulated Discharge
0.2	553,000	536,000
0.5	502,000	484,000
1.0	464,000	440,000
2.0	424,000	397,000
10.0	329,000	304,000
20.0	284,000	259,000
50.0	212,000	209,000

Figure 33 – Regulated flow frequency curve for Mississippi River at Hannibal, MO (USACE 2003)

locks, etc., and increased runoff from farming practices and urbanization all contributed to intensified flood peaks.

Munoz, *et. al* (2018), however, contends multi-proxy reconstruction of flood frequencies and flood magnitudes over the past 500 years, reveals the magnitude of floods, as measured by percent chance of being exceeded in any year, has increased by 20 per cent over those five centuries, *with about 75 per cent of this increase attributed to river engineering.* They conclude the interaction of human alterations with the Mississippi River system and dynamical modes of climate variability have elevated the current flood hazard to levels unprecedented during the past five centuries. The amplification of flood magnitudes that has occurred over the past 150 years corresponds in time with the intensification of anthropogenic modifications to the lower Mississippi River and basin, particularly the artificial channelization of the river with levees, revetments, and cut-offs in the late nineteenth and early twentieth centuries.

Pinter, *et al.* (2006) further quantify this notion in a comparison of the effects of human and river engineering modifications of the Rhine and Mississippi rivers and concluded:

“On both river systems, channel and floodplain modifications dominated net hydrologic response, overwhelming the effects of climate change, land-use shifts, and dam construction. Specific-gage analysis, which isolates the impacts of instream river modifications, documented declining flow conveyance at all stations where flood levels and frequencies increased. Increased flooding at the Mississippi River sites appears to be driven by the history of aggressive channel engineering, in particular channel constriction to increase navigation depths. In contrast, navigation infrastructure on the Rhine has not substantially degraded the river’s capacity to efficiently convey flood flows.”

5.9.6 Recent Developments in U.S. Flood Risk Management Approaches

Malamud, Turcotte and Barton (1996), all USGS hydrologists, take issue with the Log Pearson 3 (LP3) probability distribution officially used by the US Federal government (Bulletin 17B) to characterize large floods. According to the authors, the 1993 flood was approximately a 1,000 year event, using the LP3 formulation, whereas they believe it was closer to a 100-year event if one applied a different ‘power law function’. The LP3 analysis is the federally adopted probability distribution for flood-frequency estimation of extreme events. They suggest power-law statistics are preferable to LP3 analysis because it does not exclude partial duration series of floods that might occur several times during one year, whereas, the LP3 function relies exclusively on the largest flood in a given year.

Andreas Prein and Andrew Newman, National Center for Atmospheric Research (NCAR) experts in hydrology and hydrometeorology, said land-use changes, stormwater flows and channelization of the Mississippi are "probably overwhelming climate change" as drivers of flood risk. Climate change, they said, acts like an accelerant on flood conditions (Cusick, 2019).

Richard Vogel and colleagues, in a series of groundbreaking papers, have analytically quantified the relative impacts of various land use changes and river engineering alterations on streamflow dynamics, river stages and flood frequency in the United States (Gao, *et al.*, 2009; Vogel, 2011; and Read and Vogel,2015; Salas *et al.* 2018).

In particular, Vogel, *et al.* (2011) state the following, “Using historical flood data across the United States we obtain flood magnification factors in excess of 2-5 for many regions of the United States, particularly those regions with higher population densities. Similarly, we compute recurrence reduction factors that indicate what is now considered the 100-year flood, may become much more common in many watersheds. Nonstationarity in floods can result from a variety of anthropogenic processes including changes in land use, climate, and water use, with likely interactions among those processes making it very difficult to attribute trends to a particular cause.”

Olsen, *et al* (1999) considered the distribution of flood flows in the Upper Mississippi, Lower Missouri, and Illinois Rivers and their relationship to climatic indices. Global climate patterns including El Niño/Southern Oscillation, the Pacific Decadal Oscillation, and the North Atlantic Oscillation explained very little of the variations in flow peaks. However, they did find large and statistically significant upward trends of flood flows in many gauge records along the Upper Mississippi and Missouri Rivers [Figure 34].

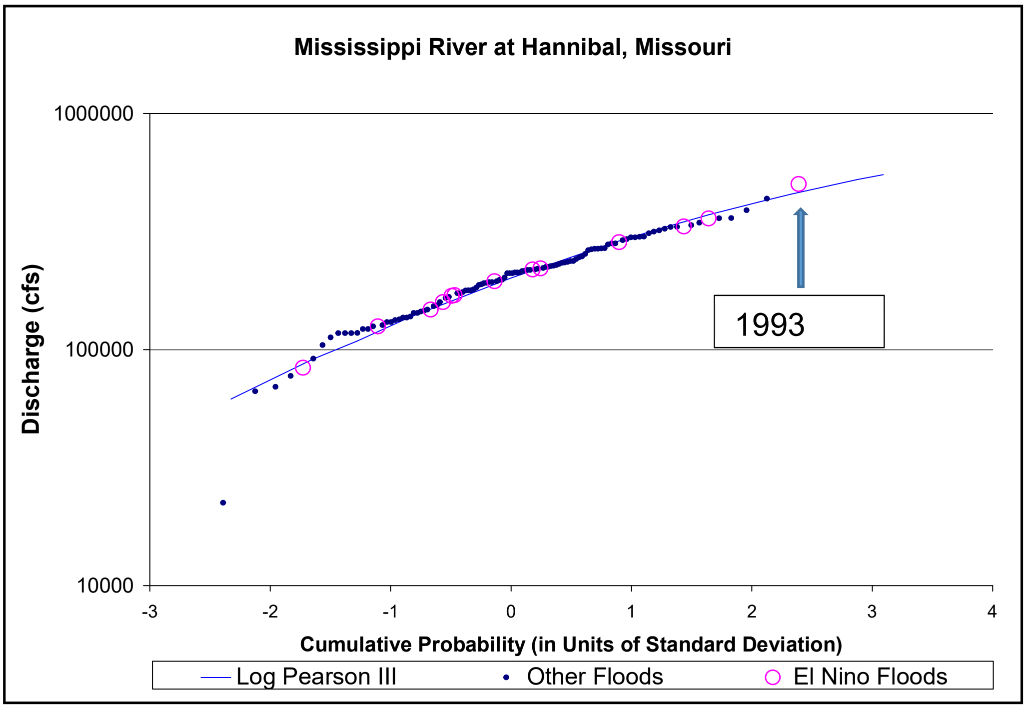


Figure 34 – ENSO-year Flood Events (Olsen, et al, 1999)

One of the more helpful recommendations, to resolve the many different approaches and the discrepancies inherent within, came during the Obama Administration. On Jan 30, 2015, President Obama issued Executive Order 13690 that revised Executive Order 11988 (1977), and proposed a new **Federal Flood Risk Management Standard [FFRMS]** **(**https://obamawhitehouse.archives.gov/the-press-office/2015/01/30/executive-order-establishing-federal-flood-risk-management-standard-and-

> *Section 1. Policy. It is the policy of the United States to improve the resilience of communities and Federal assets against the impacts of flooding. These impacts are anticipated to increase over time due to the effects of climate change and other threats. Losses caused by flooding*

> *affect the environment, our economic prosperity, and public health and safety, each of which affects our national security.*

EO 13690's **federal flood risk reduction standard** was directed only for federally funded projects. The result of those efforts was *the FFRMS represented a flexible standards-based framework to increase resilience* against flooding and help preserve the natural values of floodplains. Incorporating this FFRMS was intended to ensure agencies expanded management from the current base flood level to a higher vertical elevation and corresponding horizontal floodplain to address current and future flood risk and ensure projects funded with taxpayer dollars last as long as intended. The key section, which is related to developing specific FFRM standards reads as follows.

> *(i) Section 6(c) is amended by striking ", including at a minimum, that area subject to a one percent or greater chance of flooding in any given year" and inserting in lieu thereof:*
>
> *"The floodplain shall be established using one of the following approaches:*
>
> *"(i) the elevation and flood hazard area that result from using a climate-informed science approach that uses the best-available, actionable hydrologic and hydraulic data and methods that integrate current and future changes in flooding based on climate science. This approach will also include an emphasis on whether the action is a critical action as one of the factors to be considered when conducting the analysis;*
>
> *"(ii) the elevation and flood hazard area that result from using the freeboard value, reached by adding an additional 2 feet to the base flood elevation for non-critical actions and by adding an additional 3 feet to the base flood elevation for critical actions;*
>
> *"(iii) the area subject to flooding by the 0.2 percent annual chance flood; or*
>
> *"(iv) the elevation and flood hazard area that result from using any other method identified in an update to the FFRMS.*

In other words, because of all of the known, and as yet unresolved scientific disputes about flood frequency analysis under a non-stationary climate, coupled with the need for a more tailored approach considering different types of structures, safety factors, and community risk tolerance preference, the EO laid out four acceptable alternative approaches to undertaking and applying flood frequency based risk analysis. **The E.O. explicitly acknowledges four acceptable approaches for establishing risk tolerance thresholds, depending on particular circumstances and requirements of a community.**

The first, (i), essentially represents a full-blown, climate model based, top-down analysis, linking climate models with future flood frequency estimates. The second, (ii), rests on current standard engineering design practices, which rely on protecting for a 1 percent chance flood (100-year return period), and adds safety factors in the form of **'freeboard'** – a 2 or 3 foot extra level of protection on a levee to account for future unknown uncertainties. The third, (iii) specifies a flood protection standard for a 0.2 percent chance flood (500-year return period), primarily for protecting urban areas and critical infrastructure. The fourth (iv) essentially allows the respective federal agencies (e.g., Dept of Transportation, Bureau of Reclamation, USACE, etc.) who routinely engage in updating engineering design standards to account for advances in technology, computational sciences and future climate-associated risks, to develop new risk-based procedures and methods.

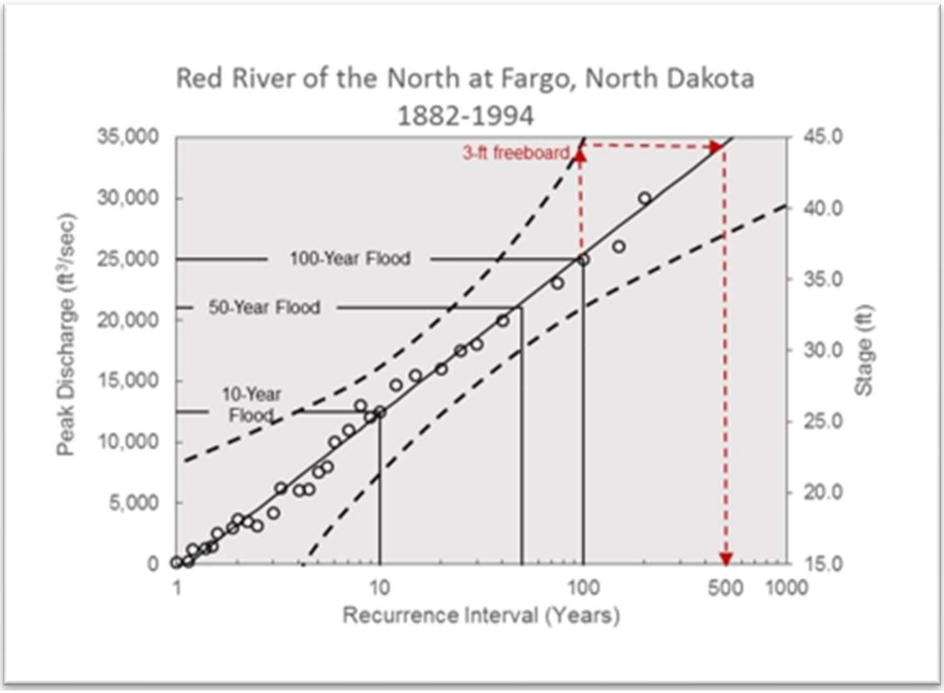


Figure 35 – Freeboard as a safety factor for hydrologic and hydraulic design uncertainties

'Freeboard' is a safety factor that can be viewed in two ways. First, as insurance against uncertainties associated with the computation of hydrologic and hydraulic designs of flood protection infrastructure. Secondly it provides an added 'safety factor' in the design of a levee system. Figure 35 shows how freeboard compensates for the uncertainties and unknowns of engineering analysis – both the hydrologic and hydraulic computations. Freeboard assures the 100-year design flood can be contained within the 95% confidence bounds. It also can be viewed as protecting against a flood of up to a 500-year return period.

While Executive Order 13690 has since been revoked (https://www.whitehouse.gov/presidential-actions/presidential-executive-order-establishing-discipline-accountability-environmental-review-permitting-process-infrastructure/) the concept of allowing federal agencies to apply new and improve existing methods to quantify flood hazard areas and include applications of the best climate and hydrologic science available continues. USACE's most recent planning and design guidance (U.S. Army Corps of Engineers; 2019) is a reflection of this change.

5.10 Observations and Conclusions

5.10.1 The Flood of 2019

1. The flood of 2019, though meteorologically and hydrologically severe, damaged a wide swath of the agricultural community and disrupted commercial transportation for months (navigation and highway transport). However, the flood was effectively contained by the extensive and robust flood control system in place, reducing direct riverine flood damages considerably, in comparison to previous floods of a similar magnitude.
2. Though the *areal extent* of the flooding and the duration of the 2019 flood was far greater than previous disasters, the damages were proportionately far less, considering the population affected, number of households and economic wealth and production affected – industries, commerce, agriculture and lost work-days.
3. Though large swathes of agricultural areas were damaged primarily via excessive rainfall, the flood control infrastructure system proved to be safe, reliable, robust and resilient, especially for the large downstream urban centers (Memphis, St. Louis, Baton Rouge, New Orleans, Vicksburg, etc.) that were especially vulnerable to this large flood.

4. Agricultural damage was considerable, but much of the agricultural economic damage stemmed from excessive and persistent rainfall, during the period Nov 2018- June 2020, rather than direct riverine flooding, preventing new planting of crops.
5. Urban flooding mostly resulted from heavy precipitation that overwhelmed storm drainage and existing sewer infrastructure's ability to convey the resulting stormwater. Future increases in extreme precipitation rates will require significant upgrades to many communities' storm drainage systems.
6. Much of the economic damage to agriculture and businesses was compensated through a variety of federal relief programs, enhancing the recovery of communities and the region.
7. Smaller communities along the river were affected adversely, as many of the very old agricultural levees, designed for floods of less than a 50-year return period, failed. The degree of damage was also exacerbated by the relative in-effectiveness of non-structural flood plain management and other mitigation measures in place for rural communities. Not every community was equally prepared for such a flood, despite recent floods with equivalent hydrological profiles (e.g., floods of 1993 and 2011).

5.10.2 Performance of the Flood Management System

1. 'Managing' for mega-disasters requires a very specialized, higher order integrated system, consisting of a robust infrastructure system that effectively protects against events of at least a 100-year return period; a well-organized flood forecasting, warning and evacuation system; a coordinated flood management system of emergency reservoir releases and decision making; an active and effective disaster assistance organization; and a robust post-recovery system.
2. The Mississippi R. flood control system is a product of successive adaptation to ever increasing frequency and magnitude of floods and population growth, which has placed an evolving array of new demands on the management of the system (environmental flows, wastewater management, municipal and industrial water supply, power cooling water, increased commercial navigation, rising recreational uses and floodplain restrictions).
3. A complex hierarchical system of governance for river basin management has evolved over the past century, with better defined lines of authority and responsibility for mega-disasters. The federal government has taken on greater responsibilities for post-disaster recovery efforts, but many of the socio-economic resilience components remain the responsibility of local entities.
4. Second only to a robust infrastructure system and a critical component of system robustness and resiliency – is the ability to accurately forecast rainfall, storage, releases and river stages to enable coordinated decisions both on the main stem and tributaries of the Mississippi R.
5. Any flood risk reduction strategy must devise socially accepted risk-tolerance design criteria and implement measures that effectively mitigate the inevitable residual risks of natural disasters. This dual strategy constitutes the essence of 'resilience'.
6. The essence of 'resilience' are measures central to quick and effective recovery efforts. Planning and coordinating the implementation and management of a broad array of federal, state, and local post-disaster mitigation measures is the key to a resilient post-disaster recovery. USACE's Silver Jackets program is an example of such coordination.
7. The fact U.S. flood damages are decreasing over time as a proportion of GDP, in the face of apparent increased flood frequency and intensity, is an important indicator of the growing

effectiveness of both structural and non-structural flood control programs as well as floodplain management measures.

8. In the U.S. federal system, a large component of implementing and monitoring 'resilience'-oriented flood reduction measures rests with the inherent authorities of states and local communities. They have the overriding responsibilities for devising floodplain management provisions that depend on local land use planning regulations, building codes,

5.10.3 Overarching Lessons Learned

1. The practice of flood risk management inevitably diverges from an ever-growing list of management principles and goals, because attaining all of the aspirational SDG goals is quite a complex and difficult task, even for a nation with the technological capacity and resources of the U.S., Japan, or Netherlands, or most of the EU nations. Continual upgrading of flood management implementation is necessary.
2. There is an explicit understanding federal, state, and local flood damage reduction policies address some socially acceptable and economically based **risk-bearing threshold – something termed 'tolerable risk'.** Societies – even those who are wealthy, cannot implement absolute **'fail-safe'** strategies. Instead, rational societies advocate **'safe-to-fail'** strategies, consisting of an array of complementary, non-structural measures and compensation programs designed to mitigate expected damages of large floods that **exceed the design capacity of hard infrastructure**. In other words, society has come to accept **residual risks** are inevitable, particularly in a future non-stationary and highly uncertain climate regime.
3. Disaster Risk Reduction (DRR) is underpinned in the U.S. by risk-based decision making, which is viewed as distinct from traditional water resources multi-objective decision making.
4. Risk-based decision making and management has also changed from a normative engineering-standards based approach, which relied substantially on flood event probabilities and engineering design infrastructure failure probabilities, to an 'analytical-deliberative informed consent' decision approach.
5. Community resilience – i.e., which is exemplified most through effective response and recovery of damaged systems after a flood disaster, primarily to deal with the after-effects of 'residual risks' – is mainly attained through adjusting the human habitat in the floodplain environment with effective resource management technologies.
6. In the U.S. system of federalism, different flood prevention and mitigation measures are the responsibility of various levels of government, as well as homeowners and the private sector.
7. A substantial component of national resilience in dealing with mega-disasters rests in macro-economic policies at the federal level. Development and sustainment of economic resilience through a vibrant, flexible, and diversified economy able to cope with shocks, is an essential component of water resources as well.
8. Hydrologic susceptibility and socioeconomic and infrastructure vulnerability increase less due to increased hydrologic variability, but more as a result of inadequate flood risk management infrastructure and management of the built environment within the floodplain.
9. There is a growing change from federally dominant 'top-down' river basin-oriented planning and governance structures to more 'bottom-up' local, sub-state level governance decision making. This transforms the traditional water-based national economic development paradigm to one of sustainable development at the local level, resulting in a less uniform approaches to risk-based decision making.
10. Climate-focused 'robust' designs and upgraded engineering design criteria can reduce future residual risks. But the uncertainties are so large, that towns and communities must always

address ever-increasing residual risks caused by growing uncertainties associated with climate change.

FIGURES

REFERENCES

Botzen, W., Deschenes, O. and M. Sanders, 2019. The Economic Impacts of Natural Disasters: A Review of Models and Empirical Studies, *Review of Environmental Economics and Policy*, Volume 13, Issue 2, Pages 167–188, https://doi.org/10.1093/reep/rez004

Brown, C., Lund, J., Cai, X., Reed, P., Zagona, E., Osfeldt, A., Hall, J., Charaklis, G., Yu, W. and L. Brekke. 2015. The future of water resources systems analysis: Toward a scientific framework for sustainable water management. Water Resources Res. Vol 52(8) pp 6110-6124. **https://doi.org/10.1002/2015WR017114**

Congressional Research Service, 2019(a) Midwest Flooding: FEMA and Other Federal Programs and Resources March 26, 2019 https://crsreports.congress.gov IN11084

Congressional Research Service, 2019(b). Flood Resilience and Risk Reduction: Federal Assistance and Programs, Updated December 17, 2019. CRS Report R45017, prepared for Members and Committees of Congress. https://crsreports.congress.gov

Cusick, D., May 13, 2019. Today's Floods Occur along "a Very Different" Mississippi River. E&E News, Scientific American. https://www.scientificamerican.com/article/todays-floods-occur-along-a-very-different-mississippi-river/

Davis, D., 2015. Sustainable Flood Risk Management. World Environmental and Water Resources Congress 2013: Showcasing the Future © ASCE 2013 pp2665-2677

Delli-Priscoli, J. and E. Stakhiv, 2015. Water-related disaster risk reduction (DRR) management in the United States: floods and storm surges. Water Policy 17, 58–88

England, J.F., Jr., Cohn, T.A., Faber, B.A., Stedinger, J.R., Thomas, W.O., Jr., Veilleux, A.G., Kiang, J.E., and Mason, R.R., Jr., 2018, Guidelines for determining flood flow frequency—Bulletin 17C (ver. 1.1, May 2019): U.S. Geological Survey Techniques and Methods, book 4, chap. B5, 148 p., https://doi.org/10.3133/tm4B5.

Environmental Law and Policy Center, 2019. High Risk Levees along the Upper Mississippi River. http://elpc.org/wp-content/uploads/2019/11/ELPC-High-Risk-Levees-Along-the-Mississippi-River.Nov_.20.19.pdf

European Court of Auditors, 2018. Floods Directive: progress in assessing risks, while planning and implementation need to improve. Special Report No. 25. https://www.eca.europa.eu/Lists/ECADocuments/SR18_25/SR_FLOODS_EN.pdf

EU Water Framework Directive, 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for community action in the field of water policy (OJ L 327, 22.12.2000, p. 1).

EU Flood Risk Management Directive, 2007. Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks (Text with EEA relevance)
OJ L 288, 6.11.2007, p. 27–34

Executive Order 11988, 1977. Floodplain management. 42 FR 26951, 3 CFR, 1977 Comp., p. 117

Fiering, M. B.,1982. Estimating resilience by canonical analysis. Water Resour. Res. 18(1), 51–57.

Flowers, B., 2018. The Economics of Natural Disasters. Page One Economics, Economic Research, Federal Reserve Bank of St. Louis.https://research.stlouisfed.org/publications/page1-econ/2018/05/03/the-economics-of-natural-disasters

Frank, T., 2020. U.S. Army Corps Looks to Avoid Repeat of 2019 Midwest Floods. E&E News on February 3, Scientific American. https://www.scientificamerican.com/article/u-s-army-corps-looks-to-avoid-repeat-of-2019-midwest-floods/

Galloway, G., 2019. Have We Done Enough To Prevent Another Catastrophic Mississippi River Flood?, Environment: Science and Policy for Sustainable Development, 61:5, 37-43, DOI: 10.1080/00139157.2019.1637684

General Accounting Office,

Global Water Partnership, 2000. Integrated Water resources Management, Technical Advisory Committee (TAC) Background Paper No. 4. Stockholm, Sweden. https://www.gwp.org/globalassets/global/toolbox/publications/background-papers/04-integrated-water-resources-management-2000-english.pdf

Haimes, 2009. On the Definition of Resilience in Systems. Risk Analysis. Volume29, Issue4 Pages 498-501 https://doi.org/10.1111/j.1539-6924.2009.01216.x

Hashimoto, T., Stedinger, J. and D. Loucks, 1982. Reliability, resiliency, and vulnerability criteria for water resource system performance evaluation. WATER RESOURCES RESEARCH, VOL. 18, NO. 1, PAGES 14-20,
https://doi.org/10.1029/WR018i001p00014

Interagency Floodplain Management Review Committee (IFMRC), 1994. Sharing the Challenge: Floodplain Management into the 21st Century, Report of the Interagency Floodplain Management Review Committee to the Administration Floodplain Management Task Force (Washington, DC: U.S. Government Printing Office 1994).

Kliesen, K., and K. Bokun, 2019 Crop Prices and Flooding: Will 2019 Be a Repeat of 1993? U.S. Federal Reserve Bank of St. Loius, Thursday, June 6, 2019
https://www.stlouisfed.org/on-the-economy/2019/june/crop-prices-flooding-2019-repeat-1993?print=true

Zbigniew W. Kundzewicz & Eugene Z. Stakhiv (2010) Are climate models “ready for prime time” in water resources management applications, or is more research needed?, Hydrological Sciences Journal, 55:7, 1085-1089, DOI: 10.1080/02626667.2010.513211

Malamud, B., Turcotte, D., and C. Barton, 1996. The 1993 Mississippi River Flood: A One Hundred or a One Thousand Year Event? Environmental and Engineering Geoscience (1996) II (4): 479–486. https://doi.org/10.2113/gseegeosci.II.4.479

Mendoza, G., Jeuken, A., Matthews, J., Stakhiv, E., Kucharski, J., and K. Gilroy 2018. Climate Risk Informed Decision Analysis (CRIDA): collaborative water resources planning for an uncertain future. UNESCO International Centre for Integrated Water Resources Management, Paris, France.

Munoz, S., Giosan, L., Therrell, M. 2018. Climatic control of Mississippi River flood hazard amplified by river engineering. *Nature* **556,** 95–98. https://doi.org/10.1038/nature26145

Nan, C., Sansavini, G., and W. Kröger (2016). Building an Integrated Metric for Quantifying the Resilience of Interdependent Infrastructure Systems. In Critical Information Infrastructures Security (pp. 159-171). Springer International Publishing.

National Research Council 1996. Understanding Risk: Informing Decisions in a Democratic Society. Washington, DC: The National Academies Press. https://doi.org/10.17226/5138.

Olsen, JR, JR Stedinger, NC Matalas, and EZ Stakhiv, 1999. Climate variability and flood frequency estimation for the Upper Mississippi and Lower Missouri Rivers: Journal of the American Water Resources Association (J. Am. Water Resour. Assoc.), vol. 35, no. 6, pp. 1509-1524, Dec 1999.

Pinter, N., Ickes, B., Wlosinski, J. and R. van der Ploeg 2006. Trends in flood stages: Contrasting results from the Mississippi and Rhine River systems. **Journal of Hydrology** Vol 331, Issues 3–4, Pp 554-566

Pielke, Jr, R. 2000. Precipitation and Damaging Floods: Trends in the United States, 1932–97. Journal of Climate 13(20):3625-3637 10.1175/1520-0442(2000)013<3625:PADFTI>2.0.CO;2

Pielke, Jr., R. 2018. The Rightful Place of Science: Disasters & Climate Change. Consortium for Science, Policy& Outcomes. Arizona State U., Tempe AZ.

Ray, P. and C. Brown, 2015. Confronting Climate Uncertainty in Water Resources Planning and Project Design: The Decision Tree Framework, Washington, DC: World Bank. doi:10.1596/978-1-4648-0477-9

Read, L. K., and R. M. Vogel (2015), Reliability, return periods, and risk under nonstationarity, Water Resour. Res., 51, 6381–6398, doi:10.1002/ 2015WR017089

Rautela, P. (2015). Lack of scientific recordkeeping of disaster incidences: A big hurdle in disaster risk reduction in India. International Journal of Disaster Risk Reduction. 15. 10.1016/j.ijdrr.2015.12.005.

Rogers, P. & Fiering, M. (1986) Use of systems analysis in water management. Water Resour. Res. 22(9), 146S–148S.

Salas, J. D., J. Obeysekera & R. M. Vogel (2018) Techniques for assessing water infrastructure for nonstationary extreme events: a review, Hydrological Sciences Journal, 63:3, 325-352, DOI: 10.1080/02626667.2018.1426858

Salinas, J. L., A. Castellarin, A. Viglione, S. Kohnová, and T. R. Kjeldsen, 2014. Regional parent flood frequency distributions in Europe – Part 1: Is the GEV model suitable as a pan-European parent? Hydrol. Earth Syst. Sci., 18, 4381–4389, www.hydrol-earth-syst-sci.net/18/4381/2014/ doi:10.5194/hess-18-4381-2014

Sandifer, P. and A. Walker (2018). Enhancing Disaster Resilience by Reducing Stress-Associated Health Impacts. Frontiers in Public Health. 6. 10.3389/fpubh.2018.00373.

Smith, A. 2020. 2010-2019: A landmark decade of U.S. billion-dollar weather and climate disasters. January 8, 2020. NOAA Climate.Gov. https://www.climate.gov/news-features/blogs/beyond-data/2010-2019-landmark-decade-us-billion-dollar-weather-and-climate

Stakhiv, E., 1995. Floodplain Planning and Management for Extreme Floods. U.S.- Italy Research Workshop on the Hydrometeorology, Impacts, and Management of Extreme Floods Perugia (Italy), November 1995 Department of the Army U.S. Army Corps of Engineers Washington, DC 20314-1000

Stakhiv, E., 2010. Practical approaches to water management under climate change uncertainty Hydrocomplexity: New Tools for Solving Wicked Water Problems. UNESCO Kovacs Colloquium, July 2010 (IAHS Publ. 338, 2010), pp62-69.

Stakhiv, E., 2011. Pragmatic Approaches for Water Management Under Climate Change Uncertainty. Journal of the American Water Resources Association (JAWRA) 47(6):1183–1196. DOI: 10.1111/j.1752-1688.2011.00589.x

UN Intergovernmental Panel on Climate Change, 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)). IPCC, Geneva, Switzerland, 151 pp.

United Nations, 2015a. Transforming our World: The 2030 Agenda for Sustainable Development. A/RES/70/1. New York, NY. sustainabledevelopment.un.org

United Nations, 2015b. Sendai Framework for Disaster Risk Reduction 2015 – 2030. UN Office for Disaster Risk Reduction. New York, NY 32 pp. https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf

United States Government Accountability Office (GAO), 2019. CLIMATE RESILIENCE: A Strategic Investment Approach for High-Priority Projects Could Help Target Federal Resources. GAO-20-127 (a report to the Ranking Member, Subcommittee on Transportation and Infrastructure, Committee on Environment and Public Works, U.S. Senate)

U.S. Army Corps of Engineers, 2003. UPPER MISSISSIPPI RIVER SYSTEM FLOW FREQUENCY STUDY, Rock Island District Mississippi River, Hydrology & Hydraulics Appendix C https://www.mvr.usace.army.mil/Missions/Flood-Risk-Management/Upper-Mississippi-Flow-Frequency-Study/

U.S. Army Corps of Engineers, 2010. Exploration of Tolerable Risk Guidelines for the USACE Levee Safety Program. Proceedings of a Workshop, 17 – 18 March 2010. Institute for Water Resources, IWR Report 10-R-8, Washington, DC. https://www.lrh.usace.army.mil/Portals/38/docs/civil%20works/IWR%20Tolerable%20Risk.pdf

U. S. Army Corps of Engineers, 2017. Principles of Risk Analysis for Water Resources. Institute for Water Resources, IWR Report 2017-R-01.

U.S. Army Corps of Engineers, 2017. Risk Assessment for Flood Risk Management Studies. Engineer, Regulation 1105-2-101. Department of the Army U.S. Army Corps of Engineers Washington, DC 20314-1000. https://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1105-2-101.pdf

U.S. Army Corps of Engineers, 2019a. Interim Approach for Risk-Informed Designs for Dam and Levee Projects. Engineering and Construction, Bulletin No. 2019-15 Issuing Office: CECW-EC Issued: 08 Oct 19 Expires: 08 Oct 21. https://www.wbdg.org/FFC/ARMYCOE/COEECB/ecb_2019_15.pdf

U.S. Army Corps of Engineers, 2019b. Risk assessment for Flood Risk Management Studies. Engineer Regulation 1105-2-101, July 15, 2109 HQUSACE, Washington, DC, https://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1105-2-101.pdf

U. S. Global Change Research Program, 2018. *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*, vol. 2 (Washington, D.C.: 2018).

U.S. Interagency Floodplain Management Review Committee, 1994. "*Sharing the Challenge: Floodplain Management into the 21st Century*". Report to the Administration Floodplain

Management Task Force, Executive Office of the President, Washington, D.C., 191 pp. +Appendices.

U.S. Water Resources Council. 1976. A Unified National Program for Floodplain Management. Washington, DC.

Vogel, Richard M., Chad Yaindl, and Meghan Walter, 2011. Nonstationarity: Flood Magnification and Recurrence Reduction Factors in the United States. Journal of the American Water Resources Association (JAWRA) 47(3):464-474. DOI: 10.1111/j.1752-1688.2011.00541.x

Wied, M., Oehmen, J., Welo, T., 2020. Conceptualizing resilience in engineering systems: An analysis of the literature. J. Systems Engineering, Vol 23(1) 3-13 https://doi.org/10.1002/sys.214912020.

Woods, D. 2015. Four concepts for resilience and the implications for the future of resilience engineering **Reliability Engineering & System Safety** Volume 141, Pg 5-9, https://doi.org/10.1016/j.ress.2015.03.0189

Yen B.C. 1987. Reliability of Hydraulic Structures Possessing Random Loading and Resistance. In: Duckstein L., Plate E.J. (eds) Engineering Reliability and Risk in Water Resources. NATO ASI Series (Series E: Applied Sciences), vol 124. Springer, Dordrecht

Yen, B. and K. Tung (Eds.), 1993. Reliability and Uncertainty Analyses in Hydraulic Design. Report prepared for ASCE Subcommittee on Uncertainty and Reliability Analysis of Hydraulic Structures. American Society of Civil Engineers, New York, NY

6. Kerala Flood: 2019 (India)

Prof. Santosh Kumar

6.1 Summary

Through the Sendai Framework of Disaster Risk Reduction (SFDRR), governments committed in 2015 to making their communities safer and more resilient to disasters by 2030 The same year, governments also confirmed the Sustainable Development Goals and the Paris Agreement on Climate Change. The Government of India is a signatory of all the three international conventions. To achieve the goals of all three conventions, various actions are being taken by different stakeholders, ministries and the state governments. The Government of India is driving all initiatives at all levels for achieving the targets and goals. Previously, disaster risk reduction was never a priority and was often ignored in favour of a focus on post-disaster relief and response. However, the frequency, intensity and impact of disasters have challenged the development process. Due to the high economic impact of disasters, countries are facing growth gaps both projected and achieved. As per the World Bank report of 2003, India on an average loses 2 per cent of its GDP and 12 per cent of its total revenue due to natural disasters.

For reducing adverse impacts of disasters, systematic interventions have been made, bringing major changes in legislation, policies, planning and institutional structure within the country, both centrally and at the state level. The Government of India had developed a national plan for disaster risk reduction in 2017, which was subsequently revised and updated in 2019. The Plan defines the roles and responsibilities of all the central agencies, departments, ministries and institutions and also suggests timelines and strategies to work in close coordination for mainstreaming and achieving DRR.

In a similar pattern, State governments have also developed their disaster management plans.

Kerala is one of the most progressive states of India with higher per capita income, literacy rates, and health facilities. It also has the highest population density (843 per sq km). As per the Census of India 2011, the population of Kerala was 3,34,06,061 or 2.76 percent of India's total population, with a sex ratio of 52 per cent women and 48 percent men. The decadal growth rate of Kerala's population was 4.9 percent, the lowest among the Indian States. On the other hand, Kerala is also one of the most disaster-prone states of India. Although Kerala has rarely encountered any large disasters, the state has identified 39 types of hazards to which the state is exposed. Kerala was, indeed, devastated by a severe flood which occurred between June to August 2018, similar to one that occurred almost 100 years previously in 1924. The Deluge of 2018 cost heavily to the state and the people of Kerala. As per the government of Kerala PDNA Report 2019, more than 433 people were killed. Atypically, nearly three times more men were killed than women, whereas in other states more women usually are lost to these disasters. During the 2018 floods, alertness and promptness of response were lacking both from government and community. Priority for DRR was low, and leaders and citizens were taken by surprise by the unexpected event. During the 2018 floods, the people of Kerala were complacent, so readiness for the response was below average. The State was still handling the long-term recovery process just one year later, when another devastating flood wreaked havoc in Kerala. The 2019 floods in Kerala affected about 1038 villages in 13 districts, killing 125 people. It's interesting to note that in the 2019 floods, 125 lives were lost as compared to 433 deaths in the 2018 floods. Several different things may have contributed to this important reduction in loss of life.

For mitigating the impact of disasters, generally, two categories of actions are recommended – structural and non-structural. In a short period, structural measures can generally only be initiated but are not completed to an extent to be able to produce concrete results. In one year, Kerala, therefore, did not have the capacity and technology to undertake structural measures at such a fast pace as to produce such positive results in terms of reducing the loss of life. Indeed, Kerala was busy conducting Post Disaster Needs Assessments and developing a strategy for a 3- to 5-year long term recovery for Building a New Kerala (Nav Keralam).

However, they could strengthen various non-structural measures with a quick and swift professional response, which helped them in reducing the mortality incurred just one year later. They had, for example, initiated a number of capacity-building activities throughout the state, especially in vulnerable districts and regions. After the devastating floods of 2018, experience combined with implementation strategies of the SFDRR, disaster risk reduction gradually became top priority and a way of life for the government and also the community.

In addition to this, the Government of Kerala, along with support from the Government of India and other State Governments, the Ministry of Defence, the Ministry of Home Affairs, the National Disaster Management Authority, the National Disaster Response Force, the State Fire & Emergency services, fishermen, the media, the private sector and individuals, led one of India's most massive rescue and relief operations in recent times. Collective and focused response minimized casualties in one of the worst floods and landslide events.

Following the overwhelming response of the local community, civil society, volunteers, women's groups and others to the 2018 floods, the citizens of Kerala believed in their own community's capacity, irrespective of caste, culture, class, or religion, to contribute with great solidarity to manage the disaster. Otherwise, the impacts would have been even more devastating. Hence, it is clear that structural recovery measures were still in progress; whereas, non-structural mitigation measures were adopted and implemented. This helped the State in reducing the rate of mortality under similar reoccurring circumstances. This unique learning supports the idea that structural measures are not the only way to reduce risk. Non-structural measures, such as community awareness and engagement, ex-ante involvement of various stakeholders, i.e. women's group, NRIs etc., building early warning systems, last-mile connectivity, or building local response systems, have resulted in commendable impacts in disaster risk reduction as evidenced by the 2019 floods.

Interestingly enough, both, the people and the government of Kerala have demonstrated their resilience yet again while combatting the Covid-19 pandemic. The first and the worst affected state has been able to flatten the curve and become the Covid-19 free state. This reinforces the premise that disaster management should be done through a holistic and all-encompassing approach. Kerala has demonstrated it again and again and has established itself as a model state for leveraging non-structural DRR strategies in a major way, along-with long-term structural measures.

6.2 Overview of Vulnerability and Disaster

6.2.1 Vulnerability Profile of Kerala

Among other natural disasters, flooding is the most common natural hazard in the state of Kerala. Approximately 14.5% of the state's land area is prone to floods, and the proportion is as high as 50% for certain districts [1]. Severe flooding and heavy discharges in rivers can be provoked by intense seasonal monsoons from the South-West (which represents 80% of Kerala's 3000-mm annual precipitation from June to September) and from the North-East (another 10% from October to December). (PDNA-WB, 2019)

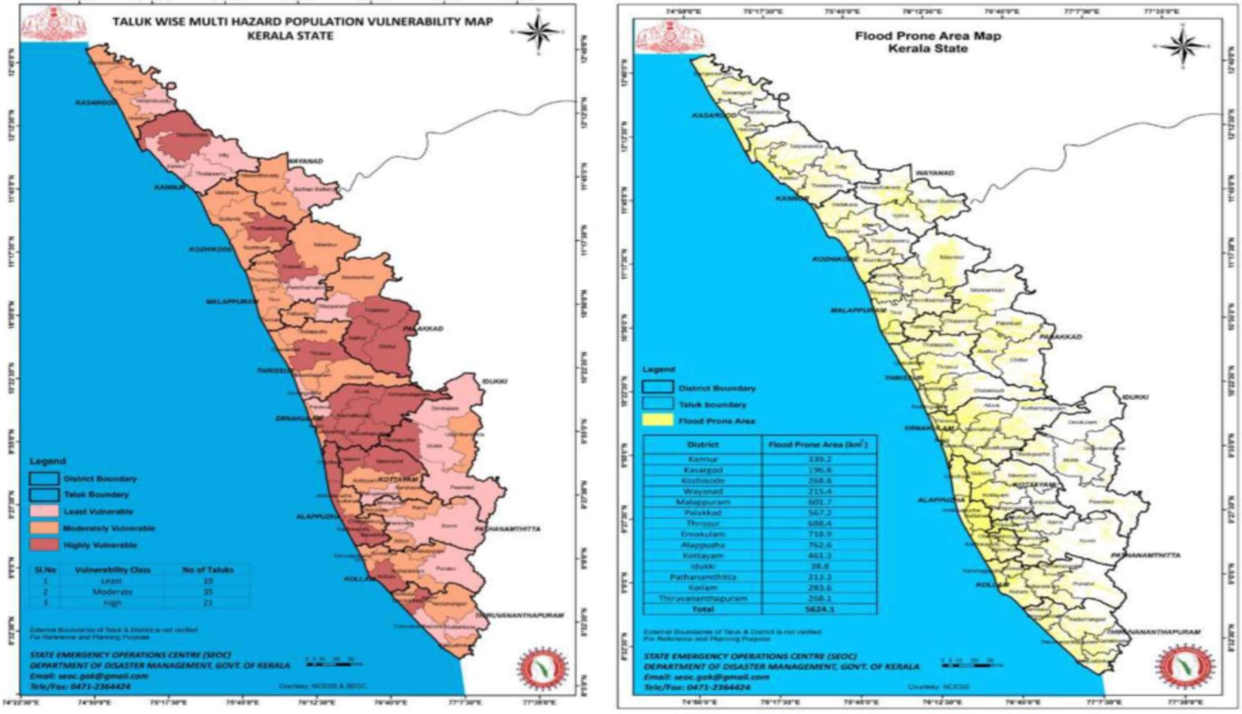
Landslides are a major hazard in eastern Kerala, especially along the western flank of the Western Ghats in Wayanad, Kozhikode, Idukki, and Kottayam districts. Some 1500 sq. km in the Western Ghats are vulnerable, with disaster risks exacerbated by the location of settlements on fragile hillsides. Every year landslides are reported with the onset of monsoons. It is known that a total of 65 fatal landslides occurred between 1961 and 2009, causing the death of 257 individuals (Kuriakose, 2010).

Seasonal drought-like conditions are also common during the summer months. Kerala experienced 66 drought years between 1881 and 2000. Dry rivers and lowering water tables in summer have led to water scarcity both in urban and rural areas.

Other major natural hazards include lightning, forest fires, soil piping, coastal erosion, monsoon storm surges, sea level rise, and high wind speed. The state also lies in seismic zone III.

Kerala is, however, an economically prosperous state as compared to many other Indian states and sits above the national average. Overall, there is less poverty and unemployment, with approximately 9.14% and 4.97% living below the poverty line in rural and urban areas respectively. Kerala has the 8th largest economy in India. Its services sector contributes63.1% to its economy. Industry represents 25.6% with numerous major corporations and manufacturing plants headquartered in Kochi, Kerala. Agriculture generates 11.3%of the economy. In addition, Kerala is an established tourist destination for both Indians and non-Indians alike, contributing to nearly 10% of the state's GDP.

Figure 6.1: Damage due to Floods and Landslides



Sl.No	Vulnerability Class	No of Taluks
1	Least	19
2	Moderate	35
3	High	21

District	Flood Prone Area (km²)
Kannur	339.2
Kasargod	196.8
Kozhikode	268.8
Wayanad	215.4
Malappuram	601.7
Palakkad	567.2
Thrissur	688.4
Ernakulam	718.9
Alappuzha	762.6
Kottayam	463.3
Idukki	38.8
Pathanamthitta	213.3
Kollam	283.6
Thiruvananthapuram	268.1
Total	5624.1

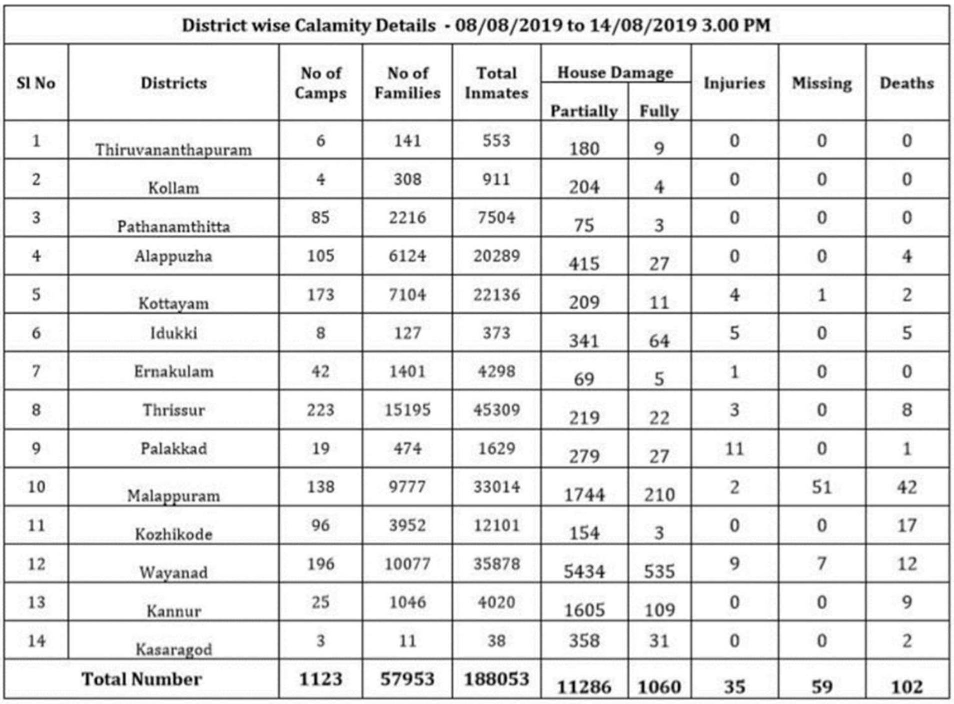
Figure 6.2: Multi-Hazard & Flood Susceptibility Map of Kerala (KSDMA)

6.2.2 The Disaster-2019 Floods

The peak of the rainfall which eventually led to devastating floods and landslides happened from 6 to 14 August 2019. In this period Kerala received 602.2 mm rainfall which is 394% more than the usual expected rainfall (122.0 mm). All districts received over 300% more rainfall during the peak period, with an average deviation of over 350%. Many of the stations of the India Meteorological Department recorded extreme rainfall events (more than 200 mm rainfall in 24 hrs). During this period the Vythiri (Wayanad), Vadakara (Kozhikode), and Ottappalam (Palakkad) stations of IMD recorded more than 1000 mm of rainfall in just 6 days [2]. Evidently, the excessive rainfall and resulting flooding had the cascading effect of provoking landslides, in particular where settlement patterns made areas more vulnerable.

Due to heavy rains, floods and landslides, one hundred and twenty-five (125) lives were lost and 42 persons were injured during the period. Table 6.2 shows the human fatalities reported per district, with Malappuram district suffering the greatest losses and injuries.

Table 6.1: District wise calamity details

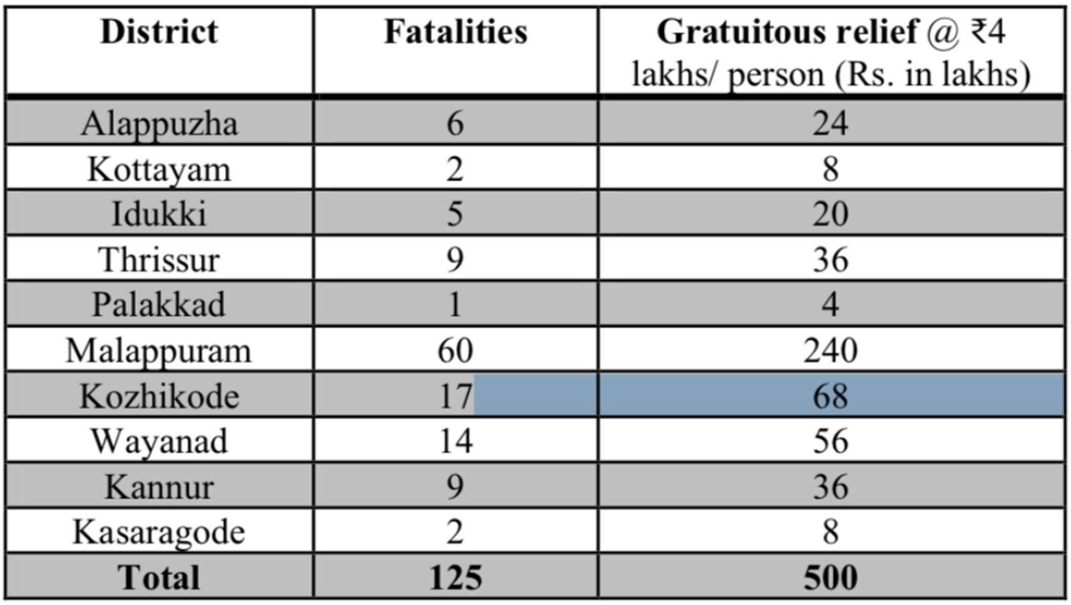


District wise Calamity Details - 08/08/2019 to 14/08/2019 3.00 PM

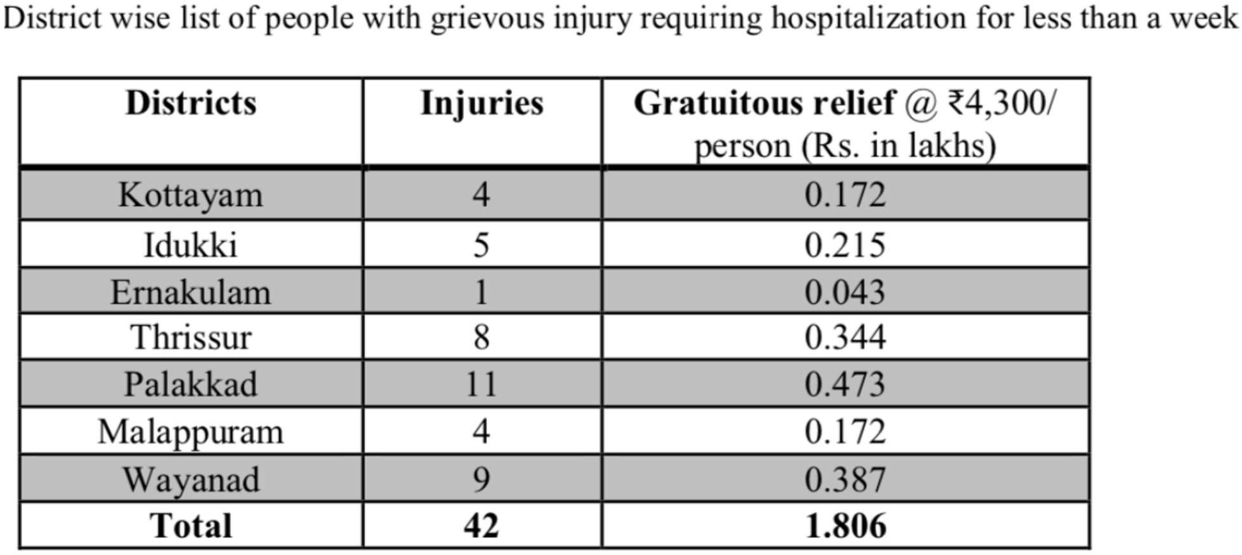
Sl No	Districts	No of Camps	No of Families	Total Inmates	House Damage		Injuries	Missing	Deaths
					Partially	Fully			
1	Thiruvananthapuram	6	141	553	180	9	0	0	0
2	Kollam	4	308	911	204	4	0	0	0
3	Pathanamthitta	85	2216	7504	75	3	0	0	0
4	Alappuzha	105	6124	20289	415	27	0	0	4
5	Kottayam	173	7104	22136	209	11	4	1	2
6	Idukki	8	127	373	341	64	5	0	5
7	Ernakulam	42	1401	4298	69	5	1	0	0
8	Thrissur	223	15195	45309	219	22	3	0	8
9	Palakkad	19	474	1629	279	27	11	0	1
10	Malappuram	138	9777	33014	1744	210	2	51	42
11	Kozhikode	96	3952	12101	154	3	0	0	17
12	Wayanad	196	10077	35878	5434	535	9	7	12
13	Kannur	25	1046	4020	1605	109	0	0	9
14	Kasaragod	3	11	38	358	31	0	0	2
Total Number		**1123**	**57953**	**188053**	**11286**	**1060**	**35**	**59**	**102**

Source: (KSDMA, 2019)

Table 6.2: District-wise Fatalities in 2019 Floods



District	Fatalities	Gratuitous relief @ ₹4 lakhs/ person (Rs. in lakhs)
Alappuzha	6	24
Kottayam	2	8
Idukki	5	20
Thrissur	9	36
Palakkad	1	4
Malappuram	60	240
Kozhikode	17	68
Wayanad	14	56
Kannur	9	36
Kasaragode	2	8
Total	**125**	**500**



District wise list of people with grievous injury requiring hospitalization for less than a week

Districts	Injuries	Gratuitous relief @ ₹4,300/ person (Rs. in lakhs)
Kottayam	4	0.172
Idukki	5	0.215
Ernakulam	1	0.043
Thrissur	8	0.344
Palakkad	11	0.473
Malappuram	4	0.172
Wayanad	9	0.387
Total	**42**	**1.806**

Source: Memorandum of Loss 2019, Govt of Kerala

Most of the losses were reported from northern Kerala which was worst hit.[5] In the Malappuram district, 795 houses were destroyed, and 3,409 houses were partially damaged. In Wayanad, 535 houses collapsed, and 5,435 houses were damaged. (KSDMA 2019). The landslides in Kavalappara in Malappuram and Puthurmala in Wayanad washed away the entire area.

6.2.3 Comparing 2018 to 2019

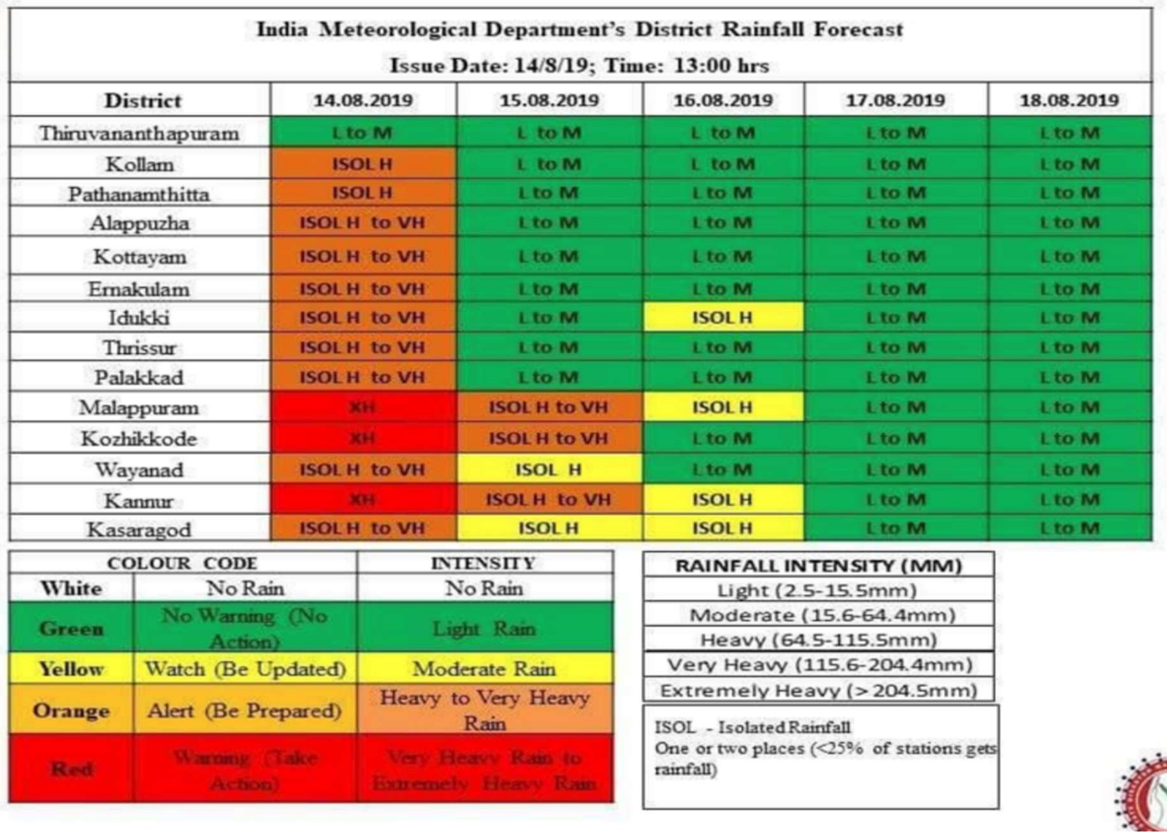
Kerala was affected by significant floods in the two consecutive years of 2018 and 2019. It faced acute impacts as its flood intensity has increased over a shortened timespan. In comparison with August 2018, there were fewer extreme rainfall events in August 2019; however, there was a greater number of rainy days in August 2019, and 10 out of 14 districts recorded a monthly cumulative rainfall higher than in August 2018. Comparing the 2018 and 2019 flood-affected districts, they are similar, although the northern districts were slightly more affected in 2019, and the southern/central districts were more affected in 2018. (KSDMA 2019) In both 2018 and 2019, landslides were an integral part of the cascading disaster.

Kerala floods 2018 had a huge impact on the economy and the people of Kerala. UNDP and the World Bank completed Post Disaster Need Assessments and Damage and loss assessments for developing a long-term recovery framework. The basic principle adopted was to BUILD BACK BETTER. The Government of Kerala further drafted a long-term recovery framework for the state.

The affected districts were engaged in this long-term recovery process, but they were again affected by flooding in 2019. In particular, the resilience of Mallapuram was reduced due to the heavy impact of the 2018 floods and landslides, so its fragility was much higher. No build back better recovery program could have been completed in such a short period of time. The life of people in Kerala was slowly getting back to normal after the 2018 floods, but the rains of 2019 took a toll on the recovery, severely affecting the district.

In the year 2018, Kerala saw the worst floods in a century where 433 lives were lost, and 1260 villages were affected. The Post-Disaster Needs Assessment led by the UN proposed a recuperation cost of Rs. 310 billion [3]. The effect of the floods and landslides in the state uncovered underlying causes that need be addressed immediately. Throughout the years, the state had lost quite a bit of its green spread because of changes in land use, for example, building and street development in the slopes which added to the harmful impacts on the biological system and biodiversity (UNDP, 2018). During the South-west storm of 2019, another downpour hit the state, wherein 1038 towns from 13 districts

Table 6.3: Rainfall data 2019, Kerala



India Meteorological Department's District Rainfall Forecast
Issue Date: 14/8/19; Time: 13:00 hrs

District	14.08.2019	15.08.2019	16.08.2019	17.08.2019	18.08.2019
Thiruvananthapuram	L to M	L to M	L to M	L to M	L to M
Kollam	ISOL H	L to M	L to M	L to M	L to M
Pathanamthitta	ISOL H	L to M	L to M	L to M	L to M
Alappuzha	ISOL H to VH	L to M	L to M	L to M	L to M
Kottayam	ISOL H to VH	L to M	L to M	L to M	L to M
Ernakulam	ISOL H to VH	L to M	L to M	L to M	L to M
Idukki	ISOL H to VH	L to M	ISOL H	L to M	L to M
Thrissur	ISOL H to VH	L to M	L to M	L to M	L to M
Palakkad	ISOL H to VH	L to M	L to M	L to M	L to M
Malappuram	XH	ISOL H to VH	ISOL H	L to M	L to M
Kozhikkode	XH	ISOL H to VH	L to M	L to M	L to M
Wayanad	ISOL H to VH	ISOL H	L to M	L to M	L to M
Kannur	XH	ISOL H to VH	ISOL H	L to M	L to M
Kasaragod	ISOL H to VH	ISOL H	ISOL H	L to M	L to M

COLOUR CODE		INTENSITY
White	No Rain	No Rain
Green	No Warning (No Action)	Light Rain
Yellow	Watch (Be Updated)	Moderate Rain
Orange	Alert (Be Prepared)	Heavy to Very Heavy Rain
Red	Warning (Take Action)	Very Heavy Rain to Extremely Heavy Rain

RAINFALL INTENSITY (MM)
Light (2.5-15.5mm)
Moderate (15.6-64.4mm)
Heavy (64.5-115.5mm)
Very Heavy (115.6-204.4mm)
Extremely Heavy (> 204.5mm)

ISOL - Isolated Rainfall
One or two places (<25% of stations gets rainfall)

Source: IMD, District wise rain forecast (Twitter 2019) were notified as affected by floods and landslides and 125 lives were lost. Sectors like housing, power, and agriculture were badly affected.

On 15 April 2019, the India Meteorological Department (IMD) predicted that the monsoon seasonal rainfall would be 96% of the Long Period Average (LPA). The forecast also suggested maximum probability for normal monsoon rainfall (96-104% of LPA) and low probability for deficient rainfall during the season. IMD issued the 2nd stage of the southwest monsoon season on 31st May 2019 in which they predicted that the monsoon rainfall would be 97% of LPA over the South Peninsula (KSDMA 2019). It was also predicted that the monthly rainfall over the country as a whole was likely to be 99% of the LPA during August. It is also indicated in the 2nd stage that the forecast probability for 'above normal' rainfall was 10% and ‘excessive’ rainfall was only 2%.

Figure 6.4: Rainfall graph from IMD (2019)

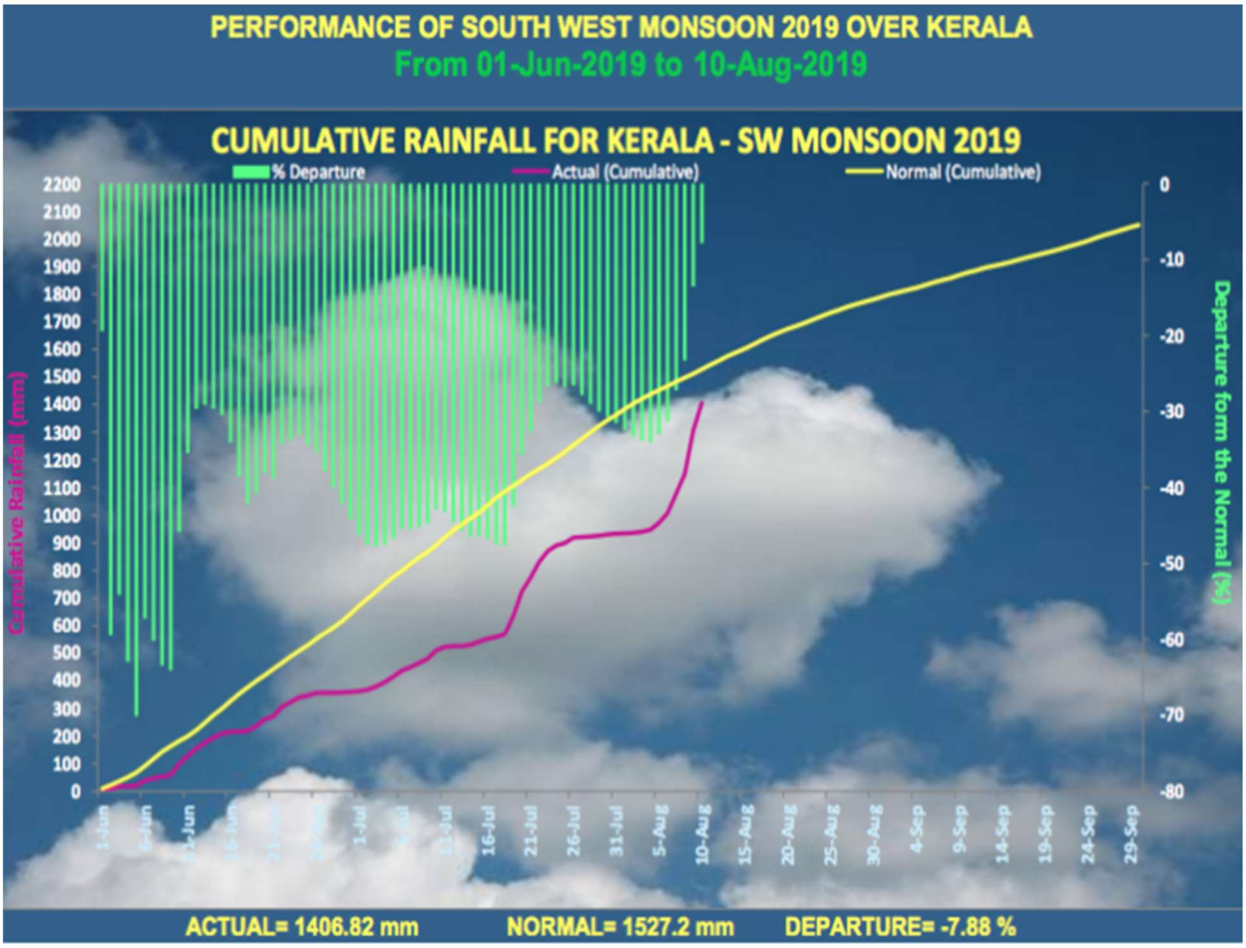
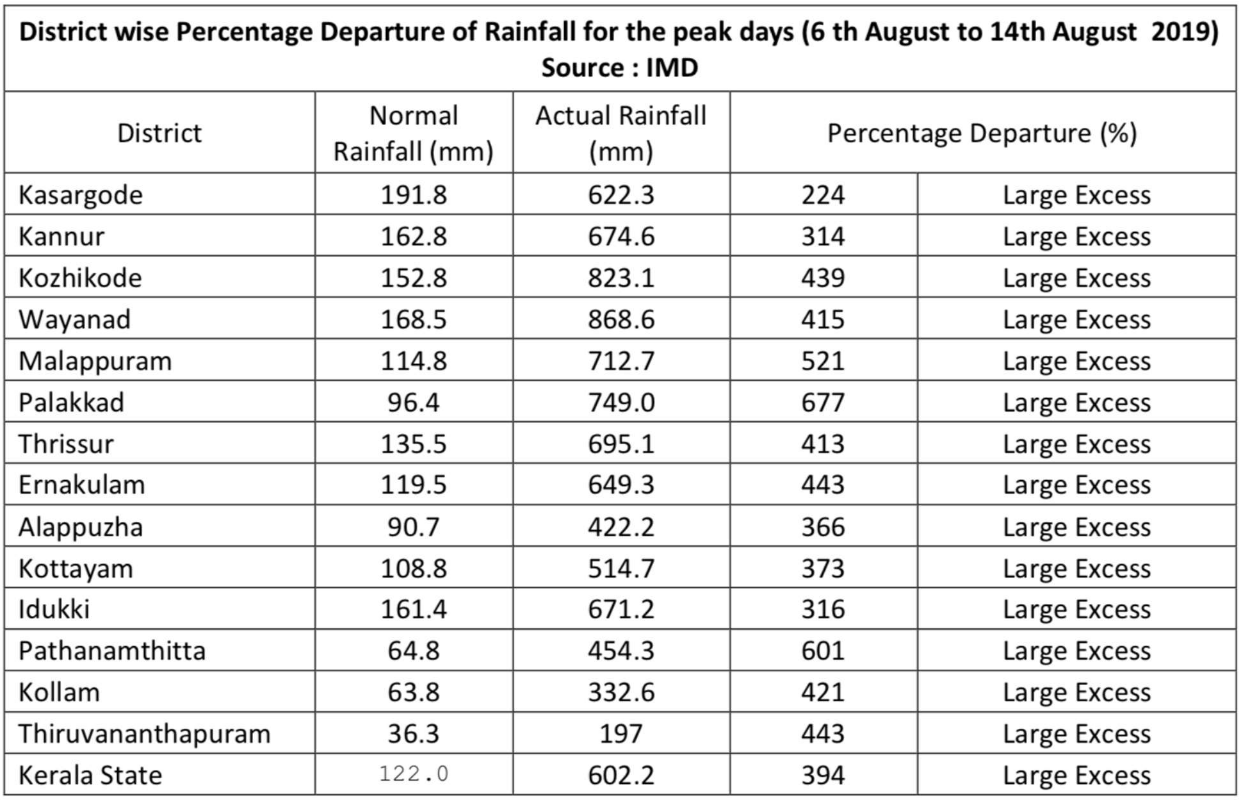


Table 6.4: Deviation from normal rainfall per district (2019)



District wise Percentage Departure of Rainfall for the peak days (6 th August to 14th August 2019)
Source : IMD

District	Normal Rainfall (mm)	Actual Rainfall (mm)	Percentage Departure (%)	
Kasargode	191.8	622.3	224	Large Excess
Kannur	162.8	674.6	314	Large Excess
Kozhikode	152.8	823.1	439	Large Excess
Wayanad	168.5	868.6	415	Large Excess
Malappuram	114.8	712.7	521	Large Excess
Palakkad	96.4	749.0	677	Large Excess
Thrissur	135.5	695.1	413	Large Excess
Ernakulam	119.5	649.3	443	Large Excess
Alappuzha	90.7	422.2	366	Large Excess
Kottayam	108.8	514.7	373	Large Excess
Idukki	161.4	671.2	316	Large Excess
Pathanamthitta	64.8	454.3	601	Large Excess
Kollam	63.8	332.6	421	Large Excess
Thiruvananthapuram	36.3	197	443	Large Excess
Kerala State	122.0	602.2	394	Large Excess

Other factors responsible for multiplying the effects include settlement patterns, location and types of housing, blind development risks, fragile assets, poverty and population density. In addition, inadequate management of dams could also have contributed to damages: Kerala has 57 large dams in the small state, whereas India has a total of more than 5000 dams taller than 15m in height, The damming effect was not reported in the 2019 floods, but in 2018 it was one of the most important causes of damages, along with the rainfall. In 2018, excessive rainfall came over a very short duration of 8 days, which overwhelmed the drainage system, leading to floods. (Santosh, Kerala flood 2018, HELP, GWP)

6.3 Response to Disaster

Action Taken by the Government

Based on the forecast, the State Relief Commissioner convened on 10 May 2019 a meeting of all the departmental heads, district collectors, scientific organizations, IMD, Geological Survey of India, National Centre for Earth Science Studies and representatives of defense forces in which all the stakeholders were assigned specific tasks for better preparedness during the monsoon season. Preparedness at the district level was reviewed by the Chief Minister and Minister for Revenue and Disaster Management at regular intervals and specific instructions were issued regarding the implementation of the decisions of the monsoon preparedness meeting (KSDMA 2019). All District Disaster Management Authorities of the states attended a meeting to ensure that the decisions for the monsoon preparedness were implemented, as was the regular practice for flood management. Soon after the warning issued by IMD and the Central Water Commission, the local governance took action.

As per the documented memorandum of the government of Kerala, the state government responded immediately with rescue and relief operations. An emergency operations centre was opened on 8 August 2019 with deployment from central and state forces with the highest level monitoring and review by Hon’ble Chief Minister *inter-alia* Chairperson SDMA.

- ★ The 24X7 Emergency Operations Centre was further strengthened into a full-fledged control room with representatives of forces including NDRF, Army, Air force, Coast Guard, ETF, MRC, Kerala Police, Fire & Rescue services.
- ★ A State Executive Committee meeting was held on 9 August 2019 to review the overall flood situation of the state. The SEC met the following days (10th August, 11th August) to discuss the critical operations needed in the affected districts, especially Malappuram & Wayanad.
- ★ On 13th August, Hon’ble Chief Minister visited the landslide affected areas and camps along with Revenue Ministers and senior officials to assess the situation.
- ★ Directions were given to camp managers with regard to the provision of food and non-food items in the camp.
- ★ A web portal at www.keralarescue.in was restarted to ensure better supply chain management of goods and services.
- ★ All the districts strengthened their District Emergency Operations Centre with additional staff working 24 x 7.
- ★ Announcements to the public were made and evacuations were done promptly.
- ★ Dam operations were monitored continuously and information on dam water release was disseminated to the public in frequent intervals.
- ★ An Inter-Agency Group (IAG) of NGOs and Civil Society Organizations at the state level was held at KSDMA on 10 August 2019.

The Kerala State Disaster Management Authority had prepared and published a handbook of Standard Operating Procedures (SOP) & Emergency Support Functions Plan (ESFP) for guiding Monsoon Preparedness, known as Orange Book on Disaster Management, which was approved by the State Executive Committee of KSDMA on 6 May 2019. (KSDMA, 2019) It guided the concerned departments to take appropriate action during emergencies.

6.4 Effectiveness of Preparedness

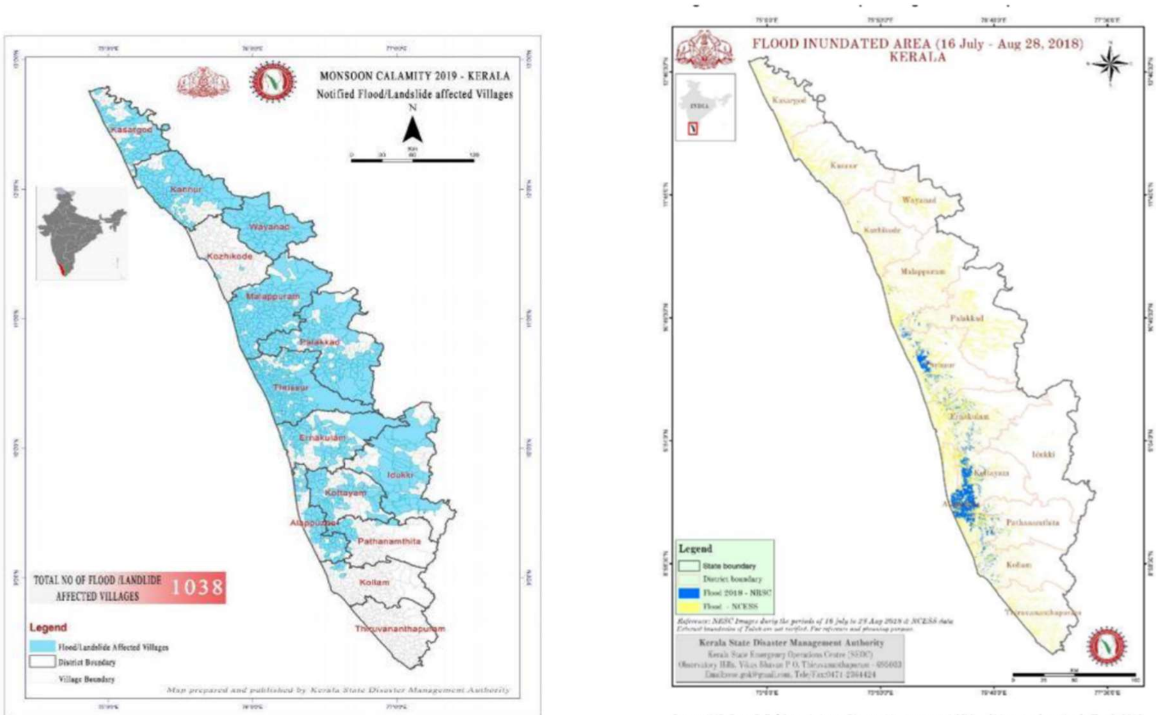
Parliament passed national legislation in 2005 called the disaster management Act of 2005 to develop a disaster management system from the national to local levels. Roles and responsibilities were clearly defined at every level of governance. For strengthening disaster response at the national level, a National Disaster Response Force was constituted with 12 specialized battalions, each containing approximately 895 personnel. The NDRF is a central force supporting the state government in times of disaster.

India is strong in cooperative federalism. Constitutionally, the central Govt provides its assistance to state governments with the additional resources of central agencies. All Government Ministries and departments extend their support to the states upon dire23ction from the National Crisis Management Committee or Ministry of Home Affairs, the nodal ministry for disaster management in India. Various agencies, including the Army, Navy, Coast Guard, NDRF, police force, volunteers and fishermen, contributed immensely to the rescue operations across Kerala.

The floods and series of landslides occurred amid rebuilding activities following the floods in 2018. In the 2018 floods, 15,664 houses were destroyed and of this, 10,840 houses were being rebuilt by the people themselves with the help of the state government. The Care Home project under the Co-operative Department of the state built 1,990 houses which had collapsed in the2018 flood (The Economic Times, 2019). About 1,260 houses were sponsored by various organisations and associations.

The rebuilding activities were taken up by the state government under an initiative called "Rebuild Kerala." Financial assistance- of Rs 400,000 for the families who are rebuilding houses on their own was distributed in three phases. Of these 10,840 families, 10,643 families received the first instalment of financial assistance from the government. For that, the government distributed Rs 840 million. In the second phase of instalments, 7,672 families have received funding, and for this, the government dispensed Rs. 1.04 billion (News Click, 2019). The third phase of financial assistance was distributed to 5,934 families, and of this, 4,457 families have completed the rebuilding works. Under the Care Home scheme, 1,662 houses have been rebuilt so far. With the sponsorship of various organisations and political parties, the construction activities of 545 houses have been completed.

Figure 6.5: Map of flood and landslide affected villages (KSDMA 2019) A & B (2018)



Source: IMD, State Relief Commissioner, Disaster Management, Additional Memorandum, Kerala Floods 2018

KSDMA and Kerala Administrative Institute are gradually revamping the local disaster system and have entered into an agreement with NIDM and USFS to bring the US system of Incident Response System (IRS) to Kerala. The NDRF, too, started operating and gearing up for the IRS to help improve response. The state government is also raising its State Disaster Management Response Force (SDRF) in Odisha.

Disaster Funding System

India has created two Funds for responding to disasters: the National Disaster Response Fund, maintained by the central government, and State Disaster Response Funds, managed by state governments. The National Fund allocates significant funding to all the state governments for immediate response, relief and recovery. The allocation and its criteria are determined by the Finance Commissions.

There is a major departure in the allocation guidelines in that for the first time in the history of disaster management, the Government of India has created an ex-ante mitigation fund to be utilized by state governments. This is due to increasing recognition, following post-disaster damage assessments, for the emergence of a projected and real growth gap in the state Domestic Product. These disaster losses and subsequently dovetailing of development funds failed to achieve the desired growth rates and hence created a “Growth Gap.”

Post-disaster recovery is largely dependent on multilateral funding, and due to the lack of funding, most of the long-term recovery goes unaddressed. For the first time, the 15th Finance commission allocated disaster mitigation and disaster recovery funds for states that are affected by disasters.

The three recent disasters, one Kerala floods 2018, 2019 and Cyclone Fani of Odisha 2019 have almost lost INR 26 billion, 19 billion and 28billion crores (Santosh, Indian Observer Feb 2020). Hence, the recovery cost of Kerala disaster recovery which is almost INR 50000 crores (2018 and 2019 floods) approx. whereas in Odisha it is INR Rs. 29315 crores approx. (PDNA Kerala, DLNA Odisha) The 15th Finance commission has made major breakthroughs for disaster management. First, for the first time it has used the words disaster Risk management (ex-ante investment). Secondly, it has recommended a long overdue Disaster Mitigation Fund along with the response fund. Thirdly, it has included disaster preparedness and capacity building (another pre-disaster fund). Fourthly, it has recommended allocations for post-disaster long-term recovery with the assessment of economic loss, direct property loss, and its impact on the economy. Finally, for the first time, it has not used expenditure-based allocation. (15th FC, Govt of India, Santosh, Indian Observer February, 2020).

These changes significantly improve the governance of disaster risk reduction and support the achievement of the goals of the Sendai Framework. For immediate relief, state governments are meant to implement a norm framed by the government of India. Accordingly, ex-gratia is given in the ex-post support to the affected people and the states. As per the 15th finance commission, these mitigation funds shall be used for those local levels of community-based interventions.

However, the total amount allocated to large-scale interventions, such as the construction of coastal walls or flood embankments, was reduced to INR 289.83 billion for the 2020-21 period. The 15th Finance Commission has also recommended the allocation of long-term disaster recovery funds. To access this fund, the state must undertake a detailed Post Disaster Need Assessment (PDNA), which will give a clear indication of direct, indirect and long-term recovery needs. Out of the total amount of Rs 289.83 billion, the share for SDRF shall be 80percent and share for SDMF 20 percent. (15th Finance commission, Govt of India, Santosh, ICN, Feb 13, 2020). This new arrangement could help the state in bridging funding gaps for recovery and reducing its growth gap.

6.5 Disaster Relief as per SDRF Norms

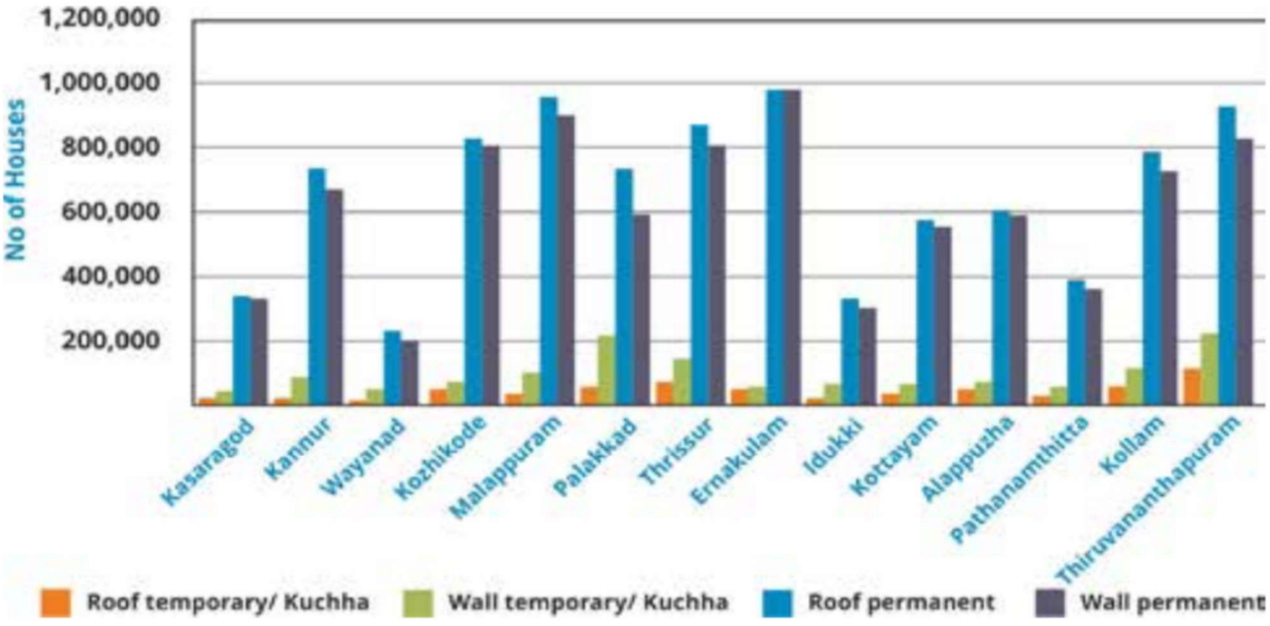
6.5.1 Housing

According to the 2011 housing census, there were 336 houses for every 1000 persons in Kerala. (For all of India, the figure is 273 houses per 1000 persons). The settlement pattern of Kerala is of a rural and urban continuum with different varieties of housing typologies, predominantly reinforced cement concrete (RCC). The housing sector, which has always been fragile, was one of the major sectors to be severely impacted by the flood and landslides. Most of the PDNA conducted across the country reflected that more than 60 percent of losses occurred in the housing sector.

Damages were partial in most cases. As the figure below shows, Kerala has very few kutcha (temporary) houses and, hence, the losses were reduced. Only 1967 houses were destroyed as compared to 19,297 houses that were severely damaged (>75%). The relief amounts have been

Figure 6.6: Housing pattern in the state of Kerala

District-wise pattern of Kuchha and Pucca roofing and walling material in Kerala (CENSUS 2011)



Source: ORGI (2011), Census of India 2011, Office of the Registrar General & Census Commissioner of India, Ministry of Home Affairs, Government of India, New Delhi.

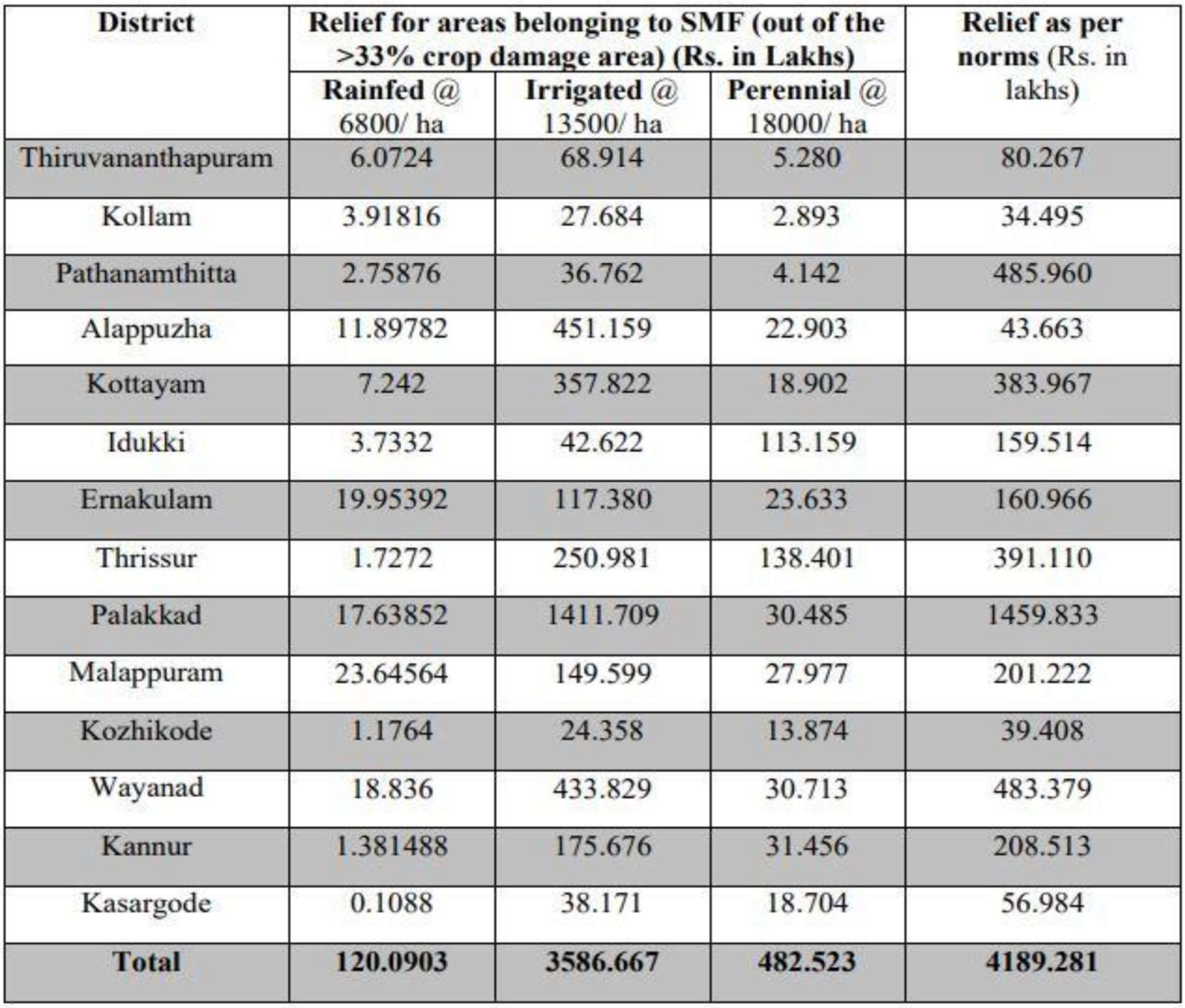
calculated as per the existing norms. i.e. Rs 95,100/- in plain areas and Rs 1,01,900/- in hilly areas (Kerala 2019).

Government relief is also given maximally for the housing rebuild. Massive investment was planned in building a new Kerala in the recovery from the 2018 floods. The Government is implementing Build Back Better in making housing a resilient investment. For DRR, 2800 masons are being recruited for building resilient dwellings. The existing building codes and guidelines are being reviewed for building resilient housing (PDNA 2018) with a timeline for completion by 2022. However, building ordinances and land use planning are not always given due importance when it comes to the execution of the government's development schemes.

6.5.2 Agricultural Loss

Nearly 52% of Kerala's population live in rural areas and 17.15% of the population depends on the agricultural sector (Including crops, livestock and fisheries) for its livelihood.

Table 6.6: Relief Distribution



District	Relief for areas belonging to SMF (out of the >33% crop damage area) (Rs. in Lakhs)			Relief as per norms (Rs. in lakhs)
	Rainfed @ 6800/ ha	Irrigated @ 13500/ ha	Perennial @ 18000/ ha	
Thiruvananthapuram	6.0724	68.914	5.280	80.267
Kollam	3.91816	27.684	2.893	34.495
Pathanamthitta	2.75876	36.762	4.142	485.960
Alappuzha	11.89782	451.159	22.903	43.663
Kottayam	7.242	357.822	18.902	383.967
Idukki	3.7332	42.622	113.159	159.514
Ernakulam	19.95392	117.380	23.633	160.966
Thrissur	1.7272	250.981	138.401	391.110
Palakkad	17.63852	1411.709	30.485	1459.833
Malappuram	23.64564	149.599	27.977	201.222
Kozhikode	1.1764	24.358	13.874	39.408
Wayanad	18.836	433.829	30.713	483.379
Kannur	1.381488	175.676	31.456	208.513
Kasargode	0.1088	38.171	18.704	56.984
Total	**120.0903**	**3586.667**	**482.523**	**4189.281**

Source: (KSDMA 2019)

Figure 6.7 : Damage to the crop across the state

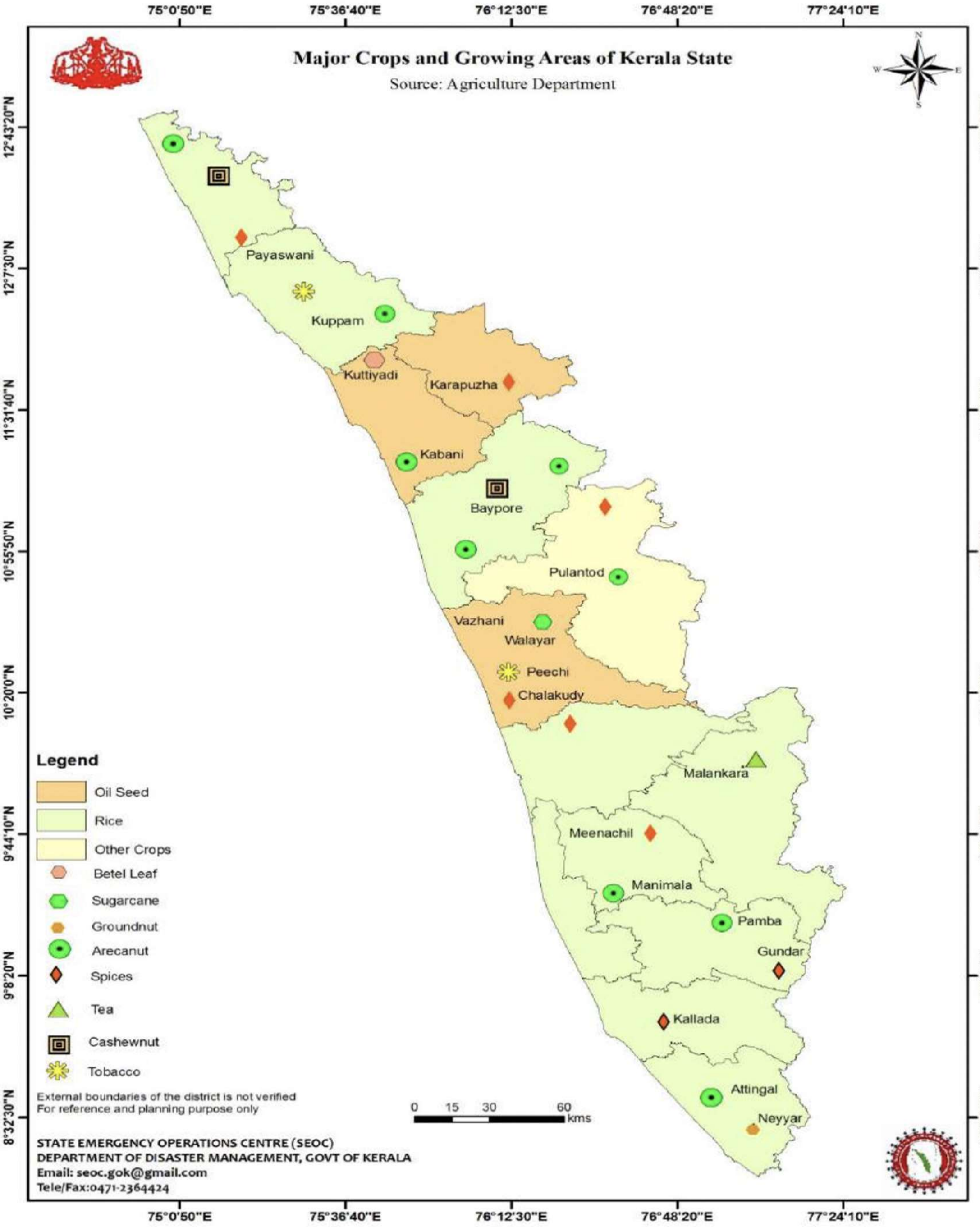
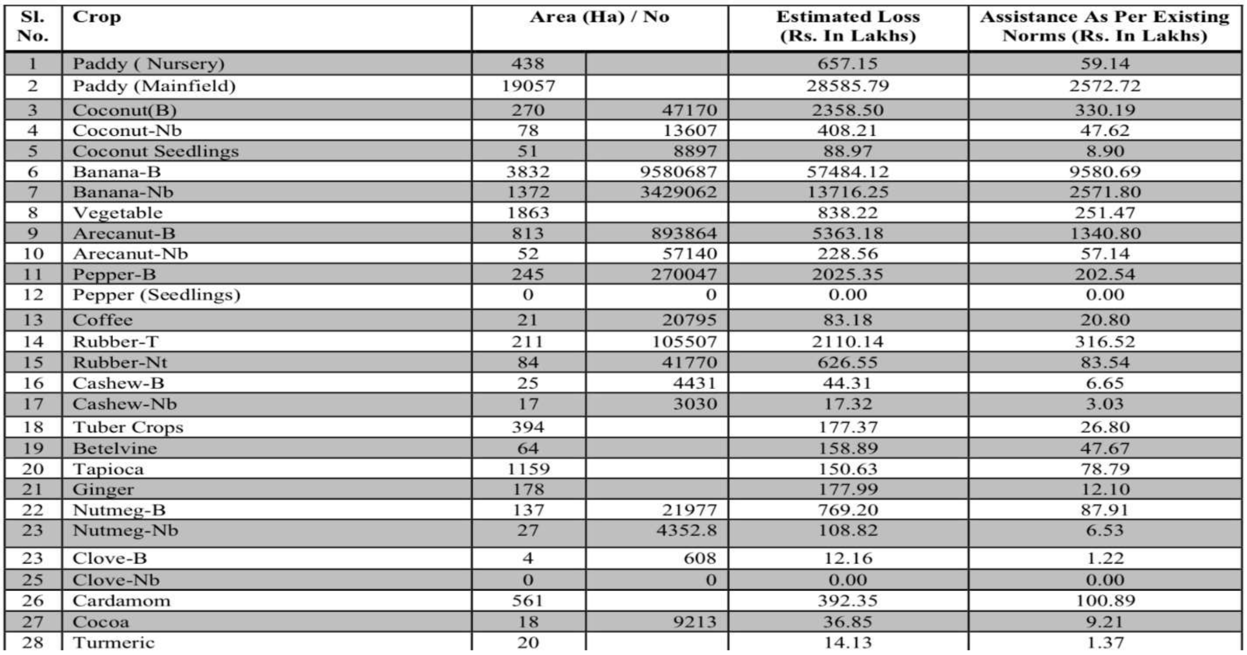


Table 6.7: Damage to the Agricultural sector and assistance provided.



Sl. No.	Crop	Area (Ha) / No		Estimated Loss (Rs. In Lakhs)	Assistance As Per Existing Norms (Rs. In Lakhs)
1	Paddy (Nursery)	438		657.15	59.14
2	Paddy (Mainfield)	19057		28585.79	2572.72
3	Coconut(B)	270	47170	2358.50	330.19
4	Coconut-Nb	78	13607	408.21	47.62
5	Coconut Seedlings	51	8897	88.97	8.90
6	Banana-B	3832	9580687	57484.12	9580.69
7	Banana-Nb	1372	3429062	13716.25	2571.80
8	Vegetable	1863		838.22	251.47
9	Arecanut-B	813	893864	5363.18	1340.80
10	Arecanut-Nb	52	57140	228.56	57.14
11	Pepper-B	245	270047	2025.35	202.54
12	Pepper (Seedlings)	0	0	0.00	0.00
13	Coffee	21	20795	83.18	20.80
14	Rubber-T	211	105507	2110.14	316.52
15	Rubber-Nt	84	41770	626.55	83.54
16	Cashew-B	25	4431	44.31	6.65
17	Cashew-Nb	17	3030	17.32	3.03
18	Tuber Crops	394		177.37	26.80
19	Betelvine	64		158.89	47.67
20	Tapioca	1159		150.63	78.79
21	Ginger	178		177.99	12.10
22	Nutmeg-B	137	21977	769.20	87.91
23	Nutmeg-Nb	27	4352.8	108.82	6.53
23	Clove-B	4	608	12.16	1.22
25	Clove-Nb	0	0	0.00	0.00
26	Cardamom	561		392.35	100.89
27	Cocoa	18	9213	36.85	9.21
28	Turmeric	20		14.13	1.37

To strengthen DRR in the agricultural sector, the government of Kerala is combining the recovery for 2018 and2019 by adopting an integrated flood resilient approach and community-based approach for water resource management. The promotion of ecological farming and the protection of traditional drainage systems as a long-term strategy should be supported, with an immediate recovery of cleaning fields, removing debris, recovering farm machinery, educating farmers on new technology, etc.

6.5.3 Animal Husbandry

The calamity also affected the Animal Husbandry sector. The unprecedented rainfall which triggered flooding in the state resulted in the death of a large number of cattle, buffaloes, goats and poultry. Further, destruction of cattle sheds, shortage of fodder, veterinary medicines and vaccines added to the plight. Damages were awarded for the loss of animals and property ranging from Rs 3,000 to 30,The Ministry of Agriculture and Animal husbandry has created an Animal Husbandry disaster management plan for the protection of livestock. All states have been requested to change the curriculum of veterinary services and provide special training for animal protection during disasters.

6.5.4 Fisheries

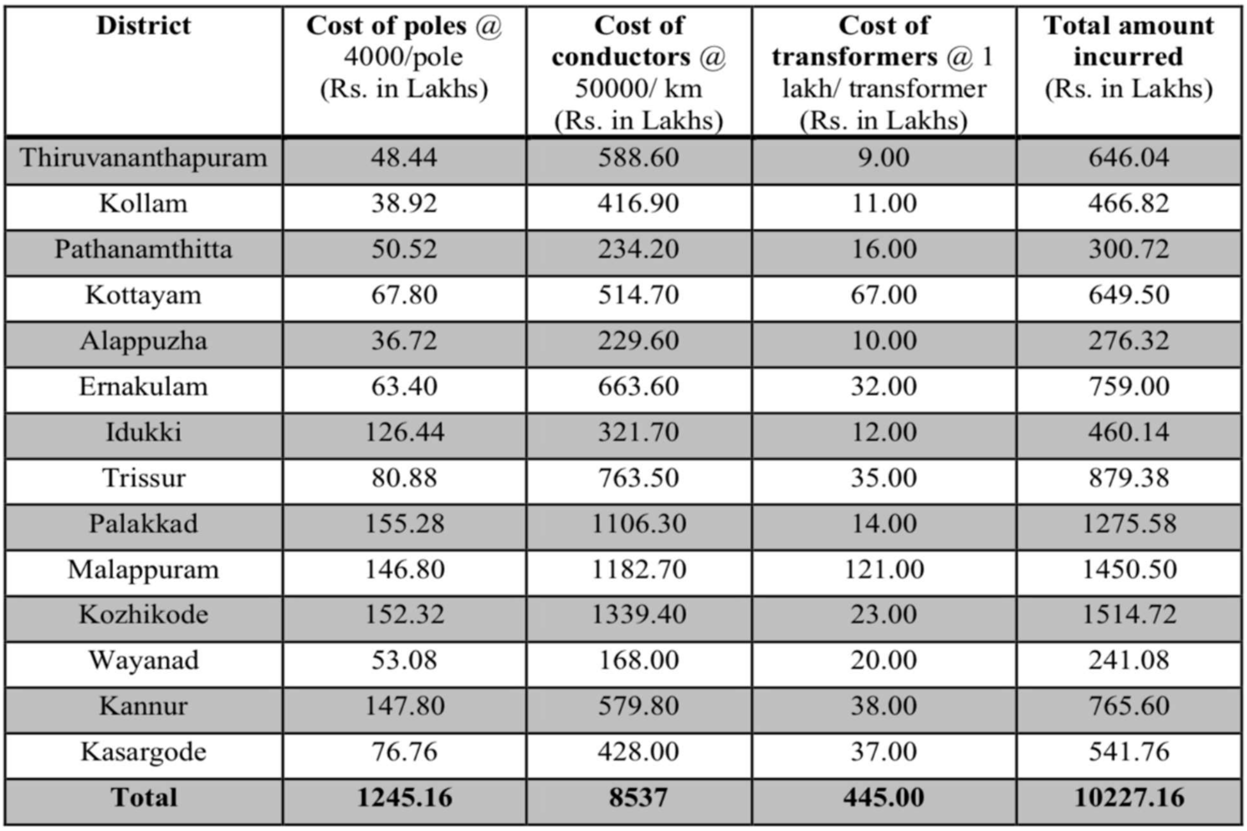
Fisheries is one of the most important and productive sectors of the state, representing about 3% of the economy. The fisheries sector contributes around 1.58% to the total GDP, and the export of marine products reached an all-time record of Rs 59.1902 billion during the 2017-18 period. The aquatic biodiversity and fish wealth of Kerala sustain more than 1 million fisher folk and support numerous additional activities including commercial fishing, aquaculture, tourism, education, etc. The floods and landslides of 2019 caused widespread damages to the fisheries sector and aquaculture of the state. Fishing assets such as boats and nets were destroyed, as well as houses.

The DRR initiative could provide the opportunity for an integrated approach with fisheries, agriculture, horticulture, and aquaculture, aligned with the government of India’s policy. However, agricultural insurance on a parametric basis could also be explored, which will not only ensure crops but agricultural and farm assets too.

6.5.5 Power

The power sector is identified with three major activities: generation, transmission and distribution of energy. The unprecedented rainfall which triggered flooding in the state resulted in heavy loss to all three activities in the Power Sector. The drowning of transfer stations during the flooding caused darkness and also impacted commercial sectors. For the restoration of the power sector, the Government of Kerala provided a total of INR 1.0227 billion rupees. (KSEB 2019) The power and telecom sectors are the most fragile infrastructure when it comes to disasters. Infrastructures are not designed or upgraded sufficiently into account the hazard exposure of the area. The Nav Keralam long-term recovery goal is addressing these issues, and most likely Kerala may become the first resilient state too. The green recovery of the power sector is planned. Alternative sources of energy are being planned, and a maximum focus is placed on solar energy for the state.

Table 6.8: Damage and Assistance for Power Sector Recovery



District	Cost of poles @ 4000/pole (Rs. in Lakhs)	Cost of conductors @ 50000/ km (Rs. in Lakhs)	Cost of transformers @ 1 lakh/ transformer (Rs. in Lakhs)	Total amount incurred (Rs. in Lakhs)
Thiruvananthapuram	48.44	588.60	9.00	646.04
Kollam	38.92	416.90	11.00	466.82
Pathanamthitta	50.52	234.20	16.00	300.72
Kottayam	67.80	514.70	67.00	649.50
Alappuzha	36.72	229.60	10.00	276.32
Ernakulam	63.40	663.60	32.00	759.00
Idukki	126.44	321.70	12.00	460.14
Trissur	80.88	763.50	35.00	879.38
Palakkad	155.28	1106.30	14.00	1275.58
Malappuram	146.80	1182.70	121.00	1450.50
Kozhikode	152.32	1339.40	23.00	1514.72
Wayanad	53.08	168.00	20.00	241.08
Kannur	147.80	579.80	38.00	765.60
Kasargode	76.76	428.00	37.00	541.76
Total	**1245.16**	**8537**	**445.00**	**10227.16**

Source: MOU , KSDMA

The restoration of the power sector has been planned on the principle of build back better. Table 7 shows the damage typology incurred in the generation, transmission and distribution activities. The replacement of transformers is going to be very challenging.

6.5.6 Public Works Department

The Public Works Department (PWD) suffered unprecedented losses in 2019 as evidenced by severe damage to physical infrastructure, especially all types of roads and bridges. A total of 3900.17 kilometres of roads and as many as 95 bridges were damaged in Kerala. (Local self-government department 2019). Around Rs.1.644922 billion would be required for rectifying the damages to bridges.

6.5.7 Irrigation and Water Sector

The gross irrigated area in the state is 540,000 ha. The entire water supply system was disrupted due to the flood. The Kerala Water Authority and Irrigation departments run a large network of water supply for drinking as well as for irrigation purposes. Both of these sectors had a broad network of pipelines and canal systems which were passing through the urban and rural areas in Kerala. Irrigation canals, Public Taps, Pipelines, Pump houses, check dams, Bunds, Irrigation Pumps and other irrigation machinery and structures were damaged due to floods, landslides and landslips (Information Public-Relations Department 2019). Most of the engineering structures were washed away by huge landslides and inundated by flooding. Huge losses in machinery, equipment, structural and non-structural assets have been estimated by the concerned authorities.

6.6 Anecdotes

I AM FOR ALLEPPEY

“***I am for Alleppey***” is a social media campaign launched in 2018 to help the flood-affected Alappuzha district in Kerala. In the flood affected Alleppey district of Kerala in 2018, the district administration took the initiative to support the flood-affected communities. This initiative continued to work in 2019 as well. The campaign was based on the social media platform, Facebook to connect the flood affected communities and government institutions with the donors such as individual contributors, corporates and NGOs in a transparent manner (IamforAlleppy, 2019). The campaign aims at helping flood-affected children; women-headed and marginalised households; people with disabilities; as well as affected institutions such as schools, Anganwadi centres and health centres. The campaign aimed at leaving no one behind who was affected by the flood. It created a depository of data and shares it with the interested donors so that the benefits can reach the affected entities directly.

Under this initiative, it has carried out the installation of water purifiers, restoration of schools, public health promotion, cattle donation etc. Through this campaign, many people joined together by donating money for rebuilding damaged hospitals, houses, Anganwadi and other public institutions in the districts.

Women Power-*Kudumbashree*

Kudunmbashree was most discussed in the 2018 floods for their innovative and powerful work. In the 2019 floods, the legacy of good work continued. *Kudumbashree* workers were active from the initial days of the flood, making packaged meals and distributing them to the last mile affected people. In the first three days of the flooding, some 16,000 food packets were distributed at relief camps in all districts. The mission also mobilised workers from non-affected or less-affected areas to carry out cleaning drives in hard-hit regions (Kudumbashree n.d.). A total of 6,757 women from the *Kudumbashree* groups were mobilised to clean living premises in different municipalities. Each cleaning team comprised about 20 to 25 women, equipped with bleaching and cleaning products. They were supported by the respective panchayats, the Health Department and Accredited Social Health Activists (ASHA workers).

Recognizing and mobilizing women’s skills and capacities as a social force and channelling them to enhance efforts to protect them, their dependents, and their communities is a major accomplishment in any disaster reduction strategy. (Kudumbashree n.d.).

Women are, however, less represented in disaster management at the policy level. There is a need to redefine gender roles and practices by breaking stereotypes. From gender blind to gender redistributive and gender-sensitive planning and policies should be made an integral part of the multi-hazard disaster management system.

6.7 Good Practices and Lessons

In the management of Kerala’s 2018 and 2019 floods, various stories have emerged of worry, threat, courage, heroism, compassion, confusion, despair and generosity.

6.7.1 Preparedness for Uncertainties and Surprises

The Prime Minister of India has outlined a 10-point agenda in the Asian Ministerial conference for building resilience and the implementation of the Sendai Framework in conjunction with climate change adaptation and the sustainable development goals. In redefining the New Normal, an integrated approach for climate change, DRR and Sustainable Development Goals should be redefined. The Government of Kerala has taken risk reduction as a mandatory requirement for its long -erm recovery. Disaster risk reduction and development must work hand in hand in order to reduce the growth gap and mitigate impacts. Building resilience is the new mantra of development.

6.7.2 Better Forecast, Dissemination and Effective Synergy

Off late, the Indian Meteorological department, INCOIS, and regional warning centers have established their scientific credibility in giving accurate warning with low or no deviation between the predicted path and the observed path for a cyclone. This has helped in reducing mortality substantially in India (cyclone Phylin, Hudood, Fani). Likewise, flood warning systems are being modernized through technology. At the national level, cooperation between different entities is improving dissemination and follow-up after forecasts. Clearly defining a line of a protocol would help to make these exchanges more effective and more meaningful, making sure that information reaches everyone to the last mile.

6.7.3 Management of Water

Growing urbanisation and the effects of climate change lead to the need to undertake integrated water management with greater urgency. This includes integrated dam management, establishing proper contour and precipitation inundation maps, formulating effective land management laws and ensuring their enforcement (Savethechildren 2019). An integrated recovery is promoting best practices whereby populations live with water and build with nature. Kerala’s Integrated water resource management program has suggested cross-disciplinary co-ordination of water, land, river basin, watershed or catchment within a complete ecosystem approach.

6.7.4 Plan for Critical Infrastructure

Significant public resources are being invested in almost all the states of the country, as in Kerala. Many in-built infrastructures are not supporting or withstanding the force of nature. The disaster management plans need to ensure that the appropriate design and quality of infrastructure are supported to ensure resilience. The inclusion of risk management and risk-informed development is the key. The Government of India has initiated the establishment of institutional mechanisms for building resilience in infrastructure. The establishment of an international organisation in Delhi -CDRI (Consortium for Disaster Resilient Infrastructure) to demonstrate and support ex-ante resilient infrastructure in the construction of critical infrastructure and its co-benefits would create a new environment of infrastructure. Re-building Kerala has the core principle of Building Back Better in the long-term recovery programme which may change the landscape of the construction sector in future.

6.7.5 Promoting Knowledge, Innovation and Technology

The Kerala floods in 2018 and 2019 was a unique experiment that demonstrated the potential of information technology in both search and rescue operations and relief camp management. It was also prominent in supply chain management, relief distribution, etc. WhatsApp and other social media platforms helped in quick communications and information dissemination.

6.7.5 Inter-state and Inter-agencies Coordination

Many states have common boundaries. Preparedness may bring good dividends to the common states with common risk in addressing the common problems collectively. During the disasters, neighbouring states can help each other through the establishment of Memorandums of Understanding.

6.7.6 Strengthening Cooperative Federalism

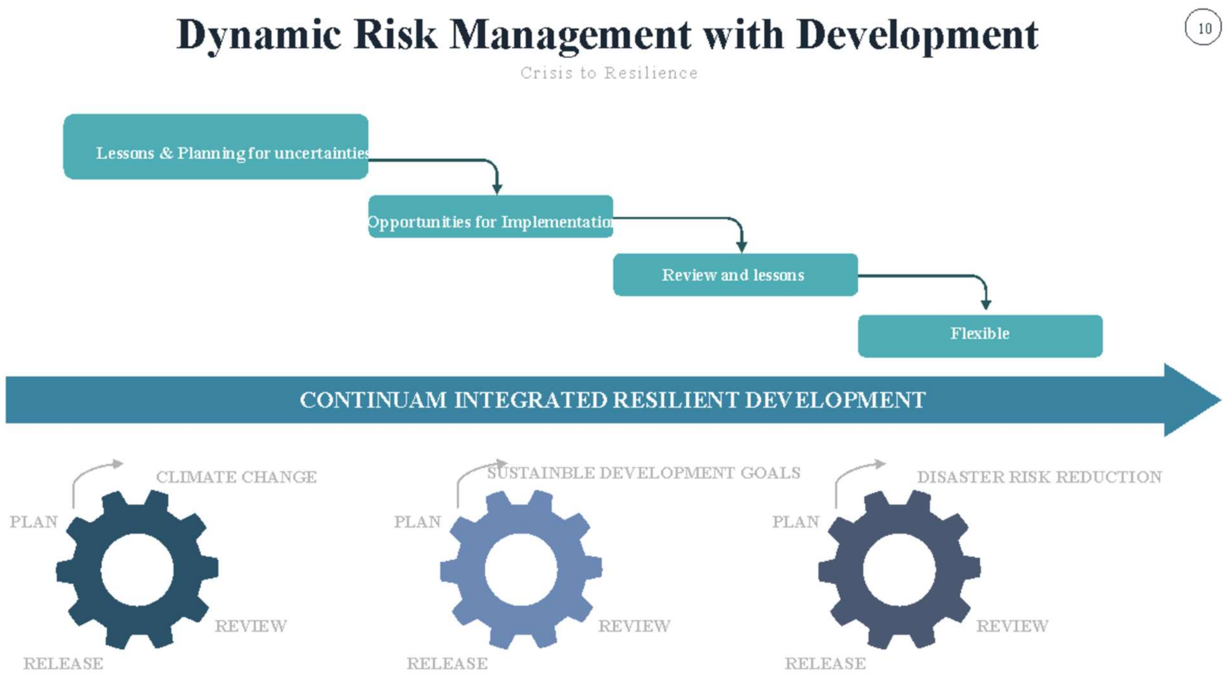
The Disaster Management System of India: India, being the federal structure, disaster management is state subject and the national government is facilitating the efforts of the state governments. At the national level, the Ministry of Home Affairs is the nodal ministry for all matters concerning disaster management. The Central Relief Commissioner (CRC) in the Ministry of Home Affairs is the nodal officer to coordinate relief operations for natural disasters. The Central Relief Commissioner receives information relating to forecasting/warning of a natural calamity from the Indian Meteorological Department (IMD) or the Central Water Commission of the Ministry of Water Resources continuously.

The Ministries/Departments/Organizations that are concerned with the primary and secondary functions relating to the management of disasters include the National Disaster Management Authority (National Policy Wing), the National Institute of Disaster Management (Capacity Building and policy research support) and the National Disaster Response Force (Disaster specialized response force). With these specialized bodies, along with the sectoral departments, the Central government provides support to the state in disaster preparedness, response, relief and long-term recovery along with the financial management system. The Indian government has enacted the Disaster Management Act of 2005, the National Policy on Disaster management in 2009 and the National DM plan in 2019 for the governance of disaster management system.

Constitutionally, Indian states are responsible for managing their own disaster risk. However, significant resources are deployed from the Central government to help them. A stronger institutional system for building cooperative federalism for disaster management and transboundary disasters would be beneficial, especially given the recent experience of COVID-19.

Agencies dealing with disasters, climate change impacts, and the achievement of the Sustainable

Development Goals need to work in close coordination as part of a dynamic cycle. The figure below shows how the review of each model could be done on a regular basis, adjusted iteratively when new learning is obtained. Space for new risks, like COVID-19, need to be considered by policy planners and practitioners in all areas. to reduce risks and to make communities more resilient.



**Conceptualized, Designed & Developed by Prof. Santosh, NIDM*

6.8 Recovery and Reconstruction

Building a New Kerala: Policy Framework for building Nava Keralan (New Kerala)

Figure 6.8: Framework of Building New Kerala

Source : PDNA. Govt Of Kerala. 2019

As the Government strives toward long-term recovery with the participation of all stakeholders, a broad policy framework was drafted based on priorities defined in the PDNA. The flood highlighted many areas of vulnerability, which operated in conjunction to aggravate the impact of the floods. The recovery, therefore, needs to be hinged on a coordinated inter-sectoral approach. This takes us towards sustainability and resilience with equity. The recovery process strategy should build on the states' legacy of public action and people's participation in local governance, upholding the principle of social inclusion. The figure below shows the milestones defined by the Government of Kerala in order to move on in a comprehensive manner. Instead of undertaking two separate recovery plans, they have been merged and are moving forward in line with the state's development plan.

6.9 Conclusion

With an all-inclusive approach and coordination amongst all stakeholders, the impacts of disasters can be mitigated. All sectoral institutions and community organisations have a crucial role to play by coordinating themselves to face the emerging challenges in the new normal.

Risk reduction, ex-ante, is always a better solution to reduce economic costs rather than post-disaster response and relief. Otherwise, the economy will be hugely impacted, and States will continue to face revenue deficits. Post-disaster long term recovery is a challenge as there is a huge funding gap in the requirements and availability. While regional institutions and cooperation need to be strengthened, high-cost structural measures are not the only solution. The loss from flooding in 2019 was reduced because of a number of non-structural mitigation measures taken by the people and the government following the floods of 2018. There are many non-structural solutions that can also be explored and strengthened. Ex-ante investments in early warning, information dissemination, public awareness, community engagement, strengthening local governance, local community capacity building, or local response systems for resilience building is sometimes the only choice for vulnerable communities in changing climatic scenarios, leading to unpredictable disasters.

Kerala is now facing floods, landslides regularly with increasing intensity and frequency. The government should institutionalize the engagement of communities and women's groups along with vulnerable populations as public policy to mitigate longer, indirect impacts of disasters.

Looking for new and innovative solutions and new financial tools will help to attain the common goals between DRR, climate resilience and sustainability, since business as usual will not work in the new normal, especially with the recent added threat of pandemics. Water management must be done holistically in the changing scenario. The Institutions of Excellence to be brought and integrated into a framework of building back better. To quote GAR 2019, "understanding and managing risk is everyone's business and integral to the success of all 2015 agendas. Disaster risk reduction requires an all-of-society engagement and partnership" and "civil society, volunteers, organized voluntary work organizations and community-based organizations need to participate, in collaboration with public institutions, too, inter-alia, advocates for resilient communities that strengthen synergies across groups."

Bibliography

Anandan, S. 2019. *Kerala Floods: Kudumbashree women play big role in clean-up.* The Hindu.

CESS, 2010. Plan Project 239. Detailed Project Report.

DAHD, Department of Animal Husbandry and Dairying. 2019. *Government of Kerala.* http://dahd.nic.in/.

ECHO. 2012. *Recognise the strength of women and girls in reducing disaster risks .* Vietnam: ECHO.

FinancialExpress. 2019. *Kerala Floods 2019 Updates .* Financial Express .

Gokhale, Vasudha. 2008. *Role of women in Disaster Management : An Analytical Study with Reference to Indian Society.* WCEE.

2019. *IamforAlleppy.* http://iamforalleppey.com/.

IMD. 2019.

Information Public-Relations Department, Govt.ofKerala. 2019. *Kerala Calling - Uplifting the spirit of survival.*Government of Kerala.

Kerala, Government of. 2019. *Disaster Management 2019 - orders on distress relief measures to be taken.*Government of Kerala.

Koppikar, Smruti. 2019. *hindustantimes.* https://www.hindustantimes.com/mumbai-news/kerala-flood-some-lessons-to-learn/story-SB1neQHMHP3sJl40s0JozM.html.

KSDMA. 2019. *Memorandum.* Kerala: KSDMA.

KSEB. 2019.

Kudumbashree, GovtofKerala. n.d. http://www.kudumbashree.org/.

Local self-government department, Government of Kerala. 2019. *Flood Relief.* Kerala: Government of Kerala.

Matthew Cappucci, Colin Daileda. 2019. *Kerala floods turn deadly as India suffers relentless monsoonal deluge.*TheWashingtonPost.

Nagendra, Harini. 2019. *Business Standard.* https://www.business-standard.com/article/current-affairs/lessons-from-kerala-floods-the-need-to-change-our-development-approach-118082400371_1.html.

NewsClick. 2019. *Kerala floods 2019.* News Click.

Ports, Department of Fisheries and. 2019. *Flood relief 2019.* Government of Kerala.

Save the children. 2019. *7 lessons to learn from the Kerala floods.* https://www.savethechildren.org.au/our-stories/seven-lessons-to-learn-from-the-kerala-floods.

Shaji, K.A. 2019. *As Flood repeat this year. experts point to climate change .* Mongabay.

Singh, C Balaji. 2019. *DailyO.* https://www.dailyo.in/variety/kerala-floods-lessons-hydrological-disasters-cyclones/story/1/26413.html.

TheEconomicTimes. 2019. *Kerala Floods Live update.* The Economic Times.

Twitter, KSDMA. 2019.

UNDP, ADB, WorldBank. 2018. *Post Disaster Needs Assessment.* Kerala: UN.

Vijayan, Pinarayi. 2019. *TheHindu.* https://www.thehindu.com/news/national/kerala/resilient-rebuilding-lessons-from-the-kerala-floods/article27134928.ece.

7. “Amphan”: A Super Cyclone during “Covid-19” Outbreak

By Malik Fida A. Khan, Executive Director, CEGIS

7.1 Introduction

The coastal region of Bangladesh is situated at the front line of many coastal hazards including tropical cyclones, storm surges, erosion and frequent inundation by high tides causing loss of lives and livelihood and often irreparable damage to infrastructure and the environment. According to an analysis by Bangladesh Bureau of Statistics (BBS) altogether 21 tropical cyclones (wind speed >117 km/hr) and severe cyclones (wind speed between 87 to 117 km/hr) struck between 1960 and 2010. All severe cyclones that have made landfall in Bangladesh during the past 50 years indicate that they would overtop 43 of the existing polders. Previously, Cyclone Sidr (2007) and Cyclone Aila (2009) were accompanied with 3 m to 5.5m level of storm surge brought the saline water into the agricultural lands and also inundated housings of many coastal communities. In total, 13-15 cyclones in last 30 years and 11 cyclones in 100 years from 1876-1977, depicts that frequency and intensity of cyclone is increasing gradually due to climate change. Damages and losses due to tropical cyclones and storm surges that accounted for 0.3% of the GDP under the baseline scenario would rise to 0.6% of GDP in 2050 (TNC, 2018). The super cyclone ‘Amphan’ very recently in 2020 hit the southwest coast of Bangladesh and caused significant losses and damages to life and property during global pandemic COVID19. The pandemic had already brought Bangladesh to a grinding halt since March 2020, with numerous cases being reported and thousands more losing their livelihoods due to the lockdown measures. The combination of Covid and Amphan caused further disruption to lives and livelihood especially for marginalized communities living in disaster-prone area and created extreme challenges for disaster management. This article focuses on revealing the scientific facts and overview of cyclone ‘Amphan’ including its loss and damages to life and property, responses from local, national and international level for disaster preparedness faced by disaster risk reduction implementation during global pandemic COVID-19.

7.2 Overview of Cyclone “Amphan”

Amphan originated from low pressure area prevailing at 300km east of Colombo, Srilanka on 13th May, 2020. This Tropical Cyclone is the 2nd strongest cyclone since Sidr (2007) to strike the Ganges Delta and the first super cyclone to occur in the Bay of Bengal since Odisha Cyclone (1999). This cyclone appeared as one of the most powerful cyclones in the Bay of Bengal worth BDT 11 billion (USD 130 million) of damages in Bangladesh. On 16 May, the India Meteorological Department (IMD) reported that the area of low pressure had developed into a depression and designated it as BOB 01. From the assessment of JTWC, on 17 May, upper level winds conduced the intensification more and as a result the increase in wind speed was observed from 140 km/h (85 mph) at 12:00 UTC to 215 km/h (130 mph). Cyclone Amphan had weakened from a super cyclone to an "extremely severe cyclonic storm" between the 20th and the 21st May 2020, causing strong winds and heavy rain in parts of Odisha, West Bengal in India and Bangladesh coastal areas as it advanced towards the India- Bangladesh coast.

Scientific Facts (Main cause and physical aspects of “Amphan”)

On 13th May, 2020, an area of low pressure developed over the South-eastern part of Bay of Bengal; about 1020 km (635 mi) to the southeast of Visakhapatnam, India. Due to warm sea surface temperatures, good equator-ward outflow and low vertical wind shear, the area of low pressure was in a favorable environment for rapid development (United States Joint Typhoon Warning Center). Within next couple of days, the system became gradually consolidated with bands of deep atmospheric convection wrapping into the system's low-level center and on 16 May, the area of low pressure had fully developed into a depression and started to move northwards (IMD Report, 14 May 2020). Along its pathway towards north, the depression continually organized and eventually turned into a cyclonic storm within a few hours, receiving the name “Amphan"(WMO/ESCAP)

After going through continuous consolidation and gaining fierce force, on 19 May, the cyclone turned into a ‘super cyclone’ lying over west central Bay and adjoining area (about 890 km southwest of the port city Chattogram previously known as Chittagong) and started to move towards more north to northeast. On 20 May, the Bangladesh Meteorological Department (BMD) issued "Signal Number Great Danger 2" for costal districts in the southern part of the country and their off-shore islands and chars. The cyclone slammed into the coastal districts of West Bengal, India and then it entered Bangladesh at the evening (6 pm BST) with a fierce wind speed of 150 kmph and drove its destruction among 26 southern and south western districts across the country.

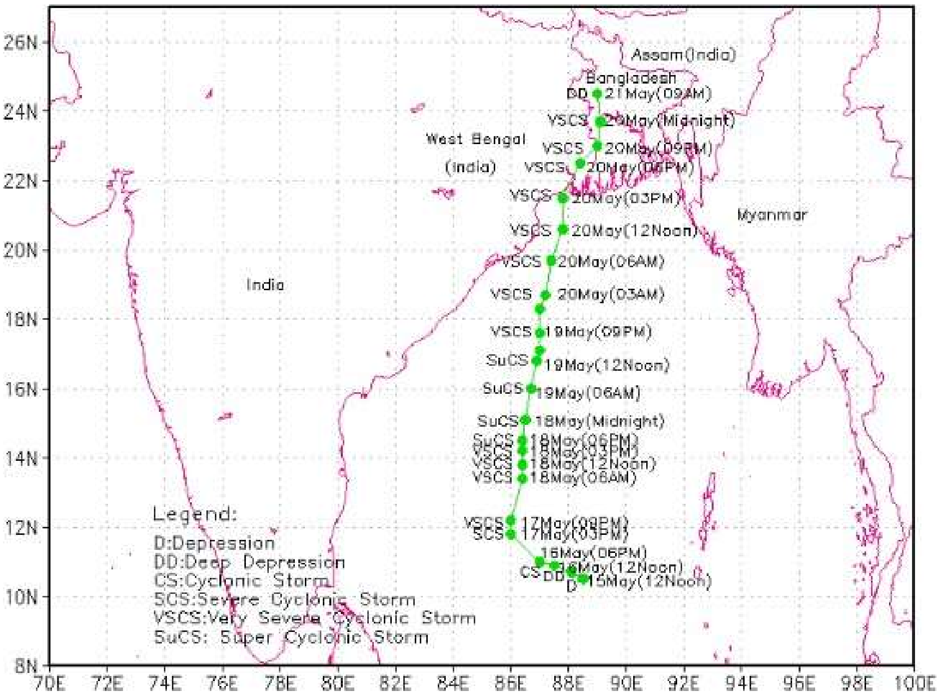


Figure 7.1: Observed Track of Super Cyclonic Storm Amphan (15-21 May, 2020)

When the storm moved through the delta, the Sundarbans with its thick mangrove forest once again not only acted as a protective shield in reducing wind speed drastically but also helped in breaking the waves and depleting triggering surges. Figure: 1 illustrates the observed track of "Amphan" during 15- 21 May, 2020. (Source: Bangladesh Meteorological Department).

7.3 Outline of Damage

Around 50% of the 47,201 sq km coastal areas in Bangladesh were severely to moderately affected by this disaster. More than 2.6 million people were affected and the death toll was recorded at 26 people; most of the deaths were crushed by falling trees, electrocuted by downed wires or buried inside collapsing buildings as cyclone Amphan pummeled the region (IFRCS, 2020). More than 200,000 houses were fully or partially damaged, and around 162,000 houses were partially damaged along with more than 176,000 hectares of productive land with standing crops and fish farms worth about BDT 3.25 billion (CHF 36 million). As water broke through embankments, 1,80,500 hatcheries, fish and shrimp farms were washed away, caused damages of around 18,707 ha of prawn and fish cultivation area, lost 14,268 livestock. The transportation system was severely damaged as 415 km of roads, 200 bridges and more than 150 km of embankments of 13 districts were breached in 84 points (MoWR) leading to intrusion the saltwater into the localities. Hundreds of trees were uprooted; mango orchards, paddy fields and other crops in most of the upazilla under Satkhira district – including Shyamnagar, Kaliganj, Ashashuni and Tala were completely damaged. The cyclonic storm cut off the power supply to around 60% of network towers (13,000 in number) of the region and about 15 million clients lost electricity. The cyclone damaged mangoes worth approximately Tk150 crore. The coastal region had to go through serious scarcity of safe drinking water source as approximately 18,235 water points were intruded. The sanitation system was disrupted as more than 40,894 latrines were completely or partially destroyed. Apart from that, the health & nutrition services were disrupted and inaccessible in many places due to lack of resources, the loss and damage of infrastructure and facilities caused by the cyclone. Assessment of Forest Department (FD) reveals around 1.67 crore

BDT of damages in the east Sundarbans, that include damages of 21 solar panels, 16 water tanks, 18 jetties made by wood, 17 ponds, 16 offices, eight staff barracks and one watch tower. Besides, several logs of Sundari trees, seized from smugglers, washed away due to the tidal surge caused by the cyclone while many trees in different office areas were uprooted during the storm. However, no evidence of losses of naturally-grown mangroves and planted trees were found. Total cost of damages caused by the cyclone in Bangladesh is about BDT 11 billion[1].

7.4 Response to Cyclone "Amphan"

Although it was extremely challenging for Bangladesh to face the twin perils of a super-cyclone and Covid-19 at the same time, through early preparedness, Inter-agency collaboration, coordination and quick response the country rose up to the challenge and managed to handle the hazardous situation.

7.4.1 Response at National Level

The Government of Bangladesh (GoB) prepared for the cyclone through the leadership of Ministry of Disaster Management and Relief (MoDMR) which started with coordination meetings with all relevant government and non-government stakeholders from 16 May. Government, non-government and other voluntary agencies worked together to prepare the refugee camps for Cyclone Amphan's impact based on Bangladesh Meteorological Department's (BMD) cyclone warning, 3 to 6-hourly severe weather forecasts that included wind gust and storm surge forecasts, and near real-time observation data. Prior to Disaster incident on 21 May 2020, the MoDMR allocated 4500 bundle CGI sheet, 5 million BDT GR cash, 13.85 million BDT take for house repairing support, 3.1 million BDT for child food, 2.8 million BDT for animal food, and 1000 Metric GR rice (NAWG, 2020). As soon as the cyclone grew in intensity from a 'Very Severe' cyclonic storm into a 'Super Cyclone', the GoB prepared 12,078 cyclone shelters in coastal regions. Local authorities were instructed to shift people from vulnerable areas to cyclone shelters. The number of cyclone shelters had eventually been raised to 14,336 where 2.4 million people, the largest tally of people ever evacuated in the country during a natural disaster. Early response teams were formed with the help of Cyclone Preparedness Programme (CPP), Bangladesh Red Crescent Society (BDRCS), Fire Service and Civil Defense (FSCD), Police, Armed Forces and other government and non-government organizations. The Health Emergency Operations Center and Control Room of the Department General for Health Services (DGHS) is activated 24/7 as well as local control rooms. Masks and hand sanitizers were distributed in each and every cyclone shelter as a precautionary measure due to outbreak of Covid-19 pandemic. More than 1,933 medical teams comprising of doctors and nurses, around 70,000 "cyclone preparedness" volunteers and rescue teams were readied with emergency medicines and reliefs. According to the Inter-Services Public Relations (ISPR) Directorate, the Bangladesh Army deployed 146 military disaster management teams with special equipment and 76 military medical teams. Bangladesh Armed Forces prepared 12,500 relief packages, 16 water purification units and 14 water bladders (NAWG, 2020). The Ministry of Environment, Forest and Climate Change constituted a special team to assess the damages to the mangrove forest Sundarbans.

7.4.2 Response at Local/Community Level

As Cyclone Amphan drew near, families in danger heeded warnings. Volunteers were actively working for the residents who couldn't get to shelters on their own such as people with disabilities and older

---

[1] https://tbsnews.net/environment/cyclone-amphan/cyclone-amphan-causes-damage-worth-tk1100cr-84139

populations. Red Crescent teams, government volunteers and community members helped one another to reach the shelters in time. As evident in many disasters, local units and volunteers are the first responders and help smoothen the response process by mobilizing local resources and volunteers. The humanitarian agencies complement preparedness and immediate response efforts in coordination with Ministry of Disaster management and Relief (MoDMR) and collaboration with local Disaster Management Committee under overall guidance of humanitarian coordination task team (HCTT).

Along with the dilemma caused by Cyclone, the response process was not so agile as expected due to Covid-19 pandemic because the movement of people and goods were restricted. Furthermore, any disaster almost always creates movement difficulty, logistical challenges as well as the paucity of time. BDRCS and Cyclone Preparedness Programme (CPP) worked together and in coordination with local authorities to implement life-saving cyclone readiness activities in line with COVID-19 situation while observing imposed restrictions in all vulnerable unions of the 13 coastal district. More than 70,000 volunteers (including 55,556 CPP volunteers, Red Crescent Youth (RCY) volunteers) engaged to disseminate early warning messages among community and camp people and helped local authorities to evacuate people to cyclone shelters, providing first aid support as necessary.

7.4.3 Response at International Level

The United Nation's Central Emergency Response Fund (CERF) allocated $5 million to complement the Bangladesh government's quick recovery efforts in the repercussion of Cyclone Amphan, while UNICEF UNICEF supported with USD 20,000. The CERF allocation provided high-impact life-saving assistance to a prioritized caseload of 250,000 persons in the districts of Khulna and Satkhira in Khulna Division and Barguna and Patuakhali districts in Barisal Division. The European Union (EU) also announced an initial funding of 1.1 million Euro for cyclone Amphan-affected people in Bangladesh. Additionally, International Federation of Red Cross and Red Crescent Societies (IFRCS) allocated 293,810 CHF, International Non-Governmental Organizations (NGOs) including members of the Start Fund Bangladesh supported the national response with 0.8 million Euro (NAWG, 2020).

7.5 Criticality of Disaster Risk Reduction during Covid-19 Pandemic

Early warning:

- Early warning messages/ advisories shall include COVID-19 prevention and protection messages.
- CPP volunteers in charge of early warning dissemination shall wear masks and gloves in addition to raincoats and gumboots. They shall be deployed in small groups (2 to 3 members per team) and should observe social distancing. They should avoid person-to-person contact, and use motorized transport to shorten time for local dissemination

Evacuation:

- Shelter preparation shall consider social distancing measures.
- Evacuees shall be requested to carry and wear their own masks.

First aid and primary healthcare:

- Healthcare provider must use personal protective equipment and extra caution.

The main concern was an unavoidable trade-off between emergency response and outbreak containment as Amphan could impact the [COVID-19] pandemic directly by disrupting health services and health infrastructure, as well as making social distancing more difficult among people displaced after the disaster. As local authorities observed CPP's adapted protocol; Inter-agency collaboration and coordination proved that the battle against impacts of a super cyclone even in a COVID-19 pandemic situation could be battled.

7.6 Effectiveness of Early Preparedness

Bangladesh has battled the twin perils of a super-cyclone and Covid-19. Bangladesh's disaster preparedness, including a network of 55,000 first responders ensured that Amphan killed fewer than 100 people in India and Bangladesh. While any death is regrettable, the country's early-warning systems and well-rehearsed evacuation drills have saved hundreds of lives over the years. The cyclone claimed more than 26 lives in Bangladesh, damaged thousands of homes. People's livelihoods, especially those who depend on cropland and fisheries were greatly affected. It is critical to acknowledge the losses and to act on them. But it's also important to focus on the number of lives saved, the infrastructure that withstood the storm and efforts that mitigated additional damage and loss of life. A diverse system of warning messages tailored to local needs which alarmed people about evacuation, ranging from social media to people on bicycles with megaphones. Bangladesh lost at least 300,000 people to the Great Bhola Cyclone in 1970 and has since invested in enormous efforts to keep people safe during storms. Bangladesh will face more challenges in future under climate change scenarios. But those early preparedness efforts will be an example which largely paid off during Cyclone Amphan.

7.7 Post-disaster Management and Way Forward

Due to the extent and severity of the catastrophic cyclone event, an effective post-disaster management become very crucial and a dire need. On 21st May, 2020, GoB mobilized resources to support affected communities. Severely distressed districts i.e. Satkhira, Khulna, Patuakhali, Barguna, Bhola, Sandwip were given the highest priority in post-disaster management (NAWG, 2020). Assistance and reliefs consisted of; cash grants, dry food packages, young child specific food, house repair items and water purification units etc. As many as 146 disaster management teams with special equipment were deployed immediately. Bangladesh Army, Navy, and Air Force; led by the Armed Forces Division provided medical assistance, emergency rescue and relief to the people living in the areas affected by cyclone Amphan. To supplement these efforts, a well-coordinated, synchronized, short term humanitarian response is required. The goal of the humanitarian response is to make sure that the most vulnerable communities receive targeted humanitarian assistance which can be identified through addressing three questions; **where activities need to be focused**, **who is most in need** and **how the programs can be best delivered**. Consequently, a medium to longer term (06 to 12 months) early recovery and reconstruction effort will be required to repair damaged infrastructure especially embankments, roads, houses, sources of safe drinking water, sanitation facilities etc. In that case, **operation and maintenance of coastal embankments** should be the first priority to protect huge mass of lands and properties from rampage of cyclones and storm surges, while timely resources mobilization and quality maintenance work should be ensured to enhance Disaster Risk Reduction (DRR) as per National Disaster Management Plan (2016-2020) built upon the UN Sendai Framework of Disaster Risk Reduction. Restoration of livelihoods, rehabilitation of agricultural land contaminated by saline water and strengthening preparedness and community support mechanism should also be given the priority. Last but not the least, evidently, Sundarbans saved Bangladesh several times that curbed the intensity of strong winds and surges during the cyclones of 1988 and 1997, of Sidr in 2007, Aila in 2009, Roanu in 2016, Bulbul in 2019, Fani in 2019 and this time Amphan. Therefore, priority should be given to protect this mangrove forest keeping past experiences in forefront.

Reference

1. NAWG (2020), Cyclone Amphan: Joint Need Assessment Report, by CARE Bangladesh under the “Supporting Bangladesh Rapid Needs Assessment (SUBARNA) Project., Bangladesh.
2. IFRCS (2020), Operation Update Report on Cyclone Amphan in Bangladesh, International Federation of Red-cross and Red Crescent Societies, Issued on 23 May 2020.
3. https://reliefweb.int/sites/reliefweb.int/files/resources/MDRBD024du1.pdf
4. https://reliefweb.int/report/bangladesh/cyclone-amphan-bangladesh-preparedness-paid
5. https://tbsnews.net/bangladesh/how-did-we-battle-cyclone-amphan-amid-covid-19-pm-hasina-writes-uk-newspaper-88282
6. https://reliefweb.int/report/bangladesh/covid-19-creates-double-whammy-threat-cyclone-amphan-nears
7. https://bdnews24.com/bangladesh/2020/05/20/bangladesh-evacuates-1.4m-people-to-cyclone-shelters-as-amphan-eyes-coast
8. https://reliefweb.int/report/bangladesh/cyclone-amphan-bangladesh-preparedness-paid
9. https://reliefweb.int/report/bangladesh/bangladesh-cyclone-amphan-operation-update-report-dref-operation-n-mdrbd024#:~:text=Attachments&text=Cyclone%20Amphan%20formed%20on%2

016,areas%20and%20south%20of%20Bangladesh.&text=The%20coastal%20region%20of%20Cox's,wind%20damages%20and%20heavy%20rains.

10. https://www.dhakatribune.com/bangladesh/nation/2020/05/21/sundarbans-once-again-protects-the-coast
11. MDRBD024ea.pdf
12. http://www.rimes.int/?q=node/597
13. https://eos.org/articles/when-natural-disasters-cross-the-path-of-covid-19
14. https://tbsnews.net/environment/cyclone-amphan/cyclone-amphan-causes-damage-worth- tk1100cr-84139

HELP Global Report on Water and Disasters 2020

Secretariat of High-level Experts and Leaders Panel on Water and Disasters (HELP)
c/o GRIPS 7-22-1 Roppongi Minato-ku Tokyo 106-8677 Japan

Chief-in-Editor: Kenzo Hiroki