National River Conservation Directorate
Ministry of Jal Shakti,
Department of Water Resources,
River Development and Ganga Rejuvenation
Government of India

Flood hazard modelling in Cauvery River Basin

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Flood hazard modelling
Cauvery River Basin

National River Conservation Directorate (NRCD)

The National River Conservation Directorate, functioning under the Department of Water Resources, River Development and Ganga Rejuvenation, and Ministry of Jal Shakti providing financial assistance to the State Government for conservation of rivers under the Centrally Sponsored Schemes of 'National River Conservation Plan (NRCP)'. National River Conservation Plan to the State Governments/ local bodies to set up infrastructure for pollution abatement of rivers in identified polluted river stretches based on proposals received from the State Governments/ local bodies.

www.nrcd.nic.in

Centres for Cauvery River Management Studies (cCauvery)

The Centres for Cauvery River Management Studies (cCauvery) is a Brain Trust dedicated to River Science and River Basin Management. Established in 2024 by IISc Bengaluru and NIT Tiruchirappalli, under the supervision of cGanga at IIT Kanpur, the centre serves as a knowledge wing of the National River Conservation Directorate (NRCD). cCauvery is committed to restoring and conserving the Cauvery River Basin (CRB) and its resources through the collation of information and knowledge, research and development, planning, monitoring, education, advocacy, and stakeholder engagement.

www.ccauvery.org

Centre for Ganga River Basin Management and Studies (cGanga)

cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The Centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this, it is also responsible for introducing new technologies, innovations, and solutions into India.

www.cganga.org

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Disclaimer

This report is a preliminary version prepared as part of the ongoing Condition Assessment and Management Plan (CAMP) project. The analyses, interpretations and data presented in the report are subject to further validation and revision. Certain datasets or assessments may contain provisional or incomplete information, which will be updated and refined in the final version of the report after comprehensive review and verification.

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Preface

In an era of unprecedented environmental change, understanding our rivers and their ecosystems has never been more critical. This report aims to provide a comprehensive overview of our rivers, highlighting their importance, current health, and the challenges they face. As we explore the various facets of river systems, we aim to equip readers with the knowledge necessary to appreciate and protect these vital waterways.

Throughout the following pages, you will find an in-depth analysis of the principles and practices that support healthy river ecosystems. Our team of experts has meticulously compiled data, case studies, and testimonials to illustrate the significant impact of rivers on both natural environments and human communities. By sharing these insights, we hope to inspire and empower our readers to engage in river conservation efforts.

This report is not merely a collection of statistics and theories; it is a call to action. We urge all stakeholders to recognize the value of our rivers and to take proactive steps to ensure their preservation. Whether you are an environmental professional, a policy maker, or simply someone who cares about our planet, this guide is designed to support you in your efforts to protect our rivers.

We extend our heartfelt gratitude to the numerous contributors who have generously shared their stories and expertise. Their invaluable input has enriched this report, making it a beacon of knowledge and a practical resource for all who read it. It is our hope that this report will serve as a catalyst for positive environmental action, fostering a culture of stewardship that benefits both current and future generations.

As you delve into this overview of our rivers, we invite you to embrace the opportunities and challenges that lie ahead. Together, we can ensure that our rivers continue to thrive and sustain life for generations to come.

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Abbreviations and Acronyms

%	Percentage
&	And
′	Minute
°	Degree
NRCD	National River Conservation Directorate
MoJS	Ministry of Jal Shakti
DoWR, RD & GR	Department of Water Resources, River Development and Ganga Rejuvenation
NMCG	National Mission for Clean Ganga
cCauvery	Centres for CRB (CRB) Management and Studies
cGanga	Centres for Ganga River Basin Management and Studies
CRB	CRB
GRBMP	Ganga River Basin Management Plan
IMD	India Meteorological Department
CWC	Central Water Commission
AWS	Automatic Weather Station
QPF	Quantitative Precipitation Forecast
FRL	Full Reservoir Level
MCM	Million Cubic Metres
BCM	Billion Cubic Metres
LPA	Long Period Average
DEM	Digital Elevation Model
LISS-III	Linear Imaging Self-Scanning Sensor (IRS Satellite)
INSAT	Indian National Satellite System
GPM	Global Precipitation Measurement
NDMA	National Disaster Management Authority
SDMA	State Disaster Management Authority
DDMA	District Disaster Management Authority
EOC	Emergency Operation Centre
SOP	Standard Operating Procedure
MME	Multi-Model Ensemble
N-E Monsoon	Northeast Monsoon
SW Monsoon	Southwest Monsoon

SRO	Standard Reservoir Operation (contextual)
HFL	Highest Flood Level
CWC–FFWN CWC	Flood Forecasting & Warning Network
IRS	Indian Remote Sensing Satellites
GIS	Geographic Information System

Continuation of Abbreviations and Acronyms

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1. Introduction

The CRB covering parts of Karnataka, Tamil Nadu, Kerala, and Puducherry is among India's most climate-sensitive and flood-prone hydrological systems. Floods in this basin arise from a combination of monsoon dynamics, extreme rainfall episodes, catchment geomorphology, reservoir operations, and land-use pressures, all of which have been extensively documented in recent government assessments. Evidence from the Central Water Commission's Study Report on the Kerala Floods of August 2018 shows that regions within the Western Ghats (including the Kabini sub-basin flowing into Cauvery) have been experiencing exceptionally high rainfall anomalies, with 2018 witnessing rainfall 42% above normal and catastrophic flooding across 13 districts of Kerala

Similarly, the Rajiv Gandhi Institute of Development Studies (RGIDS) Kerala Flood 2018 Report characterizes the 2018 event as a "disaster of the century", noting unprecedented losses in infrastructure, agriculture, biodiversity, and livelihoods, and emphasizing that rainfall in hilly districts was three times higher than usual during August 2018.

In Tamil Nadu, flood dynamics are strongly shaped by the Northeast Monsoon, which contributes nearly 48% of the annual rainfall according to the National Disaster Management Authority (NDMA) Report on Tamil Nadu Floods. The same report documents extreme rainfall episodes such as the 2015 floods, during which Chennai received 101.8 cm of rainfall in November, its highest monthly total since 1918, leading to the overflow of major river systems including the Adyar, Cooum, and Kosasthalaiyar, which are downstream-linked to Cauvery's coastal hydrodynamics. The report emphasizes that low-lying urbanized riverbanks significantly increased flood vulnerability.

The broader hydrometeorological setting of the basin is reinforced by the India Meteorological Department's Monsoon 2024 Report, which observes a rising trend in heavy rainfall events, monsoon depressions, and synoptic disturbances over South Peninsular India. IMD notes that the southwest monsoon of 2024 produced 114% of long-period average rainfall over the South Peninsula, with Kerala, Tamil Nadu, and Karnataka receiving normal-to-excess rainfall in multiple months conditions highly favourable for basin flooding. This aligns with IMD records showing that heavy rainfall events in Kerala, including those causing landslides and flooding in 2024, are now among the most severe on record.

The Flood Forecasting and Warning Network Performance Appraisal Report, 2023 published by the Central Water Commission, highlights that South India, particularly the Cauvery-linked districts in Karnataka, Tamil Nadu, and Kerala, experienced recurrent severe and extreme flood situations between 2019 and 2023. The report shows that the number of flood forecasting stations witnessing severe/extreme floods has steadily increased, reflecting intensifying hydrological volatility across the basin states.

2. Hydrometeorological Setting of the CRB

The hydrometeorological environment of the CRB is governed by the interplay of the Southwest Monsoon, the Northeast Monsoon, Bay of Bengal low-pressure systems, extreme rainfall events, and catchment-specific physiographic controls. Government assessments from IMD, CWC, NDMA, and RGIDS show that the basin is undergoing a clear shift toward more frequent and intense synoptic disturbances, higher seasonal rainfall, and rapid-onset flood episodes.

The India Meteorological Department's Monsoon 2024 Report describes the southwest monsoon as the principal hydrological driver for Karnataka and Kerala, noting that the South Peninsular region received 114% of its Long Period Average (LPA) rainfall in 2024, with excess rainfall recorded in both Coastal Karnataka and Kerala. IMD documents that the monsoon onset over Kerala in 2024 occurred earlier than normal (30 May) and progressed rapidly, covering the entire country by 2 July, six days ahead of the climatological average.

IMD further notes that the 2024 season produced 14 low-pressure systems, including 3 depressions, 3 deep depressions, and 1 cyclonic storm, contributing to frequent heavy rainfall episodes over the southern states, which directly influence inflows into the Cauvery's tributaries such as Kabini, Hemavathi, and Harangi

The NDMA Report on Tamil Nadu Floods: Lessons Learnt & Best Practices emphasizes that Tamil Nadu receives nearly 48% of its annual rainfall from the Northeast Monsoon, making the lower CRB highly sensitive to rainfall systems forming in the Bay of Bengal, including depressions and cyclones.

According to NDMA, the 2015 floods, one of the most severe in Tamil Nadu's history, were caused by four successive heavy rainfall spells generated by deep depressions and low-pressure systems over the Bay of Bengal. Chennai alone received 101.8 cm of rainfall in November 2015, the highest since 1918, overwhelming river channels and floodplains downstream of the Cauvery system. This pattern demonstrates how synoptic disturbances in the Bay of Bengal can elevate flood risk across the Tamil Nadu-Puducherry segment of the Cauvery basin.

Hydrometeorological records from IMD (Monsoon 2024) show an increasing trend in very heavy rainfall events (>124 mm/day) and extremely heavy rainfall events (>204 mm/day) across the Western Ghats and adjoining Cauvery catchments. IMD notes several instances of clustered rainfall events, especially in July and August 2024, that led to flooding in parts of Karnataka and Kerala, including landslide-triggering rainfall in Idukki, Wayanad, and Kodagu.

Similarly, the RGIDS Kerala Flood 2018 Report notes that rainfall in the hilly districts during August 2018 was three times higher than normal, resulting in unprecedented catchment saturation, extreme runoff, and large-scale landslides in the Kabini sub-basin that feeds the Cauvery.

The Flood Forecasting and Warning Network Appraisal Report 2023 by CWC states that South India has experienced a sharp rise in severe and extreme flood stages in monitored river basins, including those linked to the Cauvery. The report highlights that between 2019 and 2023, several stations in Karnataka and Tamil Nadu recorded critical flood levels due to rapid catchment response following intense monsoon depressions and sustained wet spells. CWC also documents that during the 2018 Kerala floods, all major reservoirs were already near Full Reservoir Level (FRL) by July, leaving limited buffer for extreme inflows. This resulted in simultaneous releases from major dams, contributing to rapid flood propagation downstream into river systems hydrologically linked to Cauvery.

3. State-wise Flood Analysis for the CRB

3.1. Karnataka (CRB)

In past two decades Karnataka has been frequently confronted and faced extreme weather events with various disasters such as drought, flood, hailstorm, etc., causing enormous loss and damage to life, property. Karnataka has experienced 8 years of flood situation including recent 4th consecutive years of floods of 2018, 2019, 2020 and 2021 in last decade. The rare severity floods carrying huge river flows were of rare severity. The frequency range of flood in Karnataka is 2-8 years during 2005-2021. Floods are common in the districts of Coastal and Malnad region in the range 6-8 years followed by some taluks of north Karnataka in districts of Bidar, Yadgir, Kalaburagi and Raichur districts. North interior Karnataka districts more vulnerable flood compared to south interior districts.

According to the Karnataka State Flood Risk Management Action Plan - 2022, Karnataka has experienced recurrent and severe flooding over the past two decades, with eight major flood years, including four consecutive floods from 2018 to 2021. The document notes that floods recur every 2-8 years, with the Coastal and Malnad regions facing events every 6–8 years due to intense monsoon rainfall, cyclonic circulations, and discharges from upstream reservoirs. The year 2021 was particularly severe, as Cyclone Tauktae and subsequent monsoon depressions caused widespread flooding, landslides, and infrastructure damage across 125 villages, especially in Udupi, Uttara Kannada, Shivamogga, Kodagu, Hassan, and Belagavi districts. In addition, the report highlights a sharp rise in urban floods, particularly in Bengaluru, Mysuru, Mangaluru, Belagavi, and other expanding cities, driven by rapid urbanisation, encroachment of water bodies, reduced green cover, degraded wetlands, and inadequate stormwater drainage systems, making urban flooding a major disaster management challenge in the state.

3.2. Flood Hazard Zonation- Basin Approach, Krishna Sub-Basins, and CRB

The report emphasizes a basin-wise flood hazard zonation approach, integrating hydrological, meteorological, geomorphological, and satellite datasets (IRS-1D LISS-III, Sentinel, DEM) to delineate historical flood extents, inundation layers, and annual flood zones for Karnataka's river systems. For the Krishna sub-basins, the state identifies flood-prone areas due to extreme upstream inflows from Maharashtra, meandering channels, sediment deposition, inadequate reservoir flood cushions, and low-lying catchments that frequently inundate districts such as Belagavi, Bagalkot, Raichur, Gadag, Yadgir, and Vijayapura. Heavy rainfall events exceeding 900 mm in six days in July 2021 further intensified flooding across middle and lower Krishna reaches. The Cauvery Basin, listed as one of the most vulnerable basins, witnessed extensive flooding in Kodagu, Hassan, Mysuru, Mandya, and Chamarajanagar, with the report identifying 124 flood-prone villages, including 54 under very high risk and 70 under moderate risk, largely due to steep Western Ghats slopes, heavy monsoon rainfall, and reservoir releases from Harangi, Hemavathi, Kabini, and KRS.

3.3. Flood Hazard Zonation of West-Flowing River Basins and Key Causes of Flooding

The report describes the West-Flowing River Basins including the Netravati, Kali, Sharavathi, Aghanashini, Varahi, Bedti, and Barapole as highly flood-prone due to steep gradients, short river courses, and extremely heavy rainfall exceeding 250 mm/day along the Western Ghats. These rivers overflow rapidly during the southwest monsoon, inundating adjacent villages and damaging agricultural and horticultural crops, public infrastructure, and settlements. A total of 60 villages are designated as very high flood risk and 36 villages as moderate risk in these basins. Across all basins, the report identifies key factors worsening flood disasters: persistent widespread heavy rainfall, encroachment of floodplains, sedimentation at confluences, inadequate reservoir flood absorption, insufficient river discharge capacity, and gentle floodplain slopes that allow water to spread over wide areas. Meandering channels further increase inundation on both banks, contributing to recurrent and severe flooding across Karnataka's river basins

Karnataka forms the headwater zone of the Cauvery Basin, dominated by the steep Western Ghats in Kodagu, Hassan, and Chikmagalur. The IMD Monsoon 2024 Report highlights that both Coastal Karnataka and Interior Karnataka received excess to normal rainfall during the 2024 monsoon (South Peninsula rainfall = 114% of LPA), contributing to elevated inflows into the Cauvery tributaries, particularly Kabini, Hemavathi, Harangi, and Shimsha

3.4. Major Flood Episodes

The CWC Flood Forecasting and Warning Network Appraisal Report 2023 notes that multiple stations in Karnataka recorded severe to extreme flood stages between 2019 and 2023, indicating a rising frequency of high-flow conditions in the Cauvery and its tributaries. CWC identifies southern Karnataka as one of the regions demonstrating "persistent extreme water level events" caused by heavy monsoon rainfall and rapid runoff from mountainous catchments.

3.5. Kodagu (2018 and Subsequent Years)

The 2018 Kodagu floods were particularly severe, as reflected in the CWC Study Report on Kerala Floods 2018, which documents extreme rainfall across the Western Ghats including areas hydrologically connected to Cauvery headwaters. Rainfall over the Ghats in 2018 was 42% above normal, triggering landslides and catastrophic runoff into the basin's upper rivers.

3.6. Urban Flooding (Bengaluru)

Although Bengaluru lies slightly outside the core river channel, it remains part of the greater Cauvery catchment. The IMD report documents frequent cloudburst-like rainfall spells in 2024, contributing to urban flooding, especially due to encroached lakebeds and insufficient drainage connectivity.

Fig. 1. Aerial view of the widespread destruction during the Karnataka Floods of 2019

Fig. 2. Rescue and relief operations during the Karnataka floods, showing emergency teams evacuating stranded residents through deep floodwaters, repairing damaged roads, and transporting large groups to safety

4. **Tamil Nadu (Middle & Lower Cauvery Basin)**

Tamil Nadu faces annual flooding due to cyclones, monsoon rainfall, and surplus releases from major river reservoirs, particularly during the Northeast Monsoon, which contributes nearly half of the state's total rainfall. The Tamil Nadu State Disaster Management Plan 2023 identifies floods as one of the most significant recurring hazards, highlighting the state's vulnerability due to its geographic setting along the Bay of Bengal and the presence of major river basins including the Cauvery. Over the past two decades, Tamil Nadu has experienced multiple extreme flood events, including the catastrophic 2015 Chennai floods, which caused massive urban inundation along the Adyar and Cooum rivers, as shown in the plan's disaster timeline and aerial imagery of river overflow during the event. The document also highlights repeated Northeast Monsoon-driven floods affecting Cuddalore, Nagapattinam, Thanjavur, Tiruvarur and the wider Cauvery delta, which depend heavily on monsoon rainfall and are prone to riverine overflow when upstream catchments receive extreme rainfall.

The Disaster Management Plan notes that Tamil Nadu has suffered severe impacts from cyclones and heavy monsoon spells including Thane (2011), Nilam (2012), Vardah (2016), Ockhi (2017), Gaja (2018), Nivar (2020), and heavy rains in 2021, all of which contributed to large-scale flooding across districts such as Chennai, Kancheepuram, Villupuram, Nagapattinam, and the Cauvery delta region. Many of these flood events are connected to riverine surges, backwater effects, and discharge from major reservoirs, particularly in the CRB where upstream rainfall in Karnataka triggers downstream flooding in districts like Karur, Tiruchirappalli, Thanjavur, Tiruvarur, and Nagapattinam. The Plan emphasises that monsoon depressions over the Bay of Bengal often create compound flooding, combining river overflow, urban waterlogging, and stormwater drainage failure.

The report further stresses that the Cauvery Delta is a protected agricultural zone and one of the most flood-prone socio-economic regions in Tamil Nadu. Due to low-lying terrain, silted river channels, reduced storage in tanks, and encroachment of drainage pathways, heavy monsoon spells frequently lead to widespread inundation. The plan categorises floods as a major disaster and highlights that CRB districts repeatedly feature among the most vulnerable zones in the state's hazard maps. In addition, Chennai's recurring floods led to the establishment of systems such as the Chennai Real-Time Flood Forecasting & Spatial Decision Support System, drone-based basin surveys, hydrodynamic modelling, and installation of extensive AWS and water-level monitoring networks, all of which the report profiles as state-level flood mitigation strategies relevant to other major basins, including the Cauvery Basin

Tamil Nadu receives most of its annual rainfall during the Northeast Monsoon (48%), making the lower Cauvery highly sensitive to rainfall systems originating in the Bay of Bengal. The NDMA Report on Tamil Nadu Floods highlights that cyclone-induced rainfall is the primary driver of flood disasters in the state.

4.1. North–East Monsoon Dominance

According to NDMA, the 2015 floods occurred due to four extreme rainfall spells from deep depressions and low-pressure systems over the Bay of Bengal. Chennai alone recorded 101.8 cm of rainfall in November 2015, the highest in nearly a century. Downstream effects extended into Cauvery-linked districts where river channels and floodplains could not accommodate the inflow volumes.

4.2. Recent Flood Years (2020-2023)

CWC appraisals confirm that Tamil Nadu has repeatedly witnessed severe flood levels in stations along the Cauvery and its sub-basins from 2019 onward, with multiple flood forecasting sites being triggered due to heavy NE-monsoon rainfall and cyclone activity.

Fig. 3. Aerial view of Adayar river in Saidapet during the 2015 Flood.

(Source: Tamil Nadu Disaster Management Plan 2023)

5. Kerala (Kabini Sub-Basin & Western Ghats Influence)

Kerala represents the western flank of the Cauvery Basin, particularly the Kabini sub-basin flowing into Karnataka. This region is characterized by some of the highest rainfall intensities in India, as documented by the IMD Monsoon 2024 Report and CWC Kerala Flood 2018 Study.

5.1. Kerala Flood 2018 (A Landmark Event)

The Rajiv Gandhi Institute of Development Studies (RGIDS) describes the 2018 Kerala flood as the "disaster of the century", noting that rainfall in hilly districts was three times higher than normal, causing massive landslides and hydrological shocks across Western Ghat catchments that drain into Kabini and ultimately the Cauvery.

- The CWC Kerala Floods Report identifies:
- 42% above-normal rainfall
- Widespread orographic rainfall intensification
- Reservoirs filled to near-full levels by July 2018
- Simultaneous multi-dam releases from Idukki, Idamalayar, and Pamba systems

6. Puducherry (Downstream Coastal Zone of the Basin)

Puducherry, although small in geographic area, lies within the coastal terminus of hydrological systems linked to the lower Cauvery. Its flood vulnerability is shaped primarily by NE Monsoon rainfall and cyclonic systems.

6.1. Cyclone-Linked Flooding

The NDMA Tamil Nadu Floods Report records the severe impacts of the 2015 NE monsoon and associated depressions on Puducherry, which experienced extreme rainfall comparable to neighbouring Tamil Nadu districts during the same events.

6.2. Urban Flooding and Drainage Constraints

Puducherry faces chronic inundation due to:

- Flat coastal terrain
- Poor drainage canal capacity
- Backwater effects from the Bay of Bengal during high tide
- High concentration of built-up areas

These risk factors are highlighted repeatedly in NDMA's assessment of the 2015 disaster, noting the similarity of Puducherry's conditions to Chennai and Cuddalore.

Fig. 4. NASA’s image before and after Kerala flood 2018.

Fig. 5. Aerial view of widespread flooding inundating residential areas and agricultural land, illustrating the severe impact of monsoon-driven flood events in river basin regions (Source: RGDIS)

7. Reservoir Operations & Flood Modulation

Reservoirs in and around the CRB play a dual role: they are essential for water supply, irrigation and hydropower, but under extreme monsoon conditions they can also either attenuate or amplify floods depending on how full they are and how they are operated. Evidence from recent official assessments in Kerala, Tamil Nadu and at the national level illustrates both the potential and the limitations of reservoirs as flood-modulating structures.

The Cauvery system is structured around a cascade of large storages such as Krishnaraja Sagar, Kabini, Harangi and Mettur, complemented by upstream storages in the Western Ghats, including Banasura Sagar and Karapuzha in the Kabini sub-basin and several large multipurpose reservoirs in Kerala that, although not all in the Cauvery basin, strongly influence regional flood hydrology through inter-basin linkages and operational practices.

The Central Water Commission report on Kerala Floods, August 2018 identifies that just seven major reservoirs in Kerala, Idukki, Idamalayar, Kakki, Kallada, Malampuzha, Parambikulam and Mullaperiyar account for 74% of the state's total live storage (5.806 BCM), representing about 7.4% of the annual average runoff of all 44 rivers in Kerala

Several of these reservoirs (notably Parambikulam and Mullaperiyar) are operated for the benefit of Tamil Nadu, demonstrating how upstream storage decisions affect downstream flows in Tamil Nadu's river systems including the Cauvery.

At the national scale, the Flood Forecasting and Warning Network Appraisal Report 2023 notes that 138 inflow forecasting stations are now linked to major reservoirs and barrages, enabling advance estimation of reservoir inflows and providing a technical basis for pre-emptive flood control releases where rule curves and operating policies permit such modulation.

8. Evidence from Kerala 2018: Flood Moderation and Its Limits

The 2018 Kerala floods provide a detailed, data-rich case study of how large reservoirs can both moderate and fail to significantly reduce extreme floods, depending on antecedent storage conditions and storm magnitude.

The CWC Kerala Floods report analyses key reservoirs like Idukki, Idamalayar, Kakki and Malampuzha and concludes that during the 15-17 August 2018 storm, most reservoirs were already at or very near Full Reservoir Level (FRL) before the extreme rainfall event. As a result, they "neither added to the flood nor helped in reduction of flood" in a substantial way; releases were largely "controlled" but constrained by the lack of available flood cushion. For example, in the Periyar sub-basin, which hosts about 50% of Kerala's live storage, Idukki reservoir received an inflow volume of about 435 MCM over 15-17 August 2018 and released roughly 375 MCM (including spill and power releases), thereby absorbing approximately 60 MCM of flood runoff even under nearly full conditions. This shows that some flood moderation occurred, but the sheer magnitude and spatial extent of the storm meant that downstream flooding remained severe.

In contrast, the same report notes that Malampuzha reservoir (in the Bharathapuzha basin) absorbed about 49 MCM of floodwater during 8-9 August 2018, releasing only 48 MCM against an inflow of 97 MCM. Even during 15-17 August, the net volume released above inflow (13 MCM) was insignificant compared with the basin-wide runoff of ~1510 MCM, highlighting that a single reservoir with limited relative storage cannot substantially alter a very large flood wave.

The CWC study therefore recommends that rule curves for all reservoirs with live storage above 200 MCM be reviewed to explicitly provide "dynamic flood cushion" during the early monsoon period, while recognising that even 75%-full conditions would not have been sufficient to fully mitigate an event of 2018's magnitude. This recommendation is directly relevant to large storages influencing the Cauvery system (including Kabini-side dams and trans-basin storages serving Tamil Nadu), which face similar trade-offs between water conservation and flood moderation.

9. Kabini Sub-Basin: Interaction of Dams and Untapped Catchments

Within the CRB itself, the Kabini sub-basin is analysed in detail in the CWC Kerala Floods report. Kabini originates in Wayanad district of Kerala and flows east to join the Cauvery in Karnataka. The report identifies Banasura Sagar (gross storage 209.25 MCM) and Karapuzha as the two main reservoirs in the Kabini system upstream of the CWC gauge at Muthankera, with a total contributing drainage area of 1546 km^2.

During the 8-10 August 2018 storm:

Estimated areal rainfall over the Kabini sub-basin was 104 mm (1-day), 279 mm (2-day), 311 mm (3-day).

Corresponding runoff volumes were 123 MCM, 329 MCM, 367 MCM, closely matching the runoff computed from observed discharges at Muthankera.

For Banasura Sagar, the reservoir had already been at FRL since 16 July 2018. The report notes that "whatever inflow came into the reservoir, the same was released", meaning the dam effectively acted as a run-of-the-river structure during this event. On 8-9 August, rainfall of 278 mm and 443 mm at the dam site produced inflows of 11.32 MCM and 19.67 MCM, all of which were passed through as spill

10. Lessons from Tamil Nadu: Chembarambakkam and Preparedness

Although the 2015 Chennai floods are located in the Adyar and Cooum basins rather than the Cauvery, the NDMA report “Tamil Nadu Floods - Lessons Learnt and Best Practices” provides important operational lessons for Tamil Nadu’s wider reservoir system, including those in the Cauvery Basin.

NDMA records that Chennai and neighbouring districts experienced rainfall 2.5–3.8 times normal between 1-5 December 2015, with Chembarambakkam and surrounding catchments receiving over 475 mm on a single day. Against this background, NDMA’s study team visited Chembarambakkam tank specifically to understand “its functioning and role in water management in the State” and to review preparedness and response mechanisms.

The report uses the 2015 experience to emphasise:

- The importance of clear reservoir operation manuals,
- Regular desiltation and capacity restoration,
- Pre-monsoon safety reviews and rule-curve adherence, and
- The need for integrated urban and reservoir flood management in Tamil Nadu.

These principles are directly transferable to Cauvery reservoirs in Tamil Nadu, particularly Mettur, where combined riverine and local drainage flooding poses growing risk during intense NE-monsoon events.

11. Policy Recommendations based on Official Reports

11.1. Hydrometeorological Monitoring and Forecasting

11.1.1. Use Advanced Forecasts Operationally, Not Just for Research

The India Meteorological Department “Monsoon 2024: A Report” documents the success of seasonal, extended-range and short-range forecasts, including multi-model ensemble (MME) products and district-level rainfall monitoring through Automatic Weather Stations and satellites, with most forecasts for 2024 within expected limits. The RGIDS report, however, notes that forecasts were not adequately used by state agencies before the 2018 flood and calls IMD’s current products “inadequate” for local inundation guidance

Cauvery-specific recommendation:

Formalise Standard Operating Procedures (SOPs) that link IMD’s seasonal, extended-range and 3-5-day QPFs to concrete actions on reservoir levels, pre-positioning of response teams, and early evacuation.

Co-develop sub-basin scale inundation guidance (Kabini, upper Cauvery, deltaic Cauvery, etc.) using IMD rainfall forecasts plus CWC hydrological models.

Expand Dense Local Observation Networks in Critical Urban and Basin Hotspots

The NDMA report on "Tamil Nadu Floods - Lessons Learnt and Best Practices" recommends that Chennai develop its own dense Automatic Weather Station network, one station per 4 km^2 integrated with IMD warnings and flood-forecasting software, to handle high-intensity, short-duration storms

Cauvery-specific recommendation:

Implement dense AWS and water-level sensor networks in Bengaluru, Mysuru, Srirangapatna, Erode, Karur, Tiruchirappalli and the Cauvery delta, replicating the Chennai model, with real-time feeds into both State and Basin control rooms.

Leverage and Improve the National Flood Forecasting Network

The Central Water Commission's Flood Forecasting and Warning Network Performance Appraisal Report 2023 notes that CWC now operates 338 flood forecasting sites, including 138 inflow sites, with over 90% of inflow forecasts within ±20% accuracy, and emphasises flood forecasting as the most important cost-effective non-structural measure for flood mitigation.

Cauvery-specific recommendation:

Ensure all major Cauvery reservoirs (KRS, Kabini, Harangi, Mettur and key tanks) are fully integrated into the CWC inflow-forecast system.

Use these forecasts to trigger pre-defined actions (gradual pre-releases, alert levels, downstream evacuation) under the proposed CRBSOP.

11.2. Urban Flood Management and Preparedness

Adopt Chennai's Post-2015 Urban Flood Practices Across Cauvery Cities

The NDMA Tamil Nadu floods report documents multiple measures taken after 2015: tank and culvert desilting, vulnerability mapping of urban wards based on inundation depth, creation of recharge pits, formation of "green corridors" for emergency access, and revision of disaster management plans.

Cauvery-specific recommendation:

Implement similar programmes in Bengaluru, Mysuru, Srirangapatna, Erode, Karur, Tiruchirappalli and Thanjavur, integrating stormwater network mapping, lake/tank restoration, and ward-level vulnerability zoning.

11.3. Strengthen Emergency Operations, Communication and First Response

NDMA highlights the importance of multiple-channel HAM radios, additional Emergency Operation Centres, trained first-responder teams, pre-positioned boats and heavy equipment, and clearly designated spokespersons to avoid confusion during disasters. Establish or upgrade district and municipal EOCs across the Cauvery Basin, link them to IMD and CWC data streams, and maintain trained community-based first-responder teams (Aapda Mitra-style) with boats, ropes, generators and communication tools.

11.4. Land-Use Planning, Environment and Climate Resilience

Introduce basin-wide zoning regulations that restrict high-density construction, hill-cutting and quarrying in Kodagu, Wayanad, Nilgiris and other critical slopes feeding the Cauvery. Legally protect Cauvery floodplains and wetlands (lakes, tanks, marshes) from encroachment and promote bio-engineering solutions for bank protection.

11.5. Integrate Climate Change into All Development Plans

Require that all major infrastructure, land-use and irrigation projects in the CRB include a climate and flood-risk screening, with flexible design standards that accommodate more frequent extreme rainfall.

12. Integrated CRB Flood Management Framework

Official assessments across Kerala, Tamil Nadu and national agencies consistently describe flood management challenges that cannot be solved by individual states acting independently.

The Central Water Commission's Kerala Floods Study shows how simultaneous releases from multiple reservoirs, catchment saturation, and extreme rainfall in the Western Ghats created cascading downstream impacts across administrative boundaries. Similarly, the NDMA Tamil Nadu Floods Report highlights how urban flooding, river overflows, tank breaches and drainage congestion emerge from interstate hydrological linkages that are not reflected in state-level planning. The IMD Monsoon Report 2024 emphasises that extreme rainfall clusters, depressions, and heavy monsoon spells routinely affect Karnataka, Tamil Nadu, Kerala and Puducherry within the same synoptic window, strengthening the need for cross-state hydrometeorological coordination

13. Basin-Wide Hydrometeorological Intelligence System

Based on IMD's ensemble forecasts, monsoon outlooks, and high-resolution district rainfall monitoring, the basin should operate a unified Forecast Integration Dashboard with:

- IMD Nowcasts + QPF
- CWC inflow forecasts
- AWS networks across cities (recommended by NDMA for Chennai)
- Satellite rainfall (INSAT, GPM)
- Radar-based short-term rainfall predictions

Table 1: Forecast Action Matrix

Forecast Type	**Example Trigger**	**Basin-Wide Action**
Seasonal (IMD)	Above-normal SW/NE monsoon	Pre-monsoon drawdown in major reservoirs
Extended range (10-20 days)	Sustained wet spell forecast	Lower reservoir levels, prepare advisory
Short-range (3-5 days)	Very heavy rainfall warning	Gate operation plan activated
Nowcast (0-3 hrs)	Localised cloudburst	Urban flood response + dam discharge freeze

The Integrated CRB Flood Management Framework emphasizes a unified, multi-state approach to reduce flood risk across Karnataka, Tamil Nadu, Kerala and Puducherry by coordinating hydrology, reservoir operations, and land-use planning. Drawing on lessons from the Central Water Commission's Kerala Flood Report (2018), the CWC Flood Forecasting & Warning Network Appraisal (2023), the IMD Monsoon Report (2024), the RGIDS Kerala Flood Study (2018), and the NDMA Tamil Nadu Floods Report, the framework calls for establishing a CRB Flood Management Authority to harmonize rule curves, oversee dynamic flood cushions, and synchronise dam releases with IMD-CWC forecasts. It integrates real-time rainfall and inflow forecasting, dense AWS networks, radar data, and basin-wide early-warning protocols to ensure anticipatory action. Urban flood preparedness including tank restoration, drainage clearing, and multi-agency Emergency Operation Centres is modelled on NDMA's post-2015 best practices in Tamil Nadu. Environmental safeguards such as regulating construction in Western Ghats slopes, protecting floodplains, and restoring wetlands. Finally, the framework prioritizes community resilience through local disaster management plans, trained first responders, and transparent communication of reservoir releases, creating a climate-resilient, science-driven, and socially inclusive basin management system.

14. Flood Inundation 2008-2010

The Flood Inundation 2008 dataset developed by the National Remote Sensing Centre (NRSC) provides a comprehensive and high-resolution depiction of one of the most significant flood events in the CRB, capturing the precise spatial footprint of inundation using LISS-III satellite imagery. The map shows that flooding during 2008 was heavily concentrated along the lower reaches and distributaries of the CRB, where the river branches into a dense network before entering the Bay of Bengal. Large expanses of the deltaic region characterized by flat terrain, extensive canal systems, paddy fields, and densely populated settlements experienced widespread overbank flow, leading to prolonged waterlogging across agricultural lands and rural habitations. The clustered red zones on the map indicate severe inundation along distributary channels, floodplains, and low-lying pockets where floodwaters accumulated due to limited drainage gradients. The dataset's raster format allows precise delineation of these submerged areas and serves as an essential tool for understanding historical flood behavior, validating hydrological models, and planning mitigation strategies. According to the metadata, the Flood 2008 layer was specifically created to support disaster management, flood hazard zonation, and response planning, making it a valuable reference for assessing vulnerability in the Cauvery delta and evaluating how monsoon-driven hydrological extremes interact with geomorphology and land use. The 2008 inundation pattern highlights the inherent susceptibility of the delta to large-scale riverine flooding and reinforces the necessity for improved flood forecasting, early-warning dissemination, and floodplain management in this densely cultivated and socio-economically critical segment of the basin.

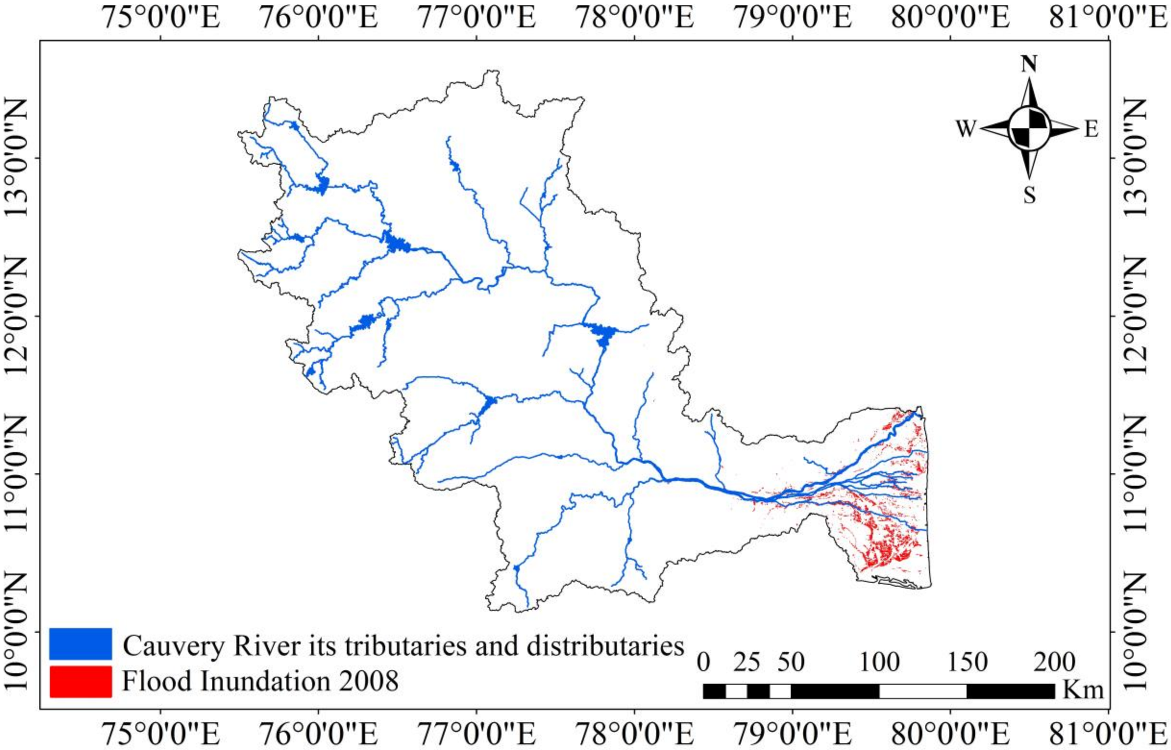

Fig. 6. Map showing the Cauvery River along with its tributaries and distributaries (in blue) and the spatial extent of the 2008 flood inundation (in red).

15. Flood Frequency Characteristics of the Cauvery Basin

Flood frequency analysis of the Cauvery River was carried out using the Gumbel Extreme Value Type-I (GEVI) distribution by Pagare et al. (2025) to estimate peak discharges corresponding to different return periods. The analysis shows that mean annual peak discharge exhibits a recurrence interval of approximately 2.33 years, while larger flood events recur at an average interval of 6.93 years, indicating moderate flood regularity in the basin. Estimated discharges for return periods ranging from 2 to 1000 years demonstrate a progressive increase in magnitude, with the observed maximum peak discharge corresponding to recurrence intervals between 36 and 636 years, reflecting the episodic nature of extreme flood events. These findings confirm that although the Cauvery Basin experiences frequent moderate floods, high-magnitude extreme floods are relatively rare but hydrologically significant. The application of GEVI provides reliable design flood estimates for infrastructure planning, reservoir safety, and floodplain management in the basin

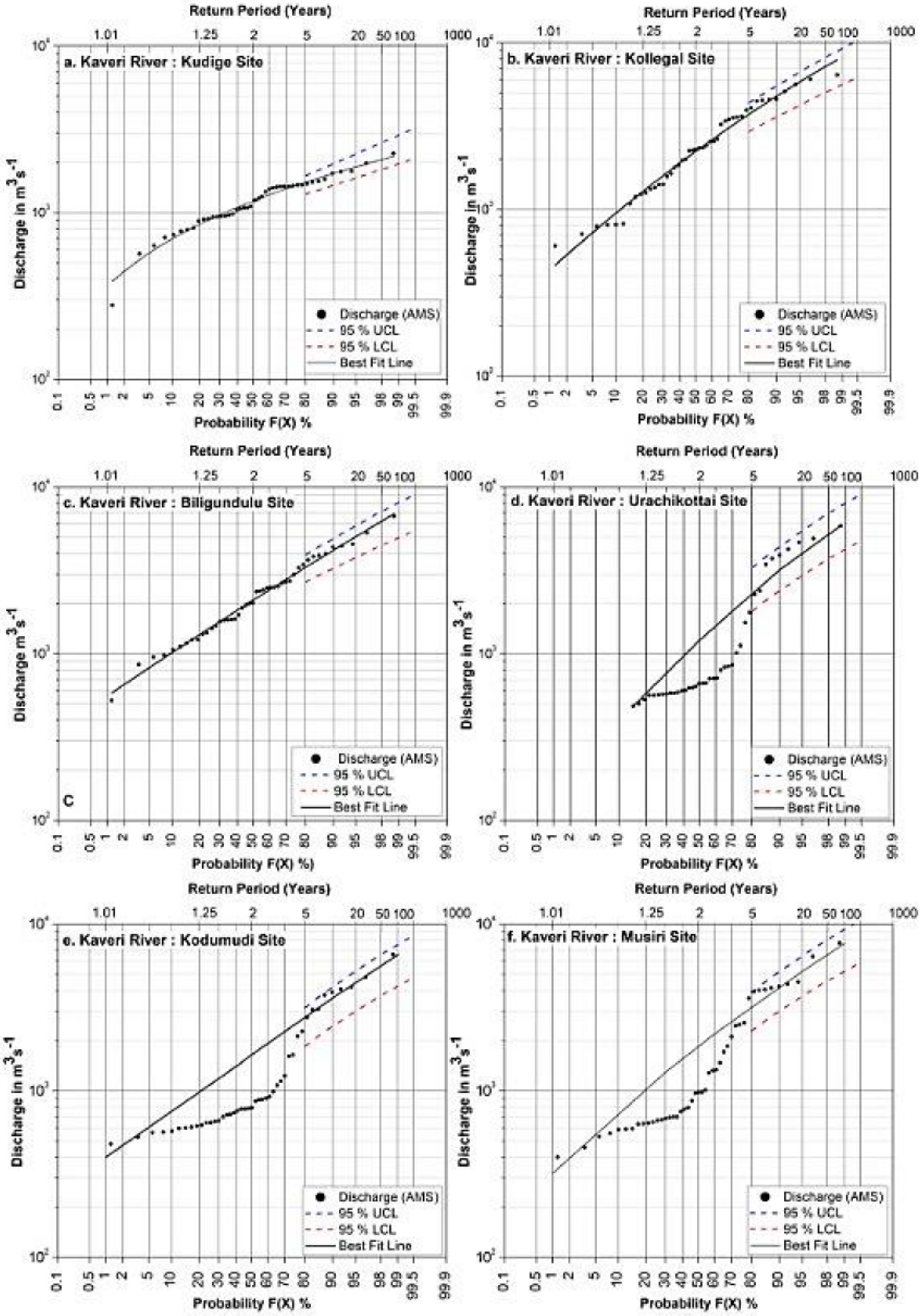

Fig. 7. Magnitude-frequency curve for discharge gauging sites on the Kaveri River represented on the Gumbel Extreme Value Type-I (GEVI) probability graph paper. UCL = Upper Confidence Limit, LCL = Lower Confidence Limit.

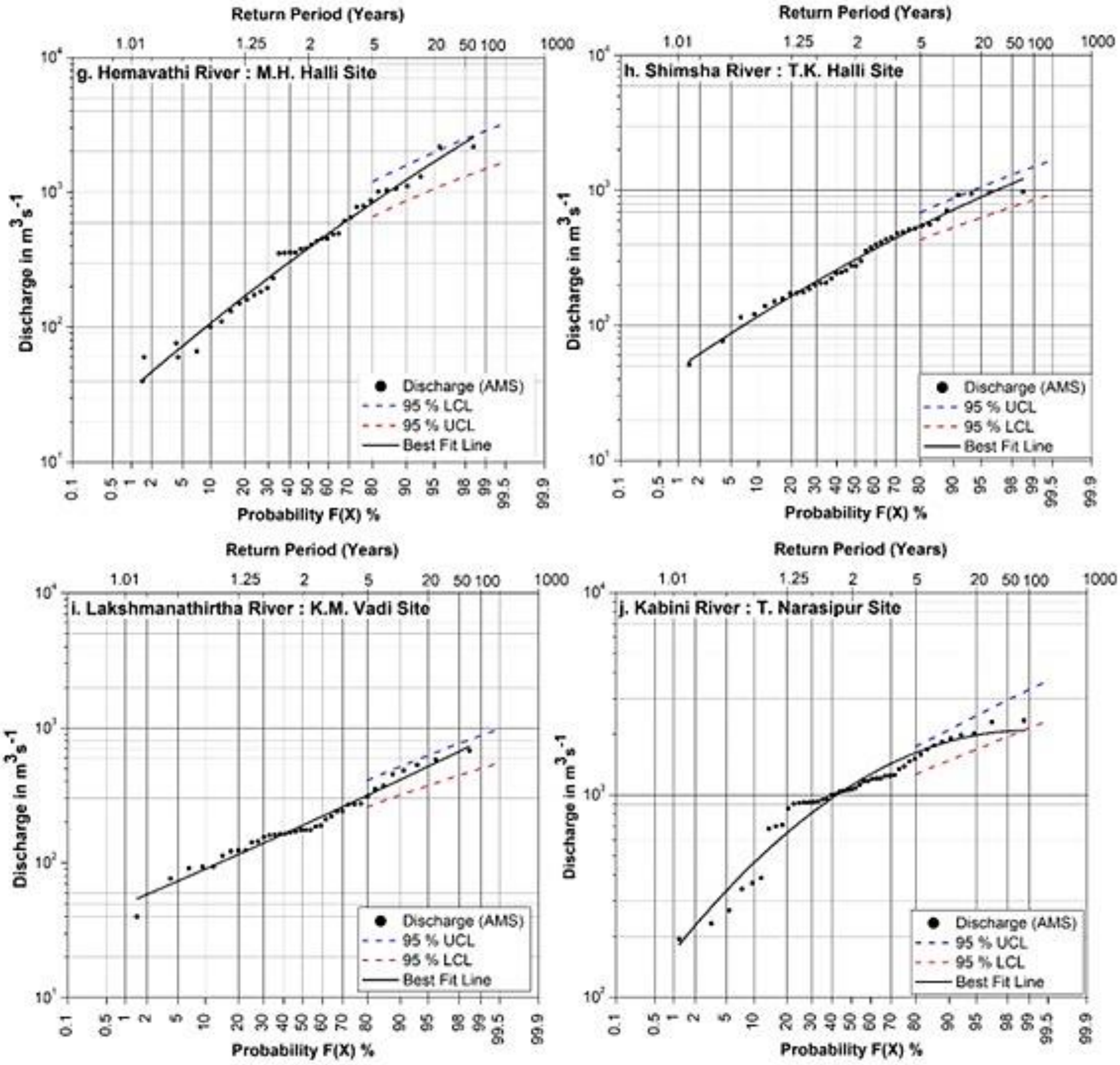

Fig. 8. Magnitude–frequency curve for discharge gauging sites on the tributaries of the Kaveri River represented on the Gumbel Extreme Value Type-I (GEVI) probability graph paper. UCL = Upper Confidence Limit, LCL = Lower Confidence Limit.

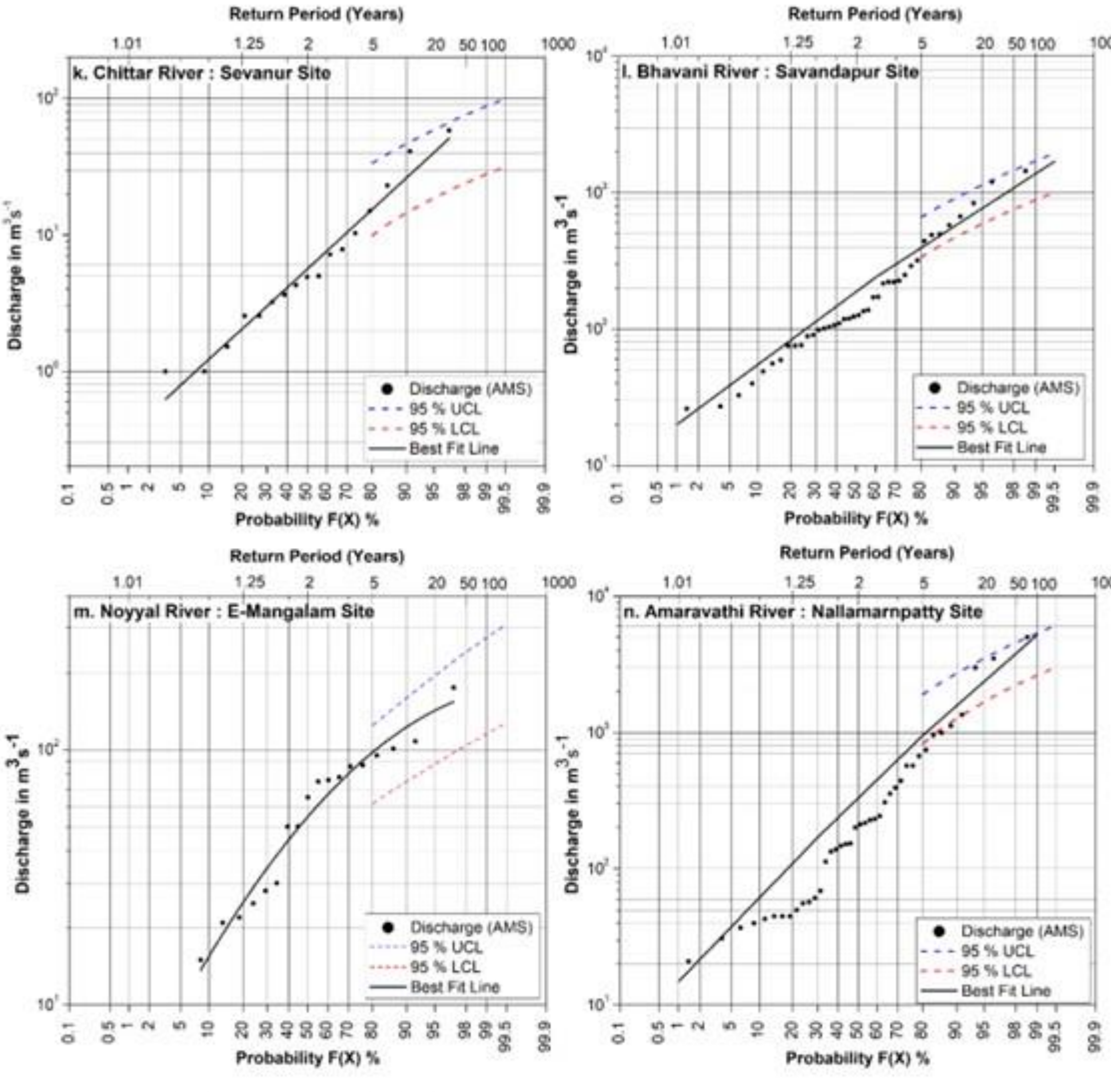

Fig. 9. Magnitude-frequency curve for discharge gauging sites on the tributaries of the Kaveri River represented on the Gumbel Extreme Value Type-I (GEVI) probability graph paper. UCL = Upper Confidence Limit, LCL = Lower Confidence Limit.

16. Comparative Assessment of Statistical and Soft Computing Techniques for Flood Prediction in the CRB

Recent research by Sahu et al. (2024) conducted a comprehensive evaluation of statistical and soft computing techniques for flood prediction in the CRB using 40 years (1980-2019) of annual peak discharge data from seven gauging stations. The study compared traditional probability distributions (Gumbel, Log Pearson Type-III, Log-Normal) with machine learning approaches including Artificial Neural Networks (ANN), Adaptive Neuro-Fuzzy Inference System (ANFIS), and a hybrid ANFIS integrated with Firefly Algorithm (ANFIS-FFA). Goodness-of-fit tests indicated that the Log Pearson Type-III distribution provided the best statistical fit at most stations. However, soft computing techniques significantly outperformed traditional statistical models. The ANFIS-FFA model achieved the highest accuracy with R^2 values up to 0.9636 and improved Wilmot Index (WI), demonstrating superior predictive capability and reduced RMSE. The results indicate that hybrid AI-based approaches offer improved reliability for flood forecasting in the Cauvery Basin compared to conventional statistical frequency analysis

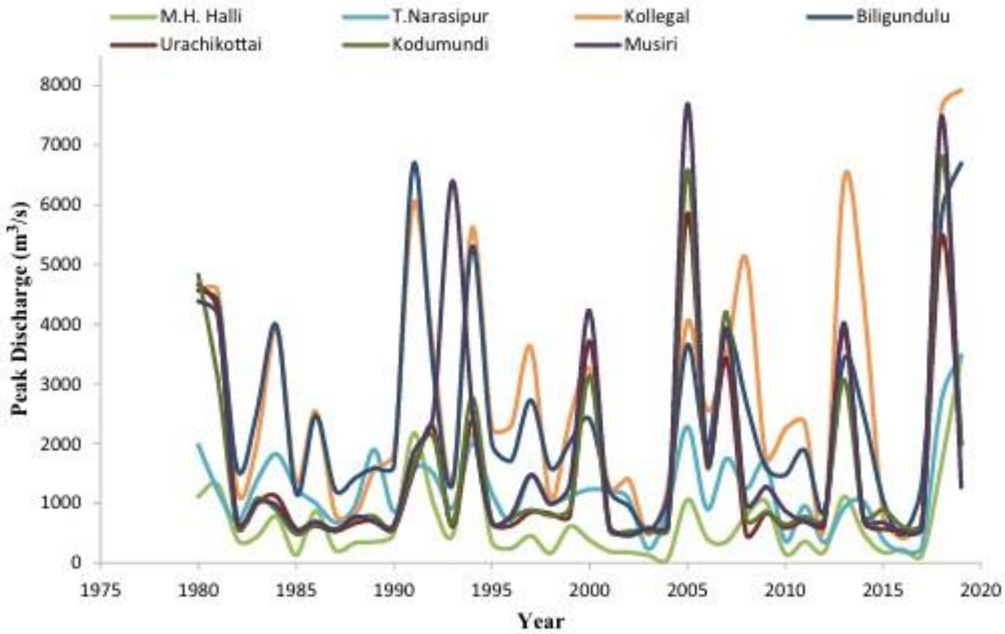

Fig. 10. Peak annual discharge measured at seven Cauvery River gauging sites (1980-2019)

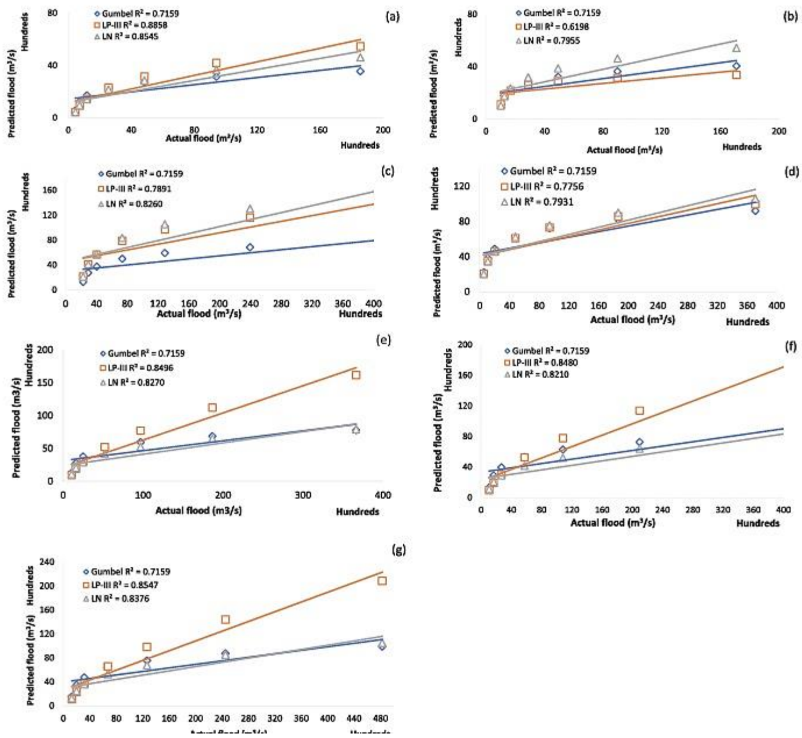

Fig. 11. Fig. 8 Graph depicting the comparison between actual and predicted values at a M.H. Halli, b T. Narasipur, c Kollegal, d Biligundulu, e Urachikottai, f Kodumudi and g Musiri gauging stations

Figure 11 presents a comparative evaluation of statistical flood frequency models; Gumbel, Log Pearson Type III (LP-III), and Log-Normal (LN) across multiple gauging stations in the CRB, showing the relationship between actual and predicted flood discharge values. Each subplot (a-g) illustrates model performance through regression lines and corresponding R^2 values, highlighting variability in predictive accuracy across stations. While the Gumbel model demonstrates moderate and relatively consistent performance ($R^2 \approx 0.7159$ across sites), the LP-III and LN distributions generally exhibit improved predictive strength at several stations, with R^2 values exceeding 0.85 in certain cases. Notably, LP-III often shows steeper regression slopes and better alignment with higher discharge values, indicating improved performance for extreme flood events. However, some variability is evident among stations, reflecting spatial heterogeneity in flood behavior across the basin. The figure demonstrates that although traditional statistical models can approximate flood magnitudes reasonably well, their performance differs by location, emphasizing the importance of selecting site-specific probability distributions for reliable flood frequency estimation in the CRB.

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