FLOOD ESTIMATION REPORT FOR KAVERI BASIN SUBZONE - 3(i)
(INCLUDING PALAR AND PONNAYYAR RIVERS BUT EXCLUDING EASTERN COASTAL REGION)

A METHOD BASED ON UNIT HYDROGRAPH PRINCIPLE

DESIGN OFFICE REPORT NO. CB/11/1985

HYDROLOGY (SMALL CATCHMENTS) DIRECTORATE
CENTRAL WATER COMMISSION
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F O R E W O R D

The empirical approaches generally followed for estimation of design flood of bridges, culverts and cross drainage works may lead to erroneous conclusions. Studies are under way for rational and scientific estimation of floods of various return periods for safe and yet economic design of structures. Such studies for the following nine subzones have been published in the form of Flood Estimation Reports:

1.	Upper Indo-Ganga Plains	- 1(e)
2.	Middle Ganga Plains	- 1(f)
3.	Lower Gangetic Plains	- 1(g)
4.	South Brahmaputra	- 2(b)
5.	Lower Godavari	- 3(f)
6.	Lower Narmada and Tapi	- 3(b)
7.	Upper Narmada and Tapi	- 3(c)
8.	Mahanadi	- 3(d)
9.	Krishna and Penner	- 3(h)

The present report presents the studies for Kaveri Basin sub-zone-3(i). The report was discussed and approved by the Planning and Co-ordinatic Committee in its 42nd meeting held in Southern Railways at Bangalore Cantt. c 13th & 14th August, 1985 and Extraordinary meeting held in Central Water Commission (CWC) at New Delhi on 27th September, 1985.

This report is a result of a joint effort by Central Water Commission of the Ministry of Water Resources, Research Designs and Standards Organisation (RDSO) of the Ministry of Transport (Railways), Ministry of Transport (Roads) and India Meteorological Department (IMD), in pursuance of the recommendations of the Khosla Committee of Engineers. The rainfall and discharge data from selected catchments was collected by Southern and South-Central Railways under the overall guidance and supervision of R.D.S.O. The storm studies were carried out by IMD. The flood studies were carried out and the report was prepared in the Hydrology (Small Catchments) Directorate of Central Water Commission.

The studies have been based on the data specially collected for a period of 5 to 10 years by the Indian Railways. Crest gauge observations are being continued by the Railways on the bridge catchments. Also the Ministry of Transport (Roads) have organised special collection of data through CWC. When more data becomes available, further refinements will be possible.

The joint efforts of the Railways, Roads and Water Resources Engineers together with Meteorologists are a landmark in the country in the field of Hydrology of small and medium catchments.

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PREFACE

The design engineer essentially requires design flood for the design of waterways and foundations of the bridges and culverts for safely negotiating the design flood consistent with economy and safety of the structures. The study of flood hydrology of rivers, therefore, becomes absolutely necessary for estimation of design flood at the point of study.

The road and railway networks cross a large number of small and medium size streams with bridges on them. For determining the waterway of bridges and their depth of foundations the design flood of required frequency are required. Detailed hydrological and meteorological investigations for a large number of small and medium catchments upto each and every new site and for adequate periods is not possible due to economic constraints. Waterway should be adequate to pass safely the design flood, but at the same time it should not be too wide involving higher cost. Therefore, it becomes necessary to reasonably estimate the flood discharge of the required return period of stream at the point of study witth sufficient care. A casual approach can lead in extreme cases to loss and destruction of structure due to floods of magnitude higher than expected or over design of structures leading to uneconomical and problematic situation.

In the early years, design discharges were calculated by well known empirical formulae vis: Dickens, Ryves, Inglis and Ali Nawaz Jung etc. In these formulae, flood discharge is related to catchment areas only and effect of all other factors are included in a constant which is to be decided by the designer from his experience. Even intensity of the storm rainfall which is a prime factor responsible for the flood and which varies substantially from place to place is not included in the above formulae. The need to evolve a method on estimation of design flood peak of desired frequency knowing the physical characteristics of the catchments and design rainfall has been recognised and a committee of engineers under the chairmanship of Dr. A.N. Khosla have recommended "___systematic and sustained collection of hydrometeorological data of selected catchments in different climatic zones of India for evolution of a rational approach for determination of flood discharges". The committee felt that design discharge should be maximum flood on record for a period not less than 50 years. Where adequate records are available extending over a period of not much less than 50 years, the design flood should be recorded floods during the period. In case, where the requisite data, as above are not available, the design flood should be decided based on the ground and meteorological characteristics obtained on the basis of design storm. Accordingly in this report, a method based on synthetic unit hydrograph and design rainfall has been evolved to represent physiographic and meteorological characteristics to estimate the design flood.

Based on the studies made utilizing the data of representative catchments, the following preliminary and subzonal reports have been brought out so far.

Under Short Term Plan

Estimation of Design Flood Peak No. 1/73 (preliminary)

Under Long Term Plan

S.No.	Subzone	Report No.
1.	Lower Gangetic Plains subzone-1(g)	2/1974
2.	Lower Godavari subzone-3(f)	3/1980
3.	Lower Narmada & Tapi subzone-3(b)	LNT/4/1981
4.	Mahanadi subzone-3(d)	M/5/1981
5.	Krishna & Penner subzone-3(h)	K/6/1982
6.	Upper Narmada & Tapi subzone-3(c)	UNT/7/1983
7.	South Brahmaputra Basin subzone-2(b)	SB/8/1984
8.	Upper Indo-Ganga Plains subzone-1(e)	UGP/9/1984
9.	Middle Ganga Plains subzone-1(f)	MGP/10/1984

The present report for Kaveri Basin is the culmination of the coordinated efforts of Southern Railway, Research Directorate (B&F Wing) of R.D.S.O., Hydrology (Small Catchments) Directorate and SC&WRS Cell of Central Water Commission, Hydromet Directorate of India Meteorological Department and Roads Wing of Ministry of Transport.

The present report deals with the estimation of 50-yr. flood for small and medium catchments in Kaveri Basin subzone-3(i) based on 50-yr. design storm rainfall and synthetic unitgraph. Besides, 25-yr. and 100-yr. 24-hr. storm rainfall maps of Kaveri subzone have been incorporated in the report for estimation of 25-yr. and 100-yr. flood using the same procedure.

The report necessarily begins with the 25-yr., 50-yr. and 100-yr. flood formulae to create interest in the users for estimation of 25-yr., 50-yr. and 100 yr. flood for ungauged catchments for preliminary designs with minimum effort. These sets of formulae are based both on the direct method and multiple regression method giving more or less the same results with lesser accuracy as compared to the detailed method.

"Application of the Report" with an illustrative example based on (1) detailed and (2) simplified approaches is incorporated in the report after "Introduction" for quick and correct understanding of the users. The basic theory behind the flood formulae by both the methods is covered in the simplified approach.

Subsequent parts of the report deal with the general aspects of the Kaveri subzone, nature and availability of data, analysis of storm rainfall and floods, derivation of synthetic unitgraph with synthetic unitgraph relations, base flow, infilteration losses, design storm rainfall and procedure for estimation of design flood peak as well as hydrograph. The report finally ends with the assumptions and conclusions.

The report is recommended for estimation of design flood (25-yr., 50-yr., and 100-yr. flood) for fixing the waterway vis-a-vis design H.F.L. for cross drainage structures according to their importance, resources available and site conditions for catchment areas ranging in size from 25 to 1000 sq.Km. Further the report may be used for larger catchments upto 3000 sq.km. based on sound judgement and considering the data of neighbouring catchment also. A formula for fixing the linear waterway of the bridges for the guidance of design engineers has also been incorporated. Flexibility has also been imparted to the report by suggesting the adoption of different constant loss rates under special conditions at the discretion of design engineer.

Further, the report may also be used for estimation of frequency flood like 100-yr. flood for safety of small dams and 10 to 25 years flood for the design of waterway of minor cross-drainage works as per the Indian Standards of the Indian Standard Institution.

The methodology adopted and conclusions arrived at, are subject to periodical review and revision in the light of further data being collected and analysed.

~~The views expressed in this report do not necessarily represent the views of Central Water Commission.~~

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SYMBOLS AND ABBREVIATIONS

SYMBOLS

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

A	:	Catchment Area in sq.km.
C.G.	:	Centre of Gravity
L	:	Length of main stream along the river course in km.
L_c	:	Length of the main stream from a point opposite to centroid of the catchment area to the gauging site in km. along the main stream.
L_i	:	Length of the ith segment of L-Section in km.
D_{i-1}, D_i	:	The depth of the river at the point of intersection of (i-1) and ith contours from the base line (datum) drawn at the level of the point of study in metres.
S	:	Equivalent stream slope in m/km.
U.G.	:	Unit Hydrograph
S.U.G.	:	Synthetic Unit Hydrograph
t_r	:	Unit rainfall duration adopted in a specific study in hours.
t_p	:	Time from the centre of unit rainfall duration to the peak of unit hydrograph in hours.
T_m	:	Time from the start of rise to the peak of Unit Hydrograph (hr.)
T	:	Time duration of rainfall in hours.
T_B	:	Base width of unit hydrograph in hours.
T_D	:	Design storm duration in hours.

q_p	:	Peak discharge of unit hydrograph per unit area in cumecs per sq.km.
Q_p	:	Peak discharge of unit hydrograph in cumecs.
W_{50}	:	Width of the U.G. measured at 50% of maximum discharge ordinate (Q_p) in hours.
W_{75}	:	Width of the U.G. measured at 75% of maximum discharge ordinate (Q_p) in hours.
W_{R50}	:	Width of the rising side of U.G. measured at 50% of maximum discharge ordinate (Q_p) in hours.
W_{R75}	:	Width of the rising side of U.G. measured at 75% of maximum discharge ordinate (Q_p) in hours.
Q_{50}	:	Maximum flood peak with a return period of 50 years in cumecs.
ARF	:	Arial reduction factor
%	:	Percent
Σ	:	Summation

ABBREVIATIONS

Cumecs	:	Cubic metres per second
Cms	:	Centimetres
Hr.	:	Hour
M.	:	Metres
Min.	:	Minutes
Km.	:	Kilometres
Sq.km.	:	Square Kilometres, Km^2
In.	:	Inches
Sec.	:	Seconds
Sq.	:	Square
R.D.S.O.	:	Research Designs and Standards Organisation (Ministry of Railways), Lucknow.
H(SC), CWC	:	Hydrology (Small Catchments) Directorate, Central Water Commission, New Delhi.
I.M.D.	:	India Meteorological Department.
C.W.C.	:	Central Water Commission
M.O.S.T.	:	Ministry of Shipping & Transport, New Delhi.

25-YEAR, 50 YEAR AND 100-YEAR FLOOD PEAK FORMULAE

(1) By Direct Method
(for loss rate = 0.5 cm/hr)

$$Q_{25} = \frac{K_{25}\ (S)^{0.176}\ A\ R_{25}}{(LL_c)^{0.353}}$$

$$Q_{50} = \frac{K_{50}\ (S)^{0.176}\ A\ R_{50}}{(LL_c)^{0.353}}$$

$$Q_{100} = \frac{K_{100}\ (S)^{0.176}\ A\ R_{100}}{(LL_c)^{0.353}}$$

The symbols in the above formulae are as under:

Q_{25}, Q_{50} and Q_{100} are 25-yr. flood, 50-yr. flood and 100-yr. flood in cumecs respectively.

A is catchment area upto the point of study in sq.km.

L is length of longest stream in km.

L_c is length of longest stream from opposite the centre of gravity of the catchment to the point of study in km.

S is equivalent slope in m/km
(see step-2 of illustrative example)

K_{25}, K_{50} and K_{100} are the values corresponding to the catchment area (A) under study read from K_{25} v/s A, K_{50} v/s A and K_{100} v/s A shown in Figs. B-1, B-2 and B-3 respectively. R_{25}, R_{50} and R_{100} are the design storm point rainfall values (cm) for the design storm duration $T_D = 0.608\ (LL_c/\sqrt{S})^{0.405}$ in hrs. (rounded upto nearest one hour) after location of catchment under study on the

25-yr., 50-yr. and 100-yr. 24-hr. storm rainfall maps (Plates 9, 10 and 11) corresponding to 25-yr., 50-yr. and 100-yr. flood with the application of reduction factors (ratios) for T_D(hrs.) in Fig. 10 of section 4.2 i.e. multiplying the 25-yr., 50-yr. and 100-yr. 24-hr. point rainfall values in cm with the ratio obtained from Fig. 10 corresponding to design storm duration T_D (hrs.)

Note (i) Application of these formulae are illustrated in B-""SIMPLIFIED APPROACH" under sections 3 and 4.

(ii) Flood estimates from the above formulae are to be used for preliminary designs only.

(iii) For familiarisation with symbols in the formulae, see the cover page.

(2) By Multiple Regression Analysis

((i) for loss rate = 0.5 cm/hr.)

$$Q_{25} = \frac{3.299\ (A)^{0.851}\ (S)^{0.181}\ (R_{25})^{1.143}}{(L)^{0.181}\ (L_c)^{0.598}}$$

$$Q_{50} = \frac{2.694\ (A)^{0.831}\ (S)^{0.187}\ (R_{50})^{1.242}}{(L)^{0.196}\ (L_c)^{0.556}}$$

$$Q_{100} = \frac{3.421\ (A)^{0.84}\ (S)^{0.174}\ (R_{100})^{1.085}}{(L)^{0.123}\ (L_c)^{0.596}}$$

((ii) for loss rate = 1.0 cm/hr.)

$$Q_{25} = \frac{2.538\ (A)^{0.829}\ (S)^{0.199}\ (R_{25})^{1.211}}{(L)^{0.135}\ (L_c)^{0.666}}$$

$$Q_{50} = \frac{2.184\ (A)^{0.815}\ (S)^{0.197}\ (R_{50})^{1.311}}{(L)^{0.164}\ (L_c)^{0.632}}$$

$$Q_{100} = \frac{2.759\ (A)^{0.821}\ (S)^{0.181}\ (R_{100})^{1.179}}{(L)^{0.104}\ (L_c)^{0.667}}$$

((iii) for loss rate = 1.5 cm/hr.)

$$Q_{25} = \frac{2.017\ (A)^{0.823}\ (S)^{0.220}\ (R_{25})^{1.178}}{(L)^{0.076}\ (L_c)^{0.686}}$$

$$Q_{50} = \frac{1.712\ (A)^{0.796}\ (S)^{0.216}\ (R_{50})^{1.312}}{(L)^{0.099}\ (L_c)^{0.654}}$$

In the above formulae by multiple regression analysis, the explanation for symbols A, L, L_c, S, R_{25}, R_{50} and R_{100} are same as for Flood Formulae by DIRECT METHOD.

Note: (i) Application of the flood formulae based on multiple regression analysis are illustrated in B - "SIMPLIFIED APPROACH" under section 7.

(ii) The values of Q_{50} for model values of loss rate of 0.75 cm/hr. and 1.25 cm/hr. may be obtained by averaging the values of Q_{50} for loss rates of 0.5 cm/hr. and 1.0 cm/hr. in the former case and, 1.0 cm/hr. and 1.5 cm/hr. for the latter case as under:

(i) for loss rate of 0.75 cm/hr.

$$Q_{50} = \frac{Q_{50\ -0.5} + Q_{50\ -\ 1.0}}{2}$$

(ii) for loss rate of 1.25 cm/hr.

$$Q_{50} = \frac{Q_{50\ -\ 1.0} + Q_{50\ -\ 1.5}}{2}$$

Similarly the values of Q_{25} and Q_{100} for modal values of loss rate 0.75 cm/hr. and 1.25 cm/hr. could be obtained as above from the respective values of Q_{25} and Q_{100} for 0.5 cm/hr., 1.0 cm/hr. and 1.5 cm/hr.

INTRODUCTION

The purpose of the report entitled "Flood Estimation Report for Kaveri Basin subzone - 3(i)" presented herein is to estimate the design flood for fixing the waterway of bridges and culverts.

The report begins with sets of flood formulae based on direct method and by regression analysis to estimate the 25-yr. flood, 50-yr. flood and 100-yr. flood with different loss rates of 0.5 cm/hr. 1.0 cm/hr. and 1.5 cm/hr.

After the sets of N-year flood formulae, the report consists of three main parts. The first two parts 'A & B' pertain to "APPLICATION OF THE REPORT" with (A) detailed and (B) simplified approach. The third part (C) is the main report of six sections dealing with general features of the Kaveri subzone, nature and period of data collected, analysis of storm rainfall and flood events to derive the unitgraph, relationships between physiographic and unitgraph parameters of the gauged catchments to derive synthetic unitgraph for ungauged catchment, design storm rainfall design loss rates, base flow, computation of design flood peak and hydrograph for ungauged catchments, formula for linear water-way of the cross drainage structures and finally assumptions and conclusions of the report.

The report herein recommends the estimation of design flood for small and medium catchments varying in size from 25 to 1000 sq.km. Further the report may be used for larger catchments up-to 3000 sq.km. based on sound judgement and considering the data of neighbouring catchments also.

The utility of the report for frequency flood estimation in respect of small dams and minor cross drainage structures has also been brought out.

APPLICATION OF REPORT

(A) Detailed Approach

The flood estimation report for Kaveri Basin subzone-3(i) may be used for estimation of design flood (50-year flood) for ungauged and inadequately gauged catchments in the subzone. In order to elucidate the procedure, an illustrative example is given below with relevant details.

The various steps necessary to estimate the design flood peak/design flood hydrograph are as under:

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

ii) Determination of physiographic parameters viz: the catchment area (A), the length of the longest stream (L), length of the longest stream opposite the centre of gravity of the catchment to the point under study (L_c) and equivalent stream slope (S).

iii) Determination of 1-hour synthetic unitgraph parameters i.e. peak discharge per sq.km. (q_p), the peak discharge (Q_p), the basin lag (t_p), the peak time of U.G. (T_m), widths of the unitgraph at 50% and 75% of Q_p(W_{50} and W_{75}), widths of the rising limb of U.G. at 50% and 75% of Q_p (W_{R50} and W_{R75}) and time base of unitgraph (T_B).

iv) Drawing of a synthetic unitgraph.

v) Estimation of design storm duration (T_D).

vi) Estimation of point rainfall and areal rainfall for design storm duration (T_D).

vii) Distribution of areal rainfall during design storm duration (T_D) to obtain rainfall increments for unit duration intervals.

viii) Estimation of rainfall excess units after subtraction of prescribed design loss rate from rainfall increments.

ix) Estimation of base flow.

x) Computation of design flood peak.

xi) Computation of design flood hydrograph.

Step No. (xi) may not be necessary for those intending to estimate the design flood peak only.

Illustrative Example

The particulars of railway bridge catchment (treated as ungauged) for illustrating the procedure are as under:

i)	Name and number of subzone	:	Kaveri subzone-3(i)
ii)	Name of site (i.e. point of study	:	Railway Br. No. 37
iii)	Name of railway section	:	Jollarpettai – Salem (S.R.)
iv)	Name of Tributary	:	Pambar
v)	Shape of the catchment	:	Oblong
vi)	Site location	:	12° 24' 0" (Latitude) 78° 30' 18" (Longitude)
vii)	Topography	:	Moderately steep slope

The procedure is explained step by step.

Step - 1 : Preparation of Catchment Area Plan

The point of interest (railway bridge site in this case) was located on the Survey of India toposheet and catchment boundary was marked using the contours along the ridge line and also from the spot levels in the plains. A catchment area plan Fig.A-1 showing the main river, contours and spot levels was prepared.

Step - 2 : Determination of Physiographic Parameters

The following physiographic parameters were determined from the catchment area plan:

i)	Area (A)	= 294.00 sq.km.
ii)	Length of the longest stream (L)	= 43.00 km.
*iii)	Length of the longest stream opposite the centre of gravity of the catchment to the point of study (L_c)	= 22.72 km.
iv)	Equivalent Stream Slope (S)	$= \sum L_i (D_{i-1} + D_i) / L^2$ = 5.13 m/km
	Where L_i	= Length of ith segment in km
D_i, D_{i-1}		= Height above datum (with reduced level at the point of study) with respect of reduced levels of contours along the longest stream at ith and (i-1)th locations in metres.
L		= Length of the longest stream in km.

For detailed calculations of 'S' refer Table A-1.

In Table A-1, cols. (2) and (4) are the reduced distances and corresponding levels along the longest stream from the point of study to the contours across the stream or spot levels on the bank. Other columns are self-explanatory. Prepare L-section (longitudinal section) of the longest stream from the source to the point of study based on the data in cols. (2) and (4) as shown in Fig. A-1.

$$LL_c / \sqrt{S} = 43.47 \times 22.72 / \sqrt{5.13} = 436.05$$

* For finding the centre of gravity of the catchment, the catchment boundary is marked on a thick cardboard sheet or on a very thick paper. The cardboard sheet is cut along the boundary. The catchment plan so obtained on a cardboard sheet is hung at three different points on the boundary along with plumb line (small weight tied to a thread) and the three lines in three different positions are marked. The inter-section point of three lines will give the point of centre of gravity (C.G.) of the catchment.

Step - 3 : Determination of Synthetic 1-hr. Unitgraph Parameters

t_r = 1-hour unit duration for the unitgraph i.e. unitgraph produced due to one centimeter depth of rainfall excess in 1-hour duration has been considered.

The 1-hr. Synthetic U.G. parameters may be found out by using one of the following approaches:

(I) By using the Synthetic Relations

(II) By using Coaxial Diagram

(I) By Using the Synthetic Relations

The following relationships have been derived for estimating the 1-hour unitgraph parameters of a catchment in the Kaveri subzone-3(i):

(i) $t_p = 0.553\,(LL_c/\sqrt{S})^{0.405}$ (3.9.3)

(ii) $q_p = 2.043/(t_p)^{0.872}$ (3.9.4)

(iii) $W_{50} = 2.197/(q_p)^{1.067}$ (3.9.5)

(iv) $W_{75} = 1.325/(q_p)^{1.088}$ (3.9.6)

(v) $W_{R50} = 0.799/(q_p)^{1.138}$ (3.9.7)

(vi) $W_{R75} = 0.536/(q_p)^{1.109}$ (3.9.8)

(vii) $T_B = 5.083(t_p)^{0.733}$ (3.9.9)

(viii) $T_m = t_p + \frac{t_r}{2}$ (3.9.10)

(ix) $Q_p = q_p \times A$ (3.9.11)

In the above equations, the physiographic parameters L, L_c and S of the catchment (Fig. A-1) and 1-hr. unitgraph (Fig. A-2) parameter t_r, t_p, t_m, q_p, Q_p, W_{50}, W_{75}, W_{R50}, W_{R75} and T_B for the catchment under study upto Br. No. 37 signify as under:

L, L_c, S and A already explained in Step - 2.

t_r = unit duration of unitgraph = 1.0 hr.

t_p = time from the centre of rainfall excess (1.0 cm) in 1-hr. unit duration to the U.G. peak in hours.

T_m = time from the start of rise to the peak of U.G (hrs.)

q_p = peak discharge of U.G. per unit area (cumecs per sq.km)

Q_p = peak discharge of U.G. (cumecs)

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

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

W_{R50} = width of the U.G. on the rising side at 50% of peak discharge ordinate (hr)

W_{R75} = width of the U.G. on the rising side at 75% of peak discharge ordinate (hr.)

T_B = Base width of the U.G. (hr.)

Using the above relationships, the 1-hr. U.G. parameters were calculated as under:

(i) Calculation of t_p using the equation 3.9.3 by substituting the value of $LL_c / \sqrt{S}$ = 436.05 estimated in Step - 2

$t_p = 0.553 \; (436.05)^{0.405} = 6.48$ hrs.

Rounded off to 6.50 hrs.

(ii) Calculation of q_p using the equation 3.9.4 by substituting the value of t_p = 6.48 hrs.

$q_p = 2.043/(6.48)^{0.872} = 2.043/5.101 = 0.400$ cumecs/sqkm.

(iii) Calculation of W_{50} using the equation 3.9.5 by substituting the value of q_p = 0.400 cumecs/sqkm.

$W_{50} = 2.197/(0.40)^{1.067} = 2.197/0.376 = 5.84$ hrs.

(iv) Calculation of W_{75} using the equation 3.9.6 by substituting the value of q_p = 0.40 cumecs/sqkm

$W_{75} = 1.325/(0.40)^{1.088} = 1.325/0.369 = 3.59$ hrs.

(v) Calculation of W_{R50} using the equation 3.9.7 by substituting the value of q_p = 0.40 cumecs/sqkm.

$W_{R50} = 0.799/(0.40)^{1.138} = 0.799/0.352 = 2.27$ hrs.

(vi) Calculation of W_{R75} using the equation 3.9.8 by substituting the value of q_p = 0.40 cumecs/sqkm.

$W_{R75} = 0.536/(0.40)^{1.109} = 0.536/0.362 = 1.48$ hrs.

(vii) Calculation of T_B using the equation 3.9.9 by substituting the value of t_p = 6.48 hrs.

$T_B = 5.083\ (6.48)^{0.733} = 5.083 \times 3.93 = 19.98$ hrs.

Say 20.0 hrs.

(viii) Calculation of T_m using the equation 3.9.10 by substituting the values of t_p = 6.50 hrs. and t_r = 1.0 hr.

$T_m = 6.5 + \frac{1}{2} = 6.5 + 0.5 = 7.00$ hrs.

(ix) Calculation of Q_p using the equation 3.9.11 by substituting the value of q_p = 0.40 cumecs/sqkm and

A = 294.00 sqkm.

$Q_p = 0.40 \times 294.00 = 117.60$ cumecs.

(II) By using Co-axial Diagram

CO-axial diagram based on synthetic relations vide equation 3.9.3 to 3.9.9 under Section-3 has been drawn in Fig. A-3 for estimating the parameters of synthetic unitgraphs. The application of co-axial diagram in Fig.A-3 with respect to the above illustrative example is explained as under:

i) Calculate $LL_c / \sqrt{S}$

L = 43.47 km, L_c = 22.72 km and S = 5.13 m/km as found out in Step-2 of illustrative example.

$LL_c / \sqrt{S} = 43.47 \times 22.72 / \sqrt{5.13} = 436.05$

ii) Move vertically upwards for the value of $LL_c / \sqrt{S}$ = 436.05 to read from Curve-1 the value of t_p = 6.48 hrs.

iii) Move horizontally for t_p = 6.48 hrs. to read from Curve-2 the value of q_p = 0.400 cumecs/sqkm.

iv) Move vertically downwards for q_p = 0.400 cumecs/sqkm to read from Curve-3 the value of W_{50} = 5.84 hrs., from Curve-4 the value of W_{75} = 3.59 hrs., from Curve-5 the value of W_{R50} 2.27 hrs. and from Curve-6 the value of W_{R75} 1.48 hrs.

v) Move vertically upwards for q_p = 0.400 cumecs/sqkm to read from Curve-7 the value of T_B = 19.98 hrs. Say 20.0 hrs.

vi) The value of t_p found out in (i) above, may be rounded off to 6.5 hrs.

T_m (peaking time) $= t_p + t_r/2$

$= 6.5 + 0.5 = 7$ hrs.

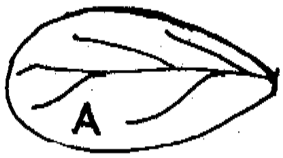
vii) Q_p (peak discharge of UG) = $q_p \times A$
= 0.40 x 294.0 = 117.60 cumecs.

Step - 4: <u>Preparation of 1-hour Synthetic Unitgraph</u>

The parameters got in Step-3 above were plotted to scale on a graph paper as shown in Fig.A-1. The points were joined to fit a trial Synthetic Unitgraph. By definition, the volume of the Unitgraph must be equivalent to 1.0 cm depth of direct runoff over the entire catchment (A) in sq.km.

(a) Volume of direct runoff from runoff depth (d) of 1.0 cm on the entire catchment (A) in sq;km.

= Ax1000 x 1000 (sq.m) x d/100 (m) = ( ) expressed in cubicmetres

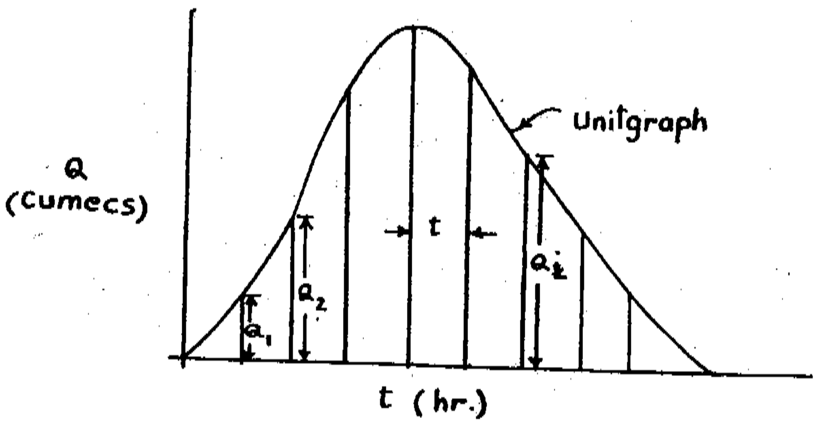


1 cm = 1/100 m depth of direct runoff over the catchment area (A) in sq;km.

(b) Volume of direct runoff graph (Synthetic Unitgraph) obtained from the addition of all the unitgraph ordinates at time interval equal to unit duration (t_r) of U.G. = $\sum Q_i \times t_r$

= $\sum Q_i$ Cubicmetre per sec. x t_r x 3600 seconds

= ( ) expressed in cubic metres.



$\sum Q_i$ = sum of the ordinates of unitgraph at t-hr. interval (in this case 1-hr.)

(a) should be equal to (b)

i.e. A x 1000 x 1000 x d/100 = $\sum Q_i \times t_r \times 3600$

Therefore $\sum Q_i$ = A/(0.36 tr)

t_r = 1 in this case

Therefore $\sum Q_i$ = A/(0.36 x 1) = A/0.36

All the ordinates of Synthetic U.G. so obtained in Fig.A-2 were summed up at 1-hr. interval to get a total volume of 816.7 cumecs which tallied with the computed value from A/(0.36 t_r) = 294.0/(0.36 x 1) = 816.7 cumecs. Therefore, the 1-hour Synthetic U.G. so drawn in Fig. A-2 was found to be in order.

In case, the summed up values of all the ordinates of Synthetic U.G. do not tally with the computed value from A/(0.36 x t_r) then some of the ordinates in the rising and falling limbs or only in the falling limb of the U.G. may be suitably changed (slightly increased or decreased) keeping at the same time the shape of U.G. a smooth one. Normally one or two trials are carried out to adjust the volume of Synthetic U.G. so as to obtain 1.0 cm of direct run-off over the entire catchment area (A) in sq.km.

Step (5) : Estimation of Design Storm Duration

The design storm duration is

T_D = 1.1 x t_p = 1.1 x 6.5 = 7.15 hrs.

Adjusting the design storm duration to nearest one hour, the adopted design storm duration (T_D) is 7.0 hrs.

Step (6) : Estimation of Point Rainfall and Areal Rainfall

The point rainfall estimate for 50-year return period and for duration of 24-hr. is read against the location of Rly. Br. No. 37 from 50-yr. 24-hr. isopluvial map (see Plate - 10 in Section 4.2). The value of 50-yr. 24-hr. point rainfall = 17.5 cm.

The design storm duration (T_D) for the catchment is 7.0 hrs. The point rainfall estimate for 7.0 hrs. was obtained by multiplying the 50-yr. 24-hr. point rainfall of 17.5 cm with the value of 0.74 read from Fig. 10 in Section 4.2.

50-yr. 7-hr. point rainfall = 17.5 x 0.74 = 12.95 cm.

The above point rainfall estimate of 12.95 cm was multiplied by areal reduction factor of 0.79 corresponding to a catchment area of 294.0 sq.km. and for a design storm duration of 17 hrs. as interpolated from Table-A-3 (areal to point rainfall ratios) or from Fig. 11(a).

50-yr. 7-hr. areal rainfall = .12.95 x 0.79 = 10.23 cm.

Step - (7) : Time Distribution of Areal Rainfall

The areal rainfall estimate for 50-yr. 7-hr. areal rainfall of 10.23 cm was distributed to give one hourly gross rainfall units by using the Distribution Co-efficients for duration of 7 hrs. from Table A-2: Time Distribution Co-efficients of Areal Rainfall as under:

Duration (hrs.)	Distribution Co-efficients	Areal Storm rainfall (cm)	1-hr. rainfall (cm)
(1)	(2)	(3)	(4)
7	1.00	10.23	0.31
6	0.97	9.92	0.30
5	0.94	9.62	0.52
4	0.89	9.10	0.61
3	0.83	8.49	0.82
2	0.75	7.67	1.33
1	0.62	6.34	6.34

Areal Storm rainfall values in Col.(3) for durations of 6, 5, 4, 3, 2 and 1 hrs. in col. (1) were obtained by multiplying the 7-hr. storm rainfall value of 10.23 cm with the distribution coefficients in col. (2) for respective durations. 1-hr. rainfall units in col. (4) were obtained by subtraction of successive values of storm rainfall from 1-hr. onwards in col. (3)

Step (8) : Estimation of Rainfall Excess Units

Design loss rate of 0.50 cm/hr. vide section 3.11 is subtracted from 1-hr. rainfall increments in col. (4) of Table in Step - 7 to obtain the 1-hr. rainfall excess units as under:

Duration (hr.)	1-hr. rainfall (cm)	Loss rate (cm/hr)	1-hr. rainfall excess (cm)
(1)	(2)	(3)	(4)
1	6.34	0.50	5.84
2	1.33	0.50	0.83
3	0.82	0.50	0.32
4	0.61	0.50	0.11
5	0.52	0.50	0.02
6	0.30	0.50	-
7	0.31	0.50	-

Step (9) : Estimation of Base Flow

The design base flow rate vide Section 3.12 is 0.05 cumecs per sq.km. Therefore, the total base flow for a catchment area of 294.0 sq.km. = 294.00 x 0.05 = 14.70 cumecs.

Step (10) : Estimation of Design Flood (Peak only)

For estimation of the peak discharge, the rainfall excess units have to be re-arranged against the unitgraph ordinates such that the maximum rainfall excess is placed against the maximum U.G. ordinate, the next lower value of rainfall excess comes against the next lower value of U.G. ordinate and so on.

In the present case, the maximum discharge ordinate of U.G. is 117.6 cumecs at 7.0 hrs. vide Fig. A-3. The maximum 1-hour rainfall excess unit of 5.84 cm (from Step-8) was placed against the max. discharge ordinate of 117.60 cumecs. Likewise the next lower rainfall excess unit was placed against the next lower U.G. ordinate in the following Table and so on. Summation of the products of cols. (2) and (3) gives the total direct runoff to which base flow is added to get the maximum discharge.

Time (hrs.)	U.G. ordinate (cumecs).	1-hr. rainfall excess (cm)	Direct runoff (cumecs)
1	2	3	4
6	103.6	0.32	33.15
7	117.6	5.84	686.78
8	109.0	0.83	90.47
9	89.0	0.11	9.79
10	70.0	0.02	1.40
		Total	821.59
		Add base flow from Step-9	14.70
		Total peak discharge	836.29

Those interested in computation of design flood hydrograph may go to Step-11.

Step (11) : Computation of Design Flood Hydrograph

The 1-hour rainfall excess sequence shown in col. 3 of Table in Step-10 was reversed to obtain the critical sequence as shown below:

Time (hrs.)	Critical 1-hr. rainfall excess (cm) sequence
(1)	(2)
1	0.02
2	0.11
3	0.83
4	5.84
5	0.32

For computation of design flood hydrograph, the U.G. ordinates for 1-hr. interval were tabulated in col. (2) of Table A-4 against time (hrs.) in col. (1). The critical sequence of rainfall sequence of 1-hr. rainfall excess units as given above were entered in cols. (3) to (7) horizontally as shown in Table A-4. The direct runoff resulting from each of the 1-hr. rainfall excess units was obtained by multiplying the 1-hr. rainfall excess unit with the synthetic U.G. ordinates in col. (2) and the direct runoff values were entered in vertical columns against each unit with a successive log of 1-hour, since the unit duration of S.U.G. is 1-hour. The direct runoff so obtained is shown in cols. (3) to (7). The direct runoffs were added horizontally and the total direct runoff is shown in col. (8). The total base flow of 14.70 cumecs was entered in col. (9). Col. (10) gives the addition of cols. (8) and (9) to get the design flood hydrograph ordinates. The total discharge ordinates in col. (10) were plotted against time in col. (1) to get the design flood hydrograph in Fig. A-4.

TABLE A-I

COMPUTATION OF EQUIVALENT SLOPE(S) OF BR. NO.- 37

(C.A. = 294.0 Sq.km.)

Sl. No.	Reduced distance starting from Bridge Site. (Kms)	Reduced levels of river bed. (m)	Length of each segment Li (Kms)	Height above datum* (Di) difference between the datum & the ith R.L. (m)	$D_{i-1}+D_i$ (m)	$L_i(D_{i-1}+D_i)$ (mxKm)
1	2	3	4	5	6	7=(4)x(6)
1.	-	365.70	-	-	-	-
2.	3.22	381.10	3.22	15.40	15.40	49.59
3.	6.44	396.34	3.22	30.64	46.04	148.25
4.	9.66	411.59	3.22	45.89	76.53	246.43
5.	13.68	426.83	4.02	61.13	107.02	430.22
6.	17.71	442.07	4.03	76.37	137.50	554.12
7.	20.12	457.32	2.41	91.62	167.99	404.86
8.	22.72	409.51	2.60	103.81	195.43	508.12
9.	24.15	472.56	1.43	106.86	210.67	301.26
10.	26.56	487.80	2.41	122.10	228.96	551.79
11.	28.98	503.05	2.42	137.35	259.45	627.87
12.	33.00	518.29	4.02	152.59	289.94	1165.56
13.	35.42	533.54	2.42	167.84	320.43	775.44
14.	40.25	609.76	4.83	244.06	411.90	1989.48
15.	42.66	685.98	2.41	320.28	564.34	1360.06
16.	43.47	762.20	0.81	396.50	716.78	580.59

$\sum L_i(D_{i-1}+D_i) = 9693.64$

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

$$= \frac{9693.64}{(43.47)^2} = 5.13 \text{ M/Km}$$

* Datum = 365.70 m (i.e. Reduced level of river bed at the point of study)

TABLE-A-2: TIME DISTRIBUTION COEFFICIENT OF AREAL RAINFALL
KAVERI BASIN SUBZONE-3 (i)

Time in Hours.	DISTRIBUTION COEFFICIENT FOR DESIGN STORM DURATION OF 2-24 HOURS																							Time in Hours.
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)
24																							1	24
23																						1.00	0.99	23
22																					1.00	0.99	0.98	22
21																				1.00	0.99	0.98	0.97	21
20																			1.00	0.99	0.98	0.97	0.96	20
19																		1.00	0.99	0.98	0.96	0.95	0.94	19
18																	1.00	0.99	0.98	0.96	0.95	0.94	0.93	18
17																1.00	0.98	0.97	0.96	0.95	0.94	0.93	0.92	17
16															1.00	0.99	0.97	0.96	0.94	0.93	0.92	0.91	0.90	16
15														1.00	0.98	0.97	0.96	0.94	0.93	0.92	0.91	0.90	0.89	15
14													1.00	0.98	0.97	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	14
13												1.00	0.98	0.97	0.95	0.93	0.92	0.91	0.90	0.89	0.88	0.88	0.87	13
12											1.00	0.98	0.96	0.95	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.87	0.86	12
11										1.00	0.98	0.96	0.94	0.93	0.92	0.91	0.90	0.88	0.87	0.86	0.86	0.85	0.84	11
10									1.00	0.98	0.97	0.94	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.84	0.83	10
9								1.00	0.98	0.96	0.95	0.92	0.90	0.89	0.88	0.87	0.87	0.86	0.84	0.83	0.82	0.82	0.81	9
8							1.00	0.98	0.96	0.94	0.93	0.90	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.80	0.80	0.79	8
7						1.00	0.98	0.95	0.93	0.92	0.90	0.88	0.87	0.85	0.84	0.83	0.82	0.81	0.80	0.79	0.78	0.78	0.77	7
6					1.00	0.97	0.94	0.93	0.91	0.89	0.87	0.84	0.83	0.83	0.82	0.81	0.80	0.78	0.77	0.77	0.76	0.75	0.75	6
5				1.00	0.95	0.94	0.92	0.89	0.87	0.84	0.83	0.82	0.81	0.80	0.79	0.78	0.76	0.76	0.75	0.74	0.73	0.72	0.71	5
4			1.00	0.94	0.90	0.89	0.87	0.84	0.82	0.79	0.79	0.79	0.78	0.76	0.75	0.74	0.73	0.72	0.71	0.70	0.69	0.69	0.67	4
3		1.00	0.93	0.87	0.83	0.83	0.81	0.79	0.76	0.74	0.73	0.73	0.73	0.72	0.70	0.68	0.68	0.67	0.66	0.65	0.63	0.63	0.63	3
2	1.00	0.87	0.83	0.79	0.75	0.75	0.73	0.70	0.67	0.65	0.64	0.66	0.66	0.64	0.63	0.63	0.62	0.61	0.59	0.58	0.58	0.57	0.57	2
1	0.80	0.69	0.69	0.66	0.64	0.62	0.61	0.55	0.53	0.51	0.51	0.55	0.55	0.54	0.53	0.51	0.50	0.49	0.48	0.48	0.47	0.45	0.44	1

Note: Read vertically up under the appropriate design storm duration to obtain distribution coefficient

TABLE-A-3: AREAL TO POINT RAINFALL RATIOS

KAVERI BASIN (SUBZONE- 3(i)

Area (Sq.km.)	Durations (hours)																								Area (Sq.Km.)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
	Point to Areal rainfall ratios																								
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0
50	0.90	0.91	0.93	0.93	0.93	0.94	0.94	0.94	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.96	0.96	0.96	0.96	0.96	0.97	0.97	0.97	0.97	50
100	0.82	0.84	0.86	0.87	0.89	0.90	0.90	0.90	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.92	0.92	0.92	0.93	0.93	0.93	0.94	0.94	0.94	100
150	0.75	0.78	0.82	0.83	0.85	0.86	0.86	0.86	0.87	0.87	0.87	0.88	0.88	0.88	0.88	0.89	0.89	0.89	0.90	0.90	0.90	0.91	0.91	0.91	150
200		0.72	0.78	0.79	0.81	0.83	0.83	0.84	0.84	0.85	0.85	0.86	0.86	0.86	0.86	0.87	0.87	0.87	0.88	0.88	0.88	0.88	0.88	0.88	200
250		0.66	0.75	0.77	0.79	0.81	0.81	0.82	0.82	0.83	0.83	0.84	0.84	0.84	0.84	0.85	0.85	0.85	0.86	0.86	0.86	0.86	0.86	0.86	250
300						0.79	0.79	0.80	0.81	0.81	0.82	0.83	0.83	0.83	0.83	0.84	0.84	0.84	0.85	0.85	0.85	0.85	0.85	0.85	300
350						0.77	0.77	0.78	0.79	0.80	0.81	0.82	0.82	0.82	0.82	0.83	0.83	0.83	0.84	0.84	0.84	0.84	0.84	0.84	350
400						0.76	0.77	0.78	0.79	0.80	0.81	0.81	0.81	0.81	0.81	0.82	0.82	0.82	0.83	0.83	0.83	0.83	0.83	0.83	400
450						0.75	0.76	0.77	0.78	0.79	0.80	0.80	0.80	0.80	0.80	0.81	0.81	0.81	0.82	0.82	0.82	0.82	0.82	0.82	450
500						0.75	0.76	0.76	0.77	0.77	0.78	0.79	0.79	0.79	0.79	0.80	0.80	0.80	0.81	0.81	0.81	0.81	0.81	0.81	500
600												0.78	0.78	0.78	0.78	0.79	0.79	0.79	0.80	0.80	0.80	0.81	0.81	0.81	600
700												0.78	0.78	0.78	0.78	0.79	0.79	0.79	0.79	0.79	0.79	0.80	0.80	0.80	700
800												0.77	0.77	0.77	0.77	0.78	0.78	0.78	0.79	0.79	0.79	0.79	0.80	0.80	800
900												0.77	0.77	0.77	0.77	0.78	0.78	0.78	0.79	0.79	0.79	0.79	0.79	0.79	900
1000												0.76	0.76	0.76	0.76	0.77	0.77	0.77	0.78	0.78	0.78	0.79	0.79	0.79	1000
1500																								0.78	1500
2000																								0.77	2000
2500																								0.77	2500

TABLE-A-4 COMPUTATION OF DESIGN FLOOD HYDROGRAPH OF PAMBAR RIVER AT RLY.BR. No.37
SUB-ZONE-3(i)

TIME IN HRS.	SYNTHETIC UNIT HYDROGRAPH ORDINATES (Cumecs)	1-HOURLY RAINFALL EXCESS (cm) DIRECT RUNOFF (CUMECS)					Total Direct runoff (Cumecs)	BASE FLOW (Cumecs)	TOTAL Flood flow (Cumecs)	REMARKS
		0.02	0.11	0.83	5.84	0.32				
1	2	3	4	5	6	7	8	9	10	11
0	0	0					0	14.70	14.70	
1	3.0	0.06	0				0.06	14.70	14.76	
2	9.0	0.18	0.33	0			0.51	14.70	15.21	
3	20.0	0.40	0.99	2.49	0		3.88	14.70	18.58	
4	38.5	0.77	2.20	7.47	17.52	0	27.96	14.70	42.66	
5	68.0	1.36	4.24	16.60	52.56	0.96	75.72	14.70	90.42	
6	103.6	2.07	7.48	31.96	116.80	2.88	161.19	14.70	175.89	
7	117.6	2.35	11.40	56.44	224.84	6.40	301.43	14.70	316.13	
8	109.0	2.18	12.94	85.99	397.12	12.32	510.55	14.70	525.25	
9	89.0	1.78	11.99	97.61	605.02	21.76	738.16	14.70	752.86	
10	70.0	1.40	9.79	90.47	686.78	33.15	821.59	14.70	836.29	Peak Discharge
11	53.0	1.06	7.70	73.87	636.56	37.63	756.82	14.70	771.52	
12	40.5	0.81	5.83	58.10	519.76	34.88	619.38	14.70	634.08	
13	31.0	0.62	4.46	43.99	408.80	28.48	486.35	14.70	501.05	
14	24.0	0.48	3.41	33.62	309.52	22.40	369.43	14.70	384.13	
15	17.5	0.35	2.64	25.73	236.52	16.96	282.20	14.70	296.90	
16	12.0	0.24	1.93	19.92	181.04	12.96	216.09	14.70	230.79	
17	7.0	0.14	1.32	14.53	140.16	9.92	166.07	14.70	180.77	
18	3.0	0.06	0.77	9.96	102.20	7.68	120.67	14.70	135.37	
19	1.0	0.02	0.33	5.81	70.08	5.60	81.84	14.70	96.54	
20	0	0	0.11	2.49	40.88	3.84	47.32	14.70	62.02	
21			0	0.83	17.52	2.24	20.59	14.70	35.29	
22				0	5.84	0.96	6.80	14.70	21.50	
23					0	0.32	0.32	14.70	15.02	
24						0		14.70	14.70	
25										

(ii) Simplified Approach

B.1 Direct 50-year Flood Peak Formula

For the field engineers interested in the 50-year flood peak only for preliminary assessment of waterway of bridges and cross drainage structures, a direct 50-year flood peak formula, an easy and simple one, has been evolved based on the studies contained in this report.

Theory

The basic equation for computation of 50-year flood peak can be expressed as follows:

$$Q_{50} = C \times q_p \times A \times R_{50} \qquad \ldots (1)$$

Where Q_{50} = 50-year flood peak (cumecs)

q_p = peak discharge of unitgraph per unit area of catchment (cumec/sq.km.)

A = catchment area (sq.km.)

R_{50} = 50-year point rainfall (cm) for design storm duration (T_D).

C = a constant factor.

In the above equation (1), the equation relating q_p with t_p i.e. $q_p = 2.043/(t_p)^{0.872}$ was substituted and further the equation relating t_p with the physiographic parameters like L, L_c and S i.e. $t_p = 0.553\left(\frac{LL_c}{S}\right)^{0.405}$ was substituted in the earlier equation to get the following derived equation:

$$Q_{50} = C \times 3.422 \frac{S^{0.176}}{(LL_c)^{0.353}} \times A \times R_{50}$$

$$Q_{50} = \frac{K_{50}(S)^{0.176} \; A \; R_{50}}{(LL_c)^{0.353}}$$

Where Q_{50}, A and R_{50} are same as in equation (1)

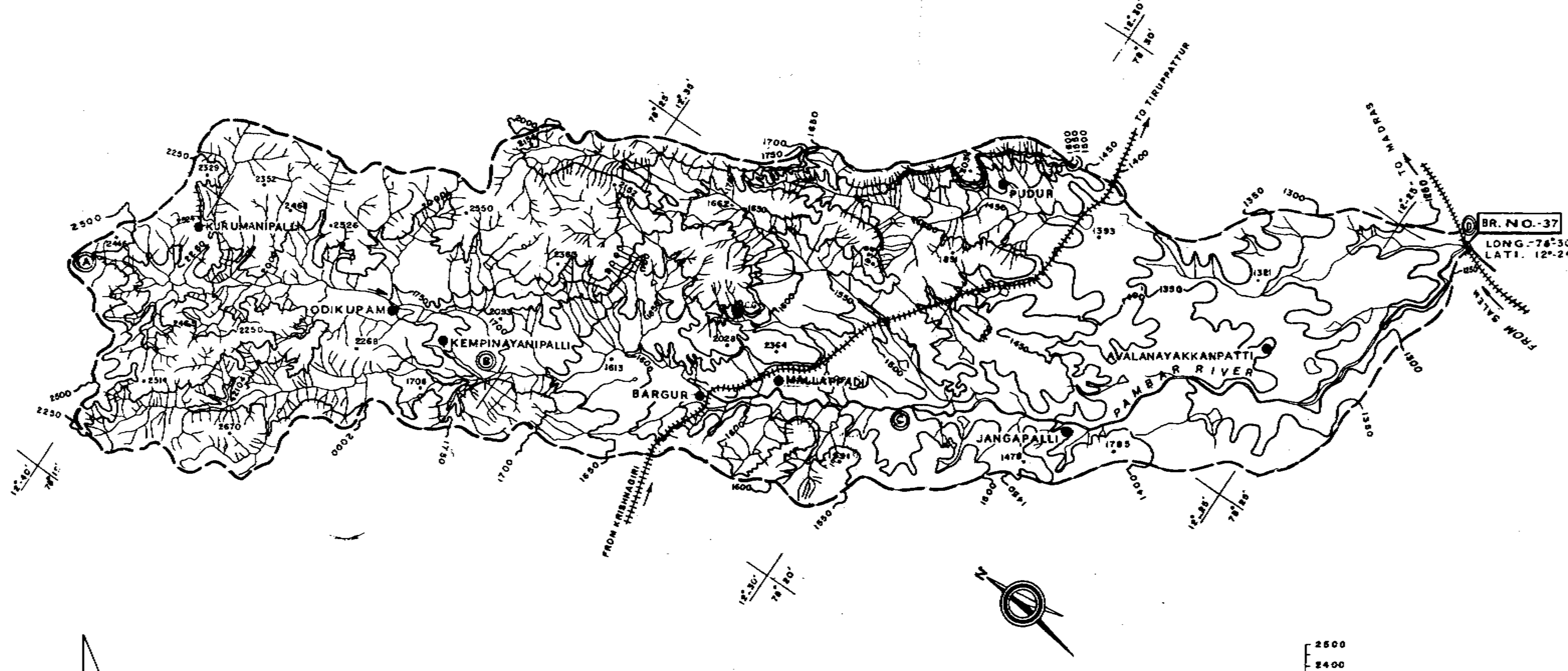
L = length of longest main stream (km)

L_c = length of longest main stream opposite the centre of gravity of the catchment area upto the point of study.

S = equivalent slope (m/km) of the main stream

K_{50} = C x 3.422 a constant factor represents the effects of point to areal reduction factor, temporal distribution of rainfall, design loss rate and base flow depending on the size of the catchment.

FIG.-A-1



NOTES

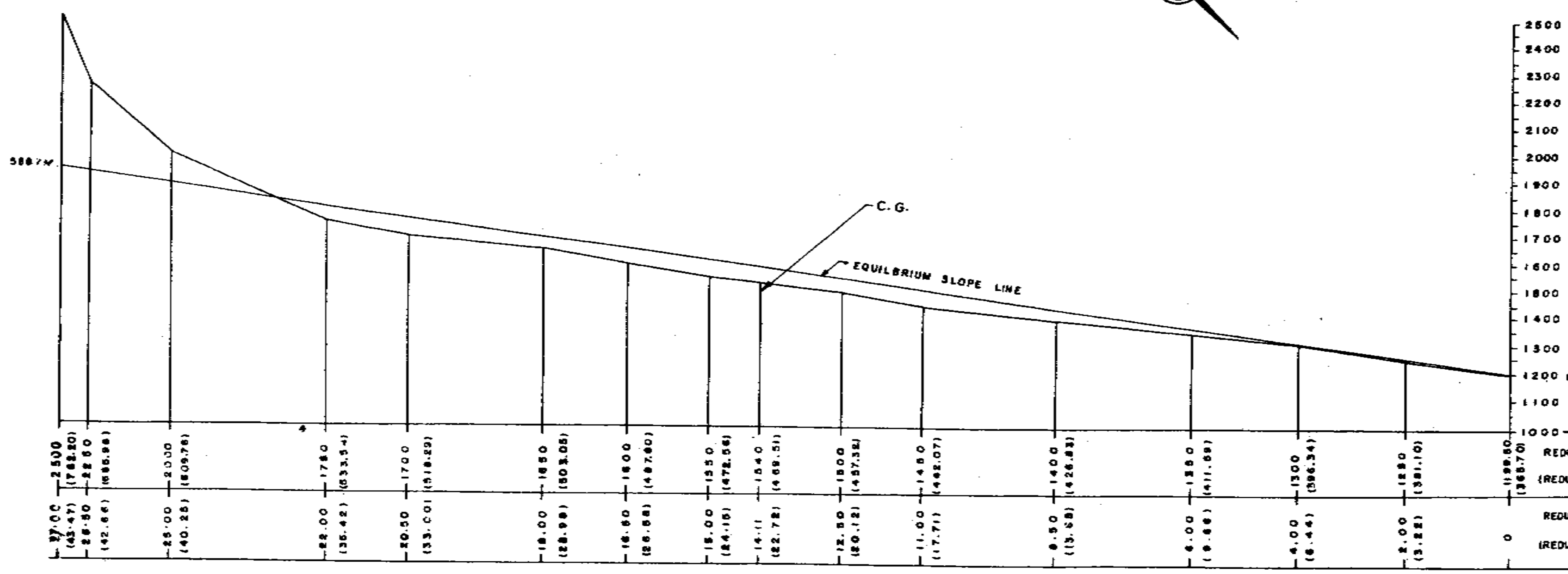
1. ALL LEVELS CORRESPOND TO G.T.S. DATUM
2. H.F.L. AT GAUGE SITE 369.22 Mts.

LEGEND

1. CATCHMENT BOUNDARY
2. RAILWAY LINE
3. RIVER
4. RAINGAUGE STATIONS
5. CONTOURS — 1500
6. SPOT LEVELS — • 1275
7. CENTRE OF GRAVITY — CG
8. TOPO SHEET NO. — 57 L/6, 7, 11 (1915 EDITION)

DETAILS OF CATCHMENT

1. AREA OF THE CATCHMENT — 294.00 Sq.km.
2. SHAPE OF CATCHMENT — OBLONG
3. L. — 43.47 km.
4. LC. — 22.72 km.
5. Wc. — 8.86 km.
6. SLOPE (EQUILIBRIUM) — 5.13 m/km.



LONGITUDINAL SECTION OF PAMBAR RIVER AT A B C D

SCALE: HORIZONTAL — FURLONGS 8 6 4 2 0 1 2 3 4 5 6 MILES; VERTICAL — FEET 200 100 0 200 400 600 800 1000 1200 FEET

SI. NO.	NAME OF RAINGAUGE STATION	LOCATION		STATION WTS.	
		LONG.	LATI.	1961	1966-69
1.	KURUMANIPALLI	78°-19'-32"	12°-40'-00"	0.152	—
2.	ODIKUPAM	78°-20'-00"	12° 36' 41"	—	0.375
3.	KEMPINAYANIPALLI	78°-20'-18"	12°-36'-00"	0.221	—
4.	BARGUR	78°-21'-40"	12° 32' 34"	0.113	—
5.	MALLAPPADI	78°-22'-42"	12° 31' 41"	—	0.358
6.	PUDUR	78°-27'-00"	12°-30'-06"	0.207	—
7.	JANGAPALLI	78°-27'-36"	12°-24'-30"	0.155	—
8.	AVALANAYAKKANPATTI	78°-27'-18"	12°-25'-36"	0.152	0.267

SCALE

FURLONGS 8 6 4 2 0 1 2 3 MILES

KMS. 1 0.5 0 1 2 3 4 5 KMS.

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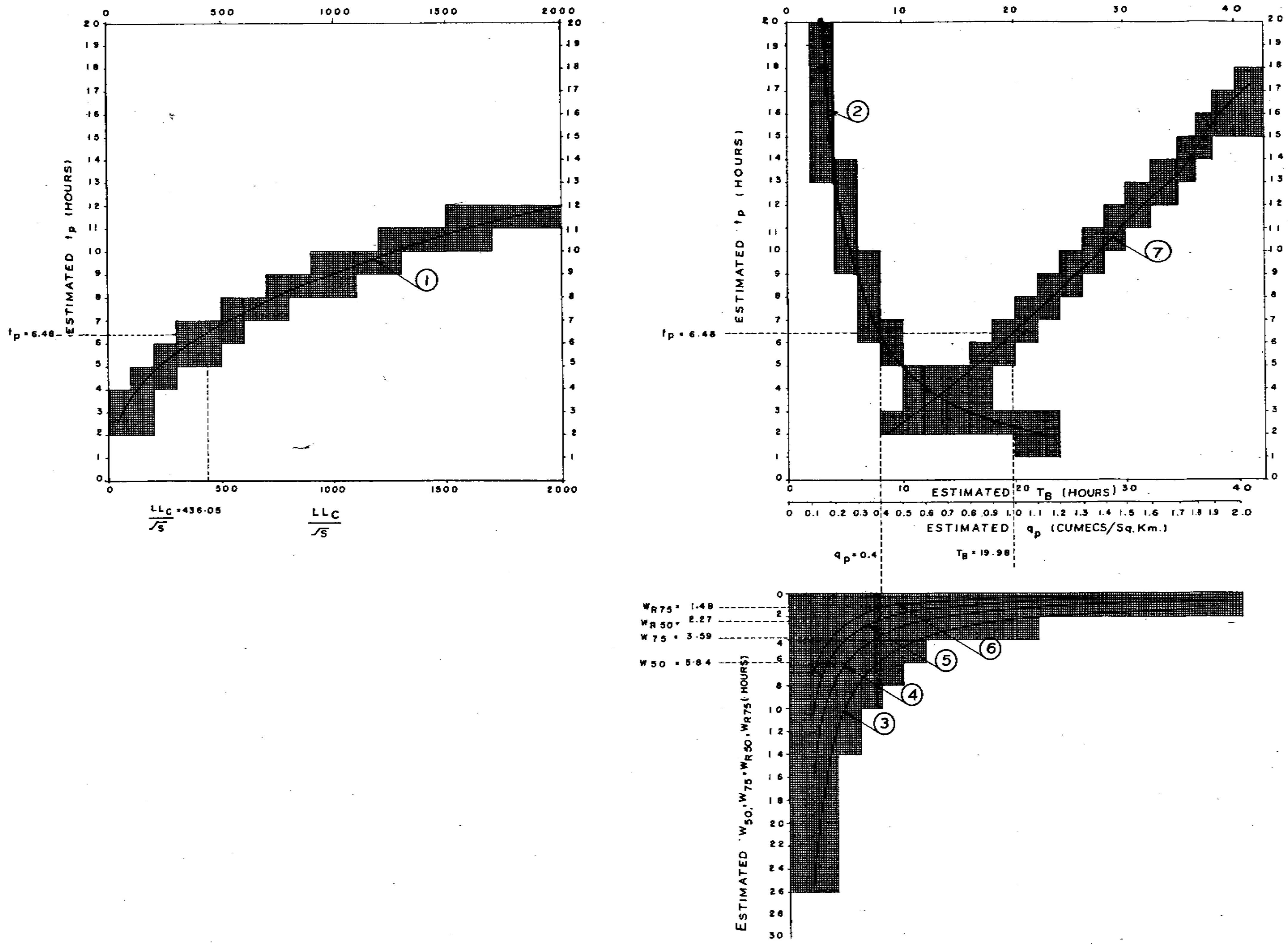
HYDROLOGY (SMALL CATCHMENTS) DTE.

CATCMENT AREA PLAN FOR BR. NO. 37 AT KM. 232/12-13 ON JALARPETTAI-SALEM SECTION. SOUTHERN RLY. SUB ZONE 3 (I)

DRAWN BY.
S. N. MALHOTRA
P. N. BHALLA

CHECKED BY.
A. K. GHOSH

FIG. A-2



CURVE NO.	INDEPENDENT VARIABLE	DEPENDENT VARIABLE
①	$\frac{LL_c}{\sqrt{S}}$	t_p
②	t_p	q_p
③	q_p	W_{50}
④	q_p	W_{75}
⑤	q_p	W_{R50}
⑥	q_p	W_{R75}
⑦	t_p	T_B

NOTE:-

1 FOR USE OF COAXIAL DIAGRAM TO ILLUSTRATIVE EXAMPLE, SEE - 3 (ii) OF APPLICATION PART OF THE REPORT

2 CHECK THE VALUE OF t_p OBTAINED FROM CURVE ① WITH THE EQUATION $t_p = 0.553\ (LL_c/\sqrt{S})^{0.405}$ FOR ABSOLUTE ACCURACY.

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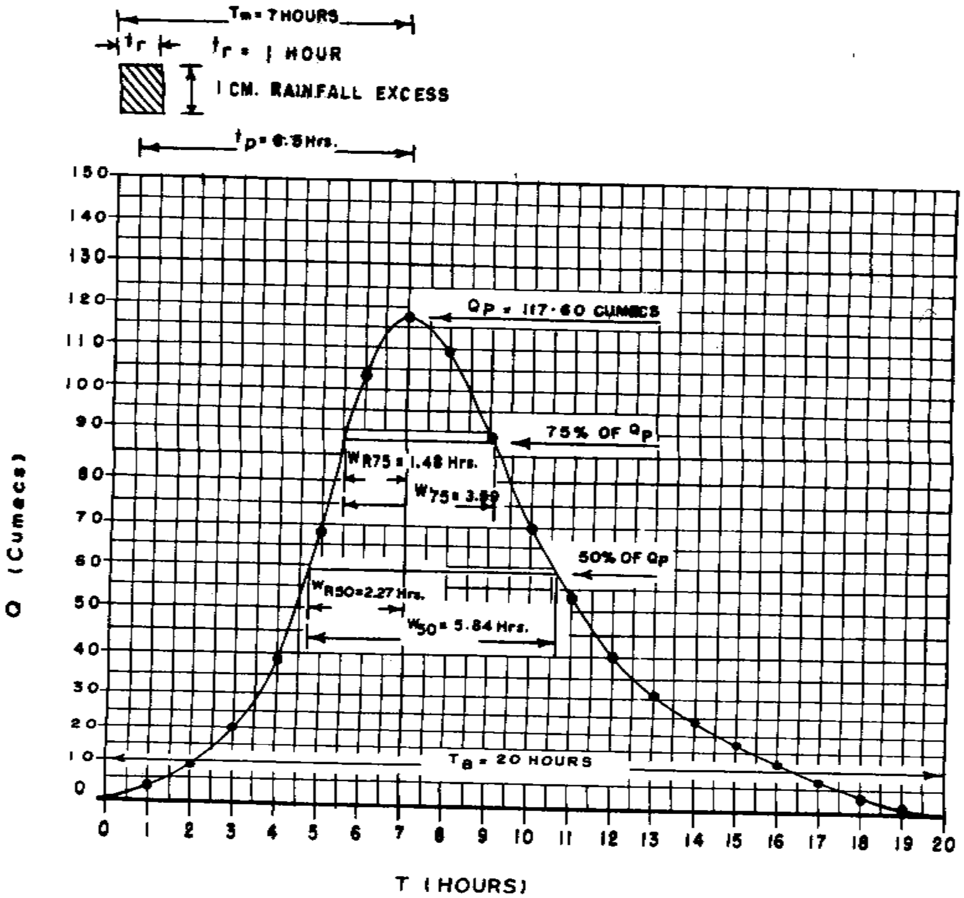
KAVERI BASIN
SUB ZONE 3(i)
COAXIAL RELATIONS FOR ESTIMATING 1-HR. SYNTHETIC UNITGRAPH PARAMETRES.

DRAWN BY	CHECKED BY
S. N. MALHOTRA P. N. BHALLA	A. K. GHOSH.

FIG.-A-3



SYNTHETIC U.G. PARAMETERS

C.A = 294.00 Sq. Km.

t_p = 6.50 HOURS.

T_B = 20.00 HOURS.

Q_P = 117.60 CUMECS.

W_{50} = 5.84 HOURS.

W_{75} = 3.59 HOURS.

W_{R50} = 2.27 HOURS.

W_{R75} = 1.48 HOURS.

q_p = 0.40 CUMECS/Sq.Km.

$\frac{L L_C}{\sqrt{S}}$ = 436.05

T_m = 7.00 HOURS.

d = 1.00 Cm.

$$\Sigma q_i = \frac{A \times d}{t_r \times 0.36} = \frac{294.00 \times 1.00}{1.00 \times 0.36}$$

= 816.70 CUMECS.

TIME IN HOURS.	SYNTHETIC U.G. ORDINATES.
0	0 (CUMECS)
1	3.0
2	9.0
3	20.0
4	38.5
5	68.0
6	103.6
7	117.6
8	109.0
9	89.0
10	70.0
11	53.0
12	40.5
13	31.0
14	24.0
15	17.5
16	12.0
17	7.0
18	3.0
19	1.0
20	0
TOTAL	816.70 CUMECS

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE

KAVERI BASIN

SUB ZONE-3(i)

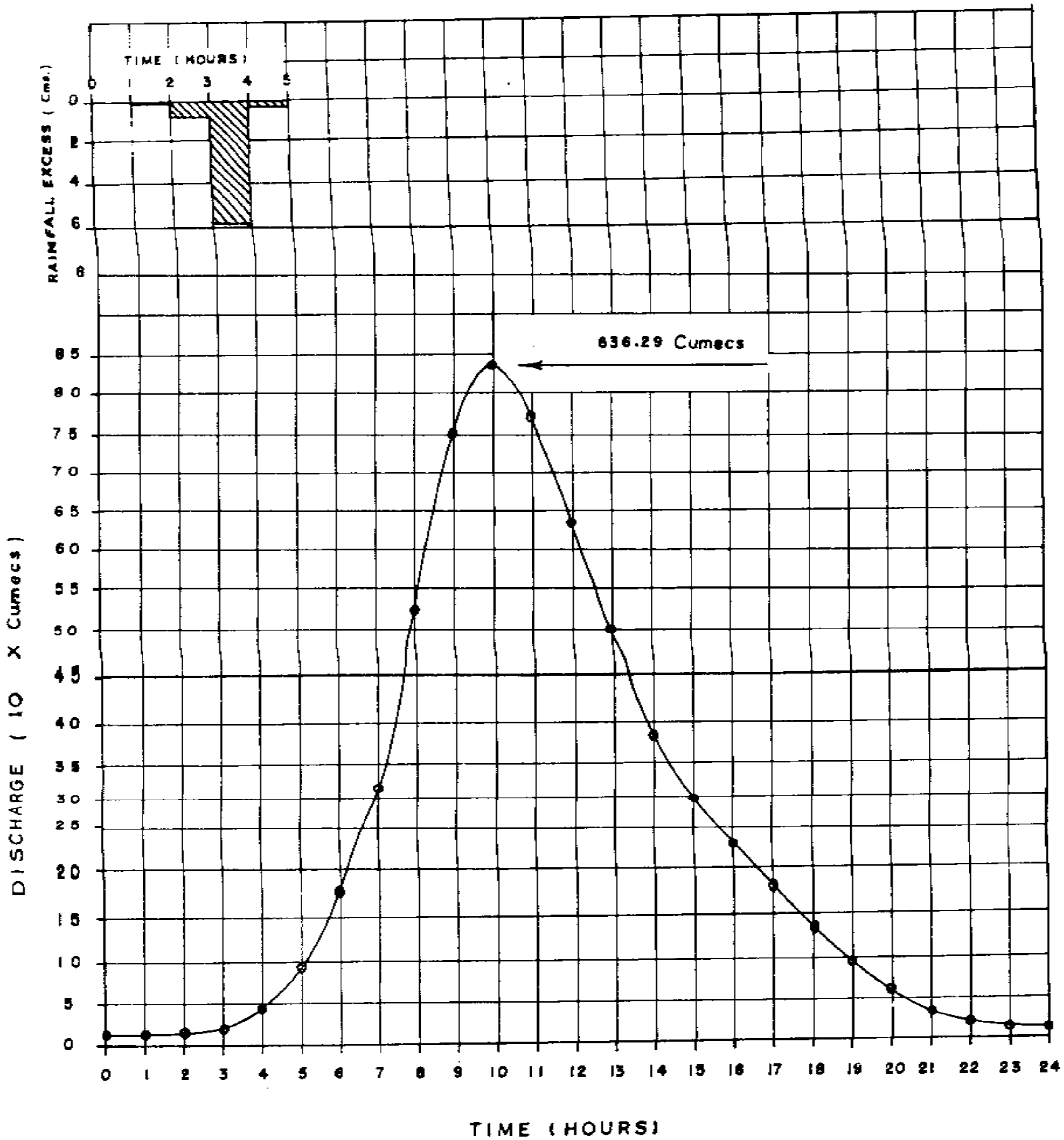
SYNTHETIC UNIT HYDROGRAPH

BRIDGE-NO. 37

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

CHECKED BY.- C. L. BAJAJ

FIG. A- 4



GOVERNMENT OF INDIA
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HYDROLOGY (SMALL CATCHMENTS) DTE

KAVERI BASIN
SUB-ZONE 3(i)
DESIGN FLOOD HYDROGRAPH
RAILWAY BR.NO.37 ON RIVER PAMBAR

DRAWN S.N. MALHOTRA P.N. BHALLA	CKD. A.K. GHOSH

The 50-year storm point rainfall R_{50} (cm) pertaining to design storm duration $(T_D) = 1.1\, t_p$

Where $t_p = 0.553\, (LL_c / \sqrt{S})^{0.405}$

Therefore, $T_D = 0.608\, (LL_c / \sqrt{S})^{0.405}$. The values of T_D in hours (hrs.) may be rounded off to the nearest whole number.

The 50-year flood peaks (Q_{50}) were computed for all the 20 railway/road bridge catchments listed in Table-2 of the report using the methodology contained therein, assuming a loss rate of 0.5 cm/hr. Individual values of K_{50} were estimated for each of the 20 catchments by substituting their values of Q_{50}, A, R, S, L and L_c in equation (2). The values of K_{50} and the corresponding values of catchment areas (A) were plotted on a graph paper and an average curve was drawn through the plotted points. These curves are shown in Figure B-2. The percentage variations between 50-yr. flood peak by formula and by detailed studies ranged from + 0.64 to +17 and - 1.76 to - 21.38. In only one case out of 20 the permissible limit of 20% variation has been exceeded by 1.38%. The 50-year flood peak estimated by the formula may, therefore, be considered reasonable.

B.2 Direct 25-Yr. and 100-Yr. Flood Peak Formulae

Similar studies for evolving a direct 25-yr. and 100-yr. flood peak formulae were carried out as for direct 50-yr. flood peak formula in Section B-1. The following 25-yr. and 100-yr. flood formulae similar to that of 50-yr. flood formula were derived:

$$Q_{25} = \frac{K_{25}\, (S)^{0.176}\, A\, R_{25}}{(LL_c)^{0.353}}$$

and

$$Q_{100} = \frac{K_{100}\, (S)^{0.176}\, A\, R_{100}}{(LL_c)^{0.353}}$$

Where A, L, L_c and S are same as in 50-yr. flood formula

Q_{25} = 25-yr. flood in cumecs

Q_{100} = 100-yr. flood in cumecs

K_{25} = to be obtained from K_{25} v/s catchment area relationship to Fig. B-1.

K_{100} = to be obtained from K_{100} v/s catchment area relationship in Fig. B-3.

R_{25} = 25-yr. design storm point rainfall (cm) corresponding to design storm duration T_D (hrs.) to be obtained from 25-yr. 24-hr. point rainfall map in plate-9 multiplied with the reduction factors (ratios) for T_D hr. duration as shown in Fig.10 of Section 4.2

R_{100} = 100-yr. design storm point rainfall (cm) corresponding to design storm duration T_D (hrs.) to be obtained from 100-yr. 24-hr. point rainfall map in plate-11 multiplied with the reduction factors (ratios) for T_D hr. duration as shown in Fig.10 of Section 4.2.

$$T_D \text{ in hrs.} = 0.608(LL_c/\sqrt{S})^{0.405}$$

Note: Loss of 0.5 cm/hr. was assumed for estimating 25-yr. and 100-yr. flood peaks for 20 Nos. railway/road bridge catchment to arrive at the respective 25-yr. and 100-yr. flood formulae.

The percentage variations between 25 yr. flood obtained from 25-yr. flood peak formula and from detailed studies ranged from +0.4 to +20.9% and -0.60 to -23.9%. In only two cases out of 20, the permissible limit of 20% variation has deviated by +0.9% and -3.9%. The 25-yr. flood peak estimated by the formula may, therefore, be considered reasonable for adoption.

Similarly, the percentage variations between 100-yr. flood obtained from 100-yr. flood peak formula and from detailed studies ranged from +1.25 to +13.9% and -0.37 to -22.6% In only one case out of 20, the permissible limit of 20% variation has been exceeded by 2.6%. The 100-yr. flood peak estimated by the formula may, therefore, be considered reasonable for adoption.

B.3 Application of Direct 50-Year Flood Peak Formula

The 50-yr. flood formula applicable to subzone-3(i) is as under:

$$Q_{50} = \frac{K_{50}\,(S)^{0.176}}{(LL_c)^{0.353}} \times A \times R_{50} \qquad \text{...........(2)}$$

The following steps are followed to compute the 50-year flood peak from the above formula for an ungauged or inadequately gauged catchment:

Step (1) : The catchment boundary upto the point of study (proposed cross drainage structure site) on a stream is marked on the Survey of India toposheets. The catchment area (A) in sq.km. and the length of the longest stream (L), the length of the longest stream opposite the centre of gravity of the catchment area upto the point of study (L_c) in km. are measured. The equivalent slope (S) in m/km of the main stream is computed as shown in Table-A.1 of the "APPLICATION". Prepare the catchment plan showing the catchment boundary and river system for record.

Step (2) : T_D for the catchment is calculated with the equation $T_D = 0.608 (LL_c/\sqrt{S})^{0.405}$ which is rounded off to the nearest 1-hr.

Step (3) : The point rainfall is obtained for the bridge site location marked on 50-yr. 24-hr. is Isopluvial map (Plate-10).

Step (4) : obtained the point rainfall (R) in cm for the design storm duration (T_D) by multiplying with the ratio of T_D to 24-hr. rainfall graph (Fig.10 vide Section 4.2) to the 50 yr. 24-hr. rainfall calculated in Step (3).

Step-(5) : Obtain the value of K_{50} for the catchment area (A) in Step (1) from the graph (Fig.B-2) of K_{50} v/s catchment area (A).

Step (6) : List out the values of A, L, L_c and S from Step (1) R from Step(4) and K_{50} from Step (5).

Step (7) : Substitute the listed values of A,L, S, R_{50} and K_{50} in the following 50-yr. flood peak formula in equation (2) to obtain 50-yr. flood peak (cumecs):

$$Q_{50} = K_{50} \frac{(S)^{0.176} \times A \times R_{50}}{(LL_c)^{0.353}}$$

The above procedure for application of direct 50-yr. flood peak formula for estimating 50-yr. flood peak shall be followed for estimating 25-yr. and 100-yr. flood using their respective flood formulae in Section B-2.

B.4 Solution of Problem by Direct Flood Formulae

The particulars of the Railway Catchment (treated as ungauged) for illustrating the procedure stepwise for application of 50-yr. flood peak formula are as under:

Details of Catchment Location

Subzone	:	3 (i)
Name of the site (point of study)	:	Rly Br. No. 37
Name of Rly. Section	:	Jallarpettai - Salem (SR)
Name of River/Tributary	:	Pambar
Bridge site location	:	$12^o 24'$ (N) Latitude $78^o 30'$ 18"(E) Longitude

50-Year Flood Peak

Step (1) The boundaries of the catchment under study after locating the bridge site on the tributary from the given latitude and longitude on the Survey of India toposheet are from any map of the area already prepared from the toposheet were marked. Catchment area plan upto Rly. Br. No.37 (Fig.A-1) was prepared. Catchment area (A) in sq. km., Length (L) in km. of the longest main stream upto the point of study and length (L_c) of longest main stream opposite of the centre of gravity of catchment area upto the point of study were measured. Equivalent stream slope (S) in m/km. was calculated as shown in Table A-1 with respect to L - section in Fig. A-1 under 'A' "APPLICATION". The values of A, L, L_c and S so obtained are as under:

A = 294.00 sq.km., L = 43.47 km., L_c = 22.72 km. and S = 5.13 m/km.

Step (2) Design storm duration (T_D) for the catchment was calculated with the following formula:

$$T_D = 0.608 \, (LL_c / \sqrt{S})^{0.405}$$

$$T_D = 0.608 \, (43.47 \times 22.72 / \sqrt{5.13})^{0.405} = 7.03$$

which is rounded off to the nearest one hour

$$T_D = 7.00 \text{ hrs.}$$

Step (3) Point Rainfall (R) = 17.50 cm was obtained for the bridge location latitude (N) 12°24' and longitude (E) 78°30'18" on the 50-yr. 24-hr. isopluvial map (Plate-10). The design storm duration (T_D) for the catchment was 7 hrs. 50-yr. 7-hr. point rainfall was worked out by multiplying the 50-yr.24hr. rainfall of 17.5 cm with a factor of 0.74 corresponding to storm duration of 7-hrs. from Fig.10 50-yr. 7-hr. rainfall = 17.5 x 0.74 = 12.95 cm.

Step (4) The value of K = 0.52 was read from the relationship of A v/s K in Fig. B-2 corresponding to catchment area of 294 sq.km.

Step (5) The values of A, L, L_c and S from Step-1, R from Step - 3 and K from Step-4 were listed as under:

A= 294 sq.km., L = 43.47 km., L_c = 22.72 km

S= 5.13 m/km. R = 12.95 cm and K = 0.178

Step (6) The values of A, L, L_c, S, R and K in Step - 5 were substituted in the following 50-yr. flood peak formula:

$$Q_{50} = \frac{K \times (S)^{0.176} \times A \times R_{50}}{(LL_c)^{0.353}}$$

$$Q_{50} = \frac{0.178 \times (5.13)^{0.176} \times 294.0 \times 12.95}{(43.47 \times 22.72)^{0.353}}$$

$$Q_{50} = \frac{0.178 \times 1.333 \times 294 \times 12.95}{11.405}$$

$$Q_{50} = 795.59 \text{ cumecs}$$

The 50-yr. flood of 795.59 cumecs was computed from 50-yr. flood formula as against 50-yr. flood of 831.77 cusecs by detailed method. The 50 yr. flood by formula is less by 4.35% as against the 50-yr. flood by the detailed method which may be considered reasonable for adoption.

25-Year Flood Peak

25-yr. flood peak is estimated for catchment upto Rly. Br. No. 37

795.53 14.70/20

with the following 25-yr. flood peak formula

$$Q_{25} = \frac{K_{25} (S)^{0.176} A R_{25}}{(LL_c)^{0.353}}$$

The values of A, L, L_c and S are same as in the above example

T_D = 7.0 hrs. as in the above example

K_{25} = 1.814 was read from Fig. B-1 for A-294 sq.km.

R_{25} = 25-yr. 7 hr. rainfall was obtained from the 25-yr. 24-hr. point rainfall map (Plate-9) after multiplication with the reduction factor of 0.740 corresponding to design storm duration T_D = 7 hrs. in Fig. 10 = 15.0 x 0.74 = 11.10 cm.

Substitute the values of A, L, L_c S, K_{25} and R_{25} in the above formula.

Therefore, $Q_{25} = \frac{1.814 \times (5.13)^{0.176} \times 294 \times 11.10}{(43.47 \times 22.72)^{0.353}}$ = 690.30 cumecs

Q_{25} = 690.30 cumecs by formula varies by +0.8% as against

Q_{25} = 685.10 cumecs based on detailed studies.

100-Years Flood Peak

Similarly 100-yr. flood peak is estimated for catchment upto Rly. Br. No.37 with the following 100-yr. flood peak formula:

$$Q_{100} = \frac{K_{100} (S)^{0.176} A R_{100}}{(LL_c)^{0.353}}$$

The values of A = 294 sq.km., L = 43.47 km., L_c = 22.72 km. and S= 5.13 m/km for the catchment upto Br.No.37 worked out for 50-yr. flood are same.

T_D = 7.0 hrs. as in the above example

K_{100} = 1.916 was read from Fig. B-3 for A = 294 sq.km.

R_{100} = 100-yr. 7-hr. rainfall was obtained from the 100-yr.24-hr. rainfall map (plate-11) after multiplication with the reduction factor of 0.740 corresponding to design storm duration T_D = 7.0 hrs. in Fig. 10

= 19.0 x 0.740 = 14.06 cm.

Substitute the values of A, L, L_c, S, K_{100} and R_{100} in the above formula:

Therefore, $$Q_{100} = \frac{1.916 \times (5.13)^{0.176} \times 294 \times 14.06}{(43.47 = 22.72)^{0.353}} = 934.25 \text{ cumecs}$$

Q_{100} = 934.25 cumecs by formula varies by +1.25% as against Q_{100} = 922.68 cumecs based on detailed studies.

B.5 Flood Formulae by Multiple Regression Analysis Theory

Theory

In this multiple regression analysis, the peak discharge (Q_N) for a return period of N years as externally dependent variable was found to be

$$Q_N = a \quad A^b \; L^c \; L_c^d \; S^e \; R_N^f$$

Where A, L, L_c, S and R_N are same as in Section B-1 as independent variables. a, b, c, d, e and f are multiple regression coefficients when a logarithmic transformation is applied to all variables. Principle of least square was used in the regression analysis to get the above relationship.

B.6 25-yr., 50-yr. and 100-yr. Flood Formula by Multiple Regression Analysis.

25-yr. flood, 50-yr. flood and 100-yr. flood values for each of the 20 Nos. gauged catchments were estimated assuming a loss rate of 0.5 cm/hr. Similarly, sets of 25-yr., 50-yr. and 100-yr. flood values were also estimated for each of the 20 Nos. gauged catchments assuming loss rates of 1.0 cm/hr. and 1.5 cm/hr.

The estimated values of Q_{25}, Q_{50} and Q_{100} (with loss rate of 0.5 cm/hr) as dependent variables were related to their respective physiographic parameters A, L, L_c, S and meteorologic parameters R_{25}, R_{50} and R_{100} as independent variables applying the least square method. The derived flood formulae with their respective coefficient of correlations (r) by multiple regression analysis (with loss rate of 0.5 cm/hr., 1.0 cm/hr. and 1.5 cm/hr.) are as under:

(i) with a loss rate of 0.5 cm/hr.

Q_N Formula	Coefficient of correlation (r)
$Q_{25} = \dfrac{3.299\ (A)^{0.851}(S)^{0.181}(R_{25})^{1.143}}{(L)^{0.181}\ (L_c)^{0.598}}$	0.99
$Q_{50} = \dfrac{2.694\ (A)^{0.831}(S)^{0.187}\ (R_{50})^{1.242}}{(L)^{0.196}\ (L_c)^{0.556}}$	0.99
$Q_{100} = \dfrac{3.421\ (A)^{0.840}\ (S)^{0.174}(R_{100})^{1.085}}{(L)^{0.123}\ (L_c)^{0.596}}$	0.99

(ii) <u>with a loss rate of 1.0 cm/hr.</u>

Q_N	Formula	Coefficient of correlation (r)
Q_{25}	$= \dfrac{2.538\ (A)^{0.829} (S)^{0.199} (R_{25})^{1.211}}{(L)^{0.135}\ (L_c)^{0.666}}$	0.99
Q_{50}	$= \dfrac{2.184\ (A)^{0.815} (S)^{0.197} (R_{50})^{1.311}}{(L)^{0.164}\ (L_c)^{0.632}}$	0.99
Q_{100}	$= \dfrac{2.759\ (A)^{0.821} (S)^{0.181} (R_{100})^{1.179}}{(L)^{0.104}\ (L_c)^{0.667}}$	0.99

(iii) <u>with a loss rate of 1.5 cm/hr.</u>

Q_N	Formula	(r)
Q_{25}	$= \dfrac{2.017\ (A)^{0.823} (S)^{0.220} (R_{25})^{1.178}}{(L)^{0.076}\ (L_c)^{0.686}}$	0.99
Q_{50}	$= \dfrac{1.712\ (A)^{0.796} (S)^{0.216} (R_{50})^{1.312}}{(L)^{0.099}\ (L_c)^{0.654}}$	0.99

The Q values of specific return period N (say 25)for any other loss rate between 0.5 and 1.5 cm/hr. may be computed by linearly interpolating between the two adjoining values of Q_N falling between the ranges of 0.5 to 1.0 and 1.0 to 1.5 cm/hr.

The symbols in the above sets of formulae are similar to that in the formulae derived by DIRECT METHOD under Section B.1

The coefficients of correlation for all the above relationships are extremely high and, therefore, the relationships derived are very reasonable.

The flood values for Q_{25}, Q_{50} and Q_{100} by the detailed method and by the above formulae for three sets of conditions (assuming 0.5 cm/hr., 1.0 cm/hr. and 1.5 cm/hr.) were estimated. The percentage variations between the estimated values based on detailed studies and formulae with respect to the estimated value, from detailed method were worked out as under:

Q_N	% variation limits
(i)	with loss rate of 0.5 cm/hr.
Q_{25}	-0.05 to -15.1, +0.03 to +13.1
Q_{50}	-0.14 to -13.85, +0.36 to +13.82
Q_{100}	-0.59 to -15.18, +0.26 to +14.6
(ii)	with loss rate of 1.0 cm/hr.
Q_{25}	-0.30 to -13.08, +2.48 to+14.55
Q_{50}	-0.40 to -14.33, +0.28 to +14.68
Q_{100}	-0.6 to -14.9, +3.7 to +14.4
(iii)	with loss rate of 1.5 cm/hr.
Q_{25}	-1.00 to -15.35, + 1.59 to+16.97
Q_{50}	-0.67 to -14.66, + 0.77 to 17.81

Comparison of percentage variations with respect to the maximum permissible limit of variation of 20% showed that in only one or two cases out of 20, the variation exceeded by a nominal percentage. Therefore, the 25-yr., 50-yr. and 100-yr. flood formulae for three sets of conditions are reasonable for adoption.

B.7 Solution of the Problem Based on Flood Formulae by Multiple Regression Analysis

Illustrative example for estimation of 25-yr., 50-yr. and 100-yr.flood for catchment upto Rly. Br. No.37 in Section B-4 BY DIRECT FLOOD FORMULAE is considered for solution of the problem by Flood Formula (Regression Analysis) The physiographic and meteorologic parameters for the catchment under study are:

$A = 294.00$ sq.km., $L = 43.47$ km., $L_c = 22.72$ km., $S = 5.13$ m/km

$R_{25} = 11.10$ cm., $R_{50} = 12.95$ cm., $R_{100} = 14.06$ cm.

The above parameters are substituted in the flood formulae for loss rates of 0.5 cm/hr., 1.0 cm/hr., and 1.5 cm/hr. in Section-6 for estimating their respective 25-yr., 50-yr., and 100-yr. flood values as under:

(i) with loss rate of 0.5 cm/hr.

$$Q_{25} = \frac{3.299\ (294)^{0.851}\ (5.13)^{0.181}\ (11.10)^{1.143}}{(43.47)^{0.181}\ (22.72)^{0.598}} = 685 \quad \text{cumecs}$$

$$Q_{50} = \frac{2.694\ (294)^{0.831}\ (5.13)^{0.187}\ (12.95)^{1.242}}{(43.47)^{0.196}\ (22.72)^{0.556}} = 835 \text{ cumecs}$$

$$Q_{100} = \frac{3.421\ (294)^{0.84}\ (5.13)^{0.174}\ (14.06)^{1.085}}{(43.47)^{0.123}\ (22.72)^{0.596}} = 925 \text{ cumecs}$$

(ii) with loss rate of 1.0 cm/hr.

$$Q_{25} = \frac{2.538\ (294)^{0.829}\ (5.13)^{0.199}\ (11.10)^{1.211}}{(43.47)^{0.135}\ (22.72)^{0.666}} = 542 \text{ cumecs}$$

$$Q_{50} = \frac{2.184\ (294)^{0.815}\ (5.13)^{0.197}\ (12.95)^{1.311}}{(43.47)^{0.164}\ (22.72)^{0.632}} = 669 \text{ cumecs}$$

$$Q_{100} = \frac{2.759\ (294)^{0.821}\ (5.13)^{0.181}\ (14.06)^{1.179}}{(43.47)^{0.104}\ (22.72)^{0.667}} = 746 \text{ cumecs}$$

(iii) with a loss rate of 1.5 cm/hr.

$$Q_{25} = \frac{2.017\ (294)^{0.823}\ (5.13)^{0.220}\ (11.10)^{1.178}}{(43.47)^{0.076}\ (22.72)^{0.686}} = 467 \text{ cumecs}$$

$$Q_{50} = \frac{1.712\ (294)^{0.796}\ (5.13)^{0.216}\ (12.95)^{1.312}}{(43.47)^{0.099}\ (22.72)^{0.654}} = 578 \text{ cumecs}$$

The estimated Q_{25}, Q_{50} and Q_{100} by both the flood formulae and detailed studies along with percentage variations with respect to their respective flood value by detailed method for three sets of loss rate conditions are as under:

	Flood Discharge (cumecs) by		
Q_N	Formula	Detailed Method	% Variation
1	2	3	4
Q (i)	with loss rate of 0.5 cm/hr.		
Q_{25}	685.28	685.10	+0.03%
Q_{50}	835.29	831.77	+0.42%
Q_{100}	925.08	922.68	+0.26%

(ii) <u>with loss rate of 1.0 cm/hr.</u>

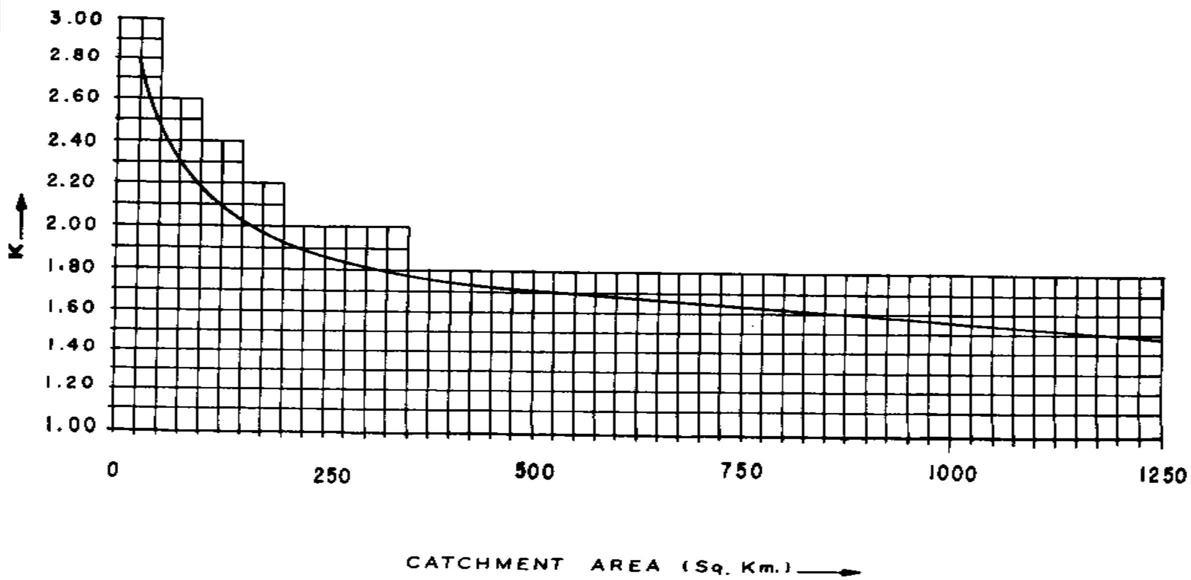
1	2	3	4
Q_{25}	542.07	550.40	-1.51%
Q_{50}	668.76	676.12	-1.09%
Q_{100}	746.35	752.30	-0.79%

(iii) <u>with loss rate of 1.5 cm/hr.</u>

Q_{25}	467.04	476.90	-2.07%
Q_{50}	577.73	582.48	-0.82%

The above table shows that the percentage variation is nominal and the estimated values of Q_{25}, Q_{50} and Q_{100} are by flood formulae are acceptable.

FIG. B-1



C.A (Sq.Km.)	K - VALUE
25	2.74
30	2.67
40	2.58
50	2.50
60	2.41
70	2.34
80	2.28
90	2.24
100	2.19
120	2.10
140	2.05
150	2.02
160	1.99
180	1.96
200	1.92
225	1.89
240	1.86
300	1.81
400	1.74
500	1.71
600	1.68
700	1.64
800	1.61
900	1.58
1000	1.56

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

KAVERI BASIN

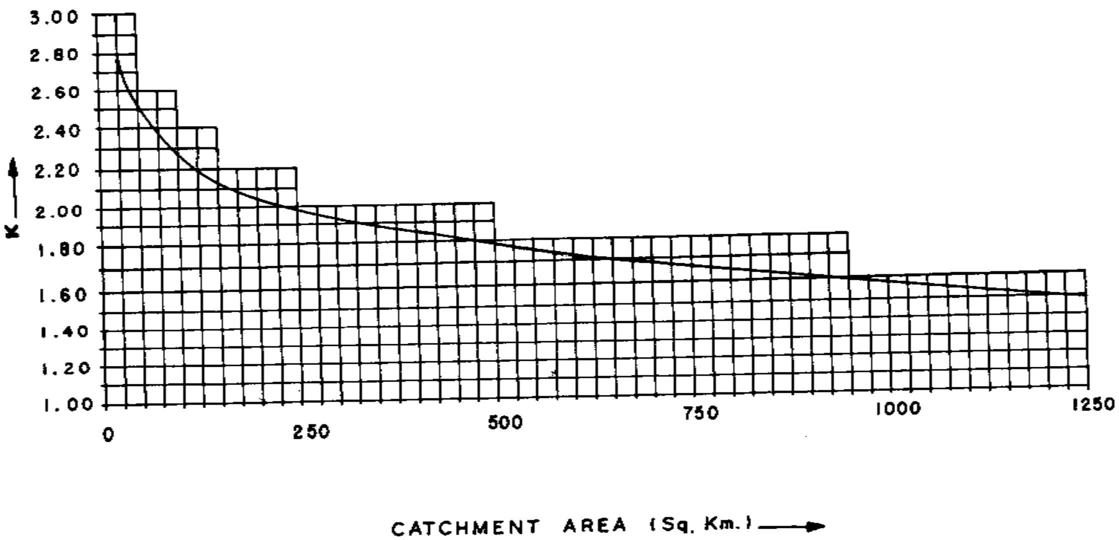
SUB ZONE 3(i)

CATCHMENT AREA Vs K_{25}

RELATIONSHIP FOR 25-YEAR FLOOD

DRAWN_ T. R. ARORA L. P. NAUTIYAL	CHECKED - A. K. GHOSH

FIG. B-2



C.A (Sq. Km.)	K_VALUE
25	2.77
30	2.67
40	2.60
50	2.53
60	2.46
70	2.39
85	2.33
100	2.26
125	2.19
160	2.12
200	2.05
250	1.98
300	1.92
400	1.85
500	1.78
600	1.71
700	1.68
800	1.64
900	1.61
1000	1.57

GOVERNMENT OF INDIA
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HYDROLOGY (SMALL CATCHMENTS) DTE.

KAVERI BASIN

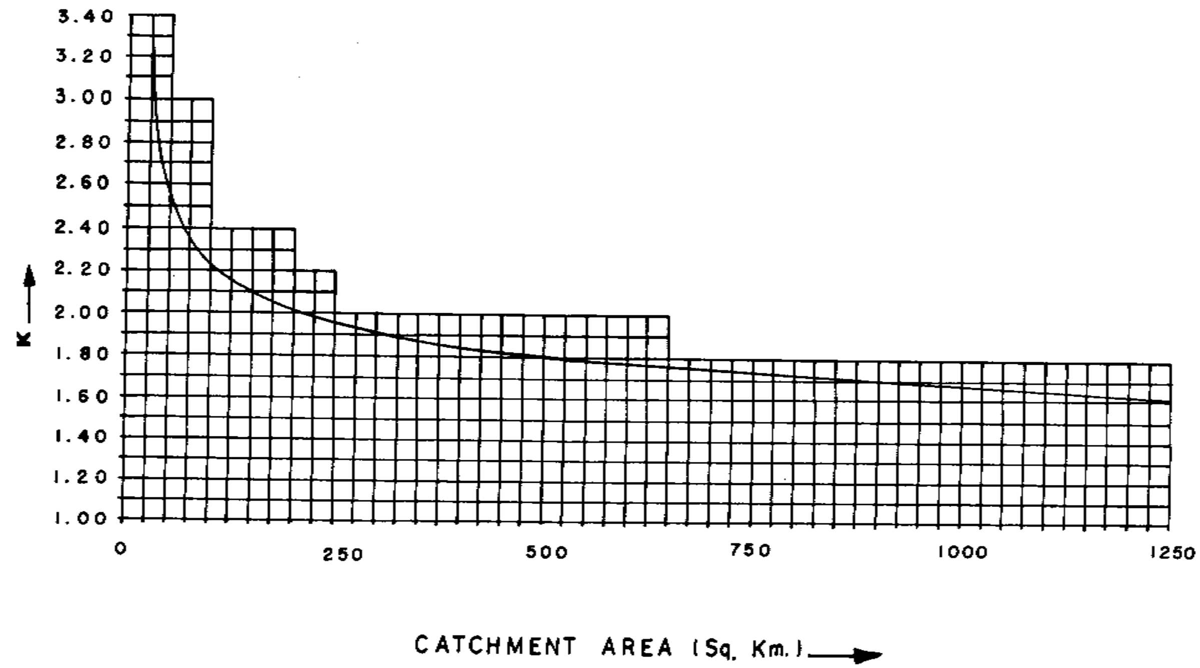
SUB ZONE 3(i)

CATCHMENT AREA Vs K_{50}

RELATIONSHIP FOR 50-YEAR FLOOD

DRAWN_T. R. ARORA L. P. NAUTIYAL	CHECKED_ A. K. GHOSH A.D

FIG. B-3



C.A (Sq.Km.)	K_VALUE
25	3.25
30	3.18
40	2.70
50	2.55
60	2.45
70	2.38
80	2.33
90	2.27
100	2.24
120	2.17
140	2.12
150	2.10
160	2.09
180	2.05
200	2.02
225	1.99
240	1.97
300	1.92
400	1.86
500	1.81
600	1.78
700	1.76
800	1.73
900	1.70
1000	1.69

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

KAVERI BASIN

SUB ZONE 3 (i)

CATCHMENT AREA Vs K_{100}
RELATIONSHIP FOR 100-YEAR FLOOD

DRAWN_ T.R. ARORA L.P. NAUTIYAL	CHECKED – A. K. GHOSH A.D.

1.0 GENERAL DESCRIPTION OF THE KAVERI SUBZONE-3(i)

1.1 LOCATION

The Kaveri subzone-3 (i) lies between longitudes 75°25' to 79°10' (East and latitudes 10° to 14° (North). The Kaveri river has its origin in the Brahmagiri range of the western ghats in Coorg District of Karnataka State. It flows eastwards for a total length of about 804 km through Karnataka and Tamil Nadu States, before outfalling into the Bay of Bengal. Small eastern parts of Kerala drained bv upper reaches of Kabbani, Bhavani and Amravati forming tributaries of Kaveri river fall in the western periphery of subzone-3(i). The upper reaches of Palar and Ponnaiyar rivers flow eastwards in the north-eastern part of subzone-3-(i). The Kaveri subzone excludes the lower eastern coast subzone-4 (b). Subzone-3(i) is mostly constituted of Plateau between eastern and western ghats. The subzone-3 (i) is bounded on the north by Krishna and Penner Basins subzone-3 (h), on the south by south-eastern coast subzone-3 (c), on the east by lower eastern coast subzone-4 (b) and on the west by Malabar coast subzone-5 (b).

Plate-1 depicts the location of the Kaveri subzone-3 (i). Some of the towns and cities in the subzone-3 (i) are Mysore, Bangalore, Hassan, Mercara, Kolar in Karanataka State and Coimbatore, Tiruchirappalli, Jollarpettai, Erode and Salem in Tamil Nadu State.

1.2 RIVER SYSTEM

Plate-2 depicts the river system of the Kaveri subzone. The main tributaries of the Kaveri river are Hemavati, Shimsha, Arkavati, Chinnar, Lakshmantirtha, Kabbani, Bhavani, Noyil, and Amravati. Besides these, the upper reaches of Palar and Ponnaiyar rivers drain the north-eastern part of the subzone, before outflowing into the Bay of Bengal.

The drainage areas of the main tributaries of Kaveri river, Palar and Ponnaiyar in the subzone are as under:

Sl.No.	River/Tributary	Drainage are (sq. km.)
1.	Hemavati	5308.37
2.	Shimsha	8413.26
3.	Arkavati	4306.79
4.	Chinnar	3104.89
5.	Lakshmantirtha	2403.79
6.	Kabbani	7511.84

7.	Bhavani	6810.74
8.	Noyil	4406.94
9.	Amravati	9214.53
10.	Other Kaveri areas (including Palar and Ponnaiyar).	44570.27
	Total:	96051.42

The total drainage area of the subzone-3 (i) is 96,051 sq.km.

1.3 TOPOGRAPHY

Plate-3 depicts the general topography of the Kaveri subzone. The Kaveri river originates almost at the very edge of the western ghats within sight of Arabian Sea at a height of about 1355m and flows eastwards crossing mountain barrier of western ghats. The river falls about 450m within a course of 8 km from its source. The upper reaches of the Kaveri and its tributaries drain the western ghats before flowing over a wide plateau. The eastern and western ghats fringe the plateau. The Kaveri subzone has a complex relief. The general elevations of the plateau vary from 900 to 600m in the north-western part and 600 to 150m in the south-eastern part interspersed with higher elevations of 3000 to 900m along the western periphery and inside the subzone.

1.4 RAINFALL

Plate-4 depicts the normal annual rainfall of the Kaveri subzone and the histograms of normal monthly rainfall at Bangalore and Coimbatore. The subzone experiences rainfall by both south-west and north-east monsoons during June to September and October to December respectively. The normal annual rainfall generally varies with the decrease in elevation along the eastern side of the western ghats from about 400 cm to 100 cm on the eastern side of the ghats in the subzone. The remaining portion of the subzone experiences a normal annual rainfall ranging from 60 cm to 80 cm.

Bangalore region experiences heavy rainfall during August to October whereas Coimbatore region experiences the maximum rainfall during October and November.

1.5 TEMPERATURE

Plate-5 depicts the normal annual temperatures in the Kaveri subzone along with the histograms of the minimum, maximum and mean monthly temperatures at Bangalore and Coimbatore. In line with the general physiography of the subzone, it is seen that the eastern portion has temperatures of the order of $20^{o} - 22.5^{o}c$. The central region, being of lower elevation, has temperatures between $22.5^{o} - 27.5^{o}c$. The east-most part being the lowest in elevation experiences temperatures greater than $27.5^{o}c$.

1.6 SOILS

Plate-6 shows the soil classification in the Kaveri subzone. The subzone is generally covered with red sandy soils barring a couple of areas of red loamy soil on the eastern and northern edges. At micro level (i.e. when small catchments are considered) the soil type may vary considerably from the above mentioned groups.

1.7 LAND USE

Plate-7 delineates the land use in the Kaveri subzone. Arable land constitutes about 60% of the subzone. About 25% of the subzone is grass land and scrubs, the rest being forest area. Most of the arable land is benefiting from irrigation by major projects like Mettar, Krishnaraja Sagar etc.

Plate-8 shows the cropping intensity in the subzone.

1.8 COMMUNICATIONS

The subzone-3 (i) has an adequate road and rail network.

1.8.1 RAILWAY LINES

The following railway lines traverse the Kaveri subzone.

Sl.No.	Railway Section	Zonal Railway
1.	Dindigul - Podanur	Southern Railway
2.	Erode - Tiruchirappalli	"
3.	Salem - Bangalore	"
4.	Bangalore - Banasandra	"
5.	Bangalore - Maysore	"
6.	Bangalore - Jolarpettai	"
7.	Bangalore - Kolar	"
8.	Mysore - Hassan	"
9.	Mysore - Ghamrajnagar	"
10.	Podanur - Ootachmund	"
11.	Podanur - Erode	"
12.	Erode - Salem	"
13.	Salem - Attur	"
14.	Salem - Jolarpettai	"
15.	Jolarpettai - Katpadi	"
16.	Karpadi - Pakala	"
17.	Salem - Metturdam	"

1.8.2 ROADS

The major Highways in the subzone are:

1. National Highway No.4 (Tumkur to Vellore)

2. National Highway No.7 (Bangalore to Dindigul)

3. National Highway No.45 (Dindigul to Thanjavur)

4. National Highway No.46 (Krishnagiri to Vellore)

5. National Highway No.47 (Salem to Coimbatore)

6. National Highway No.48 (Bangalore to Hassan)

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	2	3	4
1(a)	Luni basin & Thar (Luni & other rivers of Rajasthan and Kutch).	Luni	Luni river, Thar (Luni & other rivers of Rajasthan and Kutch, and Banas river).
1(b)	Chambal Basin	Chambal	Chambal river
1(c)	Betwa Basin & other Tributaries	Betwa	Sind, Betwa and Ken rivers and other South Tributaries of Yamuna.
1(d)	Sone Basin and Right Bank Tributaries.	Sone	Sone and Tons rivers and other South Bank Tributaries of Ganga.
1(e)	Punjab Plains including parts of Indus, Yamuna Ganga and Ramganga Basins.	Upper Indo-Ganga Plains	Lower portion of Indus, Ghaggar Sahibi Yamuna, Ganga and Upper portion of Sirsa, Ramganga, Gomti and Sai rivers.
1(f)	Gangetic Plains including Gomti, Ghagra, Gandak, Kosi and other.	Middle Ganga Plains	Middle portion of Ganga, lower portion of Gomti, Ghagra, Gendak, Kosi and middle portion of Mahanadi Basin.
1(g)	Lower Gangetic Plains including Subarnarekha and other east-flowing rivers between Ganga and Baitarani.	Lower Ganga Plains	Lower portion of Ganga, Hoogli river system and Subarnarekha.
2(a)	North Brahmaputra Basin.	North Brahmaputra	North Bank Tributaries of Brahmaputra river and Balason river.
2(b)	South Brahmaputra Basin	South Brahmaputra	South Bank Tributaries of Brahmaputra river.
2(c)	Barak and others.	Barak	Barak, Kalden and Manipur rivers.
3(a)	Mahi, including the Dhadhar, Sabarmati and rivers of Saurashtra.	Mahi and Sabarmati	Mahi and Sabarmati including Rupen & Mechha Bhandar, Ozat Shetaranji rivers of Kathiawad Peninsula.

1	2	3	4
3(b)	Lower Narmada and Tapi Basin	Lower Narmada & Tapi	Lower portion of Narmada, Tapi and Dhadhar rivers.
3(c)	Upper Narmada and Tapi Basin.	Upper Narmada & Tapi.	Upper portion of Narmada & 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 Godávari Basin.
3(f)	Lower Godavari Basin except coastal region.	Lower Godavari	Lower portion of Godavari Basin.
3(g)	Indravati Basin.	Indravati	Indravati river.
3(h)	Krishna subzone including Penner Basin except coastal region.	Krishna	Krishna & Penner rivers except coastal region.
3(i)	Cauveri & 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 Cauveri.	Lower Eastern Coast	East flowing coastal rivers, Manimukta, South Penner, Cheyyar, Palar, North Penner, Munneru, Palleru, Cundalakama and Krishna Delta.
4(c)	Sandy Coroman Belt (east flowing rivers between Cauvery & Kanyakumari).	South Eastern Coast	East flowing coastal rivers - Manimuther, Vaigai, Arjuna, Tamraparni.
5(a)	Konkan coast (west flowing rivers between Tapi and Panaji).	Konkan Coast	West flowing coastal rivers between Tapi and Maudavi rivers.

1	2	3	4
5(b)	Malabar Coast (West flowing rivers between Kanyakumari and Panaji).	Malabar Coast	West flowing coastal rivers between Mandavi and Kanyakumari
6.	Andaman and Nicobar	Andaman & Nicobar	
7.	J & K Kumaon Hills (Indus Basin).	Western Himalayas	Jhalum, Upper portion of Indus, Ravi and Beas rivers.

2.0 DESIGN FLOOD DATA AND THE METHOD ADOPTED FOR ANALYSIS

2.1 DESIGN FLOOD

The Khosla Committee of Engineers had recommended a design flood of 50-year return period for fixing the optimum waterway of the bridges. The design flood, in other words, may be defined broadly as a rational estimate of flood discharge for the design of safe and economic structure across a river. The Committee of Engineers had suggested that 50-year flood may be considered as the maximum observed discharge from the yearly peak discharge records available for not less than 50 years. Where the yearly peak discharge records are not much less than 50 year, the 50-year flood may be obtained from the probability curve of peak discharges. In the absence of adequate data of peak discharges, a storm rainfall and runoff data for the selected catchment shall be collected for a required period and detailed studies carried out to derive the unitgraphs for these catchments and to prepare storm rainfall maps for different durations. In this connection, the Committee had suggested to develop a suitable rational methodology for estimation of 50-year flood subzonewise based on application of storm rainfall to unitgraph. It has been assumed that 50-year storm rainfall applied to unitgraph may produce a flood of the same return period (50-year) as that of storm rainfall.

2.2 DATA

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

i) Hourly gauge data at the gauging site (bridge site), upstream and downstream at a reasonable distance from the gauging site.

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

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

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

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

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

In addition to the above, the data of gauged catchments, the rainfall data of self-recording raingauge stations maintained by India Meteorological Department and States falling in the subzone is also required.

Southern Railways and South Central Railways under the supervision of Research Designs and Standards Organisation had observed and collected the required data for 28 catchments in Kaveri Basin subzone-3(i) for a period of 3 to 7 years for each of the catchments. Central Water Commission on behalf of Ministry of Transport is also observing and collecting the required data since 1979 for two catchments in this subzone. The sizes of the gauged catchments varied from 27 to 2850 sq.km. The location of the gauging sites at road and railway bridges are shown in Plate-2. India Meteorological Department has collected rainfall data of IMD's SRRGs stations. Table-1 shows the name of the stream, bridge numbers, coordinates of gauging sites, catchment areas, number of raingauge stations and period of availability of data.

2.3 DESCRIPTION OF THE METHOD ADOPTED

In the report, Section-3 explains the procedure for obtaining the Synthetic Unitgraph for ungauged catchments in subzone-3(i).

Section-4 explains the procedure for obtaining the design storm input.

Section-5 explains the steps to be followed for obtaining the design flood of 50-year return period.

The adoption of Synthetic Unitgraph is recommended for ungauged catchments or inadequately gauged catchments. However, for gauged catchments with adequate data, representative unitgraph based on actual data should be preferred.

3.0 DERIVATION OF SYNTHETIC UNIT HYDROGRAPH

The Synthetic Unitgraph is a unitgraph of unit duration for a catchment under study obtained from the relations established between the physiographic and unitgraph parameters of the representative catchments in a hydro-meteorologically homogenous region. In order to obtain the Synthetic Unitgraph, the following steps have to be followed.

i) Analysis of physiographic parameters of the catchments.

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

iii) Selection of flood and corresponding storm events.

iv) Computation of hourly catchment rainfall.

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

vi) Computation of infiltration loss (Ø - index) and 1-hourly rainfall excess units.

vii) Derivation of 1-hourly unitgraphs.

viii) Drawing of representative unitgraphs and measuring the parameters.

ix) Establishing relationships between physiographic and representative unitgraph parameters.

x) Derivation of 1-hour Synthetic Unitgraph for an ungauged catchment.

The above steps are briefly described as under:

3.1 Analysis of Physiographic Parameters of the Catchment

The representative catchments selected for the study were analysed for physiographic parameters. The catchment parameters shown in Fig.1 are as under:

3.1.1. Catchment Area (A)

On the Survey of India toposheet, the watershed boundary is marked upto the gauging site. The area enclosed within this boundary is the catchment area.

3.1.2 Length of the Main Stream (L)

This implies the longest length of the main river course in the catchment.

3.1.3 Length of Main Stream from Centre of Gravity of the Catchment (L_c)

This implies the length of the river from a point opposite to the Centre of Gravity (C.G) to the gauging site.

3.1.4 Equivalent Stream Slope (S)

Longitudinal section (L - section) of the main stream was prepared from the values of the contours across the stream and the spot levels near the banks with respect to their distances from the point of interest/gauging site. A line is so drawn by trials from the point of interest on the L - section such that the areas enclosed between the L-section and the line so drawn (above and below) are equal. This line is called Equivalent Stream Slope Line. Alternatively, the L-section may be broadly divided into 3 to 4 segments representing the broad ranges of the slopes of the segments and the following formula may be used to calculate the equivalent slope (S) :

$$S = \frac{\sum L_i (D_{i-1} + D_i)}{L^2} \qquad \text{.......(3.1)}$$

Where L_i = Length of the ith segment in km.

D_{i-1}, D_i = The depth of the river at the point of intersection of (i-1)ithand ith contours from the base line (datum) drawn at the level of the point of study in meters.

L = The length of the longest stream as defined in Section 3.1.2 in km.

Table-2 shows the physiographic parametes like A, L, L_c and S for 20 catchments considered suitable for analysis.

3.2 Scrutiny of Data and Finalisation of Gauge Discharge Rating Curve

The data was scrutinised through arithmetical checks. The gauge (stage) vs. area curves and the stage vs. velocity curves were prepared to identify the outliers and reconcile the data in the plotted points of the stage-discharge curves. At many places, the average trend of the stage-area curve and the stage-velocity curve was used to obtain the discharges at various levels. Where wide dispersions were not observed in the stage-discharge curve, log-log fitting was adopted. The stages for conceivable floods were converted into discharges initially identified with reference to rise and fall in the stages of the river.

3.3 Selection of Flood and Corresponding Storm Events

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

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

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

3.4 Computation of Hourly Catchment Rainfall

The Theissen network was drawn for the raingauge stations on the catchment map and their Theissen Weights were computed. The hourly point rainfall at each station was multiplied with their respective Theissen Weight and added to obtain the catchment rainfall at one hour interval during the storm period.

3.5 Separation of Base Flow

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

3.6 Computation of Infiltration Loss (Ø-Index) and 1-Hourly Rainfall Excess Units

With the known values of 1-hourly catchment rainfall in Section 3.4 and the direct runoff depth in Section 3.5 for each flood event, the infiltration loss (constant loss rate) by trials was estimated to obtain the direct runoff depth. The 1-hourly infiltration loss was deducted from the 1-hourly rainfall to get the 1-hourly rainfall excess units.

3.7 Derivation of 1-hour Unitgraph

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

Normally 4 to 14 unitgraphs are derived for each of the 20 catchments considered.

3.8 Drawing of Representative Unitgraphs and Measuring their Parameters

The representative unitgraph is the unitgraph which reproduces in reasonable limits the direct surface runoff hydrographs corresponding to their rainfall excess of the storm from which it has been obtained. Representative 1-hour unitgraphs were drawn from a set of superimposed 1-hour unitgraphs for each of the 20 catchments and their parameters noted. The parameters of the representative unitgraph illustrated in Fig.2 were measured for each of the catchments. The parameters of the representative unitgraphs are t_r, t_p, T_m, q_p Q_p, W_{50}, W_{75}, $W_{R_{50}}$, $W_{R_{75}}$ and T_B. These parameters for 20 catchments are listed in Table-3.

3.9 Establishing Relationships between Physiographic and Representative Unitgraph Parameters

Following simple model was adopted for establishing the relationships between these parameters.

$$Y = C\, x^{P} \qquad \text{........3.9.1}$$

Where

Y	=	Dependent variable
X	=	Independent variable
C	=	A constant
P	=	An exponent.

From equation 3.9.1, it follows that

$$\text{Log } Y = \text{Log } C + P \text{ Log } x \qquad \text{......3.9.2}$$

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

Various trials of relationship between the physiographic parameters (Table-2) and one of the unitgraph parameters and among the unitgraph parameters (Table-3) themselves for 20 gauged catchments considered suitable for the studies were made. The relationship between physiographic parameters $(LL_c/\sqrt{S})$ and U.G. parameter t_p was found to be significant. Afterwards t_p was related to unit peak discharge of the U.G. (q_p) which was related to various U.G. parameters like W_{50}, W_{75}, $W_{R_{50}}$ and $W_{R_{75}}$. The time-base (T_B) could be significantly cor-related to t_p. The principle of least squares was used in the regression analysis to get the relationships in the form of equation 3.9.1 to predict the parameters of the Synthetic Unitgraph in an unbiased manner. The following relationships have been derived for estimating the 1-hour unitgraph parameters in the subzone-3 (i)

Relationships		Correlated coefficient(r)	Equation No.	Fig. No.
t_p	$= 0.553(LL_c/\sqrt{S})^{0.405}$	0.949	3.9.3	3
q_p	$= 2.043/(t_p)^{0.872}$	0.943	3.9.4	4
W_{50}	$= 2.197/(q_p)^{1.067}$	0.985	3.9.5	5
W_{75}	$= 1.325/(q_p)^{1.088}$	0.953	3.9.6	6
W_{R50}	$= 0.799/(q_p)^{1.138}$	0.897	3.9.7	7
W_{R75}	$= 0.536/(q_p)^{1.109}$	0.905	3.9.8	8
T_B	$= 5.083\ (t_p)^{0.733}$	0.960	3.9.9	9
T_m	$= t_p + t_r/2$		3.9.10	
Q_p	$= q_p \times A$		3.9.11	

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

3.10 Derivation of 1-Hour Synthetic Unitgraph for an Ungauged Catchment

Considering the hydro-meteorological homogenity of subzone-3(i), the relations established between physiographic and unitgraph parameter in Section 3.9 for 20 representative catchments are applicable for derivation of 1-hour Synthetic Unitgraph for an ungauged catchment in the same subzone.

The steps for derivation of 1-hour unitgraph are:

i) Physiographic parameters of the ungauged catchment viz. catchment area (A), length of the longest stream (L), Length of the longest stream from a point opposite to the centre of gravity of the catchment area to the gauging site (L_c) and equivalent stream slope (S) are determined from the catchment area plan $LL_c/\sqrt{S}$ is calculated.

ii) Substitute the value of $LL_c/\sqrt{S}$ in the equation 3.9.3 $t_p = 0.553 (LL_c/\sqrt{S})^{0.405}$ to obtain t_p in hour. The calculated t_p is rounded off to nearest half an hour. Then $T_m = t_p + \frac{t_r}{2} = (t_p + ½)$ hours.

iii) Substitute the value of t_p in the equation 3.9.4 to obtain q_p in cumec/sqkm.

$$q_p = 2.043/(t_p)^{0.872}$$

Then $Q_p = q_p \times A$ in cumecs.

iv) Substitute the value of q_p in the following equations 3.9.5 to 3.9.8 to obtain W_{50}, W_{75}, W_{R50} and W_{R75} in hours.

$$W_{50} = \frac{2.197}{(q_p)^{1.067}}$$

$$W_{75} = \frac{1.325}{(q_p)^{1.088}}$$

$$W_{R50} = \frac{0.799}{(q_p)^{1.138}}$$

$$W_{R75} = \frac{0.536}{(q_p)^{1.109}}$$

v) Substitute the value of t_p in equation 3.9.9

$T_B = 5.083 (t_p)^{0.73}$ to obtain T_B in hours.

vi) Plot the parameters of 1-hour unitgraph viz. T_m, T_B, Q_p, W_{50}, W_{75}, W_{R50}, W_{R75} on a graph paper as shown in illustrative Fig. 2 and sketch the unitgraph through these points. The discharge ordinate (Q_i) of the unitgraph at 1-hour (t_r) interval are summed up and the direct runoff depth in cm is obtained from the following equation 3.9.10.

$$d = \frac{0.36 \times \sum Q_i \times t_r}{A} \qquad ......3.9.10$$

where d = depth of direct runoff in cm

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

A = catchment area in sq.km.

In case the depth of runoff (d) for the Synthetic Unitgraph drawn is not equal to 1.0 cm, then suitable modification may be made in falling and rising limbs of the unitgraph to obtain 1.0 cm depth of runoff. The shape of the modified unitgraph should be kept smooth.

3.11 Design Loss Rate

Surface runoff occurs when the gross rainfall has met with the abstractions due to infiltration, evapotranspiration, interception, filling up of surface depressions, etc. Since each and every parameter cannot be observed at various locations in the catchment, a need, therefore, arises to adopt an average value of design loss rate representing all the abstractions. Variations due to the soil conditions and topography along with the spatial variations in rainfall make this loss rate a complex phenomena. In this report, the loss rate study based on Ø -index approach using the actual data of flood hydrographs provide necessary guidance in arriving at the design loss rate. In Table-4 the ranges of loss rate are presented against the number of events falling in such category for each catchment.

Table-4 exhibits certain modal values of loss rate for the following three loss rate ranges occurring for 78 flood events out of a total of 108 flood events analysed:

Loss Rate (mm/hr) (1)	Ranges (cm/hr) (2)	Modal value (cm/hr) (3)	No. of flood events. (4)	
1 to 10	0.1 to 1.0	0.50	53	Out of a total
1 to 5	0.1 to 0.5	0.30	23	of 108 flood
5 to 10	0.5 to 1.0	0.75	30	events.
10 to 15	1.0 to 1.5	1.25	25	

There could perhaps be two alternatives. One was to adopt the lowest value of loss rate and the second to adopt the modal value of loss rate. Since this report is intended at providing 50-year estimates which may not be a very rare event when considered from design point of view a modal value of design loss rate of 5.00 mm per hour (0.5 cm/hr.) is recommended for adoption.

Besides the loss rate of 0.5 cm/hr recommended above for adoption, the designer has the option to choose one loss rate out of the loss rates of 0.75 cm/hr, 1.0 cm/hr, 1.25 cm/hr and 1.5 cm/hr (out of which 0.75 cm/hr and 1.25 cm/hr are modal values) to suit the relative importance of the structures, safety, economy, site conditions, catchment wetness characteristics and storage depressions for peak flood estimation of specific return period (25-yr, 50-yr and 100-yr). Preferably the designer may check the final selection of loss rate for an ungauged catchment by comparing its run-off factor for design storm rainfall and direct runoff, if available, for the record flood events of neighbouring catchments in the subzone having similar physiographic and hydrometeorologic characteristics.

3.12 Base Flow for Design Flood

The number of flood events with various ranges of base flow are shown in Table-5. Out of 106 number of flood events, 48 flood events fall in the range of 0.01 to 0.09 cumecs per sq.km. An average value of base flow of 0.05 cumecs per sq.km. is recommended for adoption.

LIST OF SELECTED ROAD/ RAILWAY BRIDGE CATCHMENTS IN KAVERI BASIN, SUB ZONE - 3(i) AND DATA AVAILABILITY OF GAUGE, DISCHARGE AND RAINFALL.

TABLE-I

Sl. No.	NAME OF STREAM.	NAME OF SECTION WHERE BRIDGE IS LOCATED WITH RAILWAY ZONE/ROAD SECTION.	BRIDGE NO.	G&D SITE LOCATION LATITUDE DEG. MIN. SEC	LONGITUDE DEG. MIN. SEC.	CATCHMENT AREA IN SQ. KM.	NO. OF R.G. STATIONS	DATA AVAILABILITY YEARS	NO. OF YEARS	REMARKS
1	2	3	4	5	6	7	※ 8	9	10	11
A	BRIDGES CONSIDERED FOR REGRESSION ANALYSIS									
1	YAGACHI	MANGALORE - HASSAN (S.R)	28	12 58 30	76 02 00	953	7	1980-83	4	※ - HOURLY RAINFALL / S.R.R.G STATIONS.
2	AIYAR	MUSIRI - TURAIYUR —	4-MOT	11 04 40	78 32 30	423	3	1980-83	4	
3	VANNATHANAGARAI	ERODE - PODANUR (S.R)	444	11 07 00	77 15 36	364	4	1966-74	9	
4	VEPPADI	SALEM - BANGALORE ,,	81	11 56 00	78 05 20	311	4	1969,70,73,74	4	
5	PAMBAR	JOLARPETTAI - SALEM ,,	37	12 24 00	78 30 18	294	6	1961, 66-69	5	
6	LOKAPAVANI	BANGALORE - MYSORE ,,	683	12 28 50	76 43 20	288	5	1980-83	4	
7	SARABANGA	METUR DAM - SALEM ,,	18	11 44 32	78 02 15	243	5	1966-75	10	
8	MANGARAI	DINDIGUL — PODANUR ,,	27	10 24 35	77 54 35	134	3	1972-74	3	
9	SITTAR	VRIDDLACHALAM - SALEM ,,	172	11 35 50	78 34 40	133	4	1961-66	6	
10	VEPPADI	JOLARPETTAI - SALEM ,,	157	11 58 42	78 14 12	125	5	1961, 64-66	4	
11	NANGANJI	DINDIGUL - POLLACHI ,,	74	10 28 30	77 42 45	105	2	1966-71	6	
12	ELURUMAIPALLAM	PODANPUR - METTUPPALAIYAM (S.R)	89	11 13 10	76 58 15	88	2	1961-68	8	
13	UPPALLA	BOWRINGPET - KOLAR ,,	26	13 06 57	78 08 40	75	5	1962, 66-71	7	
14	MARKANDA	BANGALORE - JOLARPETTAI ,,	760	12 59 12	78 10 24	75	2	1970-74	5	
15	SANGANUR PALLAM	COIMBATORE - METTUPPALAIYAM (S.R)	29	11 02 00	76 57 00	71	2	1973-79	7	
16	PAMBAR	JOLARPETTAI - SALEM ,,	90	12 10 45	78 25 25	61	2	1972-73	2	
17	ANAMADUGU	MADRAS - JOLARPETTAI ,,	532	12 47 00	78 43 00	42	3	1965-71	7	
18	FOREST STREAM	SALEM - BANGALORE ,,	170	12 10 40	78 08 00	35	1	1969-71	3	
19	TRI. OF SHIMSHA	BANASANDRA - BANGALORE ,,	244	13 15 50	76 42 00	30	2	1962-66	5	
20	KATTEHALLA	MYSORE - CHAMRAJNAGAR ,,	845	11 56 17	76 55 36	29	2	1961-65	5	
B	BRIDGES NOT CONSIDERED FOR REGRESSION ANALYSIS									
1	SHIMSHA	BELLURU - GUBBI —	2-MOT	13 05 45	76 48 40	2850	15	1979-84	6	
2	GODDU VANKA	KATPADI - RENIGUNTA (S.C.R.)	589	13 16 55	79 06 55	608	7	1974-78	5	
3	KORANGUPPALLAM	TIRUCHCHIRAPPALLI - ERODE (S.R)	243	11 06 20	77 53 00	293	3	1967-68	2	
4	GODDU VANKA	KATPADI - RENIGUNTA (S.C.R.)	611	13 20 20	79 06 25	163	3	1975-77	3	
5	GADDAR	MADRAS - JOLARPETTAI (S.R.)	583	12 39 05	78 35 35	146	3	1972-78	7	
6	MANGALAMPATA	DHARMAVARM - PAKALA (S.C.R.)	681	12 30 00	79 03 00	131	3	1966-74	9	
7	VARATTAR	TIRUCHCHIRAPPALLI - MADURAI (S.R)	1277	10 28 25	78 08 55	65	2	1966-74	9	
8	BOMMONOHALL MORI	BANGALORE - ARSIKERE ,,	242	13 16 00	76 39 00	32	1	1969	1	
9	FOREST STREAM	MYSORE - ARSIKERE ,,	278	12 23 20	76 35 15	29	1	1966-68	3	
10	PAUCHARATTEYAR	TIRUCHCHIRAPPALLI - MADURAI (S.R)	1261	10 30 30	78 12 55	27	3	1961-66	6	

D.P.SINGH.

BASIN CHARACTERISTICS
SUB-ZONE-3(i)

TABLE-2

Sl. No.	Br. No.	$A_{So.Km.}$	$L_{Km.}$	$L_{c/Km}$	$S_{m/Km}$	$\frac{LL_c}{\sqrt{S}}$
1	2	3	4	5	6	7
1.	28	953.12	71.32	29.79	1.98	1509.90
2.	(4 MOT)	423.00	48.27	24.14	14.72	303.45
3.	44	364.18	50.14	22.94	3.11	652.23
4.	81	310.80	39.90	15.85	8.42	217.94
5.	37	294.00	43.47	22.72	5.13	436.05
6.	683	287.5	43.47	22.22	4.97	433.27
7.	18	243.15	31.86	16.09	13.39	140.09
8.	27	134.18	26.71	15.96	12.11	122.5
9.	172	132.56	25.76	10.87	6.90	106.60
10.	157	125.40	22.14	4.43	30.48	17.8
11.	74	104.89	17.89	8.05	19.64	26.45
12.	89	88.00	17.71	9.66	6.01	69.78
13.	26	74.72	14.89	7.25	8.41	37.22
14.	760	74.60	18.52	8.53	3.96	79.4
15.	29	70.65	21.90	13.04	13.64	77.32
16.	90	61.00	14.64	7.51	4.09	54.36
17.	532	42.00	14.50	5.60	18.63	18.81
18.	170	35.09	12.06	7.96	3.395	52.14
19.	244	29.79	15.77	6.92	7.14	40.84
20.	845	29.29	10.87	4.83	8.75	17.75

TABLE - 3

REPRESENTATIVE 1-Hr. UNIT GRAPH PARAMETERS
SUBZONE - 3(i)

Sl. No.	Br. No.	tp (hr)	Q_p (cumecs)	qp (Cumecs/ Sq.Km.)	tr (hrs)	TB (Hrs)	WR_{50} (hrs)	W_{75} (hrs)	WR_{50} (hrs)	WR_{75} (hrs)
1	2	3	4	5	6	7	8	9	10	11
1.	28	11.5	170.0	0.19	1	35	13.4	10.10	4.20	3.00
2.	4(MOT)	6.5	156.0	0.37	1	21	5.85	2.60	2.20	1.10
3.	444	6.5	177.0	0.49	1	18	4.70	3.10	1.50	1.20
4.	81	5.5	124.0	0.40	1	20	6.20	3.70	3.40	2.05
5.	37	6.5	118.5	0.40	1	20	5.8	3.5	2.2	1.60
6.	683	5.5	108.0	0.48	1	15	3.95	2.05	1.63	0.95
7.	18	5.5	108.0	0.45	1	20	5.40	3.6	2.0	1.4
8.	27	4.5	78.0	0.58	1	15	3.25	2.10	1.80	1.10
9.	172	3.5	119.0	0.90	1	12	2.75	1.70	1.60	1.05
10.	157	2.5	118.0	0.94	1	11	2.10	1.23	0.50	0.40
11.	74	2.5	74.0	0.70	1	9	3.60	2.10	1.30	0.80
12.	89	2.5	78.0	0.89	1	9	2.60	1.55	0.70	0.58
13.	26	2.5	63.0	0.84	1	10	2.70	1.80	1.25	0.80
14.	760	3.5	53.0	0.71	1	10	3.5	2.15	1.3	0.95
15.	29	2.5	83.0	1.18	1	9	1.70	0.90	0.45	0.30
16.	90	2.5	44.0	2.72	1	12	2.60	1.45	1.00	0.55
17.	532	1.5	52.0	1.24	1	8	1.98	1.30	0.43	0.30
18.	170	2.5	32.10	0.91	1	10	2.50	1.75	1.10	0.65
19.	244	2.5	34.0	1.14	1	10	1.95	1.30	0.80	0.60
20.	845	1.5	42.2	1.44	1	7	1.4	0.80	0.65	0.40

LOSS RATE RANGES (mm/hr) - NUMBER OF FLOOD OCCASIONS
SUBZONE - 3(i)

Table-4

Sl.No.	Br.No.	Catchment area (sq.km.)	Loss Rate Ranges (mm/hr) 0.01 to 5	5.1 to 10	10.1 to 15	15.1 to 20	20.1 to 25	25.1 to 30	30.1 to 35	35 & above	Total
			Number of Flood Occasions								
1.	28	953.12	3	1				1			4
2.	MOT- 4	423.0	1	3	3	1	1	1	-	1	11
3.	444	364.18		2	3			1			6
4.	81	310.80		3	1	1					5
5.	31	294.00	3	2							5
6.	683	287.50	1	1	2			1			5
7.	18	243.15	1	3	3						7
8.	27	134.18	3								3
9.	172	132.56	-	1	1	-	-	2	1	3	8
10.	157	125.40		2	4	1	1	1			9
11.	74	104.85	3	1							4
12.	89	88.00	1	2	3			1	1	1	8
13.	26	74.72		2	1	1	1				5
14.	760	74.60		1	2		2	1			6
15.	29	70.65	1	1			2				4
16.	90	62.00		2					1		3
17.	532	42.0	3	-							3
18.	170	35.09				1				1	2
19.	244	29.78	1				1	1			3
20.	845	29.29	2	3	2						7
	Total :		23	30	25	5	8	10	3	5	108

Table-5

BASE FLOW RANGES - NUMBER OF FLOOD OCCASIONS
SUBZONE-3(i)

Sl.No.	Br. No.	Base flow Ranges (cumecs per square kilometer) 0-0.001	0.0011 to 0.005	0.0051 to 0.009	0.01 to 0.09	0.10 to 0.19	0.20 & above	Total
		Number of Flood Occasions						
1	[illegible]				4			4
2	4-MOT	-	-	-	-	-	3	3
3	444		4		2			6
4	81		2	1	2			5
5	37	1	1	1	2			5
6	683	1	3		1			5
7	18		3	1	3			7
8	27					2	1	3
9	172	8						8
10	157				8		1	9
11	74		2		1	1		4
12	89		1	3	3	1		8
13	26	1			2	1	1	5
14	760	2	1		3			6
15	29				3		1	4
16	90				1	2		3
17	532	-	1	2	8	-	-	11
18	170	-	2	-	-	-	-	2
19	244			1	1	1		3
20	545	2	1		4			7
	Total:	15	21	9	48	8	7	108

4.0 DESIGN STORM INPUT

The areal distribution and time distribution of the rainfall of a given duration are two main meteorological factors deciding the design flood peak and the shape of the design flood hydrograph. This input has to be converted into rainfall excess and applied to the transfer function (Synthetic Unit Hydrograph) to obtain the response (Flood Hydrograph).

4.1 Design Storm Duration

The duration of the storm rainfall which causes the maximum discharge in a drainage basin is called the design storm duration. The design storm duration (T_D) for a catchment is 1.1 t_p.

$$T_D = 1.1\ t_p.$$

4.2 RAINFALL DEPTH DURATION FREQUENCY STUDIES

India Meteorological Department have conducted this study on the basis of 13 self-recording raingauge stations and 195 ordinary raingauge stations maintained by IMD/States and 26 SRRG stations maintained by Railways in 8 bridge catchments in subzone-3(i).

The annual maximum series for all the ordinary raingauge stations in and around the subzone were computed for each station from daily rainfall data of the stations for the period varying from 50 to 70 years of records. The annual extreme value series was subjected to frequency analysis by Gumbel's extreme value distribution and the rainfall estimates for 50-year return periods were computed. The daily values of rainfall estimates were converted into 24-hour rainfall estimates by using the conversion factor of 1.15. These 24-hour rainfall estimates for all the stations in the subzone were plotted on a base map of the subzone and isopluvial map of 50-year return period was drawn and shown in plate-10.

The hourly rainfall data recorded by 13 SRRG stations maintained by I.M.D. for the period were processed by frequency analysis (partial duration series method) and the rainfall estimates for 50-year return period for specified duration namely 1, 3, 6, 9, 12, 15, 18 and 24 hours were computed.

The ratios of short duration of 1, 3, 6, 9, 12, 15 and 18 hours rainfall estimates with respect to 24-hour rainfall estimates were worked out for all the SRRG's stations in the subzone. The average value of the ratio for each specified duration was computed for the basin assuming the basin as a unit.

The average ratios for durations of 1,3,6,9,12,15 and 18 hours with respect to 24-hour rainfall are as under:

Duration	Ratio
24	1.00
18	0.91
15	0.87
12	0.83
9	0.78
6	0.71
3	0.59
1	0.42

$$\text{Ratio} = \frac{\text{50-yr. T-hr. point rainfall}}{\text{50-yr 24-hr. point rainfall}}$$

Fig. 10 shows the ratios for short duration point rainfall with respect to 24-hour point rainfall.

The short duration rainfall estimates for various short durations (1,3,6,9,12,15 & 18 hours) can be computed by using the respective ratios. The value of 24-hour rainfall estimates for a particular station for 50-yr. return period can be interpolated from Plate-10 and the short duration rainfall estimates can be obtained by multiplying with the corresponding ratio for that particular short duration obtained from Fig. 10.

4.3 CONVERSION OF POINT TO AREAL RAINFALL

The short duration rainfall data of only 8 bridge catchments were used for this study. The data of remaining bridge catchments could not be utilised as the period of data were either less than 4 years and/or concurrent years data were not recorded continuously for 4 years over the stations in a bridge catchment. 2-year point rainfall values for specified duration for each station in the catchment were computed by frequency analysis. Arithmetic average of 2-year point rainfall of all the stations in the catchment was calculated to get the 2-year representative point rainfall for the catchment. Events of maximum average depth for a particular duration in each year were selected on the basis of simultaneous occurrence of rainfall at each station in the catchment. The areal rainfall series thus obtained was subjected to frequency analysis of 2-year areal rainfall depths for specified durations were computed. The percentage ratio of 2-year areal rainfall to 2-year representative point rainfall for the catchment was calculated and plotted against the area of the catchment for various durations. The best fit curves were drawn for specified durations on the points obtained for all the catchments. Fig. 11(a) and 11(b) give the curves for conversion of point rainfall into areal rainfall for 1,3,6, 12 and 24 hours. The areal reduction factor (ARF) at different intervals of catchment areas for the above durations are given in Table-A-3.

Data for bridge catchment is available only upto 950 sq.km. and point to areal curves have been extrapolated upto 2500 sq.km. on the basis of limited ARF's obtained from bridges having area less than 950 sq.m. Point to areal rainfall values may, therefore, be used with caution for areas more than 1000 sq.km.

4.4 TIME DISTRIBUTION OF INPUT STORMS

The study of time distribution of short duration rainfall has been carried out by IMD for the following categories of durations:

1. Rain Storm of 2 to 3 hours
2. Rain storm of 4 to 6 hours
3. Rain Storm of 7 to 12 hours
4. Rain Storm of 13 to 18 hours
5. Rain Storm of 19 to 24 hours

About 2308 rain storms of various durations upto 24 hours occurring in various parts of the subzone were analysed based on 155 station year data. Rain storm selected at such stations were grouped under the above 5 categories and plotted on different graphs on dimensionless curves with cumulative percentage of total rainfall along the ordinates and percentage of storm duration along the abcissa. Thus five different graphs were prepared for each station corresponding to various durations and were than examined. The average time distribution curves for the various durations were drawn for each station. All the average curves for the stations thus obtained were plotted on a single graph and a single average curve for the subzone as a whole was drawn for storms of different durations and are shown in Fig. 12.

4.5 25-YEAR AND 100-YEAR 24-HOUR POINT RAINFALL MAPS

For those interested in the design flood (25-year and 100-year flood) 25-year and 100-year 24-hr. point rainfall maps are shown in Plates-9 & 11. To obtain 6,9,12,15 and 18 hrs. from 25-year and 100-year 24 hr. rainfall, the ratios given in sections 4.3 and 4.4 may be used for conversion of point to areal rainfall and time distribution of input storm respectively. Synthetic unitgraph, design loss rate and base flow will remain the same as in the case of 50-year flood.

4.6 PROCEDURE FOR ESTIMATION OF DESIGN STORM RAINFALL

The following procedure is recommended to be adopted for estimation of critical distribution of storm rainfall to cause the maximum flood due to rainfall of a specified duration.

Step (1) : Estimate $t_p = 0.553 \, (LL_c / \sqrt{S})^{0.405}$ by substituting the know values of L, L_c and S for the catchment. Calculate the design storm duration $(T_D) = 1.1 \, t_p$. The value of T_D may be rounded off to the nearest 1-hour.

Step (2) : Locate bridge site/catchment area under study on the 50-yr., 24-hr. rainfall isopluvial map (Plate-10) and obtain the 50-yr. 24-hr. point rainfall value.

Step (3) : Read the conversion ratio for T_D hours from Fig. 10 and multiply the 24-hour rainfall in Step-2 by the ratio to obtain the 50-year T_D-hour rainfall.

Step (4) : Convert the 50-year T_D-hour point rainfall to 50-year T_D-hour areal rainfall by multiplying with the areal reduction factor (ARF) corresponding to catchment area under study and for T_D-hour duration from Table-6 or by interpolation from Fig. 11(a) and 11(b) in Section 4.3.

Step (5) : Apply the cumulative percentage of total rainfall against the cumulative percentage of storm duration curves in Fig. 12 or from Table A-2 corresponding to design storm duration T_D to obtain the depths at 1-hour interval since the unit duration of Synthetic U.G. is 1-hour.

Step (6) : Obtain the 1-hourly rainfall increments from substraction of successive 1-hour cumulative value of rainfall in Step-5.

5.0 ESTIMATION OF DESIGN FLOOD FOR AN UNGAUGED CATCHMENT

The following procedure is recommended:

Step (1) : Determine the Synthetic Unitgraph vide Section 3.9 and 3.10

Step (2) : Determine the design storm rainfall input vide Section 4.0.

Step (3) : Adopt the design loss rate of 0.5 cm/hr. vide Section 3.11.

Step (4) : Obtain the hourly rainfall excess units upto the design storm duration T_D by subtracting the design loss rate of 0.5 cm/hr. from the hourly rainfall increments in Step-6 of Section 4.6

Tabulate the U.G. discharge values obtained from Step-1 at 1-hour interval.

Arrange the rainfall excess increments against the 1-hourly Synthetic U.G. ordinates such that the maximum value of rainfall excess comes against the peak discharge of Synthetic U.G., the next lower value of rainfall excess increment comes against the next lower discharge ordinate and so on.

The sum of the product of unitgraph ordinates and the rainfall excess as tabulated above gives the 50-year flood peak value after due addition of base flow in Step-9.

However, the subsequent Step-6 to 10 should be followed, for computation of design flood hydrograph.

Step (6) : Reverse the sequence of rainfall excess increments obtained in Step-5 which will give the critical sequence of the rainfall excess.

Step (7) : Multiply the first 1-hour rainfall excess with the Synthetic U.G. ordinates at 1-hour interval which will give the corresponding direct runoff ordinates. Likewise repeat the procedure with the rest of the 1-hourly rainfall excess increments giving a lag of 1-hour to successive direct runoff ordinates.

Step (9) : Obtain the average base flow of 0.05 cumec/sq.km./vide Section 3.12 Multiply average base flow of 0.05 cumec/sq.km. with the catchment area under study to get the total base flow.

Step (10): Add the total base flow to the direct runoff ordinates at 1-hour interval in Step-8 to get the 50-year flood hydrograph. Plot the hydrograph.

6.0 FORMULA FOR LINEAR WATERWAY OF BRIDGES

Design of cross drainage structure like bridges/culverts/acquaducts encompases the primary fixation of the linear waterway to be provided, the HFL anticipated, number of spans to be provided, type of piers to be given, etc., apart from many other structural factors. This report focusses on the methodology to be used to estimate the flood produced from a rainfall which would occur with a 50-year recurrence interval. Once this estimate has been made, the usage of this discharge value would logically be the next step. A perusal of prevalent rail and road bridge design codes suggest the formula for fixing the waterway.

The linear dimension of any hydraulic structure have a bearing on the width of channel. The channel width in the case of a stable river is mostly controlled by the nature of soil, slope and roughness of terrain/channel bed as also the magnitude, duration and frequency of floods over a long period in geological time. The width of the channel, therefore, remains more or less constant for discharge magnitudes of different return periods, though the flood levels and velocities vary considerably to cater to the increase in discharge magnitudes. With this concept in view, the formulae for linear waterway related to frequency floods have been developed. Considering the dimension of discharge which is L^3/T, the adoption of $\sqrt[3]{Q}$ discharge as the ruling parameter seems to be justifiable. Taking into account the analysed bridges in subzone 3(1), the following simplified formula has been derived:

$$W = 4.98 \times \sqrt[3]{Q_{50}}$$

Where W is linear waterway in metres and Q_{50} is 50-yr. flood discharge in cumecs.

The design engineers may follow the following steps while fixing some of the primary parameters of the bridge.

(1) Estimate Q_{50} by using the methodology outlined in the report

(2) Estimate the linear waterway using the equation given above

(3) Work out the design HPL expected for Q_{50} with the waterway estimated.

The linear waterway which is estimated may seem to be inadequate or excessive as per the site conditions prevalent. In that case, the design engineer is at liberty to choose a suitable waterway not much different from the estimated waterway and thereafter fix the design HFL as per normal calculations. The above mentioned equation gives only a guide to the possible width which may have to be provided to pass the discharge at the bridge site. In case the design engineer feels that the importance of the structure warrants

Q_{25} or Q_{100} and wants to use those values for design purpose, then the linear waterway may be worked out with the following formulae:

$$W = 5.02 \times \sqrt[3]{Q_{25}}$$

$$W = 4.60 \times \sqrt[3]{Q_{100}}$$

THE FORMULAE GIVEN ABOVE ARE ONLY TO BE USED FOR FIXING THE LINEAR WATERWAY OF THE BRIDGES IN THE KAVERI SUBZONE - 3(i). THE LACEY'S REGIME WIDTH FORMULA WILL NOT BE APPLICABLE FOR FIXING THE LINEAR WATERWAY OF BRIDGES IN SUBZONE -3(i). HOWEVER FOR DETERMINATION OF SCOUR AT BRIDGE SITES, THE LACEY'S SCOUR FORMULAE BASED ON LACEY'S REGIME WIDTH AS SPECIFIED IN THE CODES FOR ROAD AND RAIL BRIDGES SHALL BE USED.

The relevant codes of practice for design flood and fixing of waterway of bridges by Indian Railway and Indian Roads Congress are as under:

(i) Code of practice by Indian Railways (revised 1985) sections 4.2, 4.3, 4.4 and 4.5.

(ii) Standard specifications and code of practice for Road bridges, section 1, General Features of Design (fifth revision) by Indian Roads Congress, 1983 - clauses 103 and 104.

7.0 UTILITY OF REPORT FOR OTHER PURPOSES

The report may also be used for estimation of frequency flood for the following categories of structures as per the Indian Standards of the Indian Standards Institution:

i) <u>Small Dams</u>

The Indian Standard - guidelines for fixing spillway capacity of Dams under clauses 3.1.2 and 3.1.3 of IS: 11223-1985 (under print) recommends 100-year flood as inflow design flood for small dams having either a gross storage behind the dam between 0.5 to 10 million m^3 or hydraulic head (from normal or annual average flood level on the downstream to the maximum waterlevel) between 7.5m to 12m. The report may be made use of for estimation of 100-year flood safety of small dams.

ii) <u>Minor Cross Drainage Works</u>

The Indian Standard - code of practice for design of cross drainage works, part -1 General features under clause 6.2 of IS: 7784 (part-1)-1975 recommends 10 to 25 years frequency flood with increased afflux for the design of waterway of minor cross drainage works. The report may be made use of for estimation of 25 year flood for fixing the waterway of minor cross drainage works. The flood of different return periods say from 10 to 20 years may be estimated by using the detailed methodology given in the report on the basis of 10 to 20 years, 24-hr. point storm rainfall determined for the ungauged catchments under study.

8.0 ASSUMPTIONS, LIMITATIONS AND CONCLUSIONS

8.1 ASSUMPTIONS

8.1.1 It is assumed that 50 year return period storm rainfall produces 50-yr. flood.

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

8.2 LIMITATIONS

8.2.1 The data of 20 catchments has been considered for developing a generalised approach for a large subzone. However, for more reliable relationships the data of more suitable catchments would be desirable.

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

8.2.3 The approach developed mostly covers the catchments with flat to moderate slopes.

8.3 CONCLUSIONS

8.3.1 The methodology for estimating the design flood of 50-yr. return period incorporated in the body of the report is recommended for adoption.

8.3.2 The report also recommends the adoption of design flood of 25-yr. and 100-yr. return periods taking into account the relative importance of the structures.

8.3.3 This report suggests a uniform loss rate of 0.5cm/hr. for the computation of design flood. However, the flexibility has been imparted to the report by suggesting further the modal values of loss rates of 0.75cm/hr. and 1.25m/hr. (also 1.0cm/hr. and 1.5cm/hr.) for the designer to choose from with the approval of competent authority. (see section 3.11).

8.3.4 The flood formulae with different return periods shall be used only for preliminary design. However, for final design, design flood shall be estimated by application of storm rainfall to synthetic unit hydrograph.

8.3.5 Formulae for fixing the linear waterway of cross drainage structures on streams in Kaveri subzone may be used at the discretion of the design engineer.

8.3.6 The report is applicable for the catchment areas ranging from 25sq.km. to 1500 Further the report may be used for larger catchments upto 3000 sq.km. based on sound judgement and considering the data of neighbouring catchments also. However, individual site conditions may necessitate special site study. Engineer-in-charge at site is advised to take a pragmatic view while deciding the design discharge of a bridge.

REFERENCES

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

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

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

4. "Engineering Hydrology" Wilson E.M.

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

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

7. Code of Practice for Road Bridges, Section 1, General Features of Design (5th Revision), 1983, Indian Roads Congress.

8. "The Design of Small Bridges and Culverts" Goverdhan Lal.

9. Flood Studies Report, Vol.I, Hydrological Studies, Natural Environment Research Council, 27, Claring Cross Road, London, 1975.

10. "Economics of Water Resources Planning" L. Douglas James/Robert R.Lee.

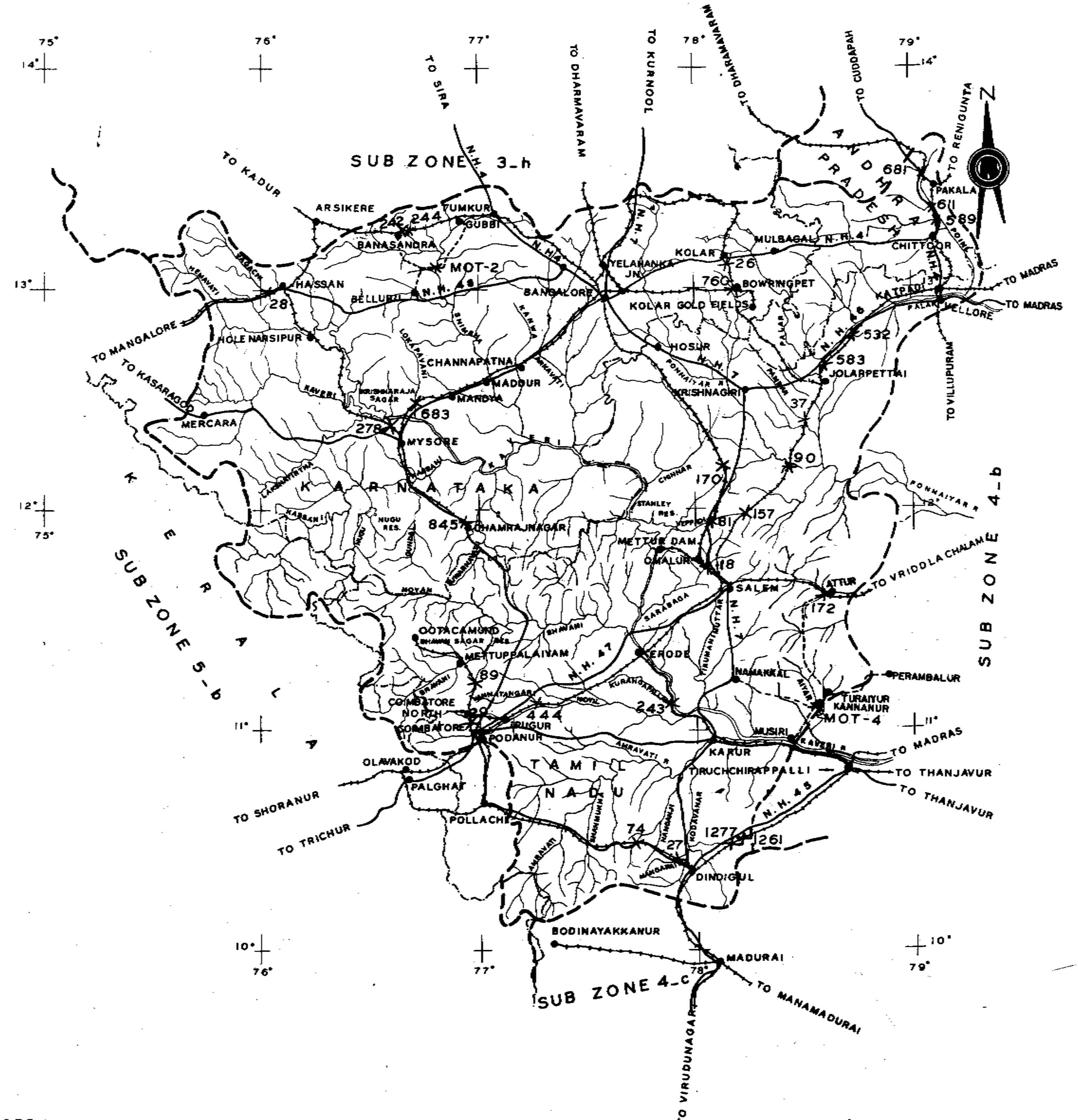
THE EXTERNAL BOUNDARY AND COAST LINE OF INDIA ON THE MAPS AGREE WITH THE RECORD COPY CERTIFIED BY THE SURVEY OF INDIA.

S.N. MALHOTRA
R.N. SHARMA

NOTE:-

(i) RESPONSIBILITY FOR THE CORRECTNESS OF INTERNAL DETAILS RESTS WITH THE PUBLISHER.

(ii) BASED UPON SURVEY OF INDIA MAP WITH THE PERMISSION OF THE SURVEYOR GENERAL OF INDIA.



LEGEND

1. SUB - ZONE BOUNDARY
2. STATE BOUNDARY
3. RAILWAY LINE
4. NATIONAL HIGHWAYS
5. ROADS
6. RIVERS & ITS TRIBUTARIES
7. BRIDGE SITES (BRIDGE NO.) 18
8. TOWNS

NOTE -:
FOR LOCATION OF BRIDGES REFER TABLE NO. 1

K.M.S 10 5 0 10 20 30 40 50 60 70 80
MILES 10 5 0 10 20 30 40 50

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

KAVERI BASIN

SUB ZONE 3 (i)
RIVER SYSTEM AND LOCATION OF ROAD AND RAILWAY BRIDGES (G & D SITES)

DRAWN BY P. N. BHALLA, S. K. BHATIA
CHECKED BY A. K. GHOSH
DRG. NO HSC/DIV-III 85_167

NOTE -:
RESPONSIBILITY FOR THE CORRECTNESS OF INTERNAL DETAILS RESTS WITH THE PUBLISHER

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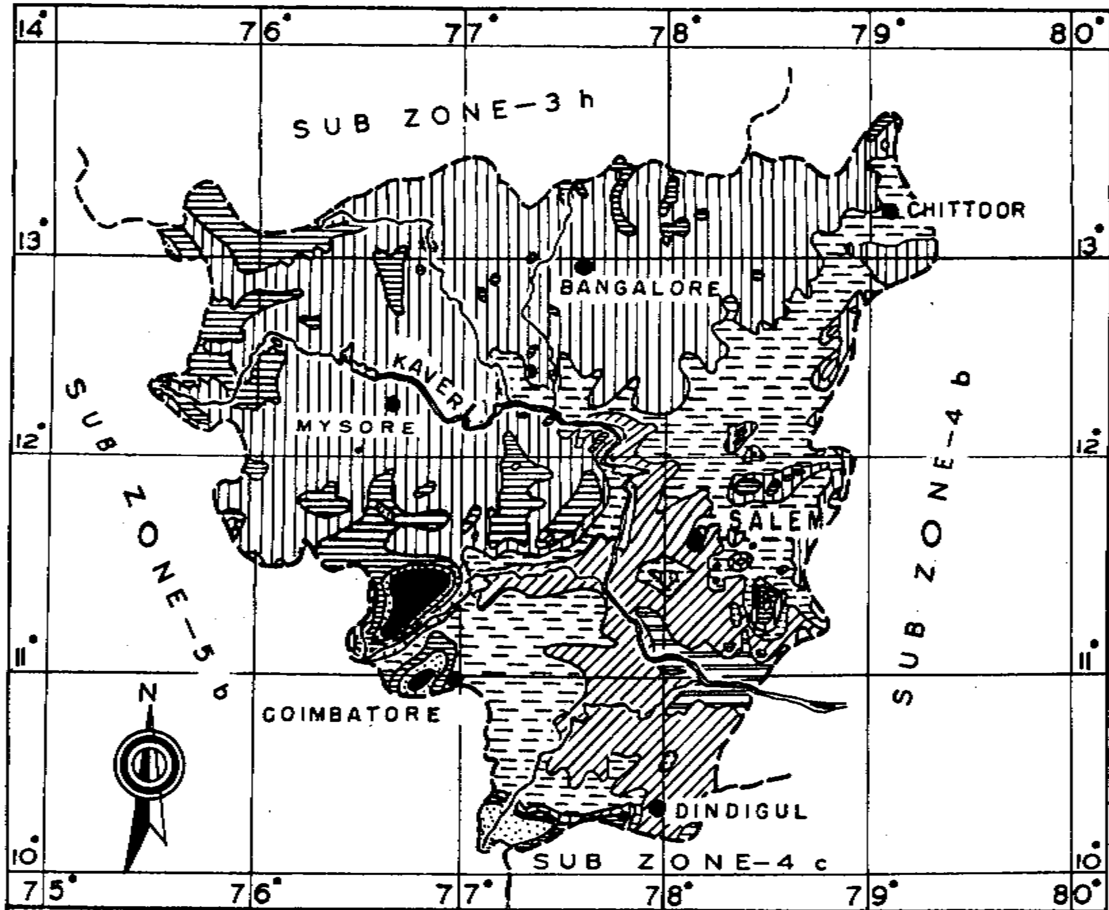


PLATE- 3

LEGEND

ALTITUDE IN METERS

0 - 150
150 - 300
300 - 600
600 - 900
900 - 1350
1350 - 1800
1800 - 3000

SCALE:-

KMS 20 0 20 40 60 80 100 120 140 160 K.M.S.

MILES 10 5 0 15 30 45 MILES

REFERENCES

1. SUB ZONE BOUNDARY.
2. RIVERS
3. TOWNS.

NOTE:-

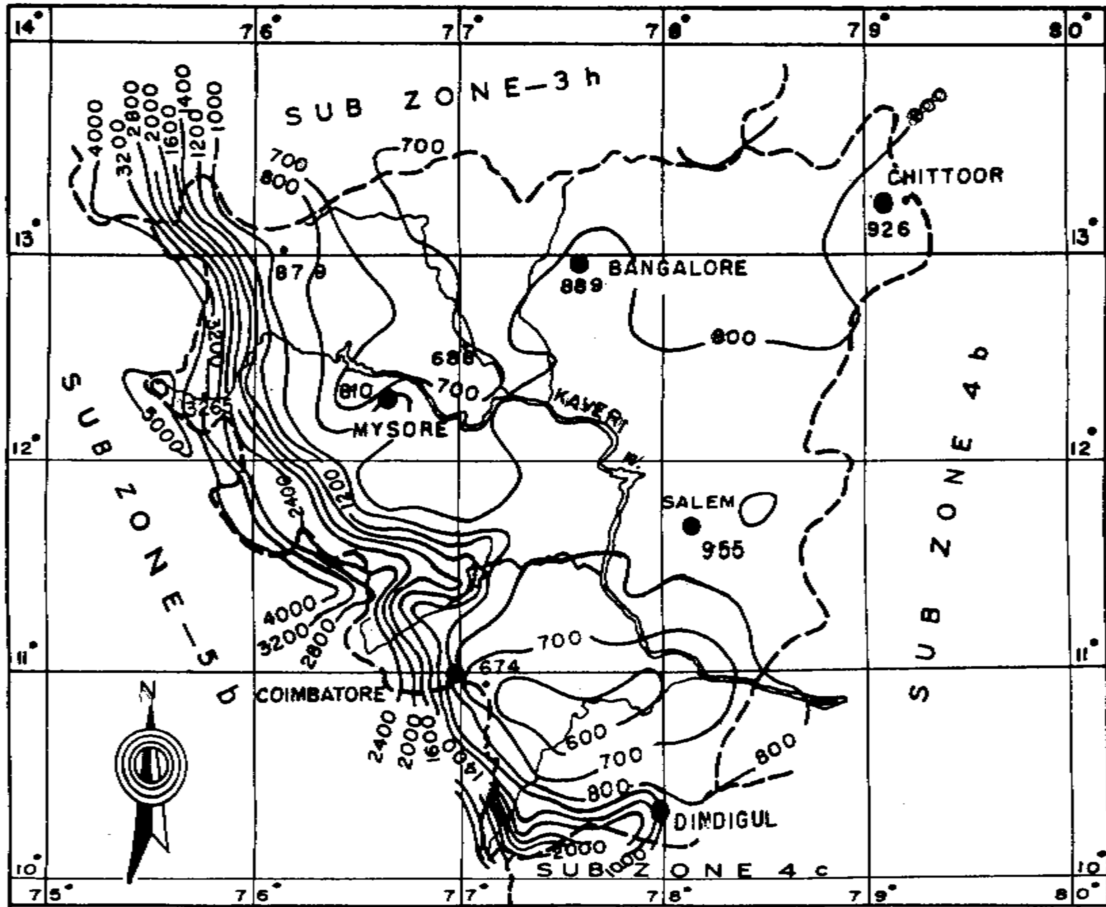
THIS MAP HAS BEEN DRAWN FROM THE IRRIGATION ATLAS OF INDIA (1972) PLATE NO. 3.

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE

KAVERI BASIN
SUB ZONE -3(I)
PHYSIOGRAPHY

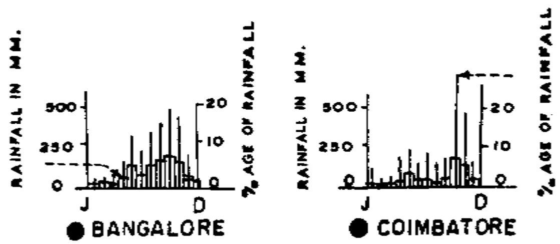
DRAWN BY	CHECKED BY
S.N. MALHOTRA R.N. SHARMA	A.K. GHOSH

PLATE - 4



REFERENCES

1. ISOHYETAL LINES WITH VALUE IN MM. (NORMAL ANNUAL) — 800
2. SUB ZONE BOUNDARY
3. RIVERS
4. TOWNS
5. SPOT RAINFALL — 955



NOTES:-

1. HISTOGRAMS FOR TWO STATIONS WITH NAMES.
2. EACH VERTICAL COLUMN REPRESENTS THE MEAN MONTHLY RAINFALL FOR EACH MONTH. (FROM JANUARY TO DECEM.)
3. THE THICK VERTICAL LINES AT THE CENTRE OF EACH COLUMN INDICATES THE PERCENTAGE OF RAINFALL IN THE MONTH TO THE MEAN ANNUAL TOTAL.
4. THIS MAP HAS BEEN DRAWN FROM THE THE IRRIGATION ATLAS OF INDIA (1972) PLATE - 6.

SCALE:-

KMS 20 0 20 40 80 120 160 KMS

MILES 20 10 0 30 60 90 MILES

GOVERNMENT OF INDIA.
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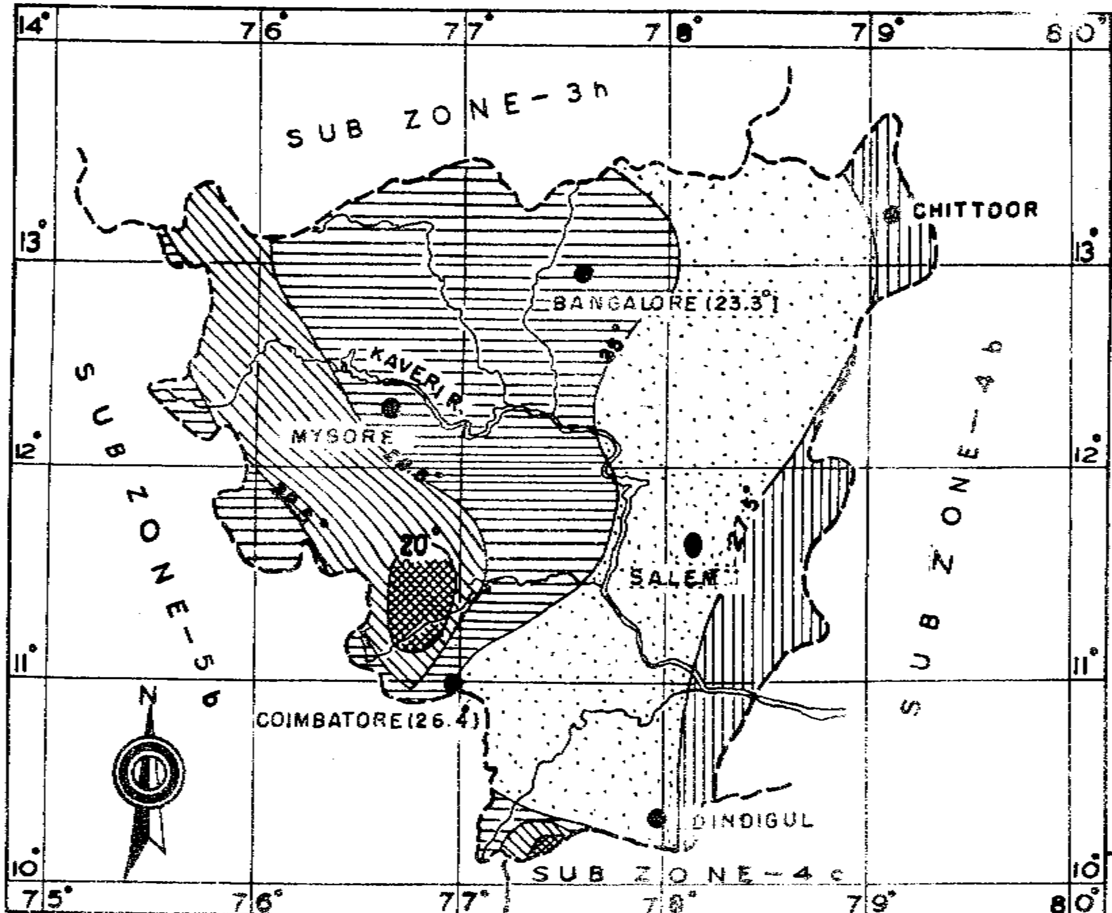
KAVERI BASIN

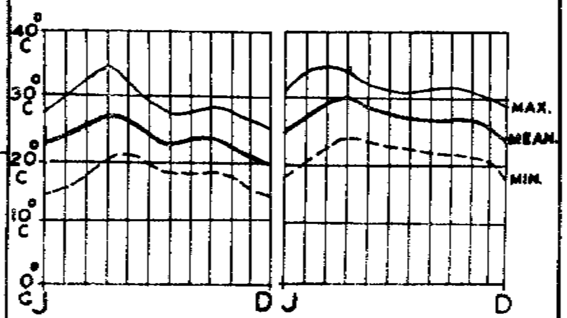
SUB ZONE - 3(i)

NORMAL ANNUAL RAINFALL mm.

DRAWN BY	CHECKED BY
S.N. MALHOTRA R.N. SHARMA	A.K. GHOSH

PLATE - 5





● BANGALORE ● COIMBATORE

NOTE:-
THIS MAP HAS BEEN DRAWN FROM THE IRRIGATION ATLAS OF INDIA (1972) PLATE NO. 4.

SCALE:-

KMS 20 0 20 40 80 120 160 KMS.
MILES 20 10 0 30 60 90 MILES

REFERENCES

1. TEMP. BELOW 20°C
2. " BETWEEN 20°C & 22.5°C
3. " " 22.5°C & 25°C
4. " " 25°C & 27.5°C
5. " " ABOVE 27.5°C
6. SUB ZONE BOUNDARY
7. TOWNS
8. RIVERS
9. ISOTHERMS WITH VALUE 25°C IN CENTIGRADE DEGREES

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE

KAVERI BASIN

SUB ZONE-3(I)

NORMAL ANNUAL TEMPERATURE

DRAWN BY	CHECKED BY
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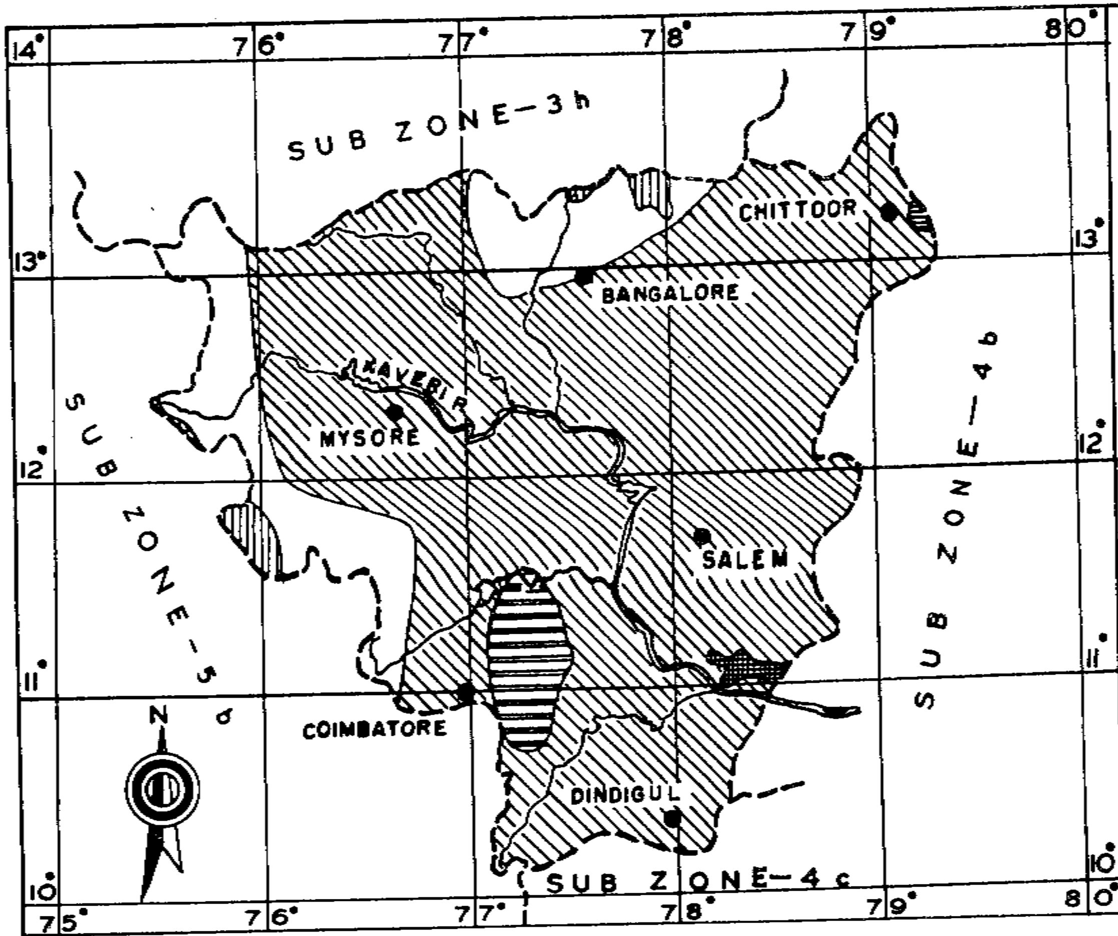
PLATE - 6



LEGEND

1. RED SANDY SOIL
2. RED LOAMY SOIL
3. MIXED RED AND BLACK SOIL
4. DELTAIC ALLUVIAL SOIL
5. LATERITE SOIL
6. COASTAL ALLUVIAL SOIL

SCALE:-

KMS 20 0 20 40 80 120 160 KMS.

MILES 20 10 0 30 60 90 MILES

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KAVERI BASIN

SUB ZONE - 3(i)

SOIL CLASSIFICATION

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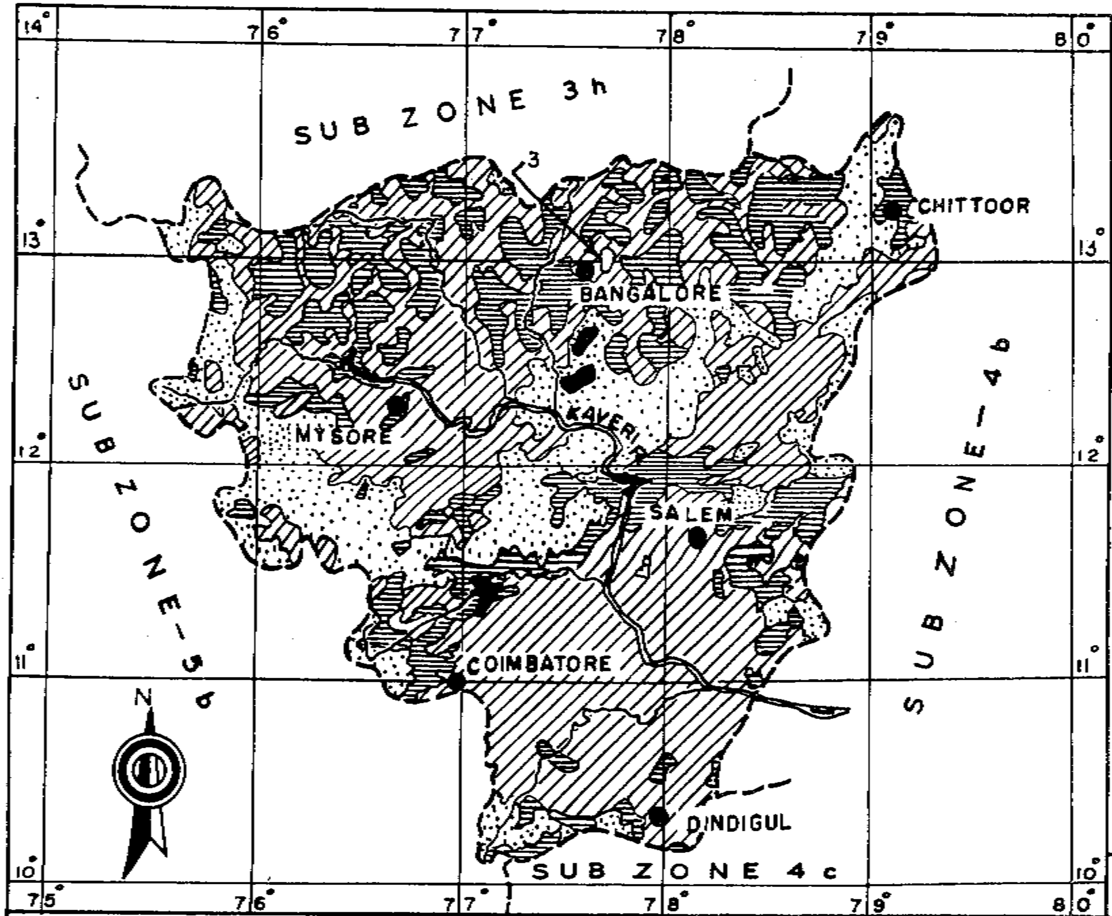
PLATE - 7



LEGEND

1. GRASSLAND & SCRUB
2. ARABLE LAND
3. URBAN AREAS
4. FOREST
5. WATER BODIES, MARSHES ETC.
6. SUBZONE BOUNDARY.
7. RIVERS.
8. TOWNS.

SCALE:-

KMS 20 0 20 40 80 120 160 KMS.

MILES 20 10 0 30 60 90 MILES

NOTE:-

THIS MAP HAS BEEN DRAWN FROM THE IRRIGATION ATLAS OF INDIA (1972) PLATE NO. 9.

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HYDROLOGY (SMALL CATCHMENTS) DTE

KAVERI BASIN

SUB ZONE - 3(i)

LANDUSE

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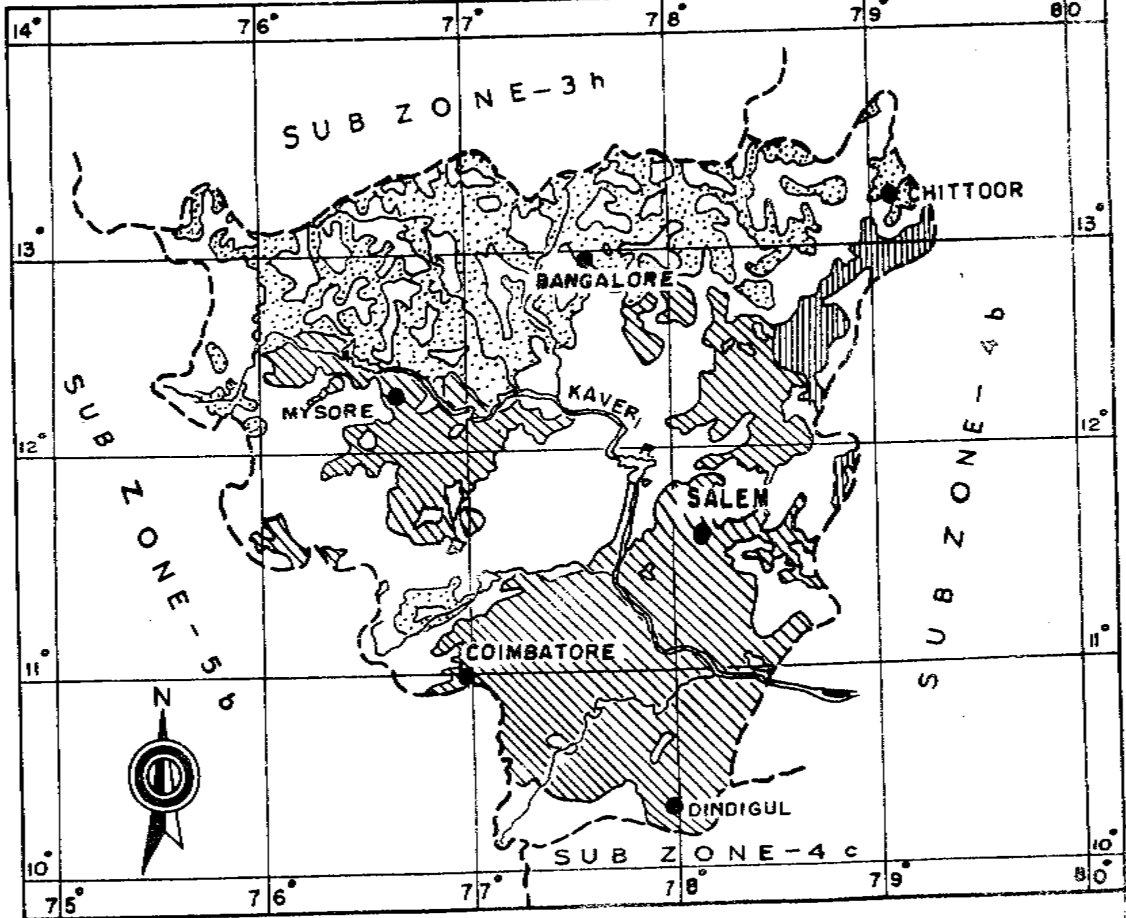
S.N. MALHOTRA R.N. SHARMA	A.K. GHOSH

PLATE- 8



LEGEND

1. PERCENTAGE OF ARABLE LAND UNDER MULTIPLE CROPPING TO TOTAL ARABLE LAND.

0 — 10

10 — 20

20 — 40

1. LAND NOT UNDER CULTIVATION

2. SUB ZONE BOUNDARY.

3. RIVERS.

4. TOWNS.

SCALE:-

KMS. 20 0 20 40 80 120 160 KMS.

MILES 20 0 30 60 90 MILES

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CENTRAL WATER COMMISSION
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KAVERI BASIN

SUB ZONE 3(i)

IRRIGATION

NOTE:- THIS MAP HAS BEEN DRAWN FROM THE IRRIGATION ATLAS OF INDIA (1972) PLATE NO. 10.

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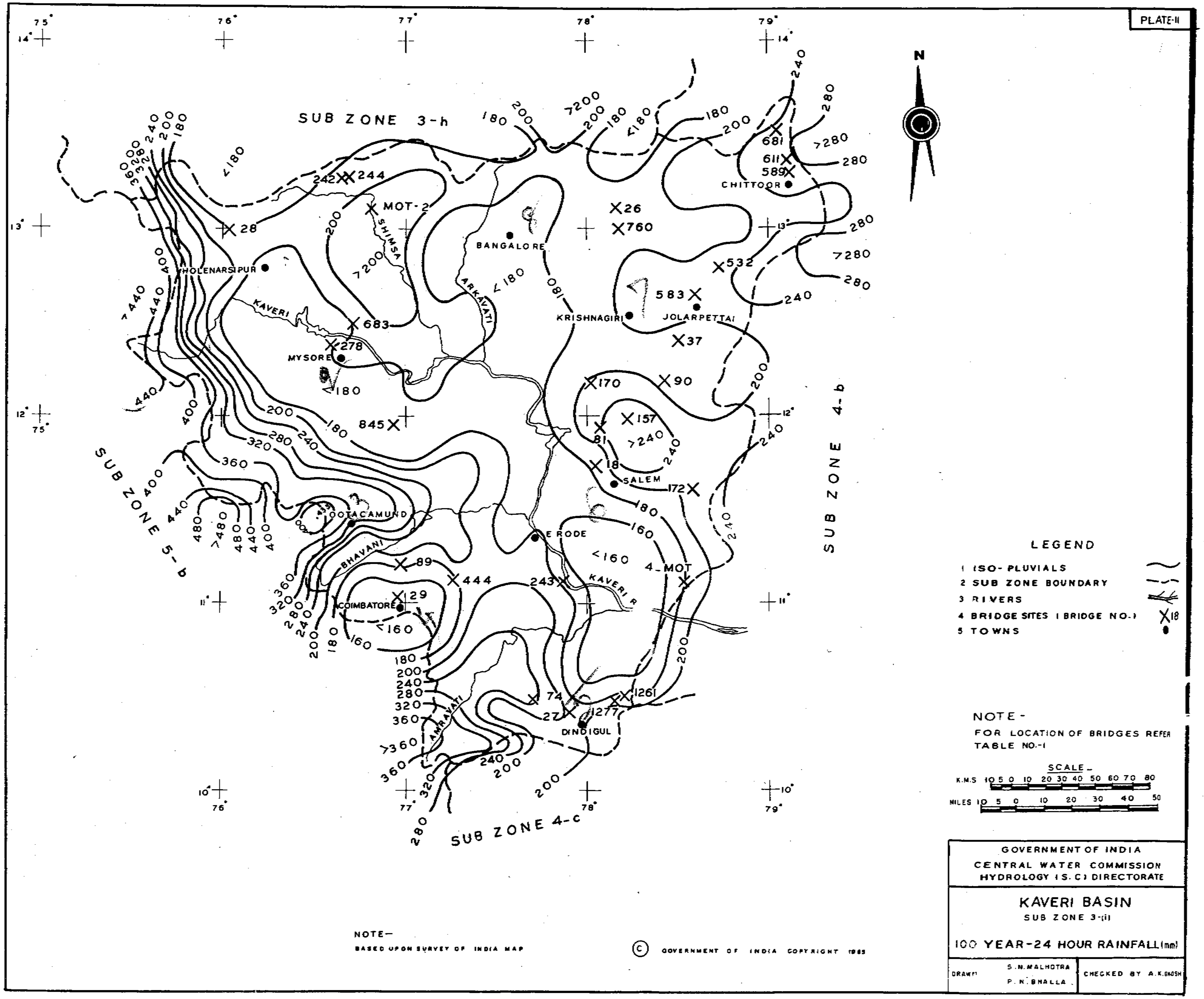
PLATE-II
SUB ZONE 3-h
SUB ZONE 5-b
SUB ZONE 4-b
SUB ZONE 4-c
N
BANGALORE
HOLENARSIPUR
MYSORE
KRISHNAGIRI
JOLARPETTAI
CHITTOOR
SALEM
OOTACAMUND
ERODE
COIMBATORE
DINDIGUL
KAVERI
KAVERI R
SHIMSA
ARKAVATI
BHAVANI
AMRAVATI
MOT-2
4-MOT
LEGEND
1 ISO-PLUVIALS
2 SUB ZONE BOUNDARY
3 RIVERS
4 BRIDGE SITES (BRIDGE NO.)
5 TOWNS
NOTE-
FOR LOCATION OF BRIDGES REFER TABLE NO.-1
SCALE
K.M.S 10 5 0 10 20 30 40 50 60 70 80
MILES 10 5 0 10 20 30 40 50
NOTE-
BASED UPON SURVEY OF INDIA MAP
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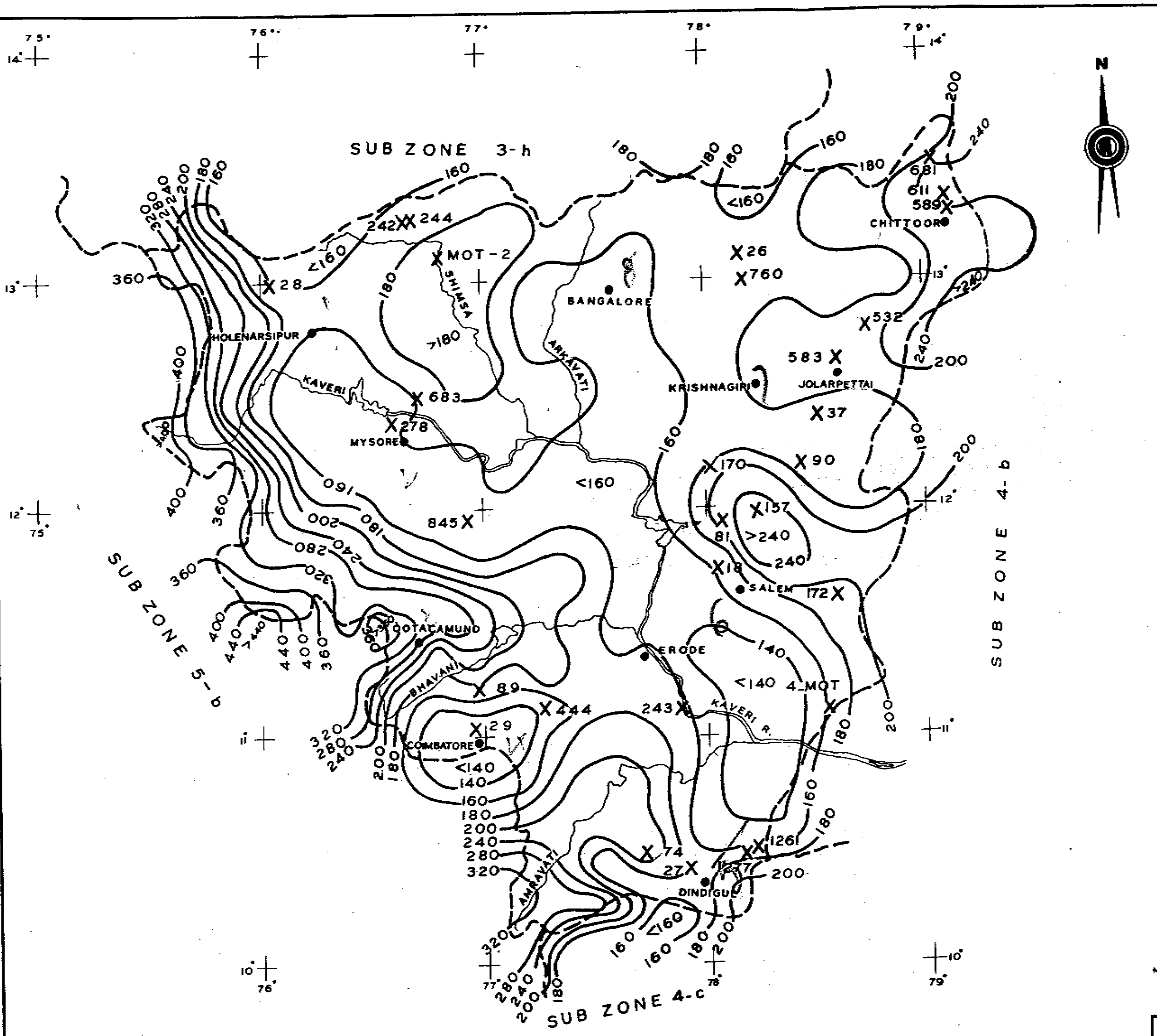
HYDROLOGY (S.C) DIRECTORATE
KAVERI BASIN
SUB ZONE 3-(i)
100 YEAR-24 HOUR RAINFALL (mm)
DRAWN S.N. MALHOTRA P.K. BHALLA
CHECKED BY A.K. GHOSH

PLATE-10



LEGEND

1 ISO-PLUVIALS
2 SUB ZONE BOUNDARY
3 RIVERS
4 BRIDGE SITES (BRIDGE NO) X18
5 TOWNS ●

NOTE–
FOR LOCATION OF BRIDGES REFER TABLE NO. 1

SCALE–
K.M.S 10 5 0 10 20 30 40 50 60 70 80
MILES 10 5 0 10 20 30 40 50

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KAVERI BASIN
SUB ZONE 3 (i)
50 YEAR-24 HOUR RAINFALL (mm)

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

NOTE–
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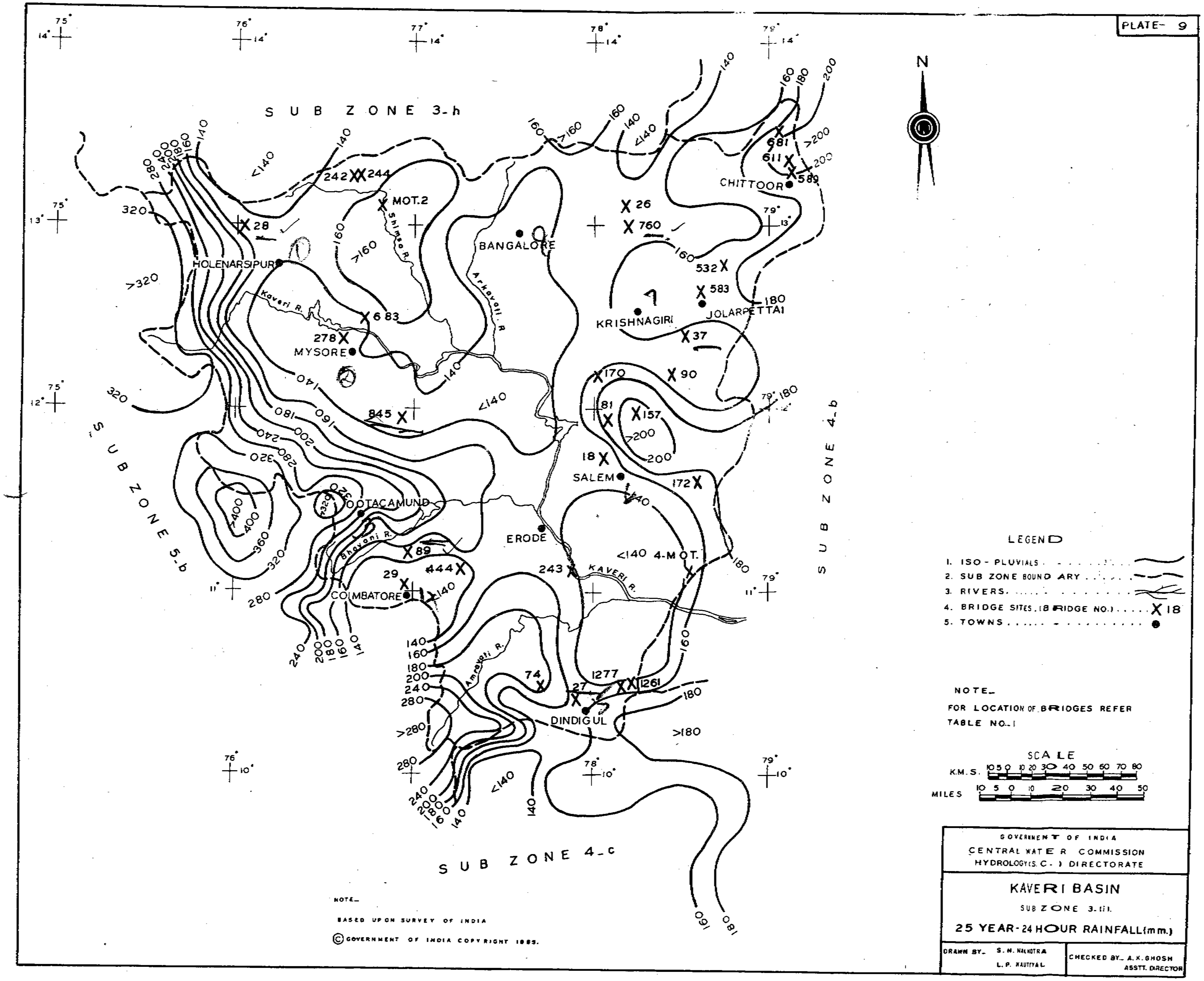

PLATE- 9
SUB ZONE 3-h
SUB ZONE 5-b
SUB ZONE 4-b
SUB ZONE 4-c
N
HOLENARSIPUR
MYSORE
BANGALORE
KRISHNAGIRI
JOLARPETTAI
CHITTOOR
SALEM
ERODE
OOTACAMUND
COIMBATORE
DINDIGUL
Kaveri R.
Shimsa R.
Arkavati R.
Bhavani R.
KAVERI R.
Amravati R.
MOT.2
4-MOT.
LEGEND
1. ISO - PLUVIALS
2. SUB ZONE BOUNDARY
3. RIVERS
4. BRIDGE SITES (BRIDGE NO.) X 18
5. TOWNS
NOTE_
FOR LOCATION OF BRIDGES REFER TABLE NO.-1
SCALE
K.M.S. 10 5 0 10 20 30 40 50 60 70 80
MILES 10 5 0 10 20 30 40 50
NOTE_
BASED UPON SURVEY OF INDIA
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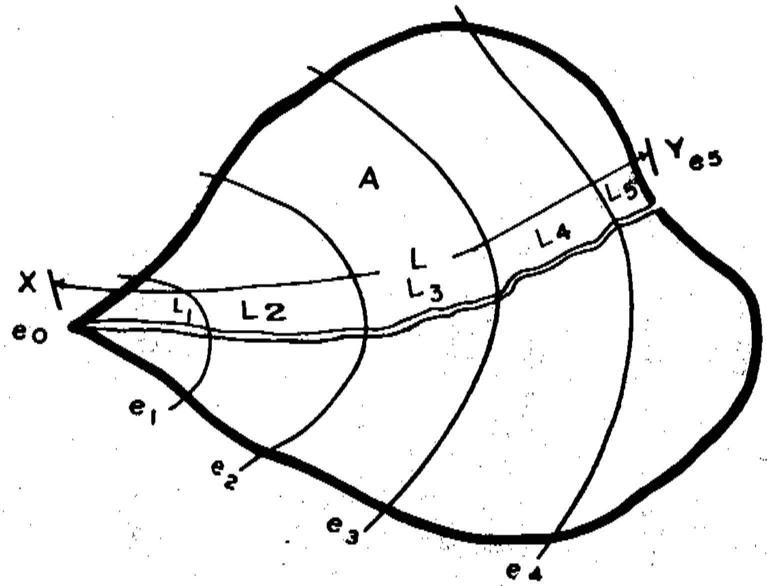
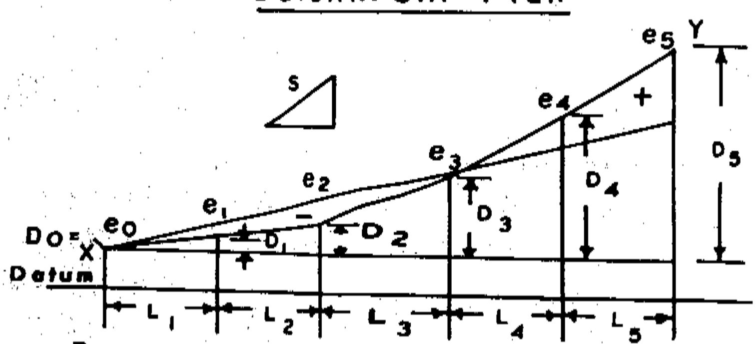
KAVERI BASIN
SUB ZONE 3.(i)
25 YEAR-24 HOUR RAINFALL(mm.)
DRAWN BY_ S. N. NALKOTRA
L. P. NAUTIYAL
CHECKED BY_ A. K. GHOSH
ASSTT. DIRECTOR

FIG.- 1



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.).

$L_i = L_1, L_2, L_3$ ---------- L_n Segment lengths (km.).

$e_i = e_0, e_1, e_2$ -------- e_n contour elevation (m).

$D_i = D_0, D_1, D_2$ -------- D_n

$= (e_0 - e_0), (e_1 - e_0)$ ---------

$(e_n - e_0)$ (m).

A = Catchment Area (Sq. km).

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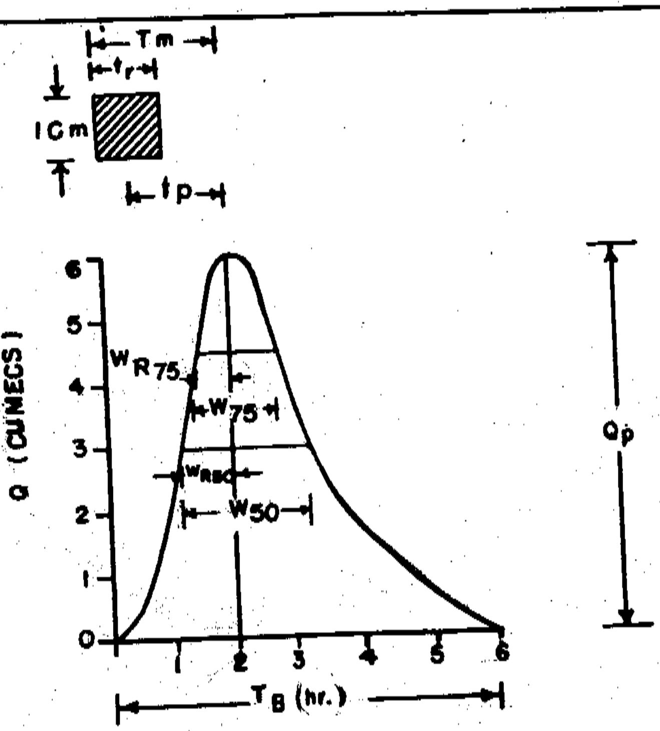
PHYSIOGRAPHIC PARAMETERS

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

FIG. – 2



U.G. = Unit Graph

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

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

Qp = Peak Discharge of Unit Hydrograph (cumecs)

tp = Time from the centre of rainfall excess duration to the U.G peak (hr.)

W_{50} = Width of the U.G. measured at 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.)

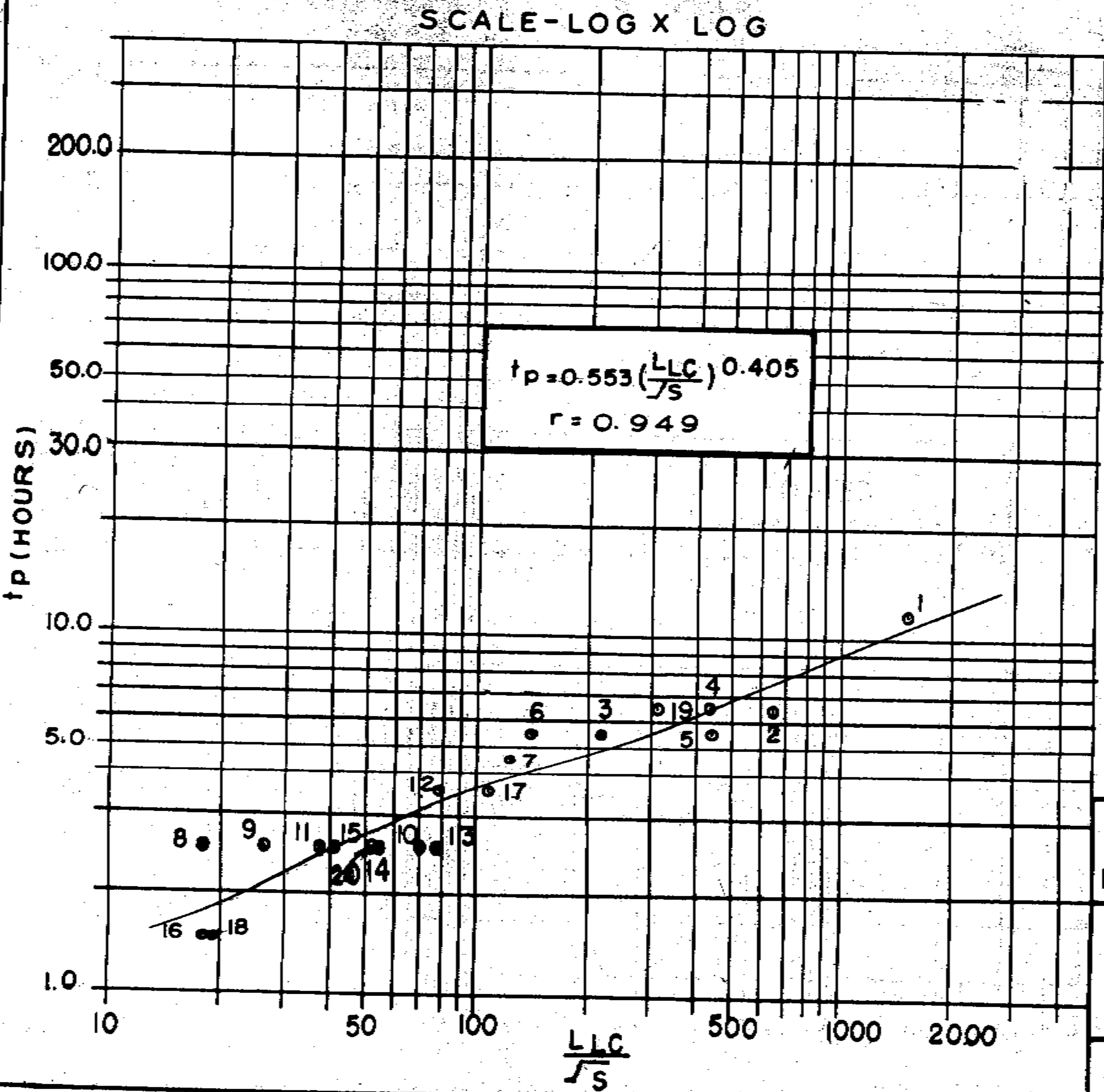
T_B = Base width of Unit Hydrograph (hr.)

A = Catchment Area (Sq. km.)

$q_p = Q_p / A$ = Cumec per sq. km.

GOVERNMENT OF INDIA CENTRAL WATER COMMISSION HYDROLOGY (SMALL CATCHMENT) DTE.	
UNIT GRAPH PARAMETERS	
DRAWN BY– S.N. MALHOTRA, P.N. BHALLA	CHECKED BY– A. K. GHOSH

FIG. - 3



S. NO.	BR. NO.	$\frac{LLC}{\sqrt{S}}$	t_p (HOURS)
1	28	1510	11.5
2	444	652	6.5
3	81	218	5.5
4	37	436	6.5
5	683	433	5.5
6	18	140	5.5
7	27	123	4.5
8	157	18	2.5
9	74	26	2.5
10	89	70	2.5
11	26	37	2.5
12	760	79	3.5
13	29	77	2.5
14	90	54	2.5
15	244	41	2.5
16	845	18	1.5
17	172	107	3.5
18	532	19	1.5
19	4 MOT	303	6.5
20	170	52	2.5

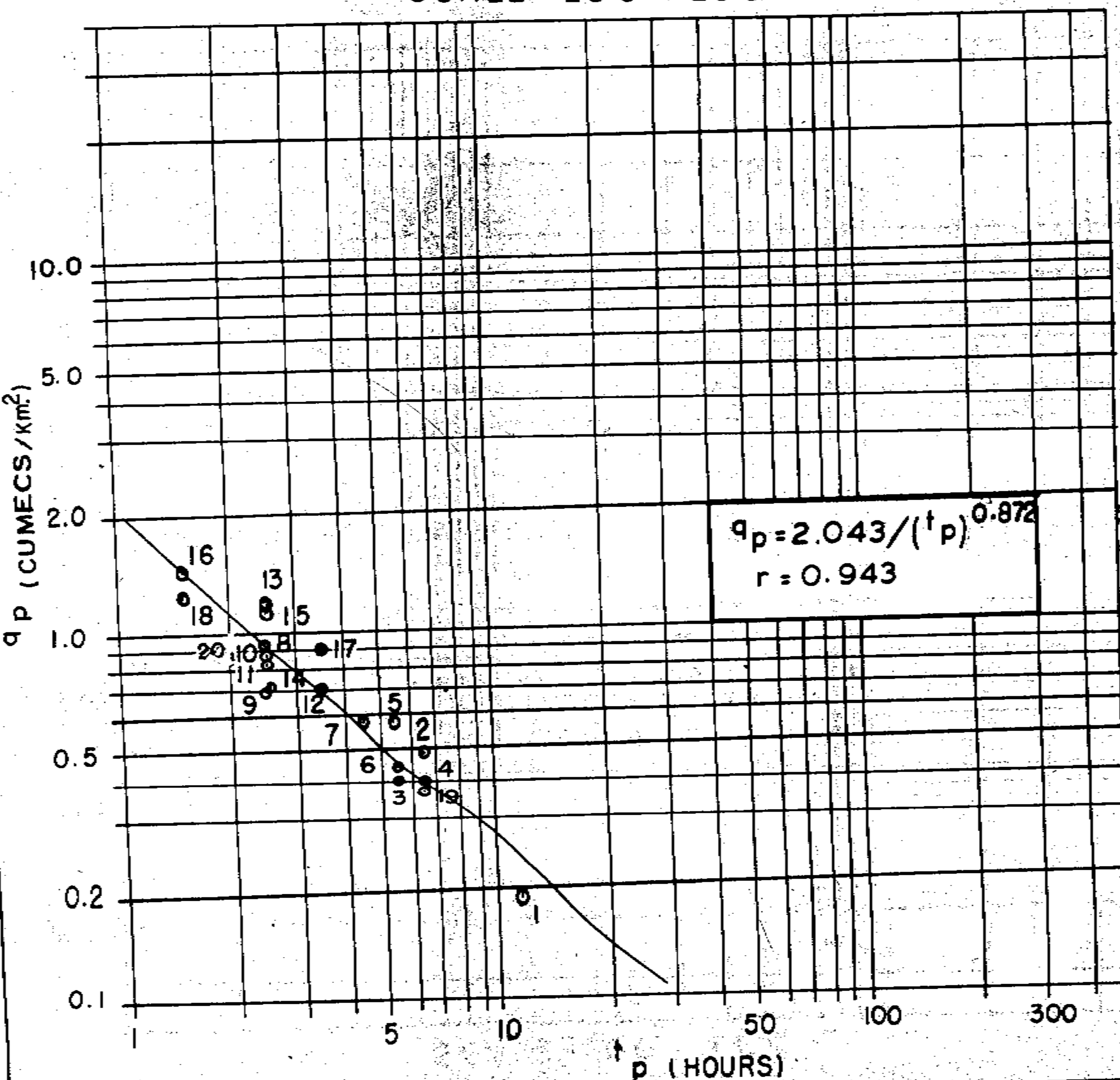
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

KAVERI BASIN
SUB ZONE-3(i)
RELATION BETWEEN
t_p AND $LLC/\sqrt{S}$

DRAWN BY_ S. N. MALHOTRA

CHECKED BY_ A. K. GHOSH

FIG.- 4



S. NO.	BR.NO.	t_p (HOURS)	q_p (CUMECS/Km²)
1	28	11.5	0.19
2	444	6.5	0.49
3	81	5.5	0.40
4	37	6.5	0.40
5	683	5.5	0.58
6	18	5.5	0.45
7	27	4.5	0.58
8	157	2.5	0.94
9	74	2.5	0.70
10	89	2.5	0.89
11	26	2.5	0.84
12	760	3.5	0.71
13	29	2.5	1.18
14	90	2.5	0.72
15	244	2.5	1.14
16	845	1.5	1.44
17	172	3.5	0.90
18	532	1.5	1.24
19	4 MOT	6.5	0.37
20	170	2.5	0.91

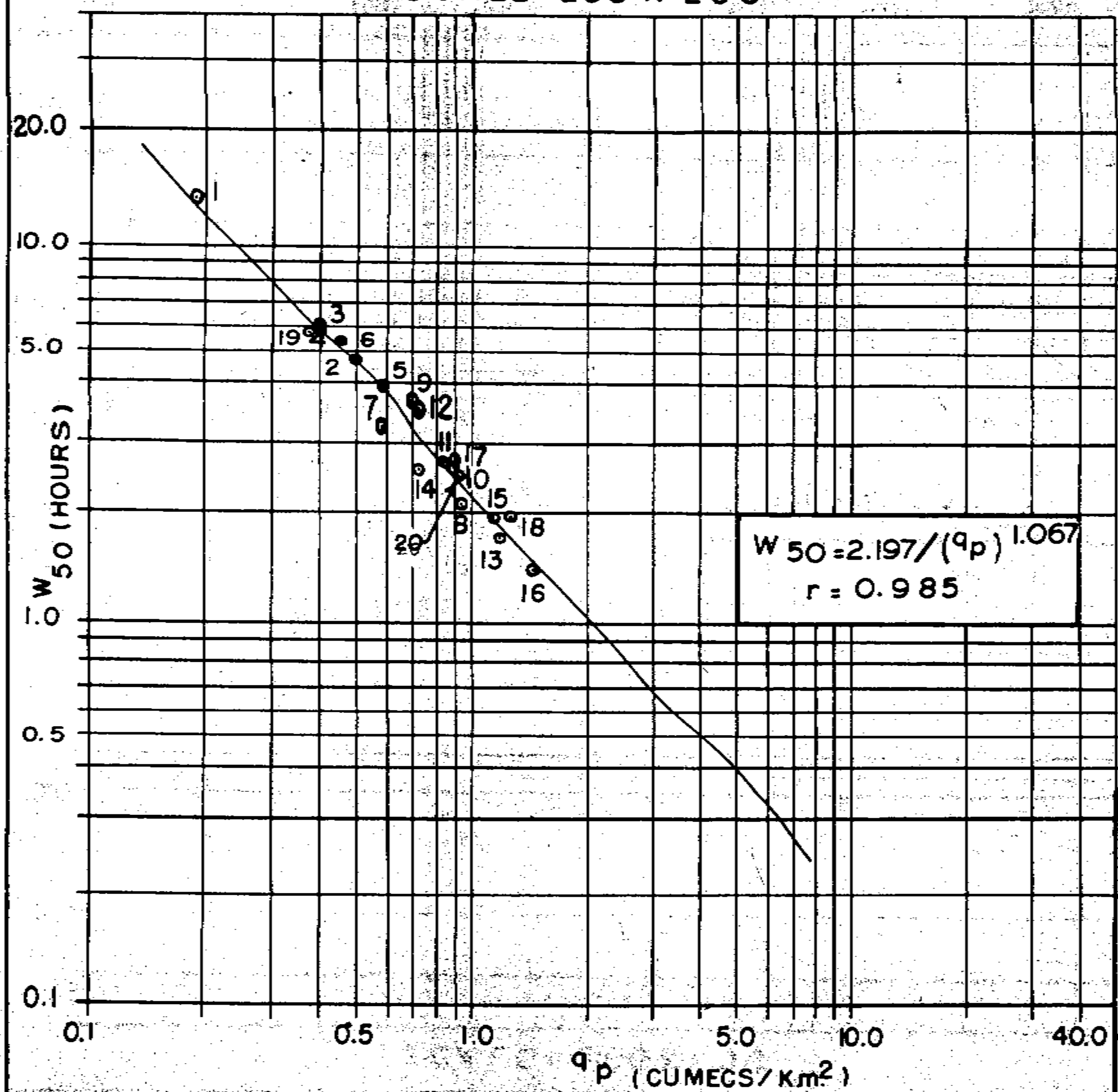
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY(SMALL CATCHMENTS)DTE.

KAVERI BASIN
SUB ZONE-3(i)
RELATION BETWEEN q_p AND t_p

DRAWN BY_	CHECKED BY_
S. N. MALHOTRA	A. K. GHOSH

FIG.- 5

SCALE- LOG X LOG



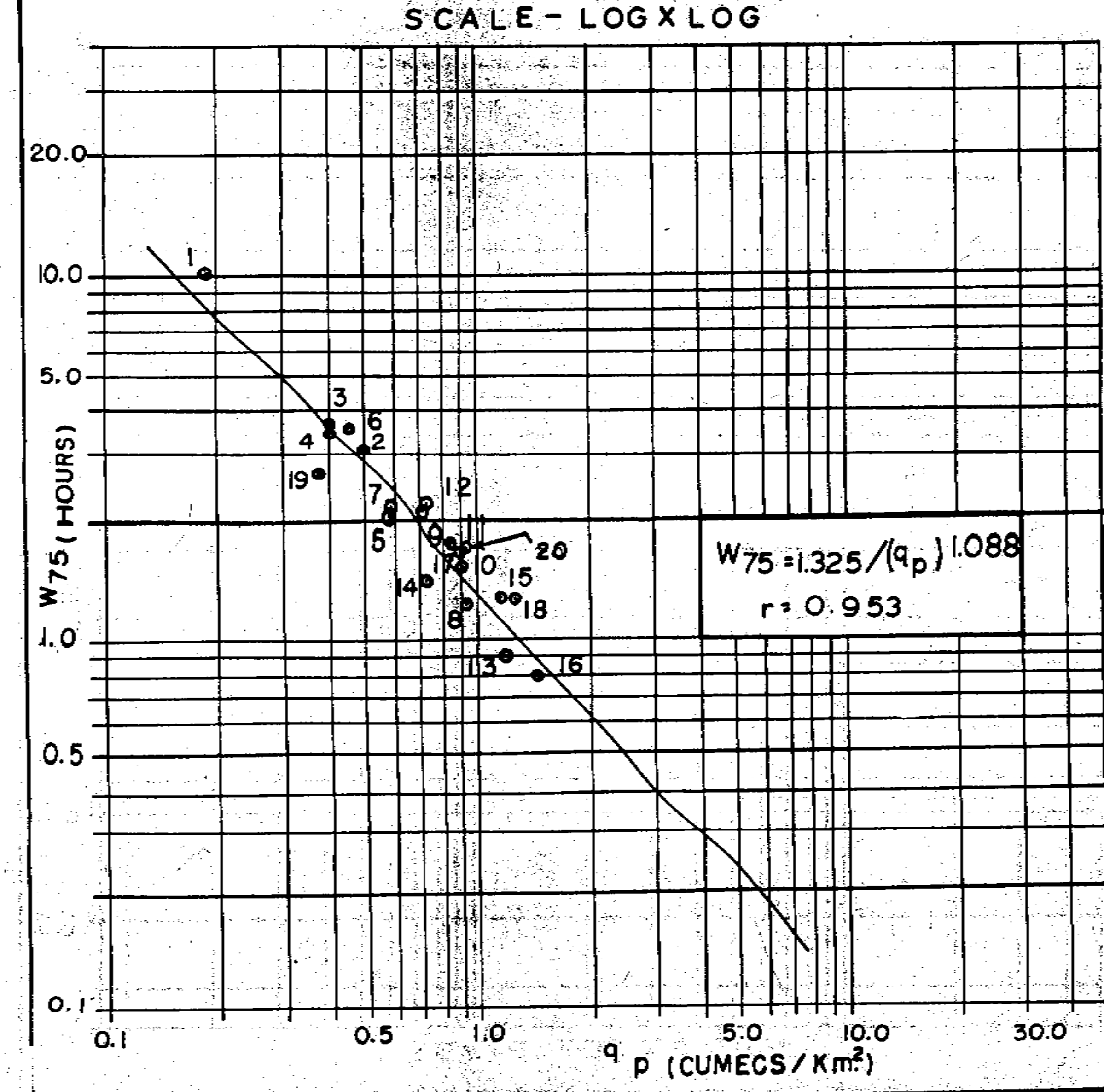
S.NO.	BR NO.	q_p (CUMECS/Km.²)	W_{50} (HOURS)
1	28	0.19	13.40
2	444	0.49	4.70
3	81	0.40	6.20
4	37	0.40	5.80
5	683	0.58	3.95
6	18	0.45	5.40
7	27	0.58	3.25
8	157	0.94	2.10
9	74	0.70	3.60
10	89	0.89	2.60
11	26	0.84	2.70
12	760	0.71	3.50
13	29	1.18	1.70
14	90	0.72	2.60
15	244	1.14	1.95
16	845	1.44	1.40
17	172	0.90	2.75
18	532	1.24	1.98
19	4 MOT	0.37	5.85
20	170	0.91	2.50

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

KAVERI BASIN
SUB ZONE-3(i)
RELATION BETWEEN
W_{50} AND q_p

DRAWN BY- S.N. MALHOTRA | CHECKED BY- A. K. GHOSH

FIG.- 6



S.NO.	BR.NO	q_p (CUMECS/ Km²)	W_{75} (HOURS)
1	28	0.19	10.10
2	444	0.49	3.10
3	81	0.40	3.70
4	37	0.40	3.50
5	683	0.58	2.05
6	18	0.45	3.60
7	27	0.58	2.10
8	157	0.94	1.25
9	74	0.70	2.10
10	89	0.89	1.55
11	26	0.84	1.80
12	760	0.71	2.15
13	29	1.18	0.90
14	90	0.72	1.45
15	244	1.14	1.30
16	845	1.44	0.80
17	172	0.90	1.70
18	532	1.24	1.30
19	4 MOT	0.37	2.60
20	170	0.91	1.75

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

KAVERI BASIN
SUB ZONE-3(I)
RELATION BETWEEN
W_{75} AND q_p

DRAWN BY-	CHECKED BY-
S. N. MALHOTRA	A. K. GHOSH

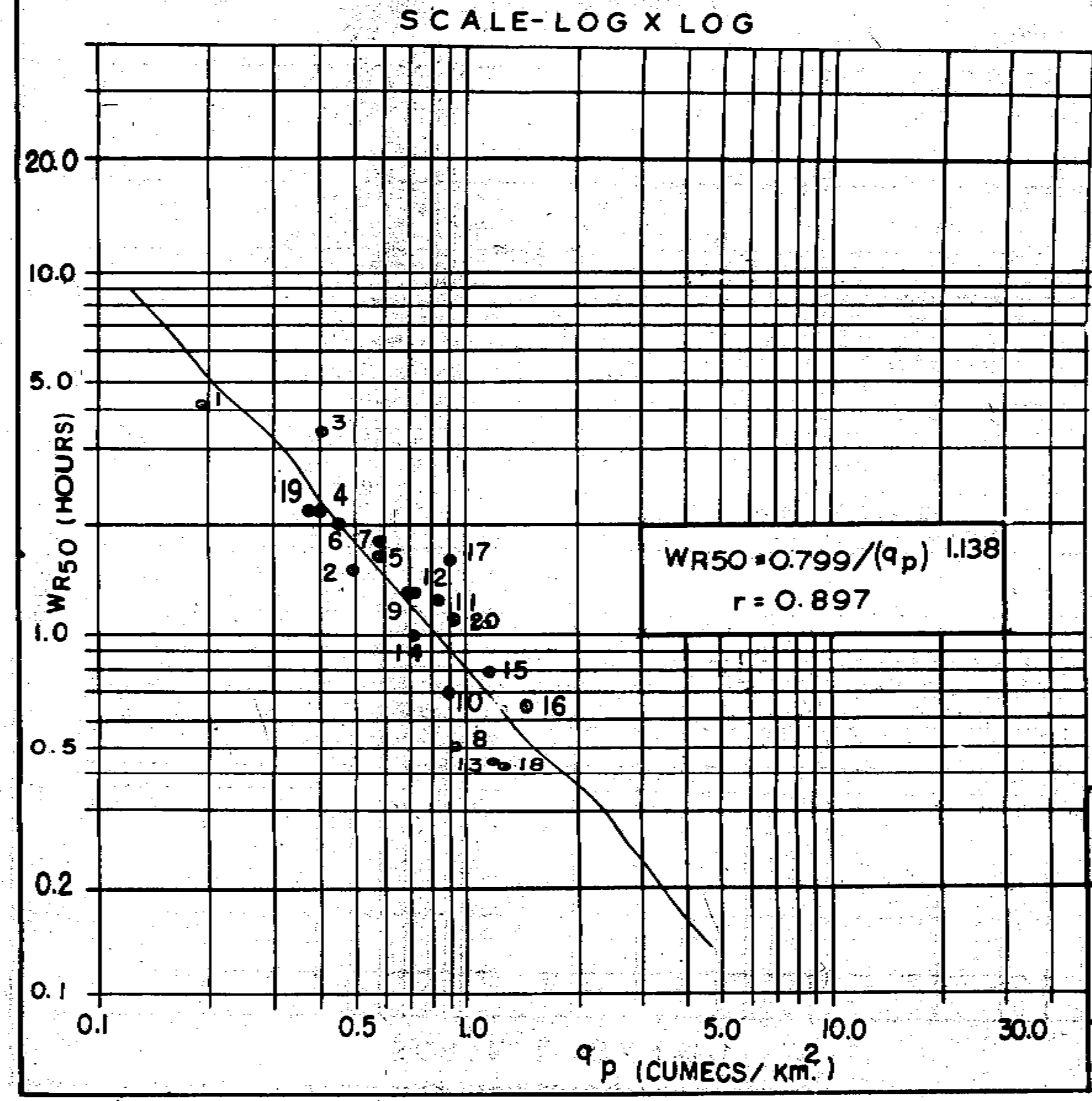


FIG._ 7

S.NO.	BR.NO.	qp (CUMECS/ Km²)	WR50 (HOURS)
1	28	0.19	4.20
2	444	0.49	1.50
3	81	0.40	3.40
4	37	0.40	2.20
5	683	0.58	1.65
6	18	0.45	2.00
7	27	0.58	1.80
8	157	0.94	0.50
9	74	0.70	1.30
10	89	0.89	0.70
11	26	0.84	1.25
12	760	0.71	1.30
13	29	1.18	0.45
14	90	0.72	1.00
15	244	1.14	0.80
16	845	1.44	0.65
17	172	0.90	1.60
18	532	1.24	0.43
19	4 MOT	0.37	2.20
20	170	0.91	1.10

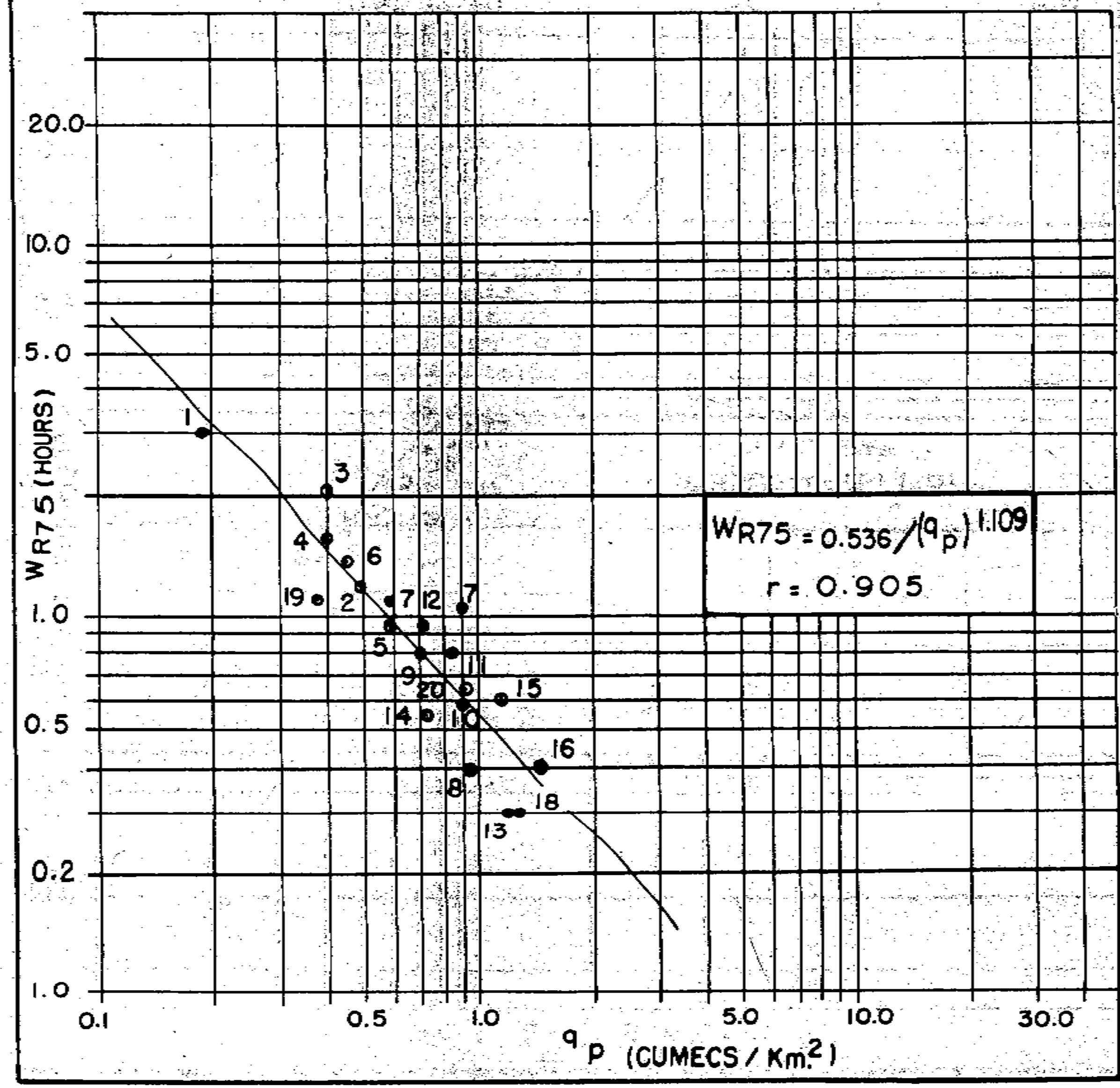
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY(SMALL CATCHMENTS) DTE.

KAVERI BASIN
SUB ZONE-3(I)
RELATION BETWEEN
WR50 AND qp

DRAWN BY_ S.N. MALHOTRA
CHECKED BY_ A. K. GHOSH

FIG._8

SCALE-LOG X LOG



S.NO.	BR.NO.	q_p (CUMECS/ Km^2)	W_{R75} (HOURS)
1	28	0.19	3.00
2	444	0.49	1.20
3	81	0.40	2.05
4	37	0.40	1.60
5	683	0.58	0.95
6	18	0.45	1.40
7	27	0.58	1.10
8	157	0.94	0.40
9	74	0.70	0.80
10	89	0.89	0.58
11	26	0.84	0.80
12	760	0.71	0.95
13	29	1.18	0.30
14	90	0.72	0.55
15	244	1.14	0.60
16	845	1.44	0.40
17	172	0.90	1.05
18	532	1.24	0.30
19	4 MOT	0.37	1.10
20	170	0.91	0.65

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

KAVERI BASIN
SUB ZONE 3(i)
RELATION BETWEEN
W_{R75} AND q_p

DRAWN BY_ S.N. MALHOTRA

CHECKED BY_ A. K. GHOSH

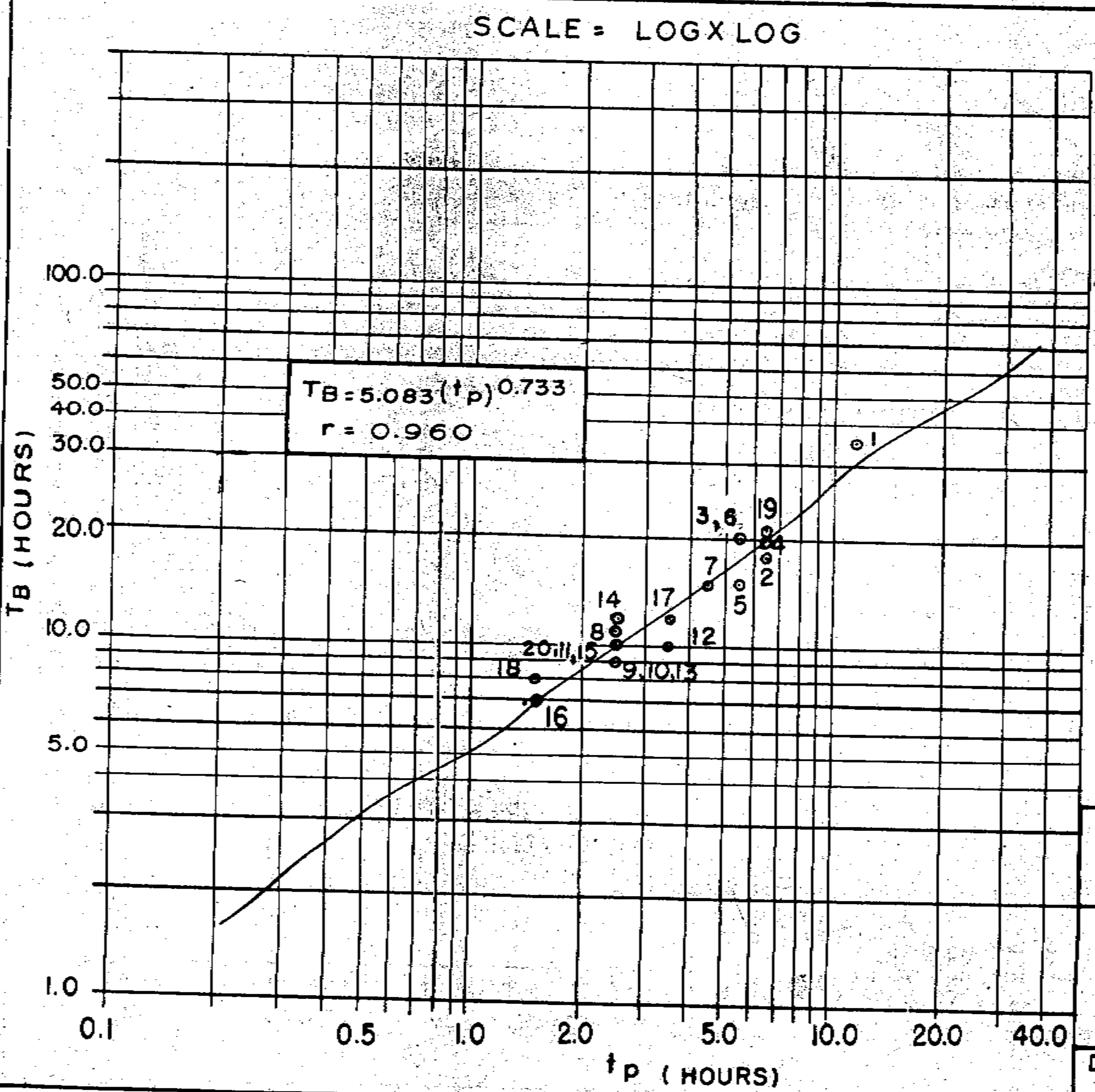


FIG. - 9

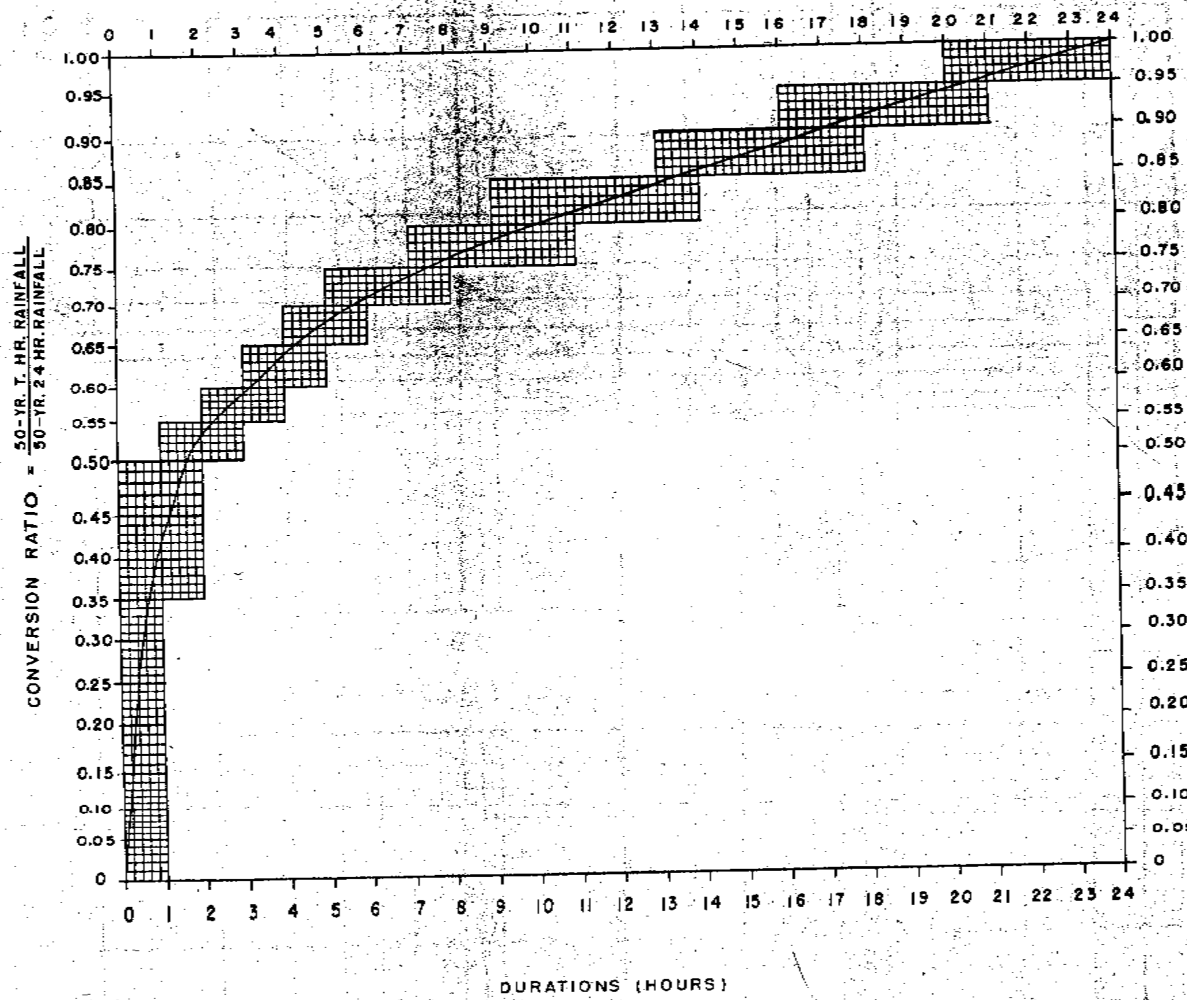
Sl. NO.	BR. NO.	t_p (HOURS)	T_B (HOURS)
1	28	11.5	35
2	444	6.5	18
3	81	5.5	20
4	37	6.5	20
5	683	5.5	15
6	18	5.5	20
7	27	4.5	15
8	157	2.5	11
9	74	2.5	9
10	89	2.5	9
11	26	2.5	10
12	760	3.5	10
13	29	2.5	9
14	90	2.5	12
15	244	2.5	10
16	845	1.5	7
17	172	3.5	12
18	532	1.5	8
19	4 M.O.T.	6.5	21
20	170	2.5	10

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

KAVERI BASIN
SUB ZONE-3(i)
RELATION BETWEEN
T_B AND t_p

DRAWN BY -	CHECKED BY -
S.N. MALHOTRA	A. K. GHOSH

FIG – 10



RATIOS OF 24 HR. POINT RAINFALL TO SHORT DURATION RAINFALL

DURATIONS (HR)	RATIO
1	0.420
2	0.530
3	0.590
4	0.640
5	0.675
6	0.710
7	0.740
8	0.760
9	0.780
10	0.800
11	0.815
12	0.830
13	0.843
14	0.855
15	0.870
16	0.885
17	0.900
18	0.910
19	0.925
20	0.940
21	0.955
22	0.970
23	0.985
24	1.000

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE

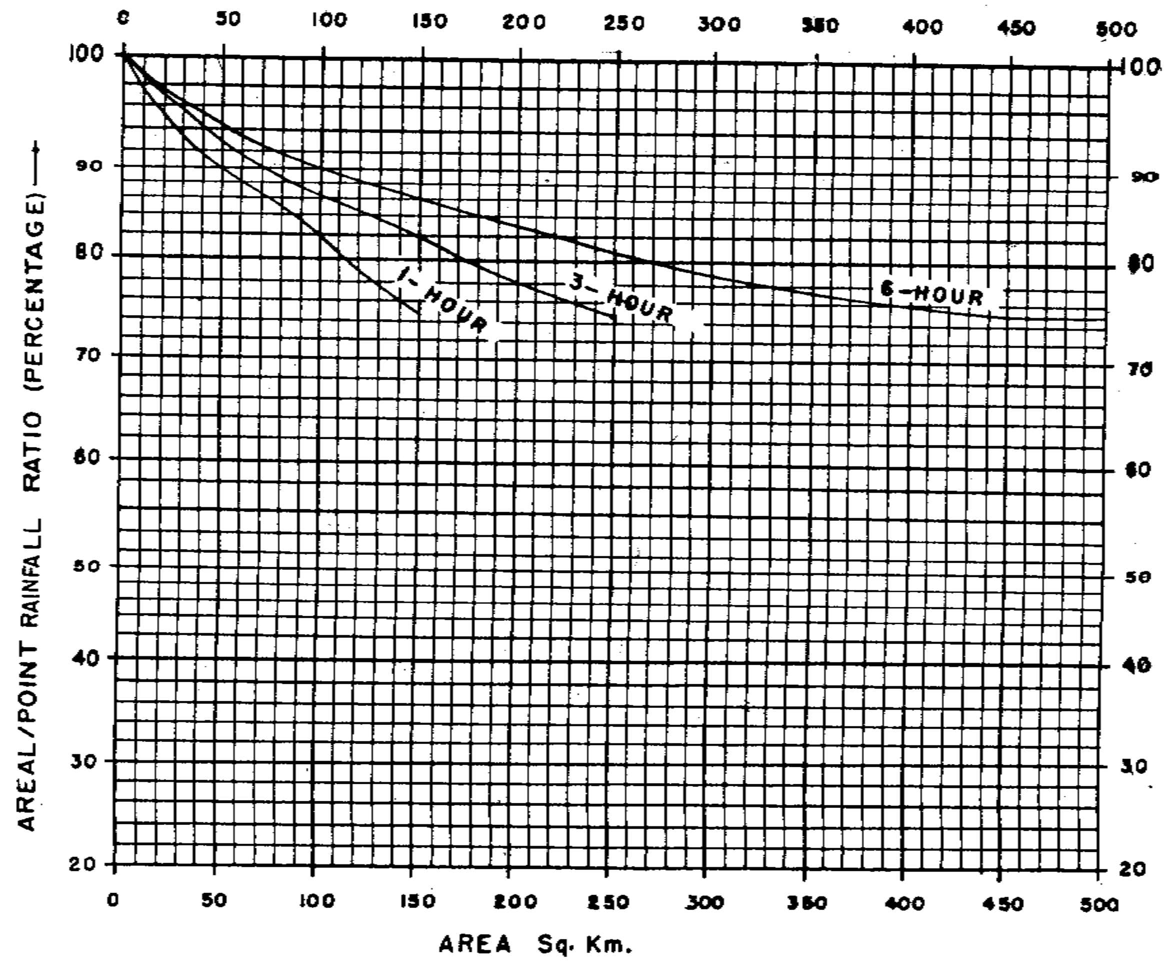
KAVERI BASIN

SUB ZONE -3(i)

DURATION vs CONVERSION RATIO

DRAWN: S.N. MALHOTRA, P.N. BHALLA | CKD: A.K. GHOSH.

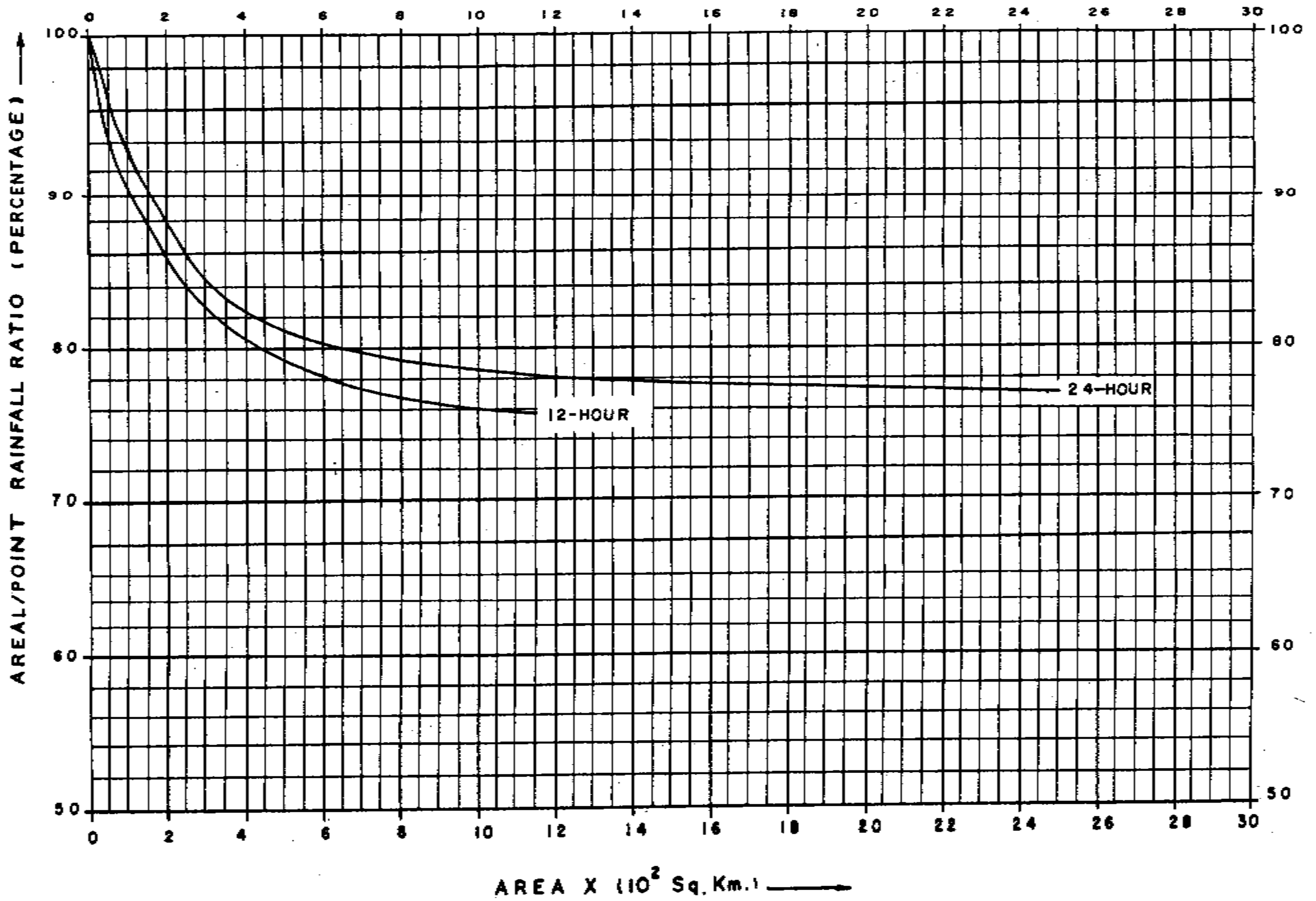
FIG: II (a)



NOTE:-
REFER TABLE A-2 FOR POINT TO AREAL RAINFALL RATIOS FOR DURATION FROM 1 TO 24 Hrs. AND FOR CATCHMENT AREAS UP TO 2500 Sq. Km.

GOVERNMENT OF INDIA CENTRAL WATER COMMISSION HYDROLOGY (SMALL CATCHMENTS) DTE.	
KAVERI BASIN SUB-ZONE 3(i) AREAL TO POINT RAINFALL RATIO (PERCENTAGE)	
DRAWN: S.N. MALHOTRA O.P. SINGH.	CKD: A.K. GHOSH.

FIG: 11 (b)



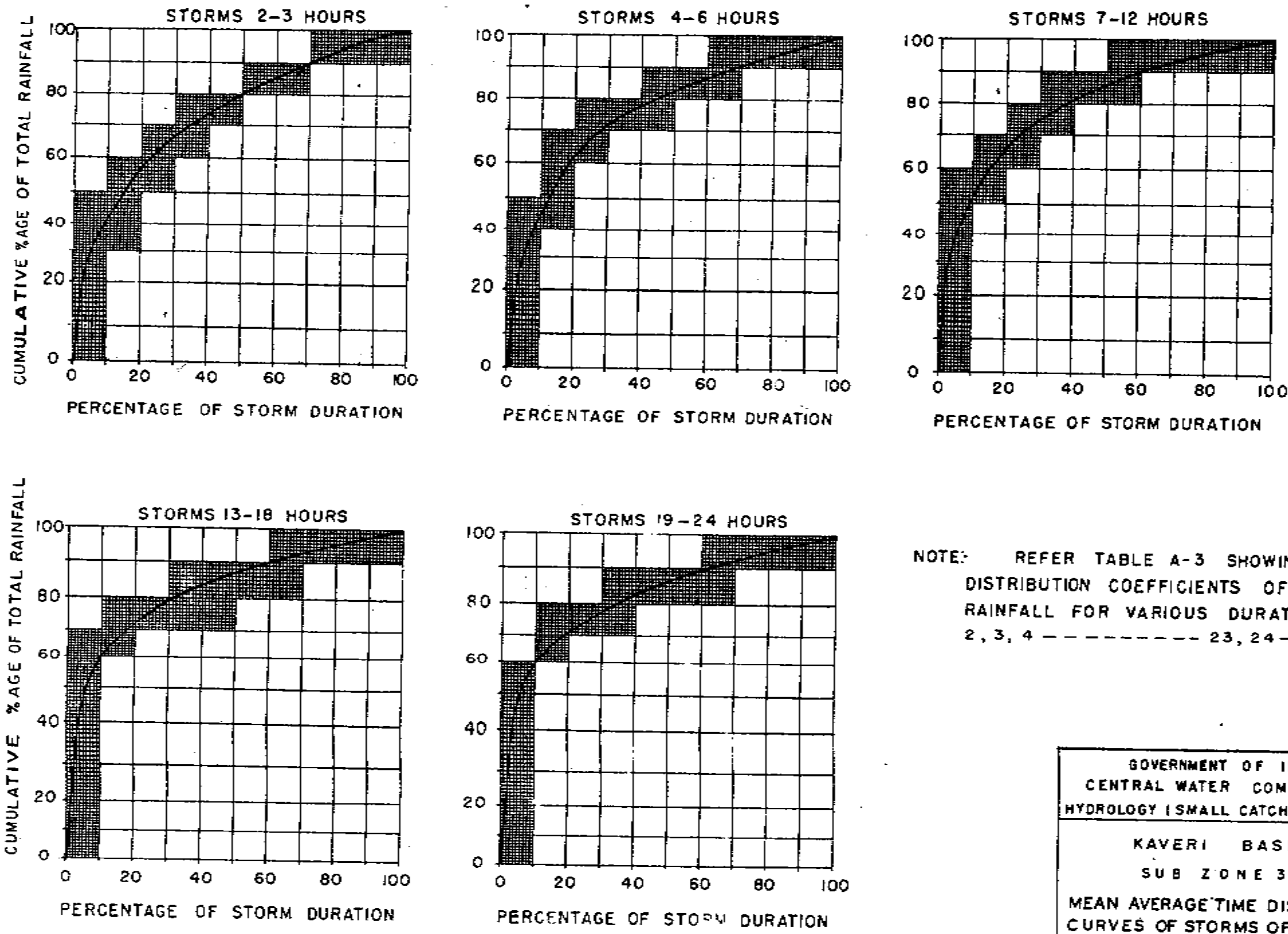
NOTE:-
REFER TABLE A-2 FOR POINT TO AREAL RAINFALL RATIOS FOR DURATION FROM 1 TO 24 Hrs. AND FOR CATCHMENT AREAS UPTO 2500 Sq. Km.

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

KAVERI BASIN
SUB ZONE 3(I)
AREAL TO POINT RAINFALL RATIO
(PERCENTAGE)

DRAWN. S. N. MALHOTRA P. N. BHALLA	CKD.- A. K. GHOSH

FIG. 12



NOTE:- REFER TABLE A-3 SHOWING TIME DISTRIBUTION COEFFICIENTS OF AREAL RAINFALL FOR VARIOUS DURATIONS OF 2, 3, 4 — — — — — — — — 23, 24–HOURS.

GOVERNMENT OF INDIA CENTRAL WATER COMMISSION HYDROLOGY (SMALL CATCHMENTS) DTE.
KAVERI BASIN SUB ZONE 3(I) MEAN AVERAGE TIME DISTRIBUTION CURVES OF STORMS OF VARIOUS DURATIONS
DRAWN: T.R. ARORA, O. P. SINGH — CKD: A.K. GHOSH

ADDENDUM

In keeping with the underlying principle of further refining the basic reports which have been published for the flood estimation of various subzones in India as and when further data is available or new ideas and modifications are thought about and accepted in principle, it was felt that the idea of assigning a constant loss rate and base flow rate for the sub-zone in consideration would not depict the true nature of the conditions existing.

Loss Rate and Base Flow Rate

An indepth study was taken into the various individual flood events analysed and which were subsequently used in the final report. It is observed that there are wide variations in the loss rates and base flow rates for the cases considered. A multiple regression formulation was used to arrive at loss rates and base flow rates for the subzone considering various physiographic and meteorologic parameters. The equations derived are as given below:

$$\text{Loss Rate} = 1.120 \frac{R^{0.611}}{T_D^{0.355}}$$

Where R = T_D hr. areal rainfall in cm. and loss rate in cm/hr.

$$q_b = \frac{0.032}{A^{0.1004}}$$

Where A = catchment area in sq.km. and q_b = base flow rate in cumecs/sq.km.

25-yr., 50-yr. and 100-yr. Flood Formulae

Using these formulae of loss rate and base flow rate, the design flood for a return period of 50 years was worked out and so also floods of 25 year and 100 year return periods. A multiple regression was also done on these flood values relating them with the physiographic parameters like area, length, slope etc. and the point rainfall of a specified return period. The equations thus arrived at are as given below:

$$Q_{25} = \frac{0.5734(A)^{0.818}(R_{25})^{1.565}(S)^{0.260}}{(L)^{0.591}} \qquad r = 0.979$$

$$Q_{50} = \frac{0.449 (A)^{0.800} (R_{50})^{1.685} (S)^{0.265}}{(L)^{0.592}} \quad = r = 0.982$$

$$Q_{100} = \frac{0.626 (A)^{0.809} (R_{100})^{1.507} (S)^{0.261}}{(L)^{0.579}} \quad r = 0.978$$

Q_{25}, Q_{50} and Q_{100} are 25-yr., 50-yr. and 100-yr. flood in cumecs.

R_{25}, R_{50} and R_{100} are 25-yr., 50-yr. and 100-yr. storm point rainfall in cm. corresponding to design storm duration.

$T_D = 0.608 (LL_c / \sqrt{S})^{0.405}$ in hours for the catchment.

A = catchment area in sq.km.

S = equivalent slope in m/km.

L = length of longest main stream in km.

L_c = Length of longest main stream opposite the centre of gravity of the catchment to the point of study in km.

Illustrative Example

For illustrative purpose the example which have been worked out in the main text of this report has been reworked (both by simplified and detailed approach) as given subsequently.

The particulars of railway bridge catchment (treated as ungauged) for illustrating the procedure are as under:

i)	Name and number of subzone	: Kaveri subzone-3 (i)
ii)	Name of site (i.e. point of study).	: Railway Br. No.37
iii)	Name of railway section	: Jollarpettai-Salem (S.R.)
iv)	Name of Tributary	: Pambar
v)	Shape of the catchment	: Oblong
vi)	Site location	: 12° 24' 0'' (Latitude) 78° 30' 18''(Longitude)
vii)	Topography	: Moderately steep slope

The procedure is explained below:

Determination of Physiographic Parameters

The following physiographic parameters were determined from the catchment area plan:

i)	Area (A)	= 294.00 sq.km.
ii)	Length of the longest stream (L)	= 43.00 km.
iii)	Length of the longest stream opposite the centre of gravity of the catchment to the point of study (L_c)	= 22.72 km.
iv)	Equivalent stream slope (S)	$= \sum L_i (D_{i-1}+D_i)/L^2$ = 5.13 m/km

where L_i = Length of ith segment in km.

D_i, D_{i-1} = Heights above datum (with reduced level at the point of study) with respect of reduced levels of contours along the longest stream at ith and (i-1) the locations in metres.

For detailed calculations of 'S' refer Table A-1.

In Table A-1, columns (2) and (4) are the reduced distances and corresponding levels along the longest stream from the point of study to the contours across the stream or spot levels on the bank. Other columns are self explanatory. Prepare L-section (longitudinal section) of the longest stream from the source to the point of study based on the data in cols. (2) and (4) as shown in Fig. A-1.

$$LL_c/\sqrt{S} = 43.47 \times 22.72/\sqrt{5.13} = 436.05$$

Determination of Synthetic 1-hr. Unitgraph Parameters, Design Storm Duration, Point Rainfall and Areal Rainfall

The 1-hr. unitgraph parameters are to be worked out in the same manner as has been done in the illustrative example given in the main text of the report (Pages 4 to 9).

I. Simplified Approach

Using the formula given earlier Q_{50} is worked out as follows:

$$Q_{50} = \frac{0.449 (A)^{0.800} (R_{50})^{1.685} (S)^{0.265}}{(L)^{0.592}}$$

$$= \frac{0.449\ (294)^{0.80}\ (12.95)^{1.685} (5.13)^{0.265}}{(43)^{0.592}} = 527$$

(For R_{50} see page - 20 of the main report)

Similarly Q_{25} and Q_{100} can be worked out as:

Q_{25} = 426

Q_{100} = 574

II. Detailed Approach

Estimation of Loss Rate

The loss rate for this bridge catchment is estimated by using the equation given in the beginning of the addendum as given below:

$$\text{Loss rate} = 1.120 \frac{R^{0.611}}{T_D^{0.355}} = 2.32 \text{ cm/hr.}$$

Estimation of Rainfall Excess Units

Using a design loss rate of 2.32 cm/hr. as given above, the rainfall excess is worked out by subtracting the loss rate from the rainfall increments as under:

Duration (hr)	1-hr. rainfall (cm)	Loss Rate (cm/hr)	1-hr. rainfall excess (2) &(3) (cm)
1	2	3	4
1	6.34	2.32	4.12
2	1.33	2.32	-
3	0.82	2.32	-
4	0.61	2.32	-
5	0.52	2.32	-
6	0.30	2.32	-
7	0.31	2.32	0

Estimation of Base Flow

The design base flow rate is estimated by using the base flow rate formula and values arrived at as under:

$$q_b = \frac{0.032}{(294)^{0.1004}} = 0.0181 \text{ cumecs/sq.km.}$$

Total base flow = 0.0181 x 294.0 = 5.32

Estimation of Design Flood (Q_{50}) (Peak only)

For estimation of flood peak the maximum rainfall excess is multiplied by maximum U.G. ordinate, then next lower values are multiplied and so on till end of rainfall excess units. The summation of these products added to base flow gives the flood peak:

$$Q_{50} \text{ Peak} = 117.6 \times 4.12 + \text{Base Flow}$$
$$= 472.75 + 5.32$$
$$= 478.07 \text{ cumecs}$$

Computation of Flood Hydrograph

Working out in the manner outlined in the main text the full hydrograph can be computed as shown in Table AD-1. The resultant flood hydrograph is plotted in Fig. AD-1.

Variation occurring due to usage of Direct Formula

The flood values for return periods of 25-yr., 50-yr. and 100-yr. have been worked out both by detailed approach and by the simplified approach. The variations between them are in general less than $\pm$ 25% which is permissible considering the Case in the usage of the formula as compared to the detailed approach except in 2 cases out of 27. The table given below shows the percentage variation both positive and negative for Q_{25}, Q_{50} and Q_{100}.

Floods	Positive % variation	Negative % variation
Q_{25}	0.02 to 19.47	2.05 to 25.00
Q_{50}	1.34 to 19.04	1.01 to 22.89
Q_{100}	1.35 to 19.04	2.65 to 23.58

III. Formula for Linear Waterway Bridges

Since there has been some changes in the basic equation for floods of 25-yr., 50-yr, and 100-yr. return period. The equations for linear waterway undergo some changes as is given below:

$$W = 5.23 \times (\sqrt[3]{Q_{25}})$$

$$W = 5.00 \times (\sqrt[3]{Q_{50}})$$

$$W = 4.77 \times (\sqrt[3]{Q_{100}})$$

These formulae given above are to give an idea of the linear waterway which should be provided to allow floods of the dimensions of Q_{25}, Q_{50} and Q_{100} to pass through, keeping in view the general configuration of the river cross section.

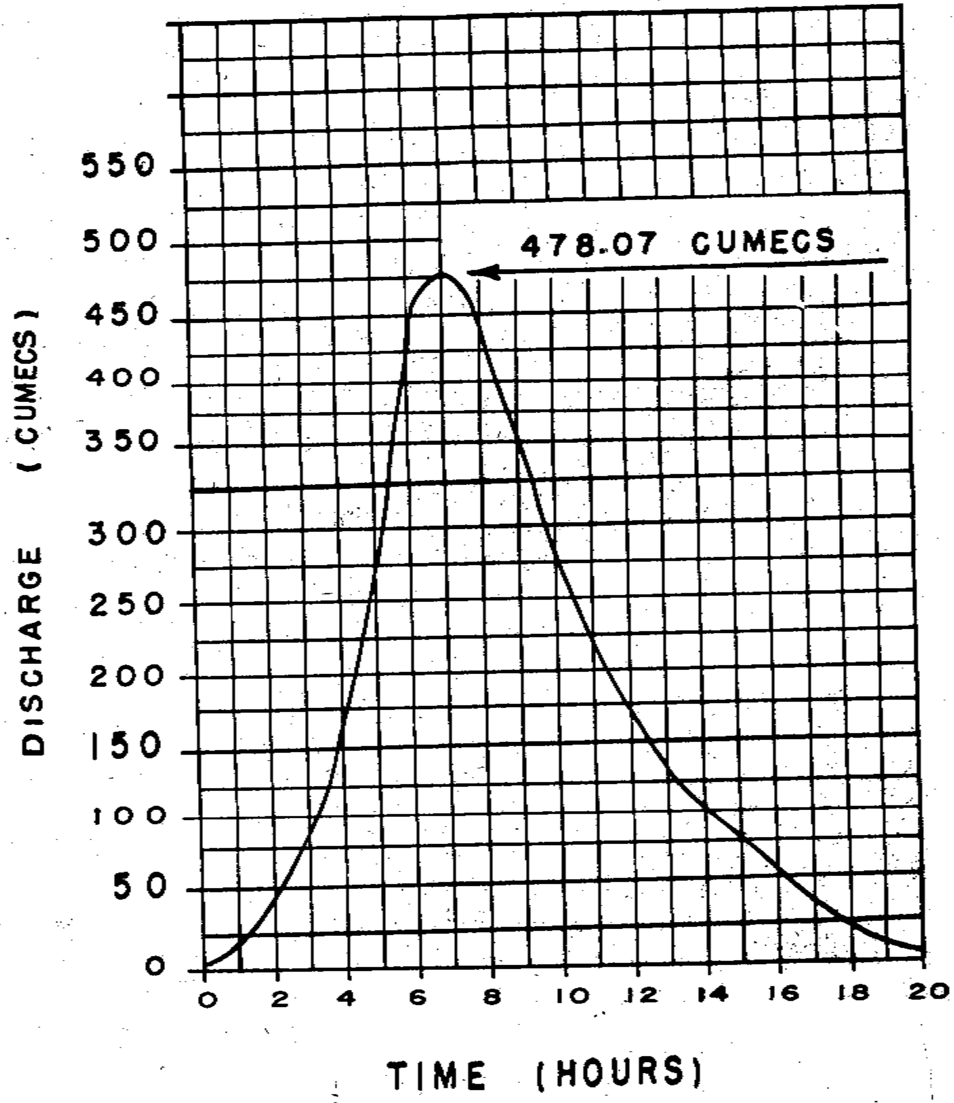
IV. Assumptions, Limitations and conclusions

All the assumptions, limitations and conclusions highlighted in the main text of the report will be applicable except for the recommendation of a uniform loss rate which is to be substituted by the loss rate derived by the formula given in the beginning. Also a uniform base flow rate is not to be considered but value derived from equation given in the beginning of the Addendum is to be adopted. The flood formula given in the addendum with different return periods are final ones and shall be used only for preliminary design. However, for final design, the design flood is to be estimated by application of storm rainfall to synthetic unit hydrograph using the detailed approach and the loss rates and base flow rates are to be calculated with the formula shown in the addendum.

Table AD-1 Computation of Design Flood Hydrograph of Pambar River at Railway Br.No. 37
sub-zone 3(i)

Sl. No.	Synthetic unit Hydrograph ordinates (cumecs)	1-Hourly rainfall excess (cm) 4.02 Direct Runoff (cumecs)	Base Flow (cumecs)	Total Flood Flow (cumecs)	Remarks
1	2	3	4	5	6
0	0	0	5.32	5.32	
1	3.0	12.06	5.32	17.38	
2	9.0	36.18	5.32	41.50	
3.	20.0	80.40	5.32	85.72	
4.	38.5	154.77	5.32	160.09	
5.	68.0	273.36	5.32	278.68	
6.	103.6	416.47	5.32	421.79	
7.	117.6	472.75	5.32	478.07	Peak discharge
8.	109.0	438.18	5.32	443.50	
9.	89.0	357.78	5.32	363.10	
10.	70.0	281.40	5.32	286.72	
11.	53.0	213.06	5.32	218.38	
12.	40.5	162.81	5.32	168.13	
13.	31.0	124.62	5.32	129.94	
14.	24.0	96.48	5.32	101.80	
15.	17.5	70.35	5.32	75.67	
16.	12.0	48.24	5.32	53.56	
17.	7.0	28.14	5.32	33.46	
18.	3.0	12.06	5.32	17.38	
19.	1.0	4.02	5.32	9.34	
20.	0	0	5.32	5.32	

FIG. A-1



GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE

KAVERI BASIN
SUB – ZONE 3(i)

DESIGN FLOOD HYDROGRAPH
RAILWAY BR.NO.37 ON RIVER PAMBAR

DRAWN. S.N. MALHOTRA, P.N. BHALLA	CHECKED. A.P. KHANNA