DESIGN OFFICE REPORT
NO. - 1 - 21/1993

केन्द्रीय जल आयोग
CENTRAL WATER COMMISSION

इन्द्रावती (उप अंचल-३जी) का बाढ़ आकलन विवरण

FLOOD ESTIMATION REPORT FOR INDRAVATI (SUB ZONE - 3 g)

DIRECTORATE OF HYDROLOGY
(REGIONAL STUDIES)
CENTRAL WATER COMMISSION
NEW DELHI - 110066.

A JOINT WORK OF
CENTRAL WATER COMMISSION
RESEARCH DESIGNS AND
STANDARDS ORGANISATION,
INDIA METEOROLOGICAL DEPTT.
& MIN. OF SURFACE TRANSPORT

FLOOD ESTIMATION REPORT OF INDRAVATI BASIN SUB ZONE 3(g) WAS APPROVED BY THE FOLLOWING MEMBERS OF THE FLOOD ESTIMATION PLANNING AND COORDINATION COMMITTEE IN ITS 51TH MEETING HELD ON 26.11.1992 AT R.D.S.O. LUCKNOW.

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FLOOD ESTIMATION REPORT OF INDRAVATI

SUBZONE 3(g)

A METHOD BASED ON UNIT HYDROGRAPH PRINCIPLE
DESIGN OFFICE REPORT NO. I/21/1992

HYDROLOGY (REGIONAL STUDIES) DIRECTORATE
CENTRAL WATER COMMISSION
NEW DELHI
1993

FOREWORD

Estimation of flood of various return periods for design of waterways and foundations of bridges and culverts having small and medium catchments, where hydrlogical data are inadequate or totally absent, is extremely difficult. In such a situation, regional method based on hydrometeorological approach involving use of design storm for specified return period and synthetic unit hydrograph has been adopted as recommended by the Committee of Engineers under the Chairmanship of Dr. A.N. Khosla set up by the Government of India in 1959. For this purpose, the country has been divided into 26 hydrometeorological homogenous subzones. The hydrometeorological and storm studies for 22 subzones have been completed and 18 flood estimation reports covering 21 subzones have been published. Flood Estimation Report of Luni subzone 1(a) is under publication.

The present report is 20th in the series and deals with the estimation of design flood of small and medium catchments in Indravati subzone 3(g). Rainfall - runoff data required for unit hydrogaph studies were not observed in the subzone. Hence, relationships between physiographic and unit hydrograph parameters developed for Lower Godavari subzone 3(f), based on observed hydro meteorological data, have been adopted to derive synthetic unit hydrographs of the catchments in this subzone. Storm studies have been carried out by the IMD based on available long term rainfall data.

The report recommends a methodology for estimation of flood with return period of 25, 50 and 100 years for structures having small and medium catchments in the Indravati subzone, till such time rainfall-runoff data of the representative catchments are available for evolving a better and more rational method of arriving at the design flood.

The report is a joint effort of Central Water Commission (CWC), India Metereeological Department (IMD), Research Design and Standard Organisation (RDSO) of Ministry of Railways and Ministry of Surface Transport (MOST) in pursuance of recommendations of Khosla Committee.

I would like to place on record my appreciation of the excellent cooperative efforts of the officers and staff of the four organisations in producing this report.

MSReddy

New Delhi

Dated March, 1993

(M.S.REDDY)
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PREFACE

Design engineers essentially need the design flood of a specific return period for fixing the waterway vis-a-vis the design HFL and foundation depths of bridges,culverts and cross drainage structures depending on their life and importance to ensure safety as well as economy. A casual approach may lead to under- estimation or over-estimation of design flood resulting in the loss and destruction of structure or uneconomic structure with problematic situation.

The use of empirical flood formulae like Dickens, Ryves, Inglis etc., has no such frequency concept, though has the simplicity of relating the maximum flood discharge to the power of catchment area with constants. These formulae do not take into account the basic meteorologic factor of storm rainfall component and other physiographic and hydraulic factors varying from catchment to catchment. Proper selection of constants in these empirical formulae is left to the discretion of design engineer, involving subjectivity.

Recognising the need to evolve a method for estimation of design flood peak of desired frequency, the committee of engineers headed by Dr. A.N. Khosla had recommended, in their report that the design discharge should be maximum flood on record for a period not less than 50 years. Where adequate records are available extending over a period of not much less than 50 years,the design flood should be 50 years flood determined from probability curve on the basis of recorded floods during the period. In case, where the requisite data as above are not available, the design flood should be decided based on the ground and meteorological characteristics obtained on the basis of design storms necessitating the systematic and sustained collection of hydro-meteorological data at selected catchments in different climatic zones of India.

Economic constraints do not justify detailed hydrological and meteorological investigations at every new site on a large scale and on a long term basis for estimation of design flood with a desired return period. Regional flood estimation studies thus become necessary for hydro-meteorological homogeneous regions in the country. Broadly, two main regional approaches namely flood frequency nd hydro-meteorological approaches are open for adoption depending on the availability of the storm rainfall and flood data. The first approach needs long term discharge observations for the representative catchments for subjecting to statistical analysis to develop a regional flood frequency model. The other approach needs concurrent storm rainfall and run-off data of the representative catchments over a period of 5 to 10 years to develop a regional "rainfall-loss-rate-runoff (UH) model" and long term rainfall records at a large number of stations to develop "design storm values". This approach has been adopted in the preparation of flood estimation reports under short term and long term plan.

Under short term plan, the report on estimation of design flood peak utilising hydro-met data available for 60 bridge catchments, spread through-out the country, was brought out in 1973, wherein the method has been recommended for estimating the design flood peak for catchment areas ranging from 25 to 500 km^2. in the country.

Under long term plan, country has been divided into 26 hydro-meteorologically homogeneous sub-zones. For preparing the flood estimation reports for these sub-zones, systematic and sustained collection of hydro-meteorological data at the representative catchments, numbering 10 to 30, for a period of 5 to 10 years in different sub-zones has been carried out in a phased manner by different zonal railways since 1965 under the supervision and guidance of Bridges and Flood Wing of Research Design and Standards Organisation of Ministry of Railways. Similarly, the Ministry of Transport had undertaken the collection of data for 45 catchments through Central Water Commission since 1979.

Regional Hydrology Studies Dte. (formerly Hydrology (SC) Directorate) of CWC carried out analysis of selected concurrent rainfall and flood data for the gauged catchments to derive unit hydrographs of mostly one hour duration on the basis of rainfall data, gauge and discharge data collected during the monsoon season. Representative 1 hr unit hydrographs have been obtained for each of the gauged catchments. The characteristics of the catchments and their unit hydrographs, prepared for several catchments in a sub-zone, have been correlated by regression analysis and the equations for synthetic unit hydrograph for the subzone are derived for estimating design flood for ungauged catchments.

Studies are also carried out by the CWC to arrive at suitable recommendations for estimating loss rate and base flow for ungauged catchments.

Studies of Rainfall-Depth-Duration-Frequency, point to areal rainfall ratios and time distribution of storms are carried out by Hydro-met Cell of IMD utilising the data collected by RDSO and the long term data collected by IMD from rain-gauge stations maintained by IMD/States.

The sub-zonal reports incorporating studies carried out by CWC and IMD are prepared and published by CWC on approval of Flood Estimation Planning and Coordination Committee.

So far, following 19 reports covering 21 sub zones have been published:-

1.	Lower Gangetic Plains Sub zone	-	1(g) -	1978
2.	Lower Godavari sub zone	-	3(f) -	1981
3.	Lower Narmada and Tapi sub zone	-	3(b) -	1982
4.	Mahanadi sub zone	-	3(d) -	1982
5.	Upper Narmada & Tapi sub zone	-	3(c) -	1983
6.	Krishna & Penner sub zone	-	3(h) -	1983
7.	South Brahmaputra Basin sub zone	-	2(b) -	1984
8.	Upper Indo Ganga Plains sub zone	-	1(e) -	1984
9.	Middle Ganga Plains sub zone	-	1(f) -	1985
10.	Kaveri Basin sub zone	-	3(i) -	1986
11.	Upper Godavari sub zone	-	3(e) -	1986
12.	Mahi & Sabarmati sub zone	-	3(a) -	1987
13.	East Coast sub zones	-	4(a)(b) & (c)	1987
14.	Sone Sub zone	-	1(d) -	1988
15.	Chambal sub zone	-	1(b) -	1989
16.	Betwa sub zone	-	1(c) -	1989
17.	North Brahmaputra Basin sub zone	-	2(a) -	1991
18.	West coast sub zones	-	5(a) & (b)	1992
19.	Luni sub zone	-	1(a)	1993

The present report deals with the estimation of design flood of 25 yr., 50 yr. and 100 yr return periods for small and medium catchments in the sub-zone 3(g) which covers parts of Madhya Pradesh and Orissa.

Rainfall - Runoff data observed at the representative catchment in the sub zone for a period 3 to 5 year duration is essentially required for developing relationships between physiography and unit graph parameters (SUG equations). There being no observational site in the entire catchment of the subzone, it was decided by the FEPCC that relations developed between physiography parameters and unit hydrograph parameters for the Lower Godavari sub zone 3(f), adjoining to 3(g) sub zone, would be considered for deriving SUG of ungauged catchments in 3(g) subzone.

The present report is based upon hydrological studies carried out for Lower Godavari sub zone 3(f) and the storm studies conducted by IMD with the rainfall data of 91 O.R.G stations maintained by IMD and State Governments and 11 S.R.R.G stations maintained by IMD in and around the subzone.

Part I of the report deals with the summary and contents of the synthetic unit hydrograph approach for design flood estimation alongwith an illustrative example. General description of the subzone detailing, river system, rainfall, temperature and types of soil are given in Part II. Part III brings out the SUH relations to be used for ungauged catchments in the sub-zone. The storm studies carried out by the IMD are dealt in Part IV of the report. Criteria and standards in regard to design flood of structures and procedures to compute the design flood of ungauged catchments are described in Part V. The Part VI highlights the limitations, assumptions and conclusions.

The report on sub zone 3(g) is recommended for estimation of design flood for small and medium catchments varying in areas from 25 to 1000 km^2. This report may also be used for catchments of areas upto 2500 km^2. judiciously after comparing the neighbouring catchments having more or less similar characteristics. For catchments of areas less than 25 Km^2. the method given in the Report No. RPF-16 published by RDSO may be used

The method adopted and conclusions arrived at, are subject to periodical review and revision in the light of adequate data being collected & analysed and also the advancements in theory and techniques.

This report is a joint effort of Hydrology (Regional Studies) Dte, Central Water Commission of Ministry of Water Resources, Research Design Standard Organisation , Ministry of Railways, Roads and Bridges Wing of Ministry of Surface Transport and Hydro-met Dte., India Meteorological Department of Ministry of Science and Technology.

Sd/-

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SYMBOLS AND ABBREVIATIONS

SYMBOLS

As far as possible well recognised letter symbols in the hydrological science have been used in this report. The list of symbols adopted is given with the units.

A	Catchment Area in km^2.
ARF	Areal Reduction Factor.
C.G.	Centre of Gravity
Cumecs	Cubic metres per second
cms	Centimetres
D_{i-1}, D_i	Depths between the river bed profile (L-section) based on the levels of (i-1) and ith contours at the inter-section points and the level of the base line (datum) drawn at the point of study in metres.
E.R.	Effective Rainfall in cms.
Hr	Hour
H(RS),CWC	Hydrology (Regional Studies) Directorate, Central Water Commission, New Delhi.
I.M.D.	India Meteorological Department
In	Inches
Km	Kilometres
L	Length of longest main stream along the river course in km.
L_c	Length of the longest main stream from a point opposite to centroid of the catchment area to the gauging site along the main stream in km.
L_i	Length of the ith segment of L-section in km.
M.O.S.T.	Ministry of Surface Transport (Roads Wing).
M	Metres
Min	Minutes

mm	Millimetres
Q_p	Peak Discharge of Unit Hydrograph in cubic metres per second.
Q_{25}, Q_{50} and Q_{100}	Flood Discharge with return periods of 25-yr, 50-yr and 100-yr respectively in cumecs
q_p	Peak Discharge of Unit Hydrograph per unit area in cumecs per sq. km.
R_{25}, R_{50} and R_{100}	Point Storm Rainfall Values for 25-yr, 24-hour 50-yr 24-hour and 100-yr 24-hour return periods respectively in cm.
R.D.S.O.	Research Designs & Standards Organisation (Ministry of Railways), Lucknow.
Seq	Equivalent stream slope in m/km.
S	Statistical stream slope in m/km.
S.U.G.	Synthetic Unit Hydrograph
Sec	Seconds
Sq	Square
Sq.km	Square Kilometres, Km^2
T	Time Duration of Rainfall in hours
T_B	Base Width of Unit Hydrograph in hours
T_D	Design Storm Duration in hours
T_m	Time from the start of rise to the peak of Unit Hydrograph in hours
t_p	Time from the centre of Unit Rainfall Duration to the Peak of Unit Hydrograph in hours
t_r	Unit Rainfall Duration adopted in a specific study in hours
U.G.	Unit Hydrograph

W_{50} Width of U.G. measured at 50% peak Discharge Ordinate (Q_p) in hours.

W_{75} Width of the U.G. measured at 75% peak Discharge Ordinate (Q_p) in hours.

W_{R50} Width of the rising side of U.G. measured at 50% of peak Discharge Ordinate (Q_p) in hours.

W_{R75} Width of the rising side of U.G. measured at 75% of peak Discharge Ordinate (Q_p) in hours.

% Percent.

< Summation

PART - I

SUMMARY OF S.U.H APPROACH

1.1 Illustrative example to estimate 50 Yr return period flood

The Flood Estimation report for Indravati sub-Zone 3(g) may be used for estimation of design flood (25-yr, 50-yr and 100-yr) for ungauged and inadequately gauged catchments in the subzone. The method adopted in this report is explained in following parts :-

Part-III explains the procedure adopted to obtain Synthetic Unit Hydrograph for catchments in the subzone.

Part-IV explains the procedure to obtain design storm rainfall and its temporal distribution.

Part-V explains steps to be followed for obtaining the design flood of 25 yr /50 yr/100 yr return period.

1.1.1 Steps necessary to estimate design flood peak/design flood hydrograph are as under :

i) Preparation of catchment area plan of the ungauged catchment.

ii) Determination of physiographic parameters viz: catchment area (A), Length of the longest stream (L) Length of stream from CG of the catchment (Lc)and statistical stream slope (S).

iii) Determination of 1-hr. SUG parameters i.e. q_p, Q_p, t_p, T_m, W_{50}, W_{75}, WR_{50}, WR_{75} & T_B.

iv) Drawing of SUH.

v) Estimation of design storm duration (TD)

vi) Estimation of point rainfall and areal rainfall for design storm duration (TD) and to obtain areal rainfall increments for unit duration intervals.

vii) Estimation of effective rainfall increments by subtracting the prescribed design loss rate from the areal rainfall increments.

viii) Estimation of base flow.

ix) Computation of design flood peak.

x) Computation of design flood hydrograph.

1.1.2. Illustrative example :-

An example of ungauged Catchment is worked out for illustrating the procedure to compute 50 yr design flood. The particulars of the catchment under study are as follow:

i) Name of Tributary	Kotri
ii) Shape of catchment	Fan
iii) Location	Lat 20^{o}-25'-00"
	Long 80^{o}-48'-00"
iv) Topography	Moderate slope

Procedure is explained stepwise:

Step-1:- Determination of physiographic parameters:

The point of interest was located on the Survey of India toposheets and catchment boundary was marked. The catchment area plan (Fig. A-1) showing the rivers, contours and spot levels was prepared.

From the catchment area plan, the area of the catchment(A)and the length of the longest mainstream(L) from the farthest catchment boundary to the point of study was measured. Centre of gravity of the catchment was determined at the point of intersection of the plumb lines by holding freely the catchment area plan cut on a card-board. Length of the main longest stream opposite to the centre of gravity to the point of study(Lc) was measured.

Statisical stream slope(S) was obtained by graphical method as shown in Fig-A-1 and by analytical method as shown in Annex-1.1

Physiographic parameters obtained are given below:

1) Area (A)	325.00 sq km
2) Length of the longest stream (L)	31.37 km
3) Length of the longest stream from a point opposite C.G. of catchment to point of study (Lc)	16.09 km

4) Statatical stream slope (Sst) 1.09 m/km

Step-2:- Derivation of 1-hr Synthetic Unitgraph:

Synthetic Unitgraph Parameters were computed using equations in para 3.3.

$$t_p = 0.353\ (LLc/\sqrt{S})^{0.45} = 5.5 \text{ hr.}$$

$$q_p = 1.968\ (t_p)^{-0.842} = 0.47 \text{ cumecs/sq km}$$

$$W_{50} = 2.30(q_p)^{-1.018} = 5.0 \text{ hr}$$

$$W_{75} = 1.356\ (q_p)^{-1.007} = 3.33 \text{ hr}$$

$$W_{R50} = 0.954\ (q_p)^{-1.078} = 2.14 \text{ hr}$$

$$W_{R75} = 0.581\ (q_p)^{-1.035} = 1.27 \text{ hr}$$

$$T_B = 4.572\ (t_p)^{0.90} = 21.0 \text{ hr}$$

$$Tm = t_p + 0.5\ tr = 6.0 \text{ hr}$$

$$Qp = qp * A = 152.75 \text{ cumecs}$$

Estimated parameters of unitgraph in step-2 were plotted on a graph paper as shown in Fig A-2. The plotted points were joined to draw synthetic unitgraph. The discharge ordinates (Qi) of the unitgraph at ti = tr = 1 hr interval were summed up and multiplied by tr (=1) i.e $\Sigma Qi \times ti = 902.78\ m^3/s$ as shown in Fig A-2 and compared with the volume of 1.00 cm Direct Runoff Depth over the catchment, computed from the formula
$Q = Axd/ti \times 0.36$

Where A = Catchment area in Sq. Km.

d = 1.0 cm depth

ti = tr (the unit duration of the UG) = 1 hr.

$$Q = \frac{A * d}{0.36 * tr} = \frac{325.00 * 1}{0.36 * 1} = 902.78 \text{ cum/sec}$$

Note:- (In case, the <Qiti for the unitgraph drawn is higher or lower than the volume of 1 cm, the falling limb of hydrograph may be suitably modified without altering the points of synthetic parameters.)

Step-3: Estimation of Design Storm:

(a) Design storm duration:

The Design Storm Duration (T_D) has been adopted as $1.1 * t_p$ (refer step 2 in Section 5.2.). Rounding the design storm duration to nearest hour, its value came as 6 hrs.

(b) Estimation of Point Rainfall and Areal Rainfall for storm duration:

Catchment under study was located on Plate -10 showing 50-yr 24-hr point rainfall. The point rainfall was found to be 32.00 cm. The Conversion factor of 0.635 was read from Fig - 3 to convert the 50-yr 24-hr point rainfall to 50-yr 6-hr point rainfall (since T_D = 6 hrs). 50-yr 6-hr point rainfall was 20.32 cm.

Areal reduction factor of 0.86 corresponding to the catchment area of 325.00 sq.km for T_D = 6-hr. was interpolated from Annex.4.2 or Fig 5(a) for conversion of point rainfall to areal rainfall. 50-yr 5-hr areal rainfall thus worked out to be 17.47 cm.

The 50-yr, 6-hr areal rainfall was split in to 1-hour rainfall increments using the time distribution coefficients given in Annex 4.1 or Fig 4.

A design loss rate of 0.50 cm /hr as recommended in para 3.4 was applied to get effective rainfall hyetograph.

Table gives the hourly effective rainfall increments

Table - 1
(Hourly rainfall Increments)

Duration 1	Distribution coefficient 2	Storm rainfall 3 (cm)	Rainfall increments 4 (cm)	Effective rainfall increments 5 (cm)
1	0.51	8.91	8.91	8.41
2	0.71	12.40	3.49	2.99
3	0.85	14.85	2.45	1.95
4	0.93	16.25	1.40	0.90
5	0.97	16.94	0.69	0.19
6	1.00	17.47	0.53	0.03

Step-4: Estimation of Base Flow:

Taking the design base flow of 0.06 cumecs per sq km as recommended in para 3.5, the base flow was estimated to be 19.50 cumecs for the catchment area of 325.00 sq.km.

Step-5: Estimation of 50-yr Flood.

(a) Computation of flood peak

For the estimation of the peak discharge, the effective rainfall increments were re-arranged against ordinates such that the maximum effective rainfall is placed against the maximum U.G. ordinate, the next lower value of effective rainfall against the next lower value of U.G. ordinate and so on, as shown in col. (2) and (3) in the Table - 2. Sum of the product of U.G. ordinates and the effective rainfall increments gives the total direct runoff to which have flow is added to get total peak discharge .

Table - 2

(50 year flood peak)

Time (hrs)	U.G. ordinate cumecs	1-hr effec. rainfall (cms)	Direct Runoff (cumecs)
1	2	3	4
1	80.00	0.19	15.20
2	124.00	1.95	241.80
3	152.75	8.41	1284.63
4	147.93	2.99	442.31
5	116.50	0.90	104.85
6	74.00	0.03	2.22
		TOTAL	2091.01
		Base Flow	19.50
		50-yr Flood Peak	2110.51

(b) Computation of Design Flood Hydrograph:

Effective rainfall increments shown in col. (3) of Table 2 in Step-5 were reversed to obtain the critical sequence as shown below:

Table - 3
(Critical sequence of rainfall)

Time in hrs	Critical 1-hr effective rainfall sequence cms
1	0.03
2	0.90
3	2.99
4	8.41
5	1.95
6	0.19

For computation of design flood hydrograph, the U.G. ordinates were tabulated in col(2) of Annex. 1.2. The critical sequence of effective rainfall increments were entered in col.3 to 8 horizontally. Direct runoff resulting from each of the effective rainfall increments was obtained by multiplying effective rainfall depths with the synthetic U.G. ordinate in col. (2) and direct runoff values were entered in columns against each unit with a successive lag of 1-hr since the unit duration of S.U.G. is 1-hr. Direct runoff values are shown in col (3) to (8). Direct runoff values were added horizontally and the total direct runoff is shown in col. (9). Adding total base flow of 19.50 m^3/sec. (col. 10), design flood hydrograph ordinates were obtained as given in col.11. The ordinates given in col. (11) were plotted against time (col.1) to get the design flood hydrograph as shown in Fig A-3.

PART - II

GENERAL DESCRIPTION OF INDRAVATI SUB ZONE

2.1 Location : The Indravati Subzone 3(g) lies approximately between 80^{0} and $83^{0}-07'$ East longitudes and $18^{0}-15'$ and $20^{0}-4'$ North latitudes. Plate-1 shows location of the sub- zone in map of India. Annexure-2.1 shows the list of the sub- zones in India.

The sub-zone is bounded by sub-zone 3(f) in the West and South, Sub-zone 3(d) in the North and 4(a) in the East.

The states covered by the sub-zone are Madhya Pradesh and Orissa. The basin area is mostly covered by forests and as such it does not have any important town, except Jagdalpur.

2.2 River System : Plate-2 depicts the river system in the sub-zone. The basin is traversed by the Indravati River, which rises at an elevation of 914 metres in the Kalahandi district of Orissa on the Western slopes of the Eastern Ghats. It flows westward through the Koraput district of Orissa and Bastar district of Madhya Pradesh. It turns south at about 531 Kms. from its source and joins the Godavari at an elevation of 82 metres. Its important tributaries are the Narangi, the Baordhig, the Kotri and the Bande on the right and the Nandiraj (Berudi) on the left.

The geophysical area of the sub-zone is 41330 Sq.Kms. The total drainage area of Indravati River upto its cofluence with Godavari River is 41665 Sq.Kms. However, entire area of the sub-zone is covered by the Indravati river.

The break up of areas covered by the tributaries in the catchment of the Indravati river is as under :

S.No.	Name of Tributary	Drainage Area Sq.Km.
(a)	Right Bank	
1	Bande	3861
2	Kotri	6590
3	Nibra	6641
4	Gudra	2832
5	Baordhig	3449
6	Narangi	3913
7	Bhaskel	2163
(b)	Left Bank	
1	Nandi Raj	1699
	Sub Total	31148
(c)	Free drainage area	10182
	Total	41330

2.3 Topograohy and Relief : Plate-4 shows the general topography of the sub-zone. The elevation in the sub-zone varies between 150 metres to 1350 metres and increases from West to East. In the central portion of the sub-zone, the elevation is around 600 meters.

2.4 Rainfall : Plate-5 shows the normal annual rainfall in the sub-zone and the histograms showing normal monthly rainfll at Jagdalpur raingauge station. The rainfall mainly occurs from May to October due to South-West Monsoon. Normal annual rainfall varies from 1400 to 1700 mm. in the sub-zone. The normal annual rainfall at Jagdalpur is 1570 mm.

2.5 Temperature : Plate-6 shows normal annual temperature in the sub-zone along with histograms showing minimum, maximum and mean monthly temperatures at Jagdalpur. The average temperature in the sub_zone varies between 22 C to 27 C. The normal annual temperature at Jagdalpur is 24.6 C .

2.6 Soils: Plate-7 shows soils in the sub-zone. The major area of the sub zone is covered with red sandy soil. Small area in the central Northern portion is covered with red and yellow soil. Towards extreme Eastern portion, red loamy soil is found. Laterite soil is found in small patches in the southern region of the sub-zone.

2.7 Land-Use: Land use map at Plate-8 has been prepared from 'Irrigation Atlas of India-1989'. The sub-zone is mainly covered by forests and to a small extent by scrubs. Small cultiviable areas are scattered in Central portion of the sub-zone where rice and millets are grown.

2.8 Communications: The Sub-zone has a poor communication network. Jagdalpur is the only important railway station in the sub-zone and is located in the Raipur-Koraput section which passes along southern boundary of the sub-zone. Besides this, the state highway passing through Jagdalpur - Koraput - Phulwani also passes through the sub-zone.

PART - III

SYNTHETIC UNIT HYDROGRAPH STUDIES

3.1 Synthetic Unit Hydrograph (SUH) :

Hydrometeorological approach has been adopted for developing a regional method for estimating design flood for small and medium catchments in various hydrometeorologically homogeneous sub-zones. In this approach, the design storm after converting it into effective rainfall (input) is applied to the unit hydrograph (transfer function) to obtain a design flood (output). It is possible to develop unit hydrograph if site specific concurrent rainfall runoff data is available for 3-4 years. Collection of adequate concurrent rainfall runoff data for every site, however is neither practicable nor economically feasible.In such a situation the regional method for developing SUH is resorted to. The SUH in the present study is a unit hydrograph of unit duration for a catchment developed from relations established between physiographic and unit hydrograph parameters of the representative catchments in hydrometeorologically homogenous regions (sub-zones). Data collected and analysed for obtaining sub-zonal SUH equations are discussed in succeeding paragraphs.

3.2 Data Required:

For conducting the unithydrograph studies for development of equations for derivation of SUH, the following concurrent rainfall and runoff data for a number of catchments of small and medium sizes representatively located in a subzone are required for a minimum period of 5 to 8 years during the monsoon season:

i) Hourly gauge data at the gauging site (bridge site) round the clock.

ii) Gauge and discharge data observed 2 to 3 times a day at the gauging site (bridge site).

iii) Hourly rainfall data of raingauge stations in the catchment. Raingauge stations are to be self-recording and/or manually operated.

The following catchment details are also required .

iv) Catchment area plans showing the river net-work, location of raingauge stations and gauge and discharge sites, contours, highway and railway network, natural and man made sto-rages, habitations, forests, agricultural and irrigated areas, soils etc.

v) Cross-sections at the bridge site (gauging site), upstream and downstream of the bridge site.

vi) Longitudinal section of the river upstream and downstream of the bridge site.

3.3.0 Relations between physiographic and unitgraph parameters.

There are no observational site in 3(g) sub zone for carring out hydrological studies for derivation of SUG for catchments in the subzone. The relations between physiographic and unit hydrograph parameters for lower Godavari, subzone 3(f) were based on hydrological studies of of 22 out Of 27 bridge catchments for which data were observed. As subzone 3(g) is situated adjacent to 3(f) subzone and both the subzones are located in the same river basin viz the Godavari basin, the relations developed for 3(f) subzone given below, have been recommended for deriving SUG of ungauged catchments in 3(g) subzone.

Relationships 1	Equation No. 2
$t_p = 0.353\ (LLc//s)^{0.45}$	3.3.1
$q_p = 1.968\ (t_p)^{-0.842}$	3.3.2
$W_{50} = 2.30(q_p)^{-1.018}$	3.3.3
$W_{75} = 1.356\ (q_p)^{-1.007}$	3.3.4
$W_{R50} = 0.954\ (q_p)^{-1.078}$	3.3.5
$W_{R75} = 0.581\ (q_p)^{-1.035}$	3.3.6
$T_B = 4.572\ (t_p)^{0.90}$	3.3.7
$Tm = Tp + 0.5Tr$	3.3.8
$Qp = A * qp$	3.3.9

Plate 3 shows the location of G&D sites, catchments area and period for the data was available in respect of 3(f) subzone. The details of various physiographic parameters considered for correlation and the unit graphs parameters are given in Fig.1 & 2.

3.3.1 Derivation of 1-hour SUG for ungauged catchments.

Considering the hydro-meteorological homogeneity of subzone the relations between physiographic and unitgraph parameters given in section 3.3 are applicable for derivation of 1-hour Synthetic unitgraph for an ungauged catchment in the subzone.

Steps for derivation of 1-hour unitgraph are :

i) Physiographic parameters of the ungauged catchment viz A, L, Lc and S are determined from the catchment area plan.

ii) Substitute LLc/√S in the equation 3.3.1 to obtain t_p and this t_p in equation 3.3.2 to get q_p in cumecs/ sq.km.

iii) Substitute the value of q_p or t_p in the equations 3.3.3 to 3.3.7 to obtain W_{50}, W_{75}, W_{R50}, W_{R75} and T_B in hours.

(iv) Compute Tm and Qp from equations 3.3.8 and 3.3.9

(v) Plot the parameters of 1-hour unitgraph viz. T_m, T_B, Q_p, W_{50}, W_{75}, W_{R50}, and W_{R75}, on a graph paper as shown in illustrative Fig.A-2 and sketch the unitgraph through these points.

(vi) Obtain sum of the discharge ordinates of tr-hr Unitgraph and compare with volume of 1Cm direct rainfall depth over the catchment using the following equation:

$$< \; Q_i = \frac{2.78\ A \ * \ d}{tr * 0.36}$$

Where Q_i = discharge ordinates at 1-hour interval (cumecs)

A = Catchment area in sq.km.

tr = Unit duration in hours.

d = 1 Cm.

Suitable modifications can be made in recession limb upto W_{50} points, and a smooth Unitgraph be drawn.

3.4 Design Loss Rate:

Direct surface runoff is the end product of storm rainfall after infiltration into surface soils, sub-surface and ground besides abstractions like evaporation, evapotranspiration, soil moisture and filling up of surface depressions. It is difficult, rather impossible, to record these various parameters at various representative locations in the catchment except by the analysis of observed storm rainfall and flood events. Conversion of gross storm rainfall units into effective rainfall units for application to unitgraph is normally done by subtraction of constant loss rate (θ-index) for the catchment, even though the loss rates in the catchments, a complex phenomena, vary due to soil conditions, soil cover complex and topography alongwith temporal and spatial variations of storm rainfall.

The model value of loss rate of 5mm \hr for the catchment area lerger than 75 km2 and a value of 2.0 MM/hr. for area less tham 75 km2 has been adopted for subzone 3 (f). These values of loss rates are recommonded for catchments in subzone 3(g).

The desingner may however, adopt any suitable value as per local site condtions.

3.5 Design Base Flow

An average value of 0.06 cumecs/sq km has been arrived for 3(f) subzone on the basis of 165 flood events. This value of 0.06 cumecs/sq km has been recommended for catchments in subzone 3(g).

PART IV

RAINFALL STUDIES

4.1 Introduction

The India Meteorological Department (IMD) has conducted rainfall studies for the Subzone. The study covers Depth-Duration Frequency analysis of rainfall data from 91 ordinary raingauge stations of IMD/States and 11 self recording raingauge stations of IMD. The Design storm components have been derived in the form of (i),25, 50 and 100 year 24 hour isopluvial maps (ii) 24 hours to short duration (1 to 23 hours)rainfall ratios, (iii) Time distribtion curves for storms of various durations (2 to 24 hours) and (iv)Point to areal rainfall ratios for specific durations (1, 3, 6, 12 and 24 hours). The methdology applied for analysis of each component and the procedure for design storm estimation is discussed in the following paras.

The results of the study serve as basic input for design flood estimation for small and medium catchments.

4.2 Data used

The rainfall data for a fairly large number of stations in and around the subzone for as long a period as possible have been collected for the purpose of this study and the following data utilised for analysis.

4.2.1 Daily Rainfall Data of 91 ordinary raingauge (ORG) stations - 3 maintained by IMD and 88 maintained by the State Governments of Madhya Pradash, Orissa, Maharashtra, and Andhra Pradesh. Of these 42 stations have 50-90 years~ record while 49 stations have 25-50 years~record. This was necessary in order to cover the areas where raingauge network is very sparse.

4.2.2 Hourly rainfall data of 11 self recording raingauge (SRRG) stations maintained by IMD having 9-18 years record.

4.3 Depth-Duration_Frequency Analysis

4.3.1 Analysis of ORG Data - Isopluvial maps

For each of the 91 ORG stations in and around the subzone, a series of annual maximum one-day rainfall was generated. The 91 station series thus formed were subjected to frequency analysis using Gumbel~s extreme value distributionn for computing one-day rainfall estimates for 25, 50 and 100-year return periods. These daily rainfall estimates (91 * 3) were converted into any 24-hour rainfall estimates by using the conversion factor of 1.15. For each return period, the 24-hour rainfall estimates for 91 stations were plotted on a base map and isopluvials were drawn. The isopluvial maps of 25,50 and 100- year 24-hour rainfall are shown in Plates 9 ,10 & 11. respectively, which can be used to derive 24 hour rainfall estimates for specific return period at any point in the sub zone.

4.3.2. Analysis of SRRG data -

4.3.2.1 Short Duration Ratios

For each of the 11 SRRG stations having at least 9 years record, the hourly rainfall data were subjected to frequency analysis using partial duration series for computing estimaten of t hour T year rainfall for t = 1,3,6,9,12,15,18 and 24-hours and T = 2,5,10,25 and 50-years return periods. These estimates (11*8*5) were converted into ratios with respect to the corresponding 24-hours estimates. Average ratios (8x5) for the subzone as a whole (mean of 11 station ratios) were then computed for each T-year t-hour pair. It was noticed that for a specified duration t, the average ratios beyond T = 5 years were comparable in magnitude. As such the average ratios (8) corresponding to 10-year t-hour rainfall have been recommended to be adopted uniformly for converting 24-hour rainfall into t-hour rainfall. These 8 conversion ratios for t =1, 3, 6, 9, 12, 15, 18 and 24 hours given below were plotted on a graph at Fig. 3, which can be used to derive conversion ratios for any duration t in general, including the intermediate durations (see Table alongside graph).

Rainfall Duration (t) in hours	Conversion ratio = 10 -year t-hour rainfall / 10-year 24-hour rainfall
1	0.320
3	0.500
6	0.635
9	0.730
12	0.800
15	0.864
18	0.917
24	1.000

Any 25, 50 or 100-year 24-hour point rainfall in the subzone as read from isopluvial maps in Plates 9 to 11 can be converted into corresponding 25, 50 or 100-year t-hour rainfall by multiplying with the t-hour ratio as read from the curve in Fig.3.

4.3.2.2 Time Distribution Curves

Based on 151 station-year data of all the 11 SRRG stations, total of 2299 rainstorms of durations ranging from 2 to 24 hours were analysed and grouped stationwise into the following 5 catagories:

1) rainstorms of 2 to 3- hour duration

2) rainstorms of 4 to 6- hour duration

3) rainstorms of 7 to 12- hour duration

4) rainstorms of 13 to 18- hour duration

5) rainstorms of 19 to 24 -hour duration

For each station, 5 different graphs corresponding to each group of rainstorms were prepared by plotting the cumulative percentage of the total storm rainfall against the percentage of the storm duration and the average time distribution curves (11x5)were drawn. Average time distribution curve (5) for the sub-zone as a whole were then drawn by plotting 11 station curve on the same graph and these are shown in Fig 4, which can be used to derive the time distribution co-efficients of storm rainfall in the sub-zone for rain storm of any duration. (see Ann 4.1).

4.3.3 Point to Areal Rainfall Studies

4.3.3.1 For deriving relationship between point rainfall and areal rainfall it is essential to have rainfall observations in a fashion which permits generating a set of co-ordinate points between rainfall magnitude and the area covered. Such relationships in the case of subzones for which flood estimation reports have already been finalised, were derived from the hourly/half hourly rainfall data of raingauge stations maintained specially by RDSO or by the CWC on behalf of Ministry of Surface Transport in various bridge catchments (with known catchment areas) of the respective subzones.

4.3.3.2 In subzone 3(g), neither RDSO nor CWC have observed any bridge data and consequently an alternate method has been developed where S.R.R.G data and ORG. data have been conjunctively made use of to develop graphs between areal rainfall to point rainfall ratios (y-axis) and the area (x-axis) for storm duration of 1, 3, 6, 12 and 24 hours.

4.3.3.3 The location map of SRRGs and ORGs inside the subzone and in the adjoining areas was scanned to select one SRRG which is surrounded by a close network of ORGs within a radius of about 50 kms. SRRG station Kanker, with a network of ORG stations at Keskal, Bhannupartappur, Marmasilli, Ghattasilli, Rudri, Dhamtari and Admabad surrounding it satisfied this requirement. Since ORG data is observed and recorded once everyday at 0830 hours IST,the SRRG data (hourly observations) need to be properly synchronised to permit conjunctive use of the two types of rainfall records.

4.3.3.4 The hourly tabulations of rainfall at SRRG station Kanker were critically examined and rainstorms of 1 hr., 3hr., 6 hr., 12 hr., and 24 hr. were selected such that their temporal spread was confined between 9th hr. (0800 to 0900 hr.) of a day to 8th hour (0700 to 0800 hr) of next day with the condition that the storm rainfall was atleast about 90% of the day's rainfall (i.e. rainfall from 0800 hrs to 0800 hrs of next day). Thus for example in the case of three hour storm at least about 90% of the day's rainfall is recorded within the storm duration (i.e 3 hr.).

4.3.3.5 Corresponding to the short duration rainstorm selected from the SRRG data of Kanker, the daily rainfall data of the surrounding ORG's was picked out. Since a day's rainfall at an ORG station implies the amount of rainfall recorded from 0830 hour of the previous day to 0830 hour of the observational day, the daily rainfall data of the ORGs were collected for the dates on which the 24-hour period (0800 hour to 0800 hour of next day), containing the respective storm durations, ended.

4.3.3.6 The procedure adopted above for selection of short duration rainstorms ensures that during an observational day only the selected rainstorms primarily affects the SRRG location. In order to make the ORG data of the surrounding stations compatible with the storm data, it is assumed that the intensities of rainfall at the SRRG location at Kanker and at any given ORG locations bear the same ratio at all times. (This assumption is not strictly valid). With this assumption the daily rainfall at the ORG stations conforms to the duration ofthe rainstorms.

4.3.3.7 For each selected rainstorm, the storm rainfall ratio with respect to the 24-hour rainfall was computed. The daily rainfall data of ORG stations was then reduced in the same proportion.

4.3.3.8 For each selected rainstorm a map of storm rainfall at the SRRG and the corresponding reduced rainfall amounts at the locations of ORG stations was prepared and analysed by isohytel method, within a radius of 30 kms around the SRRG location, to generate a graph between areal to point rainfall ratios on the Y-axis and the area on the X-axis. Graphs corresponding to rainstorms of 1 hour, 3 hour, 6 hour, 12 hour and 24 hour durations thus obtained are shown in Fig.5 (a) and 5(b) which can be used to derive the percentage areal reduction factors for converting point rainfall of any duration in the subzone into corresponding areal rainfall for any particular size of the small catchment in the subzone (Annexure-4.2)

4.4 Heaviest daily/short duration rainfall records

4.4.1 The statistics of highest ever recorded one-day station rainfall (24-hour rainfall ending 0830 hours of date), exceeding 30 cm., alongwith date of occurrence, in each of the 5 districts covering the subzone 3(g) have been compiled from the ORG data and presented in Annexure 4.3.

4.4.2. Since neither RDSO nor CWC have collected any short duration rainfall data in the bridge catchments of subzone 3(g), special efforts have been made to work out statistics of heaviest rainfall amounts, in durations of 1, 3, 6, 9, 12, 15, 18, and 24 hours (clock hours), recorded at the locations of SRRG stations maintained by IMD in and around the subzone. The archieval of the autographic rainfall records, in an organised fashion, commenced from the year 1969 and, therefore, it has not been possible to include earlier records in respect of stations installed prior to 1969. Also due to backlog in data archieval the autographic records for recent years could not become available. The statistics of heaviest short duration rainfall records based on the available data are presented in Annexure 4.4.

4.5 Procedure for Design Storm Rainfall Estimation

For a specified design storm duration TD hours (time of concentration) for a particular bridge catchment in the sub-zone, the design storm rainfall and its temporal distribution in the catchment can be computed by adopting the following procedure

Step-1 : Locate bridge catchment under study on the 50 year 24-hour isopluvial map in Plate 10 and obtain the 50-year 24-hour point rainfall value in cm. For a catchment covering more than one isopluvial, compute the average point rainfall.

Step-2: Read the conversion ratio for storm duration TD from Fig 3 and multiply the 50- year 24-hour point rainfall in step -1 to obtain 50 year TD hour point rainfall.

Step-3 Read the areal reduction factor corresponding to storm duration TD and the given area of catchment from Fig 5(a) & (b) or Annexure 4.2,and multiply the 50 year TD hour point rainfall in step 2 by this factor to obtain the 50 year TD hour areal rainfall over the catchment

Step- 4 Read the time distribution coefficients for 1, 2........(TD-1) hours correspomding to storm duration on TD from relevent graph in Fig. 4 or Ann-4.1 and multiply the 50-year TD - hours areal rainfall in step-3 by these coefficients to obtain the cumulative depths of 1,2,......(TD-1) hour catchment rainfall.

step-5 Obtain the depths of storm rainfall occuring every hour in the bridge catchment by subtraction of successive cumulative depths of 1,2,...... (TD-1) and TD hours in step-4.

PART-V

DESIGN FLOOD ESTIMATION

5.1. Criteria and Standards in regard to Design Flood of Structures of small and Medium Catchments.

The Khosla Committee of Engineers had recommended a design flood of 50-yr return period for fixing the water way of the bridges. The commitee had also recommended to design the foundation and protection work for larger discharge by increasing the design flood for waterways by 30 % for small catchments up to 500 sq km., 25 to 20 % for medium catchments upto 500 to 5000 sq km. , 20 to 10 % for large catchments upro 5000 to 25000 sq.km. and less than 10 % for very large catchments above 25000 sq km.

Criteria and standards followed for design flood for bridges, cross drainage structures and small dams are given below:

a) Indian Railway Standard Bridges Substrucures and Foudation Code revised in 1985 stipulates that all bridges shall be designed with adequate waterway for design discharge. This shall normally be the computed flood with probable recurrence interval of 50 years however at discreation of Chief Engineer/Chief Bridge Engineer, bridge damage to which is likely to have serve consequences may be designed for flood with a probable recurrenece interval of more than 50 years, while bridges on less important lines of sidings may be designed for floods with a proable recurrence interval of less than 50 years.

b) Indian Road Congress-IRC 5-1985, clause 103 of Section I "General Features of Design" Specifies that the water way of a bridge is to be designed for a maximum flood of 50-yr return period. To provide for adequate margin of safety. The foundation and protection works should be designed for larger discharge. The recommended percentage increase over the design discharge specified in clasue 103 is same as suggested by the committee of Engineers.

c) Indian Standard Code of "Practice for design of cross drainage works-IS: 7784 Part I 1975" recommends that the water way for cross drainage works should be designed for a 25-yr return period flood. To provide adequate margin of safety , the foundation and protection works should be designed for larger discharges. The percentage increse over the design discharge recommended in the code is same as suggested by the committee of Engineers.

d) Central Water Commission's criteria of 1968 specifies that the diversion dams and weirs should be designed for floods of frequency of 50-100 yrs.

e) Indian Standards Guidelines for "Fixing spillway capacity of dams under clauses 3.1.2. and 3.1.3 of IS: 11223-1985" recommends 100-yr return period flood as inflow design flood for small dams having either gross storage of the dam between 0.5 and 10 Mm^3 or hydraulic head between 7.5 m. and 12 m.

5.2 Estimation of Design Flood

To obtain design flood of required return period the effective rainfall for design storm duration is to be applied to the unit hydrograph of a catchment. Stepwise procedure for computing design flood peak and design flood hydrograph for T yr return period by SUH approach is given below:-

a) Computation of Design Flood ..ak

Step-1 Synthetic Unit Hydrograph

Derive the synthetic unit hydrograph as per section 3.3.1 and tabulate 1 hour U.G. ordinates.

Step-2 Design Storm Duration

The duration of storm which causes the maximum discharge in a drainage area is called " Design storm duration (TD)". This has been adopted as 1.1 * Tp in case of sub zone 3(f). The same has been recommended for obtaining design storm duration for catchments in subzone 3(g).

Step-3 Design storm rainfall.

i) Adopt suitable Design storm durartion(td) as explained above.

ii) Obtain design storm rainfall and hourly areal rainfall units vide section 4.6.

iii) Adopt design loss rate as recommended in section 3.4.

iv) Obtain hourly effective rainfall increments by subtrating the design loss rate.

Step-4 Design flood peak:-

(i) Arrange 1 hour effective areal rainfall values against the 1- hour U.G. ordinates such that the maximum value of effective rainfall against the maximum ordinate of U.G., the next lower value of effective rainfall value against the next lower U.G. ordinate and so on upto T_D hour duration.

(ii) Obtain the base flow for the catchment area under study vide section 3.5.

(iii) Obtain total surface runoff by summing the product of unit hydrograph ordinates as tabulated in Step 1 and the effective rainfall values as tabulated in Step 3.(iii).

(iv) Obtain flood peak by adding base flow to total surface runoff as per 3.(ii).

b) Design Flood Hydrograph

For computation of design flood hydrograph, carry out the steps from 1 to 3 and in addition, carry out the following steps.

Step-5 Reverse the sequence of effective rainfall units obtained in Step 4(i) to get the critical sequence of the effective rainfall.

Step-6 Multiply the first 1-hr effective rainfall with the ordinates of U.G. to get the corresponding direct runoff ordinates. Likewise, repeat the procedure with the rest of the hourly effective rainfall values giving a lag of 1-hr to successive direct runoff ordinates.

Step-7 Add the direct runoff ordinates at 1-hr interval to get total direct runoff hydrograph.

Step-8 Add the base flow in Step 4(ii) to the direct runoff ordinates at 1-hr interval in Step-7 to get the 50-yr flood hydrograph.

5.3 Computation of design HFL:

The design engineer has to determine the design High Flood Level corresponding to adopted design flood for the bridges and cross drainage structures under natural and constricted conditions. This elevation is very important in the analysis for foundations, scour, free board, formation levels, hydraulic forces etc.

Stage discharge relationship is represented by stage vs. discharge rating curve of a river at the point of study. The most acceptable method for establishing stage discharge rating curve is based on observed gauges and discharges covering satisfactorily the lower to upper elevation ranges. Stage discharge relation defines the complex interaction of channel characteristics including cross sectional areas, shape, slope and roughness of bed and banks. The permanent stage discharge relation is a straight line or a combination of straight lines on a logarthmic plotting depending on the channel configuration; a single straight line for a single well defined channel and a combination of two straight lines for the main channel with its berm portions. The stage discharge relation may be considered more accurate depending on the reliable and adequate observed gauge and discharge data of the river at the point of study. The gauge dishcarge rating curve so determined may be used for fixing the design HFL corresponding to design flood by extrapolation if necessary.

In the absence of observed gauge and discharge data at the point of study (bridge or cross-drainage structures location), synthetic gauge discharge rating curve has to be constructed by Area-Velocity Method, using the river cross section, slope data and nature of the cross-section. The velocity is computed by the Manning's formula.

Computation of H.F.L. is generally done with the help of Manning's formula in which roughness coefficient ('N') is an important factor affecting the discharge of a river or Nalla. The value of N is highly variable and depends on a number of factors. viz, surface roughness, vegetation, channel irregularity, channel alignments, silting and scouring, obstruction, size and shape of channel, stage and discharge, seasonal change and suspended material and bed load.

The various values of the roughness co-efficient for different types of channel are given in Table 5.6 "Open Channel Hydraulics" by Ven-Te-Chow.

The above procedure pertains to determination of design HFL corresponding to design flood of a river under natural conditions. With the type of structures in position there will generally be a constriction in the waterway. The effect of the constriction by way of raising the design HFL under natural conditions has to be evaluated in the water elevations to arrive at the revised design HFL under constricted conditions. The difference between upstream and downstream water levels corresponding to design flood due to constriction in the waterway may be termed as afflux. There are hydraulic methods for working out the final design HFL due to constriction by the structure. The weir formula or orifice formula of hydraulics is generally used depending on the upstream and downstream depths to estimate the revised design HFL under constricted conditions.

Sometimes it happens that the cross section of river or nalla on the downstream side of a cross drainage structure may be narrow than the cross section at the location of a crossing site. The flood levels at the proposed structure may also be affected by the high flood levels in the main river joining downstream in proximity of the stream. In such cases, there will be backwater effect due to the narrow gorge of the river as the design flood for the crossing site will not be able to pass through the narrow gorge in the downstream and hene there will be heading up of water in its upstream side which ultimately affects HFL of the river at the crossing site. In the latter case the tributary/stream on which the bridge is located will be under the influence of the backwater effect of the main stream joining downstream. In such cases back water study may be carried out.

In the absence of any observed levels of water profiles for computing hydraulic gradient, bed gradient of nalla shall be considered, after verifying that local depressions are not accounted for and bed gradient is computed on a reasonable length of atleast 300m. upstream and downstream of the crossing site.

If the crossing site is located across the river/drainage in the unfavourable reach i.e. not complying with the usual requirements of gauge site, the design flood elevation may be computed in a straight reach downstream of the crossing and design flood elevation may be worked out by undertaking backwater studies.

PART VI

ASSUMPTIONS, LIMITATIONS AND CONCLUSIONS

6.1.0 Assumptions:

6.1.1 It is assumed that 50-year return period storm rainfall produces 50-year flood. Similar is the case for 25-year flood and 100-year flood.

6.1.2 Due to nonavailability of rainfall-runoff data for 3(g) subzone, the SUG equations developed for 3(f) subzone have been assumed to hold good for 3(g) subzone. Similarly model values of loss rate and base flow recommended for 3(f) subzone have been considered for 3(g) subzone.

6.2.0 Limitations:

6.2.1 As explained in para 6.1.2 the SUG equations, loss rate and base flow values adopted for 3(f) subzone have been considered for 3(g) subzone. It is desirable to collect data of suitable catchments in 3(g) subzone and develop seprate relationships for more reliable results.

6.2.2 The method is applicable for reasonably free catchments with interception, if any, limited to 20% of the total catchment. For calculating the discharge, the total area of the catchment has to be considered.

6.2.3 The approach developed mostly covers the catchment with flat to moderate slopes.

6.3.0 Conclusions:

6.3.1 The methodology for e stimating the design flood of 50-yr return period is recommended for adoption. This also holds good for 25-yr flood and 100-yr flood.

6.3.2 The report recommends the adoption of design flood of 25-yr and 100-yr return periods taking in to account the type and relative importance of the structures.

6.3.3 The report is applicable for the catchment areas ranging from 25 sq km to 1000 sq km. Further, the report may be used for large catchments upto 5000 sq km based on sound judgement and considering the data of neighbouring catchments also. However, individual site conditions may necesstiate special site study. Engineer-in-charge at site is advised to take a pragmatic view while deciding the design discharge of a bridge.

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ANNEXURE - 1.1

SUB ZONE 3(g) UNGAUGED CATCHMENT

COMPUTATION OF STATISTICAL SLOPE

CA = 325.00 sq.km , L = 31.37 Km.

Sl.NO	REDUCED DISTANCE. (from point of study.) (Km)	REDUCED LEVEL (m)	LENGTH OF EACH SEGMENT li (Km)	HEIGHT ABOVE DATUM (m)	(Col 5/c (m/km)	-/si	li/-/s
1	2	3	4	5	6	7	8
1	0.000	333.760	0.000	0.000	0.000	0.000	0.00
2	0.800	335.280	0.800	1.520	1.900	1.378	0.58
3	16.090	343.470	15.290	8.190	0.536	0.735	20.80
4	17.700	350.520	1.610	7.050	4.379	2.093	0.77
5	25.740	365.760	8.040	15.240	1.896	1.375	5.85
6	28.160	381.000	2.420	15.240	6.298	2.510	0.96
7	30.570	396.240	2.410	15.240	6.324	2.514	0.96
8	31.370	411.480	0.800	15.240	19.050	4.365	0.18
						total	30.10

$$S = \frac{(L)^2}{\left(\text{Total } \frac{li}{\sqrt{si}}\right)} = \left(\frac{31.370}{30.100}\right)^2 = 1.090 \text{ m/km}$$

ANNEXURE - 1.2

COMPUTATION OF FLOOD HYDROGRAPH

UNGAUGED CATCHMENT

SUB-ZONE : 3(g)

TIME IN HOURS	S.U.H. ORDINATES IN CUMECS	RAINFALL EXCESS IN CMS 0.03	0.90	2.99	8.41	1.95	0.19	TOTAL D.S.R.O. IN CUMECS	BASE FLOW IN CUMECS	TOTAL FLOW IN CUMECS
		DIRECT RUNOFF (CUMECS)								
1	2	3	4	5	6	7	8	9	10	11
0	0.00	0.00						0.00	19.50	19.50
1	7.00	0.21	0.00					0.21	19.50	19.71
2	17.00	0.51	6.30	0.00				6.81	19.50	26.31
3	38.00	1.14	15.30	20.93	0.00			37.37	19.50	56.87
4	80.00	2.40	34.20	50.83	58.87	0.00		146.30	19.50	165.80
5	124.00	3.72	72.00	113.62	142.97	13.65	0.00	345.96	19.50	365.46
6	152.75	4.58	111.60	239.20	319.58	33.15	1.33	709.44	19.50	728.94
7	147.93	4.44	137.48	370.76	672.80	74.10	3.23	1262.80	19.50	1282.30
8	116.50	3.49	133.14	456.72	1042.84	156.00	7.22	1799.41	19.50	1818.91
9	74.00	2.22	104.85	442.31	1284.63	241.80	15.20	2091.01	19.50	2110.51
10	43.50	1.31	66.60	348.34	1244.09	297.86	23.56	1981.75	19.50	2001.25
11	28.50	0.86	39.15	221.26	979.77	288.46	29.02	1558.52	19.50	1578.02
12	19.50	0.59	25.65	130.07	622.34	227.17	28.11	1033.92	19.50	1053.42
13	14.80	0.44	17.55	85.22	365.84	144.30	22.14	635.48	19.50	654.98
14	11.50	0.35	13.32	58.31	239.69	84.83	14.06	410.54	19.50	430.04
15	9.00	0.27	10.35	44.25	164.00	55.57	8.27	282.71	19.50	302.21
16	7.00	0.21	8.10	34.39	124.47	38.03	5.42	210.60	19.50	230.10
17	5.00	0.15	6.30	26.91	96.72	28.86	3.71	162.64	19.50	182.14
18	3.50	0.11	4.50	20.93	75.69	22.43	2.81	126.46	19.50	145.96
19	2.00	0.06	3.15	14.95	58.87	17.55	2.19	96.77	19.50	116.27
20	1.30	0.04	1.80	10.47	42.05	13.65	1.71	69.71	19.50	89.21
21	0.00	0.00	1.17	5.98	29.44	9.75	1.33	47.67	19.50	67.17
22	0.00	0.00	0.00	3.89	16.82	6.83	0.95	28.48	19.50	47.98
23			0.00	0.00	10.93	3.90	0.67	15.50	19.50	35.00
24				0.00	0.00	2.54	0.38	2.92	19.50	22.42
25					0.00	0.00	0.25	0.25	19.50	19.75
26						0.00	0.00	0.00	19.50	19.50
							0.00	0.00	19.50	19.50
										0.00

ANNEXURE 2.1

LIST OF HYDRO-METEOROLOGICAL SUB-ZONE

SUBZONE	NAME OF SUBZONE (designated earlier)	Name of sub-zone (designated now)	River Basins included in the subzone
1(a)	Luni basin & thar (Luni & other rivers of Rajasthan and Kutch)	Luni	Luni river. Thar (Luni & Other rivers of Rajasthan and Kutch and Banas river)
1(b)	Chambal Basin	Chambal	Chambal river
1(c)	Betwa Basin & Other Tributaries	Betwa	Sind, Betwa and Ken rivers and other South Tributaries of Yamuna
1(d)	Sone Basin and Right Bank Tributaries.	Sona	Sone and Tons rivers and other South Bank Tributaries of Ganga.
1(e)	Punjab Plains including parts of Indus, Yamuna, Ganga and Ramganga Basins.	Upper Indo-Ganga Plains	Lower portion of indus Ghaggar Sahibi Yamuna, Ganga and Upper portion of Sirsa, Ramganga, Gomti and Sai rivers.
1(f)	Ganga Plains including Gomti, Ghagra, Gandak, Kosi and other.	Middle Ganga Plains	Middle Portion of Ganga, Lower portion of Gomti, Ghagra, Gandak, Kosi and middle portion of Mahanadi
1(g)	Lower Ganga Plains including Subarnarekha and other east-flowing rivers between Ganga and Baitarani.	Lower Ganga Plains	Lower portion of Ganga, Hoogli river system and Subarnarekha.
2(a)	North Brahmaputra Basin	North Brahmaputra	North Bank Tributaries of Brahmaputra river and Balason river.
2(b)	South Brahmaputra Basin	South Brahmaputra	South Bank Tributaries of Brahmaputra river.
2(c)	Barak and others	Barak	Barak, Kalden and Manipur rivers.
3(a)	Mahi, including the dhadhar, Sabarmati and rivers of Saurashtra.	Mahi and Sabarmati	Mahi and Sabarmati including Rupen & Mechha Bandar, Ozat Shetaranji rivers of Kathiawad Peninsula.

3(b)	Lower Narmada and Tapi Basin	Lower Narmada & Tapi	Lower portion of Narmada, Tapi and Dhadhar rivers.
3(c)	Upper Narmada and Tapi Basin	Upper Narmada & Tapi	Upper portion of Narmada and Tapi rivers.
3(d)	Mahanadi Basin including Brahmani and Baitarani rivers.	Mahanadi	Mahanadi, Baitarani and Brahmani rivers
3(e)	Upper Godarvari Basin	Upper Godavari	Upper portion of Godavari Basin.
3(f)	Lower Godavari Basin except coastal region	Lower Godavari	Lower portion of Godavari Basin.
3(g)	Indravati Basin	Indravati	Indravati river.
3(h)	Krishna subzone including penner Basin except coastal region	Krishna	Krishna & Pennner rivers except coastal region.
3(i)	Kaveri & East flowing rivers aexcekpt coastal region	kaveri	Kaveri, Palar and Ponnaiyar rivers (except coastal region).
4(a)	Circars including east flowing rivers between Mahanadi and Godavari	Upper Eastern Coast	East flowing coastal rivers between Deltas of Mahanadi & Godavari rivers.
4(b)	Coromandal Coast including east flowing rivers between Godavari and Kaveri	Lower Eastern Coast	East flowing coastal rivers, Manimukta, South Pennar, Cheyyar, Palar, North Pennar, Munneru, Palleru, Cundalakama and Krishna Delta.
4(c)	Sandy Coroman Belt (east flowing rivers between Cauvery & Kanyakumari).	South Eastern Coast	East flowing coastal rivers, Manimuther, Vaigani, Arjuna, Tamraparni.
5(a)	Konkan coast (west flowing river between Tapi and Panaji)	Konkan Coast	West flowing coastal rivers between Tapi and Maudavi rivers
5(b)	Malabar Coast (west flowing rivers between Kanyakumari and Panaji)	Malabar Coast	West flowing coastal rivers between Mandavi and Kanyakumari
6	Andaman and Nicobar	Andaman & Nicobar	
7	J & K Kumaon Hills (indus Basin).	Western Himalayas	Jhelum, Upper portion of Indus, Ravi and Beas rivers

ANNEXURE – 4.1

TIME DISTRIBUTION CO-EFFICIENTS OF CUMULATIVE HOURLY RAINFALL – SUBZONE 3(a)

INTER-MEDIATE HOURS	DESIGN STORM DURATION (HOURS)																								INTER-MEDIATE HOURS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1		0.87	0.76	0.63	0.57	0.51	0.47	0.43	0.41	0.39	0.36	0.34	0.28	0.27	0.26	0.24	0.23	0.22	0.19	0.18	0.17	0.16	0.15	0.14	1
2		1.00	0.94	0.84	0.78	0.71	0.66	0.62	0.58	0.55	0.54	0.51	0.48	0.41	0.39	0.37	0.35	0.34	0.30	0.29	0.27	0.25	0.25	0.24	2
3			1.00	0.96	0.90	0.85	0.77	0.73	0.70	0.67	0.54	0.62	0.54	0.52	0.50	0.48	0.46	0.44	0.38	0.37	0.34	0.33	0.32	0.31	3
4				1.00	0.97	0.93	0.86	0.82	0.78	0.75	0.72	0.70	0.63	0.60	0.58	0.56	0.54	0.52	0.44	0.43	0.42	0.41	0.40	0.38	4
5					1.00	0.97	0.93	0.95	0.95	0.92	0.78	0.76	0.70	0.67	0.55	0.56	0.51	0.60	0.51	0.49	0.48	0.46	0.45	0.44	5
6						1.00	0.98	0.95	0.91	0.97	0.94	0.92	0.76	0.74	0.71	0.69	0.57	0.55	0.56	0.55	0.53	0.53	0.50	0.49	6
7							1.00	0.98	0.95	0.93	0.99	0.96	0.91	0.79	0.77	0.75	0.72	0.70	0.61	0.60	0.58	0.56	0.54	0.53	7
8								1.00	0.98	0.96	0.93	0.90	0.88	0.94	0.91	0.79	0.77	0.75	0.64	0.63	0.61	0.60	0.58	0.57	8
9									1.00	0.98	0.96	0.94	0.90	0.88	0.95	0.93	0.91	0.79	0.70	0.68	0.66	0.65	0.63	0.52	9
10										1.00	0.98	0.97	0.93	0.91	0.89	0.96	0.94	0.83	0.74	0.72	0.70	0.58	0.55	0.55	10
11											1.00	0.98	0.96	0.94	0.92	0.89	0.98	0.85	0.78	0.75	0.74	0.72	0.70	0.53	11
12												1.00	0.98	0.96	0.94	0.92	0.90	0.89	0.81	0.79	0.77	0.75	0.73	0.72	12
13													1.00	0.98	0.96	0.95	0.93	0.91	0.84	0.82	0.90	0.79	0.77	0.75	13
14														1.00	0.98	0.97	0.95	0.93	0.87	0.85	0.93	0.81	0.80	0.78	14
15															1.00	0.98	0.97	0.95	0.90	0.88	0.87	0.84	0.82	0.80	15
16																1.00	0.98	0.97	0.93	0.91	0.89	0.89	0.85	0.82	16
17																	1.00	0.98	0.95	0.93	0.91	0.89	0.88	0.87	17
18																		1.00	0.98	0.96	0.94	0.92	0.91	0.90	18
19																			1.00	0.98	0.96	0.94	0.93	0.92	19
20																				1.00	0.98	0.96	0.95	0.94	20
21																					1.00	0.98	0.96	0.95	21
22																						1.00	0.98	0.96	22
23																							1.00	0.98	23
24																								1.00	24

*10

ANNEXURE - 4.2

AREAL REDUCTION FACTORS (%) FOR POINT TO AREAL RAINFALL - SUBZONE 3(g)

CATCHMENT AREA (Sq.Km.)	DESIGN STORM DURATION (HOURS)																								CATCHMENT AREA (Sq.Km.)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0
50	94.00	94.75	95.50	96.00	96.50	97.00	97.17	97.34	97.51	97.68	97.85	98.00	98.09	98.16	98.25	98.33	98.41	98.50	98.58	98.66	98.75	98.83	98.91	99.00	50
100	89.00	89.75	91.50	92.33	93.15	94.00	94.33	94.66	94.99	95.32	95.65	96.00	96.16	96.33	96.49	96.66	96.93	97.00	97.16	97.33	97.49	97.66	97.94	98.00	100
150	84.00	86.00	88.00	89.33	90.66	92.00	92.33	92.66	92.99	93.32	93.65	94.00	94.25	94.50	94.75	95.00	95.25	95.50	95.75	96.00	96.25	96.50	96.75	97.00	150
200	80.00	82.50	85.00	86.67	88.34	90.00	90.33	90.66	90.99	91.32	91.65	92.00	92.33	92.66	93.00	93.33	93.66	94.00	94.33	94.66	95.00	95.33	95.66	96.00	200
250	76.50	79.50	82.50	84.33	86.16	88.00	88.33	88.66	88.99	89.32	89.65	90.00	90.46	90.92	91.38	91.84	92.30	92.76	93.22	93.68	94.14	94.60	95.06	95.50	250
300	73.00	76.75	80.50	82.50	84.50	86.50	86.83	87.16	87.49	87.82	88.15	88.50	89.00	89.50	90.00	90.50	91.00	91.50	92.00	92.50	93.00	93.50	94.00	94.50	300
350			78.00	80.50	83.00	85.50	85.75	86.00	86.25	86.50	86.75	87.00	87.54	88.08	88.62	89.17	89.71	90.25	90.79	91.34	91.88	92.42	92.96	93.50	350
400			76.50	79.00	81.50	84.00	84.25	84.50	84.75	85.00	85.25	85.50	86.08	86.66	87.25	87.83	88.41	89.00	89.58	90.16	90.75	91.33	91.92	92.50	400
450			75.00	77.67	80.34	83.00	83.17	83.34	83.51	83.68	83.85	84.00	84.67	85.34	86.00	86.67	87.34	88.00	88.67	89.34	90.00	90.67	91.34	92.00	450
500			74.00	76.67	79.34	82.00	82.17	82.34	82.51	82.68	82.85	83.00	83.67	84.34	85.00	85.67	86.34	87.00	87.67	88.34	89.00	89.67	90.34	91.00	500
600												81.00	81.71	82.42	83.13	83.83	84.54	85.25	85.95	86.66	87.37	88.08	88.79	89.50	600
700												79.00	79.79	80.58	81.37	82.17	82.16	83.75	84.54	85.34	86.12	86.91	87.70	88.50	700
800												77.00	77.83	78.66	79.50	80.33	81.16	82.00	82.83	83.66	84.50	85.33	86.16	87.00	800
900												75.50	76.37	77.25	78.13	79.00	79.87	80.75	81.62	82.49	83.37	84.24	85.12	86.00	900
1000												74.00	74.87	75.75	76.62	77.50	78.37	79.25	80.12	81.00	81.87	82.75	83.62	84.50	1000
1100												72.50	73.42	74.34	75.25	76.17	77.09	78.00	78.92	79.84	80.75	81.67	82.59	83.50	1100
1200												71.00	71.96	72.92	73.88	74.84	75.80	76.75	77.71	78.67	79.62	80.58	81.54	82.50	1200
1300																								81.50	1300
1400																								80.50	1400
1500																								79.50	1500
2000																								76.00	2000

sjp

ANNEXURE-4

HEAVIEST DAILY RAINFALL RECORDED IN SUBZONE 3(g).

District	Station	Heaviest rainfall $\geq$ 30 cm	Date of occurrence.
MADHYA PRADESH STATE			
Durg	1. Dongarhgarh	35.9	01.08.1959
	2. Ambagarh Chowki	31.1	19.08.1939
	3. Khapari	30.6	19.08.1939
	4. Khara	30.1	12.08.1942
Bastar	5. Antagarh	30.8	30.06.1959
	6. Kanker	30.5	05.08.1911
MAHARASHTRA STATE			
Chanderpur	7. Ghorejheri	40.0	19.07.1959
	8. Ahiri	31.9	14.08.1953
	9. Garmusi	31.2	13.08.1949
	10. Sindwahi	31.2	13.08.1949
ORISSA STATE			
Koraput	11. Potangi	54.6	14.10.1931
	12. Koraput	33.7	25.06.1914
	13. Jeypore	32.7	03.08.1910
	14. Malkangiri	30.6	17.06.1907
Kalahandi	15. Bhavanipatna	31.1	02.07.1930

STATISTICS OF HEAVIEST RAINFALL RECORDED IN DURATIONS OF 1, 3, 6, 9, 12,15,18and 24 HOURS AT SRRG STATIONS INSIDE & SURROUNDING SUBZONE 3 (c).

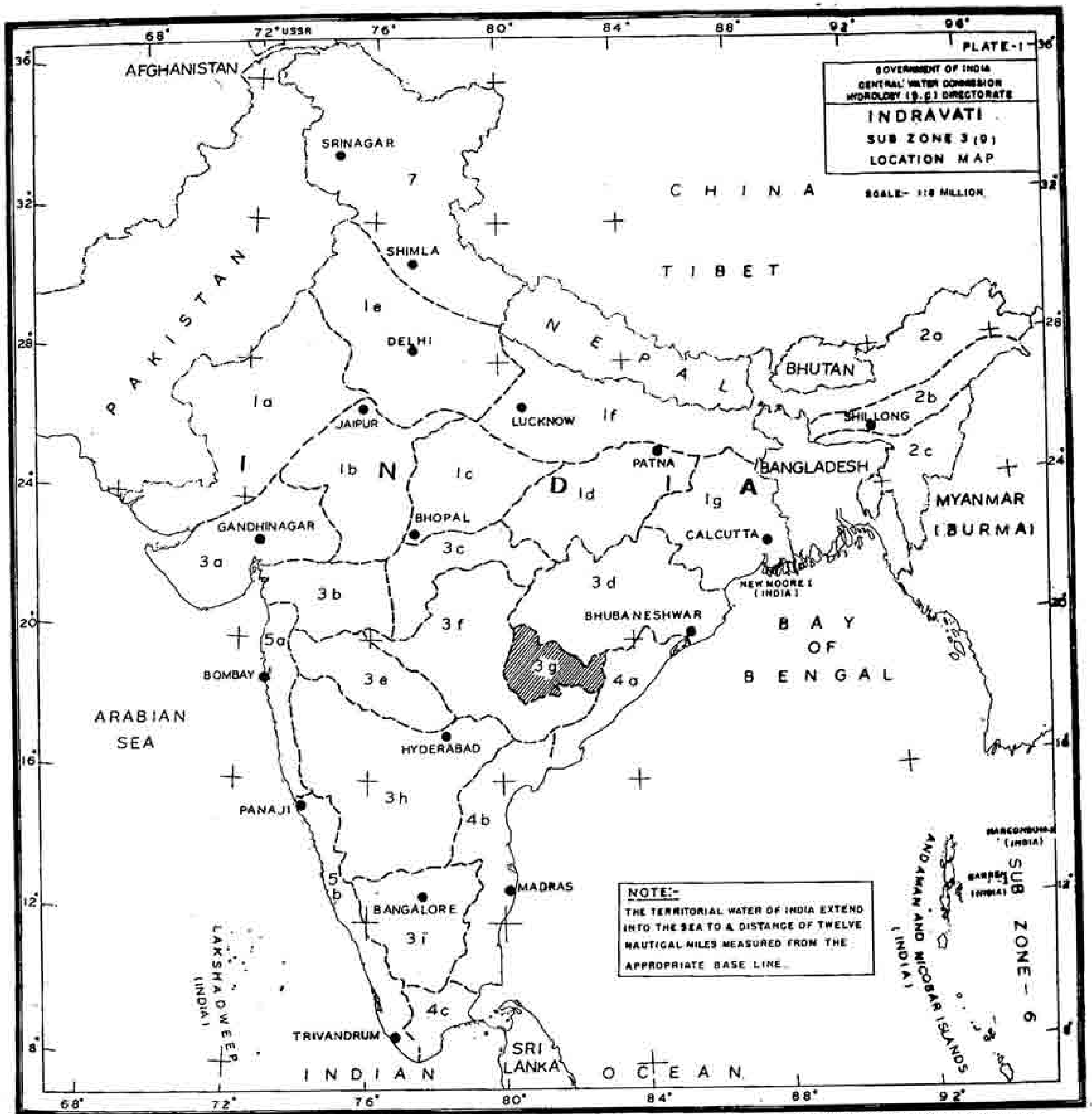
Station	* Period of record		Heaviest rainfall and time of its occurrence.											
			1-hr storm			3-hr storm			6-hr storm			9-hr storm		
	From	To	Rainfall Amount. (mm)	Time & Date From Hr.mt.	Time & Date To hr. mt.	Rainfall Amount. (mm)	Time & Date From Hr.mt.	Time & Date To Hr.mt.	Rainfall Amount. (mm)	Time & Date From Hr.mt.	Time & Date To Hr.mt.	Rainfall Amount. (mm)	Time & Date From Hr.mt.	Time & Date To Hr.mt.
Kanker	1969	1980	75.3	23 00 26.6.74	24.00 26.6.74	114.7	0200 18.9.80	0500 18.9.80	165.2	1900 16.9.69	0100 17.9.69	171.4	1900 16.9.69	0400 17.9.69
Bramhapuri	1970	1985	70.0	16 00 4.7.76	17 00 4.7.76	107.8	0200 28.6.75	0500 28.6.75	150.8	0300 28.6.75	0900 28.6.75	202.0	0200 28.6.75	1100 28.6.75
Hanamkonda	1972	1986	99.0	0200 22.6.81	0300 22.6.81	177.0	0100 22.6.81	0400 22.6.81	230.5	2300 21.6.81	0500 22.6.81	231.5	2300 21.6.81	0800 22.6.81
[illegible]anagundam	1969	1986	95.0	0500 24.10.73	0600 24.10.73	168.0	1700 5.10.83	2000 5.10.83	175.0	1500 5.10.83	2100 5.10.83	212.7	2100 23.10.73	0600 24.10.73
Jagdalpur $	1969	1986	80.0	1100 7.2.83	1200 7.2.83	80.0	1100 7.2.83	1400 7.2.83	105.2	2200 19.7.76	0400 20.7.76	129.7	0300 30.6.72	1200 30.6.72
Chandarpur	1969	1986	90.0	2300 [illegible].77	2400 [illegible].77	110.0	0100 13.8.82	0400 13.8.82	120.0	2300 12.8.82	0500 13.8.82	198.6	2300 12.8.86	0800 13.8.86
Paralkote $	1970	1986	75.0	0000 10.6.79	1000 10.6.79	115.5	0800 10.6.78	1100 10.6.78	163.7	0400 2.8.79	1000 2.8.79	177.0	2100 19.7.76	0600 20.7.76
Bhopalpatnam $	1973	1983	61.5	2100 8.8.74	2200 8.8.74	145.5	1900 8.8.74	2200 8.8.74	167.3	1900 8.8.74	0100 9.8.74	173.1	1800 8.8.74	0300 9.8.74
Sukma	1973	1986	60.5	0000 2.9.76	0100 2.9.76	110.0	0700 26.6.75	1000 26.6.75	135.7	0500 26.6.75	1100 26.6.75	140.5	0200 26.6.75	1100 26.6.75
Khijrawan	1969	1986	56.0	2100 5.6.70	2200 5.6.70	119.0	0800 20.7.76	1100 20.7.76	177.3	0500 20.7.76	1100 20.7.76	193.2	0200 20.7.76	1100 20.7.76
Titlagarh	1969	1979	80.0	0300 8.7.79	0400 8.7.79	165.9	0200 8.7.79	0500 8.7.79	252.5	0200 8.7.79	0800 8.7.79	250.3	0100 8.7.79	1000 8.7.79

* within the indicated periods there are some data gaps

$ stations inside the [illegible]

ANNEXURE - 4.4

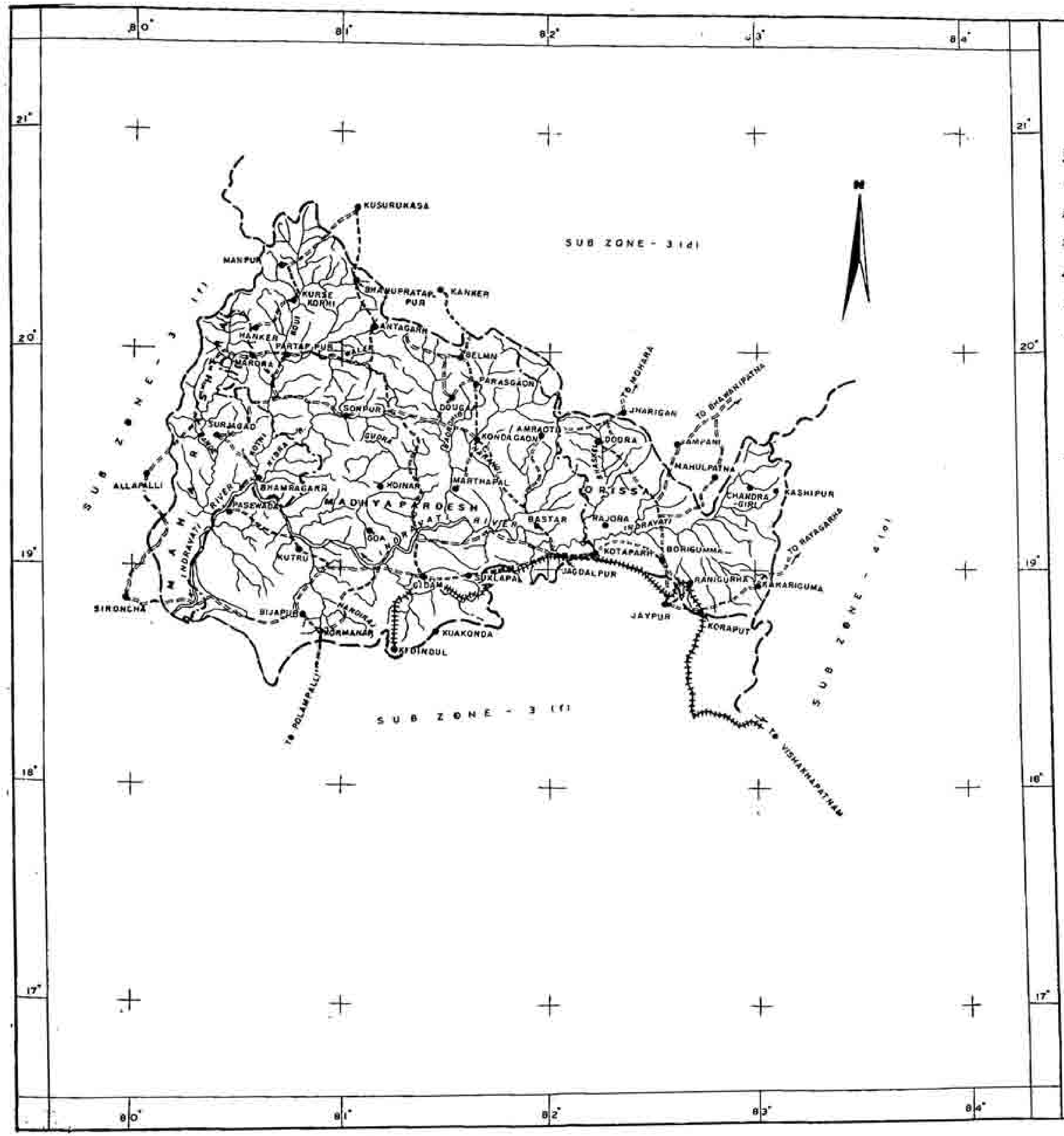
Station	* Period of record		Heaviest rainfall and time of its occurrence. @											
			12-hr storm			15-hr storm			18-hr storm			24-hr storm		
	From	To	Rainfall Amount. (mm)	Time & Date From Hr.mt.	Time & Date To Hr.mt.	Rainfall Amount. (mm)	Time & Date From Hr.mt.	Time & Date To Hr.mt.	Rainfall Amount. (mm)	Time & Date From Hr.mt.	Time & Date To Hr.mt.	Rainfall Amount. (mm)	Time & Date From Hr.mt.	Time & Date To Hr.mt.
Kanker	1969	1980	176.0	2200 17.9.80	1000 18.9.80	191.9	2000 17.9.80	1100 18.9.80	214.2	1600 17.9.80	1000 18.9.80	235.4	1500 17.9.80	1500 18.9.80
Brahmapuri	1970	1985	221.3	2100 27.6.75	0900 28.6.75	259.5	2000 27.6.75	1100 28.6.75	279.7	1700 27.6.75	1100 28.6.75	295.0	1700 27.6.75	1700 28.6.75
Hanamkonda	1972	1986	231.5	2300 21.6.81	1100 22.6.81	231.5	2300 21.6.81	1400 22.6.81	231.5	2300 21.6.81	1700 22.6.81	236.3	2300 21.6.81	2300 22.6.81
Ramagundam	1969	1986	217.2	2000 23.10.73	0800 24.10.73	217.2	2000 23.10.73	1100 24.10.73	231.2	2000 23.10.73	1400 24.10.73	237.6	2000 23.10.73	2000 24.1(
Jagdalpur $	1969	1986	179.0	1500 25.6.83	0300 26.6.83	190.4	1400 25.6.83	0500 26.6.83	196.4	1400 25.6.83	0800 26.6.83	198.5	1400 25.6.83	1400 26.6.83
Chanderpur	1969	1986	228.5	1300 13.8.86	0100 14.8.86	278.5	0000 13.8.86	1500 13.8.86	326.3	2200 12.8.86	1600 13.8.86	417.5	0000 13.8.86	2400 13.8.86
Paralkote $	1970	1986	223.5	2100 19.7.76	0900 20.7.76	254.0	2100 19.7.76	1200 20.7.76	298.2	2100 19.7.76	1500 20.7.76	316.2	1500 19.7.76	1500 20.7.76
Bhopalpatnam $	1973	1983	196.5	1900 8.8.74	0700 9.8.74	202.3	1600 8.8.74	0700 9.9.74	217.7	0100 20.7.76	1900 20.7.76	237.6	2300 19.7.76	2300 20.7.76
Sukma	1973	1986	144.9	0500 26.6.75	1700 26.6.75	160.5	0600 26.6.75	2100 26.6.75	169.3	0300 26.6.75	2100 26.6.75	197.3	0400 26.6.75	0400 27.6.75
Khijravan	1969	1986	197.0	2300 19.7.76	1100 20.7.76	205.2	2000 19.7.76	1100 20.7.76	213.5	1700 19.7.76	1100 20.7.76	280.0	1100 19.7.76	1100 20.7.76
Titlagarh	1969	1979	260.7	2200 7.7.79	1000 8.7.79	260.7	2200 7.7.79	1300 8.7.79	260.7	2200 7.7.79	1600 8.7.79	260.7	1000 7.7.79	1000 8.7.79



NOTES:-
I) BASED UPON SURVEY OF INDIA MAP WITH THE PERMISSION OF THE SURVEYOR GENERAL OF INDIA.
II) RESPONSIBILITY FOR THE CORRECTNESS OF INTERNAL DETAILS SHOWN ON THE MAPS RESTS WITH THE PUBLISHER.

S.N. MALHOTRA

PLATE - 2.



REFERENCES

1. SUB ZONE BOUNDARY
2. STATE BOUNDARY
3. ROADS
4. IMPORTANT TOWNS
5. RIVER AND IT'S TRIBUTARIES
6. RAILWAYS

NOTES

1. PHYSICAL ATRIBUTES OF THIS MAP BASED ON TO TOPO SHEET NO'S _ 44_NE AND 44-NF.
2. NAME OF THE TOWNS ARE AS PER INDIAN BRADSHAW_ 1982. EDITION.

CATCHMENT AREA = 41290 Sq. Km.
SAY : 41300 Sq. Km.

LOCATION OF UNGAUGED CATCHMENT
LONG. _ 80°_ 48'- 00"
LATI. _ 20°_ 25'_ 00"

SCALE

KMS. 10 5 0 10 20 30 40 50 60 70 80 KMS.

MILES 10 5 0 10 20 30 40 50

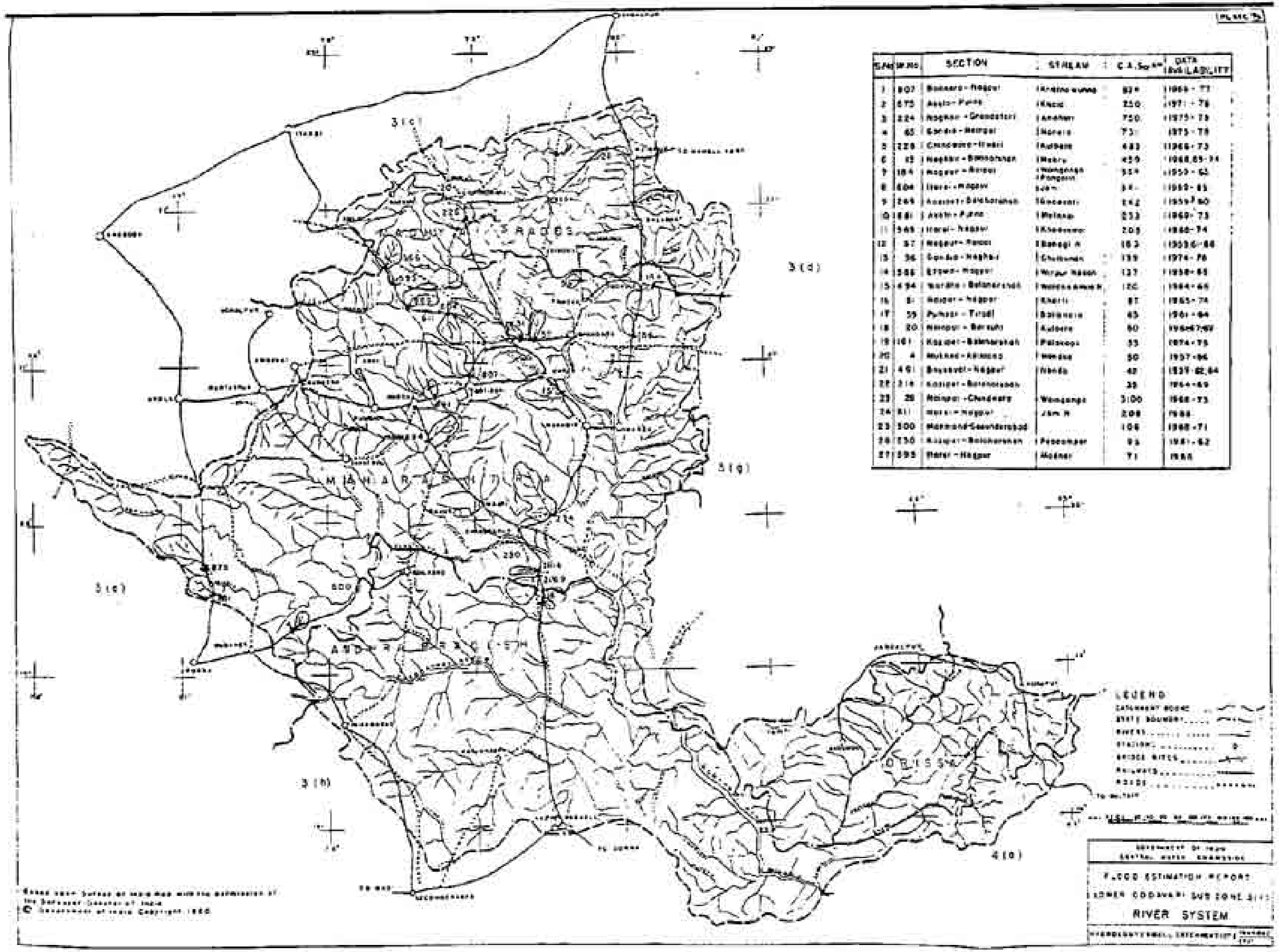
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE.

INDRAVATI BASIN
SUB ZONE- 3 (g).
RIVER SYSTEM & LOCATION OF ROADS AND RAILWAYS.

DRAWN _ S. N. MALHOTRA L. P. NAUTIYAL.	CHECKED. K. K. AICH

PLATE 3

Sl.No.	Br.No.	SECTION	STREAM	C.A. Sq.km	DATA AVAILABILITY
1	807	Bobnara - Nagpur	[illegible]	834	1966 - 77
2	675	Asola - Purna	[illegible]	250	1971 - 76
3	224	Nagpur - Grandstori	Andhari	750	1975 - 79
4	65	Gondia - Nagpur	[illegible]	73	1975 - 79
5	228	Chandrapur - Itwari	[illegible]	483	1966 - 73
6	12	Nagpur - [illegible]	[illegible]	459	1968,69 - 74
7	184	Nagpur - [illegible]	Wainganga Pangoli	354	1959 - 62
8	604	Itarsi - Nagpur	Jam	34-	1959 - 65
9	249	Kazipet - Balharshah	[illegible]	242	1959,60
10	681	Asola - Purna	[illegible]	233	1969 - 73
11	545	Itarsi - Nagpur	[illegible]	205	1968 - 74
12	57	Nagpur - [illegible]	[illegible]	183	1959,66 - 68
13	36	Gondia - Nagbhir	[illegible]	159	1974 - 76
14	586	[illegible] - Nagpur	[illegible]	137	1958 - 65
15	494	Wardha - Balharshah	[illegible]	120	1964 - 65
16	51	Nagpur - Nagpur	Khairi	87	1965 - 74
17	59	Purna - Tirodi	[illegible]	65	1961 - 64
18	20	Nagpur - [illegible]	[illegible]	60	1964,67,69
19	161	Kazipet - Balharshah	[illegible]	55	1974 - 75
20	4	Mudkhed - Adilabad	[illegible]	50	1957 - 66
21	461	Bhusawal - Nagpur	Wardha	47	1939 - 62,64
22	218	Kazipet - Balharshah		35	1964 - 69
23	28	Nagpur - Chandrapur	Wainganga	3100	1968 - 73
24	811	Itarsi - Nagpur	Jam R	208	1966
25	300	Manmad - Secunderabad		106	1968 - 71
26	230	Kazipet - Balharshah	[illegible]	95	1961 - 62
27	595	Itarsi - Nagpur	[illegible]	71	1966



Based upon Survey of India map with the permission of the Surveyor General of India
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GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION

FLOOD ESTIMATION REPORT
LOWER GODAVARI SUB ZONE 3(f)
RIVER SYSTEM

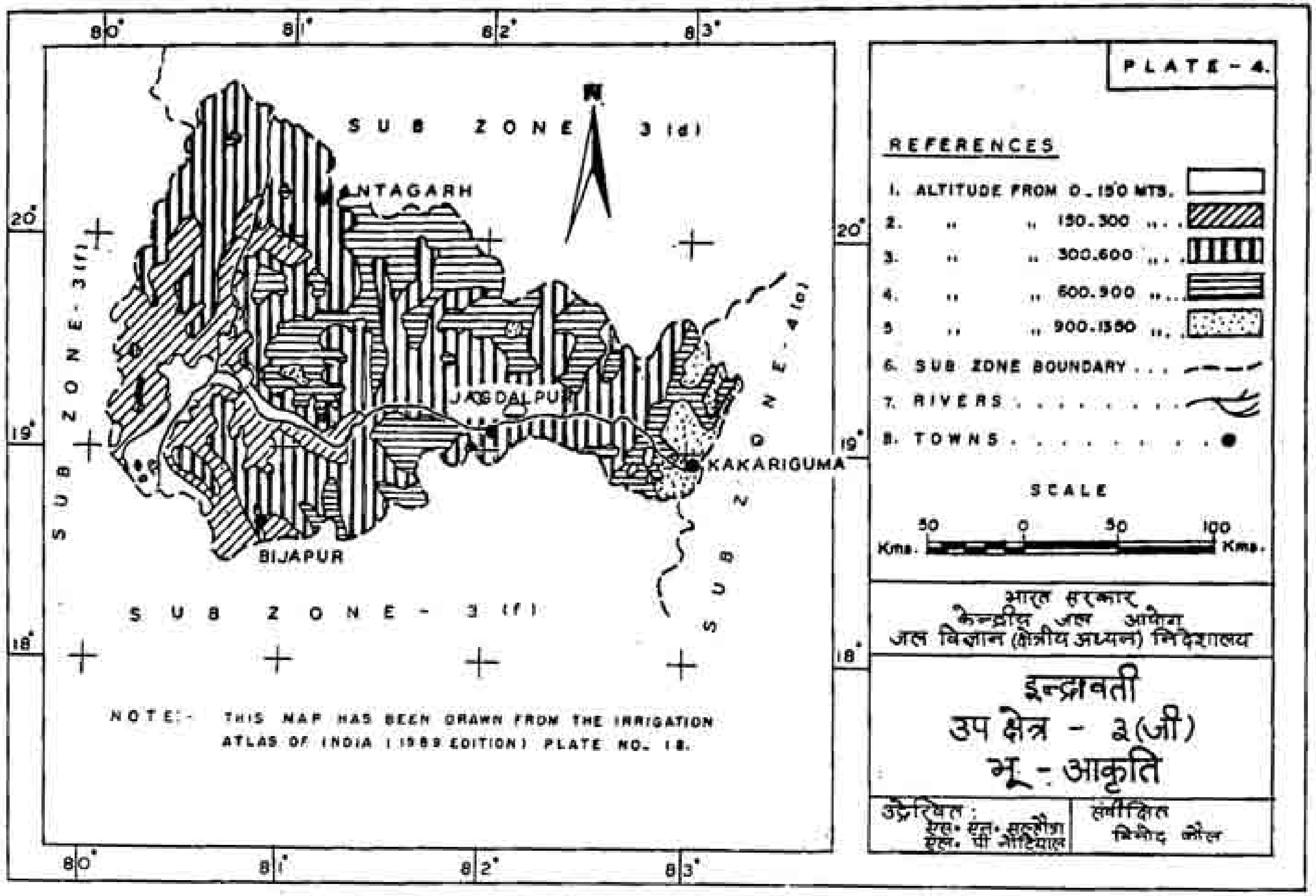


PLATE - 4.
SUB ZONE 3 (d)
SUB ZONE - 3 (f)
SUB ZONE - 4 (a)
N
ANTAGARH
JAGDALPUR
KAKARIGUMA
BIJAPUR
80°
81°
82°
83°
20°
19°
18°
NOTE:- THIS MAP HAS BEEN DRAWN FROM THE IRRIGATION ATLAS OF INDIA (1989 EDITION) PLATE NO. 18.
REFERENCES
1. ALTITUDE FROM 0 - 150 MTS.
2. " " 150 - 300 "
3. " " 300 - 600 "
4. " " 600 - 900 "
5 " " 900 - 1550 "
6. SUB ZONE BOUNDARY
7. RIVERS
8. TOWNS
SCALE
Kms. 50 0 50 100 Kms.
भारत सरकार
केन्द्रीय जल आयोग
जल विज्ञान (क्षेत्रीय अध्ययन) निदेशालय
इन्द्रावती
उप क्षेत्र - ३(जी)
भू - आकृति

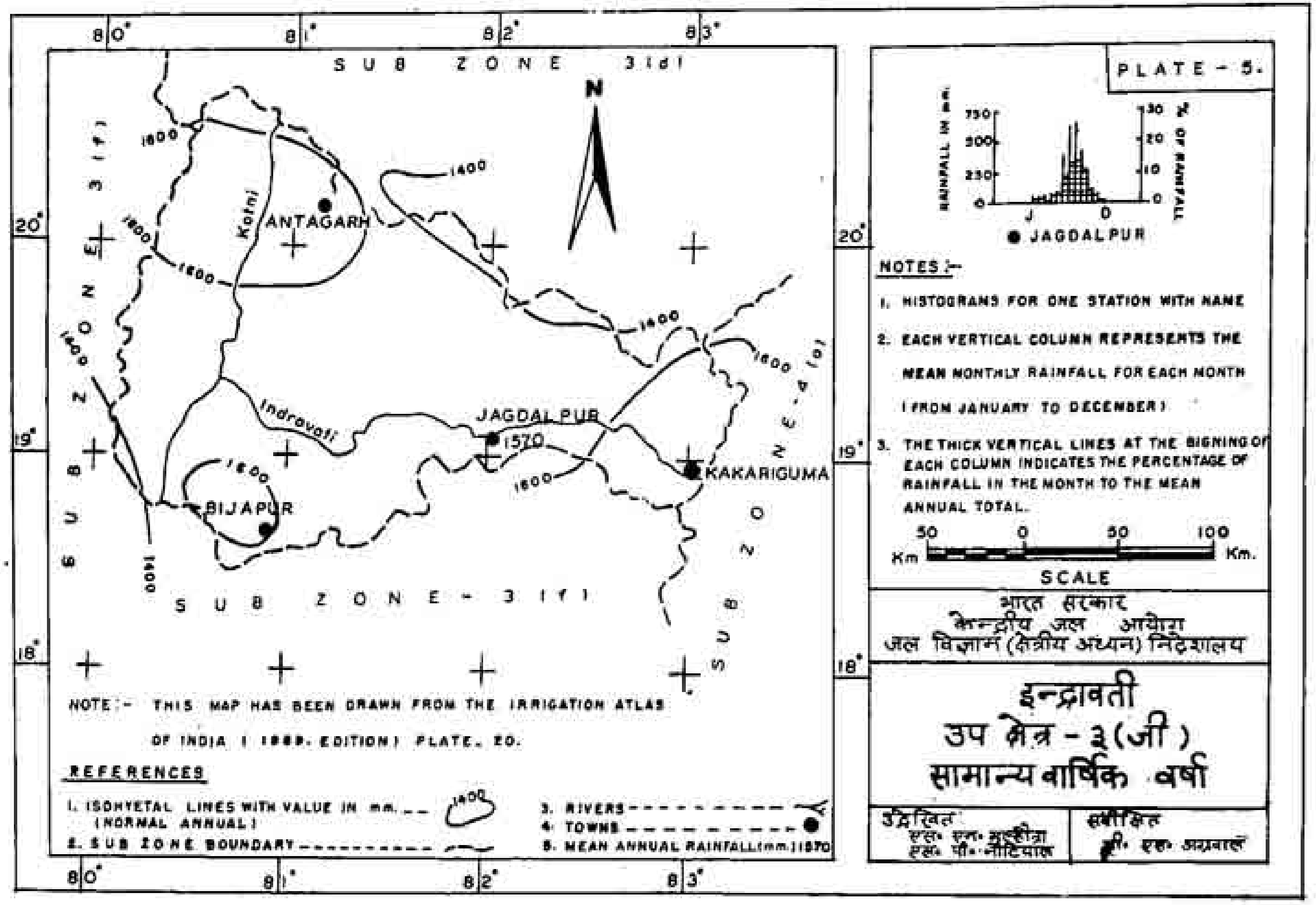


PLATE - 5.
SUB ZONE 3(d)
SUB ZONE - 3(f)
SUB ZONE 3(f)
SUB ZONE - 4(a)
N
ANTAGARH
JAGDALPUR
1570
KAKARIGUMA
BIJAPUR
Kotni
Indravati
1400
1600
1800
80°
81°
82°
83°
20°
19°
18°
RAINFALL IN mm.
750
500
250
0
% OF RAINFALL
30
20
10
0
J
D
JAGDALPUR
NOTES :-
1. HISTOGRAMS FOR ONE STATION WITH NAME
2. EACH VERTICAL COLUMN REPRESENTS THE MEAN MONTHLY RAINFALL FOR EACH MONTH (FROM JANUARY TO DECEMBER)
3. THE THICK VERTICAL LINES AT THE BIGNING OF EACH COLUMN INDICATES THE PERCENTAGE OF RAINFALL IN THE MONTH TO THE MEAN ANNUAL TOTAL.
50 0 50 100
Km Km.
SCALE
भारत सरकार
केन्द्रीय जल आयोग
जल विज्ञान (क्षेत्रीय अध्ययन) निदेशालय
इन्द्रावती
उप क्षेत्र - ३(जी)
सामान्य वार्षिक वर्षा
उद्रिखित
समीक्षित
NOTE :- THIS MAP HAS BEEN DRAWN FROM THE IRRIGATION ATLAS OF INDIA (1989. EDITION) PLATE. 20.
REFERENCES
1. ISOHYETAL LINES WITH VALUE IN mm. (NORMAL ANNUAL)
2. SUB ZONE BOUNDARY
3. RIVERS
4. TOWNS
5. MEAN ANNUAL RAINFALL(mm.) 1570

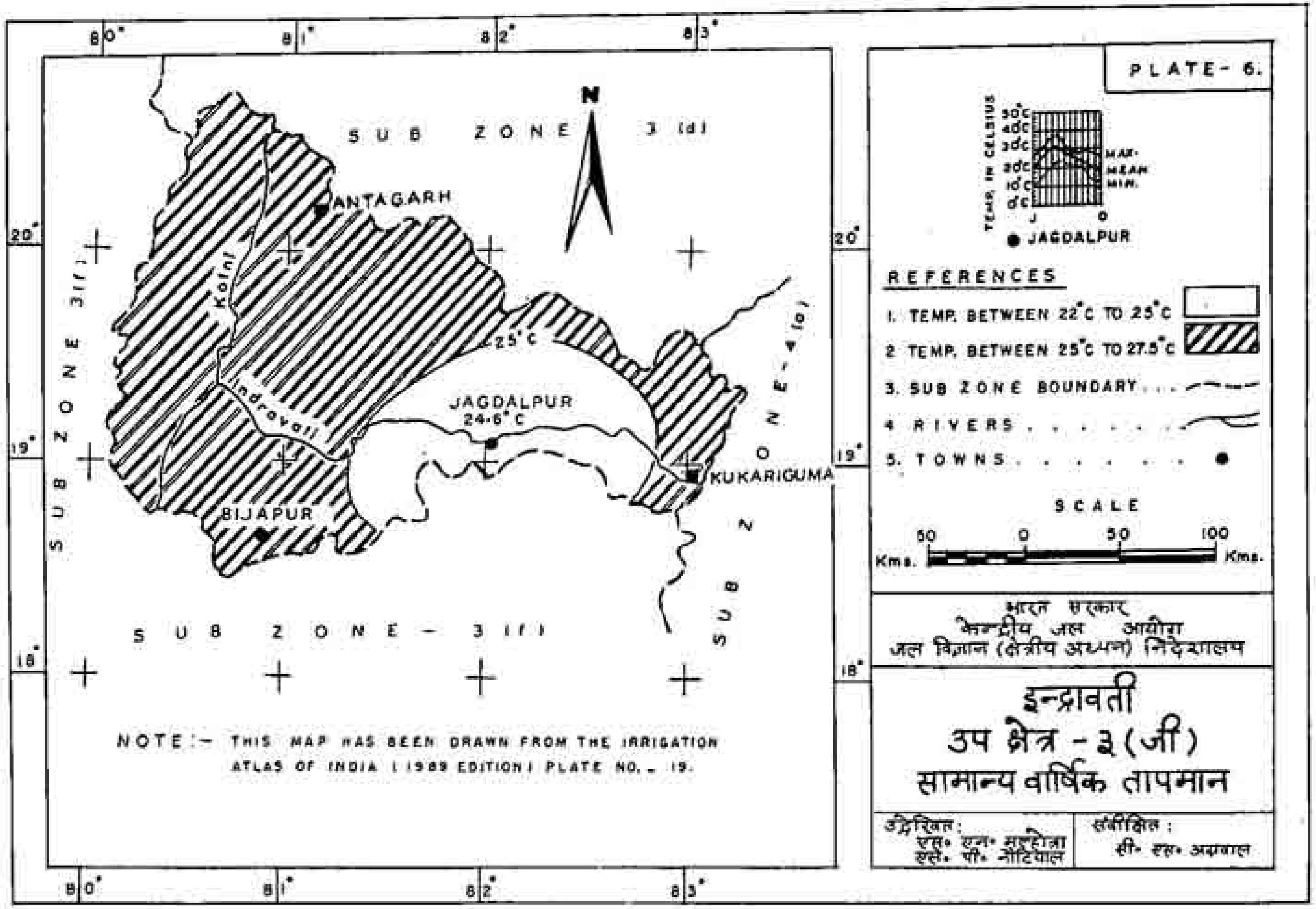


PLATE- 6.
SUB ZONE 3 (d)
SUB ZONE 3 (f)
SUB ZONE - 3 (f)
SUB ZONE - 4 (a)
SUB ZONE
N
ANTAGARH
Kotri
Indravati
25°C
JAGDALPUR
24·6°C
BIJAPUR
KUKARIGUMA
TEMP. IN CELSIUS
MAX.
MEAN
MIN.
JAGDALPUR
REFERENCES
1. TEMP. BETWEEN 22°C TO 25°C
2 TEMP. BETWEEN 25°C TO 27.5°C
3. SUB ZONE BOUNDARY
4 RIVERS
5. TOWNS
SCALE
50 0 50 100
Kms. Kms.
NOTE:- THIS MAP HAS BEEN DRAWN FROM THE IRRIGATION ATLAS OF INDIA (1989 EDITION) PLATE NO. - 19.
भारत सरकार
केन्द्रीय जल आयोग
जल विज्ञान (क्षेत्रीय अध्ययन) निदेशालय
इन्द्रावती
उप क्षेत्र - ३ (जी)
सामान्य वार्षिक तापमान
उद्रेखित:
एस. एन. मल्होत्रा
एस. पी. नौटियाल
संकलित:
सी. एल. अग्रवाल

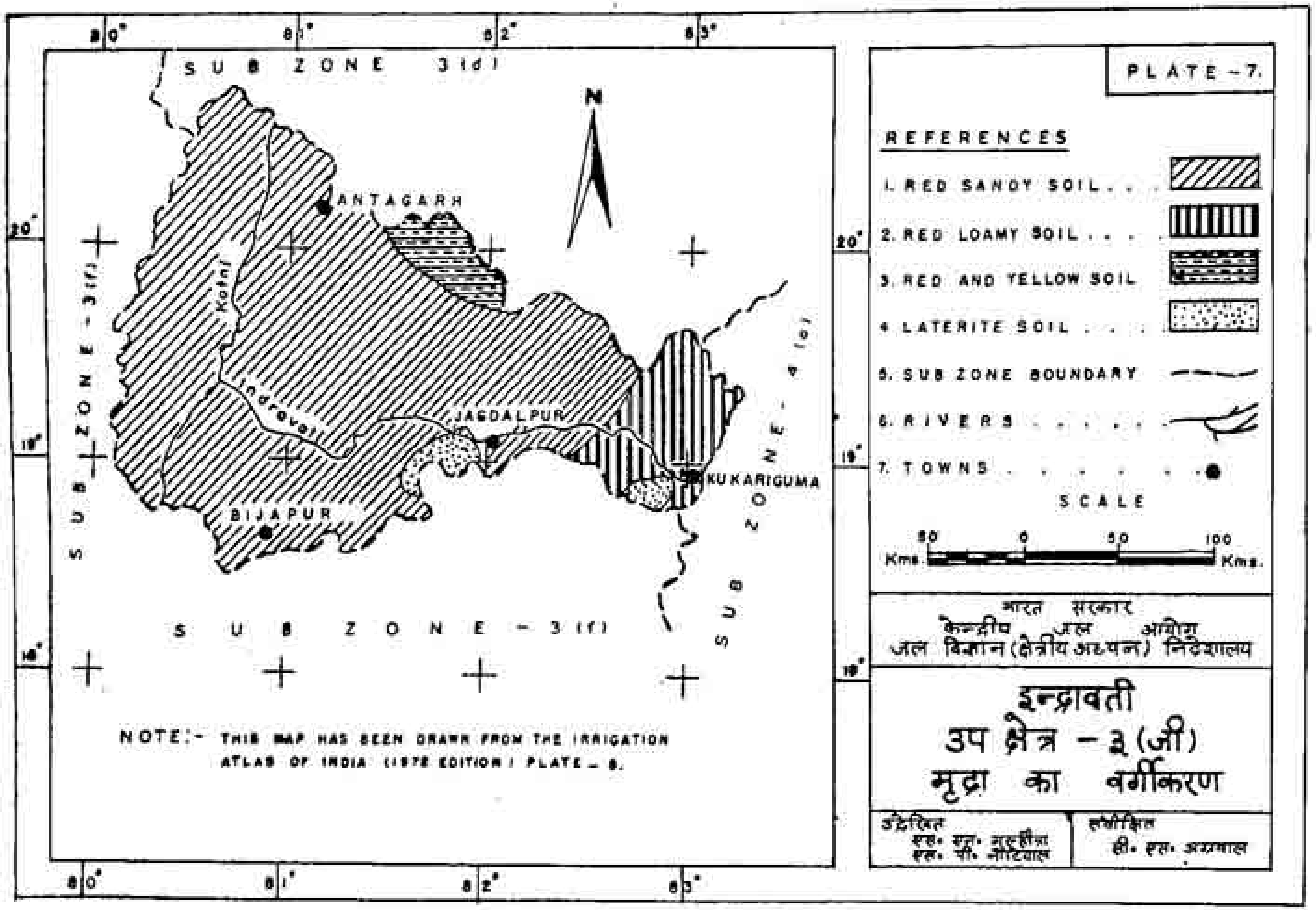


PLATE - 7.
REFERENCES
1. RED SANDY SOIL
2. RED LOAMY SOIL
3. RED AND YELLOW SOIL
4. LATERITE SOIL
5. SUB ZONE BOUNDARY
6. RIVERS
7. TOWNS
SCALE
50 0 50 100
Kms. Kms.
भारत सरकार
केन्द्रीय जल आयोग
जल विज्ञान (क्षेत्रीय अध्ययन) निदेशालय
इन्द्रावती
उप क्षेत्र - 3 (जी)
मृदा का वर्गीकरण
सर्वेक्षित
SUB ZONE 3(d)
SUB ZONE - 3(f)
SUB ZONE - 4(a)
ANTAGARH
JAGDALPUR
KUKARIGUMA
BIJAPUR
Kotri
Indravati
N
80° 81° 82° 83°
20° 19° 18°
NOTE:- THIS MAP HAS BEEN DRAWN FROM THE IRRIGATION ATLAS OF INDIA (1972 EDITION) PLATE - 8.

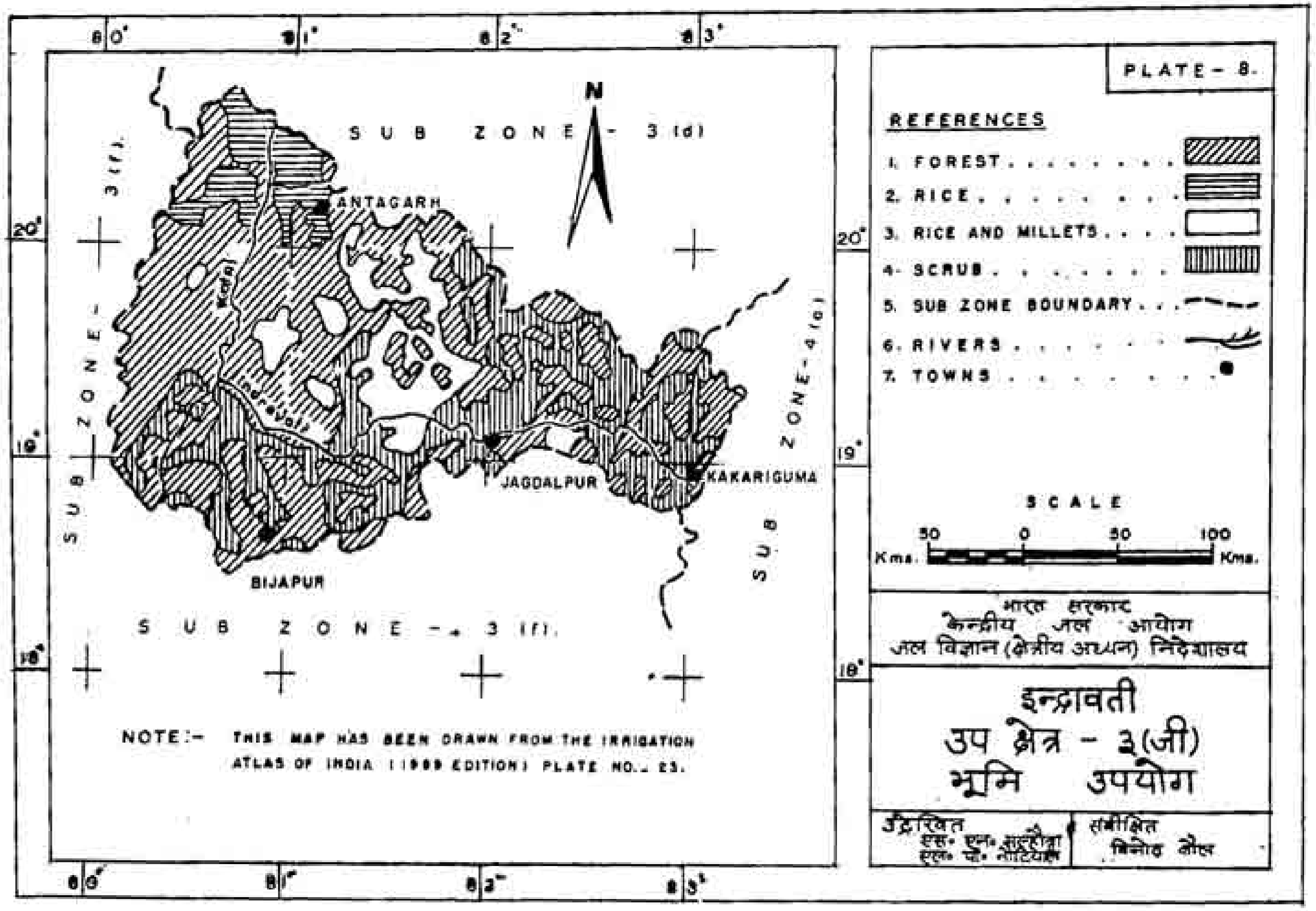


PLATE – 8.
REFERENCES
1. FOREST
2. RICE
3. RICE AND MILLETS
4. SCRUB
5. SUB ZONE BOUNDARY
6. RIVERS
7. TOWNS
SCALE
50 0 50 100
Kms. Kms.
भारत सरकार
केन्द्रीय जल आयोग
जल विज्ञान (क्षेत्रीय अध्ययन) निदेशालय
इन्द्रावती
उप क्षेत्र - 3(जी)
भूमि उपयोग
SUB ZONE – 3 (d)
SUB ZONE – 3 (f)
SUB ZONE – 4 (a)
ANTAGARH
JAGDALPUR
KAKARIGUMA
BIJAPUR
N
80° 81° 82° 83°
20° 19° 18°
NOTE:- THIS MAP HAS BEEN DRAWN FROM THE IRRIGATION ATLAS OF INDIA (1989 EDITION) PLATE NO.- 23.

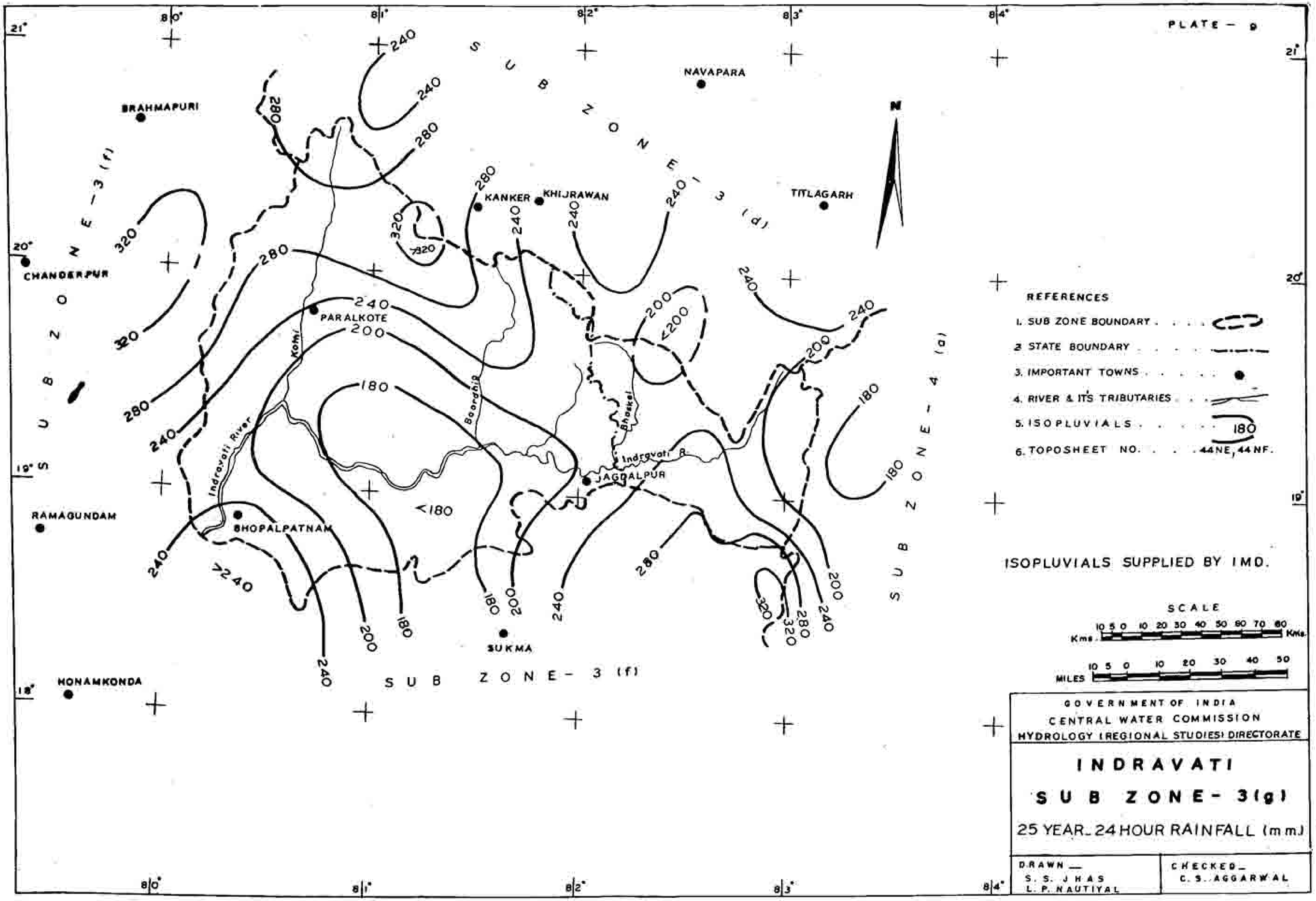


PLATE - 9
SUB ZONE - 3 (d)
SUB ZONE - 3 (f)
SUB ZONE - 4 (a)
BRAHMAPURI
CHANDERPUR
RAMAGUNDAM
HONAMKONDA
NAVAPARA
TITLAGARH
KANKER
KHIJRAWAN
PARALKOTE
BHOPALPATNAM
JAGDALPUR
SUKMA
Indravati River
Kotri
Baordhig
Bhaskel
Indravati R.
REFERENCES
1. SUB ZONE BOUNDARY
2. STATE BOUNDARY
3. IMPORTANT TOWNS
4. RIVER & ITS TRIBUTARIES
5. ISOPLUVIALS
6. TOPOSHEET NO. 44NE, 44NF.
ISOPLUVIALS SUPPLIED BY IMD.
SCALE
Kms
MILES
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DIRECTORATE
INDRAVATI
SUB ZONE - 3(g)
25 YEAR - 24 HOUR RAINFALL (mm)
DRAWN - S. S. JHAS, L. P. NAUTIYAL
CHECKED - C. S. AGGARWAL

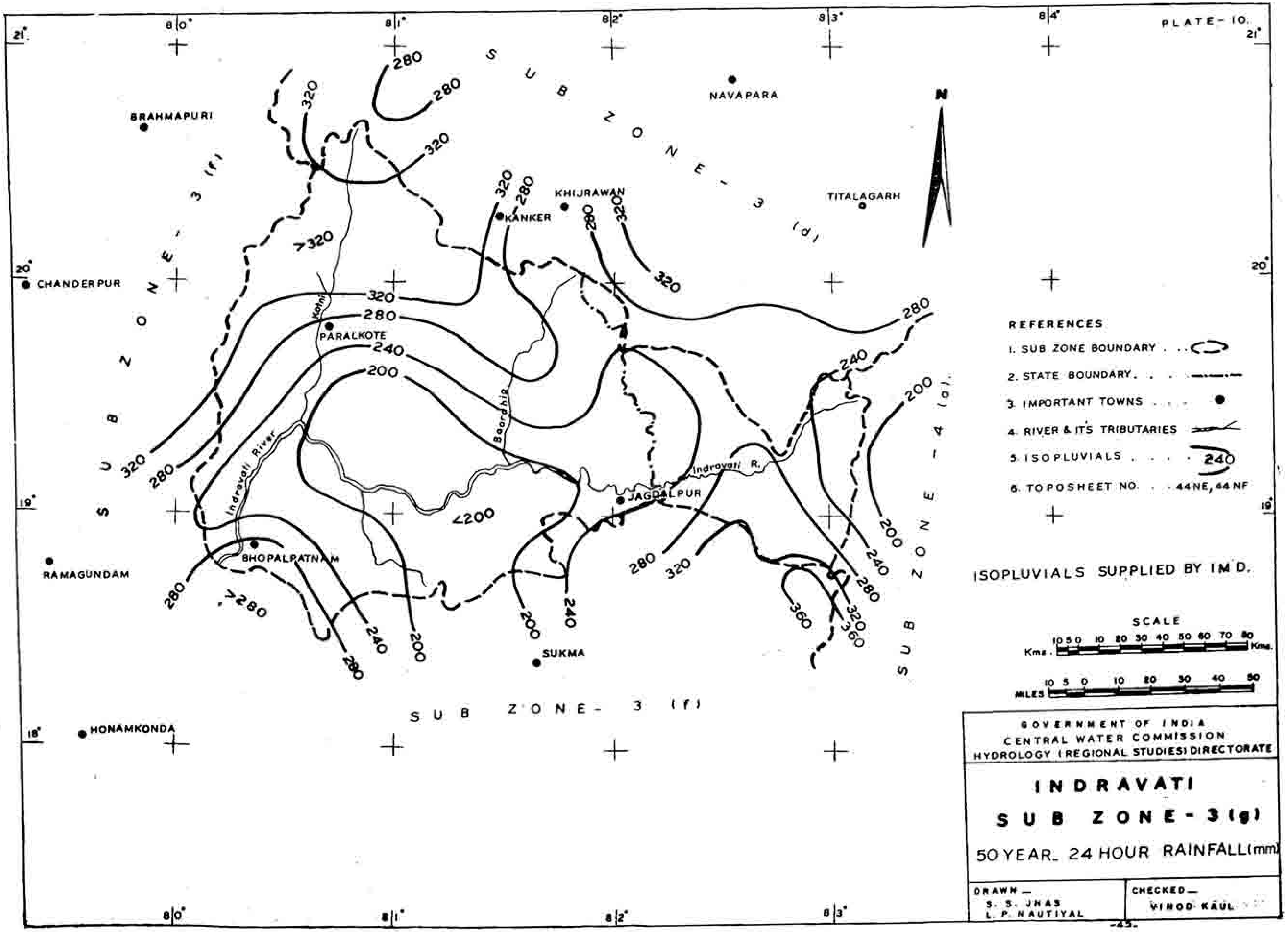


PLATE- 10.
BRAHMAPURI
CHANDERPUR
RAMAGUNDAM
HONAMKONDA
NAVAPARA
TITALAGARH
KHIJRAWAN
KANKER
PARALKOTE
BHOPALPATNAM
JAGDALPUR
SUKMA
Kotri
Indravati River
Indravati R.
Baordhia
SUB ZONE- 3 (f)
SUB ZONE- 3 (d)
SUB ZONE - 4 (a)
>320
<200
>280
REFERENCES
1. SUB ZONE BOUNDARY
2. STATE BOUNDARY
3. IMPORTANT TOWNS
4. RIVER & ITS TRIBUTARIES
5. ISOPLUVIALS
6. TOPOSHEET NO. 44NE, 44NF
ISOPLUVIALS SUPPLIED BY IMD.
SCALE
Kms.
MILES
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DIRECTORATE
INDRAVATI
SUB ZONE - 3 (g)
50 YEAR. 24 HOUR RAINFALL (mm)
DRAWN —
S. S. JHAS
L. P. NAUTIYAL
CHECKED —
VINOD KAUL
-43-

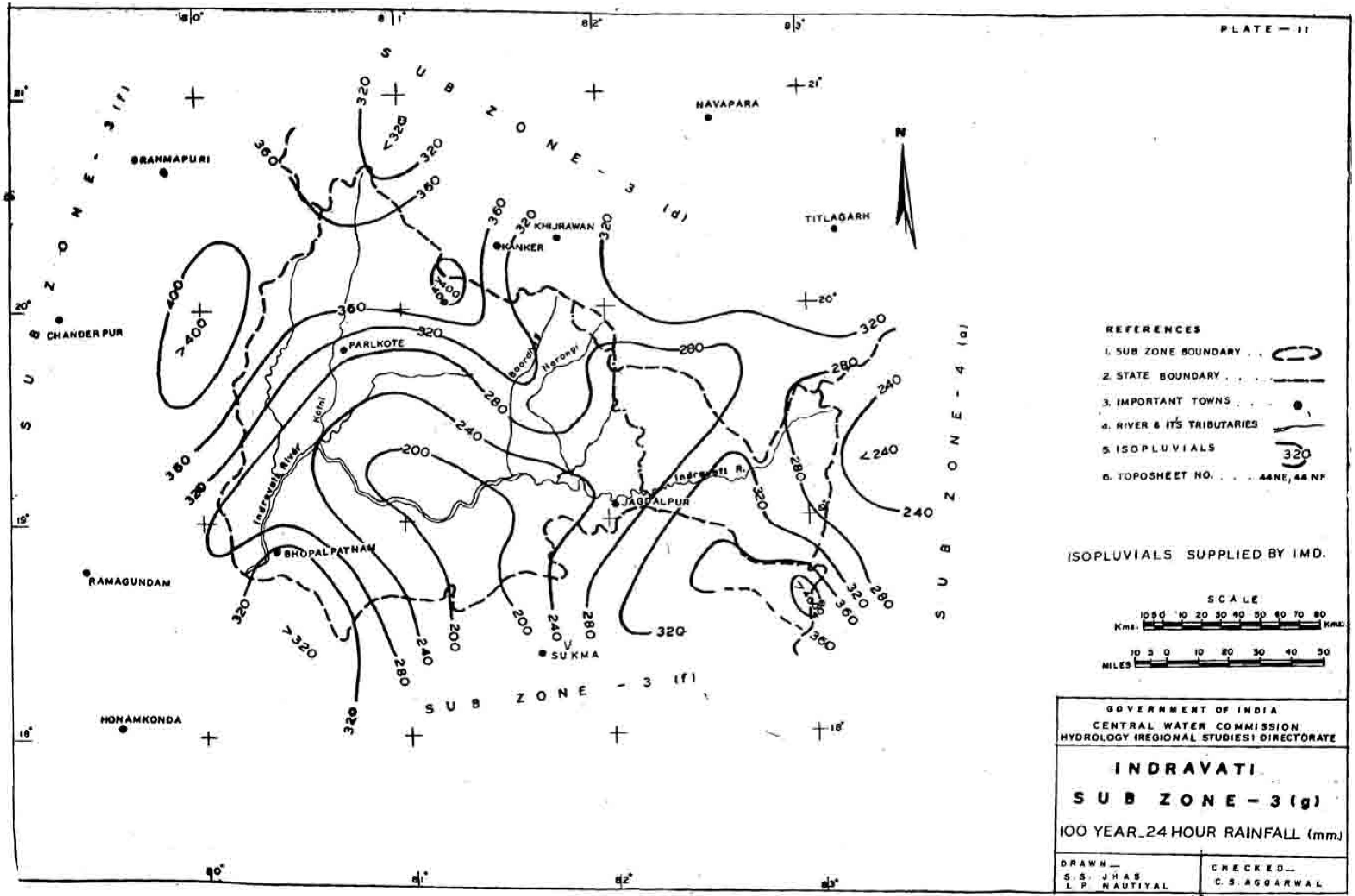


PLATE — 11
SUB ZONE - 3 (d)
SUB ZONE - 3 (f)
SUB ZONE - 4 (a)
NAVAPARA
TITLAGARH
BRAHMAPURI
KHIJRAWAN
KANKER
CHANDER PUR
PARLKOTE
JAGDALPUR
BHOPALPATNAM
RAMAGUNDAM
SUKMA
HONAMKONDA
Indravati River
Indravati R.
Narangi
N
REFERENCES
1. SUB ZONE BOUNDARY
2. STATE BOUNDARY
3. IMPORTANT TOWNS
4. RIVER & ITS TRIBUTARIES
5. ISOPLUVIALS
6. TOPOSHEET NO. 44NE, 44 NF
ISOPLUVIALS SUPPLIED BY IMD.
SCALE
Kms.
MILES
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DIRECTORATE
INDRAVATI
SUB ZONE - 3 (g)
100 YEAR_24 HOUR RAINFALL (mm)
DRAWN_
S. S. JHAS
L. P. NAUTIYAL
CHECKED_
C. S. AGGARWAL

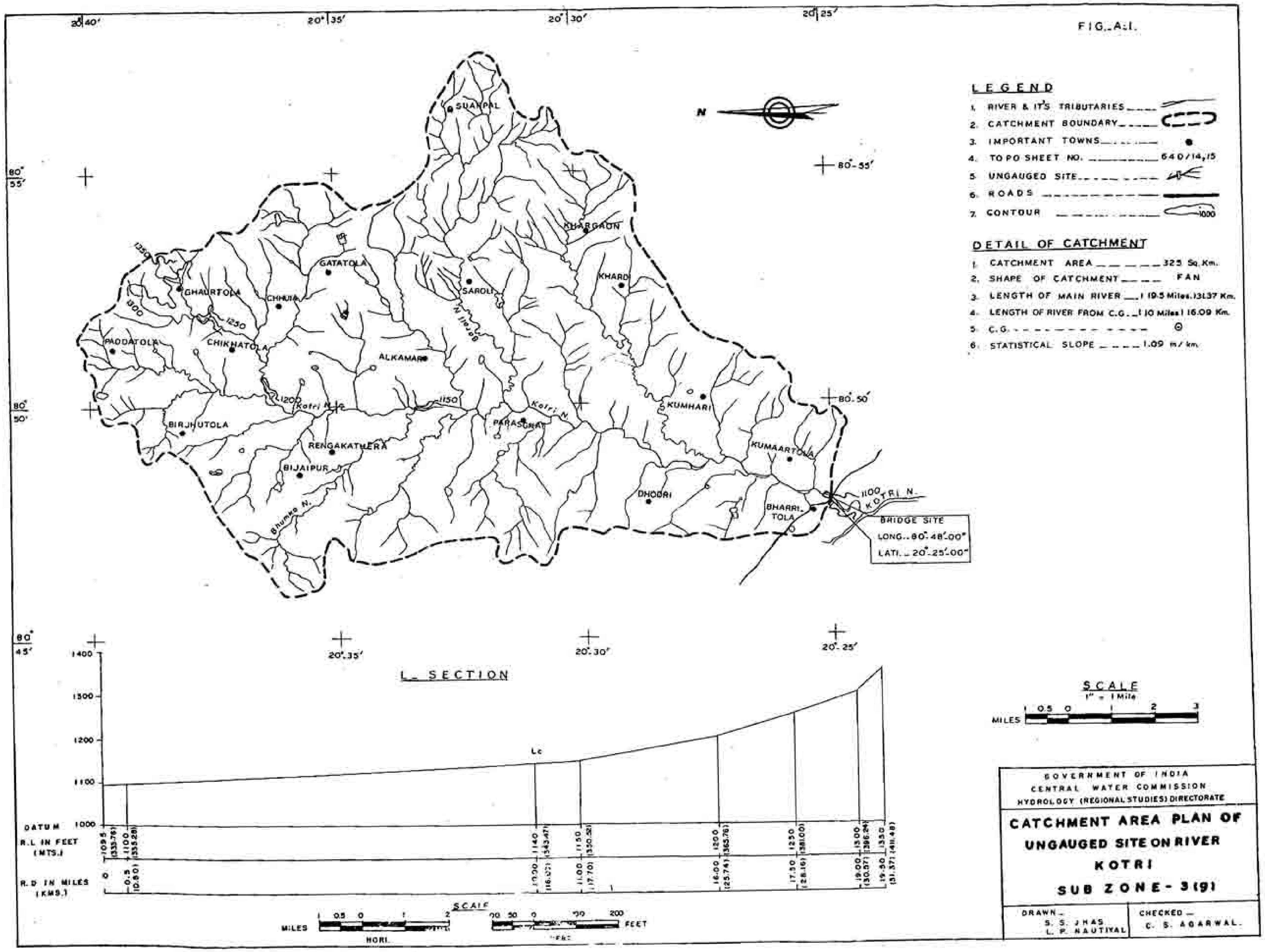
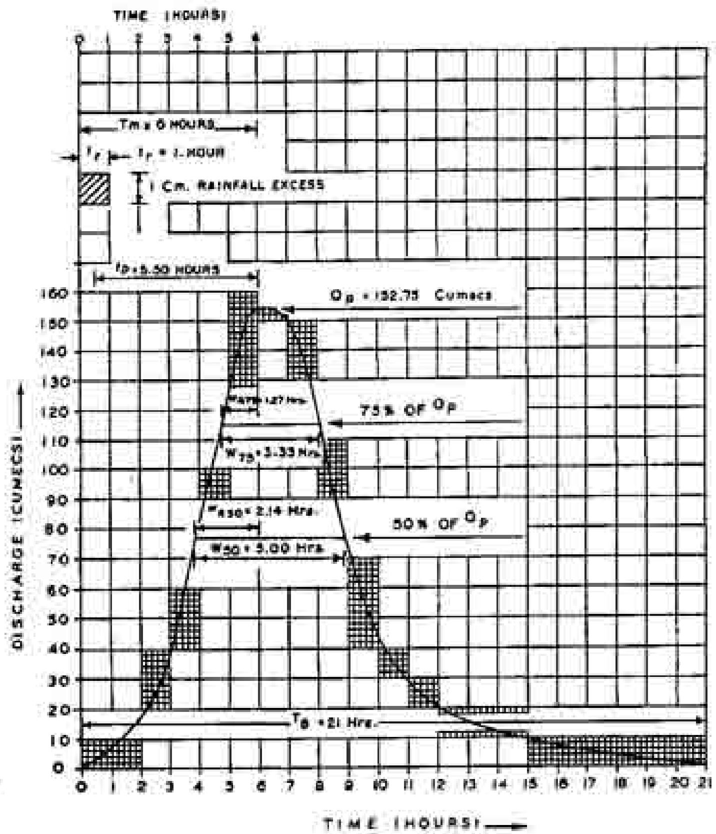


FIG._A.I.
LEGEND
1. RIVER & IT'S TRIBUTARIES
2. CATCHMENT BOUNDARY
3. IMPORTANT TOWNS
4. TOPO SHEET NO. 64 D/14,15
5. UNGAUGED SITE
6. ROADS
7. CONTOUR
1000
DETAIL OF CATCHMENT
1. CATCHMENT AREA 325 Sq.Km.
2. SHAPE OF CATCHMENT FAN
3. LENGTH OF MAIN RIVER (19.5 Miles) 31.37 Km.
4. LENGTH OF RIVER FROM C.G. (10 Miles) 16.09 Km.
5. C.G.
6. STATISTICAL SLOPE 1.09 m/km.
N
SUARPAL
KHARGAON
GATATOLA
SAROLI
KHARDI
GHAURTOLA
CHHUIA
PADDATOLA
CHIKHATOLA
ALKAMAR
KUMHARI
BIRJHUTOLA
RENGAKATHERA
PARASCHAT
KUMAARTOLA
BIJAIPUR
DHODRI
BHARRI TOLA
Kotri N.
KOTRI N.
BRIDGE SITE
LONG. 80°48'00"
LATI. 20°25'00"
L. SECTION
DATUM
R.L IN FEET (MTS.)
R.D IN MILES (KMS.)
SCALE
1" = 1 Mile
MILES
HORI.
FEET
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DIRECTORATE
CATCHMENT AREA PLAN OF UNGAUGED SITE ON RIVER KOTRI
SUB ZONE - 3(g)
DRAWN
S. S. JHAS
L. P. NAUTIYAL
CHECKED
C. S. AGARWAL.

FIG. A. 2.



1-HOUR SYNTHETIC U.G. ORDINATES

0	0
1	7.00
2	17.00
3	38.00
4	80.00
5	124.00
6	152.75
7	147.93
8	116.50
9	74.00
10	43.50
11	28.50
12	19.50
13	14.80
14	11.50
15	9.00
16	7.00
17	5.00
18	3.50
19	2.00
20	1.30
21	0
TOTAL	902.78 CUMECS

1-HOUR SYNTHETIC U.G. PARAMETERS

1. C. AREA = 325.00 Sq. Kms.
2. t_r = 1.00 HOUR
3. Q_p = 152.75 Cumecs
4. q_p = 0.47 Cumecs/Km²
5. t_p = 5.50 HOURS
6. T_m = 6.00 HOURS
7. T_B = 21.00 HOURS
8. W_{50} = 5.00 HOURS
9. W_{75} = 3.33 HOURS
10. W_{R50} = 2.14 HOURS
11. W_{R75} = 1.27 HOURS
12. d = 1.00 Cm.

$$\Sigma Q_i = \frac{A \times d}{t_r \times 0.36} = \frac{325.00 \times 1.00}{1.00 \times 0.36} = 902.78 \text{ CUMECS}$$

GOVERNMENT OF INDIA
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HYDROLOGY (REGIONAL STUDIES) DTE.

INDRAVATI

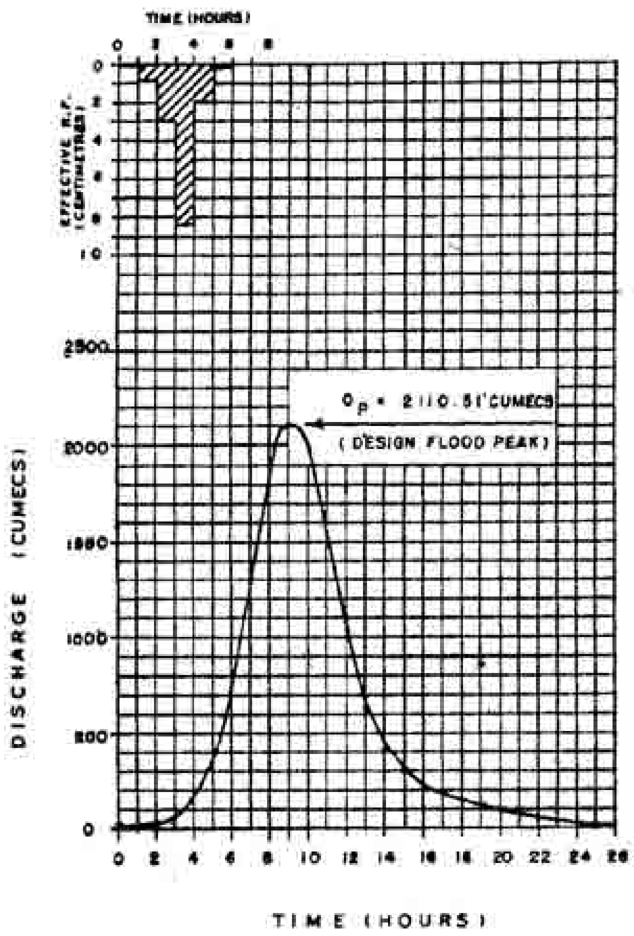
SUB ZONE - 3 (9)

SYNTHETIC UNIT HYDROGRAPH

UNGAUGED CATCHMENT

DRAWN —	CHECKED —
S. N. MALHOTRA L. P. NAUTIYAL	K. K. AICH.

FIG. A. 3.



-3-

NOTE:-

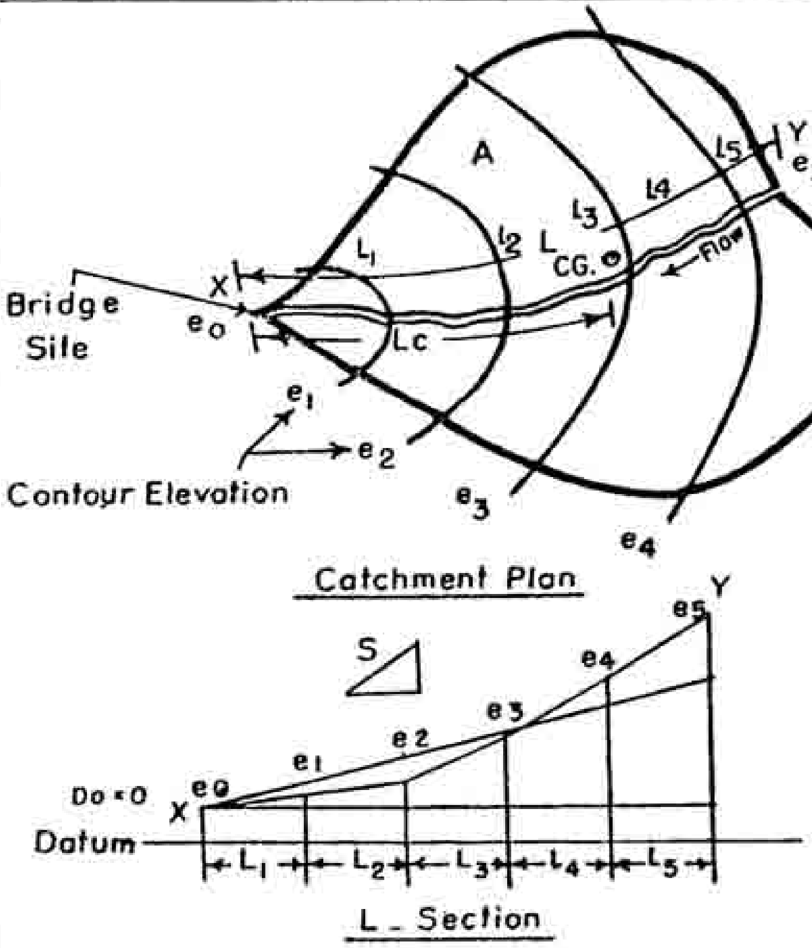
REFER ANNEXURE I.2 FOR COMPUTATION OF DESIGN FLOOD HYDROGRAPH.

CATCHMENT AREA = 328.00 Sq. Km.

GOVERNMENT OF INDIA CENTRAL WATER COMMISSION HYDROLOGY (REGIONAL STUDIES) DTE.
INDRAVATI SUB ZONE - 3(g) DESIGN FLOOD HYDROGRAPH UNGAUGED SITE ON RIVER KOTRI

DRAWN- S. N. MALHOTRA L. P. NAUTIYAL	CHECKED- K. K. AICH

FIG.-1.



S = Statistical stream slope (m/km.)

L = Length of longest stream course (km.)

Lc = Length of longest stream course from a point opposite the centre of gravity of the catchment to the Bridge site (km.)

A = Catchment Area ($km.^2$)

$$S = \left\{ \frac{L}{\frac{L_1}{\sqrt{S_1}} + \frac{L_2}{\sqrt{S_2}} + \cdots} \right\}^2$$

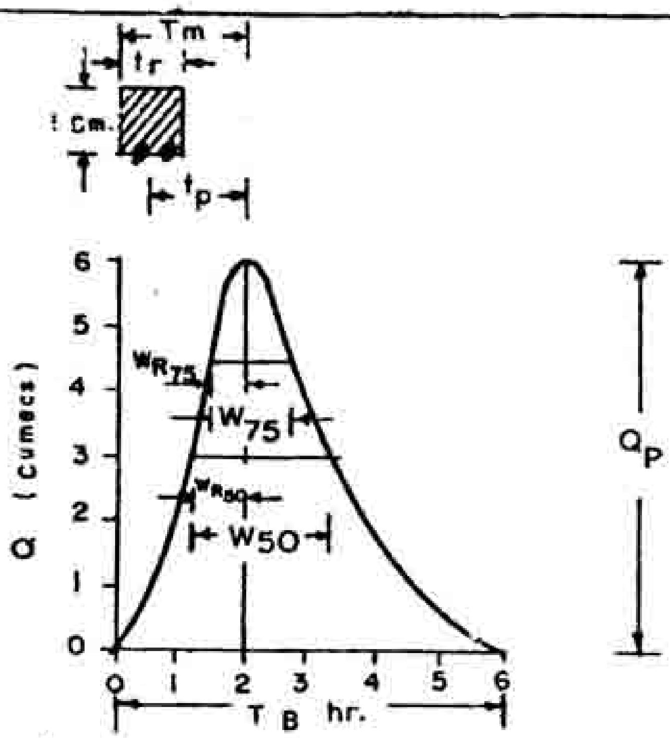
Where.—

L_1, L_2 . . . Segment Lengths (km.)

S_1, S_2 . . . Segment Slopes (mt./km.)

GOVERNMENT OF INDIA CENTRAL WATER COMMISSION HYDROLOGY (REGIONAL STUDIES) DTE.	
PHYSIOGRAPHIC PARAMETERS	
DRAWN — S.N. MALHOTRA	CHECKED — VINOD KAUL

FIG. - 2.



U. G = Unit Graph

t_r = Unit Rainfall Duration adopted in a specific study (hr.)

T_m = Time from the start of rise to the peak of the U.G (hr.)

Q_P = Peak Discharge of Unit Hydrograph (Cumecs.)

t_p = Time from the Centre of Effective Rainfall duration to the U.G Peak (hr.)

W_{50} = Width of the U.G measured at the 50% of peak discharge ordinate (hr.)

W_{75} = Width of the U.G measured at 75% of peak discharge ordinate (hr.)

W_{R50} = Width of the rising limb of U.G measured at 50% of peak discharge ordinate (hr.)

W_{R75} = Width of the rising limb of U.G measured at 75% of peak discharge ordinate (hr.)

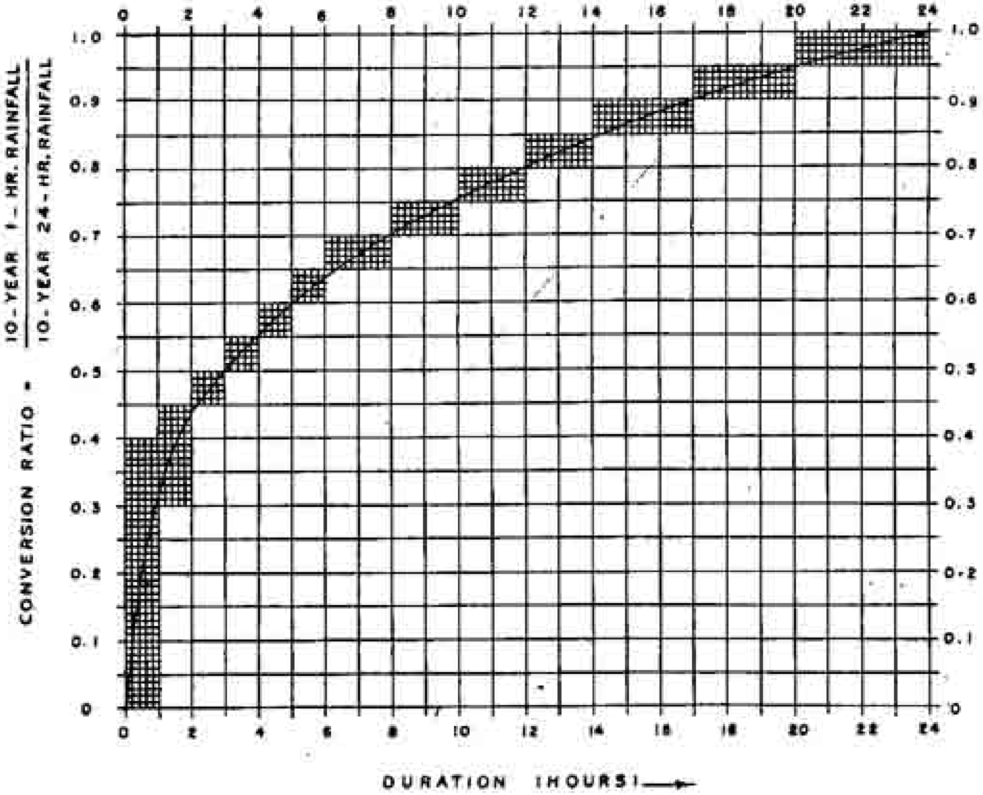
TB = Base width of Unit Hydrograph (hr.)

A = Catchment Area (Sq.km.)

q_p = Q_P / A = Cumec per sq.km.

GOVERNMENT OF INDIA CENTRAL WATER COMMISSION HYDROLOGY (R.S.) DIRECTORATE	
UNIT GRAPH PARAMETERS	
DRAWN BY.- BHATIA, NAUTIYAL	CHECKED BY.- A. K. GHOSH

FIG. – 3



RATIOS OF 24-HOUR POINT RAINFALL TO SHORT DURATION RAINFALL.

DURATION (HOURS)	RATIO
1	0.320
2	0.440
3	0.500
4	0.553
5	0.600
6	0.633
7	0.670
8	0.703
9	0.730
10	0.755
11	0.780
12	0.800
13	0.820
14	0.845
15	0.864
16	0.880
17	0.900
18	0.917
19	0.938
20	0.950
21	0.963
22	0.977
23	0.987
24	1.000

NOTE :—

CURVE SUPPLIED BY IMD.

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CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE.

INDRAVATI

SUB ZONE - 3(g)

DURATION VS. CONVERSION RATIO

DRAWN — S. N. MALHOTRA	CHECKED — C. S. AGGARWAL

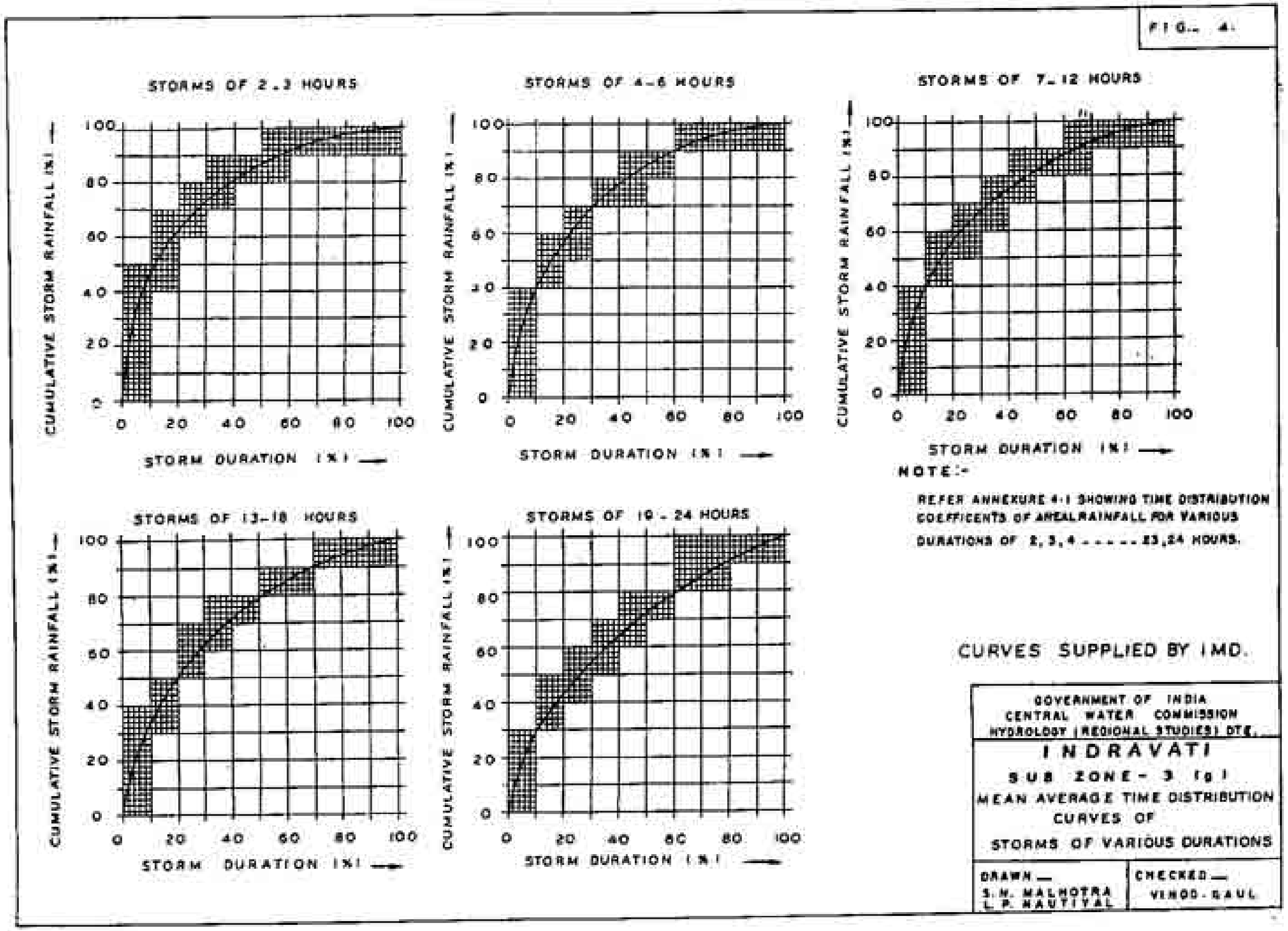
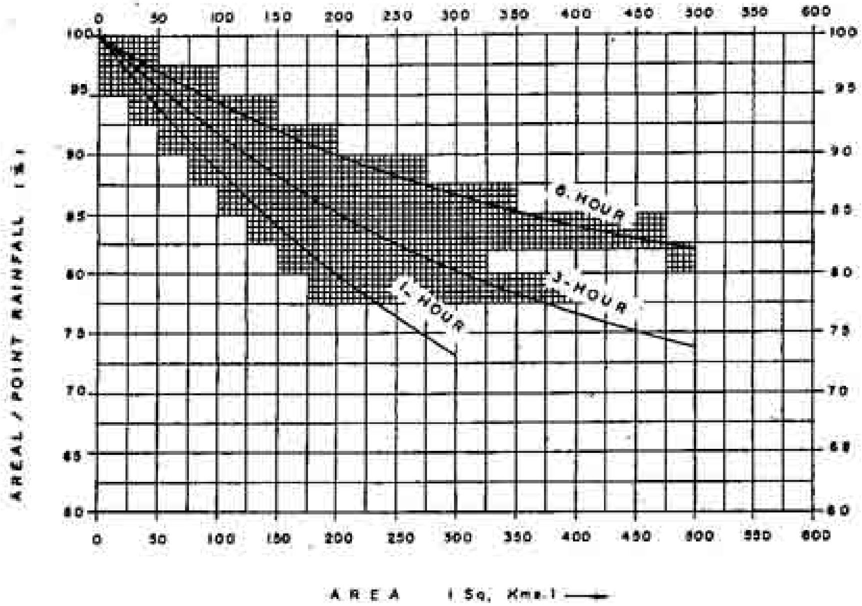


FIG. 4.
STORMS OF 2-3 HOURS
STORMS OF 4-6 HOURS
STORMS OF 7-12 HOURS
STORMS OF 13-18 HOURS
STORMS OF 19-24 HOURS
CUMULATIVE STORM RAINFALL (%)
STORM DURATION (%)
NOTE:-
REFER ANNEXURE 4.1 SHOWING TIME DISTRIBUTION COEFFICENTS OF AREAL RAINFALL FOR VARIOUS DURATIONS OF 2, 3, 4 ...... 23, 24 HOURS.
CURVES SUPPLIED BY IMD.
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE.
INDRAVATI
SUB ZONE - 3 (g)
MEAN AVERAGE TIME DISTRIBUTION CURVES OF STORMS OF VARIOUS DURATIONS
DRAWN —
S. H. MALHOTRA
L. P. NAUTIYAL
CHECKED —
VINOD - GAUL

FIG.- 3 (a).



NOTE:-

1. REFER ANNEXURE - 4.2 FOR CONVERSION OF POINT RAINFALL TO AREAL RAINFALL.

2. REFER FIG. 3 (b) FOR DURATION 12 & 24 HOURS.

CURVES SUPPLIED BY IMD.

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INDRAVATI

SUB ZONE - 3 (g)

AREAL TO POINT RAINFALL RATIO (%)

DRAWN_ S.N. MALHOTRA	CHECKED_ C. S. AGGARWAL

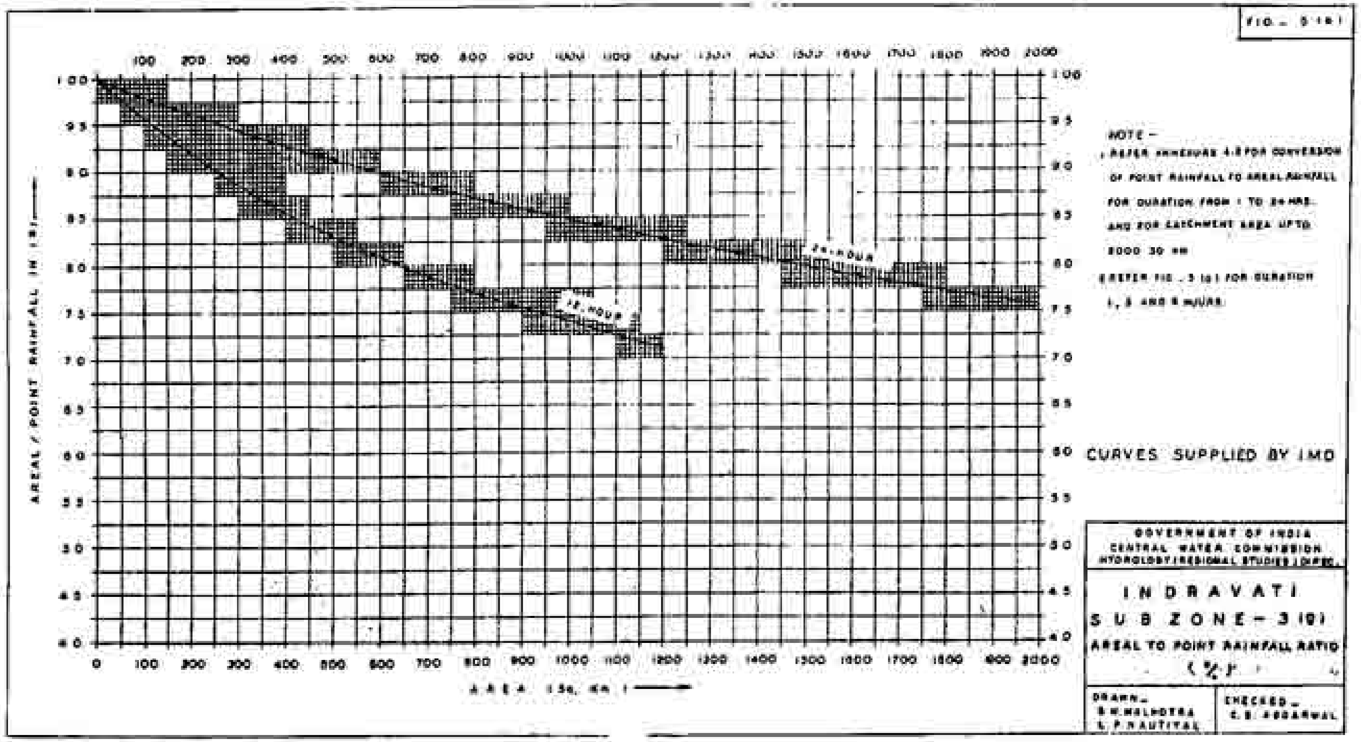
FIG. - 3 (b)
NOTE -
1. REFER ANNEXURE 4.2 FOR CONVERSION OF POINT RAINFALL TO AREAL RAINFALL FOR DURATION FROM 1 TO 24 HRS. AND FOR CATCHMENT AREA UPTO 2000 SQ KM
2. REFER FIG. - 3 (a) FOR DURATION 1, 3 AND 6 HOURS
CURVES SUPPLIED BY IMD
24-HOUR
12-HOUR
AREAL / POINT RAINFALL IN (%)
AREA (SQ. KM)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
100
95
90
85
80
75
70
65
60
55
50
45
40
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INDRAVATI
SUB ZONE - 3 (G)
AREAL TO POINT RAINFALL RATIO
(%)
DRAWN -
S.K.MALHOTRA
L.P.NAUTIYAL
CHECKED -
C.S. AGGARWAL

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LIST OF FLOOD ESTIMATION REPORTS PUBLISHED

A. UNDER SHORT TERM PLAN

1.	Estimation of Design Flood Peak	(1973)

B. UNDER LONG TERM PLAN

1.	Lower Gangetic Plains subzone-1(g)	(1978)
2.	Lower Godavari subzone-3(f)	(1981)
3.	Lower Narmada & Tapi subzone-3(b)	(1982)
4.	Mahanadi subzone-3(d)	(1982)
5.	Upper Narmada & Tapi subzone-3(c)	(1983)
6.	Krishna & Penner subzone-3(h)	(1983)
7.	South Brahmaputra Basin subzone-2(b)	(1984)
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9.	Middle Ganga Plains subzone-1(f)	(1985)
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16.	Betwa subzone 1(c)	(1989)
17.	North Brahmaputra Basin subzone 2(a)	(1991)
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