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COMPILATION OF A MANUAL FOR THE DESIGN OF ROOF DRAINAGE SYSTEMS

Padraig Timothy Culligan

A Dissertation Submitted to the Faculty of Engineering University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Engineering

December 1974

DECLARATION

I, the undersigned, declare that this dissertation:

1. is entirely my own work,
2. has not been submitted as a thesis for a Master's degree at any other University.



ACKNOWLEDGEMENTS

The Author gratefully acknowledges the guidance of Professor H I Schwartz in the conduct of this research and in the preparation of the dissertation.

The Author is deeply indebted to the Council for Scientific and Industrial Research and to the University of the Witwatersrand for providing the financial assistance necessary to carry out this research.

Thanks are due to the Johannesburg City Council for the granting of post-graduate study leave.

LIST OF CONTENTS

	Page
DECLARATION BY CANDIDATE	ii
ACKNOWLEDGEMENTS	iii
LIST OF CONTENTS	iv
LIST OF FIGURES	viii
LIST OF TABLES	ix
LIST OF GRAPHS	xi
LIST OF APPENDICES	xii
SYNOPSIS	xiii
CHAPTERS	
1 INTRODUCTION	1
2. DETERMINATION OF CRITICAL RAINFALL INTENSITY FOR GUTTER DESIGN	7
Selection of critical duration	7
Available data on short duration storms ..	7
Compilation of gutter design curves	8
3. THE CONSTRUCTION AND VERIFICATION OF A MATHEMATICAL MODEL BY MEANS OF WHICH A STANDARD GUTTER CAN BE ANALYSED	18
Definition of a standard gutter	18
Development of a theoretical analysis of a standard gutter	18
Spatially varied flow with increasing discharge	19
The numerical integration equation for spatially varied flow	22
The flowdepth at the outlet	24
Some theoretical considerations pertaining to flow over a free overfall weir	24
Proof of the assumption of free overflow conditions at the outlet	25
Selection of flowdepth at outlet	29
Conclusions	40

CHAPTERS Page

4. *THEORETICAL ANALYSIS OF A NUMBER OF STANDARD GUTTERS WITH DIFFERENT SHAPES, LENGTHS AND INFLOWS* 41

Summary of model gutter and practical applicability thereof 41
Freeboard allowance 42
Use of the model in determining required gutter sizes 42

5. ANALYSIS OF THE RESULTS OF THE MATHEMATICAL MODEL 45

Analysis of the rectangular gutter results .. 45
Conclusions 57
Analysis of trapezoidal gutter results .. 57
Conclusions 70
Analysis of half-round gutter results .. 70

6. REVIEW OF EXISTING METHODS OF GUTTER DESIGN AND COMPARISON WITH RESULTS OF PREVIOUS CHAPTER .. 76

Summary of Building Research Station method of gutter design 76

Part I - To determine the sizes of eaves gutters and downpipes and small valley gutters 76

Part II - To determine the sizes of large valley gutters, outlets of receivers and rainwater pipes 78

Summary of relevant portions of Martin method of gutter design 82

The catchment area 82
Flow capacity and design of drainage channels 85

Summary of relevant portions of Marsh method of gutter design for PVC half-round eaves gutters 87

Summary of Hollings' method of determining the optimum position of eaves gutters 88

Midgley results for flow capacity of downpipes 90

CHAPTERS Page

Li results for level channels with parallel side walls 91

Comparison of existing methods of determining required flow areas and design curves proposed in Chapter 5 94

7 CORRECTION FACTORS TO BE APPLIED TO STANDARD GUTTER RESULTS AND THE SIZING OF BOX-RECEIVERS AND DOWNPIPES 96

Correction factors to be applied to the standard gutter results 96

Sizing of box-receivers of downpipes 98

Downpipes from eaves gutters 98
Box-type receivers from valley gutters 102
Downpipes from box-receivers and valley gutters 103
Gutters other than rectangular or trapezoidal section 103

8 PRESENTATION OF A GUTTER DESIGN MANUAL FOR SOUTH AFRICAN CONDITIONS 105

Introduction 105
Position of downpipes 105
The catchment area 106
The design rainfall intensity 108
Design of drainage system 113
To determine the size of eaves gutters fitted with downpipes... 113
To determine the size of downpipes draining eaves gutters 114
To determine the size of valley and box gutters discharging freely into receiver and downpipe 115
Correction factors applied to the required area 117
To determine the size of box-receivers from valley gutters 118
The determine the size of downpipes from receivers or valley gutters 119
To determine the size of downpipes from flat roofs 120

CHAPTERS

Page

Maintenance 121

Typical examples 121

Gutter system for a residential building in Johannesburg 122
Gutter system for an industrial building in Port Elizabeth 124
Gutter system for an art gallery 128

LIST OF FIGURES

		Page
1	Delimitation of rainfall regions	9
2	Depth - duration - frequency diagram for point rainfall	10
3	Plot of intensity vs. duration for summer, winter and year-round rainfall regions ..	13
4	Gutter design curves for summer rainfall regions	15
5	Gutter design curves for winter rainfall regions	16
6	Gutter design curves for year-round rainfall regions	17
7	Diagrammatic representation of spatially varied flow	21
8	Results of tests on 0,1524m (6") true half-round gutters	27
9	Dimensions of box-type receivers	80
10	Air flow over buildings and probably trajectories for raindrops of one size	84
11	Influence of slope on discharge capacity of a drainage channel	86
12-14	Plots of intensity vs duration for the three rainfall regions	139-141
15	Section of channel with spatially varied flow	143

LIST OF TABLES

		Page
1	Depth, duration, frequency data abstracted from figure 2	11
2	Values used in plot of intensity versus M.A.P. for storms of 5 minute duration	14
3	Comparison of theoretical and experimental end depth in half-round gutters	28
4	Test results for 9" (0,229m) rectangular channel with level bottom	30
5	Adjusted Marsh results for half-round gutter	32
6	Theoretical water surface profiles in half-round gutters with n = 0,014	33
7	Comparison of theoretical and experimental peak peak depths in half-round gutters	37
8	Comparison of theoretical and experimental peak depths for a 0,229m rectangular gutter ..	38
9	Comparison of theoretical and experimental peak depths for a 0,229m rectangular gutter ..	39
10	Determination of the equations of the curves in graph 1	48
11	Calculated values of $Yb^{0,67}$, inf.x and $inf.x^{1,05}$	49
12	Comparison of the results of the proposed design equation and of CRECTI	55
13	Comparison of inf.x (given) with inf.x (calculated)	56
14	Values of inf and $A.deg^{0,25}$ for b = 0,3m and x = 10m	62
15	Values of inf.x and mean $Adeg^{0,25}/b^{0,09}$ for trapezoidal gutters	65
16	Comparison of results of TRAP and proposed design equation	67
17	Comparison of results of rectangular gutter programme and results of proposed design equation for trapezoidal gutters	69

LIST OF TABLES

		Page
18	Results of HR and comparison with results of modified BRS formula	74
19	BRS results and comparison with results of modified BRS formula	74
20	Calculation of the ratios Yp/Yo and Yd/Yo for rectangular channels	93
21	Determination of downpipe sizes required to serve eaves gutters	100
22-30	Rainfall intensities abstracted from Figure 2 for regions with different mean annual precipitations	130-138
31	Comparison of Li's results with outputs of GUT6 and CRECTI	174
32	Comparisons between outputs of TRAP and CRECTI	203
33	Comparison of Marsh results with outputs from HR	253
34	Determination of the slope of graph 4 ..	265
35	Values abstracted from graph 4 and check on validity of design equation	266
36	Values used in determining the equation of graph 3	268
37	Check on calculated equation of graph 3 ..	269
38-41	Values of inf.x and $Adeg^{0,25}/b^{0,09}$ for various base breadths	276-279
42	Determination of the slope of graph 9 ..	280
43	Values abstracted from plot of inf.x vs $Adeg^{0,25}/b^{0,09}$	281

LIST OF GRAPHS

		Page
1	Plot of log (inf) vs log (design depth) for a rectangular gutter of base breadth = 0,3m ..	46
2	Plot of log (inf) vs log ($Y.b^{0,67}$)	50
3	Plot of log (inf.x) vs log ($Y.b^{0,67}$)	51
4	Plot of log ($inf.x^{1,03}$) vs log ($Y.b^{0,67}$) ..	52
5	Plot of log(inf) vs log (A) for b = 0,2m and deg = 45°	59
6	Plot of log (inf) vs log (A) for b = 0,2m and deg = 60°	60
7	Plot of log (inf) vs log (area) for trapezoidal gutters of b = 0,3m and length = 10m ..	61
8	Plot of log (inf) vs log ($A.deg^{0,25}$) for length = 10m	63
9	Plot of log (inf.x) vs log ($A.deg^{0,25}/b^{0,09}$) ..	66
10	Plot of log (inf) vs log (x) for half-round gutters of ϕ = 0,1016m	72
11 - 15	Plots of log (inf) vs log (Y) for rectangular gutters of various base broadths	259-263

LIST OF APPENDICES

		Page
A	TABLES OF RAINFALL INTENSITY VALUES AS ABSTRACTED FROM FIGURE 2 AND TYPICAL CURVES USED TO OBTAIN THE FIVE MINUTE STORM INTENSITY VALUE ..	129
B	DERIVATION OF THE NUMERICAL INTEGRATION EQUATION FOR SPATIALLY VARIED FLOW	142
C	DETAILS OF ALL COMPUTER PROGRAMMES USED ..	146
	Programme to calculate the end depth in half-round gutters	146
	Programme to calculate the water surface profile in half-round gutters	150
	Programme to find the water surface profile in rectangular gutters	163
	Programme to determine the design depth in rectangular gutters	172
	Outputs from CRECTI	178
	Programme to determine the design depth in trapezoidal gutters with equal side slope	204
	Outputs from TRAP	207
	Programme to determine the flow capacity of true half-round gutters	251
	Outputs from HR	257
D	THE ANALYSIS OF THE RESULTS OF THE MATHEMATICAL MODEL	258
	Analysis of rectangular gutter results	258
	Determination of the equation of the design curve for rectangular gutters ..	264
	Determination of the equation of the curve for rectangular gutters as seen in graph 3	267
	Programme to analyse data for rectangular gutters	270
	Outputs from YA	272
	Analysis of trapezoidal gutter results	275
	Determination of the equation of the design curve for trapezoidal gutters (graph 9)	276
E	REFERENCES	282

SYNOPSIS

Roof drainage system design curves are determined by analysing existing data on short duration storms. These design curves are in the form of frequency - duration - mean annual precipitation curves for storms of five minute duration.

A 'standard gutter' consisting of a straight horizontal section of guttering, with uniform inflow along the length and outlet at one end is selected for theoretical analysis. A method of theoretically analysing such a gutter is presented. Proof of the adequacy of this analysis is given.

A large number of 'standard gutters' of differing shapes and lengths are theoretically analysed for various inflow rates.

The results of the above theoretical analyses are investigated and gutter design curves for trapezoidal, rectangular and half-round gutter sections are proposed.

Available literature on drainage system design is reviewed. Results from the relevant portion of this literature are compared with those from the proposed gutter design curves. The effect of variations of practical drainage systems from the 'standard gutter' is considered. Correction factors to account for such variations are presented.

The results of the previous sections are considered and a roof drainage system design manual is presented.

CHAPTER 1

INTRODUCTION

Roof drainage has for many years been a neglected subject of study in South Africa. Possibly this is due to the fact that the cost of drainage systems on any building is only a fraction of the total cost and in addition failure of the system by overflowing is seldom catastrophic. Generally, failure of the system is only of nuisance value. However in certain circumstances failure may result in damage to material within the building with resultant financial repercussions. In such instances it is desirable that gutter design be based on sound theoretical principles. Consideration should also be given to the hydroeconomics of the design. The cost of failure of the drainage system should be compared with the cost of the drainage system; buildings, such as art galleries, with a high failure cost, should have their drainage systems designed on large recurrence intervals of failure, whereas buildings, such as residential dwellings, with a low failure cost, should have their drainage systems designed on low recurrence intervals of failure.

At the present most gutter design in South Africa is based on rule of thumb techniques developed by experience. Most large firms or organisations have their own design criteria and many of these differ radically. Thus it appears that there is an urgent need for a manual outlining some rational basis, backed by sound

theoretical principles, upon which gutter design can be founded.

The problem of roof drainage was fairly comprehensively investigated by the Building Research Station in England in 1958 and again in 1969. These investigations entailed a large amount of experimentation on test gutters. Empirical formulae were then fitted to test results and design criteria were based on these formulae. Martin (1973) presented a method of drainage system design for Australian conditions. This method is essentially a modified version of the Building Research Station design method and is based on their empirical data. Martin does however present several improvements to the Building Research Station method, one of them being the introduction of the recurrence interval of failure to the design parameters.

Both of the above approaches are based on empirical data from a limited number of test gutters. In addition certain assumptions are made that, it is felt, do not always result in optimum drainage system design. Thus it was decided to seek some alternative method of gutter design based on theoretical principles.

Ward and Trim (1972) proposed a method by means of which a gutter can be theoretically analysed and their method has been adopted in this dissertation.

This investigation of drainage system design has been divided into several sections. The general aspects of these sections are briefly introduced in the following paragraphs.

(a) DETERMINATION OF THE CRITICAL RAINFALL INTENSITY FOR GUTTER DESIGN

The rainfall duration of five minutes is selected as the critical storm duration for drainage system design.

Intensity, frequency, duration, mean annual precipitation co-axial plots for the three rainfall regions in South Africa are extrapolated to obtain the intensity, frequency and mean annual precipitation values for storm durations of five minutes. The co-axial plots employed are under criticism (see Bergman (1974)) but due to the absence of further data it is felt that this is the best method at present available. These values are plotted to give roof drainage system design curves.

(b) THE CONSTRUCTION AND VERIFICATION OF A MATHEMATICAL MODEL BY MEANS OF WHICH A STANDARD GUTTER CAN BE ANALYSED

There are an extensive number of variables involved in the design of a practical roof drainage system. These variables include gutter length, cross-sectional area, size and position of downpipes and slope. If all such variables are taken into account a theoretical analysis of the drainage system will be extremely complex, if not impossible. Thus a 'standard gutter' is selected for analysis.

This 'standard gutter' consists of a straight, horizontal section of guttering, with an outlet at one end and uniform inflow along its total length. The flow condition in a standard gutter is an example of *spatially varied flow and is* analysed using an equation derived from momentum considerations.

This equation is termed the Hinds Equation, and it defines the water surface profile in the gutter in an iterative fashion However, to apply the Hinds Equation the depth of flow at any one section must be known.

It is assumed that the gutter behaves like a free overfall spillway at the outlet. Results supporting this assumption are presented. This implies that the depth of flow at the outlet is below critical depth and passes through the critical depth some distance upstream from the outlet.

A supercritical flow depth in a horizontal channel is however not in keeping with the basic assumptions on which the Hinds Equation is based. Thus the problem arises as to whether to use the actual supercritical depth at the outlet or some other hypothetical depth as the starting depth in the Hinds analysis.

It is shown that theoretical results are in good agreement with experimental results if it is assumed that the depth of flow at the outlet is equal to the critical flow depth. The critical flow depth is thus used as the starting point in the Hinds analysis.

The analysis is applied to several gutters for which experimental results are available. Good correlation between experimental and theoretical results is obtained.

The effect of the value of Manning 'n' is investigated. The value n = 0,016 gives best agreement between theoretical and experimental results and is thus selected for use.

(c) THEORETICAL ANALYSIS OF A NUMBER OF STANDARD GUTTERS WITH DIFFERENT SHAPES, LENGTHS AND INFLOWS

A large number of standard gutters with differing shapes, lengths and inflows are analysed using the mathematical model developed in Chapter (b). The output from these analyses is the required cross-sectional area of flow for any given shape, length and inflow rate.

Computer programmes were developed to perform these analyses. These programmes are discussed and the results presented in the form of computer print-outs.

(d) THE ANALYSIS OF THE RESULTS OF (c)

The output from the previous section is a vast number of computer printouts containing the required cross-sectional area of gutter for a given shape, length and inflow rate. These printouts contain all the information that is necessary for the design of the particular gutter shapes and lengths analysed. This information is however contained in a form that is not readily usable.

Methods of abbreviating this output were sought so as to make it more practical for use in a gutter system design manual. In addition means of generalising the results to cater for any drainage system design problem were investigated.

Mathematical relationships between the variables, shape, length, inflow rate and required cross-sectional area were sought. Equations were found for trapezoidal, rectangular and half-round gutters such that all the design criteria reduced to points on a

single curve for each particular shape. These curves are general design curves that can readily be used in a gutter design manual.

(e) A REVIEW OF EXISTING METHODS OF GUTTER DESIGN AND A COMPARISON WITH THE RESULTS OF (d)

Existing methods of gutter design are briefly reviewed. These design methods are compared with the design curves of the previous section.

Most practical gutter systems vary from the standard gutter that has been theoretically analysed. The effect of variation of practical gutter systems from the standard gutter are considered. Such variations are accounted for by applying correction factors to the 'standard gutter' results. Correction factor values are obtained from previous investigators' results.

(f) PRESENTATION OF A TENTATIVE ROOF DRAINAGE SYSTEM DESIGN MANUAL

The results of the analyses of standard gutters are combined with relevant portions of the previous investigators' work to produce a manual for the design of practical roof drainage systems.

CHAPTER 2

DETERMINATION OF CRITICAL RAINFALL INTENSITIES FOR GUTTER DESIGN

SELECTION OF CRITICAL DURATION

Given the recurrence interval of failure, there is a particular intensity of storm that will cause a gutter system to fail by overflowing. This intensity is termed the design intensity of the gutter system.

To determine this intensity it is necessary to consider the duration of storm that will be critical. This critical duration will equal the time elapsed from the start of the storm to when the whole roof is contributing inflow to the gutter outlet. The critical duration depends on many factors and cannot be obtained theoretically.

It is felt that a reasonable estimate of this duration for roof drainage systems is five minutes and this value has been adopted. Martin (1973) has also adopted this value.

AVAILABLE DATA ON SHORT DURATION STORMS

Van Wyk (1965) has investigated short duration, high intensity storms. The major problem encountered was the lack of data on such short duration storms. Van Wyk derived curves relating the mean annual precipitation to the rainfall intensity for different recurrence intervals and rainfall durations for the three meteorologically homogeneous regions in South Africa.

These regions are the winter, summer and year round rainfall regions as seen in Figure 1.

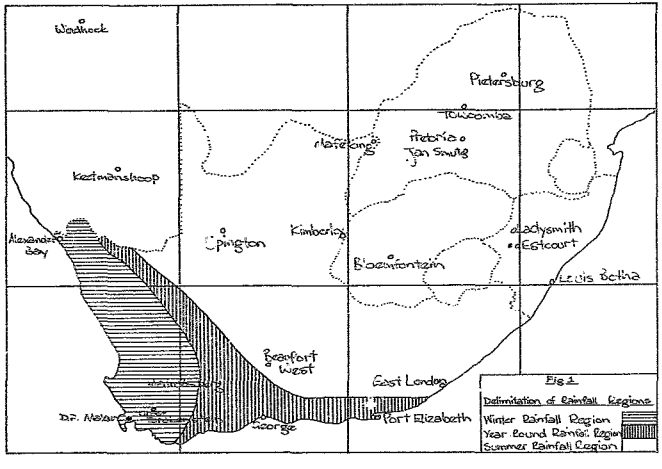
The Hydrological Research Unit (1972) employed the van Wyk curves in deriving a co-axial plot relating mean annual precipitation, frequency and duration to the depth of precipitation for the three rainfall regions. This co-axial plot is reproduced in Figure 2 and is employed in obtaining the rainfall intensities for storms of five minute duration.

COMPILATION OF GUTTER DESIGN CURVES

Data was abstracted from Figure 2 in the following manner: For a selected mean annual precipitation and recurrence interval, depths of precipitation were abstracted for the different storm durations for the three regions. The precipitation depths were converted to intensities and the process repeated for a number of mean annual precipitations and recurrence intervals.

All the abstracted values, converted to intensity values are listed in Appendix A and an example of the abstracted data for mean annual precipitation of 500 millimetres and recurrence interval of 50 years is given in Table 1.

These abstracted values were processed as follows: For a particular mean annual precipitation and recurrence interval, the intensity was plotted against time on semi-logarithmic paper. The resultant points approximated a straight line and the best fit line was drawn through these points. (It was felt that the general accuracy of the approach adopted did not warrant


Woodhock
Pietersburg
Towcomba
Mafeking
Pretoria
Jan Smuts
Keetmanshoop
Alexander Bay
Upington
Kimberley
Ladysmith
Estcourt
Bloemfontein
Louis Botha
Beaufort West
East London
Port Elizabeth
George
D.F. Malan
Fig 1
Delimitation of Rainfall Regions
Winter Rainfall Region
Year Round Rainfall Region
Summer Rainfall Region

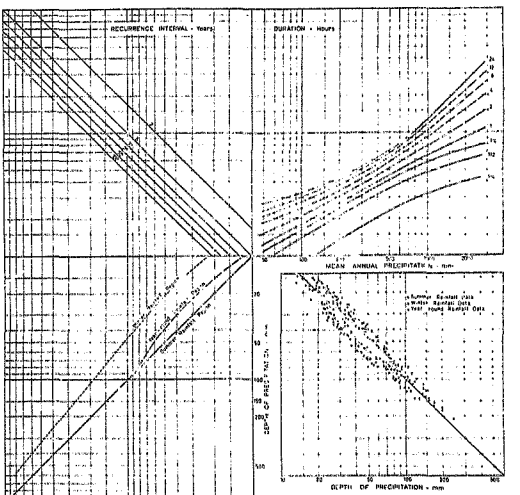


Fig 2: Depth-duration-frequency diagram for point rainfall (after H.R.U. 1972)

TABLE 1: DEPTH, DURATION, FREQUENCY DATA ABSTRACTED FROM FIGURE 2

Duration	Depth of Precipitation - mm			Intensity - mm/hr		
hrs	Summer	Winter	Year Round	Summer	Winter	Year Round
0,25	42	17,2	32	168	68,8	128
0,50	65	27	54,5	130	54	109
0,75	77,5	34	70	103,4	45,5	93,5
1,00	86	37,5	82	86	37,5	82
2,00	95	44	95	47,5	22	47,5
4,00	-	-	-			
8,00	-	-	-			
12,00	-	-	-			
24,00	-	-	-			

the drawing of regression curves through these points. In addition where a certain amount of scatter of the points existed, the line that gave a conservative result for the five minute duration intensity value was drawn.) This fitted line was then extrapolated to give the intensity for the five minute duration storm.

Examples of the curves thus obtained are in Appendix A and Figure 3 is an example for mean annual precipitation of 500 millimetres and recurrence interval of 50 years and for the summer, winter

and year-round rainfall regions.

The intensity values for the five minute duration storms are abstracted from these curves and results are listed in Table 2. The results were plotted, yielding curves of intensity versus mean annual precipitation for varying recurrence intervals for the three rainfall regions for the critical duration of five minutes. These curves are given in Figures 4, 5 and 6 and can be used to obtain the critical rainfall intensity for gutter design for buildings in South Africa.

Henceforth whenever the design intensity is referred to, it is the critical intensity for a gutter at a particular site and for a particular recurrence interval of failure as determined by these curves. It should be noted that these curves are applicable to any problem in which the five minute duration storm is considered critical.

Recent investigation has indicated that errors may exist in the co-axial plot (Figure 2) from which these design curves were derived. However in the absence of further data it is felt that the method employed is the best available. Readers are however advised to keep abreast with modern techniques of determining rainfall intensities for short duration storms.

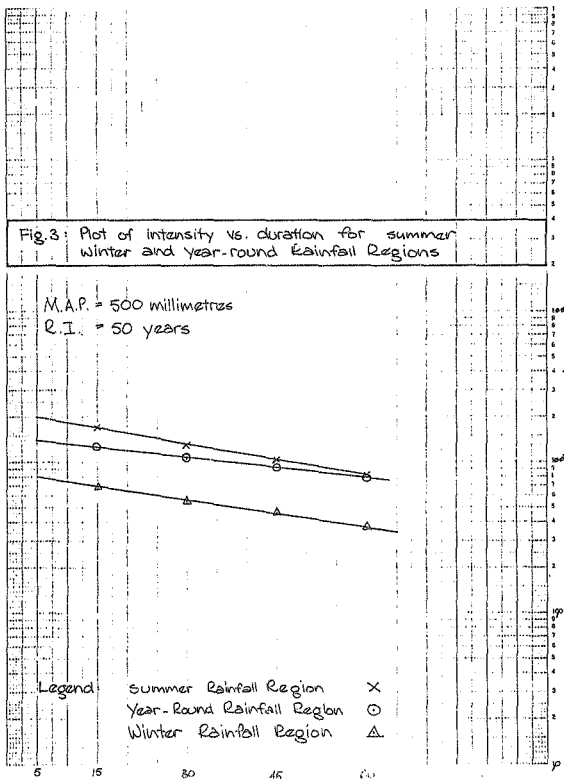


Fig. 3: Plot of intensity vs. duration for summer, winter and year-round Rainfall Regions

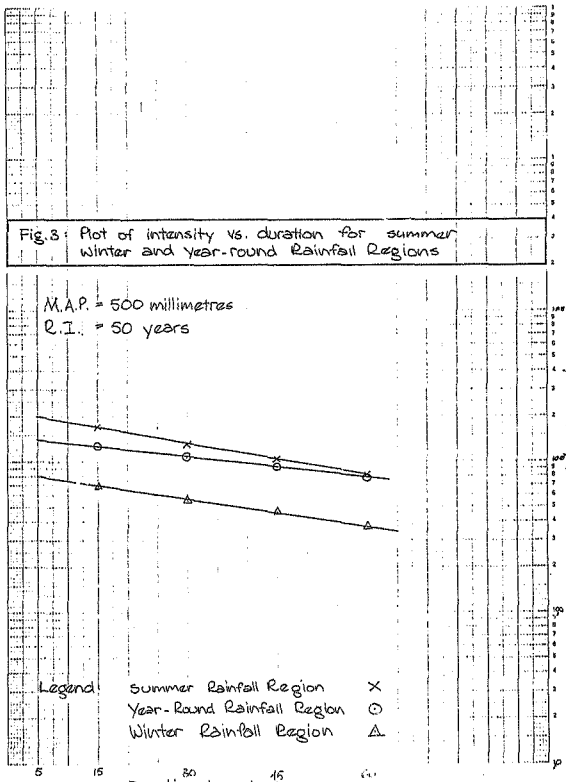


Fig.3: Plot of intensity vs. duration for summer, winter and year-round Rainfall Regions

TABLE 2: VALUES USED IN PLOT OF INTENSITY VERSUS M.A.P. FOR STORMS OF 5 MINUTE DURATION

M.A.P. in mm	R.I. in years	INTENSITY IN mm/hr		
		Summer	Winter	Year-round
50	2	-	-	-
	5	21	-	-
	10	29	-	28
	20	44	-	29
	50	44	-	30
	100	52	24	39
100	2	-	-	-
	5	42	-	36
	10	51	-	42
	20	66	25	48
	50	70	31,7	51
	100	94	38	66
200	2	36	-	32
	5	65	27	54
	10	80	28,5	64
	20	100	40	75
	50	112	50	85
	100	140	60	100
500	2	65	26	54
	5	108	52	80
	10	136	57	105
	20	160	68	120
	50	192	80	138
	100	237	95	175
750	2	82	31	61
	5	130	57	100
	10	173	68	120
	20	200	83	127
	50	270	100	170
	100	280	120	230
1000	2	100	36	70
	5	150	64	110
	10	184	77	127
	20	230	92	160
	50	270	120	210
	100	320	120	270
1500	2	106	39	76
	5	175	74	120
	10	220	85	160
	20	270	105	197
	50	310	130	260
	100	380	140	355
2000	2	112	49	85
	5	190	76	137
	10	240	95	177
	20	290	118	223
	50	350	142	300
	100	400	175	405
2200	2	130	51	90
	5	200	80	140
	10	250	98	180
	20	295	115	240
	50	360	150	318
	100	405	180	405

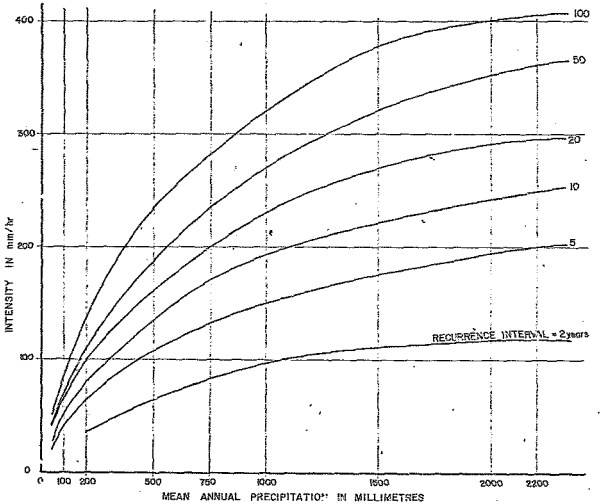


Fig. 4 GUTTER DESIGN CURVE FOR SUMMER RAINFALL REGIONS

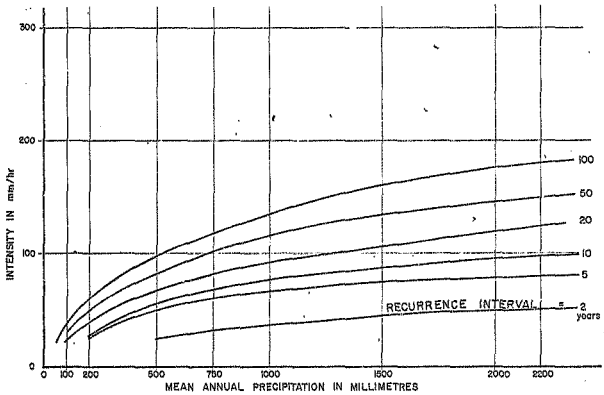


Fig. 5 GUTTER DESIGN CURVE FOR WINTER RAINFALL REGIONS

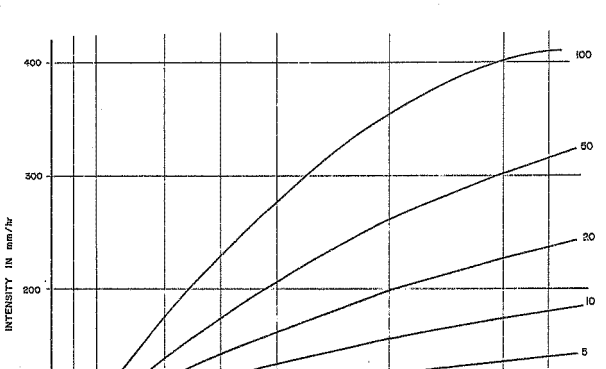


Fig. 6. GUTTER DESIGN CURVE FOR YEAR-ROUND RAINFALL REGION

CHAPTER 3

THE CONSTRUCTION AND VERIFICATION OF A MATHEMATICAL MODEL BY MEANS OF WHICH A STANDARD GUTTER CAN BE ANALYSED

DEFINITION OF A STANDARD GUTTER

Given the design intensity and the roof shape and slope, then the quantity of water flowing into a gutter can be determined. The distribution of the inflow, however, depends on the roof shape. Since the majority of practical roof systems are rectangular in shape, only gutters with uniform inflows will be considered.

The problem is further simplified by assuming;

(a) the gutter to have one outlet at one end.

(b) the gutter to be horizontal.

Thus the system to be theoretically analysed consists of a horizontal length of gutter with uniform inflow and an outlet at one end. This is referred to as the 'standard gutter'.

DEVELOPMENT OF A THEORETICAL ANALYSIS OF A STANDARD GUTTER

The analysis of a standard gutter comprises of the determination of the water surface profile in a gutter of given length and shape and for a given inflow.

The flow situation in the standard gutter is an example of spatially varied flow. This has a non-uniform discharge resulting from the addition or reduction of water along its length. The added water will cause disturbance in the energy or momentum content of the flow. As a result the hydraulic behaviour of a

spatially varied flow situation is more complicated than that of a constant discharge. Since gutter flow is a problem of increased discharge only this will be considered. A typical example of this type of flow situation is a side channel spillway.

SPATIALLY VARIED FLOW WITH INCREASING DISCHARGE

The problem was first investigated in 1926 by Julian Hinds in connection with the capacity of and energy losses in side-channel spillways. Since then much work has been done on it and equations describing the water surface profile have been developed. At this stage it must be pointed out that due to the very nature of the flow situation, with inflow normal to outflow, turbulence and secondary currents will be developed. This mixing of the added water and the water already flowing in the channel, results in high energy losses that cannot be computed. Another result of the high energy losses is that the momentum equation is found to be more convenient than the energy equation in solving the flow situation.

In the derivation of the spatially varied flow equation, the following assumptions are made:

1) The flow is unidirectional. Actually there are usually cross currents in the form of spiral flows - the effect of these currents and the accompanying turbulence cannot be easily evaluated, but is taken into account if the momentum principle is employed. IN ADDITION THE LATERAL UNEVENNESS OF THE WATER SURFACE DUE TO CROSS CURRENTS IS IGNORED.

2) The velocity distribution across the channel section

is constant and uniform. This implies that the velocity distribution coefficient is unity. Proper values of the coefficient may however be used.

4) The slope of the channel is small; thus its effect on the pressure head is small. If the slope is appreciable, corrections to this effect may be applied.

5) The Manning formula may be used to evaluate friction losses due to shear along the channel edges (viz. flow is steady and uniform)

6) The effect of air entrainment is negligible. A correction however may be applied to the computed results where necessary. (These assumptions should be noted and borne in mind when applying results of the analysis.)

Consider the diagrammatic representation of the flow situation as shown in Figure 7. By applying the momentum equation between sections (1) and (2) and using the Manning equation to derive the head loss between the sections, the dynamic equation for spatially varied flow with increasing discharge can be determined. The derivation is presented in reference 5 and the final equation has the form;

$$\frac{dy}{dx} = \frac{So - Sf - 2\alpha Qq / gA^2}{1 - \alpha Q^2 / gA^2 D}$$

where $\frac{dy}{dx}$ = rate of change of depth with distance along channel bed.

So = bed slope

Sf = friction slope = $\frac{Q^2 n^2}{A^2 R^{4/3}}$

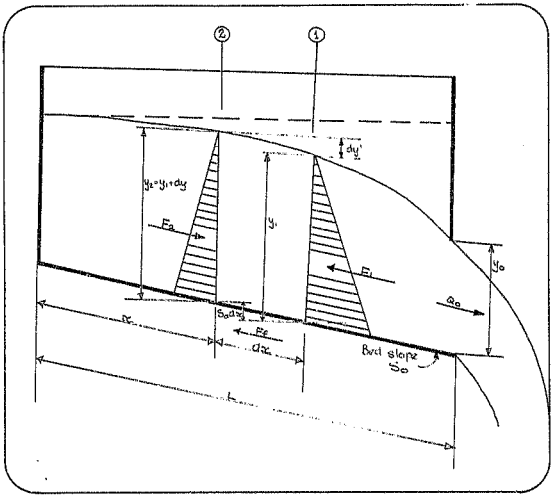


Fig 7 : Diagrammatic representation of spacially varied flow.

α = energy coefficient to account for nonuniform velocity distribution

Q = total discharge at a section

$q^* = \frac{dQ}{dx}$ = inflow per unit length

A = cross-sectional area of flow

D = hydraulic depth which is the cross-sectional area of water normal to the direction of flow in the channel divided by the width of free surface. For rectangular channels this equals the depth of flow.

Note that if q* equals zero, the equation becomes the dynamic equation for gradually varied flow with constant discharge.

For simple cases this equation can be directly integrated. However for most cases a method of numerical integration must be used. Since the numerical method is the more general method, this will be applicable in most gutter problems and for this reason the numerical integration equation is used.

THE NUMERICAL INTEGRATION EQUATION FOR SPATIALLY VARIED FLOW

This equation is derived in Appendix B by using momentum considerations. The equation is referred to as the Hinds equation and has the form:

$$\Delta y' = Sf\,\Delta x - \left(\frac{V1 + V2}{Q1 + Q2}\right).\alpha\,\frac{Q1}{g}\left(\Delta V + \frac{V2}{Q1}\,\Delta Q\right)$$

where, referring to figure 7;

$\Delta y'$ = change in elevation of water surface

Sf = slope of the energy line between the two sections

Δx = horizontal distance between the two sections

V = velocity at appropriate section

Q = discharge at appropriate section

α = energy coefficient to account for non-uniform velocity distribution

ΔV = change in velocity between sections

ΔQ = change in discharge between sections

The change in water surface elevation is given by;

$$\Delta y' = +\Delta y + So\Delta x$$

where Δy = change in flow depth

So = channel slope

The slope of the energy line is, according to the assumptions of the analysis, given by;

$$Sf = \frac{\bar{V}^2 n^2}{\bar{R}^{4/3}}$$

where $\bar{V}$ = average velocity between sections

$\bar{R}$ = average hydraulic radius between sections

n = Manning's n value

In the Hinds equation the first term on the righthand side, $Sf\Delta x$, represents the effects of friction, while the second term represents the effects of impact loss and turbulence.

In the case of the standard horizontal gutter, the slope effect falls away and;

$$\Delta y' = \Delta y$$

In addition it is assumed that the energy correction coefficient equals unity.

Thus the equation that is used to determine the water surface profile in a standard gutter is;

$$\Delta y = Sf\,\Delta x - \left(\frac{V1 + V2}{Q1 + Q2}\right) \cdot \frac{Q1}{g}\left(\Delta V + \frac{V2}{Q1}\,\Delta Q\right)$$

This equation can be solved by an iterative process and will be referred to as the Hinds equation.

THE FLOWDEPTH AT THE OUTLET

In applying the Hinds equation, the flow depth at one section must be known. The flow depth at all other sections can then be calculated.

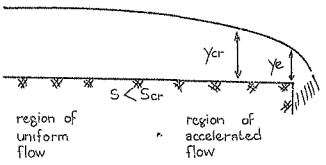
At the outlet, the depth of flow depends on several factors such as gutter size and shape, type of outlet, flowrate etc. Possible flow conditions at outlet might be approximated by; free weir, drowned weir, orifice, orifice with suction etc., or some combination of the above.

Many drainage systems serving large roof areas drain into box-receivers. Flow into these receivers will approximate free overfall conditions. In the case of vertical downpipes draining directly from the gutter, Martin (1973) considers that flow conditions will approximate weir conditions. Inspection of this type of system during periods of intense rainfall tends to verify the condition of the free weir (assuming that a bend is not situated directly beneath the outlet, causing a backup of flow). Thus in order to calculate the flow depth at the outlet, free overfall weir flow must be briefly considered.

SOME THEORETICAL CONSIDERATIONS PERTAINING TO FLOW OVER A FREE OVERFALL WEIR

Consider a channel in which the flow is subcritical, with

a free overfall weir at one end.



The critical depth, Ycr, will occur some distance upstream of the overfall, while at the overfall itself a depth Ye, the end depth, will occur. O'Brien found that for channels with a level bed the critical depth was approximately 12 Ycr upstream from the brink, the distance increasing as the channel slope increased.

Rouse (1936) has shown that for slopes less than the critical the end depth, Ye, is 0,715 Ycr or Ycr = 1,40 Ye.

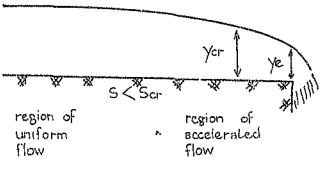
Bauer (1971) has shown that for slopes less than the critical and within the range $0,0 < S < 0,0038$ and for Manning n roughness values lying between ,011 and ,014, that Ycr = 1,2947Ye.

Thus it appears that a reasonable estimate of the end depth is the Rouse value of Ye = 0,715 Ycr.

PROOF OF THE ASSUMPTION OF FREE OVERFLOW CONDITIONS AT OUTLET

To test the assumption that flow at the gutter outlet is approximated by flow over a free overfall weir, available test results are compared with computed theoretical results.

a free overfall weir at one end.



The critical depth, Ycr, will occur some distance upstream of the overfall, while at the overfall itself a depth Ye, the end depth, will occur. O'Brien found that for channels with a level bed the critical depth was approximately 1.2 Ycr upstream from the brink, the distance increasing as the channel slope increased.

Rouse (1936) has shown that for slopes less than the critical the end depth, Ye, is 0,715 Ycr or Ycr = 1,40 Ye.

Bauer (1971) has shown that for slopes less than the critical and within the range $0,0 < S < 0,0038$ and for Manning n roughness values lying between ,011 and ,014, that Ycr = 1,2947Ye.

Thus it appears that a reasonable estimate of the end depth is the Rouse value of Ye = 0,715 Ycr.

PROOF OF THE ASSUMPTION OF FREE OVERFLOW CONDITIONS AT OUTLET

To test the assumption that flow at the gutter outlet is approximated by flow over a free overfall weir, available test results are compared with computed theoretical results.

Marsh (1968) has published experimental results giving the water surface profile in half-round gutters for various flowrates. The profiles for a 0,1524 metre (6 inch) true half-round gutter are shown in Figure 8. (It is realised that a small half-round gutter is not truly representative of the large valley gutters draining large roof areas. Experimental data on such gutters are however limited.)

The theoretical end depth is determined from the expression, $Ye = 0{,}715\ Ycr$. Hence it is necessary to determine the critical depth in the gutter for various flowrates. This can be found by using the fact that $\frac{Q^2 B}{gA^3} = 1$ when flow is critical. Where

Q = total flowrate

B = water surface width

A = cross-sectional area of flow

A programme was written to calculate the end depth in half-round gutters. This programme is discussed in Appendix C. Results of the programme are compared with experimental end depths as abstracted from Figure 8 in Table 3.

It can be seen that theoretical values are in reasonable agreement with experimental values. This strengthens the belief that flow at the outlet tends to free overflow conditions.

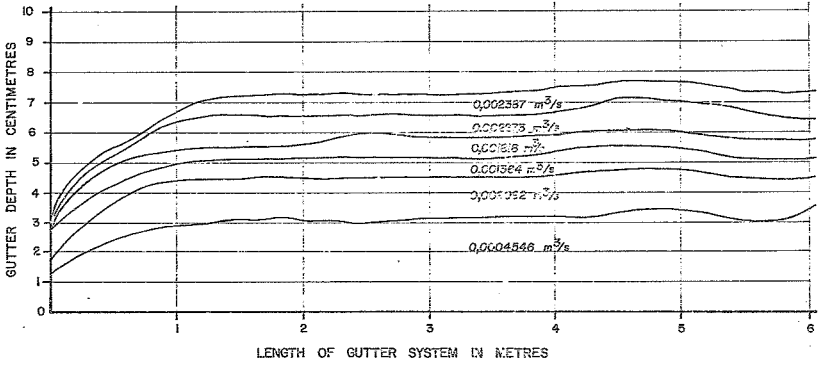


Fig. 8 RESULTS OF TESTS ON 0,1524 m (6") TRUE HALF-ROUND GUTTERS (AFTER MARSH 1973)

TABLE 3: COMPARISON OF THEORETICAL AND EXPERIMENTAL END DEPTHS IN HALF-ROUND GUTTERS

GUTTER LENGTH - 6,096 metres

GUTTER RADIUS - 0,0762 metres

GUTTER SHAPE - true half-round

DISCHARGE in m^3/s	EXPERIMENTAL DEPTH AT OUTLET in metres	CALCULATED DEPTH AT OUTLET, Ye in metres	CRITICAL DEPTH Ycr in metres	% ERROR IN DEPTH AT OUTLET
0,0004546	0,0132	0,0133	0,0187	+ 0,07
0,0009092	0,0175	0,0189	0,0264	+ 8,0
0,001364	0,0269	0,0235	0,0329	-12,6
0,001818	0,0279	0,0270	0,0378	- 3,2
0,002273	0,0294	0,0303	0,0424	+ 2,4
0,002387	0,0310	0,0314	0,04386	+ 1,3

SELECTION OF FLOWDEPTH AT OUTLET

It has been pointed out that depth of flow at outlet approaches the end depth of a free overfall weir, i.e. Ye = 0,715 Ycr. Using this end depth as the starting value in the Hinds equation however, results in a contradition to one of the basic assumptions on which the analysis is based, namely that the pressure in the flow is hydrostatic. Considering a gutter with a subcritical slope, it is impossible for the flow depth to be less than the critical if the pressure is to remain hydrostatic. Thus an end depth of Ye = 0,715 Ycr implies that the pressure at this section is non-hydrostatic (which it is) and flow is non-uniform.

For these reasons it is felt that application of the critical depth as the starting point in the Hinds analysis may result in more accurate values for the peak depth in the gutter than will result from application of the actual end depth as the starting depth. Starting with the critical depth will result in the theoretical water surface profile lying above the true profile near the outlet. It is however considered that the theoretical profile will rapidly converge on the true profile.

To determine whether to use end or critical depth as the starting value it is necessary to calculate the water surface profile using both Ye and Ycr as starting values and to compare these results with experimental results. The available experimental results are the Marsh results in Figure 8 and the Li (1955) results for rectangular channels as given in Table 4.

TABLE 4: TEST RESULTS FOR 9" (0,229m) RECTANGULAR CHANNEL WITH LEVEL BOTTOM (AFTER Li)

CHANNEL LENGTH - 2,286metres

DISCHARGE IN m^3/s	DISTANCE FROM OUTLET, x, in metres	0,0524	0,8390	1,269	1,680	2,211
		FLOW DEPTH at x in metres				
0,08665		0,3597	0,3962	0,4115	0,4237	0,4267
0,07136		0,3200	0,3475	0,3658	0,3810	0,3810
0,0640		0,3109	0,3261	0,3475	0,3597	0,3627
0,0606		0,2865	0,3139	0,3261	0,3383	0,3383
0,05239		0,2713	0,2896	0,3078	0,3170	0,3200
0,04531		0,2591	0,2774	0,2896	0,2987	0,2987
0,03540		0,2134	0,2286	0,2408	0,2408	0,2499

CHANNEL LENGTH - 1,716metres

DISCHARGE IN m^3/s	DISTANCE FROM OUTLET, x, in metres	0,516	0,841	1,283	1,678
		FLOW DEPTH at x in metres			
0,06088		0,3078	0,3261	0,3383	0,3353
0,04644		0,2865	0,3018	0,2987	0,2987
0,03936		0,2438	0,2560	0,2652	0,2682
0,02492		0,1768	0,1890	0,1859	0,1890

It is seen that the experimental water surface profiles given by Marsh are rather uneven. This is due to turbulence and secondary currents and cannot be calculated theoretically. These secondary effects are eliminated by drawing the best fit smooth curves through the actual profiles. These smooth curves define the adjusted profiles with secondary effect eliminated. The adjusted profiles are given in Table 5.

The water surface profiles in rectangular and half-round gutters are calculated with the aid of the Hinds equation. This is done by computer and the programmes are discussed in Appendix C.

Basically the programmes start with a given depth at the outlet (either end or critical depth). A value for the change in water surface elevation from the outlet to the next section is assumed. The assumed flow depth at the next section is applied in the Hinds equation to calculate the change in flow depth. The assumed and calculated flow depths are compared and if they do not agree to the specified accuracy, a new change in flow depth is assumed. The process is repeated until the required accuracy is obtained. The change in flow depth between the next two sections is then found in the same manner and in this way the water surface profile in the gutter is defined.

The results of the programme for half-round gutters are in Appendix C. The theoretical profiles found by starting with the critical depths are in Table 6.

TABLE 5: ADJUSTED MARSH RESULTS FOR HALF-ROUND GUTTER

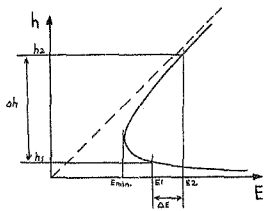
DISCHARGE IN m^3/S	0,002387	0,002273	0,001818	0,001364	0,0009092	0,0004546
DISTANCE FROM OUTLET in metres	F L O W D E P T H i n metres					
0	0,032	0,030	0,028	0,027		
0,1524	0,043	0,043	0,038			
0,3048	0,050	0,047	0,044	0,037		
0,4572	0,054	0,051	0,047			
0,6096	0,056	0,055	0,050	0,044		
0,9144	0,064	0,061	0,053	0,048		
1,219	0,070	0,065	0,054	0,050		
1,829	0,072	0,065	0,055	0,050		
2,438	0,072	0,065	0,056	0,051		
3,048	0,072	0,065	0,057	0,052		
3,658	0,072	0,066	0,058	0,052		
4,267	0,072	0,066	0,058	0,052	0,045	0,032
4,877	0,072	0,066	0,058	0,052	0,045	0,032
5,182	0,073	0,066	0,058	0,052	0,095	0,032
5,486	0,073	0,066	0,058	0,052	0,045	0,032
6,096	0,073	0,066	0,058	0,052	0,045	0,032

TABLE 7: THEORETICAL WATER SURFACE PROFILES IN HALF-ROUND GUTTERS WITH n = 0,014

DISCHARGE IN m^3/s	0,002387	0,002273	0,001818	0,001364	0,0009092	0,0004546
DISTANCE FROM OUTLET in metres	D E P T H i n m e t r e s					
0	0,04386	0,0424	0,0378	0,0329	0,0264	0,0187
0,305	0,05386	0,0524	0,0478	0,0409	0,0344	0,0247
0,610	0,0578	0,0564	0,0508	0,0439	0,0364	0,0267
0,914	0,0598	0,0584	0,0528	0,0459	0,0384	0,0277
1,219	0,0618	0,0604	0,0548	0,0469	0,0394	0,0287
1,829	0,0648	0,0634	0,0568	0,0489	0,0414	0,0307
2,438	0,0668	0,0654	0,0588	0,0509	0,0434	0,0307
3,048	0,0688	0,0674	0,0608	0,0519	0,0434	
3,658	0,0698	0,0684	0,0608	0,0519		
4,267	0,0698	0,0684	0,0608	0,0519		
4,877	0,0698	0,0684	0,0608	0,0519		
5,182	0,0698	0,0684	0,0608	0,0519		
5,486	0,0698	0,0684	0,0608	0,0519		
6,096	0,0698	0,0684	0,0608	0,0519		

Comparison of table 5 and table 6 reveals that using the end depth as the starting depth results in theoretical water surface profiles well above experimental profiles. An explanation of why this occurs follows:

Starting with a depth less than the critical, the specific energy at the outlet, El, is greater than the minimum specific energy, Emin, and the flow is *supercritical*. *In moving upstream* to the next station the flow must become subcritical (since channel slope is subcritical). In addition there is an increase of specific energy, ΔE, due to the increased flow depth. This situation is seen on the specific energy diagram below.

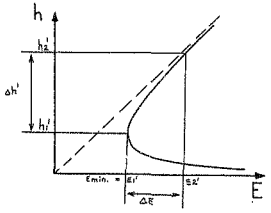


The flow depth at the upstream station is given by

$h2 = h1 + \Delta h$

Starting with the critical depth at outlet, the change in specific energy to the upstream station will be approximately the same as before i.e. ΔE. The resulting change in flow depth as

seen below, $\Delta h^1 = h2^1 - h1$, is obviously less than in the previous case.



Indications that this is what actually occurs are;

(a) The major discrepancy between the change in flow depth calculated by starting with the critical and end depths is seen to occur between the outlet section and the next upstream section. This is the large difference between Δh and Δh^1 above.

(b) At the few stations immediately upstream from the outlet the change in flow depth from station to station found using the end depth is less than the change found using the critical depth. This is due to the fact that at specific energy values close to Emin, the slope of the E/h curve is greater than at higher specific energy values. This indicates that the two starting points on the E/h diagram, E1 and $E1^1$ are as shown above.

(c) Several sections upstream from the outlet, the change in depth from section to section is the same irrespective of whether end or critical depth was used as starting value.

This implies that these sections are in the range where the slope of the E/h diagram tends to unity.

Inspection of Table 6 indicates that the theoretical water surface profiles found using critical depth as starting point are in good agreement with the experimental profiles after a few sections upstream from the outlet. The theoretical profiles rapidly converge on the experimental profiles. In this study the region of interest is the peaks of the water surface profiles and a comparison of the theoretical and experimental peaks for the half-round gutter is given in Table 7. Inspection of this table indicates that the proposed method of analysis is correct if using the critical depth as the starting depth at the outlet.

The peak depths in rectangular gutters found by starting with the critical depth were abstracted from the computed profiles. These peaks are compared with the Li experimental results in Table 8 and Table 9. The theoretical peaks were found using Manning n values of 0,014 and 0,016. Inspection of these results indicates good agreement between experimental and theoretical peaks and that the peak depth is very insensitive to the roughness value. Slightly better agreement is obtained when the Manning n value equals 0,016. It is acknowledged that this value is larger than the n value of a clean gutter, but it allows for an accumulation of rust and debris in the gutter.

TABLE 7: COMPARISON OF THEORETICAL AND EXPERIMENTAL PEAK DEPTHS IN HALF-ROUND GUTTERS

DISCHARGE in m^3/s	EXPERIMENTAL PEAK DEPTH in metres	CALCULATED PEAK DEPTH USING r = 0,014 in metres	PERCENTAGE ERROR	CALCULATED PEAK DEPTH USING n = 0,016 in metres	PERCENTAGE ERROR
0,0004546	0,0318	0,0307	-2,3	0,0307	-3,5
0,0009092	0,0446	0,0434	-2,7	0,0434	-2,7
0,001364	0,0519	0,0519	0	0,0529	+1,9
0,001818	0,0584	0,0608	+4,1	0,0608	+4,1
0,002273	0,0660	0,0684	+3,6	0,0694	+5,2
0,002387	0,0728	0,0698	-4,1	0,0714	-1,2

TABLE 8: COMPARISON OF THEORETICAL AND EXPERIMENTAL PEAK DEPTHS FOR A 0,229m RECTANGULAR GUTTER

CHANNEL LENGTH in metres	DISCHARGE in m^3/S	APPROXIMATE EXPERIMENTAL PEAK DEPTH in metres	THEORETICAL PEAK DEPTH in metres	PERCENTAGE ERROR
2,286	0,08665	0,4267	0,4274	+0,17
	0,07136	0,3810	0,3757	-1,41
	0,06400	0,3627	0,3497	-3,72
	0,06060	0,3383	0,3366	-0,50
	0,05239	0,3200	0,3067	-4,34
	0,04531	0,2987	0,2766	-6,70
	0,03540	0,2499	0,2366	-5,60
1,716	0,06088	0,3353	0,3371	+0,54
	0,04644	0,2987	0,2822	-5,85
	0,03936	0,2682	0,2534	-5,80
	0,02492	0,1890	0,1865	-1,34
1,335	0,07079	0,3810	0,3726	-2,26
	0,06994	0,3871	0,3689	-4,94
	0,05380	0,3353	0,3099	-8,20
	0,05295	0,3200	0,3070	-4,25
	0,04304	0,2686	0,2663	-0,62
	0,04248	0,2743	0,2650	-3,40
	0,03002	0,2103	0,2105	+0,95

The above are with n = 0,014

TABLE 9: COMPARISON OF THEORETICAL AND EXPERIMENTAL PEAK DEPTHS FOR A 0,229m RECTANGULAR GUTTER

CHANNEL LENGTH in metres	DISCHARGE in m^3/S	APPROXIMATE EXPERIMENTAL PEAK DEPTH in metres	THEORETICAL PEAK DEPTH in metres	PERCENTAGE ERROR
2,286	0,08665	0,4267	0,4284	+0,36
	0,07136	0,3810	0,3767	-1,13
	0,06400	0,3627	0,3517	-3,03
	0,06060	0,3383	0,3366	-0,505
	0,05239	0,3200	0,3077	-3,84
	0,04531	0,2987	0,2796	-6,40
	0,03540	0,2499	0,2366	-5,60
1,716	0,06088	0,3353	0,3371	+0,60
	0,04644	0,2987	0,2832	-5,18
	0,03936	0,2682	0,2534	-5,80
	0,02492	0,1890	0,1865	-1,34
1,335	0,07079	0,3810	0,3736	-1,94
	0,06994	0,3871	0,3698	-4,45
	0,05380	0,3353	0,3109	-7,27
	0,05295	0,3200	0,3080	-3,77
	0,04304	0,2682	0,2663	-0,71
	0,04248	0,2743	0,2649	-3,42
	0,03002	0,2103	0,2106	+0,14

The above are with n = 0,016

CONCLUSIONS

It has been shown that a mathematical model of a 'standard gutter' can be constructed. The gutter can be analysed by means of the Hinds equation using critical depth at outlet as the starting value.

A Manning n value of 0,016 is selected for use. This is larger than the n value applicable to smooth gutters and allows for an accumulation of rust and debris in the gutter.

It is noted that the experimental results used to test the programme apply to gutters that are not truly representative of large commercial gutters. The theoretical considerations employed are however completely general and since they approximate flow in the test gutters they should give reasonable estimates of the flow situation in any gutter.

CHAPTER 4

THEORETICAL ANALYSIS OF A NUMBER OF STANDARD GUTTERS WITH DIFFERENT SHAPES, LENGTHS AND INFLOWS

SUMMARY OF MODEL GUTTER AND PRACTICAL APPLICABILITY THEREOF

In the previous Chapter a mathematical model of a standard gutter has been developed and proof of the adequacy of the model presented. The assumptions used in constructing the model are summarised below;

(a) Uniform inflow per unit length

(b) Straight horizontal gutter

(c) Outlet at one end

(d) Peak point of the water surface profile can be found using the Hinds equation

(e) The starting depth in the Hinds equation is the depth at outlet, equal to critical depth

(f) Manning n = 0,016

Practical gutters often differ considerably from this model. They often contain central outlets, bends, slopes etc. These variations from the ideal complicate the analysis considerably, frequently rendering it intractable. In the approach adopted the 'standard gutter' model is employed to determine the peak depth in a particular gutter. Correction factors can then be applied to account for variations from the standard.

FREEBOARD ALLOWANCE

Turbulent mixing in the gutter results in an uneven water surface. In addition leaves and debris will reduce the effective cross-sectional area of flow with time. For these reasons a 'freeboard allowance' is added to the calculated peak depth to obtain the final design depth for a particular gutter.

The Building Research Station (1969) recommends that the gutter sides should rise vertically above the required depth by 75 millimetres to give the design depth. Martin (1973) maintains that a freeboard of not more than one-quarter of the required depth, with a maximum freeboard of 2,54 centimetres is adequate. Inspection of Tables 7, 8 and 9 indicates good agreement between theoretical and experimental results.

Thus it is felt that a reasonable estimate of freeboard is 15 percent of the required flow depth for rectangular and trapezoidal gutters and 10 percent of the required flow depth for smaller half-round gutters. This is fairly conservative and should compensate for differences between theoretical and experimental results as well as allow for uneveness of the water surface.

USE OF THE MODEL IN DETERMINING REQUIRED GUTTER SIZES

The model is used to analyse a large number of commercially available gutter shapes and sizes for all practical lengths and inflow rates. This provides data for the solution of most gutter design problems.

The gutter shapes analysed are trapezoidal, rectangular and half-round. The lengths considered are 3m, 5m, 10m, 15m, 20m, 25m and in certain instances, 30m. These lengths cover most practical roof lengths. The range of inflows considered varies for different gutter sizes. Larger inflows are used with larger gutters. The inflow rates applicable to practical gutters were determined as follows:

Maximum design intensity from Figures 4, 5 and 6 = 400mm/hr

Maximum practical roof breadth = 30m

Maximum inflow per unit length = $\frac{400 \times 30.10^{-3}}{3600}$ m^2/s

= 0,003 m^2/s

Minimum design intensity, say = 50 mm/hr

Minimum breadth, say = 5m

Minimum inflow per unit length = 0,00005m^2/s

This gives the range of inflows per unit length to practical gutters. Additional inflow rates between these limits were also selected. These can be seen on the printouts in Appendix C.

Whilst the programmes were running it was decided to extend the inflow rates and gutter sizes to obtain data for problems slightly beyond the terms of reference of this dissertation. In engineering practice many problems similar to gutter flow problems are encountered. Examples are effluent channels of sedimentation tanks and of similar units. These situations often have flow rates beyond the normal gutter flow rates. Thus by employing larger inflow rates and channel sizes, data are obtained for such design purposes.

Programmes were written to determine the design cross-sectional area of flow for trapezoidal and rectangular gutters. The programmes use the Hinds equation to calculate the peak depth in a particular gutter. A number of different gutter sizes were analysed and for each size, the design cross-sectional area was found for six different gutter lengths. Each length was in turn subjected to six different inflow rates. Thus thirty six results were obtained for each gutter size.

The programme CRECTI analysed rectangular gutters while TRAP analysed trapezoidal gutters.

Half-round gutters were analysed by determining the maximum discharge (flow capacity) that a given half-round gutter could cater for. The programme, HR, performed this analysis.

Details of the various programmes are given in Appendix C.

CHAPTER 5

ANALYSIS OF THE RESULTS OF THE MATHEMATICAL MODEL

The output from Chapter 4 consists of a vast number of computer printouts containing all the necessary information for gutter design. This information is however in a form not readily usable in a design manual. Thus methods of reducing this information to a more practical form were sought.

ANALYSIS OF THE RECTANGULAR GUTTER RESULTS

It was found that for a particular gutter base breadth and length, a plot of log (inf) against log (Y) gave a straight line, where inf = inflow per unit length and Y = design depth. The plots for base breadth = 0,3m are given as a typical example in graph 1. The plots for the remaining base breadths are in Appendix D. Attempts were made to reduce these 36 curves to a more usable number by mathematical manipulation.

Consider the plots for base breadth = 0,3m. These are straight lines with equations given by;

$$\log \text{inf} = m \log Y + c \quad \ldots\ldots \quad 5.1$$

$$\text{or} \quad \text{inf} = Y^m K \quad \ldots\ldots \quad 5.2$$

where inf = inflow per unit length in m^2/s

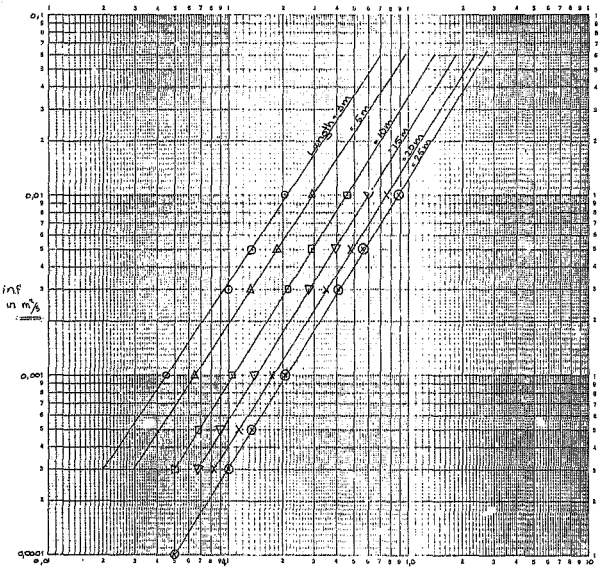
m = slope of line

Y = design depth in metres

c = constant = log K

and the slope, m, is given by $m = \frac{\log(\text{inf1}) - \log(\text{inf2})}{\log (y1) - \log (y2)}$

Graph 1: Plot of log(inf) vs log(design depth) for a rectangular gutter of base breadth = 0,3m



The above equation was used to determine the slope values for the curves shown in graph 1. The results are in Table 10.

It is seen that the slope, m, increases as the length, x, increases. The difference in slope between the curves for x = 3m and for x = 25 metres is however small. A mean value of m = 1,5414 was adopted and equation 5.2 used to determine the constant K. i.e. $K = inf/Y^{1,5414}$. Results are tabulated in Table 10.

It is seen that K decreases as length increases. It was attempted to reduce these six K values to a single value of K by inclusion of some factor of x, f(x), such that K = Constant .f(x). Various values of f(x), such as x, log x, x^n were tried with no success. Values for K = Constant/x are tabulated in Table 10.

After consideration of the form of the Martin design equation $\left(\text{viz. } f = (0,00209\ Apw^{0,5})^{0,667}\right)$ inf was plotted against $Y.b^{0,67}$ on log-log paper, where b = gutter base breadth in metres. This appeared to yield a straight line. In order to verify this, all practical results were abstracted from the data files in Appendix C and a program , YA, written to calculate $Y.b^{0,67}$. The programme and results thereof are in Appendix D.

It is seen from the output files of YA in Appendix D that for any particular gutter length and inflow, the value of $Y.b^{0,67}$ is almost constant, i.e. it is independent of the value of b. For given lengths and inflows the values of $Y.b^{0,67}$ were averaged and these results are presented in Table 11. These results were then plotted on log-log paper and resulted in the six

straight lines shown in graph 2, i.e. one straight line for each length.

Methods of dealing with the length factor were then sought. Firstly inf.x was plotted against $Y.b^{0,67}$ on log-log paper. The results are tabulated in Table 11 and plotted in graph 3. It is seen from graph 3 that the points fall within a narrow band. A conservative curve drawn through these points, as in graph 3, can result in a 20 percent overestimate of $Y.b^{0,67}$ in the lower inf.x regions, which was not considered satisfactory.

TABLE 10: DETERMINATION OF THE EQUATIONS OF THE CURVES IN GRAPH 1

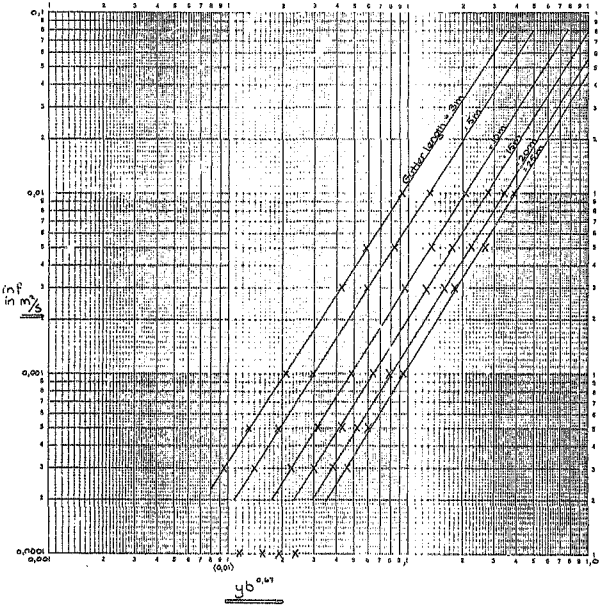
Length in metres	Slope m	K value for m = 1,5414	Constant = K.x
3	1,5048	0,11992	0,3576
5	1,5377	0,0676	0,3380
10	1,5425	0,0322	0,3220
15	1,5499	0,0208	0,3120
20	1,5583	0,01504	0,3008
25	1,5553	0,01182	0,29557

A plot of $inf.x^{n}$ versus $Y.b^{0,67}$ was then attempted. It was found, by trial and error, that n = 1,05 gave best results. Values of $inf.x^{1,05}$ and $Y.b^{0,67}$ are listed in Table 11 and plotted in graph 4. It is seen that the use of $inf.x^{1,05}$ reduces considerably the scatter of the points in graph 3. In graph 4

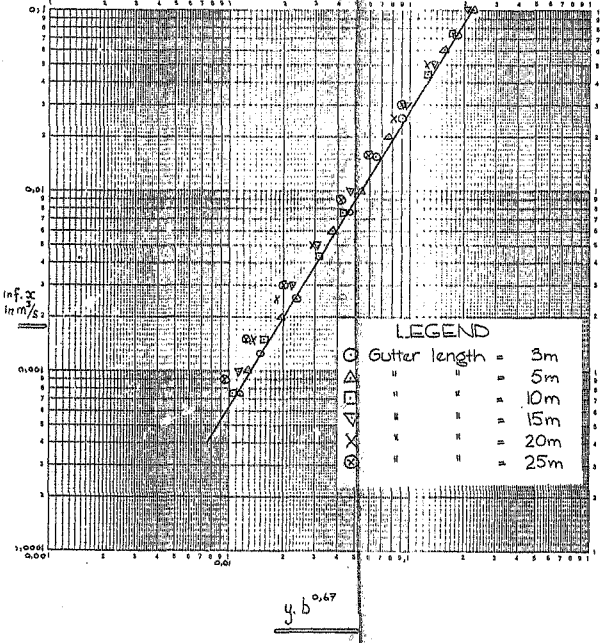
TABLE 11: CALCULATED VALUES OF $Yb^{0,67}$, inf.x and $inf.x^{1,05}$

INF in m^2/s	0,00003	0,00005	0,0001	0,0003	0,0005	0,001	0,003	0,005	0,01	0,03	0,05	LENGTH in metres
$Yb^{0,67}$ mean	,0113	,0150	,0234	,0447	,0591	,0898	,1805	,2490	,3876			25
inf.x	,00075	,00125	,0025	,0075	,0125	,025	,075	,125	,25			
$inf.x^{1,05}$	,000381	,00347	,002937	,00381	,01468	,02937	,0881	,1468	,2936			
$Yb^{0,67}$ mean	,0094	,0127	,0193	,0376	,0517	,0775	,1543	,2140	,3333			20
inf.x	,0006	,001	,002	,006	,01	,02	,06	,1	,2			
$inf.x^{1,05}$	,000697	,001162	,002323	,006969	,01162	,02323	,06969	,11616	,2323			
$Yb^{0,67}$ mean		,0103	,0154	,0305	,0415	,0627	,1262	,1747	,2721			15
inf.x		,00075	,0015	,0045	,0075	,015	,045	,075	,15			
$inf.x^{1,05}$		,0008587	,001717	,005152	,008587	,01717	,05152	,08587	1717			
$Yb^{0,67}$ mean			,0112	,0226	,0309	,0475	,0956	,1329	,3071			10
inf.x			,001	,003	,005	,01	,03	,05	,1			
$inf.x^{1,05}$			,001122	,003366	,00561	,01122	,03366	,0561	,1122			
$Yb^{0,67}$ mean				,0136	,0187	,0290	,0593	,082	,1290			5
inf.x				,0015	,0025	,005	,015	,025	,05			
$inf.x^{1,05}$				,001626	,002709	,005419	,01626	,02709	,05419			
$Yb^{0,67}$ mean				,0094	,0129	,0206	,0417	,0581	,0916		,2642	3
inf.x				,0009	,0015	,003	,009	,015	,03		,15	
$inf.x^{1,05}$				,00095	,001585	,003169	,0095	,01585	,03169		,1585	

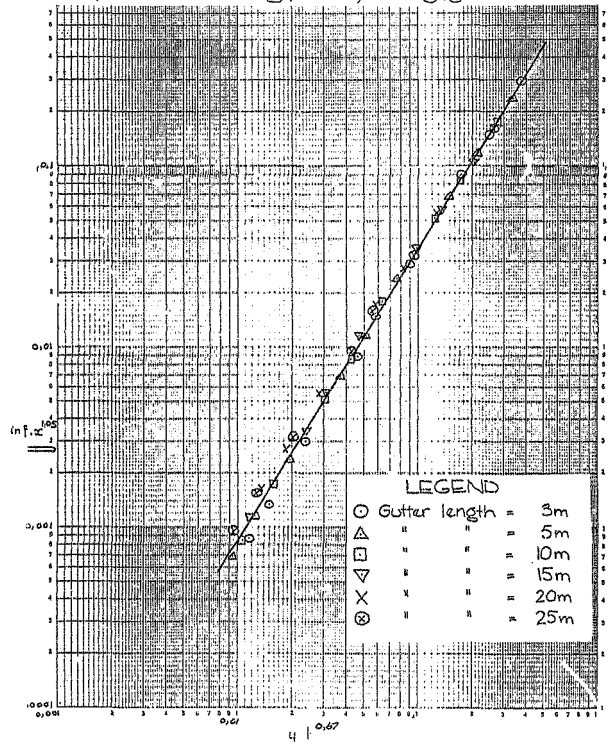
Graph 2: Plot of log(inf) vs log(y·b^0,67)



Graph 3: Plot of log(inf.x) vs. log(y.b^{0,67})



Graph 4: Plot of $\log(\text{inf.}\, x^{1,05})$ vs. $\log(y \cdot b^{0,67})$



the scatter in the higher regions is almost negligible whilst there is only a slight scatter in the lower inf.x regions.

A curve drawn through these points can therefore be used with considerable confidence as a design curve for rectangular gutters. To determine which straight line through the plotted points would be adopted as the design curve the following factors were taken into account;

1) The 'best-fit' curve would be non-conservative in the upper inf.x region.

2) The 'maximum-envelope' curve would be non-conservative if extrapolated above the plotted points.

3) A line drawn through the upper inf.x points could possibly be extrapolated to increase the range of the plot.

The curve chosen as the design curve is as shown in graph 4. It is seen that in the upper inf.x region the points all lie on the line, while in the lower regions an error of about +10 percent to -5 percent may occur.

The equation of this line has the form

$$\log \left(\text{inf.}x^{1,05}\right) = m \log \left(Y.b^{0,67}\right) + C$$

or $$\text{inf.}x^{1,05} = \left(Y.b^{0,67}\right)^{m}.K$$

where $K = \log C$

The values of m and K are determined in Appendix D

and are $m = 1,614$

$K = 1,4294$

Thus the equation of the curve is;

$$\text{inf.}x^{1,05} = 1,4294 \left(Y.b^{0,67}\right)^{1,614} \quad \ldots\ldots \quad 5.3$$

or written in a form from which the design depth can readily be determined;

$$Y = \left(\frac{\text{inf.}x^{1,05}}{1,4294}\right)^{0,620} \frac{1}{b^{0,67}} \quad \ldots\ldots \quad 5.4$$

To check the validity of this equation, a number of values of design depth were abstracted at random from the output files of CRECTI and checked against values obtained using the above equation. The results are in Table 12.

It is seen that use of the above equation results in excellent agreement with computed design depths. The cases where the percentage error is rather large, viz. +7,0 percent and +10,2 percent fall in the lower $\text{inf.}x^{1,05}$ region where the scatter of points was greatest. However in both instances a conservative result is obtained.

It was felt that the general accuracy of the whole approach to the gutter design problem might warrant the use of the curve shown in graph 3 as a design curve, i.e. the plot of inf.x against $Y.b^{0,67}$. To check this hypothesis the equation of the line in graph 3 was determined in Appendix D. The result was

$$\text{inf.}x = 1,1854 \left(Y.b^{0,67}\right)^{1,625} \quad \ldots\ldots \quad 5.5$$

This validity of this equation was checked by comparing the actual value of inf.x with the value of inf.x as given by the above equation for a particular value of $Y.b^{0,67}$. The results are given in Table 13.

TABLE 12: COMPARISON OF THE RESULTS OF PROPOSED DESIGN EQUATION AND OF CRECT 1

b in metres	inf in m^2/S	x in metres	Y from output files in metres	Y as calculated in metres	% error
0,6	0,05	3	0,37189	0,3604	-3,1
0,6	0,01	20	0,47101	0,4567	-3,0
0,6	0,003	25	0,2539	0,2505	-1,3
0,5	0,003	15	0,20104	0,2030	+1,0
0,5	0,001	25	0,14306	0,1433	+0,2
0,4	0,005	3	0,10518	0,1135	+7,0
0,4	0,001	15	0,11538	0,1194	+3,5
0,3	0,05	3	0,59142	0,5734	-3,0
0,3	0,01	10	0,46526	0,4630	-0,5
0,3	0,005	25	0,56189	0,5469	-2,6
0,3	0,01	5	0,2914	0,2949	+1,2
0,2	0,003	10	0,28101	0,2881	+2,3
0,2	0,0003	20	0,1082	0,1086	+0,4
0,2	0,0005	25	0,1754	0,1723	-1,7
0,1	0,0005	5	0,08733	0,0962	+10,2
0,1	0,005	3	0,2741	0,2874	+4,5

where Y is calculated using the expression;

$$Y = \left(\frac{inf.x^{1,05}}{1,4294} \right)^{0,62} \frac{1}{b^{0,67}}$$

TABLE 13: COMPARISON OF inf.x (GIVEN) WITH inf.x (CALCULATED)

inf.x given	γ_b 0,67	inf.x calculated
0,1	0,218	0,10038
0,07	0,175	0,07018
0,04	0,125	0,04056
0,02	0,081	0,02009
0,01	0,0532	0,01008
0,003	0,0252	0,02986
0,001	0,0128	0,00099
0,0007	0,0103	0,000695

It is seen that near perfect agreement is obtained. It is however felt that, since graph 4 has a smaller scatter of points than graph 3, the use of equations 5.3 and 5.4 is more desirable.

CONCLUSIONS

The design equation for rectangular gutters over the range $0,0007 < \text{inf.}x^{1,05} < 0,3$ is given by;

$$Q = 1,4294\,(Y.b^{0,67})\,1,614\,/\,x^{0,05}$$

$$\text{or} \quad Y = \left(\frac{Q.x^{0,05}}{1,4294}\right)^{0,62} \frac{1}{b^{0,67}}$$

where Q is the flow rate in m^3/s for which the gutter must cater.

The method used to obtain the above design equation is purely empirical and thus the equation should not be applied outside of the range of $\text{inf.}x^{1,05}$ values stipulated. It is felt that there may be good theoretical reasons to account for the manner in which the large number of results in Appendix C reduce to a single design curve. Such an investigation is however beyond the scope of this dissertation.

ANALYSIS OF TRAPEZOIDAL GUTTER RESULTS

The analysis of the results of the trapezoidal gutter programme, TRAP, proceeded as follows;

The variables involved are (i) inflow per unit length, inf (ii) length, x (iii) base breadth, b (iv) side slope, dag (v) design cross-sectional area, A.

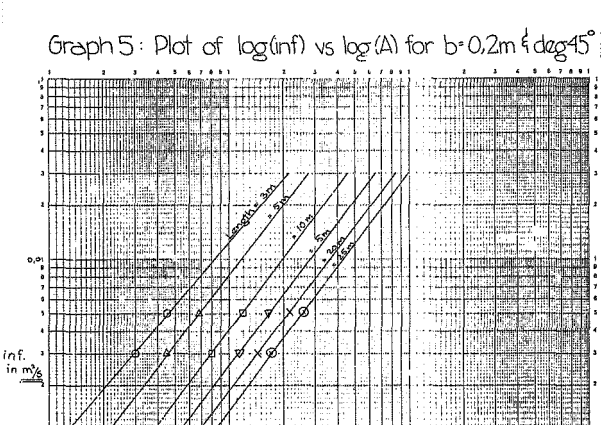
Consider the results for b = 0,2m and side slopes of 45° and 60°. A plot of log (inf) against log (A) results in a straight line for each length as seen in graphs 5 and 6.

Consider the plots for b = 0,3m and x = 10m as seen in graph 7. It is seen that the curves for different side slopes diverge as the inflow increases. It is desired to eliminate this side slope effect. It was attempted to do this by plotting inf against A.f (deg.) where deg = side slope in radians as measured from the horizontal. Values of f(deg) tried were $deg^{0,4}$, $deg^{0,2}$, $deg^{0,3}$ and $deg^{0,25}$. It was found that $deg^{0,25}$ gave best results and the results for b = 0,3 and x = 10m are tabulated in Table 14. The results of $Adeg^{0,25}$ for the three different deg values are averaged and this mean value is used in the plot of inf against $Adeg^{0,25}$ seen in graph 8. This results in a straight line.

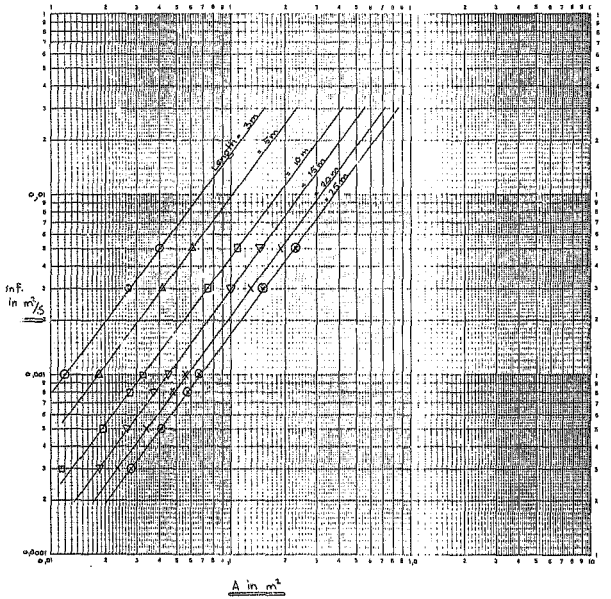
To further reduce these curves a plot of inf against $(Adeg^{0,25})^{0,67}$ was tried on log-log paper as for rectangular gutters. This was however to no avail. It was discovered that to obtain a straight line $Adeg^{0,25}$ must be divided by some function of b. Trial and error led to the conclusion that $b^{0,09}$ gave the best result.

Values of $Adeg^{0,25}/b^{0,09}$ were calculated from the data in the output files for gutters of base breadth = 0,2, 0,3, 0,4 and 0,5m. These calculated values are listed in Appendix D. For a given base breadth, inflow and length, the mean values of

Graph 5: Plot of log(inf) vs log(A) for b=0,2m & deg45°



Graph 6 : Plot of log(inf) vs. log(A) for b=0,2m & deg 60°



Graph 7: Plot of log(inf) vs. log(area) for trapezoida gutters of b.= 0,3m and length = 10m

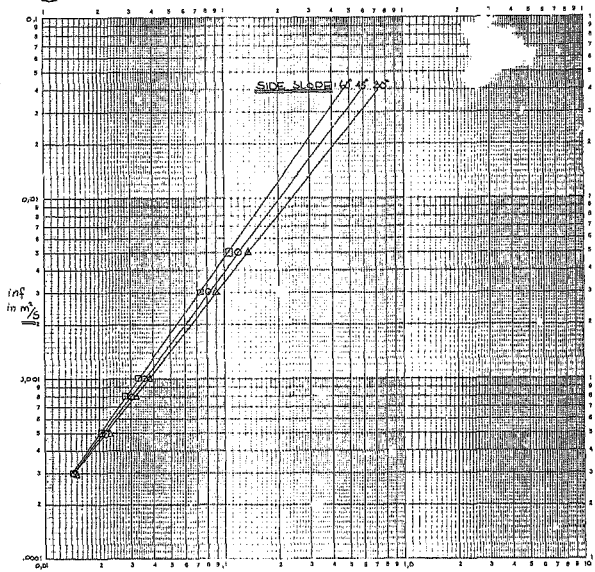


TABLE 14: VALUES OF inf AND $Adeg^{0,25}$ FOR b = 0,3m and x = 10m

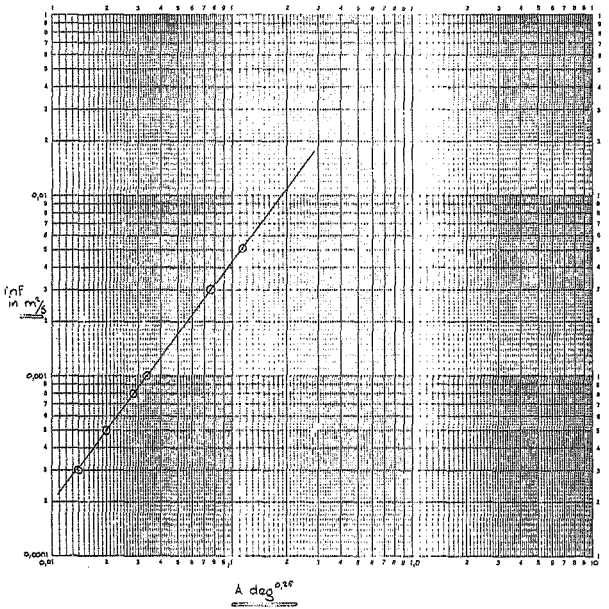
b = 0,3m

x = 10m

inf m^2/S	$Adeg^{0,25}$ for deg=0,5236	$Adeg^{0,25}$ for deg=0,7854	$Adeg^{0,25}$ for deg=1,0472	mean value of $Adeg^{0,25}$
0,0003	0,02703	0,02910	0,02935	0,02849
0.0005	0,02013	0,02091	0,02075	0,02060
0,0003	0,01393	0,01411	0,01516	0,01440
0,001	0,03239	0,03291	0,03477	0,03336
0,003	0,07532	0,07619	0,07663	0,07605
0,005	0,11298	0,11225	0,10938	0,11154

where deg is in radians

Graph 8 : Plot of log(inf) vs log($A\,deg^{0,25}$) for length=10m



$Adeg^{0,25}/b^{0,09}$ for the three different side slopes were calculated. These means are shown in Appendix D, as well as the calculated values of inf.x. All the values of the mean $Adeg^{0,25}/b^{0,09}$ value were abstracted from Appendix D, as well as the inf.x values. These are shown in Table 15. The mean of the $Adeg^{0,25}/b^{0.09}$ values was then calculated for different inf.x values as seen in Table 15. Inf. x was then plotted against these final mean values of $Adeg^{0,25}/b^{0,09}$ on log-log paper in graph 9.

A line through these points can be used as a design curve for trapezoidal gutters. Considering the factors outlined in the rectangular gutter result analysis, a straight line was drawn through these points. This line is then the design curve.

The equation of this curve is determined in Appendix D and is given by;

$$\text{inf.x} = 0,6969 \left(\frac{Adeg^{0,25}}{b^{0,09}} \right)^{1,338} \quad \ldots\ldots \quad 5.6$$

or rewritten in another form

$$A = \left(\frac{\text{inf.x}}{0,6969} \right)^{0,7474} \cdot \frac{b^{0,09}}{deg^{0,25}} \quad \ldots\ldots \quad 5.7$$

The validity of this equation, 5.7, was checked by randomly abstracting values of design area from the trapezoidal gutter output files. The values of the design area were then calculated using equation 5.7 and compared with the abstracted values. Results are in Table 16.

It is seen that reasonable agreement between the two values is obtained. The maximum error is about +10 percent,

TABLE 15: VALUES OF inf.x AND MEAN $Adeg^{0,25}/b^{0,09}$ FOR TRAPEZOIDAL GUTTERS

Inf.x in m³/s	VALUES OF MEAN $Adeg^{0,25}/b^{0,09}$ FOR				TOTAL MEAN
	b=0,2m	b=0,3m	b=0,4m	b=0,5m	
0,0025			0,01335		0,01335
0,003	0,01543	,01605			0,01479
	0,01365	,01402			
0,0045	0,02147	0,02237			0,02192
0,005	0,02245	0,02292	0,02339	0,02286	0,0228
	0,02132	0,02117	0,02102		
0,006	0,02740	0,02811			0,02777
	0,03369	0,03394			
0,008	0,03152	0,03175			0,03164
0,009	0,03933	0,04003			0,03999
	0,03197	0,04361			
0,01	0,03982	0,04038	0,04120	0,03929	0,03909
	0,03723	0,03718	0,03851		
0,0105	0,04485	0,04476			0,0448
0,012	0,0444	0,04431			0,04557
		0,04800			
0,0125	0,04822		0,04942		0,04882
0,015	0,05511	0,05626	0,05720	0,0500	0,05200
	0,04880	0,0490	0,05294	0,05417	
	0,04853	0,04980			
	0,05248	0,05230			
0,016	0,05635	0,05595			0,05615
0,,175	0,06715	0,06380			0,06507
	0,06426				
0,02	0,06580	0,06568	0,06559	0,06742	0,06612
0,0208		0,06758			0,06758
0,024	0,07976	0,07790			0,07883
0,025	0,07307	0,07174	0,07851	0,07274	0,07623
	0,08079	0,07897	0,07215	0,08084	
0,028	0,08975	0,08990			0,09028
0,03	0,08592	0,08401	0,09170	0,08547	0,08806
				0,09322	
0,045	0,1203	0,1171		0,1177	0,1164
0,05	0,1283	0,1241	0,1237	0,1244	0,1240
			0,1214	0,1219	
0,06	0,1532	0,1492		0,1467	0,1497
0,075	0,1779	0,1737	0,1694	0,1713	0,1754
	0,1827	0,1786		0,1745	
0,09				0,2030	0,2030
0,10	0,2277	0,2194	0,2141	0,2142	0,2139
			0,2087	0,2094	
				0,2038	
0,125	0,2731	0,2607	0,2576	0,2566	0,2620
0,150			0,2984	0,2958	0,2919
			0,2881	0,2852	
0,20			0,3618	0,3601	0,3625
0,25			0,4376	0,4308	0,4356
			0,4201	0,4136	
0,36			0,5077	0,4992	0,5035
0,50			0,7150	0,7209	0,7258
			0,7304	0,7167	
0,75			1,013	0,9987	1,006
1,0				1,215	1,235

Graph 9: Plot of log(infx) vs log($A\,deg^{0,25}/b^{0,09}$)

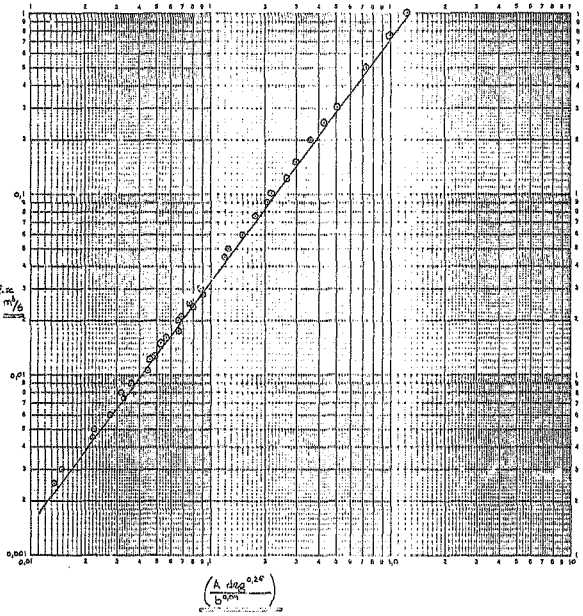


TABLE 16: COMPARISON OF RESULTS OF TRAP AND PROPOSED DESIGN EQUATIONS

BASE BREADTH b in metres	deg in degrees	inf m^3/s in m^3/s	x in metres	DESIGN AREA FROM TRAP RESULTS in m^2	DESIGN AREA AS CALCULATED BY EQUATION in m^2	% ERROR
0,2	30	0,0008	30	0,0824	0,08203	[illegible],5
	45	0,001	15	0,1121	0,11856	[illegible]
	60	0,001	10	0,0323	0,03585	+1[illegible]
0,25	30	0,005	10	0,1[illegible]5[illegible]	0,1322	+1[illegible]
	60	0,0005	30	0,04989	0,04957	-0,7
0,30	30	0,0008	35	0,0[illegible]66	0,09546	+[illegible],3
	45	0,005	15	0,1[illegible]62	0,16014	+8,1
	60	0,001	10	0,07547	0,08452	+8,9
0,35	60	0,001	30	0,0[illegible]308	0,0657	+4,4
0,40	30	0,05	10	0,8[illegible]15	0,8446	+4,1
	45	0,001	25	0,07962	0,0813	+2,2
	60	0,05	15	0,90396	0,96164	+6,4
0,45	30	0,001	30	0,09986	0,10425	+5,5
	30	0,1	5	0,81041	0,8536	+5,3
	45	0,05	10	0,72161	0,7713	+6,7
	60	0,01	15	0,26161	0,29188	+11,6
0,50	30	0,005	30	0,3319	0,3504	+5,6
	45	0,01	20	0,36127	0,3926	+8,7
	60	0,05	15	0,90466	0,9811	+10,8

Where the design area is calculated using the expression:

$$A = \left(\frac{\inf x}{0,6969}\right)^{0,7474} \frac{10,09}{\deg^{0,25}}$$

which, considering the large number of variables involved is adequate. In addition the errors tend to be on the conservative side. Thus equations 5.6 or 5.7 can safely be used as design equations for trapezoidal gutters.

To check whether the trapezoidal gutter design equation holds for rectangular gutters, values of design area were randomly abstracted from the rectangular gutter output files. The values of the design area were then calculated by means of equation 5.7 with the side-slope, deg = 1,5708 (90°). The results are listed in Table 17 and comparison of those results with those in Table 12 reveals that the results of trapezoidal gutter design equation with deg = 1,5708 radians are in good agreement with the results of the rectangular gutter design equation.

The problem then arose as to whether to employ both equations in the gutter design manual or whether to employ only the trapezoidal gutter design equation and apply it to both rectangular and trapezoidal gutters. To resolve this problem the equations were compared;

Rectangular gutter equation:

$$Y = \left(\frac{\text{inf.x}^{1,05}}{1,4294}\right)^{0,620} \frac{1}{b^{0,67}} \quad \ldots\ldots \quad 5.4$$

Trapezoidal gutter equation for gutters with side slope, deg = 1,5708 radians

$$A = \left(\frac{\text{inf.x}}{0,6969}\right)^{0,7474} \frac{b^{0,09}}{(1,5708)^{0,25}} \quad \ldots\ldots \quad 5.7$$

or rewritten in another form

$$Y = \frac{(\text{inf.x})^{0,7474}}{0,85469} \frac{1}{b^{0,91}} \quad \ldots\ldots \quad 5.8$$

TABLE 17. COMPARISON OF RESULTS OF RECTANGULAR GUTTER PROGRAMME AND RESULTS OF PROPOSED DESIGN EQUATION FOR TRAPEZOIDAL GUTTERS

BASE BREADTH b in metres	deg in degrees	inf in m^2/s	x in metres	DESIGN AREA FROM CRECTI RESULTS in m^2	DESIGN AREA AS CALCULATED BY EQUATION in m^2	% ERROR
0,6	90	0,05	3	0,22313	0,2162	-3,2
0,6	90	0,01	20	0,2826	0,2740	-3,0
0,5	90	0,003	15	0,1269	0.1252	-1,3
0,5	90	0,001	25	0,07153	0,07165	+1,7
0,4	90	0.005	3	0,04347	0,04542	+6,9
0,4	90	0,001	19	0,04615	0,04774	+3,4
0,3	90	0,05	3	0,17743	0,17202	-3,0
0,3	90	0,005	25	0,16856	0,16407	-2,1
0,2	90	0,003	10	0,05632	0,05762	+2,3
0,2	90	0,0005	25	0,03509	0,03446	-1,8
0,1	90	0,005	3	0,02739	0,02879	+5,1

where the design area is calculated using the expression;

$$A = \left(\frac{inf.x}{0,6969}\right)^{0,7474} \cdot \frac{b^{0,69}}{(1,5708)^{0,25}}$$

Comparisons of equations 5.4 and 5.8 reveals that the form of the equations is similar. Equation 5.4, however, contains a power of the length x, ($x^{1,05}$) while equation 5.8 does not. It was pointed out in an earlier section that the use of a power of x in the lower inf.x regions reduces the scatter of the points. Thus it is felt that greater accuracy will be achieved in the lower inf.x regions if equation 5.4 is used for rectangular gutters, while equation 5.7 is used only for trapezoidal gutters.

CONCLUSIONS

The design equation for trapezoidal gutters over the range $0,003 < \text{inf.x} < 1,0$ is given by;

$$Q = 0,6969 \left(\frac{A^{0,25}_{deg}}{b^{0,09}} \right)^{1,338}$$

or $$A = \left(\frac{Q}{0,6969} \right)^{0,7474} \cdot \frac{b^{0,09}}{deg^{0,25}}$$

Again it should be noted that these are empirical equations and are valid only over the specified range.

ANALYSIS OF HALF-ROUND GUTTER RESULTS

The outputs of programme HR, that calculates the flow capacity of a gutter of given size and length, are in Appendix C.

The Building Research Station (1969) has presented a formula for deriving the flow capacity of eaves gutters. This formula can be written in the form

$$Qmax = 0,8433 \ A^{1,25}$$

where Qmax is the flow capacity of the gutter in m^3/S and A is

the cross-sectional area of gutter in m^2.

This equation assumes that the flow capacity of a given gutter size is independent of gutter length. Inspection of equation 5.4 for rectangular gutters reveals that this may not be true. It was decided to determine the effect of length on the flow capacity and if necessary to modify the Building Research Station formula to account for length.

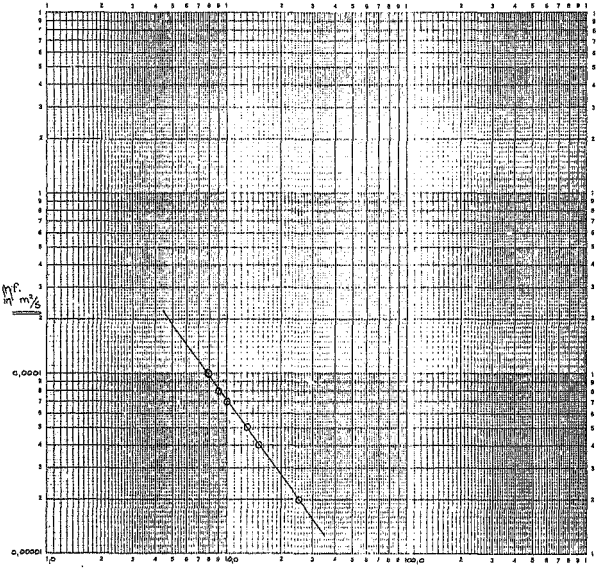
The results of programme HR for a true half-round gutter of diameter equal to 0,1016 metres are shown in Table 18. The values of inf(max) are plotted against x on log-log paper in graph 10 where inf(max) equals the inflow per unit length capacity, Qmax/x, and x is the gutter length in metres. This results in a straight line of slope m = 1,40. Hence for this particular gutter $inf(max) = Kx^{1,40}$.

This equation suggests that the Building Research Station formula might be modified by including a factor x^n in the formula, i.e. $inf(max) . x^n = 0,8433 . A^{1,25}$

An obvious estimate of x^n is $x^{1,40}$ and values of $inf(max) = 0,8433.A^{1,25}/x^{1,40}$ are tabulated in Table 18. It is seen that this overestimates the given values of inf(max).

Another estimate of n was obtained from the Building Research Station results. It is thought, though not yet confirmed, that the Building Research Station formula was based on tests performed on 6,096m (20 ft.) long gutters. Their results for various gutters sizes are tabulated in Table 19 and

Graph 10: Plot of log(inf) vs log(x) for half-round gutters of ϕ = 0,1016 m



assuming that x = 6,096m, the value of n can be found from the relationship;

$$n = \log_{6,096}\left(\frac{0,8433.A^{1,25}}{\inf(max)}\right)$$

Calculated values of n are tabulated in Table 19 (an indication that the length of the test gutters used by the Building Research Station was 6,096m can be obtained by extrapolating backwards the curve in graph 10. The value of inf(max) for a gutter diameter of 0,1016m and length of 6,096m is then obstracted and equals 0,000145 m^2/S. This approximately equals the value given by the Building Research Station in Table 19.)

It is seen that n is almost a constant value and the mean value is 1,47. Using this value of n the inflow rates for the gutter of diameter equal to 0,1016m are calculated using the relationship;

$$\inf(max) = \frac{0,8433\ A^{1,25}}{x^{1,47}}$$

The calculated values are compared with the computed values in Table 18. It is seen that good agreement is obtained between the results.

This equation is now checked against the Building Research Station data in Table 19. Results are listed in Table 19. Excellent agreement is obtained.

TABLE 18: RESULTS OF HR AND COMPARISON WITH RESULTS OF MODIFIED B.R.S. FORMULA

Gutter diameter = 0,1016metres

Cross-sectional area = 0,0081m^2

Length in metres	RESULTS OF HR		RESULTS OF MODIFIED B.R.S.	
	inf(max) in m^2/S	inf(max).x in m^3/S	$\frac{0,8433A^{1,25}}{x^{1,4}}$	$\frac{0,8433A^{1,25}}{x^{1,47}}$
8	0,0001	0,0008	0,000111	0,000096
9	0,00008	0,00072	0,000095	0,000081
10	0,00007	0,0007	0,000092	0,00009
13	0,00005	0,00065	0,000057	0,000047
15	0,00004	0,0006	0,000046	0,000038
25	0,00002	0,0005	0,000023	0,000018

TABLE 19: B.R.S. RESULTS AND COMPARISON WITH RESULTS OF MODIFIED B.R.S. FORMULA

Nominal gutter diam in metres	B.R.S. RESULTS		MODIFIED B.R.S. RESULTS	
	Flow capacity in m^3/S	inf(max)in m^2/S	n	$\frac{0,8433A^{1,25}}{x^{1,47}}$ in m^2/S
0,075	0,00042	0,000069	1,46	0,000067
0,100	0,00083	0,000136	1,43	0,000138
0,1125	0,00113	0,000185	1,47	0,000186
0,1250	0,00150	0,000246	1,465	0,000242
0,1500	0,00233	0,000382	1,467	0,000382

As a final check on the validity of the equation, the Marsh (1968) result for a gutter of diameter equal to 0,1524m (6") and length equal to 6,096m (20') is compared with the result computed using the above formula. Results as shown below.

GUTTER DIAMETER = 0,1524m

GUTTER LENGTH = 6,096m

inf(max)as found experimentally by Marsh = $0,000397 m^2/S$

$$inf(max) = \frac{0,8433A^{1,25}}{6,096^{1,47}} = 0,00041 m^2/S$$

percent error = +3,2 percent

Good agreement is obtained between theoretical and experimental results. Thus it is felt that the Building Research Station equation for half-round gutters should be altered to the following form to cater for the length factor;

$$inf(max). x^{1,47} = 0,8433A^{1,25}$$

or in terms of the discharge capacity

$$Qmax = \frac{0,8433A^{1,25}}{x^{0,47}}$$

where Qmax is in m^3/s,

A is in m^2 and x is in metres.

CHAPTER 6

REVIEW OF EXISTING METHODS OF GUTTER DESIGN AND COMPARISON WITH RESULTS OF PREVIOUS CHAPTER

At present numerous methods of gutter design are employed in South Africa. These methods are generally based on rule of thumb techniques derived from past experience. An example of such a method is that presented in the Standard Building Regulations, 1970; *'The size of a rainwater gutter shall be calculated on the basis of 7cm^2 of cross-sectional area for every 5m^2 of roof area served by such gutter. The size of rainwater downpipe shall be calculated on the basis of 7cm^2 of cross-sectional area for every 7m^2 of roof area served by such downpipes.'*

Such methods are not based on sound theoretical principles and take no account of the many variables involved in gutter design.

The Building Research Station (1958 and 1969) has produced a manual that attempts to take into account the variables involved and to rationalise gutter design. A summary of the relevant sections of B.R.S. Digest 107 (1969) is given below.

SUMMARY OF BUILDING RESEARCH STATION METHOD OF GUTTER DESIGN

PART 1 - TO DETERMINE THE SIZES OF EAVES GUTTERS AND DOWNPIPES AND SMALL VALLEY GUTTERS

Eaves Gutters

Calculate the flow load according to the pitch of the roof.

(i) For roof pitches up to 50°, the angle of pitch is ignored.

(ii) For pitches over 50°, the flow load is calculated using the plan area of the roof.

Flow Capacity (litres/minute) of level gutters, outlet at one end.

Nominal Gutter size in millimetres	Flow capacity of true half-round gutters in litres/min	in m^3/s
75	25	0,00042
100	50	0,00083
112,5	68	0,00113
125	90	0,00150
150	140	0,00233

The above table gives the flow capacity of true-half round gutters, fitted level and with outlet at one end as calculated from $Q = 0,0016A^{1,25}$ where A is in mm^2 and Q is in l/min. This formula may also be used to calculate the flow capacity of nominal half-round, segmental, ogee and other similar gutter sections.

These flow capacities can be adjusted for:

falls not less than 1/600 +40%

bends within 2m of an outlet,

on level gutters, sharp cornered bend -20%

round cornered bend -10%

on sloping gutters -25%

bends within 2-4m of an outlet, half the above figures

length, sloping gutters up to 6m long -10%

Downpipe sizes for level and sloping gutters

HR nominal gutter size	Sharp-(SC) or round-cornered (RC) outlet	Outlet at end of gutter	Outlet not at end of gutter
75	SC	50	50
	RC	50	50
100	SC	62,5	62,5
	RC	50	[illegible]
112,5	SC	62,5	75
	RC	50	62,5
125	SC	75	87,5
	RC	62,5	75
150	SC	87,5	100
	RC	75	100

Downpipe sizes appropriate to stated gutter sizes are listed in the Table above.

Rectangular and box gutters

The above method for determining the size of eaves gutters is valid for rectangular and box gutters in which the ratio of width/depth is about 2:1.

PART 2 - TO DETERMINE THE SIZES OF LARGE VALLEY GUTTERS, OUTLETS OF RECEIVERS AND RAINWATER PIPES

Shape of Gutter

The width of sole should be not less than 300 millimetres to facilitate maintenance. The sides of the gutter should rise 75 millimetres vertically above the required height to provide a freeboard allowance.

Flow Capacity for free discharge

Gutters should be provided with outlets designed to accept the flow from gutters without increasing the flow depth in the gutter.

In a gutter discharging freely, the flow capacity is given by:

$$Q = 0{,}0058 \sqrt{\frac{A^3}{B}} \qquad \ldots\ldots \qquad 6.1$$

where Q = flow capacity in litres/minute

A = area of flow at outlet in mm^2

B = width of water surface at outlet in millimetres

It is assumed that the depth of flow at outlet, Ho, is half the peak flow depth at the far end, D.

Box-type receiver

Whenever possible the gutter should discharge into a box-type receiver, the depth of which can be chosen so as to permit the use of a rainwater pipe of convenient size.

The receiver should be at least as wide as the maximum gutter width and it should be long enough to prevent the flow from the gutter over-shooting the box. A suitable shape for an external box-type receiver is shown in Figure 9 in which the recommended depth of the side is Hd + 2/3 Hd where Hd is the depth of water at the inlet to the rainwater pipe required to give the necessary discharge capacity. The length of the box Lb is given by $Lb = 2\sqrt{FHo}$ where F is the fall between water surfaces and Ho is the depth of flow at the gutter outlet.

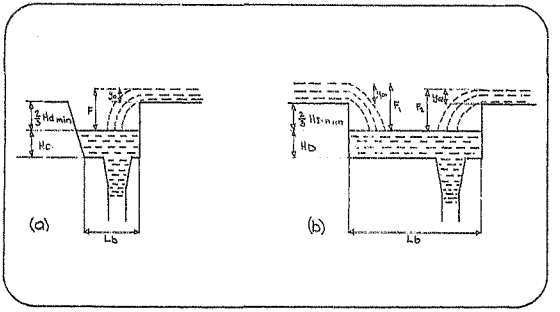


Fig 9: Dimensions of box-type receivers
(a): External length, $L_b = 2\sqrt{F y_a}$
(b): Internal length, $L_b = 2\sqrt{F_1 y_{a1}} + 2\sqrt{F_2 y_{a2}}$

Where the box is situated part way along a length of roof, a separate value Lb should be calculated for each gutter length draining into it and the two lengths added to give the total length of the box.

Rainwater pipes

Where the gutter discharges directly into a rainwater pipe, the rainwater pipe inlet, should be designed to allow free discharge from the gutter. The discharge capacity of the rainwater pipe inlet depends on the diameter of the inlet, the depth of water (head) over the inlet and on whether the water swirls about the inlet.

Swirl can be neglected if the inlet is at a distance less than its diameter from the nearest vertical side of the gutter or box. In this case the inlet acts as a weir for a head of flow H up to d/3 for which range

$$Q = 0{,}0116\ dH\sqrt{H} \qquad \ldots\ldots \qquad 6.2$$

where Q = discharge capacity of inlet in litres/minute

d = diameter of inlet in millimetres

H = head of water over inlet in millimetres

Where H is greater than d/3 the inlet acts as an orifice and

$$Q = 0{,}0039d^2\sqrt{H} \qquad \ldots\ldots \qquad 6.3$$

Swirl will occur if the inlet is at a distance greater than its diameter from the nearest vertical side. In this instance the weir discharge is unchanged but the orifice discharge is reduced by swirl to

$$Q = 0,0029d^2\sqrt{H} \quad \ldots\ldots \quad 6.4$$

When sizing the inlet to a rainwater pipe leading directly from the gutter, the head H should be taken as the depth of flow at the gutter outlet, Ho, calculated when determining the gutter capacity.

The diameter of the rainpipe can be reduced to two-thirds of the effective inlet diameter provided that the transition is made over a length of not less than the diameter of the inlet.

A second method of gutter design was proposed by Martin (1973) for Australian conditions. This method is based on the Building Research Station results and is essentially the same as the BRS method. Several improvements were however presented and these are summarized below.

SUMMARY OF RELEVANT PORTIONS OF MARTIN METHOD OF GUTTER DESIGN

THE CATCHMENT AREA

Wind influences the effective catchment area by altering the direction of the rainfall. It is argued from simply geometry that a sloping roof must intercept more wind-driven rain descending at an angle from the normal. However limited data exists upon which an estimate of such a 'wind factor' can be based.

In saw-tooth type of construction, rain will be directed onto the vertical roof portions, increasing the effective catchment area. Thus in cases of high wind a percentage of the vertical surface might be exposed to rainfall and this area must be added

to the adjacent sloping roof area in determining the effective catchment area.

High rise buildings, however, affect the intensity of rainfall during windy periods. The buildings will obstruct the flow of air and the resulting pattern of air movement will cause raindrop trajectories to diverge over the obstruction and converge on the leeward side as seen in Figure 10. Thus roofs of high buildings may be expected to receive lower intensities of rainfall than are recorded on open ground. The same would apply to roofs on adjacent buildings, but lower buildings at some distance on the leeward side might experience higher intensities.

However until further research has been performed on the effect of wind, no fixed rules can be stated. It appears that, for the present, the designer should increase the plan area of the roof to account for wind effects. This factor must be based on subjective knowledge of the wind conditions at the site. In extreme conditions, the total roof area may be taken as the catchment area.

Hail is not taken into account in the rainfall intensity data. It is generally agreed that runoff from hail and snow is lower than from rain and the major problem is due to the likelihood of blockage of drainage channels and downpipes. Downpipes may be protected by wire mesh guards.

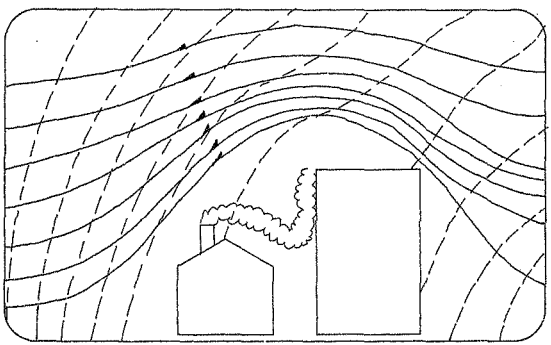


Fig 10 : Air flow over buildings and probable trajectories for raindrops of one size (broken lines) (After Martin 1973)

Eaves gutters fitted with downpipe

Martin uses an imperial unit equivalent of the BRS formula for eaves gutters to determine the flow capacity of eaves gutters.

$$Q = a^{1,25} (1 + x)$$

where Q is in gallons/minute

a is in in^2

x is a gutter design coefficient depending upon slopes, bends etc. These x values are similar to the BRS reduction factors.

Since potential damage from failure of external eaves gutters is not likely to be great, their design can be based on low recurrence intervals of rainfall intensity (say 10 years).

The optimum size of vertical downpipes to serve such gutters is given by the rule that the cross-sectional area of downpipe needs to be half the cross-sectional area of gutter. This method has worked satisfactorily in Australia for 7 years.

Valley and box gutters with free discharge to receiver and downpipe

These usually have a minimum width of 300 millimetres to facilitate maintenance. For the horizontal case with open end, the flow capacity of the gutter is given by

$$Q = 4,167 (f^3/w)^{0,5}$$

where f is the cross-sectional area of flow at outlet in in^2

W is the width of flow of the water surface at the outlet in inches.

Q is the flow capacity in gallons/minute

This is the imperial unit equivalent of the BRS formula for valley gutters.

The influence of slope has been studied empirically by Martin and Tilley (1968) and the following relationship found for both box trapezoidal and vee gutters:

Up to 1° slope the square of the discharge capacity is directly proportional to the sine of the angle of slope.

For slopes from 1° to 20° the reciprocal of the maximum depth of flow is directly proportional to the square root of the sine of the angle of slope. Figure 11 illustrates the results in terms of a relative discharge capacity factor (n). Thus if a is the calculated cross-sectional area of gutter required for the horizontal case, then $a = na^{1}$, where a^{1} is the cross-sectional area of gutter required for the sloping case.

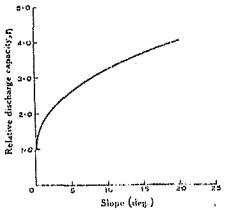


Fig. 11. Influence of slope on discharge capacity of a drainage channel. (After Martin and Tilley 1968.)

The box-type receiver and downpipe may be designed to serve the freely discharging box-gutters as recommended by the Building Research Station (1969)

Downpipes to flat roofs

Where downpipes are fed by flat areas such as sealed membrane roofs and not by gutters, separate consideration needs to be given to the estimation of the required size of the downpipe. Assuming an effective discharge velocity of 350 ft/min (1,78 m/s) in the downpipe during peak flow conditions, the discharge capacity is given by

$$Q = \frac{\pi D^2}{576} \quad 0,350 \times 6,23 \qquad \ldots\ldots \qquad 6.5$$

where Q is in gallons per minute

D is the pipe diameter in inches

Marsh (1968) has presented a design method for PVC eaves gutters. This method is based on experimental data for 6,096 metre (20 ft.) long gutters. The appropriate results are summarised below.

SUMMARY OF RELEVANT PORTIONS OF MARSH METHOD OF GUTTER DESIGN FOR PVC HALF-ROUND EAVES GUTTERS

A level gutter with an outlet at the centre has almost twice the capacity of a similar gutter with an end outlet.

A fall of 1/600 increases the level gutter flow capacity by 20 per cent.

A fall of 1/300 increases the level gutter flow capacity by 30 percent.

An angle within 6 ft. (2m) of the outlet of a level gutter, reduces the flow capacity of the straight gutter by 10 percent.

An angle further than 6 ft. (2m) from the outlet of the level gutter, reduces the flow capacity of the straight gutter by 5 percent.

An angle within 6 ft. (2m) of the outlet of a gutter fitted to a fall, reduces the flow capacity of the straight gutter by 20 percent.

SUMMARY OF HELLINGS' METHOD OF DETERMINING THE OPTIMUM POSITION OF EAVES GUTTERS

Hellings (1967) proposed a theoretical method of determining the optimum position of eaves gutters by considering the trajectory of the water flowing from the roof into the gutter. The method was verified experimentally.

This method is used to determine the trajectory of the water flowing from a valley gutter into a box receiver. The result obtained provides a check on the proposed dimensions of box-receiver presented by the Building Research Station.

The trajectory of a particle in a frictionless medium is given by

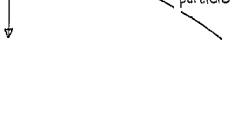
$$a = \tan(d)\, b + \frac{g.b^2}{2Vo^2.\cos^2(d)} \qquad \ldots\ldots \qquad 6.6$$

where a = vertical distance travelled by particle

b = horizontal distance travelled by particle

Vo = initial velocity

d = angle that the initial direction of the particle makes with the horizontal



Assuming that the jet of liquid discharging from a gutter behaves in a similar manner, then the trajectory of the jet of water is given by equation 6.6

It has been shown in Chapter 3 that the flow depth at outlet, Ye, is less than the critical depth, Ycr, and is approximately equal to Ye = 0,715 Ycr. Assuming the gutter to be rectangular, the outlet velocity, Vo, will then equal 1,4 Vcr, where Vcr is the critical velocity.

The critical velocity can be obtained from the expression

$$\frac{Q^2 B}{gA^3} = 1$$

i.e. $Vcr^2 = \frac{gA}{B}$

Thus $Vo^2 = \frac{gA}{B}\ (1,4)^2$

Substituting for the end velocity, Vo, into equation 6.6 gives

$$a = \tan(d).b + \frac{g.b^2}{2.(1,4)^2.\frac{gA}{B}\cos^2(d)}$$

Assuming a level gutter, i.e. $d = 0^\circ$, gives

$$a = \frac{b^2}{2.(1,4)^2 . Y}$$

Hence $b \approx 2\sqrt{a.Y}$

This equation is compared with the equation for the minimum length of box-receiver as proposed by the Building Research Station. viz. $Lb = 2\sqrt{FHo}$. It is seen that the equations are identical. Thus it is concluded that the BRS formula is based on the assumptions outlined above.

Hence the BRS formula will be adequate provided that Vo does not exceed 1,4 Vcr. This may occur in certain instances, but the effect thereof will be compensated for by inbuilt safety factors in the equation. Namely

(i) the effect of friction, which is ignored in the analysis.

(ii) the length of receiver is calculated assuming that the jet of water discharging from the gutter may not impinge on the far vertical wall of the receiver. In fact, it may without affecting the operation of the receiver.

Thus it is felt that the Building Research Station formula for design of box-receivers is adequate.

MIDGLEY RESULTS FOR THE FLOW CAPACITY OF DOWNPIPES

Midgley (1964) investigated the hydraulic characteristics of gullies and downpipes and presented a theoretical discussion on the general behaviour of typical downpipes.

The flow condition at the downpipe inlet can be

(i) free weir condition

(ii) orifice condition

(iii) orifice condition with suction

(iv) weir condition with suction

(v) pipe condition or

(vi) partial pipe condition.

The existing condition depends primarily upon the head of water at the inlet.

The Building Research Station recommends that inlets should be designed to allow free discharge from the gutter. In this case, depending on the head, either condition (i) of (ii) will hold.

If the free weir condition holds then

$$Q = Cd.\pi D.Ho^{1,5} = K.D.Ho^{1,5}$$

and if the orifice condition holds

$$Q = \frac{Cd.\pi D^2}{4}\sqrt{2g}\ Ho^{\frac{1}{2}} = K^1.D^2.H^{\frac{1}{2}}$$

where Q = discharge capacity of inlet

Cd = coefficient of discharge

D = inlet diameter

Ho = driving head

Compare the form of these equations with those presented by the Building Research Station, namely;

$$Q = 0,0116\ D\ H^{1,5} \quad \ldots\ldots \quad 6.2$$

and $$Q = 0,0039\ D^2\sqrt{H} \quad \ldots\ldots \quad 6.3$$

It is seen that the Building Research Station results are based on the theoretical flow conditions (i) and (ii) outlined above.

Since these equations have a sound theoretical backing it is felt that they can be safely applied.

LI RESULTS FOR LEVEL CHANNELS WITH PARALLEL SIDE WALLS

Li (1958) investigated spatially varied flow in level channels with parallel side walls. Using momentum considerations and assuming that the flow depth at outlet equals the critical

depth, Li showed that

$$\frac{Yp}{Yo} = \sqrt{2F_O^2 + 1}$$

where Yp = peak flow depth at upstream end of channel

Yo = flow depth at outlet

F_O = Froude number at outlet = $\frac{Q_o^2 B_o}{g A_o^3}$

Assuming the end depth = critical depth, Ycr, then $F_O = 1$ and the above equation reduces to;

$$Yp = \sqrt{3}\, Yo = 1{,}732\ Yo$$

The Building Research Station design method however assumes that Yp = 2Yo. A further estimate of the value of the ratio Yp/Yo can be obtained by abstracting data from the rectangular gutter output files and calculating the ratio Yp/Yo . This is done in Table 20.

It is seen that for rectangular gutters the ratio Yp/Yo is not constant but varies between the limits of about 1,75 to 2,0. An average value appears to be about 1,85. Thus the Building Research Station value of Yp/Yo = 2 is a conservative result.

Values of Y design are also abstracted from the output files, where Y design = the design flow depth, i.e. the upstream depth with the freeboard allowance added. Values of Y design/Yo are tabulated in Table 20.

It is seen that an average value is about 2,2.

Thus it can be concluded that conservative estimates of the peak upstream depth Yp and the design depth Yd are given by

TABLE 20: CALCULATION OF THE RATIOS Yp/Yo AND Yd/Yo FOR RECTANGULAR CHANNELS

BASE BREADTH b in metres	inf in m^2/s	LENGTH x in metres	Yo = Ycr in metres	Yp in metres	Yp/Yo	Yd in metres	Yd/Yo
0,6	0,005	5	0,05614	0,10214	1,82	0,11746	2,09
		15	0,11678	0,21478	1,84	0,2470	2,11
		25	0,16417	0,3057	1,86	0,35094	2,16
	0,05	5	0,26026	0,45650	1,75	0,52521	2,02
	0,01	25	0,26080	0,4746	1,83	0,5458	2,09
0,4	0,01	10	0,18538	0,33138	1,79	0,3811	2,06
		20	0,25428	0,51628	1,82	0,6167	2,09
	0,003	5	0,05234	0,09433	1,8	0,1088	2,07
		15	0,10886	0,20086	1,83	0,2310	2,11
		25	0,15303	0,28803	1,87	0,3312	2,16
	0,0003	5	0,01128	0,02128	1,87	0,0245	2,17
		15	0,02345	0,04845	2,06	0,0557	2,36
		25	0,03297	0,07097	2,15	0,0816	2,47
0,3	0,005	3	0,06140	0,11340	1,79	0,1304	2,05
		10	0,14147	0,25747	1,82	0,2961	2,09
	0,001	20	0,07680	0,14980	1,95	0,1723	2,24
		25	0,08912	0,17512	1,96	0,2014	2,26
0,2	0,005	10	0,18538	0,34138	1,85		
		15	0,24292	0,45092	1,85		
	0,001	5	0,08308	0,15108	1,82		
		10	0,13188	0,24488	1,86		

$Y_p = 2.Y_o$

$Y_d = 2,3 . Y_o$ where Y_o is assumed to be the critical depth

These values can be used to obtain a quick estimate of the required flow depth for a particular gutter problem.

COMPARISON OF EXISTING METHODS OF DETERMINING REQUIRED FLOW AREAS AND DESIGN CURVES PROPOSED IN CHAPTER 5

The existing methods of determining the required cross-sectional area of valley gutters for given flow conditions are all based on the Building Research Station equation

$$Q = 0,0058\sqrt{\frac{A^3}{B}} \quad \ldots\ldots \quad 6.1$$

where Q is in litres/minute, A in mm^2 and B in millimetres. Compare this with the discharge capacity obtained by assuming that the flow depth at outlet is critical, viz.

$$Q = 0,00595\sqrt{\frac{A^3}{B}}$$

Thus it is seen that the flow capacity as given by equation 6.1 is practically the same as the flow capacity obtained by assuming the outlet depth to be critical. Thus equation 6.1 assumes the outlet depth to equal the critical depth. The Building Research Station method then assumes the peak depth to be twice the critical depth. This however is not always true, as was pointed out in the previous section. It is however a reasonable, conservative estimate.

The equations proposed in this dissertation for the design of rectangular and trapezoidal gutters are:

For rectangular gutters $Y = \left(\frac{Q.x^{0,05}}{1,4[illegible]}\right)^{0,6200} \cdot \frac{1}{b^{0,67}}$

For trapezoidal gutters $[illegible] \left(\frac{[illegible]}{[illegible]69}\right)^{0,7474} \cdot \frac{b^{0,09}}{deg^{0,25}}$

It is felt that use of these equations will take better account of the variables involved in gutter design. The form of these equations is similar to that of equation 6.1 as can be seen by rewriting equation 6.1 in the form below:

$$Y = \frac{(Q)^{0,67}}{K} \cdot b^{0,33}$$

CHAPTER 7

CORRECTION FACTORS TO BE APPLIED TO STANDARD GUTTER RESULTS AND THE SIZING OF BOX-RECEIVERS AND DOWNPIPES

A number of standard gutters were analysed in Chapter 4 and the results of these analyses presented in the form of design criteria in Chapter 5. These design criteria are however only applicable to the particular standard gutters analysed i.e. to straight horizontal gutters with outlet at one end and of rectangular, trapezoidal or half-round section. Means of extending these results to include all aspects of the design of practical gutter systems were sought.

It was felt that due to the lack of data on the subject, the only feasible approach to the variations from the standard gutter would be to abstract relevant information from previous investigators' work. If different investigators employed different means of accounting for such variations, then the most conservative result will be employed.

The relevant abstracted results are as listed below:

CORRECTION FACTORS TO BE APPLIED TO THE STANDARD GUTTER RESULTS

Eaves Gutters

The discharge capacity of a standard gutter can be adjusted for:

Falls not less than 1/600 + 20%

Bends within 2m of an outlet on level gutters,

sharp-cornered bends	- 20%
round-cornered bends	- 10%
on sloping gutters	- 25%

Bends within 2m - 4m of an outlet

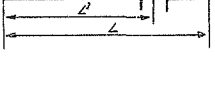
half of the above results

Non-central downpipe in a level gutter, the discharge capacity is given by $\frac{Q.L}{L^1}$ where

Q = discharge capacity

L = gutter length

L^1 = length of longer arm of gutter



Valley Gutters

No results are available on the effects of bends. Bends are seldom incorporated in large valley gutters, but if such gutters should have bends, the designer must apply correction factors of his own choice. The factors above for eaves gutters may be used as a guide.

The effect of slope can be taken into account by means of the Martin method, as outlined in the previous Chapter. It is felt that this method could be improved by determining the effect

of slope theoretically. This could be done by including slope effects in the analysis outlined in Chapter 3 and comparing these results with the horizontal gutter results. This may well result in a better understanding of the effect of slopes on a gutter.

SIZING OF BOX-RECEIVERS AND DOWNPIPES

DOWNPIPES FROM EAVES GUTTERS

Martin recommends that the cross-sectional area of downpipe be half the cross-sectional area of gutter that it is draining. The Building Research Station recommends that downpipe sizes be based on the table reproduced in Table 21.

Both these methods assume that the flow capacity of a particular gutter is fixed and hence the size of the downpipe serving such a gutter is fixed. If the modified form of the Building Research Station eaves gutter design equation is used, viz. $Q = 0{,}8433A^{1{,}25}/_{x}{}^{0{,}47}$ then the flow capacity is not fixed, but depends on the length of the gutter. Thus when applying the modified BRS equation, it is desirable to modify the Building Research Station method of downpipe sizing to take into account the gutter length, x.

The downpipe size can be found from the following theoretical analysis:

Assume that the flow conditions at the gutter outlet approximate orifice flow conditions, then the discharge capacity, Q, of the outlet according to equations 6.3 and 6.4 is given by;

$$Q = 0{,}0039\ d^2\sqrt{H}$$

or $$Q^1 = 0{,}0029\ d^2\sqrt{H}$$ if swirl occurs

where Q is in litres/minute

d is the outlet diameter in millimetres

H is the driving head in millimetres

Assume that the driving head equals the critical depth and assume that the critical depth equals half the peak depth. Then for half-round gutters

$$H = Ycr$$

$$Ycr = \frac{1}{2} Yp = \frac{D}{4}$$

where D is the gutter diameter

And the discharge capacity of the outlet is

$$Q = 0{,}00195\ d^2\sqrt{D}$$

or $$Q^1 = 0{,}00145\ d^2\sqrt{D}$$ if swirl occurs

The required outlet diameter is thus

$$d = \sqrt{\frac{513\ Q}{\sqrt{D}}} \quad \ldots\ldots \quad 7.1$$

$$d^1 = \sqrt{\frac{690\ Q^1}{\sqrt{D}}} \text{ if swirl occurs} \quad \ldots\ldots \quad 7.2$$

To check the validity of these equations, the Building Research Station equation for the flow capacity of eaves gutters, viz. $Q = 0{,}0016A^{1,25}$, is substituted into them and the downpipe sizes computed. The next largest standard downpipe size is then selected for use. The results are in Table 21.

TABLE 21: DETERMINATION OF DOWNPIPE SIZES REQUIRED TO SERVE EAVES GUTTERS

Nominal Gutter Size D in millimetres	Flow capacity, Q as found from Q=0,0016A1,25 in l/min	$d=(0.513/\sqrt{D})^{\frac{1}{0.375}}$ in millimetres	$d=(690.Q/\sqrt{D})^{\frac{1}{2}}$ in millimetres	DOWNPIPE SIZES RECOMMENDED BY THE B.R.S.		
				Sharp (S.C.) corner or round corner (R.C.) outlet	Outlet at end of gutter in millimetres	Outlet not at end of gutter in millimetres
75	25	38,5 50	44,6 50	SC RC	50 50	50 50
100	50	51,5 62,5	59,6 62,5	SC RC	62,5 50	62,5 50
112,5	68	57,4 62,5	66,6 75	SC RC	62,5 50	75 62,5
125	90	64,4 75	74,5 75	SC RC	75 62,5	87,5 75
150	140	76,7 87,5	88,7 100	SC RC	87,5 75	100 100

Note: upper r... - is d(calculated), lower one
is the n... largest standard gutter size

Comparison of these results with the downpipe sizes recommended by the Building Research Station leads to the conclusion that the above method was the method employed by the Building Research Station in determining the downpipe sizes required by gutters with sharp cornered outlets. No swirl was assumed to exist if the outlet was at the end of the gutter, while swirl was assumed to exist if the outlet was not at the end of the gutter.

Thus it appears that equations 7.1 and 7.2 can be used to determine the downpipe sizes required by half-round gutters, provided that the discharge capacity, Q, used in the equations is the actual discharge capacity of the gutter and not the adjusted discharge capacity (i.e. the discharge capacity after correction factors have been applied).

It is assumed that these equations will also hold for nominal half-round, ogee and other similar gutter sections.

Altering the units involved in equations 7.1 and 7.2 they can be written

$$d \approx \sqrt{\frac{0.973Q}{\sqrt{D}}} \quad \ldots\ldots \quad 7.3$$

or $$d^1 \approx \sqrt{\frac{1.309Q}{\sqrt{D}}} \quad \text{with swirl} \quad \ldots\ldots \quad 7.4$$

where d is in metres

D is in metres

Q is in m^3/S

Substituting the modified Building Research Station value for the discharge capacity, Q, into these equations will give a

general design formula for downpipes.

$$d = \sqrt{\frac{0{,}973 \cdot 0{,}8433A^{1{,}25}}{\sqrt{D} \quad x^{0{,}47}}}$$

or $$d = \sqrt{\frac{1{,}309 \cdot 0{,}8433A^{1{,}25}}{\sqrt{D} \quad x^{0{,}47}}} \quad \text{with swirl}$$

These reduce to

$$d = \sqrt{\frac{0{,}82A^{1{,}25}}{x^{0{,}47}\sqrt{D}}} \quad \ldots\ldots \quad 7.5$$

or $$d = \sqrt{\frac{1{,}10A^{1{,}25}}{x^{0{,}47}\sqrt{D}}} \quad \text{with swirl} \quad \ldots\ldots \quad 7.6$$

These then are the design equations for eaves downpipes, where equation 7.5 is used for round-cornered outlets and 7.6 is used for sharp-cornered outlets.

BOX-TYPE RECEIVERS FROM VALLEY GUTTERS

The Building Research Station recommendations for sizing box-receivers are discussed in Chapter 6. These will be adopted for use. The recommended receiver size, as seen in figure 9 below, depends on the depth of flow at the gutter outlet, Yo.

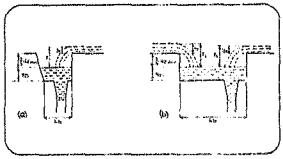


Fig 9 Dimensions of box-type receivers
(a) External length. $L_b = 2\sqrt{Y_o}$
(b) Internal length. $L_b = 2\sqrt{Y_o} + 2\sqrt{Y_o}$

The depth of flow at the outlet is less than the critical depth and is approximated by

Yo = 0,715 Ycr.

It is felt however that it is more desirable to employ the critical depth as the Yo value in the equation for box length, Lb. This provides a certain safety factor and allows for errors in the analysis used to determine the box length equation (see previous chapter).

If design is based on the design equations recommended in Chapter 5 then the critical depth can be assumed to be equal to Y design/2,3 (see Chapter 6 for explanation).

DOWNPIPES FROM BOX-RECEIVERS AND VALLEY GUTTERS

The Building Research Station method will be used. The problem exists as to what is the driving head of water over the downpipe inlet. This head will be assumed to be the critical depth and hence is given by Y design/2,3.

GUTTER SECTIONS OTHER THAN RECTANGULAR OR TRAPEZOIDAL SECTIONS

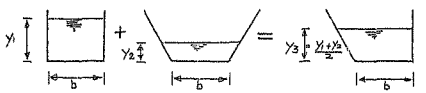
Various methods of theoretically relating the results of rectangular and trapezoidal gutters to other gutter sections were attempted without success. Attempts were made to determine a ratio between the critical depth in a rectangular section and the critical depth in a trapezoidal section with one side vertical and one side sloping, but it was found that this ratio was a variable.

It was decided that the best method of extending the results was as follows:

(i) Where a high degree of accuracy is not required

The required area of the gutter is determined by combining the results of rectangular and trapezoidal gutters with equal side slope in a suitable fashion.

For example



(ii) Where a higher degree of accuracy is required

The design depth may be assumed to be 2,3 times the critical flow depth in the gutter. Thus it will be necessary to determine the critical flow depth. This can be done by a trial and error solution of the equation

$$\frac{Q^2 B}{gA^3} = 1$$

CHAPTER 8

PRESENTATION OF A GUTTER DESIGN MANUAL FOR SOUTH AFRICAN CONDITIONS

INTRODUCTION

At present several methods of gutter design based on rule of thumb techniques are employed in South Africa. These methods often give widely differing solutions and it is felt that they do not always result in optimum drainage system design. An attempt has been made to rationalize gutter design by applying sound theoretical principles to the critical elements of a drainage system. The validity of all theoretical analyses employed was checked against available experimental data from test gutters. Where the assumptions used in the theoretical analyses resulted in conditions that differed from practical gutter systems, the effect of these assumptions is taken into account by means of correction factors.

The correction factors and several of the design equations have been abstracted from the design methods proposed by Martin (1973) and the Building Research Station (1969). The layout of this manual follows the layout of the Martin manual.

POSITION OF DOWNPIPES (after Martin (1973))

> 'Although general location of downpipes is fixed by considerations other than designing for optimum drainage, the number to be installed is usually a design variable. Obviously, the more downpipes the smaller the catchment area and the smaller

the sizing of drainage channels. However the high cost of additional downpipes to multi-storey buildings in particular, usually ensures that as few as possible will be used. Some simple commonsense rules apply. Roof catchments should be kept smaller than 900m^2 and at least two downpipes should be installed on all roofs with *total catchments greater than about 45m2.* Drainage from roofs should not be directed onto other roofs but into separate downpipes.

External downpipes are preferred on the basis of ease of maintenance, lower potential damage should blockage occur, and the facility for installing overflow weirs at the downpipe. Flat *gratings to minimize the blockage* to internal downpipes serving flat roofs should not be used unless the inlet to the downpipes is greater than 150 millimetres diameter, and then the restricted area of flow must be used in the calculations. One of the most troublesome causes of blockage of downpipes serving flat roofs to multi-storey buildings is caused by rain leaching free lime from cement-rich concrete paving. The lime is carbonated and deposited at the inlet to the downpipe as calcium carbonate. Such deposits can only be removed with difficulty by mechanical means. Neat cement powder must not be used as a drier for such concrete paving.

The detailed position of downpipes serving drainage channels will influence the discharge capacity of the channel. Where possible the position should be in the centre of the length of the channel and so located that the water in the channel does not need to traverse a bend to reach the inlet.'

THE CATCHMENT AREA

Wind influences the effective catchment area by altering the direction of the rainfall. It is argued from simple geometry that a sloping roof must intercept more wind-driven rain, descending at an angle from the normal. However very little

data exists upon which an estimate of such a 'wind factor' can be based.

In saw-tooth type of construction rain will be directed onto the vertical roof portions, increasing the effective catchment area. Thus in cases of high wind a percentage of the vertical surface might be exposed to rainfall and this area must be added to the adjacent sloping roof area in determining the effective catchment area.

High rise buildings affect the intensity of rainfall during windy periods. The buildings will obstruct the flow of air and the resulting pattern of air movement will cause raindrop trajectories to diverge over the obstruction and converge on the leeward side.

Thus roofs of high buildings may be expected to receive lower intensities of rainfall than are recorded on open ground. The same would apply to roofs on adjacent buildings, but lower buildings at some distance on the leeward side might experience higher intensities.

However until further research has been performed on the effect of wind, no fixed rules can be stated. For the present, the designer should increase the plan area of roof to account for wind effects. The amount by which it is increased should be based on subjective knowledge of the wind conditions at the particular site. In extreme circumstances the total roof area may be taken as the catchment area.

THE DESIGN RAINFALL INTENSITY

Hail is not taken into account in the design rainfall intensity. It is generally agreed that runoff from hail is lower than from rain and the major problem is due to the likelihood of blockage of drainage channels and downpipes. Downpipes may be protected by wire mesh guards.

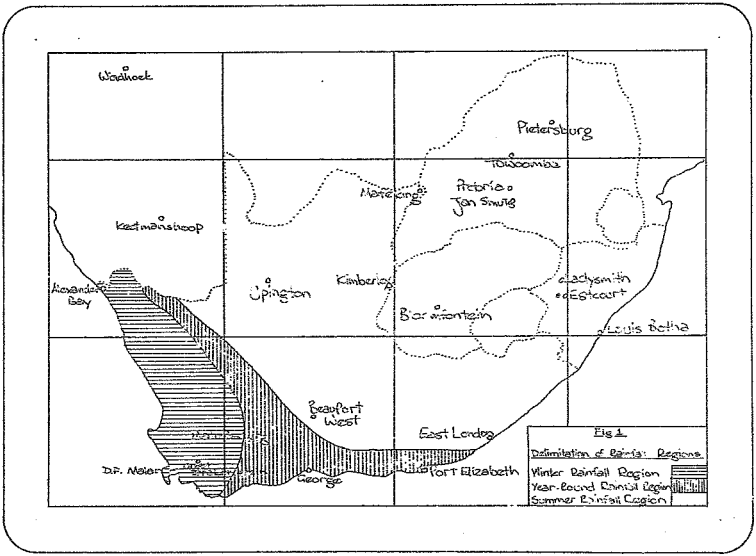
The critical duration of storm likely to cause overtopping of the drainage system is considered to be five minutes. Rainfall intensities for the three meteorologically homogeneous rainfall regions in South Africa, as seen in Figure 1, have been computed for various recurrence intervals of failure. These intensities for various recurrence intervals have been plotted against the mean annual precipitation at the particular site in Figures 2, 3 and 4.

The recurrence interval of failure employed should depend on the potential damage that may be caused by overtopping of the drainage system and leakage of water into the building. Design of external eaves gutters with low damage potential if overtopping occurs may be based on recurrence intervals of 5 to 10 years, while design of large valley gutters may be based on longer recurrence intervals of failure.

Hence the design rainfall intensity for gutter design is obtained by

(i) deciding on the appropriate recurrence interval of failure

(ii) determining the rainfall region of the gutter site from Figure 1.


Waalhoek
Pietersburg
Towoomba
Pretoria
Jan Smuts
Kestmanshoop
Alexander Bay
Upington
Kimberley
Ladysmith
Estcourt
Bloemfontein
Louis Botha
Beaufort West
East London
D.F. Malan
George
Port Elizabeth
Fig 1
Delimitation of Rainfall Regions
Winter Rainfall Region
Year-Round Rainfall Region
Summer Rainfall Region

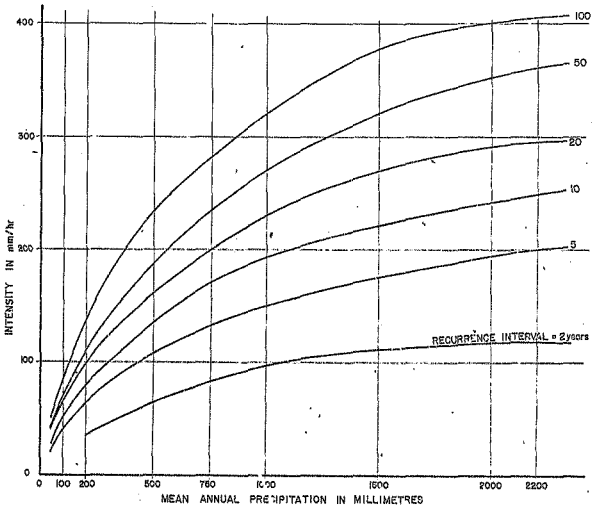


Fig. 2 GUTTER DESIGN CURVE FOR SUMMER RAINFALL REGIONS

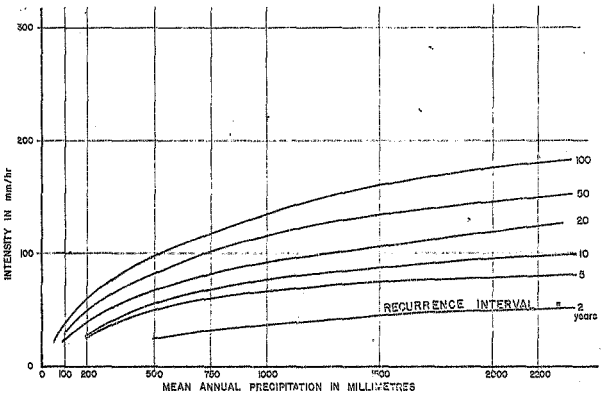


Fig. 3 GUTTER DESIGN CURVE FOR WINTER RAINFALL REGIONS

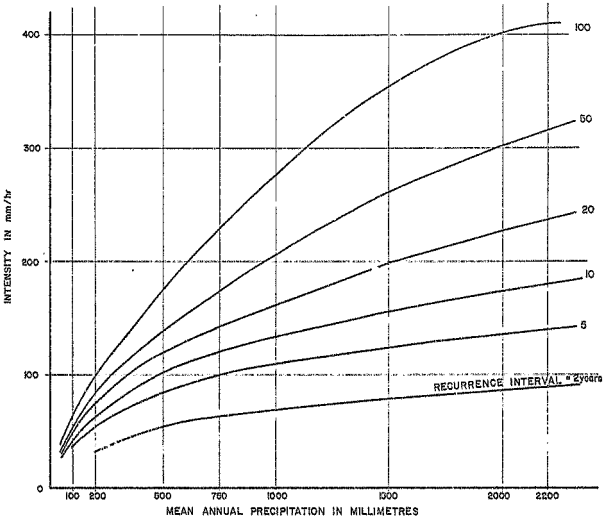


Fig. 4. GUTTER DESIGN CURVE FOR YEAR-ROUND RAINFALL REGION

(iii) determining the mean annual precipitation at the site

(iv) determining the design rainfall intensity using Figure 2, 3 or 4.

The design rainfall intensity is given in millimetres per hour. This manual is based on units of metres and seconds. To convert the intensity in millimetres per hour to metres per second multiply the intensity by $0,2778 \times 10^{-6}$.

DESIGN OF DRAINAGE SYSTEM

Eaves gutter design is based on the flow capacity of standard gutter sizes while valley gutter design is based on the determination of the required cross-sectional area of gutter to cater for the particular inflow rate.

TO DETERMINE THE SIZE OF EAVES GUTTERS FITTED WITH DOWNPIPES

The flow capacity of level eaves gutters, of half-round, segmental and ogee section, with outlet at one end is given by:

$$Q = \frac{0,8433A^{1,25}}{x^{0,47}} \quad \ldots\ldots \quad 1$$

where Q is the flow capacity in m^3/S

A is the cross-sectional area of the gutter in m^2

x is the length of the gutter in metres

The flow capacity as determined by equation 1 may be adjusted for:

Falls not less than $^1/_{600}$	+ 20%
Bends within 2m of an outlet	
on level gutters, sharp-cornered bends	- 20%

round-cornered bends - 10%

on sloping gutters, - 25%

Bends within 2 - 4m of an outlet

half of the above results

Downpipe not at end of gutter. The discharge capacity is given by $Q.\frac{x}{x^1}$ where Q is the flow capacity with downpipe at end, x is the total gutter length and x^1 is the length of the longer arm of the gutter.

Eaves gutters are designed by a trial and error process. A gutter size is estimated, the flow capacity is determined, correction factors are applied if necessary and the result is compared with the discharge that the gutter must cater for. This is repeated until the optimum solution is obtained.

TO DETERMINE THE SIZE OF DOWNPIPES DRAINING EAVES GUTTERS

The flow is influenced by the shape of the outlet, whether sharp-cornered or round-cornered. Thus separate equations exist for the two different conditions.

The size of outlets may be determined by the following equations:

$$d = \sqrt{\frac{0,82A^{1,25}}{x^{0,47}\sqrt{D}}} \quad \text{for round-cornered outlets} \quad \ldots\ldots\ldots \quad 2$$

$$d = \sqrt{\frac{1,1A^{1,25}}{x^{0,47}\sqrt{D}}} \quad \text{for sharp-cornered outlets} \quad \ldots\ldots\ldots \quad 3$$

where d is the outlet diameter in metres

A is the gutter cross-sectional area in m^2

x is the gutter length in metres

D is the nominal diameter of the gutter in metres

TO DETERMINE THE SIZE OF VALLEY AND BOX GUTTERS DISCHARGING FREELY INTO RECEIVER AND DOWNPIPE

These gutters are vee, trapezoidal or rectangular in shape and should have a minimum base width of 0,3m to facilitate maintenance. Bends are generally not incorporated and discharge is preferably via an open end into a box-receiver.

Rectangular sections:

The required cross-sectional area of gutter with freeboard is given by:

$$A = \left(\frac{0,x^{0,05}}{1,4294}\right)^{0,62} \cdot b^{0,33} \qquad \ldots\ldots \quad 4$$

Trapezoidal Sections with equal side slopes:

The required cross-sectional area of gutter with freeboard is given by

$$A = \left(\frac{Q}{0,6969}\right)^{0,7474} \frac{b^{0,09}}{deg^{0,25}} \qquad \ldots\ldots \quad 5$$

where A is the design cross-sectional area in m^2

Q is the flow rate that the gutter must carry in m^3/s

x is the gutter length in metres

b is the base width in metres

deg is the side slope in radians, as measured by the external angle that the gutter sides make with the horizontal.

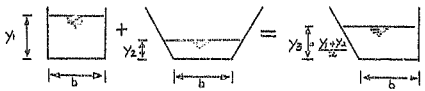
Sections other than rectangular or trapezoidal with equal side slope

The required cross-sectional area of gutter with freeboard can be determined in either of two ways.

(i) Where a high degree of accuracy is not required;

The required cross-sectional area can be found by combining the results of rectangular and trapezoidal with equal side slope gutters in a suitable fashion.

For example to size a trapezoidal gutter with one side sloping and the other side vertical, the following combination could be used.



(ii) Where a greater degree of accuracy is necessary;

The required depth of flow, with freeboard may be assumed to be 2,3 times the critical flow depth in the particular gutter.

i.e. $Yd = 2,3Ycr$ 6

The critical flow depth may be found by a trial and error solution of the following equation.

$$\frac{Q^2 B}{gA^3} = 1 \qquad \text{..... 7}$$

where Q is in flow rate that the gutter must carry in m^3/S

B is the width of water surface at outlet in metres

A is the area of flow at outlet in m^2

For the common case of trapezoidal section with one side

vertical and one side sloping, equation 7.3 is given by:

$$\frac{Q^2}{g} = \frac{\left[b.Ycr + \frac{Ycr^2}{2\tan\theta}\right]^3}{\left[b + \frac{Ycr}{\tan\theta}\right]} \quad \ldots\ldots \quad 8$$

where Ycr is the critical depth at outlet in metres

θ is the side slope in degrees

CORRECTION FACTORS APPLIED TO THE REQUIRED AREA

Bends generally are not incorporated in valley gutters and little data on their effect exists. If bends are present, then the designer must increase the required area using his judgement. The factors given for eaves gutters may be used as a guide.

The influence of slope has been studied empirically by Martin and Tilley (1968) and the following relationship found for both box trapezoidal and vee gutters.

Up to 1° slope the square of the discharge capacity is directly proportional to the sine of the angle of slope.

For slopes from 1° to 20° the reciprocal of the maximum depth of flow is directly proportional to the square root of the sine of the angle of slope. Figure 5 illustrates the results in terms of a relative discharge capacity, n. Thus if A is the calculated cross-sectional area required for the horizontal case then

$$A = nA^1$$

where A^1 is the cross-sectional area required for the sloping case.

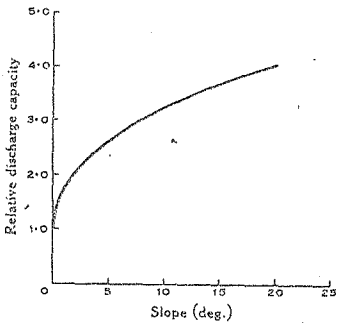


Fig. 5: Influence of slope on discharge capacity of a drainage channel. (After Martin and Tilley, 1968)

TO DETERMINE THE SIZE OF BOX-RECEIVERS FROM VALLEY GUTTERS

Box-receivers may be designed to serve the freely discharging box gutter as recommended by the Building Research Station (1969).

The receiver should be at least as wide as the maximum gutter width and should be designed to prevent the flow from the gutter overshooting the box. A suitable shape for an external box-type receiver is in Figure 6.

The value of the flow depth at outlet used in the formula to determine the length of the receiver is given by:

$$Yo = \frac{Yd}{2,3}$$

Where Yd is the peak flow depth with freeboard as found from equations 4,5 or 6.

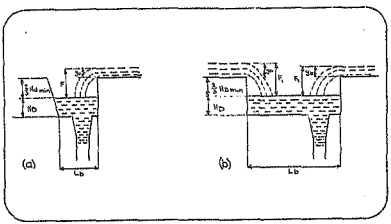


Fig. 6: Dimensions of box-type receivers
(a): External length $L_b = 2\sqrt{F_1 y_d}$
(b): Internal length, $L_b = 2\sqrt{F_1 y_{d1}} + 2\sqrt{F_1 y_{d2}}$

TO DETERMINE THE SIZE OF DOWNPIPES FROM RECEIVERS OR VALLEY GUTTERS

Where the gutter discharges directly into the downpipe, the downpipe inlet should be designed to allow for free discharge from the gutter. The discharge capacity of a downpipe depends on the inlet diameter, the head of water over the inlet and on whether the water swirls about the inlet.

The downpipe inlet should be placed at a distance less than its diameter from the nearest vertical side of the gutter or box. The required inlet size is then given by

$$d = \frac{0,1640}{H^{1,5}} \qquad \ldots\ldots \quad 9$$

provided that H is less than $\frac{d}{3}$

When H is greater than d/3 the outlet acts as an orifice and the inlet diameter is given by

$$d = \sqrt{\frac{0,487Q}{H^{0,5}}} \quad \ldots\ldots \quad 10$$

If the inlet is at a distance greater than its diameter from the nearest vertical wall, swirl will occur and the orifice discharge will change. Thus if H is greater than d/3 and swirl is present, the inlet diameter is given by

$$d = \sqrt{\frac{0,655Q}{H^{0,5}}} \quad \ldots\ldots \quad 11$$

where d is the downpipe diameter required in metres

Q is the flow rate that the downpipe must cater for in m^3/S

H is the head of water over the inlet in metres

When sizing an inlet to a downpipe leading directly from the gutter, the head H is assumed to be equal to the critical depth of flow. This can be assumed to be Yd/2,3 where Yd is the peak flow depth with freeboard as found from equations 4,5 and 6.

The diameter of the downpipe can be reduced to two-thirds of the effective inlet diameter provided that the transition is made over a length of not less than the diameter of the inlet.

TO DETERMINE THE SIZE OF DOWNPIPES FROM FLAT ROOFS

Where downpipes are fed by flat areas such as sealed membrane roofs and not by gutters, separate considerations need

to be given to the estimation of the required size of downpipe. Assuming an effective discharge velocity of 1,8m/S in the downpipe during peak flow conditions, the discharge capacity is given by:

$$Q = \pi \frac{d^2}{4} \cdot 1,8$$

i.e. $d = \sqrt{0,707Q}$

where d is the required outlet diameter in metres

Q is the discharge rate that the outlet must cater for in m^3/S.

MAINTENANCE

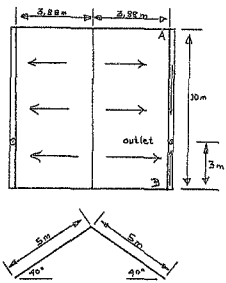
The commonest cause of drainage system failure is the accumulation of dirt and debris in the drainage channels. On buildings where the damage potential due to failure of drainage system is high, regular maintenance of the drainage channels must be performed.

TYPICAL EXAMPLES

Several simple examples are given indicating the manner in which this manual can be used to design practical roof drainage systems. It should be noted that these examples are of an elementary nature and that no attempt has been made to obtain the optimum design. In large roof drainage systems, the optimum design should always be obtained by considering several alternative designs and comparing the costs of these alternatives.

GUTTER SYSTEM FOR A RESIDENTIAL BUILDING IN JOHANNESBURG

Consider a residential building with a roof system as sketched below.



It is required to design the drainage system for this building.

Downpipe positions; *Assume that aesthetics dictated* the downpipe positions and that they are as shown.

Catchment area; Damage potential if overtopping of the gutters occurs is low, thus neglect wind effects and use the plan area of the roof as the catchment area.

Area of roof draining into gutter AB = $5,0.Cos\ 40^{o}.10\ m^{2}$

$= 38,3\ m^{2}$

Design rainfall intensity; Since damage potential is low, use a low recurrence interval of failure of say, 5 years.

Mean annual precipitation in Johannesburg = 760 millimetres

Rainfall region - summer rainfall region.

Hence design intensity from fig.4 = 134 mm/hr.

$$= 134.0,2778.10^{-6} m/S$$

$$= 37,2.10^{-6} m/S$$

Required discharge capacity of gutter; This is given by

$$37,2.10^{-6}.38,8 m^3/S$$

$$= 1,442.10^{-3} m^3/S$$

Sizing of gutter AB; Assume eaves gutters of half-round section will be used. Assume the gutter will be fitted to a fall of 1/600.

The flow capacity of a level gutter with an outlet at one end is given by

$$Q = \frac{0,8433A^{1,25}}{x^{0,47}}$$

where $x = 10m$

Thus $Q = 0,286A^{1,25}$

Correction factors to account for variations from the standard gutter can be applied to the discharge capacity. They are (i) gutter has slope of 1/600, thus increase discharge capacity by 20 percent

(ii) outlet is not at end of gutter, thus increase discharge capacity by a factor of

$$\frac{x}{x^1} = \frac{10}{7} = 1,43$$

Hence corrected discharge capacity is

$$Q = 0,286.A^{1,25}.1,20.1,43$$

$$Q = 0,491.A^{1,25}$$

Try gutter of diameter = 0,10m and A = $0,00784m^2$

Then it's discharge capacity $= 0,491.0,00784^{1,25}$

$= 1,03.10^{-3}\ m^3/s$

Compare this with the required discharge capacity of $1,442.10^{-3}m^3/s$ and it is seen that a larger gutter is required.

Try gutter of diameter = 0,125m and A = $0,0123m^2$

Then discharge capacity $= 0,491.0,0123^{1,25}$

$= 2,06.10^{-3}\ m^3/s$

Hence this gutter size will be adequate.

Sizing of downpips draining from gutter; Assume that the outlet is sharp cornered, then the required outlet diameter is given by

$$d = \sqrt{\frac{1,1\ A^{1,25}}{x^{0,47}\sqrt{D}}} \qquad \ldots\ldots \qquad 3$$

i.e.

$$d = \sqrt{\frac{1,1.\ 0,0123^{1,25}}{10^{0,47}.\sqrt{0,125}}}$$

$$= \sqrt{\frac{0,00462}{1,042}}$$

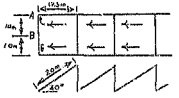
$$= 0,0665 \text{ metres}$$

$$= 66,3 \text{ millimetres}$$

The next largest standard size is then selected for use.

GUTTER SYSTEM FOR AN INDUSTRIAL BUILDING IN PORT ELIZABETH

Consider an industrial building, housing a motor car assembly plant, as sketched below.



It is required to design the drainage system for this building.

Downpipe positions; Assume that the downpipes are situated as shown.

Catchment area; Damage potential if overtopping of the gutter system occurs is fairly high. In addition strong winds are frequent in the Port Elizabeth area. Thus use the total sloping roof area as the catchment area. Area of roof draining into gutter AB = $20.10\ m^2$

= $200\ m^2$

Design rainfall intensity; Since damage potential is high use a high recurrence interval of failure, say, 50 years.
Mean annual precipitation in Port Elizabeth = 580 millimetres
Rainfall region = year-round rainfall region.
Hence design intensity from fig. 6 = 150 mm/hr

= $150.0,2778.10^{-6}\ m/S$

= $41,6.10^{-6}\ m/S$

Required discharge capacity of gutter; This is given by

$41,6.10^{-6}.200\ m^3/S$

$8,32.10^{-3}\ m^3/S$

Sizing of gutter AB; Assume that a trapezoidal gutter section with equal side slopes will be used and assume that the gutter discharges into a box-receiver and downpipe and assume that the gutter is fitted level.

The required cross-sectional area of gutter with freeboard is given by

$$A = \left(\frac{Q}{0,6969}\right)^{0,7474} \frac{b^{0,09}}{deg^{0,25}} \quad \ldots\ldots \quad 5$$

Assume a side slope of 60° and base breadth

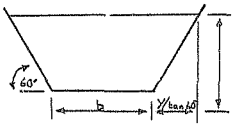
$b = 0,30$ metres, then

$$A = \left(\frac{8,32.10^{-3}}{0,6969}\right)^{0,7474} \cdot \frac{(0,30)^{0,09}}{(1,0472)^{0,25}}$$

$$= 0,0320 \ m^2$$

Thus required depth of gutter is given by

$$A = Y.b + \frac{Y^2}{\tan 60^{\circ}}$$



The solution of this is given by $Y \approx 0,10$ metres

Sizing of box-receivor from gutter; The minimum width of the receivor is given by

$b + 2.Y/\tan 60^{\circ} = 0,3 + 2.0,13/1,73$ metres

$= 0,45$ metres

The flow depth at gutter outlet, $Yo = Yd/2,3$

$= 0,1/2,3$ metres

$= 0,0435$ metres

Assume that the driving head of water in the box,

HD = 0,05 metres, then the fall from the gutter to the surface of the water in the box is given by

$$F = Yo + \frac{2}{3} HD$$

$$= 0,0435 + 0,0333 \text{ metres}$$

$$= 0,0768 \text{ metres}$$

Hence minimum box length, $Lb = 2\sqrt{FYo}$

$$Lb = 2\sqrt{0,0768.0,0435}$$

$$Lb = 0,106 \text{ metres}$$

Say $Lb = 0,110$ metres

Sizing of downpipe from box-receiver; Assume that the downpipe is situated at a distance less than its diameter from the nearest vertical wall of the box.

Thus if $H < d/3$ then the downpipe size is given by

$$d = \frac{0,1540}{H^{1,5}} \quad \ldots\ldots \quad 9$$

In this instance $H = Hl = 0,05$ metres and

$$d = 0,1540.8,3210^{-3} \text{ metres}$$
$$0,05^{1,5}$$

$$d = 0,134 \text{ metres}$$

but $H > d/3$ thus the above formula does not hold. In this instance the downpipe size is given by

$$d = \sqrt{\frac{0,487Q}{H^{0,5}}} \quad \ldots\ldots \quad 10$$

i.e. $$d = \sqrt{\frac{0,487.8,32.10^{-3}}{(0,05)^{0,5}}}$$

$$d = 0,134 \text{ metres}$$

The next largest standard downpipe size is then selected for use. The diameter of the downpipe may be reduced to

2/3 . 0,134 metres in diameter provided that this transition occurs over a distance of not less than the downpipe diameter.

GUTTER SYSTEM FOR, SAY, AN ART GALLERY

Seepage of water into a building such as an art gallery would have disastrous effects, thus the possibility of failure of the gutter system cannot be tolerated. In such an instance the total roof area would be used as the catchment area and a recurrence interval of failure of 100 years would be used. In addition safety factors should be applied to the gutter cross-sectional area.

APPENDIX A

TABLES OF RAINFALL INTENSITY VALUES AS ABSTRACTED FROM FIGURE 2 AND TYPICAL CURVES USED TO OBTAIN THE FIVE MINUTE DURATION STORM INTENSITY VALUE.

TABLE 22: RAINFALL INTENSITIES ABSTRACTED FROM FIGURE 2 FOR REGIONS WITH M.A.P. = 50mm

RECURRENCE INTERVAL in years	Time in hours	0,25	0,50	0,75	1	2	RAINFALL REGION
	INTENSITY			in	mm / hr		
2							winter year-round summer
5				14,7	10,5 12,6	6,2 7,8	w y-r s
10			1,00	15,4 18,6	12,5 15,0	7,5 9,6	w y-r s
20				17,3 22,4	14,8 18,2	8,5 5,1 11,7	w y-r s
50				20,0 26,6	10,0 17,6 22,3	6,0 10,5 11,5	w y-r s
100				14,0 24,0 32,0	11,3 20,0 27,0	7,0 12,0 16,5	w y-r s

TABLE 23: RAINFALL INTENSITIES ABSTRACTED FROM FIGURE 2 FOR REGIONS WITH M.A.P. = 100mm

RECURRENCE INTERVAL in years	Time in hours	0,25	0,50	0,75	1	2	RAINFALL REGION
	INTENSITY in mm / hr						
2					10,5	5,7 6,3	winter year-round summer
5			23,0 28,0	17,7 21,6	14,0 18,0	8,0 10,7	w y-r s
10			28,0 35,0	20,6 28,0	10,0 17,0 23,2	5,8 10,0 13,2	w y-r s
20			32,8 44,0	14,3 24,7 33,3	11,7 20,0 27,0	6,7 12,0 16,3	w y-r s
50			22,0 36,6 50,0	16,7 29,4 40,0	14,0 24,5 33,0	8,2 14,5 19,5	w y-r s
100			26,0 45,0 60,0	19,3 34,7 47,5	16,5 29,0 39,0	9,2 13,0 23,5	w y-r s

TABLE 24: RAINFALL INTENSITIES ABSTRACTED FROM FIGURE 2 FOR REGIONS WITH M.A.P. = 200mm

RECURRENCE INTERVAL in years	Time in hours	0,25	0,50	0,75	1	2	RAINFALL REGION
		INTENSITY in mm / hr					
2			21,0	15,6	12,5	7,0	winter
			25,0	19,0	16,0	9,0	year-round
							summer
5				14,7	11,7	6,6	w
		44,8	32,6	24,7	20,0	7,8	y-r
		54,0	44,0	33,4	26,5	15,5	s
10			23,0	17,3	14,2	8,0	w
		52,8	40,0	31,4	25,0	14,2	y-r
		68,0	53,0	41,4	34,5	19,5	s
20			27,0	21,4	17,0	9,5	w
		62,0	48,0	36,7	30,0	13,0	y-r
		84,0	66,0	49,5	40,0	23,5	s
50		42,0	32,0	24,7	20,0	11,7	w
		72,0	56,0	45,3	38,0	22,5	y-r
		96,0	77,0	60,0	49,0	28,0	s
100		50,0	38,0	29,4	24,0	14,0	w
		88,0	70,0	55,5	47,5	28,0	y-r
		112,0	93,0	72,0	59,0	33,5	s

TABLE 25: RAINFALL INTENSITIES ABSTRACTED FROM FIGURE 2 FOR REGIONS WITH M.A.P. = 500mm

RECURRENCE INTERVAL in years	Time in hours	0,25	0,50	0,75	1	2	RAINFALL REGION
		INTENSITY		in	mm / hr		
2		44,0 54,0	32,0 42,0	14,3 24,6 32,0	11,5 19,5 24,5	6,4 11,2 15,0	winter year-round summer
5		40,8 68,0 92.8	30,0 48,0 73,0	23,3 42,7 58,0	19,0 35,0 46,5	12,5 20,5 29,0	w y-r s
10		49,2 88,0 116,0	37,0 68,0 90,0	29,4 54,0 76,5	24,0 45,0 57,5	13,5 27,5 32,5	w y-r s
20		58,8 104,0 136,0	45,0 85,0 109,0	36,0 70,0 84,7	29,0 60,0 69,0	17,5 37,0 39,5	w y-r s
50		68,8 128,0 168,0	54,0 109,0 130,0	45,5 93,5 103,4	37,5 82,0 86,0	22,0 47,5 47,5	w y-r s
100		84,0 152,0 200,0	67,0 140,0 155,0	53,5 120,0 120,0	45,0 100,0 100,0	29,0 55,5 55,5	w y-r s

TABLE 26: RAINFALL INTENSITIES ABSTRACTED FROM FIGURE 2 FOR REGIONS WITH M.A.P. = 750mm

RECURRENCE INTERVAL in years	Time in hours	0,25	0,50	0,75	1		RAINFALL REGION
		INTENSITY		in	mm / hr		
2		52,0 66,0	22,0 37,0 50,0	17,0 30,0 40,0	14,0 24,5 33,0	8,3 14,5 19,5	winter year-round summer
5		48,0 84,0 112,0	36,0 64,0 86,0	28,7 52,7 68,7	23,5 46,0 57,5	14,0 29,0 34,0	w y-r s
10		58,8 104,0 140,8	4.,0 84,0 116,0	36,0 70,6 85,5	30,0 62,0 70,2	18,5 40,5 42,0	w y-r s
20		72,0 128,0 172,0	55,0 110,0 130,0	44,7 94,6 104,0	38,0 86,0 86,0	23,0 50,0 50,0	w y-r s
50		84,0 156,0 204,0	76,0 142,0 154,0	56,0 122,8 122,8	47,5 101,0 101,0	28,7 60,5 60,5	w y-r s
100		102,0 196,0 240,0	84,0 184,0 184,0	68,0 146,8 146,8	58,0 121,0 121,0	35,5 71,0 71,0	w y-r s

TABLE 27: RAINFALL INTENSITIES ABSTRACTED FROM FIGURE 2 FOR REGIONS WITH M.A.P. = 1000mm

RECURRENCE INTERVAL in years	Time in hours	0,25	0,50	0,75	1	2	RAINFALL REGION
		INTENSITY		in	mm / hr		
2		58,0 74,8	24,0 42,0 56,0	19,4 33,3 52,0	16,0 28,0 36,0	9,5 18,0 23,0	winter year-round summer
5		54,0 96,0 128,0	40,0 74,0 94,0	33,3 62,6 80,0	27,5 57,5 67,5	16,0 38,0 40,0	w y-r s
10		66,0 118,4 160,0	51,0 98,0 120,0	42,6 86,6 98,7	37,0 80,0 83,0	23,0 50,0 50,0	w y-r s
20		80,0 148,0 192,0	63,0 130,0 148,0	53,4 117,5 117,5	46,0 100,0 100,0	28,7 60,0 60,0	w y-r s
50		102,0 186,0 232,0	78,0 175,0 175,0	66,6 144,0 144,0	58,0 121,0 121,0	35,5 73,0 73,0	w y-r s
100		116,0 240,0 272,0	96,0 210,0 210,0	80,0 171,0 171,0	70,0 147,0 147,0	43,5 85,0 85,0	w y-r s

TABLE 28: RAINFALL INTENSITIES ABSTRACTED FROM FIGURE 2 FOR REGIONS WITH M.A.P. = 1500mm

RECURRENCE INTERVAL in years	Time in hours	0,25	0,50	0,75	1	RAINFALL REGION
		INTENSITY		in	mm / hr	
2		66,0 88,0	27,6 48,0 66,0	22,0 38,7 53,4	19,0 36,5 47,5	winter year-round summer
5		62,0 110,0 150,0	46,0 90,0 112,0	37,4 77,5 90,5	36,0 76,0 82,0	w y-r s
10		76,0 140,0 188,0	58;0 120,0 140,0	50,0 113,5 113,5	47,5 103,0 103,0	w y-r s
20		92,0 176,0 224,0	74,0 160,0 168,0	63,9 137,5 137,5	58,0 122,0 122,0	w y-r s
50		112,0 230,0 268,0	92,0 200,0 200,0	90,6 165,2 165,2	73,0 147,0 147,0	w y-r s
100		141,2 304,0 320,0	114,0 240,0 240,0	97,5 196,0 196,0	84,0 176,0 176,0	w y-r s

TABLE 29: RAINFALL INTENSITIES ABSTRACTED FROM FIGURE 2 FOR REGIONS WITH M.A.P. = 2000mm

RECURRENCE INTERVAL in years	Time in hours	0,25	0,50	0,75	1	2	RAINFALL REGION
		INTENSITY		in	mm / hr		
2		42,0 72,0 96,0	30,0 56,0 72,0	24,0 44,6 58,7	23,0 43,5 55,0	12,5 23,5 30,0	winter year-round summer
5		66,0 124,0 164,0	50,0 100,0 120,0	44,6 92,0 101,2	43,5 90,0 95,0	23,7 51,5 51,5	w y-r s
10		86,0 160,0 204,0	66,0 140,0 154,0	58,6 126,7 126,7	56,0 118,0 118,0	31,0 64,0 64,0	w y-r s
20		106,0 206,0 252,0	85,0 188,0 188,0	73,5 153,2 153,2	77,0 142,0 142,0	38,7 77,0 77,0	w y-r s
50		130,0 272,0 300,0	104,0 220,0 220,0	90,0 184,0 184,0	87,5 170,0 170,0	49,0 69,0 69,0	w y-r s
100		160,0 348,0 348,0	130,0 264,0 264,0	109,0 218,0 218,0	105,0 200,0 200,0	60,5 112,5 112,5	w y-r s

TABLE 30: RAINFALL INTENSITIES ABSTRACTED FROM FIGURE 2 FOR REGIONS WITH M.A.P. = 2200

RECURRENCE INTERVAL in years	Time in hours	0,25	0,50	0,75	1	RAINFALL REGION
		INTENSITY		in	mm / hr	
2		42,8 72,0 100,0	30,0 53,0 73,0	24,7 45,2 60,0	24,0 45,0 57,0	winter year-round summer
5		68,0 126,0 168,0	52,0 104,0 126,0	45,2 93,4 102,7	45,0 98,0 98,0	w y-r s
10		88,0 162,0 212,0	68,0 144,0 156,0	57,4 126,7 126,7	58,0 120,0 120,0	w y-r s
20		104,0 208,0 252,0	86,0 188,0 188,0	73,4 152,0 152,0	74,0 147,0 147,0	w y-r s
50		132,0 270,0 300,0	106,0 222,0 222,0	91,5 187,0 187,0	90,0 183,0 178,0	w y-r s
100		160,0 352,0 352,0	130,0 270,0 270,0	112,0 220,0 220,0	110,0 210,0 210,0	w y-r s

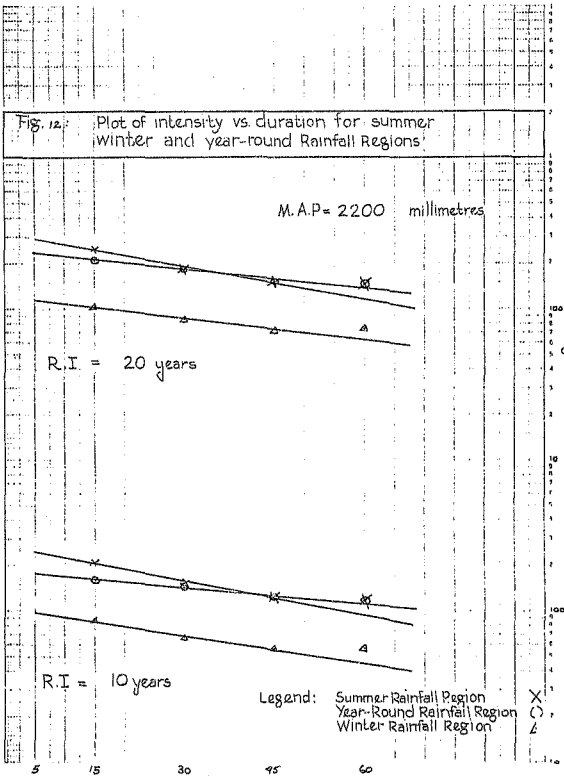


Fig. 12: Plot of intensity vs. duration for summer winter and year-round Rainfall Regions

Fig 13: Plot of intensity vs. duration for Summer Winter and year-round Rainfall Regions

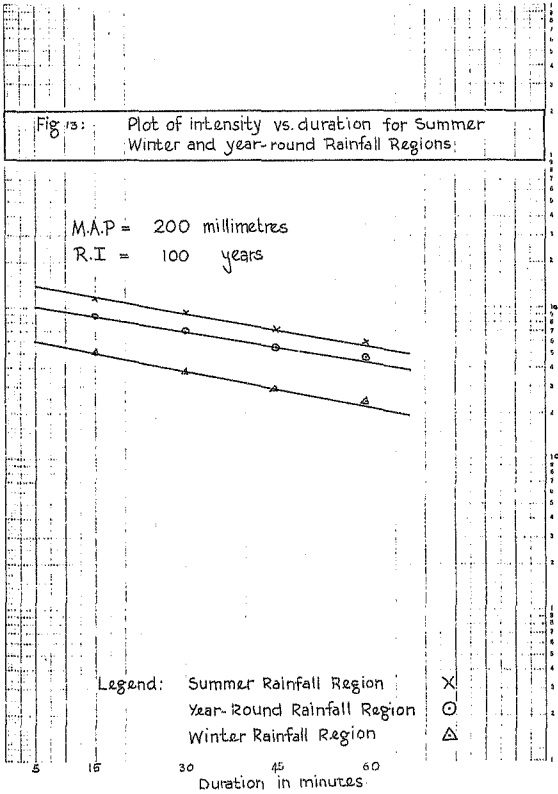
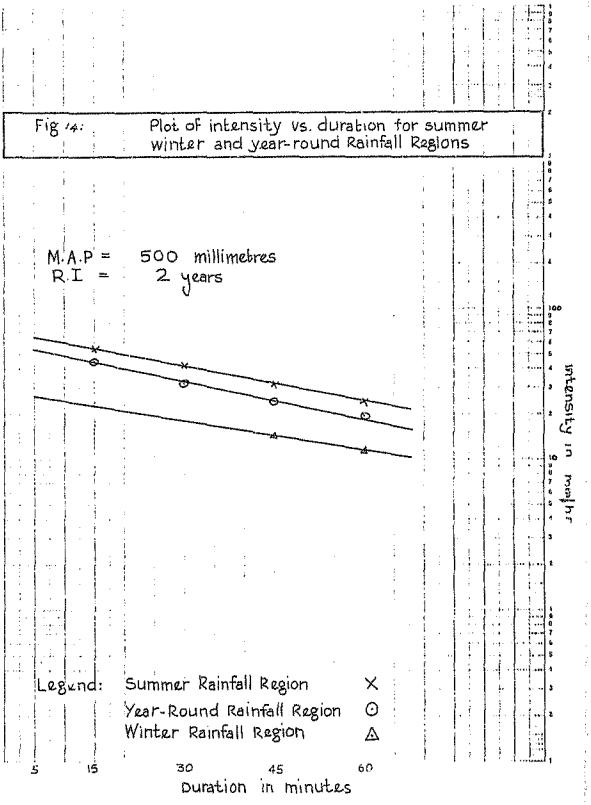


Fig 4: Plot of intensity vs. duration for summer winter and year-round Rainfall Regions



APPENDIX B

DERIVATION OF THE NUMERICAL INTEGRATION EQUATION FOR SPATIALLY VARIED FLOW

In deriving the numerical integration equation the assumptions are as outlined in Chapter 3, page 19 and the flow situation is as shown in Figure 7.

Consider Figure 7. Energy losses are high and thus momentum considerations are applied. Consider the momentum per unit time or momentum flux passing section1. This equals $Q\rho V$ where Q and V are the discharge and average velocity at section 1. Or written in another form $\frac{\gamma V Q}{g}$

Similarly the momentum flux at section 2 is $\frac{\gamma}{g}(Q + dQ)(V + d V)$ where dQ and dV are the changes in discharge and velocity between sections 1 and 2. The change of momentum flux between sections 1 and 2 is thus:-

$$\frac{\gamma}{g}(Q + dQ)(V + dV) - \frac{\gamma}{g} QV = \frac{\gamma}{g}(QdV + (V + dV)dQ)$$

This rate of change of momentum is, according to Newton II, equated to the forces causing it. These forces are the frictional force Ff, the pressure forces F_1 and F_2 and the component of the sections own weight in the direction of flow, W^1.

The values of these forces are as follows:

Let W be the weight of the body of water between the sections. Then the component of W in the flow direction is $W\sin\theta$, where

θ = channel slope and $W \sin\theta = (A + \frac{1}{2}dA)dx.So$

i.e. $W^1 \approx \gamma Adx.So$

where $So = \tan\theta \approx \sin\theta$ and 2nd order terms are neglected.

The drop in friction head between the two sections is equal to the slope of the energy line, Sf, multiplied by the section length, dx, or $hf = Sf \cdot dx$ where Sf may, by assumption, be evaluated by the Manning equation as

$$Sf = \frac{\bar{V}^2 n^2}{R^{4/3}} = \frac{\bar{Q}^2 n^2}{\bar{A}^2 R^{4/3}}$$ where the bar refers to mean values.

The frictional force along the channel floor, Ff, is then equal to the equivalent pressure due to the friction head loss multiplied by the average area.

i.e. $Ff = hf\gamma(A + \frac{1}{2}dA)$

$= Sf \cdot dx \cdot \gamma \cdot (A + \frac{1}{2}dA)$

neglecting 2nd order terms $Ff = Sf \cdot dx \cdot \gamma A$ where Sf is as shown above.

The pressure force on section 1, F_1, is the pressure at the centroid of section 1 multiplied by the area. Similarly the pressure force on section 2, F_2, is the pressure at the centroid of section 2 multiplied by the area of section 2. (see Fig.15 below).

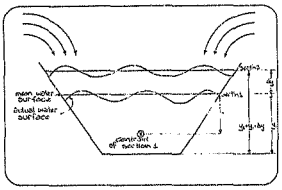


Fig 15 : Section on channel with sparsely varied flow

Thus $F_1 = \bar{z} A \gamma$

$F_2 = \gamma(\bar{z} + d y) A + \frac{\gamma}{2} d A dy$

or neglecting 2nd order terms

$F_2 = \gamma(\bar{z} + dy)A$

The resultant hydrostatic pressure force acting on the free body between sections 1 and 2 is thus: $F_1 - F_2 = -\gamma A\, dy$

Applying Newton II to the free body gives:

$$\frac{\gamma}{g}\left(QdV + dQ(V + dV)\right) = F_1 - F_2 - W^1 + Ff$$

$$= -\gamma A\, dy - \gamma A dx\, So + Sf dx\, \gamma A$$

Considering the differentials as small finite increments, the equation may be rewritten:-

$$\frac{\gamma}{g}\left(Q\Delta V + \Delta Q(V + \Delta V)\right) = -\gamma \int_0^y A dy - \gamma\, So \int_0^y A dx + \gamma\, Sf \int_0^y A dx$$

$$= -\gamma \bar{A} \Delta y - \gamma So\, \bar{A}\, \Delta x + \gamma Sf\, \bar{A}\, \Delta x$$

where $\bar{A}$ is the average area.

Since the discharge varies with the finite increment of the channel length, the average area may be taken as:-

$$\bar{A} = \frac{Q_1 + Q_2}{V_1 + V_2}$$

Also $V_2 = V_1 + \Delta V$

Thus $\frac{\gamma}{g}\left(Q_1 \Delta V + \Delta Q V_2\right) = -\gamma \bar{A} \Delta y - \gamma So\, \bar{A} \Delta x + \gamma Sf\, \bar{A} \Delta x$

i.e. $\Delta y = -So\, \Delta x + Sf \Delta x - \frac{1}{\bar{A} g}\left(Q_1 \Delta V + \Delta Q\, V_2\right)$

i.e. $\Delta y = -So\, \Delta x + Sf \Delta x - \dfrac{\left(Q_1 \Delta V + \Delta Q\, V_2\right)}{\left(\dfrac{Q_1 + Q_2}{V_1 + V_2}\right) \cdot g}$

Thus $\Delta y = -So\Delta x + Sf\Delta x - \left(\frac{V_1 + V_2}{Q_1 + Q_2}\right) \frac{Q_1}{g}\left(\Delta V + \frac{\Delta Q\, V_2}{Q_1}\right)$

Referring to Fig.7, it is seen that the change in water surface elevation between sections 1 and 2 is given by:-

$$dy^1 = y_2 + Sodx - y_1$$

$$= Sodx + dy$$

When dy^1 is the increase in depth from 1 to 2

Converting to finite increments:

$$\Delta y^1 = Sodx + \Delta y$$

Substituting for Δy *in* the equation for Δy above and introducing the energy correction factor for non-uniform velocity distribution α, gives:-

$$\Delta y^1 = Sf\Delta x - \left(\frac{V_1 + V_2}{Q_1 + Q_2}\right) \alpha \frac{Q_1}{g}\left(\Delta V + \frac{\Delta Q V_2}{Q_1}\right)$$

This equation is the numerical equation used to determine the water surface profile in a spatially varied flow situation. On the right hand side of the equation, the first term *represents* the effects of friction, while the second term represents the effects of impact loss, turbulence etc.

APPENDIX C

DETAILS OF ALL COMPUTER PROGRAMMES USED

PROGRAMME TO CALCULATE THE END DEPTH IN HALF-ROUND GUTTERS

NAME: GUT 2

OBJECT: To calculate the end depth in half-round gutters

INPUTS:

	Gutter radius	R
	Output code	K
	Gutter length	X
	Gutter discharge rate	Q

OUTLINE OF COMPUTATIONAL METHOD:

The end depth is equal to 0,715 times the critical depth. The critical depth is found using the identity:-

$$\frac{Q^2 B}{gA^3} = 1 \quad \text{when flow is critical}$$

i.e. $$\frac{Vcr^2}{g} = \frac{A}{B} = Ym \qquad \ldots\ldots \quad C.1$$

where Vcr = critical velocity

A = area of flow

B = width of water surface

Ym = mean flow depth

To determine the critical depth, an estimate of the critical depth is made and equation C.1 checked. If the two sides of the equation are not to within the specified accuracy, the critical depth is re-estimated and the process repeated until the required accuracy is obtained.

OUTPUTS: Output Code K ≠ 1 - the values of the variables after each iteration are printed out

Output Code K = 1 - the final results are printed out. The critical depth, end depth, and values of Vcr^2/g and Ym are printed out.

Calibration of Programme

The following variables were found, by trial and error, to give the best results;

(i) Initial estimate of flow depth $\left(\frac{Q^2}{(0,66R)^2 g}\right)^{0,333}$

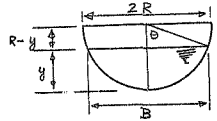
(ii) Accuracy limits of equation — 0,001 metres

(iii) Increments to initial estimate of depth-0,001 metres

Limits Placed on Programme

If the number of iterations exceeds 40 the programme stops.

Geometry and Symbols

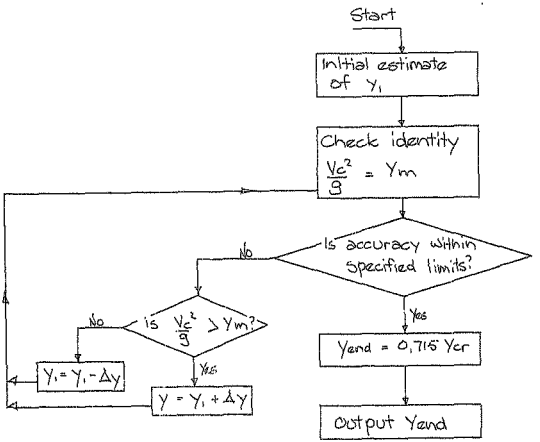


$$\theta = \cos^{-1}\left(\frac{R - Y}{R}\right)$$

$$B = 2R \sin\theta$$

$$A = \frac{1}{2} R^2 (2\theta^c - \text{Sin } 2\theta^\circ)$$

FLOW CHART FOR SUB. 2.



```
PTC      ACCT 3    DEPT OF CIVIL ENG                    FILE   GUT2                    FRI 13/12/74 (74-347)      TIME  9.20

L.0001 C      TO FIND THE CRITICAL DEPTH IN A HALF ROUND GUTTER
L.0002        REAL Y(40),THETA(40),B(40),A(40),V(40),YM(40)
L.0003        REAL YM(40)
L.0004        READ(5,1) R,K,X,C
L.0005 1      FORMAT(6X)
L.0006 C      CRITICAL DEPTH OF RECTANGULAR CHANNEL
L.0007        WRITE(6,2) R,K,X
L.0008 2      FORMAT(///T20,'RADIUS OF GUTTER=',F6.4/T20,'LENGTH OF GUTTER=',F6.4/T20,'OUTLET DISCHARGE=',F7.5)
L.0009        I=1
L.0010 C      INITIAL ESTIMATE
L.0011        Y(I)=(C*X/(2.*(SQRT(R**2-R**2)))**0.333333
L.0012        WRITE(6,13)
L.0013        WRITE(6,25) I,Y(I)
L.0014 25     FORMAT(T2,I3,T7,F4.6)
L.0015 13     FORMAT(T2,'I',T6,'ESTIMATED DEPTH',T40,'MEAN DEPTH',T60,'VEL**2/2.81'/T2,70('*'))
L.0016 C      ITERATE TO FIND CRITICAL DEPTH IN HALF-ROUND GUTTER
L.0017 7      CONTINUE
L.0018 C      ITERATE TO THE TRUE VALUE
L.0019        THETA(I)=ACOS(1-Y(I)/R)
L.0020        B(I)=R*SIN(THETA(I))
L.0021        A(I)=0.5*R**2*(2*THETA(I)-DSIN(2*THETA(I)))
L.0022        V(I)=X/A(I)
L.0023        YM(I)=A(I)/B(I)
L.0024        EN(I)=V(I)**2/9.81
L.0025        IF(ABS(YM(I)-Y(I)).LE.0.001) GO TO 3
L.0026        IF(Y(I).GT.R) GO TO 2
L.0027        IF(I.EQ.1) GO TO 17
L.0028        WRITE(6,14) I,Y(I),YM(I),EN(I),THETA(I),B(I),A(I),V(I)
L.0029 14     FORMAT(T2,I3,T20,F6.6,T40,F8.6,T60,F8.6/T2,4(F8.6,2X))
L.0030 17     I=I+1
L.0031        IF(I.EQ.39) GO TO 3
L.0032        Y(I)=Y(I-1)+0.0005
L.0033        GO TO 7
L.0034 2      IF(I.EQ.1) GO TO 18
L.0035        WRITE(6,14) I,Y(I),YM(I),EN(I),THETA(I),B(I),A(I),V(I)
L.0036 14     FORMAT(T2,I3,T20,F6.6,T40,F8.6,T60,F8.6/T2,4(F8.6,2X))
L.0037 18     I=I+1
L.0038        IF(I.EQ.39) GO TO 3
L.0039        Y(I)=Y(I-1)-0.001
L.0040        GO TO 7
L.0041 C      OUTPUT
L.0042 3      WRITE(6,11) I,Y(I),YM(I),EN(I)
L.0043        YM=0.715*Y(I)
L.0044        XCRIT=12*Y(I)
L.0045        WRITE(6,6) YM,XCRIT
L.0046 6      FORMAT(T2,'DEPTH AT DOWNPIPE=',F8.6,7X,'DIST FROM D.P. WHERE FLOW IS CRIT.=',F8.6)
L.0047 11     FORMAT(T2,I3,T20,F6.6,T40,F8.6,T60,F8.6)
L.0048        IF(I.LT.39) GO TO 12
L.0049        WRITE(6,12)
L.0050 12     FORMAT(T20,'PROGRAMME DOES NOT CONVERGE AFTER 40 ITERATIONS')
```

PROGRAMME TO CALCULATE THE WATER SURFACE
PROFILE IN HALF-ROUND GUTTERS

NAME: GUT 3

OBJECT: To calculate the water surface profile in half-round gutters, given the depth and discharge rate at outlet.

Inputs:		
	Gutter radius	R
	Number of stations	NT
	Output code	K
	Gutter length	X
	Increment to estimated depth if required accuracy is not obtained	DEL
	Limits within which the estimated and calculated flow depths must agree	ACC
	Discharge rate at outlet	Q(1)
	Flow depth at outlet	Y(1,1)

Outline of Computational Method

The depth at the outlet (station 1) is given. An estimate of the change in flow depth from station one to two is made. Using the estimated flow depth at station two and the Hinds equation, the change in flow depth from station one to two is calculated. The estimated and calculated flow depths are compared. If they do not agree to the specified accuracy, the *change* in flow depth from one to two is re-estimated and the process repeated until the required accuracy is obtained. This will define the flow depth at station two.

This iterative process is then repeated from station two to three etc., until the water surface profile in the gutter is defined.

OUTPUTS:

Code K≠1 - the values of every iteration at every station are printed out

Code K = 1 - the final values at each station are given. These include:

Station number	N
distance upstream from downpipe	DISDP(N)
discharge rate at station	Q(N)
calculated increment in depth from previous station	DELY(N,J)
assumed increment in depth from previous station	DELYAS(N,J)
flow depth	Y(N,J)

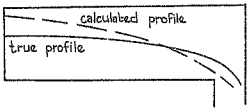
Limits placed on programme

The maximum number of iterations at any station is forty

Problems associated with programme and calibration of variables:

The programme was found to be very sensitive to the relative values of the accuracy limit (ACC) and the depth increment (DEL); If the depth increment value was much larger than the accuracy limit, the programme 'jumped' past the true depth value without the estimated and calculated depths agreeing to the specified

accuracy. The programme then oscillated about this value, never converging. On the other hand if the depth increment value was much smaller than the accuracy limit the following occurred: After about four stations the estimated depth was always greater than the true depth, thus the programme always converged on the true water surface profile from the upper side. If the depth increment value was much smaller than the accuracy value, the calculated water surface profile always lay slightly above the true profile. The error incurred at each station accumulated, resulting in an overestimate of peak depth of about 20 percent. This situation is sketched below



Thus a carefull balance had to be maintained between the depth increment and accuracy values. It was found that both the above effects were eliminated if the depth increment was twice the accuracy value (DEL = 2 x ACC). This allowed convergence and also caused the calculated water surface profile to oscillate on either side of the true profile preventing accumulation of error.

The values that gave best results were

DEL = 0,001 metres

ACC = 0,0005 metres

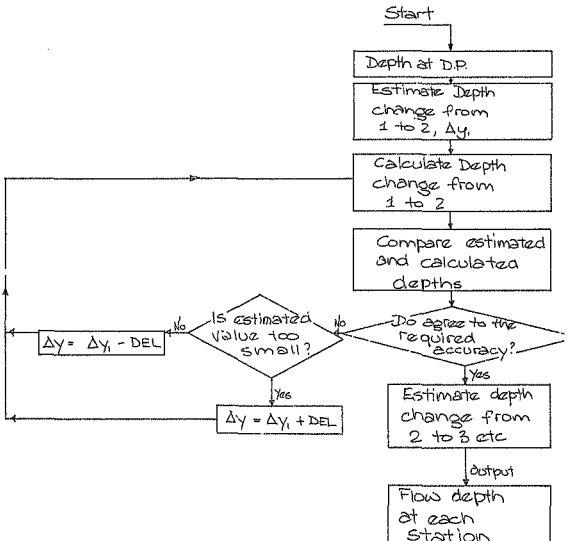
Number of Stations

NT = 20 or more, but 20 is adequate

Geometry and Symbols

as for GUT 2

FLOW CHART FOR GUT. 3



```
*****************************************************************************************************
MLM      ACCT 37   DEPT OF METALLURGY                  FILE   GUT3                  FRI 13/12/74 (74-347)      TIME  9.21
*****************************************************************************************************

L.0001 C      TO FIND THE BACKWATER CURVES IN A HALF ROUND GUTTER
L.0002        REAL Q(22),DISDP(22),DELYAS(22,40),A(22,40),V(22,40),Y(22,40),DELY(22,40),FRICY(22,40),IMPY(22,40),THETA(22,40)
L.0003        READ(6,2) R,NT,K,X,DEL,ACC,Q(1),Y(1,1)
L.0004 2      FORMAT(8F)
L.0005        DELQ=Q(1)/(NT-1)
L.0006        DELX=X/(NT-1)
L.0007        WRITE(6,13) R,X,Q(1)
L.0008 13     FORMAT(/T2,'GUTTER RADIUS=',F8.6/T2,'GUTTER LENGTH=',F8.6/T2,'OUTFLOW AT D.P.=',F8.7)
L.0009        WRITE(6,14) NT,DEL,ACC,Y(1,1)
L.0010 14     FORMAT(T2,'NO.OF STATIONS=',I3,T25,'DEL=',F6.4,T35,'ACC=',F6.4,T45,'DEPTH AT D.P.=',F8.6)
L.0011        WRITE(6,12)
L.0012 12     FORMAT(T2,'STATION NO.',I16,'DISDP',T26,'DISCH',T36,'DELY',T46,'DELYAS',T56,'Y')
L.0013        J=1
L.0014        L=1
L.0015 C      ITERATING USING HINDS FORMULA
L.0016        DO 15 N=1,NT
L.0017        I=1
L.0018        IF(N.EQ.1) GO TO 70
L.0019        DISDP(N)=(N-1)*DELX
L.0020        DELYAS(N,1)=J.01
L.0021        Q(N)=Q(N-1)-DELQ
L.0022 1      Y(N,1)=Y(N-1,J)+DELYAS(N,1)
L.0023 70     THETA(N,1)=2*ARCOS((R-Y(N,1))/R)
L.0024        A(N,1)=3.5*R**2*(THETA(N,1)-DSIN(THETA(N,1)))
L.0025        V(N,1)=Q(N)/A(N,1)
L.0026        IF(N.EQ.1) GO TO 15
L.0027        FRICY(N,1)=.016**2*((V(N,1)+V(N-1,J))/2)**2*DELX/((A(N,1)/(R*THETA(N,1))+A(N-1,J)/(R*THETA(N-1,J)))/2)**1.33333
L.0028        IMPY(N,1)=(V(N,1)+V(N-1,J))/(Q(N)+Q(N-1))*Q(N-1)/9.81*(V(N,1)-V(N-1,J)-(V(N,1)*DELQ/Q(N-1)))
L.0029        DELY(N,1)=FRICY(N,1)-IMPY(N,1)
L.0030        IF(ABS(DELY(N,1)-DELYAS(N,1)).LE.ACC) GO TO 5
L.0031        IF(I.EQ.40) GO TO 3
L.0032        IF(K.EQ.1) GO TO 17
L.0033        WRITE(6,17) N,DELY(N,1),DELYAS(N,1),Y(N,1),I
L.0034 17     FORMAT(T2,I2,T36,F7.6,T46,F7.6,T56,F7.6,T60,I2)
L.0035        IF(DELY(N,1).GT.DELYAS(N,1)) GO TO 1
L.0036        I=I+1
L.0037        DELYAS(N,1)=DELYAS(N,1-1)-DEL
L.0038        GO TO 7
L.0039 1      I=I+1
L.0040        DELYAS(N,1)=DELYAS(N,1-1)+DEL
L.0041        GO TO 7
L.0042 5      IF(DELYAS(N,1).LT.DELY(N,1)) GO TO 6
L.0043        L=L+1
L.0044        M=L-1
L.0045 6      J=1
L.0046        WRITE(6,10) N,DISDP(N),Q(N),DELY(N,[illegible]),Y(N,J)
L.0047 10     FORMAT(T2,I2,T16,F7.3,T26,F8.6,T36,F[illegible]T56,F7.6)
L.0048 15     CONTINUE
L.0049 C      [illegible]
L.0050        WRITE(6,25) M
L.0051 23     FORMAT(T2,'NO. OF TIMES [illegible] DELY =',I2)
L.0052        IF(I.LT.40) GO TO 20
L.0053 8      WRITE(6,30) N
L.0054 20     FORMAT(T2,'STATION NO.[illegible] ITERATIONS')
```

Results of GUT 3 for half-round gutters starting
with end depth Ye, at the outlet

gutter radius= .076200
gutter length=6.096000
outflow at d.p.=.0015940
no.of stations= 21 del= .0010acc= .0005depth at d.p.= .023500

station no.	disdp	disch	dely	delyas	y
2	.305	.001296	.030823	.031000	.054500
3	.610	.001228	.000900	.001000	.055500
4	.914	.001159	.000783	.001000	.056500
5	1.219	.001091	.000683	.001000	.057500
6	1.524	.001023	.000593	.001000	.058500
7	1.829	.000955	.000513	.001000	.059500
8	2.134	.000887	.000408	*.000000	.059500
9	2.438	.000818	.000370	*.000000	.059500
10	2.743	.000750	.000334	*.000000	.059500
11	3.048	.000682	.000298	*.000000	.059500
12					

gutter radius= .076200
gutter length=6.096000
outflow at d.p.=.0018180
no.of stations= 21 del= .0010acc= .0005depth at d.p.= .027000

station no.	disdp	disch	dely	delyas	y
2	.305	.001727	.036251	.036000	.063000
3	.610	.001636	.001020	.001000	.064000
4	.914	.001545	.000899	.001000	.065000
5	1.219	.001454	.000791	.001000	.066000
6	1.524	.001363	.000694	.001000	.067000
7	1.829	.001273	.000607	.001000	.068000
8	2.134	.001182	.000529	.001000	.068999
9	2.438	.001091	.000429	*.000000	.068999
10	2.743	.001000	.000387	*.000000	.068999
11	3.048	.000909	.000347	*.000000	.068999
12	3.353	.000818	.000307	*.000000	.068999
13	3.658	.000727	.000270	*.000000	.068999
14					

gutter radius= .076200
gutter length=6.096000
outflow at d.p.=.0022750
no.of stations= 21 del= .0010acc= .0005depth at d.p.= .030300

station no.	disdp	disch	dely	delyas	y
2	.305	.002159	.040299	.040000	.070300
3	.610	.002046	.001147	.001000	.071300
4	.914	.001932	.001019	.001000	.072300
5	1.219	.001818	.000904	.001000	.073300
6	1.524	.001705	.000799	.001000	.074300
7	1.829	.001591	.000703	.001000	.075300
8	2.134	.001477	.000617	.001000	.076299
9	2.438	.001364	.000538	.001000	.077299
10	2.743	.001250	.000442	*.000000	.077299
11	3.048	.001136	.000396	*.000000	.077299
12	3.353	.001022	.000352	*.000000	.077299
13	3.658	.000909	.000309	*.000000	.077299
14					

Results of GUT 3 for half-round gutters starting
with critical depth at outlet and n = 0,014

gutter radius= .376200
gutter length=5.000000
outflow at d.s.= .0005586
no.of stations= 21 dels= .0210acc= .0005 depth at d.s.= .018700

station no.	Used	Qlocal	Qdely	Qdelyas	Y
2	.105	.000852	.000846	.000000	.024700
3	.210	.000899	.001621	.000000	.026700
4	.316	.000926	.001916	.001000	.027700
5	1.311	.000954	.000812	.001000	.028700
6	1.524	.000981	.000647	.001000	.029700
7	1.737	.001010	.000510	.001000	.030700
8	1.736	.000935	.000376	*.001000	.030700
9	1.736	.000927	.000376	*.000000	.030700
10	1.945	.000950	.000207	*.000000	.030700
11	2.048	.000937	.000262	*.000000	.030700
12	2.153	.000925	.000238	*.000000	.030700
13	2.258	.000913	.000216	*.000000	.030700
14	2.363	.000900	.000196	*.000000	.030700
15	2.467	.000888	.000177	*.000000	.030700
16	2.572	.000876	.000159	*.000000	.030700
17	2.677	.000863	.000142	*.000000	.030700
18	2.782	.000851	.000126	*.000000	.030700
19	2.886	.000839	.000111	*.000000	.030700
20	2.991	.000826	.000097	*.000000	.030700
21	3.096	*.000000	.000083	*.000000	.030700

no. of times that delyas st. dely = 5
SUM= 5.55 SP= 2.67

gutter radius= .376200
gutter length=5.000000
outflow at d.s.= .0003002
no.of stations= 21 dels= .1310acc= .0005 depth at d.s.= .020400

station no.	Used	Qlocal	Qdely	Qdelyas	Y
2	.105	.000458	.000607	.000000	.034400
3	.210	.000484	.000930	.000000	.036400
4	.316	.000497	.001021	.000000	.037400
5	1.311	.000507	.000771	.001000	.038400
6	1.524	.000517	.000622	.001000	.039400
7	1.737	.000528	.000477	.001000	.040400
8	1.736	.000505	.000356	.001000	.041400
9	1.736	.000498	.000356	*.000000	.042400
10	1.945	.000510	.000197	*.000000	.043400
11	1.949	.000505	.000248	*.000000	.043400
12	2.053	.000499	.000225	*.000000	.043400
13	2.158	.000493	.000205	*.000000	.043400
14	2.263	.000487	.000186	*.000000	.043400
15	2.367	.000481	.000168	*.000000	.043400
16	2.472	.000475	.000151	*.000000	.043400
17	2.577	.000468	.000135	*.000000	.043400
18	2.682	.000462	.000120	*.000000	.043400
19	2.786	.000456	.000106	*.000000	.043400
20	2.891	.000449	.000092	*.000000	.043400
21	2.996	*.000000	.000079	*.000000	.043400

no. of times that delyas st. dely = 0
SUM= 5.57 SP= 2.54

```
gutter roughness .025000
gutter length= 5.000000
outflow at t.o.= .2313690
no.of stations= 20      dela= .2310000  lngth at d.o.= .032000
station no.    depth    disch    delv     delvas      y
  2              .521   .001202  .038823  .000000  .041000
  3              .542   .001220  .039568  .001000  .044000
  4              .563   .001240  .040259  .002000  .046900
  5             1.285   .001277  .041068  .001000  .047900
  6             1.304   .001295  .041777  .001000  .048900
  7             1.325   .001313  .042511  .001000  .049900
  8             1.346   .001331  .043262  .001000  .050900
  9             1.367   .001349  .044044  .001000  .051900
 10             1.389   .001368  .044837  .001000  .052900
 11             1.410   .001386  .045646  *.000000  .052900
 12             1.430   .001404  .046474  *.000000  .052900
 13             1.451   .001423  .047315  *.000000  .052900
 14             1.471   .001441  .048169  *.000000  .052900
 15             1.492   .001459  .049035  *.000000  .052900
 16             1.513   .001477  .049913  *.000000  .052900
 17             1.533   .001496  .050806  *.000000  .052900
 18             1.554   .001514  .051710  *.000000  .052900
 19             1.575   .001532  .052628  *.000000  .052900
 20             1.596   *.001550  .053557  *.000000  .052900
no. of times that delyas ne. dely = 7
SUM= 4.85 SUM = 2.72
```

```
gutter roughness .025000
gutter length= 5.000000
outflow at t.o.= .2313690
no.of stations= 20      dela= .2310000  lngth at d.o.= .037800
station no.    depth    disch    delv     delvas      y
  2              .521   .001230  .039023  .010000  .047900
  3              .542   .001247  .039599  .013001  .050800
  4              .563   .001264  .040170  .002000  .052800
  5             1.285   .001279  .040679  .002000  .054800
  6             1.304   .001296  .041250  .001000  .055800
  7             1.325   .001313  .041873  .001000  .056800
  8             1.346   .001330  .042516  .001000  .057800
  9             1.367   .001347  .043177  .001000  .058800
 10             1.389   .001365  .043857  .001000  .059800
 11             1.409   .001381  .044547  .001000  .060800
 12             1.430   .001398  .045255  *.000000  .060800
 13             1.451   .001415  .045979  *.000000  .060800
 14             1.471   .001431  .046719  *.000000  .060800
 15             1.492   .001448  .047475  *.000000  .060800
 16             1.513   .001465  .048246  *.000000  .060800
 17             1.533   .001482  .049032  *.000000  .060800
 18             1.554   .001498  .049833  *.000000  .060800
 19             1.575   .001515  .050648  *.000000  .060800
 20             1.596   *.001532  .051477  *.000000  .060800
no. of times that delyas ne. dely = 7
SUM= 5.13 SUM = 2.94
```

```
gutter radius= .070300
gutter length= .070300
outflow at j.p.= .0023870
no.of stations= 20      delx= .0010000  depth at d.p.= .043860
station no.    disch      disch      delq      delyas      y
  2              .532      .002851    .010452    .010000    .053800
  3              .642      .002116    .003726    .004000    .057800
  4              .783      .002019    .003539    .003900    .060800
  5             1.033      .002584    .001848    .002000    .062860
  6             1.404      .003750    .001592    .002000    .064860
  7             1.998      .001615    .001175    .001000    .065860
  8             2.496      .001498    .001014    .001000    .066860
  9             2.987      .001392    .000870    .001000    .067860
 10             3.488      .001356    .000742    .001000    .068860
 11             3.993      .001331    .000627    .001000    .069860
 12             4.520      .001315    .001524    .001000    .070859
 13             4.757      .001079    .000417   *.000000    .070859
 14             4.771      .000756    .000354   *.000000    .070859
 15             4.782      .000828    .000295   *.000000    .070859
 16             4.793      .000835    .000234   *.000000    .070859
 17             4.799      .000577    .000179   *.000000    .070859
 18             4.804      .000751    .000124   *.000000    .070859
 19             4.775      .000126    .000073   *.000000    .070859
 20             4.  [illegible]  .000018    .000024   *.000000    .070859
no. of times disk delyas wt. delq = 3
SUM= 4.03 SUM = 3.89
```

```
gutter radius= .070300
gutter length= .070300
outflow at j.p.= .0022739
no.of stations= 20      delx= .0010000  depth at d.p.= .042488
station no.    disch      disch      delq      delyas      y
  2              .531      .002357    .011[illegible]    .011000    .053400
  3              .642      .002036    .0036..    .003900    .056400
  4              .785      .001918    .003[illegible]    .003900    .059400
  5             1.033      .001704    .003205    .003900    .062400
  6             1.404      .001655    .001550    .003000    .064400
  7             1.998      .001565    .001195    .002000    .065400
  8             2.496      .001439    .001010    .001000    .066400
  9             2.987      .001336    .000870    .001000    .067400
 10             3.488      .001296    .000742    .001000    .068400
 11             3.993      .001277    .000631    .001000    .069400
 12             4.520      .001257    .001524    .001000    .070399
 13             4.757      .001019    .000417   *.000000    .070399
 14             4.771      .000696    .000354   *.000000    .070399
 15             4.782      .000768    .000295   *.000000    .070399
 16             4.793      .000775    .000234   *.000000    .070399
 17             4.799      .000517    .000177   *.000000    .070399
 18             4.804      .000691    .000124   *.000000    .070399
 19             4.775      .000066    .000073   *.000000    .070399
 20             4.  [illegible]  .000018    .000023   *.000000    .070399
no. of times disk delyas wt. delq = 7
SUM= 5.07 SUM = 3.89
```

Results of GUT 3 for half-round gutters starting with critical depth at outlet and n = 0,016

gutter radius= .[illegible]
gutter length= .[illegible]
outflow at l.p.= .[illegible]
no.of stations= [illegible] dels= .[illegible] acc= .[illegible] depth at l.p.= .018700

station no.	Hsh	Hsch	Dely	Delvas	y
2	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.024700
3	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.026700
4	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.027700
5	1.[illegible]	.[illegible]	.[illegible]	.[illegible]	.028700
6	1.[illegible]	.[illegible]	.[illegible]	.[illegible]	.029700
7	1.[illegible]	.[illegible]	.[illegible]	.[illegible]	.030700
8	2.[illegible]	.[illegible]	.[illegible]	*.[illegible]	.030700
9					
10					

gutter radius= .[illegible]
gutter length= .[illegible]
outflow at l.p.= .[illegible]
no.of stations= [illegible] dels= .[illegible] acc= .[illegible] depth at l.p.= .026400

station no.	Hsh	Hsch	Dely	Delvas	y
2	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.034400
3	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.038400
4	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.038400
5	1.[illegible]	.[illegible]	.[illegible]	.[illegible]	.039400
6	1.[illegible]	.[illegible]	.[illegible]	.[illegible]	.040400
7	1.[illegible]	.[illegible]	.[illegible]	.[illegible]	.041400
8	2.[illegible]	.[illegible]	.[illegible]	.[illegible]	.042400
9	2.[illegible]	.[illegible]	.[illegible]	.[illegible]	.043400
10	2.[illegible]	.[illegible]	.[illegible]	*.[illegible]	.043400
11					

gutter radius= .[illegible]
gutter length=[illegible]
outflow at d.p.=.[illegible]
no.of stations= [illegible] Hole= .[illegible] Depth at d.p.= .032900

station no.	Hole	Hsd	Hsd	Hsly	Hsly	Hsyns	y
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.000000	.041000
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.005000	.044000
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.002000	.046000
5	1.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.001000	.047000
6	1.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.001000	.048000
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.001000	.049000
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.001000	.050000
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.001000	.051000
10	2.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.001000	.052000
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.000000	.052000
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.000000	.052000
13							

gutter radius= .[illegible]
gutter length=[illegible]
outflow at d.p.=.[illegible]
no.of stations= [illegible] Hole= .[illegible] Depth at d.p.= .0378[illegible]

station no.	Hole	Hsd	Hsd	Hsly	Hsly	Hsyns	y
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.047000
3	1.[illegible]	.001[illegible]	.001[illegible]	.001000	.001000	.050000	
4	2.[illegible]	.001[illegible]	.000[illegible]	.001000	.001000	.050000	
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14							
15							

gutter radius= .070211
gutter length= .196200
outflow at i,e,s .022710
no.of stations 21 tole .010000 .0005 out at d,p,= .042411

station no.	dist	dely	delyns	y
2	.015	.011100	.011100	.055400
3	.031	.020000	.020000	.057400
4	.046	.020000	.020000	.057400
5	.062	.020000	.020000	.057400
6	.078	.020000	.020000	.057400
7	.093	.020000	.020000	.057400
8	.109	.020000	.020000	.057400
9	.125	.020000	.020000	.057400
10	.140	.020000	.020000	.057400
11	.156	.020000	.020000	.057400
12	.172	.020000	.020000	.057400
13	.187	.020000	.020000	.057400
14	.203	.020000	.020000	.057400

gutter radius= .070211
gutter length= .196200
outflow at i,e,s .022710
no.of stations 21 tole .010000 .0005 out at d,p,= .043811

station no.	dist	dely	delyns	y
2	.015	.011100	.011100	.055400
3	.031	.020000	.020000	.057400
4	.046	.020000	.020000	.057400
5	.062	.020000	.020000	.057400
6	.078	.020000	.020000	.057400
7	.093	.020000	.020000	.057400
8	.109	.020000	.020000	.057400
9	.125	.020000	.020000	.057400
10	.140	.020000	.020000	.057400
11	.156	.020000	.020000	.057400
12	.172	.020000	.020000	.057400
13	.187	.020000	*.020000	.057400
14	.203	.020000	*.020000	.057400
15	.218	.020000	*.020000	.057400
16	.234	.020000	*.020000	.057400
17	.250	.020000	*.020000	.057400
18	.265	.020000	*.020000	.057400
19	.281	.020000	*.020000	.057400
20	.296	.020000	*.020000	.057400
21	.312	.020000	*.020000	.057400

no. of times this delyns ne. dely = 0

PROGRAMME TO FIND THE WATER SURFACE PROFILE
IN RECTANGULAR GUTTERS

NAME: GUT 6

OBJECT: To determine the water surface profile in rectangular gutters given the discharge rate at outlet

Inputs: Base breadth B

The remaining inputs - as for GUT 3

Outline of Programme

The programme is the same as GUT 3 except that the starting depth at station one (equal to the critical depth) is calculated by the programme

General

All other facets of this programme are the same as GUT 3

```
*****************************************************************************************************************
PTC      ACCT 3    DEPT OF CIVIL ENG                    FILE   GUT6                    CUE 17/12/74 (74-351)      TIME 15.09
*****************************************************************************************************************
L.0001        REAL Q(22),INF,DISDP(22,41),DELYAS(22,41),A(22,41),V(22,41),WPER(22,41),Y(22,41),VF(22,41),WPERF(22,41),Z(22,41)
L.0002        REAL DELY(22,41),FRICY(22,41),IMPY(22,41),MAN,AF(22,41)
L.0003        INTEGER K
L.0004        READ(1,2)G,NT,K,X,DEL,ACC,Q(1)
L.0005        MAN=.014
L.0006 2      FORMAT(7X)
L.0007 INF=Q(1)/K
L.0008        DELQ=Q(1)/(NT-1)
L.0009        DELX=X/(NT-1)
L.0010        Y(1,1)=(Q(1)**2/(B**2*9.81))**0.333333
L.0011        A(1,1)=B*Y(1,1)
L.0012        V(1,1)=Q(1)/A(1,1)
L.0013        WPERF(1,1)=B+2*Y(1,1)
L.0014        DISDP(1)=0.
L.0015        I=1
L.0016        Z(1)=Y(1,1)
L.0017        VF(1)=V(1,1)
L.0018        AF(1)=A(1,1)
L.0019        WPERF(1)=WPER(1,1)
L.0020        WRITE(6,1)G,INF,X
L.0021        WRITE(6,14)NT,DELX,Q(1)
L.0022 13     FORMAT(///T22,'GUTTER BREADTH=',F6.4,'M',/T20,'INFLOW PER UNIT LENGTH =',F6.4,'CU.M/S',/T20,'GUTTER LENGTH=',I4,'M')
L.0023 14     FORMAT(T20,'NO.OF STATIONS=',I3,5X,'STATION LENGTH=',F6.3,'M',/T20,'OUTLET DISCHARGE=',F6.4,'CU.M/S')
L.0024        WRITE(6,12)
L.0025 12     FORMAT(///T2,'STATION NO',T16,'DISP',T26,'AREA',T36,'VEL',T46,'DISCH',T56,'DELY',T66,'DELYAS',T78,'Y'/T2,83('*'))
L.0026
L.0027        WRITE(6,11)A,DISDP(I),A(I,I),V(I,I),Q(I),Y(I,I)
L.0028 11     FORMAT(T6,I2,T16,F7.3,T26,F7.4,T36,F7.5,T46,F7.6,T76,F7.3)
L.0029        J=1
L.0030        DO 15 N=2,NT
L.0031        DISDP(N,1)=DISDP(N-1)+DELX
L.0032        IF(N.GT.2) GO TO 83
L.0033        DELYAS(N,1)=0.03
L.0034        IF(N.LT.3) GO TO 84
L.0035 83     DELYAS(N,1)=0.01
L.0036 84     Q(N)=Q(N-1)-DELQ
L.0037        I=1
L.0038 7      CONTINUE
L.0039        Y(N,I)=Z(N-1)+DELYAS(N,I)
L.0040        A(N,I)=B*Y(N,I)
L.0041        V(N,I)=Q(N)/A(N,I)
L.0042        WPER(N,I)=Y(N,I)*2+B
L.0043     FRICY(N,I)=(MAN**2)*((V(N,I)+VF(N-1))/2)**2)*DELX/((A(N,I)/WPER(N,I)+AF(N-1)/WPERF(N-1))/2)**1.33333)
L.0044        IMPY(N,I)=(V(N,I)+VF(N-1))/(Q(N)+Q(N-1))*Q(N-1)/9.81*((V(N,I)-VF(N-1))+V(N,I)*(Q(N)-Q(N-1))/Q(N-1))
L.0045        DELY(N,I)=FRICY(N,I)-IMPY(N,I)
L.0046        IF(ABS(DELYAS(N,I)-DELY(N,I)).LE.ACC) GO TO 5
L.0047        IF(K.EQ.1) GO TO 17
L.0048        WRITE(5,10)N,DISDP(N),A(N,I),V(N,I),Q(N),DELY(N,I),DELYAS(N,I),Y(N,I)
L.0049 17     IF(DELYAS(N,I)-DELY(N,I)) 1,5,3
L.0050 1      I=I+1
L.0051        IF(I.EQ.40) GO TO 8
L.0052        DELYAS(N,I)=DELYAS(N,I-1)+DEL
L.0053        GO TO 7
L.0054        I=I+1
```

```
L.0345      IF(I.EQ.40) GO TO 8
L.0346      DELYAS(N,I)=DELYAS(N,I-1)-DEL
L.0357      GO TO 7
L.0358 5    Z(N)=Y(N,I)
L.0359      VF(N)=V(N,I)
L.0360      AF(N)=A(N,I)
L.0361      PROF(N)=PROFIN,I)
L.0362      IF(DELYAS(N,I).LT.DELY(N,I)) GO TO 6
L.0363      J=J+1
L.0364      L=J-1
L.0365 6    WRITE(6,101)N,DISPIN),AF(N),VF(N),O(N),DELY(N,I),DELYAS(N-1),Z(N)
L.0366 15   CONTINUE
L.0367      WRITE(5,23)L
L.0368 23   FORMAT(I2,'NUMBER OF TIMES THAT DELYAS IS GREATER THAN DELY =',I3)
L.0369      IF(I.LT.40) GO TO 20
L.0370 8    WRITE(6,200)
L.0371 20   FORMAT(/I2,'STATION NO.=',I3,5X'TOO MANY ITERATIONS')
L.0372 10   FORMAT(I5,I2,T16,F7.3,T26,F7.5,T36,F7.5,T46,F7.6,T56,F8.6,T66,F8.6,T76,F7.5)
```

Results of GUT 6 for Channel with b = 0,229m, x = 2,286m, and n = 0,014

[illegible]								
[illegible]	18	2,157	.07767	.07767	.003535	.001010	.001000	.42033
[illegible]	19	2,172	.07767	.05417	.003535	.001010	.001000	.42033
[illegible]	20	2,186	.07767	*.00000	*.000000	.000202	*.000000	.42033
[illegible]	number of times that delyas is greater than dely = 11							
[illegible]								
[illegible]	18	2,157	.07767	.07767	.003535	.001010	.001000	.32673
[illegible]	19	2,172	.07767	.05417	.003535	.001010	.001000	.32673
[illegible]	20	2,186	.07767	*.00000	*.000000	.000202	*.000000	.32673
[illegible]	number of times that delyas is greater than dely = 9							
[illegible]								
[illegible]	18	2,157	.07767	.07767	.003535	.001010	.001000	.33033
[illegible]	19	2,172	.07767	.05417	.003535	.001010	.001000	.33033
[illegible]	20	2,186	.07767	*.00000	*.000000	.000202	*.000000	.33033
[illegible]	number of times that delyas is greater than dely = 10							
[illegible]								
[illegible]	18	2,157	.07767	.07767	.003535	.001010	.001000	.30674
[illegible]	19	2,172	.07767	.05417	.003535	.001010	.001000	.30674
[illegible]	20	2,186	.07767	*.00000	*.000000	.000202	*.000000	.30674
[illegible]	number of times that delyas is greater than dely = 11							
[illegible]								
[illegible]	18	2,157	.08580	.07767	.004331	.001010	.001000	.27862
[illegible]	19	2,172	.08580	.05417	.004331	.001010	.001000	.27862
[illegible]	20	2,186	.08580	*.00000	*.000000	.000202	*.000000	.27862
[illegible]	number of times that delyas is greater than dely = 12							
[illegible]								
[illegible]	18	2,157	.05417	**.06535	.003542	.000556	.001000	.23055
[illegible]	19	2,172	.05417	.03267	.001770	.000278	*.000000	.23055
[illegible]	20	2,186	.05417	*.00000	*.000000	.000139	*.000000	.23055
[illegible]	number of times that delyas is greater than dely = 0							

Results of GUT 6 for channel with B = 0,229m and x = 1,716m and n = 0,014

Y

/Gout 33								
L.033	19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
L.034	20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
L.035	21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
L.036	number of times that delyas is greater than dely = 11							

/Gout 33								
L.033	19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
L.034	20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
L.035	21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
L.036	number of times that delyas is greater than dely = 11							

/Gout 33								
L.033	19	1.544	.05803	.00725	.003636	.000535	.001000	.25541
L.034	20	[illegible]	.05803	.00721	.001050	.000353	*.000000	.25541
L.035	21	[illegible]	.05805	*.00000	*000000	.000117	*.000000	.25541
L.036	number of times that delyas is greater than dely = 10							

/Gout 33								
L.033	19	1.544	.04270	.05835	.002492	.000457	*.000000	.18648
L.034	20	1.650	.04270	.02919	.001248	.000201	*.000000	.18648
L.035	21	1.716	.04270	*.00000	*000000	.000087	*.000000	.18648
L.036	number of times that delyas is greater than dely = 11							

Results of GUT 6 with B = 0,229m and x = 1,335m and n = 0,014

y

```
/dout 33
 1.335     19          1.201    .07530    .10710    .207770    .2010691    .2013290    .37157
 1.335     20          1.248    .07552    .08477    .208450    .2007330    .2013290    .37257
 1.335     21          1.295    .07552    *.08477   *.208450   .2007330    .2013290    .37257
 1.335  number of times that delyas is greater than delv = 12
/dout 33
 1.335     19          1.201    .07825    .08778    .208450    .2008660    .2013290    .37257
 1.335     20          1.248    .07825    .08778    .208450    .2008660    .2013290    .37257
 1.335     21          1.295    .07825    *.08778   *.208450   .2008660    .2013290    .37257
 1.335  number of times that delyas is greater than delv = 13
/dout 33
 1.335     19          1.201    .07998    .07998    .208450    .2008660    .2013290    .37257
 1.335     20          1.248    .07998    .07998    .208450    .2008660    .2013290    .37257
 1.335     21          1.295    .07998    *.07998
```

Results of GUT 6 with B = 0,229m, x = 2,28m and n = 0,016

/out 33								Y
L.333	10	2.057	.07707	.07033	.0070855	.0031033	.0031033	.42734
L.334	20	2.172	.07707	.07033	.0070855	.0031033	.0031033	.42734
L.335	21	2.286	.07707	*.07033	*.0070855	.0031033	*.0031033	.42734
L.336	number of times that delyas is greater than dely =							
/out 33								
L.333	10	2.057	.07707	.07033	.0070855	.0031033	.0031033	.42734
L.334	20	2.172	.07707	.07033	.0070855	.0031033	.0031033	.42734
L.335	21	2.286	.07707	*.07033	*.0070855	.0031033	*.0031033	.42734
L.336	number of times that delyas is greater than dely =							
/out 33								
L.333	10	2.057	.07707	.07033	.0070855	.0031033	.0031033	.42734
L.334	20	2.172	.07707	.07033	.0070855	.0031033	.0031033	.42734
L.335	21	2.286	.07707	*.07033	*.0070855	.0031033	*.0031033	.42734
L.336	number of times that delyas is greater than dely = 22							
/out 33								
L.333	10	2.057	.07707	.07033	.0070855	.0031033	.0031033	.42734
L.334	20	2.172	.07707	.07033	.0070855	.0031033	.0031033	.42734
L.335	21	2.286	.07707	*.07033	*.0070855	.0031033	*.0031033	.42734
L.336	number of times that delyas is greater than dely =							
/out 33								
L.333	10	2.057	.07707	.07033	.0070855	.0031033	.0031033	.42734
L.334	20	2.172	.07707	.07033	.0070855	.0031033	.0031033	.42734
L.335	21	2.286	.07707	*.07033	*.0070855	.0031033	*.0031033	.42734
L.336	number of times that delyas is greater than dely = 11							
/out 33								
L.333	10	2.057	.06405	.05731	.0034551	.0031033	.0031033	.27362
L.334	20	2.172	.06405	.05731	.0034551	.0031033	.0031033	.27362
L.335	21	2.286	.06405	*.05731	*.0034551	.0031033	*.0031033	.27362
L.336	number of times that delyas is greater than dely = 11							
/out 33								
L.333	10	2.057	.05417	.04559	.0033540	.0031033	.0031033	.23655
L.334	20	2.172	.05417	.04559	.0033540	.0031033	.0031033	.23655
L.335	21	2.286	.05417	*.04559	*.0033540	.0031033	*.0031033	.23655
L.336	number of times that delyas is greater than dely = 0							

Results of GUT 6 with B = 0,229m and x = 1,716m and n = 0,016

y

Results of GUT 6 with B = 0,229m and x = 1,335m and n = 0,016

Y

```
/Gout 33
L.033      19          1.201   .05532   .06227   .007073   .000880   .001000   .37257
L.034      20          1.268   .05533   .04137   .003551   .000520   .001000   .37357
L.035      21          1.335   .05533   *.00000   *000000   .000175   *.000000   .37357
L.036   number of times that delyas is greater than dely = 11

/Gout 33
L.033      19          1.201   .05067   .07002   .004248   .000034   .001000   .26404
L.034      20          1.268   .05067   .03501   .002124   .000375   *.000000   .26404
L.035      21          1.335   .05067   *.00000   *000000   .000125   *.000000   .26404
L.036   number of times that delyas is greater than dely = 8

/Gout 33
L.033      19          1.201   .04822   .06227   .003003   .000497   *.000000   .21057
L.034      20          1.268   .04822   .03114   .001501   .000298   *.000000   .21057
L.035      21          1.335   .04822   *.00000   *000000   .000000   *.000000   .21057
L.036   number of times that delyas is greater than dely = 8

/Gout 33
L.033      19          1.201   .05053   .07502   .005000   .000720   .001000   .30700
L.034      20          1.268   .05053   .03500   .002000   .000520   *.000000   .30700
L.035      21          1.335   .05053   *.00000   *000000   .000234   *.000000   .30700
L.036   number of times that delyas is greater than dely = 10

/Gout 33
L.033      19          1.201   .05000   .07050   .005000   .000544   .001000   .26627
L.034      20          1.268   .05000   .03500   .002151   .000301   *.000000   .26627
L.035      21          1.335   .05000   *.00000   *000000   .000127   *.000000   .26627
L.036   number of times that delyas is greater than dely = 8

/Gout 33
L.033      19          1.201   .05067   .07002   .004248   .000034   .001000   .26404
L.034      20          1.268   .05067   .03501   .002124   .000375   *.000000   .26404
L.035      21          1.335   .05067   *.00000   *000000   .000125   *.000000   .26404
L.036   number of times that delyas is greater than dely = 8

/Gout 33
L.033      19          1.201   .04822   .06227   .003003   .000497   *.000000   .21057
L.034      20          1.268   .04822   .03114   .001501   .000298   *.000000   .21057
L.035      21          1.335   .04822   *.00000   *000000   .000000   *.000000   .21057
```

PROGRAMME TO DETERMINE THE DESIGN DEPTH
IN RECTANGULAR GUTTERS

NAME: CRECTI

OBJECT To estimate the design depth in rectangular gutters for various gutter lengths and inflow rates

Checks

The validity of the programme was checked by comparing the peak depths with those calculated by GUT 6. Both these peak depths were compared with the Li experimental peak depths. See Table 31

Inputs:		
	Gutter base breadth	B
	Number of stations	NT
	Output code	K
	Inflow per unit length to gutter	INF
	Gutter length	X

Outline of Programme

For particular inflow and length values, the critical depth at outlet is calculated. This is used as the starting depth in the Hinds analysis. The water surface profile in the gutter is calculated in the manner discussed in Appendix B. (i.e. the same approach as adopted in GUT 3). Once the water surface profile has been calculated, the upstream depth is abstracted. This is the peak depth and the design depth is obtained by adding the freeboard to it. A rough check on the design depth so calculated is obtained by multiplying the critical depth

by $\sqrt{3}$ (for an explanation see Chapter 6).

Outputs:

Code K = 1 - values of all variables after every iteration at every station are given

Code K = 2 - final values of variables and flow depths are given at each station

Code K > 2 - the values at the last upstream station are given. These include;

Gutter length	X
critical flow depth	Y(1,1)
$\sqrt{3}$ times critical flow depth	YUPS
peak flow depth	Y(NT,J)
peak flow area	A(NT,J)
design flow depth	YFIN
design flow area	AFIN

Limits placed on programme

The maximum number of iterations at any station is 40.

Problems associated with programme

Some problems as for GUT 3 and in addition a further problem occurred when analysing large gutters with large inflow rates. In such gutters the depth change between stations at the first few stations is large. If the values of accuracy bounds (ACC) and assumed depth increment (DEL) as used for smaller gutters are used with these large gutters, the programme will not converge in 40 iterations. Hence;

for gutters of base breadth greater than 0,3m use

ACC =0,001metres

DEL =0,002metres

for smaller gutters use

ACC =0,0005 metres

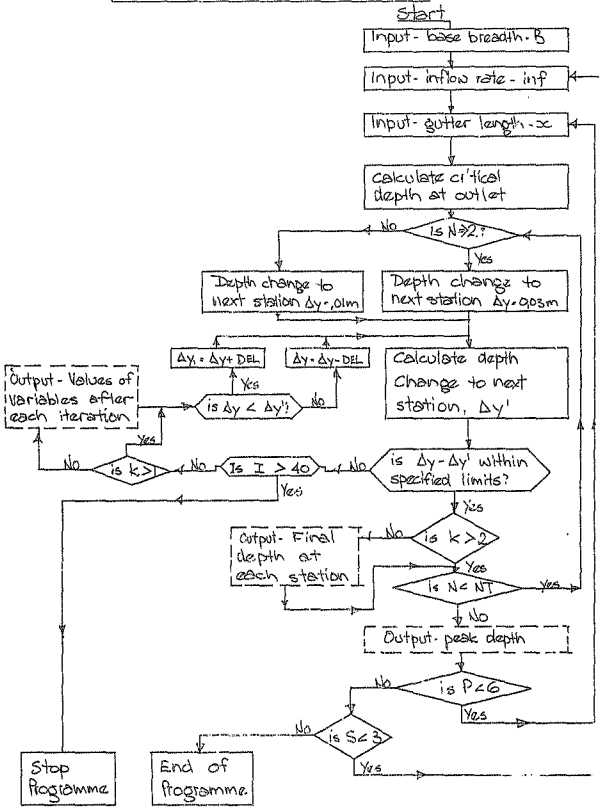
DEL = ,001 metres

In all instances it was found that twenty one stations gave adequate results, i.e. NT = 21.

TABLE 31: COMPARISON OF LI'S RESULTS WITH OUTPUTS OF GUT 6 AND CRECTI

CHANNEL LENGTH in metres	DISCHARGE RATE $m^3/'S$	PEAK DEPTH AFTER LI in metres	PEAK DEPTH FROM GUT 6 in metres	PEAK DEPTH FROM CRECTI in metres
2,286	0,06060	0,3383	0,3366	0,3365
2,286	0,08665	0,4267	0,4274	0,4279
1,716	0,02492	0,1890	0,1865	0,1864
1,335	0,05380	0,3353	0,3099	0,3114

FLOW CHART FOR CRECT 1



```
C     PROGRAM TO FIND THE MAX. WATER DEPTH IN RECTANGULAR GUTTERS
      REAL Q(22),DF,THISME(22),PELVAS(22,41),A(22,41),V(22,41),WPER(22,41),Y(22,41),DELY,FRICY,IMPY,MAN
      IMPLICIT REAL*8(A-H,O-Z)
      KOUNT=0
      IMAX=0
      READ(5,1) S,AT,K
      FORMAT(F)
      WRITE(6,2)S,AT,K
2     FORMAT(///,'S=',F8.6,2X,'AT=',F8.6,2X,'K=',F8.6)
      WRITE(6,3)
3     FORMAT(///,'*',T41,'*'/T42,'*',T91,'*'/T42,'*',2X,'RECTANGULAR GUTTER OF BASE WIDTH=',2X,F6.4,2X,'M',2X,'*')
      WRITE(6,4)
4     FORMAT(T42,'*',T91,'*'/T42,50('*'))
      READ(5,*) N
      ACCES=.01
      MAN=.015
      READ(5,*) Q(1)
C     ITERATIONS FOR DIFFERENT INFLOWS
      READ(5,*) IMP
      DO 5 I=1,IMP
      READ(5,*) DELX
5     CONTINUE
      WRITE(6,11) DELX
11    FORMAT(///,'INFLOW PER UNIT LENGTH OF GUTTER=',2X,F8.6,2X,'CU.M/S.'/T42,52('*'))
C     ITERATIONS FOR DIFFERENT GUTTER LENGTHS
      DO 12 M=1,N
      READ(5,*) X
      WRITE(6,13)X
13    FORMAT(///,'GUTTER LENGTH=',2X,F8.6,2X,'M.')
C     INITIAL VALUE AT FOURPIPE =CRITICAL DEPTH
      Q(1)=DF*X
      DELY=Q(1)/(K*(1-1))
      DELX=Q(1)/(K*1)
      Y(1,1)=(Q(1)**2/(G**2*9.81))**0.333333
      A(1,1)=B*Y(1,1)
      V(1,1)=Q(1)/A(1,1)
      WPER(1,1)=B+2*Y(1,1)
      DISCHE(1)=0.
      J=1
      I=1
C     FINDING DEPTH OF WATER AT ALL STATIONS USING HINDS FORMULA
      DO 15 I=2,NT
      DISCHE(I)=DISCHE(I-1)+DELX
      IF(I.GT.1) GO TO 83
      DELYS(M,1)=0.07
      IF(I.LT.1) GO TO 84
83    DELYS(M,I)=0.01
84    DIS=DISCHE(I-1)-DELQ
      I=I
      CONTINUE
      Y(M,I)=Y(M-1,I)+DELYS(M,I)
      A(M,I)=B*Y(M,I)
      V(M,I)=Q(I)/A(M,I)
      WPER(M,I)=B+2*Y(M,I)
C     HINDS FORMULA
      FRICY=(4*G*B**2)*((V(M,I)+V(M-1,J))/2)**2)*DELX/((((A(M,I)/WPER(M,I)+(A(M-1,J)/WPER(M-1,J))/2)**1.33333)
      IMPY=(V(M,I)+V(M-1,J))/(G(M)*Q(M-1))*Q(M-1)/9.81*((V(M,I)-V(M-1,J))+V(M,I)*(Q(M)-Q(M-1))/Q(M-1))
      DELY=FRICY-IMPY
      IF(ABS(DELYAS(M,I)-DELY).LE.ACC) GO TO 5
```

```
L.0095          IF(I1.EQ.1) GO TO 8
L.0096 C        CHECK TH E
L.0097          IF(DELY(I1).LT.0.0) GO TO 17
L.0098          IF(I1.NE.1) GO TO 22
L.0099          WRITE(6,21)
L.0100 21       FORMAT(//,1X,76,'DISDP',F20,'DISCH',123,'VELOCITY',T40,'DVDY',T49,'DELY',T58,'DELYAS',T70,'AREA',T82,'F',T89,'I')
L.0101          WRITE(6,22) (I,DISDP(I),DISCH(I),VELOCITY,DVDY,DELY,DELYAS(N,I),AL(I),I=1,I)
L.0102 22       FORMAT(I2,1X,F7.3,F10.4,F8.3,T28,F7.3,T38,F8.3,T48,F8.3,T58,F8.3,T68,F8.3,T78,F8.3,T88,I2)
L.0103 17       IF(DELYAS(N,I)-DELY) 1,5,3
L.0104 1        I=I+1
L.0105          DELYAS(N,I)=DELYAS(N,I-1)+DEL
L.0106          GO TO 4
L.0107 3        I=I+1
L.0108          DELYAS(N,I)=DELYAS(N,I-1)-DEL
L.0109          GO TO 4
L.0110 5        CONTINUE
L.0111 4        IF(I.GT.50) GO TO 24
L.0112          IF(DISDP(I).EQ.0) GO TO 27
L.0113          WRITE(6,23)
L.0114 23       FORMAT(///,1X,'DISDP',T18,'DISCH',T28,'DELYAS',T39,'AREA',T49,'Y',T58,'DELY')
L.0115          WRITE(6,25) A,DISDP(I),DISCH(I),DELYAS(N,I),AL(I),Y(N,I),DELY
L.0116 25       FORMAT(2(2X,F7.3,F7.3),F8.4,F8.3,F8.5,F8.3,F8.4)
L.0117 24       IF(DELYAS(N,I).LT.DELY) GO TO 26
L.0118          L=L+1
L.0119          J=I
L.0120 15       CONTINUE
L.0121 C        PROGRAM CHECKS
L.0122          Y.GE.1.5*DY(I,I)
L.0123 C        CORRECTION ALLOWANCE
L.0124          YC(N)=Y(N,I)+.15
L.0125          ARC=AREA(I)
L.0126          IF(L.LT.40) GO TO 20
L.0127 8        WRITE(6,14) N
L.0128 14       FORMAT(//,'CONVERGANCE ERROR AFTER 40 ITERATIONS AT STATION NO.=',I4,12)
L.0129          IF(N.EQ.40) GO TO 90
L.0130 C        CONTINUE TO 9
L.0131 20       IF(N.GT.1) GO TO 13
L.0132          WRITE(6,11)
L.0133 11       FORMAT(//2X,'GUTTER LENGTH',T17,'CRIT DEPTH',T32,'YUPS',T40,'PEAK DEPTH',T53,'AREA',T63,'*',T65,'ROD DEPTH',T80,'ROD ARE
CONT.  A*/T2,8R(*)/)
L.0134          WRITE(6,12) X,Y(1,1),YUPS,YINT,J,(AT,J),YFIN,AFIA
L.0135 6        FORMAT(F4.2,F7.3,T17,F7.5,T32,F7.5,T40,F7.5,T50,F9.7,T63,'*',,F7.5,T80,F9.7)
L.0136 90       CONTINUE
L.0137 91       CONTINUE
```

Outputs from CRECTI

```
PTC      ACCT 3    DEPT OF CIVIL ENG                    FILE  REC20                    THU 14/2/74 (74-045)    TIME 22.32

L.0001
L.0002
L.0003
L.0004
L.0005                                        ********************************
L.0006                                        *                              *
L.0007                                        *  RECTANGULAR GUTTER OF BASE WIDTH=  .1000  M  *
L.0008                                        *                              *
L.0009                                        ********************************
...0010
L.0011
L.0012
L.0013                                    INFLOW PER UNIT LENGTH OF GUTTER=  .000100  CU.M/S.
L.0014                                    ***************************************************
L.0015  GUTTER LENGTH  CRIT DEPTH     YBAR      PEAK DEPTH      AREA      * ROD DEPTH       ROD AREA
L.0016  ***************************************************************************************
L.0017      3.000      .00972       .01686      .01772      .0317717    * .02337        .0030374
L.0018      5.000      .01366       .02367      .02486      .0027659    * .03181        .0031864
L.0019     10.000      .02106       .04159      .04363      .0023844    * .05757        .0052544
L.0020     15.000      .02641       .04924      .04241      .0062412    * .07177        .0071776
L.0021     20.000      .03042       .05965      .07842      .0074918    * .09318        .0088184
L.0022     25.000      .03394       .06922      .04494      .0073959    * .10863        .0108439
L.0023
L.0024
L.0025
L.0026                                    INFLOW PER UNIT LENGTH OF GUTTER=  .000050  CU.M/S.
L.0027                                    ***************************************************
L.0028
L.0029
L.0030  GUTTER LENGTH  CRIT DEPTH     YBAR      PEAK DEPTH      AREA      * ROD DEPTH       ROD AREA
L.0031  ***************************************************************************************
L.0032      3.000      .00612       .01061      .01112      .0311121    * .01279        .0012788
L.0033      5.000      .00860       .01491      .01760      .0017684    * .02025        .0020245
L.0034     10.000      .01366       .02367      .02866      .0029669    * .03411        .0034108
L.0035     15.000      .01798       .03102      .04190      .0041838    * .04818        .0048183
L.0036     20.000      .02160       .03758      .05158      .0051582    * .05943        .0059435
L.0037     25.000      .02516       .04360      .06116      .0061160    * .07033        .0070334
L.0038
L.0039
L.0040
L.0041                                    INFLOW PER UNIT LENGTH OF GUTTER=  .000010  CU.M/S.
L.0042                                    ***************************************************
L.0043
L.0044  GUTTER LENGTH  CRIT DEPTH     YBAR      PEAK DEPTH      AREA      * ROD DEPTH       ROD AREA
L.0045  ***************************************************************************************
L.0046      3.000      .00209       .00363      .00439      .0004093    * .00471        .0004707
L.0047      5.000      .00294       .00510      .00594      .0005942    * .00683        .0006834
L.0048     10.000      .00467       .00810      .01167      .0011571    * .01342        .0013422
L.0049  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0050  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  7
L.0051     25.000      .00860       .01491      .02460      .0024604    * .02830        .0028295
```

```
PTC      ACCT 3    DEPT OF CIVIL ENG                    FILE   REC23                          FRI 15/2/74 (74-046)        TIME 12.30
L.0001
L.0002
L.0003
L.0004
L.0005                                                  ***********************************
L.0006                                                  *                                 *
L.0007                                                  *  RECTANGULAR GUTTER OF BASE WIDTH=  .1000  M  *
L.0008                                                  *                                 *
L.0009                                                  ***********************************
L.0010
L.0011
L.0012
L.0013                                                  INFLOW PER UNIT LENGTH OF GUTTER=  .003900  CU.M/S.
L.0014                                                  ***************************************
L.0015
L.0016  GUTTER LENGTH  CRIT DEPTH     YUPS     PEAK DEPTH    AREA      * ROD DEPTH      ROD AREA
L.0017  ***************************************************************************************
L.0018        3.000       .07367     .16259      .17081     .0172814   * .12644         .0198436
L.0019        5.100       .11188     .22854      .24598     .0249377   * .29276         .0292759
L.0020  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0021  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0022  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0023  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0024
L.0025
L.0026
L.0027                                                  INFLOW PER UNIT LENGTH OF GUTTER=  .000300  CU.M/S.
L.0028                                                  ***************************************
L.0029
L.0030  GUTTER LENGTH  CRIT DEPTH     YUPS     PEAK DEPTH    AREA      * ROD DEPTH      ROD AREA
L.0031  ***************************************************************************************
L.0032        1.300       .02021     .01903      .01821     .0013212   * .04394         .0043943
L.0033        5.300       .02961     .04924      .05541     .0059412   * .04372         .0063724
L.0034       10.900       .04518     .07816      .09210     .0142101   * .10532         .0159916
L.0035       15.200       .05910     .10242      .12410     .0184099   * .14271         .0162714
L.0036       20.300       .07159     .12407      .15659     .0155593   * .18028         .0180952
L.0037       25.300       .08308     .14397      .18708     .0187077   * .21514         .0215138
L.0038
L.0039
L.0040
L.0041                                                  INFLOW PER UNIT LENGTH OF GUTTER=  .000030  CU.M/S.
L.0042                                                  ***************************************
L.0043
L.0044  GUTTER LENGTH  CRIT DEPTH     YUPS     PEAK DEPTH    AREA      * ROD DEPTH      ROD AREA
L.0045  ***************************************************************************************
L.0046        3.000       .00435     .00755      .00835     .0004396   * .00961         .0009907
L.0047        5.000       .00612     .01061      .01212     .0012121   * .01396         .0013939
L.0048       10.000       .00972     .01686      .02272     .0022717   * .02612         .0026124
L.0049       15.000       .01273     .02207      .03073     .0030732   * .03536         .0035342
L.0050       20.000       .01542     .02673      .03842     .0038434   * .04419         .0044198
L.0051       25.000       .01790     .03102      .04590     .0045898   * .05278         .0052783
```

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PTC      ACCT 3    DEPT OF CIVIL ENG                    FILE  AECL9                    THU 14/2/74 (74-045)      TIME 22.32
L.0001
L.0002
L.0003
L.0004
L.0005                                  **********************************************
L.0006                                  *                                            *
L.0007                                  *  RECTANGULAR GUTTER OF BASE WIDTH=  .1000  M *
L.0008                                  *                                            *
L.0009                                  **********************************************
L.0010
L.0011
L.0012
L.0013                                  INFLOW PER UNIT LENGTH OF GUTTER=  .005000  CU.M/S.
L.0014                                  ***************************************************
L.0015
L.0016  GUTTER LENGTH  CRIT DEPTH     YUPS     PEAK DEPTH    AREA      * RUD DEPTH      RUD AREA
L.0017  ***************************************************************************************
L.0018       3.000       .13184      .22854      .23488     .2238877    * .23471L         .0274768
L.0019       5.000       .18439      .32127      .34338     .0343382    * .39469          .0399890
L.0020  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0021  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0022  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0023  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0024
L.0025
L.0026
L.0027                                  INFLOW PER UNIT LENGTH OF GUTTER=  .001000  CU.M/S.
L.0028                                  ***************************************************
L.0029
L.0030  GUTTER LENGTH  CRIT DEPTH     YUPS     PEAK DEPTH    AREA      * RUD DEPTH      RUD AREA
L.0031  ***************************************************************************************
L.0032       3.000       .06510      .07816      .08310     .0093131    * .09557          .0095566
L.0033       5.000       .08340      .10987      .11840     .0118399    * .13616          .0136159
L.0034      10.000       .13064      .17441      .19864     .0198641    * .22844          .0228437
L.0035      15.000       .13188      .22854      .26788     .0267877    * .30806          .0308058
L.0036  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0037  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0038
L.0039
L.0040
L.0041                                  INFLOW PER UNIT LENGTH OF GUTTER=  .000500  CU.M/S.
L.0042                                  ***************************************************
L.0043
L.0044  GUTTER LENGTH  CRIT DEPTH     YUPS     PEAK DEPTH    AREA      * RUD DEPTH      RUD AREA
L.0045  ***************************************************************************************
L.0046       3.000       .02861      .04924      .05241     .0052412    * .06027          .0060274
L.0047       5.000       .03994      .06922      .07594     .0075939    * .08733          .0087329
L.0048      10.000       .06340      .10987      .12740     .0127399    * .14651          .0146509
L.0049      15.000       .08308      .16397      .17138     .0171377    * .19674          .0196738
L.0050      20.000       .10064      .17441      .21464     .0214641    * .24684          .0246837
L.0051      25.000       .11678      .20239      .25678     .0256783    * .29530          .0295301
```

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*****************************************************************************************************************
PIC      ACCT 3    DEPT OF CIVIL ENG                    FILE   RECTO2                    WED 13/2/74 (74-044)      TIME 12.29
*****************************************************************************************************************

L.0001
L.0002
L.0003
L.0004
L.0005                                          ***************************************************
L.0006                                          *                                                 *
L.0007                                          *  RECTANGULAR GUTTER OF BASE WIDTH=   .2000  M  *
L.0008                                          *                                                 *
L.0009                                          ***************************************************
L.0010
L.0011
L.0012
L.0013                                          INFLOW PER UNIT LENGTH OF GUTTER=   .000100  CU.M/S.
L.0014                                          ***************************************************
L.0015
L.0016  GUTTER LENGTH  CRIT DEPTH     YUPS    PEAK DEPTH   AREA      * ROD DEPTH      ROD AREA
L.0017  ***************************************************************************************
L.0018      5.000      .00612       .01041    .01112    .0022242   * .01273         .0025578
L.0019      5.000      .00960       .01491    .01660    .0033209   * .01910         .0038190
L.0020     10.000      .01310       .02367    .02866    .0057318   * .03296         .0065915
L.0021     15.000      .01790       .03102    .03990    .0079797   * .04588         .0091766
L.0022     20.000      .02168       .03758    .04868    .0097365   * .05598         .0111969
L.0023     25.000      .02516       .04360    .05816    .0116323   * .06688         .0133768
L.0024
L.0025
L.0026
L.0027                                          INFLOW PER UNIT LENGTH OF GUTTER=   .000050  CU.M/S.
L.0028                                          ***************************************************
L.0029  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0030      5.000      .00542       .00939    .01142    .0022841   * .01313         .0026267
L.0031     10.000      .00960       .01491    .01860    .0037209   * .02140         .0042790
L.0032     15.000      .01128       .01954    .02628    .0052550   * .03022         .0060433
L.0033     20.000      .01366       .02367    .03266    .0065318   * .03756         .0075115
L.0034     25.000      .01585       .02747    .03885    .0077730   * .04468         .0089354
L.0035
L.0036
L.0037
L.0038                                          INFLOW PER UNIT LENGTH OF GUTTER=   .000010  CU.M/S.
L.0039                                          ***************************************************
L.0040  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0041      5.000      .00185       .00321    .00385    .0007707   * .00443         .0008863
L.0042  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  3
L.0043  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  4
L.0044     20.000      .00467       .00810    .01267    .0025342   * .01457         .0029143
L.0045  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
```

```
*****************************************************************************************************************
PTC      ACCT 3    DEPT OF CIVIL ENG                    FILE   RECTOB                          WED 13/2/74 174-0441      TIME 12.28
*****************************************************************************************************************

                                                  ***************************************************
                                                  *                                                 *
                                                  *  RECTANGULAR GUTTER OF BASE WIDTH=   .2000  M  *
                                                  *                                                 *
                                                  ***************************************************

                                                  INFLOW PER UNIT LENGTH OF GUTTER=   .003000  CU.M/S.
                                                  ****************************************************

GUTTER LENGTH  CRIT DEPTH     YUPS    PEAK DEPTH   AREA      * RQD DEPTH      RQD AREA
*****************************************************************************************
    3.000      .05910       .10242    .10510    .0210198    * .12986         .0241727
    5.000      .08309       .14397    .15108    .0332154    * .17374         .0347477
   10.000      .13189       .22854    .24488    .0487754    * .28161         .0543217
   15.000      .17261       .29948    .32581    .0651615    * .37468         .0749357
   20.000      .20934       .36276    .40234    .0804634    * .46208         .0925389
   25.000      .24292       .42059    .47592    .0867140    * .54501         .1090015

                                                  INFLOW PER UNIT LENGTH OF GUTTER=   .000300  CU.M/S.
                                                  ****************************************************

GUTTER LENGTH  CRIT DEPTH     YUPS    PEAK DEPTH   AREA      * RQD DEPTH      RQD AREA
*****************************************************************************************
    3.000      .01273       .02207    .02373    .0047465    * .02729         .0054584
    5.000      .01790       .03102    .03390    .0067797    * .03898         .0077966
   10.000      .02841       .04924    .05741    .0114824    * .06602         .0132047
   15.000      .03723       .06452    .07623    .0152459    * .08766         .0175328
   20.000      .04510       .07816    .09410    .0188231    * .10822         .0216431
   25.000      .05234       .09070    .11133    .0222670    * .12803         .0256070

                                                  INFLOW PER UNIT LENGTH OF GUTTER=   .000030  CU.M/S.
                                                  ****************************************************

GUTTER LENGTH  CRIT DEPTH     YUPS    PEAK DEPTH   AREA      * RQD DEPTH      RQD AREA
*****************************************************************************************
    3.000                 .00475    .00474    .0009486    * .00543         .0010909
    5.000                 .00668    .00785    .0015712    * .00903         .0018068
   10.000                 .01061    .01412    .0028242    * .01624         .0032478
   15.000                 .01390    .01902    .0038242    * .02187         .0043748
   20.000                 .01684    .02472    .0049433    * .02842         .0056848
NON CONVERGA.      .0 ITERATIONS AT STATION NO.=  2
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*****************************************************************************************************************************
PTC      ACCT 3    DEPT OF CIVIL ENG                    FILE   RECTO1                    WED 13/2/74 (74-044)      TIME 12.28
*****************************************************************************************************************************

L.0001
L.0002
L.0003
L.0004
L.0005                                          ***********************************************
L.0006                                          *                                             *
L.0007                                          *  RECTANGULAR GUTTER OF BASE WIDTH=   .2000  M  *
L.0008                                          *                                             *
L.0009                                          ***********************************************
L.0010
L.0011
L.0012
L.0013                                          INFLOW PER UNIT LENGTH OF GUTTER=   .005000  CU.M/S.
L.0014                                          ***********************************************
L.0015
L.0016  GUTTER LENGTH  CRIT DEPTH      YUPS     PEAK DEPTH   AREA      * RQD DEPTH      RQD AREA
L.0017  ***********************************************************************************************
L.0018      3.000       .04308       .14397    .14308    .0278154    * .17144          .0342877
L.0019      5.000       .11678       .20239    .21378    .0421567    * .24240          .0484802
L.0020     10.000       .18538       .32127    .34138    .0682765    * .39259          .0785179
L.0021  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0022  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0023  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0024
L.0025
L.0026
L.0027                                          INFLOW PER UNIT LENGTH OF GUTTER=   .001000  CU.M/S.
L.0028                                          ***********************************************
L.0029
L.0030  GUTTER LENGTH  CRIT DEPTH      YUPS     PEAK DEPTH   AREA      * RQD DEPTH      RQD AREA
L.0031  ***********************************************************************************************
L.0032      3.000       .02961       .04924    .05141    .0102826    * .05912          .0118247
L.0033      5.000       .03994       .06922    .07394    .0147877    * .08503          .0170059
L.0034     10.000       .06340       .10987    .11940    .0238799    * .13731          .0274618
L.0035     15.000       .08308       .14397    .16108    .0322134    * .18524          .0370477
L.0036     20.000       .10064       .17441    .19964    .0399281    * .22959          .0459174
L.0037     25.000       .11678       .20239    .23478    .0469567    * .27000          .0540002
L.0038
L.0039
L.0040
L.0041                                          INFLOW PER UNIT LENGTH OF GUTTER=   .000500  CU.M/S.
L.0042                                          ***********************************************
L.0043
L.0044  GUTTER LENGTH  CRIT DEPTH      YUPS     PEAK DEPT    AREA      * RQD DEPTH      RQD AREA
L.0045  ***********************************************************************************************
L.0046      3.000       .01790       .03102    .03290    .0065797    * .03783          .0075666
L.0047      5.000       .02516       .04360    .04716    .0094320    * .05423          .0108468
L.0048     10.000       .03994       .06922    .07794    .0155877    * .08963          .0179259
L.0049     15.000       .05234       .09070    .10433    .0208670    * .11998          .0239970
L.0050     20.000       .06340       .10987    .12940    .0258799    * .14881          .0297618
L.0051     25.000       .07357       .12750    .15257    .0305137    * .17545          .0350908
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PTC      ACCT #    DEPT OF CIVIL ENG                    FILE  RECIDS                    WED 12/2/74 (74-344)      TIME 12.28
```

```
                                        *****************************************
                                        *                                       *
                                        *  RECTANGULAR GUTTER OF BASE WIDTH=  .3000  FT  *
                                        *                                       *
                                        *****************************************

                                        INFLOW PER UNIT LENGTH OF GUTTER=  .000100  CU.M/S.
                                        ***************************************

 GUTTER LENGTH  CRIT DEPTH      YOPS     PEAK DEPTH      AREA      * ROD DEPTH       ROD AREA
 *************  ***********  ********  ***********  ***********  ***********  ***********
       3.000       .02467     .00910      .02867     .0025013   * .00797        .0029915
       5.000       .02657     .01138      .01257     .0037639   * .01445        .0049384
      10.000       .01842     .01805      .02242     .0063271   * .02579        .0077861
      15.000       .01366     .02367      .02966     .0089877   * .03611        .0102323
      20.000       .01054     .02868      .03755     .0112642   * .04618        .0123436
      25.000       .01929     .03328      .04428     .0132602   * .05583        .0143692

                                        INFLOW PER UNIT LENGTH OF GUTTER=  .000050  CU.M/S.
                                        ***************************************

 GUTTER LENGTH  CRIT DEPTH      YOPS     PEAK DEPTH      AREA      * ROD DEPTH       ROD AREA
 *************  ***********  ********  ***********  ***********  ***********  ***********
       3.000       .00294     .00510      .00994     .0017827   * .00583        .0020501
       5.000       .00414     .00717      .00914     .0026409   * .00936        .0028971
      10.000       .00657     .01138      .01457     .0043699   * .01675        .0050254
      15.000       .00850     .01491      .01960     .0058811   * .02255        .0067635
      20.000       .01042     .01806      .02562     .0076271   * .02924        .0087711
NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2

                                        INFLOW PER UNIT LENGTH OF GUTTER=  .000010  CU.M/S.
                                        ***************************************

NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
      5.000       .00141     .00245      .00341     .0010243   * .00393        .0011780
NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  3
NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
```

```
L.0001
L.0002
L.0003
L.0004
L.0005                    ********************************************
L.0006                    *                                          *
L.0007                    *  RECTANGULAR GUTTER OF BASE WIDTH=  .3000  M  *
L.0008                    *                                          *
L.0009                    ********************************************
L.0010
L.0011
L.0012                    INFLOW PER UNIT LENGTH OF GUTTER=  .003000  CU.M/S.
L.0013                    ********************************************
L.0014
L.0015
L.0016  GUTTER LENGTH  CRIT DEPTH     YUPS     PEAK DEPTH    AREA      * ROD DEPTH      ROD AREA
L.0017  ********************************************************************************
L.0018       3.000       .04910      .07816      .08110      .0243302    * .08327        .0270767
L.0019       5.000       .06340      .10987      .11540      .0344198    * .13271        .0398127
L.0020      10.000       .10764      .17461      .18564      .0556923    * .21349        .0644440
L.0021      15.000       .13188      .22454      .24548      .0747531    * .28276        .0848274
L.0022      20.000       .15976      .27686      .30176      .0905273    * .34752        .1041756
L.0023      25.000       .19538      .32127      .35438      .1063147    * .40754        .1222619
L.0024
L.0025
L.0026
L.0027                    INFLOW PER UNIT LENGTH OF GUTTER=  .000300  CU.M/S.
L.0028                    ********************************************
L.0029
L.0030  GUTTER LENGTH  CRIT DEPTH     YUPS     PEAK DEPTH    AREA      * ROD DEPTH      ROD AREA
L.0031  ********************************************************************************
L.0032       3.000       .00972      .01694      .01772      .0093150    * .02037        .0041122
L.0033       5.000       .01366      .02367      .02566      .0076977    * .02951        .0058523
L.0034      10.000       .02168      .03758      .04368      .0131047    * .05023        .0150706
L.0035      15.000       .02841      .04926      .05741      .0172236    * .06832        .0204071
L.0036      20.000       .03447      .05965      .07262      .0217256    * .08328        .0249542
L.0037      25.000       .03994      .06922      .08696      .0254816    * .09768        .0293038
L.0038
L.0039
L.0040
L.0041                    INFLOW PER UNIT LENGTH OF GUTTER=  .000030  CU.M/S.
L.0042                    ********************************************
L.0043
L.0044  GUTTER LENGTH  CRIT DEPTH     YUPS     PEAK DEPTH    AREA      * ROD DEPTH      ROD AREA
L.0045  ********************************************************************************
L.0046       3.000       .00209      .00369      .0049C9     .0012279    * .00471        .0014121
L.0047       5.000       .00294      .00510      .00594      .0017827    * .00683        .0020501
L.0048  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0049      15.000       .00612      .01061      .01512      .0043363    * .01739        .0052167
L.0050  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2                1
L.0051      25.000       .00860      .01491      .02260      .0067813    * .02600        .0077985
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*****************************************************************************************************************
PTC      ACCT 3    DEPT OF CIVIL ENG                    FILE   RECTOM                    WED 13/2/74 (74-044)      TIME 12.25
*****************************************************************************************************************

                                                  ***************************************
                                                  *                                     *
                                                  *  RECTANGULAR GUTTER OF BASE WIDTH=  .3000  M  *
                                                  *                                     *
                                                  ***************************************

                                                  INFLOW PER UNIT LENGTH OF GUTTER=  .020000  CU.M/S.
                                                  ***************************************************
GUTTER LENGTH  CRIT DEPTH     YUPS    PEAK DEPTH   AREA      * RQD DEPTH     RQD AREA
*****************************************************************************************************************
     3.000      .06340      .10987    .11340    .0340198   * .13041        .0391227
     5.000      .09412      .15445    .16012    .0492367   * .16414        .0452421
    10.000      .14167      .24517    .25747    .0772419   * .25409        .0888282
    15.000      .19534      .32127    .34238    .1027147   * .39374        .1161219
NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2

                                                  INFLOW PER UNIT LENGTH OF GUTTER=  .00[illegible]  [illegible]/S.
                                                  ***************************************************
GUTTER LENGTH  CRIT DEPTH     YUPS    PEAK DEPTH   AREA      * RQD DEPTH     RQD AREA
*****************************************************************************************************************
     3.000      .02168      .03758    .03868    .0116047   * .04448        .0133454
     5.000      .03349      .05282    .05548    .0169438   * .06495        .0194854
    10.000      .04838      .08385    .09138    .0274147   * .10503        .0315269
    15.000      .06340      .10987    .12140    .0364198   * .13761        .0413827
    20.000      .07680      .13310    .14270    .0444639   * .17227        .0516820
    25.000      .08912      .15445    .17512    .0525367   * .20139        .0604171

                                                  INFLOW PER UNIT LENGTH OF GUTTER=  .020500  CU.M/S.
                                                  ***************************************************
GUTTER LENGTH  CRIT DEPTH     YUPS    PEAK DEPTH   AREA      * RQD DEPTH     RQD AREA
*****************************************************************************************************************
     3.000      .01366      .02367    .02466    .0073977   * .02836        .0085073
     5.000      .01920      .03328    .03620    .0108602   * .04163        .0124892
    10.000      .03046      .05282    .05948    .0178438   * .06840        .0205204
    15.000      .03994      .06922    .07994    .0239816   * .09193        .0275788
    20.000      .04838      .08385    .09738    .0292147   * .11199        .0335969
    25.000      .05614      .09730    .11514    .0345429   * .13241        .0397243
```

[illegible] .3000 [illegible]

[illegible] .050000 [illegible]

3.000	.29428	.50998	.53428	.1542832	.50142	.1774256
5.000	.41667	.71689	.72967	.2189013	.83912	.2517364

[illegible] .010000 [illegible]

3.000	.10064	.17443	.17864	.0535924	.20544	.0616312
5.000	.14147	.24517	.25347	.0760420	.29149	.0874483
10.000	.22458	.38919	.40458	.1213726	.46526	.1395784
15.000	.29428	.50908	.53629	.1608831	.61672	.1850155
20.000	.35649	.61786	.65649	.1969473	.75496	.2264892
25.000	.41357	.71680	.76967	.2309012	.88512	.2655363

[illegible] .005000 [illegible]

20.000	.22458	.38918	.42058	.1261726	.48366	.1450084
25.000	.26001	.45162	.48860	.1465790	.56189	.1685658

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*****************************************************************************************************************
PTC      ACCT 3    DEPT OF CIVIL ENG                    FILE   RECTOB                          THU 14/2/74 (74-045)      TIME 11.02
*****************************************************************************************************************

L.0001
L.0002
L.0003
L.0004
L.0005                                          ****************************************************
L.0006                                          *                                                  *
L.0007                                          *  RECTANGULAR GUTTER OF BASE WIDTH=   .4000  M    *
L.0008                                          *                                                  *
L.0009                                          ****************************************************
L.0010
L.0011
L.0012
L.0013                                          INFLOW PER UNIT LENGTH OF GUTTER=   .000100  CU.M/S.
L.0014                                          ****************************************************
L.0015  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.= 2
L.0016     5.000      .00542      .00939      .01042     .0041681    * .01198          .0047933
L.0017    10.000      .00860      .01491      .01860     .0074418    * .02165          .0095990
L.0018    15.000      .01128      .01954      .02528     .0101100    * .02907          .0116265
L.0019    20.000      .01366      .02367      .03165     .0126636    * .03641          .0145631
L.0020    25.000      .01585      .02747      .03635     .0147399    * .04230          .0169539
L.0021
L.0022
L.0023
L.0024                                          INFLOW PER UNIT LENGTH OF GUTTER=   .000250  CU.M/S.
L.0025                                          ****************************************************
L.0026
L.0027  GUTTER LENGTH  CRIT DEPTH     YUPS    PEAK DEPTH    AREA      * RQD DEPTH      RQD AREA
L.0028  ***************************************************************************************
L.0029     3.000      .00243      .00421      .00443     .0017716    * .00509          .0020373
L.0030     5.000      .00341      .00592      .00741     .0029658    * .00853          .0034107
L.0031    10.000      .00542      .00939      .01242     .0049681    * .01428          .0057133
L.0032  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.= 2
L.0033    20.000      .00860      .01491      .02160     .0086418    * .02485          .0099380
L.0034  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.= 2
L.0035
L.0036
L.0037
L.0038                                          INFLOW PER UNIT LENGTH OF GUTTER=   .000012  CU.M/S.
L.0039                                          ****************************************************
L.0040
L.0041  GUTTER LENGTH  CRIT DEPTH     YUPS    PEAK DEPTH    AREA      * RQD DEPTH      RQD AREA
L.0042  ***************************************************************************************
L.0043     3.000      .00083      .00144      .00183     .0007322    * .00211          .0008420
L.0044     5.000      .00117      .00202      .00317     .0012670    * .00364          .0014571
L.0045    10.000      .00189      .00321      .00485     .0019414    * .00558          .0022326
L.0046  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.= 3
L.0047    20.000      .00204      .00510      .00894     .0035770    * .01028          .0041135
L.0048    25.000      .00341      .00592      .01041     .0041658    * .01198          .0047907
```

```
PTC      ACCT 3    DEPT OF CIVIL ENG                    FILE  REC10                    THU 14/2/74 (74-045)      TIME 16.35
L.0001
L.0002
L.0003
L.0004
L.0005                                  ********************************************
L.0006                                  *                                          *
L.0007                                  *  RECTANGULAR GUTTER OF BASE WIDTH=  .4000  M  *
L.0008                                  *                                          *
L.0009                                  ********************************************
L.0010
L.0011
L.0012
L.0013                                  INFLOW PER UNIT LENGTH OF GUTTER=  .003000 CU.M/S.
L.0014                                  ***************************************************
L.0015
L.0016  GUTTER LENGTH   CRIT DEPTH      YUPS      PEAK DEPTH    AREA       * ROD DEPTH      ROD AREA
L.0017  ***************************************************************************************
L.0018       3.000       .03321       .06452       .06623     .0269917  *  .37619          .0304697
L.0019       5.000       .05234       .09210       .09433     .0377339  *  .19842          .0417396
L.0020      10.000       .08308       .14397       .15208     .0608308  *  .17489          .0699563
L.0021      15.000       .10946       .18866       .20086     .0803447  *  .16637          .0727364
L.0022      20.000       .13188       .22854       .24608     .0985908  *  .16331          .1135436
L.0023      25.000       .15303       .26520       .28803     .1152119  *  .33123          .1324636
L.0024
L.0025
L.0026
L.0027                                  INFLOW PER UNIT LENGTH OF GUTTER=  .000150 CU.M/S.
L.0028                                  ***************************************************
L.0029
L.0030  GUTTER LENGTH   CRIT DEPTH      YUPS      PEAK DEPTH    AREA       * ROD DEPTH      ROD AREA
L.0031  ***************************************************************************************
L.0032       3.000       .00802       .01393       .01502     .0060083  *  .01727          .0069095
L.0033       5.000       .01128       .01954       .02128     .0085100  *  .02647          .0097865
L.0034      10.000       .01790       .03102       .03390     .0143593  *  .04128          .0165132
L.0035      15.000       .02345       .04065       .04445     .0193814  *  .05572          .0222396
L.0036      20.000       .02841       .04924       .06041     .0241648  *  .06967          .0277895
L.0037      25.000       .03297       .05714       .07097     .0283874  *  .08161          .0326455
L.0038
L.0039
L.0040
L.0041                                  INFLOW PER UNIT LENGTH OF GUTTER=  .000030 CU.M/S.
L.0042                                  ***************************************************
L.0043
L.0044  GUTTER LENGTH   CRIT DEPTH      YUPS      PEAK DEPTH    AREA       * ROD DEPTH      ROD AREA
L.0045  ***************************************************************************************
L.0046       3.000       .00173       .00297       .00373     .0014911  *  .00429          .0017148
L.0047  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0048      10.000       .00385       .00668       .00886     .0035423  *  .01018          .0040737
L.0049  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  4
L.0050      20.000       .00612       .01061       .01612     .0064484  *  .01854          .0074156
L.0051      25.000       .00710       .01231       .01910     .0076411  *  .02197          .0087873
```

```
*****************************************************************************************************************
PTC      ACCT 3    DEPT OF CIVIL ENG                FILE   RECTO7                    THU 14/2/74 (74-C45)      TIME 13.15
*****************************************************************************************************************

                                                  ***************************************
                                                  *                                     *
                                                  *  RECTANGULAR GUTTER OF BASE WIDTH=  .4000  M  *
                                                  *                                     *
                                                  ***************************************

                                                  INFLOW PER UNIT LENGTH OF GUTTER=  .005000  CU.M/S.
                                                  ***************************************************

GUTTER LENGTH  CRIT DEPTH     YUPS     PEAK DEPTH    AREA      * RQD DEPTH      RQD AREA
*****************************************************************************************
    3.000       .05234      .09070     .09233     .0369339    * .10618         .0424739
    5.000       .07357      .12750     .13157     .0526274    * .13130         .0605215
   10.000       .11678      .20239     .21278     .0851133    * .24470         .0978803
   15.000       .15303      .26520     .27903     .1116114    * .32086         .1283536
   20.000       .18538      .32127     .34338     .1373510    * .39489         .1579559
   25.000       .21512      .37280     .40012     .1600470    * .46014         .1840540

                                                  INFLOW PER UNIT LENGTH OF GUTTER=  .001000  CU.M/S.
                                                  ***************************************************

GUTTER LENGTH  CRIT DEPTH     YUPS     PEAK DEPTH    AREA      * RQD DEPTH      RQD AREA
*****************************************************************************************
    3.000       .01790      .03102     .03190     .0127593    * .03668         .0154732
    5.000       .02516      .04360     .04716     .0189641    * .05423         .0216937
   10.000       .03994      .06922     .07594     .0303755    * .08733         .0349318
   15.000       .05234      .09070     .10033     .0401339    * .11538         .0461540
   20.000       .06340      .10987     .12340     .0493597    * .14191         .0567636
   25.000       .07357      .12750     .14457     .0578274    * .16625         .0665014

                                                  INFLOW PER UNIT LENGTH OF GUTTER=  .000500  CU.M/S.
                                                  ***************************************************

GUTTER LENGTH  CRIT DEPTH     YUPS     PEAK DEPTH    AREA      * RQD DEPTH      RQD AREA
*****************************************************************************************
    3.000       .01128      .01954     .02028     .0081100    * .02332         .0093264
    5.000       .01585      .02747     .02985     .0119399    * .03433         .0137309
   10.000       .02516      .04360     .04916     .0196640    * .05653         .0226136
   15.000       .03297      .05714     .06577     .0263874    * .07586         .0303456
   20.000       .03994      .06922     .08194     .0327754    * .09423         .0376917
   25.000       .04635      .08032     .09534     .0381380    * .10969         .0438586
```

[illegible] .4000

[illegible] .010000 [illegible]

3.000	.68368	.14397	.24708	.0588310	.16934	.0676556
5.000	.11676	.20239	.20478	.0819135	.25550	.0942005
10.000	.18538	.32127	.33135	.1325531	.38100	.1524360
15.000	.24292	.42098	.43892	.1755682	.50476	.2018033
20.000	.28428	.50998	.53628	.2145108	.61672	.2466874
25.000	.34148	[illegible]	.62748	.2509912	.72360	.2886398

[illegible] .050000 [illegible]

3.000	.24292	.42098	.42492	.1699682	.48866	.1954634
5.000	.34348	.59178	.59948	.2397923	.68940	.2757598
10.000	.54206	.93940	.96206	.3848240	1.10657	.4425483

RECTANGULAR GUTTER OF BASE WIDTH= .9000 M

INFLOW PER UNIT LENGTH OF GUTTER= .000100 CU.M/S.

GUTTER LENGTH	CRIT DEPTH	YUPS	PEAK DEPTH	AREA	* RQD DEPTH	RQD AREA
3.000	.00332	.00576	.00632	.0031614	* .00727	.0034356
9.000	.00467	.00810	.00767	.0043855	* .01112	.0059658
NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.= 2						
15.000	.00917	.01604	.02272	.0111583	* .02612	.0130626
20.000	.01177	.02040	.02777	.0133854	* .03194	.0159682
25.000	.01366	.02367	.03266	.0161294	* .03756	.0187799

INFLOW PER UNIT LENGTH OF GUTTER= .000950 CU.M/S.

GUTTER LENGTH	CRIT DEPTH	YUPS	PEAK DEPTH	AREA	* RQD DEPTH	RQD AREA
3.000	.00209	.00361	.00409	.0022465	* .00471	.0025935
5.00	.00294	.00510	.00534	.0029712	* .00683	.0034169
NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.= 2						
15.000	.00612	.01061	.01512	.0075605	* .01739	.0086945
NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.= 2						
25.000	.00860	.01491	.02260	.0113022	* .02600	.0129975

INFLOW PER UNIT LENGTH OF GUTTER= .000010 CU.M/S.

GUTTER LENGTH	CRIT DEPTH	YUPS	PEAK DEPTH	AREA	* RQD DEPTH	RQD AREA
3.000	.00072	.00124	.00172	.0008578	* .00197	.0009865
5.000	.00101	.00174	.00301	.0015031	* .00346	.0017285
10.000	.00160	.00277	.00460	.0022984	* .00529	.0026434
15.000	.00209	.00363	.00609	.0030468	* .00701	.0035035
20.000	.00254	.00439	.00754	.0037678	* .00867	.0043330
NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.= 2						

```
PTL     ACCT 3    DEPT OF CIVIL ENG                    FILE   REC10                    THU 14/2/74 (74-0451)      TIME 11.02

L.0001
L.0002
L.0003
L.0004
L.0005                                    ***************************************************
L.0006                                    *                                                 *
L.0007                                    *  RECTANGULAR GUTTER OF BASE WIDTH=   .5000  M   *
L.0008                                    *                                                 *
L.0009                                    ***************************************************
L.0010
L.0011
L.0012
L.0013                                    INFLOW PER UNIT LENGTH OF GUTTER=   .003930  CU.M/S.
L.0014                                    ***************************************************
L.0015
L.0016  GUTTER LENGTH  CRIT DEPTH     YUPS     PEAK DEPTH    AREA      * RQD DEPTH      RQD AREA
L.0017  ***************************************************************************************
L.0018     3.000       .03208       .05560    .05708    .0235420    * .04565         .0324233
L.0019     5.000       .04510       .07816    .08210    .0410503    * .09442         .0472078
L.0020    10.000       .07159       .12467    .13159    .0657767    * .15133         .0756661
L.0021    15.000       .09382       .16258    .17481    .0874071    * .20104         .1005182
L.0022    20.000       .11365       .19695    .21265    .1064240    * .24455         .1222726
L.0023    25.000       .13188       .22854    .24708    .1239386    * .28506         .1425292
L.0024
L.0025
L.0026
L.0027                                    INFLOW PER UNIT LENGTH OF GUTTER=   .000300  CU.M/S.
L.0028                                    ***************************************************
L.0029
L.0030  GUTTER LENGTH  CRIT DEPTH     YUPS     PEAK DEPTH    AREA      * RQD DEPTH      RQD AREA
L.0031  ***************************************************************************************
L.0032     3.000       .00691       .01198    .01291    .0064560    * .01485         .0074244
L.0033     5.000       .00972       .01684    .01872    .0093593    * .02152         .0107426
L.0034    10.000       .01542       .02673    .03142    .0157121    * .03614         .0180689
L.0035    15.000       .02021       .03503    .04221    .0211058    * .04854         .0242716
L.0036    20.000       .02448       .04243    .05148    .0257423    * .05921         .0296037
L.0037    25.000       .02841       .04924    .06141    .0307060    * .07062         .0353118
L.0038
L.0039
L.0040
L.0041                                    INFLOW PER UNIT LENGTH OF GUTTER=   .000030  CU.M/S.
L.0042                                    ***************************************************
L.0043  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0044  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  3
L.0045    10.000       .00332       .00576    .00832    .0041614    * .00957         .0047856
L.0046    15.000       .00435       .00755    .01135    .0056771    * .01306         .0065287
L.0047  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0048  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
```

```
L.0001
L.0002
L.0003
L.0004
L.0005                                  ********************************
L.0006                                  *                              *
L.0007                                  * RECTANGULAR GUTTER OF BASE WIDTH= .5000  M *
L.0008                                  *                              *
L.0009                                  ********************************
L.0010
L.0011
L.0012
L.0013                                  INFLOW PER UNIT LENGTH OF GUTTER= .2E5000 CU.M/S.
L.0014                                  *************************************************
L.0015
L.0016  GUTTER LENGTH  CRIT DEPTH     YUPS     PEAK DEPTH     AREA      * ROD DEPTH      ROD AREA
L.0017  ***************************************************************************************
L.0018        3.000       .04510     .07314       .09110    .0405969  *  .03127       .0468328
L.0019        5.000       .06350     .10767       .13440    .0571592  *  .11156       .0667706
L.0020       10.000       .10044     .17461       .19254    .0911254  *  .21304       .1054144
L.0021       15.000       .13101     .22854       .24198    .1269385  *  .27816       .1390792
L.0022       20.000       .15976     .27686       .29476    .1473789  *  .33397       .1494657
L.0023       25.000       .18698     .32127       .34438    .1721913  *  .37604       .1580179
L.0024
L.0025
L.0026
L.0027                                  INFLOW PER UNIT LENGTH OF GUTTER= .2C1000 CU.M/S.
L.0028                                  *************************************************
L.0029
L.0030  GUTTER LENGTH  CRIT DEPTH     YUPS     PEAK DEPTH     AREA      * ROD DEPTH      ROD AREA
L.0031  ***************************************************************************************
L.0032        3.000       .01942     .07671       .02862    .0142121  *  .01269       .0163419
L.0033        5.000       .02168     .03758       .04068    .0201411  *  .04478       .0239123
L.0034       10.000       .03442     .05965       .06562    .0327091  *  .07523       .0378154
L.0035       15.000       .04519     .07816       .08710    .0435503  *  .10017       .0500828
L.0036       20.000       .05464     .09469       .10764    .0539178  *  .12378       .0618905
L.0037       25.000       .06348     .10987       .12440    .0621987  *  .14306       .0715296
L.0038
L.0039
L.0040
L.0041                                  INFLOW PER UNIT LENGTH OF GUTTER= .000500 CU.M/S.
L.0042                                  *************************************************
L.0043
L.0044  GUTTER LENGTH  CRIT DEPTH     YUPS     PEAK DEPTH     AREA      * ROD DEPTH      ROD AREA
L.0045  ***************************************************************************************
L.0046        3.000       .00972     .01684       .01772    .0088583  *  .02037       .0101870
L.0047        5.000       .01366     .02367       .02566    .0128294  *  .02951       .0147538
L.0048       10.000       .02168     .03758       .04268    .0213411  *  .04908       .0245423
L.0049       15.000       .02841     .04924       .05841    .0292060  *  .06717       .0335868
L.0050       20.000       .03442     .05965       .07042    .0352090  *  .08098       .0404903
L.0051       25.000       .03994     .06922       .08294    .0414693  *  .09538       .0476897
```

.5000

.010000

3.000	.07159	.12407	.12559	.0627970	.14443	.0722165
5.000	.10064	.17442	.17864	.0593206	.20544	.1027137
10.000	.15976	.27686	.28576	.2428791	.32862	.1643109
15.000	.20934	.36279	.37734	.1986712	.43394	.2169718
20.000	.25360	.43949	.45960	.2998002	.52854	.2642707
25.000	.29428	.50998	.53628	.2681385	.61672	.3083592

.050000

3.000	.20934	.36279	.36534	.1926712	.42016	.2100716
5.000	.29428	.50998	.51628	.2581387	.50372	.2968594
10.000	.46714	.80955	.82714	.4135676	.95123	.4756026

```
PIC      ACCT 3    DEPT OF CIVIL ENG                    FILE   REC16                    THU 14/2/74 (74-045)        TIME 13.15
```

```
                                        ********************************************
                                        *                                          *
                                        *  RECTANGULAR GUTTER OF BASE WIDTH=  .60CC M  *
                                        *                                          *
                                        ********************************************

                                        INFLOW PER UNIT LENGTH OF GUTTER=  .0001CC  CU.M/S.
                                        ***************************************************

 GUTTER LENGTH   CRIT DEPTH      YUPS     PEAK DEPTH     AREA      * ROD DEPTH       ROD AREA
 ***************************************************************************************
     3.000         .00234        .00512      .00574      .0015655  * .00683          .0041931
     5.000         .00414        .00717      .00914      .0043813  * .00936          .0056141
    10.000         .00657        .01138      .01457      .0087399  * .01475          .0100508
    15.000         .00763        .01491      .01906      .0117627  * .02255          .0135275
    20.000         .00842        .01806      .02542      .0152542  * .02924          .0175423
    25.000         .01210        .02095      .02910      .0174573  * .03346          .0200759

                                        INFLOW PER UNIT LENGTH OF GUTTER=  .0200CC  CU.M/S.
                                        ***************************************************

 GUTTER LENGTH   CRIT DEPTH      YUPS     PEAK DEPTH     AREA      * ROD DEPTH       ROD AREA
 ***************************************************************************************
     3.000         .00185        .00321      .00385      .0023121  * .00443          .0026599
 NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
    10.000         .00414        .00717      .01414      .0067818  * .01166          .0069941
    15.000         .00542        .00939      .01342      .0080522  * .01543          .0092630
    20.000         .00657        .01138      .01657      .0099398  * .01996          .0119757
    25.000         .00762        .01321      .01962      .0117718  * .02256          .0135375

                                        INFLOW PER UNIT LENGTH OF GUTTER=  .000010  CU.M/S.
                                        ***************************************************

 GUTTER LENGTH   CRIT DEPTH      YUPS     PEAK DEPTH     AREA      * ROD DEPTH       ROD AREA
 ***************************************************************************************
     3.000         .00063        .00110      .00163      .0009802  * .00188          .0011272
 NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
    10.000         .00141        .00245      .00441      .0026486  * .00508          .0030459
 NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
 NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
    25.000         .00261        .00452      .00861      .0051634  * .00990          .0059379
```

```
PTC      ACCT 3    DEPT OF CIVIL ENG                    FILE  REG17                          THU 14/2/74 (74-045)        TIME 13.15
```

```
L.0001
L.0002
L.0003
L.0004                                          ***********************************************
L.0005                                          *                                             *
L.0006                                          *  RECTANGULAR GUTTER OF BASE WIDTH=  .6000 M *
L.0007                                          *                                             *
L.0008                                          ***********************************************
L.0009
L.0010
L.0011
L.0012
L.0013                                          INFLOW PER UNIT LENGTH OF GUTTER=  .003000 CU.M/S.
L.0014                                          ***************************************************
L.0015
L.0016  GUTTER LENGTH  CRIT DEPTH     VOPS    PEAK DEPTH    AREA    * RQD DEPTH      RQD AREA
L.0017  ***************************************************************************************
L.0018          5.000       .02841      .34924      .05161      .0134472  * .05312        .0134742
L.0019          9.000       .03796      .58922      .07209      .0437432  * .07389        .0437776
L.0020         10.000       .04140      .70987      .11245      .0726325  * .12561        .0731365
L.0021         15.000       .04938      .14397      .15408      .0924461  * .17719        .1063110
L.0022         20.000       .05564      .17441      .19866      .1111965  * .21624        .1301626
L.0023         25.000       .11678      .20039      .22378      .1324762  * .25380        .1523695
L.0024
L.0025
L.0026
L.0027                                          INFLOW PER UNIT LENGTH OF GUTTER=  .009000 CU.M/S.
L.0028                                          ***************************************************
L.0029
L.0030  GUTTER LENGTH  CRIT DEPTH     VOPS    PEAK DEPTH    AREA    * RQD DEPTH      RQD AREA
L.0031  ***************************************************************************************
L.0032          3.000       .02612      .31761      .01112      .0366725  * .01279        .0376716
L.0033          5.000       .03960      .01491      .01660      .0093627  * .01913        .0114570
L.0034         10.000       .01366      .02367      .02765      .0169993  * .03181        .0190466
L.0035         15.000       .01730      .03102      .03790      .0227398  * .04358        .0261498
L.0036         20.000       .02168      .03768      .04648      .0280594  * .05368        .0321138
L.0037         25.000       .02516      .04360      .05516      .0330361  * .06343        .0389605
L.0038
L.0039
L.0040
L.0041                                          INFLOW PER UNIT LENGTH OF GUTTER=  .000010 CU.M/S.
L.0042                                          ***************************************************
L.0043  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.=  2
L.0044          5.000       .00185      .00321      .00385      .0023121  * .00443        .0026589
L.0045         10.000       .00296      .00510      .00674      .0041655  * .00798        .0047903
L.0046         15.000       .00336      .00668      .00986      .0059135  * .01133        .0068005
L.0047         20.000       .00467      .00810      .01267      .0076026  * .01457        .0087430
L.0048         25.000       .00542      .00939      .01542      .0092522  * .01773        .0106400
```

[illegible]

[illegible]

[illegible]

```
L.0001
L.0002
L.0003
L.0004
L.0005                                  ********************************************
L.0006                                  *                                          *
L.0007                                  *  RECTANGULAR GUTTER OF BASE WIDTH=  .6000  M  *
L.0008                                  *                                          *
L.0009                                  ********************************************
L.0010
L.0011
L.0012
L.0013                                  INFLOW PER UNIT LENGTH OF GUTTER=  .010000  CU.M/S.
L.0014                                  ****************************************************
L.0015
L.0016  GUTTER LENGTH  GUTT DEPTH     YOPS     PEAK DEPTH     AREA      % RQD DEPTH     RQD AREA
L.0017  ********************************************************************************************
L.0018        3.000       .06147      .10297      .11250      .0674376    * .12026        .0775555
L.0019        6.000       .09912      .15644      .15912      .0934742    * .18239        .1097941
L.0020       10.333       .14147      .20617      .20437      .1276437    * .23254        .1455464
L.0021       15.000       .17532      .2127       .23234      .1491795    * .32226        .2293633
L.0022       20.333       .22458      .33913      .47700      .2643463    * .47101        .2926546
L.0023       25.000       .26060      .45152      .47600      .2367578      .54578        .3236714
L.0024
L.0025
L.0026
L.0027                                  INFLOW PER UNIT LENGTH OF GUTTER=  .050000  CU.M/S.
L.0028                                  ****************************************************
L.0029
L.0030  GUTTER LENGTH  GUTT DEPTH     YOPS     PEAK DEPTH     AREA      % RQD DEPTH     RQD AREA
L.0031  ********************************************************************************************
L.0032        3.000       .10538      .32127      .32138      .1962275    * .37189        .2231334
L.0033        6.000       .20665      .45162      .45650      .2739579    * .52509        .3150514
L.0034       10.000       .41357      .71539      .72967      .4379026      .83832        .5026722
L.0035       15.000       .64586      .95166      .95166      .5731375      1.10967       .6652026
L.0036  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.= 2
L.0037  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.= 2
L.0038
L.0039
L.0040
L.0041                                  INFLOW PER UNIT LENGTH OF GUTTER=  .100000  CU.M/S.
L.0042                                  ****************************************************
L.0043  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.= 2
L.0044  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.= 2
L.0045  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.= 2
L.0046  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.= 2
L.0047  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.= 2
L.0048  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO.= 2
```

PROGRAMME TO DETERMINE THE DESIGN DEPTH IN TRAPEZOIDAL GUTTERS WITH EQUAL SIDE SLOPES

NAME: TRAP

OBJECT: To determine the design depth in trapezoidal gutters with equal side slopes for various gutter lengths and inflow rates.

Checks: A side slope value of 90° was used and the results of the programme were checked against the outputs of the rectangular gutter programme, CRECTI. The comparison is seen in Table 32

Inputs:

Gutter base breadth	B
Gutter side slope in degrees	SS
Number of stations	NT
Output code	K
Inflow per unit length to gutter	INF
Gutter length	X

Outline of Programme:

For particular inflow and length values the critical depth at the outlet is first calculated. This is done by an iterative process as follows; An estimate of critical depth is made, and the expressions Vc^2/g and Ym (see discussion on GUT 2) are calculated and compared. If these expressions do not agree to the required accuracy the critical depth is re-estimated and the expression recalculated. In this manner the critical depth is determined. This is then used as the starting

depth in the Hinds analysis and the water surface profile is determined in the manner outlined as for GUT 3. The peak depth is abstracted from the profile and the freeboard added to obtain the design depth and hence design area of gutter.

Outputs:

Code, K = 1 - values of all variables after every iteration at every station are given

Code, K = 2 - final values of variables and flow depths are given at each station. These flow depths define the water surface profile.

Code, K > 2 - the values at the last upstream station are given. These include;

length	X
critical depth at outlet	YCRIT
peak depth	Y(NT,J)
peak area	A(NT,J)
design depth	YFIN
design area	AFIN

Limits placed on programme:

The maximum number of iteration at the outlet when determining the flow depth is sixty

The maximum number of iterations at any particular station is forty.

Problems associated with programme:

Some problems as for GUT 3 and CRECTI and in addition it

was found that convergence on the critical depth at the outlet was slow. Thus it was necessary to allow at least sixty iterations at the outlet when determining the critical depth.

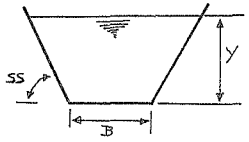
The values of accuracy limit and depth increment that gave best results were:

DEL = 0,002m

ACC = 0,001m

It was found that 21 stations were adequate, i.e. NT = 21

Geometry



SS is in degrees, while SSR is the value of SS in radians.

TABLE 32 COMPARISON BETWEEN OUTPUTS OF TRAP AND CRECTI

BASE BREADTH in metres	INFLOW RATE in m^3/S	LENGTH in metres	PEAK DEPTH FROM TRAP in metres	PEAK DEPTH FROM CRECTI in metres
0,3	0,01	10	0,4046	0,4062
0,3	0,005	20	0,4206	0,4192
0,2	0,0003	25	0,1113	0,11133
0,2	0,003	5	0,1511	0,15108

```
*****************************************************************************************************
MLM      ACCT 27   DEPT OF METALLURGY                    FILE   TRAP                    FRI 13/12/74 (74-347)      TIME  9.21
*****************************************************************************************************

L.0001 C     PROGRAMME TO FIND THE MAXIMUM WATER DEPTH IN TRAPEZOIDAL GUTTERS
L.0002       REAL Q(22),INF,LHS,Y(22,60),A(22,60),V(22,40),WPER(22,40),DELYAS(22,40),DISOP(22),DELY,PRICY,IMPY,MAN
L.0003       INTEGER S,K,P,SS
L.0004       KW=5
L.0005 C     INPUT
L.0006       READ(1,1) B,SS,N7,K
L.0007 1     FORMAT(4Y)
L.0008       WRITE(KW,10) B
L.0009       WRITE(KW,47)SS
L.0010 10    FORMAT(///T42,50('*')/T42,'*',T91,'*'/T42,'*',2X,'TRAPEZOIDAL GUTTER OF BASE WIDTH=',2X,F6.4,2X,'M',2X,'*')
L.0011 47    FORMAT(T42,'*',T47,'SIDE SLOPE=',2X,I2,2X,'DEG.',T91,'*'/T42,'*',T91,'*'/T42,50('*'))
L.0012       DELY=.002
L.0013       ADDL=.001
L.0014       MAN=1.014
L.0015       DO 91 S=1,2
L.0016 C     ITERATING FOR DIFFERENT INFLOWS
L.0017       READ(1,2) INF
L.0018 2     FORMAT(Y)
L.0019       WRITE(KW,11) INF
L.0020 11    FORMAT(//T42,'INFLOW PER UNIT LENGTH OF GUTTER=',2X,F8.6,2X,'CU.M./S.'/T42,53('*'))
L.0021 C     ITERATING FOR DIFFERENT GUTTER LENGTHS
L.0022       DO 90 P=1,6
L.0023 34    READ(1,4) X
L.0024 9     FORMAT(Y)
L.0025 C     TO FIND CRITICAL DEPTH AT DOWNPIPE
L.0026       N=1
L.0027       I=1
L.0028       Q(1)=INF*X
L.0029       SSR=0.31749*SS
L.0030       Y(1,1)=(Q(1)**2/(11.4*B)**2*9.81))**0.333333
L.0031 8     A(1,1)=Y(1,1)*(B+Y(1,1)/TAN(SSR))
L.0032       LHS=Q(1)/A(1,1)**2/9.81
L.0033       RHS=A(1,1)/(B+2*Y(1,1)/TAN(SSR))
L.0034       IF(ABS(LHS-RHS).LE.0.003) GO TO 5
L.0035       IF(K.GT.1) GO TO 12
L.0036       IF(I.GT.1) GO TO 40
L.0037       WRITE(KW,40)
L.0038 40    FORMAT(T4,'I',T11,'VC**2/G',T24,'YM',T32,'DEPTH'/T2,37('*'))
L.0039       WRITE(KW,13) I,LHS,RHS,Y(1,1)
L.0040 13    FORMAT(T3,I2,T10,F8.6,T20,F8.6,T30,F8.6)
L.0041 12    IF(I.GT.99) GO TO 7
L.0042       IF(LHS-RHS) 4,5,6
L.0043 4     I=I+1
L.0044       Y(1,I)=Y(1,I-1)-0.002
L.0045       GO TO 8
L.0046 6     I=I+1
L.0047       Y(1,I)=Y(1,I-1)+0.002
L.0048       GO TO 8
L.0049 7     WRITE(KW,33)
L.0050 33    FORMAT(T2,'NON CONVERGANCE AT STATION NO 1')
L.0051       GO TO 90
L.0052 5     J=1
L.0053       Y(1,J)=Y(1,I)
L.0054       A(1,J)=A(1,I)
```

```
L.0055        V(I,J)=Q(I)/A(I,J)
L.0056        WPER(I,J)=W+2*Y(I,J)/SIN(SSR)
L.0057        DISDP(I)=0
L.0058        YCRIT=Y(I,J)
L.0059        L=0
L.0060 C      FINDING DEPTH AT ALL STATIONS USING HINDS FORMULA
L.0061        DELQ=Q(I)/(NT-1)
L.0062        DELX=X/(NT-1)
L.0063        DO 15 N=2,NT
L.0064        DISDP(N)=DISDP(N-1)+DELX
L.0065        IF(N.GT.2) GO TO 83
L.0066        DELYAS(N,I)=0.05
L.0067        IF(I.GT.3) GO TO 84
L.0068 83     DELYAS(N,I)=0.01
L.0069 84     DIN(N)=Q(N-1)-DEL
L.0070        I=1
L.0071 16     CONTINUE
L.0072        Y(N,I)=Y(N-1,J)+DELYAS(N,I)
L.0073        A(N,I)=Y(N,I)*(Q+Y(N,I)/TAN(SSR))
L.0074        V(N,I)=Q(N)/A(N,I)
L.0075        WPER(N,I)=W+2*Y(N,I)/SIN(SSR)
L.0076 C      HINDS FORMULA
L.0077        FRICY=(MAX*W*2)*((V(N,I)+V(N-1,J))/2)**2)*DELX/(((A(N,I)/WPER(N,I)+A(N-1,J)/WPER(N-1,J))/2)**1.333333)
L.0078        IMPY=(V(N,I)+V(N-1,J))/(Q(N)+Q(N-1))*Q(N-1)/9.81*((V(N,I)-V(N-1,J))+V(N,I)*(Q(N)-Q(N-1))/Q(N-1))
L.0079        DELY=FRICY-IMPY
L.0080        IF(ABS(DELYAS(N,I)-DELY).LE.ACC) GO TO 19
L.0081        IF(I.GT.19) GO TO 24
L.0082 C      OUTPUT NO 1
L.0083        IF(K.GT.1) GO TO 17
L.0084        IF(I.GT.1) GO TO 22
L.0085        WRITE(KW,22)
L.0086 22     FORMAT(//T3,'N',T10,'DISDP',T20,'DISCH',T30,'FRICY',T40,'IMPY',T49,'DELY',T59,'DELYAS',T69,'AREA',T79,'DEPTH',T89,'I'/T
CONT.  2,90('*'))
L.0087        WRITE(KW,23) N,DISDP(N),Q(N),FRICY,IMPY,DELY,DELYAS(N,I),A(N,I),Y(N,I),I
L.0088 23     FORMAT(T2,I2,T5,F7.3,T18,F8.6,T28,F8.6,T38,F8.6,T48,F6.5,T58,F6.5,T68,F8.6,T78,F8.6,T88,I2)
L.0089 17     IF(DELYAS(N,I)-DELY) 18,19,20
L.0090 18     I=I+1
L.0091        DELYAS(N,I)=DELYAS(N,I-1)+DEL
L.0092        GO TO 16
L.0093 20     I=I+1
L.0094        DELYAS(N,I)=DELYAS(N,I-1)-DEL
L.0095        GO TO 16
L.0096 C      OUTPUT NO 2
L.0097 19     IF(K.GT.2) GO TO 21
L.0098        IF(N.GT.2) GO TO 27
L.0099        WRITE(KW,27)
L.0100 27     FORMAT(//T3,'N',T10,'DISDP',T20,'DISCH',T29,'DELYAS',T40,'DELY',T50,'AREA',T60,'DEPTH'/T2,64('*'))
L.0101        WRITE(KW,21) N,DISDP(N),Q(N),DELYAS(N,I),DELY,A(N,I),Y(N,I)
L.0102 21     FORMAT(T2,I2,T5,F7.3,T18,F8.6,T28,F6.5,T38,F6.5,T48,F8.6,T58,F8.6)
L.0103        IF(DELYAS(N,I).LT.DELY) GO TO 26
L.0104        L=L+1
L.0105 26     J=1
L.0106 15     CONTINUE
L.0107 C      FREEBOARD ALLOWANCE
L.0108        YFIN=Y(NT,J)+1.15
L.0109        AFIN=YFIN*(B+YFIN/TAN(SSR))
L.0110        IF(I.LT.40) GO TO 25
L.0111 24     WRITE(KW,25) N
L.0112 25     FORMAT(T2,'NON CONVERGENCE AFTER 40 ITERATIONS AT STATION NO*',1X,I2)
```

```
L.0113      IF(I.GT.10) GO TO 32
L.0114 C    OUTPUT TO 3
L.0115      IF(P.GT.1) GO TO 31
L.0116      WRITE(6,4)
L.0117 31   FORMAT(//T9,'LENGTH',T18,'YCRIT',T31,'DEPTH',T41,'AREA',T55,'*',T58,'YFIN',T71,'AFIN'/T2,79('*'))
L.0118      WRITE(6,2) X,YCRIT,YINT,J,AINT,J),YFIN,AFIN
L.0119 32   FORMAT(T4,F7.1,T17,F7.4,T30,F7.5,T46,F9.7,T55,'*',1X,,F7.5,T70,F9.7)
L.0120 90   CONTINUE
L.0121 91   CONTINUE
```

OUTPUTS OF TRAP

PTC ACCT # DEPT OF CIVIL ENG FILL T14 WED 27/2/74 (74-058) TIME 13.22

Programme to check results of TRAP against results of CRECT1

```
*****************************************
*                                       *
*  TRAPEZOIDAL GUTTER OF BASE WIDTH= .2000 M *
*                  SIDE SLOPE= 90 DEG.  *
*                                       *
*****************************************
```

FLOW PER UNIT LENGTH OF GUTTER= .009009 CU.M./S.

LENGTH	VCRIT	DEPTH	AREA	*	YFIX	AFIX
[illegible]	.1769	.14469	.02744[illegible]	*	.1617	.0137473
[illegible]	.18206	.17095	.0361759	*	.2323	.0129957
[illegible]	.11521	.14127	.0272915	*	.1524	.0103613
[illegible]	.2674	.09258	.0142234	*	.1134	.0107774
[illegible]	.13333	.09331	.0111978	*	.0692	.0077475
[illegible]	.14235	.08845	.0117733	*	.0711	.0115914

FLOW PER UNIT LENGTH OF GUTTER= .003009 CU.M./S.

LENGTH	VCRIT	DEPTH	AREA	*	YFIX	AFIX
1.[illegible]	.[illegible]8617	.13417	.0[illegible]7	*	.1256	.0241237
5.[illegible]	.[illegible]2[illegible]	.16963	.0297452	*	.1710	.0342791
10.[illegible]	.1[illegible]1[illegible]	.[illegible]43[illegible]	.0[illegible]3263	*	.2795	.0554233
15.[illegible]	.17217	.12459	.0[illegible]7859	*	.1736?	.0[illegible]7656
20.[illegible]	.20910	.10110	.0[illegible]2670	*	.1612[illegible]	.0[illegible]3153
25.[illegible]	.24[illegible]	.[illegible]7[illegible]	.0[illegible]6385	*	.[illegible]437[illegible]	.[illegible]389497

FLOW PER UNIT LENGTH OF GUTTER= .001009 CU.M./S.

LENGTH	VCRIT	DEPTH	AREA	*	YFIX	AFIX
1.[illegible]	.[illegible]2761	.[illegible]6[illegible]	.[illegible]0[illegible]933	*	.[illegible]3592	.[illegible]113[illegible]
5.[illegible]	.[illegible]3[illegible]	.[illegible]7[illegible]	.[illegible]7[illegible]32	*	.[illegible]8168	.[illegible]143[illegible]
10.[illegible]	.06742	.12942	.0[illegible]0889	*	.13[illegible]	.[illegible]27[illegible]
15.[illegible]	.[illegible]0269	.[illegible]6269	.[illegible]97[illegible]	*	.[illegible]8710	.[illegible]37[illegible]
20.[illegible]	.[illegible]2[illegible]	.[illegible]9[illegible]	.[illegible]39[illegible]	*	.[illegible]2685	.[illegible]453749
25.[illegible]	.[illegible]1686	.23[illegible]	.[illegible]46[illegible]	*	.[illegible]6745	.[illegible]335109

TRAPEZOIDAL GUTTER WITH BASE WIDTH .2000 M
SIDE SLOPE 35 DEG.

FLOW PER UNIT LENGTH OF GUTTER= .000200 CU.M./S.

LENGTH	VCRIT	DEPTH	AREA	=	VFIN	AFIN
1.000	.6711	.4710	.4252561	=	.38774	.3131374
10.000	.6711	.4710	.4252561	=	.21671	.2444611
20.000	.6711	.4710	.4252561	=	.13357	.0572929
30.000	.6711	.4710	.4252561	=	.09708	.0247369
50.000	.6711	.4710	.4252561	=	.06787	.0123926
100.000	.6711	.4710	.4252561	=	.04734	.0036722

FLOW PER UNIT LENGTH OF GUTTER= .000900 CU.M./S.

LENGTH	VCRIT	DEPTH	AREA	=	VFIN	AFIN
10.000	.9333.2	.7611.2	.0196565	=	.07518	.0225679
15.000	.96927	.07727	.0237998	=	.38887	.7314543
20.000	.96462	.07242	.0232832	=	.12629	.6646784
25.000	.96203	.07483	.0235653	=	.12756	.5432982
30.000	.96066	.07867	.0243351	=	.13428	.0560361
35.000	35.960	.07613	.0527861	=	.14525	.6854581

FLOW PER UNIT LENGTH OF GUTTER= .000300 CU.M./S.

LENGTH	VCRIT	DEPTH	AREA	=	VFIN	AFIN
10.000	.72963	.09563	.0126841	=	.09232	.0152692
15.000	.73178	.09371	.0127436	=	.26745	.0214378
20.000	.72.05	.09273	.0221768	=	.07969	.0760357
25.000	.72.32	.09127	.0276785	=	.07367	.0338273
30.000	30.000	.09287	.0324780	=	.06953	.0390132
						.0562191

TRAPEZOIDAL GUTTER OF BASE WIDTH= .0000 M
SIDE SLOPE= 30 DEG.

FLOW PER UNIT LENGTH OF GUTTER= .005000 CU.M./S.

LENGTH	VELOCITY	DEPTH	AREA	= VELOCITY	AFLUX
3.00	.11469	.11469	.0131576	* .12245	.0021673
6.00	.11745	.11745	.0137925	* .13075	.0041131
12.00	.12107	.12107	.0146624	* .13269	.0082692
24.00	.12586	.12586	.0158419	* .13660	.0164387
48.00	.13133	.13133	.0172417	* .13862	.0328241
96.00	.13635	.13635	.0185937	* .13931	.0656915

FLOW PER UNIT LENGTH OF GUTTER= .003000 CU.M./S.

LENGTH	VELOCITY	DEPTH	AREA	= VELOCITY	AFLUX
3.00	.07581	.07581	.0057463	* .09010	.0023005
6.00	.08069	.08069	.0065126	* .12740	.0049123
12.00	.08626	.08626	.0074421	* .12700	.0096649
24.00	.09209	.09209	.0084789	* .12692	.0193680
48.00	.09819	.09819	.0096412	* .12692	.0387968
96.00	.10486	.10486	.0109956	* .12727	.0779937

FLOW PER UNIT LENGTH OF GUTTER= .001000 CU.M./S.

LENGTH	VELOCITY	DEPTH	AREA	= VELOCITY	AFLUX
3.00	.05369	.05369	.0028813	* .06772	.0019480
6.00	.05722	.05722	.0032746	* .06788	.0038978
12.00	.06142	.06142	.0037724	* .06939	.0078498
24.00	.06580	.06580	.0043289	* .12710	.0155332
48.00	.07022	.07022	.0049312	* .14682	.0310178
96.00	.07496	.07496	.0056191	* .14746	.0621196

TRAPEZOIDAL GUTTER OF BASE WIDTH= .2000 M
SIDE SLOPE= 45 DEG.

FLOW PER UNIT LENGTH OF GUTTER= .000860 CU.M./S.

LENGTH	VELOCITY	DEPTH	AREA	*	VELOCITY	AREA
[illegible]	[illegible]	[illegible]	.0242726	*	.04735	.0211993
[illegible]	[illegible]	[illegible]	.0337575	*	.10394	.0124501
[illegible]	[illegible]	[illegible]	.0427735	*	.14187	.0092326
[illegible]	[illegible]	[illegible]	.0511223	*	.16938	.0073383
[illegible]	[illegible]	[illegible]	.0590773	*	.19257	.0062715
[illegible]	[illegible]	[illegible]	.0669494	*	.21716	.0046629

FLOW PER UNIT LENGTH OF GUTTER= .000900 CU.M./S.

LENGTH	VELOCITY	DEPTH	AREA	*	VELOCITY	AREA
10.000	.03750	.00642	.0012941	*	.04679	.0027621
15.000	.04727	.00927	.0025915	*	.06477	.0029267
20.000	.05642	.01262	.0033176	*	.11569	.0026394
25.000	.06493	.01645	.0041565	*	.13246	.0043552
30.000	.07286	.02069	.0047956	*	.14907	.0051692
35.000	.08023	.02511	.0060322	*	.16345	.0058125

FLOW PER UNIT LENGTH OF GUTTER= .000900 CU.M./S.

LENGTH	VELOCITY	DEPTH	AREA	*	VELOCITY	AREA
10.000	.02749	.00769	.0011548	*	.05462	.0019873
15.000	.03478	.00973	.0014516	*	.07722	.0019551
20.000	.04129	.01221	.0016344	*	.08889	.0020804
25.000	.04727	.01507	.0020271	*	.10267	.0021783
30.000	.05287	.01827	.0023566	*	.11490	.0024587
35.000	.05816	.02176	.0026192	*	.12668	.0043684

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PTC      ACCT 3 H  DEPT OF CIVIL ENG                    FILE   T5                    TUE 26/2/74 (74-C57)      TIME 19.51
```

```
                                                  ***************************************************
                                                  *                                                 *
                                                  *  TRAPEZOIDAL GUTTER OF BASE WIDTH=   .2000  M  *
                                                  *                       SIDE SLOPE=  45  DEG.     *
                                                  *                                                 *
                                                  ***************************************************

                                                  INLOW PER UNIT LENGTH OF GUTTER=   .005000  CU.M./S.
                                                  ***************************************************
```

LENGTH	YCRIT	DEPTH	AREA	*	YFIN	AFIN
3.000	.07269	.11669	.0369661	*	.13427	.0449538
5.	.09056	.19696	.0559324	*	.18065	.0684368
10.000	.14524	.27529	.0959259	*	.25968	.1189573
15.000	.19776	.27685	.1326470	*	.31539	.1650503
20.000	.22933	.32133	.1675461	*	.36952	.2129039
25.000	.23635	.33335	.2031269	*	.41711	.2523044

```
                                                  INLOW PER UNIT LENGTH OF GUTTER=   .003000  CU.M./S.
                                                  ***************************************************
```

LENGTH	YCRIT	DEPTH	AREA	*	YFIN	AFIN
3.000	.05287	.08667	.0249215	*	.09990	.0297618
5.000	.07269	.11669	.0369661	*	.13427	.0449538
10.000	.10474	.17374	.0645621	*	.17900	.0794133
15.000	.13689	.21689	.0904322	*	.24542	.1121139
20.000	.16110	.25110	.1132877	*	.28876	.1411601
25.000	.18086	.28086	.1390787	*	.32299	.1689517

```
                                                  INLOW PER UNIT LENGTH OF GUTTER=   .001000  CU.M./S.
                                                  ***************************************************
```

LENGTH	YCRIT	DEPTH	AREA	*	YFIN	AFIN
3.000	.02749	.04349	.0105908	*	.05002	.0125958
5.000	.03702	.06302	.0165792	*	.07249	.0197903
10.000	.05642	.09642	.0285848	*	.11389	.0344767
15.000	.07269	.12269	.0399968	*	.14110	.0481339
20.000	.08722	.14522	.0501373	*	.16700	.0612966
25.000	.09856	.16456	.0600021	*	.18925	.0736753

```
                                        ********************************************
                                        *                                          *
                                        *  TRAPEZOIDAL GUTTER OF BASE WIDTH=  .2000  M  *
                                        *                        SIDE SLOPE=  60  DEG.  *
                                        *                                          *
                                        ********************************************

                                        INFLOW PER UNIT LENGTH OF GUTTER=  .006800  CU.M./S.
                                        ********************************************

   LENGTH      YCRIT       DEPTH       AREA        *  YFIN        AFIN
  ********** ********** ********** ********** *** ********** **********
    10.000      .11812      .09118      .0237372   *  .10645      .0272210
    15.000      .16772      .11721      .0313734   *  .13478      .0376409
    20.000      .17771      .14171      .0379628   *  .16071      .0479352
    25.000      .21772      .16122      .0427555   *  .18546      .0569138
    30.000      .19147      .18197      .0455212   *  .20927      .0651467
    35.000      .21214      .19814      .0623588   *  .22786      .0795635

                                        INFLOW PER UNIT LENGTH OF GUTTER=  .006800  CU.M./S.
                                        ********************************************

   LENGTH      YCRIT       DEPTH       AREA        *  YFIN        AFIN
  ********** ********** ********** ********** *** ********** **********
    10.000      .07920      .06048      .0106469   *  .07519      .0191151
    15.000      .09927      .08221      .0224584   *  .10767      .0326212
    20.000      .11842      .10042      .0340748   *  .12669      .0439173
    25.000      .13683      .12683      .0546579   *  .14584      .0561493
    30.000      .07669      .14069      .0395726   *  .16188      .0676805
    35.000      .08413      .15413      .0453056   *  .17955      .0545302

                                        INFLOW PER UNIT LENGTH OF GUTTER=  .006800  CU.M./S.
                                        ********************************************

   LENGTH      YCRIT       DEPTH       AREA        *  YFIN        AFIN
  ********** ********** ********** ********** *** ********** **********
    10.000      .07749      .05149      .0118161   *  .07922      .0138649
    15.000      .13678      .06678      .0199331   *  .07686      .0187679
    20.000      .06329      .08129      .0200757   *  .09149      .0237455
    25.000      .04927      .07527      .0242797   *  .10957      .0288471
    30.000      .05427      .10427      .0279701   *  .12290      .0333035
    35.000      .06216      .11816      .0316953   *  .13588      .0378406
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L.0006                    ********************************************
L.0007                    *                                          *
L.0008                    *  TRAPEZOIDAL GUTTER OF BASE WIDTH=  .2000  M  *
L.0009                    *                        SIDE SLOPE=  60  DEG.  *
L.0010                    *                                          *
L.0011                    ********************************************
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L.0013
L.0014                    INLOW PER UNIT LENGTH OF GUTTER=  .005000  CU.M./S.
L.0015                    ********************************************
L.0016
L.0017
L.0018   LENGTH      YCRIT       DEPTH       AREA          *  YFIN        AFIN
L.0019   ********************************************************************
L.0020     3.000     .07467      .12645      .0379357      *  .1434E      .0405569
L.0021     5.000     .13486      .17955      .0747168      *  .19615      .0714558
L.0022    10.000     .15729      .25329      .1577133      *  .29128      .1372624
L.0023    15.000     .19826      .31256      .1191105      *  .33979      .1467298
L.0024    20.000     .23315      .36933      .1426530      *  .42473      .1791418
L.0025    25.000     .26636      .41635      .1820617      *  .47651      .2264947
L.0026
L.0027
L.0028
L.0029                    INLOW PER UNIT LENGTH OF GUTTER=  .003000  CU.M./S.
L.0030                    ********************************************
L.0031
L.0032
L.0033   LENGTH      YCRIT       DEPTH       AREA          *  YFIN        AFIN
L.0034   ********************************************************************
L.0035     3.000     .05687      .09037      .0223427      *  .1145)      .0272267
L.0036     5.000     .07660      .12663      .0346101      *  .1457E      .0414E09
L.0037    10.000     .11704      .19164      .0592906      *  .21370      .0718207
L.0038    15.000     .14889      .24283      .0826539      *  .27932      .1009332
L.0039    20.000     .17515      .28715      .1052292      *  .33416      .1289961
L.0040    25.000     .19886      .31886      .1224998      *  .38665      .1510E54
L.0041
L.0042
L.0043
L.0044                    INLOW PER UNIT LENGTH OF GUTTER=  .001000  CU.M./S.
L.0045                    ********************************************
L.0046
L.0047
L.0048   LENGTH      YCRIT       DEPTH       AREA          *  YFIN        AFIN
L.0049   ********************************************************************
L.0050     3.000     .02749      .04549      .0162940      *  .09232      .0123443
L.0051     5.000     .03902      .06532      .0354472      *  .09478      .0181275
L.0052    10.000     .06042      .10442      .0271830      *  .12009      .0323469
L.0053    15.000     .07669      .13469      .0574186      *  .15490      .0448343
L.0054    20.000     .09122      .15922      .0464857      *  .18310      .0559643
L.0055    25.000     .10456      .18256      .0557645      *  .20995      .0674500
```

TRAPEZOIDAL GUTTER OF BASE WIDTH= .2500 M
SIDE SLOPES 30 DEG.

FLOW PER UNIT LENGTH OF GUTTER= .000300 CU.M./S.

DEPTH	WIDTH	DEPTH	AREA	V	YFIX	AFIX
[illegible]	[illegible]	.1674	.0132526	=	.12357	.0016377
[illegible]	[illegible]	.1525	.0109626	=	.1.3629	.0149416
[illegible]	[illegible]	.1.443	.0104493	=	.66771	.0224197
[illegible]	[illegible]	.1.015	.0031612	=	.2.7376	.0279467
[illegible]	[illegible]	.1.127	.0.2.7377	=	.1.3697	.0146391
[illegible]	[illegible]	.1.1.1	.0.3.1.1	=	.07873	.0.403620

FLOW PER UNIT LENGTH OF GUTTER= .000500 CU.M./S.

DEPTH	WIDTH	DEPTH	AREA	V	YFIX	AFIX
[illegible]	[illegible]	.1993	.0.3393	=	.63952	.0.217015
[illegible]	[illegible]	.1.241	.0.2.5.6	=	.1.1.163	.0.274424
[illegible]	[illegible]	.1.4.19	.0.4.929	=	.1.7369	.0.379226
[illegible]	[illegible]	.1.432	.0.4.1.8	=	.1.9735	.0.411178
[illegible]	[illegible]	.1.4.42	.0.2.9.42	=	.11319	.0.454512
[illegible]	[illegible]	.1.4.5	.0.3.1.23	=	.12.59	.0.487149

FLOW PER UNIT LENGTH OF GUTTER= .000300 CU.M./S.

DEPTH	WIDTH	DEPTH	AREA	V	YFIX	AFIX
[illegible]	[illegible]	.0.4.7.1	.0.2.7.7.1	=	.11.1.8	.0.6.9.903
[illegible]	[illegible]	.1.9.32	.1.5.1.1.8	=	.16.857	.0.9.8.824
[illegible]	[illegible]	.1.1.5.16	.1.1.7.3.1	=	.2.6.6.61	.1.2.5.0.259
[illegible]	[illegible]	.2.1.1.52	.1.5.2.1.6	=	.2.1.1.25	.1.5.7.4.771
[illegible]	[illegible]	.2.4.5.1.5	.1.7.3.3.1.6	=	.2.8.1.16	.1.9.1.5.033
[illegible]	[illegible]	.2.6.1.6.3	.1.9.1.9.7.2	=	.3.1.1.73	.2.2.2.9.775

```
PTC      ACCT 3    DEPT OF CIVIL ENG                FILE   T111                    MCK  4/3/74 (74-C63)    TIME 12.50

                                                  *****************************************************
                                                  *                                                   *
                                                  *  TRAPEZOIDAL GUTTER OF BASE WIDTH=   .2500  M   *
                                                  *                 SIDE SLOPES  30  DEG.             *
                                                  *                                                   *
                                                  *****************************************************

                                                  FLOW PER UNIT LENGTH OF GUTTER=   .025000  CU.M./S.
                                                  ***************************************************

     LENGTH        YCRIT        DEPTH        AREA          *  YFIN         AFIN
     ***************************************************************************************
      [illegible]   .35322       .12722       .0597420      *  .14630       .0736548
      [illegible]   .1[illegible]  .1[illegible]  .1[illegible]  *  .21171       .1305797
      [illegible]   .1[illegible]  .2[illegible]  .1[illegible]  *  .25346       .1861172
      [illegible]   .1[illegible]  .2[illegible]  .1[illegible]  *  .32325       .2351232
      [illegible]   .1[illegible]  .2[illegible]  .2[illegible]  *  .33732       .2514623
      [illegible]   .[illegible]  .3[illegible]  .2[illegible]  *  .37347       .3353398

                                                  FLOW PER UNIT LENGTH OF GUTTER=   .010000  CU.M./S.
                                                  ***************************************************

     LENGTH        YCRIT        DEPTH        AREA          *  YFIN         AFIN
     ***************************************************************************************
      [illegible]   .12[illegible]  .10212       .1[illegible]  *  .20[illegible]  .1283269
      [illegible]   .1[illegible]  .25767       .1[illegible]  *  .29635       .2262307
      [illegible]   .21277       .31677       .2530365      *  .36429       .3[illegible]
      [illegible]   .2[illegible]  .35836       .3128236      *  .41269       .3942373
      [illegible]   .2[illegible]  .40425       .3[illegible]  *  .46489       .4[illegible]
      [illegible]   [illegible]  ATTEMPT NO 1

                                                  FLOW PER UNIT LENGTH OF GUTTER=   .001000  CU.M./S.
                                                  ***************************************************

     LENGTH        YCRIT        DEPTH        AREA          *  YFIN         AFIN
     ***************************************************************************************
      [illegible]   .[illegible]  .05246       .0178826      *  .20[illegible]  .0213875
      [illegible]   .[illegible]  .[illegible]  .0317[illegible]  *  .[illegible]  .0[illegible]
      [illegible]   .[illegible]  .10122       .0[illegible]  *  .11638       .0525585
      [illegible]   .[illegible]  .12171       .0[illegible]  *  .13557       .0[illegible]
      [illegible]   .[illegible]  .13722       .0[illegible]  *  .15780       .0825984
      [illegible]   .[illegible]  .15197       .0[illegible]  *  .17477       .0[illegible]
```

TRAPEZOIDAL GUTTER OF BASE WIDTH= .2500 M
SIDE SLOPE= 45 DEG.

FLOW PER UNIT LENGTH OF GUTTER= .000300 CU.M./S.

	LENGTH	WIDTH	DEPTH	AREA		VEL	AREA
	[illegible]	.1625	.0375	.0121914	*	.12847	.2773276
	[illegible]	.2525	.0425	.0173686	*	.16959	.3144766
	[illegible]	.3425	.0475	.0233288	*	.18961	.3825365
	[illegible]	.4325	.0525	.0293736	*	.20736	.4297315
	[illegible]	.5225	.0575	.0356929	*	.22313	.4511149
	[illegible]	.6125	.0625	.0422867	*	.23713	.5364699

FLOW PER UNIT LENGTH OF GUTTER= .000500 CU.M./S.

	LENGTH	WIDTH	DEPTH	AREA		VEL	AREA
	[illegible]	.2125	.0375	.0102723	*	.04932	.0126371
	[illegible]	.3025	.0425	.0150935	*	.06723	.0213282
	[illegible]	.3925	.0475	.0206934	*	.08459	.0291461
	[illegible]	.4825	.0525	.0270731	*	.10155	.0373198
	[illegible]	.5725	.0575	.0339349	*	.11795	.0455766
	[illegible]	.6625	.0625	.0412791	*	.13379	.0518858

FLOW PER UNIT LENGTH OF GUTTER= .000600 CU.M./S.

	LENGTH	WIDTH	DEPTH	AREA		VEL	AREA
	[illegible]	.4525	.0375	.0342645	*	.12328	.0464215
	[illegible]	.5425	.0425	.0454913	*	.16197	.0698447
	[illegible]	.6325	.0475	.0605927	*	.19131	.1111264
	[illegible]	.7225	.0525	.0796757	*	.21846	.1467741
	[illegible]	.8125	.0575	.1141143	*	.24366	.1691834
	[illegible]	.9025	.0625	.1511947	*	.26719	.2004378

```
L.  1 MODEL
L.  2
L.  3
L.  4
L.  5                    ********************************************
L.  6                    *                                          *
L.  7                    *  TRAPEZOIDAL WEIRS OF BASE WIDTH= .2500  M *
L.  8                    *                SIDE SLOPES= 45  DEG.     *
L.  9                    *                                          *
L. 10                    ********************************************
L. 11
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L. 13                    FLOW PER UNIT LENGTH OF SLOTTED= .2500  CU.M./S.
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PTC PAGE 4 PART OF CIVIL ENG FILE TITLE MON 4/22/74 (74-C631) TIME 12.51

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* TRAPEZOIDAL GUTTER OF BASE WIDTH= .2500 F *

* SIDE SLOPES AT DEG. *

*

*

FLOW PER UNIT LENGTH OF GUTTER= .000400 CU.M./S.

	WIDTH	DEPTH	AREA		VELS	AFLO
	.1573	.0267	.0031715	#	.1317	.0004205
	.2023	.037	.0051322	*	.1511	.0007754
	.1354	.0	.0019112	*	.2021	.0003861
	.1317	.0	.0021963	*	.1826	.0004010
	.1523	.0	.0029292	*	.1365	.0003998
	.1811	.0	.0023617	*	.1695	.0004003

FLOW PER UNIT LENGTH OF GUTTER= .000500 CU.M./S.

	WIDTH	DEPTH	AREA		VELS	AFLO
	.1783	.0291	.0039242	*	.1332	.0005195
	.1966	.0	.0042766	*	.1693	.0007239
	.1627	.0	.0027929	*	.1339	.0003739
	.1810	.0	.0029588	*	.1175	.0003520
	.1762	.0	.0034362	*	.1283	.0004406
	.1723	.0	.0029412	*	.1405	.0004133

*

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TRAPEZOIDAL GUTTER OF SIDE SLOPE

FLOW PER UNIT LENGTH OF GUTTER

LENGTH	YCAIT	DEPTH	AREA	*	YCIL	AFIL
[illegible]	.17322	.19322	.0313617	*	.17620	.0418822
[illegible]	.20[illegible]	.21713	.[illegible]	*	.20[illegible]	.0[illegible]
[illegible]	.[illegible]	.[illegible]	.1220946	*	.13156	.1469791
[illegible]	[illegible]	.[illegible]	.15[illegible]	*	.[illegible]	.1[illegible]
[illegible]	.25[illegible]	.26711	.733	*	.[illegible]	.2[illegible]
[illegible]	[illegible]	.[illegible]	.677	*	.[illegible]	.2[illegible]

FLOW PER UNIT LENGTH OF GUTTER

LENGTH	YCAIT	DEPTH	AREA	*	YCIL	AFIL
[illegible]	.16219	.[illegible]	.0[illegible]	*	.[illegible]	.[illegible]
[illegible]	.21367	.23767	.1402911	*	.[illegible]	.1[illegible]
[illegible]	.25[illegible]	.29[illegible]	.[illegible]	*	.[illegible]	.2[illegible]
[illegible]	.31[illegible]	.[illegible]	.[illegible]	*	.[illegible]	.3[illegible]
[illegible]	.35[illegible]	.39676	.[illegible]	*	.[illegible]	.3[illegible]
[illegible]	.[illegible]	.39[illegible]	.[illegible]	*	.[illegible]	.[illegible]

FLOW PER UNIT LENGTH OF GUTTER

LENGTH	YCAIT	DEPTH	AREA	*	YCIL	AFIL
[illegible]	.[illegible]	.[illegible]	.0165987	*	.[illegible]	.0[illegible]
[illegible]	.[illegible]	.[illegible]	.0[illegible]	*	.[illegible]	.0[illegible]
[illegible]	.[illegible]	.[illegible]	.0[illegible]	*	.[illegible]	.0[illegible]
[illegible]	.[illegible]	.[illegible]	.0[illegible]	*	.[illegible]	.0[illegible]
[illegible]	.[illegible]	.[illegible]	.0[illegible]	*	.[illegible]	.0[illegible]

TRAPEZOIDAL GUTTER OF BASE WIDTH= .300C M
SIDE SLOPE= 30 DEG.

FLOW PER UNIT LENGTH OF GUTTER= .C5090C CU.M./S.

LENGTH	VCUIT	DEPTH	AREA		VFIX	AFIX
10.000	.03968	.05147	.0259451	*	.07619	.0617692
12.500	.04318	.05351	.0311221	*	.07935	.0644645
15.000	.04625	.05571	.0367958	*	.08196	.0678971
17.500	.04901	.05791	.0427656	*	.08383	.0726172
20.000	.05151	.06001	.0488417	*	.08547	.0781317
22.500	.05381	.06201	.0548896	*	.08693	.0846829

FLOW PER UNIT LENGTH OF GUTTER= .05090C CU.M./S.

LENGTH	VCUIT	DEPTH	AREA		VFIX	AFIX
10.000	.03921	.05127	.0199925	*	.05939	.0236715
12.500	.04303	.05312	.0258324	*	.07548	.0321209
15.000	.04631	.05471	.0317313	*	.07831	.0432678
17.500	.04942	.05642	.0378929	*	.08149	.0493293
20.000	.05242	.05842	.0449311	*	.08779	.0593712
22.500	.05537	.06047	.0533985	*	.09491	.0674634

FLOW PER UNIT LENGTH OF GUTTER= .000900 CU.M./S.

LENGTH	VCUIT	DEPTH	AREA		VFIX	AFIX
10.000	.01111	.03793	.0113708	*	.04362	.0163813
12.500	.01257	.04049	.0134316	*	.05552	.0226974
15.000	.01386	.04246	.0154706	*	.06255	.0292336
17.500	.01504	.04442	.0174614	*	.06748	.0347294
20.000	.01614	.04627	.0194802	*	.07119	.0417611
22.500	.01719	.04793	.0213126	*	.07413	.0481204

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                                        ********************************************
                                        *                                          *
                                        *  TRAPEZOIDAL GUTTER OF BASE WIDTH=  .3000 M *
                                        *                        SIDE SLOPE= 30  DEG. *
                                        *                                          *
                                        ********************************************

                                        INFLOW PER UNIT LENGTH OF GUTTER=  .000000  CU.M./S.

  LENGTH      YCRIT       DEPTH       AREA        *  YFIX        AFIX
 ---------------------------------------------------------------------------
   3.000     .36462      .07969      .0212719    *  .10739      .0049791
   6.000     .47369      .11364      .0407270    *  .13765      .0741171
   9.000     .53239      .13634      .0548766    *  .15655      .1024096
  12.000     .57179      .15329      .0658526    *  .16918      .1248268
  15.000     .60139      .16639      .0749376    *  .17915      .1429424
  18.000     .62469      .17663      .0824813    *  .18743      .1580151

                                        INFLOW PER UNIT LENGTH OF GUTTER=  .000000  CU.M./S.

  LENGTH      YCRIT       DEPTH       AREA        *  YFIX        AFIX
 ---------------------------------------------------------------------------
   3.000     .34179      .06729      .0268529    *  .07739      .0335910
   6.000     .53642      .09362      .0412919    *  .10399      .0693291
   9.000     .43922      .11922      .0722413    *  .13595      .0985399
  12.000     .49724      .14366      .1002197    *  .16440      .1297924
  15.000     .52619      .12010      .1293690    *  .23011      .1667697
  18.000     .54129      .22379      .1593596    *  .25578      .1912827

                                        INFLOW PER UNIT LENGTH OF GUTTER=  .001000  CU.M./S.

  LENGTH      YCRIT       DEPTH       AREA        *  YFIX        AFIX
 ---------------------------------------------------------------------------
   3.000     .21993      .03393      .0121728    *  .03957      .0143627
   6.000     .32927      .04729      .0103267    *  .05528      .0213097
  10.000     .54621      .07691      .0316794    *  .08751      .0338837
  15.000     .56667      .09862      .0442574    *  .11033      .0565677
  21.000     .56751      .11351      .0566719    *  .13015      .0686778
  25.000     .58569      .12969      .0689494    *  .14945      .0832810
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                                        *  TRAPEZOIDAL GUTTER OF BASE WIDTH=  .3000  M  *
                                        *                SIDE SLOPE=  45  DEG.         *
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                                        INFLOW PER UNIT LENGTH OF GUTTER=   .005000  CU.M./S.
                                        ******************************************************

  LENGTH      VELOCITY      DEPTH        AREA          *   YFIN          AFIN
 ********************************************************************************
  10.000      .02670        .00749       .0020137      *   .78145        .0027650
  20.000      .04595        .01035       .0029687      *   .83645        .0041536
  30.000      .06271        .01271       .0044474      *   .88204        .0061699
  40.000      .07851        .01468       .0060143      *   .91653        .0084469
  50.000      .09381        .01637       .0076497      *   .94263        .0107895
  60.000      .10868        .01788       .0093824      *   .96292        .0130166

                                        INFLOW PER UNIT LENGTH OF GUTTER=   .010000  CU.M./S.
                                        ******************************************************

  LENGTH      VELOCITY      DEPTH        AREA          *   YFIN          AFIN
 ********************************************************************************
  10.000      .03745        .00930       .0037900      *   .76119        .0049793
  20.000      .06437        .01282       .0054732      *   .87934        .0081182
  30.000      .08794        .01561       .0072610      *   .94961        .0103179
  40.000      .11009        .01797       .0090642      *   .98278        .0125694
  50.000      .13167        .02006       .0108962      *   .99669        .0148972
  60.000      .15286        .02196       .0127513      *   .99911        .0169138

                                        INFLOW PER UNIT LENGTH OF GUTTER=   .000000  CU.M./S.
                                        ******************************************************

  LENGTH      VELOCITY      DEPTH        AREA          *   YFIN          AFIN
 ********************************************************************************
  10.000      .00000        .00000       .0000000      *   .00000        .0000000
  20.000      .00000        .00000       .0000000      *   .00000        .0000000
  30.000      .00000        .00000       .0000000      *   .00000        .0000000
  40.000      .00000        .00000       .0000000      *   .00000        .0000000
  50.000      .00000        .00000       .0000000      *   .00000        .0000000
  60.000      .00000        .00000       .0000000      *   .00000        .0000000

  LENGTH      VELOCITY      DEPTH        AREA          *   YFIN          AFIN
 ********************************************************************************
  10.000      .21134        .03703       .0123175      *   .04362        .0149884
  20.000      .27269        .04243       .0181002      *   .05972        .0212727
  30.000      .31246        .04656       .0226043      *   .07183        .0267694
  40.000      .34739        .04992       .0272615      *   .08398        .0322678
  50.000      .37936        .05283       .0319275      *   .09579        .0379137
  60.000      .40737        .05533       .0367421      *   .10503        .0429426
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PTC      ACCT 3    DEPT OF CIVIL ENG                    FILE   TR1                    TUE 26/2/74 (74-0471)      TIME 15.03

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L.0005                                                  ***************************************
L.0006                                                  *                                     *
L.0007                                                  *  TRAPEZOIDAL GUTTER OF BASE WIDTH=   .3000  M  *
L.0008                                                  *                       SIDE SLOPE=  45  DEG.   *
L.0009                                                  *                                     *
L.0010                                                  ***************************************
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L.0015                                                  INLOW PER UNIT LENGTH OF GUTTER=   .005000  CU.M./S.
L.0016                                                  ***************************************
L.0017
L.0018
L.0019
L.0020   LENGTH        YCRIT        DEPTH        AREA        =  YFIN        AFIN
L.0021   ***************************************************************************
L.0022   [illegible]   .[illegible]   .[illegible]   .2332271   =  .11[illegible]   .0453654
L.0023   [illegible]   .[illegible]   .13169   .0568555   =  .13145   .0[illegible]3762
L.0024   [illegible]   .[illegible]   .[illegible]   .0[illegible]   =  .22453   .1172868
L.0025   [illegible]   .15[illegible]   .24729   .1353542   =  .2[illegible]   .1662[illegible]
L.0026   [illegible]   .13[illegible]   .[illegible]   .1730[illegible]   =  .33315   .2[illegible]
L.0027   [illegible]   .[illegible]   .32140   .1[illegible]   =  .36[illegible]   .2[illegible]
L.0028
L.0029
L.0030
L.0031
L.0032
L.0033   LENGTH        YCRIT        DEPTH        AREA        =  YFIN        AFIN
L.0034   ***************************************************************************
L.0035   [illegible]   .[illegible]   .[illegible]   .[illegible]   =  .[illegible]   .[illegible]
L.0036   [illegible]   .[illegible]   .[illegible]   .[illegible]   =  .11119   .0[illegible]
L.0037   10.000   .[illegible]   .14922   .0[illegible]   =  .17[illegible]   .0[illegible]
L.0038   15.000   .[illegible]   .18954   .0[illegible]   =  .21[illegible]   .1124[illegible]
L.0039   20.000   .13[illegible]   .22[illegible]   .1[illegible]   =  .25541   .1418[illegible]
L.0040   25.000   .15[illegible]   .25129   .1[illegible]   =  .2[illegible]   .1702[illegible]
L.0041
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L.0049   LENGTH        YCRIT        DEPTH        AREA        =  YFIN        AFIN
L.0050   ***************************************************************************
L.0051   [illegible]   .[illegible]   .[illegible]   .0113[illegible]   =  .[illegible]   .0132[illegible]
L.0052   [illegible]   .[illegible]   .[illegible]   .0[illegible]   =  .[illegible]   .0[illegible]
L.0053   15.   .[illegible]   .[illegible]   .0[illegible]   =  .[illegible]   .0[illegible]
L.0054   20.000   .[illegible]   .12391   .0[illegible]   =  .1[illegible]   .0[illegible]
55       25.000   .[illegible]   .14169   .0[illegible]   +  .16[illegible]   .0[illegible]
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TRAPEZOIDAL GUTTER OF BASE WIDTH= .1000 M
SIDE SLOPE= 60 DEG.

FLOW PER UNIT LENGTH OF GUTTER= .000800 CU.M./S.

LENGTH	YCRIT	DEPTH	AREA	*	YBIA	ABIA
[illegible]	.0755	.07261	.0047178	*	.07345	.0022149
[illegible]	.0757	.07317	.0033754	*	.07365	.0022559
[illegible]	.06723	.07071	.0027805	*	.07124	.0019796
[illegible]	.0771	.07351	.0033677	*	.07411	.0024976
[illegible]	.07171	.06971	.0026103	*	.07047	.0018387
[illegible]	.07357	.06965	.0026589	*	.07030	.0018688

FLOW PER UNIT LENGTH OF GUTTER= .000900 CU.M./S.

LENGTH	YCRIT	DEPTH	AREA	*	YBIA	ABIA
10.000	.0774.0	.0532.	.0159336	*	.06119	.0029170
15.000	.07392	.07302	.0249875	*	.07098	.0029269
20.000	.0764.1	.07001	.0230735	*	.07121	.0028785
25.000	.07662	.07042	.0367856	*	.07279	.0033456
30.000	.07862	.07062	.0427560	*	.07389	.0035199
35.000	.08010	.07210	.0479070	*	.07431	.0036279

FLOW PER UNIT LENGTH OF GUTTER= .000300 CU.M./S.

LENGTH	YCRIT	DEPTH	AREA	*	YBIA	ABIA
10.000	.02145	.05993	.0120896	*	.04992	.0049932
15.000	.02749	.05569	.0117067	*	.05152	.0020629
20.000	.03446	.06466	.0217379	*	.07413	.0029126
25.000	.03922	.07722	.0265362	*	.08858	.0011056
30.000	.04329	.08729	.0305892	*	.10039	.0039368
35.000	.04943	.09733	.0346703	*	.11193	.0040147

***

TRAPEZOIDAL GUTTER OF BASE WIDTH= .3500 M
SIDE SLOPE= 35 PCT.

FLOW PER UNIT LENGTH OF GUTTER= .030500 CU.M./S.

LENGTH	VCRIT	DEPTH	AREA	*	VTIA	ATIA
[illegible]	.3643	.2031	.0163461	*	.291957	.0132395
[illegible]	.2674	.1676	.0241143	*	.2179	.0126136
15.[illegible]	.2572	.1619	.0234402	*	.271151	.0233244
[illegible]	.4432	.2761	.0394476	*	.27921	.0824698
[illegible]	.6904	.3833	.0615732	*	.276641	.0494892
[illegible]	.4134	.2557	.0412914	*	.27.960	.0331696

FLOW PER UNIT LENGTH OF GUTTER= .031060 CU.M./S.

LENGTH	VCRIT	DEPTH	AREA	*	VTIA	ATIA
5.[illegible]	.2674	.1674	.0239242	*	.296115	.0215308
[illegible]	.4231	.2611	.0378589	*	.279931	.0185351
15.[illegible]	.4232	.2611	.0461383	*	.32560	.0369432
[illegible]	.413	.2571	.0379239	*	.32360	.0269572
25.[illegible]	.7097	.3093	.0673267	*	.33847	.0461847
[illegible]	.6903	.3993	.0621987	*	.35955	.0303215

FLOW PER UNIT LENGTH OF GUTTER= .030800 CU.M./S.

LENGTH	VCRIT	DEPTH	AREA	*	VTIA	ATIA
3.[illegible]	.7090	.3145	.0627341	*	.33167	.0206192
10.000	.3595	.2253	.0472817	*	.35269	.0331698
15.000	.3547	.2192	.0472603	*	.34196	.0323957
20.000	.3536	.2434	.0501139	*	.38209	.0331635
25.000	.3643	.2243	.0519339	*	.31339	.0297030
30.000	.3936	.2436	.0630945	*	.34680	.0329755

```
PTN.      SCAT 1    PLOT OF CIVIL CAS                FILE   T115                    MON  4/3/74 (74-063)        TIME 12-51

                                                  *****************************************************
                                                  *                                                   *
                                                  *  TRANSITIONAL OUTFLOW OF GAS DEPTH=   .3700  M  *
                                                  *                       SIDE SLOPE=  30  DEG.       *
                                                  *                                                   *
                                                  *****************************************************

                                                  FLOW PER UNIT LENGTH OF GUTTER=   .010000  CU.M./S.
                                                  ***************************************************

                  YOUTH          DEPTH      AREA          *  YFIN          AFIN
                  ***************************************************************
                  .1[illegible]      .16[illegible]     .1[illegible]4273    *  .19[illegible]      .1[illegible]4334
                  .[illegible]       .[illegible]       .[illegible]4[illegible]     *  .27[illegible]      .[illegible]7[illegible]
                  .[illegible]       .[illegible]       .[illegible]4[illegible]76    *  .33590      .3191118
                  .[illegible]       .[illegible]       .[illegible]1[illegible]1316    *  .3[illegible]      .3[illegible]7[illegible]
                  .[illegible]       .[illegible]       .[illegible]3[illegible]3[illegible]    *  .44[illegible]      .4[illegible]4[illegible]
                  .[illegible]       .[illegible]       .[illegible]4[illegible]7[illegible]    *  .47871      .5[illegible]5590

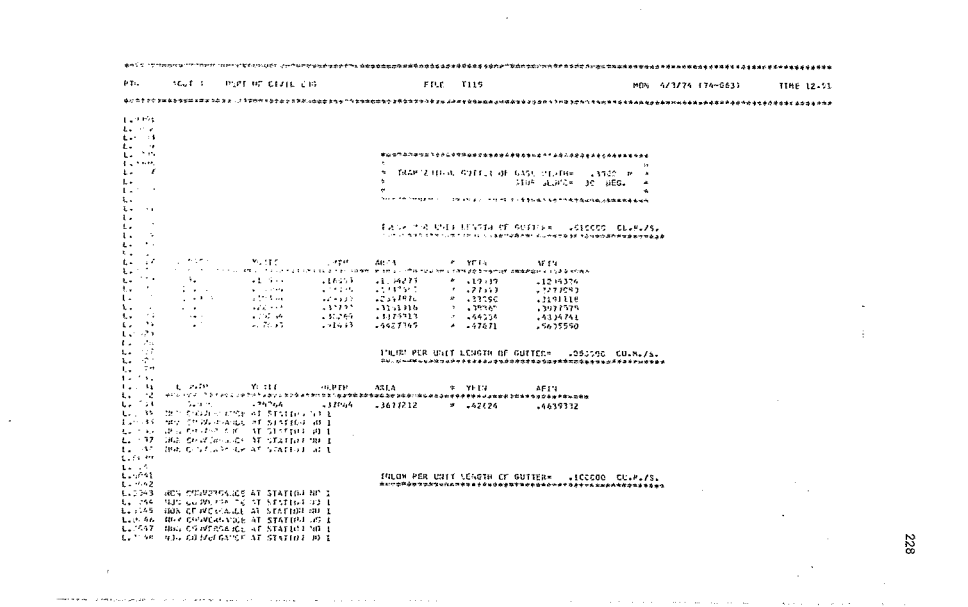
                                                  FLOW PER UNIT LENGTH OF GUTTER=   .050000  CU.M./S.
                                                  ***************************************************

                  YOUTH          DEPTH      AREA          *  YFIN          AFIN
                  ***************************************************************
                  .[illegible]       .[illegible]7[illegible]4     .3[illegible]7[illegible]12    *  .42[illegible]4      .4[illegible]9332

                  NON CONVERGENCE AT STATION NO 1
                  NON CONVERGENCE AT STATION NO 1
                  NON CONVERGENCE AT STATION NO 1
                  NON CONVERGENCE AT STATION NO 1
                  NON CONVERGENCE AT STATION NO 1
                  NON CONVERGENCE AT STATION NO 1

                                                  FLOW PER UNIT LENGTH OF GUTTER=   .100000  CU.M./S.
                                                  ***************************************************

                  NON CONVERGENCE AT STATION NO 1
                  NON CONVERGENCE AT STATION NO 1
                  NON CONVERGENCE AT STATION NO 1
                  NON CONVERGENCE AT STATION NO 1
                  NON CONVERGENCE AT STATION NO 1
                  NON CONVERGENCE AT STATION NO 1
```



TRAPEZOIDAL GUTTER OF BASE WIDTH= .3500 M
SIDE SLOPE= 45 DEG.

INCH PER UNIT LENGTH OF GUTTER= .000900 CU.M./S.

LENGTH	VELOCITY	DEPTH	AREA	*	YFIX	AFIX
5.000	.21611	.2431	.0181767	*	.12257	.0124626
10.000	.27676	.4174	.0536348	*	.19855	.0227616
15.000	.31980	.5482	.0826013	*	.27137	.0311637
20.000	.3521	.6613	.0334359	*	.33961	.0379338
25.000	.37959	.7597	.0379937	*	.40137	.0436249
30.000	.4043	.8498	.0468168	*	.11CEC	.0352668

INCH PER UNIT LENGTH OF GUTTER= .001000 CU.M./S.

LENGTH	VELOCITY	DEPTH	AREA	*	YFIX	AFIX
5.000	.32676	.4476	.0176617	*	.09145	.0208566
10.000	.4217	.7619	.0516270	*	.18931	.0310899
15.000	.4933	.9533	.0526415	*	.18962	.0503749
20.000	.5493	.11339	.0536551	*	.1326C	.0635674
25.000	.59959	.13447	.0661679	*	.13967	.0780630
30.000	.643 9	.14009	.0744153	*	.17145	.0895129

INCH PER UNIT LENGTH OF GUTTER= .003000 CU.M./S.

LENGTH	VELOCITY	DEPTH	AREA	*	YFIX	AFIX
5.000	.47605	.12249	.0373827	*	.14287	.0801541
10.000	.61395	.18595	.0773947	*	.21335	.1202232
15.000	.74432	.23412	.1367303	*	.26746	.1669434
20.000	.87136	.27956	.1723993	*	.31689	.2113612
25.000	.99463	.32843	.2631127	*	.35470	.2497921
30.000	.21596	.36356	.2383167	*	.39510	.2944318

```
L.0001
L.0002
L.0003
L.0004
L.0005                                          ********************************
L.0006                                          *                              *
L.0007                                          *  TRAPEZOIDAL SECTION OF MASS WIDTH=  .3500  M  *
L.0008                                          *                    SIDE SLOPE= 45  DEG.      *
L.0009                                          *                              *
L.0010                                          ********************************
L.0011
L.0012
L.0013                                          FLOW PER UNIT LENGTH OF SECTION=  .12500  CU.M./S.
L.0014                                          ================================
L.0015
L.0016
L.0017    LENGTH        VCRIT        DEPTH        AREA          F  YFIX        AFIX
L.0018    ********************************************************************************
L.0019       9.000      .11111      .19339      .0676357      *  .21535      .1104767
L.0020      19.000      .11111      .20196      .0707077      *  .32733      .2744128
L.0021      29.000      .11111      .18339      .0641697      *  .38935      .2541233
L.0022      39.000      .11111      .17339      .0606697      *  .44468      .2691591
L.0023      49.000      .11111      .16664      .0583039      *  .48214      .2813678
L.0024      59.000      .11111      .16053      .0561869      *  .51741      .2938894
L.0025
L.0026
L.0027                                          FLOW PER UNIT LENGTH OF SECTION=  .05000  CU.M./S.
L.0028                                          ================================
L.0029
L.0030
L.0031    LENGTH        VCRIT        DEPTH        AREA          F  YFIX        AFIX
L.0032    ********************************************************************************
L.0033       9.000      .28944      .42384      .1311144      *  .40294      .4159240
L.0034      19.000      .49714      .42394      .1762249      *  .44453      .7756059
L.0035   NON CONVERGANCE AT STATION NO 1
L.0036   NON CONVERGANCE AT STATION NO 1
L.0037   NON CONVERGANCE AT STATION NO 1
L.0038   NON CONVERGANCE AT STATION NO 1
L.0039
L.0040
L.0041                                          FLOW PER UNIT LENGTH OF SECTION=  .10000  CU.M./S.
L.0042                                          ================================
L.0043
L.0044
L.0045    LENGTH        VCRIT        DEPTH        AREA          F  YFIX        AFIX
L.0046    ********************************************************************************
L.0047       5.000      .49714      .55994      .3700128      *  .42593      .7174205
L.0048   NON CONVERGANCE AT STATION NO 1
L.0049   NON CONVERGANCE AT STATION NO 1
L.0050   NON CONVERGANCE AT STATION NO 1
L.0051   NON CONVERGANCE AT STATION NO 1
L.0052   NON CONVERGANCE AT STATION NO 1
```

PTG ACCT 5 DEPT OF CIVIL ENG FILE FLOC MON 4/3/74 (74-063) TIME 12.51

TRAPEZOIDAL GUTTER WIDTH= .3500 FT
SIDE SLOPE= 45 DEG.

INFLOW PER UNIT LENGTH OF GUTTER= .000500 CU.FT./S.

LENGTH	WIDTH	DEPTH	AREA		YFIN	AFIN
[illegible]	[illegible]	.1713	.0111423	*	.3407	.0129737
[illegible]	[illegible]	.2034	.0147465	*	.4038	.0223555
[illegible]	[illegible]	.1647	.0099369	*	.2787	.0247015
[illegible]	[illegible]	.1725	.0124239	*	.2961	.0391937
[illegible]	[illegible]	.2043	.0327938	*	.4197	.0665261
[illegible]	[illegible]	.1983	.0298211	*	.3711C	.0505551

INFLOW PER UNIT LENGTH OF GUTTER= .001000 CU.FT./S.

LENGTH	WIDTH	DEPTH	AREA		YFIN	AFIN
5.000	.2967	.1667	.0246213	*	.4537	.0204922
10.000	.2421	.2760+	.0299797	*	.5825	.0395536
15.000	.2553	.1713	.0413638	*	.1165	.0486138
20.000	.2673	.1710	.0513382	*	.1615	.0612637
25.000	.2766	.1699	.0603746	*	.1657	.0716775
30.000	.2879	.1703	.0692349	*	.1705	.0809789

INFLOW PER UNIT LENGTH OF GUTTER= .005000 CU.FT./S.

LENGTH	WIDTH	DEPTH	AREA		YFIN	AFIN
5.000	.3763	.1349	.0353594	*	.1527	.0655324
10.000	.3129	.1799	.0529697	*	.2248	.1167403
15.000	.3232	.2562	.1276591	*	.2976	.1533527
20.000	.3256	.3116	.1570713	*	.3667	.1938427
25.000	.3263	.3663	.1809762	*	.4313	.2272581
30.000	.3196	.3596	.2142253	*	.4116	.2661177

```
PTC     ACCT 3    DEPT OF CIVIL ENG                    FILE   TIZE                              MON  4/3/74 174-0631          TIME 15:38
L.0001
L.0002
L.0003
L.0004
L.0005                                        ********************************************
L.0006                                        *                                          *
L.0007                                        *  TRAPEZOIDAL GUTTER OF BASE WIDTH=  .1500 *
L.0008                                        *                        SIDE SLOPE=  60  DEG.  *
L.0009                                        *                                          *
L.0010                                        ********************************************
L.0011
L.0012
L.0013                                    INFLOW PER UNIT LENGTH OF GUTTER=  .010000  CU.M./S.
L.0014                                    ********************************************
L.0015
L.0016
L.0017   LENGTH          YCRIT          DEPTH          AREA          =  YFIX          AFIX
L.0018   ********************************************************************************
L.0019      5.000         .11355         .19753         .0214379    =  .22713        .1079236
L.0020     10.000         .13134         .29556         .0349619    =  .31777        .1634812
L.0021     15.000         .23156         .37196         .0517413    =  .42715        .2539198
L.0022     20.000         .27378         .43798         .0669855    =  .51268        .3227231
L.0023     25.000         .31264         .49264         .0824163    =  .58654        .3836463
L.0024     30.000         .34683         .53884         .0957345    =  .64781        .4346321
L.0025
L.0026
L.0027                                    INFLOW PER UNIT LENGTH OF GUTTER=  .030000  CU.M./S.
L.0028                                    ********************************************
L.0029
L.0030
L.0031   LENGTH          YCRIT          DEPTH          AREA          =  YFIX          AFIX
L.0032   ********************************************************************************
L.0033      5.000         .11264         .49264         .0936771    =  .55904        .3722092
L.0034     10.000         .45794         .67994         .1233367    =  .80033        .6462598
L.0035     15.000         .57005         .85409         .1729427    =  .10443        .9342778
L.0036     20.000         .66173         .98573         .2062534    =  1.12399       1.1790347
L.0037   NON CONVERGANCE AT STATION NO 1
L.0038   NON CONVERGANCE AT STATION NO 1
L.0039
L.0040
L.0041                                    INFLOW PER UNIT LENGTH OF GUTTER=  .100000  CU.M./S.
L.0042                                    ********************************************
L.0043
L.0044
L.0045   LENGTH          YCRIT          DEPTH          AREA          =  YFIX          AFIX
L.0046   ********************************************************************************
L.0047      5.000         .45794         .67994         .5213310    =  .78903        .6671666
L.0048     10.000         .66173         .97973         .8973413    =  1.12669       1.1275816
L.0049   NON CONVERGANCE AT STATION NO 1
L.0050   NON CONVERGANCE AT STATION NO 1
L.0051   NON CONVERGANCE AT STATION NO 1
L.0052   NON CONVERGANCE AT STATION NO 1
```

TRAPEZOIDAL GUTTER BASE WIDTH= .4000 FT
SIDE SLOPE= 30 DEG.

INFLOW PER UNIT LENGTH OF GUTTER= .005000 CU.M./S.

LENGTH	VELOCITY	DEPTH	AREA	*	YFIX	AFIX
3.000	.1911	.2911	.0111363	*	.91497	.0127808
6.000	.2417	.3422	.0142930	*	.94922	.0135677
9.000	.2826	.3776	.0169543	*	.96985	.0138824
12.000	.3176	.4076	.0189518	*	.98139	.0142672
15.000	.3472	.4325	.0207259	*	.99217	.0291293
18.000	.3727	.4527	.0359627	*	.99497	.0361737

INFLOW PER UNIT LENGTH OF GUTTER= .001000 CU.M./S.

LENGTH	VELOCITY	DEPTH	AREA	*	YFIX	AFIX
3.000	.2469	.3603	.0192061	*	.94452	.0228846
6.000	.3199	.4252	.0233369	*	.97678	.0295987
9.000	.3727	.4727	.0267015	*	.99157	.0353866
12.000	.4186	.5102	.0296456	*	.99999	.0403034
15.000	.4603	.5451	.0324779	*	.99206	.0913241
18.000	.4969	.5763	.0351689	*	.95239	.0932538

INFLOW PER UNIT LENGTH OF GUTTER= .005000 CU.M./S.

LENGTH	VELOCITY	DEPTH	AREA	*	YFIX	AFIX
3.000	.4683	.6683	.0640521	*	.12516	.0771995
6.000	.6296	.8296	.1048835	*	.18465	.1323275
9.000	.7655	.9655	.1434827	*	.23261	.1843829
12.000	.8929	.1093	.1875985	*	.26928	.2326515
15.000	.9787	.1179	.2261748	*	.32345	.2809114
18.000	.9886	.1189	.2329097	*	.33449	.3276295

```
PTC      ACCT #    DEPT OF CIVIL ENG                    FILE  7131                              MON  4/12/76 (174-043)        TIME 15.38

L.0001
L.0002
L.0003
L.0004
L.0005                                                  ********************************
L.0006                                                  *                              *
L.0007                                                  *  TRAPEZOIDAL CHANNEL WITH FIX  *
L.0008                                                  *                              *
L.0009                                                  ********************************
L.0010
L.0011
L.0012                                                  INLCK PER UNIT LENGTH OF CHANNEL=  .010000  CU.M./S.
L.0013                                                  ****************************************
L.0014
L.0015
L.0016
L.0017    LENGTH          YCRIT           DEPTH           AREA          *  VFIX            AFIX
L.0018    ********************************************************************************
L.0019          3.000         .73932          .69939         1.87772   *  1.1457          1.9134477
L.0020         15.000         .14717          .13263         .1693955  *  .36469          .2232035
L.0021         15.000         .19611          .17611         .2134929  *  .42673          .2835275
L.0022         20.000         .21715          .19315         .3193567  *  .47752          .3151543
L.0023         25.000         .24295          .21726         .3846243  *  .51649          .3572728
L.0024         30.000         .26613          .23913         .4445935  *  .54975          .3922855
L.0025
L.0026
L.0027                                                  INLCK PER UNIT LENGTH OF CHANNEL=  .050000  CU.M./S.
L.0028                                                  ****************************************
L.0029
L.0030
L.0031    LENGTH          YCRIT           DEPTH           AREA          *  VFIX            AFIX
L.0032    ********************************************************************************
L.0033          5.000         .24294          .35946         .3366939  *  .41249          .4461378
L.0034         10.000         .34515          .51314         .6339280  *  .57261          .3114554
L.0035  NON CONVERGANCE AT STATION NO 1
L.0036  NON CONVERGANCE AT STATION NO 1
L.0037  NON CONVERGANCE AT STATION NO 1
L.0038  NON CONVERGANCE AT STATION NO 1
L.0039
L.0040
L.0041                                                  INLCK PER UNIT LENGTH OF CHANNEL=  .100000  CU.M./S.
L.0042                                                  ****************************************
L.0043
L.0044
L.0045    LENGTH          YCRIT           DEPTH           AREA          *  VFIX            AFIX
L.0046    ********************************************************************************
L.0047          5.000         .34514          .50314         .6339280  *  .57861          .3114554
L.0048  NON CONVERGANCE AT STATION NO 1
L.0049  NON CONVERGANCE AT STATION NO 1
L.0050  NON CONVERGANCE AT STATION NO 1
L.0051  NON CONVERGANCE AT STATION NO 1
L.0052  NON CONVERGANCE AT STATION NO 1
```

TRAPEZOIDAL GUTTER CF BASE WIDTH= .4000 FT
SIDE SLOPE= 45 DEG.

INFLOW PER UNIT LENGTH OF GUTTER= .0009500 CU.M./S.

LENGTH	YCRIT	DEPTH	AREA	*	YFIN	AFIN
[illegible]	.01611	.02731	.0015272	*	.01117	.0013606
[illegible]	.0240	.0406	.0019796	*	.01702	.0020255
[illegible]	.01676	.02836	.0016274	*	.01213	.0011959
[illegible]	.03027	.05132	.0034697	*	.02599	.0043645
23.000	.04432	.07433	.0068608	*	.03697	.0068197
15.000	.04027	.06821	.0061395	*	.03297	.0059362

INFLOW PER UNIT LENGTH OF GUTTER= .0010000 CU.M./S.

LENGTH	YCRIT	DEPTH	AREA	*	YFIN	AFIN
5.000	.02400	.04069	.0017471	*	.01632	.0023725
[illegible]	.03002	.05092	.0032736	*	.02738	.0038560
15.000	.04027	.06827	.0043819	*	.03267	.0051694
[illegible]	.04642	.07870	.0053784	*	.04219	.0063374
28.000	.04885	.08283	.0059235	*	.04586	.0079226
30.000	.05067	.08591	.0063189	*	.04915	.0092459

INFLOW PER UNIT LENGTH OF GUTTER= .0009500 CU.M./S.

LENGTH	YCRIT	DEPTH	AREA	*	YFIN	AFIN
5.000	.04013	.06803	.0041423	*	.03258	.0070265
10.000	.04496	.07622	.0047012	*	.03675	.0076113
15.000	.04833	.08193	.0051036	*	.03981	.0080782
23.000	.05329	.09034	.0057079	*	.04479	.0087136
28.000	.05587	.09472	.0060154	*	.04725	.0091078
30.000	.05676	.09623	.0061242	*	.04819	.0092665

```
PTC      ACCT 3    DEPT OF CIVIL ENG                    FILE  TEXT                          MON  4/29/74 (74-120)        TIME 15.39
*****************************************************************************************************************************

L.0001
L.0002
L.0003
L.0004
L.0005                                                  ********************************************************************
L.0006                                                  *                                                                  *
L.0007                                                  *  RAPPENDIAL OUTFLOW OF GASS NEIGHB  .4000  *  -
L.0008                                                  *                     SIDE SLOPES  45  DEG.  *
L.0009                                                  *                                                                  *
L.0010                                                  ********************************************************************
L.0011
L.0012
L.0013                                                  INLET PER UNIT LENGTH OF GUTTER=  .010000  CU.M./S.
L.0014                                                  ********************************************************************
L.0015
L.0016
L.0017   LENGTH          YCRIT          DEPTH          AREA          *  YBIN          ACIN
L.0018   ********************************************************************************************************************
L.0019      5.000        .19932         .17132        .0279156       *  .13772        .1172334
L.0020     10.132        .14253         .25613        .1447705       *  .33493        .2756793
L.0021     15.259        .12411         .32311        .2139436       *  .46913        .3982562
L.0022     20.385        .11313         .37319        .2898162       *  .59412        .4957449
L.0023     25.512        .10716         .41395        .3636237       *  .69379        .5773153
L.0024     30.638        .10613         .46613        .4337319       *  .78235        .6511619
L.0025
L.0026
L.0027                                                  INLET PER UNIT LENGTH OF GUTTER=  .050000  CU.M./S.
L.0028                                                  ********************************************************************
L.0029
L.0030
L.0031   LENGTH          YCRIT          DEPTH          AREA          *  YBIN          ACIN
L.0032   ********************************************************************************************************************
L.0033      5.036        .27336         .41286        .3346922       *  .67473        .6154119
L.0034     10.229        .19314         .58914        .5765562       *  .87251        .7221119
L.0035     15.093        .16359         .71758        .8020593       *  .92561        1.7112641
L.0036   NON CONVERGANCE AT STATION NO 1
L.0037   NON CONVERGANCE AT STATION NO 1
L.0038   NON CONVERGANCE AT STATION NO 1
L.0039
L.0040
L.0041                                                  FLOW PER UNIT LENGTH OF GUTTER=  .100000  CU.M./S.
L.0042                                                  ********************************************************************
L.0043
L.0044
L.0045   LENGTH          YCRIT          DEPTH          AREA          *  YBIN          ACIN
L.0046   ********************************************************************************************************************
L.0047      5.003        .39316         .58314        .5734130       *  .67061        .7191012
L.0048   NON CONVERGANCE AT STATION NO 1
L.0049   NON CONVERGANCE AT STATION NO 1
L.0050   NON CONVERGANCE AT STATION NO 1
L.0051   NON CONVERGANCE AT STATION NO 1
L.0052   NON CONVERGANCE AT STATION NO 1
```

TRAPEZOIDAL GUTTER OF BASE WIDTH= .4000 FT
SIDE SLOPES 60 DEG.

FLOW PER UNIT LENGTH OF GUTTER= .005000 CU.M./S.

LENGTH	V-UNIT	DEPTH	AREA	*	YFIX	AFIX
[illegible]	.21811	.2711	.0217467	*	.10417	.0130299
[illegible]	.20617	.2481	.0157711	*	.11152	.0121433
[illegible]	.18326	.2026	.0093197	*	.10915	.0099362*
[illegible]	.14175	.1552	.0052066	*	.10639	.0068179
[illegible]	.10412	.1251	.0031361	*	.11157	.0069867
[illegible]	.05127	.0927	.0014672	*	.11417	.0053548

FLOW PER UNIT LENGTH OF GUTTER= .001000 CU.M./S.

LENGTH	V-UNIT	DEPTH	AREA	*	YFIX	AFIX
[illegible]	.02407	.1493	.0151799	*	.06422	.0021815
[illegible]	.03412	.1762	.0211239	*	.09169	.0036247
[illegible]	.05127	.2927	.0423353	*	.12727	.0049528
[illegible]	.06762	.4124?	.0552646	*	.12529	.0063693
[illegible]	.07803	.5148	.0627195	*	.15944	.0073578
[illegible]	.08869	.6468	.0711969	*	.16172	.0080178

FLOW PER UNIT LENGTH OF GUTTER= .005000 CU.M./S.

LENGTH	V-UNIT	DEPTH	AREA	*	YFIX	AFIX
[illegible]	.12043	.0567650	*	.13996	.0067356	
[illegible]	.11896	.1885E	.0959634	*	.21619	.0113078
[illegible]	.14253	.2385]	.0242792	*	.27431	.0151703
[illegible]	.16929	.2132?	.1596641	*	.32578	.0191145
[illegible]	.19367	.3218?	.0312427	*	.37755	.0229401
[illegible]	.21886	.3608E	.0219619	*	.41459	.0264710

```
PTC      ACCT 3    DEPT OF CIVIL ENG                    FILE  TL29                          MCV  6/3/74 1734-C031        TIME 11:58
L.0001
L.0002
L.0003
L.0004
L.0005                                                  ********************************
L.0006                                                  *                              *
L.0007                                                  *  TRANSITIONAL FLOW IN TRAPEZOIDAL  *
L.0008                                                  *                              *
L.0009                                                  ********************************
L.0010
L.0011
L.0012
L.0013                                                  ENTER PER UNIT LENGTH OF GUTTER=  .1E0000  GL,M,V/L,
L.0014                                                  ********************************************************
L.0015
L.0016
L.0017    LENGTH        YCRIT         DEPTH      AREA          *  YBIA          ABIA
L.0018    ********************************************************************************
L.0019       5.000      .31137       .33937     .1139632      *  .21112        .1154731
L.0020      10.000      .57163       .62183     .3743778      *  .41521        .4169781
L.0021      15.000      .81311       .89613     .7347726      *  .61429        .9214763
L.0022      20.000      1.0713       1.1614     1.2673657     *  .82737        1.3241131
L.0023      25.000      1.3086       1.4256     1.8127596     *  1.0473        1.8983236
L.0024      30.000      1.5613       1.7013     2.3603159     *  1.2666        2.4583265
L.0025
L.0026
L.0027                                                  ENTER PER UNIT LENGTH OF GUTTER=  .1E0000  GL,M,V/L,
L.0028                                                  ********************************************************
L.0029
L.0030
L.0031    LENGTH        YCRIT         DEPTH      AREA          *  YBIA          ABIA
L.0032    ********************************************************************************
L.0033       5.000      .29686       .33622     .1077276      *  .52999        .1746442
L.0034      10.000      .63716       .66711     .5216338      *  .77191        .4928630
L.0035      15.000      .94959       .98733     .7254313      *  .98171        .9531693
L.0036      20.000      1.2557       1.3037     1.0126971     *  1.1983        1.1378699
L.0037    NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO=  2
L.0038    NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO=  2
L.0039
L.0040
L.0041                                                  ENTER PER UNIT LENGTH OF GUTTER=  .1E0000  GL,M,V/L,
L.0042                                                  ********************************************************
L.0043
L.0044
L.0045    LENGTH        YCRIT         DEPTH      AREA          *  YBIA          ABIA
L.0046    ********************************************************************************
L.0047       5.000      .63716       .66514     .5216927      *  .76491        .6632244
L.0048      10.000      .93557       .96757     .9976826      *  1.1847        1.1717747
L.0049    NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO=  2
L.0050    NON CONVERGANCE AT STATION NO 1
L.0051    NON CONVERGANCE AT STATION NO 1
L.0052    NON CONVERGANCE AT STATION NO 1
```

TRAPEZOIDAL GUTTER OF BASE WIDTH= .4500 F
SIDE SLOPE= 30 DEG.

FLOW PER UNIT LENGTH OF GUTTER= .300000 CU.M./S.

LENGTH	VERIT	DEPTH	AREA	*	YRIN	ARIN
[illegible]	.2412	.0311501	*	.02173	.0135175
[illegible]	.2424	.0312548	*	.02182	.0231297
[illegible]	.2436	.0313595	*	.02191	.0326176
[illegible]	.2448	.0314643	*	.02201	.0421356
[illegible]	.2460	.0315690	*	.02210	.0516839
[illegible]	.2471	.0316737	*	.02220	.0612621

FLOW PER UNIT LENGTH OF GUTTER= .600000 CU.M./S.

LENGTH	VERIT	DEPTH	AREA	*	YRIN	ARIN
[illegible]	.3723	.0419505	*	.04782	.0224443
[illegible]	.3753	.0423293	*	.04819	.0413181
[illegible]	.3783	.0427082	*	.04856	.0604689
[illegible]	.3813	.0430867	*	.04893	.0797401
[illegible]	.3843	.0434657	*	.04930	.0990808
[illegible]	.3873	.0438446	*	.04967	.1184910

FLOW PER UNIT LENGTH OF GUTTER= .905000 CU.M./S.

LENGTH	VERIT	DEPTH	AREA	*	YRIN	ARIN
[illegible]	.4226	.0476274	*	.06041193	*	.11757	.0768563
[illegible]	.4257	.0479927	*	.06091927	*	.11856	.1359911
[illegible]	.4287	.0483579	*	.06142662	*	.11954	.1951913
[illegible]	.4317	.0487231	*	.06193396	*	.12053	.2544551
[illegible]	.4347	.0490883	*	.06244131	*	.12151	.3137824
[illegible]	.4377	.0494535	*	.06294865	*	.12250	.3731732

```
L.0051
L.0052
L.0053
L.0054
L.0055                                          ********************************************
L.0056                                          *                                          *
L.0057                                          *  TRANSITIONAL GUTTER IN BASE ANGLE  .4500  *
L.0058                                          *                  SIDE SLOPES 30 DEG.     *
L.0059                                          *                                          *
L.0060                                          ********************************************
L.0061
L.0062                                          FLOW PER UNIT LENGTH OF GUTTER=  .100000  CU.M./S.
L.0063                                          ++++++++++++++++++++++++++++++++++++++++++++++++
L.0064
L.0065
L.0066   LENGTH       WIDTH       DEPTH      AREA          * VEL          QFIX
L.0067   ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
L.0068      3.00        .78647      .13227      .1040347      *  .9613          .1000296
L.0069     15.00        .78647      .27295      .2146145      *  .7551          .1620641
L.0070     15.00        .78647      .27453      .2158585      *  .7517          .1622933
L.0071     22.50        .78647      .37139      .2920567      *  .6966          .2034278
L.0072     22.50        .78647      .39576      .3112416      *  .6929          .2156954
L.0073     30.00        .78647      .49351      .3881213      *  .6554          .2543682
L.0074
L.0075
L.0076                                          FLOW PER UNIT LENGTH OF GUTTER=  .100000  CU.M./S.
L.0077                                          ++++++++++++++++++++++++++++++++++++++++++++++++
L.0078
L.0079
L.0080
L.0081   LENGTH       WIDTH       DEPTH      AREA          * VEL          QFIX
L.0082   ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
L.0083      3.00        .29426      .39526      .3731311      *  .6277          .4923362
L.0084     10.00        .53643      .69643      .6440132      *  .5686          .8157714
L.0085     15.000       .61071      .59671      .8853983      *  .4862          1.1246052
L.0086   NOA CONVERGANCE AT STATION NO 1
L.0087   NOA CONVERGANCE AT STATION NO 1
L.0088   NOA CONVERGANCE AT STATION NO 1
L.0089
L.0090
L.0091                                          FLOW PER UNIT LENGTH OF GUTTER=  .100000  CU.M./S.
L.0092                                          ++++++++++++++++++++++++++++++++++++++++++++++++
L.0093
L.0094
L.0095
L.0096   LENGTH       WIDTH       DEPTH      AREA          * VEL          QFIX
L.0097   ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
L.0098      5.000       .53643      .49243      .6416934      *  .5663          .8154143
L.0099   NOA CONVERGANCE AT STATION NO 1
L.0100   NOA CONVERGANCE AT STATION NO 1
L.0101   NOA CONVERGANCE AT STATION NO 1
L.0102   NOA CONVERGANCE AT STATION NO 1
L.0103   NOA CONVERGANCE AT STATION NO 1
```

```
PTC      ACCT 3    DEPT OF CIVIL ENG                    FILE   T170                    WED  6/3/74 (74-065)      TIME 16.58

                                                  ***************************************************
                                                  *                                                 *
                                                  *  TRAPEZOIDAL GUTTER OF BASE WIDTH=   .4500  M  *
                                                  *                       SIDE SLOPE=  45  DEG.     *
                                                  *                                                 *
                                                  ***************************************************

                                                  INLOW PER UNIT LENGTH OF GUTTER=   .000500  CU.M./S.
                                                  ***************************************************

   LENGTH        YCRIT        DEPTH      AREA          *  YFIN         AFIN
   ***************************************************************************
     5.000       .01371       .02571     .0122300      *  .02957       .0141786
    10.000       .02259       .04059     .0199116      *  .04667       .0231826
    15.000       .03036       .05636     .0285367      *  .06461       .0333651
    20.000       .03550       .06750     .0349350      *  .07763       .0409615
    25.000       .04224       .07824     .0413292      *  .08997       .0485847
    30.000       .04666       .09066     .0490194      *  .10426       .0577906

                                                  INLOW PER UNIT LENGTH    GUTTER=   .001000  CU.M./S.
                                                  ***************************************************

   LENGTH        YCRIT        DEPTH      AREA          *  YFIN         AFIN
   ***************************************************************************
     5.000       .02259       .03859     .0188533      *  .04437       .0219382
    10.000       .03550       .06350     .0326109      *  .07303       .0381983
    15.000       .04666       .08466     .0452672      *  .09736       .0532941
    20.000       .05684       .10283     .0568538      *  .11826       .0672065
    25.000       .06435       .11835     .0672662      *  .13610       .0797729
    30.000       .07337       .13337     .0778099      *  .15338       .0925506

                                                  INLOW PER UNIT LENGTH OF GUTTER=   .005000  CU.M./S.
                                                  ***************************************************

   LENGTH        YCRIT        DEPTH      AREA          *  YFIN         AFIN
   ***************************************************************************
     5.000       .06435       .10835     .0604987      *  .12460       .0715990
    10.000       .10027       .16627     .1024756      *  .19121       .1226173
    15.000       .12705       .21105     .1395245      *  .24270       .1681386
    20.000       .15295       .25095     .1759180      *  .28859       .2131718
    25.000       .17291       .28691     .2114530      *  .32995       .2573749
    30.000       .19345       .31345     .2393324      *  .36047       .2921854
```

```
0301
 302
 303
 304
 305
 306                                  ********************************************
 307                                  *                                          *
 308                                  *  TRAPEZOIDAL GUTTER OF BASE WIDTH=  .4500  M *
 309                                  *                        SIDE SLOPE= 45  DEG.  *
 310                                  *                                          *
 311                                  ********************************************
 312
 313                                  INFLOW PER UNIT LENGTH OF GUTTER=  .15 000  CU.M./S.
 314                                  ********************************************
 315
 316
 317   LENGTH       YCRIT       DEPTH       AREA        *  YFIN        AFIN
 318  ********************************************************************
 319      5.000     .10027      .16427     .1059144     *  .16051      .1277019
 320     10.000     .14219      .24413     .1727418     *  .23164      .2761273
 321     15.000     .17349      .32769     .2329359     *  .31137      .3948537
 322     20.000     .20133      .41133     .2919461     *  .41452      .5237971
 323     25.000     .22626      .49526     .3504188     *  .49900      .6619435
 324     30.000     .24896      .57896     .4067212     *  .58169      .7972194
 325
 326
 327                                  INFLOW PER UNIT LENGTH OF GUTTER=  .050000  CU.M./S.
 328                                  ********************************************
 329
 330
 331   LENGTH       YCRIT       DEPTH       AREA        *  YFIN        AFIN
 332  ********************************************************************
 333      5.000     .09826      .09826     .0379111     *  .09826      .0379111
 334     10.000     .13863      .13863     .0770057     *  .13870      .0771100
 335     15.000     .16872      .16871     .1221477     *  .16852      .1220483
 336     20.000     .19365      .19365     .1803667     *  .19389      .1804843
 337   NON CONVERGANCE AT STATION NO 1
 338   NON CONVERGANCE AT STATION NO 1
 339
 340
 341                                  INFLOW PER UNIT LENGTH OF GUTTER=  .10.000  CU.M./S.
 342                                  ********************************************
 343
 344
 345   LENGTH       YCRIT       DEPTH       AREA        *  YFIN        AFIN
 346  ********************************************************************
 347      5.000     .37963      .96963     .5758356     *  .65146      .7639726
 348     10.000     .53965      .77965     .7994633     *  .91959      1.2557160
 349   NON CONVERGANCE AT STATION NO 1
 350   NON CONVERGANCE AT STATION NO 1
 351   NON CONVERGANCE AT STATION NO 1
 352   NON CONVERGANCE AT STATION NO 1
```

```
L.0001
L.0002
L.0003
L.0004
L.0005                                  ********************************************
L.0006                                  *                                          *
L.0007                                  *  TRAPEZOIDAL GUTTER OF BASE WIDTH= .45000 M *
L.0008                                  *                SIDE SLOPES 60 DEG.       *
L.0009                                  *                                          *
L.0010                                  ********************************************
L.0011
L.012
L.013                                   FLOW PER UNIT LENGTH OF GUTTER=  .055000  CU.M./S.
L.014                                   ***************************************************
L.015
L.016
L.017   LENGTH          YCRIT          DEPTH          AREA          = VELO          HEIG
L.018   ********************************************************************************
L.0019     7.000       .07413          .07413        .0319491      =  .67733       .0274963
L.0021    10.000       .07921          .07921        .0359367      =  .67867       .0277463
L.0023    15.000       .08703          .08703        .0426311      =  .68167       .0282438
L.0025    20.000       .09318          .09318        .0476111      =  .68417       .0286578
L.0027    25.000       .09833          .09833        .0519455      =  .68633       .0290178
L.0029    30.000       .10291          .10291        .0557924      =  .68833       .0293490
L.0031
L.0032
L.0033
L.0034                                  FLOW PER UNIT LENGTH OF GUTTER=  .055000  CU.M./S.
L.0035                                  ***************************************************
L.0036
L.0037
L.0038
L.0039   LENGTH          YCRIT          DEPTH          AREA          = VELO          HEIG
L.0040   ********************************************************************************
L.0041     5.000       .07323          .07323        .0315439      =  .69412       .0281785
L.0042    10.000       .08633          .08633        .0436446      =  .69621       .0365176
L.0043    15.000       .09601          .09601        .0527754      =  .69891       .0351987
L.0044    20.000       .10446          .10446        .0608121      =  .70117       .0363963
L.0045    25.000       .11224          .11224        .0682223      =  .70297       .0375635
L.0046    30.000       .11951          .11951        .0751156      =  .70443       .0387099
L.0047
L.0048
L.0049
L.0050                                  FLOW PER UNIT LENGTH OF GUTTER=  .055000  CU.M./S.
L.0051                                  ***************************************************
L.0052
L.0053
L.0054
L.0055   LENGTH          YCRIT          DEPTH          AREA          = VELO          HEIG
L.0056   ********************************************************************************
L.0057     5.000       .06624          .11224        .0577032      =  .12767       .2687059
L.0058    10.000       .10327          .17957        .0966165      =  .20136       .1141658
L.0059    15.000       .13298          .23698        .1319687      =  .26163       .1369167
L.0060    20.000       .15771          .27171        .1649125      =  .31247       .1572592
L.0061    25.000       .18049          .31949        .1953642      =  .35971       .2342711
L.0062    30.000       .20349          .34349        .2229925      =  .39525       .2682959
```

```
PTC      ANCT 3    DEPT OF CIVIL ENG                    FILE  1174                        MON  4/3/74 174-0431        TIME 16.05
L.0001
L.0002
L.0003
L.0004
L.0005                                                  ********************************************
L.0006                                                  *                                          *
L.0007                                                  *  TRAPEZOIDAL GUTTER OF BACK SLOPE=  .0500  *  =
L.0008                                                  *              SIDE SLOPE=  60.00,         *  =
L.0009                                                  *                                          *
L.0010                                                  ********************************************
L.0011
L.0012
L.0013                                                  FLOW PER UNIT LENGTH OF GUTTER=  .050000  CU.M./S.
L.0014                                                  ********************************************
L.0015
L.0016
L.0017     LENGTH          WIDTH          DEPTH          AREA          *  VELX          DELX
L.0018  ********************************************************************************************
L.0019        5.000        .27526         .44226         .3100722      *  .9.629        .3262554
L.0020       10.000        .41643         .64443         .5237743      *  .74111        .6217344
L.0021       15.000        .52272         .83027         .7326565      *  .72742        .9541272
L.0022       20.000        .61168         .92965         .8119541      *  1.06449       1.1335435
L.0023  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO=  2
L.0024  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO=  2
L.0025
L.0026
L.0027                                                  FLOW PER UNIT LENGTH OF GUTTER=  .100000  CU.M./S.
L.0028                                                  ********************************************
L.0029
L.0030
L.0031     LENGTH          WIDTH          DEPTH          AREA          *  VELX          DELX
L.0032  ********************************************************************************************
L.0033        5.000        .27526         .44226         .3100722      *  .9.629        .3262554
L.0034       10.000        .41643         .64443         .5237743      *  .74111        .6217344
L.0035       15.000        .52272         .83027         .7326565      *  .72742        .9541272
L.0036       20.000        .61168         .92965         .8119541      *  1.06449       1.1335435
L.0037  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO=  2
L.0038  NON CONVERGANCE AT STATION NO 1
L.0039  NON CONVERGANCE AT STATION NO 1
L.0040  NON CONVERGANCE AT STATION NO 1
L.0041
L.0042
L.0043
L.0044                                                  FLOW PER UNIT LENGTH OF GUTTER=  .150000  CU.M./S.
L.0045                                                  ********************************************
L.0046  ********************************************************************************************
L.0047        5.000        .41643         .64243         .5274875      *  .7389G        .6477222
L.0048       10.000        .61165         .91965         .9023581      *  1.05759       1.1217798
L.0049  NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO=  2
L.0050  NON CONVERGANCE AT STATION NO 1
L.0051  NON CONVERGANCE AT STATION NO 1
L.0052  NON CONVERGANCE AT STATION NO 1
```

TRAPEZOIDAL GUTTER OF BASE WIDTH= .5000 F
SIDE SLOPE= 30 DEG.

INFLOW PER UNIT LENGTH OF GUTTER= .005000 CU.M./S.

LENGTH	YCRIT	DEPTH	AREA	*	YFIN	AFIN
5.000	.05866	.09666	.0645170	*	.11116	.0769867
10.000	.09942	.14842	.1123119	*	.17668	.1359106
15.000	.11538	.19738	.1545164	*	.21548	.1881864
20.000	.13564	.21966	.1936175	*	.25261	.2348471
25.000	.15413	.24813	.2307328	*	.28535	.2831424
30.000	.17128	.27528	.2689202	*	.31657	.3319038

INFLOW PER UNIT LENGTH OF GUTTER= .003000 CU.M./S.

LENGTH	YCRIT	DEPTH	AREA	*	YFIN	AFIN
5.000	.04204	.07204	.0450102	*	.08284	.0533126
10.000	.06521	.11121	.0770296	*	.12789	.0922799
15.000	.08496	.14296	.1068908	*	.16441	.1290324
20.000	.10091	.16681	.1316138	*	.19183	.1596715
25.000	.11538	.18938	.1568220	*	.21779	.1900331
30.000	.12700	.21100	.1826276	*	.24265	.2233263

INFLOW PER UNIT LENGTH OF GUTTER= .001000 CU.M./S.

LENGTH	YCRIT	DEPTH	AREA	*	YFIN	AFIN
5.000	.02133	.03533	.0198248	*	.04662	.0231714
10.000	.03350	.05750	.0346799	*	.06613	.0406401
15.000	.04204	.07604	.0480363	*	.08744	.0569696
20.000	.05166	.09166	.0603836	*	.10541	.0719517
25.000	.05866	.10666	.0730394	*	.12206	.0873551
30.000	.06521	.11721	.0824040	*	.13479	.0988700

```
*****************************************************************************************************************
PTC      ACCT 3    DEPT OF CIVIL ENG                    FILE   T165                          WED  6/3/74 (74-065)      TIME 15.47
*****************************************************************************************************************

                                                  ***************************************************
                                                  *                                                 *
                                                  *  TRAPEZOIDAL GUTTER OF BASE WIDTH=   .5000  M  *
                                                  *                         SIDE SLOPE=  30  DEG.   *
                                                  *                                                 *
                                                  ***************************************************

                                                  INLOW PER UNIT LENGTH OF GUTTER=   .010000  CU.M./S.
                                                  ***************************************************

   LENGTH        YCRIT        DEPTH       AREA          *  YFIN         AFIN
 ***************************************************************************************
     5.000       .09042       .14642     .1103503      *  .16833       .1333095
    10.000       .13566       .21566     .1884008      *  .24801       .2305595
    15.000       .17128       .26728     .2574006      *  .30737       .3173594
    20.000       .20064       .31264     .3256603      *  .35954       .4037201
    25.000       .22515       .35115     .3891897      *  .40382       .4844170
    30.000       .24954       .38554     .4502774      *  .44337       .5622390

                                                  INLOW PER UNIT LENGTH OF GUTTER=   .050000  CU.M./S.
                                                  ***************************************************

   LENGTH        YCRIT        DEPTH       AREA          *  YFIN         AFIN
 ***************************************************************************************
     5.000       .22515       .34115     .3721961      *  .39232       .4628054
    10.000       .32527       .48327     .6462491      *  .55576       .8129817
    15.000       .39912       .58512     .8856956      *  .67289      1.1208649
     2.000       .13566       .21166     .1834396      *  .24341       .2243434
NON CONVERGANCE AT STATION NO 1
NON CONVERGANCE AT STATION NO 1

                                                  INLOW PER UNIT LENGTH OF GUTTER=   .100000  CU.M./S.
                                                  ***************************************************

   LENGTH        YCRIT        DEPTH       AREA          *  YFIN         AFIN
 ***************************************************************************************
     5.000       .32527       .48127     .6419070      *  .55346       .8074118
NON CONVERGANCE AT STATION NO 1
NON CONVERGANCE AT STATION NO 1
NON CONVERGANCE AT STATION NO 1
NON CONVERGANCE AT STATION NO 1
NON CONVERGANCE AT STATION NO 1
```

```
PTC      ACCT 3    DEPT OF CIVIL ENG                  FILE   T168                    WED  6/3/74 (74-065)      TIME 16.19

                                                 ***********************************************
                                                 *                                             *
                                                 *  TRAPEZOIDAL GUTTER OF BASE WIDTH=   .5000  F  *
                                                 *                  SIDE SLOPE=  45  DEG.      *
                                                 *                                             *
                                                 ***********************************************

                                                 INLOW PER UNIT LENGTH OF GUTTER=   .005000  CU.M./S.
                                                 ***********************************************

   LENGTH        YCRIT        DEPTH       AREA          *  YFIN          AFIN
 ***********************************************************************************
    5.000       .06066       .10266      .0618726      *  .11806        .0729720
   10.000       .09442       .15842      .1043132      *  .18218        .1242905
   15.000       .12138       .20338      .1436640      *  .23388        .1716607
   20.000       .14366       .23966      .1772807      *  .27561        .2137833
   25.000       .16413       .27413      .2122371      *  .31525        .2570395
   30.000       .18328       .30128      .2414340      *  .34647        .2933112

                                                 INLOW PER UNIT LENGTH OF GUTTER=   .003000  CU.M./S.
                                                 ***********************************************

   LENGTH        YCRIT        DEPTH       AREA          *  YFIN          AFIN
 ***********************************************************************************
    5.000       .04404       .07404      .0425029      *  .08514        .0498242
   10.000       .06921       .11721      .0723457      *  .13479        .0855680
   15.000       .08896       .15096      .0982787      *  .17361        .1169528
   20.000       .10481       .18081      .1231089      *  .20793        .1472164
   25.000       .12138       .20538      .1448813      *  .23618        .1738923
   30.000       .13500       .23100      .1688746      *  .26565        .2034130

                                                 INLOW PER UNIT LENGTH OF GUTTER=   .001000  CU.M./S.
                                                 ***********************************************

   LENGTH        YCRIT        DEPTH       AREA          *  YFIN          AFIN
 ***********************************************************************************
    5.000       .02133       .03733      .0200565      *  .04292        .0233054
   10.000       .03350       .05950      .0332931      *  .06843        .0388980
   15.000       .04404       .08004      .0464276      *  .09204        .0544971
   20.000       .05166       .09566      .0549822      *  .11001        .0671083
   25.000       .06066       .11066      .0675796      *  .12726        .0798295
   30.000       .06921       .12721      .0797907      *  .14629        .0945514
```

```
*****************************************************************************************************************************
PTC      ACCT 3    DEPT OF CIVIL ENG                    FILE   T166                    WED  6/3/74 174-0651        TIME 15.47
*****************************************************************************************************************************

                                                  ***********************************************
                                                  *                                             *
                                                  *  TRAPEZOIDAL GUTTER OF BASE WIDTH=   .5000  M  *
                                                  *                       SIDE SLOPE=  45  DEG.  *
                                                  *                                             *
                                                  ***********************************************

                                                  INLOW PER UNIT LENGTH OF GUTTER=   .010000  CU.M./S.
                                                  ***********************************************

     LENGTH        YCRIT         DEPTH      AREA          *  YFIN         AFIN
  ***********************************************************************************
      5.000        .09442        .15642     .1026834      *  .17988       .1223076
     10.000        .14366        .23566     .1733789      *  .27101       .2089681
     15.000        .18328        .29528     .2348537      *  .33557       .2851261
     20.000        .21664        .34864     .2959093      *  .40094       .3612694
     25.000        .24715        .39315     .3511828      *  .45212       .4309302
     30.000        .27354        .43554     .4075177      *  .50087       .5013764

                                                  INLOW PER UNIT LENGTH OF GUTTER=   .050000  CU.M./S.
                                                  ***********************************************

     LENGTH        YCRIT         DEPTH      AREA          *  YFIN         AFIN
  ***********************************************************************************
      5.000        .24715        .38315     .3384176      *  .44062       .4145107
     10.000        .36527        .55327     .5828356      *  .63626       .7230796
     15.000        .45312        .68112     .8046277      *  .78329      1.0053720
      2.000        .14366        .25166     .1695091      *  .26641       .2041953
     25.000        .59157        .87757    1.2091408      * 1.00920      1.5233565
NON CONVERGANCE AT STATION NO 1

                                                  INLOW PER UNIT LENGTH OF GUTTER=   .100000  CU.M./S.
                                                  ***********************************************

     LENGTH        YCRIT         DEPTH      AREA          *  YFIN         AFIN
  ***********************************************************************************
      5.000        .36527        .55127     .5796257      *  .63396       .7790074
     10.000        .52653        .78053     .9996722      *  .89761      1.2547445
NON CONVERGANCE AT STATION NO 1
NON CONVERGANCE AT STATION NO 1
NON CONVERGANCE AT STATION NO 1
NON CONVERGANCE AT STATION NO 1
```

```
*****************************************************************************************************************
PTC      ACCT 3    DEPT OF CIVIL ENG                    FILE   T169                    WED  6/2/74 (74-C651)      TIME 16.57
*****************************************************************************************************************

L.0001
L.0002
L.0003
L.0004
L.0005                                    ***************************************************
L.0006                                    *                                                 *
L.0007                                    *  TRAPEZOIDAL GUTIER OF BASE WIDTH=   .5000  F  *
L.0008                                    *                       SIDE SLOPE=  60  DEG.     *
L.0009                                    *                                                 *
L.0010                                    ***************************************************
L.0011
L.0012
L.0013                                    INLOW PER UNIT LENGTH OF GUTTER=   .005000  CU.M./S.
L.0014                                    ***************************************************
L.0015
L.0016
L.0017   LENGTH        YCRIT        DEPTH       AREA          *  YFIN         AFIN
L.0018   ***************************************************************************
L.0019     5.000       .06266       .10666      .0599015      *  .12266       .0700202
L.0020    10.000       .09642       .16642      .0992064      *  .19138       .1168469
L.0021    15.000       .12538       .21538      .1344933      *  .24768       .1592777
L.0022    20.000       .14766       .25766      .1671744      *  .29631       .1988651
L.0023    25.000       .17213       .29613      .1987198      *  .34055       .2372653
L.0024    30.000       .19329       .32928      .2272660      *  .37867       .2721590
L.0025
L.0026
L.0027                                    INLOW PER UNIT LENGTH OF GUTTER=   .003000  CU.M./S.
L.0028                                    ***************************************************
L.0029
L.0030
L.0031   LENGTH        YCRIT        DEPTH       AREA          *  YFIN         AFIN
L.0032   ***************************************************************************
L.0033     5.000       .04406       .07604      .0413592      *  .08744       .0481391
L.0034    10.000       .06921       .12121      .0690899      *  .13939       .0809172
L.0035    15.000       .09096       .15896      .0940779      *  .16281       .1107073
L.0036    20.000       .10881       .19081      .1164363      *  .21943       .1375298
L.0037    25.000       .12538       .21938      .1374878      *  .25228       .1629062
L.0038    30.000       .14100       .24700      .1587378      *  .28405       .1886272
L.0039
L.0040
L.0041                                    INLOW PER UNIT LENGTH OF GUTTER=   .001000  CU.M./S.
L.0042                                    ***************************************************
L.0043
L.0044
L.0045   LENGTH        YCRIT        DEPTH       AREA          *  YFIN         AFIN
L.0046   ***************************************************************************
L.0047     5.000       .02133       .03733      .0194676      *  .04292       .0225266
L.0048    10.000       .03350       .06150      .0329363      *  .07073       .0382537
L.0049    15.000       .04406       .08204      .0449070      *  .09434       .0523136
L.0050    20.000       .05366       .09966      .0555657      *  .11461       .0648900
L.0051    25.000       .06266       .11666      .0661914      *  .13416       .0774760
L.0052    30.000       .06921       .13121      .0755479      *  .15089       .0885954
```

```
L.0001
L.0002
L.0003
L.0004
L.0005                                  ********************************
L.0006                                  *                              *
L.0007                                  *  TRAPEZOIDAL OUTLET OF BASE WIDTH=  .4500  F  *
L.0008                                  *                  SIDE SLOPE= 60. DEG.  *
L.0009                                  *                              *
L.0010                                  ********************************
L.0011
L.0012
L.0013                                  TABLE PER UNIT LENGTH OF OUTLET=  .2100000  CU.M./S.
L.0014
L.0015
L.0016
L.0017   LENGTH          VCRIT          DEPTH          AREA          F  VFIN          AFIN
L.0018 ********************************************************************************
L.0019      5.000         .39587         .41962         .4111551    *  .41478         .1194526
L.0020      5.333         .41499         .43369         .4313551    *  .39171         .1295328
L.0021     10.333         .41528         .43323         .4307344    *  .37137         .2693176
L.0022     10.000         .37994         .41534         .4260111    *  .43776         .3338691
L.0023     15.000         .42914         .43315         .4306424    *  .43912         .4373473
L.0024     20.000         .42954         .43254         .4302243    *  .45147         .4511939
L.0025
L.0026
L.0027                                  TABLE PER UNIT LENGTH OF OUTLET=  .2050000  CU.M./S.
L.0028
L.0029
L.0030
L.0031   LENGTH          VCRIT          DEPTH          AREA          F  VFIN          AFIN
L.0032 ********************************************************************************
L.0033      5.000         .40515         .42113         .4134210    *  .48832         .1776462
L.0034      8.350         .39727         .42127         .4337420    *  .71446         .4512773
L.0035     15.404         .39112         .39512         .3944520    *  .96127         .9064963
L.0036     20.000         .39151         .39253         .3946352    *1.03961         1.1132.881
L.0037   NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO=  2
L.0038 NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO=  2
L.0039
L.0040
L.0041                                  TABLE PER UNIT LENGTH OF OUTLET=  .2000000  CU.M./S.
L.0042
L.0043
L.0044
L.0045   LENGTH          VCRIT          DEPTH          AREA          F  VFIN          AFIN
L.0046 ********************************************************************************
L.0047      5.000         .39727         .41727         .4311489    *  .71214         .4492319
L.0048     10.000         .39853         .39653         .3934641    *1.02871         1.1296104
L.0049 NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO=  2
L.0050 NON CONVERGANCE AFTER 40 ITERATIONS AT STATION NO=  2
L.0051 NON CONVERGANCE AT STATION NO 1
L.0052 NON CONVERGANCE AT STATION NO 1
```

PROGRAMME TO DETERMINE THE FLOW CAPACITY OF
TRUE HALF-ROUND GUTTERS

NAME: *HR*

OBJECT: To determine the flow capacity of true half-round gutters of various lengths

Checks: *The validity of the programme was checked by comparing* the peak depths as calculated by the programme with the Marsh experimental peaks. This comparison is made in Table 33.

Inputs:

Gutter diameter	D
Number of stations	NT
Output code	K
Gutter length	X
Initial estimate of maximum inflow rate per unit length	INF

Outline of programme:

An estimate of the maximum inflow per unit length that the gutter can cater for is made. The critical depth at outlet is found in an iterative fashion and this is employed as the starting depth in the Hinds analysis. The water surface profile is determined as explained for GUT 3 and the peak flow depth is abstracted. The freeboard allowance is added to the peak flow depth. This depth is compared with the gutter radius and if the two values do not agree to a specified accuracy another estimate of the maximum inflow rate is made and the process repeated until

the required accuracy is obtained.

Outputs:

Code, K = 1 - values of all variables after every iteration at every station for every estimated inflow rate value.

Code, K = 2 - final values of variables and flow depths are given at each station for every estimated flow depth value.

Code, $K > 2$ and p = 1 - the values of variables at the last upstream section are given for every estimated flow depth value

Code, $K > 2$ and $p \neq 1$ - the values of variables at the last upstream section are given only for the maximum permissible flow depth.

These variables include:

Maximum inflow rate per unit length	INF
Critical depth at outlet	YCRIT
Peak depth	Y(NT,J)
Peak area of flow	A(NT,J)
Design depth	YFIN
Design area of flow	AFIN

Limits placed on programme:

Maximum number of iterations when determining critical depth at outlet equals forty

Problems associated with programme:

As for previous programmes

Geometry:

As for GUT 2

TABLE 33: COMPARISON OF MARSH RESULTS WITH OUTPUT FROM HR

Discharge rate in m^3/S	Inflow per unit length in m^2/S	Marsh Peak Depth in metres	'HR' Peak Depth in metres
0,0004546	0,0000745	0,0318	0,03076
0,0009092	0,000149	0,0446	0,04366
0,001364	0,000224	0,0519	0,05270
0,001818	0,000298	0,0584	0,06104
0,002273	0,000373	0,0660	0,06870
0,002387	0,000392	0,0728	0,07078

```
*****************************************************************************************************************
PTC      ACCT 3    DEPT OF CIVIL ENG                    FILE   FR                    TUE 17/12/74 (74-351)      TIME 15.09
*****************************************************************************************************************

L.0001 C      PROGRAMME TO FIND THE MAX CAPACITY OF TRUE HALF-ROUND GUTTERS
L.0002        REAL MAN,Q(22),A(22,40),V(22,40),DISOP(22),DELYA(22,40),FRICY,IMPY,THETA(22,40),Y(22,40),INF
L.0003        INTEGER P,S
L.0004        KW=5
L.0005 C      INPUT
L.0006        READ(1,1) D,NT,K
L.0007 1      FORMAT(3Y)
L.0008        WRITE(KW,13) D
L.0009 10     FORMAT(///T42,47('*')/T42,'*',T88,'*'/T42,'*',2X,'HALF-ROUND GUTTER OF DIAMETER=',2X,F6.4,2X,'M'2X,'*'/T42,'*',T88,'*'
C0017  /T42,47('*'))
L.0010        DEL=0.001
L.0011        ACC=0.0005
L.0012        MAN=0.014
L.0013        P=1
L.0014        READ(1,3) X
L.0015 3      FORMAT(Y)
L.0016        WRITE(KW,12) X
L.0017 12     FORMAT(/T50,'GUTTER LENGTH=',2X,F7.3,2X,'M'/T50,29('*'))
L.0018 C      ITERATING TO FIND MAXIMUM CAPACITY
L.0019        READ(1,9) INF
L.0020 9      FORMAT(Y)
L.0021 C      TO FIND CRITICAL DEPTH AT DOWNPIPE
L.0022        P=0/2
L.0023 67     T=1
L.0024        I=1
L.0025        DISOP(I)=0
L.0026        Q(1)=INF*X
L.0027 C      INITIAL ESTIMATE
L.0028        Y(1,I)=Q(1)**2/((0.66*R)**2*9.81))**0.333333
L.0029 7      CONTINUE
L.0030        THETA(1,I)=2*DARCOS((R-Y(1,I))/R)
L.0031        B=2**DSIN(THETA(1,I)/2)
L.0032        A(1,I)=0.5*R**2*(THETA(1,I)-DSIN(THETA(1,I)))
L.0033        V(1,I)=Q(1)/A(1,I)
L.0034        YM=A(1,I)/B
L.0035        EN=V(1,I)**2/9.81
L.0036        IF(ABS(EN-YM).LE.0.001) GO TO 57
L.0037        IF(I.GT.39) GO TO 5
L.0038        IF(K.GT.1) GO TO 8
L.0039        IF(I.GT.1) GO TO 4
L.0040        WRITE(KW,4)
L.0041 4      FORMAT(//T4,'I',T12,'DISCH',T22,'AREA',T32,'YMEAN',T43,'EN',T51,'DEPTH'/T4,52('*'))
L.0042        WRITE(KW,8) I,Q(1),A(1,I),YM,EN,Y(1,I)
L.0043 8      FORMAT(T3,I2,T9,F8.6,T19,F8.6,T29,F8.6,T39,F8.6,T49,F7.5)
L.0044        IF(EN-YM) 13,3,15
L.0045 13     I=I+1
L.0046        Y(1,I)=Y(1,I-1)-0.0005
L.0047        GO TO 7
L.0048 15     I=I+1
L.0049        Y(1,I)=Y(1,I-1)+0.0005
L.0050        GO TO 7
L.0051 5      WRITE(KW,14)
L.0052 14     FORMAT(T2,'NCA CONVERGANCE AT STATION NO 1')
L.0053 GO TO 90
```

```
L.0054 C      OUTPUT NO 2
L.0055 57      IF(K.GT.2) GO TO 17
L.0056        WRITE(KW,16)
L.0057 16     FORMAT(/T2,'STATION NO',T13,'I',T19,'DISDP',T26,'DISCH',T37,'AREA',T46,'FRICY',T56,'IMPY',T65,'DELY',T75,'DELYAS',T85,'
CONT.  DEPTH'/T2,85('*'))
L.0058        WRITE(KW,17) N,DISDP(I),Q(I),A(I,I),Y(I,I)
L.0059 17     FORMAT(T5,I2,T16,F7.4,T24,F8.6,T34,F8.6,T84,F7.5)
L.0060        J=1
L.0061        YCRIT=Y(I,I)
L.0062        ACRIT=A(I,I)
L.0063 C      FINDING DEPTHS AT ALL STATIONS USING HINDS FORMULA
L.0064        DELQ=Q(I)/(NT-1)
L.0065        DELY=X/(NT-1)
L.0066        DO 18 N=2,NT
L.0067        I=1
L.0068        DISDP(N)=DISDP(N-1)+DELX
L.0069        DELYAS(N,I)=DELQ
L.0070        Q(N)=Q(N-1)+DELQ
L.0071 25     Y(N,I)=Y(N-1,J)+DELYAS(N,I)
L.0072        IF(Y(N,I).GT.P) GO TO 51
L.0073        THETA(N,I)=2*DARCCS((R-Y(N,I))/R)
L.0074        A(N,I)=0.5*R**2*(THETA(N,I)-DSIN(THETA(N,I)))
L.0075        V(N,I)=Q(N)/A(N,I)
L.0076        FRICY=DSIN(2*(V(N,I)+V(N-1,J)/ 2))*2*DELX/((A(N,I)/(R*THETA(N,I))+A(N-1,J)/(R*THETA(N-1,J)))/2)**1.33333
L.0077        IMPY=(V(N,I)+V(N-1,J))/(Q(N)+Q(N-1))*Q(N-1)/9.81*(V(N,I)-V(N-1,J)-(V(N,I)*DELQ/Q(N-1)))
L.0078        DELY=FRICY-IMPY
L.0079        IF(ABS(DELYAS(N,I)-DELY).LE.ALC) GO TO 19
L.0080        IF(I.GT.99) GO TO 20
L.0081 C      OUTPUT NO 1
L.0082        IF(K.GT.1) GO TO 21
L.0083        WRITE(KW,21) N,I,DISDP(N),Q(N),A(N,I),FRICY,IMPY,DELY,DELYAS(N,I),Y(N,I)
L.0084 21     FORMAT(T5,I2,T12,I2,T16,F7.4,T24,F8.6,T34,F8.6,T44,F8.6,T54,F8.6,T63,F8.6,T74,F8.6,T84,F7.5)
L.0085        IF(DELYAS(N,I)-DELY) 23,19,24
L.0086 23     I=I+1
L.0087        DELYAS(N,I)=DELYAS(N,I-1)+DEL
L.0088        GO TO 25
L.0089 24     I=I+1
L.0090        DELYAS(N,I)=DELYAS(N,I-1)-DEL
L.0091        GO TO 25
L.0092 19     IF(K.GT.2) GO TO 42
L.0093 C      OUTPUT NO 2
L.0094        WRITE(KW,21) N,I,DISDP(N),Q(N),A(N,I),FRICY,IMPY,DELY,DELYAS(N,I),Y(N,I)
L.0095 42     J=1
L.0096 18     CONTINUE
L.0097 C      FREEBOARD ALLOWANCE
L.0098        YFIN=Y(NT,J)*1.1
L.0099        THET=2*DARCCS((R-YFIN)/R)
L.0100        AFIN=0.5*R**2*(THET-DSIN(THET))
L.0101        IF(I.LT.40) GO TO 27
L.0102 20     WRITE(KW,27) K
L.0103 27     FORMAT(T2,'NCA CONVERGANCE AT STATIONNO =',1X,I2,)
L.0104        IF(I.GT.39) GO TO 22
L.0105        IF(ABS(YFIN-R).LE.0005) GO TO 58
L.0106        IF(P.GT.1) GO TO 31
L.0107        WRITE(KW,31)
L.0108 31     FORMAT(//T6,'INFLOW',T19,'YCRIT',T31,'DEPTH',T43,'AREA',T55,'*',T59,'YFIN',T73,'AFIN'/T2,79('*'))
L.0109        WRITE(KW,32) INF,YCRIT,Y(NT,J),A(NT,J),YFIN,AFIN
L.0110 32     FORMAT(T4,F8.6,T17,F7.5,T30,F7.5,T40,F9.7,T55,'*',1X,F7.5,T70,F9.7)
L.0111        IF(R-YFIN) 84,58,82
```

```
L.0112 82    INF=INF+0.00001
L.0113       P=P+1
L.0114       GO TO 67
L.0115 84    INF=INF-.00001
L.0116       P=P+1
L.0117       GO TO 67
L.0118 58    IF(P.GT.1) GO TO 63
L.0119       WRITE(KW,31)
L.0120 63    WRITE(KW,32) INF,YCRIT,Y(NT,J),A(NT,J),YFIN,AFIN
L.0121       IF((YFIN-R).LT..005) GO TO 38
L.0122 51    WRITE(KW,38) N
L.0123 38    FORMAT(//T2,'THE GUTTER OVERFLOWS AT STATION NO=',1X,I2)
L.0124 90    CONTINUE
L.0125 91    CONTINUE
```

Results of HR

HALF-ROUND GUTTER OF DIAMETER= .1016 M

GUTTER LENGTH= 10.000 M

INFLOW	YCRIT	DEPTH	AREA	*	YFIN	AFIN
.037079	.02642	.04642	.0036091	*	.05106	.0044402

HALF-ROUND GUTTER OF DIAMETER= .1016 M

GUTTER LENGTH= 15.000 M

INFLOW	YCRIT	DEPTH	AREA	*	YFIN	AFIN
.060840	.02396	.04496	.0034616	*	.04946	.0039174

HALF-ROUND GUTTER OF DIAMETER= .1016 M

GUTTER LENGTH= 25.000 M

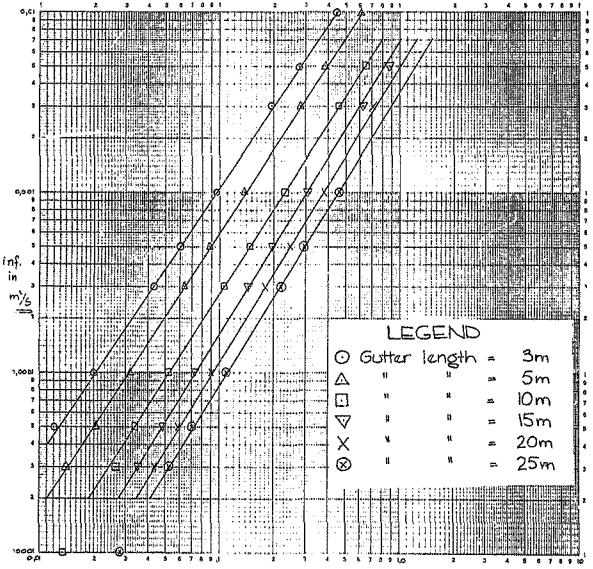
INFLOW	YCRIT	DEPTH	AREA	*	YFIN	AFIN
.000020	.02180	.04480	.0034457	*	.04928	.0038995

APPENDIX D

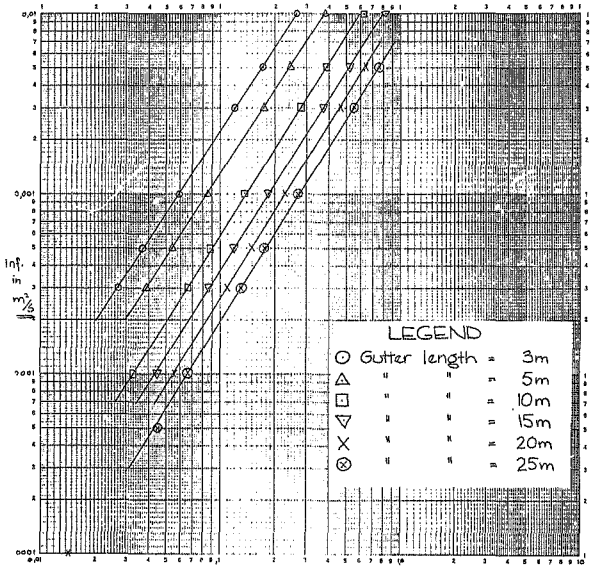
THE ANALYSIS OF THE RESULTS OF THE MATHEMATICAL MODEL

Analysis of the Rectangular gutter results

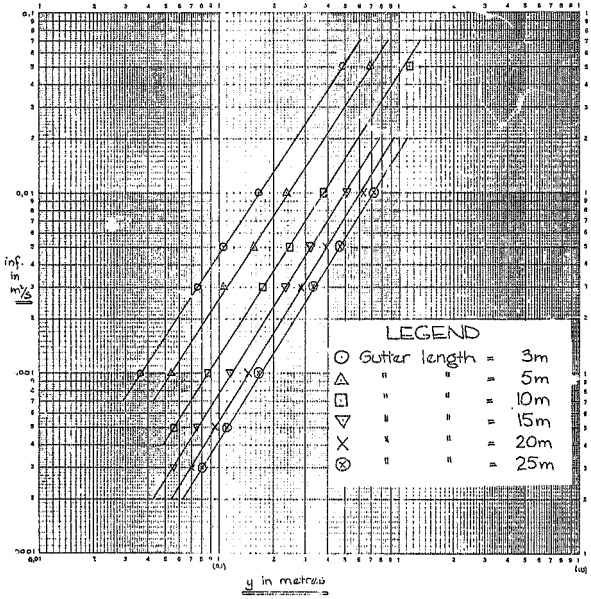
Graph 11: Plot of log(inf) vs log(y) for b= 0,1m for rectangular gutters



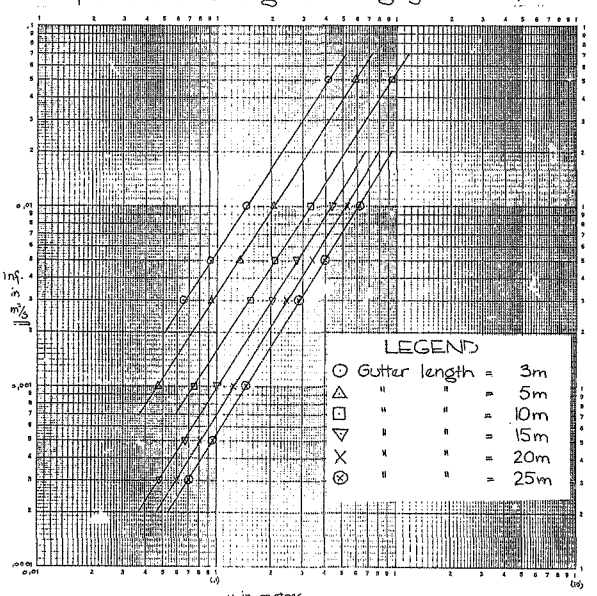
Graph 12: Plot of log(inf) vs log(y) for b= 0,2m



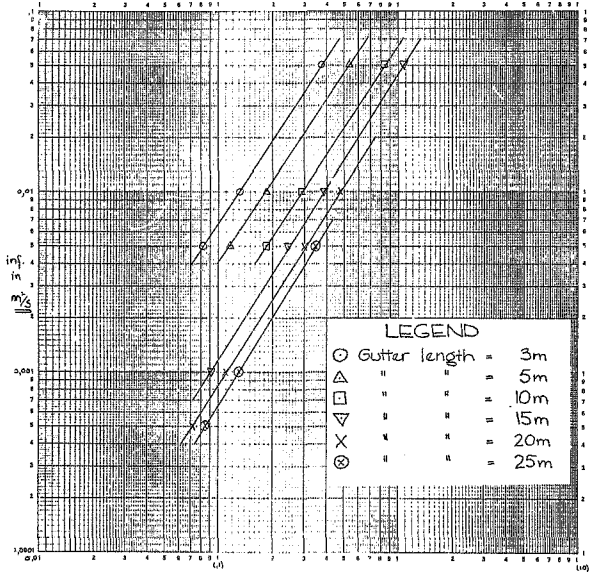
Graph 13: Plot of log (inf) vs log (y) for b = 0.4m



Graph14 : Plot of log(inf) vs log(y) for b= 0,5m



Graph 15: Plot of log(inf) vs log(y) for b = 0,6m



DETERMINATION OF THE EQUATION OF THE DESIGN CURVE
FOR RECTANGULAR GUTTERS

The equation of the curve as seen in graph 4 has the form

$$\log (inf.x^{1,05}) = m \log (yb^{0,67}) + C$$

or $$inf.x^{1,05} = (yb^{0,67})^m \cdot K$$

where $$K = \log C$$

and the slope m $$= \frac{\log (inf.x^{1,05})1 - \log (inf.x^{1,05})2}{\log (yb^{0,67})1 - \log (yb^{0,67})2}$$

To determine the values of m and K accurately a large number of values of $inf.x^{1,05}$ and $yb^{0,67}$ lying on the curve were abstracted from graph 4.These values are listed in Table 34 Pairs of $inf.x^{1,05}$ and $yb^{0,67}$ values were then used to determine the slope m by means of the above formula. The results are in Table 34. The mean value of m is 1,6144 and this value of m is used to determine K from the formula

$$K = \frac{inf.x^{1,05}}{(yb^{0,67})^{1,6144}}$$

The values of K thus determined are listed in Table 35. The mean value is then determined and is K = 1,4294.

Thus the equation of the curve is given by

$$inf.x^{1,05} = 1,4294 (yb^{0,67})^{1,614}$$

This equation is checked by calculating the values of $inf.x^{1,05}$ using given values of $yb^{0,67}$ and the above equation. The results are listed in Table35 and it is seen that the equation gives excellent agreement with the abstracted values of $inf.x^{1,05}$.

TABLE 34: DETERMINATION OF THE SLOPE OF GRAPH 4

inf.$x^{1,05}$	$yb^{0,67}$	slope, m
0,0007	0,0089	1,61294
0,08	0,1680	
0,0009	0,0105	1,62099
0,10	0,1920	
0,007	0,0368	1,60959
0,30	0,3800	
0,01	0,0465	1,62377
0,10	0,1920	
0,001	0,0111	1,6074
0,01	0,0465	
0,002	0,0171	1,6176
0,10	0,1920	
0,004	0,0262	1,6157
0,20	0,2950	
0,02	0,0705	1,6019
0,15	0,2480	
0,01	0,0465	1,6188
0,08	0,1680	
0,03	0,0910	1,6130
0,20	0,2950	

Mean slope m = 1,614369

TABLE 35: VALUES ABSTRACTED FROM GRAPH 4 AND CHECK ON VALIDITY OF DESIGN EQUATION

Inf.$x^{1,05}$ as abstracted from graph 4	$yb^{0,67}$	K	$1,4294(yb^{0,67})^{1,614}$
0,0007	0,0089	1,43088	0,000700
0,0009	0,0105	1,40875	
0,001	0,0111	1,43097	0,001001
0,002	0,0171	1,42456	
0,004	0,0262	1,43072	0,004002
0,007	0,0368	1,44675	
0,01	0,0465	1,41605	0,0101
0,02	0,0705	1,447'ɔ	
0,03	0,0910	1,43762	0,02986
0,05	0,1260	1,41687	
0,08	0,1680	1,42478	0,00803
0,1	0,1920	1,43502	0,09963
0,15	0,2480	1,42458	
0,20	0,2950	1,43533	0,1993
0,30	0,3800	1,43060	0,29996

Mean K = 1,42940

DETERMINATION OF THE EQUATION OF THE CURVE FOR RECTANGULAR GUTTERS AS SEEN IN GRAPH 3

The equation of the curve also has the form

$$\log (\text{inf.}x) = m \log (yb^{0,67}) + C$$

or $$\text{inf. } x = (yb^{0,67})^m . K.$$

Values of inf.x and $yb^{0,67}$ were abstracted from graph 3 and are listed in Table 36. These values were then used to determine the slope values. Results are in Table 36.

The mean of all of these m values is 1,6287. It is seen that the m values marked with an asterisk differ considerably from the mean value. This is due to the difficulty in accurately abstracting the $yb^{0,67}$ values from graph 3. If these * values are neglected, the mean m value is equal to 1,62513.

The value of K is found using both of these values. Results are listed in Table 36. The mean values are

(i) for m = 1,629, $\bar{K}$ = 1,20833

(ii) for m = 1,625, $\bar{K}$ = 1,18541

To check which of these gives the best results the value of inf.x is calculated using the formula

$\text{inf.}x = (yb^{0,67})^m . K$ and the 2 sets of m and K values. Results are listed in Table 37.

It is seen that $\text{inf.}x = 1,1854\ (yb^{0,67})^{1,625}$ gives slightly better agreement with the actual values. Thus this is the equation of the curve in graph 3.

TABLE: 36: VALUES USED IN DETERMINING THE EQUATION OF GRAPH 3

inf.x in m^3/S	$yb^{0,67}$	slope ,m	K for m = 1,629	K for m = 1,625
0,1	0,218		1,19579	1,18852
		1,62321		
0,08	0,190		1,19674	1,18882
		1,62372		
0,07	0,175		1,19726	1,18895
		1,61023		
0,05	0,142		1,20197	1,17909
		1,74966*		
0,04	0,125		1,18357	1,17378
		1,56414*		
0,03	0,104		1,19777	1,18697
		1,62224		
0,02	0,081		1,19980	1,18780
		1,64882		
0,01	0,0532		1,18984	1,17596
		1,58837*		
0,007	0,0425		1,20075	1,18568
		1,16343		
0,005	0,0345		1,70465	1,18854
		1,62624		
0,003	0,0252		1,20570	1,18809
		1,64672		
0,002	0,0197		1,20045	1,18174
		1,60758		
0,001	0,0128		1,21159	1,19066
		1,63252		
0,0009	0,0120		1,21131	1,19008
		1,64513		
0,0007	0,0103		1,20833	1,18642
MEANS			1,20037	1,18541

TABLE 37: CHECK ON CALCULATED EQUATION OF GRAPH 3

$y_b^{0,67}$	$1,1854(y_B^{0,67})^{1,625}$	$1,20037(y_B^{0,67})^{1,629}$	(inf.x) actual
0,218	0,0997	1,00383	0,1
0,175	0,06979	0,070182	0,07
0,125	0,04039	0,04056	0,04
0,081	0,019959	0,0200095	0,02
0,0532	0,01008	0,01008	0,01
0,0252	0,002993	0,002986	0,003
0,0128	0,0009956	0,00099074	0,001
0,0103	0,0006994	0,0006953	0,0007

PROGRAMME TO ANALYSE DATA FOR RECTANGULAR GUTTERS

NAME: YA

OBJECT: To analyse the data for rectangular gutters

Inputs:

Gutter length	x
Number of depth inputs	m
Inflow rate	inf
base breadth	b
design depth	yfin

Method of Computation:

The programme calculates

$db = yfin \cdot b^{0,67}$ for a specified number of design depth values

Outputs:

The outputs are inflow rate, base breadth, design depth (required depth) and $db = y.b^{0,67}$.

```
PTC      ACCT 3    DEPT OF CIVIL ENG                    FILE   YA                    PRI 13/12/74 (74-347)      TIME 10.2

L.0001        REAL INF
L.0002        K=5
L.0003        READ(1,1) X,Y
L.0004 1      FORMAT(2F)
L.0005        WRITE(6,3) X
L.0006 2      FORMAT(//T23,'BASE LENGTH =',1X,F5.2,2X,'M'/T23,23('*'))
L.0007        WRITE(6,5)
L.0008 5      FORMAT(//T3,'INVERT',T19,'BASE BREADTH',T34,'RCD DEPTH',T47,'CB'/T7,44('*'))
L.0009        DO 40 I=1,Y
L.0010        READ(1,3) INF,S,YFIN
L.0011 3      FORMAT(3F)
L.0012        DEPTH(I)=S
L.0013        WRITE(6,4) INF,S,YFIN,DB
L.0014 8      FORMAT(T2,F8.6,T22,F5.3,T31,F6.4,T45,F6.4)
L.0015 40     CONTINUE
```

Outputs from YA

gutter length = 3.00 m
****

Inflow	Lane breadth	rod depth	dh
.000300	.100	.0470	.0008
.000500	.100	.0603	.0120
.001000	.100	.0965	.0206
.001000	.100	.1076	.0422
.003000	.200	.1200	.0413
.005000	.100	.2736	.0585
.005000	.200	.1601	.0575
.005000	.300	.1306	.0522
.010000	.200	.2600	.0915
.010000	.300	.2056	.0917
.010000	.400	.1601	.0915
.050000	.400	.4887	.2645
.050000	.500	.4201	.2640
.050000	.600	.3710	.2641

END OF FILE (2ND LINE AFTER STMNT 5)
/CAN?
/canEXEC 1.50 SEC
GO

gutter length = 5.00 m
****

Inflow	Lane breadth	rod depth	dh
.000300	.100	.0637	.0136
.000500	.100	.0873	.0107
.001000	.100	.1362	.0201
.001000	.200	.0950	.0289
.003000	.100	.2792	.0585
.003000	.200	.1737	.0591
.003000	.300	.1327	.0592
.005000	.200	.2401	.0917
.005000	.300	.1841	.0829
.010000	.200	.3011	.1296
.010000	.300	.2003	.1296
.010000	.400	.2755	.1275
.010000	.500	.2074	.1291
.050000	.500	.5804	.4733
.050000	.600	.5251	.3729

EXEC 2.02 SEC
GO

gutter length = 10.00 m
****

Inflow	Base breadth	rod depth	db
.000100	.100	.0525	.0112
.000300	.100	.1050	.0226
.000500	.100	.1465	.0313
.000500	.200	.0906	.0395
.001000	.100	.2284	.0488
.001000	.200	.1373	.0467
.001000	.300	.1051	.0460
.003000	.200	.2216	.0952
.003000	.300	.2135	.0953
.005000	.200	.3006	.1335
.005000	.300	.2061	.1322
.005000	.400	.2447	.1324
.010000	.300	.4676	.2087
.010000	.400	.3810	.2062
.010000	.500	.3206	.2065
.050	.600	.8301	.5950

EXEC 1.74 [illegible]
00

gutter length = 15.00 m
****

Inflow	Base breadth	rod depth	db
.000050	.100	.0482	.0107
.000100	.100	.0718	.0154
.000300	.100	.1407	.0705
.000500	.100	.1067	.0421
.000500	.200	.1200	.0400
.001000	.200	.1950	.0630
.001000	.300	.1700	.0627
.003000	.200	.3757	.1275
.003000	.300	.2800	.1262
.003000	.400	.2310	.1250
.005000	.300	.3037	.1757
.005000	.400	.3000	.1737
.010000	.500	.4340	.2728
.010000	.600	.3800	.2716

END OF FILE (2ND LINE AFTER STMT 5)
/CAN2
/cooEXEC 1.70 SEC
00

```
                    gutter length = 20.00  m
                    ************************

      Inflow     base breadth    rad depth     db
   ***********************************************
     .000050          .100       .0594          .0127
    .000030          .100       .0442          .0094
     .000100          .100       .0992          .0103
    .000[illegible]          .100       .1901          .0305
     .000[illegible]          .200       .1082          .0308
     .000[illegible]          .100       .2468          .0528
     .000500          .200       .1488          .0506
    .000500          .300       .1120          .0500
     .001000          .200       .2906          .0781
     .001000          .300       .1725          .0766
     .003000          .300       .3470          .1549
    .005000          .400       .2849          .1537
     .005000          .500       .4037          .2150
    .005000          .600       .3040          .2137
     .005000          .700       .3700          .2171
     .005000          .600       .3997          .2135
     .010000          .500       .5285          .3302
    .010000          .600       .4710          .3345
END OF FILE  (2ND LINE AFTER STUNT 5)
/CAN?
/canEXEC  1.94 SEC
GO

                    gutter length = 25.00  m
                    ************************

      Inflow     base breadth    rad depth     db
   ***********************************************
     .000030          .100       .0528          .0115
    .000050          .100       .0703          .0150
     .000100          .100       .1080          .0231
     .000100          .200       .0640          .0238
     .000300          .100       .2151          .0460
     .000300          .200       .1080          .0435
     .000500          .200       .1774          .0507
    .000500          .300       .1204          .0501
     .001000          .200       .2700          .0018
    .001000          .300       .2011          .0000
     .001000          .400       .1662          .0000
    .003000          .300       .4075          .1010
     .003000          .400       .3312          .1703
    .003000          .500       .2851          .1702
     .005000          .500       .3060          .2490
    .005000          .600       .3700          .2409
     .010000          .500       .6167          .3876
    .010000          .600       .5458          .3876
END OF FILE  (2ND LINE AFTER STUNT 5)
/CAN?
/canEXEC  1.92 SEC
GO
```

ANALYSIS OF THE TRAPEZOIDAL GUTTER

RESULTS

Values of inf.x and $= \frac{Adeg^{0,25}}{b^{0,09}}$ were calculated for various base-breadths using the output data from TRAP in Appendix C. These values are shown in tables 38 to 41.

DETERMINATION OF THE EQUATION OF THE DESIGN CURVE FOR TRAPEZOIDAL GUTTERS (GRAPH 9);

The analysis proceeded in exactly the same manner as outlined for rectangular gutters. The mean slope is determined in table 42, and is given by $\bar{m} = 1,337971$. The mean K value is determined in table 43 and is given by $K = 0,69687$. The equation of graph 9 is thus $inf.x = 0,6969 \left(\frac{Adeg^{0,25}}{b^{0,09}} \right)^{1,338}$

This equation is then checked by calculating inf.x using the above formula and comparing the value so obtained with the actual value of inf.x obstracted from graph 9. Excellent agreement is obtained as seen in table 43.

TABLE 3 D: VALUES OF inf.x AND $\phi = \frac{Adoq^{0,25}}{b^{0,09}}$ FOR b = 0,2 metres

Inf in m^2/S	x in metres	Inf.x in m^3/S	ϕ for Deg = 30	ϕ for Deg = 45	ϕ for Deg = 60	ϕ mean
0,0008	10	0,008	0,030871	0,03176	0,03194	0,03152
	15	0,012	0,044599	0,04493	0,04379	0,0444
	20	0,016	0,05633	0,05668	0,05604	0,05635
	25	0,0208	0,066835	0,06804	0,06657	0,06715
	30	0,024	0,081009	0,07974	0,07852	0,07876
	35	0,028	0,092101	0,09179	0,08835	0,09075
0,0005	10	0,005	0,022190	0,02236	0,02281	0,02245
	15	0,0075	0,0309267	0,03082	0,02113	0,03096
	20	0,01	0,040143	0,03965	0,03966	0,03982
	25	0,0125	0,048464	0,04772	0,04847	0,04822
	30	0,015	0,057066	0,05605	0,0552	0,05511
	35	0,0175	0,0643607	0,06465	0,06376	0,06426
0,0003	10	0,003	0,01495	0,01513	0,01622	0,01543
	15	0,0045	0,023078	0,02139	0,02194	0,02147
	20	0,006	0,026486	0,02794	0,02777	0,02740
	25	0,0075	0,033260	0,03381	0,03373	0,03360
	30	0,009	0,039149	0,03989	0,03894	0,03933
	35	0,0105	0,045247	0,04504	0,04425	0,04485
0,005	3	0,015	0,048367	0,04880	0,04742	0,04820
	5	0,025	0,072896	0,07446	0,07185	0,07307
	10	0,05	0,130074	0,1294	0,1254	0,1283
	15	0,075	0,182527	0,1796	0,1716	0,1779
	20	0,1	0,233031	0,2290	0,2212	0,2277
	25	0,125	0,280704	0,2745	0,2648	0,2731
0,003	3	0,009	0,0318479	0,0326	0,03181	0,03197
	5	0,015	0,0483676	0,04880	0,04841	0,04853
	10	0,03	0,087375	0,08641	0,08398	0,08592
	15	0,045	0,120946	0,1220	0,1180	0,1203
	20	0,06	0,155270	0,1536	0,1508	0,1532
	25	0,075	0,187792	0,1838	0,1766	0,1827
0,001	3	0,003	0,0132619	0,01361	0,01408	0,01365
	5	0,005	0,0211964	0,02149	0,02127	0,02132
	10	0,01	0,036369	0,03752	0,03781	0,03723
	15	0,015	0,052636	0,05237	0,05243	0,05248
	20	0,02	0,065228	0,06670	0,06546	0,06580
	25	0,025	0,083317	0,08017	0,67887	0,08079

TABLE AF: VALUES OF inf.x AND $\phi = \frac{Ada^{0,25}}{b^{0,09}}$ FOR b = 0,30metres

Inf in m^2/s	x in metres	inf.x in m^3/s	ϕ for Deg = 30	ϕ for Deg = 45	ϕ for Deg = 60	ϕ mean
0,0008	10	0,008	0,030117	0,03240	0,03272	0,03175
	15	0,0120	0,04362	0,04448	0,04482	0,04431
	20	0,016	0,05498	0,05576	0,05712	0,05595
	25	0,0208	0,06676	0,06872	0,06727	0,06758
	30	0,024	0,0772	0,07766	0,07883	0,07760
	35	0,028	0,09164	0,08981	0,08795	0,08980
0,0005	10	0,005	0,02244	0,02318	0,02313	0,02292
	15	0,0075	0,03045	0,03168	0,03300	0,03171
	20	0,01	0,04007	0,04019	0,04089	0,04038
	25	0,0125	0,04733	0,04780	0,04887	0,04800
	30	0,015	0,05628	0,05556	0,05694	0,05626
	35	0,0175	0,06395	0,06348	0,06396	0,06380
0,0003	10	0,003	0,01551	0,01573	0,01690	0,01605
	15	0,0045	0,02161	0,02212	0,02327	0,02237
	20	0,006	0,02771	0,02902	0,02865	0,02813
	25	0,0075	0,03292	0,03383	0,03507	0,03394
	30	0,009	0,03859	0,03977	0,04052	0,04003
	35	0,0105	0,04372	0,04463	0,04601	0,04476
0,005	3	0,015	0,04733	0,04780	0,04887	0,04800
	5	0,025	0,07026	0,07174	0,0724	0,07147
	10	0,05	0,1259	0,1252	0,1219	0,1243
	15	0,075	0,1762	0,1744	0,1706	0,1737
	20	0,1	0,2228	0,2213	0,2142	0,2194
	25	0,125	0,2673	0,2598	0,2551	0,2607
0,003	3	0,009	0,03184	0,03286	0,03313	0,03261
	5	0,015	0,04713	0,04907	0,05001	0,04880
	10	0,03	0,08394	0,08488	0,08508	0,08463
	15	0,045	0,1174	0,1190	0,1160	0,1171
	20	0,06	0,1524	0,1489	0,1463	0,1492
	25	0,075	0,1813	0,1786	0,1758	0,1796
0,001	3	0,003	0,01359	0,01388	0,01508	0,01402
	5	0,005	0,02018	0,02117	0,02217	0,02117
	10	0,01	0,03610	0,03648	0,03675	0,03718
	15	0,015	0,05173	0,05283	0,05230	0,05220
	20	0,02	0,06511	0,06588	0,06604	0,06568
	25	0,025	0,07895	0,07918	0,07881	0,07897

TABLE 40: VALUES OF inf.x AND $\phi = \frac{Adeq^{0,25}}{b^{0,09}}$ FOR b = 0,4 metres

inf in m^2/s	x in metres	inf.x in m^3/s	ϕ for Deg = 30	ϕ for Deg = 45	ϕ for Deg = 60	ϕ mean
0,0005	5	0,0025	0,0120	0,01374	0,01431	0,01335
	10	0,005	0,02207	0,02378	0,02432	0,02339
	15	0,0075	0,03127	0,03261	0,03289	0,03226
	20	0,01	0,03942	0,04156	0,04263	0,04120
	25	0,0125	0,04779	0,04928	0,05118	0,04942
	30	0,015	0,05641	0,05705	0,05843	0,05730
0,001	5	0,005	0,02086	0,02144	0,02317	0,02182
	10	0,01	0,03658	0,03890	0,04012	0,03851
	15	0,015	0,05163	0,05275	0,05443	0,05294
	20	0,02	0,06402	0,06533	0,06742	0,06559
	25	0,025	0,0767	0,0814	0,08048	0,07953
	30	0,03	0,09168	0,08123	0,09216	0,09170
0,005	5	0,025	0,07132	0,07183	0,07331	0,07215
	10	0,05	0,1228	0,1233	0,1251	0,1237
	15	0,075	0,1703	0,1695	0,1683	0,1694
	20	0,01	0,2143	0,2175	0,2105	0,2141
	25	0,0125	0,2595	0,2575	0,2559	0,2576
	30	0,015	0,3026	0,3009	0,2916	0,2984
0,01	5	0,05	0,1214	0,1202	0,1225	0,1214
	10	0,1	0,2099	0,2092	0,2074	0,2087
	15	0,15	0,2915	0,2891	0,2842	0,2883
	20	0,2	0,3691	0,3638	0,3568	0,3632
	25	0,25	0,4487	0,4375	0,4256	0,4376
	30	0,3	0,5173	0,5131	0,4926	0,5077
0,05	5	0,25	0,4251	0,4247	0,4111	0,4203
	10	0,5	0,7496	0,7382	0,7171	0,7350
	15	0,75		1,034	0,9929	1,013
0,1	5	0,5	0,7496	0,7341	0,7094	0,7304

TABLE 41: VALUE OF inf.x AND $\phi = \frac{Adep^{0,25}}{b^{0,09}}$ FOR b = 0,5 metres

inf. in m^3/s	x in metres	inf.x in m^3/s	ϕ for Deg = 30	ϕ for Deg = 45	ϕ for Deg = 60	ϕ mean
0,005	5	0,025	0,06971	0,07312	0,07539	0,07279
	10	0,05	0,1230	0,1245	0,1258	0,1244
	15	0,075	0,1704	0,1720	0,1715	0,1713
	20	0,1	0,2144	0,2142	0,2141	0,2142
	25	0,125	0,2569	0,2575	0,2595	0,2586
	30	0,315	0,3005	0,2939	0,2930	0,2958
0,003	5	0,015	0,04827	0,04990	0,05183	0,0500
	10	0,03	0,08355	0,08574	0,08713	0,08547
	15	0,045	0,1168	0,1172	0,1192	0,1177
	20	0,06	0,1446	0,1475	0,1481	0,1467
	25	0,075	0,1730	0,1742	0,1754	0,1742
	30	0,09	0,2022	0,2038	0,2031	0,203
0,001	5	0,005	0,02098	0,02335	0,02426	0,02286
	10	0,01	0,03680	0,03898	0,04118	0,03923
	15	0,015	0,05188	0,05461	0,05632	0,05417
	20	0,02	0,06514	0,06724	0,06988	0,06742
	25	0,025	0,07912	0,07999	0,08342	0,08084
	30	0,03	0,08952	0,09474	0,09539	0,09322
0,01	5	0,05	0,1207	0,1226	0,1223	0,1219
	10	0,1	0,2088	0,2094	0,2100	0,2094
	15	0,15	0,2837	0,2857	0,2861	0,2852
	20	0,2	0,3655	0,3620	0,3548	0,3608
	25	0,25	0,4386	0,4314	0,4225	0,4308
	30	0,3	0,5091	0,5024	0,486	0,4992
0,05	5	0,25	0,4190	0,4133	0,4060	0,4136
	10	0,50	0,7161	0,7245	0,7021	0,7209
	15	0,75	1,015	1,007	0,974	0,9987
	2	0,10	0,2031	0,2046		0,2038
0,1	5	0,5	0,7110	0,7204	0,6988	0,7167
	10	1,0		1,257	1,212	1,235

TABLE 42: DETERMINATION OF THE SLOPE OF GRAPH 9

inf.x in m^3/s	$\frac{A.deg^{0,25}}{b^{0,09}}$	m
0,003	0,0171	
		1,34106
0,09	0,216	
0,004	0,0211	
		1,337615
0,04	0,118	
0,005	0,025	
		1,333612
0,5	0,79	
0,007	0,0322	
		1,341819
0,09	0,216	
0,01	0,0422	
		1,336528
0,8	1,12	
0,02	0,07	
		1,330674
0,2	0,395	
0,04	0,118	
		1,346137
0,15	0,31	
0,005	0,025	
		1,342385
0,15	0,315	
0,07	0,178	
		1,326923
0,3	0,533	
0,01	0,0422	
		1,342958
0,15	0,317	

Mean m = 1,337971

TABLE 43: VALUES ABSTRACTED FROM PLOT OF inf.x VERSUS $A.deg^{0,25}/b^{0,09}$

inf.x in m^3/S	$\frac{Adeg^{0,25}}{b^{0,09}}$	K using m=1,338	$0,6969\left(\frac{Adeg.^{0,25}}{b^{0,09}}\right)^{1,338}$
0,003	0,0171	0,69402	0,003009
0,004	0,0211	0,698506	0,003986
0,005	0,025	0,695867	0,005001
0,007	0,0322	0,694363	0,007016
0,01	0,0420	0,695172	0,01001
0,02	0,07	0,701922	0,01983
0,04	0,118	0,6980425	0,03988
0,05	0,139	0,700836	0,04965
0,07	0,178	0,704752	0,06913
0,09	0,216	0,699429	0,08956
0,15	0,315	0,703642	0,14837
0,20	0,395	0,693079	0,20084
0,3	0,533	0,696242	0,2999
0,5	0,79	0,6854014	0,50773
0,8	1,12	0,6874423	0,80996

Mean K = 0,69687

Thus $inf.x = 0,6969\left(\frac{Adeg^{0,25}}{b^{0,09}}\right)^{1,338}$

APPENDIX E

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Name of thesis Compilation Of A Manual For The Design Of Roof Drainage Systems. 1974

PUBLISHER:
University of the Witwatersrand, Johannesburg
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