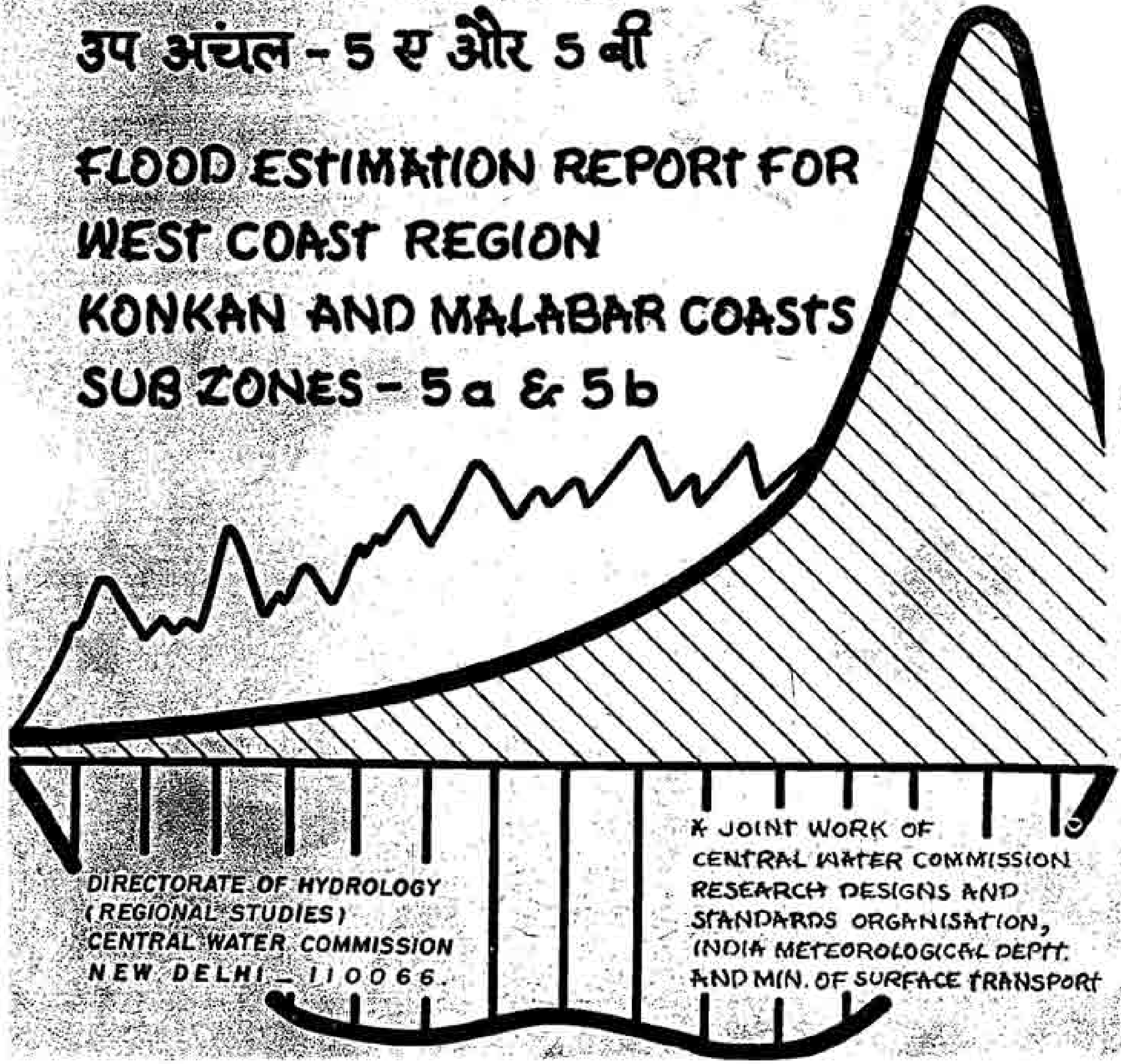
DESIGN OFFICE REPORT
NO.- K&M/19/1992.

केन्द्रीय जल आयोग

Central Water Commission

परिचमी क्षेत्रिय तट का बाढ़ आकलन विवरण
कोंकण और मालाबार तट
उप अंचल - 5 ए और 5 बी

FLOOD ESTIMATION REPORT FOR WEST COAST REGION
KONKAN AND MALABAR COASTS
SUB ZONES - 5a & 5b



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.
AND MIN. OF SURFACE TRANSPORT

FLOOD ESTIMATION REPORT OF WESTERN COAST REGION (KONKAN AND MALABAR COAST) SUB ZONE 5(a) AND 5(b) WAS APPROVED BY THE FOLLOWING MEMBERS OF THE FLOOD ESTIMATION PLANNING AND COORDINATION COMMITTEE IN ITS 50TH MEETING HELD ON 17-1-1992 AT R.D.S.O, LUCKNOW.

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FLOOD ESTIMATION REPORT OF WEST COAST REGION
(KONKAN AND MALABAR COAST)
SUBZONES 5(a) AND 5(b)

A METHOD BASED ON UNIT HYDROGRAPH PRINCIPLE
DESIGN OFFICE REPORT NO. K & M/19/1992

HYDROLOGY (REGIONAL STUDIES) DIRECTORATE
CENTRAL WATER COMMISSION
NEW DELHI

1992

F O R E W O R D

Em pirical approaches were followed till late sixties for design of large number of bridges in India. Consequently the waterway and other hydraulic parameters adopted for the design of structures proved in many cases grossly inadequate. The Committee of Engineers under the Chairmanship of Dr. A.N. Khosla set up by the Government of India in 1959 after reviewing the methods available for estimating the design flood discharge, recommended the adoption of rational methodology involving use of design storm and unit hydrograph for the estimatition of design flood. It is not economically justifiable, to collect data and carry out detailed hydrological and meteorological studies at every new site on a large scale. Hence a regional approach for development of methods for flood estimation was adopted. For this purpose the country has been divided into 26 hydrometeorologically homogenous sub zones. Studies for 19 sub zones have already been completed and 17 flood estimation reports covering these studies have been brought out.

The present report is 18th in the series and covers West Coast Region of Konkan and Malabar.

The report is the result of joint efforts of Central Water Commission(CWC), Research Design and Standards Organisation (RDSO), India Meteorological Department (IMD) and Ministry of Surface Transport (MOST) in pursuance of the recommendations of the Khosla Committee of Engineers.

The rational methodology contained in this report is recommended for estimation of floods for 25 years, 50 years and 100 years for structures having a small and medium catchments in the West Coast Region.

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.

M S Reddy

(M.S.Reddy)
Member(Water Planning)
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New Delhi
Dated : 6.3.1992

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 economy. A casual approach may lead to underestimation 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 hydralic 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 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 necesstiating the need of systematic and sustained collection of hydro-meteorlogical 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-meteorologically homogeneous regions in the country. Broadly, two main regional approaches namely flood frequency and 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 from 25 to 500 km^2 in the country.

Under Long term plan, country has been divided in 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 co-related by regression analysis and the equations for synthetic unit hydrograph for the suzone are derived for estimating design flood for ungauged catchments.

Studies are also carried 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 ratios and time distribution of storm 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 by CWC and IMD are prepared and published by CWC on approval of Flood Estimation Planning and Coordination Committee.

So far, following 17 reports covering 19 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

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-zones 5(a) and 5(b) which cover mainly parts of Gujarat, Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu.

For preparing the report, the data of six bridge catchments observed by the Southern and South Central Railways under the guidance of RDSO and 11 catchments observed by Central Water Commission on behalf of Ministry of Surface Transport varying for a period of 2 to 9 years has been collected. The report is based on hydrological studies carried out considering the hydro-meteorological data of 13 catchments found suitable and storm studies caried out with the rainfall data of 278 ordinary raingauge stations and 22 S.R.R.Gs maintained by state Government/IMD/Rly/CWC.

The part I of the report deals with the summary and contents of the synthetic unit hydrograph approach of design flood estimation alongwith an illustrative example. General description of the subzone detailing location of gauging sites, river systems, rainfall, temperature and types of soil are given in part II. Part III brings out the SUH relations to be used in the sub-zones. The storm studies carried out by the IMD are dealt in Part IV of the report. The procedures to compute the design flood are described in Part V. The Part VI highlights the limitations, assumptions and conclusions made in the report.

The report on sub zone, 5(a) and 5(b) is recommended for estimation of design flood from small and medium catchments varying in areas from 25 to 1000 km^2. This report may also be used for catchments areas upto 5000 km^2. judiciously after comparing loss-rate values in the neighbouring catchments having more or less similar characteristics. For catchments areas less than 25 Km^2. the method given in the Report No. RPF-16 published by RDSO may be used

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

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

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SYMBOLS AND ABBREVATIONS

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 (Region 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.
S	Equivalent stream slope in m/km.
S.U.G.	Synthetic Unit Hydrograph
S.R.H.	Surface Runoff Hydrograph
D.R.H.	Direct Runoff 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 AND CONTENTS OF S.U.H APPROACH

The Flood Estimation report for Konkan (5a) and Malabar (5b) coastal sub-Zones may be used for estimation of design flood (25-yr, 50-yr and 100-yr) for ungauged and inadequately gauged catchments in the subzones. In part III & V of the report, detailed proceedure for derivation of synthetic unit hydrograph (SUH) and its use to compute design flood / peak is explained. The method described therein is summarised below with an illustrative example.

1.1 Various steps necessary to estimate the design flood peak/design flood hydrograph are as under :

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

ii) Determination of physiographic parameters viz: catchment area (A), Length of the longest stream (L) and equivalent 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.

1.2 An example with reference to road bridge Catchment (treated as ungauged) is worked out for illustrating the procedure to compute 50 yr design flood. The particulars of the catchment under study are as follows:

i) Name of sub-zone Malabar coastal Region 5(b)

ii) Name of Tributary — Anjarakandipuzha

iii) Name of site (i.e. point of study) — Road Br. MOT-9

vi) Name of Road Section — Virarajeudrapete - Tellichery Road Section

v) Shape of catchment — Oblong

vi) Location — Lat 11^{o}-52'-25" Long 75^{o}-34'-40"

vii) Topography — Moderate slope

Procedure is explained stepwise:

Step-1:- Determation of physiographic parameters:

The point of interest (Road Bridge Site in this case) was located on the Survey of India toposhcat and catchment boundary was marked using the contours along the ridge line and also from the spot levels in the plains. A 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)in sq km and the length of the longest mainstream(L) in km from the farthest catchment boundary to the point of study is measured. Centre of gravity of the catchment is 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 centrte of gravity to the point of study(L) is measured in km.

Equivalent stream slope(S) was obtained by graphical method as shown in fig-1 and by analytical method as shown in Anx-1.

Physiographic parameters obtained are given below:

1) Area (A)	176.00 sq km
2) Length of the longest stream (L)	38.48 km
3) Length of the longest stream from a point opposite C.G. of catchment to point of study (Lc)	20.29 km
4) Equivalent stream slope (S)	4.21 m/km

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

Synthetic Unitgraph Parameters are computed using equations in para 3.4.3.

i) $q_p = 0.9178\ (L/S)^{-0.4313}$

$= 0.9178\ (9.14)^{-0.4313}$

$= 0.353$ Cumecs per sq km

ii) $t_p = 1.5607\ (q_p)^{-1.0814}$

$= 1.5607\ (0.353)^{-1.0814}$

$= 4.80$ hrs

(rounded off to 4.50 hrs.)

iii) $W_{50} = 1.925/(q_p)^{-1.0896} = 1.925(0.353)^{-1.0896}$

$= 5.98$ hrs

iv) $W_{75} = 1.0189\ (q_p)^{-1.0443} = 1.0189\ (0.353)^{-1.0443}$

$= 3.02$ hrs.

v) $W_{R50} = 0.5788\ (q_p)^{-1.1072} = 0.5788\ (0.353)^{-1.1072}$

$= 1.83$ hrs.

vi) $W_{R75} = 0.3469(q_p)^{-1.0538} = 0.3469(0.353)^{-1.0538}$

$= 1.04$ hrs.

vii) $T_B = 7.380/(t_p)^{0.7343} = 7.380(4.5)^{0.7343}$

$= 22.27$ hrs.

Say 22.00 hrs.

viii) $t_m = t_p + t_r/2 = 4.5+0.5 = 5.00$ hrs

ix) $Q_p = q_p \times A = 0.353 \times 176.00$

$= 62.20$ 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 <Qi ti = $488.89 m^3/s$ 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/tix0.36

Where A = Catchment area in Sq. Km.

d = 1.0 cm depth

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

$$Q = \frac{A * d}{0.36 * tr} = \frac{176.00 * 1}{0.36 * 1} = 488.89 \text{ cum/sec}$$

In case, the <Qiti for the unitgraph drawn is higher or lower then the volume of 1 cm, the failing 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 $1.1 * t_p$ as this value of storm duration gives the higher value of flood peak (refer Section 4.1) Rounding the design storm duration to nearest hour, its value came as 5 hrs.

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

Catchment under study was located on Plate - 13 showing 50-yr 24-hr point rainfall. The point rainfall was found to be 37.00 cm. The Conversion factor of 0.570 was read from Fig - 10 to convert the 50-yr 24-hr point rainfall to 50-yr 5-hr point rainfall (since T_D = 5 hrs). 50-yr 5-hr point rainfall is 21.10 cm.

Areal reduction factor of 0.8519 corresponding to the catchment area of 176.00 sq.km for T_D = 5-hr. was interpolated from Annex.4.2 or Fig 11(a) for conversion of point rainfall to areal rainfall. 50-yr 5-hr areal rainfall thus worked out to be 18.00 cm.

Note : When the catchment under study falls between two isohyets, the point rainfall may be computed for the catchment taking into account both the isohyets.

The 50-yr, 5-hr areal rainfall was split in to 1-hourly rainfall increments using the time distribution coefficients given in Annexure 4.3 (col 16) or fig 12.

A design loss rate of 0.19 cm /hr as recommended in para 3.5 was applied to get effective rainfall hyetograph.

The table given below 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	0.50	9.00	9.00	8.81
2	0.73	13.14	4.14	3.95
3	0.81	15.66	2.52	2.33
4	0.95	17.10	1.44	1.25
5	1.00	18.00	0.90	0.71

Step-4: Estimation of Base Flow:

Taking the design base flow of 0.15 cumecs per sq km as recommended in para 3.6, the base flow was estimated to be 26.40 cumecs for the catchment area of 176.00 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 following table. Sum of the product of U.G. ordinates and the effective rainfall increments gives the total direct runoff peak as under.

Table - 2

(50 year flood peak)

Time (hrs)	U.G. ordinate cumecs	1-hr effec. rainfall (cms)	Direct Runoff (cumecs)
1	2	3	4
4	48.00	2.33	111.84
5	62.20	8.81	547.98
6	58.39	3.95	230.64
7	45.20	1.25	56.50
8	37.60	0.71	26.70
		Total	973.66
		Base Flow	26.40
		50-yr Flood Peak	1000.06

(b) Computation of Design Flood Hydrograph:

Effective rainfall increments shown in col. (3) of Table in Step-10 was 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	0.71
2	1.25
3	3.95
4	8.81
5	2.33

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 7, 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 vertical 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 (7). Direct runoff were added horizontally and the total direct runoff is shown in col. (8). Adding total base flow of 26.40 m^3/sec. (col. 9), design flood hydrograph ordindates are given in col.10. The ordinates given in col. (10) were plotted against time (col. 11) to get the design flood hydrograph as shown in Fig A-3.

PART - II

GENERAL DESCRIPTION OF KONKAN AND MALABAR SUBZONES

2.1 Location:

The Western Coastal belt comprising of the Konkan coast 5(a) and Malabar Coast 5(b) subzones lie approximately between 72°-30' and 78° - 00' longitudes (East) and 8° and 21° latitudes (North). Plate-1 shows the location of Konkan and Malbar coast Subzones and Annexure 2.1 shows the list of sub-zones in India.

The Sub-zones 5(a) & (b) are bounded by Arabian Sea in the West, Indian ocean in the South, Sub-zone 3(b) on the north and four Sub-zones 3(e), 3(h), 3(i) and 4(c) on the east.

The states covered by these subzones are Gujarat, Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu. The important towns and cities in the subzones are Daman, Bombay, Kalyan, Ratnagri, Panaji, Karwar, Udupi, Mangalore, Palghat, Trichur, Cochin, Trivandrum, Kanyakumari.

2.2 River System

Plate-2 and 3 depict the river system of the Konkan Coast 5(a) and Malabar coast 5(b) subzones respectively. The Sub-zones 5(a) & 5(b) are drained by numerous streams, rivers and rivulets. Some of the important rivers are Damanganga, Kalu and Savitri in sub-zone 5(a) and Kalinadi, Sharavati, Netravati, Beypore, Periyar in the subzone 5(b). Kali Nadi is the biggest having a drainage area of 5302.96 Sq. Km followed by Kalu, Periyar, Netravati and Sharavati.

The drainage areas of the river systems in Western Coastal belt (subzone 5(a) and 5(b)) are as under:

S.No.	Name of river/ tributary	Drainage area (sq.km.)
1	2	3
Subzone 5(a) Konkan Coast:		
1.	Damanganga	2471.28
2.	Kalu	4736.63
3.	Savitri	2265.34
4.	Other rivers	59941.75
	Sub-total:	69415.00
Subzone 5(b) Malabar Coast:		
5.	Kalinadi	5302.96
6.	Sharavati	2934.65
7.	Netravati	3758.41
8.	Beypore	3222.96
9.	periyar	4633.66
10.	Achankovil	1338.61
11.	Other rivers	19278.75
	Sub-total:	40470.00
Total area of Konkan & Malbar coast subzone		109885.00

2.3 Topography and Relief:

Plate - 4 shows the general topography of subzone - 5(a) & (b). The coastal areas have an elevation ranging from 0 to 150 metres. In western part of the region lies the gingatic Sahyadri Hill Range, the elevation of which ranges from 300 to 900 metres. To the west of this range of hills spread from north to south lies Deccan Plateau having a mean elevation of 300 to 600 metres. The rivers in the region have steep slopes in the upper reaches and traverse on the coastal plains for 50 to 100 kms before joining Arabian Sea.

2.4 Rainfall:

Plate - 5 shows the normal annual rainfall of the Sub-zone 5(a) & 5(b) and the histograms of normal monthly rainfall at Bombay, Mahabaleswar, Manglore and Trivandrum. The south-west and North east monsoon causes the rainfall in the subzones from May to October. The normal annual rainfall varies from 1000 mm to 4000 mm.

2.5 Temperature:

Plate-6 shows the normal annual temperature in the subzone alongwith the histograms showing the minimum, maximum and mean monthly temperature at Bombay, Mahabaleswar, Mangalore and

Trivandrum. The variation of the mean annual temperature in the subzone is between 20 ^{0}c to 27 ^{0}c.

2.6 Soil:

The subzones 5(a) & (b) comprise of variety of soils as shown in Plate - 7. Broadly they can be classified into seven groups viz red loamy soil, red sandy soils, coastal alluvial soils, medium black soils, laterite soil, peaty and saline peaty soils and mixed red and black soils. Red loamy soils cover about 38 percent of the total area and are found along the coast line from Bombay to Trivandrum. Next major soil found is Laterite soils which cover about 28 percent of the area of the subzones. The laterite soils are found along the coastal line from Mahabaleswer to Trivandrum. Small patches of coastal alluvial soil are found near Mangalore and Chalakudy near the sea coast. Other soils form 34 percent of the total area.

2.7 Land use:

The land use map at Plate 8 has been prepared from the Irrigation Atlas of India 1972. The subzones 5(a) & (b) have considerable area of forests which might have undergone changes in the recent times because of more inhabitations. The main' crops grown in the region are rice, coconut, taploca, wheat and millets. The area under rice is the maximum when compared to other crops in the sub-zones.

2.8 Communications:

a) Railway sections:

The following railway sections traverse partly or fully through the subzones - 5(a) & (b):

5(a)	1.	SURAT - BOMBAY	-	WR
	2.	BOMBAY - KALYAN - IGATPURI	-	CR
	3.	KALYAN - PUNE JN	-	CR
5(b)	1.	MARMAGOA - LONDA - DHARWAR	-	SCR
	2.	BELGAUM - LONDA	-	SCR
	3.	SHIMOGA - TALAGUPPA	-	SCR
	4.	ALNAVAR - DANDELI	-	SCR
	5.	MANGALORE - KANYAKUMARI	-	SR
	6.	SHORANUR - NILAMPUR	-	SR
	7.	SHORANUR - PODANUR - SALEM	-	SR
	8.	PODANUR - OTTACAMUND	-	SR
	9.	PODANUR - POLLACHI	-	SR
	10.	PALGHAT -POLLACHI - DINDIGAL	-	SR
	11.	CHALAKUDY - VALPARA	-	SR
	12.	QUILON - TIRUNALVELI	-	SR

b) Highways:

The following major Highways partly or fully pass through the subzones 5(a) & (b):

5(a)	NH-8	BROACH - BOMBAY
	NH-3	BOMBAY - NASIK
	NH-17	KALYAN - KARWAR
	NH-4	BOMBAY - PUNE - BANGALORE
5(b)	NH-17A	VENGURLA - KARWAR
	NH-4A	KARWAR - BELGAUM
	NH-17	KARWAR - TRICHUR
	NH-47	SALEM-TRICHUR-TRIVANDRUM-KANYAKUMARI
	NH-48	MANGALORE - HASSAN - BANGALORE
	NH-7	KANYAKUMARI - MADURAI

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 hydrometeorological 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 economicably 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 a hydrometeorological homogenous regions (sub-zones). Data collected and analysed for obtaining sub-zonal SUH equations are discussed in succeding 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 dischar-ge 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 Data Collected:

The Western ,Southern and South Central railways under the supervision and guidance of Research Designs and Standards Organisation (RDSO) has observed and collected the data for 6 catchments for a period ranging from 2 to 6 years. The Central Water Commission on behalf of the Ministry of Transport (Surface) has also observed and collected the required data since 1980 for 11 catchments for a period of 4 to 6 years. The size of the gauged catchments vary from 37 sq.km to 988 sq.km. Concurrent rainfall, gauge and discharge data for 96 bridge catchment years from 17 catchments were available for the studies. The number of gauged catchments in sub-zone 5(a) and 5(b) are 7 and 10 respectively.

Location of the gauging sites at road and railway bridges in the subzones 5(a) and 5(b) are shown in Plate-2 and 3 respectively. Annex.3.1 shows the names of streams, railway/road bridge numbers with railway sections, road sections, their catchment areas, number of raingauge stations and the period of availability of concurrent rainfall, gauge and discharge data.

3.4 Analysis of Data for obtaining sub-zonal synthetic unit hydrograph equations (one hour):

To obtain a synthetic unitgraph, the following steps are followed:

i) Analysis of physiographic parameters of the catchments.

ii) Scrutiny of data and finalisation of gauge discharge rating curves.

iii) Selection of flood and corresponding storm events.

iv) Computation of 1-hour catchment rainfall.

v) Separation of base flow and computation of direct runoff-depth.

vi) Computation of infilteration loss (ϕ-index) and 1-hour rainfall excess units.

vii) Derivation of 1-hour unitgraph.

viii) Drawing of representative unitgraphs and measuring the parameters.

ix) Establishing relationships between physiographic and representative unitgraph parameters.

x) Derivation of 1-hour synthetic unitgraph using such equations for an ungauged catchment.

The above steps are briefly described as under:

3.4.1 Physiographic parameters of the catchment:

Physiographic parameters indicated in Fig. 1 are discussed in the following paragraphs :

3.4.1.1 Catchment Area(A):

The gauging site is located on a toposheet and the watershed boundary is marked. The area enclosed in this boundary upto the gauging site may be referred to as the catchment area.(A)

3.4.1.2 Length of the Main Stream (L) :

This implies the Longest length of the main river from the farthest watershed boundary of the catchment area to the gauging site.

3.4.1.3 Length of the main stream from a point near to the centre of gravity of catchment to the bridge site (Lc) :

For finding the centre of gravity of the catchment, usually the boundary of the catchment is cut on a card board, which is then hung in three diffreent directions in vertical planes and the plumb lines are drawn from the point of hanging. The point of intersection gives the centre of gravity of the catchment. The stream may or may not pass through the centre of gravity but the nearest point to the centre of gravity is considered to find the length of the main river from the centre of gravity to the point of study.(Lc)

3.4.1.4 Equivalent Stream Slope (S):

One of the physiographic parameter is slope. The slope may be equivlent slope or statistical slope. In this report equivalent stream slope has been used for developing the SUH relation. The same can be computed by any one of the following methods.

(a) Graphical Method:

Longitudinal section (L-section) of the main stream was prepared from the values of the contours across the stream or the spot levels near the banks with respect to their distances from the point of interest/gauging site. A line is so drawn by trials from the point of interest on the L-section such that the areas of the L-section (profile) above and below the line are equal. This line is called equivalent stream slope line.

(b) Analytical Method.

L-section is broadly divided into 3 to 4 segments representing the broad ranges of the slopes of the segments and the following formulae is used to calculate the equivalent slope (S) :

$$S = \frac{\sum L_i (D_{i-1} + D_i)}{(L)^2}$$

where L_i = Length of the ith segment in km.

D_{i-1}, D_i = Elevations of river bed at ith intersection points of contours reckoned from the bed elevation at points of interest considered as datum, and D(i-1) and D are the heights of successive bed location at contour and intersections.

L = Length of the longest stream as defined in section 3.4.1.2 in km.

Physiographic parameters A, L, Lc and S obtained for 13catchments , found suitable for analysis are shown in Annex.3.2

3.4.2 Unit hydrograph Studies:

3.4.2.1 Scrutiny of data and finilisation of gauge discharge rating curve:

The data was scrutinised through arithmetical checks. Where wide dispersions were observed in the stage-discharge curve, log-log fitting was adopted. The stages for conceivable floods were converted into discharges initially identified with reference to rise and fall in the stages of the river.

3.4.2.2 Selection of flood and corresponding storm events:

The general guidelines adopted for selection of flood events for each catchment are as under :

i) The flood should not have unduly stagnating water levels.

ii) The selected flood should result from significant rainfall excess generally not less than one cm.

3.4.2.3 Computation of hourly catchment rainfall:

The Thiessen network was drawn for the raingauge station the catchment map and then Thiessen Weights were computed. 1-hour point rainfall at each station was multiplied by their respective Thiessen Weights and added to obtain the catchment rainfall for each hour duration during the storm period.

3.4.2.4 Computation of Infiltration loss (ϕ-index) and 1-hour effective rainfall units:

With the known values of 1-hour catchment rainfall and the direct runoff depth for each flood event, the infiltration loss (constant loss rate) by trials was estimated. 1-hour infiltration loss * was deducted from 1-hour rainfall to get 1- hour rainfall excess units.

3.4.2.5 Separation of base flow:

The selected flood events were plotted on the normal graph paper. The base flow was separated through the normal procedure to obtain direct surface runoff hydrographs and the direct runoff depth over the catchment was computed for each flood events.

3.4.2.6 Derivation of 1-Hour Unitgraph:

A unit duration of 1-hour was adopted for derivation of unitgraphs. The 1-hour unitgraphs were derived from the rainfall excess hyetographs and their corresponding direct runoff hydrographs by iterative methods. The iterations were carried out till the observed and estimated direct runoff hydrographs compared favourably. Normally 3 unitgraphs were derived for each of 13 catchments considered.

3.4.2.7 Drawing of representative Unitgraphs and measuring their parameters:

Set of Unitgraphs as obtained vide para 3.4.2.6 above were superimposed and an average/representative Unitgraph (RUG) was derived. This excercise was repeated for all samples. Each RUH was then tested by reproducing the direct surface run-off hydrograph by applying RUH ordinates to the corresponding observed rainfall excesses and comparing with the observed hydrograph. The relevant parameters of RUH i.e. t_p, q_p, W_{50}, W_{75}, W_{R50}, W_{R75} and T_B (as illustrated in Fig.2) were measured for each Catchment. List showing these parameters for 13 catchments is given in Annex.3.3

3.4.3 Establishing relationships between physiographic and Representative Unitgraph Parameters:

Following simple model was adopted for establishing the relationships between RUH parameters and catchment characterstics.

$$Y = C\ X^{P} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 3.4.3.1$$

where

Y = Dependent variable
X = Independent variable
C = A constant
P = An exponent
From above equation, it follows that
Log Y = Log C + P log X

Thus if Y and X are plotted on a log-log paper, one may expect a straight line relationship.

Various trials of relationship between the physiographic parameters (Annex.3.2) and one of the unitgraph parameter (Annex. 3.3) for 13 gauged catchments considered suitable for the studies were made. The relationship between physiographic parameters (L/S) and U.G. parameter q_p was found to be significant. Afterwards t_p was related to unit peak discharge of the U.G. (q_p) and q_p was related to various U.G. parameters like W_{50}, W_{75}, WR_{50}, WR_{75}. The T_B could be significantly correlated to tp. The principle of least squares was used in the regression analysis to get the relationships in the form of equation 3.4.3.1 to obtain the parameters of the Synthetic unitgraph in an unbiased manner. The following relationships have been derived for estimating the 1-hr unitgraph parameters in the subzones- 5(a) and 5(b).

Relationships 1	Equation No. 2	Fig.No. 3
$q_p = 0.9178(L/S)^{-0.4313}$	3.4.3.2	3
$t_p = 1.5607\ (q_p)^{-1.0814}$	3.4.3.3	4
$W_{50} = 1.9251(q_p)^{-1.0896}$	3.4.3.4	5
$W_{75} = 1.0189(q_p)^{-1.0443}$	3.4.3.5	6
$W_{R50} = 0.5788(q_p)^{-1.1072}$	3.4.3.6	7
$W_{R75} = 0.3469(q_p)^{-1.0538}$	3.4.3.7	8
$T_B = 7.3801(t_p)^{0.7343}$	3.4.3.8	9
$T_m = t_p + t_r/2$	3.4.3.9	
$Q_p = q_p \times A$	3.4.3.10	

Relations developed are shown in Figures 3 to 9. Attempts were made to develop a confidence band which could cover all the 13 samples and it was found that with a 95% upper and lower band all the 13 samples are within the band. List of catchment and unit hydrograph parameters studied to establish relationships and co-effecient of correlations are shown in Annexure-3.4

The above relationships may be utilised to estimate the parameters of 1-hour synthetic unitgraph for an ungauged catchment with its known physiographic characteristics like A, L, Lc and S.

3.4.4 Derivation of 1-Hour Synthetic Unitgraph for an Ungauged catchment:

Considering the hydro-meteorological homogeneity of subzones-5(a) and 5(b), the relations established between physiographic and unitgraph parameters in section 3.4.3 are applicable for derivation of 1-hour Synthetic unitgraph for an ungauged catchment in the subzones.

The 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. L/S is then calculated.

ii) Substitute L/S in the equation 3.4.3.2 to obtain q_p and this q_p in equation 3.4.3.3 to get t_p in hours.

iii) Substitute the value of q_p/t_p in the equations 3.4.3.4 to 3.4.3.8 to obtain W_{50}, W_{75}, W_{R50}, W_{R75} and T_B in hours.

iv) 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. 2 and sketch the unitgraph through these points.

Sum of discharge ordinates of tr-hr Unitgraph is accuratety obtained by using the following equation:

$$\sum Q_i = \frac{2.78\ A}{tr}$$

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

A = Catchment area in sq.km.

tr = Unit duration in hours.

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

3.5 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 (ϕ-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.

Loss rates computed based on observed storm rainfall and runoff for 111 flood events analysed for 13 bridge catchments are tabulated under different loss rate ranges at intervals of 0.2cm/hr as shown in Annex.3.5

The modal value of loss rate computed as 0.19 cm/hr and is recommonded for adoption as Design Loss Rate. The designer can however modify this value as per the local site conditions.

3.6 Design Base Flow:

Base flow values for 111 flood events tabulated in different ranges are shown in Annex.3.6. Out of 111 flood occasions,64 flood events fall under the range upto 0.135 - 0.185. Base flow rate of 0.15 cumecs/sq.km may be adopted for estimating base flow for a catchment.

PART IV

DESIGN STORM INPUT

The point rainfall amount for the design storm duration and its areal and time distribution are the three main meteorological factors deciding the shape of design flood hydrograph. Studies on such components have been carried out by India Meteorological Department and the results have been given in the form of 25, 50 and 100 year 24 hour isopluvial maps, ratios for short durations to 24 hours, ratio for point to areal values and time distribution values. Methodology adopted for analysis for each component is discussed in subsequent paras.

4.1 Design Storm Duration:

The duration of the storm rainfall which causes the maximum discharge in a drainage basin is called the design storm duration (TD). Alternative studies were carried out assuming Td= 1.1 x tp and TD = TB for estimating 25yr, 50yr and 100yr flood for 13 gauged catchments by synthetic unit hydrograph relations with loss rate of 0.19cm/hour as shown in Annex.4.1. It is seen that in 6 catchments TD=1.1tp gave higher discharge and remaining 7 catchments TD=TB gave the higher discharge. It is therefore suggested to consider that value of TD, ranging between TD= 1.1x Tp and TD = TB, Which gives higher value of peak.

4.2 Rainfall Depth-Duration-Frequency Analysis:

India Meteorological Department have conducted this study utilizing the data of 22 Self Recording Raingauge Stations and 26 Ordinary Raingauge Stations maintained departmentally, 201 Ordinary Raingauge maintained by the state governments of Maharashtra, Karnataka, Goa, Tamil Nadu and Kerala, and 35 raingauge stations maintained by Railways, Central Water Commission for recording short duration rainfall in 9 bridge catchments falling in sub-zones 5(a) and 5(b).

The annual maximum series of one-day rainfall were formed for each of 227 ordinary raingauge stations in and around two sub-zones using the rainfall records of 50 to 80 years. The annual extreme value series were subjected to frequency analysis by Gumbel's extreme value distribution and the rainfall estimates for one-day corresponding to 25, 50 and 100 year return periods were computed. The daily values of 25-years, 50 years and 100 years rainfall estimates were converted into 24 hour rainfall estimates of corresponding return periods by using the conversion factor of 1.15. These 24-hour rainfall estimates for all the stations in and around the sub-zone were plotted on base maps and isopluvial maps of 25-year, 50-year and 100-year return period were drawn. These maps are shown in Plates 9, 10 & 11 for sub-zone 5(a) and in Plates 12, 13 & 14 for sub-zone 5(b).

The hourly rainfall data recorded at 22 Self Recording Raingauge Stations maintained by India Meteorological Department were analysed by frequency analysis (partial duration series) method and the rainfall estimates for various return periods (viz. 2,5,10,25,50 and 100 years) were computed for durations 1,3,6,9,12,15,18 and 24 hours. The rainfall estimates corresponding to these durations in respect of all the 22 stations were converted into ratios with respect to 24 hours estimates for each of the above mentioned return periods. Averaged ratios for different durations were then computed for the two sub-zones taken together for each return period. It was noticed that for a specified duration the average ratios, except for return periods of 5 years and less, were comparable in magnitude. The average ratios for selected duration, based on 50-year estimates, are given below and are recommended to be adopted for converting 24-hour rainfall into short duration rainfall. Ratios for other durations can be read from the graph in Fig.10.

Duration (t) in hours	Ratio *
1	.32
3	.48
6	.61
9	.70
12	.78
15	.85
18	.91
24	1.00

$$* \text{ Ratio} = \frac{\text{50-year t-hour point rainfall}}{\text{50-year 24-hour point rainfall}}$$

These ratios, when multiplied by 24-hour rainfall estimates corresponding to a selected return period, will generate 1-hour, 3-hour... 18-hour etc. rainfall estimates having the same return period.

4.3 Point to Areal Rainfall:

Railway and Central Water Commission had temporarily installed and maintained a network of 51 stations in 16 bridge catchments in sub-zones 5(a) and 5(b) and collected hourly/half hourly rainfall data for these locations. However, data of only 35 stations located in 9 bridge catchments could be processed and used for this study. The data of remaining 7 bridge catchments could not be utilized as the data series were either for less than 4 years or concurrent data were not recorded continuously for 4 years at all the stations in these bridge catchments. 2-year point rainfall values for specified durations (1,3,6,12 and 24 hours) for each station in the catchments were computed by partial duration method. Arithmetic average of 2-year point rainfall of all the stations in the catchment was calculated to get the 2-year representative point rainfall for the catchment for each duration.

As a second step, events of maximum average depth for a particular duration in each year were then selected on the basis of simultaneous occurrence of rainfall at all the stations in the catchment. The areal rainfall series thus obtained were subjected to frequency analysis and 2-year areal rainfall depths for specified durations were computed. The percentage ratios of 2-year areal rainfall to 2-year representative point rainfall for the catchments were calculated and plotted against the catchment area of the bridges for various durations. The best fit curves were drawn for various durations on the basis of points obtained from data of all the catchments. Figures 11(a) and 11(b) give the curves for conversion of point rainfall of 1,3,6,12 and 24 hours into corresponding areal rainfall.The areal reduction factors (ARF) for selected catchment sizes for the above durations are also given in Annex.4.2.

4.4 Time Distribution Studies:

The time distribution studies have been carried out for the following five groups of rainstorms.

1) Rain storms of 2 to 3 hours durations

2) Rain storms of 4 to 6 hours durations

3) Rain storms of 7 to 12 hours durations

4) Rain storms of 13 to 18 hours durations

5) Rain storms of 19 to 24 hours durations

4476 rainstorms of durations ranging from 1 hour to 24 hours, occurring at locations of self recording raingauges of IMD in the two sub-zones, were analysed based on 332 station-year data of self recording stations. Rainstorms selected at each station were grouped under the above 5 categories and plotted on different graphs as dimensionless curves with cumulative percentage of the total rainfall along the ordinate and the percentage of the storm duration along the abscissa. Thus, five different graphs were prepared for each station corresponding to above durations. The average time distribution curves for various groups of storms were then drawn for each station. All the 22 average curves thus obtained for a particular group of storms were plotted on a single graph and a single average curve for the two sub-zones was drawn for that group of storms. In this fashion 5 average time distribution curves were drawn for the 5 groups of storms which are shown in Fig.12. Time distribution co-effecients for different durations read from these curves are given in Annex.4.3.

4.5 Heaviest Daily Rainfall Records:

It may often be of interest to know the heaviest recorded daily rainfall at various places in the sub-zones. Heaviest daily recorded rainfall in each and every district of the sub-zones 5(a) and 5(b) have been compiled and presented in Annex.4.4. In general, only such stations have been included in these tables where rainfall exceeding 35 cm as recorded on a single day (0830 hours to 0830 hours next day). Exception has been made only in the case of those districts where not a single station recorded rainfall exceeding 35 cm on any single day. In such cases only one station in each district, which recorded the heaviest rainfall of the district, has been included in these Annexures.

4.6 Computation of Design Storm Rainfall:

Following procedure is followed for computation of storm rainfall and its distirbution.

Step-1: Estimate T_D vide para 4.1.0

Step-2: Locate bridge catchment under study on the 50-yr, 24-hr isopluvial map (Plate-10 or 13) and obtain the 50-yr 24-hr point rainfall value in cms. For catchment covering more than one isohyet, compute the average point storm rainfall.

Step-3: Read the conversion ratio for T_D hours from Fig. 10 and multiply the 50-yr 24-hr rainfall in Step-2 by the ratio to obtain 50-yr T_D-hr point rainfall.

Step-4: Convert the 50-yr T_D -hr point rainfall to 50-yr T_D -hr areal rainfall by multiplying it with the areal reduction factor (ARF) corresponding to the given values of catchment area and T_D -hr duration from Annex.4.2 or by interpolation from Fig. 11(a) and 11(b) in section 4.1.2.

Step-5: Apply the cumulative percentage of total rainfall against the cumulative percentage of storm duration curves in Fig. 12 or from Annex.4.3 corresponding to design storm duration T_D to obtain the rainfall depths at 1-hr interval, since the unit duration of synthetic U.G. is 1-hour.

Step-6: Obtain the 1-hour areal rainfall increments by subtraction of successive 1-hour cumulative values of rainfall in step-5.

Step-7: Obtain one hour effective rainfall increments by substracting the design loss rate from one hour areal rainfall increments.

PART V

DESIGN FLOOD ESTIMATION

5.1. Criteria and Standàrds in regard to Design Flood of Structures of smalland Medium Catchments.

The Khosla Committee of Engineeers had recommended a **design flood of 50-yr return** period for fixing the water way of **the bridges.** Criterias and standards followed for design flood for **bridges,** cross drainage structures and small dams are given **below:**

a) Indian **Railway Standard - 1963** (revised in 1985) **specifies that** 50 yr flood is to be used for smaller bridges **carrying railways** of less importance like minor lines and branch **lines.** In the case of larger bridges on main lines and from important lines, a 100-yr flood is to be adopted.

b) Indian Road Congress-IRC 5-1970, 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.

c) Indian Standaru 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 frequency flood and the safety of the foundation and free-boards etc. should be checked for 50-yr or 100-yr flood.

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 floods as inflow design flood for small dams having either gross storage of the dam between 0.5 to 10 Mm^3 or hydraulic head between 7.5 mt. to 12 mt.

The report covers the proceedures for estimating design flood for 25 yrs, 50 yrs and 100 yrs return period covering above criterias.

5.2 Estimation of Design Flood by S.U.H approach.

Procedure for computing design flood peak and design flood hydrograph for 50 yr return period by SUH approach is as under:

a) Computation of Design Flood Peak

Step-1 Derive the synthetic unit hydrograph as per section 3.4.4 and tabulate 1 hour U.G. ordinates.

Step-2 Obtain design storm rainfall and 1 hour areal rainfall increments as per section 4.2.

Step-3 Adopt the design loss rate as recommended vide section 3.5.

Step-4 Obtain one hour effective rainfall values for the design storm duration T_D by subtracting the design loss rate from the areal rainfall values.

Step-5 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 values against the next lower U.G. ordinate and so on upto T_D hour duration.

Step-6 Obtain the base flow for the catchment area under study vide section 3.6.

Obtain 50 year flood peak values by summing the product of unit hydrograph ordinates as tabulated for Step 1 and the effective rainfall values as tabulated in Step 5 after addition of base flow in Step 6.

b) Computation of Design Flood Hydrograph

For computation of design flood hydrograph, carry out the steps from 1 to 6 and in addition, carry out the following steps.

Step-7 Reverse the sequence of effective rainfall units obtained in Step 5 to get the critical squence of the effective rainfall rainfall.

Step-8 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 ualues giving a lag of 1-hr to successive direct runoff orinates.

Step-9 Add the direct runoff ordinates at 1-hr interval to get total direct runoff hydrograph.

Step-10 Add the base flow in Step 6 to the direct runoff ordinates at 1-hr interval in Step-9 to get the 50-yr flood hydrograph.

5.3 Computation of Design H.F.L. Corresponding to Design Flood:

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 orrifice 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 across 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 efffects 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 affect 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 profilies 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 300mt. 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 A generalised conclusion regarding the base flow and loss rate are assumed to hold good during the design flood event.

6.2.0 Limitations:

6.2.1 The data of 7 bridge catchments in sub zone 5(a) and 6 brdige catchments in sub zone 5(b) were found suitable. Hence separate relationship could not be developed for each sub zone 5(a) and 5(b).

For more reliable results it is desirable to collect the data for more brdige catchment of each sub zone and develop a separate relationships for each sub zone.

6.2.2 The method would be 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 estimating the design flood of 50-yr return period incorporated in the body of the report is recommended for adoption, which also holds good for 25-yr flood and 100-yr flood.

6.3.2 The report also 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 25-yr, 50-yr and 100-yr flood may be estimated using design loss rate of 0.19 cm/hr.

6.3.4 The report is applicable for the catchment area 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 necessitate special site study. Engineer-in-charge at site is advised to take a pragmatic view while deciding the design discharge of a bridge.

Referances:

1. Report of the Khosla Committee of Engineers (October, 1959) Government of India, Ministry of Railways.

2. "Hand Book of Hydrology", Ven Te Chow

3. "Open Channel Hydraulics", Ven Te Chow

4. Guide to Hydrological Practices (Third Edition) World Meteorological Organisation No. 168, 1974.

5. Estimation of Design Flood "Recommended Procedures" (September, 1972), Central Water Commission, New Delhi.

6. "Engineering Hydrology" Wilson E.M.

7. Code of Practice by Indian Railways (Revised 1985).

8. IRC : 5 - 1985 - Standard specifications and code of practice for Road Bridges, Section - 1, General Features of Design 6th Revision) 1985, Indian Roads Congress.

9. IRC : SP : 13 - 1973 - Guidelines for the Design of Small Bridges and Culverts.

10. Flood Studies Report. Vol. 1 Hydrological Studies, Natural Environment Research Council, 27, Charing Cross Road, London, 1975.

11. "Economics of Water Resources Planning" L. Douglas James/Rober L. Lee.

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)
8. Upper Indo-Ganga Plains subzone-1(e) (1984)
9. Middle Ganga Plains subzone-1(f) (1985)
10. Kaveri Basin subzone-3(i) (1986)
11. Upper Godavari subzone-3(e) (1986)
12. Mahi & Sabarmati subzone-3(a) (1987)
13. East Coast subzone-4(a), (b) & (c) (1987)
14. Sone subzone-1(d) (1988)
15. Chambal subzone 1(b) (1988)
16. Betwa subzone 1(c) (1989)
17. North Brahmaputra Basin subzone 2(a) (1991)

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S/Shri Rajkumari Tahiliaramani, V. Suresh,
Neelam Sehgal, Sushila, Sudesh Sharma - Jr. Computor.

ANNEXURE - 1.1

SUB ZONE 5(B) BR.NO.MOT-9

COMPUTATION OF EQUIVALENT SLOPE

CA = 176.00 sq.km , L = 38.46 Km.

Sl.NO	REDUCED DISTANCE. (from point of study.) (Km)	REDUCED LEVEL (m)	LENGTH OF EACH SEGMENT L_i (Km)	HEIGHT ABOVE DATUM (m)	$(D_{i-1} + D_i)$ (m)	$L_i*(D_{i-1} + D_i)$
1	2	3	4	5	6	7
1	0.000	18.288	0.000	0.000	0.000	0.000
2	15.768	30.480	15.768	12.192	12.192	192.243
3	20.273	42.672	4.505	24.384	36.576	164.775
4	22.848	45.720	2.575	27.432	51.816	133.426
5	26.227	60.960	3.379	42.672	70.104	236.881
6	28.962	76.200	2.735	57.912	100.584	275.097
7	30.893	91.440	1.931	73.152	131.064	253.085
8	32.502	152.400	1.609	134.112	207.264	333.488
9	33.950	228.600	1.448	210.312	344.424	498.726
10	35.076	304.800	1.126	286.512	496.824	559.424
11	36.363	457.200	1.287	438.912	725.424	933.621
12	37.329	609.600	0.966	591.312	1030.224	995.196
13	38.455	899.160	1.126	880.872	1472.184	1657.679
						6233.642

$$S = \frac{(L_i * (D_{i-1} + D_i))}{L^2} = \frac{6233.642}{1479.172}$$

$$= 4.214 \text{ m/km}$$

DATUM = 18.288 M ,i.e R.L of river bed at the point of study .

ANNEXURE - 1.2

COMPUTATION OF FLOOD HYDROGRAPH

BR. NO. -- MOT - 9

SUB-ZONE : 5(b)

TIME IN HOURS	S.U.H. ORDINATES IN CUMECS	RAINFALL EXCESS IN CMS 0.71	1.25	3.95	8.81	2.33	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	
0	0.00	0.00					0.00	26.40	26.40	
1	5.60	3.98	0.00				3.98	26.40	30.38	
2	14.80	10.51	7.00	0.00			17.51	26.40	43.91	
3	28.00	19.88	18.50	22.12	0.00		60.50	26.40	86.90	
4	48.00	34.08	35.00	58.46	49.34	0.00	176.88	26.40	203.28	
5	62.20	44.16	60.00	110.60	130.39	13.05	358.20	26.40	384.60	
6	58.39	41.46	77.75	189.60	246.68	34.48	589.97	26.40	616.37	
7	45.20	32.09	72.99	245.69	422.88	65.24	838.89	26.40	865.29	
8	37.60	26.70	56.50	230.64	547.98	111.84	973.66	26.40	1000.06	--->PEAK
9	32.00	22.72	47.00	178.54	514.42	144.93	907.60	26.40	934.00	
10	27.40	19.45	40.00	148.52	398.21	136.05	742.23	26.40	768.63	
11	23.80	16.90	34.25	126.40	331.26	105.32	614.12	26.40	640.52	
12	20.50	14.56	29.75	108.23	281.92	87.61	522.06	26.40	548.46	
13	18.00	12.78	25.63	94.01	241.39	74.56	448.37	26.40	474.77	
14	15.60	11.08	22.50	80.98	209.68	63.84	388.07	26.40	414.47	
15	13.30	9.44	19.50	71.10	180.61	55.45	336.10	26.40	362.50	
16	11.20	7.95	16.63	61.62	158.58	47.77	292.54	26.40	318.94	
17	9.20	6.53	14.00	52.54	137.44	41.94	252.44	26.40	278.84	
18	7.30	5.18	11.50	44.24	117.17	36.35	214.44	26.40	240.84	
19	5.40	3.83	9.13	36.34	98.67	30.99	178.96	26.40	205.36	
20	3.60	2.56	6.75	28.84	81.05	26.10	145.29	26.40	171.69	
21	1.80	1.28	4.50	21.33	64.31	21.44	112.86	26.40	139.26	
22	0.00	0.00	2.25	14.22	47.57	17.01	81.05	26.40	107.45	
23			0.00	7.11	31.72	12.58	51.41	26.40	77.81	
24				0.00	15.86	8.39	24.25	26.40	50.65	
25					0.00	4.19	4.19	26.40	30.59	
26						0.00	0.00	26.40	26.40	

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

SUB ZONE 5(a)&(b)

ANNEXURE 3.1

LIST OF RAILWAY BRIDGE/M.O.T. CATCHMENTS AND AVAILABILITY OF GAUGE, DISCHARGE AND RAINFALL DATA

Sl.No	Name of Stream	Name of Section where bridge is located with Railway zone/Road Section	Railway bridge No./site No.	SUB ZONE 5	G.Site Location Latitude Deg.	Latitude Min.	Latitude Sec.	Longitude Deg.	Longitude Min.	Longitude Sec.	Catchment area (sq.km)	No of rain-gauge	Data availability	No. of years
(A) BRIDGES CONSIDERED FOR REGRESSION ANALYSIS														
1	AMLIKA	BANSDA - VYDRA	MOT-6	A	20°	51	30	73°	20	10	988.00	8	1980-86	7
2	PINJAL	MANOR - VADA	MOT-4	A	19	40	10	73	04	45	610.00	5	1981-86	6
3	KAPRI	WAGHAT - BANSDA	MOT-5	A	20	49	00	73	30	30	480.00	4	1983-86	4
4	CHIMONI PUZHA	SHORANUR - COCHIN HARBOUR(S.R)	104	B	20	47	30	73	30	08	388.50	5	1961-64	4
5	SWARNA	JADKAL - MANGALORE	MOT-8	B	13	17	35	74	58	50	327.00	2	1980-88	9
6	AMBA	KOLAD - PANVEL	MOT-2	A	18	32	00	73	12	00	310.00	2	1980-86	7
7	KAL	KOLAD - MAHAD	MOT-1	A	18	14	00	73	17	00	259.00	2	1980-86	7
8	KODAVADI PALLAM	POLLACHI - PODANUR(S.R.)	273	B	10	45	45	77	01	10	200.21	6	1961-66	6
9	VELLIAR	SHORANUR - NILAMPUR(S.R.)	117	B	11	03	40	76	16	22	189.07	5	1961-64	4
10	ITHIKARA	TRIVANDRUM -KOTTAYAM	MOT-11	B	8	53	25	76	52	00	177.00	2	1980-86	7
11	ANJARAK-ANDIPUZHA	VIRARAJEUDRAPETE - TELLICHERY	MOT-9	B	11	52	25	75	34	40	176.00	1	1980-86	7
12	BENNEHOLE	HUBLI - KUMATA	MOT-7	B	14	31	30	74	36	30	62.00	1	1980-85	6
13	ACHIPATTI - NULLAH	PODANUR - POLLACHI(S.R)	260	B	10	49	40	77	01	00	48.02	1	1969-72	4
BRIDGES NOT CONSIDERED FOR REGRESSION ANALYSIS														
14	ULHAS	KALYAN - KHOPOLI	MOT-3	A	19	09	00	73	15	00	863.50	6	1981-86	6
15	ACHONKVOIL	PANDALAM - PATHANAMTHITTA	MOT-10	B	9	13	50	76	45	20	768.00	6	1980-87	8
16	VAROLI	BOMBAY-SUAT (WR)	228	A	20	11	00	72	49	00	230.82	NA	1965	1
17	TIPPAM	DINDIGUL-PATTI POLLACHI (SR)	229	B	10	39	00	77	06	00	36.93	2	1967,68	2

ANNEXURE. 3.2

Subzones-5(a) & 5(b)

BASIN CHARACTERISTICS OF SELECTED CATCHMENTS

Sl.NO	Bridge	Area (sq.km)	Sub-zone	L (km)	Lc (km)	SEQ (m/km)	L/S
1	2	3	4	5	6	7	8
1	MOT-6	988.00	5(A)	82.05	48.27	4.74	17.31
2	MOT-4	610.00	5(A)	68.38	37.00	3.47	19.71
3	MOT-5	480.00	5(A)	71.44	37.81	4.61	15.50
4	104	388.50	5(B)	50.36	29.77	0.89	56.58
5	MOT-8	327.00	5(B)	33.63	12.06	7.03	4.78
6	MOT-2	310.00	5(A)	34.75	14.48	3.10	11.21
7	MOT-1	259.00	5(A)	38.29	20.92	5.05	7.58
8	273	200.21	5(B)	24.94	12.87	5.58	4.47
9	117	189.07	5(B)	25.74	10.46	0.88	29.25
10	MOT-11	177.00	5(B)	30.59	13.68	2.32	13.19
11	MOT-9	176.00	5(B)	38.48	20.29	4.21	9.14
12	MOT-7	62.00	5(B)	12.55	11.26	8.21	1.53
13	260	48.02	5(B)	12.87	7.24	7.62	1.69

ANNEXURE. 3.3

REPRESENTATIVE 1-HR UNIT GRAPH PARAMETERS 5(A) & 5(B)

Sl.NO	Bridge	Area (sq.km)	Sub-zone	tp hrs	qp cumecs/km	Qp cumecs	tr hrs	TB hrs	W50 hrs	W75 hrs	WR50 hrs	WR75 hrs
1	2	3	4	5	6	7	8	9	10	11	12	13
1	MOT-6	988.00	5(A)	2.50	0.60	594.52	1.00	15.00	3.70	1.77	0.90	0.57
2	MOT-4	610.00	5(A)	4.50	0.40	248.03	1.00	15.00	6.40	2.90	1.90	0.90
3	MOT-5	480.00	5(A)	3.50	0.36	175.00	1.00	22.00	6.60	3.50	1.40	0.90
4	104	388.50	5(B)	28.50	0.08	31.90	1.00	100.00	28.25	14.75	11.25	6.50
5	MOT-8	327.00	5(B)	5.50	0.32	105.00	1.00	20.00	7.85	4.00	3.00	1.75
6	MOT-2	310.00	5(A)	1.50	0.43	133.58	1.00	15.00	2.30	1.04	0.77	0.40
7	MOT-1	259.00	5(A)	4.50	0.45	117.69	1.00	17.00	5.35	2.23	1.65	0.68
8	273	200.21	5(B)	4.50	0.63	125.27	1.00	16.00	3.40	2.10	1.00	0.70
9	117	189.07	5(B)	6.50	0.34	63.41	1.00	24.00	6.60	3.50	2.80	1.70
10	MOT-11	177.00	5(B)	13.50	0.12	20.91	1.00	70.00	19.60	8.90	4.40	2.20
11	MOT-9	176.00	5(B)	10.50	0.18	31.50	1.00	55.00	12.55	6.35	3.80	2.15
12	MOT-7	62.00	5(B)	1.50	0.88	55.00	1.00	13.00	2.00	1.23	0.75	0.50
13	260	48.02	5(B)	3.50	0.63	30.40	1.00	15.00	3.30	1.70	0.90	0.50

ANNEXURE - 3.4

Subzones-5(a) & 5(b)

LIST OF PHYSICAL AND UNIT HYDROGRAPH PARAMETERS STUDIED TO ESTABLISH RELATIONSHIPS

Sl. No.	Independent variables Physiographic Parameters/unit graph parameters	Constant	Dependent variables Unitgraph Parameters	Exponent
1	2	3	4	5
1	LLc/_/S	1.378	qp	-0.238
2	Lc/_/S	1.006	qp	-0.473
3	Lc/S	0.686	qp	-0.426
4	L/S	0.918	qp	-0.431
5	tp	1.137	qp	-0.746
6	qp	1.561	tp	-1.081

ANNEXURE 3.5

Subzones-5(a) & 5(b)

LOSS RATE RANGES(cms/hr.)-NO. OF FLOOD OCCASIONS

SL. NO.	BRIDGE NO |---->		MOT-6 (UNAI)	MOT-3 (BADLAPUR	MOT-4 (PALI)	MOT-5 (BARI)	104	MOT-8 (YENNC-HOLE)	MOT-2 (PALI AT AMBER)	MOT-1 (MANGAON)	273	117	MOT-11 (AYUR	MOT-9 (MARVAM)	260	
	CATCHMENT AREA---> IN sq.Km		988.00	863.50	610.00	480.00	388.50	327.00	310.00	259.00	200.21	189.07	177.00	176.00	48.02	
	LOSS RATE RANGES															
	LB	UB	NUMBER OF OBSERVED FLOODS													ROW-TOTAL
1	0.0	0.1	2	3	2			2	1	2		2	2	5		21
2	0.1	0.3	1	1	2		6	4	2	2			6	9		33
3	0.3	0.5					2	3	1		2	5	3	3		19
4	0.5	0.7				2	1	3	1	2		2	2	2		15
5	0.7	0.9	1			1					3	7	2	1		15
6	0.9	1.1				2										2
7	1.1	1.3						1				1				2
8	1.3	1.5										1				1
9	1.5	1.7											1			1
10	1.7	1.9														
11	1.9	2.1														
12	2.1	2.3														
13	2.3	2.5														
14	2.5	2.7														
15	2.7	3.0													1	1
16	3.10	and above.													1	1
	COL.TOTAL		4	4	4	5	9	13	5	6	5	18	16	20	2	G.TOTAL 111

$$\text{MODAL LOSS RATE} = Li + \frac{(FM - F1) * (H)}{(2FM - F1 - F2)} = 0.19 \text{ cm/hr.}$$

WHERE ,

- Li ---> Lower limit of the modal class. (0.1)
- FM ---> Frequency of the modal class. (33)
- F1 ---> Frequency of the class preceding the modal class. (21)
- F2 ---> Frequency of the class succeeding the modal class. (19)
- H ---> Width of the modal class. (0.2)

Subzones-5(a) & 5(b)

ANNEXURE 3.6

BASE FLOW RANGES(cumec/sqkm.)-NO. OF FLOOD OCCASIONS

SUBZONE - 5(A) & 5(B)

SL. NO.	BRIDGE NO |---->		MOT-6 (UNAI)	MOT-3 (BADLAPUR	MOT-4 (PALI)	MOT-5 (BARI)	104	MOT-8 (YENNC-HOLE)	MOT-2 (PALI AT AMBER)	MOT-1 (MANGAON)	273	117	MOT-11 (AYUR	MOT-9 (MARVAM)	260	
	CATCHMENT AREA---> IN sq.Km		988.00	863.50	610.00	480.00	388.50	327.00	310.00	259.00	200.21	189.07	177.00	176.00	48.02	
	BASE FLOW RANGES		NUMBER OF OBSERVED FLOODS													
	LB	UB														ROW-TOTAL
1	0.000	0.009	0	0	0	1	0	0	0	0	1	0	1	0	0	3
2	0.009	0.018	0	1	0	0	0	0	0	0	1	0	0	0	1	3
3	0.018	0.027	0	0	0	0	0	0	0	0	1	0	2	0	1	4
4	0.027	0.036	0	0	0	0	0	0	0	0	2	0	0	0	0	2
5	0.036	0.045	0	0	0	0	0	0	0	0	0	0	8	0	0	9
6	0.045	0.054	0	0	0	0	1	0	0	0	0	0	1	0	0	2
7	0.054	0.063	0	0	0	0	0	0	0	0	0	2	1	0	0	3
8	0.063	0.072	0	0	0	0	0	0	0	0	0	0	1	0	0	1
9	0.072	0.081	0	0	0	0	0	0	0	0	0	0	1	0	0	1
10	0.081	0.090	1	2	0	0	0	0	0	0	0	1	1	0	0	5
11	0.090	0.099	0	0	0	0	0	0	0	0	0	2	0	0	0	2
12	0.099	0.108	0	0	0	0	1	0	0	0	0	0	0	1	0	2
13	0.108	0.117	0	0	0	1	0	0	0	0	0	2	0	0	0	3
14	0.117	0.126	0	0	0	1	0	2	0	0	0	1	0	0	0	4
15	0.126	0.135	0	0	0	0	0	0	0	0	0	1	0	0	0	1
16	0.135	0.185	1	1	0	2	0	0	0	1	0	6	0	9	0	20
17	0.185	0.235	0	0	0	0	4	0	1	0	0	1	0	1	0	7
18	0.235	0.335	1	0	1	0	1	2	2	0	0	1	0	4	0	12
19	0.335	0.435	0	0	2	0	2	0	0	0	0	1	0	5	0	10
20	0.435	0.535	0	0	1	0	0	0	2	1	0	0	0	0	0	4
21	0.535	0.735	1	0	0	0	0	0	0	2	0	0	0	0	0	3
22	0.735	0.935	0	0	0	0	0	7	0	2	0	0	0	0	0	9
23	0.935 and above		0	0	0	0	0	2	0	0	0	0	0	0	0	2
	COL.TOTAL		4	4	4	5	9	13	5	6	5	18	16	20	2	G.TOTAL 111

Out of the 111 flood occasions 64 flood events fall within 0.185 cumecs/sq.km ,i.e below class range of 0.135 - 0.185 . Hence base flow of 0.15 cumecs/sq.km has been adopted.

SUB-ZONE 5(a) & 5(b)

ANNEXURE. 4.1

Comparision of Q_{25}, Q_{50} and Q_{100} obtained by SUH method with $T_D = T_B$ and $T_D = 1.1 \times t_p$.

Sl.NO	Bridge	Area (sq.km)	Sub-zone	TD = 1.1 * tp Q25	TD = 1.1 * tp Q50	TD = 1.1 * tp Q100	TD = TB Q25	TD = TB Q50	TD = TB Q100
1	2	3	4	5	6	7	8	9	10
	Gauged Catchments								
1	MOT-6	988.00	5(A)	4285.38	4342.85	5225.21	4309.05	4541.64	5309.85
2	MOT-4	610.00	5(A)	2795.67	3153.40	3562.44	3009.19	3427.84	3884.88
3	MOT-5	480.00	5(A)	2410.24	2726.32	2960.25	2571.04	2922.06	3178.82
4	104	388.50	5(B)	903.93	959.17	1108.11	919.92	978.95	1132.24
5	MOT-8	327.00	5(B)	1781.65	1926.98	2138.32	1832.07	1985.4	2199.18
6	MOT-2	310.00	5(A)	1730.76	1918.38	2159.34	1823.95	2042.47	2313.16
7	MOT-1	259.00	5(A)	1571.53	1694.54	1861.29	1500.44	1623.31	1797.64
8	273	200.21	5(B)	563.95	754.15	824.34	517.29	709.85	778.66
9	117	189.07	5(B)	628.93	716.40	784.93	646.03	740.51	811.82
10	MOT-11	177.00	5(B)	585.94	665.34	689.37	569.45	649.51	675.61
11	MOT-9	176.00	5(B)	853.71	1000.06	1062.50	834.52	988.15	1046.37
12	MOT-7	62.00	5(B)	719.92	788.29	838.04	632.37	691.37	736.55
13	260	48.02	5(B)	241.00	307.67	336.59	209.89	272.24	297.49
	Ungauged Catchments								
14	4	1800.00		6317.58	7188.10	8024.69	5898.40	6742.00	7589.09
15	1	593.00		3374.78	3637.29	4034.97	3146.26	3399.01	3789.45
16	2	555.19		2509.96	2784.00	3068.38	2326.41	2597.23	2877.93
17	5	452.83		2630.11	2944.03	3134.55	2488.07	2777.32	2970.32

Note : Out of the 13 gauged catchments 6 catchments namely Mot-1, Mot-7, Mot-9,Mot-11,273 & 260 are showing higher values for TD=1.1*tp than TD=TB and remaining 7 catchments are showing higher values for TD=TB than TD=1.1*tp
The simplified equations derived considering TD=1.1*tp & TD=TB hrs have been mentioned in the report (para 3.7).
It is suggested to compute design storm flood with TD=1.1*tp & TD=TB hrs.
Whichever gives higher discharge values has to be adopted for design.

SUB-ZONE 5 (a & b)

POINT TO AREAL RAINFALL RATIOS (PERCENTAGES)

AREA IN SQ KM	DURATIONS (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	AREA IN SQ KM
0	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	0
50	87.00	89.50	92.00	93.00	94.00	95.00	95.33	95.67	96.00	96.33	96.67	97.00	97.04	97.08	97.13	97.17	97.21	97.25	97.29	97.33	97.38	97.42	97.46	97.50	50
100	81.00	84.50	88.00	89.00	90.00	91.00	91.50	92.00	92.50	93.00	93.50	94.00	94.04	94.08	94.13	94.17	94.21	94.25	94.29	94.33	94.38	94.42	94.46	94.50	100
150	76.00	80.00	84.00	85.33	86.67	88.00	88.58	89.17	89.75	90.33	90.92	91.50	91.58	91.67	91.75	91.83	91.92	92.00	92.08	92.17	92.25	92.33	92.42	92.50	150
200			80.50	82.17	83.83	85.50	86.08	86.67	87.25	87.83	88.42	89.00	89.17	89.33	89.50	89.67	89.83	90.00	90.17	90.33	90.50	90.67	90.83	91.00	200
250			77.50	79.33	81.17	83.00	83.75	84.50	85.25	86.00	86.75	87.50	87.67	87.83	88.00	88.17	88.33	88.50	88.67	88.83	89.00	89.17	89.33	89.50	250
300						81.00	81.83	82.67	83.50	84.33	85.17	86.00	86.17	86.33	86.50	86.67	86.83	87.00	87.17	87.33	87.50	87.67	87.83	88.00	300
350						79.00	79.92	80.83	81.75	82.67	83.58	84.50	84.71	84.92	85.12	85.33	85.54	85.75	85.96	86.17	86.38	86.58	86.79	87.00	350
400						77.50	78.50	7V.50	80.50	81.50	82.50	83.50	83.71	83.92	84.12	84.33	84.54	84.75	84.96	85.17	85.38	85.58	85.79	86.00	400
450						76.00	77.08	78.17	79.25	80.33	81.42	82.50	82.71	82.92	83.12	83.33	83.54	83.75	83.96	84.17	84.38	84.58	84.79	85.00	450
500						75.00	76.08	77.17	78.25	79.33	80.42	81.50	81.71	81.92	82.12	82.33	82.54	82.75	8..96	83.17	83.38	83.58	83.79	84.00	500
600												8..00	80.21	80.42	80.62	80.83	81.04	81.25	81.46	81.67	81.88	82.08	82.29	82.50	600
7..												77.50	77.83	78.17	78.50	78.83	79.17	79.50	79.83	80.17	80.50	80.83	81.17	81.50	700
800												77.00	77.29	77.58	77.88	78.17	78.46	78.75	79.04	79.33	79.63	79.92	80.21	80.50	800
900												76.00	76.29	76.58	76.88	77.17	77.46	77.75	78.04	78.33	78.63	78.92	79.21	79.50	900
1000												75.00	75.29	75.58	75.88	76.17	76.46	76.75	77.04	77.33	77.63	77.92	78.21	78.50	1000
1100												74.00	74.33	74.67	75.00	75.33	75.67	76.00	76.33	76.67	77.00	77.33	77.67	78.00	1100
1200												73.00	73.38	73.75	74.13	74.50	74.88	75.25	75.63	76.00	76.38	76.75	77.13	77.50	1200
1300																								77.30	1300
1400																								77.00	1400
1500																								76.50	1500
2000																								75.00	2000
2500																								75.00	2500

ANNEXURE - 4.3

Subzones-5(a) & 5(b)

TIME DISTRIBUTION CO-EFFECIENTS OF AREAL RAINFALL

TIME	DISTRIBUTION CO-EFFECIENTS FOR DESIGN STORM DURATION OF 2 -24 HOURS																						TIME
HOURS	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	HOURS
24																							1.00	24
23																						1.00	0.98	23
22																					1.00	0.98	0.96	22
21																				1.00	0.98	0.96	0.94	21
20																			1.00	0.98	0.96	0.94	0.92	20
19																		1.00	0.98	0.95	0.93	0.91	0.89	19
18																	1.00	0.98	0.95	0.93	0.91	0.89	0.87	18
17																1.00	0.98	0.95	0.92	0.90	0.88	0.86	0.84	17
16															1.00	0.98	0.96	0.92	0.90	0.88	0.86	0.84	0.82	16
15														1.00	0.98	0.95	0.93	0.89	0.87	0.85	0.83	0.81	0.79	15
14													1.00	0.97	0.95	0.93	0.91	0.86	0.84	0.82	0.80	0.78	0.76	14
13												1.00	0.97	0.95	0.92	0.90	0.88	0.83	0.81	0.79	0.77	0.76	0.74	13
12											1.00	0.97	0.95	0.92	0.89	0.87	0.85	0.80	0.78	0.76	0.74	0.72	0.70	12
11										1.00	0.98	0.94	0.91	0.88	0.86	0.84	0.82	0.77	0.74	0.72	0.70	0.69	0.68	11
10									1.00	0.97	0.95	0.90	0.87	0.85	0.83	0.81	0.78	0.73	0.71	0.69	0.67	0.65	0.64	10
9								1.00	0.97	0.94	0.91	0.86	0.84	0.82	0.79	0.77	0.75	0.68	0.66	0.64	0.62	0.61	0.60	9
8							1.00	0.97	0.94	0.90	0.87	0.82	0.79	0.77	0.75	0.73	0.70	0.64	0.63	0.60	0.58	0.57	0.55	8
7						1.00	0.96	0.92	0.89	0.85	0.82	0.77	0.75	0.73	0.70	0.68	0.65	0.60	0.58	0.56	0.54	0.53	0.51	7
6					1.00	0.96	0.91	0.87	0.84	0.80	0.77	0.72	0.69	0.67	0.65	0.63	0.60	0.54	0.53	0.51	0.49	0.48	0.46	6
5				1.00	0.96	0.89	0.85	0.80	0.77	0.73	0.70	0.65	0.62	0.60	0.57	0.55	0.53	0.48	0.46	0.44	0.42	0.41	0.40	5
4			1.00	0.95	0.90	0.82	0.77	0.72	0.69	0.65	0.62	0.57	0.54	0.52	0.50	0.48	0.45	0.41	0.40	0.38	0.36	0.35	0.34	4
3		1.00	0.94	0.87	0.81	0.71	0.66	0.62	0.59	0.55	0.51	0.47	0.44	0.42	0.40	0.38	0.35	0.33	0.32	0.30	0.29	0.28	0.27	3
2	1.00	0.91	0.81	0.73	0.66	0.56	0.53	0.49	0.46	0.43	0.39	0.36	0.33	0.30	0.28	0.27	0.26	0.24	0.23	0.21	0.20	0.19	0.19	2
1	0.82	0.68	0.57	0.50	0.45	0.36	0.31	0.30	0.28	0.26	0.24	0.19	0.18	0.17	0.16	0.15	0.13	0.12	0.12	0.12	0.11	0.10	0.10	1

Note : Hourly rainfall distribution co-effecients are given in the vertical columns for various design storm durations from 2 - 24 hours.

ANNEXURE - 4.4

SUB ZONE 5(a)&(b)

STATEMENT OF HIGHEST RECORDED DAILY RAINFALL

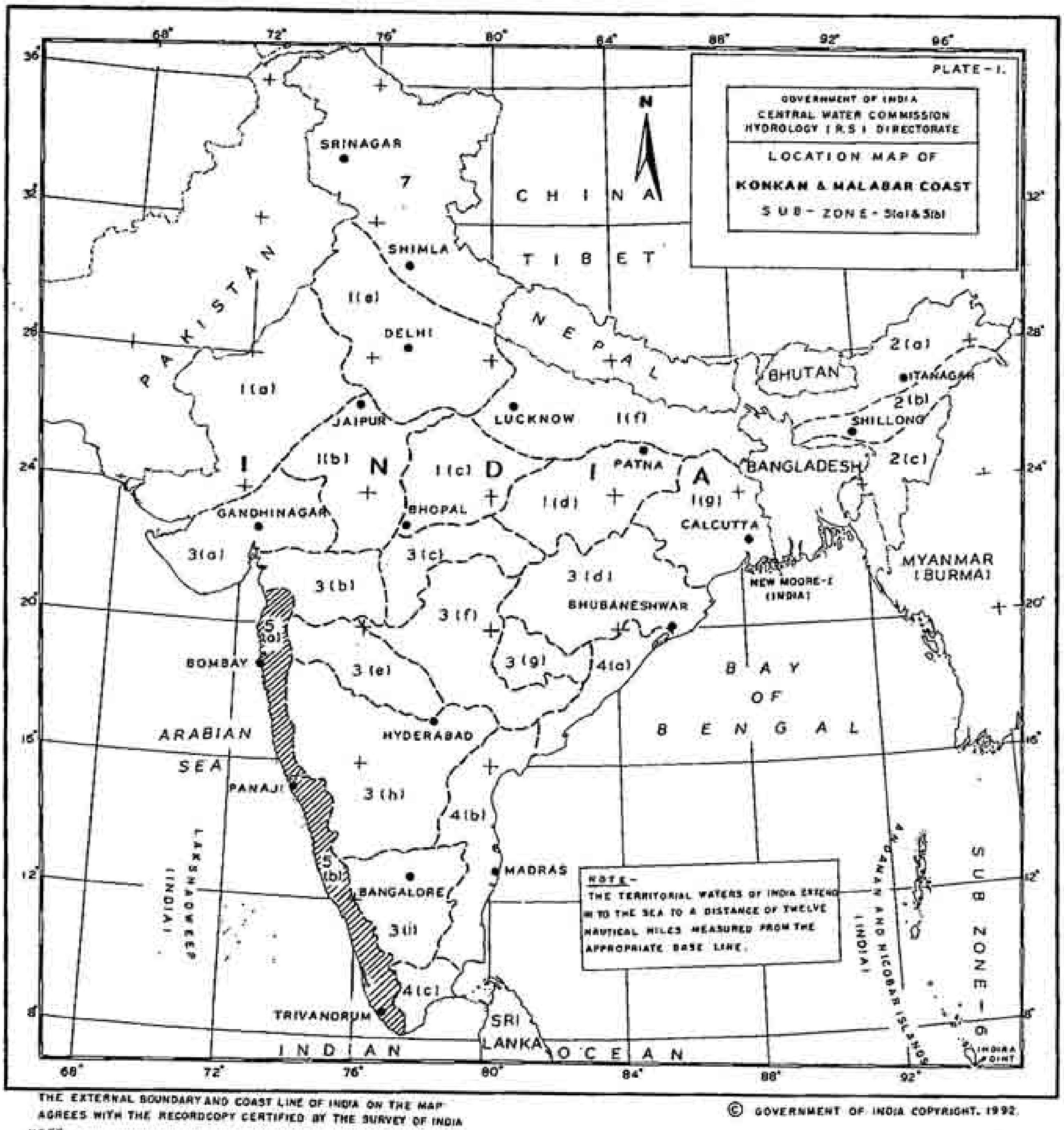
S. NO	DISTRICT	STATION	HEAVIEST ONE-DAY RAINFALL	DATE
	MAHARASHTRA STATE		SUB-ZONE 5 (A)	
1	Nasik	Igatpuri	450.90	21.07.1894
2		Peint	473.70	02.07.1941
3		Trimbak	410.70	02.07.1941
4	Satara	Mahabaleshwar	458.50	30.07.1896
5	Goa	Mormugao	307.60	22.05.1918
6		Volpoi	503.90	13.08.1960
7	Pune	Khandala	516.40	19.07.1958
8		Lonavala	493.00	02.08.1956
9	Kolhapur	Radhanagari	312.40	01.07.1941
10	Bombay	Kurla	354.30	27.06.1915
11		Colaba	548.10	10.09.1930
12	Thana	Murbad	386.60	23.07.1921
13		Shahpur	441.20	06.07.1905
14		Mokhada	394.70	02.07.1941
15		Bhiwandi	469.10	17.07.1885
16		Mahim	356.60	21.09.1923
17		Vada	459.20	19.06.1953
18		Dahanu	481.00	01.09.1958
19		Kalyan	458.50	17.07.1885
20	Colaba	Alibag	407.70	23.09.1949
21		Panvel	458.50	17.07.1885
22		Pen	500.00	07.09.1973
23		Karjat	605.00	18.07.1958
24		Mathern	657.30	24.07.1921
25		Roha	629.90	18.06.1886
26		Mangaon	460.00	05.07.1946
27		Mahad	388.60	19.07.1923
28	Ratnagiri	Ratnagiri	356.40	12.06.1951
29		Vengurla	730.50	25.06.1958
30		Malvan	370.10	03.07.1902
31		Devgad	475.00	19.07.1977
32		Chiplan	533.40	04.06.1882
33		Khed	391.60	16.07.1965
34		Dapoli	535.40	03.06.1882
35		Mandangad	396.50	26.06.1915
36		Banda	363.00	26.07.1931
37	Dhulia	Navapur	343.00	05.08.1968

KERALA STATE SUB-ZONE 5 (B)

1	Kottayam	Devikulam	483.90	17.07.1924
2		Changanachery	355.60	22.06.1959
3	Palghat	Ottapalam	415.00	28.05.1941
4	Kozhikode	Vaylthri	533.40	02.07.1961
5		Kuttiyadi	419.30	03.06.1924
6		Tirurangadi	617.20	19.05.1882
7		Kozhikode	468.60	19.05.1882
8	Cannanore	Irikkur	379.70	07.07.1953
9		Taliparamba	378.70	10.06.1941
10		Tellichery	383.80	22.05.1936
11		Cannanore	359.70	04.06.1924
12	Quilon	Karunagappalli	317.00	04.06.1967
13	Ernakulam	Karikode	305.80	23.07.1924
14	Trivandrum	Trivandrum	401.50	18.10.1964
15	Trichur	Mukundapuram (Iringalakuda)	315.70	26.05.1933

KARNATAKA STATE SUB-ZONE 5 (B)

16	Shimoga	Hosanagar	884.00	26.06.1972
17	Chikmangalore	Koppa	311.40	07.08.1923
18	South Kanara	Mangalore	360.90	08.05.1909
19		Belthangady	359.90	11.06.1941
20		Coondapur	373.90	30.07.1902
21	Coorg	Mercara	364.50	17.07.1924
22		Virajpet	366.50	07.07.1926
23		Ammathy	410.70	25.07.1924
24	North Kanara	Bhatkal	360.70	09.07.1923
25		Siddapur	406.40	22.06.1975
26		Honavar	485.7	08.08.1923
27		Kumla	480.6	11.10.1987
28	Belgaum	Khanapur	307.3	05.08.1914



THE EXTERNAL BOUNDARY AND COAST LINE OF INDIA ON THE MAP AGREES WITH THE RECORD COPY CERTIFIED BY THE SURVEY OF INDIA

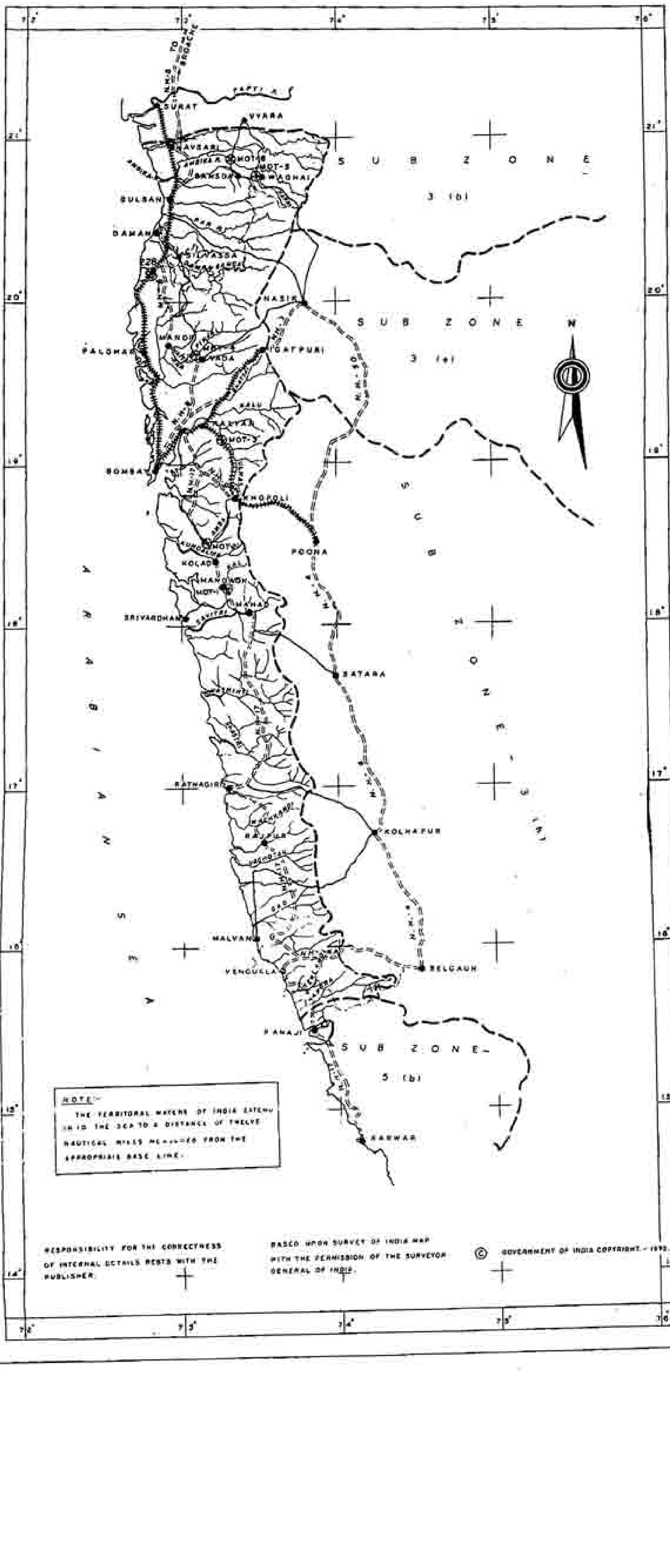
NOTE

RESPONSIBILITY FOR THE CORRECTNESS OF INTERNAL DETAILS RESTS WITH THE PUBLISHER.

BASED UPON SURVEY OF INDIA MAP WITH THE PERMISSION OF THE SURVEYOR GENERAL OF INDIA

S N MALHOTRA, L P NAUTIYAL

PLATE - 2, 5 (a)



R E F E R E N C E S

1. SUB ZONE BOUNDARY
2. STATE BOUNDARY
3. RAILWAY LINE
4. NATIONAL HIGHWAYS
5. RIVER & ITS TRIBUTARIES
6. BRIDGE SITES
7. TOWNS
8. ROADS

N O T E S

1. FOR LOCATION OF BRIDGES REFER ANNEXURE-3.1
2. PHYSICAL ATRIBUTES OF THIS MAP BASED ON MAP NOS-ND-43, NE-43, NF-43
3. NAME OF THE RAILWAY STATIONS ARE AS PER INDIAN BRADSHAW-1982 EDITION.

SCALE

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

MILES 10 5 0 10 20 30 40 50

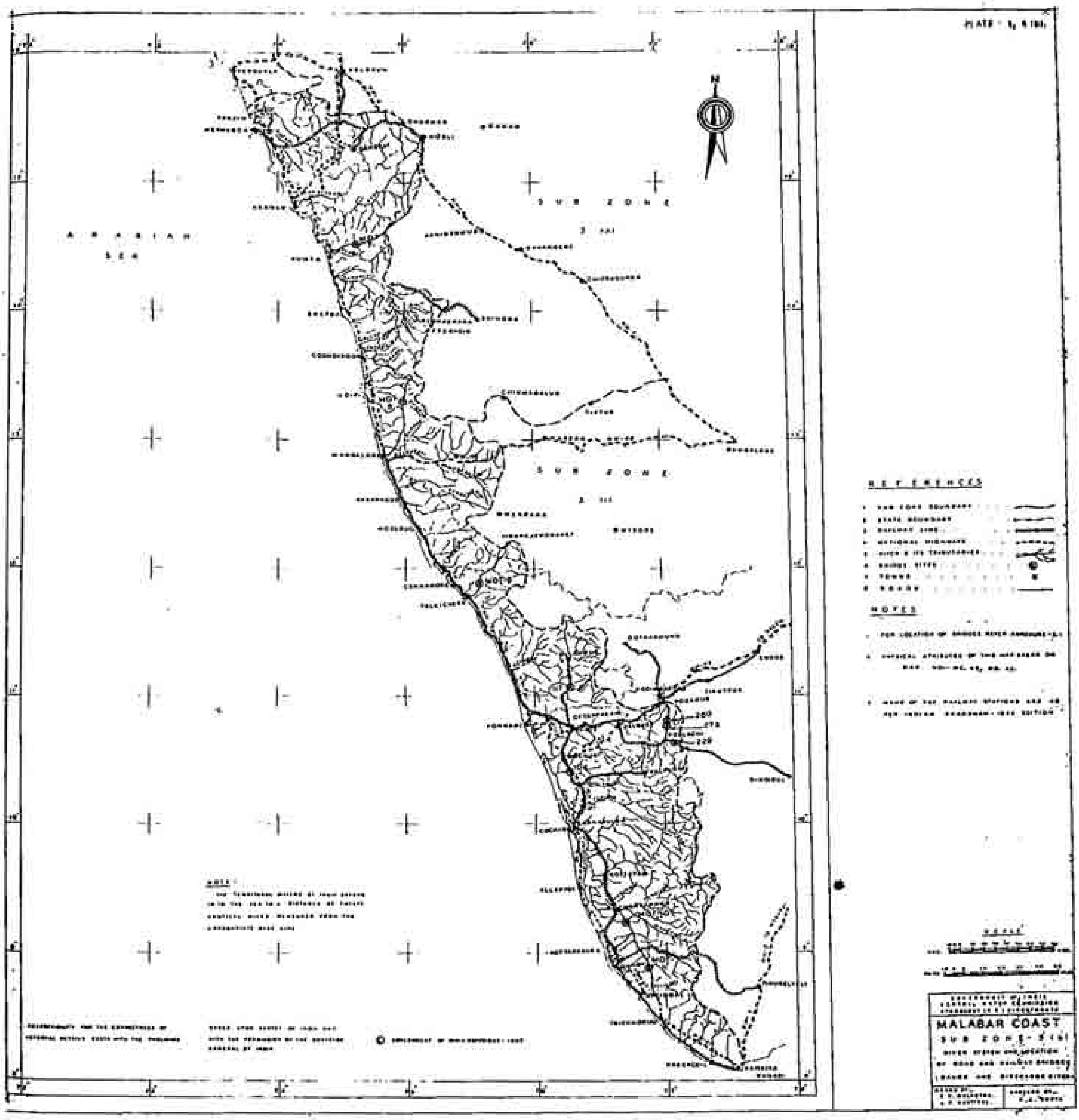
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (R.S.) DIRECTORATE

KONKAN COAST

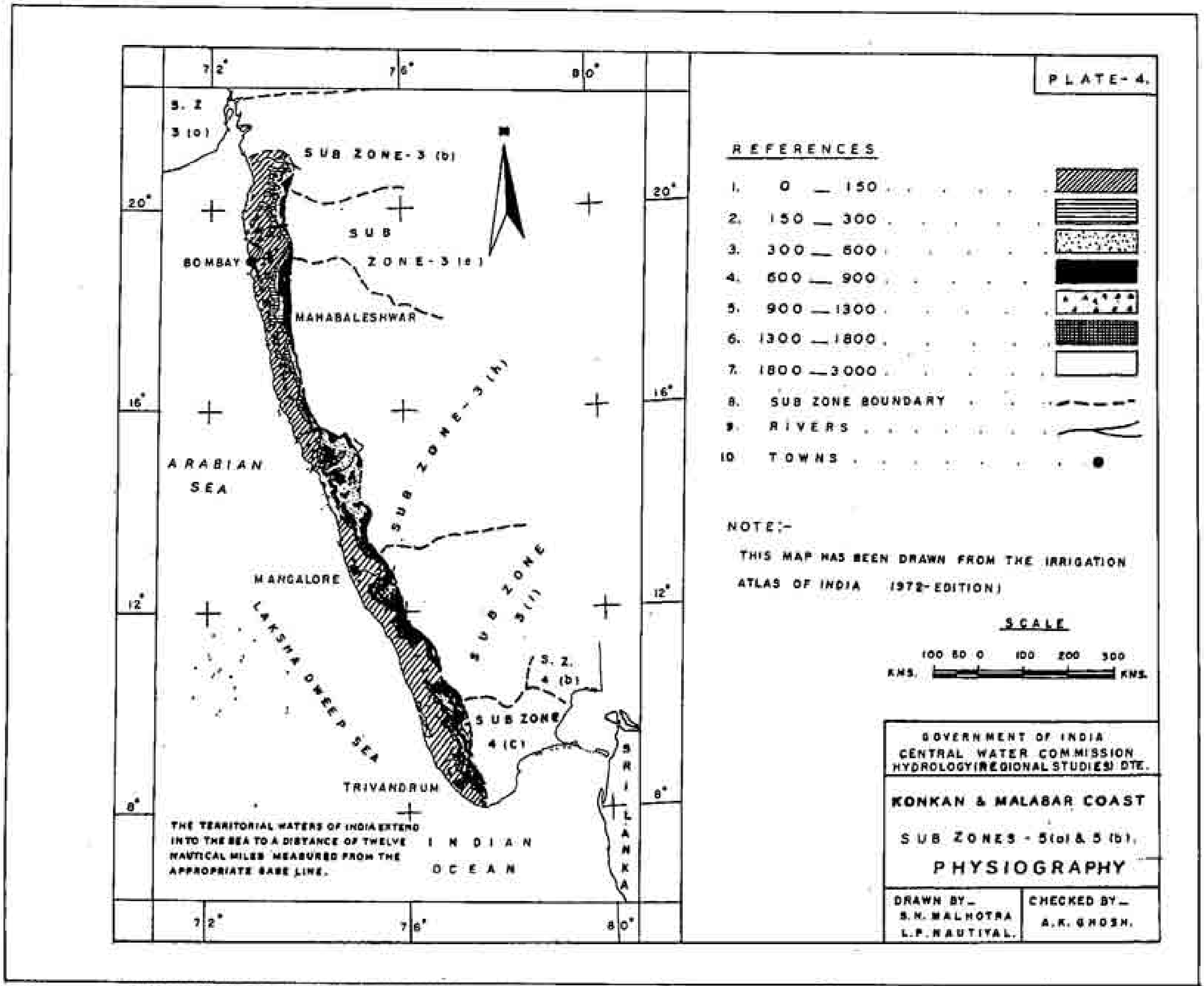
SUB ZONE - 5 (a)

RIVER SYSTEM AND LOCATION OF ROAD AND RAILWAY BRIDGES (G.A.D SITES)

DRAWN BY- S.K. MALHOTRA, L.P. NAUTIYAL	CHECKED BY- A. K. GHOSH

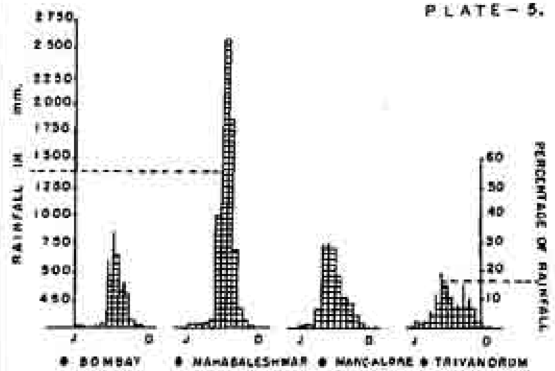


ARABIAN SEA
SUB ZONE
REFERENCES
NOTES
MALABAR COAST



THE COAST LINE OF INDIA ON THE MAP AGREES WITH THE RECORD COPY CERTIFIED BY THE SURVEY OF INDIA.

PLATE – 5.



NOTES :—

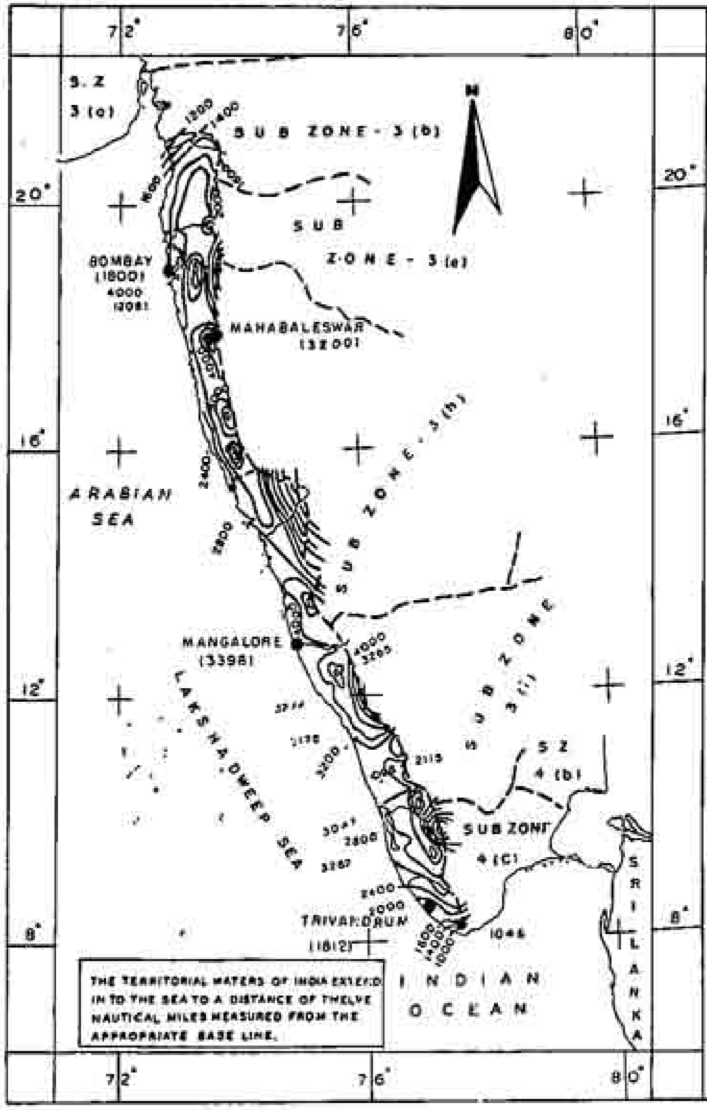
1. HISTOGRAMS FOR FOUR STATIONS WITH NAMES.
2. EACH VERTICAL COLUMN REPRESENTS THE MEAN MONTHLY RAINFALL FOR EACH MONTH (FROM JANUARY TO DECEMBER).
3. THE THICK VERTICAL LINES AT THE BIGINNING OF EACH COLUMN INDICATES THE PERCENTAGE OF RAINFALL IN THE MONTH TO THE MEAN ANNUAL TOTAL.
4. THIS MAP HAS BEEN DRAWN FROM THE IRRIGATION ATLAS OF INDIA (1989), PLATE – 20.

REFERENCES :—

1. ISOHYETAL LINES WITH VALUE IN mm. NORMAL ANNUAL (1800)
2. SUB ZONE BOUNDARY
3. RIVERS
4. TOWNS
5. MEAN ANNUAL RAIN-FALL (mm.) (1812)

SCALE

100 50 0 100 200 300 KM.



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

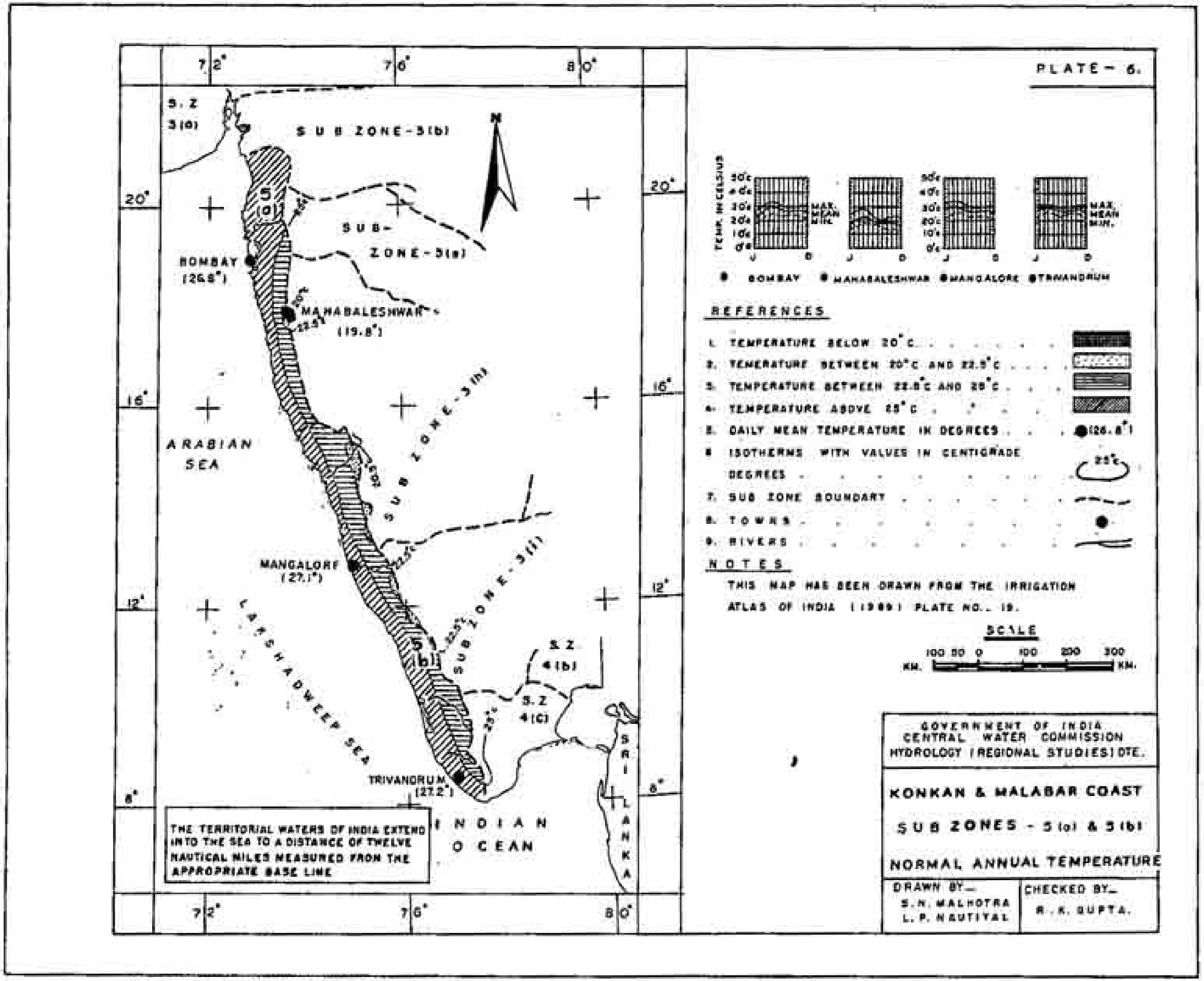
KONKAN & MALABAR COAST

SUB ZONES – 5 (a) & 5 (b)

ANNUAL RAINFALL

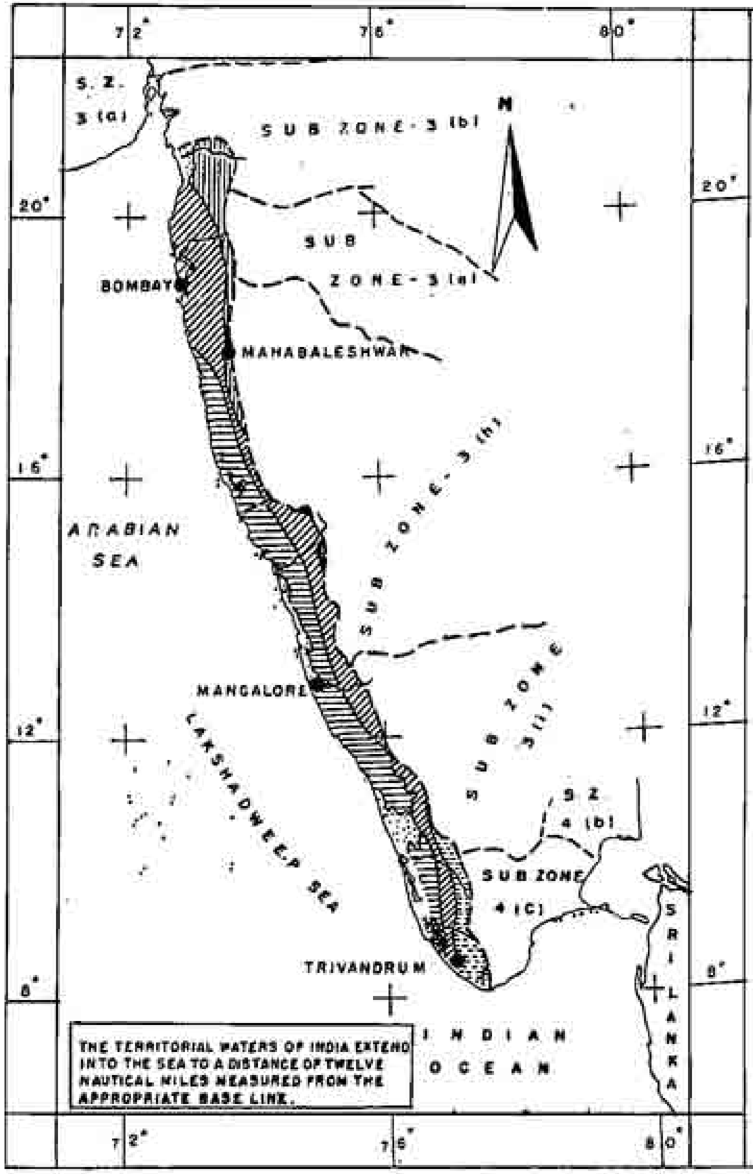
DRAWN BY—	CHECKED BY—
S. N. MALHOTRA L. P. NAUTIYAL	A. K. GHOSH.

THE COAST LINE OF INDIA ON THE MAP AGREES WITH THE RECORD COPY CERTIFIED BY THE SURVEY OF INDIA.



THE COAST LINE OF INDIA ON THE MAP AGREES WITH THE RECORD COPY CERTIFIED BY THE SURVEY OF INDIA.

PLATE- 7.



REFERENCES

1. COASTAL ALLUVIAL SOILS
2. MEDIUM BLACK SOILS.
3. RED LOAMY SOILS.
4. LATERITE SOILS.
5. PEATY AND SALINE PEATY SOILS
6. RED SANDY SOILS
7. MIXED RED AND BLACK SOILS.
8. SUB ZONE BOUNDARY.
9. RIVERS.
10 TOWNS.

NOTE

THIS MAP HAS BEEN DRAWN FROM THE IRRIGATION ATLAS OF INDIA (1978-EDITION) PLATE - 8.

SCALE

KMS. 100 50 0 100 200 300 KMS

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

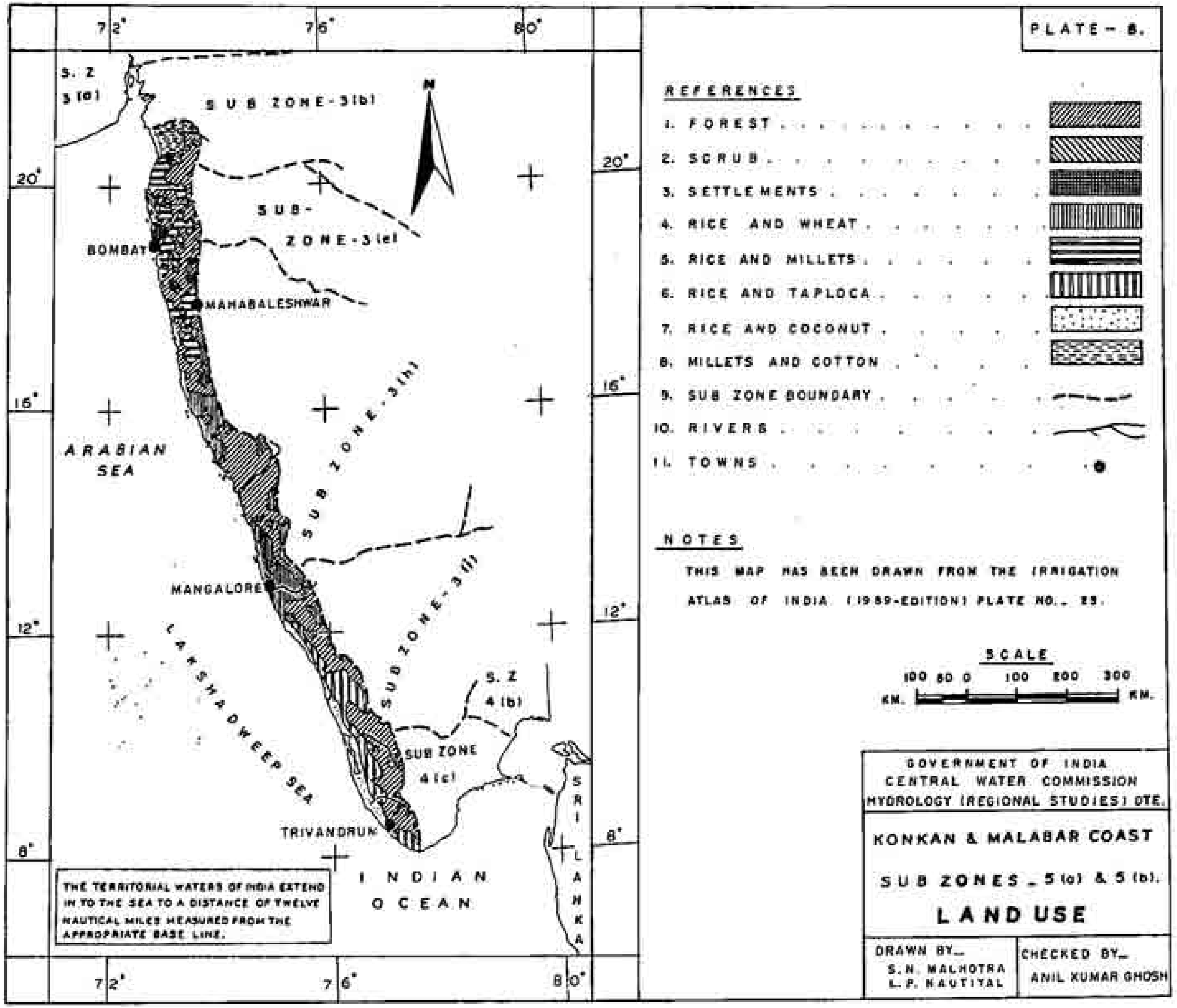
KONKAN & MALABAR COAST

SUB ZONES - 5 (a) & 5 (b)

SOILS CLASSIFICATION

DRAWN BY.	CHECKED BY.
S. N. MALHOTRA L. P. NAUTIYAL	A. K. GHOSH

THE COAST LINE OF INDIA ON THE MAP AGREES WITH THE RECORD COPY CERTIFIED BY THE SURVEY OF INDIA.



THE COAST LINE OF INDIA ON THE MAP AGREES WITH THE RECORD COPY CERTIFIED BY THE SURVEY OF INDIA

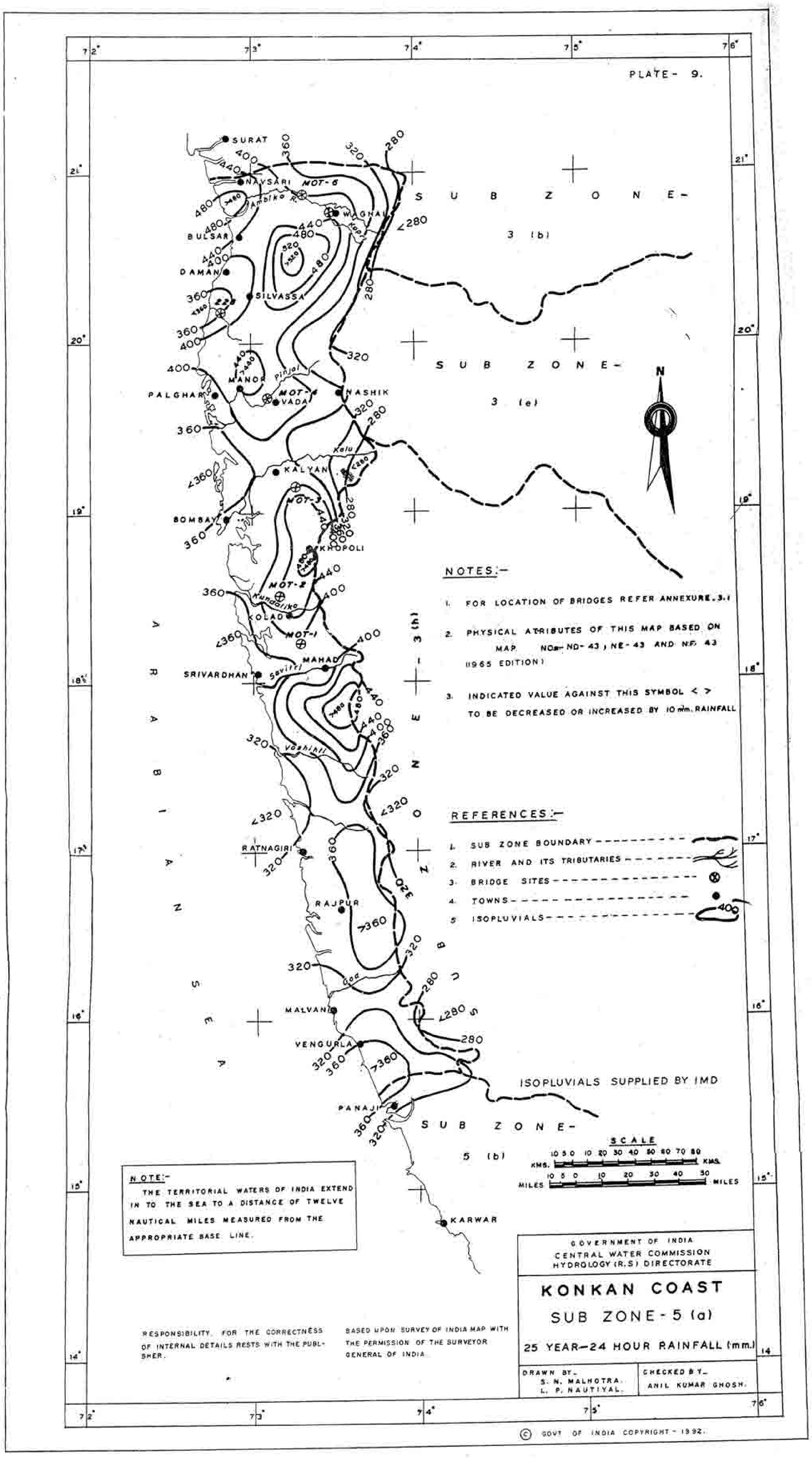


PLATE- 9.
SUB ZONE- 3 (b)
SUB ZONE- 3 (e)
SUB ZONE- 3 (h)
SUB ZONE- 5 (b)
N
ARABIAN SEA
SURAT
NAVSARI
MOT-6
WAGHAI
BULSAR
DAMAN
SILVASSA
MANOR
PALGHAR
VADA
MOT-4
NASHIK
KALYAN
MOT-3
BOMBAY
KHOPOLI
MOT-2
KOLAD
MOT-1
MAHAD
SRIVARDHAN
RATNAGIRI
RAJPUR
MALVAN
VENGURLA
PANAJI
KARWAR
Ambika R.
Pinjal
Kalu
Kundalika
Savitri
Vashisti
NOTES:-
1. FOR LOCATION OF BRIDGES REFER ANNEXURE-3.1
2. PHYSICAL ATRIBUTES OF THIS MAP BASED ON MAP. NOs- ND-43, NE-43 AND NF-43 (1965 EDITION)
3. INDICATED VALUE AGAINST THIS SYMBOL < > TO BE DECREASED OR INCREASED BY 10 mm. RAINFALL
REFERENCES:-
1. SUB ZONE BOUNDARY
2. RIVER AND ITS TRIBUTARIES
3. BRIDGE SITES
4. TOWNS
5. ISOPLUVIALS
ISOPLUVIALS SUPPLIED BY IMD
SCALE
KMS.
MILES
NOTE:- THE TERRITORIAL WATERS OF INDIA EXTEND IN TO THE SEA TO A DISTANCE OF TWELVE NAUTICAL MILES MEASURED FROM THE APPROPRIATE BASE LINE.
RESPONSIBILITY FOR THE CORRECTNESS OF INTERNAL DETAILS RESTS WITH THE PUBLISHER.
BASED UPON SURVEY OF INDIA MAP WITH THE PERMISSION OF THE SURVEYOR GENERAL OF INDIA.
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (R.S) DIRECTORATE
KONKAN COAST
SUB ZONE - 5 (a)
25 YEAR-24 HOUR RAINFALL (mm.)
DRAWN BY - S. N. MALHOTRA. L. P. NAUTIYAL.
CHECKED BY - ANIL KUMAR GHOSH.
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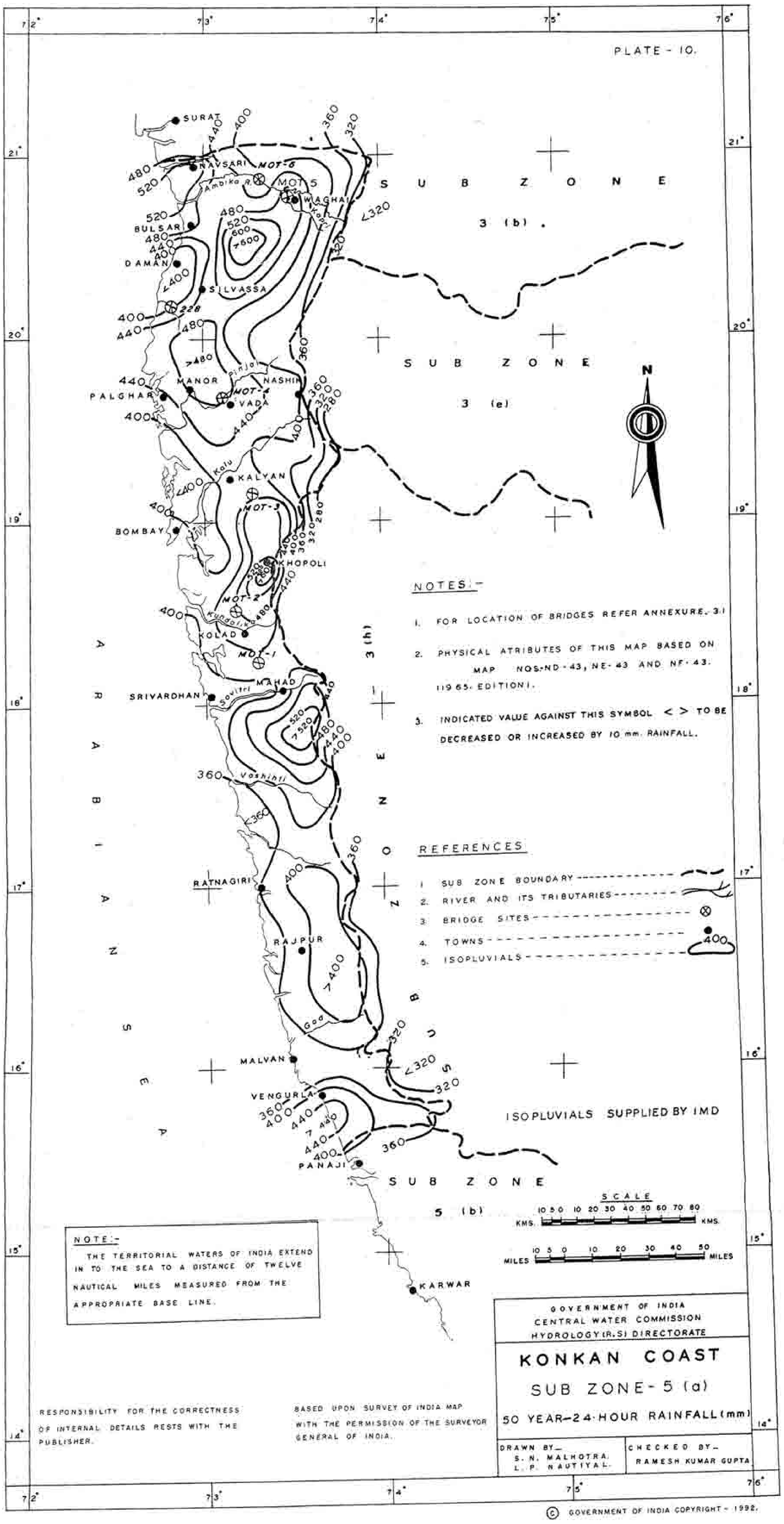
PLATE - 10.
SURAT
NAVSARI
BULSAR
DAMAN
SILVASSA
MANOR
NASHIK
PALGHAR
VADA
KALYAN
BOMBAY
KHOPOLI
KOLAD
MAHAD
SRIVARDHAN
RATNAGIRI
RAJPUR
MALVAN
VENGURLA
PANAJI
KARWAR
SUB ZONE 3 (b)
SUB ZONE 3 (e)
SUB ZONE 3 (h)
SUB ZONE 5 (b)
ARABIAN SEA
NOTES:-
1. FOR LOCATION OF BRIDGES REFER ANNEXURE-3.1
2. PHYSICAL ATRIBUTES OF THIS MAP BASED ON MAP NOS-ND-43, NE-43 AND NF-43. (1965- EDITION).
3. INDICATED VALUE AGAINST THIS SYMBOL < > TO BE DECREASED OR INCREASED BY 10 mm. RAINFALL.
REFERENCES
1. SUB ZONE BOUNDARY
2. RIVER AND ITS TRIBUTARIES
3. BRIDGE SITES
4. TOWNS
5. ISOPLUVIALS
ISOPLUVIALS SUPPLIED BY IMD
SCALE
KMS.
MILES
NOTE:- THE TERRITORIAL WATERS OF INDIA EXTEND IN TO THE SEA TO A DISTANCE OF TWELVE NAUTICAL MILES MEASURED FROM THE APPROPRIATE BASE LINE.
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (R.S) DIRECTORATE
KONKAN COAST
SUB ZONE - 5 (a)
50 YEAR-24-HOUR RAINFALL (mm)
DRAWN BY - S. N. MALHOTRA. L. P. NAUTIYAL.
CHECKED BY - RAMESH KUMAR GUPTA
RESPONSIBILITY FOR THE CORRECTNESS OF INTERNAL DETAILS RESTS WITH THE PUBLISHER.
BASED UPON SURVEY OF INDIA MAP WITH THE PERMISSION OF THE SURVEYOR GENERAL OF INDIA.
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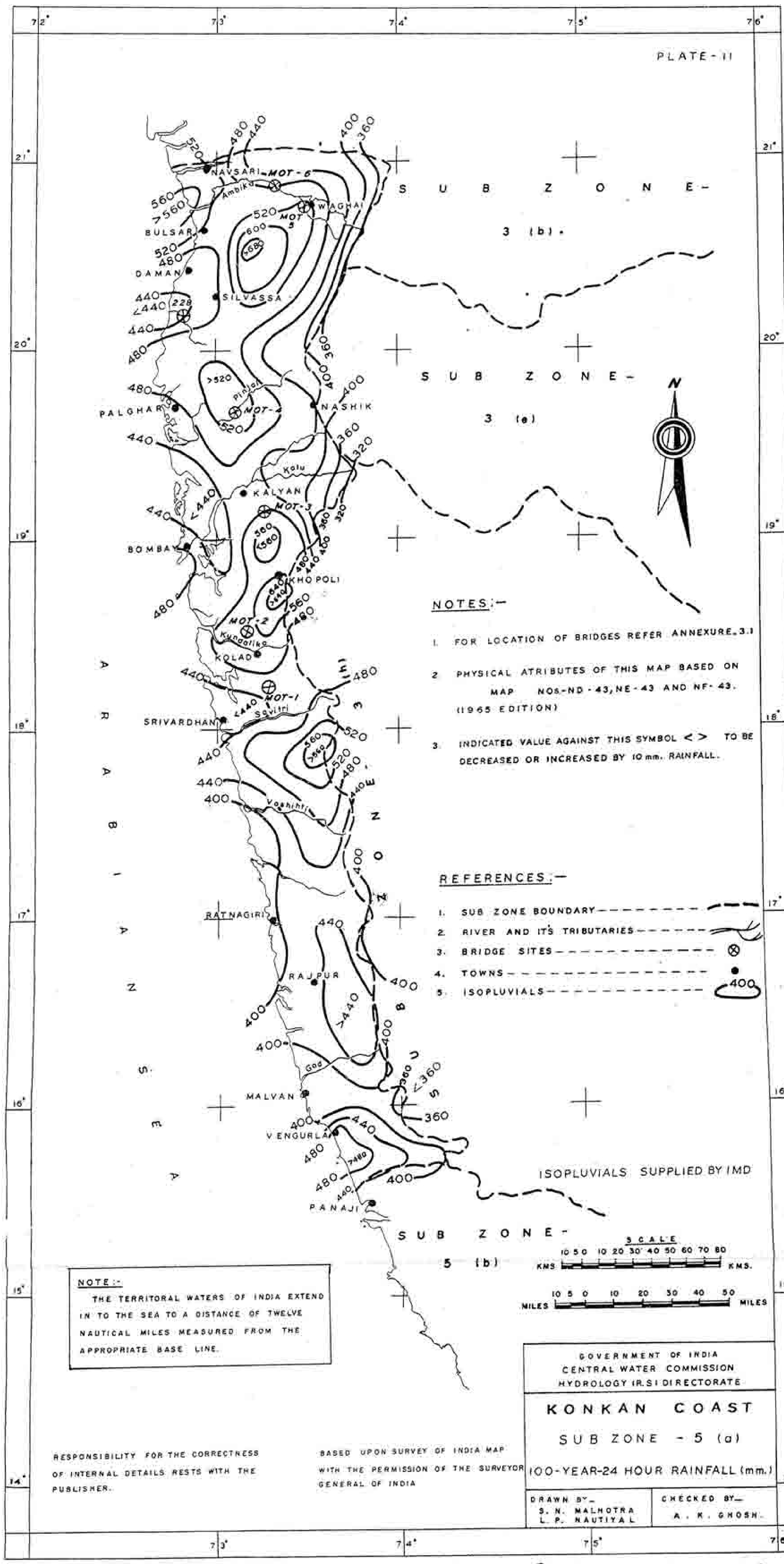
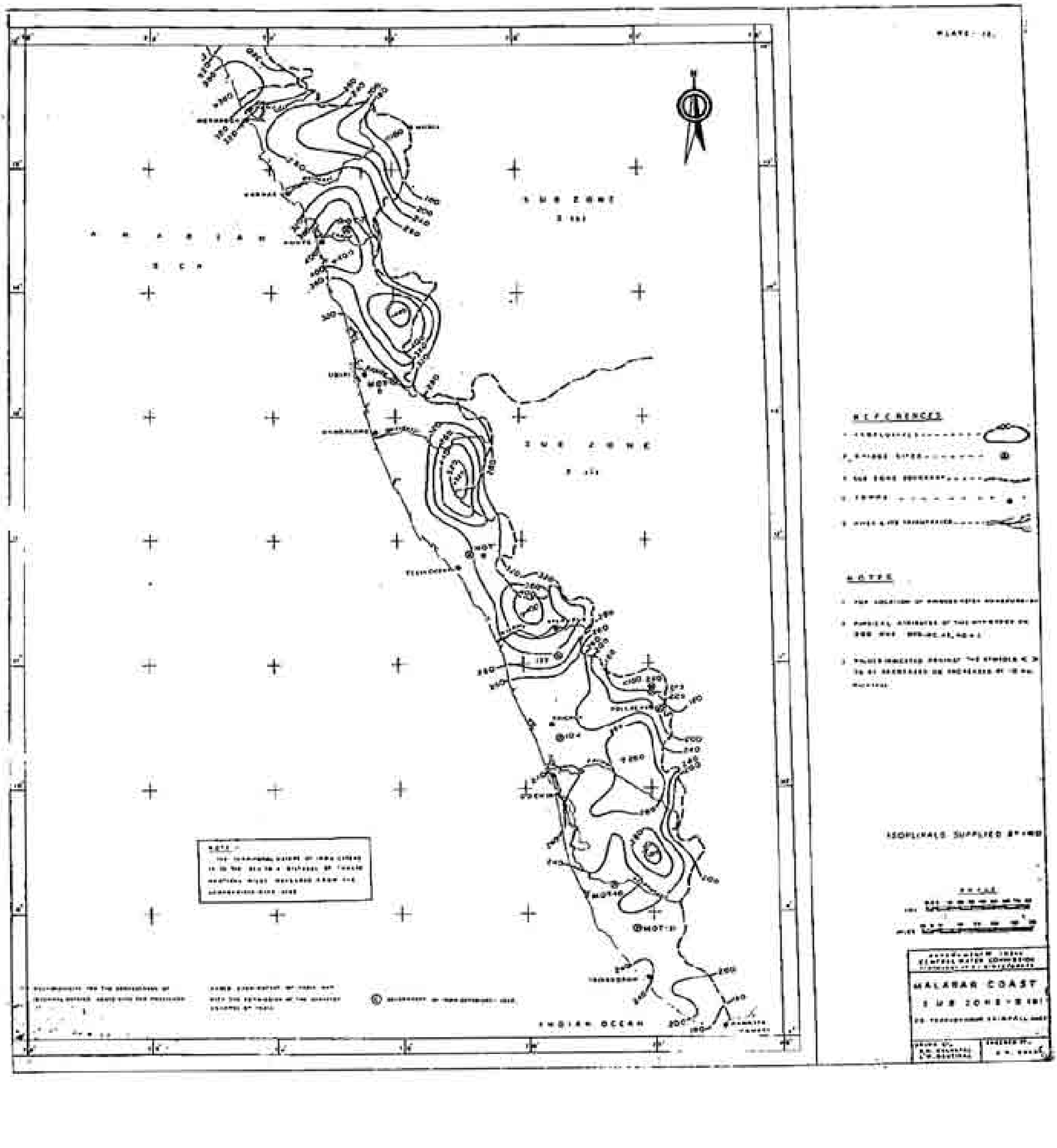


PLATE - II
SUB ZONE - 3 (b).
SUB ZONE - 3 (a)
SUB ZONE - 5 (b)
ARABIAN SEA
NAVSARI
MOT-6
Ambika
WAGHAI
MOT-5
BULSAR
DAMAN
SILVASSA
PALGHAR
Pinjal
MOT-4
NASHIK
Kalu
KALYAN
MOT-3
BOMBAY
KHOPOLI
MOT-2
Kundalika
KOLAD
MOT-1
Savitri
SRIVARDHAN
Vashishti
RATNAGIRI
RAJPUR
God
MALVAN
VENGURLA
PANAJI
NOTES:-
1. FOR LOCATION OF BRIDGES REFER ANNEXURE. 3.1
2. PHYSICAL ATRIBUTES OF THIS MAP BASED ON MAP NOS.-ND-43, NE-43 AND NF-43. (1965 EDITION)
3. INDICATED VALUE AGAINST THIS SYMBOL < > TO BE DECREASED OR INCREASED BY 10 mm. RAINFALL.
REFERENCES:-
1. SUB ZONE BOUNDARY
2. RIVER AND ITS TRIBUTARIES
3. BRIDGE SITES
4. TOWNS
5. ISOPLUVIALS
ISOPLUVIALS SUPPLIED BY IMD
SCALE
KMS 10 5 0 10 20 30 40 50 60 70 80 KMS.
MILES 10 5 0 10 20 30 40 50 MILES
NOTE:-
THE TERRITORAL WATERS OF INDIA EXTEND IN TO THE SEA TO A DISTANCE OF TWELVE NAUTICAL MILES MEASURED FROM THE APPROPRIATE BASE LINE.
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (R.S) DIRECTORATE
KONKAN COAST
SUB ZONE - 5 (a)
100-YEAR-24 HOUR RAINFALL (mm.)
DRAWN BY- S. N. MALHOTRA L. P. NAUTIYAL
CHECKED BY- A. K. GHOSH.
RESPONSIBILITY FOR THE CORRECTNESS OF INTERNAL DETAILS RESTS WITH THE PUBLISHER.
BASED UPON SURVEY OF INDIA MAP WITH THE PERMISSION OF THE SURVEYOR GENERAL OF INDIA



SUB ZONE
SUB ZONE
ARABIAN SEA
INDIAN OCEAN
REFERENCES
NOTES
ISOPLUVIALS SUPPLIED BY IMD
CENTRAL WATER COMMISSION
MALABAR COAST

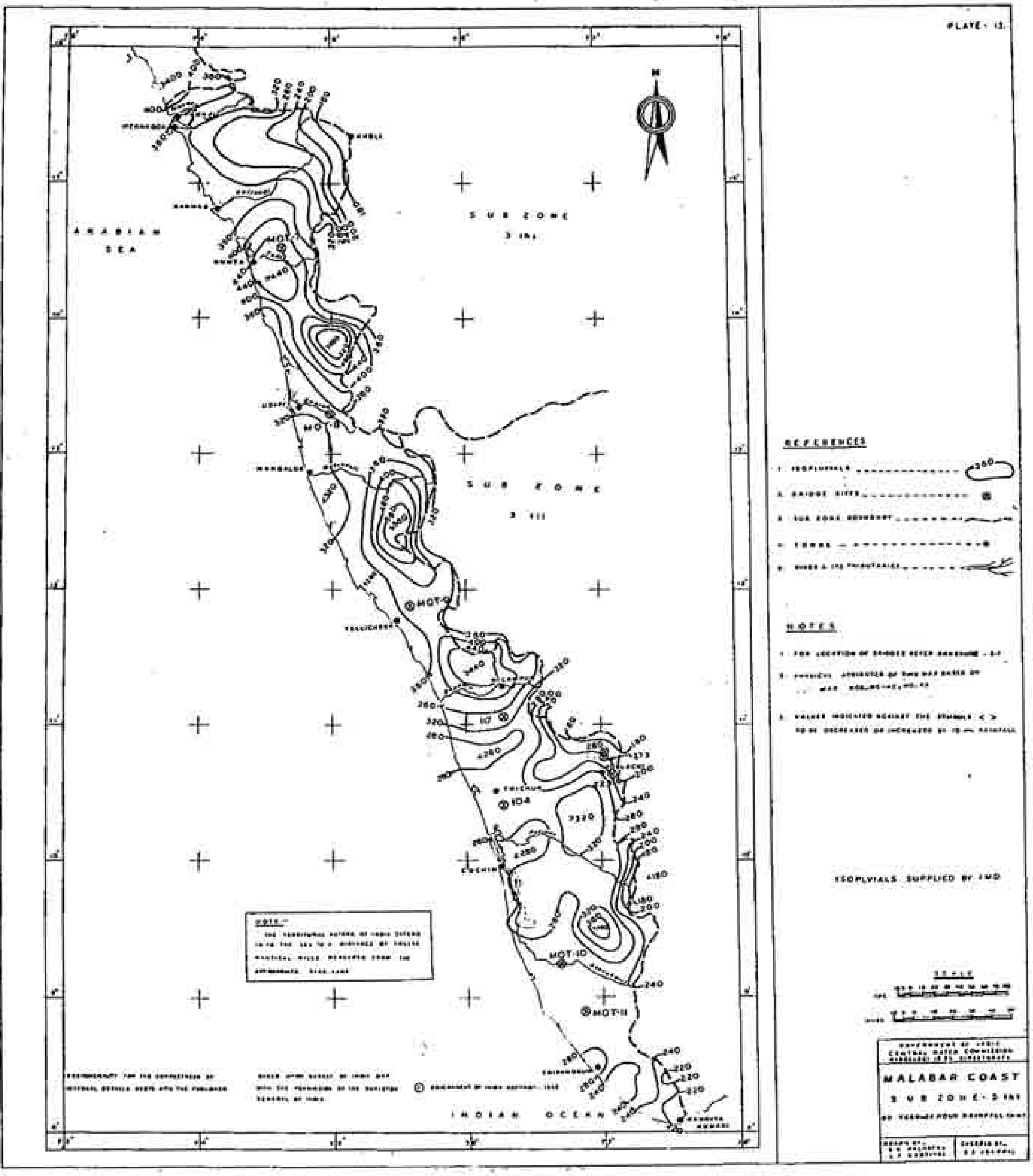


PLATE- 13
ARABIAN SEA
SUB ZONE
SUB ZONE
MANGALORE
TELLICHERRY
TRICHUR
COCHIN
MOT-10
MOT-11
INDIAN OCEAN
REFERENCES
NOTES
ISOPLUVIALS SUPPLIED BY IMD
MALABAR COAST

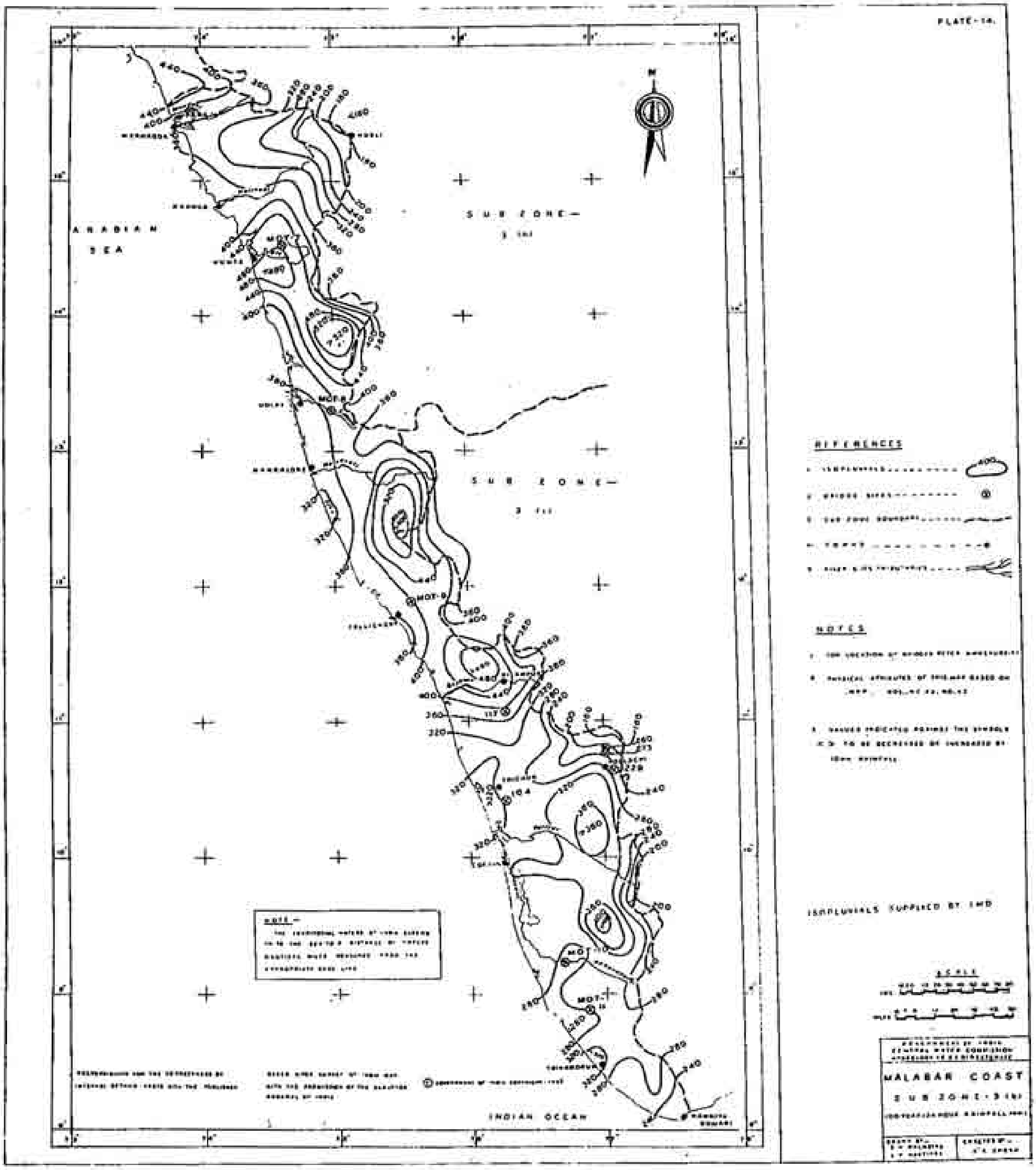
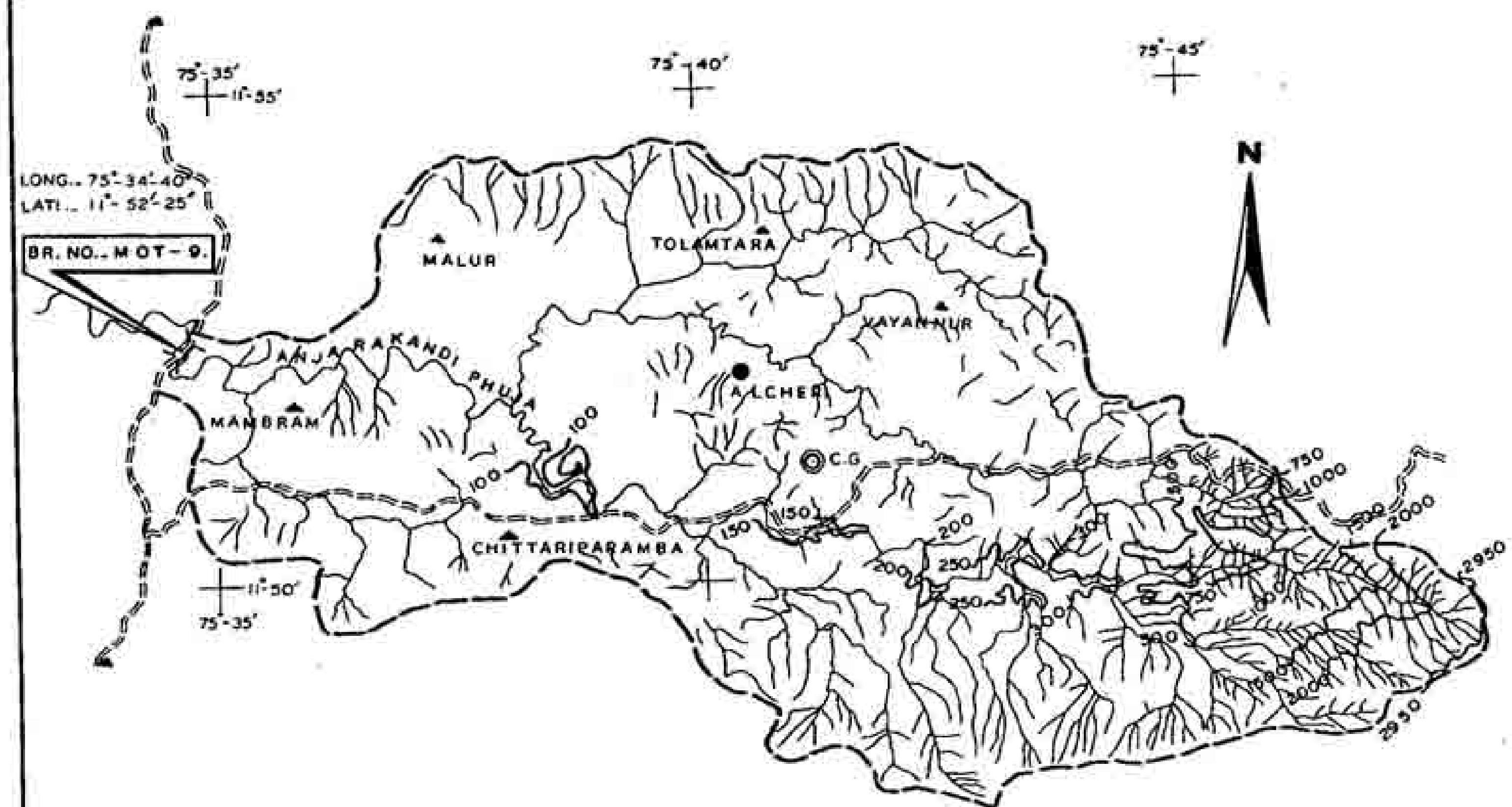


PLATE-14.
ARABIAN
SEA
SUB ZONE-
3 (a)
SUB ZONE-
3 (c)
INDIAN OCEAN
MANGALORE
TRIVANDRUM
REFERENCES
NOTES
ISOPLUVIALS SUPPLIED BY IMD
SCALE
MALABAR COAST
SUB ZONE-3 (b)

FIG. - A. I.



NOTE

1. ALL LEVELS CORRESPOND TO G.T.S DATUM

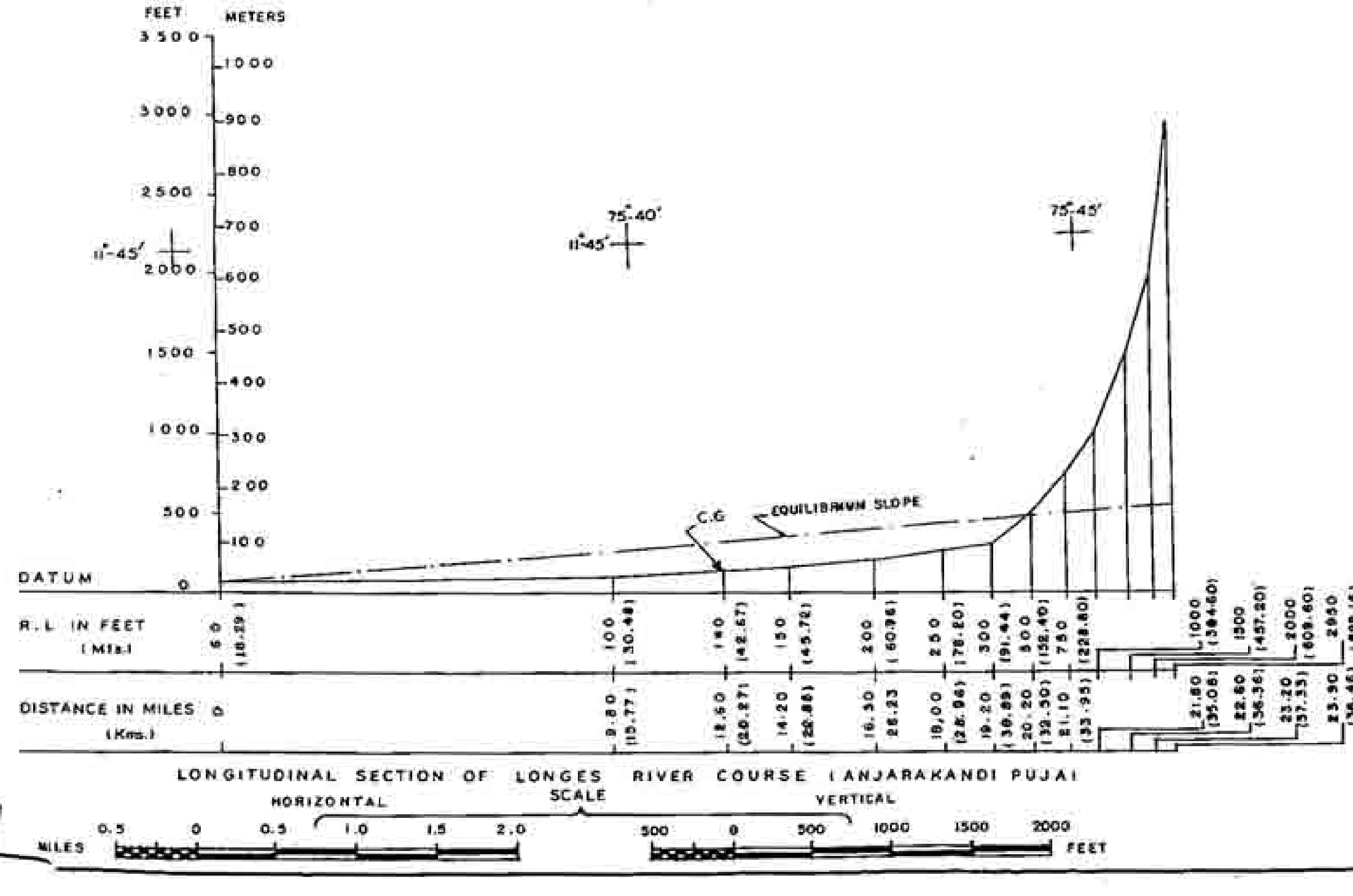
REFERENCES

1. CATCHMENT BOUNDARY
2. RIVER AND IT'S TRIBUTARIES
3. ROADS
4. RAINGAUGE STATION
5. TOWNS
6. CENTER GRAVITY
7. CONTOURS
8. TOPO SHEET NO.- 49 M/9 & 49 M/13

DETAILS OF THE CATCHMENT AREA

1. CATCHMENT AREA - 176.00 Sq. Kms.
2. SHAPE OF CATCHMENT - LEAF
3. L - 38.48 Km.
4. LC - 20.29 Km.
5. WC - 9.34 Km.
6. EQUILIBRIUM SLOPE - 4.21 M/Km.

SL. NO.	NAME OF THE R.G. STATION	LOCATION LONG.	LOCATION LATI	STATION WTG.
1.	ALCHERI	75°-40'-25"	11°-52'-10"	1



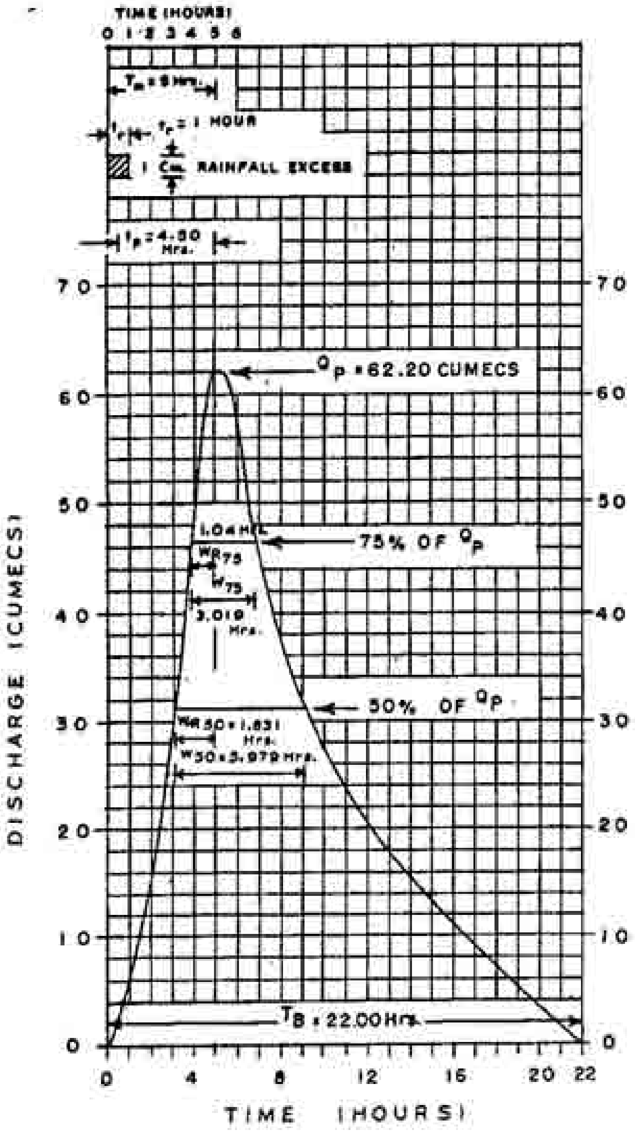
LONGITUDINAL SECTION OF LONGES RIVER COURSE (ANJARAKANDI PUJA)

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

CATCHMENT AREA PLAN OF RIVER
ANJARAKANDI PUZHA SITE MERUVAMBAI
BR. NO.-MOT-9, SUB ZONE - 5(b)

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

FIG.- A - 2.



1 - HOUR SYNTHETIC U.G ORDINATCE

TIME IN HOURS	1- HOUR SYNTHETIC U.G ORDINATES (CUMECS)
0	0
1	5.60
2	14.80
3	28.00
4	48.00
5	62.20
6	58.39
7	45.20
8	37.60
9	32.00
10	27.40
11	23.80
12	20.50
13	18.00
14	15.60
15	13.30
16	11.20
17	9.20
18	7.30
19	5.40
20	3.60
21	1.80
22	0
TOTAL	488.89 CUMECS

1-HOUR SYNTHETIC U.G PARAMETERS

1. C. AREA = 176.00 Sq. Km.
2. t_r = 1.00
3. Q_p = 62.20 CUMECS
4. q_p = 0.353
5. t_p = 4.50 Hrs.
6. T_m = 5.00 Hrs.
7. T_B = 22.00 Hrs.
8. W_{50} = 5.979 Hrs.
9. W_{75} = 3.019 Hrs.
10. W_{R50} = 1.831 Hrs.
11. W_{R75} = 1.04 Hrs.
12. d = 1.00 Cm.

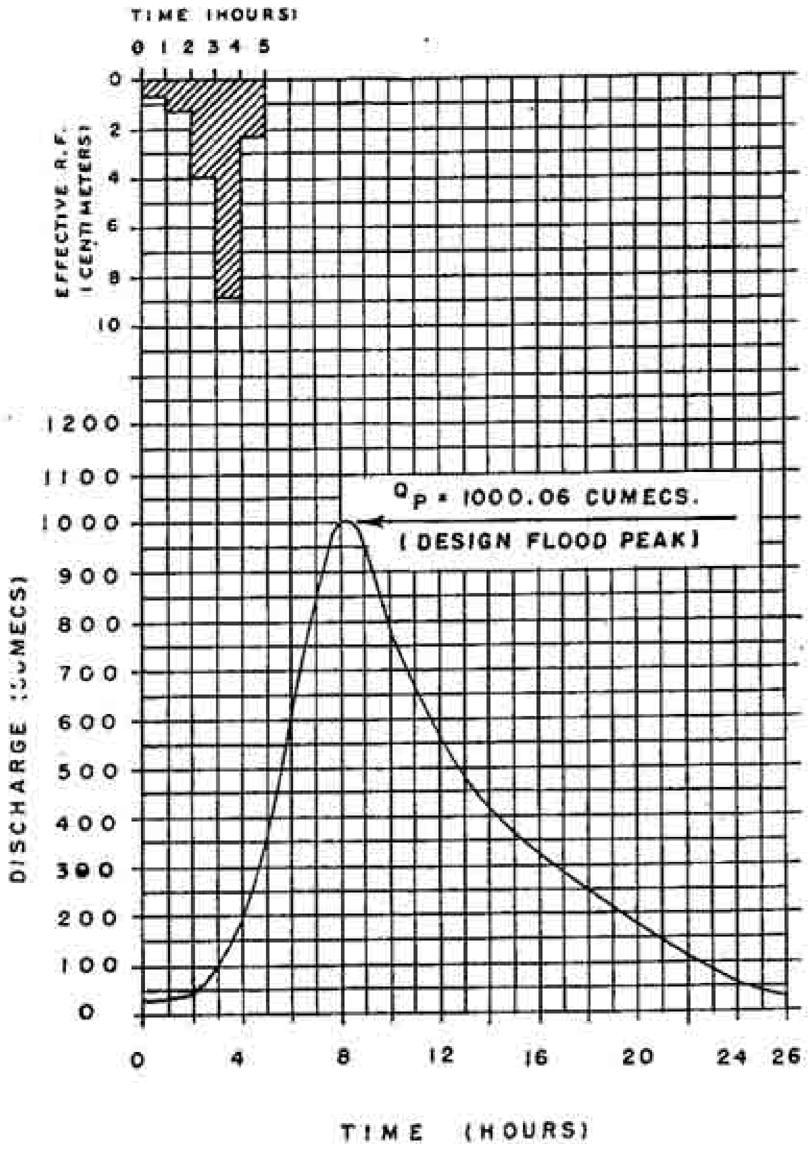
$$\sum Q_i = \frac{A \times d}{t_r \times 0.36}$$

$$= \frac{176.00 \times 1.00}{1.00 \times 0.36}$$

$= 488.89$ CUMECS.

GOVERNMENT OF INDIA CENTRAL WATER COMMISSION HYDROLOGY (REGIONAL STUDIES) DTE.	
KONKAN & MALABAR COAST SUB ZONES-5 (a) & 5(b) SYNTHETIC UNIT HYDROGRAPH BRIDGE NO.- MOT-9.	
DRAWN BY- S.N. MALHOTRA L.P. NAUTIYAL	CHECKED BY- VINOD KAUL

FIG. - A - 3.



NOTES :-

REFER ANNEXURE - 1.2 FOR COMPUTATION OF DESIGN FLOOD HYDROGRAPH.

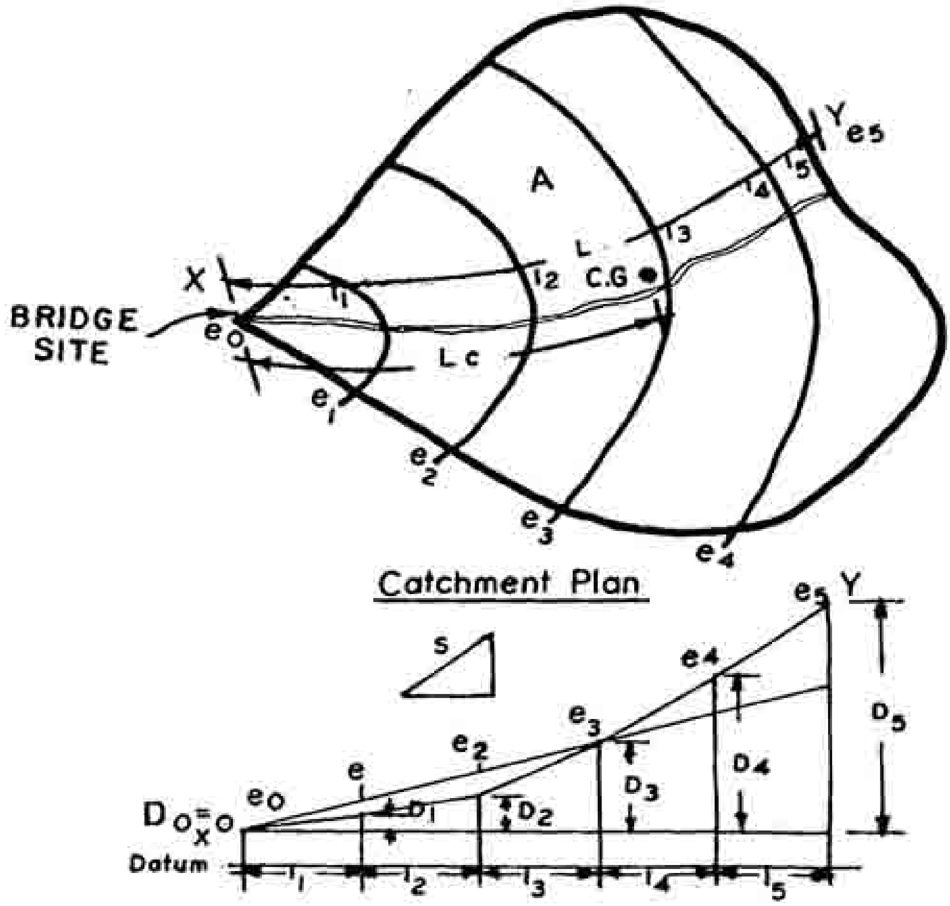
CATCHMENT AREA = 176.00 Sq. Km.

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

KONKAN & MALABAR COAST
SUB ZONES - 5 (a) & 5 (b)
DESIGN FLOOD HYDROGRAPH
BR. NO. - MOT-9 ON RIVER
ANJARAKANDI PHUJA

DRAWN BY-	CHECKED BY-
S.N. MALHOTRA L.P. NAUTIYAL	C.S. AGARWAL

FIG. I



$$S = \frac{\sum_{1}^{n} (D_i + D_{i-1})\, l_i}{L^2}$$

Where: S = Equivalent stream slope (m/km)

L = Length of longest stream course (km)

$l_i = l_1, l_2, l_3, \ldots l_n$ = Segment lengths (km)

$e_i = e_1, e_2, \ldots e_n$ = contour elevation (m)

$D_i = D_0, D_1, D_2, \cdots D_n$
$= (e_0 - e_0), (e_1 - e_0), (e_2 - e_0) \cdots (e_n - e_0)$ (m)

A = Catchment area (km²)

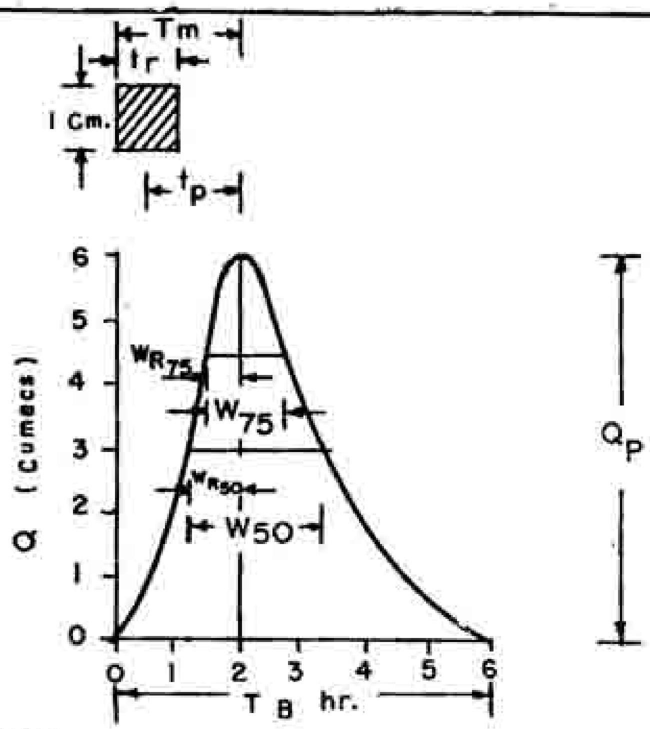
Lc = Length of longest stream course from a point opposit the centre of gravity of the catchment to the point of study (Km.)

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.)

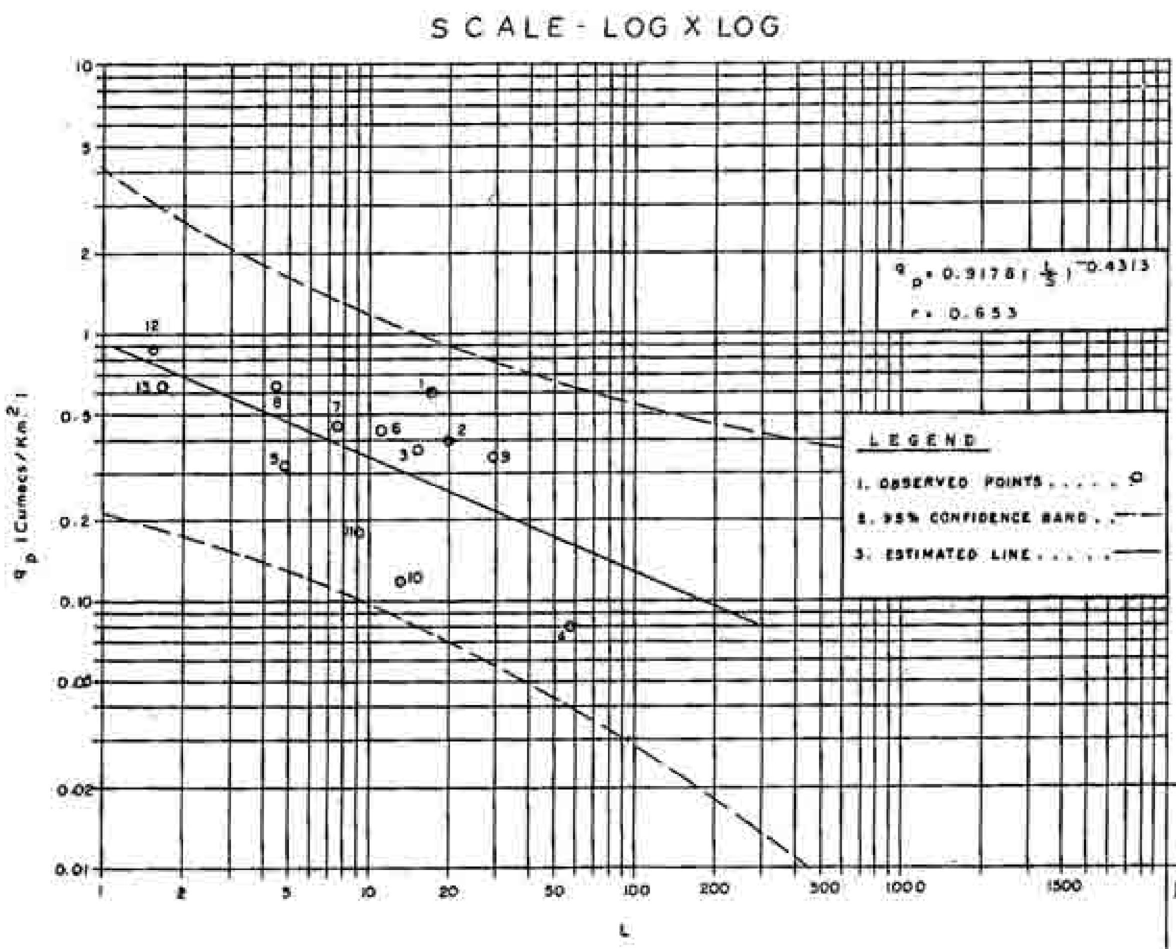
T_B = Base width of Unit Hydrograph (hr.)

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.



SL. NO.	BRIDGE NO.	L/S	q_p (Cumecs/Km^2)
1.	MOT-6	17.31	0.600
2.	MOT-4	19.71	0.400
3.	MOT-5	15.50	0.360
4.	104	56.58	0.080
5.	MOT-8	4.78	0.321
6.	MOT-2	11.21	0.430
7.	MOT-1	7.58	0.450
8.	273	4.47	0.630
9.	117	29.25	0.340
10.	MOT-11	13.19	0.118
11.	MOT-9	9.14	0.179
12.	MOT-7	1.53	0.880
13.	260	1.69	0.630

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

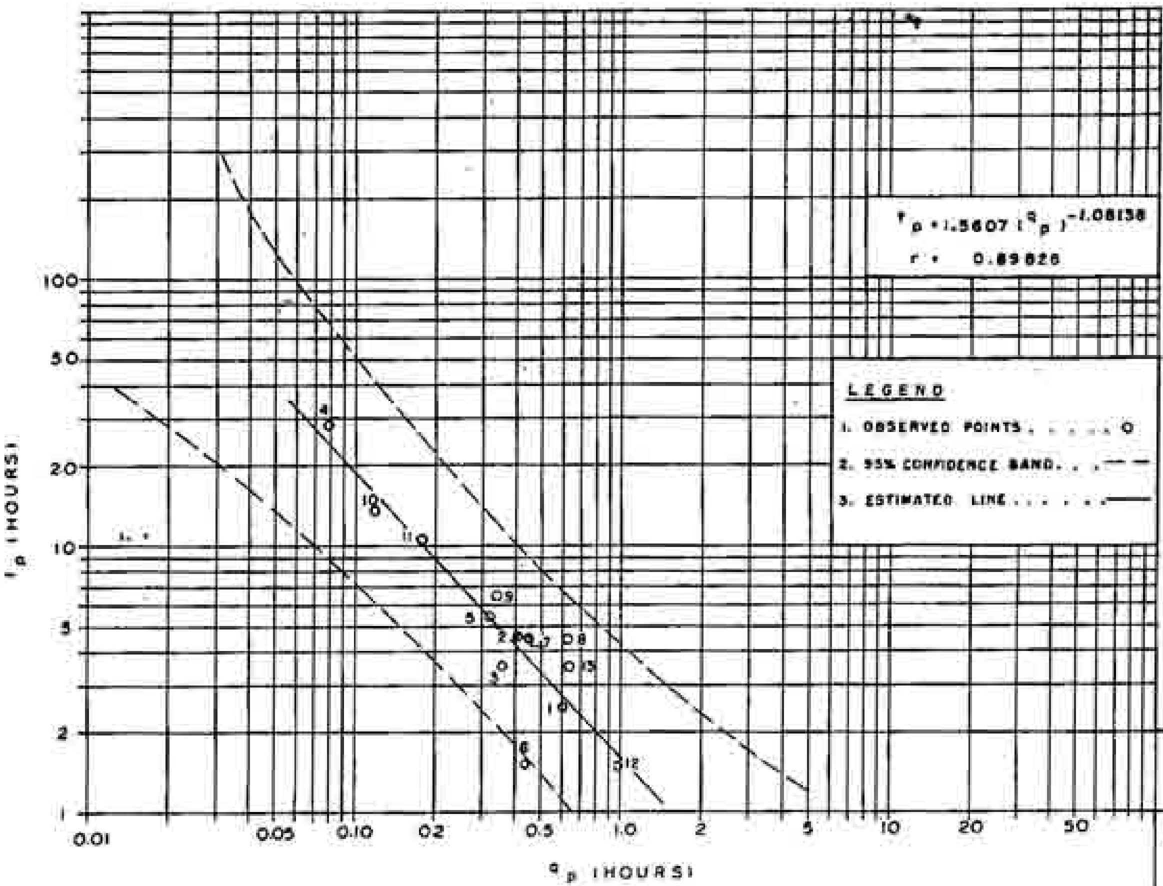
KONKAN & MALABAR COAST

SUB ZONES - 5(a) & 5(b)
RELATION BETWEEN
L/S AND q_p

DRAWN BY-	CHECKED BY-
S. N. MALHOTRA L. P. NAUTIYAL	VINOD KAUL

FIG.- 4.

SCALE - LOG.X LOG.



SL. NO.	BRIDGE NO.	q_p (HOURS)	t_p (HOURS)
1.	MOT-6	0.600	2.500
2.	MOT-4	0.400	4.500
3.	MOT-5	0.360	3.500
4.	104	0.080	28.500
5.	MOT-8	0.321	5.500
6.	MOT-2	0.430	1.500
7.	MOT-1	0.450	4.500
8.	273	0.630	4.500
9.	117	0.340	6.500
10	MOT-11	0.118	13.500
11	MOT-9	0.179	10.500
12	MOT-7	0.880	1.500
13	260	0.630	3.500

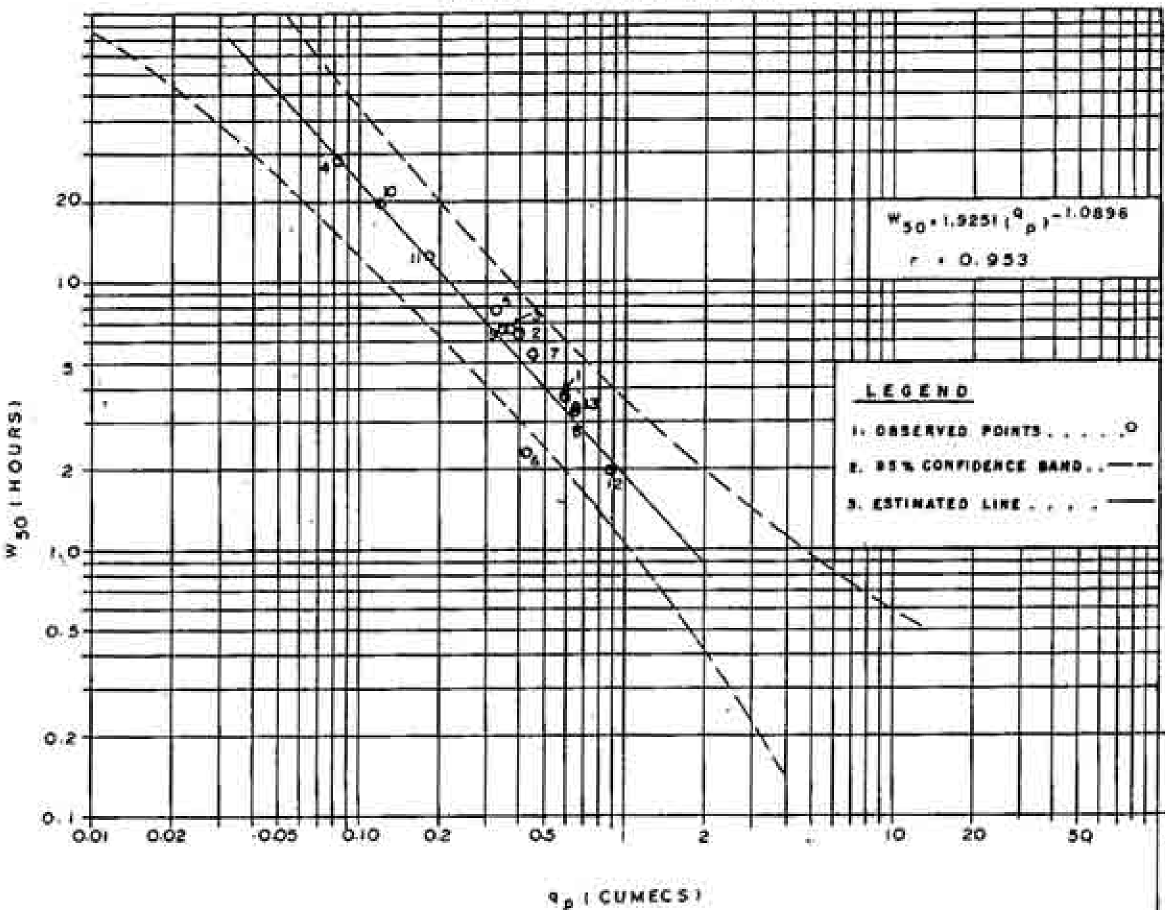
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE.

KONKAN & MALABAR COAST
SUB ZONES-5(a) & 5(b)
RELATION BETWEEN
q_p AND t_p

DRAWN BY_	CHECKED BY_
S.N. MALHOTRA. L.P. NAUTIYAL.	R. K. GUPTA.

FIG. - 5.

SCALE.- LOG. X LOG.



SL. NO.	BRIDGE NO.	q_p (Cums./km²)	W_{50} (HOURS)
1.	MOT-6	0.600	5.700
2.	MOT-4	0.400	6.400
3.	MOT-5	0.360	6.600
4.	104	0.080	28.250
5.	MOT-8	0.321	7.650
6.	MOT-2	0.430	5.300
7.	MOT-1	0.450	5.550
8.	273	0.630	3.400
9.	117	0.340	6.600
10.	MOT-11	0.118	19.600
11.	MOT-9	0.179	12.550
12.	MOT-7	0.880	2.000
13.	260	0.630	3.300

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KONKAN & MALABAR COAST

SUB ZONES 5(a) & 5(b)

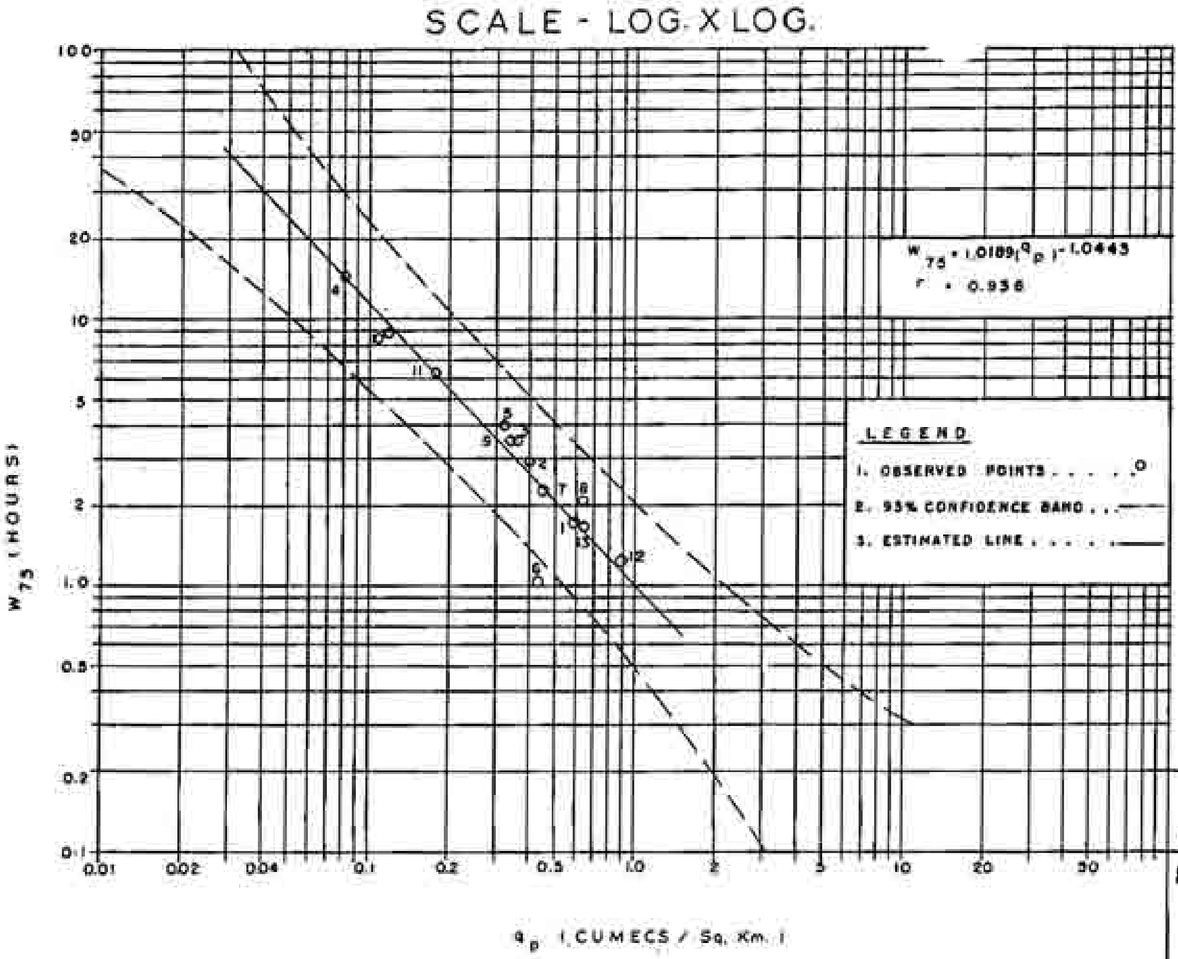
RELATION BETWEEN

q_p AND W_{50}

DRAWN BY:- S.N. MALHOTRA, L.P. NAUTIYAL

CHECKED BY:- R. K. GUPTA

FIG. — 6.



SL. NO.	BRIDGE NO.	q_p (CUMECS/KM²)	W_{75} (HOURS)
1.	MOT-6	0.800	1.77
2.	MOT-4	0.400	2.90
3.	MOT-5	0.360	3.50
4.	104	0.080	14.75
5.	MOT-8	0.321	4.00
6.	MOT-2	0.430	1.04
7.	MOT-1	0.450	2.23
8.	273	0.630	2.10
9.	117	0.340	3.50
10.	MOT-11	0.118	8.90
11.	MOT-9	0.179	6.35
12.	MOT-7	0.880	1.23
13.	260	0.630	1.70

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KONKAN & MALABAR COAST

SUB ZONES.5 (a) & 5 (b)

RELATION BETWEEN

q_p AND W_{75}

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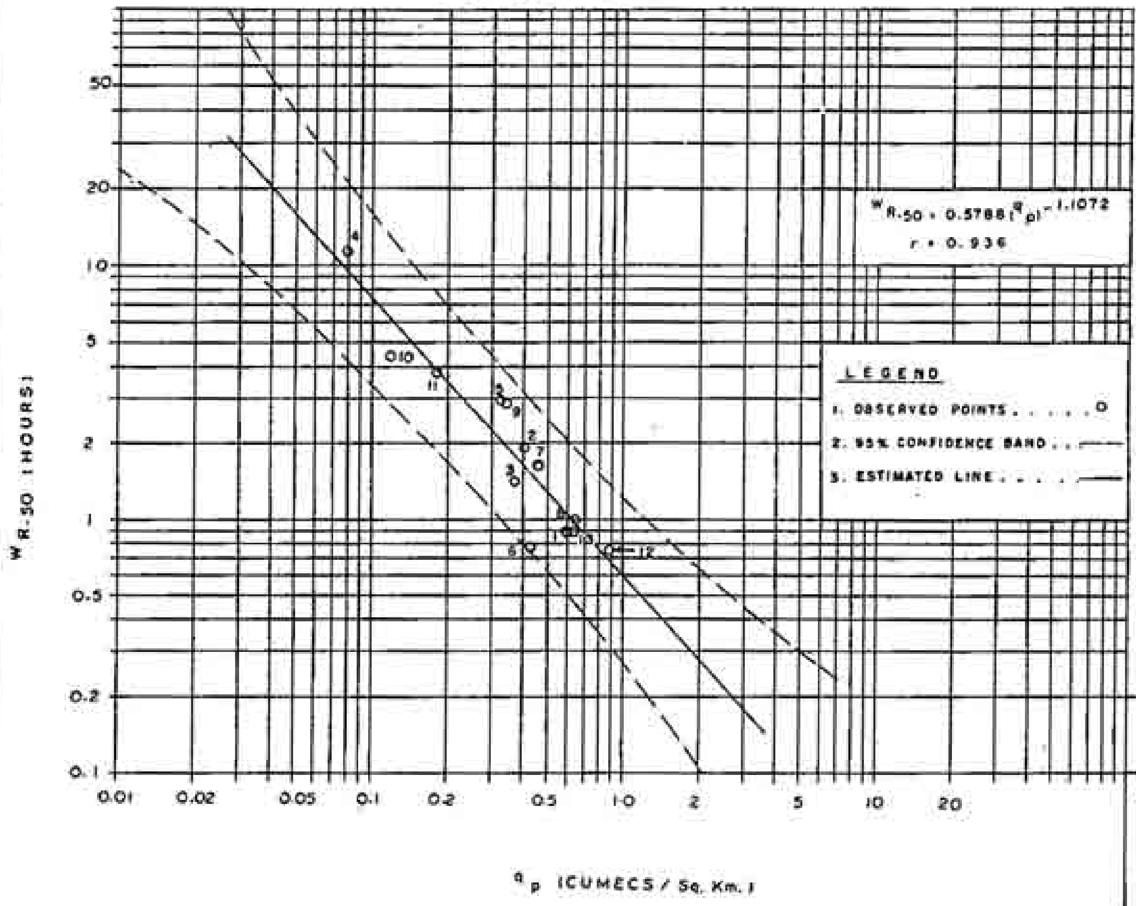
S. N. MALHOTRA, L. P. NAUTIYAL.	ANIL KUMAR GHOSH.

FIG. - 7

SCALE - LOG. X LOG.



SL. NO.	BRIDGE NO.	q_p (Cums./Km²)	$W_{R.50}$ (HOURS)
1.	MOT-6	0.600	0.90
2.	MOT-4	0.400	1.90
3.	MOT-5	0.360	1.40
4.	104	0.080	11.25
5.	MOT-8	0.321	3.00
6.	MOT-2	0.430	0.77
7.	MOT-1.	0.450	1.65
8.	273	0.630	1.00
9.	117	0.340	2.80
10.	MOT-11	0.118	4.40
11.	MOT-9	0.179	3.80
12.	MOT-7	0.880	0.75
13.	260	0.630	0.90

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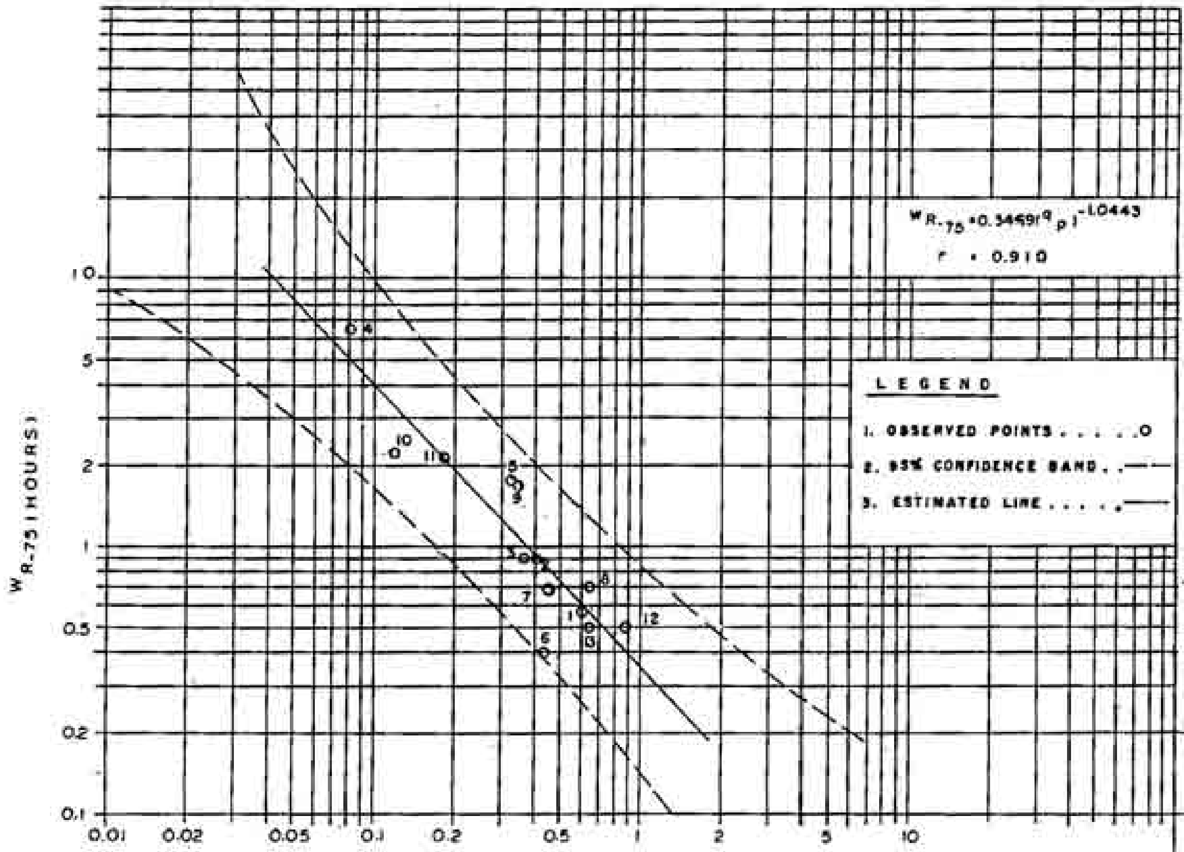
KONKAN & MALABAR COAST
SUB ZONES-5(a) & 5(b)
RELATION BETWEEN
q_p AND $W_{R.50}$

DRAWN BY- S.N. MALHOTRA, L.P. NAUTIYAL | CHECKED BY- R.K. GUPTA

FIG. - 8.

SCALE - LOG. X LOG.



SL. NO.	BRIDGE NO.	q_p (Cums./Km²)	W_{R-75} (HOURS)
1.	MOT - 6	0.600	0.57
2.	MOT - 4	0.400	0.90
3.	MOT - 5	0.360	0.90
4.	134	0.080	6.50
5.	MOT - 8	0.321	1.75
6.	MOT - 2	0.430	0.40
7.	MOT - 1	0.450	0.68
8.	273	0.630	0.70
9.	117	0.340	1.70
10.	MOT - 11	0.118	2.20
11.	MOT - 9	0.179	2.15
12.	MOT - 7	0.880	0.50
13.	260	0.630	0.50

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KONKAN & MALABAR COAST
SUB ZONES-5 (a) & 5 (b)
RELATION BETWEEN
q_p AND W_{R75}

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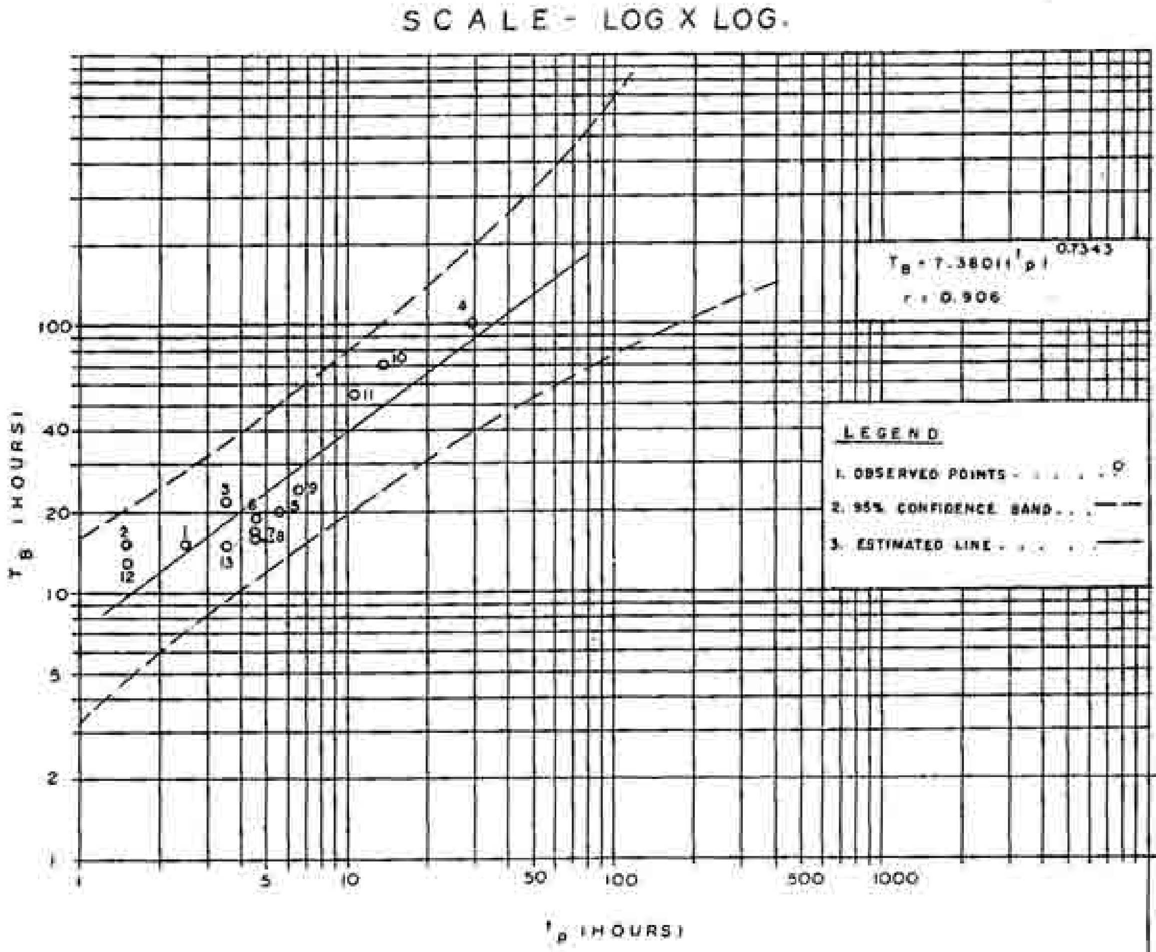
CHECKED BY- A. K. GHOSH.

FIG.— 9



SL. NO.	BRIDGE NO.	t_p (HOURS)	T_B (HOURS)
1.	MOT-6	2.50	15.00
2.	MOT. 4	4.50	15.00
3.	MOT-5	3.50	22.00
4.	104	28.50	100.00
5.	MOT-8	5.50	20.00
6	MOT-2	1.50	15.00
7.	MOT-1	4.50	17.00
8.	273	4.50	16.00
9.	117	6.50	24.00
10.	MOT-11	13.50	70.00
11.	MOT-9	10.50	55.00
12.	MOT-7	1.50	13.00
13.	260	3.50	15.00

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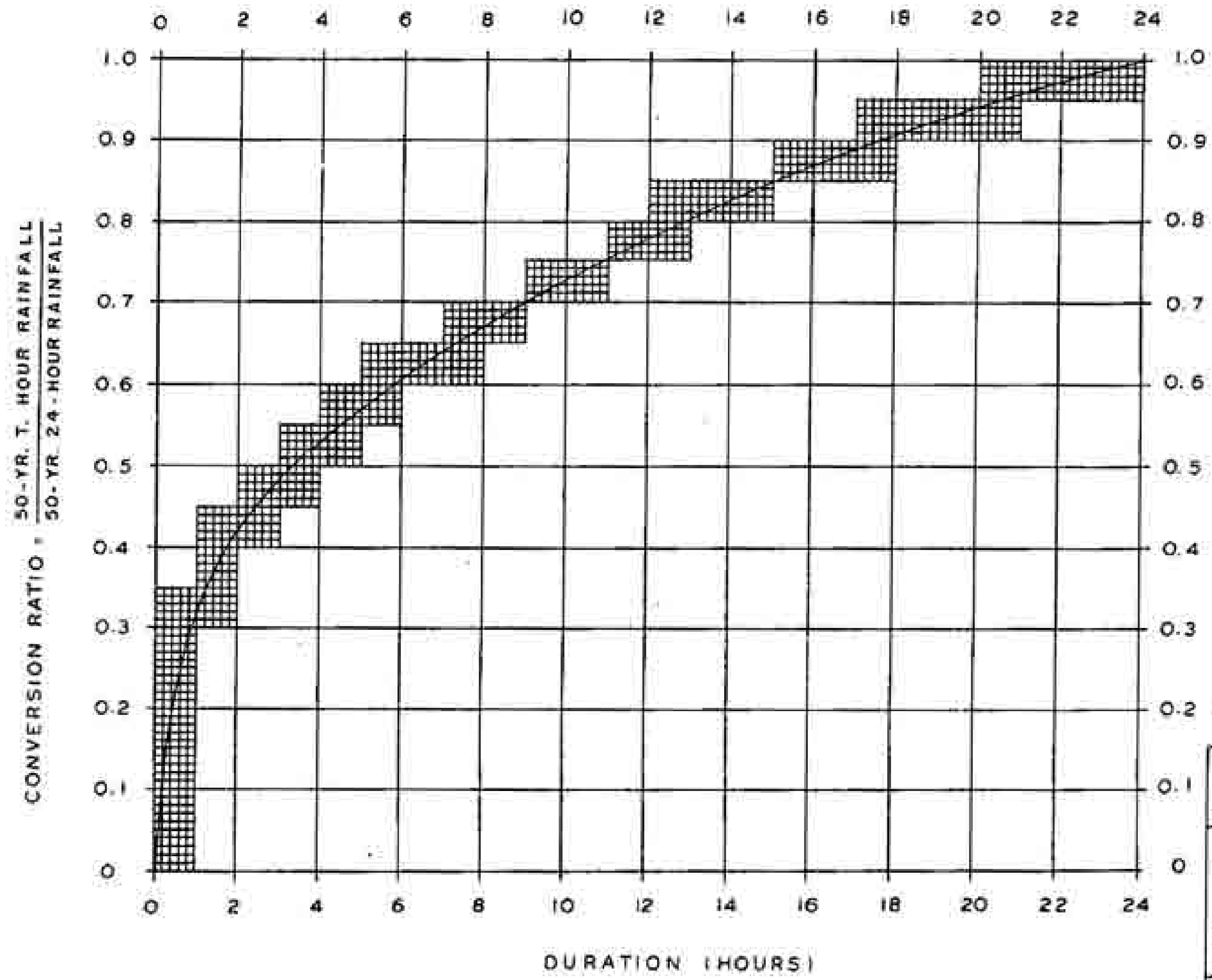
KONKAN & MALABAR COAST
SUB ZONES - 5(a) & 5(b)
RELATION BETWEEN
t_p AND T_B

DRAWN BY—	CHECKED BY—
S.N. MALHOTRA L.P. NAUTIYAL	A. K. GHOSH

FIG.- 10.



RATIOS OF 24-HOURS POINT RAINFALL TO SHORT DURATION RAINFALL

DURATION (HRS.)	RATIO
1	0.320
2	0.420
3	0.485
4	0.525
5	0.570
6	0.610
7	0.640
8	0.670
9	0.700
10	0.730
11	0.755
12	0.780
13	0.805
14	0.830
15	0.850
16	0.870
17	0.890
18	0.910
19	0.925
20	0.940
21	0.955
22	0.970
23	0.985
24	1.000

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KONKAN & MALABAR COAST
SUB ZONES - 5 (a) & 5 (b).
DURATION VS. CONVERSION RATIO

DRAWN BY-	CHECKED BY-
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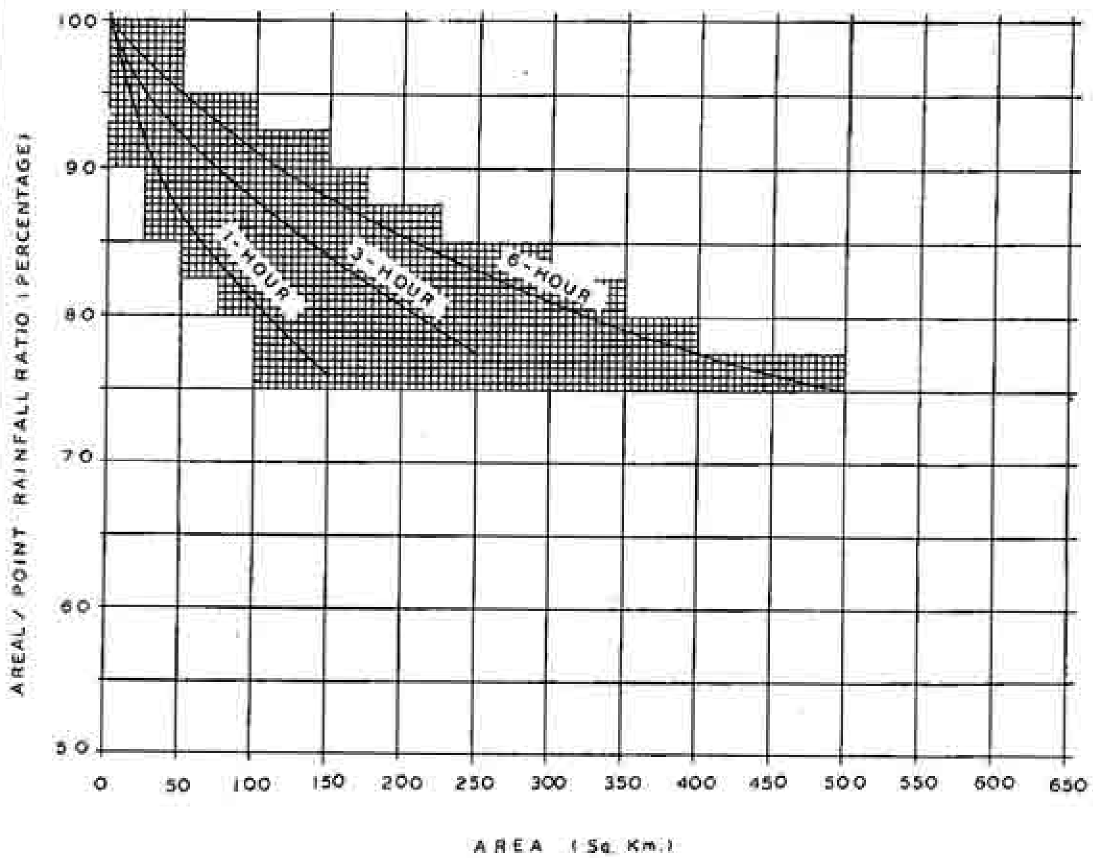
FIG. - 11 (a).



NOTES:-

REFER ANNEXURE 4·2 FOR CONVERSION OF POINT RAINFALL TO AREAL RAINFALL.

CURVES SUPPLIED BY I. M. D

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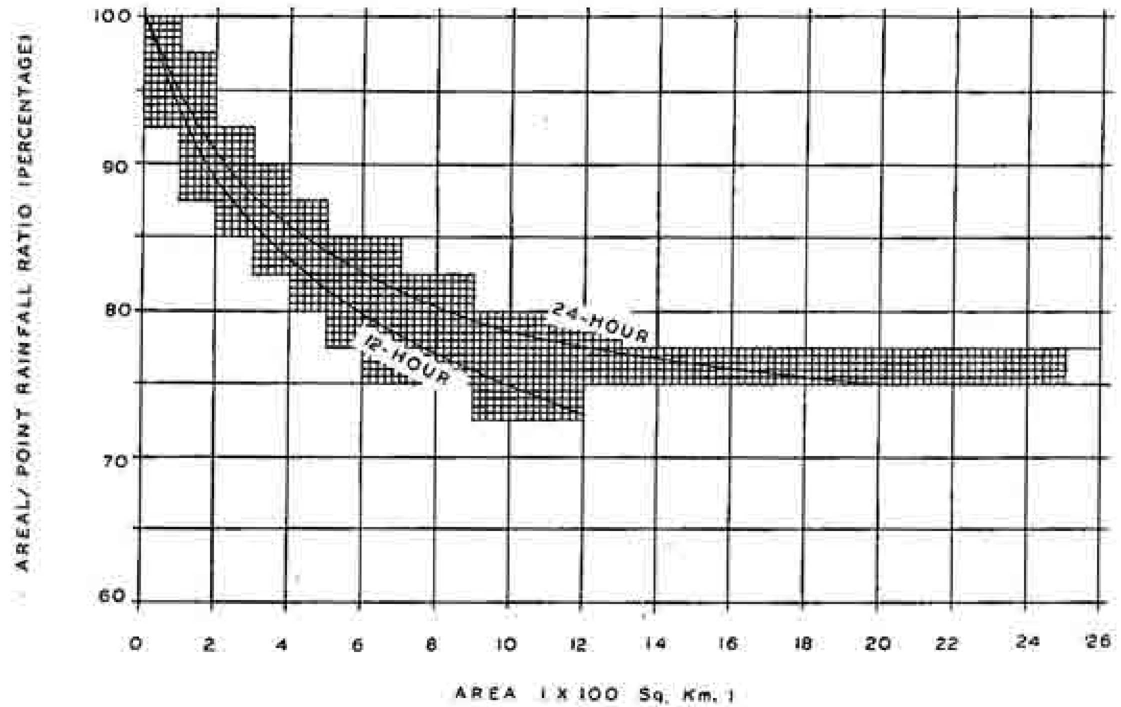
KONKAN & MALABAR COAST

SUB ZONES - 5 (a) & 5 (b).

AREAL TO POINT RAINFALL RATIO (PERCENTAGE)

DRAWN BY -	CHECKED BY -
S. N. MALHOTRA L. P. NAUTIYAL	A. K. GHOSH.

FIG. - 11 (b).



NOTE:-

REFER ANNEXURE 4-2 FOR CONVERSION OF POINT RAINFALL TO AREAL RAINFALL.

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KONKAN & MALABAR COAST

SUB ZONES-5 (a) & 5 (b)

AREAL TO POINT RAINFALL RATIO

(PERCENTAGE)

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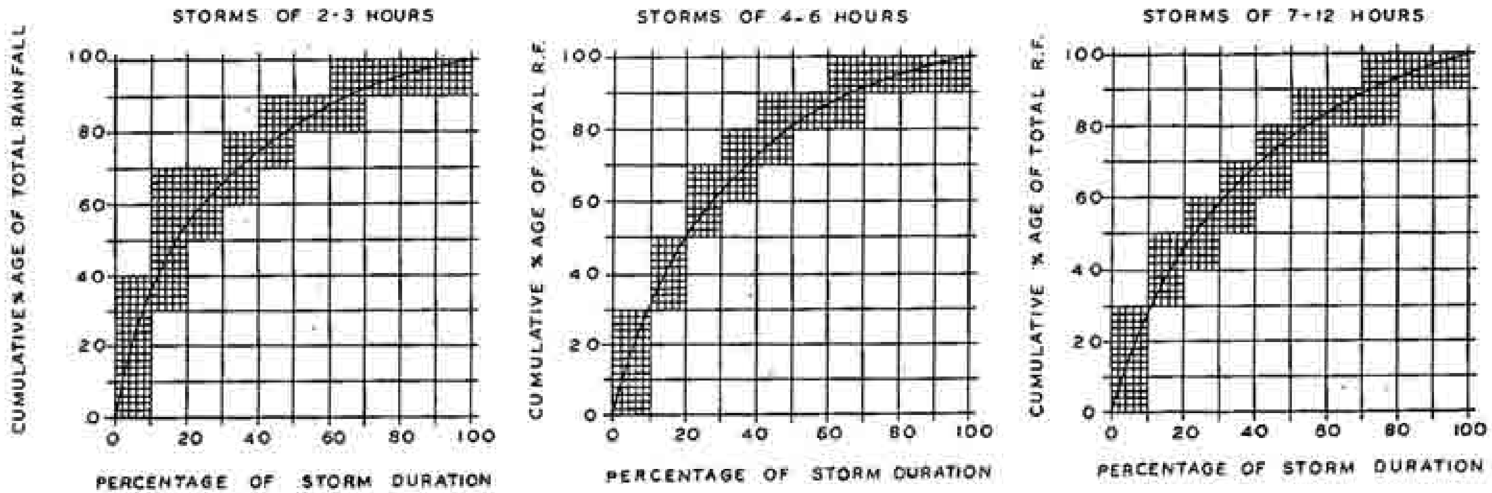
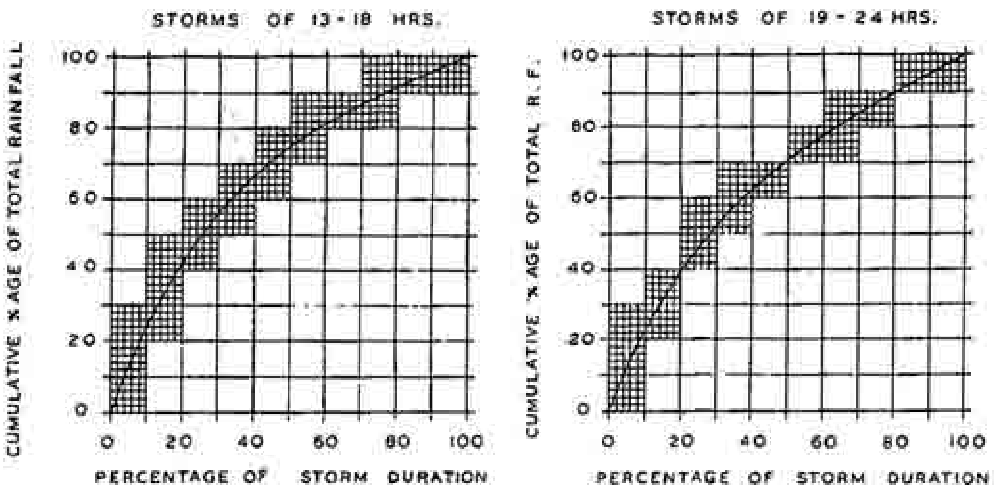
FIG. - 12.





NOTE:- REFER ANNEXURE 4-3 SHOWING TIME DISTRIBUTION COEFFICENTS OF AREAL RAINFALL FOR VARIOUS DURATION OF 2, 3, 4 .... - 23, 24 - HOURS.

CURVES SUPPLIED BY IMD

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KONKAN & MALABAR COAST SUB ZONES - 5(a) & 5(b) MEAN AVERAGE TIME DISTRIBUTION CURVES OF STORMS OF VARIOUS DURATIONS	
DRAWN BY- S. N. MALHOTRA. L. P. NAUTIYAL.	CHECKED BY- C. S. AGARWAL

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