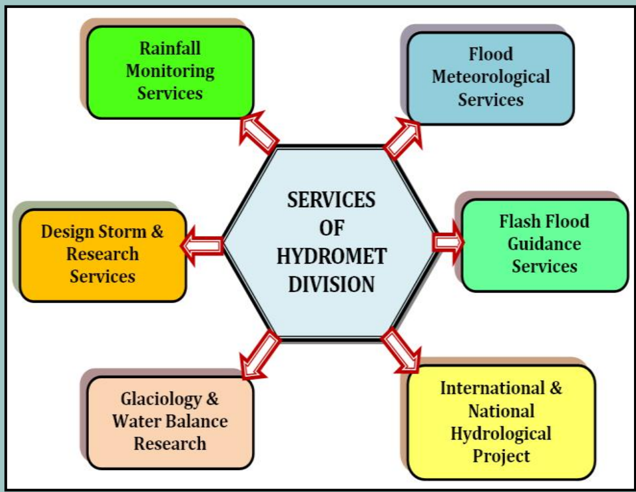
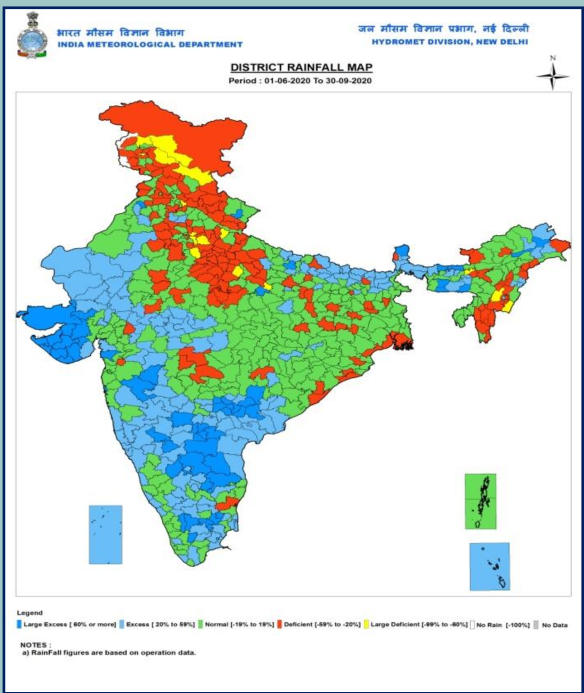
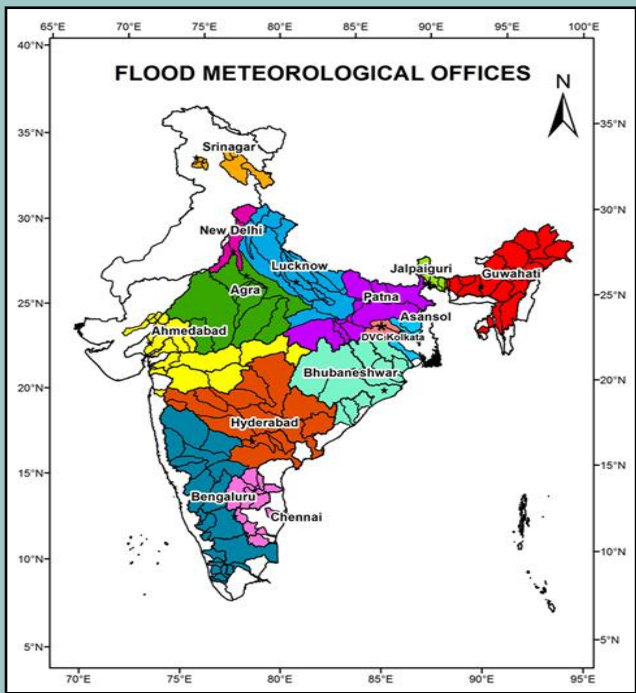
MINISTRY OF EARTH SCIENCES

INDIA METEOROLOGICAL DEPARTMENT

STANDARD OPERATING PROCEDURE HYDROMETEOROLOGICAL SERVICES IN INDIA







HYDROMET DIVISION

INDIA METEOROLOGICAL DEPARTMENT

MINISTRY OF EARTH SCIENCES

GOVERNMENT OF INDIA

MARCH, 2021

STANDARD OPERATING PROCEDURE

FOR

HYDROMET SERVICES

Committee:

Shri B P Yadav, Sc.-'F', DDGM (H), Chairman

Shri Rahul Saxena, Sc.-'F'

Dr. Ashok Kumar Das, Sc.-'E'

Ms. Hemlata M Bharwani, Sc.-'C'

Shri Asok Raja S. K, Sc.-'C'

Shri S. K. Manik, Sc.- 'C', Member Secretary

PREFACE

"Water is elixir of Life" aptly describes the importance of water in human life. India receives 75% of its annual rainfall during the southwest monsoon season and 11% during Northeast Monsoon season. Rainfall over the country during these seasons shows a wide range of spatial and temporal variation due to orographic influences and preferential occurrence of rain-bearing systems in certain regions. High variability of rainfall over time and space often leads to flood and drought situations in different parts of the country. A specialized division has been established to provide Hydrometeorological services including Rainfall Monitoring, sub-basin wise quantitative precipitation forecasting (QPF), Flash Flood guidance and Design Storm studies.

To manage the water resources both at the micro and macro level; daily, weekly, monthly and seasonal rainfall statistics and thematic maps are prepared at the district, meteorological subdivision, state and country level in the real-time basis throughout the year. This information is very useful to many user agencies especially for agricultural planning and flood monitoring.

IMD provides river sub-basin wise Quantitative Precipitation Forecast (both deterministic and probabilistic) and heavy rainfall warning, station wise significant rainfall and sub-basin wise daily areal average precipitation for riverine flood forecasting by Central Water Commission.

Flash floods are among the world's deadliest natural disasters and have a different character than riverine floods notably very short lead time over a localized area. Knowing the damage potential of Flash Floods and a general lack of flash flood warning capabilities especially over South Asian member countries, IMD (recognized as Regional Centre by WMO) in joint collaboration with the US National Weather Service, the US Hydrologic Research Centre (HRC), USAID and NOAA have developed and operationalized a Flash Flood Guidance System (FFGS) for South Asian region. The system has capabilities for providing flash flood threat and risk in real time mode for about 30,000 watersheds for the south Asian countries namely Bhutan, Bangladesh, India, Nepal and Sri Lanka.

The hydraulic structures in India are mainly designed for the purposes of irrigation, hydro-power generation, flood control, water supply and drainage systems. The designing of the structures requires analysis of historical rainfall storms to evaluate the corresponding maximum depth of precipitation over a specified project area. Hydrometeorology Division of IMD is the only nodal agency in the country to provide Standard Project Storm, Probable Maximum Precipitation & Time Distribution for calculating the Probable Maximum Flood (PMF) to help the design engineers about the strength and dimension for constructing the Dam, Barrage, reservoir etc. IMD also provides return period analysis for construction of small and medium infrastructure projects viz. highways, metro rail, railways lines, drainage systems etc.

"Standard Operation Procedures (SOP) for Hydromet Services" documents the details of rule based tools and standardisation of techniques, procedures & methodologies for preparing River basin QPF, Flash flood Guidance, preparation of rainfall statistics & thematic maps and design storm Analysis. This document aims to improve these services with regards to accuracy, precision, timely preparation and effective dissemination of the information to the various users and stake holders for taking informed decision and timely action.

(Dr. Mrutyunjay Mohapatra)
Director General of Meteorology

Acknowledgements

I am very much thankful to all the Officers and staffs of Hydrometeorology Division for their coordinated efforts that went into the formulation of the Manual entitled "Standard Operating Procedure for Hydrometeorological Services".

I hereby place on record my deep appreciation for the valuable contributions made by Shri B P Yadav, Sc.-'F', Head Hydrometeorology Division, Shri Rahul Saxena, Sc.-'F', Dr. Ashok Kumar Das, Sc.-'E', Shri Swapan Kumar Manik, Sc.-'C', Ms. Hemlata Bharwani, Sc.-'C', Shri Asok Raja S. K, Sc.-'C' of Hydrometeorology Division towards preparation, compilation, edition, review and publication of this manual. I express my thanks to Dr. Naga Ratna Kopparthi, Sc.-E, Dr. Geeta Agnihotri, Sc.-E for their valuable inputs.

I also express my sincere thanks and appreciation to Shri P. K. Gupta, Met-'B', Ms.Shashi Chauhan, Met-'A', Shri Maninder Singh, Met.-A, Shri Dhara Singh, Met.-A, Shri Manvir Singh, Met-'A', Shri Davinder Sharma, SA, Shri Ashok Kumar, SA, Ms.Charu, SA, Ms. Jyotsna Dhingra, SA for their technical support in publication of this document.

.

Dr. Mrutyunjay Mohapatra

March-2021 **Director General of Meteorology**

Contents

List of abbreviations:

DRMS - District Rainfall Monitoring System

CWC – Central Water Commission

QPF - Quantitative Precipitation Forecast

PQPF – Probabilistic Quantitative Precipitation Forecast

FMO - Flood Meteorological Offices

CHO - Central Hydrometeorological Observatory

NDMA – National Disaster Management Authority

IMD – India Meteorological Department

SPS – Standard Project Storm

BAF – Barrier Adjustment Factor

LAF – Location Adjustment Factor

MAF - Moisture Adjustment Factor

PMP – Probable Maximum Precipitation

AWS- Automated Weather Station

ORG – Ordinary Rain Guages

ARG – Automated Rain Guage

SRRG- Self Recording Rain Guage

CRIS – Customised Rainfall Information System

IHP - International Hydrological Programme

MC – Meteorological Centre

RMC – Regional Meteorological Centre

IDF - Intensity Duration Frequency

DAD – Depth Area Duration

IDW - Inverse Distance Weighted

FFD – Flood Forecasting Division

GFS – Global Forecasting System

WRF – Weather Research and Forecasting

MoES - Ministry of Earth Sciences

SASIAFFGS: South Asia Flash Flood Guidance System

FFGS: Flash Flood Guidance System

WMO: World Meteorological Organization

AMS: American Meteorological Society

HRC: Hydrologic Research Center

NMHS: National Meteorological and Hydrological Services

FFT: Flash Flood Threat

IFFT – Imminent Flash Flood Threat

FFG: Flash Flood Guidance

DEM: Digital Elevation Model

Introduction to Hydromet Services

The Hydromet Division at New Delhi was established in 1971 to cater to the need of hydro-meteorological inputs particularly for Water Resources Development and Water Related Disaster (like floods and drought) monitoring / management.

It provides services in the following fields:

1. Rainfall Monitoring
2. Hydromet Forecasting {Quantitative Precipitation Forecast (QPF)}
3. Hydromet Design
4. National and International Co-operation and Public Awareness.

Main Activities taken up by Hydromet Division are as follows:

1. Real Time Monitoring of Rainfall and preparation of rainfall summary
2. Meteorological support for flood warning and flood control operations to field units of Central Water Commission (CWC) through its Flood Meteorological Offices (FMOs).
3. Hydro-meteorological analysis of different river catchments for project authorities.

The main units of Hydromet Division are as follows:

1. Rainfall Monitoring Unit
2. Design Storm Unit
3. Storm Analysis Unit
4. Flood Meteorological office
5. SAsiaFFGS (South Asia Flood Forecasting Guidance System)
6. International Hydrological Programme

Also, Division is maintaining Central Hydromet Observatory (CHO) for the purpose of creating awareness among the students of different schools / colleges even upto the level of M. Tech from IIT, Trainees of the SDM/DM level from NDMA and PhD scholars of different institute in the field of Hydro-meteorology.

<u>STANDARD OPERATING PROCEDURE</u>

FOR

<u>RAINFALL PRODUCTS</u>

Supported by :

Shri Rahul Saxena, Sc.-‘F’

Shri S. K. Manik, Sc.- 'C'

Shri Manvir Singh, Met-‘A’

Shri Davinder Sharma, SA

18.1 SOP for Preparation of Rainfall Products:

Introduction:

In ancient India, it was believed that the sun causes rainfall (Adityat Jayate Vrishti) and that good rainfall in the rainy season is the key to bountiful agriculture and food for the people. Kautilya's Arthashastra contains records of scientific measurements of rainfall and its application to the country's revenue and relief work. Rainfall data are used for a variety of purposes and are required at a range of time scales. While Policy makers take keen interest in the Annual Rainfall figures, Indian Summer Monsoon Rainfall is of special interest since-out of an average of about 125 cm annual rainfall of country, more than 75% of the annual rainfall is received in the four rainy months of June to September.

Real time rainfall data are required for flood forecasting and hydel power and reservoir operation. Summaries of storm rainfall event data are required for assessment of the severity of events at weekly or monthly time scales. Rainfall Statistics for agricultural and irrigation operations are needed at different time and spatial scales as well.

Background :- In 1890, The Rainfall Resolution of India made India Meteorological Department as controlling authority for all rainfall measuring agencies. Initially, Rainfall Summary on weekly basis for Met sub-Divisions used to be compiled by ADGM (R) office while dissemination to Govt. Departments was done through Hydromet Division, New Delhi. Afterwards Hydromet Division started compiling District / Met sub-Divisional and Country's rainfall summary for appraisal of Rainfall situation.

The Hydromet Division at New Delhi was established in 1971 to cater to the need of hydromet inputs particularly of Water Resources Development and Water Related Disaster (like floods and droughts) monitoring / management.

Major Milestones

- (Till 1979) : Weekly and monthly rainfall summary for 32 meteorological divisions and country as a whole during SW Monsoon season used to be prepared in the delayed mode.
- 1980-1989 : District-wise rainfall summary on a near real time basis was prepared on experimental basis and Statistics supplied only to Ministry of Agriculture, Planning Commission, Prime Minister's office etc.
- 1989-1990 :District-wise Rainfall Monitoring Scheme (DRMS) initiated on persistent demands from Ministry of Agriculture, Planning Commission, Prime Minister's office and other agencies. Weekly, Monthly, Seasonal and Annual basis rainfall statistics calculated for all the four seasons in addition to daily rainfall statistics ~~also~~ prepared during Monsoon Season (June-Sept). Statistics were computed manually using Calculators.
- 1990: Software Developed Indigenously. Partial automation of the Rainfall Statistics Summary
- 1993: Weekly rainfall statistics generated for all the four seasons
- 2008: Daily rainfall statistics summary started for SW Monsoon season
- 2009: Automation of subdivision-wise Rainfall maps
- 2012 :Automation of District-wise Rainfall Maps.

- ❖ Till 2015 : Preparation of the Rainfall Statists and creation of Maps and Statistics done through MKRain and MKRMS software .
- ❖ 2015-Till date : Customised Rainfall Information System (CRIS) operationalised. Generation of the Rainfall Statistics summary through CRIS.
- ❖ 2017: Rainfall statistics calculated on daily basis in addition to weekly basis for all the seasons
- ❖ 2017: - Setting up Regional Center for South Asia Flash Flood Guidance system.

Main Responsibilities:

i. RMU has been entrusted the Key task of monitoring the rainfall over the entire country during all the four seasons.

ii. The rainfall data is used to compile and generate the Rainfall products in various Temporal and Spatial domain. These products are disseminated to both the general public and many user agencies, particularly from agriculture and planning sectors.

iii. RMU also brings out updated monthly, seasonal and annual rainfall statistics after incorporating the late receipt data.

iv. Supply of rainfall data to various government organizations / Ministries & private organizations on their demand on cost basis as per IMD norms.

v. Monitoring of R.G. stations is carried by RMC's/MC's and providing guidelines time to time.

vi. Preparation of technical reports like annual rainfall summary, Cabinet summary etc. IMD News Letter etc.

vii. Distribution of Rainfall Data / Summary on demand to Cauvery Board, State Departments, CWC etc.

Software Used :

- MKRain (For RC/MC's)
- MKRMS (For HQ)
- Customised Rainfall Information System
- MS Access (MKRain), PostgreSQL (CRIS)

18.1.1 Data Collection :-

A total of more than 4783 Station under 22 RMC/MC are covered under DRMS network. (**Fig- 1**). The station wise rainfall data from all the departmental and part time observatories, rain-gauge stations of states and various central agencies is received at RMC/MC's in manual datasheets for the region under their jurisdiction. The data is processed and compiled district wise in the domain of MC/RMC. The data acts as an input to MKRain which is independently run at each MC/RMC for generating districts/subdivision and state-wise rainfall statistics, maps etc. under their domain.

These station wise data are created as an .xls files in MKRain Format and sent to Hydromet Division which in turn goes as input to MKRMS and CRIS s/w. The cutoff time for reception of data in Hydromet Division is 1330 hrs.

The map (**Fig-1**) shows the spatial distribution of the observational network of DRMS stations including AWS/ORG/ARG/SRRG network. The state-wise distribution showing the coverage is as per **Annexure-I**. Each district being represented by at least one raingauge station. The network consists of all the observatories both Departmental and non-Departmental including State Government.

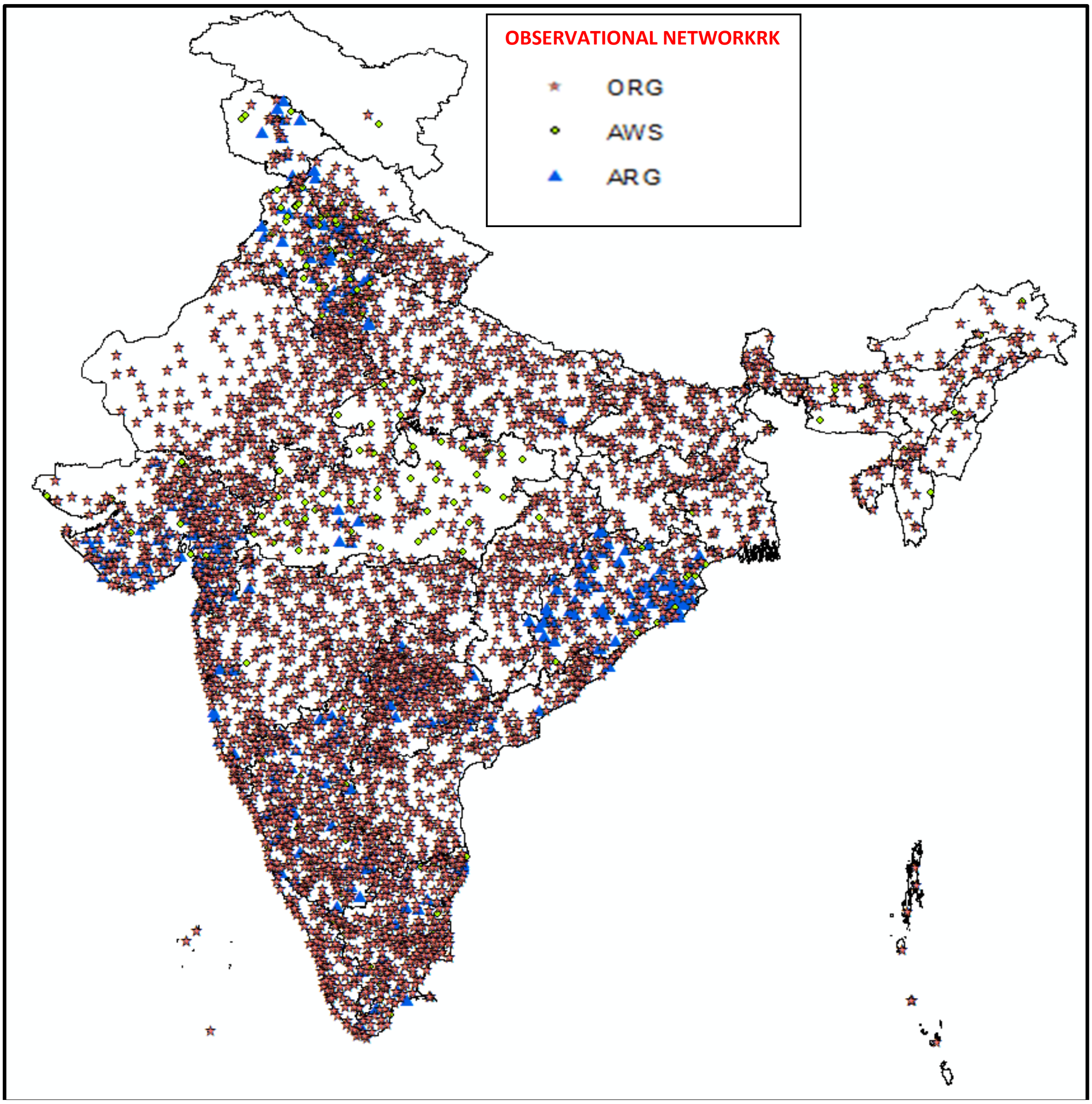


Fig-1 : DRMS Network

The Product generation of rainfall statistics, Maps and Graphs goes through steps of data collection, data compiling and quality checking, Product generation and dissemination is an automised process through CRIS and MKRMs.

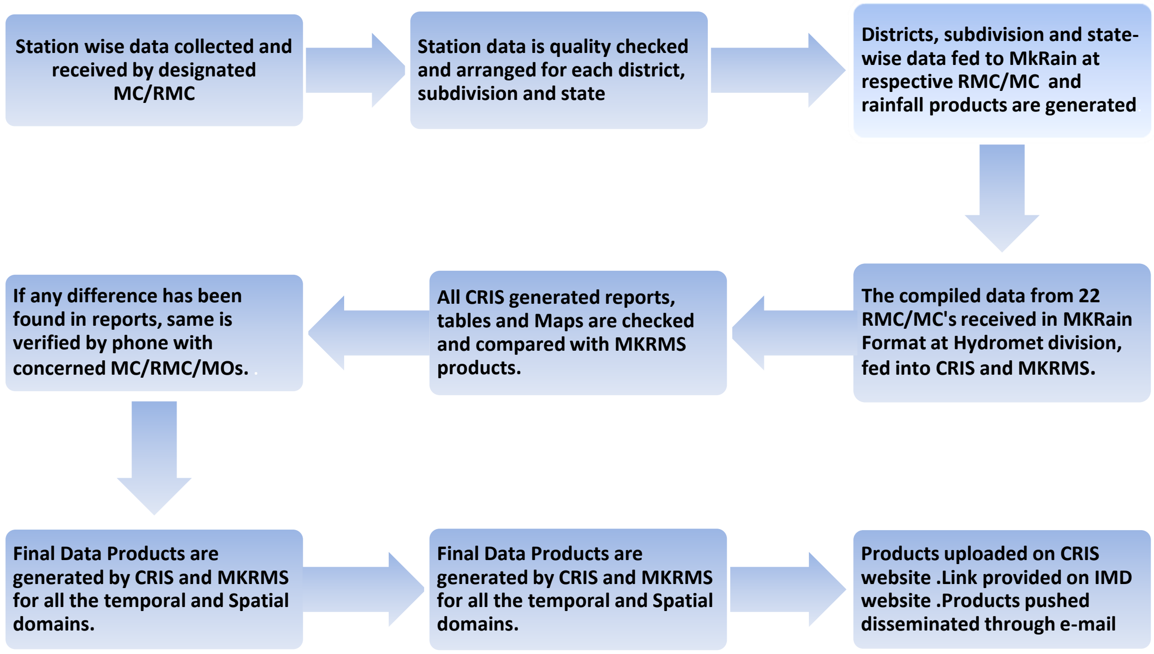
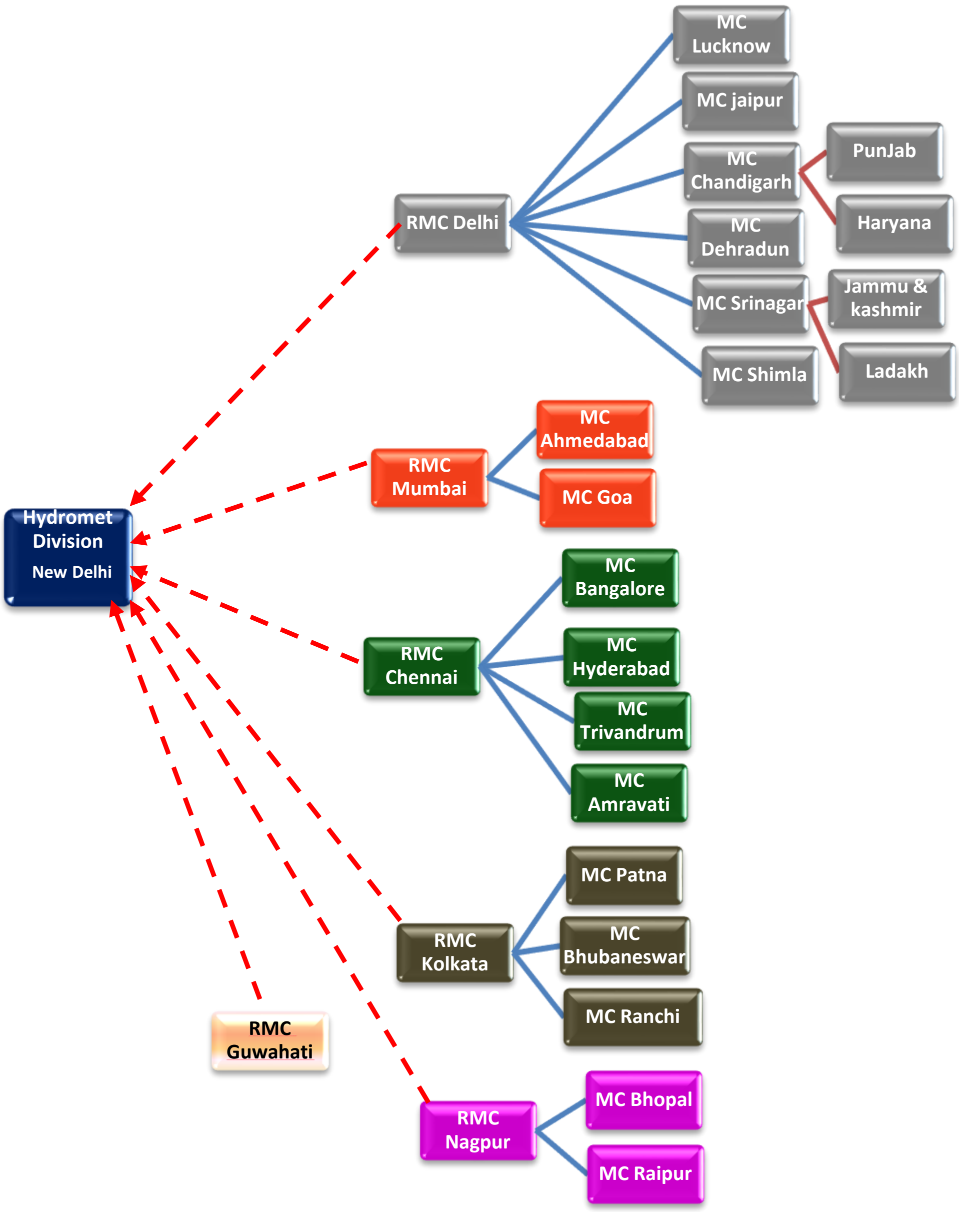


Fig-2: Schematic diagram of Product generation process



Fig–3: Organizational structure for data collection

18.1.2 Preparation of Rainfall Statistics:

18.1.2.1 Generation of Rainfall Statistics (District/Subdivision/state/Country and four homogenous regions)

a. **District rainfall**

It is calculated by Arithmetic Mean Method as follows:

$\mathbf{P_{Dist} = \sum P_i / N}$ **……………………………….. (1)**

P_{Dist} is the district wise average precipitation
$\sum P_i$ is arithmetic sum of the rainfall of all the stations falling in a district,
N is the total number of stations in that district (Annexure -I)

District Rainfall		DAYS								
		Day 1	Day 2	Day 3	…	…	…	…	…	Day (n)
STATIONS	Stn. 1	…	…	…	…	…	…	…	…	…
	Stn. 2	…	…	…	…	…	…	…	…	…
	…	…	…	…	…	…	…	…	…	…
	…	…	…	…	…	…	…	…	…	…
	…	…	…	…	…	…	…	…	…	…
	…	…	…	…	…	…	…	…	…	…
	…	…	…	…	…	…	…	…	…	…
	…	…	…	…	…	…	…	…	…	…
	Stn. (m)	…	…	…	…	…	…	…	…	…
District Averages		Avg. 1	Avg. 2	Avg. 3	…	…	…	…	…	Avg. (n)

Table- 1

b. District Rainfall for 'n' No. of days = Avg.1+Avg.2+Avg.3+ … +…+…+…+Avg.(n)

c. For both Subdivision and State, the Area weighted estimate of rainfall for both is made by taking Area Weighted Average Rainfall of Districts of within the sub Division and Area weighted average rainfall of the districts within the state.
$P_{\text{subdivision/state}} = (P_{\text{Dist-1}} \times A_{\text{Dist-1}} + P_{\text{Dist-2}} \times A_{\text{Dist-2}} + \text{- - -} + P_{\text{Dist-n}} \times A_{\text{Dist-n}}) / A_{\text{subdivision/state}}$.

d. The rainfall summary for country as whole is compiled as area weighted average rainfall of met sub Divisions in similar way.
$$P_{\text{Country}} = \sum (P_{\text{subdivision}} \times A_{\text{subdivision}}) / A_{\text{Country}}$$

e. The rainfall summary for the four homogenous regions is compiled as area weighted average rainfall of met sub Divisions in similar way.
$$P_{\text{homogenous}} = \sum (P_{\text{subdivision}} \times A_{\text{subdivision}}) / A_{\text{homogenous}}$$
Where, $A_{\text{homogenous}}$ = sum of the area of the subdivisions in the homogenous region

18.1.2.2 Rainfall Normal:

The office of Additional Director General of Meteorology, Pune maintains, computes, compiles and publishes the RF normal at suitable intervals. These normal are used for calculating the rainfall statistics. While rainfall normal for the period 1951-2000 were used to calculate the rainfall summary till the year 2018. A revised normal calculated for the period from 1961-2010 is now being used. (**Fig -4**)

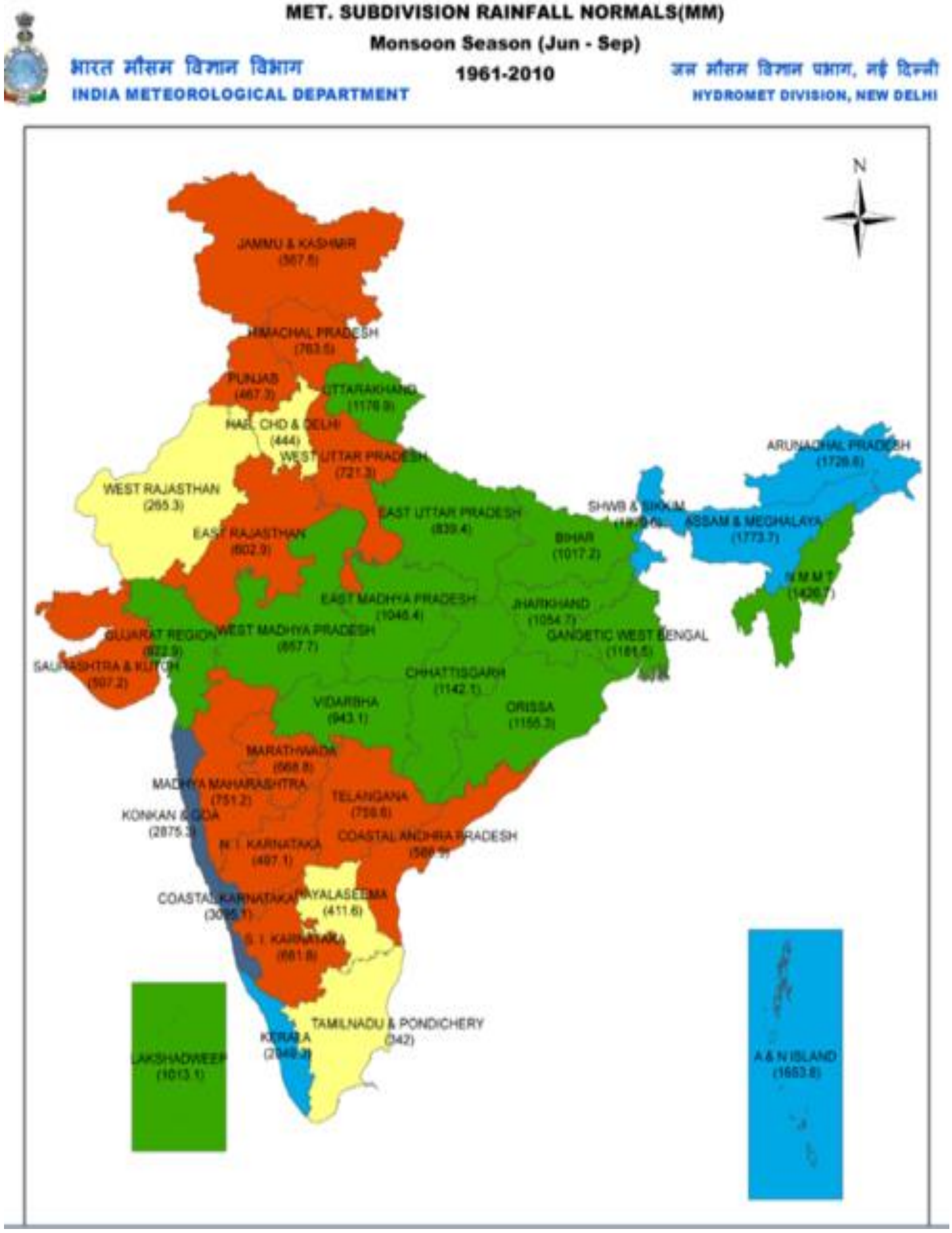


Fig-4: Rainfall Normal (1961-2010)

18.1.2.3 Calculation of rainfall departure:

The summary for District, Sub-Division, State, Region and Country comprises of Actual Rainfall Estimate, Normal Rainfall for given period and Departure from Normal. The departures are carried out as follows. For District level , the Actual R/F is the simple Arithmetic average P in eq(1) while for subdivision, state, homogenous regions and country as a whole the Area weighted rainfall "Actual R/F" is defined as $P_{subdivision}$, P_{state}, $P_{homogenous}$ and $P_{country}$ respectively in the points b, c and d above.

Departure (As %) = (Actual R/F – Normal R/F)x 100 / Normal R/F

Departures (%) are categorized into Normal, Excess, Large Excess, Deficient and Large Deficient depending as per the ranges defined in Table-2 for spatial domain of District, Met Sub division and State/UT.   Each category is associated with the color representing each of the categories.

CATEGORY	**% DEPARTURES OF RAINFALL**	Colour Code
Large Excess (LE or L. Excess)	**≥ 60%**	
Excess (E)	**≥ 20% and ≤ 59%**	
Normal (N)	**≥ - 19% and ≤ + 19%**	
Deficient (D)	**≥ - 59% and ≤ - 20%**	
Large Deficient (L. Deficient)	**≥ - 99% and ≤ - 60%**	
No Rain (NR)	**= - 100%**	
No Data (*)	**Data Not Available**	

Table- 2: Rainfall Category

18.1.3 Product Generation

18.1.3.1 Temporal Domain

- Daily Rainfall summary is generated every day for the 24-hour observed rainfall (observed till 03 UTC). These products include daily / cumulative rainfall statistics for all the 685 districts, 37 states and UT's and 36 Met subdivisions at the district, subdivision state and country as a whole. The graph is generated for the cumulative daily rainfall for four homogenous regions. Products are generated in both Tables and Graphical Format Annexure - II
- Weekly Rainfall summary is generated on every Wednesday for the previous week. The statistics include the weekly and seasonal cumulative rainfall covering 685 Districts, 36 Met. Sub Divisions, 37 States including UTs, 4 Homogenous Regions and for the country as a whole. Besides, statistics is also prepared for 61 selected river basins of India. For a given week (period) Fig 4.
- Monthly, Seasonal and Annual statistics are generated on the performance of rainfall for Monsoon and other three seasons (Pre-Monsoon, Post Monsoon and Winter season). The Annual Rainfall statistics summary is published every year with a copy being uploaded on IMD's website. The annual summary is available on website for last five years. The statistics include the weekly, monthly, seasonal and annual rainfall summary for the Pan India.

18.1.3.2 Spatial Domain

The products are generated on district, sub Division, State and Country as a whole along with the four homogenous regions (North-West, East and North-East India, West India and South India).

18.1.3.3 River sub-basin wise:-

Near Real time rainfall statistics is generated for 61 river sub basins on daily /cumulative, weekly /cumulative and monthly/cumulative basis. They are categorised into large excess, excess, normal, deficient and large deficient as per the rainfall's departures from normal. The actual area weighted rainfall is calculated by considering the area of the districts in the river sub-basin.

18.1.4 Responsibility for rainfall product generation:

The responsibilities for generation of Rainfall products & maps through **MKRAin** for RMC/MC level. and through **CRIS and MKRMS** at Hydromet Division at HQ are given in figure below :-

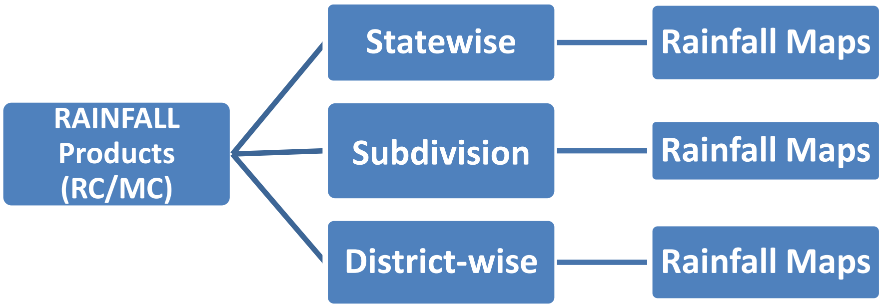


Fig-5 : Products generated by RMC/RC (through MKRain)

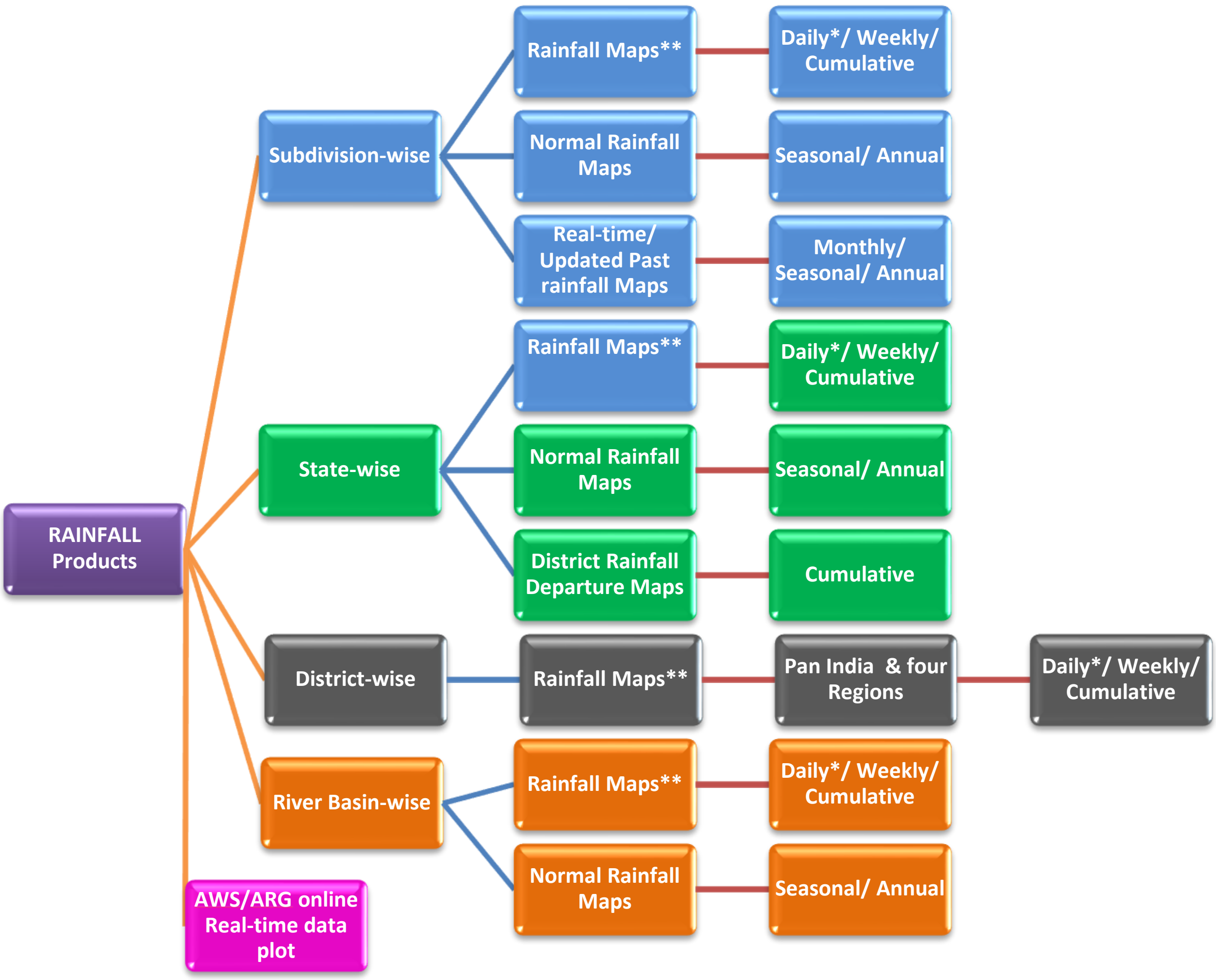


Fig -6 : Products types generated by RMC/RC (through CRIS / MKRMS)

Temporal → / Spatial ↓	Daily	Weekly	Daily & Weekly Cumulative	Monthly	Seasonal	Annual
District wise	Maps/ statistics	Maps/ statistics	Maps /Statistics	Maps/ statistics	Maps/ statistics	Maps/ statistics
Subdivision wise	Maps/ statistics	Maps/ statistics	Maps /Statistics	Maps/ statistics	Maps/ statistics	Maps/ statistics
State wise	Maps/ statistics	Maps/ statistics	Maps /Statistics	Maps/ statistics	Maps/ statistics	Maps/ statistics
Homogenous Region	Graphs	Maps/ Graphs statistics	Graphs	Maps/ statistics	Graphs	Maps/ statistics
River Basins (61)	Maps /Spatial Analysis	Maps / Spatial Analysis	Maps	Maps	Maps	Maps
Country wise	Maps/ Graphs / Statistics	Maps/ Graphs / statistics	Maps / Graphs / Statistics	Maps/ statistics	Maps/ statistics	Graphs

Table 3: Products generated in CRIS/MkRain

18.1.5 SOP for adding station/District in CRIS and MKRain

Over a period of years changes involving the addition of new stations / new districts have become frequent. Number of districts has increased to 685. These demands occur due to the changes in the administrative boundaries of a state, creation of new districts or migration of a station from one district to another district. These changes lead to the changes in the area of a district or a subdivision leading to hence recalculation of the areal weighted normal and actual area weighted rainfall is done. Creation of a new state (e.g. Telangana and Jammu & Kashmir and Ladakh) or modification in the area of a state due to addition of new areas.

18.1.6 SOP for Adding a new station (Rain gauge Location)/ Shifting of Rainguage station from Old District to New District

The following criterion needs to be satisfied before adding a new station:

- The proposed rain gauge stations is to be confirmed to the exposure conditions as per WMO criteria/IMD guidelines.
- Possibility of receiving of rainfall data on real time basis.
- Quality of received rainfall data (Compare with nearby existing ORG Station).
- Mode of transmission of rainfall data needs to be a robust mechanism of email.
- Financial implication, if any.

Send the List of stations to be added to DGM (Hydromel), New Delhi in the format given Table-4 & 5

Station Name	**Station Code from MK Rain Software**	**New District (if Shifted)**	**District Area (if New District)**	**Station Name**

Table 4: Stations shifted in another district in CRIS/MkRain

Sl. No.	**Name of Station**	**Latitude (N) in Degree Minutes**	**Longitude (E) in Degree Minutes**	**Name of Taluka/Tehsil under which the R/G station falls**	**Name of District under which the R/G station falls)**	**Name of Met. Subdivision under which the R/G station falls**	**Agency (If Departmental then enter 'DEPARTMENTAL' else if Non-Departmental then enter Agency to which the R/G belongs**	**Scheme to which the R/G belongs**

Table 5: Addition of New Stations in CRIS/MkRain

DGM (Hydromet) will provide a unique code for each of the station. This code is to be used while entering the station details in steps below:

i) Run mkRAIN_2016 by clicking on its icon on your desktop and Click on DRMS command available on the Menu bar.

ii) Select Station from the DRMS Options window and Click on Confirm button.

iii) Select Add New Station tab from the screen that follows. You need to enter the details of the station that you want to add in the database.

iv) Enter the Station Code provided to you by HQ (in 4 digits) as mentioned in above.

v) Enter Station Name (max. 21 characters long).
vi) Enter Catchment Code (max. 3 digits long).
vii) Enter Type of Obsy., like ORG, AWS, ARG etc.
viii) Enter Agency, like Departmental, State, PWD, REV etc.
ix) Enter Height a.m.s.l. (in metres) of the stations.
x) Enter Latitude and Longitudes in 4 digits in DDMM (Degree Minute) format, first 2 digits represent Degree and last 2 digits represent Minute. E.g. Latitude and Longitude entries for New Delhi (28° 39' N; 77° 13' E) will be 2839 and 7713 respectively.
xi) Enter the Year of Starting in YYYY format.
xii) From the List Boxes**,** Select the Met. Subdivision and District in which the station lies. Click on the ADD New Station button. Click OK to the message that appears for successful addition of the station in the database.

18.1.7 SOP for Adding a new District in mkRAIN database

Adding a new district to mkRAIN database, following preliminary tasks need to be accomplished.

Name of the District	District Area	Subdivision Name	Station Name

18.1.8 Adding the district and editing the area:

Prepare a list of Districts to be added, names of the Met. Subdivisions and States to which they belong and obtain their geographical area (in SqKm) and also the revised areas of all the affected districts because of the creation of new districts from state authorities and send it to Hydromet Division, New Delhi. Hydromet division will provide you a **unique code** for each of the district.

18.1.9 Editing the affected Station Network

Prepare a list of raingauge stations falling in the new districts. In most cases, the stations in new district will be from the existing network only and may have been shifted from one district to another, because of the creation of new district. Sometimes, the new district and stations in it may shift to nearby Met. Subdivision. You should have the information in the following format ready to use while editing the station network in step ay 18.6.1.
Get the updated shapefile of the district boundary from state authorities.

18.1.10 Adding/Editing the Normal Rainfall of new and affected district, Subdivision or State

RMU at HQ would request ADGM(R) office, Pune to prepare Daily Accumulated Rainfall Normal of the district for each of the season. Pune office would also revise normal of all the affected districts, from which the new district has been carved out and the rainfall normal of Met. Subdivisions and States, if needed. Pune office would send these normal to DGM (Hydromet) for approval, and would send the approved normal to concerned RMC/MC

Name of the station	Name of Old District to which the station belongs	Code of Old District	Name of New District to which the station will now belong	Code of New District	Name of Old Met. Subdivision to which the station belongs	Code of Old Met. Subdivision	Name of New Met. Subdivision to which the station will now belong	Code of New Met. Subdivision

Run mkRAIN_2016 by clicking on its icon on your desktop and Click on DRMS command available on the Menu bar.

Select District from the DRMS Options window and Click on Confirm button.

18.1.11 Select Add New District. (You need to enter the details of the district that you want to add in the database).

i) Enter the District Code provided to you by HQ (in 3 digits) as mentioned in 18.1.8 above.
ii) Enter District Name (max. 21 characters long).
iii) Enter District Area (in km^2).
iv) From the List Boxes, Select the Met. Subdivision and State in which the district.
v) Click on the ADD New District button. Click OK to the message that appears for successful addition of the district in the database.

STANDARD OPERATING PROCEDURE

FOR

DESIGN STORM ANALYSIS

Supported by :

Shri S. K. Manik, Sc.- 'C'

Shri P. K. Gupta, Met-'B'

Ms. Shashi Chauhan, Met-'A'

18.2 SOP for Design Storm Analysis:

Introduction:

The hydraulic structures in India are mainly designed for the purposes of irrigation, hydro-power generation, flood control, water supply, drainage systemetc. The designing of the structures is dependent on the size (dam height and reservoir storage capacity) of the structure and the risk involved. It is necessary to obtain the spatial and temporal of rainfall associated with the historical storm and to evaluate the corresponding depth of precipitation over a specified area during the storm period. Generally, the specified area for such project is the natural drainage basin, which is often called a river basin.

Definitions:

Design Storm is the estimate of rainfall amount and its distribution over a given drainage basin which is adopted as the basis for the derivation of the design flood. It consists of SPS, PMP and temporal distribution.

Rainstorm: A spatial distribution of rainfall yielding average depth of precipitation which equals or exceeds a specified threshold value over a region in association with some meteorological phenomena like Depression, Monsoon trough, Cyclone etc. is termed as Rainstorm.

Standard Project Storm (SPS): It is defined as the magnitude of highest rainstorm occurred over the basin or its neighborhood. There is no other safety consideration than the highest magnitude in record.

Probable Maximum Precipitation: PMP is defined as the greatest depth of precipitation for a given duration meteorologically possible for a design watershed or a given storm area at a particular location at a particular time of year (with no allowance made for long-term climatic trends) (WMO, 2009)

The objective of PMP estimate is to calculate the Probable Maximum Flood (PMF) which is used for the design of a given project at a particular geographical location in a given watershed and to further provide information that could assist in designing the size of the given project and dimension of the flood-carrying structures (spillway) of the project. A Design Storm is defined as the estimate of rainfall amount and its distribution over a given drainage basin which is adopted as the basis for the computation of design flood. The design storm is usually selected after consideration of the pertinent facts represented by basin characteristics, rainfall regime and the nature of the project. When an area is thickly populated or industrially developed and the failure of the project will result in great loss of life and property, a design on the basis of the Maximum Probable Storm, called PMP may be justified, whereas if no such risk is involved, the maximum average depth of precipitation over the project area associated with the historical storm called Standard Project Storm (SPS) of the region will suffice.

Moisture Adjustment Factor (MAF): Moisture Adjustment Factor (**MAF**) is the ratio of highest liquid water content recorded during rainstorm season near the centre of rainstorm to the persistent liquid water content recorded during rainstorm period.

$$\textbf{MAF} = \frac{\text{Liquid water content corresponding to maximum persisting dew-point Temperature reduced to 1000 hPa at storm site in fortnight of storm occurred on record}}{\text{Liquid water content corresponding to persisting dew point Temperature reduced to1000 hPa during the storm period}}$$

Liquid Water Content: It is estimated from surface dew point temperature at 1000 hPa assuming that environment is fully saturated and follows pseudo-adiabatic lapse rate.

Spatial Distribution of storm rainfall: The spatial distribution of storm rainfall provides an idea about volume of water precipitated during a rainstorm.

Temporal Distribution of storm rainfall: The temporal distribution of storm rainfall highlights intensity of rainfall experienced during different times of rainstorm duration. The highest intensity of rainfall decides the time of occurrence of peak flood, magnitude of peak discharge and consequently water level rising in river or stream.

Depth-Area-Duration Curve: The curve between Average depths of precipitation (cm) and the corresponding cumulative areas (km).

Also, PMP estimates for 1-day and 2-day at each grid points within and around the Basin have been provided. Sub-basin wise time distribution curves for 24 hour and 48 hour rainstorms have been given in tabular and graphical form in the Atlases. Station wise point PMP values for 1-day, 2-day and 3-day duration have also been computed by using Statistical Method.

Return Period: The return period is a statistical parameter used in "frequency" analysis and is a measure of the probable time interval between the occurrence of a given event and that of an equal or greater event. Return period values for the period 1-day, 2-day and 3-day for 2yr, 5yr……, 1000 yr have also been provided. These atlases will provide a generalised idea of PMP estimates for different durations for any sub-basin within that River Basin for small and medium hydraulic structures.

Hydromet Division, IMD is doing two types of storm analysis i) Storm Analysis for Short Duration and ii) Storm Analysis of long duration.

18.2.1 Storm Analysis for Short Duration:

The whole country has been divided in to 7 zones and 26 hydro-meteorological homogeneous subzones for computing the design flood of a specific return period for small and medium catchments. For this, Depth-Duration-Frequency analysis using ORG/SRRG data has to be carried out. This study comprises of formation of extreme series of defined duration and 24 hrs. to short duration rainfall ratios.

Flow chart of computation of Return Period Estimates and Isopluvial map by using Statistical method is given in Figure- 7

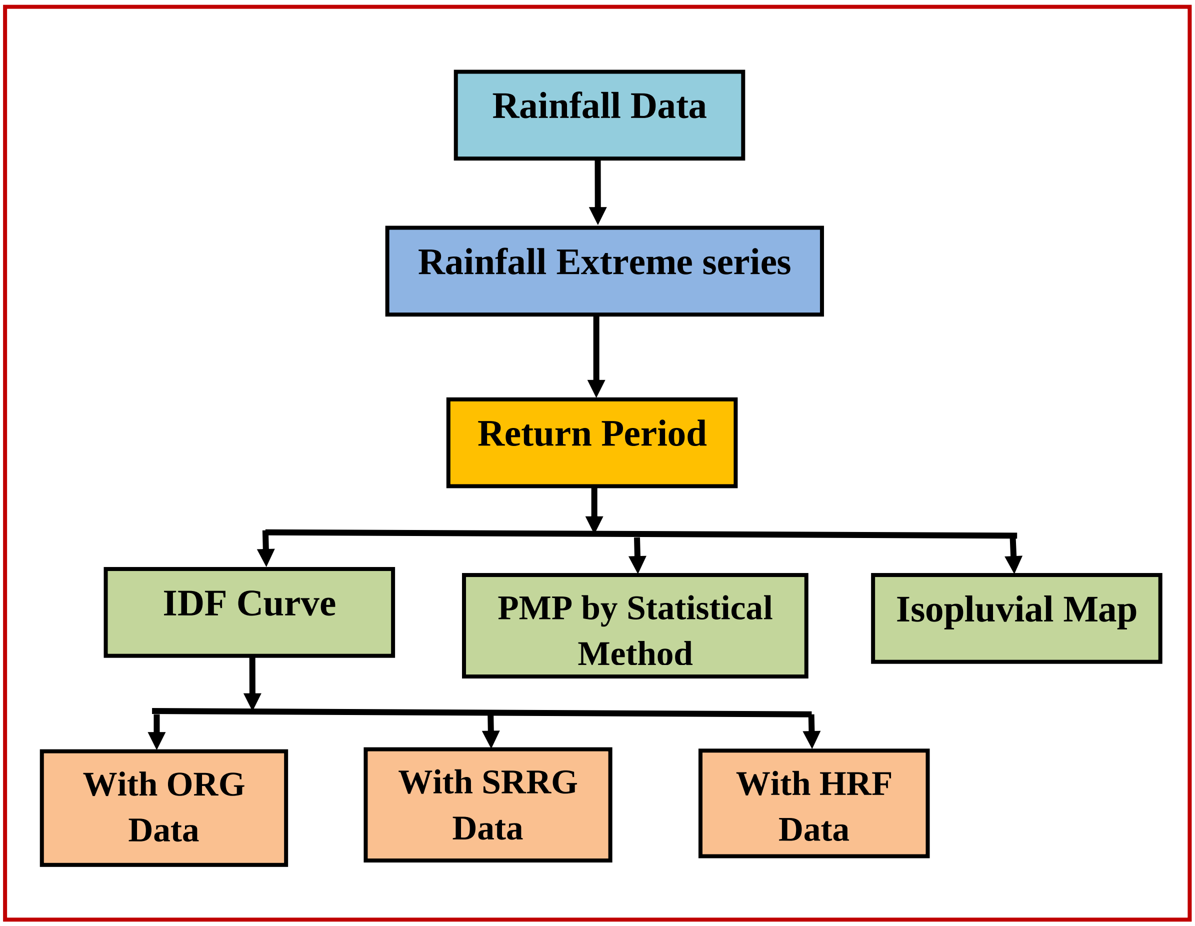


Fig-7 :Flow Chart of Storm Analysis for Short Duration

18.2.1.1 Preparation of Daily Rainfall Extreme Series for each station:

The rainfall data for a station consisting of daily rainfall data for 'N' No. of years, (Total No. of observations/records = 365 x N) will be the input for preparing this product. **Annual Maximum Extreme Series (the output) comprises of** highest one day rainfall for each year ('N'No. of Records: Date vs Rainfall). A series of 'N' extreme values are formed for a station.

Criteria for preparation of extreme series:

i) Only those years will be considered for preparation of extreme series in which **at least 300 days of records with a minimum of 100 days of rainfall records during the monsoon season (June 1 to Sept. 30)** are available. The Annual maximum extreme series are to be prepared for all the stations in and around the project area using the above mentioned method. Such a series should also contain the date (dd/mm/yyyy) for selected extreme values of rainfall.

ii) Extreme rainfall series for each of the stations prepared at (i) above are used to compute return periods by Gumble Distribution Method. The software computes the return periods using two methods, i.e. Least Squares method and method of moments. However, the return period values obtained from any one of the methods are to be used for further processing.

18.2.1.2 Return Period

The return period is a statistical parameter used in "frequency" analysis and is a measure of the probable time interval between the occurrence of a given event and that of an equal or greater event. The different return period estimates are used depending upon the type of the structure and risk involved.

The average interval of time within which the value *x* of variable X will be equalled or exceeded once is called the **Recurrence interval or return period (T)**. The return period estimates at a particular location or point are determined from the frequency analysis of annual maximum rainfall series. The annual maximum series at a particular station is obtained by selecting the highest one-day maximum rainfall observation in each year. In the annual maximum series, number of observations is equal to the number of years of data.

If a hydro meteorological variable (X) equal to or greater than *x* occurs on the average once in T years, then the probability of occurrence $P(X \geq x)$ of such a variable is

$$P(X \geq x) = \frac{1}{T}$$

$$T = \frac{1}{P(X \geq x)}$$

The probability that *x* will not occur is

$$P(X \leq x) = 1 - P(X \geq x)$$

$$P(X \leq x) = 1 - \frac{1}{T}$$

$$T = \frac{1}{1 - P(X \leq x)}$$

The standard method for estimation of rainfalls for different return periods is to fit a theoretical frequency distribution to the annual maximum rainfall data series and estimate parameters by the statistical methods. Among the many existing theoretical distributions like lognormal, Gumbel, log Gumbel, Pearson type III, log Pearson type III, Weibull, GEV and so on. Hershfield and Kohlar (1960), Reich (1963) and Mukherjee et.al. (1991) concluded after comparing several distributions that the Gumbel extreme value distribution fits the data reasonably well. The return period values of different durations have been computed by using Gumbel extreme value distribution.

18.2.1.2.1 Gumbel's Extreme value distribution

According to Gumbel (1958), the cumulative probability that any extreme value of a variable X will be equal to or less than x for Gumbel distribution is given by:

$$P(X \leq x) = \exp[-\exp\{-\alpha(x-u)\}] \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Let $y = \alpha(x-u)$

Then,

$$X = u + \frac{1}{\alpha}Y \qquad \text{.................................. (2)}$$

By Definition,

$$T = \frac{1}{1 - P(X \leq x)}$$

$$T = \frac{1}{1 - e^{-e^{-y}}}$$

$$y = -\log_e \log_e \frac{T}{T-1}$$

The parameters of the distribution can be measured by method of moments or least square. The fitted distribution can be used not only to interpolate, but also to extrapolate; that is to find return periods of maximum rainfalls that were not apparent during the relative short periods of records.

(a)Method of Moments:

The mode (u) of the distribution is defined as

$$u = \overline{X} - \frac{C}{\alpha}$$

Where

$\overline{X}$ = Mean of extreme (X) series

C = Euler's constant≈ 0.58

And

$$\frac{1}{\alpha} = \frac{\sqrt{6}}{\pi}s \approx 0.78 \times s$$

Where s is the standard deviation of the extreme series

$$\frac{C}{\alpha} = (0.58) \times (0.78 \times s) \approx 0.45s$$

Equation (2) can be written as

$$X_T = \overline{X} - 0.45\,s + 0.78\,s(Y_T)$$

Where, X(bar) and s are the mean and the SD of a given series of data, then parameters α (scale parameter) and u (location parameter) can be obtained. Thus, for any value of X, T can be calculated.

(b)Method of Least Squares

It may be seen from above that Gumbel's method is straight line fitting in X and Y. It has been pointed out by many researchers that the least square method gives better estimates than the method of moments. The method of least square is also recommended by Chow (1953).

From section **(a) above,**

$$X = A + B\,Y$$

Where, A & B are the parameters to be estimated by minimizing 'error sum of squares'. Substituting the value of T, equation becomes

$$Y = -\log_e \log_e \frac{N+1}{N+1-m}$$

For a given N, reduced variate can be calculated for all values of m. (m = 1, 2…..N). Since reduced variate is only a function of N and m, these may be calculated in advance. Then from the solutions of minimal equations, A and B can be calculated as

$$B = \frac{\overline{X.Y} - \bar{X}.\bar{Y}}{\overline{Y^2} - \bar{Y}^2} \quad \text{and} \quad A = \bar{X} - B\bar{Y}$$

$$\text{Where} \quad \bar{X} = \frac{1}{N}\Sigma X \quad , \quad \bar{Y} = \frac{1}{N}\Sigma Y$$

$$\bar{Y}^2 = \left(\frac{1}{N}\Sigma Y\right)^2, \qquad \overline{Y^2} = \frac{1}{N}\Sigma Y^2$$

$$\bar{X}.\bar{Y} = \left(\frac{1}{N}\Sigma X\right)\left(\frac{1}{N}\Sigma Y\right) \qquad \overline{X.Y} = \frac{1}{N}\Sigma XY$$

Rainfall estimates for various return periods (2, 5, 10, 25, 50 and 100, 150, 200, 500, 1000, 5000 and 10,000 years) will be computed. The return period values obtained from Gumbel software by Least Square method will be used for further data processing. The output table containing the information for Station Name, mean, median, standard deviation, Coefficient of Variability (CV) and 2-yr RPV, 5 yr. RPV, 10 yr. RPV, 25 yr. RPV, 50 yr. RPV and 100 yr. RPV.....10000 RPV will be generated.

18.2.1.3 Intensity Duration Frequency (IDF) Curve:

An **intensity-duration-frequency curve** (**IDF curve**) is a mathematical function that relates the rainfall intensity with its duration and frequency of occurrence. These **curves** are commonly used in hydrology for flood forecasting and civil engineering for urban drainage design. Intensity duration Frequency curve may be prepared from ORG, SRRG and Heavy Rainfall (HRF) data.

18.2.1.3.1 With ORG Data (One Day rainfall recorded at 0830 Hrs. IST)

Annual Maximum Series comprises of highest one day rainfall data for each year ('N' No. of Records: Date vs Rainfall) may be prepared for all the stations. A series of 'N' extreme values are formed for a station. Such a series should also contain the date (dd/mm/yyyy) for selected extreme values of rainfall. Maximum rainfall series for each of the stations are used to compute return periods by Gumble Distribution Method. However, the return period values obtained from any one of the methods are to be used for further processing for calculation of IDF curve. For this, Illustration is attached at Annexure-III.

18.2.1.3.2 With SRRG Data (One Day rainfall recorded at 0830 Hrs. IST)

As in case of ORG data explained above, the process is same for the SRRG stations. But before that the raw data received from CRS, Pune has to be run through a software (RFSTT) to get the annual extreme of 1 hr., 3 hr., 6 hr...24hr. then this series has to be run in Gumble(Distribution) software for getting Return Period Estimates. In SRRG data eight (8) number of series are prepared. Rest is same as of ORG Data.
Return period values are calculated for 2, 5, 10, 25, 50, 100, 150, 200, 500, 1000, 5000 and 10000 years forthe selected station. Illustration for this is attached at Annexure-IV.

18.2.1.3.3 Heavy Rainfall (HRF) Analysis for very short period (15 min interval) data

Formation of extreme series

a. To prepare the annual extreme series for 15 min, 30 min, 45 min and 60 min time intervals for each station from the received 15 min interval rainfall data.

b. The rainfall data provided will be in terms of spells for say 'M' No. of years. For any particular year, the **highest** 15 min rainfall amount is picked up **(manually)**from each of the spell and the highest of these will be the extreme 15 min. rainfall for that year. So, a series of maximum 'M' extreme observations of 15 min rainfall will be formed. Such a series should also contain the date and time interval for selected extreme value of extreme 15 min. rainfall.

Similar procedure shall be applied for 30 min, 45 min and 60 min duration rainfall. While preparing the 30-min series, rainfall of 2 consecutive 15 min. time intervals of the same spell will be added up. Similarly, for 45 min. duration, rainfall of 3 consecutive 15 min. time intervals and for 60 min. duration, 4 consecutive 15 min. time intervals will be added up. Illustration for this is attached at Annexure-V.

18.2.1.4 PMP by Statistical Method (Hershfield Technique)

The Hershfield (1961) statistical method of estimating PMP and later modified by Hershfield (1965) is based on the general frequency formula of Chow (1951). Chow (1951) has shown that most frequency functions for hydrologic analysis can be generalized to

$$X_T = \overline{X}_n + K\sigma_n$$

Where X_T is the rainfall depth for the return period T, $\overline{X}_n$ and σ^n respectively are the average and standard deviation of the series of n annual maximum rainfalls and K is a variable frequency factor dependent on the probability distribution that fits the extreme value series.

It is very convenient to use but gives PMP values at a point and requires area reduction curves to adjust the values for various area sizes.

Hershfield considered that for the PMP estimation there is a value of K which will not be exceeded say Km and used the following equation.

$X_{PMP} = \bar{X}_n + K_m \sigma_n$

Where:

X_{PMP} = PMP rainfall for a given station for a given duration,

$\bar{X}_n$=The average of the series of n annual maximum rainfalls for a given station for a given duration,

σ_n= the standard deviation of the series of n annual maximum rainfalls for a given duration,

K_m= the frequency factor which is the largest of all the calculated K_m values for all stations in a given area.

The value of factor K_m for a station is calculated using the following equation.

$$K_m = \frac{(X_{max} - \bar{X}_{n-1})}{\sigma_{n-1}}$$

Where

X_{max} = is the highest recorded value from the series of n annual maximum rainfalls,

$\bar{X}_{n-1}$=the average value of n-1 annual maximum rainfalls excluding the highest value of X_{max} and

σ_{n-1} = the standard deviation of n-1 annual maximum rainfalls excluding the highest value of X_{max}

The values of K_m are computed for all the stations for different durations in the river Basin. For any given duration, the values of K_m are plotted against the mean rainfalls for all stations and an envelope curve is drawn. Thus, the PMP at each station is determined by using equation of section 5.1.2.2, after substituting the value of K from the enveloping curve.

18.2.1.5 Preparation of Return Period (Isopluvial Maps)

The station wise return period values are plotted on the river basin map and isopluvials (equal return period values) are drawn. These maps are prepared for 2, 5, 10, 25, 50, 100, 200, 500 and 1000 yr return period for 1-day, 2-day and 3-day durations.

- The Extreme series formed in Case I, II and III (any one) above shall be subjected to return period analysis by Gumble techniques and rainfall estimates for various return periods (2, 5, 10, 25, 50, 100 years or so on) will be computed. The return period values obtained from Gumble program by Least Square method will be used for further data processing.
- The table generated above will be used for preparation of the Isopluvial maps (lines of equal return period values) of different return periods. For generation of Isopluvial maps, minimum number of station should be five (5).
- A suitable rainfall interval should be adopted between the isopluvial lines according to return period estimates.

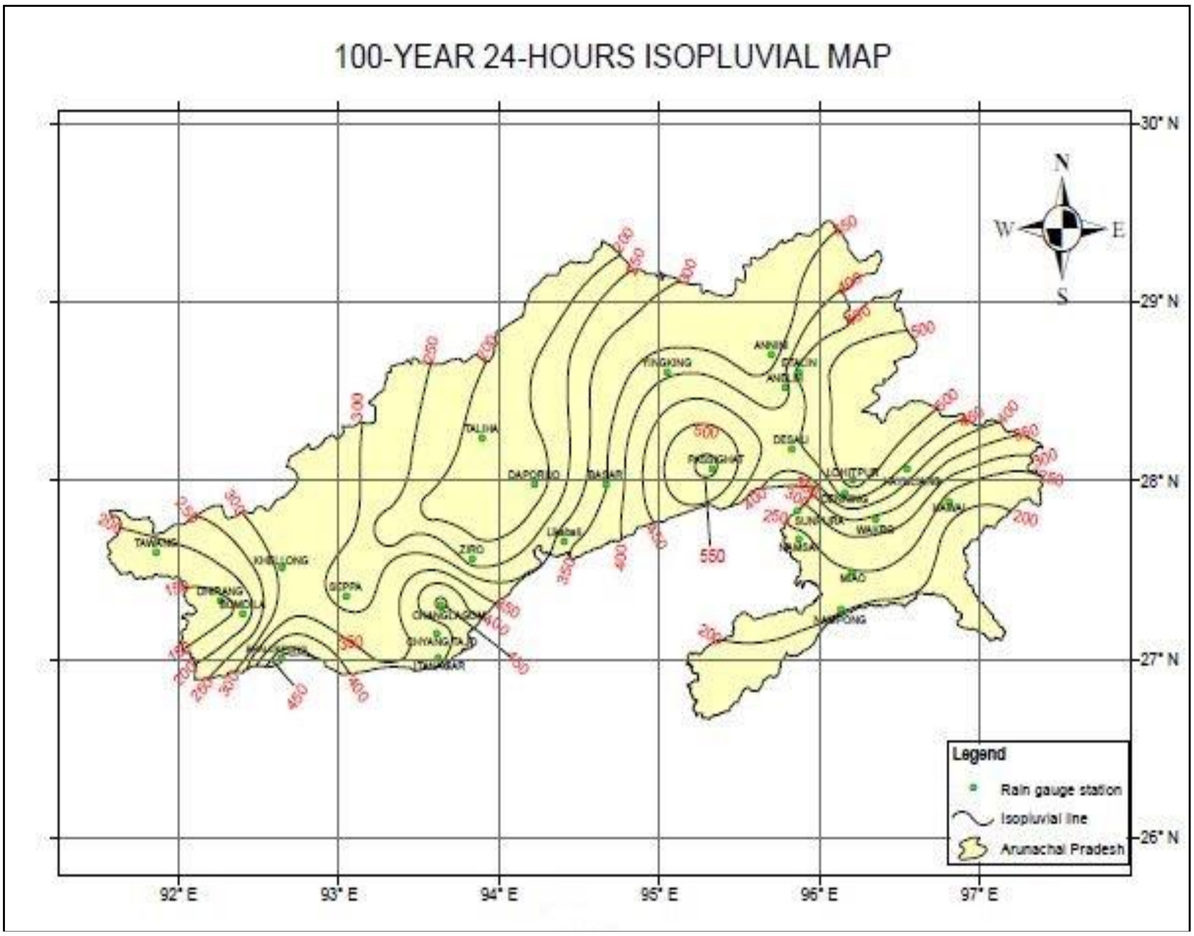


Fig- 8: Isopluvial Map

Note :

i) When successive 15 minutes intervals exceed 18, first 17 intervals are keyed in cols. 24-74 and 'X' is keyed in col. 75 and 01 is keyed in cols. 76-77. The 18th interval onwards data are keyed in cols. 24 onwards in record No. 2.

ii) When successive 15 minutes intervals exceed 35, 18-34 intervals are keyed in cols. 24-74 of record No. 2 and 'X' is keyed in col. 75 and 02 is keyed in cols. 76-77. The 35th interval onwards data are keyed in cols. 24 onwards in record No. 3. Similarly, it is repeated for more than 35 intervals.

iii) When the number of spells are between 100-199, last two digits are entered with alpha characters in col. 80.

iv) When the number of spells are between 200-299, last two digits are entered with alpha characters in col. 80.

Note : Autographic Rainfall is in 0.1 mm (i.e. 1234 means 123.4 mm).

18.2.2 Storm Analysis for 1 to 3 days:

For building the hydraulic structures for the purposes of irrigation, hydro-power generation, flood control, water supply, drainage etc. the design storm studies are required which is dependent on the size (dam height and reservoir storage capacity) of the structure and the risk involved. For this, IMD used to compute the SPS and PMP Values for the project authorities by using the followings:

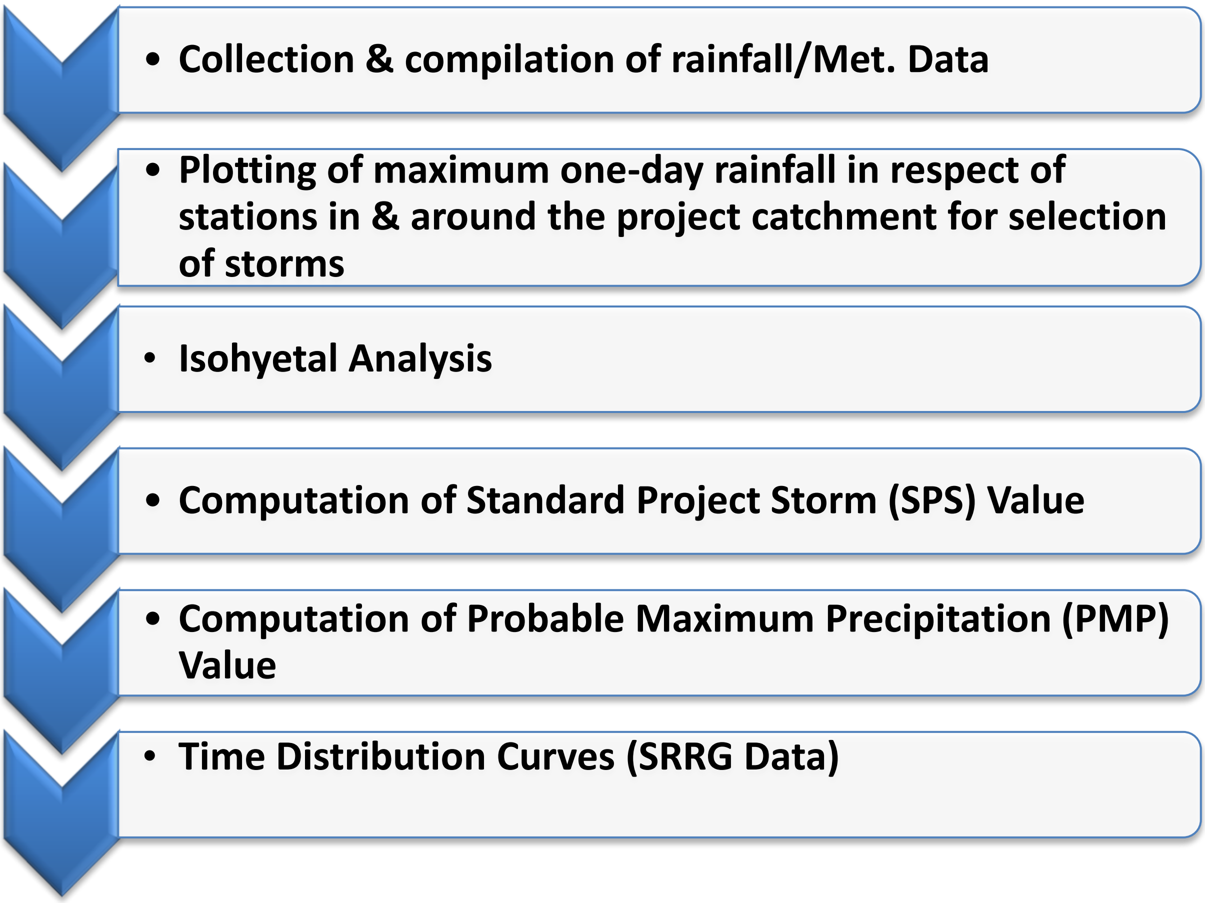


Fig-9: Flow Chart of Storm Analysis for longer Duration

18.2.2.1. Collection & compilation of rainfall/Met. Data.

i). Collect the rainfall data in and around i.e. up to periphery of about 300 km from the project

area for which study has to be carried out.

ii). Identify SRRG station/stations in and around the project for which hourly data is available.

18.2.2.2 Plotting of Maximum Point Rainfall in & around the project catchment for storm selection

For any hydrometeorological study, it is necessary to make a judicious selection of the pertinent storms over the river catchment or sub-catchment. By reviewing all the rainfall data available with India Meteorological Department (IMD) like Daily Rainfall Tables, Depression/Storm tracks, most recent or historical storms, etc., listing of all rainstorms period is prepared.

Also search out the completed projects in the vicinity of catchment for which design values have already been computed. This will help in searching out the heaviest rainstorms in the project region over time.

- The 1-day/2-day/3-day (as the case may be) maximum point rainfall values have to be plotted in respect of stations in and around the project area to obtain suitable rainstorm.

- Select at least 3-4 rainstorms with higher rainfall values, if possible

18.2.2.3 Isohyetal Method:

By drawing isohyets (places joining by line of equal rainfall) by interpolation method as per the existing rainfall recorded by the station. After plotting the rainfall values, isohyets are then drawn. While drawing these isohyets, the following important points should be kept in mind:

(a) Careful attention should be given to fit in all the available rainfall values as far as possible or to reject the doubtful values after suitable comparison with respect to neighbouring stations.
(b) Besides the catchment area under study, data of some stations around the catchment boundary should also be considered and isohyets extended.
(c) Consideration should be given to the topography of the region.
(d) Before drawing isohyets, locate the areas of heavy rainfall and the peripheral stations recording lower values. An isohyet of convenient magnitude is drawn and the storm pattern obtained. Subsequent isohyets are then drawn following the storm pattern.
(e) No two isohyets are to be intersected.
(f) Convenient intervals between isohyetal lines should be kept, for instance in the lower rainfall range, isohyets at an interval of 2.0 cm may be drawn, in the medium range, 5.0 cm interval and in the higher range of rainfall values, the interval to be 10.0 cm. above 100 cm, an interval of 25.0 or 50.0 cm may be kept.

However, the limitation of this method is that the accuracy of the results depend upon the skill of the analyst.

Isohyetal technique can be divided into two categories:

(a) Manual and

(b) Software

18.2.2.3.1 Manual Method:

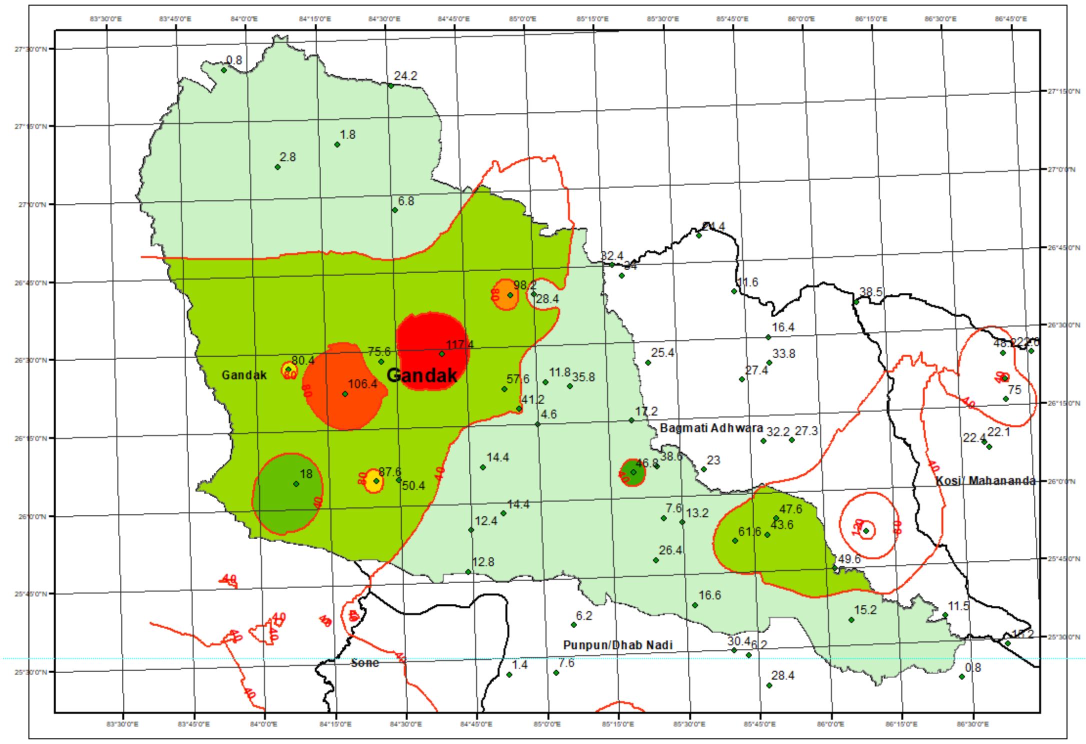


Fig-10: Map showing Isohyets

Mean Isohyets	No. of square	Volume	Cumulative Volume	Cumulative Area
20.4	9.5	190.8	190.8	9.5
60	12	720	910.8	21.5
20	13.5	270	1180.8	35
93.2	1	93.2	1274	36
98.7	1	98.7	1372.7	37
29	1	29	1401.7	38
			AAP	36.87

Table-6: Manual Calculation of Average Areal Precipitation

18.2.2.3.2 Software Technique:

The Software interpolation technique is again sub-divided into seven categories.

(i) Trend Method
(ii) Spline Method
(iii) Natural Neighbour

(iv) Kriging Method
(v) Point Interpolation Method
(vi) Topo to raster Method
(vii) Inverse Distance Weighted (IDW) technique

(a) Inverse Distance Weighted (IDW) technique:

The IDW method should be used when the set of points is dense enough to capture the extent of local surface variation for analysis. IDW determines cell values using a liner-weighted combination set of sample points. The weight assigned is a function of the distance of an input point from the output cell location. The greater the distance, the less the influence the cell has on the output value.

(b) Topo to Raster Method:

By interpolation elevation values for a raster, the Topo to Raster method imposes constraints that ensures hydrologically correct digital elevation model that contains a connected drainage structure and correctly represents ridges and streams from input data. It uses an iterative finite difference interpolation technique that optimizes the computational efficiency of local interpolation without losing the surface continuity of global interpolation.

Minimum contour	Maximum contour	Mean	Area	Cumulative area	Volume	Cum_vol	Depth
80	117.4	98.7	567.66	567.66	56028.40	56028.40	98.70
80	106.4	93.2	608.10	1175.77	56675.36	112703.76	95.86
80	98.2	89.1	76.93	1252.69	6854.15	119557.92	95.44
80	87.6	83.8	44.49	1297.18	3728.24	123286.16	95.04
80	80.4	80.2	25.12	1322.30	2014.26	125300.42	94.76
40	80	60	1207.07	2529.37	72424.21	197724.62	78.17
40	80	60	8894.04	11423.41	533642.63	731367.26	64.02
18	61.6	39.8	540.47	11963.89	21510.76	752878.01	62.93
40	46.8	43.4	64.38	12028.27	2794.29	755672.30	62.82
0	40	20	15681.02	27709.29	313620.4	1069292.70	38.59

Table-7: Calculation of Average Areal Precipitation by Topo to Raster interpolation

18.2.2.4 Computation of Standard Project Storm (SPS)

Standard Project Storm(SPS) value of the project catchment may be dependent under the following factors:

- **Area and Topography of the catchment**
- **Correction Factors for Finalising of Standard Project Storm (SPS)**

18.2.2.4.1 Area and Topography of the catchment:

(a) When the area of catchment is less than 500 sq km

(i)**When the catchment lies in plain region:** The SPS may be decided on the basis of point rainfall value plotted in and around the catchment. Suitable factor for Location, may be applied if the storm is more than 100 km far away from project catchment.

(ii) **When the catchment lies in hilly terrain:** By applying Altitude Correction Factor (ACF) (If the difference of altitude between the storm centre and average height of the catchment is more than 800 meter) the SPS value may be calculated. **However, if difference of altitude of the catchment is less than 1500 meter, then no need to apply any correction for altitude.**

(b)When the area of catchment is more than 500 sq km:

In this case, generally 1day/2day/3day SPS values have to be computed and we have to go for isohyetal analysis. The isohyets are to be drawn for the selected rainstorms plotted around the project catchment. Draw isohyets for each rainstorm separately.

(i) Catchment lies in the plain region:

Transposition technique will be applied for plane region project. Search out the storms in and around the catchment whose duration is 2-day or more. Select at least 3 to 4 historical (heaviest) rainstorms. Similar procedure is to be adopted in respect of all other rainstorms selected for the study. Average depth of precipitation is to be computed by filling the entries as per "computation sheet". Among the three storms which gives the maximum average precipitation over the project area for each duration shall be listed along with the DAD values at the original location and values at transposed location.

Do isohyetal analysis and transpose all selected rainstorms over the project catchment. The rainstorm which contribute maximum rain-depth for the catchment may be adopted as final rainstorm. The transposed values may be adopted as SPS values for that catchment. However, it may also be possible that a particular rainstorm may contribute highest rain-depth for only one-day duration or for two-day duration, Some other rainstorm may contribute highest rain-depth. Like this, some other possibilities may also occur.

The average depth of precipitation for 1-day, 2-day, 3-day, etc. is thus obtained for the storm duration. Similar procedure is adopted in respect of all other rainstorms selected for the study.

Meteorologically Homogeneous Region :

Storm transposition technique can only be applied in areas which are meteorologically similar. Broadly speaking, it is a region which is affected by the same moisture source, experiences the same type of storms (or combination of same synoptic situations), has the same rainfall pattern and where the major topographic features are the same.

For the purpose of storm transposition a meteorologically homogeneous region is defined as the one in which the probability of occurrence of rain storms of a given intensity is the same at every point in that area.

The main factors which affect the homogeneity of an area are:-

- distance from the sea
- direction of the prevailing winds
- mean annual temperature
- altitude
- topography

Transposition of Rainstorm:

Storm transposition technique was first developed in U.S.A. in 1930's and the chief advocates of this method at that time were Gail Hathaway of the Corps of Engineers and Merril Bernard of the Office of Hydrology, U.S. Weather Bureau.

The main purpose of the storm transposition is to increase the storm experience of a basin by considering not only the storms which have occurred over or near the basin in the past but also those storms which have resulted in heavy rainfall on adjacent areas that are meteorologically similar.

The storms occurring on one side of the mountain range cannot be transposed to the other side. Further, storms occurring over mountainous area should not be transposed to other areas, plain or mountainous, as the orography highly modifies the susceptibility of the clouds to shed their moisture, other meteorological conditions remaining same.

During transposition the following points should be taken into consideration:

- The orientation of the rainstorm with respect to the basin and if necessary, a tilt in the orientation of the storm's (major) axis to a maximum of **± 20°** may be given in order to obtain the highest depth of precipitation.

- A coastal storm lying within a distance of 50 km. from coast, should not be further transposed in inland. However, it can be transposed along the coastal line within a range of ±5 degree. In all these situations, we have to select transposed depth accordingly.
- Transposition can be done for coastal projects in the Western Ghats. In this case, transposition will be done along the Coast line parallel to the western Ghats i.e. in N & S direction.

(ii) Catchment lies in hilly terrain:

In this case, the normal technique of storm transposition cannot be applied. The SPS may be decided on the basis of DAD estimate obtained from DAD Curve corresponding to the area of the project catchment. This DAD value may be calculated subject to applying Altitude Correction Factor. This worked out value may be adopted as **SPS Value.**

Depth-Area-Duration (D-A-D Method)

In this method, rainstorm is considered as a unit of study. The Depth-Area-Duration Analysis is carried out to determine the greatest precipitation amounts for various size areas and durations over different regions and for certain seasons. Only the major rainstorms with centres or centre of heavy rainfall over or near the catchment area are subjected to Depth-

Area-Duration analysis. The day on which the highest total rainfall is obtained is considered as the maximum 1-day rainstorm, the consecutive two days the highest total rainfall is considered as maximum 2-day and so on. The rainfall values are then plotted on base maps and isohyets are drawn at convenient intervals.

- After drawing the isohyets of each rain storm for different durations, i.e., 1-day 2-day, 3-day, the area enclosed between successive isohyets is measured (manually by using planimeter/ automatically by using ArcGIS) and average rain depth is computed.

- The average rain depths (cm) are plotted against cumulative area (sq.km.) and a smooth curve is drawn. The starting point is taken to be the central storm precipitation value (Highest) and plotted against 'Point' area, i.e., on Y-axis itself. After plotting all other points, a smooth curve is drawn passing through all the points (with the help of "Railway Curves"). **Under no circumstances any point should be above the smooth curve.** If, so, it is advisable to check the computation or even isohyetal analysis. The enveloping curve is known as D-A-D curve of rainstorm. Such Depth-Area-Duration Curves are plotted for all the major rainstorms for durations of 1-day, 2-day, 3-day and so on separately. Out of these curves, only curves corresponding to heaviest and most intense rainstorms are utilised for constructing the Envelope Curves for various durations. Thus, the Envelope Curve is envelopes of the Depth-Area-Duration curve corresponding to the most intense rainstorms which has the highest central rainfall value contributing for smaller areas, whereas for larger areas, the heaviest and well distributed rainstorm contribute to the envelope curve.

- From these curves, rain depth values for standard area, like, 1000, 2000, 5000, -----, 50000 etc. sq.km. for different durations for each of the analysed rainstorms are picked- up. These values give average rain depths over standard areas from rainstorm centre. These values give the maximum rainfall depths averaged over standard areas. These are maximum in time sense, but averaged over an area.

- In general, the depth-duration analysis gives the storm distribution characteristics of the catchment under study, whereas the Depth-area-duration analysis ensures that the possibility of occurrence of the severest neighbouring storm over the catchment under study. **If the entire region is meteorologically homogeneous, then the transposition of the severest rainstorm over the area under study is advisable.** However, for large catchment areas which are meteorologically homogeneous, it is in order to subject the rainstorm to Depth-Area-Duration analysis with catchment as a Unit because the rainstorm either wholly or most of it lies within the catchment under study. Such analysis ensures better results for estimating the time and areal distribution of the storm rainfall that has occurred within the catchment than to transpose one which has occurred away from the catchment area.

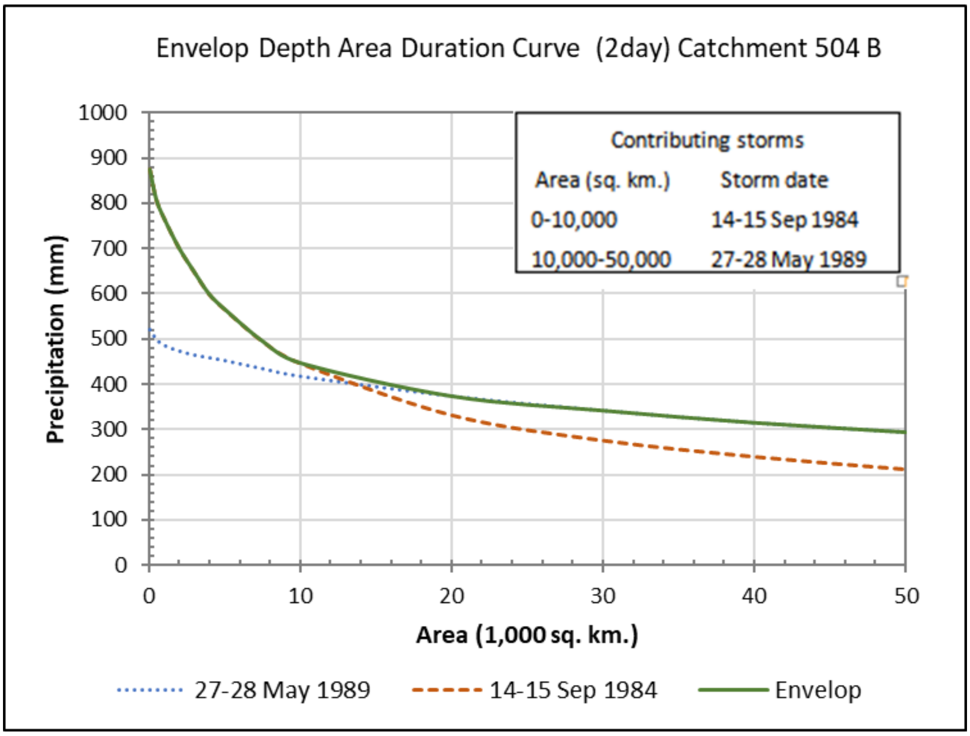


Fig-11: Envelope Depth Area Duration Curve

18.2.2.4.2 Correction Factors for Finalising of Standard Project Storm (SPS):

The following correction factors have to be applied for computation of SPS:

(a)Location Adjustment Factor:

The tables for reading precipitable water for corresponding values of dew point temperatures will be provided by IMD and will form part of the database. There shall be an interface for the user to manually provide the dew point temperature to the system.

Location Adjustment Factor = W_2/ W_1

Where

W_1 is Precipitable water corresponding to maximum dew point temperature ...^{0}C for the same fortnight in which storm occurred at the location of storm.

W_2 is Precipitable water corresponding to maximum dew point temperature .. ..^{0}C at transposed site.

(b)Altitude Correction Factor (ACF):

The software should have provision to apply altitude correction where the average height of catchment is more than 1500 m. ACF=1 for the average height less than 1500m.

Altitude Correction Factor (ACF) = $(W_1 – W_3) / (W_1 - W_4)$

Where

W_1 is Precipitable water corresponding to maximum dew point temperature ……….^{0}C for the same fortnight in which storm occurred at the location of storm.

W_3 is Liquid water content corresponding to maximum dew point temperature ………^{0}C at average height of catchment

W_4 is Liquid water content corresponding to maximum dew point temperature ………^{0}C at height of storm centre.

Standard Project Storm (SPS) Value :

The values of SPS shall be computed for the three maximum storms listed above using the following formula:

1-day SPS = LAF× ACF × DAD
2-day SPS= LAF× ACF× DAD
3-day SPS =LAF× ACF× DAD

The values of SPS may be kept in mm up to one place of decimal**.**

18.2.2.5 Probable Maximum Precipitation (PMP) by Physical Method:

Probable Maximum Precipitation (PMP) over a river basin refers to the amount of precipitation depth that is close to the physical upper limit for a given duration over a particular area. An estimate of Probable Maximum Precipitation is made by the method of Storm Transposition and Maximisation for Moisture Charge. In other words, the Probable Maximum Precipitation envisages the physical upper most limit to storm rainfall and is used for such design purposes where no risk could be undertaken.

18.2.2.5.1 Storm Rainfall Maximisation:

The rainstorms are associated with cloud systems into which the moist air converges at lower levels and then rises to some greater heights. During the ascent, the moist air undergoes adiabatic expansion thereby cooling takes place resulting in cloud formation and consequently the precipitation occurs. In order to estimate the probable maximum precipitation, one is required to maximise the storm precipitation that is realised. This storm maximization is based on the assumption:-

(i) Precipitation can be expressed as the product of available moisture and the combined effect of storm efficiency and inflow wind.
(ii) The most effective combination of storm efficiency and inflow wind has either occurred or has been closely approached in the historical storms on record. This second assumption often necessitates storm transposition, that is, the transposition of a historical storm from the area of its occurrence to the basin under study with in the same region of meteorological homogeneity.

The maximisation of observed storm precipitation for determining Probable Maximum Precipitation (PMP) involves moisture adjustment, the basic assumption being that a storm efficiency was such that it would have produced maximum precipitation had the maximum moisture supply been available. The method of moisture adjustment commonly used involves the estimation of air-mass moisture content from surface level dew point observations and the procedure followed in this method is discussed in detail under para 18.2.2.5.1.

Lastly, the composite method of maximisation is comprised of Sequential Maximisation and Spatial Maximisation. Reducing the observed time interval between storm over a basin, or between bursts within a storm is the sequential maximisation. Rearrangement of storms or bursts within the sequence is permissible and is not restricted to the chronological order of the original sequence. Spatial maximization consists of reducing the distance between simultaneous storm bursts. In tropical countries, like India, it is quite possible that a river catchment may come under the influence of two separate meteorological systems causing two rainstorms widely apart but occurring at the same time. For example, Narmada Basin may be under the influence of a Bay Depression/Storm over its eastern portion and the accentuation of trough along Gujarat-Maharashtra Coast causing active monsoon conditions along the western end of the Narmada basin. It is necessary that for spatial maximisation, the areal extent of the storm or storms should be within the catchment area. The composite method of maximisation in which the Spatial and Sequential maximisation are used together, it is, therefore, a hypothetical rearrangement of observed storms or storm bursts, for the assessment of possible future storms.

18.2.2.5.2 Moisture Maximisation

The purpose of moisture maximisation of a storm is to determine its Moisture Adjustment Factor (MAF) defined as **the ratio of the maximum total moisture in an atmospheric column of unit cross section in the region to the total moisture in a similar column that prevailed during the storm period.** Therefore, the moisture maximisation of a storm requires the estimation of two moisture contents - one corresponding to the highest value on record for 30-50 years at the location and during the season and the other is the moisture value during the storm period. In order to obtain these values, the 'Identifier' commonly used in tropics is "Dew Point" temperature. The surface dew points in the inflowing tropical air in or near a storm, identify the storm moisture content whereas the moisture content corresponding to either the highest dew point on record at the location and season or the dew point of some specific return period say 25 years or 50 years is considered sufficiently close to the maximum dew point. Both the storm and maximum dew points from stations (generally at higher elevations) are reduced to a standard isobaric level of 1000 hPa. with the help of a thermodynamic diagram (One such thermodynamic diagram is popularly known as TEPHIGRAM in which the dew point temperatures are reduced to 1000 mb along the dew point lines, i.e., humidity mixing ratio lines given dotted from top to bottom inclined to isotherms).

18.2.2.5.3 Maximum Dew Point

Where surface dew point data are available, a satisfactory method for obtaining the maximum dew point is to examine the long period record for the same fortnight in which storm has occurred in respect of several stations within (or near) the region under study and also on the path of inflow moisture and then examine for the highest values for each station/ stations. These highest dew point temperatures are adjusted to 1000hPa isobaric level and may be used to compute MAF.

18.2.2.5.4 Storm Dew Point:

To obtain the prevailing dew point during the storm which represents the observed storm moisture, the highest dew points in the warmest air mass flowing into the storm area identified on Surface Weather Charts. This determination may be made within the storm area between the storm area and the sea. Figure 2 illustrates how the storm dew point determination is made, based on the available dew point data of four stations, enclosed by rectangles, one inside the heavy rainfall area and the other three in the path of moisture inflow. On each consecutive day for the duration of a storm, the maximum dew point is averaged over these four stations as illustrated in Figure 2. If the data in respect of all these stations are not available, then it would be quite appropriate to rely on the dew point at only one suitably located station. While selecting the station, care should be taken that the storm centres should invariably fall close to the station or the station lies in the region of inflow of warm moist air into the system causing the rainstorm.

Based on the values of maximum dew point and prevailing dew point for the storm period and reduced to 1000 mb. isobaric level, the moisture content in the atmosphere upto a level of 500 hPa. **(upto 500 mb. will be enough as no significant moisture contribution comes from the isobaric level between 500 mb. and 200 mb.)** is obtained with the help of the Table showing the depths of precipitation water in a column of air of given height above 1000hPa. isobaric level. The ratio of the maximum moisture content to the prevailing moisture content gives the Maximisation Factor for the rainstorm.

The precipitable depth values for 1-day, 2-day, etc. yielded by the heaviest rainstorms over the region corresponding to standard project storm are then multiplied by the Maximisation Factor to obtain the Maximum Probable Storm for design purposes.

18.2.2.5.5 Moisture Adjustment Factor:

Moisture Adjustment Factor (MAF) = W_1/ W_5

Where

W_1 is Precipitable water corresponding to maximum dew point temperature ($^{\circ}$C) for the same fortnight in which storm occurred at the location of storm.
W_5 is Precipitable water corresponding to persistent dew point temperature ($^{\circ}$C) during the period of the storm.

Probable Maximum Precipitation (PMP):

1-day PMP Value= MAF × 1-day SPS

2-day PMP Value= MAF × 2-day SPS

3-day PMP Value= MAF × 3-day SPS

The values of PMP may be kept in mm up to one place of decimal. Case study is attached as Annexure-VI.

18.2.2.6 Time Distribution Curves (SRRG Data)

For selection of the rainstorms, hourly rainfall data of a particular station for consecutive 2 day (or 24 hr), 3 days (for 48 hr.) and for 4 observational days (for 72 hr rainstorm) are to be scanned and consecutive 24-hour, 48-hour and 72-hour spells during which maximum rainfall is recorded, are to be selected **as per criteria** given below:

i. **For 24-hour storm, minimum rainfall should be 50 mm or more and there should not be consecutive three hourly observations with zero rainfall. i.e. no break of rainfall for continuous three hours. The total no. of observations with zero rainfall should not be more than five (5).**

ii. **For 48-hour storm, minimum rainfall should be 80 mm or more and there should not be consecutive five hourly observations with zero rainfall. i.e. no break of rainfall for continuous five hours. The total no. of observations with zero rainfall should not be more than eight (8).**

iii. **For 72-hour storm, minimum rainfall should be 100 mm or more and there should not be consecutive seven hourly observations with zero rainfall. i.e. no break of rainfall for continuous seven hours. The total no. of observations with zero rainfall should not be more than ten (10).**

By using the above criteria, maximum number of storms are to be selected from available SRRG data (hourly rainfall data) for a station. For each storm, 3 consecutive hours having maximum rainfall within that 24-hour storm are to be selected. Similarly, consecutive 6-hours, consecutive 9-hours and so on upto 24 hour are to be selected. The design engineers generally require maximum of the percent rainfall for these consecutive 3-hour, 6-hour, 9-hour, …………, 24-hour for a 24 hour, for determining storm hydrograph characteristics. Accordingly, this maximum rainfall value of each duration storm i.e. 3,6,9,.....24 hr is expressed as percentage of 24 – hour rainfall value. The percentages values so derived for each storm and duration (3-hour, 6-hour, 9-hour, …………, 24-hour) are to be averaged over the no. of selected rainstorm over a specific station and these averaged percentage values are to be plotted against durations to obtain Time Distribution Curves for 24-hour rainstorm.

Similar procedure is to be adopted for 48-hour and 72-hour rainstorms for computation of Time Distribution.

From the curves, percentage values for each duration 3,6, 9,………, 24hour/48-hour/72 –hour are to be picked up and to be represented in graphical as well as in tabular form as per following table and graph:

Durations (hours)	24 hr Avg (%)	48 hrs Avg (%)	72-hrs Avg (%)
1	16	16.5	14.3
3	34.5	32.3	26
6	53	48.9	35
9	66	58.9	41
12	77	65.2	47
15	86.4	70.2	52
18	93.5	74.7	57
21	97.8	79.2	61
24	100	82.7	65
27		85.7	69
30		88.3	73
33		90.7	77
36		93.1	81
39		95.2	84
42		97.3	87
45		99	89
48		100	91
51			93
54			94
57			95
60			96
63			97
66			98
69			99
72			100

Table-8: Time Distribution

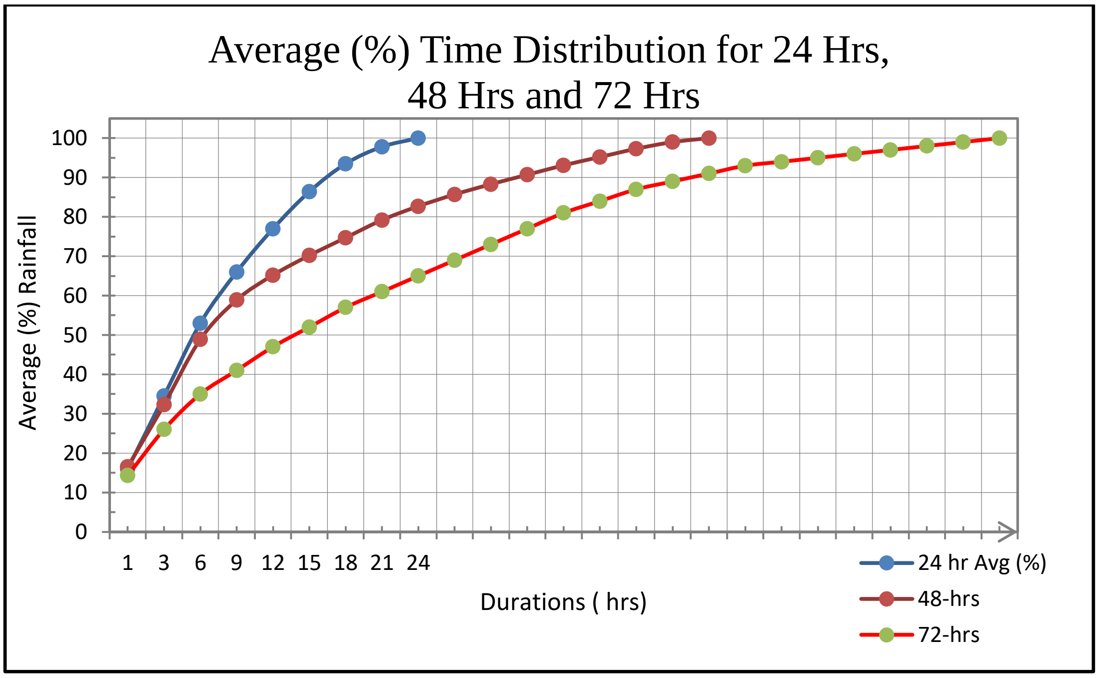


Fig-12: Time Distribution curve

Standard Operational Procedure(SOP)

For

Quantitative Precipitation Forecast

Supported by

Dr. Ashok Kumar Das, Sci.-E

Dr. Naga Ratna Kopparthi, Sci.-E

Dr Geeta Agnihotri, Sci.-E

Sh. Maninder Singh, Met.-A

Sh. Dhara Singh, Met.-A

Ms Charu, SA

Ms Jyotsna Dhingra, SA

18.3 SOP for QPF:

Introduction:

Flood forecasting is a joint operational responsibility of India Meteorological Department (IMD) and Central Water Commission (CWC). IMD provides sub basin wise Quantitative Precipitation Forecast (QPF) and other weather-related inputs in the form of QPF & Hydromet Bulletins generally during flood season through its Flood Meteorological Offices (FMOs) and the same will be used by CWC to issue the flood forecast. Flood Meteorological Offices (FMOs) are established to provide meteorological support to concerned Flood Forecasting Divisions (FFDs) of Central Water Commission (CWC). This Hydrometeorological service is operational from 14 IMD offices viz., Ahmedabad, Asansol, Bhubaneswar, Guwahati, Hyderabad, Jalpaiguri, Lucknow, New Delhi including Agra, Patna, Srinagar, Chennai, Bengaluru and DVC Kolkata (Fig.-20). These functions under the technical control of office of DDGM(Hydromet), New Delhi, while their administrative control rests with DDGM (RMCs).

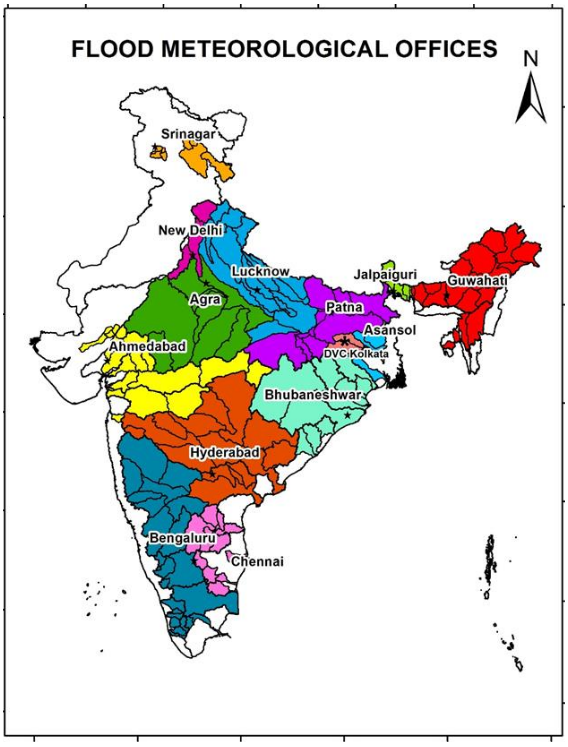


Fig.- 13: Flood Meteorological Offices & their area of jurisdiction

The technical aspects of FMOs should be referred to HQ office by FMOs directly. Regarding administrative aspects of FMOs, the recommendations of the concerned RMCs will be necessary to take further action on those aspects. Where MC and FMO co-exist, FMOs should work in close collaboration with MCs. RMCs concerned are to be seen that the technical work of FMOs should not suffer due to administrative reasons. As the basin areas may extend beyond the jurisdiction of a single RMC, the FMOs may correspond with such offices / centres as necessary for meeting their data requirements for the issue of 'Hydromet Bulletin'

18.3.1 Flood Season

The flood season may vary depending upon location of basin and onset/withdrawal of S-W monsoon. As per the guidelines from CWC vide notification no 3/120/2019-FFM/ dated 22nd April, 2019, the flood season is as follows;

(i) Brahmaputra & Barak (including Teesta, Rivers flowing in States of Tripura, Manipur, Mizoram, Nagaland, Meghalaya, North Bengal, Sikkim) Basins and Jhelum Sub-Basin of Indus Basin from 1st May to 31st October

(ii) All other basins upto Krishna basin from 1st June to 31st October and

(iii) Basins south of Krishna basin (Pennar, Cauvery and southern rivers) form 1st June to 31st December.

18.3.2 Preparation of QPF

Sub basin wise QPF, Probabilistic QPF other relevant information is to be prepared by each FMO as per area of their jurisdiction for issuing 'QPF Bulletin'(proforma at Annexure- VII(a) &VII(b)) and 'Hydromet Bulletin'(proforma at Annexure- VIII (a) & VIII(b) during Flood Season.

Rainfall Analysis, Synoptic charts, synoptic analogues, NWP products, satellite imageries/products and RADAR products (if available) (Fig. - 21) etc. are to be utilized for formulation of QPF Bulletin and Hydromet Bulletin.

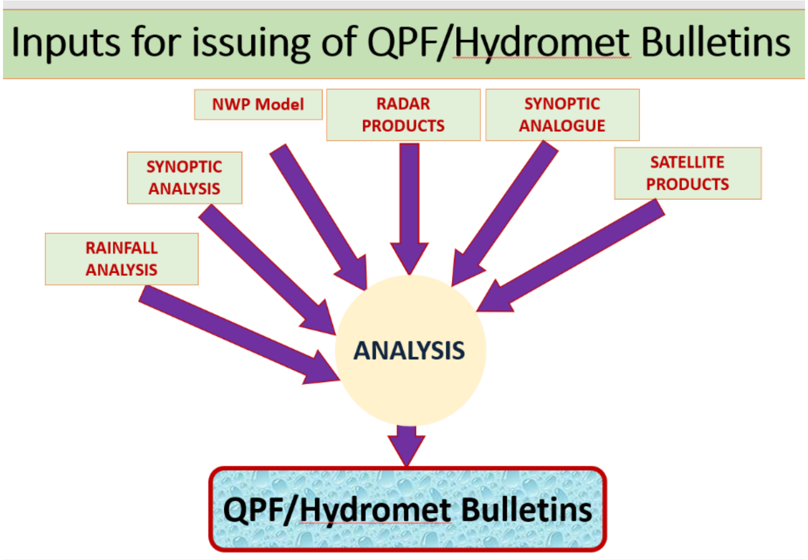


Fig. - 14: Inputs for issuing QPF and Hydromet Bulletin

18.3.3 SOP for Formulation of QPF & Hydromet Bulletin

The prescribed proforma for 'QPF Bulletins' and 'Hydromet Bulletins' are given in Annexure-VII(a) &VII(b) and Annexure-VIII (a) & VIII(b) respectively. QPF and Hydromet Bulletin consist of following information;

i). The sub basin wise QPFs (Table-9(a) & 9(b)), spatial distribution (Table-10), intensity distribution (Table-11) and categorical probability of occurrence (Table-12) which are to be included in the hydromet Bulletin are shown in the following tables:

Category of QPF (mm)	Colour Code
0.0 - No Rain	
0.1 -10	
11-25	
26-50*	
51-100*	
>100	

Table-9(a): Sub basin wise Categorical QPF and their colour Code

Category of QPF (mm)	Colour Code
0.0 - No Rain	
0.1 -10	
11-25	
26-37	
38-50	
51-75	
75-100	
>100	

Table-9(b): Sub basin wise Categorical QPF and their colour Code

Spatial Distribution of Rainfall		
DRY	Dry	No Station reported rainfall
ISOL	One or two Places	25% or less number of stations recorded rainfall 2.5 mm
SCT	At a few Places	26%-50% number of stations recorded rainfall 2.5 mm
FWS	At many Places	51%-75% number of stations recorded rainfall 2.5 mm
WS	At most places	76%-100% number of stations recorded rainfall 2.5 mm

Table-10: Spatial distribution of Rainfall and their colour Code

Intensity of Rainfall					
M.Dry	NIL	0 cm	VL	Very Light Rainfall	Trace
L	Light Rainfall	Upto 1 cm	M	Moderate rainfall	02-06 cm
H	Heavy rainfall	07-11 cm	VH	Very Heavy rainfall	12-20 cm
EH	Extremely Heavy rainfall	21 cm or More			
ExH	Exceptionally Heavy Rainfall	When the amount is a value near about the highest recorded rainfall at or near the station for the month or season. However, this term will be used only when the actual rainfall amount exceeds 12 cm			

Table-11: Intensity of Rainfall and their colour Code

Probability of Occurrence (%)	Colour Code
0-5	
5-25	
25-50	
50-75	
75-100	

Table-12: Probability of Occurrence of categorical QPF and their colour Code

[*QPF of wider ranges i.e. 26-50 mm and 51-100 mm may be bifurcated within the main ranges as 26-37 mm, 38-50 mm and 51-75 mm, 76-100 mm, respectively as per requirement of Concerned FFD.]

ii). The forecast issued in 'QPF Bulletin' will be valid for 3 days i.e. Day-1 to Day-3 which will contain sub basin wise categorical QPF.

iii). The forecast issued in 'Hydromet Bulletin' will be valid for 3 days i.e. Day-1 to Day-3 with daily outlook for subsequent 4 days i.e. Day-4 to Day-7. It will contain following information; Synoptic situation (over the jurisdiction area), sub-basin wise QPF, Spatial & Intensity distribution of Rainfall, Categorical Probabilistic QPF, Heavy Rainfall Warnings (HRW), Outlook, Significant Rainfall (≥5cm) and Realized basin average rainfall at 0830 hrs IST.

Other than flood season, QPF bulletin is to be issued under following eventualities:

i). During the period of 'Flood Alert' for specified basins as notified by concerned FFD.

ii). During the weather situations where there is expectation of significant rainfall leading to floods in a particular basin/sub-basin.

iii). If heavy rainfall is expected during non-flood season or in the event of formation of Cyclone, concerned FMO need not to wait for any demand from concerned FFD to issue QPF/HM Bulletins. Joined with flood season.

Following SOP is to be followed for formulating QPF and Hydromet Bulletin;

18.3.3.1 Synoptic Charts Analysis:

FMOs co-located with Met. Centres should use the weather analysis charts prepared by them. FMOs which are not co-located with MCs should consult/obtain from the respective RMC/MC, the real time weather charts prepared by them. NWP model-based analysis maps may also be used.

18.3.3.2Rainfall Chart Analysis:

Rainfall analysis maps using isohyetal analysis based on station wise observed rainfall data should be prepared for computation of sub basin-wise Areal Average Precipitation (AAP). Normally rainfall analysis may be prepared daily or more frequently if situation so demands. FMOs need to use customized GIS based software for the rainfall analysis in place of manual analysis on Basin Maps.

(a) Selection of stations

Rainfall data are collected from IMD surface observatories, FMO network and other IMD observatories as well as other organisation’s observatories. If it is considered necessary, data may also be sought from selected state rain gauges in the basin. The rainfall data should also be collected for the stations laying in the river basins from concerned FFD. It may be ensured that rainfall data received from the network maintained by other agencies confirm to IMD Standards. Some raingauge stations of CWC are kept at some height above ground level (which does not confirm to WMO criteria). These stations should be flagged so that they are not used for climatological purpose. FMO should carry out the effect of variation of rainfall of raingauges installed at different height from ground level. However, those raingauge data may be used for operational purpose when raingauge at ground level is submerged. AWS/ARGs data, within the area of basin/sub-basin, may be used after scrutiny/validation of data and rainfall data from those stations.

(b) Frequency of collection

(i) FMOs receive rainfall data from Hydromet observatories recorded at 0830 hrs. IST as a routine. The data observed other than these routine hours may be requisitioned from selected rain gauges during the flood season, if needed.

(ii) In case of expectation of heavy to very heavy rainfall as per climatology, FMOs in consultation with RMCs may examine the possibility of obtaining rainfall data at more frequent intervals, for instance, once in six hours.

(iii) Rainfall data from SRRGs which form the network of the FMO and are installed at concerned FFD sites may be obtained at 6-hourly intervals during the ‘Flood Alert’ periods.

(iv) Hourly rainfall data from selected AWS/ARG stations available at CRIS at http://hydro.imd.gov.in/hydrometweb/ may also be used.

(v) Real time daily GTS ORG available on CRIS at http://hydro.imd.gov.in/hydrometweb/& river basin rainfall statistics on CRIS at http://hydro.imd.gov.in/hydrometweb/ may be used.

(c) Collection of Rainfall data

(i) The rainfall data may be collected by landline telephone, Fax, mobile phone, e-mail, internet, websites etc.

(ii) When the normal mode of communications fail, efforts should be made for transmission of rainfall data through alternate channels including seeking help of the local police authorities and state government officials for use of their channels of communication in extreme cases.

(iii) During the failure of internet services which is generally mode of communication for exchange of all information and data, other means of communication may be pre-decided and used with co-ordination with CWC.

(d) Station with significant Rainfall:

Preparation the list of rainfall stations which receives 5cm or more rainfall during the last 24 hrs till 08:30 hrs IST.

18.3.3.3 River sub basin QPF based on NWP Model:

Sub basin wise Rainfall estimates from NWP models may be used as an additional input for framing sub-basin wise QPF which is available operationally as given in the table below.

NWP Model	**Days**	Website link	Example
WRF (3km) (00utc)	Day-1 to Day-3	http://hydro.imd.gov.in/hydrometweb /(S(hcrlyu45hpa1ep55iieiugrv)) /PRODUCTS/QPF/index.html	Fig.15.
GFS (12km) (00utc)	Day-1 to Day-7		Fig. 16.
NCUM (12km) (00utc)	Day-1 to Day-7		Fig. 17.

It is mentioned that above NWP models rainfall estimates should not be used directly. However, it should be value added by using any other regional/global models viz., ECMWF, NCEP, NOAA, COLA etc. may also be referred. For finalizing operational QPF.

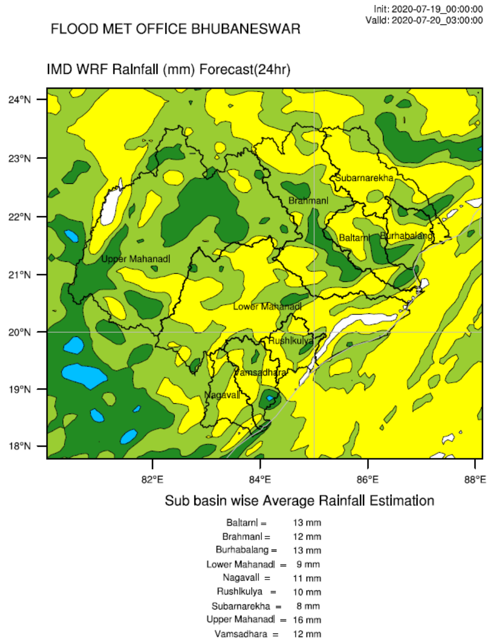


Fig.-15: WRF based sub basin wise Avg. Rainfall Estimation

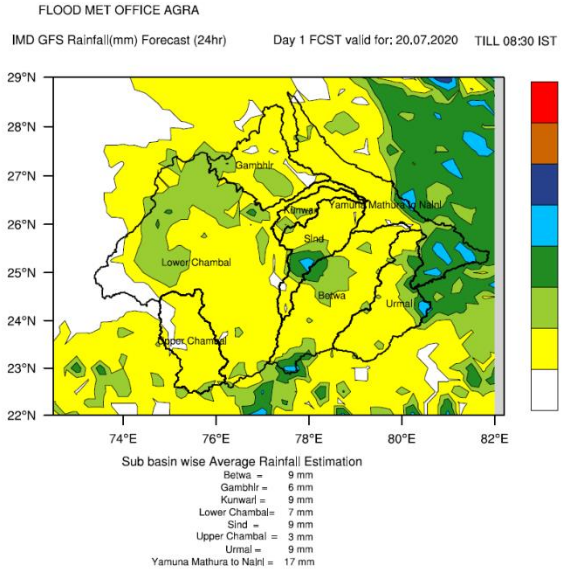


Fig.-16: GFS based sub basin wise Avg. Rainfall Estimation

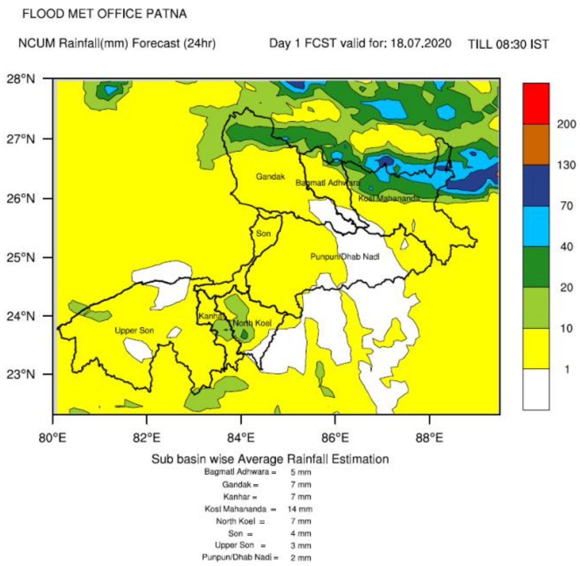
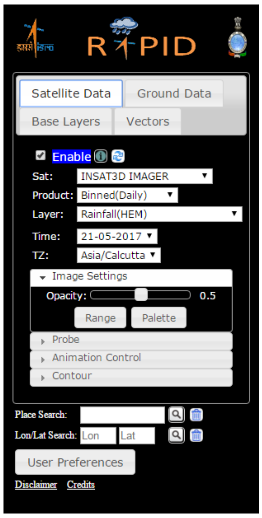


Fig.-17: GFS based sub basin wise Avg. Rainfall Estimation

Additional NWP model-based forecast products are available in the following links;

a. https://internal.imd.gov.in/
b. https://mausam.imd.gov.in/
c. Real time NWP model forecast & analysis; http://nwp.imd.gov.in/
d. Any other regional/global model

18.3.3.4 Satellite based sub basin wise Rainfall Products



RAPID stands for Real Time Analysis of Products and Information Dissemination is the gateway to Indian Weather Satellite data, which is hosted in IMD website at;

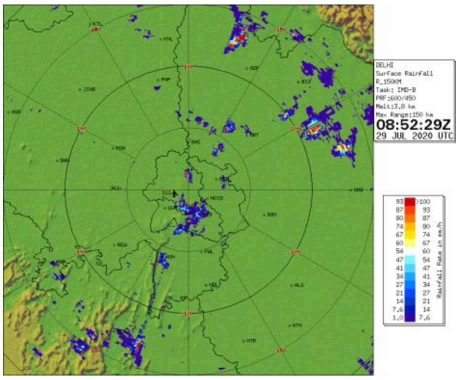
a. Sat. Met. products http://satellite.imd.gov.in/insat.htm
b. RAPID products; http://www.rapid.imd.gov.in/ with basin layer base

Sub basin wise Quantitative Precipitation Estimate (QPE) of INSAT 3D based on HEM/ IMR/ GPI techniques are available operationally as given at Fig.-6.Also,various satellite products of Cooperative Institute for Meteorological Satellite Studies (CIMMS), University of Wisconsin-Madison viz., Lower level Convergence, Upper level Divergence, Lower Level Winds, Upper Level Winds, wind shear etc. may be referred. In addition to above, any other information regarding the satellite products from different sources for this activity may also be explored.

Fig. 18: Satellite INSAT 3D based estimated sub basin wise rainfall

18.3.3.5 Radar Rainfall Products:

RADAR based products(Figs.-7&8) may be used as available at https://internal.imd.gov.in/pages/radar_main.php.



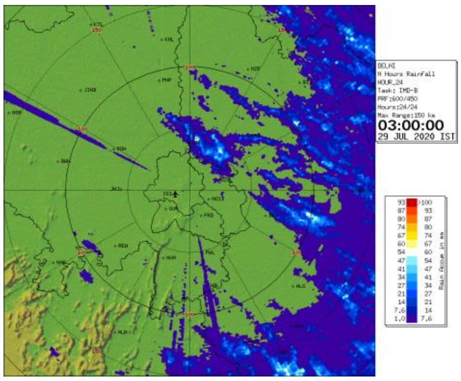


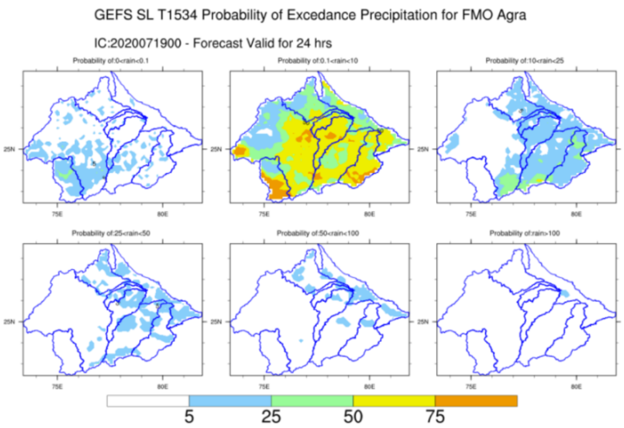
Fig.-19: Radar based estimated Rainfall Intensity **Fig.-20 Radar based estimated 24 hr Rainfall**

18.3.3.6 Synoptic Analogue:

Synoptic-cum-statistical analogue models for each basin /sub basin under the jurisdiction of FMOs are to be used as forecasting tool as per current weather situation for issuing QPF.

18.3.3.7 Probabilistic QPF:

Dynamical model GEFS (Fig.-9) and NUCUM (Fig.-10) based categorical probabilistic QPF values for Day-1 to Day-5 are available in the IMD internal website at http://hydro.imd.gov.in/hydrometweb/(S(yh3m3b45bj3onzfbjr15c2rq))/Login.aspx which may be used for PQPF.



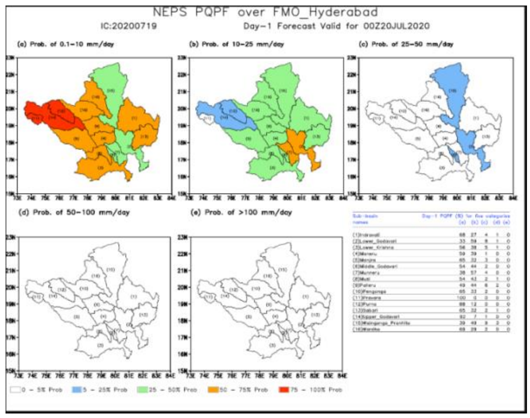


Fig.-21: GEFS based sub basin wise categorical PQPF

Fig. -22: NEPS based sub basin wise categorical PQPF

18.3.3.8 Thumb rule for formulation of QPF and Hydromet Bulletin

a) Awareness of Sub-basin wise prevailing Flood situation
b) Large scale monsoon features (ENSO, IOD, MJO)
c) Over all monsoon situation (Active-Break)
d) Basin wise SOP/ Check lists,
e) Climatology of Sub basins
f) Synoptic appreciation
g) Real-time Rainfall observations
h) Updated Synoptic cum Statistical Analogue
i) Satellite Products and animations (Rapid, HEM, IMR, QPE etc)
j) DWR products and animations (Rain rate, cumulative rain etc)
k) Flash Flood Guidance Products, E-flow products
l) NWP guidance(National & International) (SM), Meteograms, Indices
m) General Forecasts and Heavy Rainfall warnings

18.3.3.9 Dissemination of Bulletins

(i) The QPF Bulletins and Hydromet Bulletin prepared on daily basis during flood season are to be provided to concern FFD by **0930 hrs** IST with copy to Hydromet Division (HQ) which is to be formulated based on 00 UTC data and by 1730 hrs IST based on 09 UTC data as a routine every day for every sub-basin and "Hydromet Bulletin" by 1230 hrs IST with updated QPF, if necessary, based on 03UTC Charts.

(ii) If any significant development of weather takes place after issue of Hydromet bulletin, it needs to be communicated to concerned FFD.

(iii) Advance rainfall warning may be given so that concerned FFD is in a position to issue 'Flood Alert' (In the case of Depression / Cyclonic storms, likely direction of movement may form the basis of such warnings).

(iv) In case concerned FFD desires, rainfall analysis map may be supplied.

(v) Communication mode will be Landline telephone, Fax, mobile phone, e-mail, internet, websites etc.During the failure of internet services which is generally mode of communication for exchange of all information and data, other means of communication may be pre-decided and used in co-ordination with CWC.

18.3.4 User Interaction and feedback:

There will be user interaction, discussion with different users may be conducted for collecting their feedback regarding these Hydrometeorological activities.

18.3.5 Documentation:

All the Extreme rainfall events resulting to flood situation which has occurred during the year has to be documented for publication in the form of technical reports/research papers.

18.3.6 Annual Review

Based on the verification, feedback from users and documentation, the procedure, tools and techniques are to be updated for issuing QPF in the coming flood season. Similarly, check list, SOP, Climatology synoptic cum statistical analysis model has to be updated and modified.

18.3.7 Additional Activities of FMOs

i). FMOs should pass information regarding brief account of the flood situation together with flood levels and departure from highest flood level as well as QPF issued to Head, Hydromet Division, New Delhi during every 'Flood Alert' period on daily basis by concerned FMOs to HQ as per format at Annexure-IX.

ii). When a 'Flood Alert' is in operation, there should be round the clock watch till it is withdrawn. FMOs may revert to normal watch hours after the 'Flood Alert' is withdrawn by concerned FFD.

iii). All FMOs should keep records of Synoptic Charts, Synoptic Analogue product, NWP products etc. used for sub-basin wise rainfall forecast.

iv). All FMOs should intimate to Head, Hydrology Division, New Delhi, and the date of onset and withdrawal of monsoon from the area of their jurisdiction by fax and e-mail.

v). FMOs to prepare the station wise daily rainfall data as per format given at Annexure-X and sub basin wise daily rainfall data & forecast is to be prepared as per format given at Annexure-XI on real time basis as well as with updated data (late receipt data). The real time data is to be sent to Head, Hydrology Division, New Delhi operationally and updated data on monthly basis within 15 days after completion of the month.

vi). QPF/HRW verification reports with actual updated data in Excel sheet by using the software programme provided by O/o DDGM (H) should be sent to HQ, New Delhi positively within the first quarter after the end of SW monsoon season as well as end of flood Season.

vii). As per guide lines of WMO, verification of QPF in Daily, monthly, seasonal or any flood period are to be carried out for various skill scores. FMOs should submit a monthly report of verification of QPF and Heavy Rainfall Warnings (HRW) during flood season in the prescribed format at Annexure-XII to DDGM(H) by the 15th of the following month (AAP should be based on updated data). The modified software for verification of sub-basin wise QPF will be sent to all FMOs by Hydromet Division, New Delhi. Verification reports for cyclone period/non-flood season, if any, should also be sent to Head, Hydrology Division, New Delhi along with the realised rainfall data. The detail procedure is given at Annexure-XIII.

viii). For verification of forecasts, FMOs should make efforts to use the late received data, re-analyse the relevant Isohyetal maps for determination of areal rainfall. On occasions when QPF is out by two ranges or more, a brief account of self-appraisal giving justification for issuing the forecasts and the factors responsible for non-realisation may be incorporated.

ix). A weekly flood situation report containing consolidated synoptic features, flood observed period, daily gauge readings during the period, QPF and Heavy Rainfall Warning (HRW) with realised rainfall with verification, significant rainfall, flood damage during the week in all rivers/ tributaries within the jurisdiction of FMO should be sent to the counterpart concerned FFD after the end of every week (seven days from the date of commencement of flood alert) with a copy to HQ, New Delhi.

x). Annual Flood Report should be prepared in detail and as per format provided (Annexure –XIV).

xi). Scrutiny, Tabulation, Keying & Archival of Rainfall Data : ORG data and SRRG charts along with tabulation should also be sent to NDC, Pune and the scan copy of SRRG chart should be kept at FMOs for record. The tabulated hourly data in Standard Format & also tabulated 15 minute data for heavy rainfall analysis i.e.≥12mm per hour (Annexure-XV) should be sent to Head, Hydrology Division, New Delhi. The soft copy of hourly and 15 minutes tabulated data should be dispatched to NDC, Pune.

xii). Development of sub basin wise synoptic-cum-statistical analogue model: It is essential to have synoptic-cum-statistical analogue models for each basin/sub basin under the jurisdiction of respective FMO. On the basis of the availability of longer data sets, FMOs should prepare such analogues for the basins. Existing analogue, if prepared more than five years back should be updated. In addition to this, FMOs may develop models for issuing QPF for the sub-basins under their region. Technique for synoptic analogue model is available at Annexure-XVI.

xiii). Hydro-meteorological Studies: FMOs have to compile the hydrometeorology of the concerned basins comprehensively. All such studies have to be compiled in the form of monograms/ reports which will serve the basis of all Water Management Studies. The frame work for compilation of hydrometeorology has been supplied to FMOs with necessary guidelines. Required rainfall and other meteorological data may be obtained from NDC, Pune. Some input parameters like major rainstorms, Return Period Values etc., may also be included.

Standard Operating Procedures

For

Flash Flood Guidance Services

Supported By:

Ms. Hemlata Bharwani

Sh. Asok Raja S.K

18.4 Flash Flood Guidance Services

18.4.1 Introduction:

Flash floods are among the world's deadliest natural disasters with more than 5,000 lives lost annually and result in significant social, economic and environmental impacts. Accounting for approximately 85% of the flooding cases, flash floods also have the highest mortality rate (defined as the number of deaths per number of people affected) among different classes of flooding (e.g., riverine, coastal).
Flash floods have a different character than river floods, notably short time scales and occurring in small spatial scales, which make forecasting of flash floods quite a different challenge than traditional flood forecasting approaches. In forecasting of flash floods, we are concerned foremost with the forecast of occurrence, and herein have focused on two causative events:
1. Heavy rainfall and
2. Rainfall on saturated soils.

Flash floods occur throughout the world, and the time thresholds vary across regions from minutes to several hours depending on land surface, geomorphological and hydro climatological characteristics of the region. However, for the majority of these areas there exists no formal process for flash flood warnings, there is a lack of general capacity to develop effective warnings for these quick response events.

18.4.2 Definition of Flash Flood:

Flash floods are floods of short duration with a relatively high peak discharge usually less than 6 hours between the occurrence of rainfall and the peak flood. In other words, any hydro-meteorological disasters and heavy or excessive rainfall associated hazards in a short period of time that produce immediate runoff creating a flood of short duration within minutes or few hours during or after the rainfall.

WMO defines flash flood as "A flood of short duration with a relatively high peak discharge".

AMS defines flash flood as "A flood that rises and falls quite rapidly with little or no advance warning, usually the result of intense rainfall over a relatively small area".

In nutshell, **Flash floods** are defined as events that are the result of heavy or excessive amounts of rainfall within a short period of time, usually less than 6 hours, causing stream waters to rise and fall quite rapidly.

Flash floods are a hydro-meteorological hazard unlike other weather-related events with specific geographic locations; every location where rainfall occurs has the potential to produce a deadly flash flood. As a forecaster, one is aware that flash floods are not always the result of meteorological conditions. Although heavy rainfall is usually a factor, it is the interaction between the meteorological conditions and hydrologic characteristics of the watershed where the rain is occurring that may result in a flash flood.

18.4.3 Background of Flash Flood Guidance System

As part of WMO's Flood Forecasting Initiative and on the basis of a 4-party Memorandum of Understanding signed by the World Meteorological Organization (WMO); US NOAA National Weather Service (US NWS); the Hydrologic Research Center (HRC), San Diego, USA; and U.S. Agency for International

Development/Office of U.S. Foreign Disaster Assistance (USAID/OFDA), the signatories have established a cooperative initiative for the Flash Flood Guidance System with Global Coverage Project.

The South Asia Flash Flood Guidance System (*SAsiaFFGS)* was launched in 2016, covering Bangladesh, Bhutan, India, Nepal and Sri Lanka **(Fig 23).** The India Meteorological Department (IMD) was selected as the regional center to provide forecast products and data to the participating countries, provide good IT infrastructure i.e., computation and dissemination server for smooth data exchange and internet connection, Issue flash flood guidance bulletins for each member country on daily basis and conduct verification studies in collaboration with the NMHSs and WMO.

Fig 23: SAsiaFFGS Member Countries

18.4.4 Objectives

1) To provide real-time informational guidance products pertaining to the imminence of potential small-scale flash flooding.
2) To issue guidance alerts warnings in association with nowcast or forecasts of rainfall on potential small watersheds for preparation of any disastrous events.

18.4.5 Flash Flood Guidance Model

The Flash Flood Guidance System (FFGS) is a diagnostic tool ingesting real-time satellite precipitation data, on-site gauge precipitation and temperature data, model-forecasted precipitation, and, on the basis of available spatial databases, produces flash-flood-occurrence diagnostic and prognostic indices over small flash flood prone catchments.
In this context, flash flood guidance of duration T for a small catchment is the volume of rainfall accumulated over a future period T that is just enough to cause bankfull flow at the outlet of the draining stream. Thus, if the volume of accumulated rainfall is greater than flash flood guidance during the future period then overbank flow is expected (minor flash flooding). The diagnostic flash flood guidance index may then be used with nowcast or forecast rainfall volumes of the appropriate durations to identify the likelihood of flash flooding at the outlet of specific small catchments.

Flash Flood Guidance (FFG) is the amount of rainfall of a given duration over a small drainage area needed to cause minor flooding (bankfull) condition at the outlet of the stream which drains that basin. Flash Flood Guidance is an index of how much rainfall is needed to overcome soil and channel storage capacities and to cause minor flooding.

Flash Flood Threat (FFT) is the amount of rainfall of a given duration in excess of the corresponding Flash Flood Guidance value. The flash flood threat, when used with observed rainfall, is an indicator of areas where flooding is imminent and where immediate action may be needed.

18.4.6 SAsiaFFGS User Interface

The SAsiaFFGS system is comprises of regional computational and dissemination servers that are accessed by authorized users. The regional user interface is accessible through a password protected website and is composed of two main parts: the **Product Console** and the **Dashboard**. The primary page for hydrologists and meteorologists on duty is the Product Console **(Fig-24).** The Product Console presents the complete system products in overview features access links to detailed output which forecasters are trained to use. The Dashboard is designed primarily for system administrators and provides a summary of system processes. The Dashboard also helps forecasters to get a brief inspection of the system status **(Fig-25).** Information is available for each 28780 small watersheds delineated through 30m DEM from 153 sub basins of India. There are about 17 types of dynamic products and 19 types of base layers available in this system for the forecasters to visualize their area of interest and take quick decision accordingly.

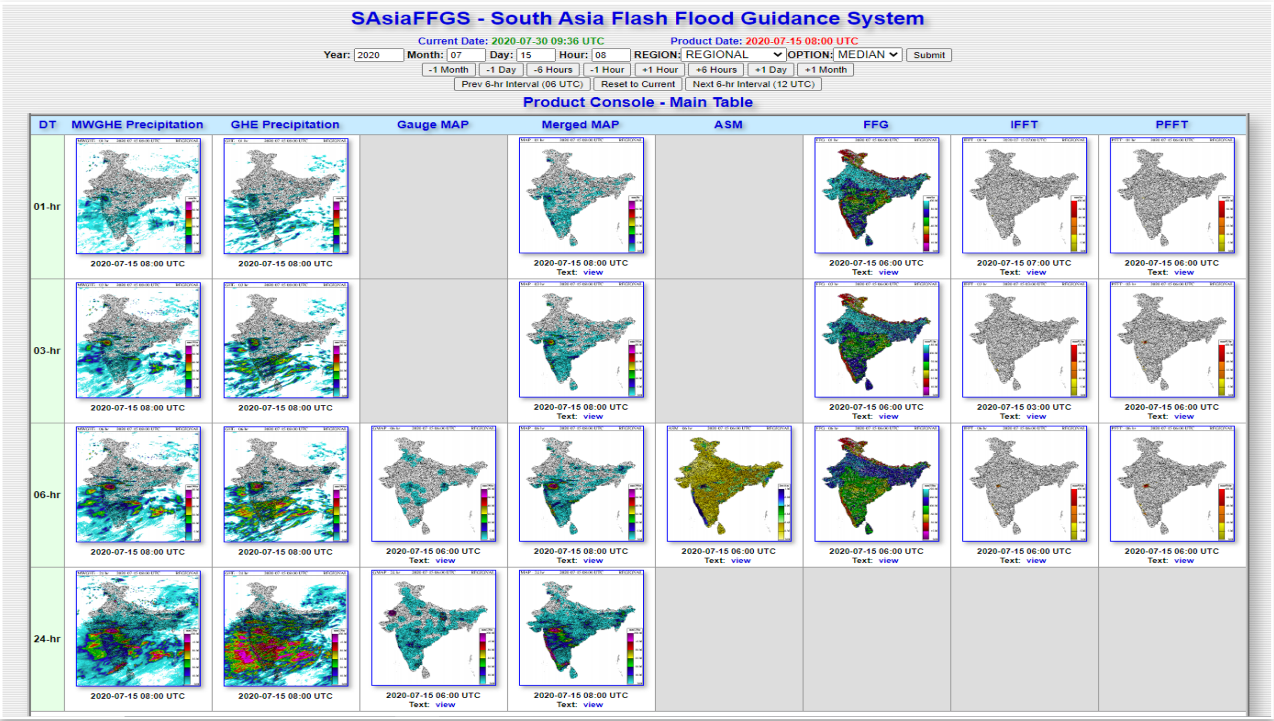


Fig 24: SAsiaFFGS Product Console Interface Page

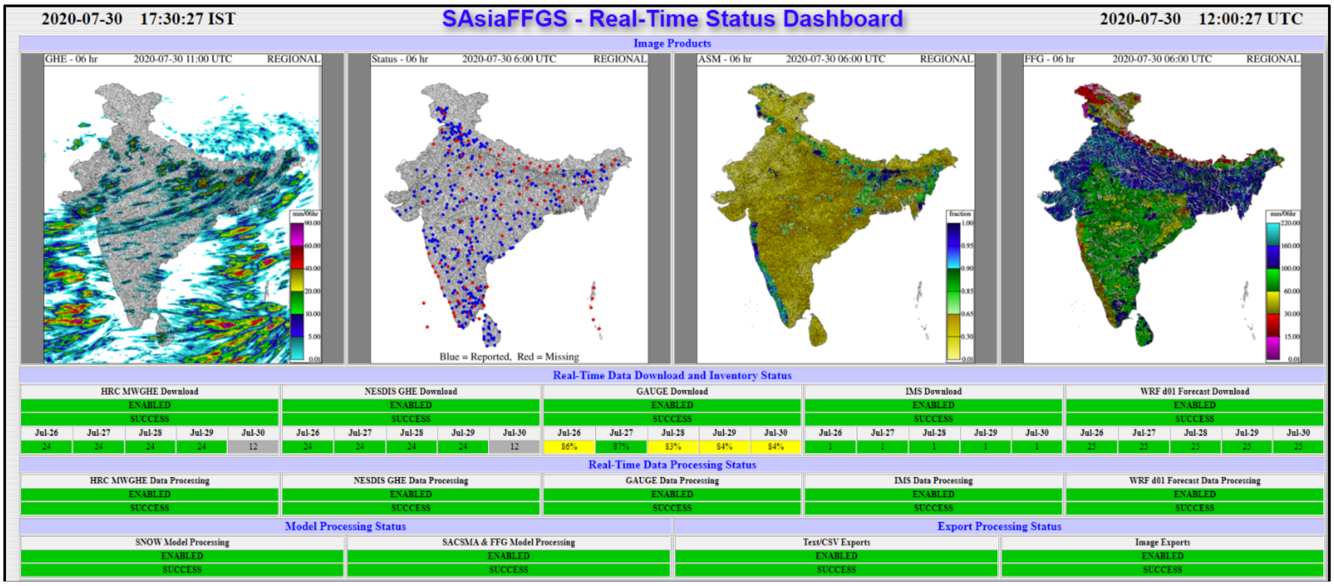


Fig 25: SAsiaFFGS Dashboard Page

18.4.7 SOP for Flash Floods occurrence associated with Heavy or Excessive Rainfall

18.4.7.1 Synoptic conditions:

- Low pressure systems like lows, depressions and troughs etc.
- Confluence of winds
- Wind discontinuity
- Interaction of dry and moist winds over particular region
- Upper air Jet stream etc.

18.4.7.2Dynamic conditions

- Barotropic Atmosphere
- High wind shear
- High lower level convergence
- High upper level divergence
- High vorticity etc.

18.4.7.3Thermo-dynamical indices

- Inversion in mid-upper level
- Convective Available Potential Energy
- Convective Inhibition Energy
- Total totals index
- K Index
- Showalter index
- Cloud condensation level
- Freezing temperature
- Lifting condensation level
- High lapse rate
- 0° C isotherm level etc.

18.4.7.4 Hydrological Condition:

- Topography
- Type of Soil
- Soil Saturation Conditions
- Steep Slopes or Prone of land erosion

18.4.8 SOP of SAsiaFFGS Operations and Products:

18.4.8.1 SAsiaFFGS Operations:

The main component of FFGS System includes Global Hydroestimator, Microwave global Hydroestimator, observed gauge data, radar data and WRF model output with hydrological land surface model i.e. Sacramento Soil Moisture Accounting as base running model. The SAsiaFFGS system comprises of two types of servers i.e. Computational and dissemination servers that are accessed by authorized users. Flowchart for the same is given **Fig. 26**.

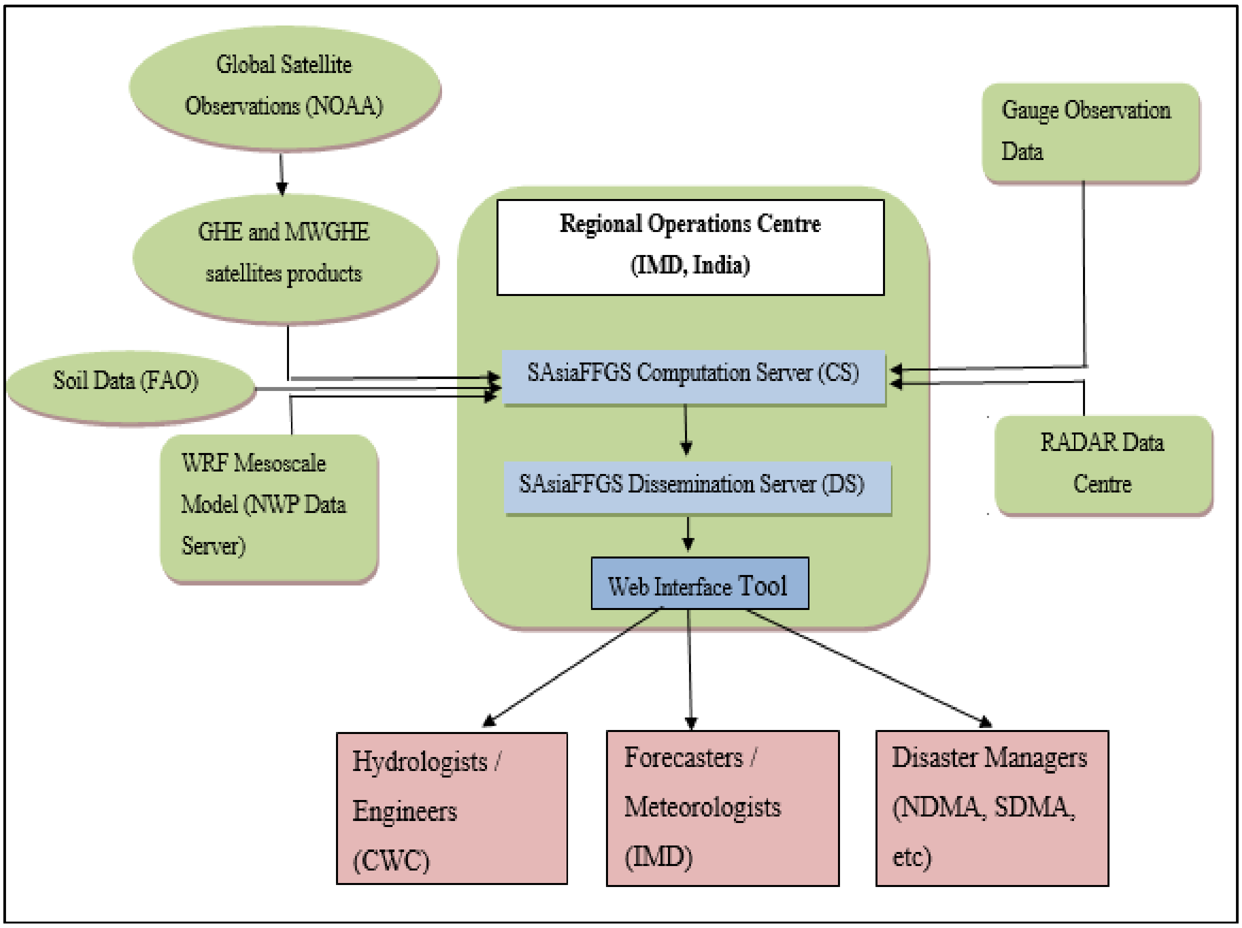


Fig 26: Schematic Diagram for Data Operational Mechanism

18.4.8.2 SAsiaFFGS Products:

SAsiaFFG system comprises of 12 dynamic observation, land surface and forecasting products. Names are as follows:

1) Microwave-adjusted Global Hydro Estimator (MWGHE).
2) Global Hydro Estimator (GHE).
3) Gauge Mean Areal Precipitation (GMAP).
4) Merged Mean Areal Precipitation (MAP).
5) Average Soil Moisture product (ASM).
6) Flash Flood Guidance value (FFG).
7) WRF Forecast Precipitation (FCST).
8) Forecast Mean Areal Precipitation (FMAP).
9) Imminent Flash Flood Threat (IFFT).
10) Persistence Flash Flood Threat (PFFT).
11) Forecast Flash Flood Threat (FFFT).
12) Flash Flood Risk (FFR)

The detailed list of all products and its descriptions are enclosed at Annexure-XVII**.**

18.4.8.3 Monitoring and issuance of Flash Flood guidance:

18.4.8.3.1 Monitoring of rainfall

Amount of rainfall is monitored through observations products like MWGHE, GHE, GMAP and MAP**.** The text and images provide gridded 1-hour, 3-hour, 6-hour and 24-hour accumulations of satellite-based rainfall estimates (mm) ending on the current hour.

18.4.8.3.2 Monitoring of soil moisture

Average soil moisture updated in every 6 hours is an important product in flash flood monitoring. The soil moisture saturation level gives a fair idea of water runoff and occurrence of potential flash flood events.

18.4.8.3.3 Monitoring of land surface products

The most important product in flash flood monitoring is the Flash flood Guidance value. Consequently, rainfall volumes of the same duration that are greater than the FFG value indicate a likelihood of overbank flows at the draining stream outlet. Each of the FFG products is updated every hour.

Issuance of Flash flood guidance: The flash flood guidance is issued in terms of Flash flood threat and potential risk. The three products i.e. IFFT, PFFT and FFFT gives Imminent, Persistence and Forecast threat respectively for 1hr, 3hr and 6 hr. The potential risk is given by FFR based on WRF rainfall for 12hr, 24hr and 36 hr.

The essence of flash flood guidance is timely and correct analysis of all the inputs in real time because of short lifespan of such weather events. The primary responsibility of detecting and monitoring lies with the forecaster. However, last minute inputs from Observatories, radar offices, FMOs, AWS/ARG, etc. can prove to be very useful in issuing flash flood guidance bulletin.

18.4.8.4 Analysis and Forecasting

Duty Forecaster will analyze all the received data on the workstation available to him continuously. For fulfilling it, a digital signature to record the proof of his time of analysis should be provided at his work station. **Fig 27** show the schematic diagram for decision making process in terms of issuing flash flood guidance bulletin.

18.4.8.5Issuance of operational flash flood guidance bulletin:

18.4.8.5.1 Time, Frequency and Validity of products.

Issue of Flash Flood Warning involves mostly meso-scale weather events with short spatial and temporal scale. Thus, lead time and frequency of issuing the Flash Flood Guidance will play a vital role in its successful implementation. Various stages of meso-scale processes, i.e. monitoring, analysis, detection, decision making process of warnings will have to be synchronized, so that the objective of Flash Flood Warning is achieved efficiently.

All forecast/warnings will be issued at the time scale of 00, 06, 12, 18 UTC with validity of 6 hours and spatial scale of watersheds in districts.

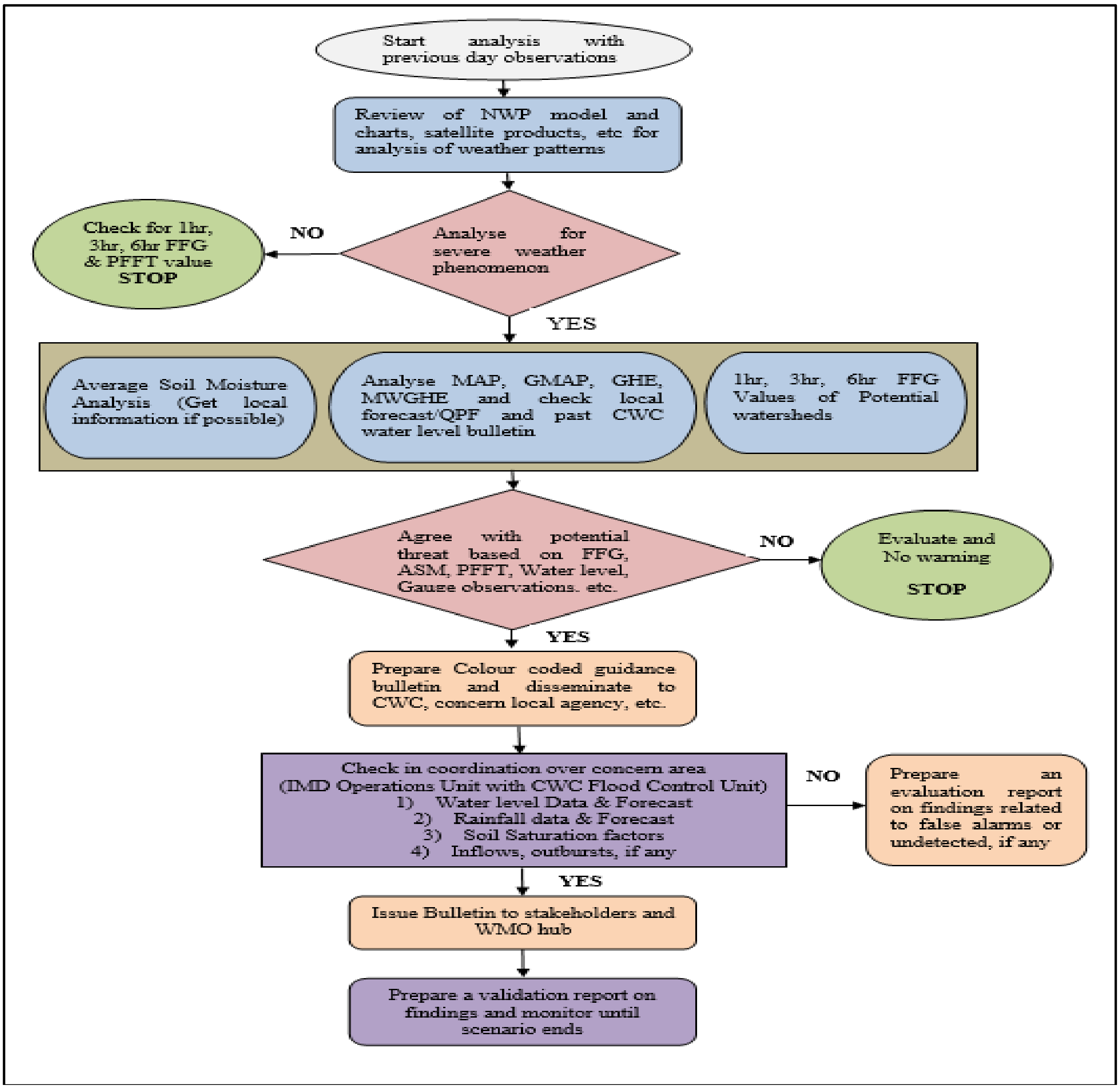


Fig 27: Schematic Diagram for Decision Making Process

18.4.8.5.2 Criteria for Flash Flood Guidance Bulletin:

18.4.8.5.2.1 Flash Flood and its Likelihood Alerts

(a) No Flash Flood
(b) Less Likely Flash Flood
(c) Likely Flash Flood
(d) Most Likely Flash Flood

18.4.8.5.2.2 Guidance warnings of Flash Floods:

Low Risk Probability	<30% probability of Flash Flood occurrence	
Moderate Risk Probability	30 - 60% probability of Flash Flood occurrence	
High Risk Probability	> 60% probability of Flash Flood occurrence	

18.4.8.6 Flash Flood Guidance/ warning services

18.4.8.6.1 Guidance warning products

The Flash Flood Guidance warning consists of the following formats:

18.4.8.6.1.1 Text product

All forecast/warnings will be issued at the time scale of 06 hours and spatial scale of small watersheds in the districts. National level guidance will be issued by Regional Centre at time scale of 00, 06, 12, 18 hours with 4 times daily updating depending on the severity of the short-term event. Bulletin formats are attached in **Annexure XVIII** for National correspondence and **Annexure XIX** for International Correspondence.

18.4.8.6.1.2 Visual Products

Occurrence of impending weather event associated with flash flood occurrence will be depicted in the district level map of FFGS with color coded legends.

18.4.8.6.1.3 Checklist

Preparation of Check list as per **Table 13** related to Flash Flood Guidance parameters to be filled by the forecaster before issuing the Flash Flood warning.

18.4.9 Guidance /Warning Dissemination

The forecast will follow the standard dissemination procedure as per **Table 14.** The forecaster will provide appropriate oral briefing to user as and when required. The briefing should be timely, concise, relevant and consistent with the forecast; the feedback from the user should be solicited.

Who is responsible for this report? Mr/Ms. XXXX
What region are you focusing on? India
Date and Time: 08th June, 2020 & 00 UTC

S.No	Evaluation Checklist	Yes/No	Remarks
1	**A) SYNOTPTIC CONDITION:**		
	i. Has there been any rainfall in the last 24 hours?		
	ii. Inference on Surface Charts (850 hpa)		
	iii. Inference on Upper Air Analysis (500 hpa)		
	iv. Inference on Monsoon Charts		
	B) Near Real-time Satellite Rainfall (INSAT)		
	i. QPE (mm/hr)		
	ii. HEM (mm/hr)		
	iii. ISMR (mm/hr)		
	C) Is any DWR data currently available?		
	i. Reflectivity (dBz)		
	ii. SRI (mm/hr)		
	D) Meteorological Warnings		
	i. Is there any Rainfall Warnings (Day 1)		
	ii. Is there any NOWCAST Warnings (Next 6 hours)		
	iii. Is any imminent ARG/AWS hourly data available?		
2	**NWP PROGNOSTIC PARAMETER:**		
	A) Is additional rainfall expected in next 6 hours?		
	i. WRF FCST 06h		
	ii. NCUM FCST 06h		
	iii. GFS FCST		
	B) Is there any persistent synoptic situation		
	i. Divergence		
	ii. Convergence		
	iii. Wind Shear		
	iv. Vorticity		
3	**FFGS DIAGNOSTIC PARAMETER:**		
	(A) Near Real-time Guidance Products		
	i. MWGHE Satellite Estimate (mm/hr)		
	ii. GHE Satellite Estimate (mm/hr)		
	iii. Merged Areal Precipitation (mm/hr)		
	iv. Average Soil Moisture (%)		
3	**PROGNASTIC PARAMETER:**		
	i. Forecast Mean Areal Precipitation (mm/hr)		
	ii. Forecast Flash Flood Threat (Next 6 hours)		
	iii. Forecast Flash Flood Risk (Next 12 Hours)		
	iv. Forecast Flash Flood Risk (Next 24 Hours)		
4	**HYDROLOGICAL PARAMETER:**		
	i. Is the top soil moisture saturation above 70%?		
	ii. Are the Flash Flood Guidance Model (FFG in mm/hr) values fairly low?		
	iii. Are there areas where you would be concerned for flash flooding or has occurred during past 24 hours?		
	iv. Are there any Water Level alerts/Wx issued by CWC nearer to potential areas?		
5	**FFG THREAT PARAMETER**		
	i. Imminent Flash Flood Threat		
	ii. Persistent Flash Flood Threat 06 hr		
	Specify location of concern (Area of Interest)	**If Yes, please mention…………………….**	

Table 13: *Forecaster's Checklist for Flash Flood Guidance Bulletin*

Bulletin issuing authority	**End user**	**Mode of dissemination**	**Time of receipt by end user**
Regional Centre (HS)	Respective NMHS for member countries, Respective RMC's, MC's, FMO's within the country, Disaster Authority.	Email, Website	Communication Time only
NWFC	All met offices like RWFCs/ SWFCs/ FMOs and Disaster managers, National Media, other govt. departments.	Email, Website, Social Media TV/ Print Media	Communication Time only
RWFCs	Flood Directorates, Transport Dept. Irrigation Dept. Revenue Dept. Health Dept. DMs, SDMA & DDMA and other local Govt. agencies like Municipal Corporation etc.	Email, Website, Social Media TV/ Print Media	Communication Time only
MC's	Local Flood Directorates & administration	Email, Social Media & SMS direct to the concerned users Personal Briefing to authorities.	Communication Time only
FMOs	Local Flood Directorates & administration	Email, Social Media & SMS direct to the concerned users. Personal Briefing to authorities.	Communication Time only

Table 14: *Checklist for dissemination of Flash Flood Guidance bulletin*

18.4.10 Post Event Review, feedback and documentation

Depending on the severity of the Flash Flood Event, the Regional Centre (SAsiaFFGS) may decide on conducting a post event analysis. Feedback will be taken from CWC, Member countries, FMOs, MC, RMC, disaster authorities, local Govt. bodies, media, etc. Annual review meeting, workshop, seminars with all the stakeholders will be organized for continuous learning and upgrading forecasting system of flash flood guidance from time to time.

Annexures:

Annexure –I

STATEWISE DISTRIBUTION OF NO. OF DISTRICTS , AWS, ARG AND ORG STATIONS

S. NO.	STATES	NO. OF DISTT.	NO. OF AWS STN.	NO. OF ARG STN.	NO. OF (AWS+ARG) STN.	NO. OF ORG STN.	TOTAL NO. OF STN.
1	A & N ISLAND (UT)	3	1	0	1	7	8
2.	ARUNACHAL PRADESH	16	16	0	16	31	47
3.	ASSAM	27	27	0	27	78	105
4.	MEGHALAYA	7	6	0	6	15	21
5.	NAGALAND	11	27	1	28	12	40
6.	MANIPUR	9	7	2	9	12	21
7.	MIZORAM	8	8	0	8	16	24
8.	TRIPURA	4	4	0	4	15	19
9.	SIKKIM	4	4	3	7	20	27
10.	WEST BENGAL	19	26	26	52	161	213
11.	ODISHA	30	13	79	92	166	258
12.	JHARKHAND	24	0	0	0	80	80
13.	BIHAR	38	0	0	0	139	139
14.	UTTAR PRADESH	75	0	0	0	272	272
15.	UTTARAKHAND	13	0	0	0	71	71
16.	HARYANA	21	24	27	51	106	157
17.	CHANDIGARH (UT)	1	2	0	2	2	4
18.	DELHI	9	10	0	10	10	20
19.	PUNJAB	20	26	28	54	64	118
20.	HIMACHAL PRADESH	12	15	0	15	93	108
21.	JAMMU & KASHMIR	22	21	10	31	28	59
22.	RAJASTHAN	33	35	0	35	336	371
23.	MADHYA PRADESH	51	46	6	52	212	264
24.	GUJARAT	33	26	61	87	261	348
25.	DADRA & NAGAR HAVELI (UT)	1	0	0	0	3	3
26.	DAMAN & DIU (UT)	2	1	1	2	3	5
27.	GOA	2	0	0	0	11	11
28.	MAHARASHTRA	36	14	17	31	383	414
29.	CHHATISGARH	27	0	0	0	154	154
30.	ANDHRA PRADESH	13	0	25	25	242	267
31.	TELANGANA	33	0	52	52	274	326
32.	TAMILNADU	32	15	19	34	281	315
33.	PUDUCHERRY (UT)	4	0	0	0	4	4
34.	KARNATAKA	30	11	41	52	351	403
35.	KERALA	14	0	0	0	83	83
36.	LAKSHADWEEP (UT)	1	0	0	0	4	4
	TOTAL	685	385	398	783	4000	4783

Table11 : DRMS network as on date

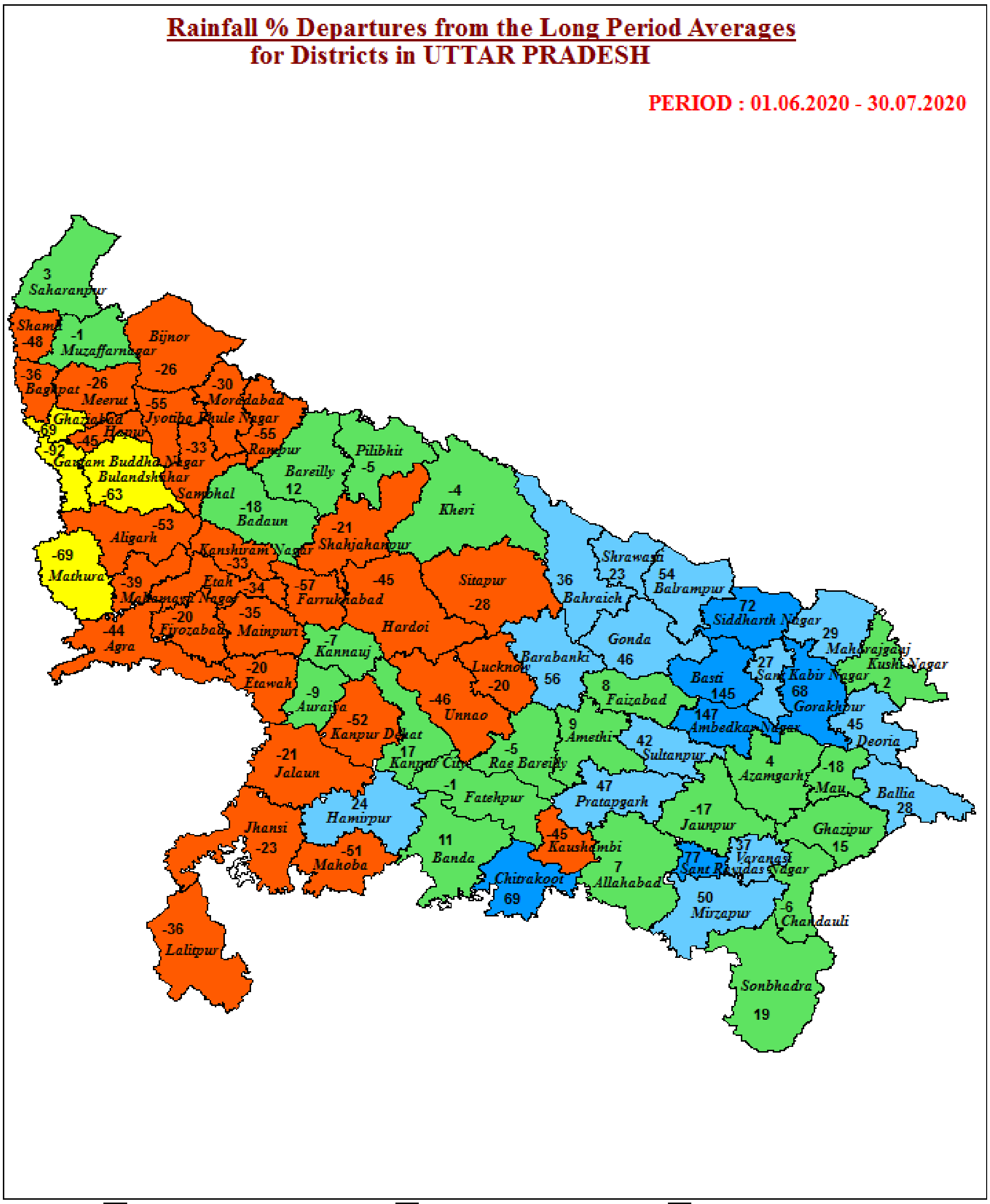
Annexure II

SUBDIVISION-WISE RAINFALL (MM) DISTRIBUTION									
S. NO.	METEOROLOGICAL SUBDIVISIONS	WEEK : 28.05.2020 ACTUAL	NORMAL	TO % DEP.	03.06.2020 CAT.	PERIOD: 01.03.2020 ACTUAL	NORMAL	TO % DEP.	31.05.2020 CAT.
EAST & NORTH EAST INDIA		58.5	53.9	9%		401.2	376.8	6%	
1	ARUNACHAL PRADESH	70.3	90.9	-23%	D	599.0	772.9	-22%	D
2	ASSAM & MEGHALAYA	86.5	90.8	-5%	N	663.5	587.8	13%	N
3	N M M T	65.4	70.3	-7%	N	286.7	483.0	-41%	D
4	SHWB & SIKKIM	58.5	83.0	-29%	D	506.0	442.9	14%	N
5	GANGETIC WEST BENGAL	81.2	25.9	213%	LE	358.0	185.8	93%	LE
6	JHARKHAND	32.6	13.1	149%	LE	218.6	83.3	162%	LE
7	BIHAR	19.0	14.5	31%	E	182.5	81.7	123%	LE
NORTH WEST INDIA		19.6	7.6	158%		149.4	114.4	31%	
1	EAST U.P.	12.6	5.6	126%	LE	97.6	32.4	201%	LE
2	WEST U.P.	17.1	4.8	255%	LE	88.5	29.9	196%	LE
3	UTTARAKHAND	34.8	15.9	119%	LE	238.4	155.3	54%	E
4	HAR. CHD & DELHI	36.3	5.1	612%	LE	118.3	39.3	201%	LE
5	PUNJAB	17.8	3.0	492%	LE	131.6	55.1	139%	LE
6	HIMACHAL PRADESH	34.5	10.2	238%	LE	271.1	243.4	11%	N
7	JAMMU & KASHMIR	19.5	13.6	43%	E	330.5	336.1	-2%	N
8	WEST RAJASTHAN	18.9	4.6	310%	LE	44.7	22.5	99%	LE
9	EAST RAJASTHAN	13.9	5.1	173%	LE	45.2	19.0	138%	LE
CENTRAL INDIA		18.8	8.5	121%		76.5	37.5	104%	
1	ODISHA	36.6	16.6	120%	LE	265.4	128.4	107%	LE
2	WEST MADHYA PRADESH	7.4	4.1	80%	LE	27.4	12.9	113%	LE
3	EAST MADHYA PRADESH	12.5	3.9	221%	LE	82.7	23.6	250%	LE
4	GUJARAT REGION	1.4	5.6	-74%	LD	4.3	6.3	-31%	D
5	SAURASHTRA & KUTCH	1.7	3.3	-50%	D	1.1	4.0	-73%	LD
6	KONKAN & GOA	50.4	36.2	39%	E	12.2	36.0	-66%	LD
7	MADHYA MAHARASHTRA	34.6	12.8	170%	LE	32.6	32.5	0%	N
8	MARATHWADA	33.5	9.9	238%	LE	32.7	27.4	19%	N
9	VIDARBHA	10.2	5.2	96%	LE	41.8	27.4	53%	E
10	CHHATTISGARH	21.5	5.9	265%	LE	119.5	41.0	192%	LE
SOUTH PENINSULA		37.5	21.6	74%		116.6	121.3	-4%	
1	A & N ISLAND	83.5	104.4	-20%	D	266.1	466.8	-43%	D
2	COASTAL A. P.& YANAM	14.3	11.9	20%	E	82.3	98.7	-17%	N
3	TELANGANA	39.9	9.2	334%	LE	62.2	58.9	6%	N
4	RAYALASEEMA	29.5	13.8	114%	LE	65.3	82.1	-20%	D
5	TAMIL., PUDU. & KARAIKAL	19.5	13.5	44%	E	77.5	126.4	-39%	D
6	COASTAL KARNATAKA	90.5	68.5	32%	E	171.9	155.7	10%	N
7	N. I. KARNATAKA	34.5	17.4	98%	LE	111.8	80.0	40%	E
8	S. I. KARNATAKA	42.0	25.5	65%	LE	177.5	140.4	26%	E
9	KERALA & MAHE	120.8	82.1	47%	E	386.5	361.5	7%	N
10	LAKSHADWEEP	145.6	77.8	87%	LE	237.3	203.3	17%	N
COUNTRY AS A WHOLE		29.1	18.1	61%		158.5	131.7	20%	

Table12 : Sub division wise Rainfall Statistics

INDIA METEOROLOGICAL DEPARTMENT

MC LUCKNOW



LEGEND: L. EXCESS (+60% OR MORE) EXCESS (+20% TO +59%) NORMAL (+19% TO -19%) DEFICIENT (-20% TO -59%) L. DEFICIENT (-60% TO -99%) NO RAIN (-100%) NO DATA

Fig -28: District wise rainfall map generated by CRIS

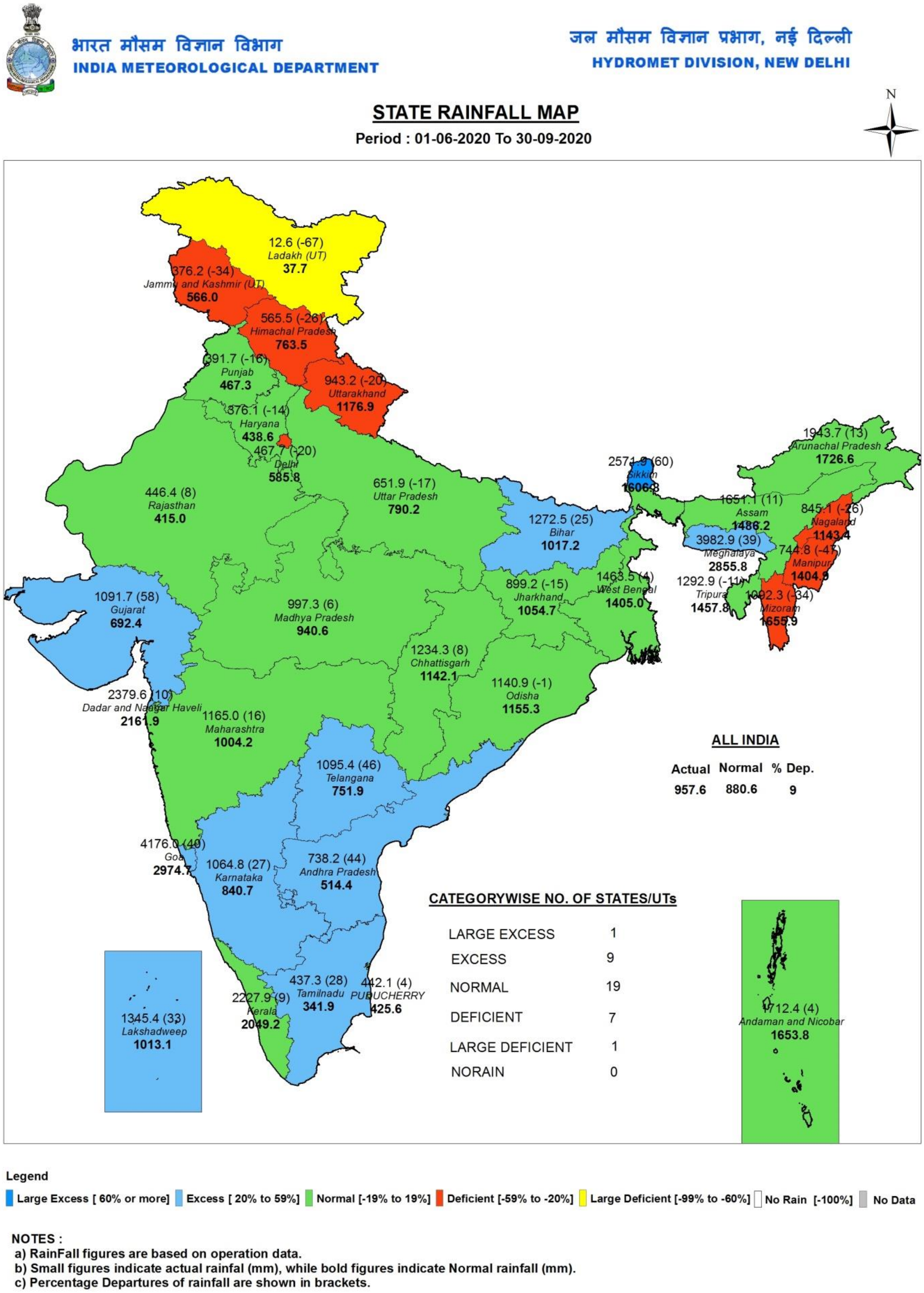


Fig -29: State wise rainfall map generated by MKRAIN

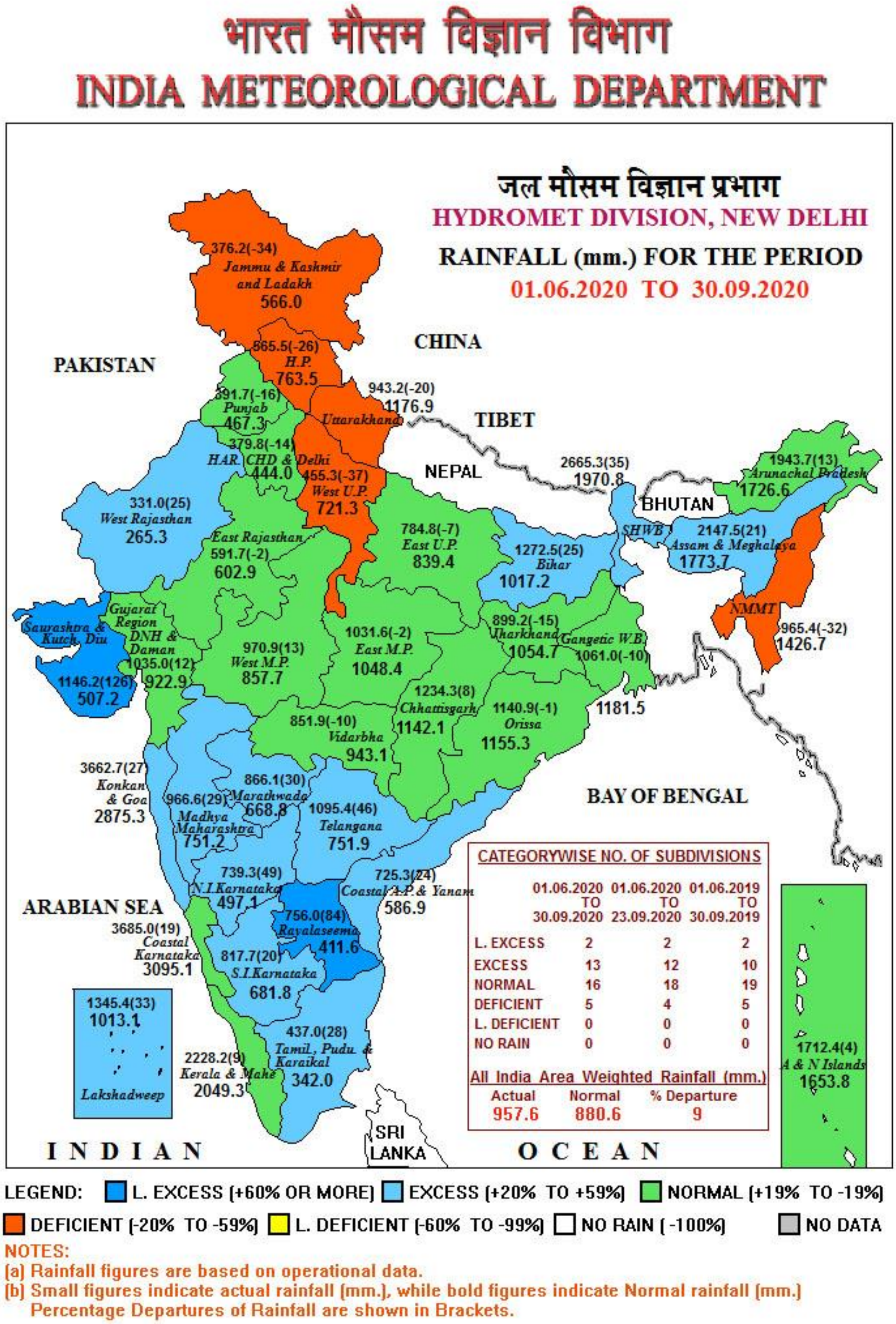


Fig -30: Met sub division wise rainfall map generated by CRIS

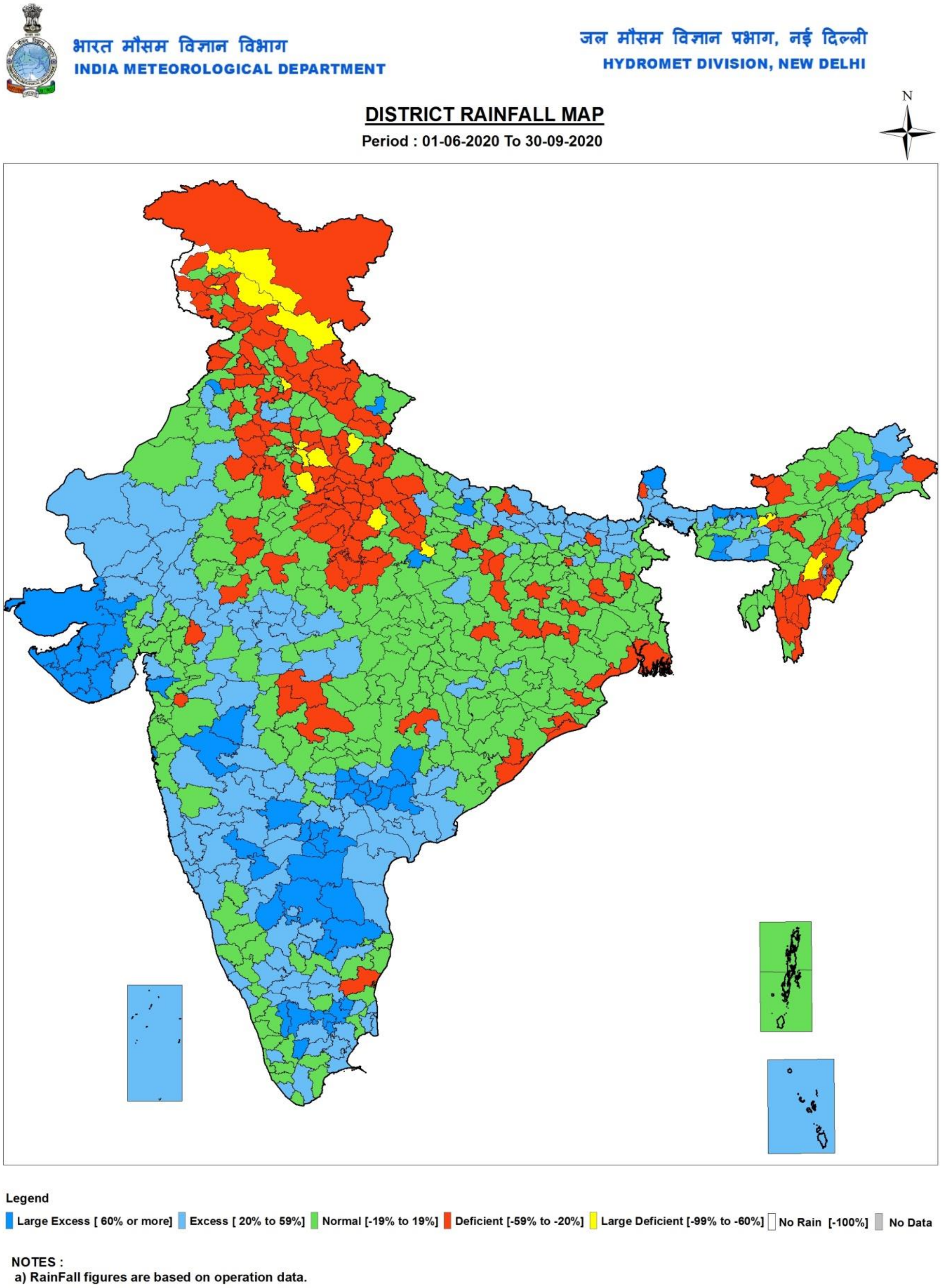


Fig -31: District wise rainfall map of the country generated by CRIS

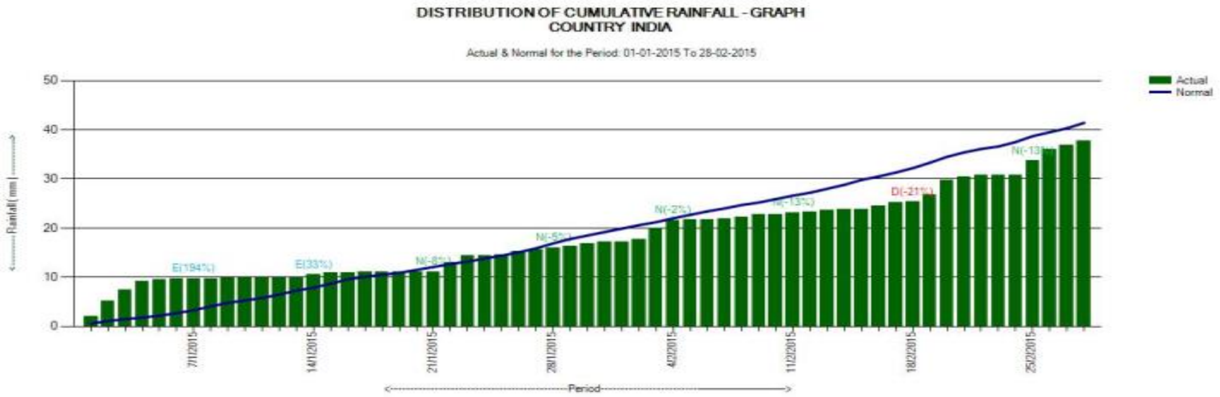


Fig- 32 : Distribution of Cumulative Rainfall Graph generated by CRIS

Annexure-III

Generation of Intensity Duration Frequency curve by ORG data

Station: Supaol (Bihar)
Rainfall data used : 101 years
Estimated rainfall for 2-year RPV : 131.1 mm

Conversion Ratio Table for converting 24 hour estimated rainfall into specific hour rainfall (In this case, the table is taken from Flood Estimation Report for Subzone-1(f)

Duration in Hour	Conversion Ratio
1	0.31
3	0.50
6	0.65
9	0.75
12	0.82
15	0.89
18	0.94
24	1

Table-13: Conversion ratio

A computation table for rainfall intensity has to be prepared by using above **Conversion Ratios (**Estimated 24 hour rainfall: 131.1 mm x corresponding **Conversion Ratios).**

Duration (hr)	1	3	6	9	12	15	18	24
Estimated Rainfall (mm)	40.6	65.6	85.2	98.3	107.5	116.7	123.2	131.1
Rainfall Intensity (mm/hr)	40.6	21.9	14.2	10.9	8.9	7.8	6.8	5.5

Table-14: Rainfall Intensity Table

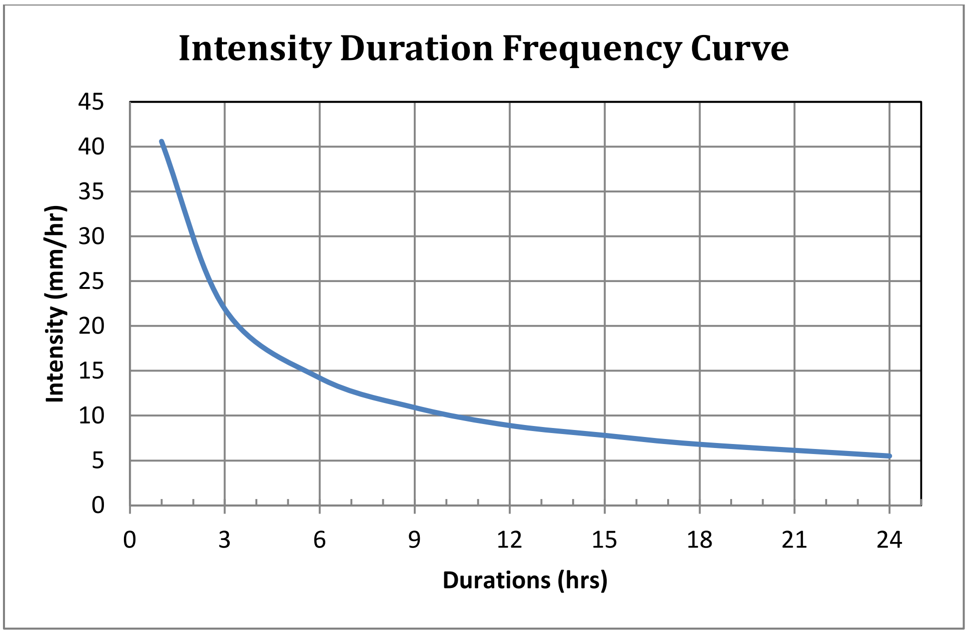


Fig-33: IDF Curve

Annexure-IV

Generation of Intensity Duration Frequency curve by SRRG data (One Day rainfall recorded at 0830 Hrs. IST)

As in case of ORG data explained above, the process is same for the SRRG stations. But before that the raw data received from CSR, Pune has to be run through a software (RFSTT) to get the annual extreme of 1 hr, 3 hr, 6 hr...24hr. then this series has to be run in Gumble software for getting Return Period Estimates. In SRRG data eight (8) number of series are prepared. Rest is same as in case of ORG Data. Return period values are calculated for 2, 5, 10, 25, 50, 100, 150, 200, 500, 1000, 5000 and 10000 years for the selected station.

Illustration:
Station: Aurangabad
Rainfall data used : 36 years

Duration (hours)	25 years		100 years	
	Estimated Rainfall (mm)	Intensity (mm/hr)	Estimated Rainfall (mm)	Intensity (mm/hr)
1	72.5	72.5	92.0	92.0
3	114.3	38.1	141.0	47.0
6	142.7	23.8	176.3	29.4
9	154.0	17.1	190.2	21.1
12	161.6	13.5	199.9	16.7
15	174.9	11.7	217.5	14.5
18	187.2	10.4	234.0	13.0
24	206.2	8.6	259.7	10.8

Table-15: Rainfall Intensity Table

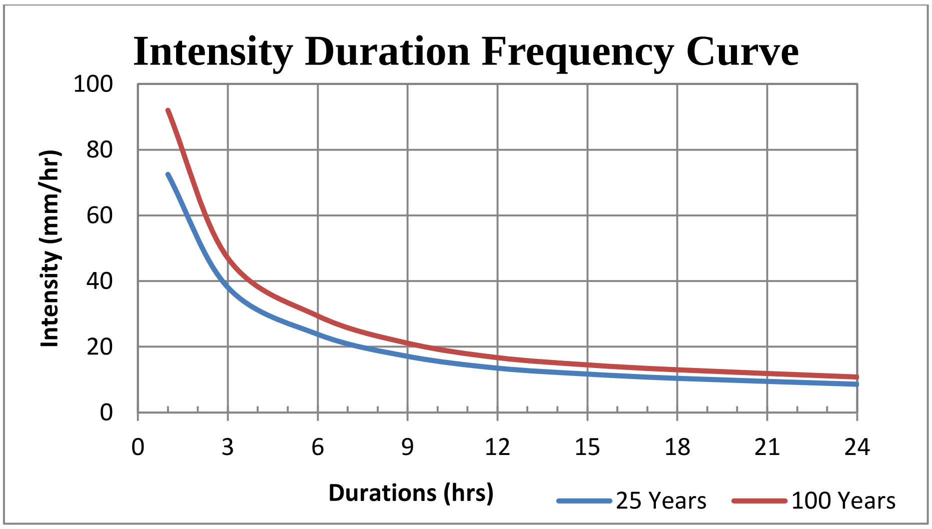


Fig-34: Rainfall IDF Curve

Annexure-V

Generation of Intensity Duration Frequency curve by Heavy Rainfall (15 min interval) Data

Formation of extreme series

a. To prepare the annual extreme series for 15 min, 30 min, 45 min and 60 min time intervals for each station from the received 15 min interval rainfall data

b. The rainfall data provided will be in terms of spells for say ‘M’ no. of years. For any particular year, the **highest** 15 min rainfall amount is picked up **(manually)**from each of the spell and the highest of these will be the extreme 15 min. rainfall for that year. So, a series of maximum ‘M’ extreme observations of 15 min rainfall will be formed. Such a series should also contain the date and time interval for selected extreme value of extreme 15 min. rainfall.

c. Similar procedure shall be applied for 30 min, 45 min and 60 min duration rainfall. While preparing the 30-min series, rainfall of 2 consecutive 15 min. time intervals of the same spell will be added up. Similarly for 45 min. duration, rainfall of 3 consecutive 15 min. time intervals and for 60 min. duration, 4 consecutive 15 min. time intervals will be added up.

Illustration:
Station: **Aurangabad**
Rainfall data used : 7 years

Duration (minutes)	5-years		25-years	
	Estimated Rainfall (mm)	Intensity (mm/hr)	Estimated Rainfall (mm)	Intensity (mm/hr)
15	22.6	90.4	27.8	111.2
30	37.5	75.0	47.3	94.6
45	48.0	64.0	61.5	82.0
60	57.0	57.0	72.5	72.5

Table 16: Rainfall Intensity Table

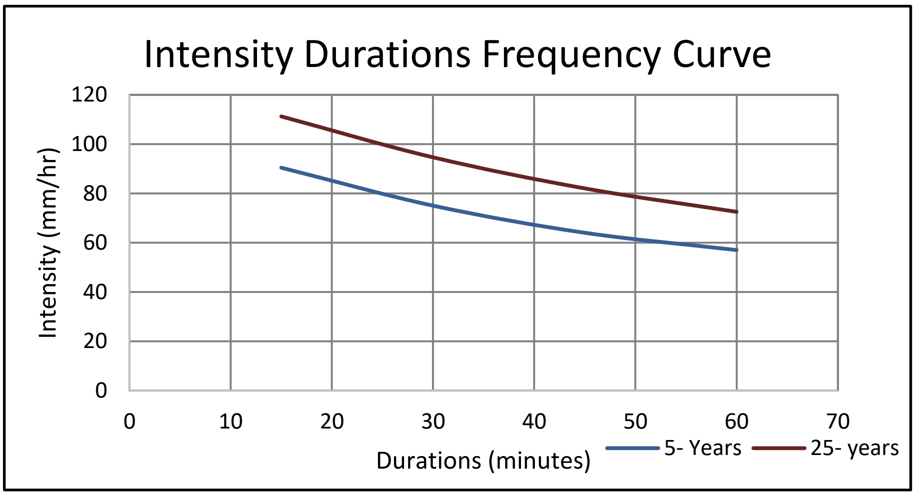


Fig-35: Rainfall IDF Curve

Annexure-'VI'

Calculation Standard Project Storm

Project Name: Sonna Barragein Karnataka

Project Area: 53328 sq km

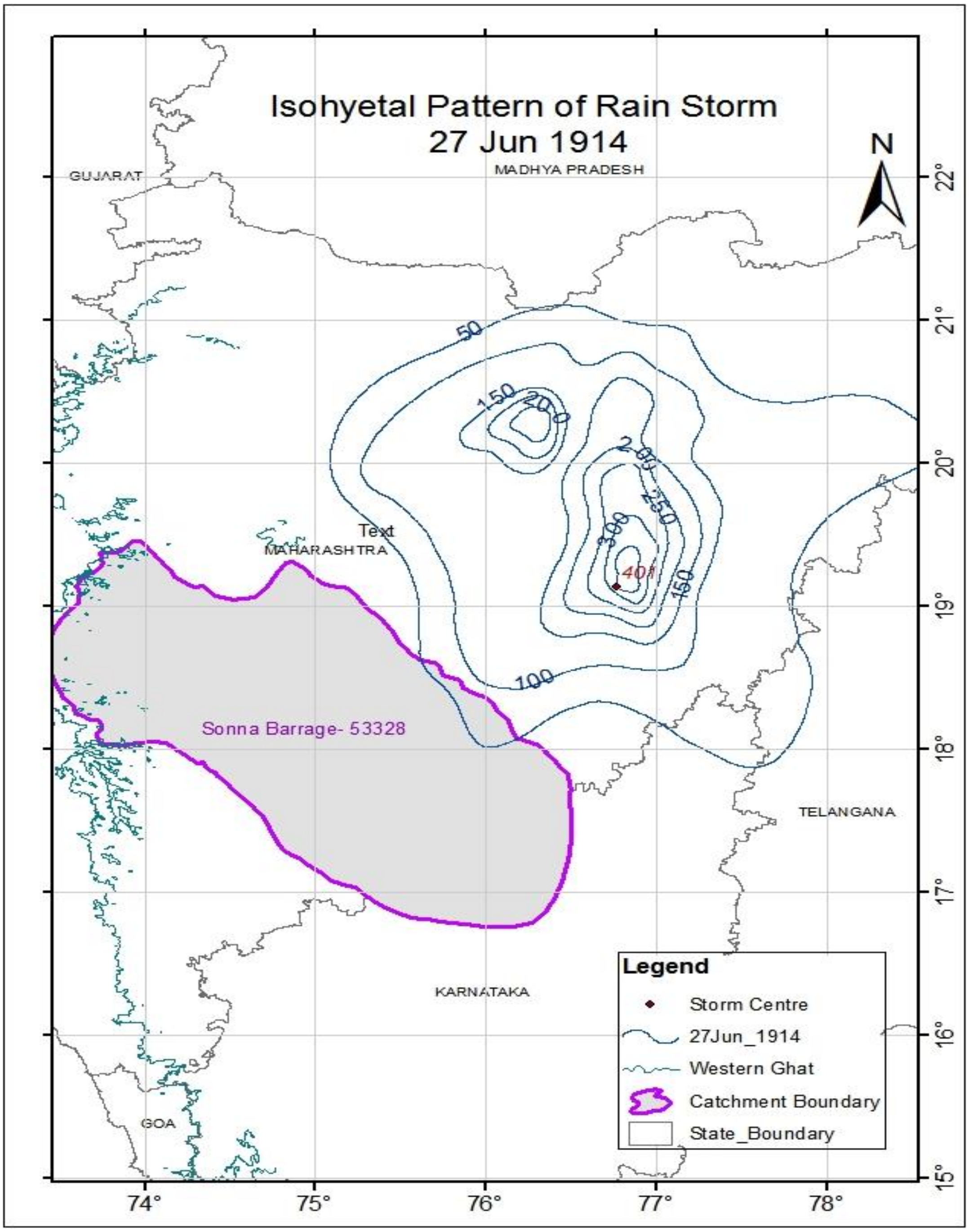


Fig-36: Isohyet Pattern before transposed

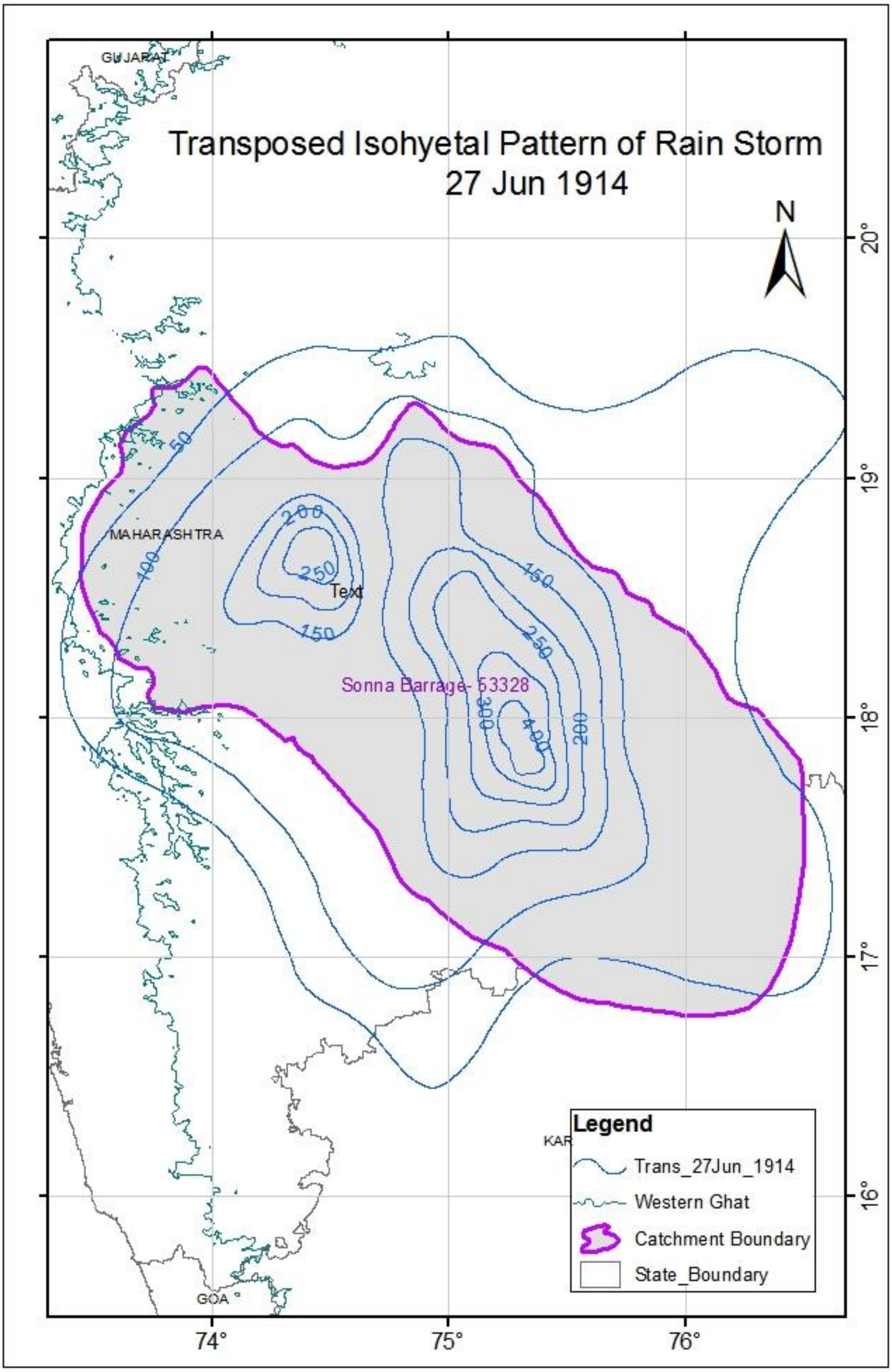


Fig-37: Isohyet Pattern after transposed

Computation Sheet for the rainstorm of 27 Jun 1914

S.No.	Isohyetal Range mm From	Isohyetal Range mm To	Mean	Area (SqKm.)	Cumulative Area	Volume (cubic Km)	Cumulative Volume	Average Depth of Rainfall(mm.)
1	401	400	400.5	444.8	444.8	178125.1	178125.1	400.5
2	400	300	350	1119.3	1564.0	391739.8	569864.9	364.4
3	300	250	275	2365.0	3929.0	650369.1	1220234.0	310.6
4	250	250	250	472.8	4401.8	118196.9	1338430.8	304.1
5	250	200	225	3079.3	7481.1	692840.9	2031271.8	271.5
6	250	200	225	939.8	8420.9	211459.5	2242731.2	266.3
7	200	150	175	1541.4	9962.3	269752.2	2512483.4	252.2
8	200	150	175	6078.1	16040.5	1063671.4	3576154.8	222.9
9	150	100	125	18843.9	34884.3	2355485.0	5931639.8	170.0
10	100	50	75	14677.5	49561.8	1100810.0	7032449.8	141.9
11	50	20	35	3766.2	53328.0	131816.9	7164266.7	**134.3**

Table-17: Computation of SPS

1-day SPS value = 13.4 **cm**

Max. Dew Point Temperature: 28.0^{o} C

Persistent Dew Point Temp. during the Storm Period: 25.0^{o} C

Moisture Adjustment Factor (MAF) = W_1/ W_5

Where

W_1 is Precipitable water corresponding to maximum dew point temperature 28.0^{0}C for the same fortnight in which storm occurred at the location of storm.

W_5 is Precipitable water corresponding to persistent dew point temperature 25.0^{0}C during the period of the storm

MAF = W_1/ W_5

= 94.2/72

= **1.31**

1-day PMP Value = MAF × 1-day SPS

= 1.31×13.4

= **17.6cm**

Annexure-VII(a)

भारत सरकार
भारतमौसमविज्ञानविभाग
(पृथ्वी विज्ञान मँत्रालय)
पता :
फोन न.
फैक्स न.

GOVERNMENT OF INDIA
INDIA METEOROLOGICAL DEPARTMENT*(Ministry of Earth Sciences)*
Flood Meteorological Office,
(Address)
Phone and Fax:

Ref No:FM/QPF Bulletin/

Dated: DD/MM/YYYY
Time of Issue: …..hrs IST

QPF Bulletin

S. No.	BASIN NAME	SUBBASIN CODE/NAME	QPF (mm)		
			Day-1	**Day-2**	**Day-3**
1	B	B1	**0**	**0.1-10**	**11-25**
		B2	**26-50**	**51-100**	**>100**
		B3			
2	G	G1			
		G2			
		G3			
		G4			

(Name)
Designation of in-Charge
FLOOD MET.OFFICE

QPF in Ranges (mm)	**0**	**0.1-10**	**11-25**	**26-50**	**51-100**	**>100**

Forecast and Warning for any day is valid from 0830 hours IST of day till 0830 hours IST of next day

Annexure-VII(b)

भारत सरकार
भारतमौसमविज्ञानविभाग
(पृथ्वी विज्ञान मँत्रालय)
पता :
फोन न.
फैक्स न.

GOVERNMENT OF INDIA
INDIA METEOROLOGICAL DEPARTMENT*(Ministry of Earth Sciences)*
Flood Meteorological Office,
(Address)
Phone and Fax:

Ref No:FM/QPF Bulletin/

Dated: DD/MM/YYYY
Time of Issue: …..hrs IST

QPF Bulletin

S. No.	BASIN NAME	SUBBASIN CODE/NAME	QPF (mm)		
			Day-1	**Day-2**	**Day-3**
1	B	B1			
		B2			
		B3			
2	G	G1			
		G2			
		G3			
		G4			

(Name)
Designation of in-Charge
FLOOD MET.OFFICE

QPF in Ranges (mm)	0	0.1-10	11-25	26-37	38-50	51-75	76-100	>100

Forecast and Warning for any day is valid from 0830 hours IST of day till 0830 hours IST of next day

Annexure-VIII(a)

भारत सरकार
भारतमौसमविज्ञानविभाग
(पृथ्वी विज्ञान मँत्रालय)
पता :
फोन न.
फैक्स न.

GOVERNMENT OF INDIA
INDIA METEOROLOGICAL DEPARTMENT*(Ministry of Earth Sciences)*
Flood Meteorological Office,
(Address)
Phone and Fax:

Ref No:FM/HM Bulletin/

Dated: DD/MM/YYYY
Time of Issue: …..hrs IST

Hydromet Bulletin

I. SYNOPTIC SITUATION:

II(a) DETERMINISTIC FORECAST (QPF)

S. No.	BASIN NAME	SUBBASIN CODE/NAME	QPF (mm)		
			Day-1	**Day-2**	**Day-3**
1	B	B1	**0**	**0.1-10**	**11-25**
		B2	**26-50**	**51-100**	**>100**
		B3			
2	G	G1			
		G2			
		G3			
		G4			

QPF in Ranges (mm)	**0**	**0.1-10**	**11-25**	**26-50**	**51-100**	**>100**

Forecast and Warning for any day is valid from 0830 hours IST of day till 0830 hours IST of next day

II(b) DETERMINISTIC FORECAST(DISTRIBUTION)

S. No.	BASIN NAME	SUBBASIN CODE/NAME	INTENSITY (I) & SPATIAL DISTRIBUTION (D)					
			Day-1		**Day-2**		**Day-3**	
			I	**D**	**I**	**D**	**I**	**D**
1	B	B1						
		B2						
		B3						
2	G	G1						
		G2						
		G3						

III. HEAVY RAINFALL WARNING

NAME OF BASIN/SUB- BASIN	**Day-1**		**Day-2**		**Day-3**	
	I	**D**	**I**	**D**	**I**	**D**

Spatial Distribution of Rainfall		
DRY	Dry	No Station reported rainfall
ISOL	One or two Places	25% or less number of stations recorded rainfall 2.5 mm
SCT	At a few Places	26%-50% number of stations recorded rainfall 2.5 mm
FWS	At many Places	51%-75% number of stations recorded rainfall 2.5 mm
WS	At most places	76%-100% number of stations recorded rainfall 2.5 mm

Intensity of Rainfall					
M.Dry	NIL	0 cm	VL	Very Light Rainfall	Trace
L	Light Rainfall	Upto 1 cm	M	Moderate rainfall	02-06 cm
H	Heavy rainfall	07-11 cm	VH	Very Heavy rainfall	12-20 cm
EH	Extremely Heavy rainfall	21 cm or More			
ExH	Exceptionally Heavy Rainfall	When the amount is a value near about the highest recorded rainfall at or near the station for the month or season. However, this term will be used only when the actual rainfall amount exceeds 12 cm			

Forecast and Warning for any day is valid from 0830 hours IST of day till 0830 hours IST of next day

IV. PROBABILISTIC FORECAST

S. No.	BASIN NAME	SUBBASIN CODE/NAME	**Day-1**						**Day-2**						**Day-3**					
			0 mm	0.1-10 mm	11-25 mm	26-50 mm	51-100 mm	>100 mm	0 mm	0.1-10 mm	11-25 mm	26-50 mm	51-100 mm	>100 mm	0 mm	0.1-10 mm	11-25 mm	26-50 mm	51-100 mm	>100 mm
1	B	B1																		
		B2																		
		B3																		
2	G	B4																		
		G1																		
		G2																		
		G3																		
		G4																		

Probability of occurrence (%)	**0-5**	**5-25**	**25-50**	**50-75**	**75-100**

Forecast and Warning for any day is valid from 0830 hours IST of day till 0830 hours IST of next day

V. OUTLOOK FOR SUBSEQUENT FOUR DAYS

NAME OF BASIN/SUB-BASIN	OUTLOOK			
	Day-4	**Day-5**	**Day-6**	**Day-7**

VI. STATIONS RECORDED SIG. RAINFALL (≥5cm) RECORDED AT 0830 HRS IST OF TODAY:

NAME OF SUB-BASIN	NAME OF STATION (RAINFALL), …
NAME OF SUB-BASIN	NAME OF STATION (RAINFALL), …

VII. REALISED BASIN AVERAGE RAINFALL AT 0830 HRS IST OF TODAY:

S. No.	BASINS NAME	SUB-BASIN CODE/NAME	REALISED AVERAGE RAINFALL (mm)
1	B	B1	
		B2	
		B3	
		B4	
2	G	G1	
		G2	
		G3	
		G4	

(Name)
Designation of in-Charge
FLOOD MET.OFFICE

Annexure-VIII(B)

भारत सरकार
भारतमौसमविज्ञानविभाग
(पृथ्वी विज्ञान मँत्रालय)
पता :
फोन न.
फैक्स न.

GOVERNMENT OF INDIA
INDIA METEOROLOGICAL DEPARTMENT*(Ministry of Earth Sciences)*
Flood Meteorological Office,
(Address)
Phone and Fax:

Ref No:FM/HM Bulletin/

Dated: DD/MM/YYYY
Time of Issue: …..hrs IST

Hydromet Bulletin

II. SYNOPTIC SITUATION:

II(a) DETERMINISTIC FORECAST (QPF)

S. No.	BASIN NAME	SUBBASIN CODE/NAME	QPF (mm)		
			Day-1	**Day-2**	**Day-3**
1	B	B1	**0**	**0.1-10**	**11-25**
		B2	**26-50**	**51-100**	**>100**
		B3			
2	G	G1			
		G2			
		G3			
		G4			

QPF in Ranges (mm)	**0**	**0.1-10**	**11-25**	**26-37**	**38-50**	**51-75**	**76-100**	**>100**

Forecast and Warning for any day is valid from 0830 hours IST of day till 0830 hours IST of next day

II(b) DETERMINISTIC FORECAST(DISTRIBUTION)

S. No.	BASIN NAME	SUBBASIN CODE/NAME	INTENSITY (I) & SPATIAL DISTRIBUTION (D)					
			Day-1		**Day-2**		**Day-3**	
			I	**D**	**I**	**D**	**I**	**D**
1	B	B1						
		B2						
		B3						
2	G	G1						
		G2						
		G3						

III. HEAVY RAINFALL WARNING

NAME OF BASIN/SUB- BASIN	**Day-1**		**Day-2**		**Day-3**	
	I	**D**	**I**	**D**	**I**	**D**

Spatial Distribution of Rainfall		
DRY	Dry	No Station reported rainfall
ISOL	One or two Places	25% or less number of stations recorded rainfall 2.5 mm
SCT	At a few Places	26%-50% number of stations recorded rainfall 2.5 mm
FWS	At many Places	51%-75% number of stations recorded rainfall 2.5 mm
WS	At most places	76%-100% number of stations recorded rainfall 2.5 mm

Intensity of Rainfall					
M.Dry	NIL	0 cm	VL	Very Light Rainfall	Trace
L	Light Rainfall	Upto 1 cm	M	Moderate rainfall	02-06 cm
H	Heavy rainfall	07-11 cm	VH	Very Heavy rainfall	12-20 cm
EH	Extremely Heavy rainfall	21 cm or More			
ExH	Exceptionally Heavy Rainfall	When the amount is a value near about the highest recorded rainfall at or near the station for the month or season. However, this term will be used only when the actual rainfall amount exceeds 12 cm			

Forecast and Warning for any day is valid from 0830 hours IST of day till 0830 hours IST of next day

IV. PROBABILISTIC FORECAST

S. No.	BASIN NAME	SUBBASIN CODE/NAME	Day-1								Day-2								Day-3							
			0 mm	0.1-10 mm	11-25 mm	26-37 mm	38-50 mm	51-75 mm	76-100 mm	>100 mm	0 mm	0.1-10 mm	11-25 mm	26-37 mm	38-50 mm	51-75 mm	76-100 mm	>100 mm	0 mm	0.1-10 mm	11-25 mm	26-37 mm	38-50 mm	51-75 mm	76-100 mm	>100 mm
1	B	B1																								
		B2																								
		B3																								
2	G	B4																								
		G1																								
		G2																								
		G3																								
		G4																								

Probability of occurrence (%)	0-5	5-25	25-50	50-75	75-100

Forecast and Warning for any day is valid from 0830 hours IST of day till 0830 hours IST of next day

V. OUTLOOK FOR SUBSEQUENT FOUR DAYS

NAME OF BASIN/SUB-BASIN	OUTLOOK			
	Day-4	**Day-5**	**Day-6**	**Day-7**

VI. STATIONS RECORDED SIG. RAINFALL (≥5cm) RECORDED AT 0830 HRS IST OF TODAY:

NAME OF SUB-BASIN	NAME OF STATION (RAINFALL), …
NAME OF SUB-BASIN	NAME OF STATION (RAINFALL), …

VII. REALISED BASIN AVERAGE RAINFALL AT 0830 HRS IST OF TODAY:

S. No.	BASINS NAME	SUB-BASIN CODE/NAME	REALISED AVERAGE RAINFALL (mm)
1	B	B1	
		B2	
		B3	
		B4	
2	G	G1	
		G2	
		G3	
		G4	

(Name)
Designation of in-Charge
FLOOD MET.OFFICE

Annexure-IX

DGM (Hydrometeorology), New Delhi / RMC, XXXX

Sub: Flood Situation in XXXXX Basin.

As per 'routine Gauge reading data' and 'Level Forecast' issued by FFD, XXXX and received by FMO XXXXX over mail/fax at hhhh hrs. IST on dd/mm/yyyy, flood situation in XXXXXRiver basin follows:

Name of Station	Sub-basin No./Name	Warning Level (M)	**Danger Level** (M)	Previous Highest Flood Level		Gauge Level at hhhh hours (M)	Trend
				Level(M)	Date		

Level Forecast Issued by CWC on DD/MM/YYYY:

Level Forecast for xxxxxx :

Date	Hour	Gauge Station	Water Level (M)	Trend
DD/MM/YYYY				

QPF issued at xxxx hrs. for xxxxxx Sub-basin(A). xx-xx mm

Significant amount of rainfall in xxxx Sub-basin(A) (cm.):

QPF issued at xxxx hrs. for xxxx Sub-basin(B). xx-xx mm

Significant amount of rainfall in xxxx Sub-basin(B)(cm.) :

The rivers'/tributaries' stage at remaining gauge sites are below Warning/Danger level mark.

In-Charge, FMO XXXXX

FMO xxxxx UOI No. FM-xx / Dated: dd/mm/yyyy

Annexure - X

Sub: Station-wise daily rainfall.

Name of FMO ………………………………..........

Month………………….
Year……………………..

Daily Rainfall(mm)																	
Sl. No.	Name of Catchment	Name of Sub Catchment	S. No. for Stations within Sub catchments	Name of Stations	Lat. (Deg. Dec.)	Long. (Deg. Dec.)	Dates →								
							1	2	3	4	5	6	7	8	….	31

Note: Rainfall data with updated values in the above format on monthly basis may also be supplied.

Annexure -XI

Sub: Daily QPF with realised rainfall in Excel sheet

Name of FMO ………………………………..........

Month………………….
Year……………………..

Date of issue	Name of the Basin	Name of Sub-basin	QPF(mm) issued at 1230hrs IST valid for Day-1	QPF(mm) issued at 1230hrs IST valid for Day-2	QPF(mm) issued at 1230hrs IST valid for Day-3	AAP(mm) (Observed) at 0830 hrs IST

Annexure-XII

FMO ……………………………………..

Report on verification of QPF for the month of _________________________

(1) Period of Flood Alert: (issued by FFD of CWC) …………………………….

(2) Detail of QPF issued:

Daily-wise QPF with realised rainfall (updated) in Excel sheet.

Date of issue	Name of the Basin	Name of Sub-basin	QPF(mm) issued at 1230hrs IST valid for Day-1	QPF(mm) issued at 1230hrs IST valid for Day-2	QPF(mm) issued at 1230hrs IST valid for Day-3	AAP(mm) (Observed) updated

(3) Verification:

Total No. of occasions when QPF are issued during the month for all the catchments: …

No. of occasion when realized rainfall was:

(i) within the forecast range ………………

(ii) out by one range ………………………

(iii) out by two ranges or more ..…………

(4) Brief account of self –appraisal: (Reasons for QPF being out by two ranges or more)

Annexure-XIII

Verification of QPF by categorical method:

The performance of categorical QPF issued for different river catchments is to be verified with contingency table given below:

Observed Rainfall Range (mm)	Rainfall Forecast range (mm)						
	0	0.1-10	11-25	26-50	51-100	>100	Total
0	a	b	c	d	E	F	A
0.1-10	g	h	i	j	K	L	B
11-25	m	n	o	p	Q	R	C
26-50	s	t	u	v	W	X	D
51-100	y	z	aa	ab	ac	Ad	E
>100	ae	af	ag	ah	ai	Aj	F
Total	G	H	I	J	K	L	T

The QPF issued for different river catchments are verified by computing; Percentage Correct Forecast (PC), Heidke Skill Score (HSS) and Critical Success Index (CSI) from Contingency table which are as follows:

$$\text{PC} = \frac{(\boldsymbol{a + h + o + v + ac + aj})}{\boldsymbol{T}} X100$$

$\text{CSI} = \frac{\boldsymbol{a}}{\boldsymbol{A+G-a}}, \ \frac{\boldsymbol{h}}{\boldsymbol{B+H-h}}, \ \frac{\boldsymbol{o}}{\boldsymbol{C+I-o}}, \frac{\boldsymbol{v}}{\boldsymbol{D+J-v}}, \frac{\boldsymbol{ac}}{\boldsymbol{E+K-ac}}, \ \frac{\boldsymbol{aj}}{\boldsymbol{F+L-aj}}$ for all six categories of forecast

$$\text{HSS} = \frac{\{T(a + \text{h} + \text{o} + \text{v} + \text{ac} + \text{aj}) - (\text{AG} + \text{BH} + \text{CI} + \text{DJ} + \text{EK} + \text{FL})\}}{\text{T} * \text{T} - (\text{AG} + \text{BH} + \text{CI} + \text{DJ} + \text{EK} + \text{FL})}$$

The POD, FAR, MR, C-NON, CSI, BIAS, PC, TSS and HSS for each category is to be computed by reducing the above contingency table into 2 × 2 contingency table for occurrence / non-occurrence (YES/NO) Deterministic forecast. The computing procedure for various skill scores tests are as follows for sub basins:

Observed	Forecast	
	Yes	No
Yes	A	B
No	C	D

$$\text{Probability of Detection (POD)} = \frac{A}{A+B}$$

$$\text{False Alarm Rate (FAR)} = \frac{C}{C+A}$$

$$\text{Missing Rate (MR)} = \frac{B}{A+B}$$

$$\text{Correct Non} - \text{Occurrence(C} - \text{NON)} = \frac{D}{C+D}$$

$$\text{Critical Success Index (CSI)} = \text{ Threat Score } = \frac{A}{A+B+C}$$

$$\text{Bias for Occurrence (BIAS)} = \frac{A+C}{A+B}$$

$$\text{Percentage Correct (PC)} = \text{Hit Rate X 100} = \frac{\text{A+D}}{\text{A+B+C+D}} \text{ X 100}$$

$$\text{True Skill Skore (TSS)} = \frac{A}{A+B} + \frac{D}{C+D} - 1$$

$$\text{Heidke Skill Score (HSS)} = 2\left(\frac{AD-BC}{B^2+C^2+2AD+(B+C)(A+D)}\right)$$

The final skill score will be the average of these.

For perfect forecast, POD=1, FAR=0, MR=0

The Warnings for Heavy, Very Heavy and Extremely Heavy Rainfall are also to be verified with this 2 × 2 contingency table.

Annexure – XIV

Proforma of Annual Flood Report

Name of FMO: ……………………………………………….

Under RMC: ………………………………………………....

Annual Flood Report for the year ………………………………

1. Brief Paragraphs regarding the geographical and climatogical conditions of rivers under jurisdiction.

2. Flood periods: - For each flood period (In order of severity) the following details may be included:

(A) Flood period……………………..

(i)………………………………....

(a) QPF verification:

<table>
<tr><th rowspan="3">Duration of flood</th><th rowspan="3">No. of QPF issued</th><th colspan="5">No. of occasions when realized rainfall was</th></tr>
<tr><th rowspan="2">Within range
(%)</th><th colspan="2">Out by one Stage</th><th colspan="2">Out by two or more stages</th></tr>
<tr><th>Under estimate
(%)</th><th>Over estimate
(%)</th><th>Under estimate
(%)</th><th>Over estimate
(%)</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

(b) Heavy Rainfall Warning verification:

<table>
<tr><th colspan="3">HR</th><th rowspan="2">Total</th></tr>
<tr><th></th><th>Realized</th><th>Not realized (*)</th></tr>
<tr><td>HRW issued</td><td></td><td></td><td></td></tr>
<tr><td>HRW not issued</td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Total</td><td></td></tr>
</table>

(c) Date wise significant rainfall (50 mm and above) during the flood alert/flood.

(d) Date wise river water level during the flood alert period.
(e) Isohyetal analysis map of the severest rainstorm from the each of actual flood event.
(f) Summary of Synoptic situation during the flood alert/flood period.

(g) In case QPF is wrong by one or more stage, the Post-mortem analysis for missing points leading to wrong forecast and lesson learnt.

(h) Damage report:

 (i) Loss of public and private properties (in Rs.)……………

 (ii) Damage of crop (in Rs.)……………

 (iii)Paper cutting and damage report from News paper and respective State Govt.

*. Self appraisal.

3. Basin map (A-4 size), including Sub-basins details along with areas; rain-gauge network etc.

4. Onset & Withdrawal of SW monsoon distribution over basin.

5. Main synoptic system during flood period.

Annexure –XV

INDIA METEOROLOGICAL DEPARTMENT

Name of FMO ……………………………….........

Sub: Analysis of Heavy Rainfall over short periods (intensity 12 mm or more per hour)

Period: (Month)………….

State…………….., District..............….. Station…, Lat………..N, Long………E

Date	Duration		Amount (mm.) and Intensity (mm/hr.)		Fall in successive 15 minutes intervals in mm.															Heaviest rainfall in 15 min. (mm)	Remarks
	from	to			1	2	3	4	5	6	7	8	9	10	11	..	..	31		
	hr. min.	hr. min.																		

Annexure-XVI

Synoptic cum Statistical Analogue Model: A tool for formulating Sub-basin wise QPF

Introduction:

Synoptic Analogue method is one of the helpful tool to issue QPF. It is based on synoptic systems and their location which are responsible for rainfall over the river basins.

Data and Methodology:

Each Flood Met Office (FMO) will identify the rain-bearing synoptic systems e.g. Low Pressure Area/Well Marked Low Pressure Area, Depression/Deep Depression, Upper Air Cyclonic Circulation, position of Monsoon Trough, Cyclone etc. which are responsible for rainfall over their basin area of jurisdiction and their location e.g. over the basin/sub-basin, near E/W/S/N direction of the basin/sub-basin and over the adjoining area like state which effect AAP over their sub-basin/sub-basins.

I. In order to prepare synoptic analogue for each and every sub-basin, synoptic situations based on 0000UTC Upper Air Charts and 0300UTC Surface Charts during at least last 5 years which are responsible for different ranges of rainfall may be taken in to consideration.

II. Various synoptic systems responsible for different ranges of rainfall may be coded (i) as:

1- Low Pressure Area/Well Marked Low Pressure Area

2- Depression/Deep Depression

3- Upper Air Cyclonic Circulation

4- Position of Monsoon Trough

5- Cyclone

…………………………………………

III. Location of the synoptic situation in respect of various area may be coded (j)

1- Over the sub-basin

2- N/E/S/W of the sub-basin

3- N/E/S/W of the state/sub-division etc.

…………………………………………

Now a table will be prepared as mentioned below:

IV. AAP is to be calculated for each sub-basin daily corresponding to the prevailing synoptic situations of the previous day. Average Areal Precipitation (AAP) in the ranges of 01-10,11-25,26-50,51-100 and >100mm during the South West monsoon season over a particular sub-basin/sub-basins are to be grouped.

V. Then identified observation Sij in a frequency table is to be prepared as follows

Sub-basin → (Sij) ↓	Sub-basin A						Sub-basin B						Sub-basin C										
	01-10	11-25	26-50	51-100	>100	Total	01-10	11-25	26-50	51-100	>100	Total	01-10	11-25	26-50	51-100	>100	Total					
S11																							
S12																							
S13																							
……..	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…					
Total																							
S21																							
S22																							
S23																							
……..	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…					
Total																							
S31																							
S32																							
S33																							
……..	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…					
Total																							

Table 12: Frequency table of occurrence of AAP in different ranges for various synoptic conditions and locations.

VI. On the basis of above table determine the probability of rainfall in different ranges over a particular sub-basin for each Sij

$$\text{Probability of } S_{ij} = \frac{\text{Total frequency of particular AAP category over a particular sub-basin}}{\text{Total Number of all categories frequency over a particular sub-basin}}$$

It is noted that rainfall recorded (AAP) on a particular day in a particular sub-basin may be categorized corresponding to the prevailing synoptic conditions of the previous day.

Sub-→ basin (Sij) ↓	**Probability over Sub-basin A**					**Probability over Sub-basin B**					**Probability over Sub-basin C**									
	01-10	**11-25**	**26-50**	**51-100**	**>100**	**01-10**	**11-25**	**26-50**	**51-100**	**>100**	**01-10**	**11-25**	**26-50**	**51-100**	**>100**					
S11																				
S12																				
S13																				
……..	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…					
……..	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…					
S21																				
S22																				
S23																				
……..	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…					
……..	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…					
S31																				
S32																				
S33																				
……..	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…					
……..	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…					

Table 13: Probability Table

Ref.: 1) Hydromet Manual, 2010, Chapter-XI entitled ‘Role of Flood Meteorological Offices & QPF’ by Dr.(Mrs) Surinder Kaur & A. K. Das at Annexure-II page 291-293.

2.) “OPF model for Sabarmati basin on Synoptic analogue method” by Kamaljit Ray, B.N. Joshi, I.M. Vasoya, N.S. Darji and L.A. Gandhi published in Mausam, 63 (2012) page 565-572.

Annexure-XVII

List of products available in SAsiaFFGS

S.No	List of Products/ Observations	Type of Data	Frequency	Format	Remarks
1	Microwave-adjusted Global Hydro Estimator (MWGHE)	Gridded	1-hour, 3-hour, 6-hour and 24-hour accumulations of satellite-based rainfall estimates (mm) The MWGHE data products are updated every hour with a latency of approximately 45 minutes.	Text & Images	NOAA-NESDIS Global Hydro Estimator (infrared-based) and adjusted by the NOAA-CPC CMORPH microwave-based satellite rainfall product.
2	Global Hydro Estimator Satellite-based Precipitation Estimates (GHE)	Gridded	1-hour, 3-hour, 6-hour and 24-hour accumulations of satellite-based rainfall estimates (mm). The data products are updated every hour with a latency of approximately 25 minutes.	Text & Images	NOAA-NESDIS Global Hydro Estimator displayed over a background of system sub-basin boundaries.
3	Gauge Mean Areal Precipitation (GMAP)	Gridded	6-hour and 24-hour accumulations of mean areal precipitation (mm) estimates for each sub-basin produced from interpolation of precipitation gauge data updates every hour.	Text & Images	Actual Observations from SYNOP, Mobile SYNOP, DRMS etc.
4	Merged Mean Areal Precipitation (MAP)	Gridded	1-hour, 3-hour, 6-hour and 24-hour totals of the Merged Mean Areal Precipitation (mm) for each system sub-basin.	Text & Images	The Merged MAP 01-hour accumulation product is applied during model processing as the precipitation input to the Sacramento Soil Moisture Accounting Model.
5	Average Soil Moisture (ASM)	Gridded	00, 06, 12 & 18 UTC. Every 6 hours.	Text & Images	Soil water saturation fraction (dimensionless ratio of contents over capacity) for the upper zone (approximately 20-30 cm depth) of the Sacramento Soil Moisture Accounting Model for each of the sub-basins
6	Flash Flood Guidance (FFG) Value	Gridded	1-hour, 3-hour and 6-hour Flash Flood Guidance (mm) for each sub-basin. Each value indicates the total volume of rainfall over the given duration which is just enough to cause bankfull flow at the outlet of the draining stream.	Text & Images	Nowcasts or forecasts of rainfall considering other local information to estimate the risk of flash flooding in the sub-basins
7	WRF FCST Forecast Precipitation	Gridded	3-hour, 6-hour and 24-hour totals of forecast precipitation (mm) produced by using	Text & Images	Forecast likely to update every 3 hours and reflect precipitation forecasts from

			numerical forecasts from IMD 9km WRF Model.		the navigation hour over the corresponding interval
8	WRF FMAP	Gridded	3-hourly and 6-hourly totals of mean areal precipitation (mm) for each catchment produced by using numerical forecasts from the IMD 9km WRF Model	Text & Images	Likely to update every 3 hours, which reflects basin-average precipitation forecasts from the navigation hour over the corresponding interval.
9	Forecast Flash Flood Threat (FFFT)	Gridded	00, 06, 12 & 18 UTC.	Text & Images	Forecast Flash Flood Threat (mm) for each sub-basin values indicate the difference of forecasts of mean areal rainfall of the given duration using the FMAP and the corresponding current FFG of the same duration
10	Imminent Flash Flood Threat (IFFT)	Gridded	1-hour, 3-hour and 6-hour Imminent Flash Flood Threat (mm) for each sub-basin. The	Text & Images	IFFT provides the forecaster with an idea of likely regions of imminent flash flood threats based on current observation.
11	Persistence Flash Flood Threat (PFFT)	Gridded	1- hour, 3-hour and 6-hour Persistence Flash Flood Threat (mm) for each sub-basin	Text & Images	The last 1-hour, 3-hour and 6-hour durations of Merged MAP are persisted and considered with current corresponding FFG in the computation of PFFT. In this sense, the PFFT is considered a “forecast” with persistence used as the rainfall forecast.
12	Flash Flood Risk (FFR)	Gridded	12-hour, 24-hour and 36-hour relative frequency of positive flash flood threat for the entire forecast lead time interval that is due to forecast rainfall of 3-, or 6-hour duration from WRF Model Forecast.	Text & Images	Risk potential from Mesoscale forecast based.

Annexure-XVIII

SAMPLE NATIONAL BULLETIN

GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
INDIA METEOROLOGICAL DEPARTMENT
HYDROMET DIVISION
FLASH FLOOD GUIDANCE CELL

Ministry of Earth Sciences

National Flash Flood Guidance Bulletin

DATED: 26.11.2020 **TIME OF ISSUE: 1300 IST** **VALID TILL 1730 IST**

From: **India Meteorological Department, New Delhi**
(Email Id: sasiaffg.imd@gmail.com)

To: **RMC Chennai, MC Hyderabad, MC Bengaluru.**

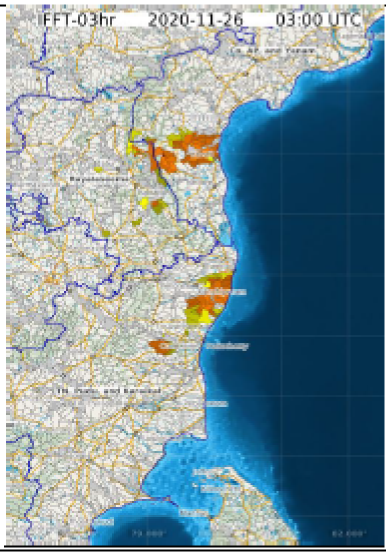
Area of Concern (AoC): Some watersheds & neighbourhoods in the districts of North Tamil Nadu, Puducherry & Karaikal, South Interior Karnataka, South Coastal Andhra Pradesh and Rayalaseema Subdivisions.

Diagnostic Guidance: Based on Merged Mean Areal Precipitation (Gauge, Satellite and Radar) of **0530 IST**, recorded rainfall is **86.3 to 187.3 mm** in last 6 hours and **121 to 318 mm** in last 24 hours over AoC. Real-time Satellite Estimates indicates **HIGH** convective activity with INSAT 3D CTBT value of **-80 Deg C over AoC**. Land Surface Model shows **several nearly saturated watersheds up to 90%** and **some fully saturated watersheds** over AoC.

Prognostic Guidance: Dynamic Global (GFS) & Mesoscale Model (WRF & NCUM) forecasts **HIGH RAINFALL** up to **300 mm** in next 24 hours over AoC.

Observed Flash Flood Threat (IFFT) Till 1130 IST of 26.11.2020:

Based on the Real-time Observations some watersheds & neighbourhoods of **Chennai, Kanchipuram, Chengalpattu, Cheyur, Nagapattinum, Cuddalore, Karaikal districts** of **Tamil Nadu & Puducherry** subdivisions; **Kadappa, Tirupati** districts of Rayalaseema sub divisions; **Nellore, Prakasam** districts of Coastal Andhra Pradesh subdivision **perceive Imminent Threat with Surface Run Off, water logging Conditions** at several places due to continuous rainfall during past 6 hours.



Disclaimer: This is only a guidance bulletin and not a warning for flash floods.
Contact: WMO Regional Centre (SASIAFFGS),
Hydromet Division, Flash Flood Guidance Cell
Phone: 011-43824359/011-43824410
Email: sasiaffg.imd@gmail.com

National Bulletin 1/2

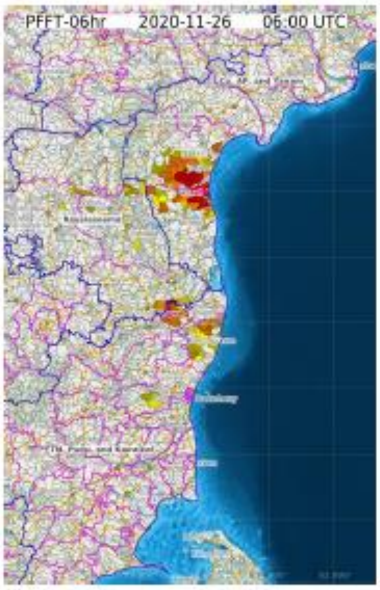
GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
INDIA METEOROLOGICAL DEPARTMENT
HYDROMET DIVISION
FLASH FLOOD GUIDANCE CELL

Ministry of Earth Sciences

Forecast Flash Flood Threat (PFFT) Till 1730 IST of 26.11.2020:

MODERATE TO HIGH THREAT over some watersheds & neighbourhoods of **Chennai**, **Kanchipuram, Thiruvallur, Chengalpattu, Vellore, Cheyur, Cuddalore, Villupuram, Karaikal districts** of **Tamil Nadu & Puducherry** subdivisions; **Kadappa, Tirupati** districts of Rayalaseema sub divisions; **Nellore, Prakasam** districts of Coastal Andhra Pradesh subdivision in next 6 hours.

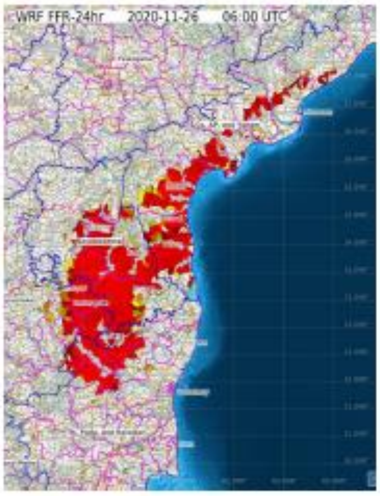
With persisting Very High Rainfall due to influence of **CS NIVAR**, **surface runoff conditions may occur.**



24 hours Outlook for the Flash Flood Risk Till 1130 IST of 27.11.2020:

MODERATE RISK over some watersheds & neighborhoods in the districts of **North Tamil Nadu, Puducherry & Karaikal and South Coastal Andhra Pradesh sub divisions in next 12 hours.**

MODERATE TO HIGH RISK over some watersheds & neighborhoods of **Bengaluru Urban, Bangalore Rural, Kolar, Tumkur** districts of **South Interior Karnataka** and **Anantpur, Chittoor, Kadappa, Tirupati** districts of **Rayalaseema Subdivisions** in **next 24 hours**.



Note: Next Bulletin will be issued on 1300 IST of 26.11.2020.

Disclaimer: This is only a guidance bulletin and not a warning for flash floods.

Contact: WMO Regional Centre (SASIAFFGS),
Hydromet Division, Flash Flood Guidance Cell
Phone: 011-43824359/011-43824410
Email: sasiaffg.imd@gmail.com

National Bulletin 2/2

Annexure-XIX

SAMPLE REGIONAL BULLETIN

Ministry of Earth Sciences	**GOVERNMENT OF INDIA** **MINISTRY OF EARTH SCIENCES** **INDIA METEOROLOGICAL DEPARTMENT** **HYDROMET DIVISION** **FLASH FLOOD GUIDANCE CELL**	

South AsiaFlash Flood Guidance Bulletin

DATED: 24.11.2020 **TIME OF ISSUE: 1300 UTC** **VALID TILL 2330 UTC**

From: India Meteorological Department, New Delhi (FAX NO. 24643965/24699216)

To: **National Meteorological and Hydrological Services, Sri Lanka**

Copy To: National Meteorological and Hydrological Services, Nepal
National Meteorological and Hydrological Services, Bhutan
National Meteorological and Hydrological Services, Bangladesh

Area of Concern (AoC): Some Watersheds & Neighbourhoods over North & North Central parts of Sri Lanka.

Diagnostic Guidance: Based on Merged Mean Areal Precipitation (Gauge and Satellite) of 1200 UTC, recorded rainfall is **15 – 58 mm** during last 6 hours & **30 – 76 mm** in last 24 hours over some northern watersheds of Srilanka. Real-time Satellite indicates **Moderate** convective activity with INSAT 3D CTBT value of -60 Degree C over AoC, expected heavy precipitation over North & North Central Parts of Srilanka in next 36 hours under the influence of "Cyclonic Storm Nivar" formed over SW BoB. Land Surface Model shows unsaturated dry watersheds with 55% saturation and some partially saturated watersheds up to 85% over **northern parts covering Kilinochchi & Vavuniya areas of Srilanka**.

NIL convective activity over Nepal, Bhutan & Bangladesh.

This Regional Guidance Bulletin should be modified by the respective NMHS as per latest meteorological and hydrological conditions.

Disclaimer: This is only a guidance bulletin and not a warning for flash floods.

Contact: WMO Regional Centre (SASIAFFGS),
Hydromet Division, Flash Flood Guidance Cell
Phone: 011-43824359/011-43824410
Email: sasiaffg.imd@gmail.com

Regional Bulletin Page 1/3

Prognostic Guidance: Global (GFS) & Mesoscale Model (WRF & NCUM) forecasts Moderate up to 160 mm rainfall in next 24 hours and up to 210 mm in next 48 hours over AoC.

Observed Flash Flood Threat (IFFT) Till 1200 UTC of 24.11.2020:

Based on 1200Z Real-time conditions some watersheds & neighbourhoods of Northern Sri Lanka indicates surface runoff conditions with imminent moderate threat perceived over **Kilinochchi area** with sudden rainfall due to persisting Cyclonic Circulation over the SW BoB.

Forecast Flash Flood Threat (PFFT) Till 1800 UTC of 24.11.2020:

Moderate Threat over some watersheds & neighbourhoods of Northern & North Central parts of Sri Lanka.

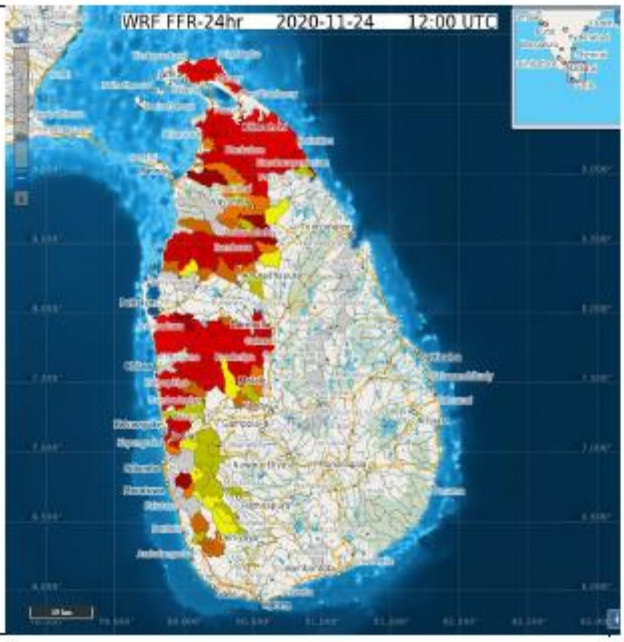
GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
INDIA METEOROLOGICAL DEPARTMENT
HYDROMET DIVISION
FLASH FLOOD GUIDANCE CELL

Ministry of Earth Sciences

24 hours Outlook for the Flash Flood Risk Till 1200 UTC of 25.11.2020:

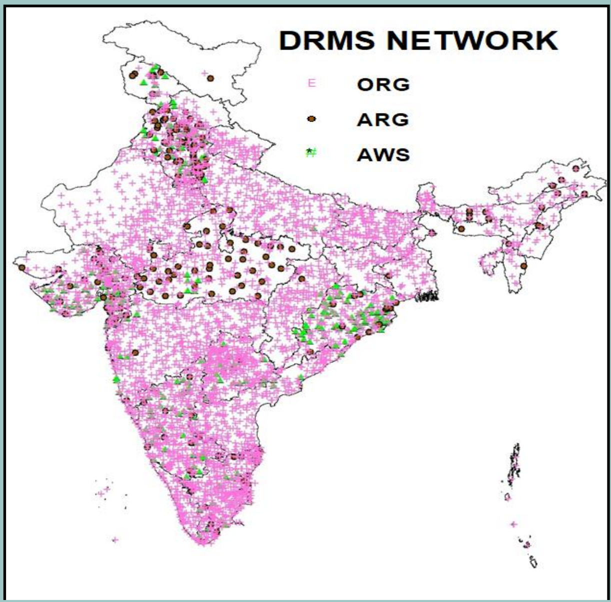
Moderate to High Risk over watersheds & neighbourhoods of North & North Central parts covering Kilinochchi & Vavuniya areas of Sri Lanka till 1200 UTC of 25.11.2020 due to the influence of Cyclonic Storm Nivar formed on SW BoB.

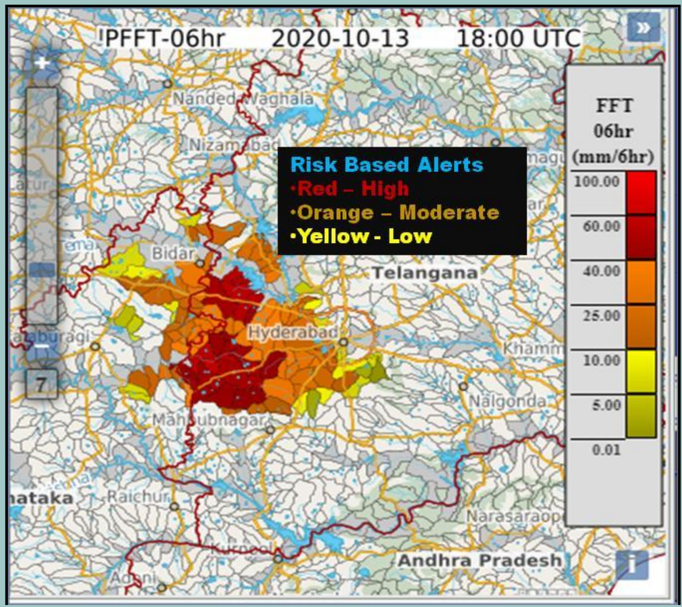
Situation is under constant watch & surveillance.

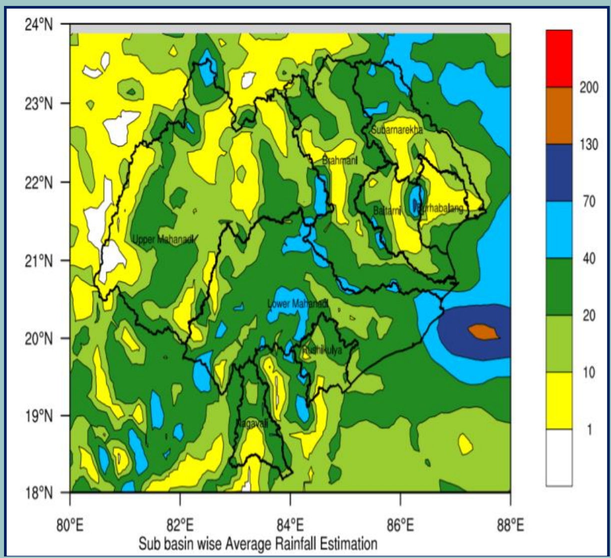


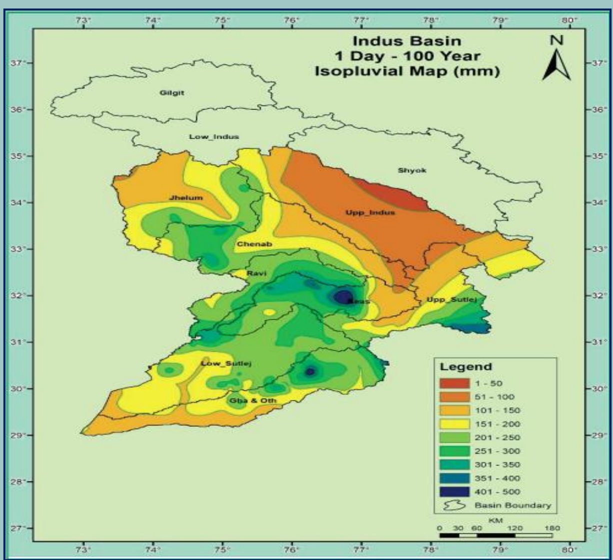
Note: Next Bulletin will be issued on 0700 UTC of 25.11.2020.

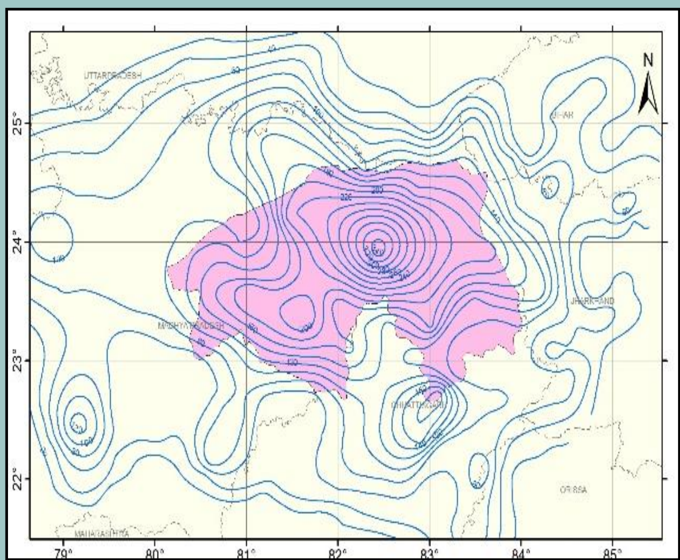
Contact: WMO Regional Centre (SASIAFFGS),
Hydromet Division, Flash Flood Guidance Cell
Phone: 011-43824359/011-43824410
Email: sasiaffg.imd@gmail.com











HYDROMETEOROLOGICAL DIVISION
INDIA METEOROLOGICAL DEPARTMENT
MAUSAM BHAWAN, LODI ROAD, NEW DELHI - 110003