3227 → TRa/om
3705 → Mi
3409 → Shob'sh
3603

अभिकल्प कार्यालय विवरण
DESIGN OFFICE REPORT
नं.:केपी-3(सी)/आर-6/46/2002
NO. UNT-3(c)/R-6/46/2002

केन्द्रीय जल आयोग
CENTRAL WATER COMMISSION

ऊपरी नर्मदा एवं तापी (उप अँचल - 3 सी) का बाढ़ ऑकलन विवरण (परिशोधित)

FLOOD ESTIMATION REPORT FOR UPPER NARMADA AND TAPI SUBZONE - 3(c) (REVISED)

88598

जल विज्ञान निदेशालय
क्षेत्रीय अध्ययन
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का संयुक्त कार्य

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A JOINT WORK OF
CENTRAL WATER COMMISSION
INDIA METEOROLOGICAL DEPTT.
RESEARCH DESIGN AND STANDARDS ORGANISATION, MINISTRY OF RAILWAYS
MINISTRY OF SURFACE TRANSPORT

अक्तूबर 2002
October,2002

Revised Flood Estimation Report for Upper Narmada and Tapi subzone – 3(c) was discussed and approved by the following members of Flood Estimation Planning and Co-ordination Committee in its 56th Meeting held on 25.9.2001 at Central Water Commission, New Delhi.

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DESIGN OFFICE REPORT
NO. UNT-3(c)/R-6/46/20[illegible]2

सत्यमेव जयते

CENTRAL WATER COMMISSION

FLOOD ESTIMATION REPORT FOR UPPER NARMADA AND TAPI SUBZONE - 3(c) (REVISED)

HYDROLOGY (REGIONAL STUDIES) DIRECTORATE
HYDROLOGY STUDY ORGANISATION
NEW DELHI

FOREWORD

In the past, the estimation of design flood for design of waterways and foundations of railway and road bridges, culverts, cross drainage works, spillways of minor tanks having small and medium catchments has generally been based on empirical formulae. These formulae were evolved with a small data base for a particular region as available at those points of time. Such estimation is totally unrealistic being based on very simplified assumptions. Therefore, a need for evolving a suitable rational method for estimating the design floods of small and medium ungauged catchments was felt.

For the purpose of evolving a method of estimation of design flood of desired frequency on regional basis by hydrometeorological approach, the country has been divided into 7 zones and further into 26 hydrometeorologically homogenous subzones. So far, 21 flood estimation reports covering 24 subzones have been published.

In addition, there is also a periodic revision of such subzonal reports, whenever additional data become available and revision becomes due. The flood estimation reports of Lower Ganga Plain Subzone 1 (g), Lower Godavari Subzone 3(f), Mahanadi Subzone 3(d), South Brahmaputra Subzone 2(b) and Krishna and Pennar Subzone 3(h) have already been revised and published. This report is a revision of the flood estimation report of Upper Narmada and Tapi Subzone 3(c) published in the year 1983 on the basis of additional hydrometeorological inputs received thereafter. It gives the method to compute design flood of 25, 50 and 100 year return period for ungauged catchments located in Upper Narmada and Tapi Subzone 3 (c).

This report is a joint effort of the Central Water Commission (CWC), India Meteorological Department (IMD), Research Design and Standards Organisation (RDSO) of the Ministry of Railways and the Ministry of Surface Transport (MOST).

I wish to place on record my appreciation of the cooperative efforts of the officers and staff of the four organisations in bringing out this report

New Delhi.

October, 2002

(R. JEYASEELAN)
MEMBER(D&R), CWC
& Ex-officio Additional Secretary to Govt. of India.

PREFACE

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

The use of empirical flood formulae like Dickens, Ryves, Inglis etc. has the simplicity of relating the maximum flood discharge to the catchment area with constants. But these formulae do not take into account the basic meteorological component of storm rainfall and other physiographic and hydrologic factors, varying from catchment to catchment. Proper selection of constants in these empirical formulae is left to the discretion of design engineer, involving subjectivity. They also do not have frequency concept.

Recognising the need to evolve a rational and scientific method for estimating design flood peak of desired frequency, the committee of engineers headed by Dr. A.N. Khosla have recommended, in their report in the year 1959, that the design discharge for bridges should be the maximum flood on record for a period of not less than 50 years. Where adequate records are available, extending over a period not less than 50 years, the design flood should be the 50-years flood determined from the probability curve prepared on the basis of the recorded floods during that period. In case, where the requisite data as above are not available, the design flood should be decided based on the ground and meteorological characteristics obtained on the basis of design storms necessitating the systematic and sustained collection of hydro-meteorological data at selected catchments in different climatic zones of India.

Economic constraints do not justify detailed hydrological and meteorological investigations at every new site on a large scale and on a long-term basis for estimation of design flood with a desired return period. Regional flood estimation studies, thus, become necessary. Broadly, two main regional approaches, namely flood frequency and hydrometeorological approaches are open for adoption depending upon the availability of the storm rainfall and flood data. The first approach involves long-term discharge data observations for the representative catchments for subjecting the data to statistical analysis to develop a regional flood frequency model. The other approach, viz, hydrometeorological approach involves assessment of the causative factor i.e. rainfall and catchment response function, antecedent conditions etc. separately. In this method concurrent storm rainfall and runoff data of the catchment over a period of 5-10 years is used to develop representative unit hydrographs of the catchments located in the region, so that synthetic unit hydrograph may be obtained for the region (subzones). The long term rainfall records at a large number of stations is used to develop design storm values. This hydrometeorological approach has been adopted for preparing flood estimation reports.

The regional flood estimation was attempted on both short term and long term plans. Under short-term plan, the report on estimation of design flood peak utilising hydromet data available for 60 bridge catchments, spread throughout the country, was brought out in 1973, wherein the method has been recommended for estimating the design flood peak for catchment areas ranging from 25 to 500 sq.km. in the country.

Under long-term plan, the entire country was divided into 7 zones and 26 hydro-meteorologically-homogeneous subzones. For preparing the flood estimation reports for these subzones, systematic and sustained collection of hydrometeorological data at the representative catchments, numbering 10 to 30, for a period of 5 to 10 years in different subzones 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 Designs and Standards Organisation (RDSO) of Ministry of Railways. Similarly, the Ministry of Surface Transport (MOST) had undertaken the collection of data for 45 catchments through Central Water Commission since 1979.

Hydrology (Regional Studies) Directorate, Central Water Commission (CWC) carried out analysis of collected concurrent rainfall and flow data for the gauged catchments to derive unit hydrographs of mostly one-hour duration. Representative unit hydrographs are prepared for each of the gauged catchments from the selected flood events. The characteristics of the catchments and the unit hydrographs, prepared for several catchments in a subzone are correlated by regression analysis and the equations for synthetic unit hydrograph for the subzone are derived for estimating design flood for ungauged catchments. The response functions on convolution with the storm input as studied and provided by IMD gives the estimated design flood for that ungauged catchment. Studies are also carried out by the CWC to arrive at suitable recommendations for estimating loss rate and base flow for ungauged catchments.

India Meteorological Department (IMD) conducts depth - duration - frequency analysis of rainfall for each subzone to provide meteorological input for estimation of design flood.

The subzonal reports incorporating studies carried out by CWC and IMD are prepared and published by CWC on approval of Flood Estimation Planning and Coordination Committee (FEPCC).

So far, following 21-Flood Estimation Reports (FERs) covering 24 Subzones have been published :

1. Lower Ganga Plains Subzone 1 (g) (1978)
2. Lower Godavari Subzone 3 (f) (1981)
3. Lower Narmada and Tapi Subzone 3 (b) (1982)
4. Mahanadi Subzone 3(d) (1982)
5. Upper Narmada & Tapi Subzone 3 (c) (1983)
6. Krishna & Pennar Subzone 3 (h) (1983)

7. South Brahmaputra 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 subzones 4 (a), (b) & (c) (1987)
14. Sone Subzone 1(d) (1988)
15. Chambal Subzone 1 (b) (1989)
16. Betwa Subzone 1 (C) (1989)
17. North Brahmaputra Subzone 2 (a) (1991)
18. West Coast Region Subzone 5 (a) & (b) (1992)
19. Luni Subzone 1 (a) (1993)
20. Indravati Subzone 3 (g) (1993)
21. Western Himalayas zone 7 (1994)

Hydrometeorological inputs in the FERs at serial number 1 to 7 were based on Self Recording Raingauges (SRRGs) data alone and consisted of :

(i) Isopluvial maps for 24 hour and/or shorter duration corresponding to 50 year return period only;

(ii) Time distribution of storm rainfall, and

(iii) Point to areal rainfall ratios.

However, in the subsequent reports, IMD modified the methodology and prepared the hydrometeorological inputs based on conjunctive use of ordinary raingauges (ORG) and SRRG data. It was accordingly, recommended and desired by the FEPCC to revise the FERs at serial No. 1 to 7, so that all the reports are uniform so far as methodology is concerned. It was further decided while updating the meteorologoical component, validation of hydrological studies must also be carried out to find out any significant changes. The hydrological study was to be revised based on the additional hydrological data, collected subsequent to the preparation of the original reports. The FER for Lower Ganga Plains Subzone 1 (g), published in 1978; Lower Godavari Subzone 3 (f), published in 1981; Mahanadi Subzone 3 (d) published in 1982; South Bramhaputra subzone 2(b), published in 1984 and Krishna & Pennar Subzone 3(h), published in 1983 have already been revised, where the additional hydrometeorological input has been included as per revised methodology.

Present report is the revision/validation of the flood estimation report of Upper Narmada and Tapi Subzone 3 (c) and deals with the estimation of design flood of 25 year, 50 year and 100 year return period for small and medium catchments in the Subzone.

The original flood estimation report of Subzone 3 (c) was prepared and published in 1983. The rainfall-runoff data of 18 catchments having catchment area between 30

Sq.km.to 2100 Sq.km. for a period of 2 to 10 years during the period from 1958 to 1979 have been collected from Railways. 108 bridge years' data of 18 catchments was utilised for the study carried out earlier. In the present study, additional data of 29 bridge years for 5 (4 old and 1 new) catchments was collected subsequent to the preparation of earlier report. Thus, a total of 137 bridge years' data from 18 catchments has been used for present unit hydrograph study.

IMD while updating the storm studies used the rainfall data of 170 O.R.G. stations (69 inside the subzone and 101 around the subzone) and 23 Self Recording Raingauge (SRRG) stations in the study.

The report is in six parts. Part-I of the report "Introduction" gives the summary of the earlier and revised studies. Physiographic, climatic and hydrometeorological features of the subzone have been explained in Part-II. Part-III brings out the Synthetic Unit Hydrograph (SUH) relations to be used for ungauged catchments in the Subzone.

The storm studies carried out by IMD are dealt in Part-IV of the report. Criterion and standards in regard to design flood of structures and procedures to compute the design flood of ungauged catchments are described in Part - V along with an illustrative example. Part-VI highlights the limitations, assumptions and conclusions.

The report on Subzone 3 (c) is recommended for estimation of design flood for small and medium catchments varying in areas from 25 Sq.km. to 2500 Sq.km. This report may also be used for catchments having areas up to 5000 Sq.km. judiciously after comparing the neighbouring catchments having more or less similar characteristics.

This report is a joint effort of Hydrology (Regional Studies) Dte, Central Water Commission (CWC) of Ministry of Water Resources, India Meteorological Department (IMD) of Ministry of Science and Technology, Research Designs and Standards Organisation (RDSO) of Ministry of Railways and Ministry of Surface Transport (MOST). This Report has been approved by Flood Estimation Planning and Coordination Committee (FEPCC) in its meeting held on 25th September, 2001.

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Hydrology (RS) Dte
Central Water Commission

New Delhi

October,2002

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PLATES

FIGURES

SYMBOLS AND ABBREVIATIONS

Symbols

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

A	Catchment area in km^2
ARF	Area of Reduction Factor
C.G.	Centre of Gravity
Di_{-1} & Di	Depths between the river bed profile (L-Section) based on the levels of i-th and (i-1) th contours at the inter-section points and the level of the base line (datum) drawn at the points of study in metres
F	Shape factor of catchment ($F = L^2/A$)
Q_{25}, Q_{50}	Flood Discharge with a return period of 25-year, 50-year and 100- year And Q_{100} respectively in cumecs
Q_p	Peak discharge of Unit Hydrograph (cumecs)
q_p	Peak Discharge of Unit Hydrograph per Unit Area in cumecs per sq.km
S	Equivalent stream slope (m/km)
S_1, S_2	S lope of Individual Channel Segment (m/km)
T_B	Base period of Unit Hydrograph in hours.
T_D	Design Storm Duration (hr)
T_m	Time from start of rise to the peak of unit hydrograph ($T_m = t_p + t_r/2$)
t_p	Time lag from centre of unit rainfall duration to the peak of Unit hydrograph in hours
t_r	Unit rainfall duration in hours
U.G.	Unit Hydrograph
W_c	Minimum width of catchment area through the centre of gravity of the catchment
W_{50}	Width of Unit Hydrograph measured at 50% of maximum peak discharge (Q_p) in hours.

W_{75}	Width of Unit Hydrograph measured at 75% of peak discharge (Q_p) in hours
W_{R50}	Width of the Hydrograph at 50% of Q_p between the rising limb and Q_p ordinate in hours
W_{R75}	Width of the Unit Hydrograph at 75% of Qp between the rising limb of unit hydrograph and Qp ordinate in hours
%	Percent
Σ	Summation

ABBREVIATIONS

Cumec	Cubic metre per second
Cms.	Centimetres
Hr.	Hour
In.	Inches
Min.	Minutes
M.	Metre
Km.	Kilometres
Sec.	Seconds
Sq.km.	Square kilometre
Yr.	Year

CHAPTERS

PART – I

INTRODUCTION

1.1 GENERAL

Background of the Committee:

The Committee of Engineers headed by Dr. A.N. Khosla recommended to develop regional methodology for estimating design flood for small and medium catchments. On the recommendations of the committee, the country was divided into 7 zones and 26 hydrometeorological homogeneous subzones. The various subzones into which the country has been divided are listed in Annexure 1.1.

Upper Narmada and Tapi Subzone 3 (c) is one of the 26 hydrometeorologically homogeneous subzones covering Upper Narmada and Tapi basin lying in the states of Madhya Pradesh, Chattisgarh and Maharashtra.

1.2 NEED FOR REVISION OF REPORT

Rainfall maps of 50 year return period for duration of 1, 3, 6, 9, 12, 15 and 24 hours were furnished in flood estimation reports, published till 1984. These reports were based on data of sparse self-recording raingauges network. After publication of these subzonal reports, India Meteorological Department (IMD) upgraded the methodology of storm study, for preparing the isopluvial maps using rainfall data of ORG and SRRG in and around the subzone, in addition to the data within the subzone.

Background.

Flood Estimation Planning and Coordination Committee (FEPCC) in its 51st meeting agreed to revise these reports in a phased manner, incorporating the revised isopluvial maps prepared using ORG and SRRG data for 25, 50 and 100 year for 24 hour duration and other corresponding inputs. It was also decided by FEPCC to review and revise/validate the hydrological study of these reports, utilising additional rainfall-runoff data collected subsequent to the preparation of the reports.

The flood estimation report of Upper Narmada and Tapi Subzone 3(c), (Design Office Report No.UNT/7/1983) was published in 1983. The present report is validation/revision of the earlier report. The earlier report contained the inputs for estimating the design flood of 50 year return period only, where as the present report provides inputs for estimating design floods of 25, 50 and 100 years return period.

1.3 REVISED STUDY

Hydrological and Storm Studies as carried out in preparing the report of 1983 and the supplementary/additional studies carried out to revise that report are brought out in this revised report. The brief of these is outlined as under.

1.3.1 Hydrological study

The hydrological study carried out earlier in 1982-83 was based on rainfall-runoff data of 18 catchments having catchment area between 30 sq.km. to 2100 sq.km. observed for a period of 2 to 10 years during the period 1958-79. Thus, 108 bridge years' data of 18 catchments was utilized. Representative Unit Hydrograph (RUG) of 1-hour duration were derived from the selected flood events from the available data. The equations relating unit hydrograph parameters and basin parameters were developed for deriving 1-hr. synthetic unit hydrograph.

Subsequent to the preparation of the 1983 report, additional data in respect of five key gauging sites (bridge No. 802, 930, 505, 776 and 791/2(new) for a period of 29 bridge years for the period 1982-96 was made available by Research Design and Standards Organisation (RDSO). These data have now been utilised and integrated with the earlier studies.

Equivalent Slope has been considered as one of the physiographic parameters in the revised study in place of the Statistical Slope. Recommendations regarding the suitable values of loss rate and base flow have also been revised considering additional data. The hydrological study carried out by CWC is given in Part-III of the report.

1.3.2 Storm Study

The earlier report published in 1983, contained isopluvial maps of 50-year return period for different duration, time distribution curves and areal to point rainfall ratios. The present report contains :

(i) Align Isopluvial maps of 25, 50 and 100 year for 24-hours based on available rainfall data of ORG and SRRG in and around the Subzone.
(ii) Short duration rainfall ratios for converting 24 hours rainfall to short duration rainfall.
(iii) Time distribution curves for storms of various duration.
(iv) Point to areal ratios for different duration.

In the present study, IMD has utilised the rainfall data of a large number of stations in and around the subzone for as long period as possible. Ordinary Raingauge (ORG) data of 456 stations (292 inside the subzone and 164 around the subzone) and Self-Recording Raingauge (SRRG) data of 24 stations have been utilised. The storm studies carried out by IMD are given in Part-IV of the report.

1.4 PROCEDURE TO ESTIMATE DESIGN FLOOD

The flood estimation report for Subzone 3 (c) may be used for estimation of design flood (25-year, 50-year and 100-year) for ungauged or inadequately gauged catchments in the Subzone. Part-V explains procedure for obtaining the design flood of specified return period along with an illustrative example.

PART-II

GENERAL DESCRIPTION OF UPPER NARMADA AND TAPI SUBZONE

2.1 LOCATION

The Upper Narmada & Tapi Subzone 3 (c) lies between East longitudes 76°12' to 81°45' and North latitudes of 20°10' to 23° 45', Lying in the northern extremity of the Deccan plateau, the sub-zone covers the states of Madhya Pradesh and Maharashtra. The sub-zone is bounded by Chambal basin 1 (b), Betwa basin 1(c), and Sone basin 1(d) on the North, Lower (Narmada and Tapi) subzone 3(b) on the West, Lower Godavari subzone 3(f) on the South and Mahanadi subzone 3(d) on the East. Plate 1 shows location of Upper Narmada and Tapi Subzone on the map of India.

2.2 RIVER SYSTEM

The subzone 3 (c) comprises of upper portion of Narmada and Tapi basins and constitutes about 50% of the entire area of the combined Narmada and Tapi basins. Common boundary dividing the two sub-zones falls approximately along a line joining the points at 76°15' to 76°30' longitutudes on the northern and southern boundaries respectively of these two sub-zones. The Narmada, westward flowing river rises near Amarkantak in the Mahaikala range in the Shahdol district of Madhya Pradesh at an elevation of about 1000 metres above sea level. It flows for a length of about 1300 km before it outfalls into the gulf of Cambay in the Arabian sea. Upper Narmada and its tributaries drains a total area of 62264 sq.km. which form 72% of the area of subzone. The river Tapi rises near Multai in the Betwa district of Madhya Pradesh and like Narmada it flows westward for a length of about 725 km before outfalling into the gulf of Cambay.

The lengths of main Narmada and Tapi rivers in the upper sub-zone are 813 km and 219 km respectively. The upper subzone covers parts of Madhya Pradesh and Maharashtra States. The important tributaries of Upper Narmada are Burhnar, Banjar, Sher, Shakkar, Dudha, Tawa, Ganjal and Chhota Tawa along left bank and Hiran, Tendori, Barna, Kolar, Jamner and Datuni along right bank. Purna is the main tributary of Tapi. Upper parts of Purna fall in the upper subzone 3(c).

The drainage areas of Upper Narmada and Tapi rivers and their tributaries included in subzone 3(c) is given in Table 2.1 as follows.

Table 2.1
(DRAINAGE AREA)

Sl.No.	Basin/Sub-basin	Drainage Area (Sq. Km)
1	Burhnar	4,505
2	Banjar	3,855
3	Sher	2,813
4	Shakkar	2,883
5	Dudha	1,722
6	Tawa	4,555
7	Ganjal	2,072
8	Chhota Tawa	3,825
9	Hiran	4,505
10	Tendori	1,762
11	Kolar	1,302
12	Purna (only main tributary of Upper Tapi river)	24,089
13	Main Upper Narmada and Tapi and other minor tributaries	28,465
	Total Area of Subzone 3 (c)	86,353

Plate-2 shows the river system/Gauge and discharge sites in the subzone.

2.3 GENERAL TOPOGRAPHICAL FEATURES

2.3.1 Physiography

The basin is sloping in general towards west. The altitude varies from 900 m along the eastern boundary to 150 m towards western boundary. The important cities and towns within the subzone are Sihora, Jabalpur, Betul, Akola, Maltai, Dhupgarh etc. The physiography of the subzone is shown at plate 3.

2.3.2 Soils

The subzone 3(c) has a variety of soils as shown at Plate- 4. Two broad soil groups in the subzone are red soils and black soils. The soil group has further been classifed as mixed red and black soils, deep black soils, medium black soils, shallow black soils, red and yellow soils and skeletal soils. Areas from Sinora to Hardakhas along the left bank of Narmada river have deep black soil and covers a substantial portion of the subzone. Areas from Khaknar to Khandwa along both sides of Tapi river have medium black soil. There is a pocket of shallow black soil from Betul to Maltai. Areas from the right bank of Narmada river have in general skeletal soil. There is a pocket of red and yellow soil between Khajarwar and Nainpur and mixed red and black soil around Dhupgarh. However, this broad classification may vary considerably at micro level.

2.3.3 Land Use

The land use map is appended at Plate-5. The map has been prepared from Irrigation Atlas of India, 1989. It can be seen from the map that only about 20% area of the subzone is under scrub and forest and the remaining is cultivable area. The main crops in the subzone are wheat, millets, pulses, cotton and rice.

2.4 CLIMATOLOGICAL FEATURES

2.4.1 Rainfall features

2.4.1.1 Annual normal rainfall

The isohyetal map of annual normal rainfall for the subzone 3(c) is shown in plate-6. The subzone receives most of the rainfall from South West monsoon. About 90% rainfall is received in months of June to October; July and August being the wettest months. The amount of rainfall varies from 80 cm. in South Western part of the subzone to more than 200 cm. in the South-Central parts of this subzone. Station Pachmarhi receives the heaviest annual rainfall of more than 200 cm. The rainfall from the South-Central part of the subzone decreases sharply and then increases to 160 cm. towards both Western and Eastern parts. Further towards South West, it decreases to less than 80 cm. The far Eastern part of the subzone receives rainfall of the order of 140 cm.

2.4.1.2 Monthly rainfall distribution

Monthly rainfall distribution at six representative stations, viz, Akola, Hoshangabad, Jabalpur, Kannod, Mandla and Pachmarhi is illustrated through bar charts appended to the annual normal rainfall maps (Plate-6). In the bar charts, alphabets along abscissa indicate names of months, whereas heights of rectangles are proportional to normal rainfall of respective months.

It can be seen from the bar charts that the period June to September constitute the main rainy season over the subzone. The months of October is also the month of good rainfall activity. The rainfall in the months of July & August is considerable at all the six stations and constitute 49% to 63% of the annual rainfall. Normal rainfall for the five months (June to October) at Akola, Hoshangabad, Jabalpur, Kannod, Mandla and Pachmarhi is 91%, 94%, 92%, 95%,91% & 95% of the annual rainfall, respectively.

2.4.2 TEMPERATURE DISTRIBUTION

2.4.2.1 Mean daily temperature (annual)

Mean daily temperature distribution over the subzone is shown in plate-7. The Mean daily temperature are worked out as average of mean maximum and mean minimum temperature over the year. It may be seen from the map that about 50% of the subzone on western side is having a mean temperature greater than 26°C ranging from 26.3°C to

27.6°C. The Eastern part is having mean temperature varying from 24.3°C to 25.8°C except over a pocket surrounding Pachmarhi, where temperature is less than 22°C.

2.4.2.2 Monthly Temperature variations at selected stations

Monthly variations of mean maximum, mean minimum and mean daily temperature for five representative stations viz, Akola, Narsinghpur, Kannod, Mandla and Pachmarhi are shown graphically in plate-7 below the map of mean daily temperature. It may be seen from these graphs that the highest maximum temperatures are observed in the month of May at all the five representative stations. Minimum temperature is observed in the month of December for three representative stations except at Kannod and Narsinghpur, where it is observed in the month of January.

2.5 COMMUNICATION

2.5.1 Railways

The railway sections of Central Railways, South-Central Railways and South Eastern Railways falling in the subzone are given in Table 2.2 as follows:

Table 2.2
(Railway Section)

Sl.No.	Railway – Section	Railway
1	Bhusaval-Itarsi-Jabalpur-Katni	Central Railway
2	Bhopal-Itarsi-Amla	Central Railway
3	Murtizapur-Achalpur	Central Railway
4	Bhusaval-Badnera	Central Railway
5	Khandwa-Akola	South Central Railway
6	Gondia-Jabalpur	South Eastern Railway

2.5.2 Roads

The important National Highways in the subzone are given in Table 2.3.

Table 2.3
(National Highway)

Sl.No.	Highway	Section
1	NH-6	Bombay – Calcutta
2	NH-7	Varanasi - Kanyakumari via Nagpur
3	NH-12	Jabalpur-Jaipur via Bhopal
4	NH-26	Jhansi – Lakhnadon

PART III

SYNTHETIC UNIT HYDROGRAPH STUDIES

3.1 SYNTHETIC UNIT HYDROGRAPH (SUG)

Hydrometeorological approach has been adopted for developing a regional method for estimating design flood for small and medium catchments (25 km^2. to 2500 km^2.) in various hydrometeorologically homogeneous subzones. SUG is a unit hydrograph of unit duration for a catchment developed from relations established between physiographic and unit hydrograph parameters of the representative gauged catchments in a hydrometeorologically homogeneous region (Subzone). 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 (basin response). It is possible to develop unit hydrograph, if site-specific concurrent rainfall-runoff data is available for a period of 5-8 years or few selected severe storm events. Collection of adequate concurrent rainfall-runoff data for every site, is however, neither practicable nor economically feasible. In such a situation, the regional method for developing synthetic unit hydrograph (SUG) is resorted to. Data collected and analysed for obtaining subzonal SUG equations are discussed in succeeding paragraphs.

3.2 DATA REQUIRED

For carrying out the unit hydrograph studies for development of equations for derivation of Synthetic UG parameters, the following concurrent rainfall and runoff data for a number of catchments of small and medium size representatively located in a Subzone are required for a period of 5 to 8 years during the monsoon season covering high flood periods;

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

ii) Gauge and discharge data observed preferably 2 to 3 times a day at the gauging site. In the absence of this, even daily discharge data at these stations can be used.

iii) Hourly rainfall data of raingauge stations in the catchments. Raingauge stations may be of SRRG/ORG type.

The following catchment details are also required;

(iv) Catchment area plan showing the river network, location of raingauge stations, gauge and discharge sites, storages, habitations, forests, agricultural and irrigated areas, soils etc.

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

(vi) Longitudinal section of the river from the origin to the bridge site.

3.3 DATA COLLECTED

South-Central Railways, Central Railways and South-Eastern Railways under the overall guidance and supervision of Research Design and Standards Organisation, Ministry of Railways, Lucknow had collected rainfall, gauge and discharge data of 18 bridge catchments for a period of 2 to 10 years during 1957-1979. After various consistency checks, data of 18 bridge catchments for 108 bridge years found suitable were utilised in the study carried out during 1983. Additional data for 29 bridge years for 5 bridge sites shown in Table 3.1 was collected subsequent to the preparation of the report. Thus, a total of 137 bridge year data have been collected for developing co-relation between unit hydrograph and physiographic parameters for development of Synthetic Unit Hydrograph (SUG).

Table 3.1
(Additional data for 5 bridge sites)

Sl.No.	Site	Additional Data	Bridge Years
1	802	1982-94	13
2	930	1983-89, 91-94	11
3	505	1995-96	2
4	776	1996	1
5	791/2 (new)	1995-96	2
		Total	29 Years

Annexure 3.1 shows the name of the stream, railway bridge number, railway section, catchment area, number of rain gauge stations and period of availability of rainfall, runoff data of 18 bridge catchments having catchment areas more than 25 Sq.km. This also includes additional data of 5 catchments, collected subsequent to the preparation of the report. It can be seen from Annexure 3.1 that the catchment area of gauge sites ranges between 25 to 2500 Sq.km.

3.4 DERIVATION OF SYNTHETIC UNIT HYDROGRAPH

Procedure to obtain physiographic parameters and unit hydrograph parameters of the catchments and establishing relationships between these parameters to develop SUG is described in the following paragraphs.

3.4.1 Physiographic parameters

The physiographic parameters considered in the present study are catchment area (A), length of main stream (L), length of the main stream from a point nearest to the centre of gravity of catchment area to the observation site (Lc) and equivalent stream slope (S). The parameters are indicated in Figure-1. Estimation of these are explained 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 is referred to as the catchment area (A).

3.4.1.2 Length of the Main Stream (L)

This implies the length of the longest main stream/river from the farthest point on the watershed boundary of the catchment area to the gauging site.

3.4.1.3 Length of the main stream from a point nearest to the centre of gravity of catchment area to the observation site (Lc)

For finding the centre of gravity of the catchment, usually the boundary of the catchment is cut on a cardboard, which is then hung freely in three different 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 parameters is slope. The slope may be equivalent or statistical. In the present study, equivalent stream slope has been used instead of statistical slope used in the previous study. Equivalent slope can be computed by the following methods.

(a) Graphical method

Longitudinal section (L-section) of the main stream was prepared using the contour plain (topographic maps). In case the contours are not directly available, the nearest spot level is used. The basic concept of equivalent slope line so drawn is that on an average basis the cutting and filling of ground are equal (Ref. Figure 1) i.e. 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 10 or 12 segments representing the broad ranges of the slopes of the segments and the following formula is used to calculate the equivalent slope (S) in m/km.

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

Where,

L_i = Length of the ith segments in km.

D_{i-1}, D_i = Elevations of river bed at i-i and ith, intersection points of contours reckoned from the bed elevation at point of interest considered as datum

D(i-i) and Di are the heights of successive bed location at contour intersections.

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

Physiographic parameters A, L, Lc and S are obtained for 18 catchments used for analysis and are shown in Annexure 3.2.

3.4.2 UNIT HYDROGRAPH PARAMETERS

3.4.2.1 Scrutiny of data and finalisation of gauge discharge rating curve

Data of 18 catchments (108 bridge years) were utilised for the unit hydrograph study contained in the earlier report. The additional data of 5 catchments, (29 bridge years) was scrutinized through arithmetical checks and gauge and discharge rating curve(s) were developed and updated. The hourly discharges for the duration of the selected floods were obtained from the rating curves.

3.4.2.2 Selection of floods and corresponding storm events

In the previous study 138 flood events of 18 catchments were found suitable for U.G. studies. In the present study, 172 flood events from 18 catchments have been found suitable. The general guidelines followed for selecting a flood event are given below.

i) The flood should not have undue stagnant water levels.
ii) The selected flood should result from significant excess of rainfall not less than 1 cm.
iii) The flood events should be derived from isolated storm events.

34 Flood events shown in Table 3.2 were found suitable from the additional data collected at 5 bridge catchments. The catchments considered in the present study are the same catchments that were found suitable in the previous study.

Table 3.2
(Selected flood events)

SL.NO.	SITE	EVENTS		TOTAL EVENTS
		Utilised Earlier	Additional Events	
1	802	11	17	28
2	930	9	14	23
3	505	6	3	9
4	776	8	No suitable flood	8
5	791/2 (new)	-	No suitable flood	-

3.4.2.3 Computation of hourly catchment rainfall

The raingauge network remains the same in the subzone and hence, the station weights computed earlier have been used in the present study also.

3.4.2.4 Separation of base flow

The selected flood events of 5 Bridge catchments were plotted on the usual graph paper. The base flow was separated through the standard procedure to obtain direct surface runoff hydrograph and the direct runoff depth over the catchment was computed for each flood event.

3.4.2.5 Computation of Infiltration loss (φ-index) and 1-hour effective rainfall

With the known values of 1-hour catchment rainfall and the direct runoff depth for each flood event, the infiltration loss (constant loss rate) was estimated for selected flood events of 5 Bridge catchments viz. 802, 930, 505, 776 and 791/2 (new).

3.4.2.6 Derivation of 1-hour unit hydrograph

The studies to derive 1-hour unit hydrograph were confined to only those flood events found suitable from the additional data of three out of five bridge catchments. The 1-hour unitgraphs were derived from the rainfall excess hyetograph, obtained by subtracting loss rate from 1-hour rainfall and their corresponding direct runoff hydrograph.

3.4.2.7 Drawing of representative unitgraphs and measuring their parameters

The representative unit hydrograph (RUG) of 3 catchments were derived utilising UGs obtained from the additional data and unit hydrograph derived earlier. Integrated RUGs of 3 sites have been tested on observed floods. RUGs of remaining 15 sites developed earlier were utilised as such without any modifications. Following parameters of RUGs as indicated in Figure-2 for 18 catchments were obtained and are furnished at Annexure 3.3.

(a) Time from the centre of unit excess rainfall duration to the peak of unit hydrograph in hours (tp).

(b) Peak discharge of unit hydrograph in cubic meters per second (Q_p). This is the product of peak discharge per sq. km.(q_p) and catchment area (A).

(c) Base width of unit hydrograph in hours (T_B).

(d) Width of unit hydrograph measured at discharge ordinate equal to 50% of Q_p in hours (W_{50}).

(e) Width of unit hydrograph measured in hours at discharge ordinate equal to 75% of Qp (W_{75}).

(f) Width of the rising side of unit hydrograph measured in hours at discharge ordinates equal to 50% of Q_p (WR_{50}).

(g) Width of the rising side of unit hydrograph measured in hours at discharge ordinates equal to 75% of Qp (WR_{75}).

(h) Time from the start of rise to the peak of the unit hydrograph (T_m). This is the summation of t_p and 0.5*tr where tr is the unit duration of unit hydrograph.

3.4.3 Establishing relationships between physiographic and representative unitgraph parameters.

For establishing the relationship between RUG parameters and physiographic parameters of the catchments, linear and non-linear equations were tried. A nonlinear equation as described below was found to be the best fit.

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

Where

Y = Dependent variable

X = Independent variable

C = A constant

p = An exponent

Various relationships attempted are shown in Annexure 3.4. The relationship between L, Lc, S as physiographic parameters and U.G. parameter t_p was found to be significant. Similarly, q_p was related to time to peak discharge of the UG (t_p). UG parameters W_{50}, W_{75}, WR_{50}, WR_{75} were related to q_p. The UG parameter T_B is correlated to t_p. The principle of least square errors was used in the regression analysis to establish the relationship 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 for an ungauged catchment in the Subzone 3 (c) as shown in Table 3.3 as follows:

Table 3.3
(Recommended SUG relations)

Sl. No	Relationship		Equation No.
	Based on Report of 1983	**Revised Relationship**	
1	$t_p = 0.854\,(LLc/\sqrt{s})^{0.28}$ $r = 0.93$	$t_p = 0.995\,(LLc/\sqrt{s})^{0.2654}$ $r = 0.8908$	3.4.3.2
2	$q_p = 2.009\,(t_p)^{-0.85}$ $r = 0.91$	$q_p = 1.665\,(t_p)^{-0.71678}$ $r = 0.8452$	3.4.3.3
3	$W_{50} = 2.259\,(q_p)^{-1.08}$ $r = 0.98$	$W_{50} = 1.9145\,(q_p)^{-1.2582}$ $r = 0.940$	3.4.3.4
4	$W_{75} = 1.519\,(q_p)^{-0.99}$ $r = 0.92$	$W_{75} = 1.1102\,(q_p)^{-1.2088}$ $r = 0.8772$	3.4.3.5
5	$W_{R50} = 0.844\,(q_p)^{-1.24}$ $r = 0.87$	$W_{R50} = 0.7060\,(q_p)^{-1.3859}$ $r = 0.8214$	3.4.3.6
6	$W_{R75} = 0.583\,(q_p)^{-1.19}$ $r = 0.82$	$W_{R75} = 0.45314\,(q_p)^{-1.3916}$ $r = 0.7627$	3.4.3.7
7	$T_B = 4.84\,(t_p)^{0.74}$ $r = 0.97$	$T_B = 5.04537\,(t_p)^{0.71637}$ $r = 0.9809$	3.4.3.8
8	$T_m = t_p + t_r/2$	$T_m = t_p + t_r/2$	3.4.3.9
9	$Q_p = q_p \times A$	$Q_p = q_p \times A$	3.4.3.10

Relations developed are shown in Figures 3 to 9. Details of relationships so developed using physiographic and unit hydrograph parameters and their co-efficients of correlation is given in Annexure 3.4. It can be seen from the above table, that the coefficient of correlation has reduced in the present study when compared to earlier one. This is due to the reason that the additional data for three bridge catchments have been used in developing the integrated RUG which have been collected during different time span when catchment characteristics may have undergone change. The RUG parameters of these three catchments are as follows. The 25, 50 and 100 year flood peaks for 18 selected bridges have been computed using the new relations given in Table 3.3 and also from the RUGs of these bridges taking critical storm duration as $T_D = 1.1 * t_p$, as explained in para 5.2. Annexure 3.5 shows the comparison of flood peaks using SUGs and corresponding RUGs

Sl.No	Bridge No.802 (C.A. 945.23 Km^2)			Bridge No.930 (C.A. 223.77 Km^2)			Bridge No.505 (C.A. 70.18 Km^2)		
	AsPer Earlier Report (1975-79)	Additional Data (1982-94)	Integrated Data	As Per Report (1969-73)	Additional Data (1983-89 1991-94)	Integrated Data	As Per Report (1965-69)	Additional Data (1995-96)	Integrated Data
Q_p	342	362	352	152.00	91.00	122.00	51	23.9	38.00
q_p	0.36	0.38	0.37	0.68	0.41	0.54	0.73	0.34	0.54
t_p	7.5	6.5	7.5	4.5	7.5	6.5	3.5	4.5	4.5
T_B	19	21	20	15	22	18	10	20	15
W_{50}	7.2	5.6	6.1	3.2	4.9	4.0	3.4	7.4	4.4
W_{75}	4.7	3.0	3.7	2.2	2.5	2.3	2.75	4.4	2.6
W_{R50}	3.5	2.2	2.6	1.0	1.9	1.4	1.3	2.7	1.4
W_{R75}	2.6	1.6	1.7	0.8	1.2	1.0	1.5	1.8	1.0

From the above, it can be seen that RUG parameters have changed. This may be due to the developmental activities resulting in changes in the physiographic features of the catchment. The effect of these three catchments have affected the overall coefficient of correlation.

It would have been better, if data of all the catchments could have been collected to study the man made changes in the subzone. In the absence of these details and till such times the same are collected, the present relations will hold good.

3.4.4 Derivation of 1-hour Synthetic Unit Hydrograph for an ungauged catchment.

Considering the hydro-meteorologically homogeneity of Subzone, 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 Subzone.

The steps for derivation of 1-hour unitgraph are:

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

ii) Obtain t_p, q_p W_{50}, W_{75} WR_{50} WR_{75} and T_B by substituting appropriate basin/unit hydrograph parameters given in equations 3.4.3.2 to 3.4.3.10.

iii) Plot the parameters of 1-hour unitgraph viz.; T_m, T_B, Q_p, W_{50}, W_{75}, WR_{50} and WR_{75} on a graph paper as shown in illustrative Figure 2 and sketch and adjust the unitgraph through these points.

Sum of discharge ordinates of tr-hr unitgraph is obtained and compared with the theoretical value found by using the following general equation:

$\Sigma Qi \quad = [2.78*A] / tr$

Where

Qi = discharge ordinates at 1-hour interval (cumecs)
A = catchment area in Sq.km.
t_r = Unit duration in hours.

In this report, the unit duration is 1 hr. hence tr = 1 which means $\Sigma Qi = [2.78 \times A]$. Suitable adjustment can be made in falling limb region from W_{50} point to the tail of the unitgraph and a smooth curve be drawn to make the volume equal to the volume of the unitgraph.

3.5 SIMPLIFIED APPROACH

To assess quickly the peak of 25 year, 50 year and 100 year return period flood, a simplified approach has been developed. The physiographic parameters and corresponding 25 year, 50 year and 100 year 24-hr. point rainfall as read from the isopluvial maps (plates 8,9,10) supplied by IMD are obtained and substituted in the empirical relation developed on the basis of regression analysis using 25 year, 50 year and 100 year flood peaks for each of the 18 gauged catchment for different sizes as computed by detailed approach. The values of Q_{25}, Q_{50} and Q_{100}, for the 18 catchments so obtained are treated as dependent variables were related to their respective physiographic parameters A, L, Lc and 24 hour point rainfall values at that observation site for 25, 50 and 100 years as (R_{25}, R_{50} and R_{100}) as independent variables using multiple regression analysis and using method of least square techniques for fitting. The derived flood formulae for Q_{25}, Q_{50} and Q_{100} and their respective coefficient of correlation 'r' are as under. The correlation of dependent variables Q_{25}, Q_{50} and Q_{100} with independent variables were studied.

$$Q_{25} = 0.6671 (A)^{0.9019} (L)^{-0.1456} (Lc)^{-0.0908} (S)^{0.0512} (R_{25})^{1.081} \quad r = 0.999$$

$$Q_{50} = 0.7166 (A)^{0.9129} (L)^{-0.1432} (Lc)^{-0.1045} (S)^{0.0412} (R_{50})^{1.0519} \quad r = 0.999$$

$$Q_{100} = 0.6494 (A)^{0.9050} (L)^{-0.1431} (Lc)^{-0.0900} (S)^{0.0490} (R_{100})^{1.0801} \quad r = 0.999$$

Where Q_{25}, Q_{50} and Q_{100} are 25 year, 50 year and 100 years flood in cumec respectively.

A is the catchment area upto point of study in Sq.km.
L is the length of longest main stream along the river course in km.

Lc   is the length of the longest main stream from a point opposite to the centroid of the catchment area to the gauging site along the main stream in km.

R_{25}, R_{50} ,and R_{100} are 24 hour point storm rainfall values in cm for 25 year, 50-year and 100 year return periods respectively.

3.6 DESIGN LOSS RATE → 1 mm/hr

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/assess 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 rate in the catchments, is complex phenomena, varying due to soil conditions, soil cover and topography along with temporal and spatial variations of storm rainfall.

In the annexure 3.6, the variation of the loss rate can be seen. There is a wide variation in the loss rate ranging from 0.1 mm/hr to a high of 18 mm/hr. This is so because the estimation of catchment rainfall depends on many hydrological factors such as antecedent moisture condition, size of the catchment, soil type etc, but also the estimation of catchment rainfall depends upon the location of the raingauge stations, which also affects the estimation of the areal rainfall depth with respect to runoff observed at the outlet of the catchment.

As the flood potential of a catchment will depend on the loss rate, we can see from the table that as many as 36 flood events fall under the category of 0.1-2 mm/hr. An average of this range i.e. 1 mm/hr can, therefore, be recommended as the loss rate for any ungauged catchment in this subzone.

However, the user can assess any loss rate value based on the information available to him.

3.7 DESIGN BASE FLOW → 0.05 cumec/Sq.km.

Base flow values for 172 flood events inclusive of additional flood events of 3 catchments tabulated in different ranges are shown in Annexure 3.7. Out of 172 flood events, 107 flood events fall under the range of 0.01 - 0.09 cumec/Sq.km. The average base flow rate of 0.05 cumec/Sq.km. is recommended for estimating base flow for a catchment in the Subzone. The designer may, however, adopt any other suitable value as per site condition.

PART IV

STORM STUDIES

4.1 INTRODUCTION

The India Meteorological Department (IMD) has conducted detailed rainfall studies for Upper Narmada & Tapi Basin Subzone 3 (c) which is presented in this chapter. The study covers Depth-Duration-Frequency analysis of available daily/short duration rainfall data in and around the subzone. The design storm components have been derived in the form of (i) 25, 50 and 100-year 24-hour isopluvial maps, (ii) 24 hours to short duration (1 to 23 hours) rainfall ratios, (iii) Time distribution curves for storm of different durations (2 to 24 hours), and (iv) point to areal rainfall ratios for specified durations (1,3,6,12 and 24 hours). The methodology for analysis of each component and the procedure for design storm estimation is discussed in Section-4.3 & 4.5. The results of the study serve as basic input for design flood estimation for small and medium catchments.

4.2 DATA USED

The rainfall data for a large number of stations in and around the subzone for as long a period as possible have been used. Ordinary raingauge (ORG) data of 170 stations (69 inside the subzone and 101 around the subzone) and self recording rainguage (SRRG) data of 23 stations have been utilised.

4.3 DEPTH DURATION FREQUENCY ANALYSIS

4.3.1 ISOPLUVIAL MAPS

For each of the 170 ORG stations in and around the subzone, a series of annual maximum one-day rainfall was generated. The 170 stations series, thus formed, were subjected to frequency analysis using Gumbel's extreme value distribution for computing one day rainfall estimates for 25, 50 and 100-year return periods. These daily rainfall estimates (170 x 3) were converted into 24 - hour rainfall estimates by using the conversion factor of 1.15. For each return period, the 24-hour estimates for 170 stations were plotted on the base map and isopluvial were drawn. The isopluvials maps of 25, 50 and 100 - year 24 - hour rainfall are shown in Plates 8, 9 and 10 respectively, which can be used to derive 24-hour rainfall estimates for specific return periods at any desired location in the subzone.

4.3.2 SHORT DURATION RATIOS

There are 23 SRRG stations in the subzone and most of the stations are having data of more than 8 years. The hourly rainfall data were subjected to frequency analysis using partial duration series for computing T - year t- hour rainfall estimates for T = 2, 5, 10, 25 and 50 years and t = 1, 3, 6, 9, 12, 15, 18 and 24 hours. These estimates (23 x 8 x 5) were converted into ratio with respect to the corresponding 24 - hour estimates. Average ratios (8 x 5) for the zone as a whole (mean of 23 station ratio) were then computed for each T - year t - hour pair. It was noticed that for a specified duration t, the average ratios beyond T = 5 years were comparable in magnitude. As such the average ratios (8) corresponding to 10-year t-hour rainfall have been recommended to be adopted uniformly for converting 24 - hour rainfall into t - hour rainfall. These 8 conversion ratios for t = 1, 3, 6, 9, 12, 15, 18 and 24 hours given below were plotted on graph and a smooth curve was drawn as shown in graph at Fig.10, which can be used to derive conversion ratios for any duration (t) in general, including the intermediate durations.

Duration (t) In Hours	Conversion Ratio $\frac{\textbf{10-Year t-Hour Rainfall}}{\textbf{10-Year 24 Hour Rainfall}}$
1	0.34
3	0.50
6	0.63
9	0.72
12	0.79
15	0.86
18	0.91
24	1.00

Any 25, 50 or 100 - year 24 - hour point rainfall in the subzone, as read from isopluvial maps in Plates 8, 9 and 10, can be converted into corresponding 25, 50 or 100 - year t - hour rainfall by multiplying with t-hour ratio as read from the curve in Fig.10, or, by making use of table alongside the graph.

4.3.3 TIME DISTRIBUTION CURVES

Based on hourly rainfall data of all the 23 SRRG stations, a total of 4447 rainstorms of durations ranging from 2 to 24 hours were analyzed and grouped station wise into the following 5 categories.

a) rainstorms of 2 to 3 - hour duration (986 rainstorms)
b) rainstorms of 4 to 6 - hour duration (1217 rainstorms)
c) rainstorms of 7 to 12 - hour duration (1182 rainstorms)
d) rainstorms of 13 to 18 -hour duration (498 rainstorms)
e) rainstorms of 19 to 24 -hour duration (564 rainstorms)

For each station, 5 different graphs corresponding to each group of rainstorms were prepared by plotting the cumulative percentage of the total storm duration and the average time distribution curves (23 x 5) were drawn. Average time distribution curves (5) for the subzone, as a whole, were then drawn by plotting 23 station curves on the same graph and average curves are drawn, which are given in Fig.11. These curves can be used to derive the time distribution co-efficient of storm rainfall in the sub zone for the rainstorms of any duration (Annexure 4.3).

4.3.4 POINT TO AREAL RAINFALL RATIOS

In the present study, the availability of a fairly dense network of SRRGs in the subzone made it possible to adopt the best scientific procedure for deriving point to areal relationship based on SRRG data and concurrent ORG data in preference to bridge data. The data of 23 SRRG stations in and around the catchment were used. SRRG data of 23 stations were scrutinized to collect the rainstorms of various durations (t = 1,3,6,12 & 24 hrs) and about 50 rainstorms were selected. The hourly rainfall records of SRRG's and daily rainfall data of surrounding ORG's were carefully examined for various storm durations (5) to select t - hour representative rainstorms based on the following considerations :

- (i) A maximum central value of t-hour rainfall being nearest to the corresponding 24-hour rainfall ending 0830 hours;
- (ii) The availability of adequate concurrent data of surrounding ORG stations;
- (iii) Each duration t being entirely contained in the 24-hour period ending 0830 hours.

About 50 representative rainstorms were selected for analysis. For each representative rainstorm, the ratio of rainstorm rainfall to corresponding 24-hour rainfall was computed and the daily rainfall values of surrounding ORG stations were reduced in the same proportion. Isohyetal maps of 50 representative rainstorms were then prepared using concurrent rainfall values of SRRG stations and surrounding ORG stations (reduced values) corresponding to the date and time of each representative rainstorm. By planimetering each isohyetal map around the rainstorm centre and plotting the ratios of areal rainfall depth to point rainfall against the areas, the best fit curves (5) were drawn as shown in the graph at Figs. 12(a) and 12(b), which can be used to derive the percentage areal reduction factors for converting point rainfall of any duration in the subzone into corresponding areal rainfall for any particular small catchment in the subzone (Annexure 4.4)

4.4. HEAVIEST RAINFALL RECORDS

4.4.1 ORG Data

The highest ever recorded one day station rainfall (24 hours rainfall ending 0830 hrs. of date) alongwith date of occurrence in each of the 15 districts covering subzone 3(c) have been compiled from the ORG data and presented in Annexure 4.1. Normal annual rainfall for each station is also given in the Annexure.

4.4.2 SRRG Data

The heaviest storm rainfall in duration of 24, 12, 6, 3 and 1 hour along with date and time of occurrence at the 17 SRRG stations have been compiled and presented in Annexure 4.2.

4.5. PROCEDURE FOR DESIGN STORM RAINFALL ESTIMATION

For a specified design storm duration T_D-hour (time of concentration), for a particular bridge catchment in the subzone, the design storm rainfall and its temporal distribution in the catchment can be computed by adopting the following procedure.

Step-1 : Locate bridge catchment under study on the 50-year, 24-hour isopluvial map in plate 9 and obtain the 50-year, 24-hour point rainfall value in cm. For a catchment covering more than one isopluvial, compute the average point rainfall.

Step- 2 : Read the conversion ratio for storm duration T_D from fig.10 and multiply the 50-year 24-hour point rainfall in step-1 to obtain 50-year T_D -hour point rainfall.

Step- 3 : Read the areal reduction factor corresponding to storm duration T_D and the given area of catchment from fig.12(a) and 12(b) or Annexure - 4.4 and multiply the 50-year T_D -hour point rainfall in step-2 by this factor to obtain the 50-year T_D -hour areal rainfall over the catchment.

Step- 4 : Read the time distribution co-efficients for 1,2 .... (T_D-1) hours corresponding to storm duration T_D from relevant graph in fig.11 or Annexure 4.3 and multiply the 50 yr. T_D -hour areal rainfall in Step-3 by these co-efficients to obtain the cumulative depths of 1,2.................... (T_D-1) hour catchment rainfall.

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

PART - V

DESIGN FLOOD ESTIMATION

5.1 CRITERIA AND STANDARDS IN REGARD TO DESIGN FLOOD OF STRUCTURES OF SMALL AND MEDIUM CATCHMENTS

The Committee of Engineers headed by Dr. A.N.Khosla, had recommended a design flood of 50-year return period for fixing the waterway of the bridges. The committee had also recommended to design the foundation and protection work for larger discharge by increasing the design flood for waterways by 30% for small catchments upto 500 Sq.km., 25 to 20% for medium catchments upto 500 to 5000 Sq.km., 20 to 10% for large catchments upto 5000 to 25000 Sq.km. and less than 10% for very large catchments above 25000 Sq.km.

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

a) **Indian Railway Standard Bridges Substructures and Foundation Code** revised in 1985 stipulates that all Railway bridges shall be designed with adequate waterway for design discharge. This shall normally be the computed flood with probable recurrence interval of 50 years. However, at the discretion of Chief Engineer/Chief Bridge Engineer, if a bridge is likely to have severe consequences, it may be designed for floods with a probable recurrence interval of more than 50 years, while bridges on less important lines or sidings may be designed for floods with a probable recurrence interval of less than 50 years.

b) **Indian Road Congress - IRC 5-1985, clause 103 of Section-I** "General Features of Design" specifies that the waterway of a road bridge is to be designed for a maximum flood of 50-yr return period. To provide for adequate margin of safety, the foundation and protection works should be designed for larger discharge as computed under clause 103. The recommended percentage increase over the design discharge specified in clause 103 is given under clause 110.1.2 of IRC-5-1985. These recommendations are the same as given in the report of the Committee of Engineers and are reproduced as under.

Sl. No.	Catchment Area	Increase In Design Discharge
1	Upto 500 Km^2	30% to 25% decreasing with increase in area.
2	500 to 5000 Km^2	25% to 20% decreasing with increase in area.
3	5000 to 25000 Km^2	20% to 10% decreasing with increase in area
4	Above 25000 Km^2	Upto 10%

c) **Indian Standard Code** of "**Practice for design of cross drainage works - IS; 7784 Part-I, 1975**" recommends that the waterway for cross drainage works should be designed for a 25 yr. return period flood. To provide adequate margin of safety, the foundation and protections works should be designed for larger discharges. The percentage increase over the design discharge recommended in the code is same as suggested by the Committee of Engineers and reproduced in para (b) above.

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

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

5.2 Estimation of Design Flood

To obtain design flood of required return period, the effective rainfall for design storm duration is to be applied to the unit hydrograph of a catchment.

Procedure for computing design flood peak and design flood hydrograph for T-year return period by SUG approach is as under; -

Step -1: Synthetic unit hydrograph

Derive the synthetic unit hydrograph as per section 3.4 .4 and tabulate in 1-hour U.G. ordinates.

Step -2: Design storm duration

The duration of storm, which causes maximum flow in a river at a specified location, is called **"Design Storm Duration"**. The SUG of 18 catchments have been derived using the parameters computed from recommended equations given in Table-3.3. Annexure 5.1 shows the computed UG parameters. It has been studied that the critical storm duration, which causes severe floods in small and medium catchments as used in this subzone, is equal to 1.1*tp. The flood peaks of 25 yrs, 50 yrs and 100 yrs return period is computed for this storm duration.

It is, therefore, recommended to adopt the value of Design storm duration (T_D) as 1.1*tp. The design engineer may, however, adopt a different value of T_D as per site conditions.

Step -3 : Design storm rainfall

i) Adopt suitable design storm duration (T_D) as explained in Step-2.

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

iii) Adopt design loss rate as recommended in section 3.7.

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

Step –4:

(a) Design flood peak

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

ii) Obtain the base flow for the catchment area under study vide section 3.8.

iii) Obtain total surface runoff by summing the product of unit hydrograph ordinates and effective rainfall consecutively.

iv) Obtain the total flow by adding the base flow to the computed total surface runoff in step (iii) above. This will give the peak value of the flood.

b) Design flood hydrograph.

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

Step-5:

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

Step –6:

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

Step –7:

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

Step –8:

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

5.2.1. Illustrative example.

1. Bridge No.930 on Itarsi-Jabalpur section, Central Railway has been marked out as ungauged catchment for illustrating the procedure to compute 50-year design Flood. The catchment plan is enclosed at figure A-1.

   The particulars of the catchment under study are as follows:

(i) Name of Subzone	:	Upper Narmada & Tapi
(ii) Name of Tributary	:	Umar
(iii) Name of Railway Section	:	Itarsi-Jabalpur
(iv) Shape of catchment	:	Leaf
(v) Location	:	Lat 23" 08' 36" Long 79" 25' 48"
(vi) Topography	:	Moderate slope

Procedure is explained below:

Step-1 : **Physiographic Parameters**

Physiographic parameters obtained are given below:

1) Area (A)-Refer fig. A-1. = 223.77 Sq.km
2) Length of the longest stream (L) = 33.60 km
3) Length of the longest stream from a point opposite to C.G.(Lc) = 19.32 km
4) Equivalent stream slope (S_{eq}) = 2.69 m/km

The computation of equivalent Slope is shown at Annexure 5.2.

Step 2 : **1 hr Synthetic Unitgraph**

Unitgraph parameters of the synthetic unit hydrograph were computed using equation in para 3.4.3. The results are given in the following table.

Table 5.1
(Synthetic UG Parameters)

Sl. No	SUG Parameters	
1	$t_p = 0.995(LLc/\sqrt{S})^{0.2654}$	= 4.5 hrs
2	$q_p = 1.665(t_p)^{-0.71678}$	= 0.57 cumecs/sq.km
3	$W_{50} = 1.9145\ (q_p)^{-1.2582}$	= 3.88 hrs
4	$W_{75} = 1.1102\ (q_p)^{-1.2088}$	=2.19 hrs
5	$WR_{50} = 0.706(q_p)^{-1.3859}$	= 1.54 hrs
6	$WR_{75} = 0.45314(q_p)^{-1.3916}$	= 0.99 hrs
7	$T_B = 5.04537(t_p)^{0.71637}$	=15 hrs
8	$T_m = tp + tr/2$	= 5.00 hrs where tr =1.0 hr
9	$Q_P = q_p \times A$	= 127.55 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. $Q_i \times t_i$ = 621.58 cumecs and compared with the theoretical volume of 1.00 cm. direct run off depth over the catchment, computed from the formula Q = (A x d) (t_i x 0.36).

Where A = Catchment area in Sq.km.

d = 1.0 cm. depth.

t_i = t_r = 1 hr. (the unit duration of UG)

$$Q = \frac{A \times d}{0.36 \times tr} = \frac{223.77 \times 1}{0.36 \times 1} = 621.58 \text{ cumec.}$$

Note: In case, ΣQi*ti for the unitgraph drawn is higher or lower than the volume of 1 cm, the falling limb of hydrograph may be suitably modified without altering the points of synthetic parameters such that the sum of all the ordinates under the UG is equal to theoretical value as computed above.

Step 3: Estimation of design storm

a) Design storm duration

The design storm duration (T_D) has been adopted as 1.1 x t_p

The value of 1.1 x t_p	= 1.1 x 4.5
	= 4.75
Rounded off to nearest full hour	= 5.00 hrs.
∴ Design Storm Duration (T_D)	= 5.00 hrs.

b) Estimation of point rainfall and areal rainfall for storm duration

The site under study was located on plate 9 showing 50 year, 24 hr point rainfall. The point rainfall was found to be 28.0 cm. The conversion factor of 0.59 was read from Fig. 10 to convert the 50 year-24 hour point rainfall to 50 year, T_D (5.00) hrs point rainfall. 50 yrs, 5 hr point rainfall, thus worked out to be 0.59 x 28.0 cm = 16.52 cm.

Areal reduction factor of 0.8754 corresponding to the catchment area of 223.77 Sq.km. for T_D = 5.00 hour was interpolated from Annexure 4.4 or fig. 12(a) for conversion of point rainfall to areal rainfall. 50 yr, 4.00 hr. areal rainfall thus works out to be 0.8754 x 16.52 cm = 14.46 cm.

The 50 yr., 5.00 hour areal rainfall has been split into 1 hour rainfall increments using time distribution coefficients given in Annexure 4.3 or figure 11. The hourly ordinates are given in Table 5.2.

A design loss rate of 0.10 cm/hr, recommended in para 3.7 was applied to get effective rainfall hyetograph.

Table 5.2
(Hourly effective rainfall increments)

Duration (hr)	Distribution co-efficient	Storm rainfall (cm)	Rainfall increments (cm)	Loss rate/hour (cm)	Effective Hourly Rainfall (cm)
1	2	3	4	5	6
1	0.61	8.82	8.82	0.10	8.72
2	0.81	11.71	2.89	0.10	2.79
3	0.91	13.16	1.45	0.10	1.35
4	0.97	14.03	0.87	0.10	0.77
5	1.00	14.46	0.43	0.10	0.33

Step 4: Estimation of base flow

Adopting a design base flow of 0.05 cumec per sq.km. recommended for this zone (Para 3.8) the base flow for the catchment under study was estimated to be 0.05 x 223.77 = 11.19 cumecs.

Step 5 : Estimation of 50 year flood peak

(a) Computation of Flood Peak.

For estimation of the peak discharge, the effective rainfall increments were rearranged against ordinates such that the maximum rainfall is placed against the maximum U.G.ordinate, next lower value of effective rainfall against next lower value of SUG ordinate and so on, as shown in col. 2 & 3 in Table 5.3. Sum of the product of SUG ordinates and effective hourly rainfall gives total direct surface run off to which base flow is added to get total peak discharge.

Table 5.3
(50 year Flood Peak)

Time in Hours.	S.U.G. Ordinates (cumec)	1-Hour Effective Rainfall (cm)	Direct Runoff (cumec)
1	2	3	4
4	100.00	1.35	135.00
5	127.55	8.72	1112.24
6	101.00	2.79	281.79
7	73.00	0.77	56.21
8	47.00	0.33	15.51
		Total:	1600.75
		Add Base Flow	11.19
		Peak discharge (Q 50)	1611.94 cumec

(b) Computation of design flood hydrograph

Effective hourly rainfall shown in col.(3) of Table 5.3 in Step 5(a) were reversed to obtain critical sequence as shown in Table 5.4.

Table 5.4
(Critical Sequence of Rainfall)

Time (Hrs)	Critical 1-hr. Effective rainfall sequence in cm.
1	2
1	0.33
2	0.77
3	2.79
4	8.72
5	1.35

For computation of design flood hydrograph, the SUG ordinates were tabulated in col 2 of Annexure 5.3. The critical sequence of effective rainfall increments were entered in col.3 to col.7 horizontally. Direct run off resulting from each of the effective rainfall depths with the U.G. ordinates in Col (2) were entered in columns against each unit with a successive lag of 1 hour since the unit duration of SUG is 1 hr. Direct runoff values were added horizontally and total direct runoff is shown in col. 8. Total hydrograph ordinates were obtained by adding base flow of 11.19 m3/s in col. 9 and are given in col. 10. Design Flood Hydrograph was plotted against time as shown in Fig. A-3. The peak of the flood hydrograph obtained was 1611.94 m3/sec which tallies with the Peak shown in table 5.3.

5.3. COMPUTATION OF FLOOD PEAK USING FLOOD FORMULA

For estimation of 25 year, 50 year, and 100 year, the same bridge catchment No.930 is considered for selection of the problem by flood formula. The physiographic and meteorologic parameters for the catchment under study are :

Catchment area (A) = 223.77 Sq.km.

Length of the longest stream (L) = 33.60 km.

Length of the longest stream from a point opposite to C.G. of catchment to point of study (Lc) = 19.32 km.

Equivalent slope (S_{eq}) = 2.69 m/km.

25 yr., 24 hr point rainfall (R_{25}) = 24.00 cm
50 yr., 24 hr point rainfall (R_{50}) = 28.00 cm
100 yr., 24 hr point rainfall (R_{100}) = 32.00 cm

$$Q_{25} = 0.6671\,(A)^{0.9019}\,(L)^{-0.1456}\,(Lc)^{-0.0908}\,(S)^{0.0512}\,(R_{25})^{1.081}$$
$$= 0.6671\,(223.77)^{0.9019}\,(33.60)^{-0.1456}\,(19.32)^{-0.0908}\,(2.69)^{0.0512}\,(24.0)^{1.081}$$
$$= 1313.66 \text{ cumecs}$$

$$Q_{50} = 0.7166\,(A)^{0.9129}\,(L)^{-0.1432}\,(Lc)^{-0.1045}\,(S)^{0.0412}\,(R_{50})^{1.0519}$$
$$= 0.7166\,(223.77)^{0.9129}\,(33.60)^{-0.1432}\,(19.32)^{-0.1045}\,(2.69)^{0.0412}\,(28.0)^{1.0519}$$
$$= 1539.65 \text{ cumecs}$$

$$Q_{100} = 0.6494\,(A)^{0.9050}\,(L)^{-0.1431}\,(Lc)^{-0.0900}\,(S)^{0.0490}\,(R_{100})^{1.0801} \quad r = 0.999$$
$$= 0.6494\,(223.77)^{0.9050}\,(33.60)^{-0.1431}\,(19.32)^{-0.0900}\,(2.69)^{0.0490}\,(32.0)^{1.0801}$$
$$= 1785.23 \text{ cumecs}$$

The percentage variations in the values of Q_{25}, Q_{50} and Q_{100} as estimated by the detailed approach and as estimated by the flood formulae for the catchment under study are shown in Table no.5.5.

Table No. 5.5
(Comparison of Results)

Br. No	Catchment Area (Km²)	By SUG			By Flood Formula			Variation With Respect to SUG (%)		
		Q_{25}	Q_{50}	Q_{100}	Q_{25}	Q_{50}	Q_{100}	Q_{25}	Q_{50}	Q_{100}
930	223.77	1373.23	1611.94	1847.12	1313.66	1539.65	1785.23	-4.53	-4.64	-3.47

The variation is within acceptable limit. Therefore, the flood values for 25 yr, 50 yr. and 100 yr. return periods estimated by the respective flood formulae are reasonable for adoption in preliminary designs.

5.4 COMPUTATION OF DESIGN H.F.L

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 line on a logarithmic plotting depending on the channel configuration; a single straight well defined channel and a combination of two straight lines for the main channel with its firm 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 discharge 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 HFL 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 can be obtained from any standard text book on channel hydraulic. 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 added to the water elevation to arrive at the revised H.F.L under constricted conditions. The difference between upstream and downstream water levels corresponding to design flood due to constriction in the waterway may be termed as afflux. There are hydraulic methods for working out the final design HFL due to constriction by the structure. The weir formula or orifice formula of hydraulics is generally used depending on the upstream and downstream depths to estimate the revised design HFL under constricted conditions.

Sometimes it happens that the cross section of river or nalla on the downstream side of a cross drainage structure may be narrow than the cross section at the location of a crossing site.

The flood levels at the proposed structure may also be affected by the high flood levels in the main river joining downstream in proximity of the stream. In such cases, there will be backwater effect due to the narrow gorge of the river as the design flood for the crossing site will not be able to pass through the narrow gorge in the downstream. There will, therefore, be heading up of water in its upstream side which ultimately affects HFL of the river at the crossing site. In the latter case, the tributary/stream on which the bridge is located, will be under the influence of the backwater effect of the main stream joining downstream. In such cases, backwater study may be carried out.

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

If the crossing site is located across the river/drainage in the unfavorable 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, CONCLUSIONS AND RECOMMENDATION

6.1 ASSUMPTIONS

Following assumptions have been made in the present study:-

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

2. A generalised conclusion regarding the base flow and loss rate is assumed to hold good during the design flood event.

3. The catchments used in the analysis are treated as homogeneous.

6.2 LIMITATIONS

1. 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.
2. The generalised values of base flow and loss rate has been assumed to hold good for the whole Subzone. The designer may adopt other suitable values of base flow and loss rate as per site conditions.
3. The data of only 18 catchments have been considered for developing a generalised approach. However, for more reliable results, the data of more catchments uniformly distributed would be desirable.

6.3 CONCLUSIONS

The methodology for estimating the design flood of 50-yr. return period incorporated in the body of the report is recommended for adoption. This also holds good for 25-yr. flood and 100 yr. flood.

The report also recommends the adoption of design flood of 25 yr. 50 yr.and 100-yr. return periods taking into account the type and relative importance of the structures.The report is applicable for the catchment areas ranging from 25 Sq. km. to 2500 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 study. Engineer-in-charge at site is advised to take a pragmatic view while deciding the design discharge of a bridge.

6.4 RECOMMENDATIONS

1. In case the physiographic parameters of the ungauged catchment matches with any the gauged catchment, the unit hydrograph parameters of the gauged catchments can be proportionately transposed to the ungauged catchment and UG, so derived, be adjusted.

2. When the parameters of ungauged catchment do not match with any of the gauged catchment, preference can be given to gauged catchment close to location of ungauged catchment.

3. When none of the above two conditions are fulfilled one should go in for the use of recommended relations.

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ANNEXURES

Annexure I.1

LIST OF HYDRO-METEOROLOGICAL SUB ZONES

Sub Zone	Name Of Subzone (Designated Earlier)	Name Of Subzone (Designated Now)	River Basins Included In The Subzone
1(a)	Luni basin and Thar (Luni and other rivers of Rajasthan and Kutch).	Luni	Luni river and Thar (Luni & other rivers of Rajasthan and Kutch and Banas rivers)
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.	Sone	Sone & 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 others.	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 rivers 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.	

Sub-Zone	Name of Subzone (Designated earlier)	Name of Subzone (Designated now)	River Basins included in the Subzone
3 (b)	Lower Narmada and Tapi Basin	Lower Narmada and 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 Godavari 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 Pennar Basin except coastal region.	Krishna & Pennar	Krishna and Pennar rivers except coastal region.
3 (i)	Kaveri & East flowing rivers except 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 and 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 Coromandal Belt (east flowing rivers between Cauvery and Kanyakumari)	South Eastern Coast.	East flowing coastal rivers, Manimuthar, Vaigai, Arjuna, Tamraparni.
5 (a)	Konkan Coast (west flowing river between Tapi and Panaji)	Konkan Coast.	West flowing coastal rivers between Tapi and Mandavi rivers.
5 (b)	Malabar Coast (west flowing rivers between Kanyakumari and Panaji)	Malabar Coast.	West flowing coastal rivers between Mandavi and Kanyakumari.
6	Andaman & Nicobar	Andaman and Nicobar.	
7	J & K, Kumaon Hills (Indus Basin)	Western Himalayas.	Jhelum, Upper portion of Indus, Ravi and Beas rivers).

Annexure – 3.1

LIST OF RAILWAY/ROAD BRIDGE IN SUBZONE – 3(c) (UPPER NARMADA & TAPI) AND AVAILABILITY OF GAUGE, DISCHARGE AND RAINFALL DATA

Sl. No.	Name of the Stream	Railway/Road Section	Railway/ Road Bridge Site No	Bridge Site Location		Catch-Ment Area (Km^2)	No. of Rain Gauge Stations	Data Availa-bility	No.of Years	Remarks
				Latitude	Longitude					
				Deg – min –Sec.	Deg- min- Sec.					
1	2	3	4	5	6	7	8	9	10	11
A: BRIDGES CONSIDERED FOR REGRESSION ANALYSIS										
1	Sakker	Itarsi-Jabalpur.C.R.	863	22-54-25	78-48-30	2110.85	9	1966-73	8	
2	Chandrabhaga	Murtizapur-Ellichpur.C.R.	644	20-55-35	77-19-35	989.80	8	1969-73	5	
3	Machana	Itarsi-Betul.C.R.	802	22-12-00	77-55-00	945.23	9	1975-79,82-89	13	
4	Sukta	Khandwa-Akola.C.R.	578	21-45-35	76-24-55	676.00	9	1975-79,82	6	
5	Kalimachak	Itarsi-Khandwa.S.C.R.	625	22-06-10	76-46-05	535.40	7	1970-73	4	
6	Temur	Gondia-Jabalpur.S.E.	249	22-51-00	79-50-30	518.67	7	1961-65	5	
7	Uma	Bhusaval-Bandnera.C.R.	394/2	20-45-50	77-28-58	348.92	6	1958-66	9	
8	Baloorena	Itarsi-Allahabad.C.R.	557	22-56-55	79-07-48	343.17	5	1958-61	4	
9	Katepurna	Akola-Purna.S.C.R.	787	20-21-40	77-04-25	321.16	6	1975-79	5	
10	Umar	Itarsi-Jabalpur.C.R.	930	23-08-36	79-25-48	223.77	4	1969-73,83-89, 91-94	16	
11	Sakatwar	Itarsi-Amla.C.R.	776	22-24-22	77-49-10	179.90	3	1968-74	7	
12	Lakhora	Khandwa-Akola.S.C.R.	584	21-44-10	76-27-15	139.08	3	1967-73	7	
13	Hatear	Bhusaval-Itarsi.C.R.	454	22-34-15	77-38-45	118.49	7	1958-64	7	
14	Tyria	Gondia-Jabalpur.S.E.	253	22-52-36	79-50-08	114.22	2	1965-74	10	
15	Passa	Itarsi-Allahabad.C.R.	505	22-45-25	78-21-56	70.18	3	1965-69,95-96	7	
16	Ol-Nadi	Itarsi-Jabalpur.C.R.	517/1	22-46-30	78-32-30	55.15	4	1957-64,66	9	
17	Khara	Akola-Khandwa.S.C.R.	710	20-59-25	77-02-20	41.47	3	1968-73	6	
18	Kareli	Itarsi-Jabalpur.C.R.	889	22-55-40	79-03-12	30.10	2	1968-69	2	

PHYSIOGRAPHIC PARAMETRS OF SELECTED CATCHMENTS

Sl.No.	Br. No.	Catchment Area (A) (Sq.Km.)	Length (L) (Km)	Length from Centroid of the Catchment to the Outlet (L_c) (Km)	Equivalent Slope (Seq) m/km
1	2	3	4	5	6
1	863	2110.85	160.48	90.16	2.53
2	644	989.80	87.00	54.70	3.23
3	802	945.23	113.50	44.27	3.42
4	578	676.00	99.82	40.25	3.66
5	625	535.40	64.40	28.18	4.92
6	249	518.67	56.51	28.89	3.00
7	394/2	348.92	46.53	20.61	2.38
8	557	343.17	47.17	11.59	2.45
9	787	321.16	35.61	19.72	3.42
10	930	223.77	33.60	19.32	2.69
11	776	179.90	22.94	8.86	4.06
12	584	139.08	26.97	14.49	2.70
13	454	118.49	34.37	18.76	2.61
14	253	114.22	35.42	15.29	4.14
15	505	70.18	23.10	12.88	4.03
16	517/1	55.15	16.10	8.05	4.47
17	710	41.47	20.93	9.66	2.94
18	889	30.10	12.08	4.43	1.17

Annexure - 3.3

ONE HOUR REPRESENTATIVE UNIT-HYDROGRAPH PARAMETERS OF SELECTED CATCHEMNTS FOR UPPER NARMADA AND TAPI BASIN

Sl.No	Br. Catchment No.	T_p (Hour)	Q_p (Cumec)	Q_p (Cumec/Sq. km.)	t_r (Hour)	T_B (Hour)	W_{50} (Hour)	W_{75} (Hour)	W_{R50} (Hour)	W_{R75} (hour)
1	2	3	4	5	6	7	8	9	10	11
1	863	9.5	920	0.44	1	27	4.9	2.0	2.0	0.8
2	644	7.5	323	0.33	1.	21	7.9	5.2	3.5	2.6
3	802	7.5	353	0.37	1	20	6.1	3.7	2.6	1.7
4	578	5.5	366	0.54	1	15	4.7	3.3	2.2	1.7
5	625	6.5	254	0.47	1	19	4.9	3.5	2.2	1.7
6	249	6.5	173	0.33	1	20	8.0	5.2	3.4	2.4
7	394/2	5.5	155	0.44	1	18	4.4	2.8	1.6	1.0
8	557	6.5	145	0.42	1	21	5.1	2.8	2.0	0.8
9	787	4.5	271	0.84	1	15	2.6	1.7	2.05	1.3
10	930	6.5	122	0.54	1	18	4.0	2.3	1.4	1.0
11	776	2.5	137	0.76	1	10	3.25	2.21	1.25	1.0
12	584	4.5	76	0.55	1	14	4.5	2.5	2.0	1.2
13	454	4.5	48	0.40	1	15	6.6	4.3	3.0	2.3
14	253	4.5	54	0.47	1	16	5.2	3.0	1.8	1.2
15	505	4.5	38	0.54	1	15	4.4.	2.6	1.4	1.0
16	517/1	2.5	54	0.98	1	9	2.3	1.35	0.9	0.47
17	710	2.5	40	0.96	1	10	1.2	0.6	0.3	0.2
18	889	2.5	27	0.90	1	10	2.4	1.35	0.7	0.45

RELATION BETWEEN PHYSIOGRAPHIC AND UNIT HYDROGRAPH PARAMETERS STUDIED

Sl.No.	X	Y	A	B	R
1	$LLc/\sqrt{S}$	t_p	0.995	0.265	0.89
2	t_p	q_p	1.665	0.717	0.84
3	q_p	W_{50}	1.914	-1.258	0.94
4	q_p	W_{75}	1.110	-1.208	0.88
5	q_p	WR_{50}	0.706	-1.386	0.82
6	q_p	WR_{75}	0.453	-1.392	0.88
7	t_p	T_B	5.045	0.716	0.98

NOTE : Equation is of the form of $Y = A * X^B$

Annexure 3.5

COMPARISON OF FLOOD PEAK BASED ON RUGs and SUGs

Sl.No.	Br. No.	Q_{25} in cumec			Q_{50} in cumec			Q_{100} in cumec		
		RUG	SUG	% Diff.	RUG	SUG	% Diff.	RUG	SUG	% Diff.
1	863	12662.52	8926.36	(+)29.51	13103.28	9230.58	(+)29.55	14790.19	10431.75	(+)29.47
2	644	2804.90	3042.52	(-)8.47	2967.42	3219.51	(-)8.50	3628.02	3936.62	(-)8.50
3	802	4969.22	4924.61	(+)0.90	5651.40	5602.01	(+)0.87	6336.18	6280.55	(+)0.88
4	578	3684.62	2906.07	(+)21.13	4400.80	3474.20	(+)21.06	4796.22	3787.20	(+)21.03
5	625	2931.91	2908.25	(+)0.81	3269.71	3244.16	(+)0.78	3828.17	3797.47	(+)0.79
6	249	2059.88	2566.24	(-)24.58	2431.06	3015.97	(+)24.06	2713.65	3371.94	(-)24.26
7	394/2	1248.36	1354.86	(-)8.53	1464.71	1590.00	(-)8.55	1608.53	1746.28	(-)8.56
8	557	1717.63	2160.53	(-)25.79	1991.00	2500.07	(-)25.57	2126.18	2671.56	(-)25.65
9	787	2143.72	1523.72	(+)28.92	2583.96	1840.87	(+)28.76	3023.99	2151.65	(+)28.85
10	930	1354.71	1373.23	(-)1.37	1587.57	1611.94	(-)1.54	1819.91	1847.12	(-)1.50
11	776	1556.46	1432.03	(+)7.99	1782.86	1640.41	(+)7.99	2007.89	1848.87	(+)7.92
12	584	852.02	886.80	(-)4.08	1015.62	1057.12	(-)4.09	1108.38	1151.58	(+)4.09
13	454	681.99	891.98	(-)30.79	781.72	1021.00	(-)30.61	880.76	1150.17	(-)30.58
14	253	714.65	838.44	(-)17.32	822.64	965.01	(-)17.31	876.58	1028.20	(-)17.30
15	505	605.68	691.59	(-)14.18	6+83.86	778.02	(-)13.80	733.20	833.47	(-)13.67
16	517/1	784.44	692.27	(+)11.75	855.60	755.02	(+)11.76	926.78	817.65	(+)11.78
17	710	360.31	261.85	(+)27.33	433.63	314.39	(+)27.50	507.19	363.73	(+)28.28
18	889	345.74	327.97	(+)5.14	394.48	368.81	(+)6.51	425.57	403.65	(+)5.15

Annexure 3.6

LOSS RATE RANGES - NUMBER OF FLOOD EVENTS

Sl. No.	Br. No.	CA (Km^2)	LOSS RATE (mm/hour)										Total	Remarks
			0.1 to 1	1 to 2	2 to 4	4 to 6	6 to 8	8 to 10	10 to 12	12 to 14	14 to 16	16 to 18		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	863	2110.85	2	3	1	1							8	
2	644	989.80	1	1	3	3			1				9	
3	802	945.23	5	2	8	8	3	2					28	
4	578	676.00	1		3	3	1						11	
5	625	535.40	4	1									5	
6	249	518.67	1	2	3	3				1			7	
7	394/2	348.92		3	1	1							8	
8	557	343.17	1		2	2	1						5	
9	787	321.16		1	2	2				1		1	9	
10	930	223.77	1	2	4	4	2	2	2	3			23	
11	776	179.90		2	2	2				1			8	
12	584	139.08			1	1	2				2		7	
13	454	118.49			3	3							3	
14	253	114.22	1	1	1	1		3	3			1	12	
15	505	70.18	1	1	1	1	1	1				1	9	
16	517/1	55.15	1		4	4	2	1	1			1	13	
17	710	41.47			1	1			1				2	
18	889	30.10			2	2	1					1	5	
			19	19	42	48	13	9	8	6	3	5	172	

AVERAGE BASE FLOW RANGES FOR STUDIED FLOOD EVENTS

SL. NO.	BRIDGE NO.	AVERAGE BASE FLOW RANGES(CUMEC/SQ.KM.)					TOTAL
		0.001 TO 0.005	0.0051 TO 0.009	0.01 TO 0.09	0.10 0.19	0.20 AND ABOVE	
1	2	3	4	5	6	7	8
1	863	-	-	8	-	-	8
2	644	1	1	6	1	-	9
3	802	2	6	20	-	-	28
4	578	-	5	6	-	-	11
5	625	1	-	3	1	-	5
6	249	-	1	5	-	-	7
7	394/2	-	3	5	-	-	8
8	557	2	-	5	-	-	5
9	787	-	-	9	-	-	9
10	930	1	3	15	2	2	23
11	776	1	-	6	1	1	8
12	584	-	4	2	-	1	7
13	454	1	-	3	-	-	3
14	253	-	-	4	4	4	12
15	505	-	2	5	2	-	9
16	517/1	-	-	1	6	6	13
17	710	-	-	2	-	-	2
18	889	-	-	2	2	1	5
	Total	5	25	107	19	15	172

FLOOD VALUES BY SYNTHETIC UNIT GRAPH AND FLOOD FORMULAE

Sl.No.	Br. No.	By S.U.G.			By Flood Formulae			Variation with respect to S.U.G. (%)		
		Q_{25}	Q_{50}	Q_{100}	Q_{25}	Q_{50}	Q_{100}	Q_{25}	Q_{50}	Q_{100}
1	863	8926.36	9230.58	10431.75	9051.65	9331.80	10723.72	1.38	1.08	2.67
2	644	3042.52	3219.51	3936.62	2942.34	3138.00	3848.33	-3.40	-2.60	-2.29
3	802	4924.61	5602.01	6280.55	4822.41	5474.14	6246.63	-2.12	-2.34	-0.54
4	578	2906.07	3474.20	3787.20	2887.88	3453.95	3815.29	-0.63	-0.59	-0.74
5	625	2908.25	3244.16	3797.47	2970.92	3296.32	3928.93	2.11	1.58	3.33
6	249	2566.24	3015.97	3371.94	2748.03	3244.45	3671.32	6.62	7.04	8.15
7	394/2	1354.86	1590.00	1746.28	1353.83	1609.71	1762.03	-0.08	-1.22	-0.89
8	557	2160.53	2500.07	2671.56	2090.13	2448.47	2610.12	-3.37	-2.11	-2.35
9	787	1523.72	1840.87	2151.65	1497.17	1819.73	2146.67	-1.77	-1.16	-0.70
10	930	1373.23	1611.94	1847.12	1313.66	1539.65	1785.23	-4.53	-4.64	-3.47
11	776	1432.03	1640.41	1848.87	1477.10	1691.96	1923.65	3.05	3.05	3.89
12	584	886.80	1057.12	1151.58	906.85	1060.88	1188.14	2.21	0.35	3.08
13	454	891.98	1021.00	1150.17	872.72	990.24	1138.03	-2.21	-3.11	-1.07
14	253	838.44	965.01	1028.20	843.04	960.18	1039.57	0.55	0.50	1.09
15	505	691.59	778.02	833.47	692.84	756.09	840.03	0.18	5.28	0.78
16	517/1	692.27	755.02	817.65	658.87	704.42	777.57	-5.07	-7.18	-5.15
17	710	261.85	314.39	363.73	270.32	324.48	384.54	3.13	3.11	5.41
18	889	327.97	368.81	403.65	329.34	370.37	406.15	0.42	0.42	0.61

Annexure 3.9

NUMBER OF FLOOD EVENTS STUDIED

Sl. No.	Bridge No.	No. of Flood Events
1	863	8
2	644	9
3	802	28
4	578	11
5	625	5
6	249	7
7	394/2	8
8	557	5
9	787	9
10	930	23
11	776	8
12	584	7
13	454	3
14	253	12
15	505	9
16	517/1	13
17	710	2
18	889	5
Total		172

Annexure 4.1

Statistics of Heaviest Daily Rainfall & Annual Normal Rainfall in Subzone 3 (c).

Sl.No.	State/District	Station	ORG Heaviest Rainfall (Cm)	Date Of Occurrence	Annual Normal Rainfall (Cm)
1	2	3	4	5	6
MADHYA PRADESH					
1	Balaghat	Balihar	28.5	14.7.1875	154.1
		Jamunia	23.9	12.7.1942	136.3
2	Betul	Betul(obsy)	36.1	30.7.1991	112.9
		Shahpur	29.0	03.7.1930	109.8
3	Chhindwara	Chhindwara	24.9	02.8.1913	107.7
		Tamia	39.5	12.7.1942	178.7
4	Dewas	Kannod	27.3	20.8.1939	106.8
5	East Nimar	Punasa	20.8	10.8.1979	89.7
6	Hoshangabad	Hoshangabad(obsy)	32.1	20.8.1983	126.7
		Pachmarhi	45.9	02.8.1913	207.5
7	Jabalpur	Jabalpur(obsy)	34.3	30.7.1915	138.0
		Pariat	39.1	25.8.1952	146.2
8	Mandla	Mandla	23.1	19.7.1869	149.9
		Dindori	31.7	25.6.1946	142.5
9	Narsinghpur	Narsinghpur	42.2	07.9.1891	121.3
		Mohpani	46.0	31.8.1976	138.0
10	Raisen	Salvani(Silwani)	30.6	14.9.1977	130.1
		Udaipura	29.3	27.6.1977	125.0
11	Sehore	Nasrullaganj	25.3	26.8.1987	124.0
12	Seoni	Seoni	28.2	02.8.1913	139.0
		Lakhnadon	25.3	05.7.1898	121.0
MAHARASHTRA					
1	Akola	Akola	36.5	15.9.1959	77.5
		Patur	26.2	22.7.1988	87.6
2	Amraoti	Chikalda	43.1	19.8.1886	171.5
		Dharni	41.1	25.8.1965	117.5
3	Buldhana	Jalgaon	22.9	22.9.1945	74.9
		Shegaon	28.8	14.9.1959	73.7

Heaviest 24-Hours & Shorter Durations Rainfall Recorded in Subzone 3 (c)

State/District	SRRG Station	Highest Observed Storm Rainfall (mm)	Duration (Hr)	Date & Time Of Occurrence	Clock Hour
1	2	3	4	5	6
MADHYA PRADESH					
1. Betul	1 Betul	263	24	13-14.8.1975	(18-18)
		237	12	13-14.8.1975	(22-10)
		167	6	14.8.1975	(01-07)
		119	3	14.7.1971	(06-09)
		65	1	18.7.1988	(19-20)
	2. Sarni dam	390	24	29-30.7.1991	(04-04)
		260	12	29-30.7.1991	(13-01)
		213	6	13.9.1977	(10-16)
		183	3	13.9.1977	(12-15)
		84	1	13.9.1977	(13-14)
2. Chhindwara	1.Harrai	199	24	28-29.8.1980	(02-02)
		170	12	29-30.8.1990	(14-02)
		168	6	29.8.1990	(14-20)
		150	3	18.8.1990	(02-05)
		77	1	10.6.1991	(18-19)
3.Dewas	1.Kannod	185	24	30.6-1.7.1978	(15-15)
		179	12	1.7.1978	(01-13)
		112	6	22-23.7.1977	(20-02)
		105	3	22.7.1977	(20-23)
		51	1	22.7.1977	(20-21)
4.East Nimar	1.Punasa	220	24	17-18.8.1972	(03-03)
		137	12	30.8.1973	(01-13)
		115	6	14-15.7.1973	(23-05)
		85	3	9.8.1973	(02-05)
		58	1	9.8.1973	(04-05)
5.Hoshangabad	1.Bagratawa	285	24	2-3.7.1970	(01-01)
		257	12	27.8.1987	(05-17)
		222	6	27.8.1987	(08-14)
		175	3	27.8.1987	(11-14)
		81	1	2.7.1973	(09-10)
	2.Pachmarhi	448	24	18-19.8.1974	(03-03)
		269	12	18.8.1974	(06-18)
		169	6	18.8.1974	(12-18)

		117	3	18.8.1974	(14-17)
		76	1	15.8.1975	(07-08)
	3. Tawadam	240	24	6-7.8.1989	(12-12)
		179	12	6-7.8.1989	(22-10)
		138	6	30.6-1.7.1978	(21-03)
		95	3	27.8.1987	(11-14)
		57	1	21.7.1989	(09-10)
6.Jabalpur	1.Jabalpur	268	24	29-30.8.1972	(04-04)
		221	12	14-15.8.1972	(21-09)
		197	6	14-15.8.1972	(22-04)
		146	3	15.8.1972	(00-03)
		90	1	17.6.1980	(14-15)
	2.Jamtara	275	24	23-24.8.1991	(04-04)
		209	12	23-24.8.1991	(14-02)
		158	6	23.8.1991	(17-23)
		107	3	23.8.1991	(19-22)
		70	1	17.8.1984	(17-18)
7. Mandla	1.Mandla	193	24	6-7.8.1974	(23-23)
		178	12	7.8.1974	(07-19)
		173	6	7.8.1974	(11-17)
		151	3	7.8.1974	(14-17)
		90	1	7.8.1974	(15-16)
8.Narsinghpur	1.Barmanghat	253	24	28-29.8.1980	(11-11)
		190	12	25.6.1980	(02-14)
		157	6	25.6.1980	(02-08)
		133	3	25.6.1980	(02-05)
		80	1	4.7.1975	(18-19)
	2.Narsinghpur	226	24	26-27.6.1977	(08-08)
		189	12	5-6.8.1989	(22-10)
		132	6	11.7.1976	(02-08)
		98	3	11.7.1976	(02-05)
		60	1	18.7.1981	(10-11)
MAHARASHTRA					
9. Akola	1.Akola	329	24	17-18.7.1986	(17-17)
		283	12	17.18.7.1986	(20-08)
		207	6	18.7.1986	(00-06)
		128	3	18.7.1986	(03-06)
		63	1	25.9.1970	(03-04)
10.Amraoti	1.Chikalda	257	24	28-29.8.1978	(10-10)
		179	12	28-29.8.1978	(17-05)
		107	6	26.6.1979	(01-07)
		82	3	26.6.1979	(04-07)
		72	1	9.9.1976	(15-16)

	2.Daryapur	174	24	4-5.8.1981	(20-20)
		107	12	5.8.1981	(06-18)
		74	6	9.7.1983	(11-17)
		73	3	9.7.1983	(11-14)
		61	1	11.1.1982	(21-22)
	3.Dharni	321	24	28-29.8.1978	(17-17)
		256	12	28-29.8.1978	(22-10)
		174	6	29.8.1978	(03-09)
		105	3	29.8.1978	(03-06)
		48	1	23.6.1979	(02-03)

TIME DISTRIBUTION CO-EFFICIENTS (PERCENTAGE) OF CUMULATIVE HOURLY RAINFALL

Inter-Mediate Hours	Design Storm Duration (Hours)																							Inter-Mediate Hours
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1	100	91	80	68	61	57	44	42	37	35	32	29	30	27	27	24	24	24	17	17	17	17	13	13	1
2	-	100	97	86	81	76	68	63	58	56	52	51	42	41	38	39	38	36	30	28	28	26	26	24	2
3	-	-	100	97	91	87	77	75	72	69	65	63	54	50	50	48	46	45	38	37	35	35	33	31	3
4	-	-	-	100	97	94	88	84	80	76	74	72	64	62	59	57	55	52	46	44	43	41	39	39	4
5	-	-	-	-	100	98	93	91	87	84	81	77	72	70	66	64	62	61	52	51	50	49	47	46	5
6	-	-	-	-	-	100	97	95	93	89	87	84	78	76	73	72	67	67	60	58	57	54	53	52	6
7	-	-	-	-	-	-	100	97	96	93	91	88	83	81	79	76	74	72	65	63	61	58	57	57	7
8	-	-	-	-	-	-	-	100	98	96	95	92	86	85	83	81	79	76	69	67	66	64	63	61	8
9	-	-	-	-	-	-	-	-	100	98	96	95	90	88	86	84	83	81	73	72	70	67	66	66	9
10	-	-	-	-	-	-	-	-	-	100	98	97	93	91	90	87	86	85	77	76	74	73	71	69	10
11	-	-	-	-	-	-	-	-	-	-	100	98	95	93	92	89	87	86	80	80	77	76	74	73	11
12	-	-	-	-	-	-	-	-	-	-	-	100	97	95	94	92	91	89	82	83	81	79	77	76	12
13	-	-	-	-	-	-	-	-	-	-	-	-	100	97	96	94	92	91	85	86	83	82	81	77	13
14	-	-	-	-	-	-	-	-	-	-	-	-	-	100	97	96	95	93	87	89	86	84	83	82	14
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	98	96	94	91	91	90	86	85	84	15
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	98	96	93	94	92	91	88	87	16
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	98	95	96	94	93	91	89	17
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	97	97	96	95	93	91	18
19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	98	98	96	95	94	19
20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	99	98	97	95	20
21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		100	99	98	97	21
22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	99	98	22
23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	99	23
24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	24

AREAL REDUCTION FACTORS (%) FOR POINT TO AREAL RAINFALL

CATCHMENT AREA (KM²)	Design Storm Duration (Hours)																							CATCHMENT AREA (KM²)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
00	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	00
50	94.00	94.50	95.00	95.33	95.67	96.00	96.17	96.33	96.50	96.67	96.83	97.00	97.08	97.17	97.25	97.33	97.42	97.50	97.58	97.67	97.75	97.83	97.92	98.00	50
100	89.50	90.38	91.25	91.83	92.42	93.00	93.37	93.75	94.12	94.50	94.87	95.25	95.40	95.54	95.69	95.83	95.98	96.12	96.27	96.42	96.56	96.71	96.85	97.00	100
150	85.75	86.88	88.00	88.83	89.67	90.50	91.00	91.50	92.00	92.50	93.00	93.50	93.69	93.88	94.06	94.25	94.44	94.62	94.81	95.00	95.19	95.37	95.56	95.75	150
200	82.00	83.25	84.50	85.67	86.83	88.00	88.67	89.33	90.00	90.67	91.33	92.00	92.21	92.42	92.62	92.83	93.04	93.25	93.46	93.67	93.87	94.08	94.29	94.50	200
250	78.50	80.25	82.00	83.17	84.33	85.50	86.29	87.08	87.87	88.67	89.46	90.25	90.48	90.71	90.94	91.17	91.40	91.62	91.85	92.08	92.31	92.54	92.77	93.00	250
300	75.50	77.50	79.50	80.83	82.17	83.50	84.42	85.33	86.25	87.17	88.08	89.00	89.29	89.58	89.88	90.17	90.46	90.75	91.04	91.33	91.62	91.92	92.21	92.50	300
350			76.75	78.17	79.58	81.00	82.08	83.17	84.25	85.33	86.42	87.50	87.83	88.17	88.50	88.83	89.17	89.50	89.83	90.17	90.50	90.83	91.17	91.50	350
400			74.00	75.67	77.33	79.00	80.25	81.50	82.75	84.00	85.25	86.50	86.81	87.12	87.44	87.75	88.06	88.37	88.69	89.00	89.31	89.62	89.94	90.25	400
450			72.00	73.67	75.33	77.00	78.37	79.75	81.12	82.50	83.87	85.25	85.60	85.96	86.31	86.67	87.02	87.37	87.73	88.08	88.44	88.79	89.15	89.50	450
500			70.00	71.67	73.33	75.00	76.54	78.08	79.62	81.17	82.71	84.25	84.60	84.96	85.31	85.67	86.02	86.37	86.73	87.00	87.44	87.79	88.15	88.50	500
600												82.00	82.42	82.83	83.25	83.67	84.08	84.50	84.92	85.33	85.75	86.17	86.58	87.00	600
700												80.25	80.67	81.08	81.50	81.92	82.33	82.75	83.17	83.58	84.00	84.42	84.83	85.25	700
800												78.50	78.92	79.33	79.75	80.17	80.58	81.00	81.42	81.83	82.25	82.67	83.08	83.50	800
900												79.25	77.58	77.92	78.25	78.58	78.92	79.25	79.58	79.92	80.25	80.58	80.92	81.25	900
1000												75.50	75.94	76.38	76.81	77.25	77.69	78.12	78.56	79.00	79.44	79.87	80.31	80.75	1000
1100												74.50	74.92	75.33	75.75	76.17	76.58	77.00	77.42	77.83	78.25	78.67	79.08	79.50	1100
1200												73.00	73.42	73.83	74.25	74.67	75.08	75.50	75.92	76.33	76.75	77.17	77.58	78.00	1200
1300																								77.50	1300
1400																								76.50	1400
1500																								75.50	1500
2000																								72.50	2000

Annexure 5.1

LIST OF SUG PARAMETERS OBTAINED FROM EQUATIONS

Sl.No.	Br.No.	C.A. (Km^2)	Q_P Cumec	Q_p Cumec per sq.km	Tp Hrs	W_{50} Hrs	W_{75} Hrs	WR_{50} Hrs	WR_{75} Hrs	T_B Hrs.	1 Cm Volume (Cumec)
1	2	3	4	5	6	7	8	9	10	11	12
1	863	2210.85	612.15	0.29	11.50	9.09	4.96	3.92	2.54	29	5863.47
2	644	989.80	356.33	0.36	8.50	6.92	3.82	2.91	1.88	23	2647.92
3	802	945.23	340.28	0.36	8.50	6.92	3.82	2.91	1.88	23	2717.44
4	578	676.00	263.64	0.39	7.50	6.26	3.46	2.60	1.68	21	2100.11
5	625	535.40	262.35	0.49	5.50	4.70	2.63	1.90	1.22	17	818.17
6	249	518.67	228.21	0.44	6.50	5.38	2.99	2.20	1.42	19	942.57
7	394/2	348.92	170.97	0.49	5.50	4.70	2.63	1.90	1.22	17	621.62
8	557	343.17	195.61	0.57	4.50	3.88	2.19	1.54	0.99	15	349.27
9	787	321.16	183.06	0.57	4.50	3.88	2.19	1.54	0.99	15	379.83
10	930	223.77	127.55	0.57	4.50	3.88	2.19	1.54	0.99	15	395.79
11	776	179.90	122.20	0.68	3.50	3.11	1.77	1.20	0.77	12	100.89
12	584	139.08	79.28	0.57	4.50	3.88	2.19	1.54	0.99	15	237.83
13	454	118.49	67.54	0.57	4.50	3.88	2.19	1.54	0.99	15	399.11
14	253	114.22	65.10	0.57	4.50	3.88	2.19	1.54	0.99	15	266.25
15	505	70.18	47.72	0.68	3.50	3.11	1.77	1.20	0.77	12	148.21
16	517/1	55.15	47.43	0.86	2.50	2.31	1.33	0.87	0.56	10	61.30
17	710	41.47	28.20	0.68	3.50	3.11	1.77	1.20	0.77	12	117.92
18	889	30.10	25.89	0.86	2.50	2.31	1.33	0.87	0.56	10	49.47

COMPUTATION OF EQUIVALENT SLOPE OF BRIDGE CATCHMENT NO. 930

Sl. No.	Reduced Distance		Reduced Level		Length of Each segment (Li) (Km)	Height above the datum (Di) (m)	Di-1+Di (m)	Li (Di-1 + Di) (Km.m)
	RD (Miles)	RD (Km)	RL (Feet)	RL (Meters)				
1	2	3	4	5	6	7	8	9
1	0	0	1160	353.55	0	0	0	0
2	9.19	14.80	1250	380.98	14.80	27.43	27.43	405.96
3	10.44	16.81	1300	396.22	2.01	42.67	70.10	140.90
4	12.00	19.32	1322	402.93	2.51	49.38	92.05	231.04
5	16.34	26.31	1350	411.46	6.99	57.91	107.29	749.96
6	19.84	31.94	1500	457.18	5.63	103.63	161.54	909.47
7	20.87	33.60	2000	609.57	1.66	256.02	359.65	597.02
							Sum	3034.35

Datum (i.e. R.L. of river bed at point of study) = 353.55 m

$$S_{eq} = \frac{\Sigma Li\,(D_{I-1}+D_I)}{(L)^2}$$

$$= \frac{3034.35}{(33.62)^2}$$

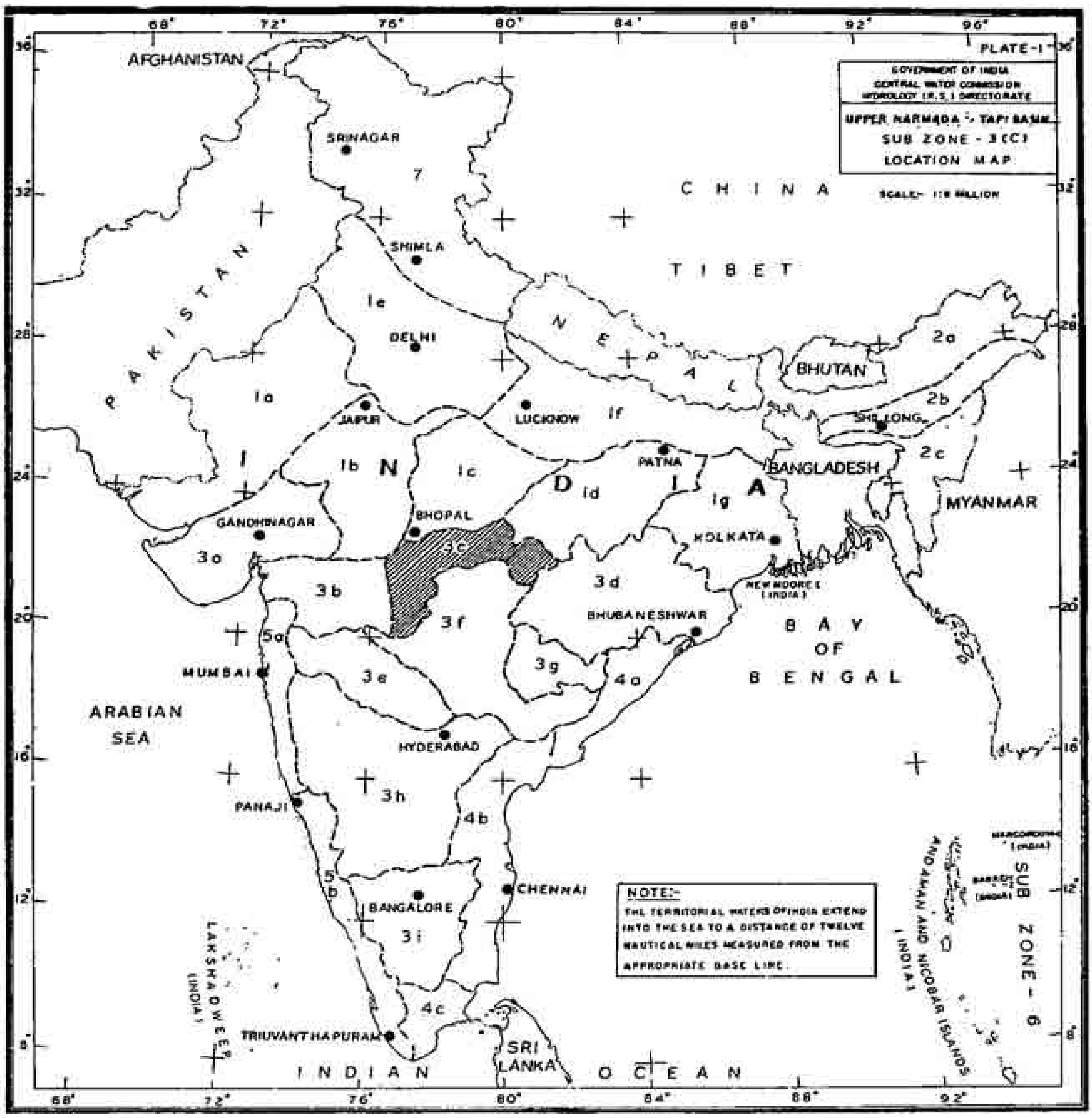
$$= 2.69 \text{ m/km}$$

Annexure 5.3

COMPUTATION OF DESIGN FLOOD HYDROGRAPH OF BRIDGE CATCHMENT NO. 930

Hours	SUH Ordinates (m³/s)	Rainfall Excess in (cm) 0.33	0.77	2.79	8.72	1.35	Total DSRO (m³/s)	Base Flow (m³/s)	Total Flow (m³/s)
		Direct Runoff (m³/s)							
1	2	3	4	5	6	7	8	9	10
0	0.00	0.00					0.00	11.19	11.19
1	7.00	2.31	0.00				2.31	11.19	13.50
2	20.00	6.60	5.39	0.00			11.99	11.19	23.18
3	42.00	13.86	15.40	19.53	0.00		48.79	11.19	59.98
4	100.00	33.00	32.34	55.80	61.04	0.00	182.18	11.19	193.37
5	127.55	42.09	77.00	117.18	174.40	9.45	420.12	11.19	431.31
6	101.00	33.33	98.21	279.00	366.24	27.00	803.78	11.19	814.97
7	73.00	24.09	77.77	355.86	872.00	56.70	1386.42	11.19	1397.61
8	47.00	15.51	56.21	281.79	1112.24	135.00	1600.75	11.19	**1611.94**
9	33.00	10.89	36.19	203.67	880.72	172.19	1303.66	11.19	1314.85
10	25.00	8.25	25.41	131.13	636.56	136.35	937.70	11.19	948.89
11	19.00	6.27	19.25	92.07	409.84	98.55	625.98	11.19	637.17
12	14.00	4.62	14.63	69.75	287.76	63.45	440.21	11.19	451.40
13	8.50	2.81	10.78	53.01	218.00	44.55	329.15	11.19	340.34
14	4.53	1.49	6.55	39.06	165.68	33.75	246.53	11.19	257.72
15	0.00	0.00	3.49	23.72	122.08	25.65	174.93	11.19	186.12
16			0.00	12.64	74.12	18.90	105.66	11.19	116.85
17				0.00	39.50	11.48	50.98	11.19	62.17
18					0.00	6.12	6.12	11.19	17.31
19						0.00	0.00	11.19	11.19

PLATES

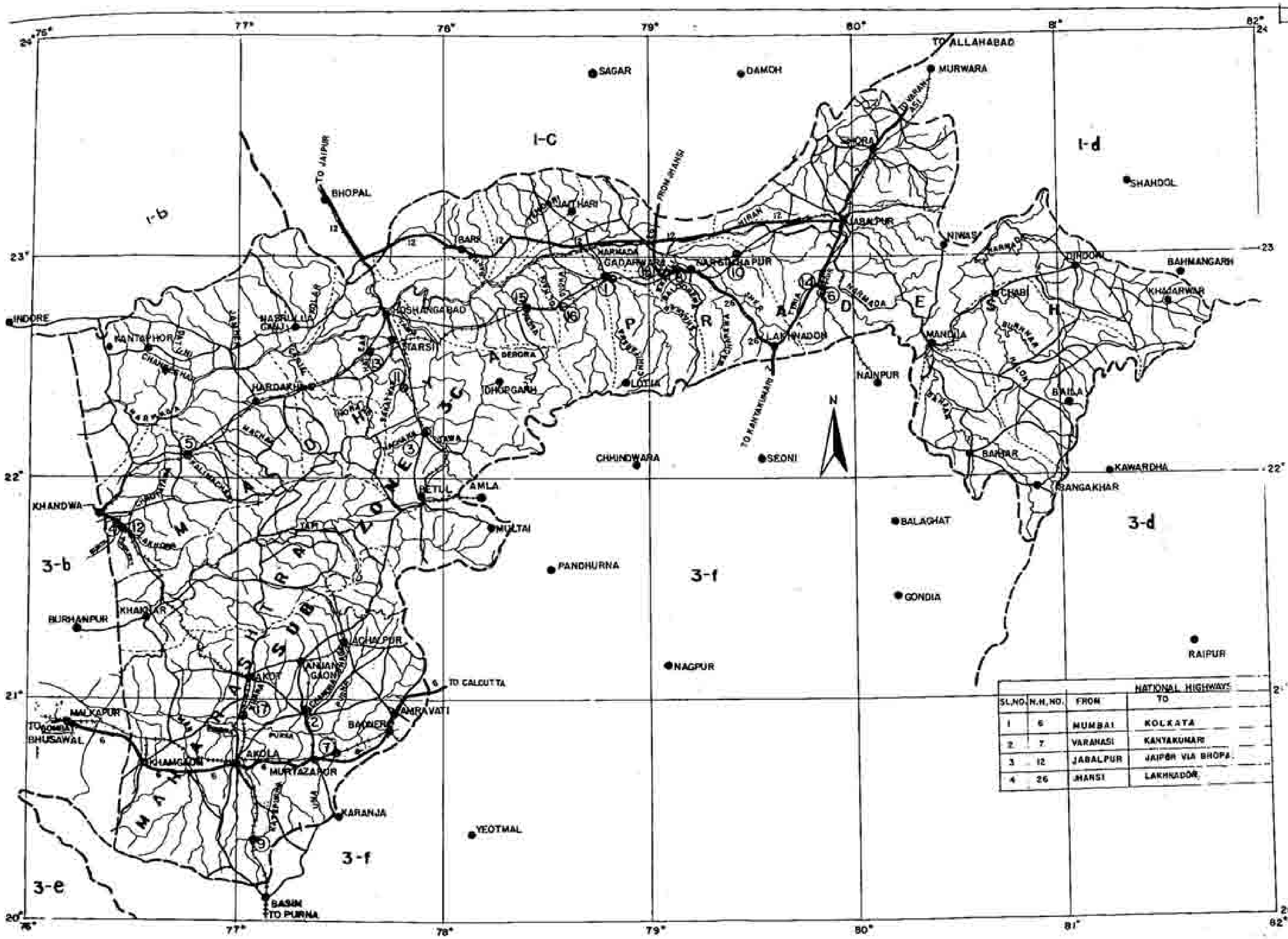


NOTES:- I) BASED UPON SURVEY OF INDIA MAP WITH THE PERMISSION OF THE SURVEYOR GENERAL OF INDIA.

II) RESPONSIBILITY FOR THE CORRECTNESS OF INTERNAL DETAILS SHOWN ON THE MAPS RESTS WITH THE PUBLISHER.

P.1

PLATE-2



SL.NO.	N.H.NO.	FROM	TO
1	6	MUMBAI	KOLKATA
2	7	VARANASI	KANYAKUMARI
3	12	JABALPUR	JAIPUR VIA BHOPAL
4	26	JHANSI	LAKHNADON

NATIONAL HIGHWAYS

SL.NO.	Br.NO.	SECTION	NAME OF STREAM	C.A. in Sq. Kms.	DATA AVAILABILITY OF YEARS
1	653	ITARSI-JABALPUR C.R.	SAKKER	290-85	66-73
2	644	MURTIZAPUR-ELLICHPUR	CHANDRABHAGA	985-80	66-73
3	802	ITARSI-BETUL C.R.	MACHNA	945.23	73-79,82,84
4	378	KHANDWA-AKOLA C.R.	SUKTA	675.00	75-78
5	625	ITARSI-KHANDWA S.C.R.	KALIMACHAK	555.40	70-73
6	249	GONDIA-JABALPUR S.E.	TEMUR	516.67	57-65
7	394/2	BHUSAWAL-BADNERA C.R.	UMA	348.92	58-66
8	557	ITARSI-ALLAHABAD C.R.	BALOOREWA	343.17	55-61
9	787	AKOLA-PURNA S.C.R.	KATEPURNA	321.16	75-79
10	950	ITARSI-JABALPUR C.R.	UMAR	223.77	69-73,83,88,91-94
11	776	ITARSI-AMLA C.R.	SAKATWAR	178.80	66-74,80
12	584	KHANDWA-AKOLA S.C.R.	LAKHORA	156.08	66-73
13	464	BHUSAVAL-ITARSI C.R.	HATEAR	118.49	58-64
14	253	GONDIA-JABALPUR S.E.	TYRA	114.22	66-74
15	505/813	ITARSI-ALLAHABAD C.R.	PASSA	70.18	65-68,85-88
16	817/1	ITARSI-JABALPUR C.R.	OL-NAGI	55.15	57-64,68
17	710	AKOLA-KHANDWA S.C.R.	KHANA	41.47	66-73
18	868	ITARSI-JABALPUR C.R.	KARELI	30.10	66-69

LEGEND

1. SUB-ZONE BOUNDARY
2. RIVERS AND ITS TRIBUTORIES
3. ROADS
4. NATIONAL HIGHWAY
5. RAILWAY LINE
6. BRIDGE SITES
7. STATE BOUNDARY
8. RIVER SUB-BASIN

SCALE 1:1,000,000

KILOMETERS / ENGLISH MILES

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

FLOOD ESTIMATION REPORT
UPPER NARMADA & TAPI BASIN SUB-ZONE(3C)
LOCATION OF RLY. BRIDGES (G.&.D. SITES) & RIVER SYSTEM

DRAWN.... L.P. NAUTIYAL, L.K. PANT
CHECKED.... R. K. AICH
SUBMITTED....
NEW DELHI-110066.
DRG.NO.

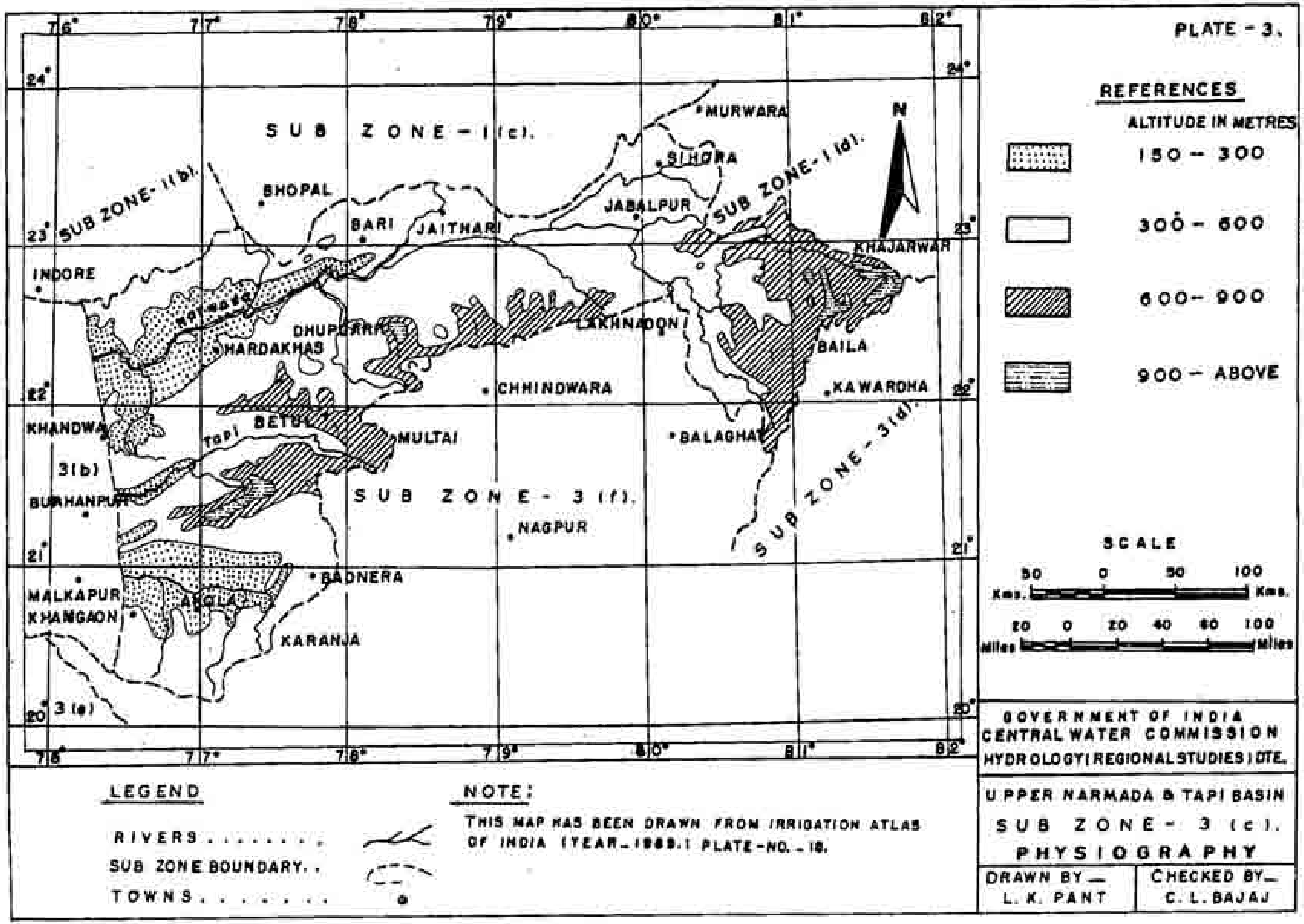
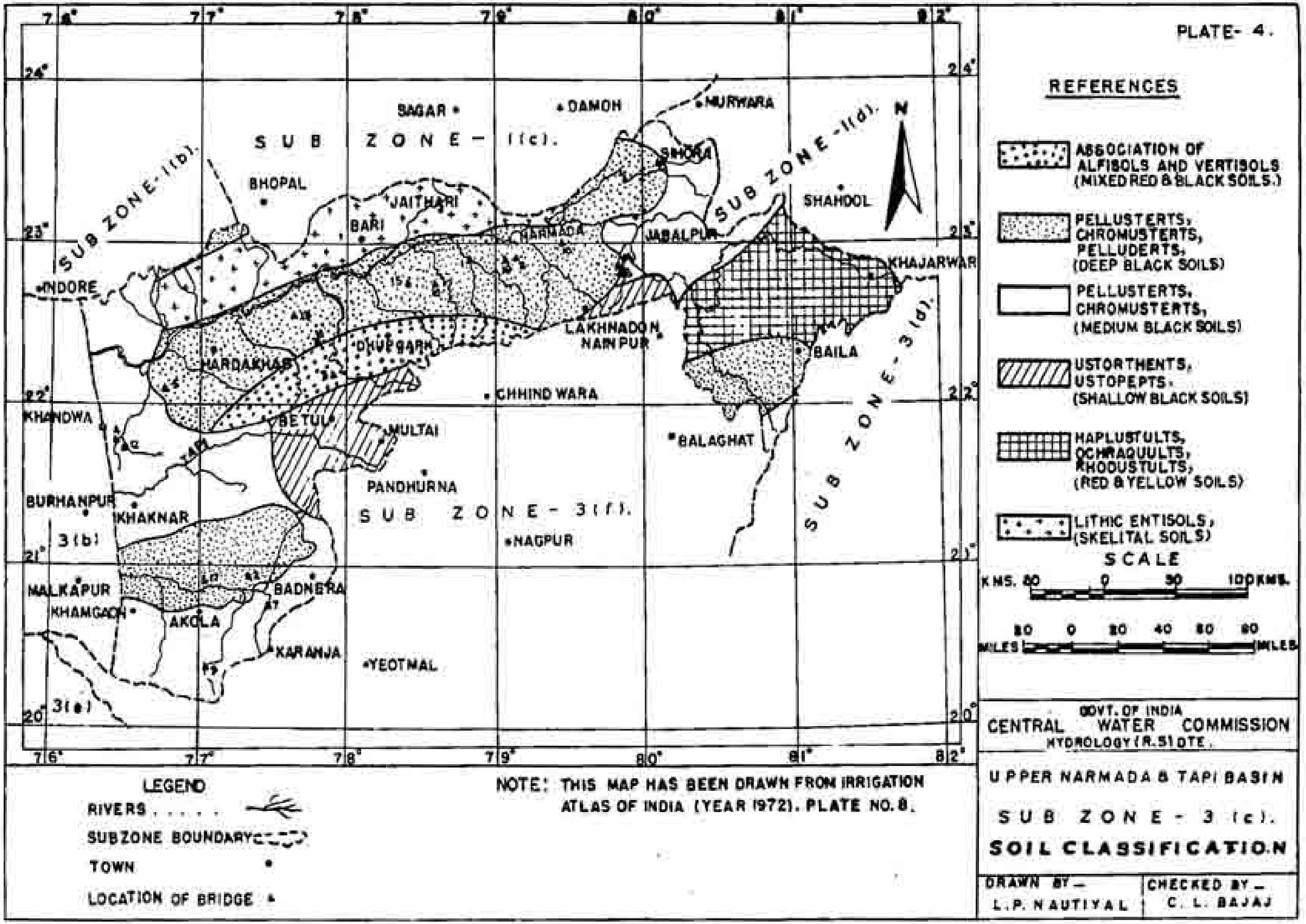


PLATE - 3.
REFERENCES
ALTITUDE IN METRES
150 - 300
300 - 600
600 - 900
900 - ABOVE
SCALE
Kms. 50 0 50 100 Kms.
Miles 20 0 20 40 60 100 Miles
SUB ZONE - 1(c).
SUB ZONE - 1(b).
SUB ZONE - 1(d).
SUB ZONE - 3(f).
SUB ZONE - 3(d).
3(b)
3(e)
N
MURWARA
SIHORA
JABALPUR
BHOPAL
BARI
JAITHARI
KHAJARWAR
INDORE
DHUPGARH
HARDAKHAS
LAKHNADON
BAILA
KAWARDHA
CHHINDWARA
KHANDWA
Tapi
BETUL
MULTAI
BALAGHAT
BURHANPUR
NAGPUR
BADNERA
MALKAPUR
KHAMGAON
AKOLA
KARANJA
LEGEND
RIVERS........
SUB ZONE BOUNDARY..
TOWNS.......
NOTE:
THIS MAP HAS BEEN DRAWN FROM IRRIGATION ATLAS OF INDIA (YEAR_1969.) PLATE-NO._18.
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY(REGIONAL STUDIES) DTE.
UPPER NARMADA & TAPI BASIN
SUB ZONE - 3 (c).
PHYSIOGRAPHY
DRAWN BY_
L. K. PANT
CHECKED BY_
C. L. BAJAJ



NOTE: THIS MAP HAS BEEN DRAWN FROM IRRIGATION ATLAS OF INDIA (YEAR 1972). PLATE NO. 8.

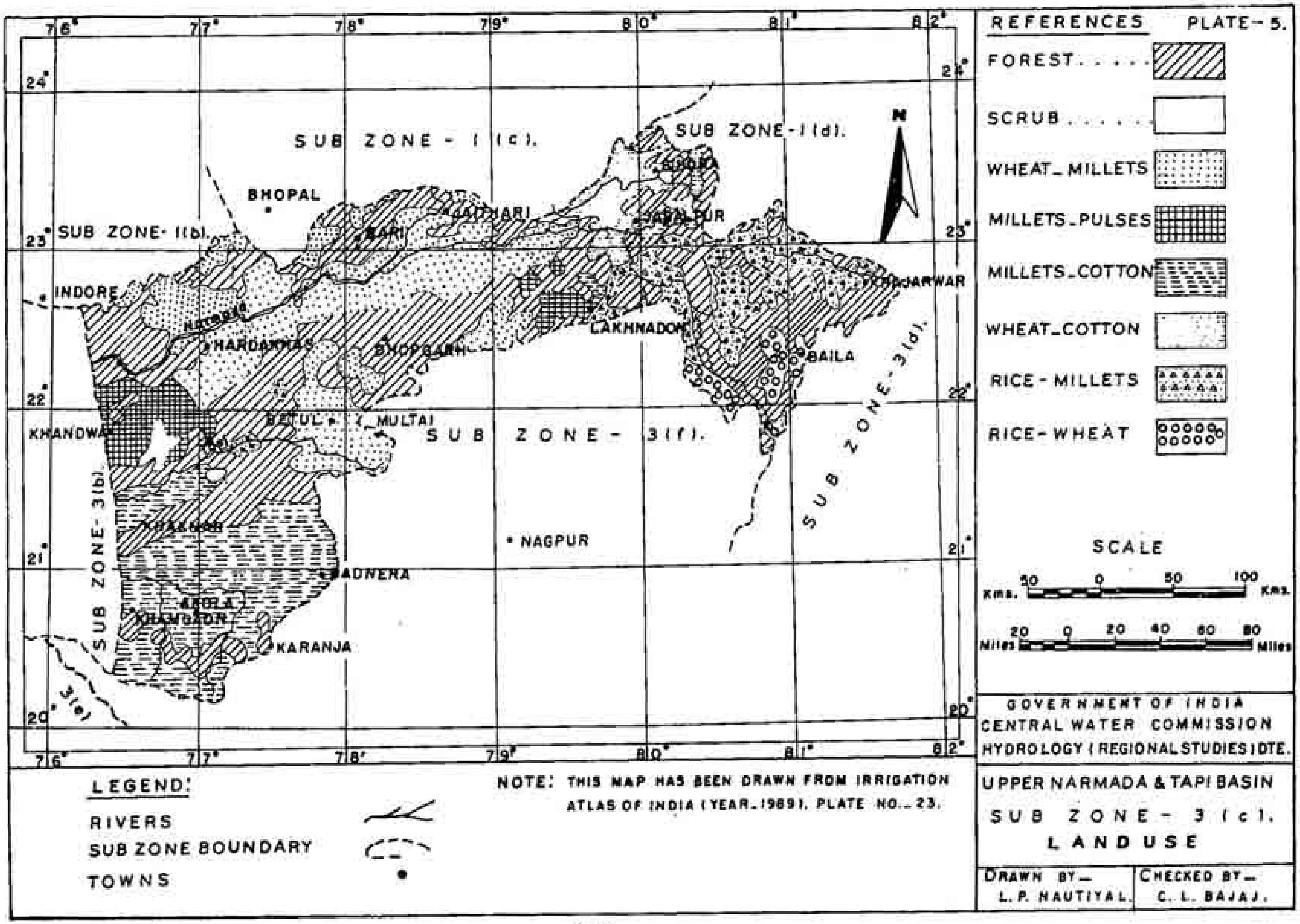
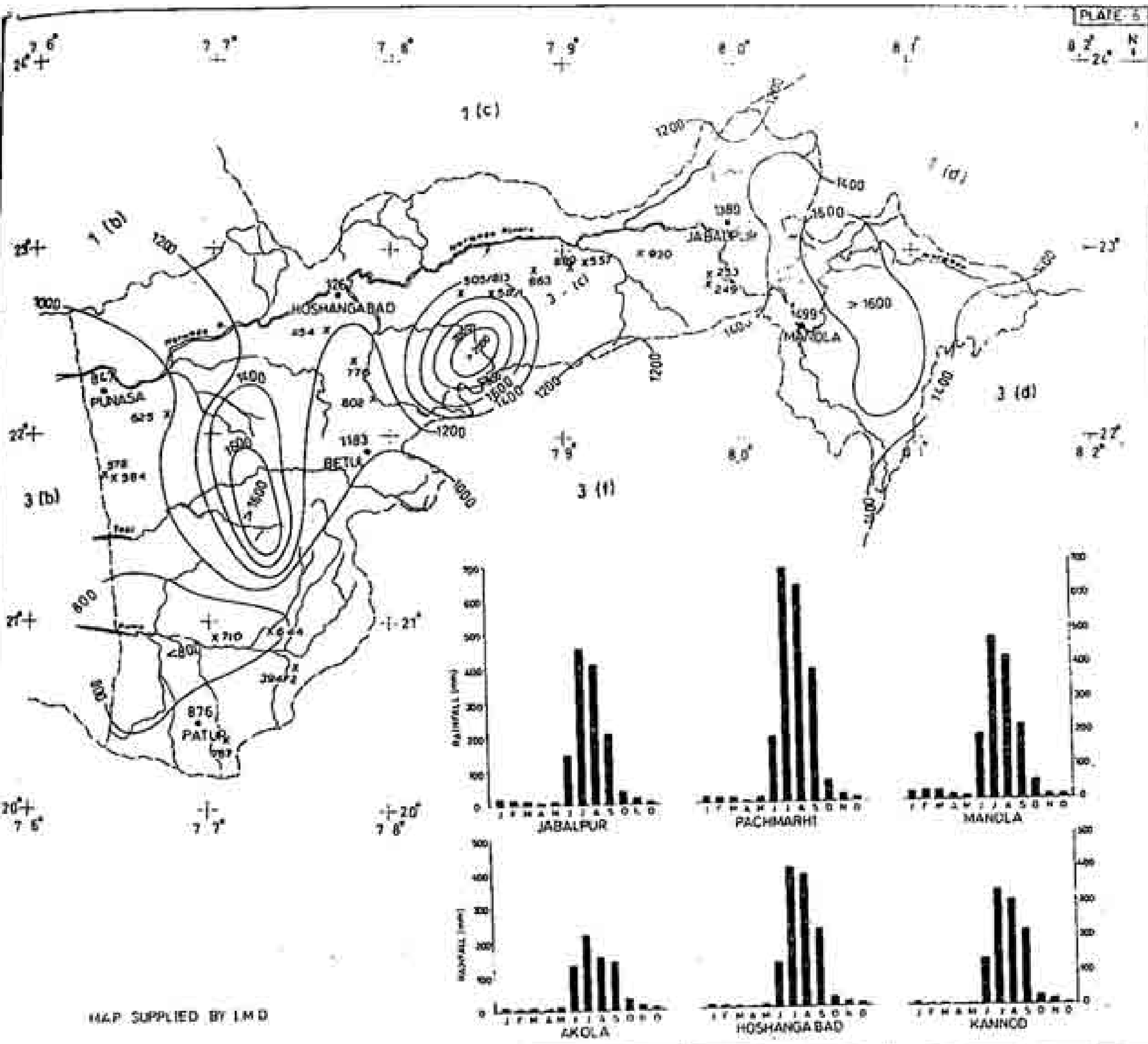

REFERENCES
PLATE-5.
FOREST
SCRUB
WHEAT_MILLETS
MILLETS_PULSES
MILLETS_COTTON
WHEAT_COTTON
RICE-MILLETS
RICE-WHEAT
SCALE
Kms. 50 0 50 100 Kms.
Miles 20 0 20 40 60 80 Miles
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE.
UPPER NARMADA & TAPI BASIN
SUB ZONE - 3 (c).
LAND USE
DRAWN BY- L.P. NAUTIYAL.
CHECKED BY- C.L. BAJAJ.
SUB ZONE - 1 (c).
SUB ZONE - 1 (d).
SUB ZONE - 1 (b).
SUB ZONE - 3 (f).
SUB ZONE - 3 (d).
SUB ZONE - 3 (b).
3 (e)
BHOPAL
INDORE
KHANDWA
BARI
JABALPUR
LAKHNADON
BAILA
BHOPGARH
HARDA
BETUL
MULTAI
NAGPUR
BADNERA
AKOLA
KHAMGAON
KARANJA
N
76° 77° 78° 79° 80° 81° 82°
24° 23° 22° 21° 20°
LEGEND:
RIVERS
SUB ZONE BOUNDARY
TOWNS
NOTE: THIS MAP HAS BEEN DRAWN FROM IRRIGATION ATLAS OF INDIA (YEAR-1989), PLATE NO.-23.

PLATE-5



REFERENCES

1. SUB ZONE BOUNDARY
2. TOWNS
3. ISOHYETES
4. RIVERS
5. BRIDGE SITES x 707

NOTES

1. THE ALPHABETS ALONG ABSCISSA INDICATE NAME OF MONTHS
2. COLUMN HEIGHTS REPRESENT RAINFALL IN MM
3. FIGURES ABOVE COLUMN INDICATE MONTHLY RAINFALL AS PERCENT OF ANNUAL RAINFALL

RESPONSIBILITY FOR CORRECTNESS OF INTERNAL DETAILS SHOWN ON THE MAP RESTS WITH PUBLISHER

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

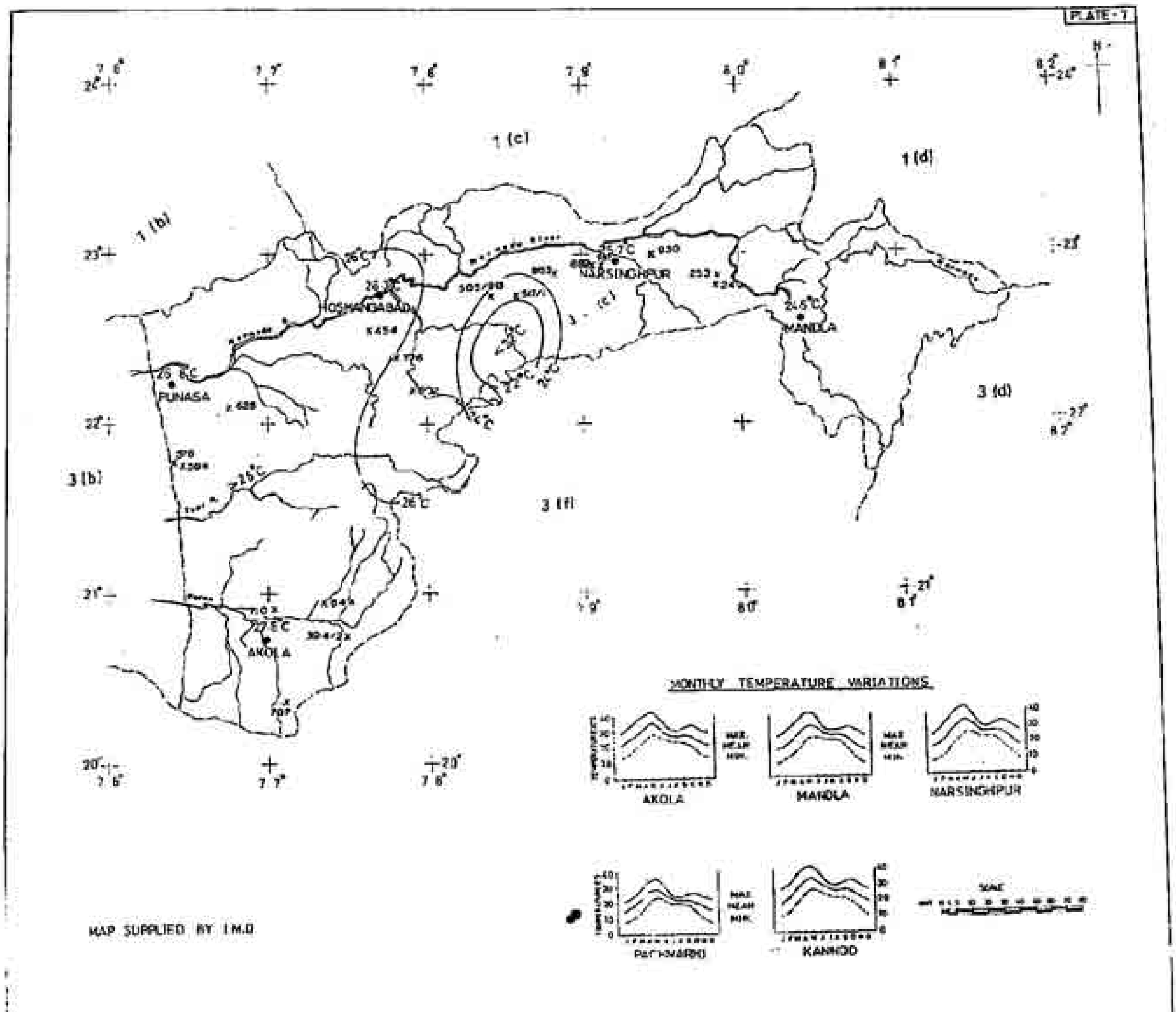
THE TERRITORIAL WATERS OF INDIA EXTEND INTO THE SEA TO A DISTANCE OF TWELVE NAUTICAL MILES MEASURED FROM APPROPRIATE BASE LINE

SCALE

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION

नर्मदा एवं ताप्ती बेसिन
NARMADA & TAPI BASIN
SUB ZONE - 3 (c)
ANNUAL NORMAL RAINFALL (M.M.)

PLATE - 7



REFERENCES

1. SUBZONE BOUNDARY
2. TOWNS
3. ISOTHERMS (C°)
4. RIVERS
5. BRIDGE SITES X 787

NOTES

1. RESPONSIBILITY FOR CORRECTNESS OF INTERNAL DETAILS SHOWN ON THE MAP RESTS WITH PUBLISHER.
2. BASED UPON SURVEY OF INDIA MAP WITH PERMISSION OF THE SURVEYOR GENERAL OF INDIA.

THE TERRITORIAL WATER OF INDIA EXTEND INTO SEA TO A DISTANCE OF TWELVE NAUTICAL MILES MEASURED FROM THE APPROPRIATE BASE LINE

NARMADA & TAPI BASIN

SUB ZONE - 3 (c)

ANNUAL MEAN DAILY TEMPERATURE (C°)

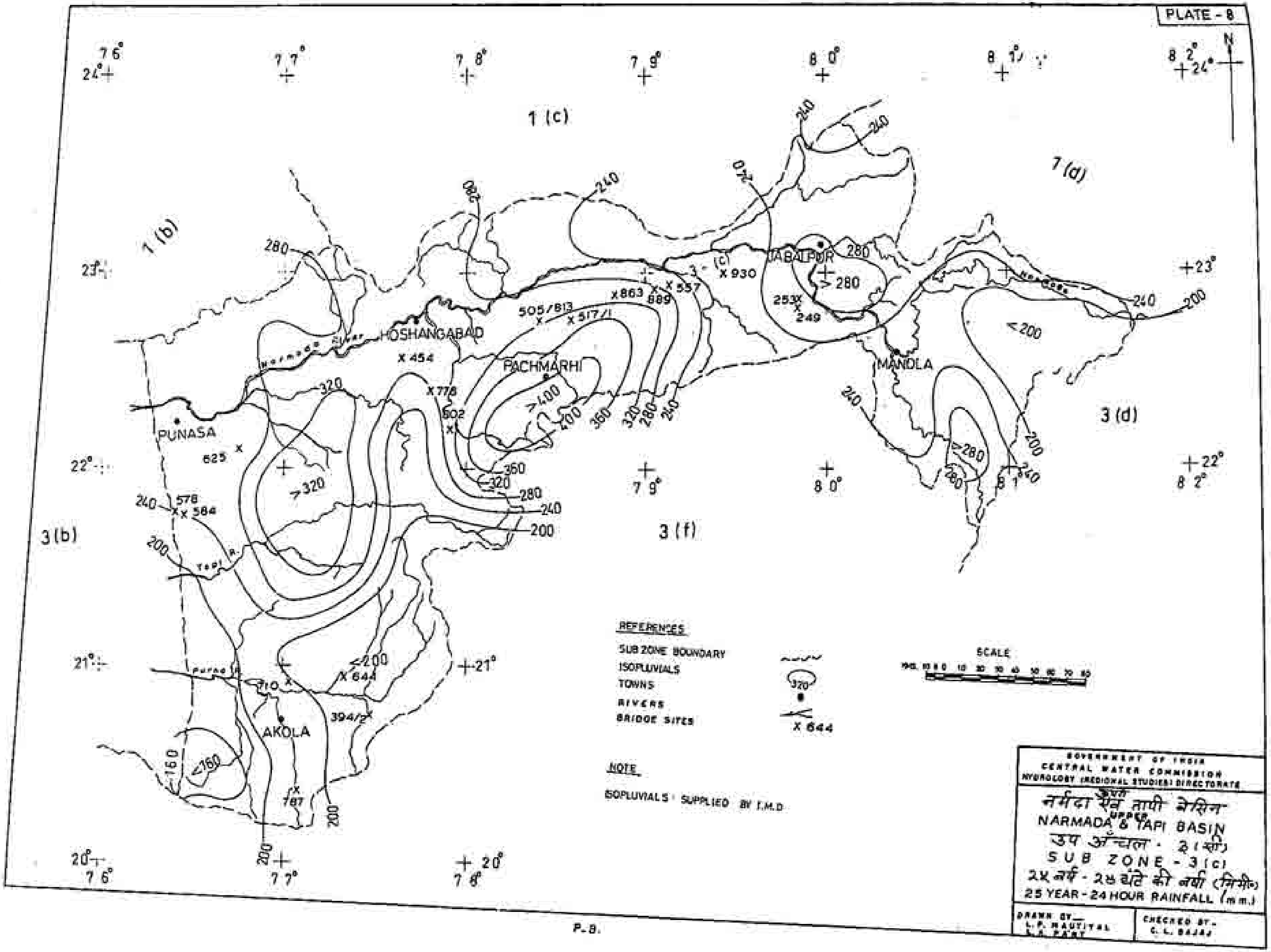


PLATE - 8
1 (c)
1 (b)
7 (d)
3 (b)
3 (f)
3 (d)
HOSHANGABAD
PACHMARHI
JABALPUR
MANDLA
PUNASA
AKOLA
Narmada River
Tapi R.
REFERENCES
SUB ZONE BOUNDARY
ISOPLUVIALS
TOWNS
RIVERS
BRIDGE SITES
SCALE
NOTE
ISOPLUVIALS : SUPPLIED BY I.M.D
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DIRECTORATE
नर्मदा एवं ताप्ती बेसिन
NARMADA & TAPI BASIN
UPPER
उप अंचल - 3 (सी)
SUB ZONE - 3 (c)
25 YEAR - 24 HOUR RAINFALL (mm.)
DRAWN BY
CHECKED BY
C. L. BAJAJ

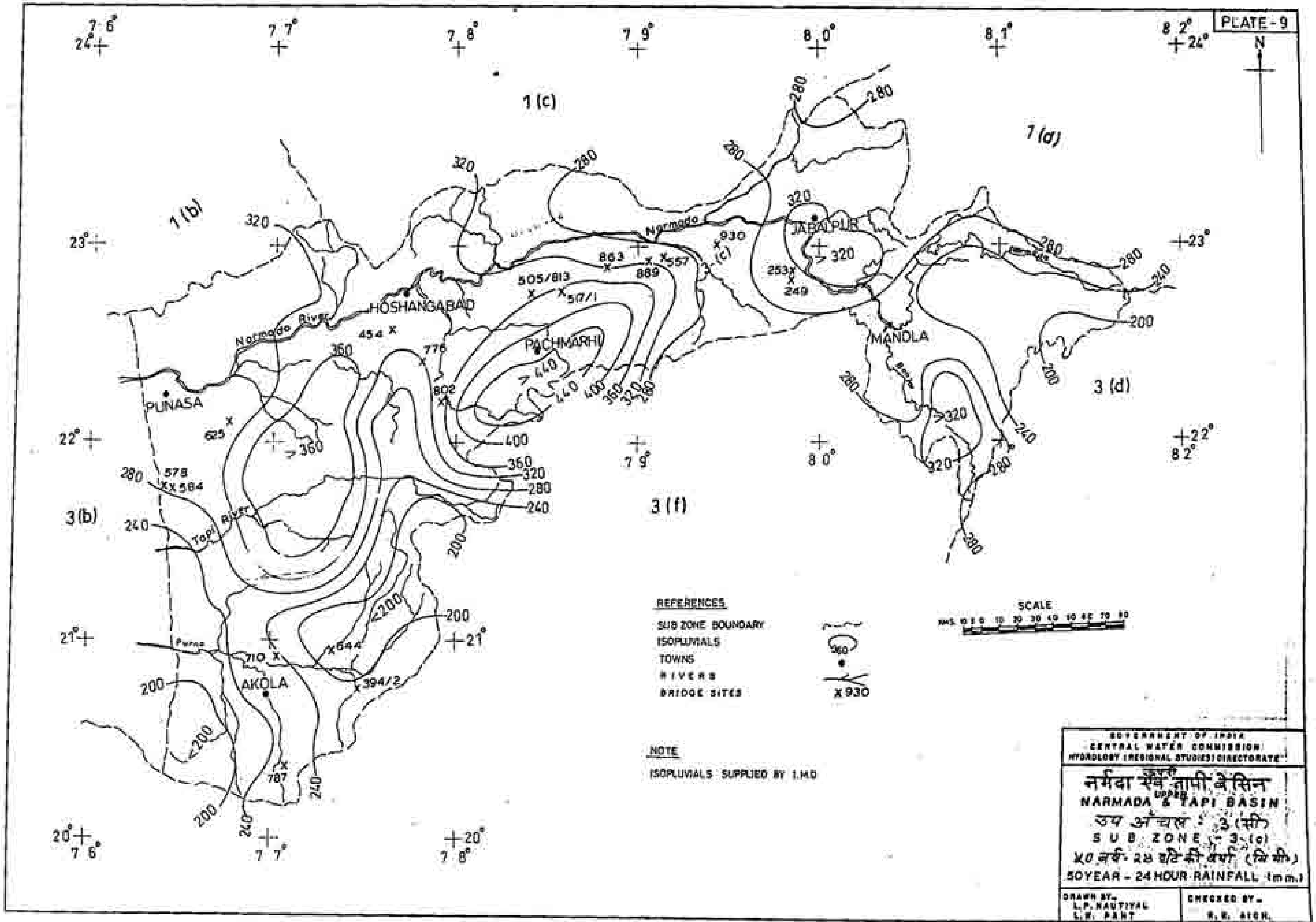


PLATE - 9
N
1 (c)
1 (d)
1 (b)
3 (b)
3 (f)
3 (d)
Narmada River
Narmada
Tapi River
Purna
HOSHANGABAD
PUNASA
PACHMARHI
JABALPUR
MANDLA
AKOLA
REFERENCES
SUB ZONE BOUNDARY
ISOPLUVIALS
TOWNS
RIVERS
BRIDGE SITES
NOTE
ISOPLUVIALS SUPPLIED BY I.M.D
SCALE
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DIRECTORATE
नर्मदा उपरी एवं तापी बेसिन
NARMADA & UPPER TAPI BASIN
उप अंचल : 3 (सी)
SUB ZONE - 3 (c)
50 वर्ष - 24 घंटे की वर्षा (मि.मी.)
50YEAR - 24 HOUR RAINFALL (mm.)
DRAWN BY - L.P. NAUTIYAL L.K. PANT
CHECKED BY - R.K. AICH

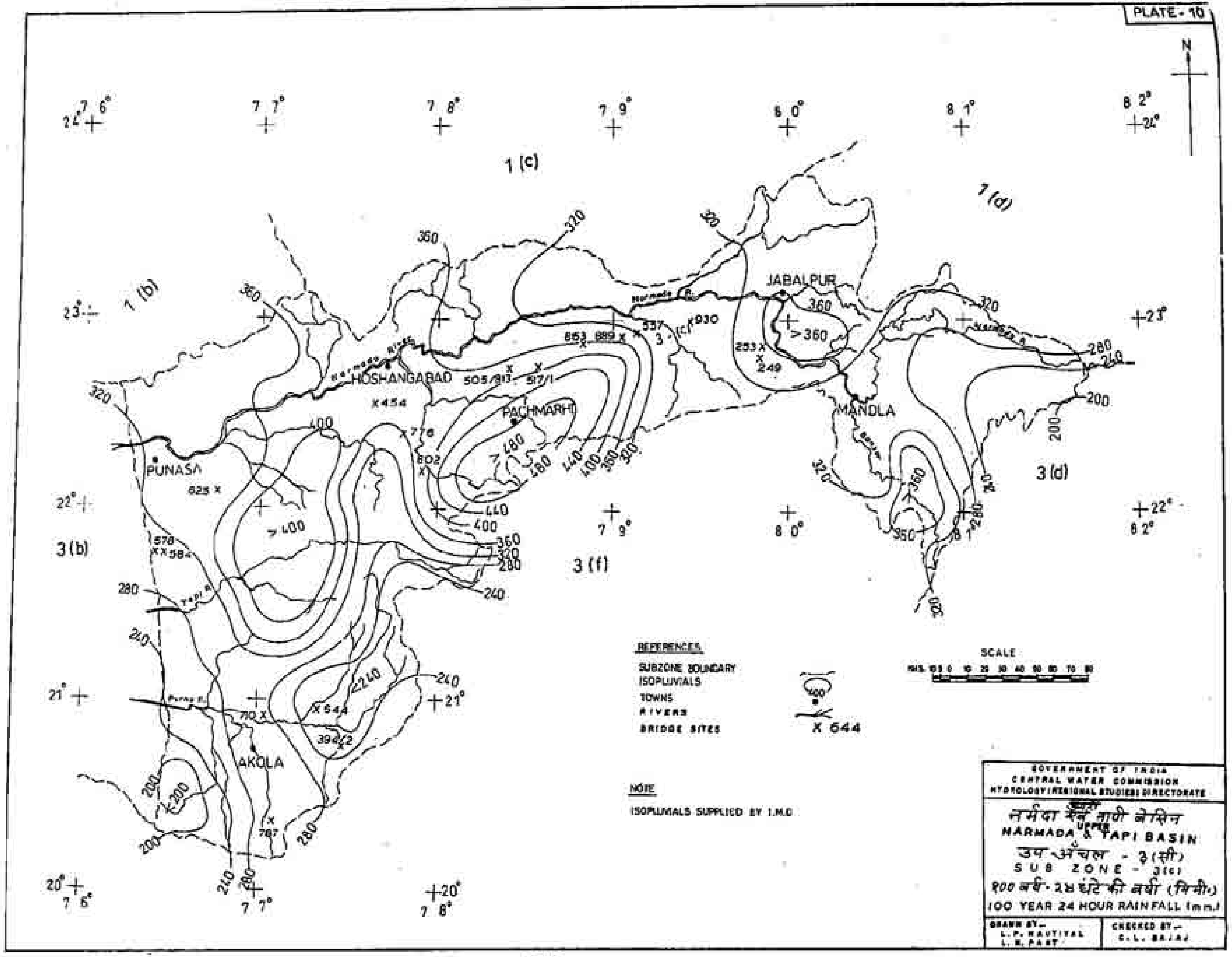
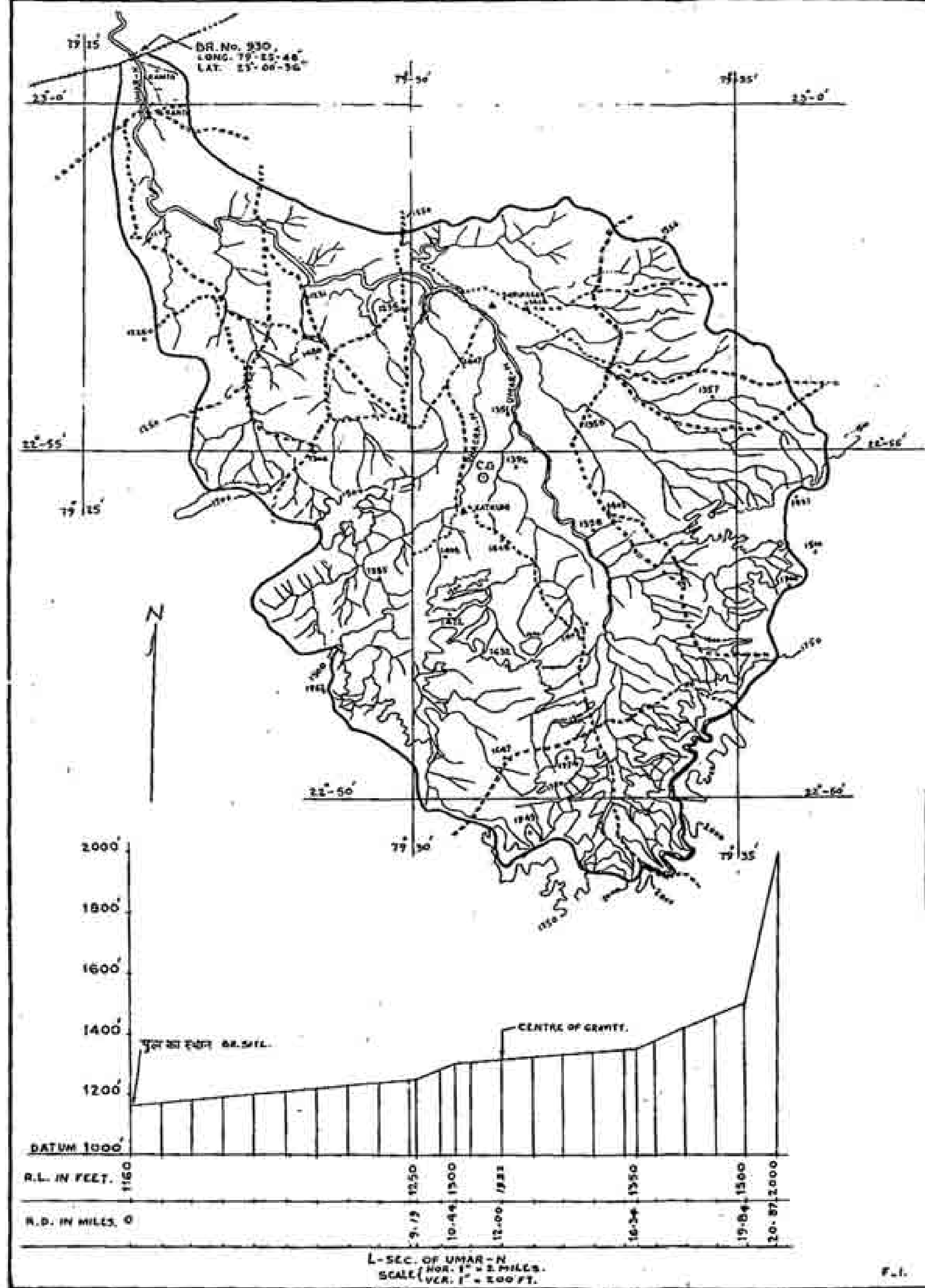


PLATE - 10
N
1 (c)
1 (d)
1 (b)
3 (b)
3 (f)
3 (d)
JABALPUR
HOSHANGABAD
PACHMARHI
MANDLA
PUNASA
AKOLA
Narmada R.
Tapi R.
Purna R.
REFERENCES
SUBZONE BOUNDARY
ISOPLUVIALS
TOWNS
RIVERS
BRIDGE SITES
X 644
NOTE
ISOPLUVIALS SUPPLIED BY I.M.D.
SCALE
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DIRECTORATE
नर्मदा एवं ताप्ती बेसिन
NARMADA & TAPI BASIN
उप अंचल - ३(सी)
SUB ZONE - 3(c)
१०० वर्ष - २४ घंटे की वर्षा (मिमी)
100 YEAR 24 HOUR RAINFALL (mm)
DRAWN BY -
L. P. NAUTIYAL
L. N. PANT
CHECKED BY -
C. L. BAJAJ

FIGURES



F.I.

FIG.- A.I.

टिप्पणी NOTE:-

1. सभी तल जी.टी. एस के अनुकूल हैं | ALL LEVELS CORRESPONDS TO G.T.S. DATUM.
2. पुल के स्थान पर एच.एफ.एल. | H.F.L. AT BR. SITE. =

संदर्भ | REFERENCES.

1. जलग्रहण सीमा | CATCHMENT BOUNDARY.
2. रेलवे लाईन | RAILWAY LINE.
3. नदी तथा उसकी सहायक नदियाँ | RIVER & ITS TRIBUTARIES.
4. सड़के | ROADS.
5. वर्षा मापी केन्द्र | RAINGAUGE STATION
6. समोच्च रेखायें | CONTOURS.
7. स्थान की ऊँचाई | SPOT LEVELS.
8. स्थलाकृति संख्या | TOPO SHEET No. 55 ⅝, ⅞, ⅝

जलग्रहण का विवरण | DETAIL OF CATCHMENT.

1. जल ग्रहण का क्षेत्रफल | AREA OF THE CATCHMENT. = 223.77 SQ.KM.
2. जल ग्रहण का आकार | SHAPE OF CATCHMENT = LEAF SHAPE.
3. नदी तथा सहायक नदियों की कुल लम्बाई | = 381.57 KM. TOTAL LENGTH OF RIVER & ITS TRIBUTARIES. =
4. लम्बाई | L = 20.90 MILES = 33.6 K.M.
5. एल सी | Lc = 12 MILES = 19.32 KM
6. डब्ल्यू सी | Wc = 7.9 MILES = 12.72 KM.
7. घनत्व | D. = 1.705 KM/SQ. KM.
8. एस ई क्यू | Seq. = 2.63 M/KM

SOIL PARTICULARS.

1. BLACK COTTON. 63.31%
2. BLACK COTTON MIXED WITH YELLOW. 36.69%.

LAND USE.

1. CULTIVATED. 77.27%
2. FOREST. 22.73%

क्र.सं. S.N.	वर्षा मापी केन्द्र का नाम NAME OF RAINGAUGE STNS.	देशान्तर LONG.	अक्षांश LAT.	स्टेशन वेट। STN. WT. 1971	1972-73.
1.	कटहरी. KATHUNI.	79-30-46	22-54-15	0.601	0.601
2.	श्रीनगर. SRINAGAR.	79-31-15	22-57-6	0.284	0.284
3.	कान्ती. KANTI.	79-26-0	22-59-46	0.115	0.111
4.	पुल का स्थान. BR. SITE.	79-25-48	23-0-36	—	0.004

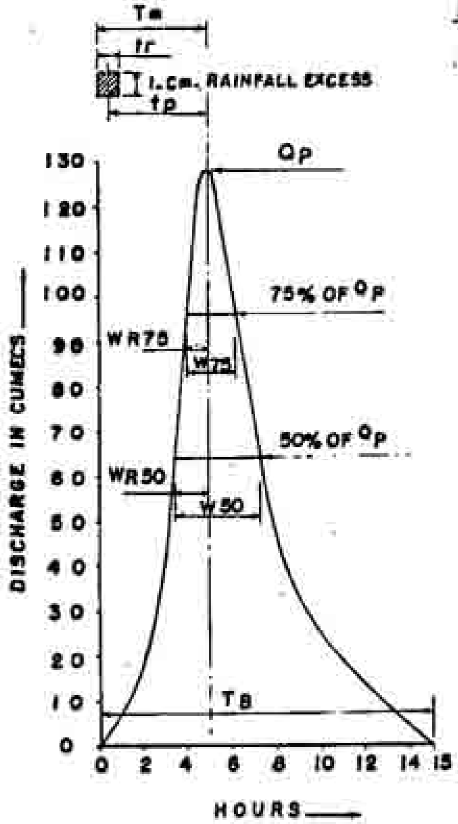
SCALE:- 1" = 1 MILE.

भारत सरकार
GOVT. OF INDIA
केन्द्रीय जल आयोग
CENTRAL WATER COMMISSION
जल विज्ञान (छोटे जल ग्रहण) निदेशालय
HYDROLOGY (S.C.) DIRECTORATE.

CATCHMENT AREA PLAN FOR BR. No. 930 AT K.M. 930/12-13. ON ITARSI-JUBBULPORE SEC. CENTRAL RAILWAY SUBZONE 3(C).
SHOWING.

DRAWN BY.-	CHECKED BY.-
L. K. PANT	K. K. AICH.

FIG.- A.2.



SYNTHETIC U.G. PARAMETERS

1. C.A. = 223.77 Km^2
2. T_m = 5.00 HOURS
3. t_r = 1.00 HOUR
4. t_p = 4.50 HOURS
5. Q_p = 127.55 HOURS
6. WR75 = 0.99 HOURS
7. W_{75} = 2.19 HOURS
8. WR50 = 1.54 HOURS
9. W_{50} = 3.86 HOURS
10. T_B = 15.00 HOURS
11. q_p = 0.57 $Cms./Km^2$
12. d = 1.00 Cm.

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

$$\Sigma Q_i = \frac{223.77 \times 1.00}{1.00 \times 0.36}$$

$$= 621.58 \text{ CUMECS}$$

1-HOUR SYNTHETIC U.G ORDINATES

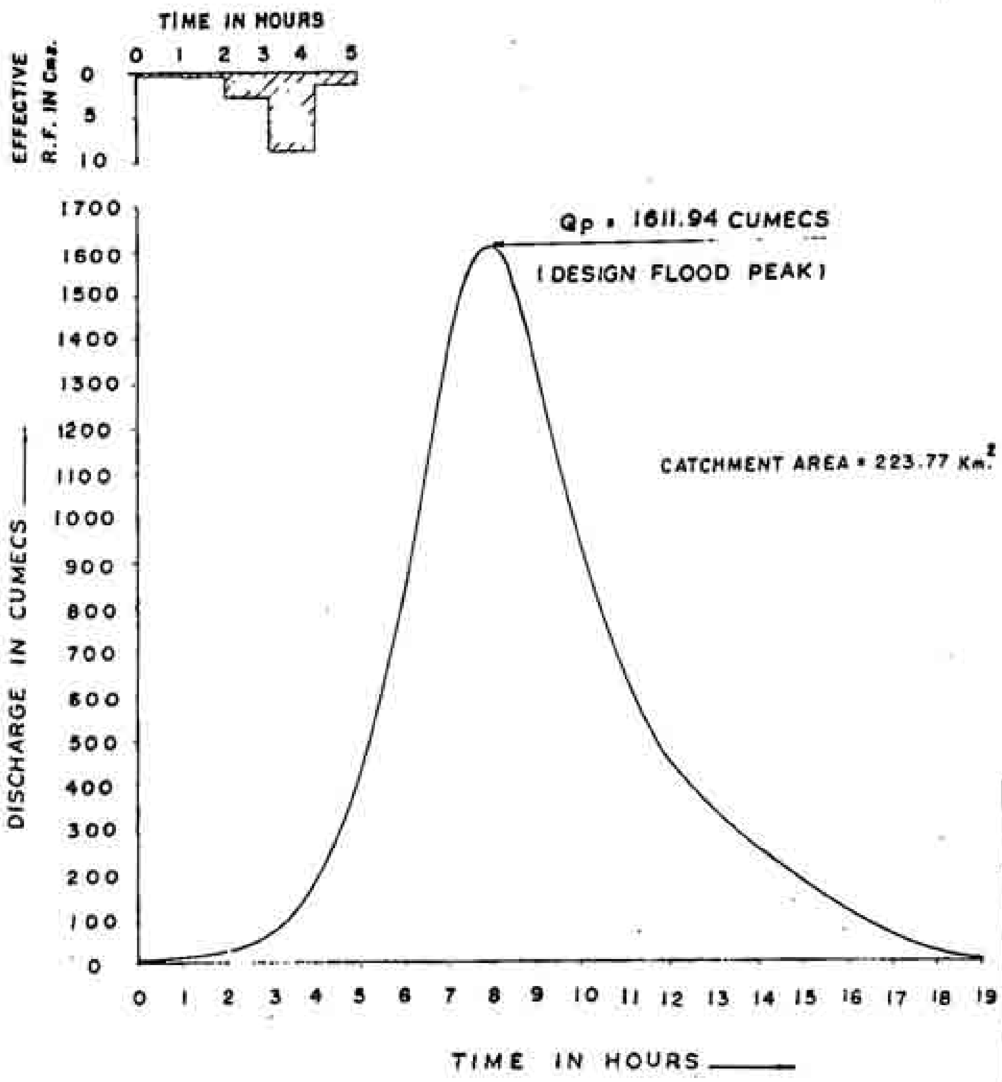
HOURS	ORDINATES
0	0
1	7.00
2	20.00
3	42.00
4	100.00
5	127.55
6	101.00
7	73.00
8	47.00
9	33.00
10	26.00
11	19.00
12	14.00
13	8.50
14	4.53
15	0
	621.58 CUMECS

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

UPPER NARMADA & TAPI
SUB ZONE - 3 (C)
SYNTHETIC UNIT HYDROGRAPH
OF BRIDGE NO.-930

DRAWN BY— L.P. NAUTIYAL
CHECKED BY— K.K. AICH

FIG. - A. 3.



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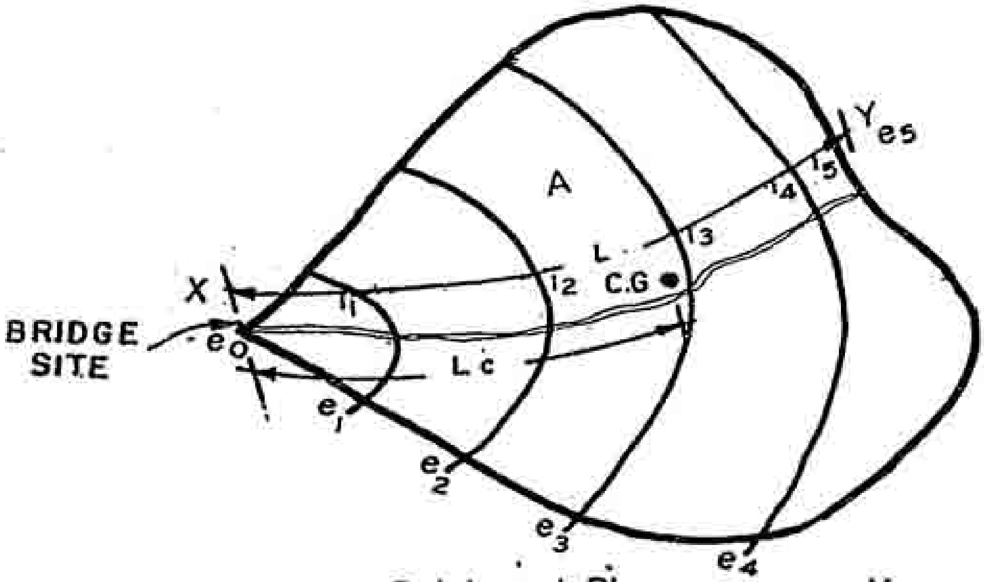
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE.

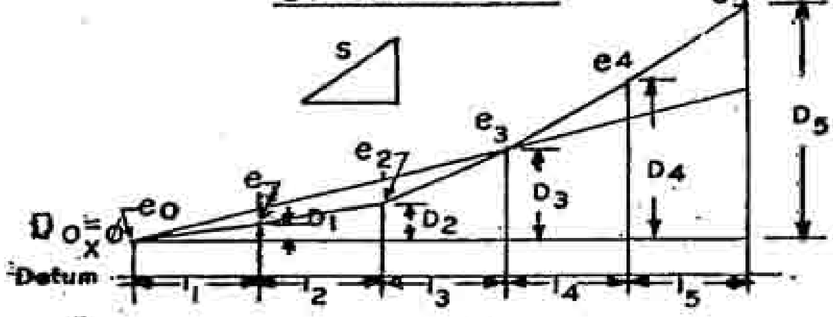
UPPER NARMADA AND TAPI
SUB ZONE - 3 (C)
DESIGN FLOOD HYDROGRAPH
OF BRIDGE NO.- 930.

DRAWN BY — L. K. PANT.	CHECKED BY — K. K. AICH.

FIG. I



Catchment Plan



L – Section

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

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)

$D_i = D_0, D_1, D_2, \ldots D_n$

$= (e_0 - e_0), (e_1 - e_0), (e_2 - e_0) \ldots (e_n - e_0)$ (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.)

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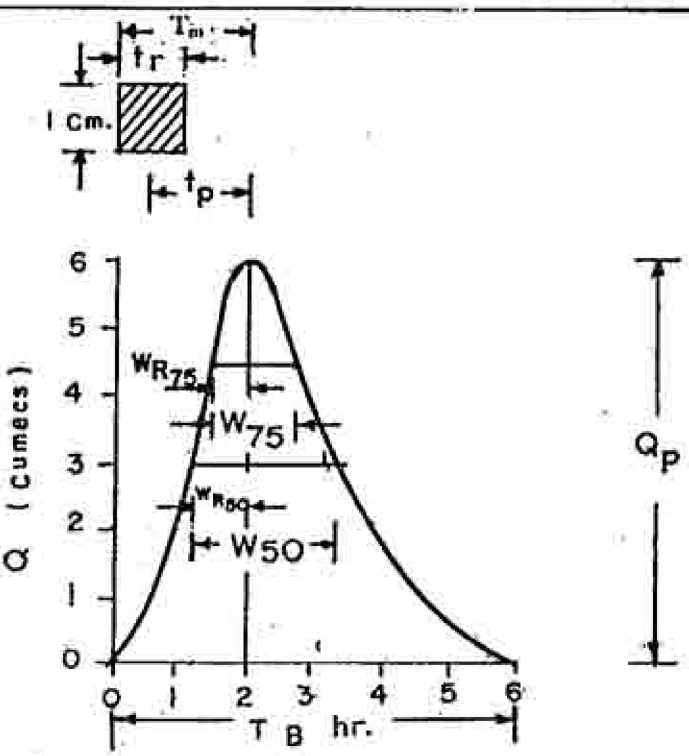
PHYSIOGRAPHIC PARAMETERS

DRAWN	CHECKED

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.

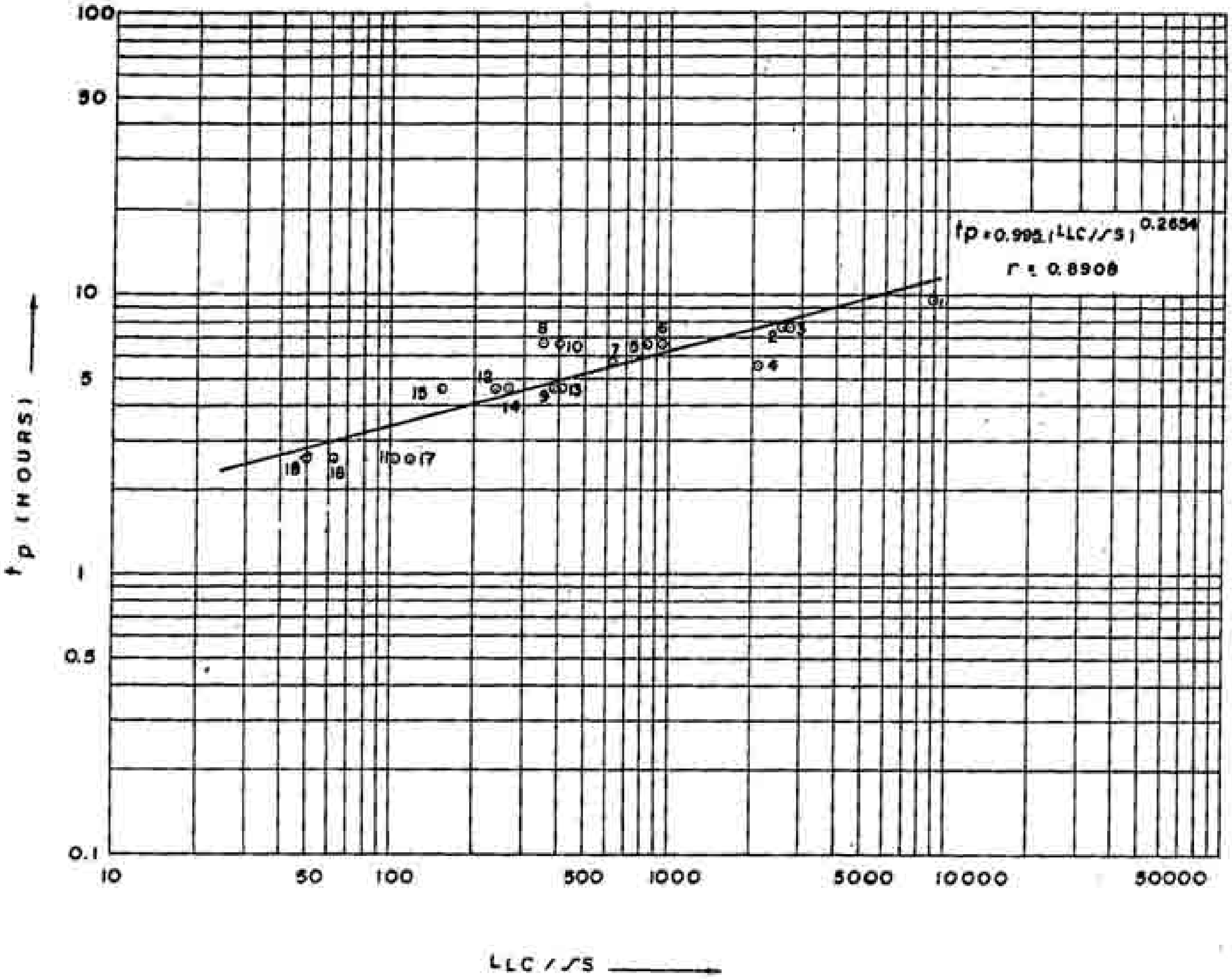
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (R.S.) DIRECTORATE

UNIT GRAPH PARAMETERS

DRAWN BY- NAUTIYAL | CHECKED BY- Chakraborty

FIG. — 3

SCALE - LOG. X LOG.



Sl. No.	Bridge No.	$L_{LC}/\sqrt{S}$	t_p (HOURS) Obs. Value	Estt. Value
1	663	9091.97	9.50	11.18
2	644	2647.92	7.50	8.06
3	602	2717.44	7.50	8.11
4	578	2100.11	5.50	7.58
5	625	818.17	6.50	5.90
6	249	942.57	6.50	6.13
7	394/2	821.62	5.50	5.49
8	557	348.27	6.50	4.71
9	787	379.83	4.50	4.81
10	930	395.79	6.50	4.87
11	776	100.89	2.50	3.39
12	584	237.83	4.50	4.25
13	454	399.11	4.50	4.88
14	253	266.25	4.50	4.36
15	505	148.21	4.50	3.75
16	517/1	61.30	2.50	2.97
17	710	117.92	2.50	3.53
18	869	49.47	2.50	2.80

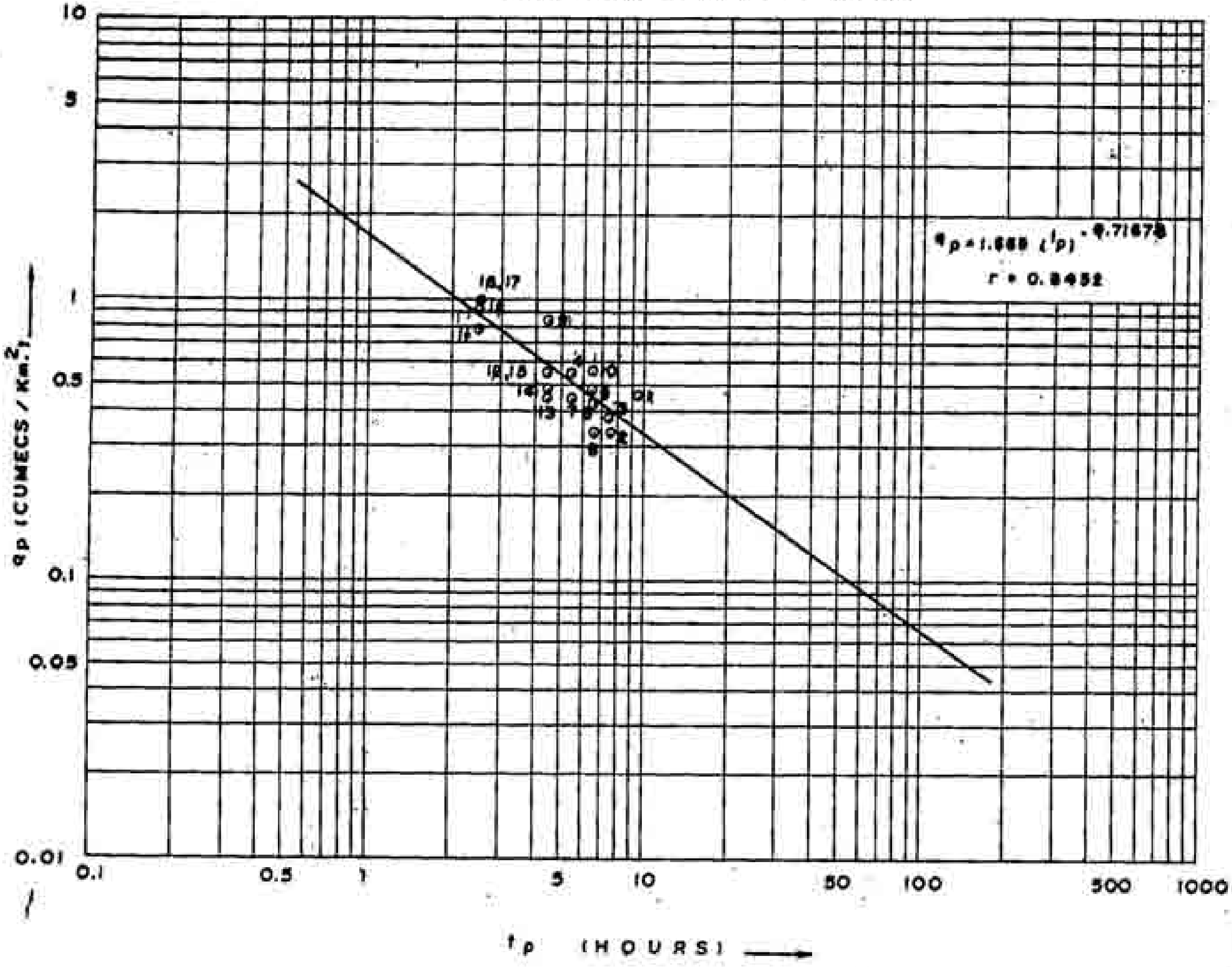
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE.

UPPER NARMADA & TAPI
SUB ZONE - 3 (c)
RELATION BETWEEN
$L_{LC}/\sqrt{S}$ AND t_p

DRAWN BY—	CHECKED BY—
L.K. PANT	K. K. AICH

FIG. — 4.

SCALE - LOG X LOG



Sl. NO	BRIDGE NO	t_p (HOURS)	q_p (CUM / Km^2) OBS. VALUE	q_p (CUM / Km^2) ESTI. VALUE
1	863	9.50	0.44	0.33
2	844	7.50	0.33	0.39
3	802	7.50	0.37	0.39
4	878	5.50	0.54	0.49
5	628	6.50	0.47	0.44
6	249	6.50	0.33	0.44
7	394/2	5.50	0.44	0.49
8	557	6.50	0.42	0.44
9	757	4.50	0.84	0.57
10	930	6.50	0.54	0.44
11	776	2.50	0.76	0.86
12	584	4.50	0.55	0.57
13	454	4.50	0.44	0.57
14	253	4.50	0.47	0.57
15	605	4.50	0.54	0.57
16	517/1	2.50	0.98	0.86
17	710	2.50	0.96	0.86
18	899	2.50	0.90	0.86

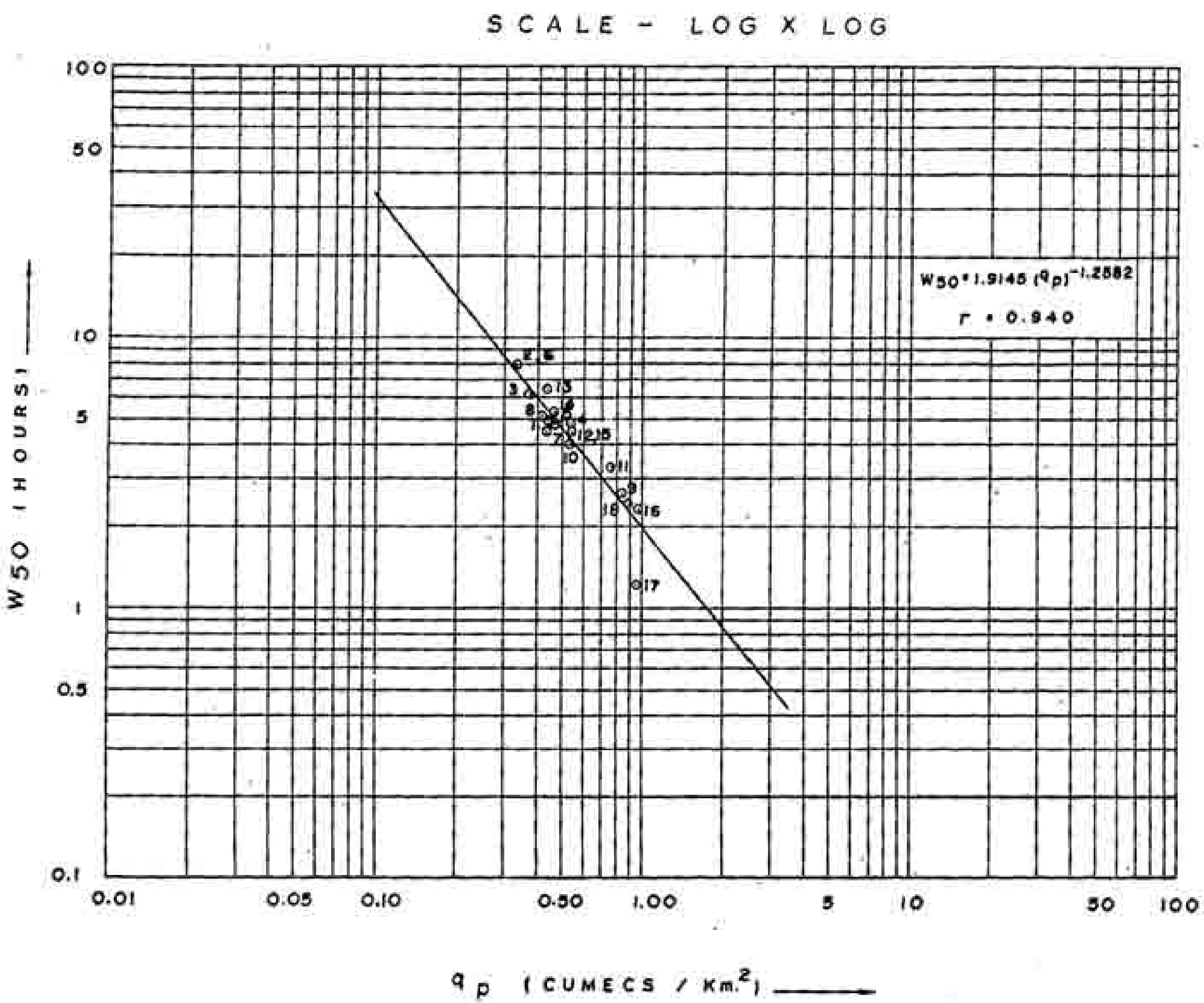
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE.

UPPER NARMADA & TAPI
SUB ZONE - 3 (C)
RELATION BETWEEN
t_p AND q_p

DRAWN BY—	CHECKED BY—
LALIT KUMAR PANT.	C. L. BAJAJ

F - 7.

FIG. — 5.



Sl. No.	Bridge No.	q_p (cum./km.²)	W50 Hours Observed Value	W50 Hours Esti. Value
1	863	0.44	4.90	5.38
2	644	0.33	7.90	7.72
3	802	0.37	6.10	6.69
4	578	0.54	4.70	4.16
5	625	0.47	4.90	4.95
6	249	0.33	8.00	7.72
7	394/2	0.44	4.40	5.38
8	557	0.42	5.10	5.70
9	787	0.84	2.80	2.38
10	930	0.54	4.00	4.18
11	778	0.76	3.25	2.70
12	584	0.55	4.50	4.06
13	454	0.44	6.60	5.38
14	253	0.47	5.20	4.95
15	505	0.54	4.40	4.18
16	517/1	0.98	2.30	1.98
17	710	0.98	1.20	2.02
18	889	0.90	2.40	2.19

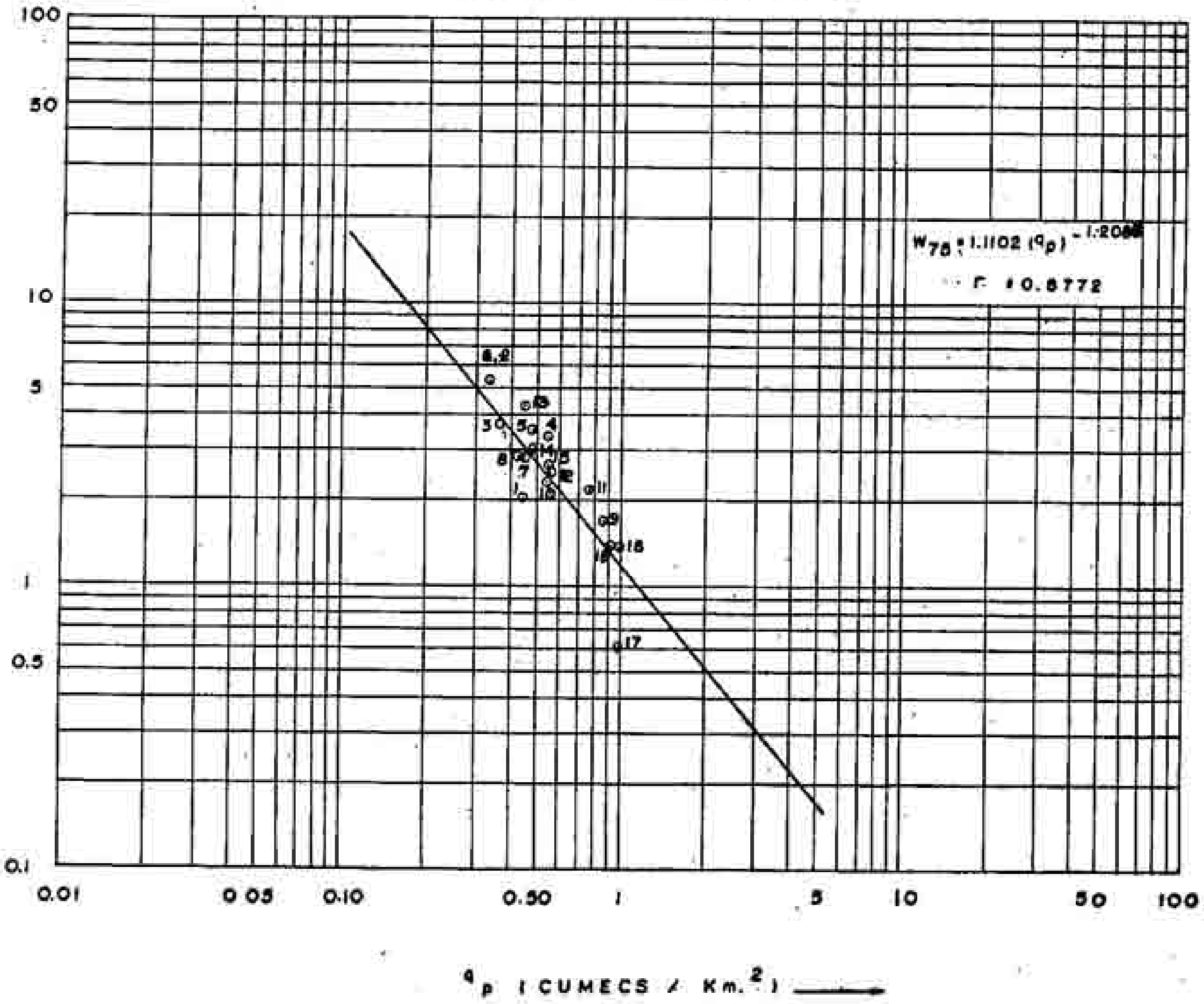
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE.

UPPER NARMADA & TAPI
SUB ZONE - 3 (C)
RELATION BETWEEN q_p AND W50

DRAWN BY–	CHECKED BY–
L.P. NAUTIYAL	C. L. BAJAJ

FIG. — 6.

SCALE - LOG X LOG



Sl. NO	BRIDGE NO	q_p (CUM/ km.^{2})	W_{75} (HOURS) OBSERVED VALUE	ESTIMATED VALUE
1	863	0.44	2.00	2.99
2	644	0.33	5.20	4.24
3	802	0.37	3.70	3.69
4	578	0.54	3.30	2.34
5	625	0.47	3.50	2.76
6	249	0.33	5.20	4.24
7	394/2	0.44	2.80	2.99
8	567	0.42	2.80	3.17
9	787	0.84	1.70	1.37
10	930	0.54	2.30	2.34
11	776	0.76	2.21	1.65
12	584	0.59	2.50	2.29
13	484	0.44	4.30	2.99
14	253	0.47	3.00	2.76
15	506	0.54	2.60	2.34
16	517/1	0.98	1.35	1.14
17	710	0.96	0.60	1.17
18	869	0.90	1.35	1.26

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

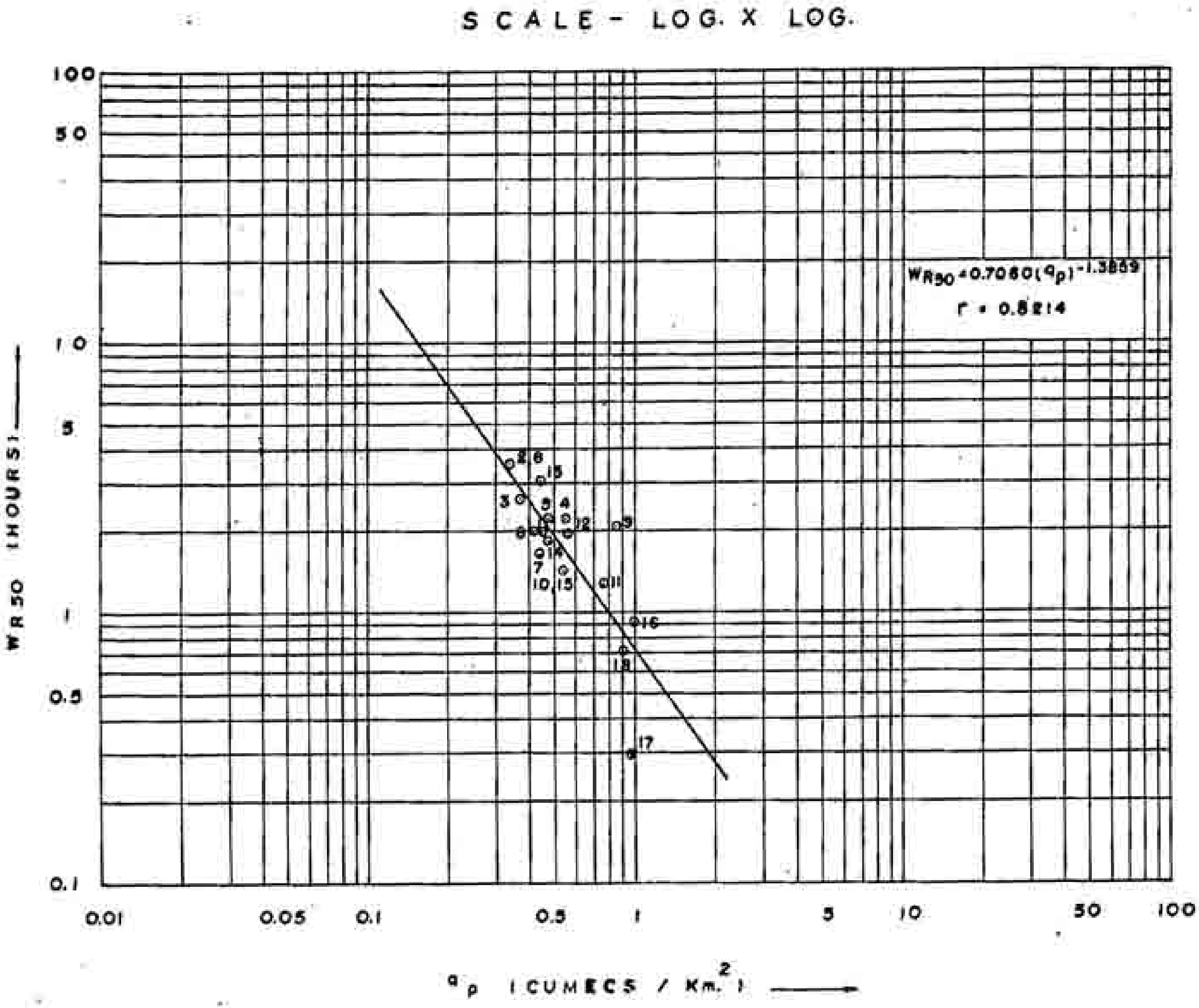
UPPER NARMADA & TAPI

SUB ZONE - 3 (C)
RELATION BETWEEN
q_p AND W_{75}

DRAWN BY— L. K. PANT.	CHECKED BY— K. K. AICH.

F - 9.

FIG.— 7.



Sl. No.	BRIDGE NO	q_p (CUM./Km.²)	WR50 (HOURS) OBS. VALUE	WR50 (HOURS) ESTI. VALUE
1	663	0.44	2.00	2.20
2	644	0.33	3.50	3.28
3	802	0.37	2.60	2.80
4	578	0.54	2.20	1.66
5	625	0.47	2.20	2.01
6	249	0.33	3.40	3.28
7	394/2	0.44	1.60	2.20
8	557	0.42	2.00	2.35
9	787	0.84	2.05	0.90
10	930	0.54	1.40	1.66
11	776	0.76	1.25	1.03
12	584	0.65	2.00	1.62
13	454	0.44	3.00	2.20
14	263	0.47	1.60	2.01
15	506	0.54	1.40	1.66
16	517/1	0.98	0.90	0.73
17	710	0.96	0.30	0.75
18	889	0.90	0.70	0.82

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

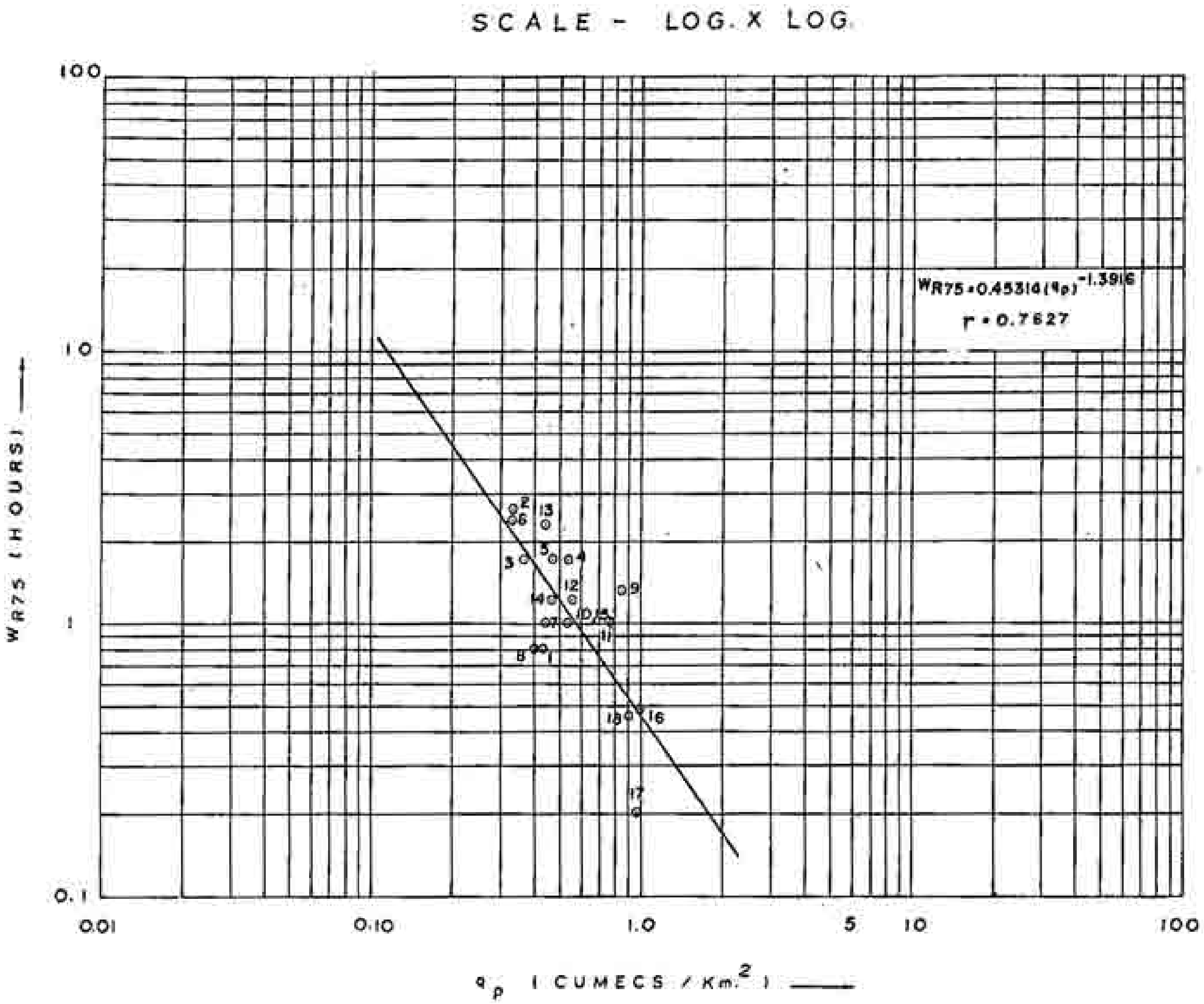
UPPER NARMADA & TAPI

SUB ZONE - 3 (C)

RELATION BETWEEN q_p AND WR_{50}

DRAWN BY—	CHECKED BY—
L. P. NAUTIYAL	C.L. BAJAJ

FIG. —8.



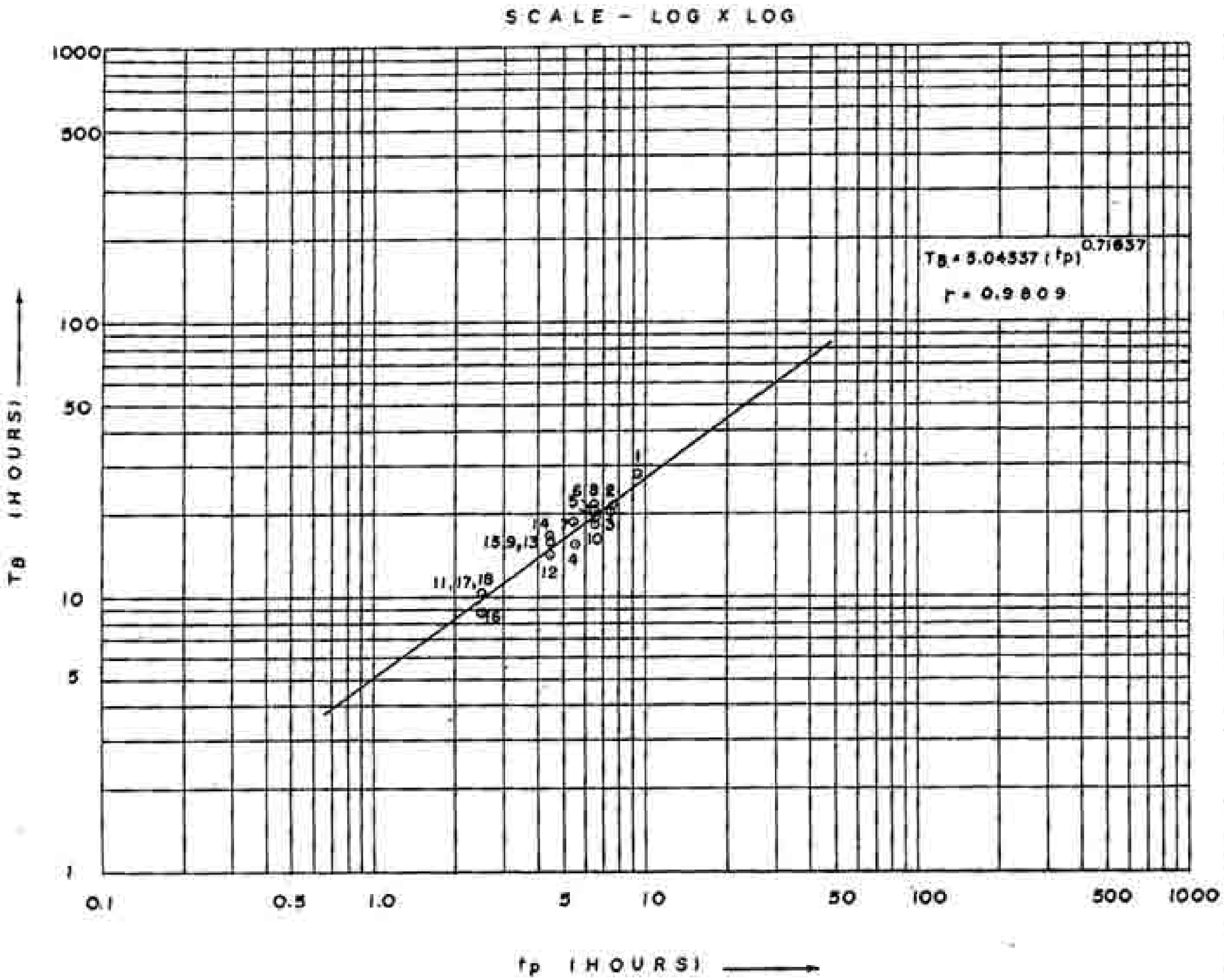
Sl. NO.	BRIDGE NO.	q_p CUMECS/ Km^2	W_{R75} (HOURS) OBS.	ESTI.
1	863	0.44	0.80	1.42
2	644	0.33	2.60	2.12
3	802	0.37	1.70	1.81
4	578	0.54	1.70	1.07
5	628	0.47	1.70	1.30
6	249	0.33	2.40	2.12
7	394/2	0.44	1.00	1.42
8	557	0.42	0.88	1.52
9	787	0.84	1.30	0.58
10	930	0.54	1.00	1.07
11	776	0.76	1.00	0.66
12	584	0.55	1.20	1.04
13	454	0.44	2.30	1.42
14	253	0.47	1.20	1.30
15	505	0.54	1.00	1.07
16	517/1	0.98	0.47	0.47
17	710	0.98	0.20	0.48
18	889	0.90	0.45	0.52

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

UPPER NARMADA & TAPI
SUB ZONE - 3 (C)
RELATION BETWEEN q_p AND W_{R75}

DRAWN BY — L. K. PANT
CHECKED BY — K. K. AICH

FIG. _9



Sl. No.	Bridge No.	t_p (Hours)	TB (Hours) Observed Value	TB (Hours) Esti. Value
1	863	9.50	27	25.31
2	844	7.50	21	21.37
3	802	7.50	20	21.37
4	578	5.50	15	17.11
5	628	6.50	19	19.29
6	249	6.50	20	19.29
7	394/2	5.50	18	17.11
8	557	6.50	21	19.29
9	787	4.50	15	14.82
10	930	6.50	19	19.29
11	776	2.50	10	9.73
12	584	4.50	14	14.82
13	454	4.50	15	14.82
14	253	4.50	16	14.82
15	505	4.50	15	14.82
16	517/1	2.50	9	9.73
17	710	2.50	10	9.73
18	889	2.50	10	9.73

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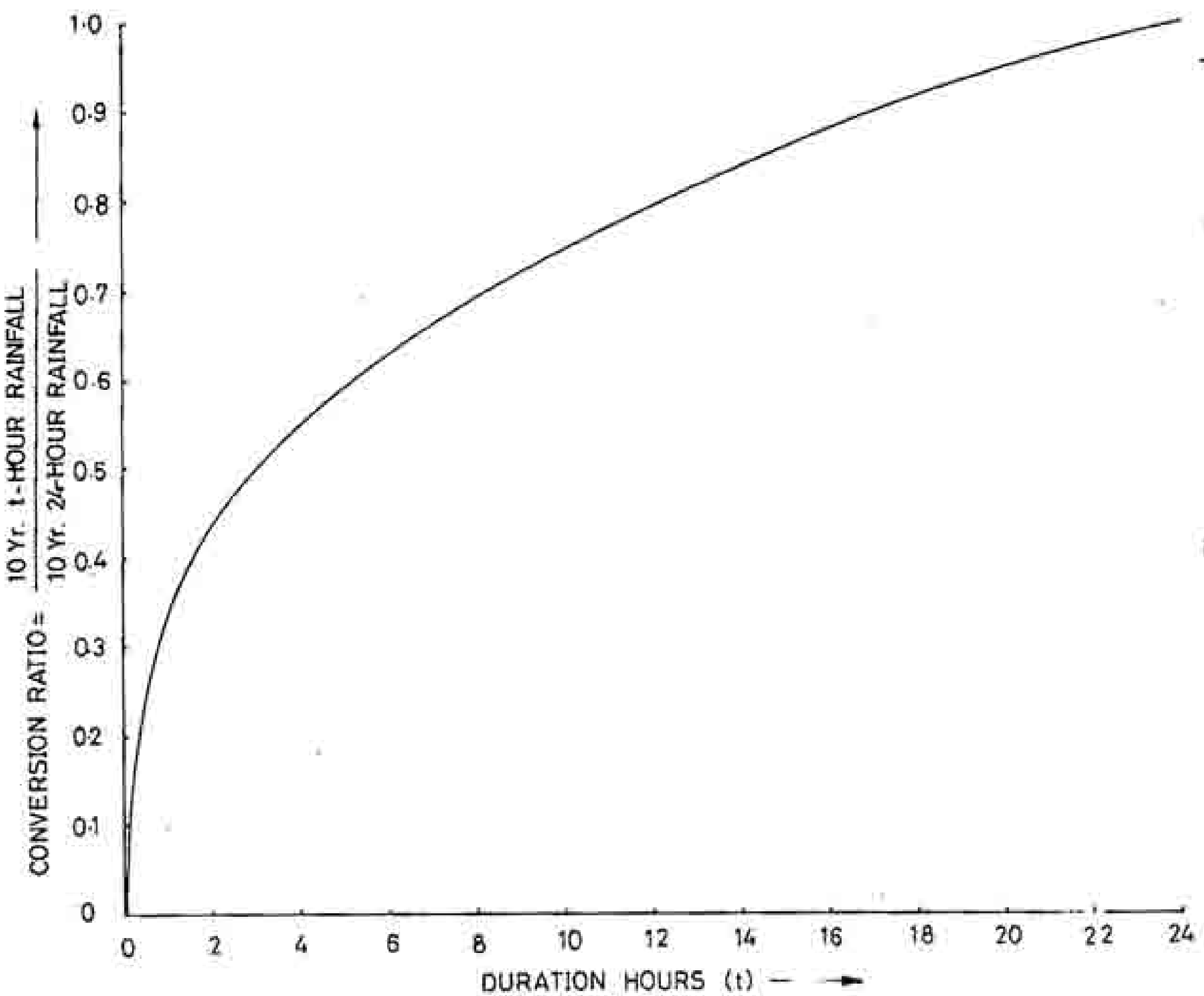
UPPER NARMADA & TAPI
SUB ZONE - 3(C)
RELATION BETWEEN
t_p AND TB

DRAWN BY— L. P. NAUTIYAL	CHECKED BY— C. L. BAJAJ

Fig - 10



RATIOS OF 24 HOURS POINT RAINFALL TO SHORT DURATION RAINFALL

DURATION (HOURS)	RATIOS
1	0·34
3	0·50
6	0·63
9	0·72
12	0·79
15	0·86
18	0·91
24	1·00

NOTE - CURVE SUPPLIED BY I.M.D

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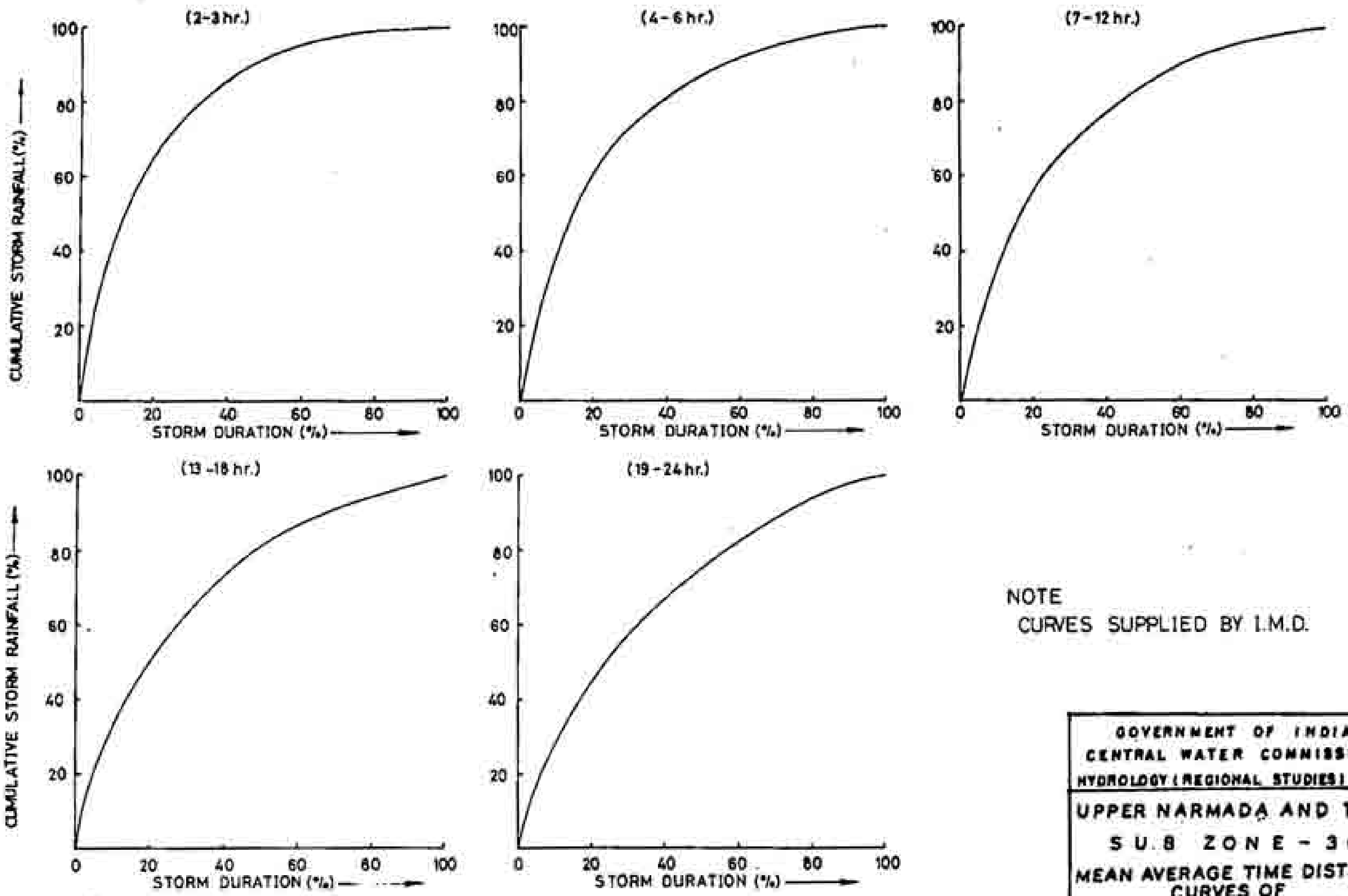
UPPER NARMADA AND TAPI
SUB ZONE - 3(C)
DURATION Vs. CONVERSION RATIO

DRAWN BY_	CHECKED BY_
L. P. NAUTIYAL L. K. PANT	M. R. CHAKARBORTY

Fig-11



NOTE
CURVES SUPPLIED BY I.M.D.

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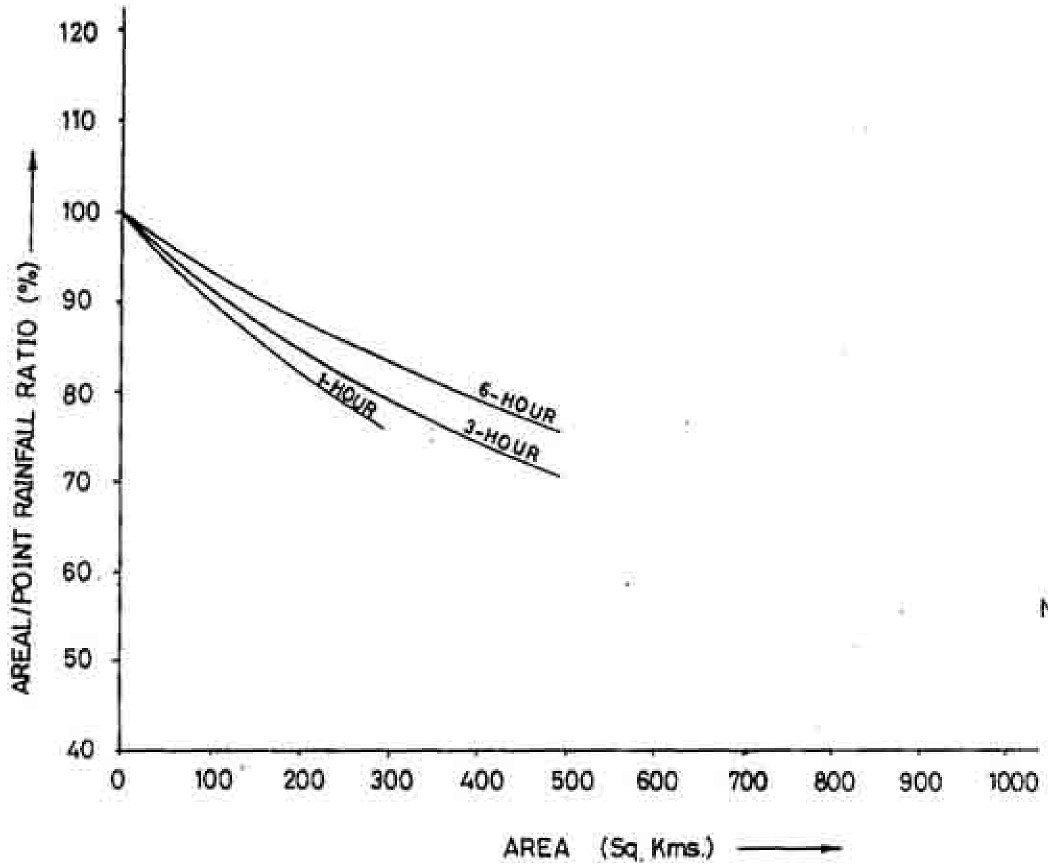
UPPER NARMADA AND TAPI
SUB ZONE - 3(C)
MEAN AVERAGE TIME DISTRIBUTION CURVES OF STORMS OF VARIOUS DURATIONS

DRAWN BY— L. P. NAUTIYAL	CHECKED BY— P. N. SINGH

Fig - 12(a)



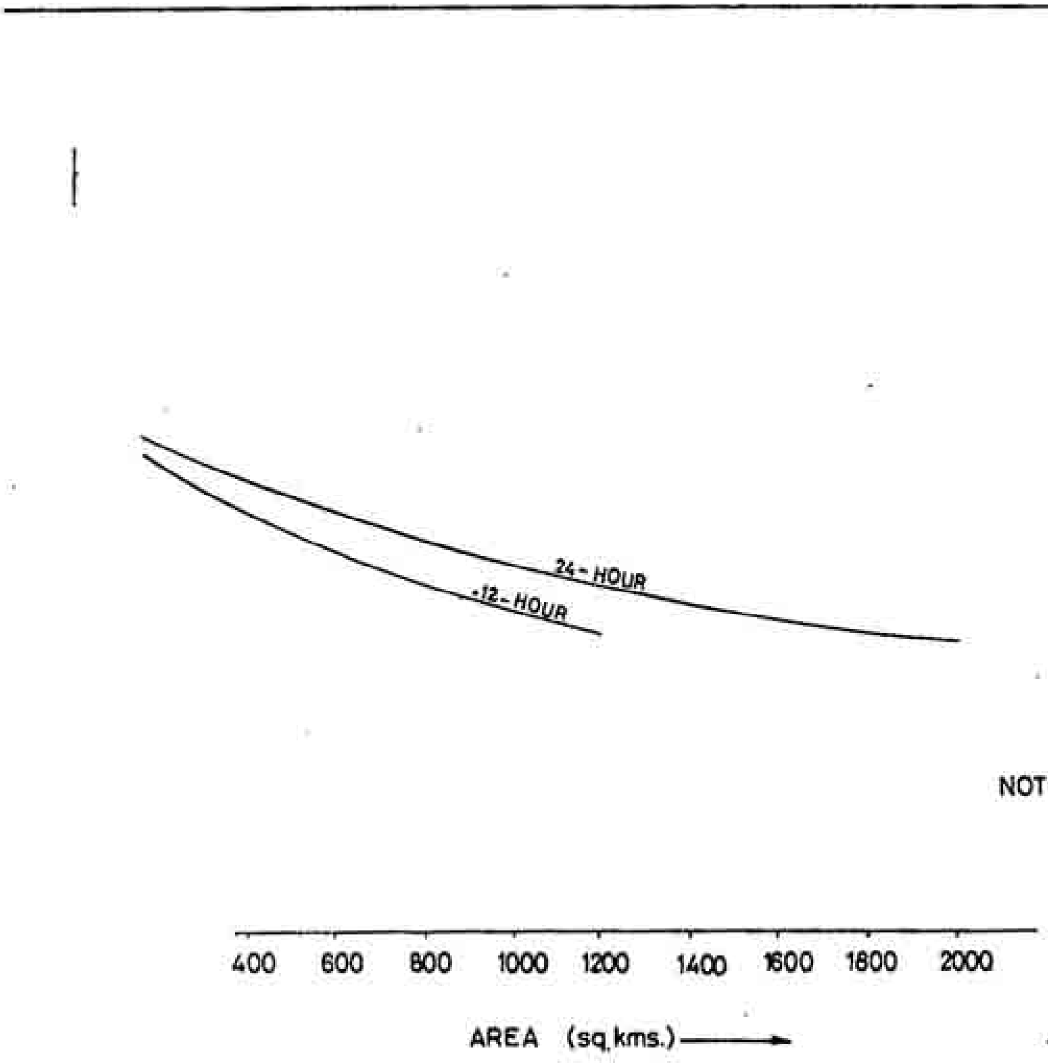
NOTE - CURVE SUPPLIED BY I.M.D

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

UPPER NARMADA AND TAPI
SUB ZONE - 3(C)
AREAL TO POINT RAINFALL RATIO
FOR 1-Hr, 3 Hrs, 6 Hrs. (%)

DRAWN BY— L.K. PANT	CHECKED BY— N.R.CHAKARBORTY

Fig - 12(b)



NOTE - CURVE SUPPLIED BY I.M.D

GOVERNMENT OF INDIA CENTRAL WATER COMMISSION HYDROLOGY (R.S.) DIRECTORATE	
UPPER NARMADA AND TAPI SUB ZONE -3(C) AREAL TO POINT RAINFALL RATIO FOR 12-Hrs. 24-Hrs. (%)	
DRAWN BY — L.P. NAUTIYAL	CHECKED BY — P. N. SINGH

NAMES OF THE OFFICIALS ASSOCIATED WITH THE PREPARATION OF FLOOD ESTIMATION REPORT OF SUBZONE (C)

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5.	Shri Samay Singh	Section Engineer (Works)

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6.	Smt. Indu	Senior Observer
7.	Shri Raju Bhargav	D'man

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6.	Shri P.K. Guin	Extra Assistant Director(HM)
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14.	Smt. Shashi Gupta	Stenographer
15.	Shri. P.K.Das	LDC

A. UNDER SHORT TERM PLAN

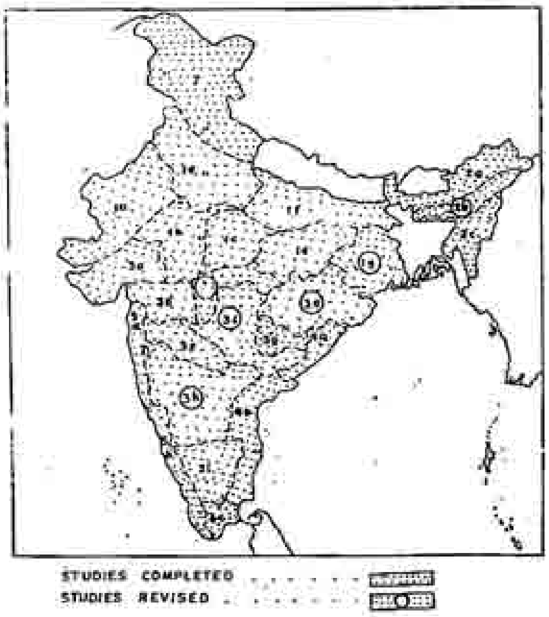
1.	Estimation of Design Flood Peak	(1973)

B. UNDER LONG TERM PLAN

1.	Lower Ganga Plains Subzone 1 (g)	(1978)
2.	Lower Godavari Subzones 3 (f)	(1981)
3.	Lower Narmada and Tapi Subzone 3(b)	(1982)
4.	Mahanadi Subzone 3(d)	(1982)
5.	Upper Narmada & Tapi Subzone 3(c)	(1983)
6.	Krishna & Pennar Subzone 3(h)	(1983)
7.	South Brahmaputra 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 subzones 4(a), (b) & (c)	(1987)
14.	Sone Subzone 1(d)	(1988)
15.	Chambal Subzone 1(b)	(1989)
16.	Betwa Subzone 1(c)	(1989)
17.	North Brahmaputra Subzone 2(a)	(1991)
18.	West Coast Region Subzone 5(a)&(b)	(1992)
19.	Luni Subzone 1(a)	(1993)
20.	Indravati Subzone 3(g)	(1993)
21.	Western Himalayas zone 7	(1994)

Revised Flood Estimation Reports

1.	Lower Ganga Plains Subzone 1(g)	(1994)
2.	Lower Godavari Subzone 3(f)	(1995)
3.	Mahanadi Subzone 3(d)	(1997)
4.	South Brahmautra Subzone 2(b)	(2000)
5.	Krishna & Pennar Subzone 3(h)	(2000)



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