सत्यमेव जयते

Floods Challenges and its Management
Case Study of Gujarat Floods - 2017

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Resilient India - Disaster free India

National Institute of Disaster Management (NIDM)
(Ministry of Home Affairs, Government of India)

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Resilient India - Disaster Free India

Maj. Gen. Manoj Kumar Bindal
VSM
Executive Director

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राष्ट्रीय आपदा प्रबंधन संस्थान
(गृह मंत्रालय, भारत सरकार)

National Institute of Disaster Management
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FOREWORD

India has very high exposure to flooding including riverine, flash and coastal flooding. It has been a recurrent phenomenon in India and causes huge losses to lives, properties, livelihoods systems, infrastructure and public utilities. Out of the total geographical area of 329 mha, more than 40 mha is flood prone. The deadliest flooding events from 2000 to 2019 were the June 2013 floods in India (6,054 deaths) (UNISIDAR).

This document focuses on Gujarat floods 2017; identify the causes, improve planning and preparedness, strengthen early warning systems. Almost all part of Gujarat state is prone to floods (NDMA). According to the IMD, from 01st to 28th July, 2017, the state received about 559.4 mm of rainfall, as against the average of 339.6 mm between July 1stand 28thwhich shows exceptionally heavy rainfall during 2017. In the history of 112 years, it was the heaviest rainfall in the affected area of Banaskantha and Sabarkantha district. This led to a very heavy inflow into the dams and consequent flooding in large parts of the State with Aravalli, Banaskantha, Morbi, Patan and Surendra Nagar districts among the worst affected. The 2017 Gujarat floods resulted in the loss of lives, livestock, crops, durable assets, and damage to public and private infrastructure.

With the implementation of PM 10 Point Agenda no. 9, the document is prepared to understand the best practices and lessons learned to improve the policy and disaster governance.

I express my deep appreciation to Prof. Surya Parkash, Head GMR Division and his team for preparing this document. We are sure that this study will help other State Governments plan flood preparedness, response and rehabilitation efforts.

MKBindal

(Manoj Kumar Bindal)

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I take this opportunity to thank Maj. Gen. Manoj Kumar Bindal, ED NIDM for his unwavering support to carry out the case study on Gujarat floods 2017 as well as to other initiatives towards Disaster Risk Reduction (DRR).

My special thanks to Lt. Col. Dinesh Chander Vashista Joint Director, NIDM for his constant support in conducting this study including the field visit.

I acknowledge the support and cooperation extended by the Government of Gujarat in our efforts to document the best practices adopted during the 2017 floods.

My sincere thanks to Shri P. K. Taneja, Director General, Gujarat Institute of Disaster Management (GIDM), Shri. Harshadkumar R Patel, IAS, Chief Executive Officer, Gujarat State Disaster Management Authority (GSDMA) and their staff for arranging site visits as well as facilitate our interaction with officials, affected community members and other stakeholders, without which this study could not have been completed.

I thank Shri Victor Mecwan, IAS, Additional Chief Executive Officer, Gujarat State Disaster Management Authority (GSDMA) and Dr Pavan Kumar, Joint Advisor, NDMA for reviewing the document and whose comments/suggestions helped improve and clarify this document.

Sincere thanks to co-author Dr. Harjeet Kaur, Junior Consultant NIDM who made every effort to collect, compile, analyse and assess all available information on Gujarat floods 2017 and helped in the preparation and finalization of this document.

My special thanks are due to the GMRD team members Mr. Pranav Dhawan, Former Consultant Flood Monitoring Cell, NIDM; Dr. Raju Thapa, JC NIDM; Mr. Anil Kathait, JC NIDM; Mr Ritesh Singhal, Stenographer and NIDM publication team without which it would not have been possible in the preparation of this document completed.

Last but not the least, I would like to thank my wife Reeta and daughter Rasika, without whose consistent moral and logistic support, I would not have been able to give due attention and time to this work.

Finally, I am grateful to the Almighty without whose grace and kindness, I would not have been capable to carry this task successfully.

Prof. Surya Parkash
Head GMR Division, NIDM

CONTENTS

1. Introduction

1.1 Physical and demographic profile of the state Gujarat

The state of Gujarat is situated on the north-west coast of India between 20d6'N - 68d.10'E to 24d.42'N – 74d.25'E, the state is bordered by the Arabian Sea in the west, Rajasthan in the north and Maharashtra in the south and south-east. Gujarat shares an international border with Pakistan on the north-western fringe. The state covers a geographical area of 1,96,000 sq. km and it has the longest coastline run along 1600 km.

For administrative purposes, Gujarat State has 26 districts, 226 talukas (talukas /blocks are administrative units within a district), 18,618 villages and 242 cities/towns. The State has a population of over 50 million (5.07 crore) with a decadal growth rate of 22.66 % compared to the national rate of 21.53 % (Census of India 20011). Sex ratio stands at 920 females per 1000 males, lower than the national average of 933. Literacy rate stands at 69.14 %, higher than the national rate of 64.80 %, with female literacy at 57.80 % and male literacy at 79.66 %.

1.2 Rainfall

Rainfall in Gujarat varies from place to place - the average rainfall varies from 33 to 152 cm. The northern region receives rainfall ranging from 51 to 102 cm whereas the southern region receives 76 to 152 cm of rainfall. Rainstorms are also common at the western edge of the Aravallis and the Satpuras in north and northeast, which cause flood discharge in Banas, Sabarmati and Mahi rivers. As these rivers disgorge hilly terrain to flat lands, floodwaters spread out and damage large populated stretches. Cities like Ahmedabad, Vadodara, Surat, Bharuch, Navsari and Valsad lie in such flat alluvial plains. Southern Gujarat is endowed with moderate to high rainfall, with substantial water resources concentrated in Narmada and Tapi, which have their catchments in the Central uplands of the Indian peninsula. Occasional heavy rainstorms in their middle and upper catchments can cause heavy flooding in these river basins. The arid region around the Rann of Kutch faces an acute scarcity of water, due to lack of rainfall in these areas.

1.3 Hydrogeology

The large alluvial tract extending from Banaskantha district in the north to Surat and Valsad districts in the south constitutes the largest and most potential groundwater reservoir in the state. Almost the entire Saurashtra and Kachchh regions are occupied by a variety of hard and fissured formations which include basalt and consolidated sedimentary formations with semi-consolidated sediments along the low-lying coastal areas. The coastal and deltaic areas in the state form a narrow linear strip and are underlain by Tertiary sediments and Alluvium.

1.4 Hazard and vulnerability profile of Gujarat

Gujarat is inherently susceptible to riverine and flash floods, cyclones, earthquakes and droughts. These disasters occur with alarming regularity. Its coastal terrain, high seismicity due to its location adjacent to the inter-plate boundary and riverine nature are to a large extent responsible for its multi-hazard profile. GSDMA prepared Seasonality of hazards matrix by understanding the approximate occurrence of hazard, the state may remain prepared for the respective hazards by activating the relevant departments for the same. Figure1 is indicative of the occurrence of a hazard.

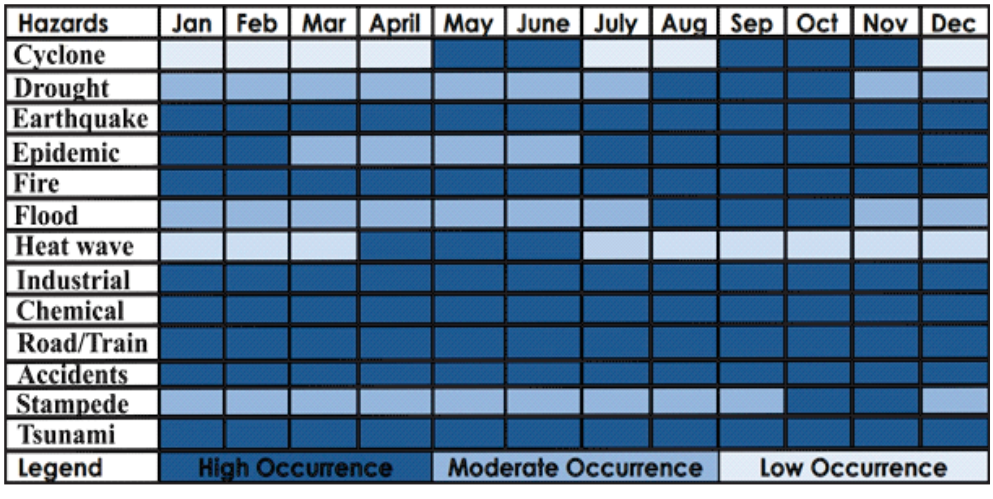


Figure 1: Seasonality of hazards (Source: GSDMA)

The climatology of Gujarat is influenced by the Arabian Sea in the West and three hill ranges along its Eastern border. A long coastline makes parts of arid Saurashtra and Kutch occasionally experience very high rainfall. These occasional heavy rainstorms are responsible for most of the floods in the State. While the Northern part of the State is mostly arid and semi-arid, the Southern part is humid to sub-humid. Extremes of climate, be it rainfall or temperatures are quite common in this region. All major rivers in the State pass through a wide stretch of the very flat terrain before reaching the sea. These flat lowlands of lower river basins are prone to flooding. Cities like Ahmedabad, Surat and Bharuch are located on the flat alluvial plains of large rivers. Concentrated runoff resulted by heavy rainfall cause flash floods in the small river basin of Saurashtra and Kutch because of their fairly impervious catchments (rocky or black cotton soils) and steep sloping upper catchments. The flood prone river sections were identified from settlement level analysis. Flood prone river sections in Saurashtra extend to the upper basins due to the presence of dams which have to resort to emergency discharge during heavy rainstorms. Even small valleys in Saurashtra are used for agriculture. Hence flooding in these zones impacts both residents and settlements.

The flood risk in Saurashtra is lower than that of the South Gujarat plains. The relatively flat plains in the lower basic areas with hilly catchments in upper parts of South Gujarat accentuate flood risks. Few villages in the North Gujarat are flood prone too.

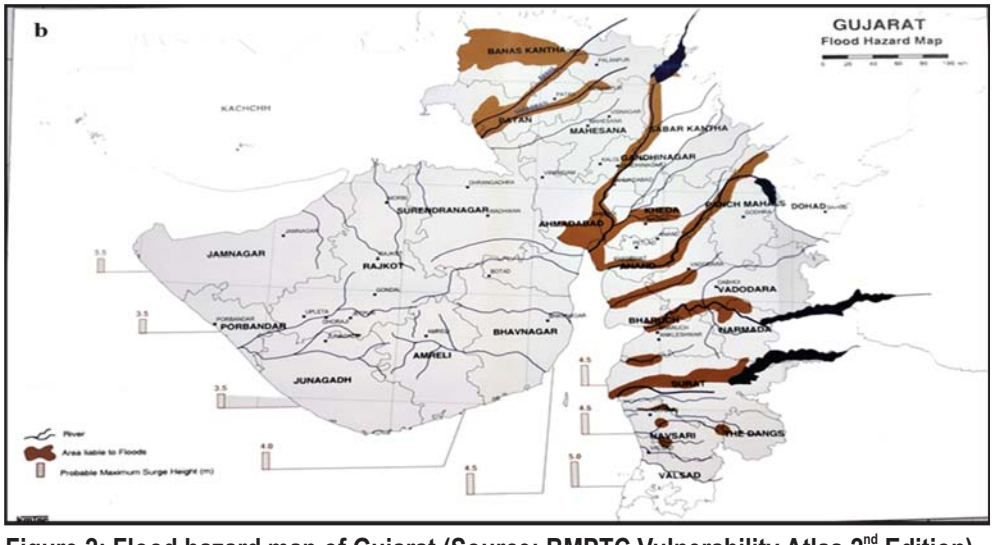


Figure 2: Flood hazard map of Gujarat (Source: BMPTC Vulnerability Atlas 2nd Edition)

2. Field visit

A field trip to Gujarat was planned from 3rd January, 2021 to 10th January, 2021 to understand the impacts of flooding in Gujarat which happened in July, 2017 and the present scenario for flood management in Gujarat (Figure 3). The field trip included travelling to the affected districts in the state which are Banaskantha, Pathan, Gandhinagar, Morbi, Surendra Nagar. The NIDM team included Dr. Surya Parkash (Prof. and Head, GMR Division), Dr. Harjeet Kaur, Junior Consultant and Mr. Pranav Dhawan, Former Consultant, NIDM.

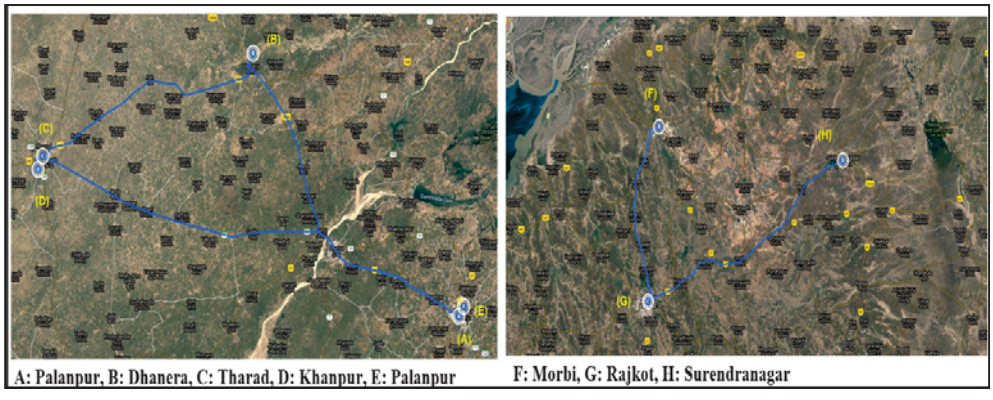


Figure 3: Road map fallowed for field visit (Source: Google Earth Imagery)

3. Study area

3.1 Banas Basin

3.1.2 Geographical description of the basin :

The Banas basin is the Northern basin and is situated between 23°30' & 24°55' North latitudes and 71°15' to 73°15' East longitudes approximately. Banas basin is bordered by Saraswati and Luni basins form the Southern and Northern and Aravalli hills form its Eastern extremity. The Banas drains an area of 8674 sq km, out of which nearly 37.69% lies in Rajasthan state and remaining 62.31% falls in Gujarat state (Austin, 2017).

Table 1: Banas drainage area distribution

Sl. No.	Name of the State	Name of the District	Length of river (km)	Drainage area (sq km)	% of total CA
1	Gujarat	Banaskantha	119	4638	53.47
2	Rajasthan	Sirohi	78	3269	37.69
3	Gujarat	Mehasana	69	767	8.84
Total			**266**	**8674**	**100.00**

Table 2: Description of the Water Storage

Sl. No.	Name of the Project	River	Torage Capacity (mm^3)		Purpose
1	Sipu Dam	Sipu	177.8	156	Irrigation
2	Dantiwada Dam	Banas	464	444	Irrigation

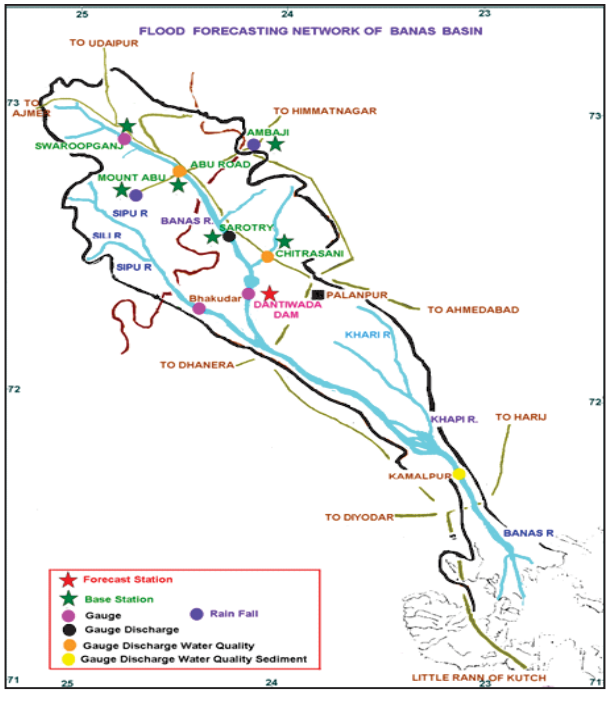


Figure 4: Flood forecasting network of Banas river (Source: CWC 2018)

CWC: central water Commission (2018). Hydrological data (unclassified) book

3.2 Machchhu Basin

3.2.1 Basin Description

The Machhu basin is geographically located between 22010' to 230 10' North latitude and 70° 40' to 71° 15' East longitude. Machhu River rises in the hills of Jasdan near village Khokhara in Chotila taluk of Surendra Nagar districts at an elevation of 220 m above m.s.l. This is one of the North flowing rivers of Saurashtra in Gujarat state. The river Machhu originates from the hill ranges of Jasdan Sardar and Mandva in Rajkot district and Chotila in Surendra Nagar district and flows in North Westerly direction along the district boundry of Surendra Nagar and Rajkot upto village Beti and then flows mostly towards North in Rajkot district and finally disappears near Malia in the little Rann of Kachh. Machhu alongwith its tributaries flows 52 % in the hilly area and 48 % in plain region. Machhu drains an area of 2515 sq km out of which more than 75 % lies in Rajkot district (Austin, 2017).

Table 3: The district wise distribution is shown as below

Name of the District	Drainage are (sq km)	% of total
Rajkot	1924	76.51
Surendra Nagar	591	23.49
Total	**2515**	**100.00**

3.2.2 Major/medium irrigation projects in river basin machhu

At present there are five medium irrigation schemes completed in the catchment of Machhu 1. Adhia Irrigation Scheme 2. Kuvadva Irrigation Scheme 3. Ghunda Irrigation Scheme 4. Machhora Irrigation Scheme 5. Vadsar and Amarsar Irrigation Scheme. There are two important Irrigation schemes viz Machhu I & Machhu II. Machhu Irrigation Scheme No. 1 is on river Machhu in Wankaner Taluka of Distt. Rajkot. The Gross storage capacity of this dam at FRL is 72.74 MM^3, having 70.8 MM^3 as effective storage capacity. Machhu Irrigation Scheme No.2 is on Machhu in Morbi Taluka of Distt. Rajkot. The Gross storage capacity of this dam is 100.55 MM^3, having 90.8 MM^3 as effective storage capacity.

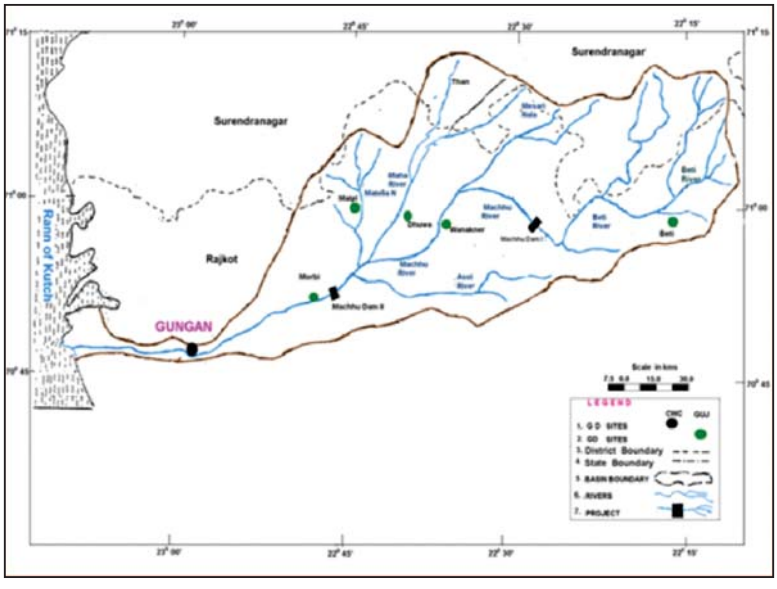


Figure 5: Machchhu Basin (Source: CWC 2018)

4. Dams in study area

4.3.1 Dantiwada Dam

It is a mud and masonry dam located on the west Banas River near Dantiwada, Banaskantha district of northern Gujarat. The dam was constructed in 1965 for flood control and irrigation.

Total number of villages are 111 under command of the Dantiwada Dam, out of which twelve villages are partially submerged. Total land submerged under the reservoir includes 2,025 hectares (5,000 acres; 7.82 sq mi) cultivable land; 1,215 hectares (3,000 acres; 4.69 sq mi) forest land and 810 hectares (2,000 acres; 3.1 sq mi) wasteland. In 1973, 8 years after DAM constructed, the Dantiwada Dam failed.

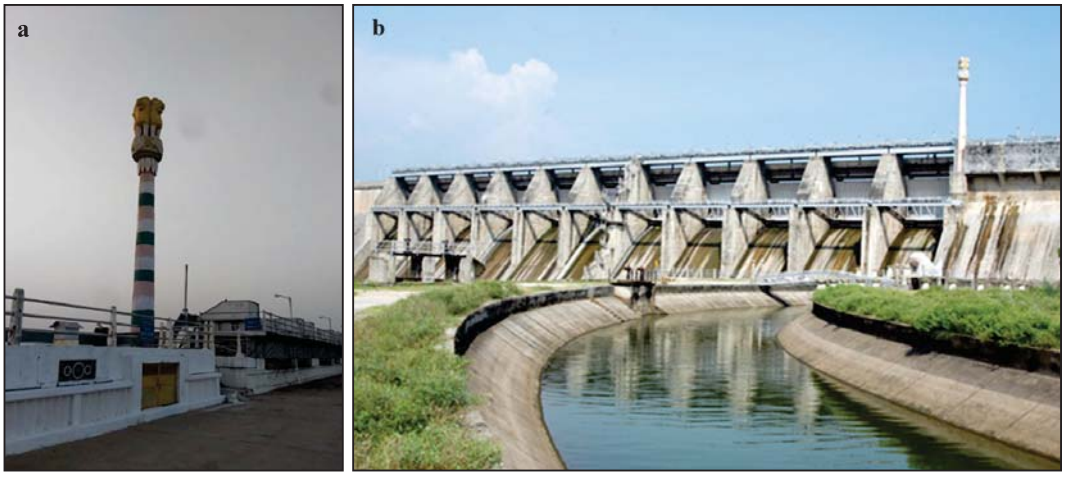


Figure 6 a & b: Dantiwada dam on the West Banas River near Dantiwada, Banaskantha district of northern Gujarat in India. (https://banaskantha.nic.in)

Table 4: Salient Features of Dantiwada Dam

1.	**Name of the project**	**Dantiwada Reservoir Project**
2.	**Location**	
a.	Across River	Banas
b.	Nearest village	Dantiwada
c.	Taluka	Dantiwada
d.	District	Banaskantha
e.	State	Gujarat
f.	Geographical location of dam	Lat.24◦ - 10'N, Long. 72◦ 29'E
g.	Nearest Railway Station	Palanpur Station on the Ahmedabad Delhi Broad guage line W.R 29 km from Dam site
h.	Road Communication	13 km from Palanpur Kandla N.H.14 and 6 km from Deesa-Chitrasani road and 29 km from Palanpur

3.	**Hydrology**		
A.	Catchment area	Sq. Km.	Sq. Miles
i.	Total catchment area at site	7656	2967.44
ii.	Catchment area in Rajasthan territory	1119	433.72
iii.	Catchment area in Gujarat territory	6537	2533.72
iv.	Catchment area consider for availability of water at Dantiwada Dam site	Guj – 1742.84 Raj. – 119.00 1861.84	Guj. – 675.51 Raj. – 433.72 1109.24
v.	Net free catchment area available at Dharoi for water planning	2861.84	1109.24
B. i.	Average rainfall in entire catchment	mm.	Inch
ii.	Average rainfall in entire catchment of Rajasthan	530	20.87
iii.	Average rainfall in entire catchment of Gujarat	973	38.31
iv.	Maximum Rainfall in 1997	1969.20	77.53
v.	Minimum Rainfall in year 1987	28 (M.abu)	
vi.	Average Rainfall in year 1869	940	
Reservoir Capacity Data		**mm^3**	**MAFT**
i.	Design gross capacity @ F.R.L 184.10 Revised gross capacity@ F.R.L. 184.10	464.39 393.616	0.376 0.319
ii.	Design dead storage @ RL 161.85 Ft Revised dead storage@ RL161.85 Ft	19.68 6.207	0.0159 0.005
iii.	Design live storage Revised storage	444.71 3.87.409	3.60 0.314

Details of Dam			
River gorge portion 20000 M		m	Ft
a.	Earthern dam	L/S.548	
	R/S286.20	R/S. 1797.44	939
b.	Spillway (11 Gate of 41' x 27)	164.90	541.00
c.	Non overflow	113.08	371.00

Table 5: Village under Command

a) District	b) Taluka	c) No. of villages
Banaskantha	Palanpur	18
	Dhanera	2
	Deesa	31
	Kankrej	8
Mehsana	Patan	49
	Siddhpur	3
	Total	**111**

4.3.2 Sipu Dam

The Sipu reservoir project is located across river Sipu, a tributary of Banas River near village Atal in Dhanera Taluka of Banaskantha District in north Gujarat, for irrigating 22080 Ha. area in CCA of 16000 Ha. The dam site is about 170 Km. from Ahmedabad city.

The Sipu Reservoir Project comprises of an earthen dam 6.86 km long and masonry spillway and non-overflow section 0.28 km long having 12 no. of radial gates for passing design flood of 8603 cumecs. The reservoir has a gross and live storage of 177.8 M.Cum and 156.00 M.Cum respectively at F.R.L.

The entire Sipu command is on the right bank side. Sipu Main Canal having 21.63 km length and carrying capacity of 10.19 cumecs at the head off takes at

Ch.5030 m of the dam through head regulator. A 12.92 km long branch canal is off taking at Ch.9.25 km of the main canal. Minors are off taking from the branch canal as well as main canal. The entire distribution system is lined with 5 cm thick P.C.C blocks and 7.5 cm thick cast in situ concrete upto 8 ha block. Gross command area (GCA) of the canal system is 17937 ha and CCA 16000 ha. The annual irrigation is 22080 ha. The project will benefit 25 villages of Deesa Taluka in Banaskantha district of North Gujarat.

Figure 7: Sipu Dam at Sipu River
(Source: Divya Bhaskar local newspaper, Gujarat)

Table 6: Sipu Dam salient features

S.No.	Attribute	Value
1	Irrigation Project Name	Sipu Major Irrigation Project
2	Irrigation Project Name Alias	
3	Purpose	Irrigation
4	Type	Major
5	Engineering Type	Storage
6	Status	Completed
7	State	Gujarat
8	Districts Benefited	BanasKantha
9	Basin	West flowing rivers of Kutch and Saurashtra including Luni
10	River	Sipu
11	Project Sharing	None
12	Intercountry	None
13	Interbasin	No
14	Work Started in 5 Year Plan	AP (1978-80)
15	Completed in 5 Year Plan	IX-Plan
16	Project Approval Status	Planning Commission
17	Year of Approval by Planning Commission	1980
18	Approved Cost (Rs. in cr)	18.8
19	Actual Cost (Rs. in cr)	119.09
20	Culturable Command Area (CCA) (th ha)	16

21	Ultimate Irrigation Potential (UIP) (th ha)	22.08
22	Potential Created (PC) (th ha)	22.08
23	Project Covered under ERM Scheme	No
24	Project Covered under CADA Scheme	No
25	Project Covered under AIBP Scheme	Yes
26	Studies Conducted	\
27	Project Covered under Tribal Sub-Plan	Yes
28	Project Covered under Drought Prone Area Programme (DPAP)	Yes

4.3.3 Machu II Dam

Machhu river rises in the hills of Jasdan near village Khokhara in Chotila Taluk of Surendra Nagar districts at an elevation of 220m above m.s.l. This is one of the North flowing rivers of Saurashtra in Gujarat state. The Machhu basin is situated between 22° 10' to 23° 10' North latitude and 70° 40' to 71° 15' East longitude. The river Machhu originates from the hill ranges of Jasdan Sardar and Mandva in Rajkot district and Chotila in Surendra Nagar district and flows in North Westerly direction along the district boundry of Surendra Nagar and Rajkot upto village Beti and then flows mostly towards North in Rajkot district and finally disappears near Malia in the little Rann of Kachchh. Machhu along with its tributarieis flows 52% in the hilly area and 48% in plain region. The river fertilise Malia, Morbi, Wankaner, Jasdam and Rajkot taluks of Rajkot districts and part of Chotila Taluk in Surendra Nagar district. Machhu drains an area of 2515 sq. km out of which more than 75% lies in Rajkot district. Basin map of Machhu Basin is enclosed. The district wise distribution in shown as below.

Table 7: Salient features of Machu Dam II

Information	
Location	Vill: Jodhpur Ta: Morbi, Dist. Rajkot.
Purpose	Irrigation & Water supply
River	Machhu

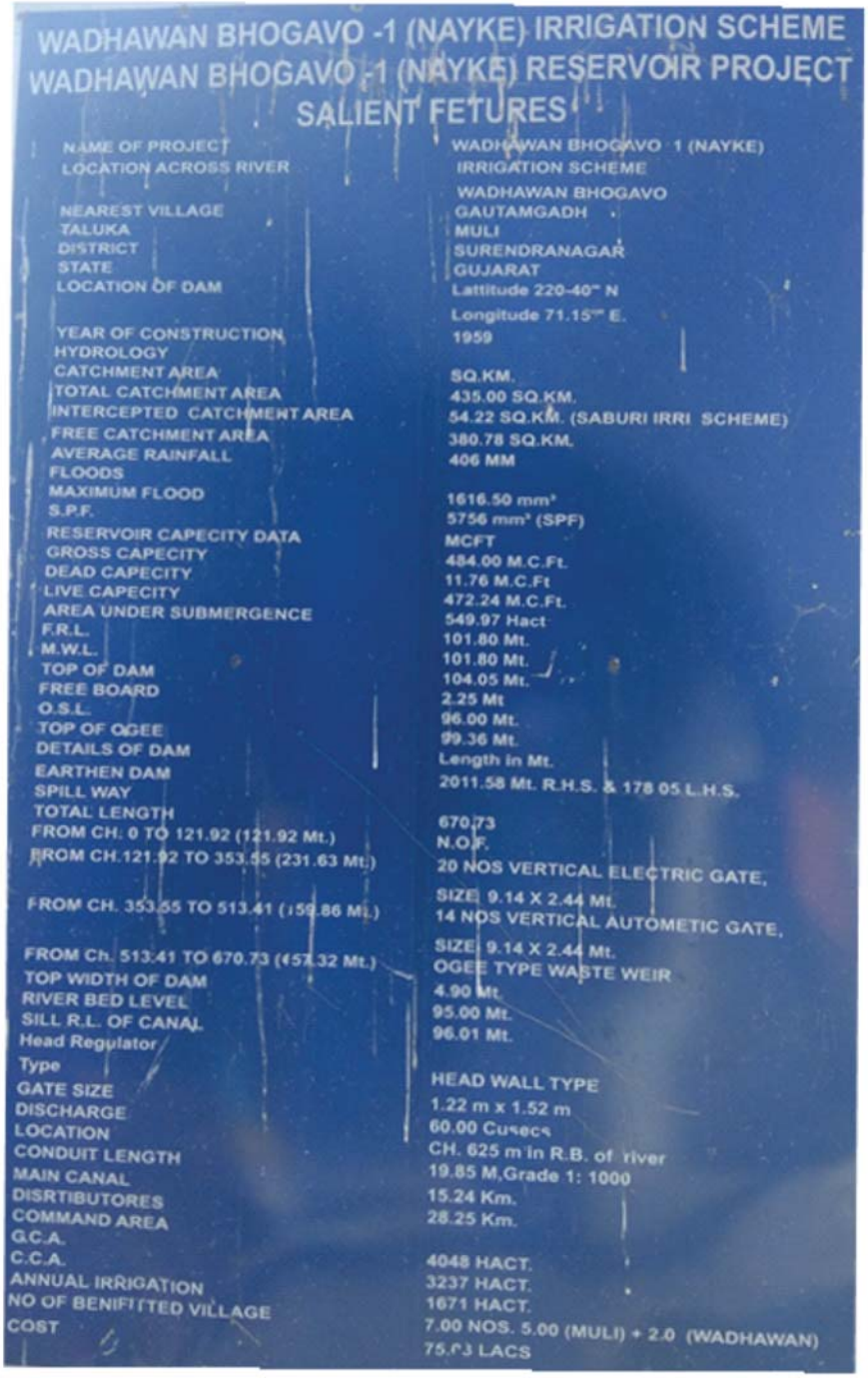
Area of catchment	1193 KM^2	
Mean annual rainfall	560 MM	
Year of commencement of construction work	October 1986	
Year of completion	Under progress	
Dam		
Type	Earthen & Masonry	
Bed Rock	Basalt	
Maximum height above the lowest point of foundation	.25 M	
Length at the top of the dam	5125 M	
Total Volume Content:		
Concrete	0.040 MM^3	
Masonry	0.064 MM^3	
Earthwork	2.456 MM^3	
Reservoir		
Area at full reservoir level	13.96 KM^2	
Gross storage capacity	100.55 MM^3	
Effective storage capacity	90.80 MM^3	
Area under submergence		
a) Forest	b) Waste land	c) Culturable
a) + b) + c) = 1396.20 ha		
No. of villages under submergence		Nil

Geology		
Name of Scheme	District	Rock type encountered at the dam site
Machhu-II	Rajkot	Porphyritic amygdaloidal basalt, Tuff, Sandstone, Shale, Tufficeous basalt.
Villages under command		
a) District	b) Taluka	c) No. of villages
Rajkot	Morbi	20
	Total	20

Figure 8: Machu Dam II (Field Trip 7th January, 2021)

4.3.4 Wadhawan Bhogavo -1 Dam

Dholidhaja Dam (alternatively Wadhawan Bhogavo -1) across the Bhogavo River is located near Surendra Nagar city and in the urban area of Surendra Nagar Dudhrej Municipality in the state of Gujarat, India. The purpose of Dam is to provides drinking and utility water to 300,000 to 400,000 people of Surendra Nagar, Wadhwan, Joravar Nagar and Ratanpar.



WADHAWAN BHOGAVO -1 (NAYKE) IRRIGATION SCHEME
WADHAWAN BHOGAVO -1 (NAYKE) RESERVOIR PROJECT
SALIENT FETURES

NAME OF PROJECT	WADHAWAN BHOGAVO -1 (NAYKE) IRRIGATION SCHEME
LOCATION ACROSS RIVER	WADHAWAN BHOGAVO
NEAREST VILLAGE	GAUTAMGADH
TALUKA	MULI
DISTRICT	SURENDRANAGAR
STATE	GUJARAT
LOCATION OF DAM	Lattitude 220-40" N Longitude 71.15"" E.
YEAR OF CONSTRUCTION	1959
HYDROLOGY	
CATCHMENT AREA	SQ.KM.
TOTAL CATCHMENT AREA	435.00 SQ.KM.
INTERCEPTED CATCHMENT AREA	54.22 SQ.KM. (SABURI IRRI SCHEME)
FREE CATCHMENT AREA	380.78 SQ.KM.
AVERAGE RAINFALL	406 MM
FLOODS	
MAXIMUM FLOOD	1616.50 mm³
S.P.F.	5756 mm³ (SPF)
RESERVOIR CAPECITY DATA	MCFT
GROSS CAPECITY	484.00 M.C.Ft.
DEAD CAPECITY	11.76 M.C.Ft
LIVE CAPECITY	472.24 M.C.Ft.
AREA UNDER SUBMERGENCE	549.97 Hact
F.R.L.	101.80 Mt.
M.W.L.	101.80 Mt.
TOP OF DAM	104.05 Mt.
FREE BOARD	2.25 Mt
O.S.L.	96.00 Mt.
TOP OF OGEE	99.36 Mt.
DETAILS OF DAM	Length in Mt.
EARTHEN DAM	2011.58 Mt. R.H.S. & 178 05 L.H.S.
SPILL WAY	
TOTAL LENGTH	670.73
FROM CH. 0 TO 121.92 (121.92 Mt.)	N.O.F.
FROM CH.121.92 TO 353.55 (231.63 Mt.)	20 NOS VERTICAL ELECTRIC GATE,
	SIZE 9.14 X 2.44 Mt.
FROM CH. 353.55 TO 513.41 (159.86 Mt.)	14 NOS VERTICAL AUTOMETIC GATE,
	SIZE 9.14 X 2.44 Mt.
FROM Ch. 513.41 TO 670.73 (157.32 Mt.)	OGEE TYPE WASTE WEIR
TOP WIDTH OF DAM	4.90 Mt.
RIVER BED LEVEL	95.00 Mt.
SILL R.L. OF CANAL	96.01 Mt.
Head Regulator	
Type	HEAD WALL TYPE
GATE SIZE	1.22 m x 1.52 m
DISCHARGE	60.00 Cusecs
LOCATION	CH. 625 m in R.B. of river
CONDUIT LENGTH	19.85 M,Grade 1: 1000
MAIN CANAL	15.24 Km.
DISRTIBUTORES	28.25 Km.
COMMAND AREA	
G.C.A.	4048 HACT.
C.C.A.	3237 HACT.
ANNUAL IRRIGATION	1671 HACT.
NO OF BENIFITTED VILLAGE	7.00 NOS. 5.00 (MULI) + 2.0 (WADHAWAN)
COST	75.03 LACS

Figure 9: Salient features of Dholidhaja Dam (Pictured capture on 7th January, 2021)

Figure 10: Wadhawan Bhogavo -1 Dam
(Source: https://www.gujaratsamachar.com/)

5. Overview of the event

In July, 2017, Gujarat state was affected by severe flooding that led to significant loss of infrastructure and life, destruction to properties, houses and loss of livestock. According to the Human Development and Research Centre (HDRC), 4.5 lakhs (approximately) of people were affected out of whom 213 people lost their lives. This is said to be the worst Southwest monsoon in the last 70 years.

Satellite plays an crucial role in the detection and monitoring of flood situations over large regions. Figure 11 shows the INSAT-3D visible image of 24 July, 2017 showing dense clouds over Gujarat. During 2017 flood scenario in India, the data from SCATSAT-1 was used for the detection of the flood situations (Figure 12).

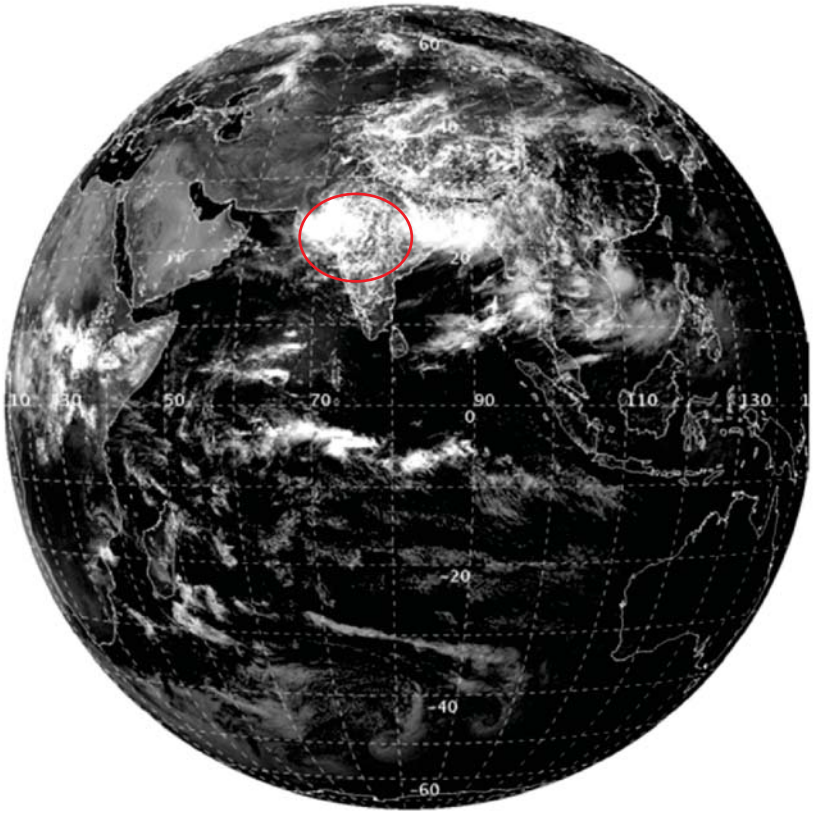


Figure 11: INSAT-3D visible image of 24th July, 2017 showing dense clouds over Gujarat (Source: ISRO)

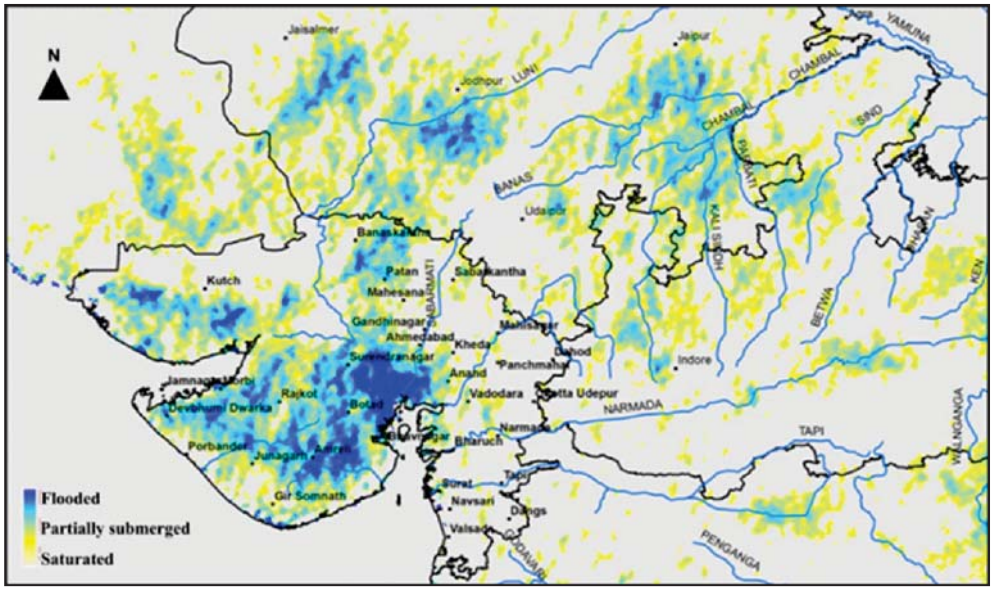


Figure 12: Flood inundation change analysis (6th – 10th July vs. 22nd-26th July) over Gujarat using SCATSAT-1 (Source: ISRO)

5.1 Location of the event

The worst affected districts were Banaskantha, Patan, Morbi, Sabarkantha, Surendra Nagar, Mehsana, Mahisagar, Anand, Aravalli and Ahmedabad (Figure 13), have been recognised by the state revenue department as 'Disaster-Affected Areas' under the Gujarat State Disaster Management Act (GSDMA), 2003. In Banaskantha total 6 of the total 12 talukas were suffered (Figure 14).

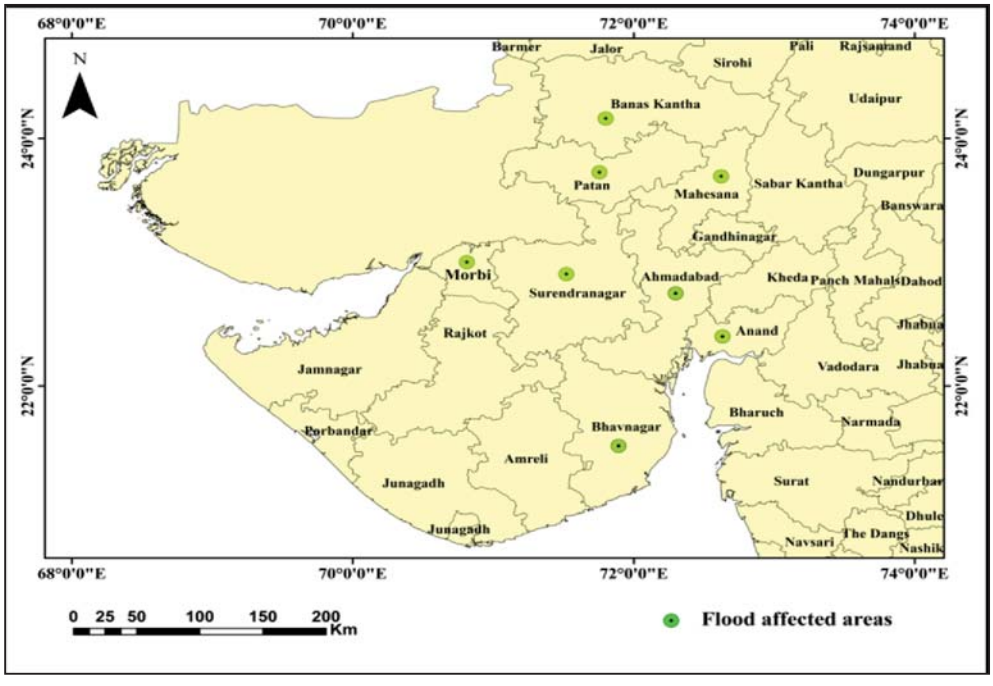


Figure 13: Gujarat map showing worst affected areas during Flood 2017

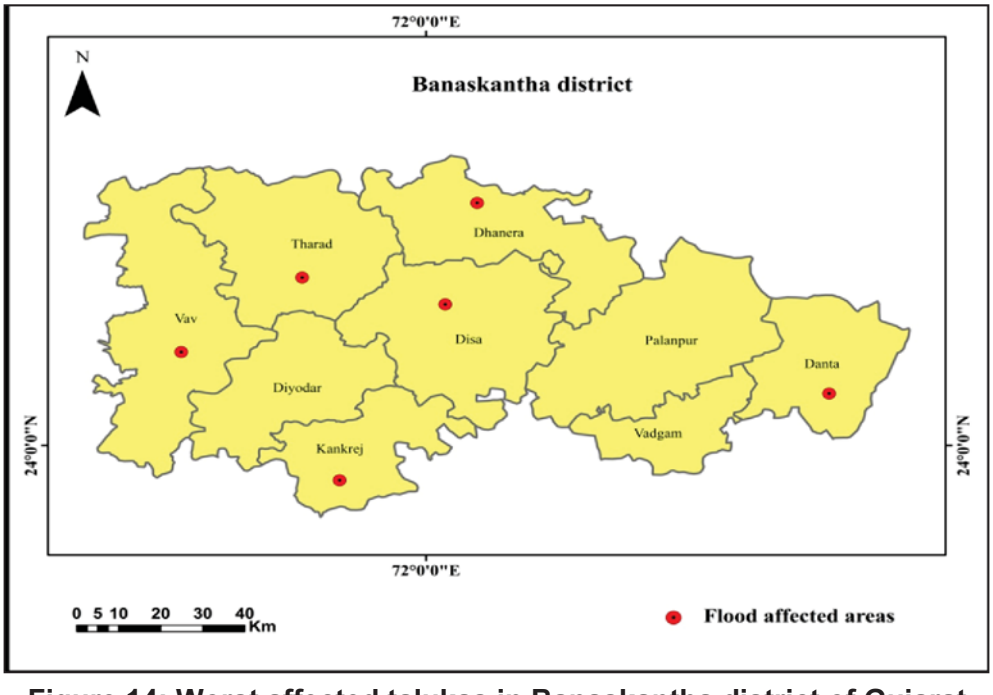


Figure 14: Worst affected talukas in Banaskantha district of Gujarat

6. Damage and loss assessment

As of 30th July, at least 213 people had died and 4170 livestock had lost in floods in Gujarat (Figure 15) (Disaster Management Division, Ministry of Home Affairs-2017). The electricity supply was cut off for 753 villages. The runway of the Ahmedabad Airport had damaged due to torrential rainfall (Financial Express, 2017), it is the main commercial hub of the state, which was partially flooded, forcing airlines to divert flights (Figure 16). The transportation system was also affected. About 370 roads, including 674 Panchayat roads; 153 State Highways and 6 National Highways were flooded and closed for vehicle traffic (Figure 17). 2017 floods also impacted on business where more than 150 factories were forced to shut down. US$1.4 million and US$3.8 million were assessed for damages of National and State Highways respectively.

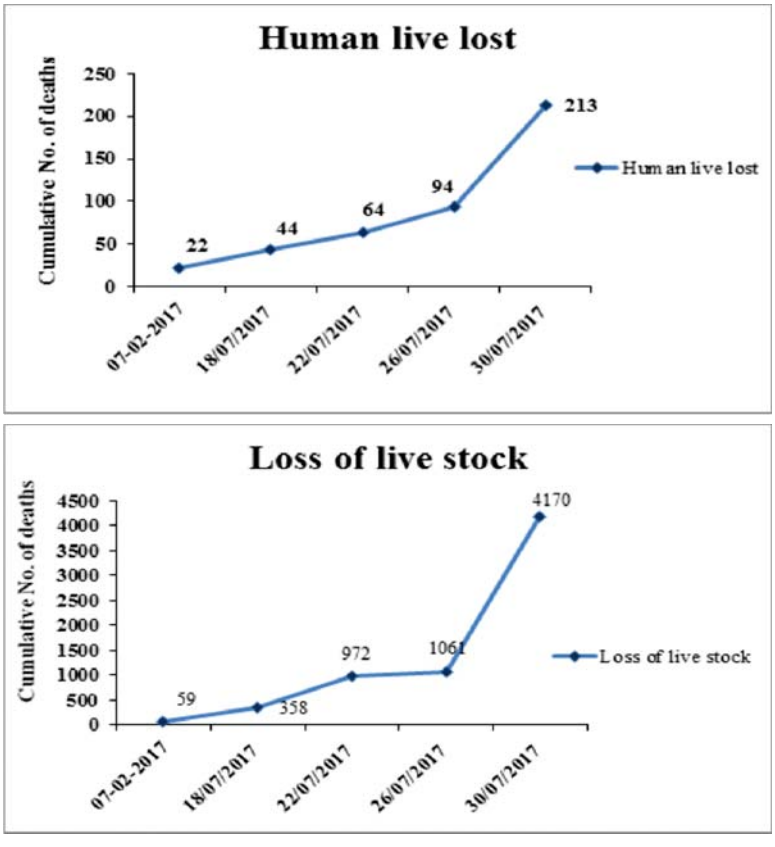


Figure 15: (a) Cumulative number of deaths of human and (b) Total death of live stocks

Figure 16: Ahmedabad Airport flooded after City Receives 200 mm rain in 24 hours (Source: India Today, 2017)

Figure 17: Transportation system damage due to flood in Gujarat (Source: India Today, 2017)

Gujarat agriculture minister Chimanbhai Shapariya informed that about 10.98 lakh hectares of agricultural land of 4,333 villages were affected due to floods besides 16,808 hectares of horticulture area in 2,431 villages. The calamity has 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.

Figure 18: Damages to the assets and livestock losses during Gujarat flood-2017 (Source: Dhar, D/ The Wire, 2017)

7. Response and relief

The detailed response and relief work during the 2017 flood is published by NDMA in their report on Gujarat flood 2017 (https://ndma.gov.in/sites/default/files/PDF/Reports/gujrat-flood-study-2017.pdf).

7.1 Preparedness Measures by State Government

Government of Gujarat had taken several preparedness measures pre-monsoon to deal with any disaster situation. One of such measures included updating of District Disaster Management Plans. The state government held a review meeting with all the Resident Additional Collectors and directed them to update all the information related to flood preparedness measures. Subsequently, all the District Disaster Management Plans were revised.

Government of Gujarat has constituted a Weather Watch Group which meets every week during the monsoon season. This group collects information, interprets it and subsequently disseminates it. The composition of the Weather Watch Group is at Annexure-II. In 2017 Monsoon Season, frequent meetings with the Weather Watch Group were held and weather forecasts were converted into district-wise warnings and these warnings were further disseminated to the concerned district. It was noted that by and large these weather predictions and warnings were accurate.

The State government was also in continuous touch with the India Meteorological Department (IMD) to keep a watch on weather conditions and rainfall. Administrative machinery in the Districts concerned were made aware of the IMD's forecast and directed to widely disseminate the information and plan the prior evacuation of people along with their belongings to safer places. In all, about 1,12,878 people of which 68,672 people were from Banaskantha and Patan, were evacuated in time thus preventing a huge loss of life (NDMA and GIDM, 2017).

7.2 Role of NDMA in Flood 2017

NDMA Team visited the office of Principal Secretary, Revenue on 01st September, 2017 and interacted with Shri Pankaj Kumar, IAS, Principal Secretary and Shri A. J. Shah, IAS, Commissioner of Relief. Principal Secretary gave a detailed account of the flood - 2017 and measures taken by the Government of Gujarat. The Team also visited the State Emergency

Operation Centre (SEOC) and interacted with officials. Information received during these interactions is mentioned in the subsequent paragraphs.

7.3 Role of NGO

After the water receded, the first relief to reach the victims was from private sources like non-governmental organisations (NGO), groups of social workers and local volunteers. There were teams from various religious and community-based organisations like Jamiat Ulema-e Hind, Jalaram Seva Kendra affiliated to the Rashtriya Swayamsevak Sangh (RSS), BDS, Rashtriya Dalit Adhikar Manch, Umiya Mitra Mandal of Patidars from Ahmedabad who distributed water, ready-made food, utensils and tents to camp in.

Figure 19: Relief work by NGOs. (Source: Dhar, D 2017 / The Wire)

8. Rescue operations

Ten NDRF teams were normally stationed in Gujarat (Five each in Ahmedabad and Baroda). Eight teams reached via rail from Pune Battalion. According to the NDM situation report dated on 03rd August, 2017, NDRF teams engaged in distribution of relief material at Districts distributed Food packets 68,c968 Nos, Water bottles/Pouches 81150 Nos, Dry Ration 1750 Bags, Biscuits/Namkeen 2225 packets, Old Clothes 175 Bags, Blankets 75 Nos, Medicines 12 Boxes and distributed medicines to 815 flood affected persons. So far teams have rescued/evacuated 8641 persons, 27 livestock and retrieved 11 dead bodies. Logistic support provided by the Ministry of Defence was Army 09 Colum, Air Force-17 Choppers have been deployed in Gujarat State. Army set up base camp hospitals in Dharah, Kankrej with the help of State administration. While State supplied medicines, the Army provided healthcare workers and doctors.

Multiple air sorties were conducted. Indian Oil Corporation cooperated wholeheartedly in re-fuelling choppers. Again, Deesaair base could only handle four choppers while the requirement was for 17 choppers. Additional helipads were identified and set up quickly so that no time is lost in conducting the sorties once the choppers arrive. All choppers from nearby air bases (Jamnagar, Ahmedabad, Jodhpur, Phalodi, Uttarlai) were engaged from 26th July, 2017 onwards.

Thus, a three-tier rescue planning was done for seamless communication-Chief Secretary and top officers from these agencies at the top, middle-level officers in the WhatsApp group and relatively junior officers manning the State emergency Operation Centre (SEOC).

Inflatable boats were mobilized from Municipal Corporations which were not affected by floods. These 10 boats were then provided to SDRF (NDMA). Another six additional boats were received from NDRF. Hence, a total of 16 extra boats were deployed which enhanced the capacity to undertake rescue operations (Each NDRF team normally has 3-4 boats).

In Jamnagar, the Fire Brigade team of the Corporation helped the district administration to carry out combat and rescue operation in other parts of the district.

As South Gujarat was the least affected but receives maximum rainfall in the State otherwise, NDRF teams from South Gujarat were strategically

withdrawn and deployed in other areas. This was done in view of the availability of NDRF teams in Pune which could be mobilised at a short notice in case of an emergency.

650 personnel of SDRF (stationed at 11 locations across the State) were also deployed for search and rescue operations. Lack of equipment was a concern. Equipment made available to Municipal Corporations through GSDMA and additional boats received from NDRF were provided to SDRF personnel.

At least 18,000 people were rescued. Of these, 8641were saved by NDRF followed by Army and Air Force. A total of 220 BSF personnel (120 from Dantiwada camp and 100 from Ahmedabad) were also used for carrying out rescue operations.

Personnel from the Indian Navy were also used for the rescue operations. Banas River does not enter the sea, it spreads out in the Rann of Kutch. At least 6-7 lakh cusecs of water were flowing through the Radhanpur and Santalpur areas with overflowing Banas and Sipu rivers. It was decided that air sorties should be conducted to assess the damage to lives, both human and cattle, and choppers from the Navy were used for the same. Personnel from Irrigation Department were armed with GPS coordinates and conducted air surveys of the entire river from Banaskantha and Dantiwada Dam to Rann at a very low height. This was done to find whether people or cattle have been washed away by the floods. 8 bodies (human) were missing (Disaster Management Division, Flood Situation report-2017).

Massive shifting operations were undertaken by the district administration. In these two districts, around 70,000 people were shifted overnight (45,000 from Banaskantha). More than 112878 people were evacuated across the State (Disaster Management Division, Flood Situation report-2017). All possible government agencies and other stakeholders (political parties, panchayats, community, and mass media) were involved. In fact, a clear village-wise plan complete with the number of people to be evacuated was drawn and followed perfectly, arguably resulting in fewer deaths.

Figure 20: Rescue work carried out by NDRF (Sources: NDRF)

9. Relief works

It was decided that the cash dole distribution should start the moment water recedes from an area. So, both rescue and relief operations were conducted simultaneously (Immediate relief included moving people into safe shelters, arrangements for essentials like food, water, medicines, etc.).

State Government also enhanced the compensation amount as defined under various norms per unit across various heads (households, crop loss, etc.). State Disaster Relief Fund norms of Rs. 3,800 per household were increased by Rs. 3,200 to Rs. 7,000 per household.

The number of days for which the compensation was to be given to each affected person was fixed at 10 days at the rate of Rs. 60 per day at the state-level itself so that there is no difference in the amount of compensation across districts. This standardisation prevented dissatisfaction among people and an issue with a potential to explode was turned into a non-issue.

In 2015, the cash doles were deposited in the bank accounts of the beneficiaries under the DBT (Direct Benefit Transfer) scheme. However, it was decided that this time, cash doles would be handed out to the affected people in cash so that it is easier for them to purchase essentials. (Arranging for the

cash and managing distribution required efforts as many banks were also affected by floods).

Free distribution of fodder for cattle was also undertaken. Sources for grass supplies (fodder depots across the State) were identified; transportation and distribution arrangements were done. State's strong dairy network (their documentation/list of cattle owners, their distribution network) was used for free distribution of grass to the cattle owners. This was continued for about 15-20 days until the growth of fresh grass.

Cattle assistance was enhanced from Rs. 30,000 to Rs. 40,000 for each cattle loss. Also, the cap on the number of cattle for which assistance was made available was increased from three to five.

By 3rd August 2017, the State Government came up with a special package of Rs. 1,500 crores for Banaskantha and Patan. Relief norms were enhanced without exception.

9.1 Relief Package

The relief camps were opened with immediate effect for people affected. State Government immediately announced financial assistance in case of human death, injury, cash doles and fodder. The disbursement of financial assistance was made in cash through the district administration.

State Government declared special relief package of Rs. 1500 Crores for severely affected Banaskantha and Patan districts. Key highlights of the package are as under:

- Rs. 1336 Crore for Agriculture and land reform.
- Waiver of Rs. 50 Crore towards electricity bills of farmers affected for three months Rs. 20 Crore for financial assistance in case of loss of livestock.
- Rs. 15 Crore for trade, commerce and industries.
- Rs. 79 Crore for the schemes for relief measures of Revenue Department.

The rates of relief assistance were revised as under:

- Revised from Rs. 6800/- to Rs. 10000/- for crop loss in the non-irrigated area.
- Revised from Rs. 13500/- to Rs. 20000/- for irrigated area.

- Revised from Rs. 12800/- to Rs. 25000/- for land erosion.
- Revised from Rs. 60000/- to Rs. 80000/- for severe land erosion.
- Assistance in Cash of Rs. 75000/- for affected permanent large cabin shop holder.
- Assistance in Cash of Rs. 15000/- for affected permanent small cabin shop holder.
- Assistance in Cash of Rs. 5000/- for the affected moving shop on trolley holder.
- Waiver of interest on a bank loan of up to Rs. 10 lakh for two years to the merchants having a monthly turnover of more than Rs. 5 Lakh.

10. Reasons for the flooding

The reason for the flooding in each area differs, and as a result, so does the impact on the affected people. Districts have suffered significant loss of life, property and agriculture land. The reason for flooding is determined to be:

- Very heavy rainfall in North Gujarat and parts of Rajasthan necessitated the release of 2.3 Lakh cusecs of water from Dantiwada dam on 24th July, 2017. Another 2.48 lakh cusecs were released from Sipu dam against 20,000 cusecs during the normal monsoon.
- Incoming flow from Rajasthan

The breach in Jaitpura dam and over spilling of Jawai dam in Jalor Rajasthan has inundated several villages. First of all the break of Jetpura dam has been underplayed and hardly mentioned or explained. Discussion with Dantiwada Dam Authority, The incessant rain in the adjoining districts of Rajasthan caused flood and the flood water entered North Gujarat overflowing the dams and damaging the roads.

In the meanwhile, the Jetpura dam of Rajasthan has been completely washed away on the midnight of July, 24, midnight, which deluged Dhanera, causing massive destruction.

Figure 21: Dantiwada Dam visit (Picture captured 6th January, 2021)

- Water released from Dantiwad, Sukhbhadar and Sipu dams.

Dantiwada, Vasna, Sukhbhadar and Sipu dams were opened after massive inflow of water from Rajasthan. Due to heavy inflow from Rajasthan, about 4053326 cusecs and 1.3 lakh cusec of water was released from Dantiwada Dam and Dharoi Dam respectively. Thus release of water submerged the lower of Sabarmati river front in Ahmedabad. Vasna Barrage was also open to release water from the river. After the water was released, the adjoining regions and downstream districts including some villages, were inundated.

Table 8: Discharge of water during 2017 flood from Dantiwada dam

Date	Time	Gate No.	Discharge in cusec
24-07-2021	14	7	60500
	15	9	91000
	16	10	91000
	17	7	162000
	18	11	228341
	19	11	228341
	20	11	228321
	21	11	227345
	23	11	227341

	24	11	228341
25/07/2017	1	11	223896
	5	11	173318
	10	11	173318
	15	11	173318
	20	11	173318
	24	7	30383
26/07/2017	1	7	30383
	5	5	30900
	10	4	24375
	15	1	1797
	24	7	39125
27/07/2017	1	7	39125
	5	5	27738
	10	5	27738
	15	4	18813
	20	5	28155
	24	5	27947
28/07/2017	1	6	33536
	5	3	16643
	10	3	16643
	15	3	16643
	20	2	11095
	24	2	12467
29/07/2017	1	3	16768

	5	3	16705
	10	1	32590
	15	4	40526
	20	5	32265
	24	4	25812
30/07/2017	1	4	25812
	5	3	19359
	10	3	19359
	15	2	16642
	20	2	13111
	24	2	13111
31/07/2017	1	4,7	13111
	5	4,7	13111
	10	4,7	13111
	15	4,7	9265
	20	4,7	9265
	24	4,7	9265
1/08/2017	1	4,7	9265
	5	4,7	9265
	10	4,7	7416
	15	4,7	7416
	20	4,7	7416
	24	4,7	5560
02/08/2017	1	4,7	5560
	5	4,7	5560

	10	4	5560
	15	4	2780
	20	4	2780
	24	4	2780
03/08/2017	1	4	2780
	5	4	2780
	10	4	2780
	15	4	2780
	20	4	2780
	24	4	2780
4/08/2017	1	4	2780
	5	4	2780
	10	4	2780
	15	4	2780
	20	8	2780
	24	8	2780
05/08/2017	1	8	2780
	5	8	2780
	10	8	2780
	11	-	Nil
	24	-	Nil

- Breach in Narmada canal

The flood situation compounded further with a major breach in the Narmada canal near Kankrej and Thar in Banaskantha. The canal supplies Narmada water to Rajasthan. According to officials, the death toll would have been far less if the canal had not breached. Picture taken by Indian Express shows that the canal has been breached at several places within a one kilometre area.

Figure 22: Aerial photograph shows that the canal has been breached at several places. (Source: https://indianexpress.com/article/india/gujarat-floods-the-deluge-4775591/)

- Of the three lakes in Dhanera, one was filled up incessant torrential rain due to simultaneous activation of Arabian Sea and Bay of Bengal low-pressure systems (a rare phenomenon) has resulted into floods in several parts of Gujarat this year.
- According to the IMD, July 01 to 28, state received 559.4 mm of rainfall, as against the average of 339.6 mm between July 1st and 28th which shows an excess of 65% (Figure 22).

The districts of Aravali, Banaskantha, Patan, Morbi, and Surendra Nagar received 666 mm, 951 mm, 775 mm, 726 mm and 697 mm respectively of their total rainfall for the same period Figure 22. In the history of 112 years, it was the heaviest rainfall in the affected area of Banaskantha and Sabarkantha district.

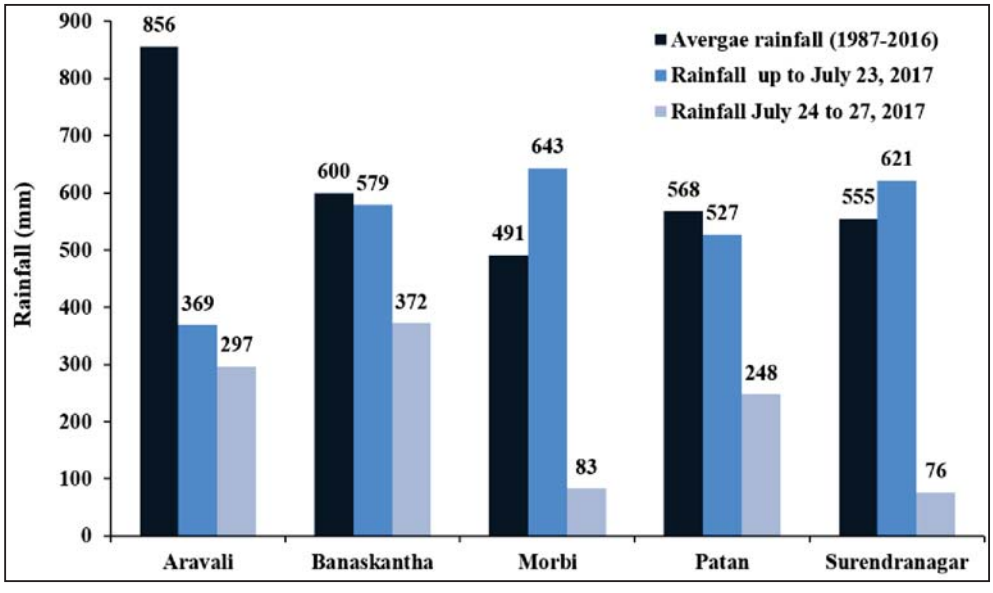


Figure 23: Shows rainfall data of the worst affected districts (Data collected from IMD)

On 24th July, several districts of north Gujarat received more than 200 mm of rainfall in 24 hours. Among which Dhanera received 235 mm (in 6 hours on 24th July), Deesa recorded 269 mm rain while Idar recorded 151 mm on 25 July rainfall. Dhanera was flooded by the water released from the Jetpura Dam and Rauva Dam, from Rajasthan, which merges with the waters of the river Rail (The Indian Express, 2017). Mximum rainfall of 219 mm was observed in Sabarkantha, followed 150 mm rainfall in Banaskantha. The rainfall received was close to higest rainfall in 112 years in the affected region. At the same time, the release of waters from the Sipu Dam into the Banas river flooded the villages along its banks, primarily in the DeesaTalukas and then in Kankrej (Gujarat Samachar, 2017). Reports also suggest that delay in opening the dam gates led to damaging of the outlet channels from the dam in some villages (HDRC).

Rainfall (mm) data for Banas River Basin-2017 flood											
Region	**Date (Month of July, Year 2017)**										
	21st	**22nd**	**23rd**	**24th**	**25th**	**26th**	**27th**	**28th**	**29th**	**30th**	**31st**
Amirgadh	9	0	50	246	337	150	55	8	82	4	5
Bhabhar	4	44	108	92	174	28	8	54	48	13	3
Danta	0	14	29	179	167	104	70	43	34	21	15
Dantiwada	6	17	44	342	463	21	21	41	18	10	4
Deesa	13	15	86	212	210	119	19	8	16	15	15
Deodar	73	145	204	172	284	106	0	30	5	55	12
Dhanera	7	31	18	231	275	139	10	0	12	10	8
Kankrej	40	63	67	120	154	39	3	14	5	8	0
Lakhani	14	30	99	221	305	51	9	11	7	39	20
Palanpur	7	51	30	255	380	62	46	23	25	49	7
Suigam	7	29	25	72	122	19	8	32	115	50	19
Tharad	20	40	470	119	180	59	6	12	4	39	8
Vadgam	70	40	17	200	357	60	28	19	13	29	14
Wav	2	15	15	82	187	46	8	10	10	45	10
Average rainfall	20	29	60	182	257	72	21	22	29	28	10

- **Morphology**

Dryland alluvial sequences, owing to their sensitivity to minor climatic perturbations that result in significant changes in flow regime, sediment transport, and associated channel style (Nanson and Tooth,1999), provide great potential for paleo environmental reconstructions(Reid et al., 1998; Nanson and Tooth, 1999). Considering that semiarid regions cover a large proportion of Earth's land surface (Graf, 1988) and theephemeral fluvial system constitutes one of the important geomorphic agents (Reid and Frostick, 1997), it is therefore important to under standriver responses to climate variability.

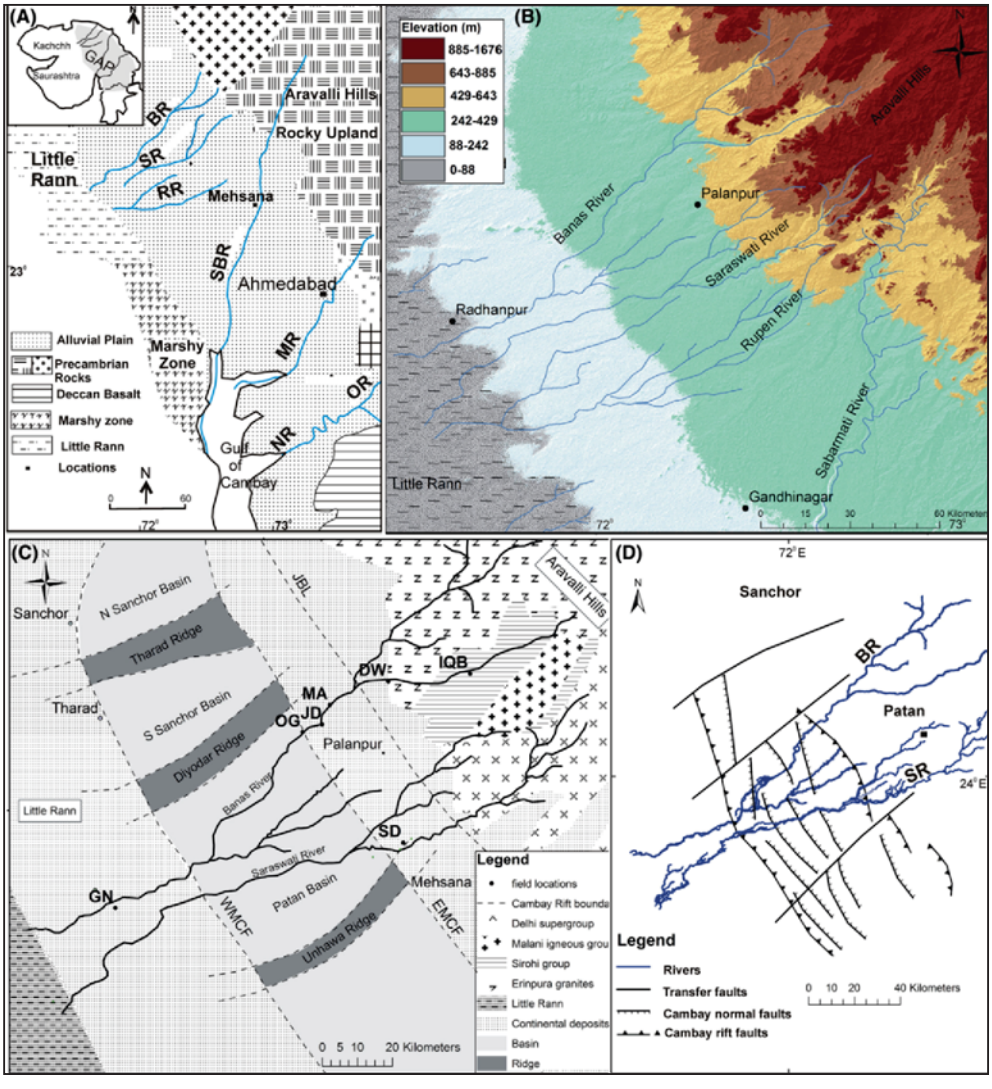


Figure 24: Figure showing locations of (A) Gujarat alluvial plain (GAP) and the drainages flowing from the Aravalli Hills towards the Little Rann and Gulf of Cambay. BR = Banas River, SR =Saraswati River, RR = Rupen River, SBR = Sabarmati River, MR = Mahi River, NR = Narmada River, OR = Orsang River. (B) DEM of Gujarat alluvial plain and drainages.(C) Structural configuration of the Cambay basin of Gujarat alluvial plain dominated by ridges and basins. (D) Cambay rift and subsidiary normal and transfer faults traversing through the Banas and Saraswati River basins (after Kundu and Wani, 1992). Note that the Banas and Saraswati

rivers occupy the Patan sub-basin. EMCF = Eastern Margin Cambay Fault,WMCF = Western Margin Cambay Faults, and JBL = Jaipur Barwani Lineament. Field locations are shown along the Banas and Saraswati rivers (IQB = Iqbalgarh, DW = Dantiwada, MA = MotiAkhol, JD = Juna-Deesa, OG = Goliya, GN = Gotnath, and SD = Siddhpur). (Source: Bhattacharya et al. 2017)

Banas River morphology and flood 2017

The Banas basin has a total catchment area of 8674 km^2. In which, 3269 km^2 lies in Rajasthan State while the remaining 5405 km^2 lies in Gujarat. Banas River originates from Aravallihills which is in Rajasthan and it flows gradually in a South-West direction. Total length of Banas River is 266 km from which 78 km is in Rajasthan and remaining 188 km is in Gujarat state. It continues south through the plains of Gujarat state, flowing through Banaskantha and Patan districts to empty into Little Rann of Kutch seasonal wetland. Figure 1 shows location map of Banas River basin, which shows 62.3% of total basin area falls in Gujarat state and mostly in Banaskantha district. The Banas River passes through the 13 districts namely, Sawai Madhopur, Jaipur, Ajmer, Tonk, Rajsamand, Banswara, Chittaurgarh, Udaipur, Bhilwara, Dausa, Sikar, Nagaur and Karauli.

There is Sipu River, which is the only right bank main tributary of Banas River while another six tributaries are on the left bank of Banas River, which are mainly the Khari, Suket, Baaram, Sukli, Batria and Sewaran which finally drain into the main channel.

Dhanera, which has a population of 30,000, was flooded up to 10 feet. The town was totally cut off for 48 hours as all of its approach roads were inundated. Power and telecommunication lines had also crashed.

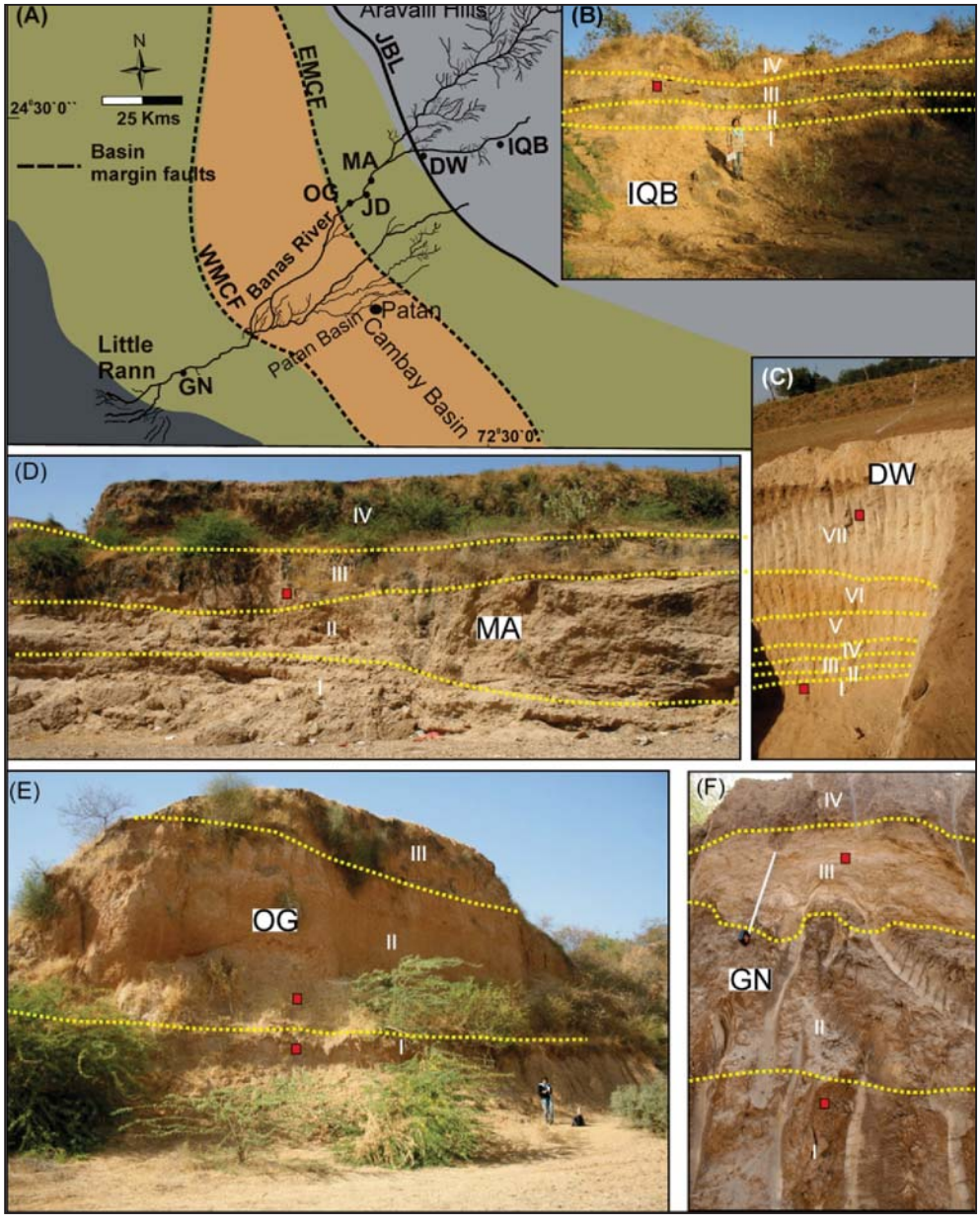


Figure 25: (A) The Banas River emerges from the Aravalli upland and drains into the Little Rann. Locations of the field photographs are marked as follows: (B) IQB = Iqbalgarh, (C) DW = Dantiwada, (D) MA = MotiAkhol, (E) OG = Goliya, and (F) GN = Gotnath. (Source: Bhattacharya et al. 2017). The stratigraphic units are marked in roman numbers and OSL sample locations are shown by red boxes.

(For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

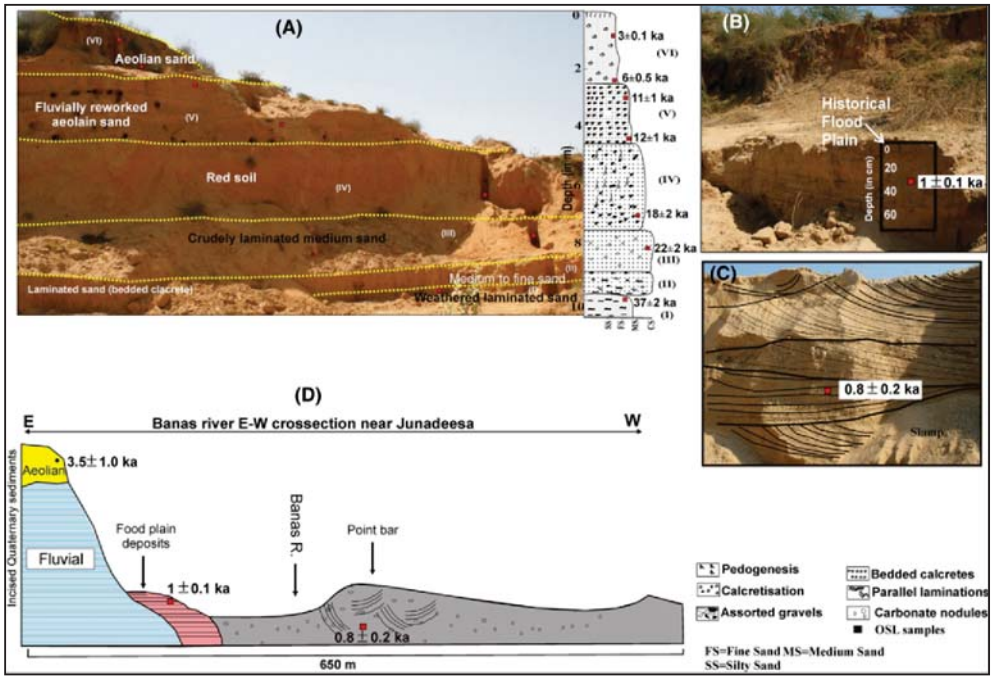


Figure 26: Alluvial sequence at (A) JD = Juna-Deesa along with detailed stratigraphy. OSL sample locations are indicated by red boxes. (B) Floodplain deposit at JD. (C) Point bar deposit at JD. (D) Schematic cross section between the left bank alluvial cliff and point bar deposit at JD (Banas River). (Source: Bhattacharya et al. 2017) (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

Rel River morphology and flood 2017

Rel River (SukalNadi) basin originates from Keshua Village, Aravalli Hills of Rajasthan State, and fows in Gujarat. The Rel River basin is the northern basin and lies between 24° 50′ N to 24° 75′ N latitude and 72° 00′ E to 72° 45′ E longitude and covers an area of approx 442 km^2. The basin is bounded both in the east and west by prominent hills of Aravalli range. The hills on the western side are higher and are part of Mt. Abu range. The streams originating from hills fow in NE–SW directions and drain into little Rann of Kutch. Being part of

the Mt. Abu range, the maximum elevation seen within the basin is about 609 m., while the general elevation within hilly part is in the 250–750m range. The overall slope of the terrain is northeast to southwest direction. The lowest point is near Dhanera Taluka and Dhanera City itself, and it is located near the exit point of the basin at southwest of Abu road, Banaskantha District. Further, Rel River basin and its watersheds are divided into 52 micro-watersheds, with an average area of 7 km^2. Entire study area falls within the toposheet numbered 45 D/02, 03, 06 at the scale of 1:50,000. It is considered a hot semiarid region in western India and experiences hot summer from March to mid-June. The maximum dry temperature ranges between 42 and 45 °C. The region encompasses three distinct seasons: winter, summer and monsoon. The temperature increases from January onwards having maximum values during May and gradually decreases afterward. With the onset of monsoon, southwest winds are strong and humid, with relative humidity more than 50%. The region is predominately inhabited by the tribal population, which till a few decades ago is mainly depended on forests for its livelihood and now also practices subsistence agriculture for food and fodder.

Rel River is having very steep topography in the upper catchment with a maximum elevation of 609 m and reduces to 77 m in the plain area near Dhanera Tehsil; such a large variation in elevation of river catchments leads to a fash food in catchment. Recently, Rel River catchment has recorded an average rainfall of 257 mm on 24th–25th 2017. It was close to the heaviest rainfall in 112 years in this region, resulted very heavy runof in the catchment of Rel River. Due the lack of the discharge carrying capacity of the river and heavy rain on catchment, Dhanera area and Dhanera City were flooded more than 30 hand observed under an inundation of 2.5–3 m in water. Near about 72 people died,81,609 cattle killed, and property damaged worth INR 2000 crore was in Banaskantha, Patan and Kutch districts. Dhanera was the highest food-affected city among the other of Banaskantha District. Entire stretch of Banaskantha District was under catastrophic food, and very heavy damages were reported. The Government of India announced an interim food relief package of INR 500 crore as initial assistance. The state government demands INR 4700 crore as compensation for damages. Around INR 1700 crore is the estimated loss for agricultural production and agricultural land, while INR 700 crore is for damage to state highway and village roads. Public infrastructure facilities like schools, colleges, hospitals demanded more than

INR 1000 crore. To restore public amenities and other private properties, it is at most important to distribute the food relief package as per the food hazards in this area; however, due to lack of the information of basin geomorphology, hazard and food risk area, the FRP allocation process is slowed down, hampering the restoration process in this region

10.1 Unprecedented floods, an unprecedented response

The torrential downpour struck Gujarat from 23rd to 27th July, While the rains were severed statewide, the badly affected districts were Surendra Nagar, Morbi, Rajkot and Ahmedabad. Figure 26 represents the flood inundated area in Gujarat state and the worst hits were Banaskantha and Patan districts.

In the first month of the monsoon, these places normally receive around 30% of annual rainfall. Against this, Banaskantha received 163%, while Patan recorded 140%. The highest rainfalls of 463mm were recorded in DantiwadaTaluka and in Palanpur talukas was 380mm on 25th July, 2017. The average rainfall recorded till 28th July, 2017 in Dantiwadataluka and Deodar taluka of Banaskantha was 252.55% and 226.82% of the normal rains respectively which are exceptionally high. Dhanera taluka in Banaskantha, recorded 231 mm and 275 mm rainfall on 24th and 25th July respectively, While Dantiwada Taluka received 342 mm and 463 mm.

As far as precipitation in Patan district is concerned, the highest rainfall of 295 mm was recorded in Patan taluka and 217 mm in Saraswatitaluka on 25thJuly, 2017. The rainfall recorded till 28th July in Patan district was 138.28% to average rainfall. A huge inflow unprecedented flood water entered Banaskantha from Rajasthan. Mount Abu received 97 inches of rain in three days, resulting in the water flowing down from a height and compounding the problem further. The heavy rainfall in North Gujarat and parts of Rajasthan necessitated the heavy release of water (2.3 lakh cusecs from Dantiwada dam) on 24th July. The discharge from Sipu dam was 2.48 lakh cusecs, which is 20,000 cusecs during a normal monsoon.

Dhanera town, population 30,000 got inundated with water levels from 4 to 10 feet. It was totally cut off for 48 hours as all approach roads were submerged, electricity and telecommunication lines were damaged, making the situation worse. The Banas River catchment area received extremely heavy rainfall on the 24th and 25thJuly, 2017. The little Rann of Kutch, which drains the Banas,

got saturated due to high inflow of water. Tharad, Dhanera, Kankrej, Lakhani, Suigam and Deesa blocks of Banaskantha; besides Santalpur, Sami and Harji blocks of Patan District were heavily flooded. In this disastrous situation, the state Government immediately began rescue and relief operations, as thousands were stranded in the flood waters.

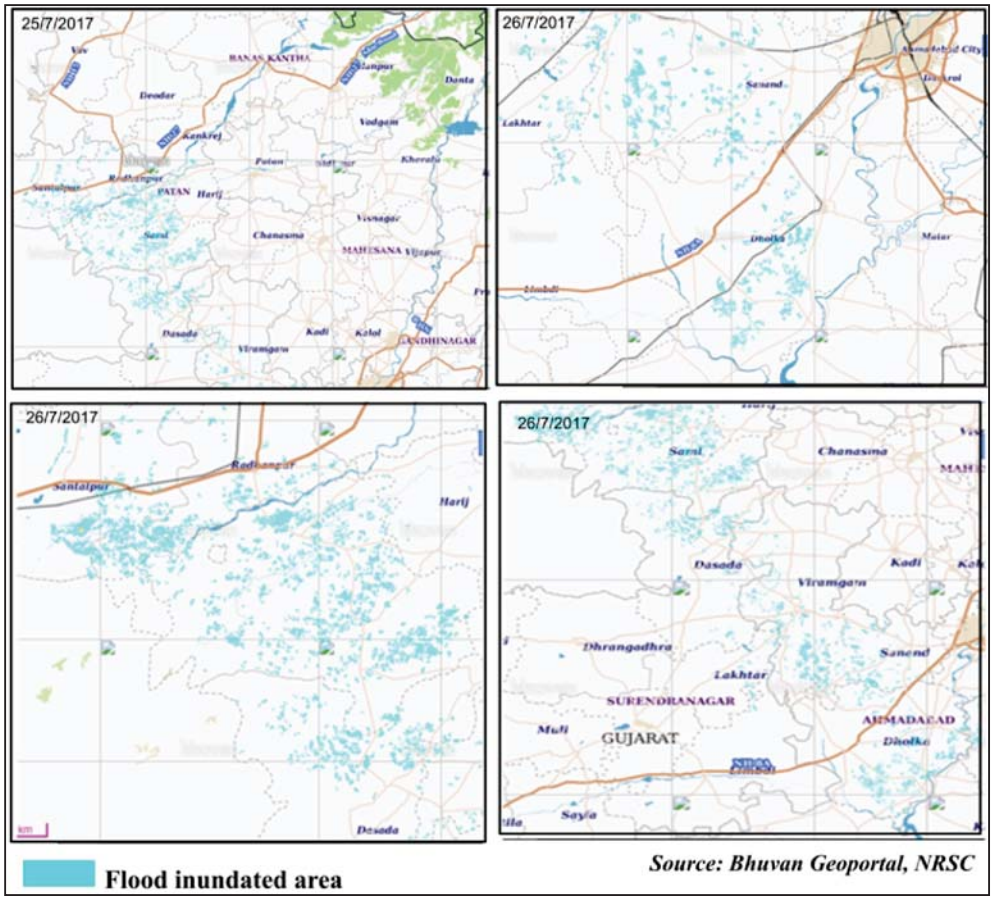


Figure 27: Flood inundated area in Gujarat (Source: BhuvanGeoportal, NRSC)

11. Lesson learnt

Disasters have much in common besides the devastation of lives and property they leave behind. They all teach hard lessons, whether the destruction comes from floods, fires, windstorms or other events. Those lessons are as valuable as they are difficult for disaster risk management professionals, making it

urgent to use them to reduce risk and build resilience ahead of the next big event. With every disaster, the weakest point of the management gets exposed. It is said that a chain is as strong as its weakest link. The flood of 2017 in Gujarat points out the vulnerability and weakness of the state to disasters. The lack of preparedness and fatality of the flood made it highly challenging for the state to cope up. The flood brought attention to a number of structural constraints that left Gujarat unprepared for major natural disasters or climate change shocks. This involves inadequate policies and institutional frameworks to control critical natural resources such as water and land, the lack of risk-proof spatial and sectoral planning policies and frameworks that drove to extensive urban turmoil, uncontrolled construction in hazard-prone areas and absence of disaster risk preparedness in key socioeconomic sectors, lack of basic infrastructure in urban areas along with aging and poorly maintained infrastructure, poor capacity of institution to anticipate and respond to extreme events, scarcity of availability and sharing of reliable data for disaster risk planning and management due to weak hydro-met system, and limited fiscal resources as well as absence of pre-financing modalities for risk pooling and sharing.

11.1 Learn ways to manage water

A large part of India is prone to hydrological disasters on an account of drought, floods and cyclones. Hence we, at various levels, need to learn to manage scarcity as well as excess water. Growing urbanization and the effects of climate change are forcing us to do this with greater urgency. It needs to take a careful look at proper drainage channel, clearance of garbage from drains, integrated dam management, proper contour and precipitation inundation maps, formulate effective land management laws ensure their enforcement. Use of better technology, ensuring political will at different levels and institutionalizing resolve to enforce rules and regulations is need of the hour.

a. Desilting of basin:

The Rel river bed in most of the areas of Dhanera indicates excessive deposition of sand (Figure 27). Similarly the sand deposition has risen to very crucial level in bridge, where the river bed is merely 4-5 ft below the railway track (Figure 28). During the field investigation (04/01/2021), it was observed that the river bed has raised about 10 ft. in just 10 years which is a major

concern in flood management in Dhanera area. In 2017 there was a heavy rain in the Rel River catchment with an average rainfall of 257 mm. Moreover Rel River has a very steep topography at upstream catchment ranging from 609 to 77 in the plane area near Dhanera region. Such variation in elevation along with heavy rainfall can lead to flash flood in the catchment, which has already taken place on 2017.

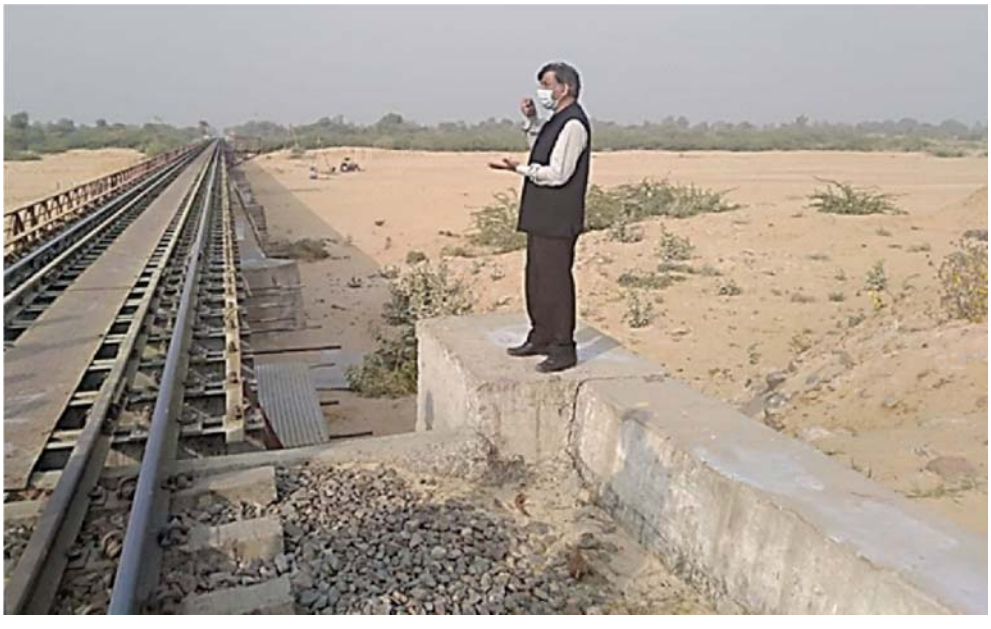


Figure 28: Sand deposit in Rel River at Gogabapaji Railway Overbridge, Dhanera (Picture captured on 4/01/2021)


a


b

Figure 29: (a & b) Sand deposition at Rel River (c) agricultural lands lying lower to Rel river bed (picture captured on 4/01/2021)

11.2 Drainage Improvement

Surface water drainage congestion due to inadequacy of natural or artificial drainage channels to carry the storm water discharge within a reasonable period causes damage. It is often difficult to distinguish between flood and drainage congestion situations. This problem is rather acute in North Gujarat. Therefore, improvement of drainage by construction of new channels or improvement in the discharge capacity of the existing drainage system is recommended as an integral part of the flood management programme in the country.

Stress has to be laid on improving the existing natural drainage system in the flood plains so that what should essentially be flooding of a few days should not get prolonged for months. In this context, the importance of the system 'dhars' or 'old channels', which efficiently served the function of draining away the spillage and surface flows generated by local rains, must be recognized.

The blocking of these natural drainage channels, which is normally done in the name of “reclamation for development” because of paucity of land or vested interest, must be firmly discouraged. This applies also to all natural depressions, which are targeted for reclamation. The adequacy of existing sluices and drainage channels should be reviewed in areas suffering from drainage congestion. If the capacities of existing sluices in embankments and drainage channels are inadequate, this should be improved by increasing the vents and improving outfall conditions.

Figure 30: (a & b) Canal near Tharad taluka is submerged with water (picture captured on 4th January, 2021) (c) Interaction & Discussion with Mamladar/Talukdar of Tharad taluka (picture captured on 4/01/2021)

11.3 Connectivity of nallas & tributaries to pond and to river

From the study of the flooding scenario as per existing topography of Gujarat and additional area, it is proposed to connect the nallas and tributaries with ponds coming in drainage path and further connecting the outfall channel to other pond or to the tributary leading to river provided with river training.

11.4 Better forecast and effective synergy

Weather forecasting needs to become more effective. To achieve this, not only the science of forecasting but also its dissemination and follow-on actions after the forecast need to be improved. Agencies such as India Meteorology Department (IMD), Central Water Commission (now Ministry of Jal Shakti) and Indian National Centre for Ocean Information Services (INCOIS) should have pre-notified national and state-level agency liaison protocols for appropriate information and warning.

11.5 Strengthening of critical infrastructure

In order to increase the flood resilience in country, it is also crucical to make the critical infrastructures function resilient. There is need for appropriate disaster management plans to ensure these infrastructures are well protected from disasters. It is sad to see some critical infrastructure facilities like airports which were critical to mounting a response were shut as they were impacted.

(a) Building conservation

Mani temple in Morbi district is historic buildings have been affected by the heavy rains and flooding that occurred during 1979, 2015 and 2017. Figure 30 shows the marked High flood level (HFL) in Mani temple. The HFL marking shows the extent and depth of flooding that occurred in 1979. This marking should be used to prepare flood inundation map at regional level. Inundation maps are one factor used to determine where changes should take place in building codes to help communities be more resilient; where evacuation routes should be; where (and how high) a bridge or road should be; and other community planning efforts.

Figure 31: HFL marked in Mani temple in Morbi (picture captured on 6/01/2021)

Figure 32: Food grain storage house of Food Corporation of India (picture captured on 6/01/2021)

11.6 Timely evacuation of people to safer locations (along with cattle)

These timely interventions also reduced the number of cattle deaths. In a district with a cattle population almost equivalent to the human population, the death toll is much lesser that the previous flood of 2015. A major factor behind this was the timely evacuation. Advanced warning also ensured that people moved out with their cattle. The severity of 2017 floods is far greater (5-7 times more) in comparison to 2015 floods. Agricultural losses and damage to crops are the right indicators for judging the severity of a flood (even better that the measurement of rainfall) as they cannot be moved and are open for the devastation

11.7 Promote support to NGOs

It is once again demonstrated that the NGOs can move in quickly and support relief efforts in a meaningful manner. Due to their flexibility, NGOs are able to address the specific needs of the survivors. NGOs need resources to

undertake their efforts and the government should help NGOs and promote their efforts to enable them to raise resources. One way the government can support NGOs is by creating a level playing field by provisioning tax exemptions to the donors on par with the tax exemptions available for the Prime Minister's Relief Fund and Chief Minister's Relief Fund. In the absence of a level playing field, NGOs will find it difficult to raise resources.

11.8 Strengthen local capacities

There is a need to develop community based approach so that the community moved quickly and participated in rescue operations shoulder to shoulder with the national rescue agencies. This very well demonstrates the importance of local capacities to deal with disasters. There should be clearly articulated efforts to strengthen community capacities to cope with disasters. Suitable system and operational procedures should also be in place to extend government support to local community efforts during disasters.

11.9 Capacity Development

Capacity development should be undertaken at various levels. In particular it should: Raise public awareness of flood preparedness response by public education including school children, and the handicapped. A shorter terms strategy to raise the awareness of the adult population to flood mitigation issues would also be beneficial. Such a program could include:

- The publication of flood hazard mapping at regional mapping
- Making these maps widely available at public offices and on the internet;
- Pamphlets outlining flood risks, flood mitigation measures, preparedness measures and response resources; and
- Articles in local newspapers prior to each monsoon season reminding the public about these issues and the resources available.
- Appropriate flood awareness training for government officials and elected representatives, and for professionals working in this field (engineers, town planners, social workers etc);
- Develop, in consultation with the NDMA, programs for training of trainers;
- Provide the basis for the development of a Flood Disaster Management Plan;

- Provide training for full time disaster management personnel, inter-agency training and training of ancillary staff;
- Research into flood related issues; and
- Dissemination of flood related information.

11.10 Taking the Apda Mitra Scheme forward

National Disaster Management Authority (NDMA) has approved a centrally sponsored scheme focused on training 6000 community volunteers in disaster response in 350 Districts in India. The districts have been identified taking into account occurrence of floods in the past. The State Governments may accept these identified districts or in their opinion if they find some other district more flood prone and vulnerable, they may indicate their preference, citing reasons.

The said NDMA scheme is to provide the community volunteers with the basic skills that they will need to respond to their community's immediate needs in the aftermath of a disaster (with afocus on flood). These trained volunteers can assist in saving lives using the basic techniques of disaster response, coordination and management

Implementation of the lessons learnt can be a path to reduce future disaster damages also it can map out the ways to decrease vulnerabilities of the state to disasters. In future Gujarat must prioritize eco friendly development across the state and also should keep a keen eye to the flood preparedness.

Recommendations

The lesson learnt from the deluge of Gujarat in 2017 paints the path of the way forward to a secure future of the state. It is very much important to implement the lessons that were learnt from the Gujarat flood 2017 so that in future the causalities are avoided and a well-protected and sustainable society is developed.

- Suitable institutional arrangements should be made between Gujarat and Rajasthan to improve preparedness for any probable flood in Banas and Sipu rivers as the two States share the catchment areas of both the river systems.
- Regular monitoring of flood preparedness in the vulnerable areas, collection and compilation of post disaster data, documentation of best

practices and lessons learnt has to be done by the state/ district(s). This can further be used for capacity building activities.

- Training Walls should invariably be designed as Reinforced Cement Concrete (RCC) structures instead of coarse rubble masonry as practiced in the earlier construction. Coarse rubble masonry may not withstand heavy flood as was experienced in the case of Dantiwada Dam during the 2017 floods.
- Improve coordination among inter alia departments
- Dhanera Municipal Corporation should be shifted to a higher altitude. Currently, Dhanera Municipal Corporation is placed at a lower altitude area and usually get flooded.
- Development of Smart Apps i.e., people-friendly for Gujarat state. As, technology played an important role in evacuation, alerting the people in a risk area and remote area.
- The Land use policy of the state should be made stricter. Illegal construction in restricted area must be stopped. Existing vulnerable land should be protected so that in future years there will not be any damage due to flood.
- Timely desiltating for Rel river is recommended to avoid any future flood inundation.
- Sustainable Sand Mining Management should be carried out for Rel and Banas River. In its current stage, sand is heavily deposited in the Rel river. If these are mined at this stage and used for construction purpose, then a major portion of sediment can be reduced.
- Check dams, settling basins, vegetation covers, agricultural practices, etc. may be adopted wherever applicable to control sedimentation.
- There is need for improvement of drainage by construction of new channels or improvement in the discharge capacity of the existing drainage system which is recommended as an integral part of the flood management programme in the country.
- Scheme like Apda Mitra developed by NDMA should be taken forward.

- Capacity building of the community should be done so that they can effectively respond to any kind of exigencies. Awareness generation regarding safeguarding the environment must be carried out extensively and intensively.
- Local volunteers must be trained and appointed for responding to disasters.
- Water level management at all dams in the state: Elaborate instructions are given in the FM. Rule levels have also been provided for each reservoir. These shall be strictly adhered to unless the safety of the structure is in danger. Every day data is being collected at 8 am from all the dams and compiled report is circulated by 10.30 am. Since data collection is a mammoth task, a system of data collection through SMS as well as internet software has also been put in place. However, to be doubly sure, manual data collection by phone is also being continued. During floods, in case of gated dams, water releases would be required to maintain the rule level after taking into consideration the volume of water that could be accommodated in the reservoir
- Dewatering pumps, placements: 10 truck-mounted 50 HP pumps with GWRDC are kept ready with the necessary operating crew, pipelines and other necessary fittings. These shall be deployed at important places in the state based on past experience so that these can be rushed to trouble spots in a very short time.
- Attempts should be made to procure satellite phones for all major dams. Personnel handling dam site flood cell, as well as zonal flood cells, are provided with mobiles.
- In case of interstate rivers like Daman Ganga, Tapi, Mahi, Narmada, the respective focal officers need to keep continuously in touch with their counterparts in respective States of MP, Maharashtra and Rajasthan as well as with Central Water Commission so that advance action could be taken. Coordination meeting needs to be held with Chief Engineers of Rajasthan, Maharashtra and Madhya Pradesh before monsoon and operations are handled in close co-ordination with them.

- District administration needs to be informed well in advance, in case, releases are required to be made from any dam.
- Hotlines need to be installed at all major dams for emergency communication.
- Realizing the need for renovation & modernization of the old canal system, the Government has taken up this activity, to improve the water use efficiency by enhancing the area under coverage and bridging the gap between irrigation potential created and potential utilized.
- Water auditing shall also be carried out simultaneously for each project every year. Following performance indicators are decided to be reviewed:
  - Hectare of land irrigated per unit of water
  - Crop yield per unit of water
  - O & M Cost per unit of water
  - Assessment & recovery of charges per unit of water
- Reappraisal of irrigation potential has also been taken up because of modification in cropping pattern as well as land use pattern. It is envisaged to complete the renovation, extension and remodeling of the entire canal system of the State over a period of 5 years. Up till now, strengthening of the canal system in 2,50,000 ha area has been completed. Necessary corrective actions would be taken up based on above exercise.
- Dam safety activities are directly related to the Department's priority to ensure reliable and efficient delivery of water and hydro power. The Department has launched a massive program of conducting Safety evaluation of all the dams and has taken up necessary corrective steps to ensure the safety of all these dams. Necessary guidelines and manuals for conducting safety inspection of earth, masonry and concrete dams and gates as well as other electrical and mechanical components of the dams have been issued. Checklists have also been prescribed and various levels of officers are assigned duty to inspect the dams twice a year – immediately after the monsoon and before the monsoon. These officers have imparted training on how to inspect, what to inspect, how to record findings and what follow up action to take after dam inspection. Further,

preparation of Emergency Preparedness Plans (EPP) for dams is also taken up. Necessary rectification of dams was also taken up.

- Operation, Maintenance and Repairs
- The Department through its cadres, operates, maintains and repairs almost all facilities including dams, barrages, canals and drains. The programme also involves carrying out associated water management activities which are designed to ensure that such facilities are operated and maintained in a manner that protects State's investment. It includes examination of all structures and their repairs/ rectification if required. Minor canals where Water Users Associations have taken over the canals, such activities are performed by them. In respect of all other canals, the Departmental staff carries out all activities under this program.
- A programme for inspection and examination of all canal structures was launched. Engineers conducted a 'walk through' inspection and recorded the deficiencies.
- A time-bound programme is chalked out and is under implementation for rectification/ refurbishment of such structures.

- Water for irrigation is planned to be supplied on a rotation basis decided in consultation with agriculture experts and Advisory Committees for respective irrigation schemes.
- The drains and filters play an important role in preventing the migration of particles that, otherwise, can initiate piping and overtopping. The processes of filtration, interface behavior and time-dependent changes that take place within the filter medium in a dam should be studied in further details
- A proper canal will be constructed along with the low level of contour line at 108m then flooding to avoid flooding as there is no proper natural drain to runoff the rain water which results in flood.
- There is a need to strengthen State Disaster Management Plan and District Disaster Management Plans for Gujarat state.
- Initiative must be taken to create a network of amateur radio in Gujarat to strengthen community based disaster preparedness.

- Broadcasting techniques and systems for use in emergency communications needs to be continuously improvised
- Suitable institutional arrangements should be made between Gujarat and Rajasthan to improve preparedness for any probable flood in Banas and Sipu rivers as the two States share the catchment areas of both the river systems.
- Training Walls should invariably be designed as Reinforced Cement Concrete (RCC) structures instead of coarse rubble masonry as practised in the earlier construction. Coarse rubble masonry may not withstand heavy flood as was experienced in case of Dantiwada dam during 2017 floods.
- There is a need to adopt and identified Municipal Corporations as regional rescue centres and mandated therewith one of their regular activities so that they can operate functionally during any crisis. Such an association actually helped during the floods in Gujarat.
- Regular monitoring of flood preparedness in the vulnerable areas, collection and compilation of post-disaster data, documentation of best practices and lessons learnt have to be done by the state/ district(s). This can further be used for capacity building activities. These timely interventions also reduced the number of cattle deaths. In a district with a cattle population almost equivalent to the human population, the death toll is much lesser than the previous flood of 2015. A major factor behind this was the timely evacuation. The advanced warning also ensured that people moved out with their cattle.
- Develop village tanks and lakes that have the best water harvesting performance. They reach maximum extension at the end of the monsoon and maintain water throughout the post-monsoon season.

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