# TEMPORAL DISTRIBUTION OF STORM RAINFALL ON THE WITWATERSRAND AND ITS EFFECT ON PEAK FLOWS

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A project report 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.

Johannesburg, 1991

DECLARATION

I declare that this project report is my own, unaided work. It is being submitted for the degree of Master of Science in Engineering in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

(Signature of candidate)

6th day of May 1991.

ABSTRACT

The temporal distribution of rainfall can have a significant effect on peak runoff, especially so in the small catchments that are typical of the Witwatersrand. This report investigates the shape of the natural hyetograph and its use in the analysis of peak runoff.

It describes the climatology of the sub-continent and rain-producing systems. Then, more specifically, aspects of rainfall over Johannesburg are discussed.

Some of the more commonly-used temporal distributions of rainfall are reviewed and the relationship between intensity-time distributions and mass curves is illustrated.

Mass curves are derived using data from a raingauge in Norwood, Johannesburg. The data is analysed with the assistance of a computer program and classified into quartiles. The quartiles are further analysed in an attempt to define their characteristics in greater detail.

The mass curves are used with a hydrological model to generate hydrographs. The values of runoff peaks are found to be comparable with those obtained using currently accepted temporal rainfall distributions.

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| | |
|---|---|
| Total rainfall depth | $P$ |
| Precipitation before storm peak | $P_b$ |
| Precipitation after storm peak | $P_a$ |
| Peak rainfall intensity | $I$ |
| Rainfall intensity before storm peak | $I_b$ |
| Rainfall intensity after storm peak | $I_a$ |
| Storm duration | $t_d$ |
| Time to peak | $t_b$ |
| Time from peak to end of storm | $t_a$ |
| Time to peak ratio | $r$ ; $a_0$ |
| Constants | $a;b;c$ |
| Recurrence interval | $T$ |
| Probability of occurrence | $r$ |
| Length of record | $L$ |

# 1 INTRODUCTION

Rainfall, often viewed as a life-giving resource, can also pose a considerable threat in the form of flood damage. In urban areas such as the Pretoria - Witwatersrand - Vereeniging (PWV) complex, high population densities increase the risk of property damage and loss of life as a result of flooding.

To compound the problem, urbanisation itself usually aggravates the situation by increasing the area and degree of surface impermeability as well as canalising stormwater runoff. Peak flow rates and runoff volumes can be significantly increased as a result (Kolovopoulos, 1986).

In order to quantify the magnitude of peak flow rate and flood volume in urban areas, use is often made of "deterministic" methods which mathematically model the process whereby rainfall is converted into runoff. Clearly for such methods the accuracy of runoff prediction (and hence effectiveness of flood-control measures) relies on the quality of input data, one of which is rainfall.

The importance of temporal rainfall distribution can best be illustrated by reference to the "hydrological equation" which states that :

> Rate of outflow from a system equals the difference between the rate of inflow and the rate of change of storage within the system.

In this context, the rate of outflow is described by an outflow hydrograph, the rate of change of storage by time-dependent losses such as infiltration and depression storage. The rate of inflow is, to a large extent, the temporal distribution of the rainfall. The different time-distributions of rainfall and losses can significantly affect runoff peak flows and volumes. For instance a high rainfall intensity towards the end of a storm could result in unusually high runoff as infiltration tails off and depression storage fills up.

The effect of temporal distribution of rainfall is likely to be more pronounced over a small catchment than a large catchment, due to factors such as the areal extent of the storm and the volume of storage within the catchment. The very name "Witwatersrand" - Ridge of White Waters - almost implies small-catchment hydrology, since this ridge is so high that it forms the continental divide for rivers draining to the east and west of the subcontinent. Urban development along the ridge is thus likely to be particularly sensitive to the temporal distribution of rainfall.

Temporal distribution of rainfall has been the subject of increasing attention as one of the consequences of the introduction of computer techniques, with their attendant ability to deal with complex calculations. Such temporal distribution is often described by a design storm, defined as " a rainfall event which is developed for the design of specific types of objects, such as pipes or retention basins " (Arnell et al, 1984).

The simplest form of design storm is the uniform-intensity or rectangular storm. Obtained from standard Intensity-Duration-Frequency (IDF) curves it has the disadvantage that it ignores variations in rainfall intensity during the storm.

Keifer and Chu (1957) derived a temporal rainfall distribution, based on standard IDF curves, as part of an extensive auxiliary outlet sewer construction programme for the City of Chicago. Commonly known as the Chicago design storm, it has, for all durations, the same average intensities as those given by the IDF curves. This has the advantage that only one runoff calculation is necessary to establish the peak flowrate for each recurrence interval. It has the disadvantage however of an unnaturally high peak intensity, often resulting in an overestimation of peak flowrates. Use of the Chicago distribution for South African conditions has been investigated by Watson (1981), Op Ten Noort and Stephenson (1982) and Lambourne and Stephenson (1986).

Huff (1967) prepared a set of dimensionless mass curves by plotting the relationship between cumulative percent of precipitation and cumulative percent of storm time. He found that a major portion of the total storm rainfall occurred in a small part of the total storm time. To accommodate this, he classified storms into four groups or quartiles, depending on whether the heaviest rainfall occurred in the first, second, third or fourth quarter of the storm period. Because of the great variability in the characteristics of the distribution from storm to storm, he found it necessary to express the time distributions in each quartile in probability terms. The data on which the curves were based was obtained from a network of rain gauges in Illinois, USA. Storms derived from the dimensionless mass curves have been referred to as the Illinois State Water Survey design storms (Arnell et al, 1984).

van Wyk and Midgley (1966) and Wiederhold (1969) investigated temporal rainfall distributions using South African data - also presented as mass curves.

Mass curves were prepared by the National Environmental Research Council (1975) in the United Kingdom as part of their Flood Studies Report. These were derived from data centred on the most intense part of the storm and thus result in a design storm with a more pronounced peak intensity than one derived from Huff's data.

Yen and Chow (1980) used a triangle to represent the distribution of rainfall intensity as a function of time. A considerable amount of work has been done locally on this distribution. Constantinides (1982) found the original distribution unsuitable for storms with a long tail off period with little rainfall. He thus developed a method for preserving the value and time of occurrence of the peak intensity. However this method results in a more severe storm than even the natural storm. Sutherland (1983) developed a method to overcome this by preserving the time of occurrence of the peak intensity together with the rainfall depths before and after the peak. Green (1984) used Intensity - Duration - Frequency curves to preserve storm duration and total precipitation. Lambourne and Stephenson (1986) noticed that a hyetograph with two peaks would describe recorded rainfall data better than the single-peaked triangular distributions used previously. Due to the ease with which the shape could be computed, they developed a double or bimodal triangular distribution.

Thus, although much investigation has been done locally into a mathematical representation of the temporal distribution of rainfall, less has been done to describe the natural distribution. In particular, no investigation has been done to determine the local applicability of the dimensionless mass curves of Huff or to derive similar curves.

The aims of this investigation are:

1. To produce mass-curves of rainfall from a raingauge in Norwood, Johannesburg.
2. To compare the Norwood mass-curves with those produced by Huff.
3. To compare runoff resulting from the use of the Norwood mass-curves in a typical deterministic stormwater model with that resulting from other commonly-used rainfall distributions.

# 2 RAIN PRODUCING SYSTEMS AND RAINFALL OVER JOHANNESBURG

Before embarking on a study of individual storms, a review of rainfall-producing events is necessary if the storms are to be understood in a wider context. In this chapter the atmospheric circulation and synoptic climatology of southern Africa is first considered. Thunderstorms, which contribute significantly to Johannesburg's annual precipitation, are then described. The causes of rainfall over Johannesburg and its spatial, seasonal, diurnal and long-term variations are described. Finally, the incidence of hail, one of the consequences of thunderstorms, is discussed.

## 2.1 Southern African rain-producing systems.

### 2.1.1 Atmospheric circulation over Southern Africa.

Africa south of about 20° S is dominated by the subtropical anticyclones. The South Atlantic anticyclone lies well to the west of the west coast in a relatively stationary position. By contrast, the position of the South Indian anticyclone is less static, moving towards the East coast in winter and withdrawing eastwards in summer. South of the anticyclones, the zone of the westerlies occurs in which frontal depressions form and travel in an easterly direction (Jackson and Tyson, 1971).

Low-level circulation (850 hPa) over the land mass varies from summer to winter conditions. In January a weak low pressure zone is situated over the central interior, linked by a trough to a tropical low north of Botswana. The latter wanders in an east-west direction, occasionally coming southward. A weak ridge of high pressure is also evident over the northern Cape. In July a strong anticyclone exists over much of the land mass, the change to this single high pressure cell having occurred by March (Tyson, 1986).

In the higher levels of the atmosphere (500 hPa and 200 hPa), airflow is westerly although easterly flow occurs north of about 23° S when the westerlies move polewards in January. Contours of the mean 850 hPa and 500 hPa surfaces in January and July are shown in Figure 2.1.

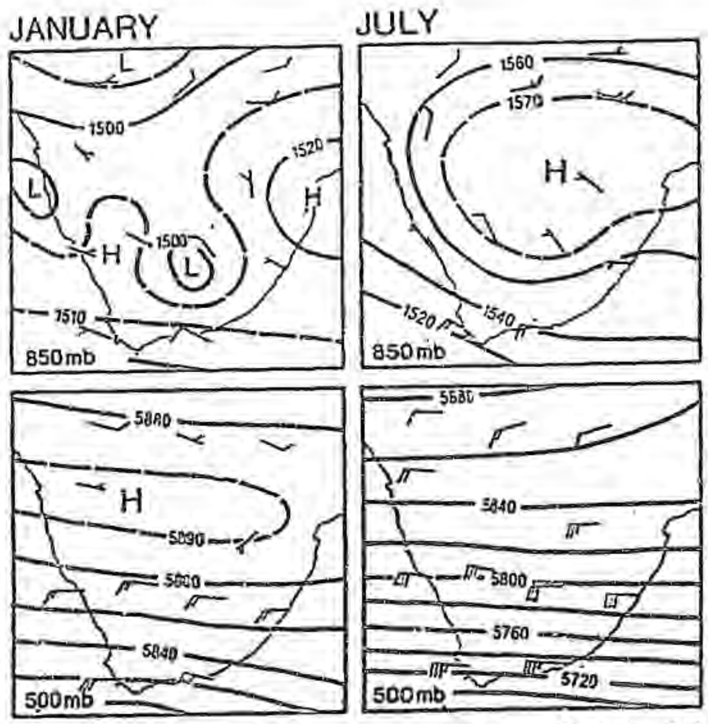



Figure 2.1 Contours of mean 850 hPa and 500 hPa surfaces over southern Africa in January and July. (Tyson, 1986)

### 2.1.2 Rainfall-producing circulation types.

Mean circulation patterns however only provide a background against which the synoptic peturbations, responsible for the climate and weather of the region, occur. Beginning in 1955, a number of synoptic classifications of southern Africa weather systems have been proposed, often for a specific purpose (e.g. temperature and rainfall distribution, hail-producing conditions, generation of wind energy).

The most recent classification of rain-producing circulation types over southern Africa is that by Tyson (1986) using three categories of circulation patterns :

- Fine - weather and mildly disturbed conditions.
- Tropical disturbances associated with tropical easterly airflow.
- Temperate, mid-latitude disturbances associated with westerly airflow

These patterns are shown schematically in Figure 2.2 and are briefly described below (after Tyson, 1986).

Fine - weather and mildly disturbed conditions.

These conditions are associated with anticyclonic vorticity in large anticyclones over the subcontinent. They result in fine, clear conditions and little or no rainfall and are common over the Highveld in winter.

Tropical disturbances in the easterlies.

Troughs and isolated low-pressure depressions, originating from the higher latitudes and known as easterly wave and lows, draw in moist air from the Indian Ocean fed by the South Indian anticyclone. Easterly lows often result in copious rainfall which may be of a few days duration. Easterly waves are associated with heavy rainfall, often in the form of thunderstorms which develop in a convergence zone to the east of a surface trough. The thunderstorms typically form squall lines advancing from the south west.

Another form of disturbance associated with easterly airflow occurs when upper westerly waves are remote from the continent and a strong surface anticyclonic vortex, often confined to the upper troposphere, may form over southern Africa. This is usually associated with clusters of cumulonimbus clouds extending south from the tropics and may result in heavy rainfall over parts of South Africa.

Temperate disturbances in the westerlies.

Westerly peturbations are more varied than their easterly counterparts and six classes are recognised. Although presented as discretely occuring types they often merge with and change into each other on a daily basis.

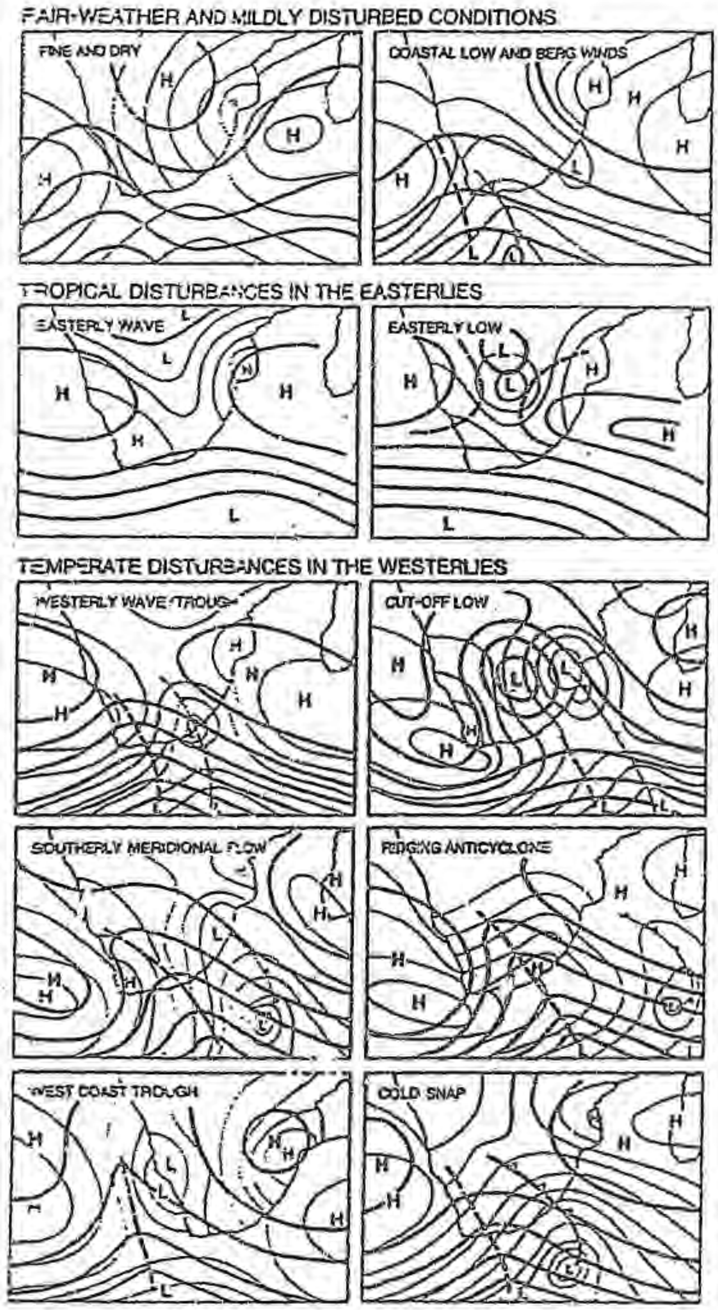



Figure 2.2 Schematic classification of southern Africa weather types based on circulation patterns at the surface (light lines) and at 500 hPa (heavy lines).
(Tyson, 1986)

Westerly waves. These produce ideal conditions for sustained uplift of air resulting in cloud and precipitation to the rear of a surface trough. Heavy rainfall resulting directly from the westerly wave is rarely experienced inland of the Escarpment although inland rainfall may be induced through squall-line convection occurring in association with the front that often accompanies the wave. Westerly waves appear to be modulated on a semi-annual cycle with maximum frequency of occurrence in October to November and again in January to March.

Cut-off lows. When a trough in the westerlies becomes displaced equatorward, out of the basic westerly current, a closed circulation cut-off low is formed. These occur on a semi-annual cycle with peak occurrences in March-May and September-November and account for many of the flood-producing rains over South Africa.

Southerly meridional flow. A strong pressure gradient between a high to the west and a low to the east and a clear westerly wave at 500 hPa results in sustained rainfall which tends to be confined to coastal regions and the Transvaal Lowveld.

Ridging anticyclones. A ridging anticyclone associated with a westerly wave at 500 hPa causes advection of moist Indian Ocean air and general uplift over the land. General rains or thunderstorm activity over eastern South Africa may result, occurring between October and May.

West coast troughs. A surface trough of low pressure over the west coast and an upper westerly wave to the west of the subcontinent can result in widespread rains over the western parts of South Africa.

Cold fronts. These occur together with westerly waves, depressions or cut-off lows and should not be considered in isolation from these systems. They are however associated with invasions of cold air from the south and south-west, producing characteristic cold snaps of of a few days duration and it is thus useful to consider them separately. They occur most frequently in winter when the amplitude of the westerly disturbances is greatest. Ahead of the front, stable and cloud-free conditions exist, whilst to the rear, conditions favourable for convection are created.

Tyson notes that, in practice circulation types tend to occur together in complex composite situations which may result in heavy and widespread precipitation. In particular, interaction between easterly and westerly disturbances offers a mechanism for the extraction of heat from the tropics to the temperate latitudes. Such interactions often result in extensive cloud bands linking tropical and middle latitudes over southern Africa. The notorious Laingsburg flood of 25 January 1981 was associated with the interaction between a tropical easterly low and a westerly wave and cut-off low.

2.1.3. Other important rain-producing systems.

Other important rain-producing systems are thunderstorms (typically of short duration and with high rainfall rates) and tropical cyclones (typically producing copious rainfall and lasting several days).

Thunderstorms.

Synoptic conditions determine the dynamic controls (vertical motion) and thermal environment (stability) in which convective systems can grow. Many different types of synoptic situations are conducive to storm formation, common ones being a trough in the tropical easterlies and a frontal passage. Often no single mechanism is responsible for a major storm and usually it is a combination of synoptic and mesoscale forcing and the local heating cycle that are the cause of severe storms.

Thunderstorms may be of the single-cell, multi-cell or supercell type and may occur as isolated, scattered or line storms (Preston-Whyte and Tyson, 1988). Isolated storms tend to be single-cell type, with surface heating as the major cause of uplift. Scattered storms tend to be stronger, more multi-cellular and clustered and result from a combination of heating effects, mesoscale forcing and larger scale synoptic controls. Both isolated and scattered storms require a non-suppressive synoptic condition for their generation. Line storms are caused predominantly by synoptic forcing and tend to form preferentially ahead of a front with the same orientation as the line of storms, separating a warm moist airstream to the north-east from a cooler drier airstream to the south-west. Most line storms are multi-cellular.

Over the Transvaal Highveld, relative frequencies of scattered, isolated and line storms are 54%, 39% and 7% respectively. Despite their comparative rarity, squall line storms contribute significantly to rainfall, particularly during the period November to January. Most thunderstorms over central South Africa move on westerly to south-westerly tracks at speeds of 25 to 30 km/h.

Single-cell storms. These are usually 5 to 10 km in horizontal extent, last for less than an hour and change markedly with time. Updraughts cause raindrops to grow in size until a size is reached at which precipitation begins to fall. In doing so a downdraught is created, often reaching the ground as a highly turbulent gust. The boundary between the spreading chilled downdraught air and the surrounding warmer air is termed a squall line. Hail seldom results from such storms because the mechanism for its recirculation is lacking. As indicated above, characteristic changes in pressure, temperature and wind fields result from the passage of a mature storm cell.

Multi-cell storms. Typically 30 to 50 km in horizontal extent, these usually consist of a number of evolving cells, each going through the lifecycle of the single-cell type. The life-span of the multi-cell cluster may be hours, with up to 30 cells developing during this time. Rainfall is heavy during the mature stage and light and steady during the dissipating stage. Multi-celled storms are common over the Pretoria-Johannesburg region. A schematic plan of a multi-cell Highveld storm is shown in Figure 2.3.

Supercell storms. Supercell storms are the most powerful of the thunderstorms to occur over the subcontinent. Their occurrence, although not common, usually results in havoc and devastation. They usually exhibit a massive, circular to elliptical, single-cell structure, 20 to 30 km in horizontal extent and 12 to 15 km high. Hail falling during the storm is often very large.

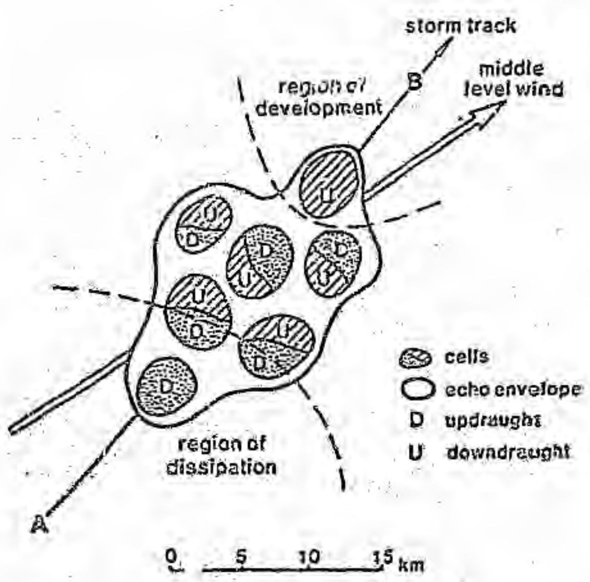



Figure 2.3 Schematic plan view of a multi-cell Highveld storm. (Tyson, 1986)

Tropical cyclones.

These regularly form over the Indian Ocean, occasionally crossing the coast of the subcontinent but seldom moving inland of the Escarpment. Inland penetration may have devastating effects, as caused by cyclones Domoina and Imboa in 1983/1984.

## 2.2 Rainfall over Johannesburg.

Johannesburg is situated approximately at latitude 26° S and longitude 28° E. Its elevation varies from about 1800 m above mean sea level (amsl) to 1500 m amsl and its topography is characterised by a number of east-west trending ridges.

2.2.1 Causes.

Rainfall over Johannesburg can be attributed to a number of causes (Tyson and Wilcocks, 1971) :

> The action of the South Indian anticyclone in feeding moist, warm and potentially unstable air can give rise to rainy spells of a few days duration. The presence of a depression over the plateau can give rise to widespread rainfall, showers or thunderstorm activity.
>
> A second effect of the anticyclone is the generation of thunderstorms of high intensity and short duration, often occurring as line squalls.
>
> Another class of thunderstorm occurs, associated to a greater extent with local heating and mesoscale uplift than the former.

Thunderstorms contribute greatly to Johannesburg's annual precipitation and both these and longer duration showers tend to move across the region in a south-west to north-east track.

2.2.2 Temporal variation.

Analysis of data from the Joubert Park raingauge covering the period 1900 to 1969 has indicated that, for practical purposes, the mean annual precipitation has not significantly changed over this period (Tyson and Wilcocks, 1971). Since the year-to-year data is by no means constant, varying from 1184 mm in 1918 to 518 mm in 1935, it was examined for preferred fluctuations. This resulted in the identification of 2,7-year; 4-year; 13-year and 30-year peaks.

Using annual rainfall data (October to September) for the summer rainfall region, Tyson (1986) has recently identified an 18-year cycle of wet and dry spells. The nine-year period 1962/63 to 1970/71 has been identified as a dry spell and the ten-year period 1971/72 to 1980/81 as a wet spell. Even though inter-annual variability may be marked, when the entire spell is examined the underlying rhythm begins to manifest itself.

The 1971 Joubert Park analysis included examination of mean monthly rainfall data, revealing a distinct seasonal pattern. An average of 724 mm, 93% of the annual average of 769 mm, occurred between October and March. Many engineering projects, especially those along streams, exploit this seasonal nature of the region's rainfall by programming work to occur during the "dry" season (April to September). On average, falls of more than 10 mm were found to occur on 28 days a year, a fact which will be referred to later.

Diurnal variation of rainfall indicates the effect of local heating on storm generation, with a distinct peak occurring in the late afternoon.

2.2.3 Spatial variation.

From their analysis of 57 years (1911 to 1968) of data from 46 stations in the area, Tyson and Wilcocks (1971) concluded that the spatial variation of rainfall over greater Johannesburg was controlled by topography. The suburbs to the north of the Witwatersrand ridges experienced as much as 25% less precipitation than the city centre and the ridges themselves. The decrease to the south however was not as pronounced. There was a tendency for south-facing slopes to receive the highest rainfall, due to their being windward of storms advancing from the southwest. The ridges are associated with more rain days and less rainfall variability than the lower-lying areas. Rainfall variability increases westwards, consistent with regional trends over most of the Transvaal. They noted that the extent to which the higher precipitation over the urban core was enhanced by the effects of urban heating was difficult to establish.

2.2.4 Hailstorms.

One of the consequences of the high incidence of thunderstorms in the region is a correspondingly high incidence of hail. Since 1962, hailstorms in a 40 km by 70 km rectangular area, extending from Johannesburg to Pretoria, have been studied and a significant amount of data has been obtained (Held, 1974).

Although there are occasional occurrences during winter, hail is predominantly a summer phenomenon in the area, falling mainly during the months October to April, with November being the peak month (Carte and Held, 1978). Hailfalls can be continuous or intermittent (with up to eight bursts recorded) and their average duration varies from about six minutes for continuous falls to approximately 11 minutes for intermittent ones.

Isohyetal patterns for the summer months closely match the pattern of hail incidence with Johannesburg experiencing more rain and hail than Pretoria. Carte and Held attribute this to the fact that Johannesburg lies approximately 300 m higher than Pretoria. Urban areas experienced more occurrences of hail than rural areas, suggesting that in such areas urban effects are more important even than topography.

Hailstones of 10 mm diameter and smaller occurred on about half of the hail days, with diameters exceeding 30 mm having been only rarely recorded. The storms which produced the largest hailstones were generally those of greatest areal extent. In general only small amounts of hail occurred, with sufficient hail to cover the ground in only about 20 % of all falls. Hail from a single storm was recorded over areas varying from a few square kilometres to more than 1 000 $km^2$, with a mean value of 150 $km^2$.

## 2.3 Summary

Atmospheric circulation over southern Africa is characterised by the South Atlantic and South Indian anticyclones bounded by the temperate westerlies and subtropical easterlies. A strong anticyclone over the interior in winter contributes to the seasonal distribution of rainfall. It is against this background that the synoptic peturbations, responsible for the climate and weather of the region, occur.

Rainfall-producing circulation types have been classified into three categories, which in practice tend to occur in complex, composite situations. They are :

Fine-weather and mildly disturbed conditions.

Tropical disturbances associated with tropical easterly airflow.
Temperate, mid-latitude disturbances associated with westerly airflow.

Thunderstorms make a significant contribution to Johannesburg's annual precipitation. Here scattered, multi-cellular storms and isolated, single-cell storms are the most common types. Surface heating plays an important part in the generation of these storms. Despite their relative rarity, line storms, caused predominantly by synoptic forcing, can result in considerable precipitation. Tropical cyclones seldom move inland of the Escarpment and thus are not relevant to a discussion of Johannesburg's rainfall.

The mean annual precipitation of Johannesburg (recorded at a fixed location) is, for practical purposes, constant - although annual precipitation may vary considerably and cycles from 2,7 years to 30 years duration have been identified. Rainfall is seasonal with over 90 % falling in the six-month summer season. As a result of local heating rain often falls in the late afternoon. There is considerable spatial variation of rainfall over Johannesburg, strongly influenced by topography. Storms tend to move on a south-west to north-east track with the result that areas north of the ridges receive as much as 25 % less rain than the southern slopes. Due to the high incidence of thunderstorms, hail is fairly common.

# 3 REVIEW OF COMMONLY-USED TEMPORAL DISTRIBUTIONS OF RAINFALL

This chapter presents some of the more common models for temporal distribution of rainfall used in current techniques for hydrograph generation. Particular attention is given to the various triangular and mass curve hyetographs. A comparison of the structure of some hyetographs is made - comparisons of runoff resulting from their use can be found in Chapter 5.

## 3.1 Uniform-intensity or rectangular hyetograph.

This hyetograph results from the assumption that rainfall intensity is constant for the duration of the storm. The value for intensity is usually obtained from Intensity-Duration-Frequency relationships such as those published as a co-axial plot by Midgley and Pitman (1978) and subsequently as a mathematical relationship by Op ten Noort and Stephenson (1982). Figure 3.1 shows a uniform-intensity hyetograph.

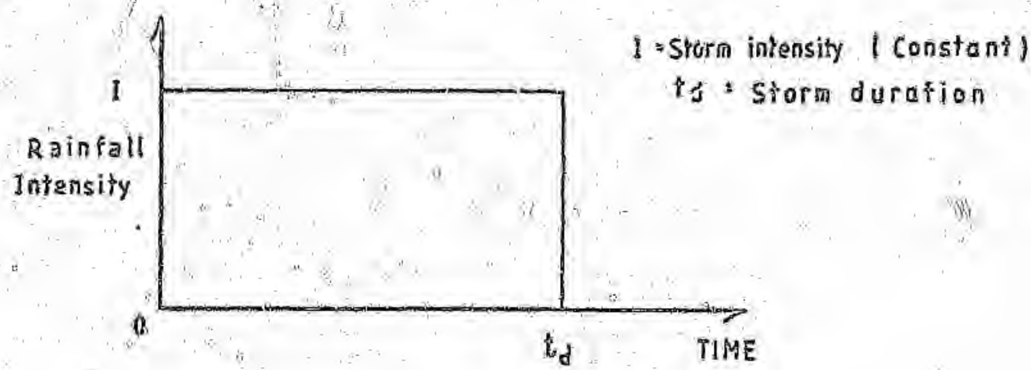



Figure 3.1 Uniform-intensity hyetograph.

## 3.2 Chicago-type rainfall distribution.

The distribution is so named because it was developed for studies in Chicago USA. It is based on the assumption that the average intensity for the entire storm duration, as well as the average intensities for shorter durations distributed around the peak, are the same as average intensities of the uniform hyetographs of corresponding durations. The Chicago-type hyetograph thus represents the correct average rainfall intensity for any storm within the selected duration. Originally developed by Keifer and Chu (1957), later work by Bandyopadhyay (1972) resulted in more easily-used equations. By defining the time to peak ratio (r), two equations can be obtained, one for the period before the storm peak and one for the period after:

$$I_b = \frac{a((1-c)(t_b/r)+b)}{((t_b/r)+b)^{1+c}}$$

$$I_a = \frac{a((1-c)(t_a/(1-r))+b)}{((t_a/(1-r))+b)^{1+c}}$$

where $I_b$ = intensity before the peak
$I_a$ = intensity after the peak
$t_b$ = time to peak
$t_a$ = time from peak to end of storm
$r$ = time to peak ratio
$= t_b/t_d$
$= t_b/(t_b+t_a)$
a;b;c = constants

The currently-accepted South African values for the constants are based on data used by Midgley and Pitman (1978) in preparing their co-axial plot. They have been tabulated in the report by Lambourne and Stephenson (1986), which also describes alternative methods for calculating the time to peak ratio, r. It should be noted that in equations 2.2; 2.3; 2.4a; 2.4b of Lambourne and Stephenson's 1986 report, constants b and c should be transposed.

The Chicago-type ~~hyetograph~~ hyetograph is shown in Figure 3.2.

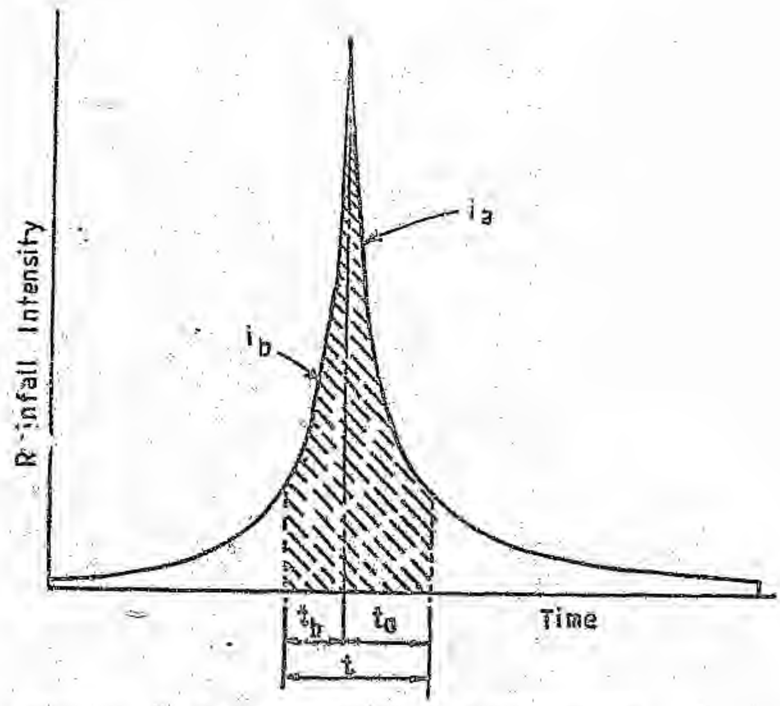



Figure 3.2 Chicago-type hyetograph.
(Lambourne and Stephenson, 1986)

### 3.3 Triangular rainfall distribution.

The original version of the triangular hyetograph was developed by Yen and Chow (1980), on the assumption that the natural hyetograph could be approximated by a triangular distribution. The total depth of rainfall and storm duration are preserved and the peak intensity is obtained by equating the area of the triangle with the total rainfall depth. The time to peak ratio ($a_0$) is obtained by equating first moments of the natural and triangular hyetographs about the horizontal (zero rainfall) axis.

Yen and Chow's triangular hyetograph is illustrated in Figure 3.3 where:

$a_0$ = time to peak ratio

$I$ = peak rainfall intensity = $2P/t_d$

where $P$ = total rainfall depth
$t_d$ = storm duration

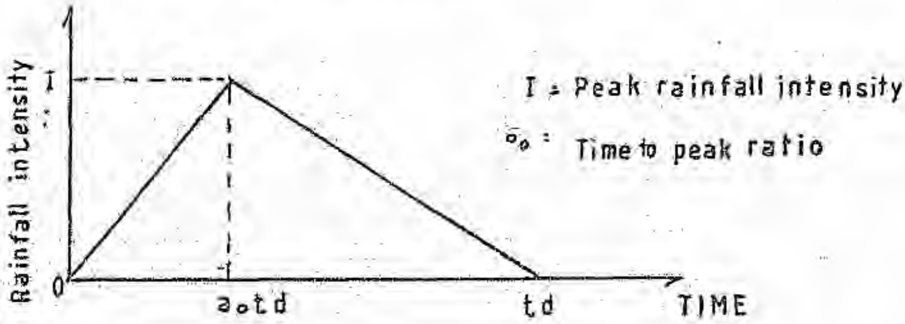



Figure 3.3 Triangular hyetograph
(After Yen and Chow, 1980)

However Constantinides (1982) found that, for certain storms with a long tail-off period of little rainfall, the geometry of the triangle can be unrealistic in that peak intensity lies outside the storm duration (Figure 3.4).

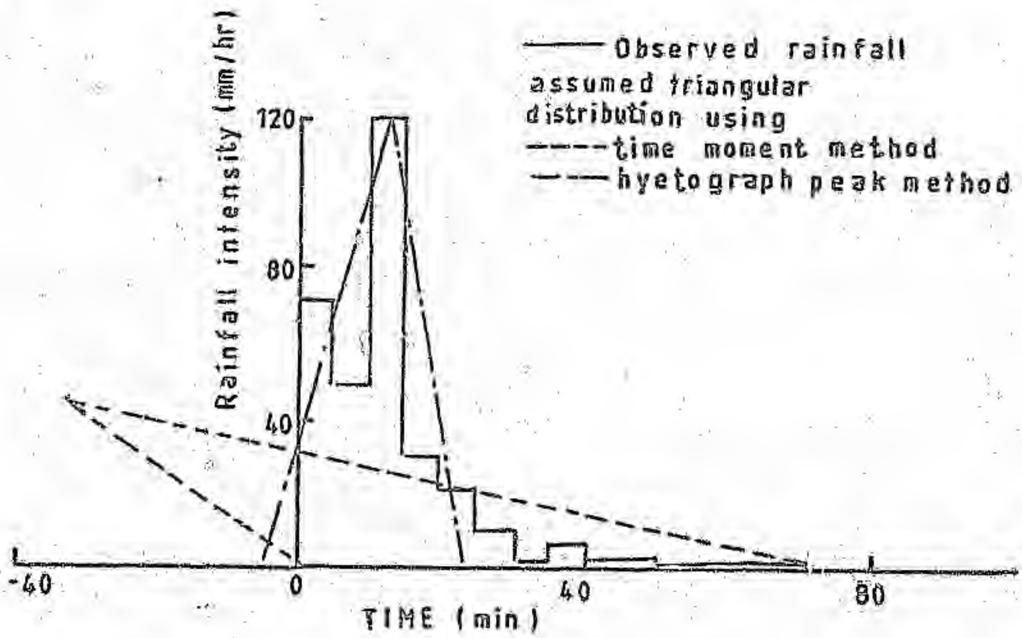



Figure 3.4 Observed and assumed triangular
distributions. Norwood storm 17 January
1964.
(Constantinides, 1982)

He thus proposed a modified method of calculating the triangular hyetograph. The value of peak intensity and its time of occurrence are preserved. By equating depths of rainfall before the peak, the time to peak can be established and by equating depths of rainfall after the peak, the storm duration can be obtained.

Constantinides (1982) referred to this method as the "hyetograph peak method" to distinguish it from the method used by Yen and Chow (1980), which he termed the "time moment method". Since the hyetograph peak method shortens the storm duration, it results in a more severe storm than either the natural storm or the synthetic storm produced by the time moment method. This is not necessarily undesirable since it results in over- rather than under-prediction when used for design purposes.

To overcome the problem of over-concentration of the storm, resulting from the use of the hyetograph peak method, Sutherland (1983) proposed a third method for generating a triangular hyetograph, which he termed the "triangular moment method".

The time of occurrence of peak intensity, together with rainfall depths before and after the peak is preserved, as in the hyetograph peak method. Moments are taken about the horizontal axis as in the time moment method but here they are used to establish the value of peak intensity and not time to peak ratio. By equating rainfall depths of the natural and triangular storms before, and again after the peak, storm duration can be obtained. The triangular moment method is illustrated in Figure 3.5.

A fourth method of generating a triangular hyetograph was described by Green (1984). Using IDF curves, total rainfall depth and storm duration are preserved, unlike the preceding methods however this does not represent a single storm since the IDF curves are based on data from a number of storms. Peak intensity is obtained by equating the area of the triangle with the total rainfall depth. Finally, as a simplification of Yen and Chow's method, instead of equating moments to obtain the time to peak ratio, a range of values from 0,3 to 0,4 are recommended based on Yen and Chow's results amongst others. Green notes that Watson (1981) found a time to peak ratio of 0,28 for the Johannesburg region.

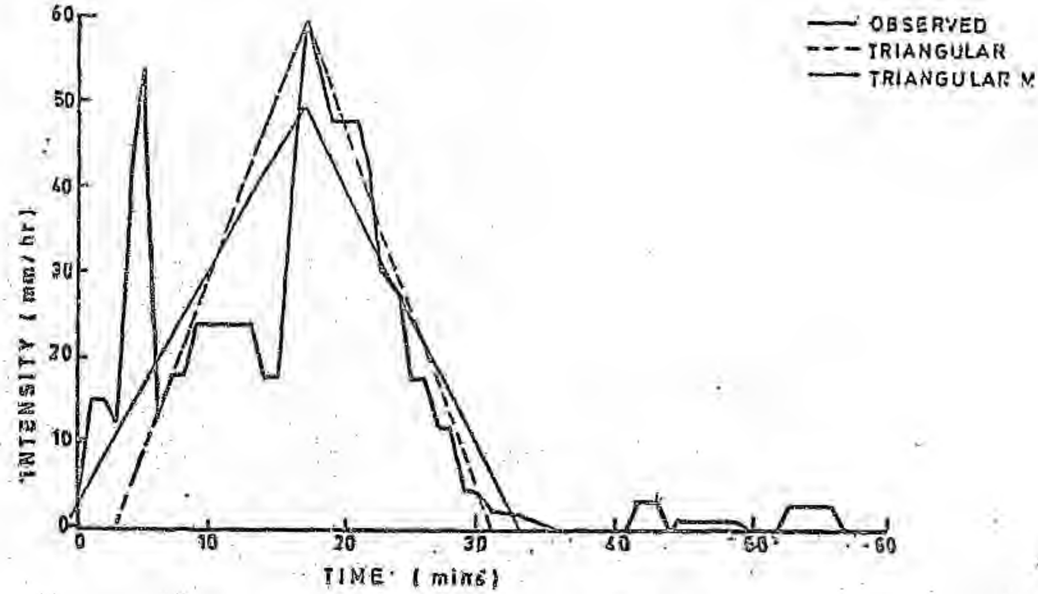



Figure 3.5 Comparison of hyetographs obtained by the triangular and triangular moment methods (Sutherland, 1983)

Further refinement to the concept of a triangular hyetograph was made by Lambourne and Stephenson (1986). Their examination of rainfall data from catchments in the Johannesburg area indicated that a double triangular or bimodal distribution was a better representation of the natural hyetograph than the single-peaked hyetographs used previously. This they confirmed by examining data from all parts of South Africa. Triangular distributions were selected because they provided the easiest shapes to compute. The resulting distribution was referred to as a bimodal triangular distribution and is illustrated in Figure 3.6.

Instead of the three parameters needed to describe a unimodal triangular distribution i.e. :

Peak intensity
Storm duration
Time to peak ratio

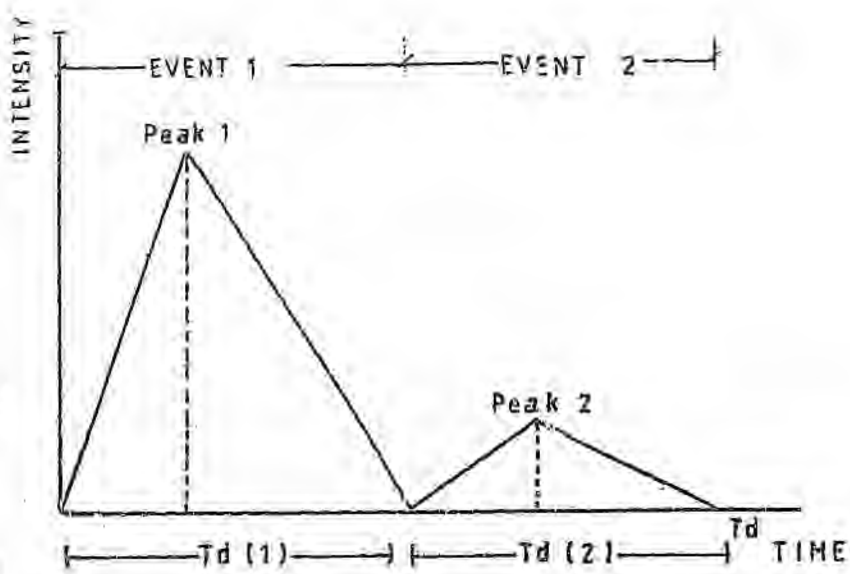



Figure 3.6 Bimodal triangular rainfall distribution.
(Lambourne and Stephenson, 1986)

the bimodal triangular distribution requires seven parameters for its description. These are :

- Total rainfall depth
- Total duration of storm
- Depth of first event to total rainfall ratio
- Duration of first event to total duration ratio
- Duration of second event to total duration ratio
- Time to first peak to duration of first event ratio
- Time to second peak to duration of second event ratio

However the last five parameters can be regionalised, requiring only total rainfall depth and storm duration as variable inputs at a given locality.

The times of occurrence of the larger and smaller peak intensities are preserved, as are rainfall depths before and after each peak. Thereafter, the bimodal triangular distribution can be generated either by preserving the values of peak intensities, as in the hyetograph peak method or by equating moments about the horizontal axis, as in the triangular moment method. Lambourne and Stephenson (1986) referred to these two approaches in a more explicit fashion as peak intensity preservation method and moment preservation method respectively.

In concluding this section, mention should be made of the type of data used to generate the synthetic triangular hyetographs. Data used by Midgley and Pitman (1978) was based on discrete, rather than continuous, time intervals. Lambourne and Stephenson (1986) have pointed out that the data abstracted in this way may not be true maxima. In addition, data from Midgley and Pitman's (1978) co-axial diagram does not represent single storm events. This means that it cannot be used to generate those triangular hyetographs that are transformations of natural hyetographs.

The natural hyetographs used by Constantinides (1982) and Sutherland (1983) were obtained from records of an autographic raingauge in Norwood, Johannesburg with an effective length of record of 16 years. In addition to this data, Lambourne and Stephenson (1986) used data from 30 stations throughout South Africa. The effective length of record from these stations was only nine years (although one station had a 43-year record length). Use of such short periods requires application of mathematical methods to produce Depth - Duration - Frequency (DDF) curves. Constantinides (1982) developed a technique for this purpose, later adopted by Lambourne and Stephenson (1986) for their analysis. However the natural length of record was not as long as that used by Midgley and Pitman (1978).

Table 3.1 summarises some of the triangular distributions described in this section.

## 3.4 Mass curves.

Mass curves are normally plotted as a percentage of storm rainfall against a percentage of storm duration to facilitate the presentation of a number of curves on a single diagram. Such a presentation is referred to as a dimensionless mass curve. To illustrate that mass curves are only a representation of a particular temporal distribution of rainfall, the mass curves of

Table 3.1 Summary of triangular rainfall distributions

| METHOD | PARAMETERS RETAINED FROM OBSERVED HYETOGRAPH | PARAMETERS SYNTHESISED |
| --- | --- | --- |
| A: <u>Unimodal</u> | | |
| 1. Yen + Chow (1980)<br><br>"Time moment" | i) Duration, $t_d$<br>ii) Total rainfall depth, P<br>iii) First moment w.r.t. time | i) Peak intensity, $I = 2\,P / t_d$<br>ii) Time to peak ratio, $a_o = 3/t_d\,(\Delta t / P\,(\sum_{j=1}^{n} (j-0,5)d_j))-1$ |
| 2. Constantinides (1982)<br><br>"Hyetograph peak" | i) Peak intensity, I<br>ii) Total rainfall depth, P<br>iii) Rainfall depths :<br>before peak intensity, $P_b$<br>after peak intensity, $P_a$ | i) Duration, $t_d = 2\,(P_b + P_a) / I$<br>ii) Time to peak ratio, $a_o = 2\,P_b / I\,t_d$<br>$= 1 - (2\,P_a / I\,t_d)$ |
| 3. Sutherland (1983)<br>"Triangular moment" | i) Total rainfall depth, P<br>ii) Rainfall depths<br>before peak intensity, $P_b$<br>after peak intensity, $P_a$<br>iii) First moment w.r.t. time | i) Peak intensity, $I = 3/P\,(\Delta t/2\,(\sum_{j=1}^{n} (d_j + d_{j-1}) / 2)^2)$<br>ii) Duration $t_d = (2 / I)\,(P_b + P_a)$<br>iii) Time to peak ratio, $a_o = 2\,P_b / I\,t_d$<br>$= 1 - (2\,P_a / I\,t_d)$ |

Table 3.1 Summary of triangular rainfall distributions (ctd.)

| METHOD | PARAMETERS RETAINED FROM OBSERVED HYETOGRAPH | PARAMETERS SYNTHESISED |
|---|---|---|
| B. Bimodal | | |
| 1. Lambourne and Stephenson (1986)<br><br>"Bimodal triangular distribution" | i) Total rainfall depth, $P$<br><br>ii) Rainfall depths :<br>before peak intensity, $P_{b_j}$<br>after peak intensity, $P_{a_j}$ | |
| i) Peak intensity preservation method | iii) Peak intensities, $I_j$ | i) Duration of peaks, $t_{d_j} = 2\,(P_{a_j} + P_{b_j})\,/\,I_j$<br><br>ii) Time to peak ratio, $a_j = 2\,P_{b_j}\,/\,I_j\,t_{d_j}$<br>$= 1 - (2\,P_{a_j}\,/\,I_j\,t_{d_j})$ |
| ii) Moment preservation method | iii) First moment w.r.t. time | i) Peak intensities, $I_j = 3\,/P_j\,(\Delta t/2\,(\sum_{i=1}^{n}(d_i + d_{i-1})/2)^2)$<br><br>ii) Time to peak, $t_{b_j} = 2\,P_{b_j}\,/I_j$<br><br>iii) Duration, $t_d = t_{b_1} + t_{a_1} + t_{b_2} + t_{a_2}$ |

rectangular and triangular storms have been derived in Appendix A. The resultant equations are:

For rectangular storms :

$$p(t)/P = t/t_d$$

For unimodal triangular storms :

Before peak :

$$p_b(t)/P = [1/(a_0)](t/t_d)^2$$

After peak :

$$p_a(t)/P = [1/(1-a_0)][-a_0+2(t/t_d)-(t/t_d)^2]$$

Huff (1967) analysed data from a network of 49 recording raingauges in Illinois USA covering the 11-year period 1955 to 1966. He defined a storm as "a rain period separated from preceding and succeeding rainfall by 6 hours or more". He then selected storms in which the network mean rainfall exceeded 0,50 inch (12,5mm) and/or one or more gauges recorded over one inch (25mm). This gave 261 network storms with durations varying from three to 48 hours. The time distribution of average rainfall in 30 minute increments was then computed for:

* areas of 50; 100; 200; 400 square miles (130; 260; 520; 1040 $km^2$)
* point rainfall at five gauges in the network

The storms selected included periods of no rain. For instance the median percentage of total storm period with precipitation, for point rainfall, varied from 79% to 42%, decreasing with increasing storm duration.

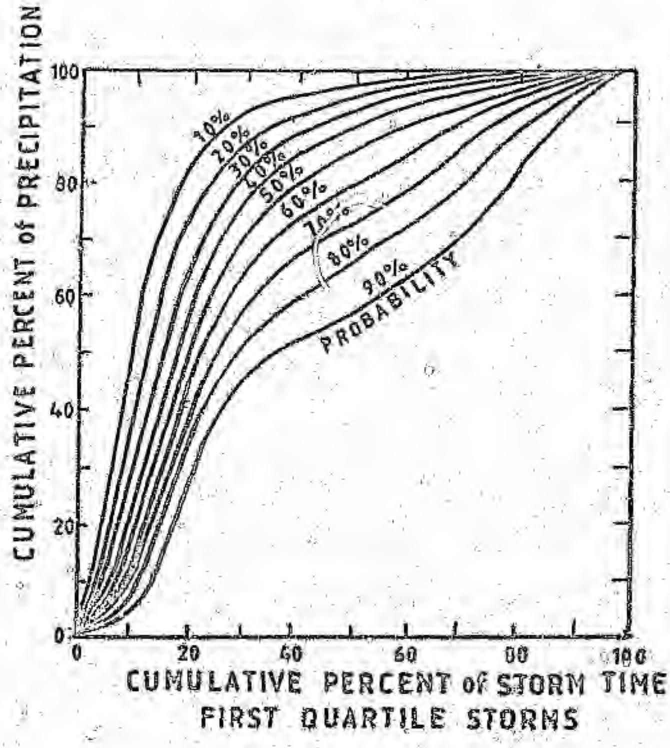
Huff noticed that a major proportion of the total storm rainfall occurred in only a short period of the total storm duration. He consequently decided to classify the storms into four groups, depending on whether the heaviest rainfall occurred in the first, second, third or fourth quarter of the storm. He found a trend for longer, heavier storms to dominate the fourth-quartile grouping whilst the short-duration storms accounted for a major portion of the first and second quartile groups.

Because areal grouping showed only small changes in time distribution, an average relationship for areas of 50 to 400 square miles (130 to 1040 $km^2$) was determined. It was found necessary to express time distributions in probability terms due to the great variability in the characteristics of the distributions from storm to storm. Huff prepared four diagrams, one for each quartile, showing the average time distributions for probabilities of exceedence of 10% to 90% as smooth curves. He noted that due to the averaging of rainfall (30 minute periods) the curves did not exhibit the burst characteristics of a mass curve. Huff's diagrams are shown in Figure 3.7 and he felt that they should be applicable to areas of similar rainfall, climate and physiography as the study area (i.e. the USA's Midwest). He classified storms according to rain type and found that the majority of first, second and third quartile storms were thunderstorms.

van Wyk and Midgley (1966) examined non-dimensional mass curves of numerous storms in the Pretoria area without detecting a significant pattern. They did however report that the lower envelopes of stor s of similar duration showed a significant tendency to approach the rising diagonal with increasing storm duration. This appears to conflict with Huff's findings that longer storms tend to dominate the fourth quartile grouping, with second and third quartile storms lying closest to the rising diagonal.

They then examined the mass curves of 65 storms at various locations within South Africa, analysing the most intense 60 minutes of each to obtain the frequency of occurence associated with 15-; 30-; 45-; and 60-minute durations. The ratio of <u>return period</u> to <u>maximum return period</u> was plotted against the ratio of <u>duration</u> to <u>time to maximum return period</u> to obtain dimensionless curves for the envelope and average of all 65 storms. Using values for maximum return period and time to maximum return period, the diagram can be used to synthesise mass curves.

Wiederhold (1969) produced mass curves for storms of up to 25 hours duration recorded at a single raingauge in Pretoria. He manipulated the lower envelopes of storms of similar duration, first by a technique to smooth the curves and then by adjusting the smoothed curves of durations of eight hours and less. His reason for



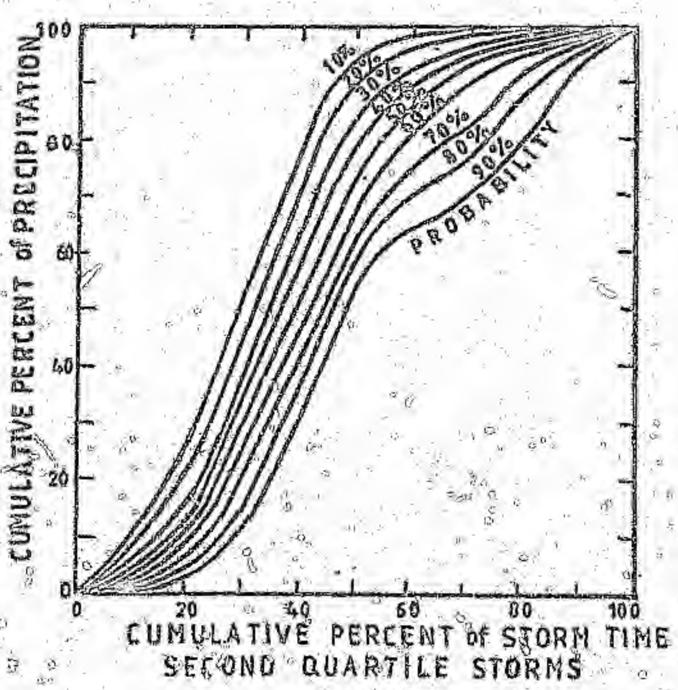
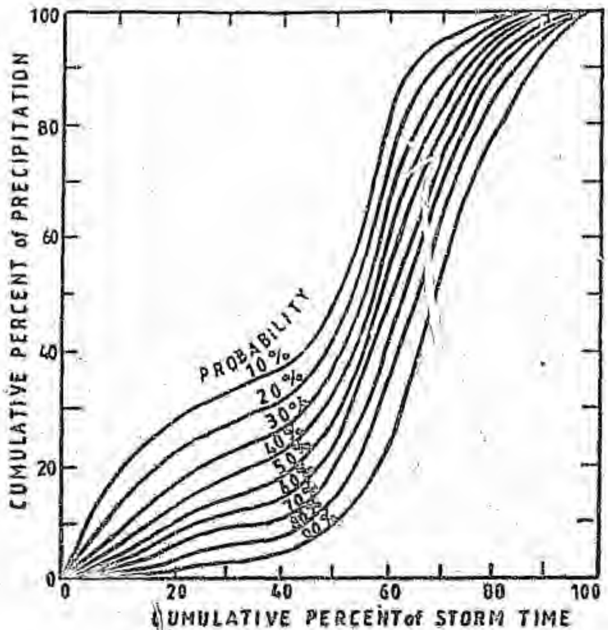
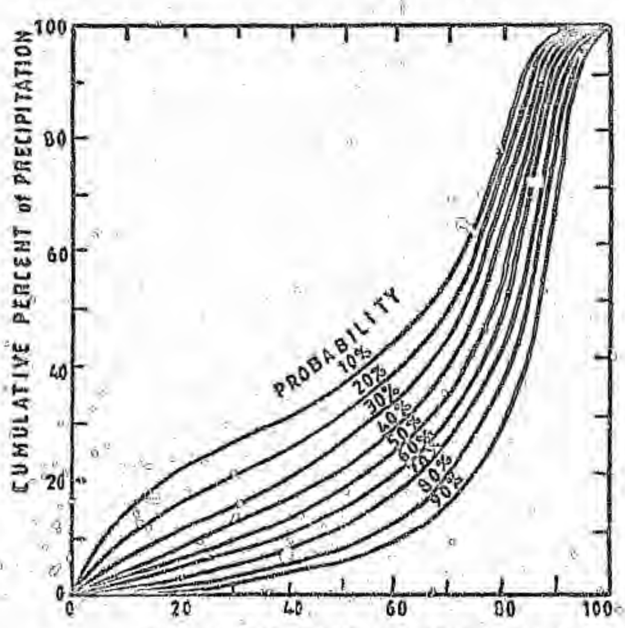




FIGURE 3·7 Time distribution of Illinois storms
(Huff, 1967)




THIRD QUARTILE STORMS




FOURTH QUARTILE STORMS

FIGURE 3·7 Time distribution of Illinois storms (ctd)

(Huff, 1967)

adopting the lower envelopes was that he considered the critical curve, with regard to flood response, likely to be one whose intensity increases with time. Selection of the lower envelope has implications for the return period of the storm but Wiederhold does not address this (Alexander, 1990). There again appears to be conflict with Huff's findings in that the long duration curves tend to first quartile shapes while short duration curves tend to fourth quartile shapes.

Eagleson (1970) defined a mass curve of storm rainfall as a plot of cumulative rainfall depth versus time from beginning of rainfall. When cumulative depth and times were presented as percentages of totals, he referred to such diagrams as percentage mass curves. His presentation (based on U.S. Weather Bureau data) showed a family of mass curves for different rainfall depths with a fixed storm duration. As indicated by Huff, heavier storms tend to move away from the first quartile distribution.

The U.K. Flood Studies Report (1975) contained an analysis of selected large storms in which each storm was centred on the shortest duration which gave at least 50% of the rainfall. The mean profile for selected durations was obtained for each of two seasons, summer (May to October) and winter (November to April). For storms of 24 hour duration, cumulative percent duration was plotted against cumulative percent rainfall for the two seasons. A total of 80 summer storms and 32 winter storms were analysed. Intensity, as a proportion of mean intensity, was also plotted against cumulative percent duration. Both sets of graphs were drawn in forms of percentiles of profile peak, an attempt to accommodate the shape of the hyetograph. When the analysis was extended to durations as long as four rain days and as short as one hour, it was found that the mean profile of both summer and winter storms showed no systematic variation with storm duration. This conflicts with the findings of Wiederhold. Further analysis showed no systematic variation of median storm profile with return period.

Pilgrim and Cordery (1975) presented a methodology for the derivation of design temporal patterns, consistent with the particular requirements of design flood estimation, based on the following considerations:

(1) Design rainfall derived from

frequency-duration data represents not complete storms but intense bursts coming at any time within the actual storm.

(2) If average values of all other parameters are used, the frequency of the derived flood should be approximately equal to the frequency of the design rainfall.

In their classification of published temporal patterns of design rainfall into three general types (arbitrary patterns, patterns based on the regional frequency - duration relationship and patterns based on observed raingauge records) they stated that the latter type involves averaging resulting in considerable smoothing, with the ultimate patterns unlike most individual storms. This makes them unsatisfactory for design as they do not adequately reflect the variation in intensity during the great majority of heavy rains. They felt that the fact that Huff needed to group storms into quartiles, indicated the lack of a single pattern. They proceeded to construct dimensionless mass curves for intense bursts of rain with durations of 30 minutes to four hours. They analysed curves under the following groupings.

(1) Duration of intense rain
(2) Duration of total storm
(3) Thunderstorms only
(4) Month of occurence
(5) Ranges of return period
(6) Total rainfall amount

They concluded that, in general, common patterns could not be found, a conclusion that agrees with the U.K. Flood Studies Report. However they noted a single exception - the isolated thunderstorms - where "the expected high early intensities were evident".

## 3.5 Summary

The simplest form of temporal distribution is the uniform distribution, rain falls at a steady rate and there is no change in intensity during the storm.

The Chicago distribution is time-related and represents the correct average rainfall intensity for any storm within the selected duration.

A number of triangular distributions have been developed in the last decade and five versions are presented. Intensity rises linearly to a peak value and falls to zero, usually at a different rate. One version of the triangular distribution uses two triangles to model the storm.

Mass curves can be used to model all the preceding distributions. They can also be used to model storms without recourse to the mathematical manipulation required to create the preceding models. The most commonly-used mass curves appear to be those of Huff, based on data from 261 storms over Illinois, USA during an 11 year period. The resultant dimensionless mass curves relate to four quartiles, depending on when the majority of the rain fell.

Mass curves were investigated in South Africa in the late 1960's by van Wyk and Midgley and Wiederhold. Both studies used data from the Pretoria area, the former also used data from 65 storms countrywide. One conclusion of both studies that appears to conflict with Huff's findings was that the longer the storm duration the more rain fell earlier in the storm.

Mass curves have also been prepared by the U.S. Weather Bureau and were investigated for the U.K. Flood Studies Report. After investigating data for Sydney, Australia Pilgrim and Cordery concurred with a conclusion of the U.K. Flood Studies Report, that common patterns could not be found. However they noted an exception - isolated thunderstorms. The preceding chapter indicated that thunderstorms were common over Johannesburg, in the following chapter mass curves are derived for the region.

# 4 DERIVATION OF MASS CURVES FROM LOCAL RAINFALL DATA

Data used in this study was collected in the Johannesburg suburb of Norwood, at an autographic raingauge. Rainfall data from this gauge has been digitised, stored on computer and used in previous rainfall studies (the studies are referred to later in this chapter). It is because data was available in a form that facilitated manipulation that this raingauge was selected.

This chapter describes the raingauge and its location. It examines the way in which data has been used in previous studies. Annual precipitation figures are examined to identify periods of above- or below-average rainfall. Anomalies in data are identified, the concept of "storm" is examined and mass curves of rainfall data are presented in a number of ways.

## 4.1 Gauge location, description and length of record.

The gauge is located at a City Engineer's Department depot to protect it from vandalism. It has been operated and maintained by the City Engineer's Department since 1963. The depot straddles the north-flowing Sandspruit and is situated close to the source of the stream. It lies at an elevation of 1645 m (amsl) and is about 1,5 km north of a prominent east-west ridge which, with a mean crest elevation of 1770 m (amsl), forms the northern edge of the Witwatersrand basin. As discussed in section 2.2.3, it is likely that the gauge lies in the rain-shadow of the ridge.

The raingauge is a continuous-recording syphon gauge, allowing ten millimetres of precipitation to collect before syphoning. A float mechanism with a pen at one end records precipitation depth on a chart fixed to a clockwork-driven rotating drum. A detailed description together with a sketch of the gauge can be found in Appendix B.

Storms selected for the data base occurred during a period of slightly less than 27 years - from November 1963 to September 1990. From Appendix C the following emerges from an analysis of rainfall from a 26-year record (records for one year during the period were incomplete):

- -The mean annual precipitation (MAP) was 654 mm, 115 mm less than the mean of 769 mm reported by Tyson and Wilcocks for the Joubert Park gauge (Refer section 2.2.2).

- -The total annual precipitation in any one year varies from a minimum of 419 mm (64% of MAP) to a maximum of 1043 mm (159% of MAP). The minimum and maximum figures for the Joubert Park gauge are 518 mm and 1184 mm respectively.

- -Of the twenty-five complete hydrological years studied, thirteen (52%) had total annual precipitation in the range 600 mm to 800 mm.

The recurrence interval represented by the 25-year period of complete record was calculated as follows :

$$r = 1-(1-1/T)^{L}$$

where:

r = probability of occurrence
T = recurrence interval
L = life (length of record)

Solving for T gives:

$$(1-1/T)^{L} = 1-r$$
$$1-1/T = (1-r)^{1/L}$$
$$1/T = 1-(1-r)^{1/L}$$
$$T = 1/\{1-(1-r)^{1/L}\}$$

If r = 0,95 and L = 25 years, then :

$$T = 8,86$$

So for a 95% probability of occurrence or better, the data cannot be used for a recurrence interval of more than nine years.

## 4.2 Selection of data and previous use.

Data from the Norwood gauge, for the period November 1963 to February 1980, was used by Watson (1981) to derive constants for use with Chicago-type storms. He selected 54 storms using depth and intensity as selection criteria. This is discussed in greater detail in section 4.3.

This record was extended by the author to September 1990 using Watson's selection criteria. A further 28 storms were thus identified, giving a total of 82 storms from the period November 1963 to September 1990 for analysis.

Watson's selection and digitising of the 54 storms proved to be of great value. The data was used by Constantinides (1982) in formulating his "hyetograph peak" triangular distribution. Sutherland (1983) used it in deriving his "triangular moment" version of the triangular distribution. And Lambourne and Stephenson (1986) used it, as well as other data, in preparing their bimodal triangular distribution.

## 4.3 Storm definition.

As noted by Lambourne and Stephenson (1986) the concept of "storm" must be clearly defined in an analysis such as this. The definition should relate to the purpose for which the storm will be used, in this case the generation of a runoff hydrograph.

Keifer and Chu (1957) do not explicitly define their use of "storm", it may or may not accommodate periods of zero rainfall based as it is on Intensity - Duration - Frequency (IDF) curves. Huff (1967) defined a storm as " a rain period separated from preceding and succeeding rainfall by 6 hours or more ". It is likely that the 6-hour interval was chosen as a matter of convenience since it is also the minimum timescale for the recording rainfall charts analysed. Yen and Chow (1980) defined storm duration as " a period of continuous non-zero rainfall ". Watson (1981) derived IDF curves from data which included periods of zero rainfall and this same data was used by Constantinides (1982), Sutherland (1983) and Lambourne and Stephenson (1986). Irrespective of whether or not data used to generate the synthetic hyetographs proposed by the above authors contained periods of no rain, all hyetographs represent continuous rainfall.

The discussion in section 2.1.3 on rain-producing systems has indicated that a rain-producing event on the Highveld may include a period of no rain. Rainfall experienced at a point will depend on factors such as the size, shape and rate and direction of movement of the storm cell or cells. Colloquially, depending on the length of the period of no rain, the event would probably be regarded as a single storm as long as there was some cloud cover.

As illustrated by Figure 4.1, zero rainfall within a storm period could be caused by the shape and rate of movement of a storm cell.

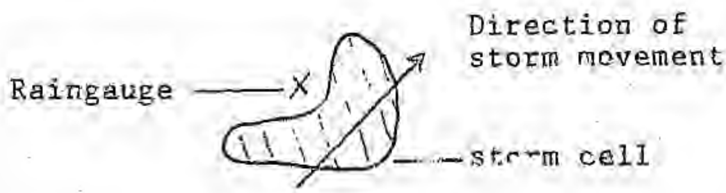



Figure 4.1 Storm cell and [illegible] tion to single raingauge

Watson (1981) stated that he selected the 54 storms on the following basis:

- For the periods of non-zero precipitation their depth of rain for selected durations exceeded the following :

| | | | | | | |
|---|---|---|---|---|---|---|
| Duration (min) | : | 5 | 15 | 30 | 60 | 120 |
| Depth (mm) | : | 7 | 13 | 20 | 22 | 22 |

  A storm has only to meet one of the five above limits for acceptance. Although storms were selected from the City Engineer's Department's records on the above basis, Watson's re-analysis shows that eight storms do not meet the depth criterion (Storm nos. 7;14;22;24;26;29;31;49). (The author experienced this with two of the additional 28 storms (Nos. 11 and 13). Despite this, all 82 storms were retained for analysis.)

Although not stated, it appears that a second criterion was:

- They resulted in total precipitation of ten millimetres or more.

Analysis of the data-set showed that 49 of the 82 storms (i.e. 60%) included periods of no rain, with one storm having 17 such periods. The length of period varied from 5 to 120 minutes. Apart from the number of storms with zero rainfall, application of the two selection criteria also results in storms being separated by at least 16 hours (storms of 11/1/76 and 12/1/76 ). There is thus a clear distinction between the two hours of no rain within a storm and the 16 hours of no rain between storms. Cursory analysis by the author, of another raingauge in Montgomery Park has indicated that periods of zero-rainfall may be as long as 289 minutes (4,8 hours) (storm on 15/12/1982), still distinct from the 16 hours of no rain between storms recorded at Norwood.

It is noted by Lambourne and Stephenson (1986) that very low intensity rain could be digitised as zero rain due to the resolution of rainfall charts. Periods digitised as having no rain may thus not in fact be entirely dry.

Lambourne and Stephenson (1986) applied the technique proposed by Restrepo Posada and Eagleson (1982) to data from Jan Smuts airport to determine the independence criterion of storms. Although they felt that further research was required before the criterion could be used for South African conditions it is worth noting that the technique indicated a minimum period of 4,5 hours between storms, a result which accommodates the criteria for the Norwood storms.

Lambourne and Stephenson (1986) used an additional criterion, that a rain period must be separated by preceding and succeeding rain by 30 minutes or more. Using this for the Norwood storms effects 17 of the 82 events (21%), one of these events (on 21/1/1987) containing four periods of zero rainfall equal to or exceeding 30 minutes. The events would thus either be considered as more than one storm or, if any period of non-zero rainfall resulted in less that 10 mm of rainfall, then that period would not be considered a storm at all.

If storms with rainfall less than specified minimum (say 10 mm) will be rejected then it would be best to include periods of zero rainfall in a definition of "storm" in order to obtain as many events for analysis as possible. If however the criterion is not the amount of rain but a specified minimum intensity then it would be best to exclude periods of zero rain from the definition.

Perhaps the best argument in favour of the former approach is that, implicit in its adoption, may be compensation for the condition of the soil (antecedent moisture content and infiltration rate) since the storm would extend over a longer period of time. In any event the use of both total rainfall and intensity as done by Watson appears to be a practical compromise between these two approaches. Perhaps it is the use of both criteria that makes it necessary to include periods of zero rainfall.

## 4.4 Mass curves of Norwood data.

Programs (NORANAL and NORMOR) were written for a Hewlett Packard 9816 microcomputer to analyse the 82 storms selected and print the total duration and precipitation depth of each storm, the percentage of storm rainfall occurring in each quartile and the quartile into which the storm fell. Program listings and output from NORANAL and NORMOR can be found in Appendix D.

Results are summarised in Table 4.1 below:

Table 4.1 Quartile classification of Norwood storms and comparison with results by Huff(1967).

| | Quartile | | | |
|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th |
| Norwood: | | | | |
| Total no. | 46 | 19 | 12 | 5 |
| Percentage | 56 | 23 | 15 | 6 |
| Huff (Table 1): | | | | |
| Percentage | 30 | 36 | 19 | 15 |

To determine the reliability of the Norwood percentages, the cumulative annual percentages were plotted from the start of the record. Figure E1 in Appendix E shows that within the first 14 years of record, cumulative percentages had stabilised to within one or two percent of the values in Table 4.1. It is thus concluded that the record length is adequate for the purpose of quartile classification.

It is suggested that the reason for the preponderence of first-quartile Norwood storms, not reflected in

Huff's results, is that more thunderstorms were experienced at Norwood.

In an attempt to characterise the storms in each quartile, the range of total rainfall and storm duration was plotted for each quartile (refer Figures E2 and E3 in Appendix E). It was anticipated that first-quartile storms would be of significantly shorter duration than fourth-quartile storms, due to the different rain-producing mechanisms suggested in the previous paragraph - thunderstorms being "short, sharp showers". This was however not the case and no clear pattern emerges. Figure E4 (Appendix E) is a plot of total rainfall versus storm duration for all storms showing the spread of results. Again no pattern is readily apparent. It could be that such a pattern does not exist. As described in section 3.4, van Wyk and Midgley (1966) and Wiederhold (1969) found that long-duration storms were closest to the rising diagonal.

The monthly distribution of storms in each quartile was investigated and the results are shown in Table 4.2

Table 4.2 Monthly and seasonal distribution of storms

| Season | | | Summer | | | | | | Winter | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| No. storms: | | | | | | | | | | | | |
| 1st q. | 1 | 8 | 8 | 12 | 8 | 5 | 4 | - | - | - | - | - |
| 2nd q. | 2 | 4 | 3 | 4 | 2 | 3 | 1 | - | - | - | - | - |
| 3rd q. | 1 | 2 | 4 | 4 | - | - | - | - | - | - | - | 1 |
| 4th q. | - | 3 | - | 1 | - | 1 | - | - | - | - | - | - |
| Totals | 4 | 17 | 15 | 21 | 10 | 9 | 5 | - | - | - | - | 1 |

Values from NORANAL and NORMOR were used to plot dimensionless mass curves for each of the four quartiles as follows:

1. Storms in each quartile were identified.
2. For each quartile cumulative percentage precipitation for each storm was listed at the 25; 50 and 75% durations.
3. Total and mean cumulative percentage precipitation was calculated at the 25; 50 and 75% durations for each quartile, giving average values for the mass curve.
4. The highest and lowest cumulative percentage precipitation was identified at each of the 25; 50 and 75% durations, giving the upper and lower limits to the envelope for each quartile.

Figures E5 to E8 in Appendix E are the dimensionless mass curves for each quartile and represent the data shown in Tables E1 to E4. Values for points on the average dimensionless mass curves in each quartile are given in Table 4.3 below.

Table 4.3 Cumulative percentages of total precipitation for average dimensionless mass curves (Norwood data)

| Quartile | Percentage of total storm duration 25% | 50% | 75% |
|---|---|---|---|
| 1st | 65% | 87% | 96% |
| 2nd | 23% | 79% | 94% |
| 3rd | 8% | 26% | 87% |
| 4th | 20% | 28% | 44% |

Notes:

1. In terms of total precipitation:
   For 1st quartile storms 65% occurs in the first quartile.
   For 2nd quartile storms 56% occurs in the second quartile.
   For 3rd quartile storms 61% occurs in the third quartile.
   For 4th quartile storms 56% occurs in the fourth quartile.

For purposes of comparison, Huff's corresponding 50% values were estimated from his dimensionless mass curves (Figures 2; 4; 5 and 6 of Huff's paper) and are listed in Table 4.4.

Table 4.4 Cumulative percentages of total precipitation for average dimensionless mass curves (Huff's data)

| Quartile | Percentage of total storm duration 25% | 50% | 75% |
|---|---|---|---|
| 1st | 65% | 85% | 95% |
| 2nd | 19% | 72% | 95% |
| 3rd | 12% | 28% | 88% |
| 4th | 8% | 18% | 44% |

It is noted that there is very close agreement (within 2%) on the values for first quartile storms and reasonable agreement (within 4%) for second and third quartile storms.

The possibility of using a single mass curve to represent all storms was investigated. Values for this curve are listed in Table E5 and the curve is plotted in Figure E9. The envelope is very wide, indicating the degree of diversity in the storm patterns.

## 4.5 Summary

The raingauge which provided data for this study is located in Norwood, a township in the north-eastern section of Johannesburg. The gauge is a continuous-recording syphon gauge with rainfall being recorded on a strip chart. A 26-year length of record has been examined, from November 1963 to September 1990 and data from this record was analysed in this study. It is calculated that, for this period, the data cannot be used for a recurrence interval exceeding nine years if a confidence level of 95% or better is desired.

The mean annual precipitation during the period of record was approximately 654 mm (the record is incomplete), varying from 419 mm or 64% of MAP to 1043 mm or 159% of MAP.

A total of 82 storms have been selected for analysis, 54 of which have been used in the past decade to develop local values for parameters for the Chicago storm, the "hyetograph peak" and "triangular moment" triangular storms and the bimodal triangular storm.

Different researchers use different definitions for "storm". Some include periods of zero-rain, others do not. The 82 storms studied were selected using both total depth and incremental depths (in effect an intensity criterion) as criteria and include periods of zero-rain up to two hours long.

Analysis of the storms results in their being classified into each of four quartiles as follows:

56% are first quartile
23% are second quartile
15% are third quartile
6% are fourth quartile

The high percentages of first and second quartile storms could reflect the number of thunderstorms that occur in the region. Confirmation of this could form part of a further study.

To produce mass curve data for use in a hydrological model, the percent of total storm depth has been calculated at 25, 50 and 75 percent of total storm duration. The following chapter investigates the use of these locally-derived mass curves in a hydrological model.

# 5 USE OF LOCAL MASS CURVES IN A HYDROLOGICAL MODEL

In this chapter the mass curves derived from local data in Chapter 4 are used to create input to the hydrological computer model HYDROSIM. The results are compared with those generated using other rainfall distributions.

## 5.1 Preparation of data input.

HYDROSIM can either be used to generate hyetographs for selected temporal distributions or it can accept "user-input" hyetographs. For the catchment used in this example HYDROSIM was used to generate uniform hyetographs for a range of durations to identify the storm duration which resulted in the highest peak runoff. This resulted from a storm of approximately 20 minutes duration and all subsequent work was done using this duration.

"User-input" hyetographs were prepared for the following storm distributions :

1. Uniform intensity
2. Triangular
3. Bimodal triangular (BTD)
4. Mass curves

for a storm of a five-year recurrence interval and 20 minute duration. Lambourne and Stephenson (1986) describe how the depth of precipitation used in analysis depends not only on storm duration and frequency but also on the temporal distribution of the storm. The effect of this was also investigated.

Using Lambourne and Stephenson (1986) (section 6.9) parameters were derived for the uniform, triangular and bimodal triangular distributions. These are listed in Table F1 in Appendix F.

Appendix F also contains a list of the intensity-time pairs for the triangular and bimodal triangular hyetographs (Table F2), as well as the hyetographs themselves (Figure F1).

Since there is no published relationship between storm depth, duration and frequency for the derived mass curves, a number of relationships were used on the derived quartile distributions. Using the same DDF relationships applicable to each of the above distributions, and hence total rainfall depths, together with the values in Table 4.3 for each quartile, intensity-time pairs were derived for each relationship. These are listed in Table F3, Appendix F.

HYDROSIM uses a single DDF relationship for storms for which it generates data, based on a uniform-intensity hyetograph. The effect of using a single DDF relationship was investigated by running the program with three program-generated rainfall distributions :

1. Uniform-intensity
2. Triangular
3. Chicago

The triangular distribution in this instance is that developed by Green (1984).

Intensities for the program-generated rainfall distributions are calculated using the mathematical expression of Op ten Noort and Stephenson (1982) for the co-axial plot of Midgley and Pitman (1978).

## 5.2 Description of the model.

After calculating excess rain by subtracting initial abstraction and infiltration, HYDROSIM routes overland flow using the kinematic equations for one-dimensional flow. The resulting flow can be :

1. Routed through conduits - either using kinematic methods or by time-shift routing. Conduit overflows can be allowed to flow in separate channels with the facility to rejoin the conduit (if it has sufficient capacity) at a downstream node.
2. Accumulated and stored at nodes.

The program can be run either in design or analysis mode. In the former, pipe sizes are calculated with no provision for storage or overflow. In the latter, conduit sizes must be specified and excess flow will either be stored at a node or overflowed into a separate channel. Hydrographs can be obtained at any node to assess storage or overflow potential.

The three catchments selected for testing lie in the townships of Emmarentia and Emmarentia Extension 1, about 10 km west of the Norwood raingauge site. These are residential townships with erven of about 1000 $m^2$ and 1400 $m^2$ respectively. The total area of each catchment is 1,7 ; 27,6 and 54,7 ha.. The catchments are shown in Figure 5.1 and the parameters used to describe their subcatchments are shown on the computer data listing in Appendix G. The catchments were selected because the adequacy of their existing reticulation was being investigated at the time of this study.

Runoff resulting from different storm distributions on these catchments is given in Table 5.1.

The effect of the unequal number of storms in each quartile was investigated as follows. For each node and DDF relationship, each of the four quartile peak values from Table 5.1 was multiplied by the proportion of total storms (as given in Table 4.1) in that quartile. These weighted peak flows were then summated to give the values in Table 5.2.

Table 5.2 Weighted average of quartile runoff peaks

| DDF Relationship | Q max ($m^3$/s) at Node 60 | 20 | 59 |
|---|---|---|---|
| j. Uniform | 0,4 | 3,9 | 8,5 |
| k. Triangular | 0,6 | 5,1 | 11,2 |
| l. BTD | 0,3 | 2,6 | 5,5 |

The resultant peak flows are shown graphically in Figure 5.2 from which it can be concluded that results are grouped approximately in three categories:

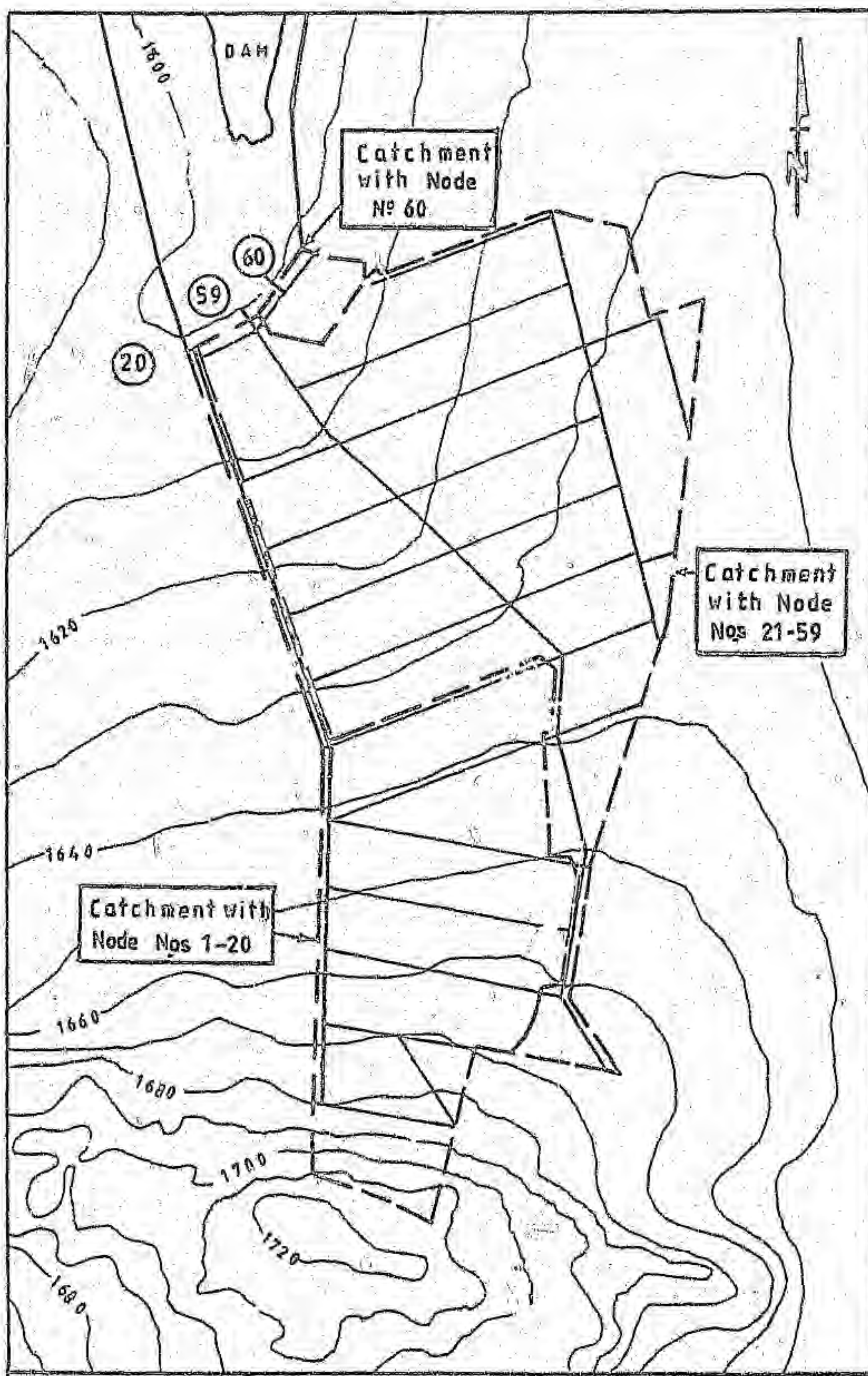



FIGURE 5·1 Test catchment

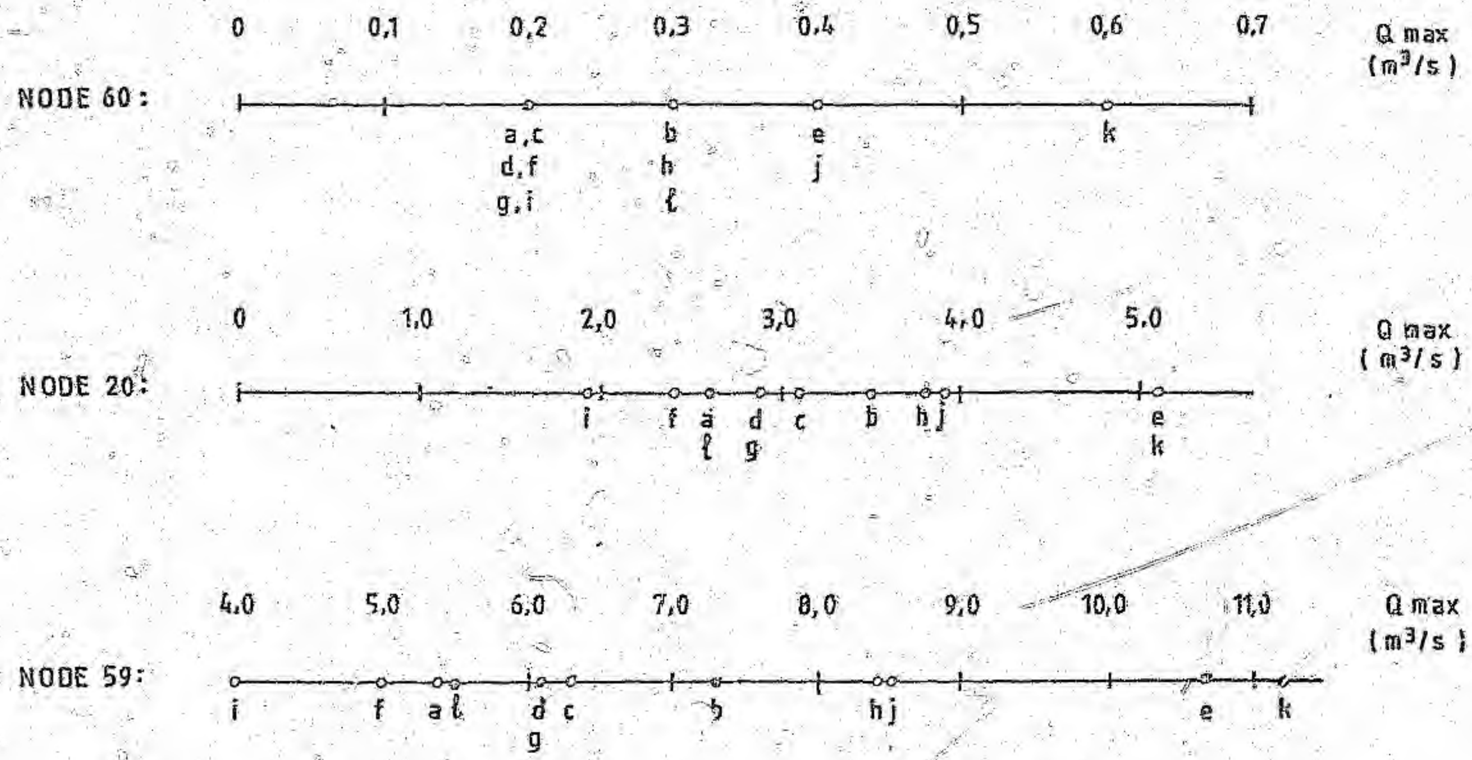
Scale 1:10000

Table 5.1 Peak flows and time to peak for different storms

| Storm distribution. | DDF relationship. | Q max at Node 60 | 20 ($m^3/s$) | 59 | Time to peak. (min) |
|---|---|---|---|---|---|
| COMPUTER GENERATED | | | | | |
| a. Uniform | Uniform | 0,2 | 2,6 | 5,4 | 20 |
| b. Triangular | Uniform | 0,3 | 3,5 | 7,3 | 12-15 |
| c. Chicago | Uniform | 0,2 | 3,1 | 6,3 | 11-14 |
| USER-INPUT | | | | | |
| d. Uniform | Uniform | 0,2 | 2,9 | 6,1 | 20 |
| e. Triang. | Triang. | 0,4 | 5,1 | 10,7 | 12-15 |
| f. BTD | BTD | 0,2 | 2,4 | 5,0 | 8-10 |
| Quartiles: | | | | | |
| 1st. | Uniform | 0,4 | 3,7 | 7,4 | [illegible]-10 |
| | Triang. | 0,6 | 4,7 | 9,4 | [illegible]-10 |
| | BTD | 0,3 | 2,5 | 5,1 | 5-10 |
| 2nd | Uniform | 0,5 | 4,0 | 9,4 | 10 |
| | Triang. | 0,6 | 5,3 | 12,9 | 10 |
| | BTD | 0,3 | 2,6 | 5,6 | 10 |
| 3rd | Uniform | 0,5 | 4,5 | 10,6 | 15 |
| | Triang. | 0,7 | 6,0 | 14,7 | 15 |
| | BTD | 0,3 | 3,0 | 6,6 | 15 |
| 4th | Uniform | 0,4 | 4,1 | 9,6 | 20 |
| | Triang. | 0,6 | 5,6 | 13,4 | 20 |
| | BTD | 0,3 | 2,8 | 6,1 | 20 |
| Average | g. Uniform | 0,2 | 2,9 | 6,1 | 10 |
| | h. Triang. | 0,3 | 3,8 | 8,4 | 10 |
| | i. BTD | 0,2 | 1,9 | 4,0 | 10 |

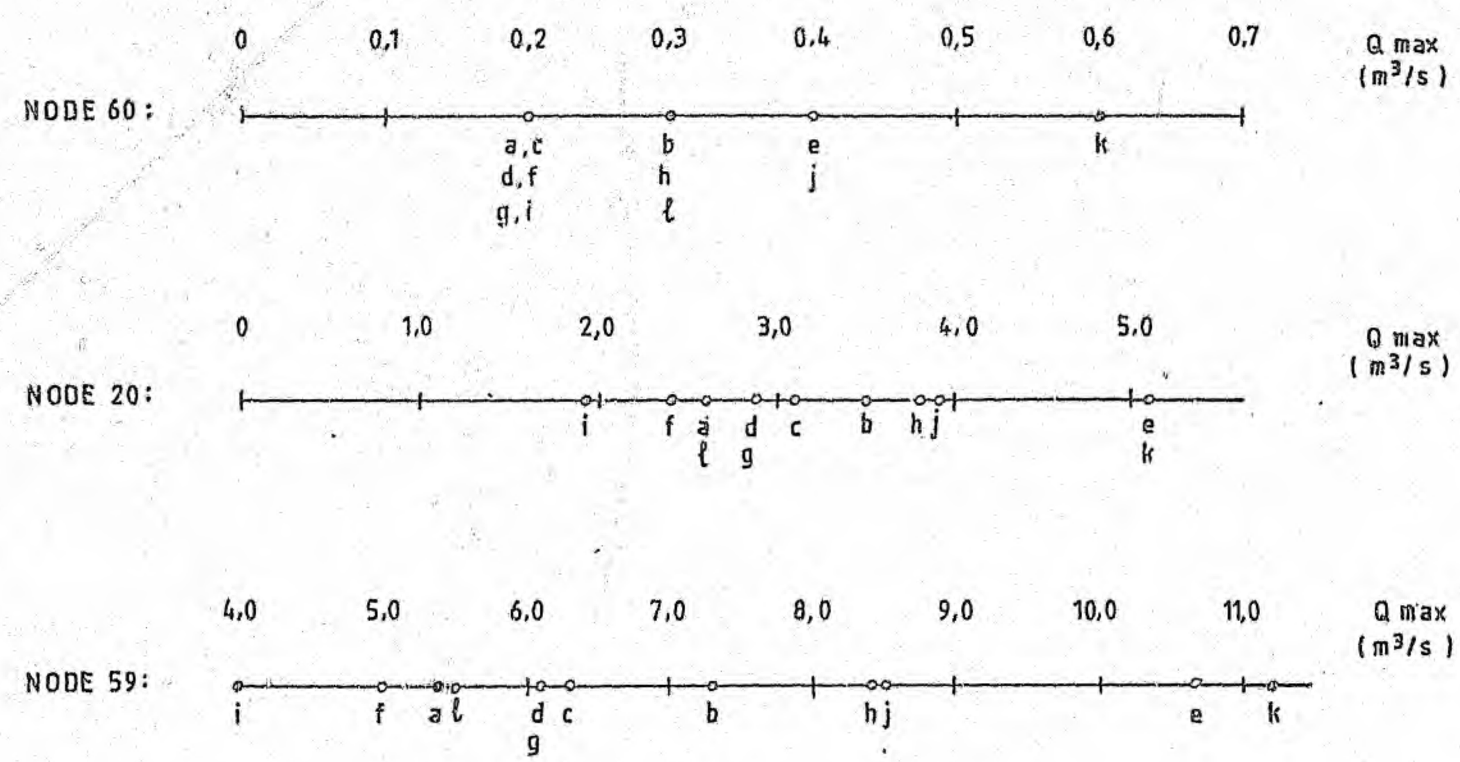
Note:

1. BTD = Bimodal Triangular Distribution.
2. Time-to-peak ratio is 0,4 for computer generated triangular and Chicago distributions as well as for user-input triangular distribution.
3. Values in rows marked a. to i. plotted in Figure 5.2.




(REFER TO TABLES 5,1 AND 5,2 FOR MEANING OF a,b,c etc.)

**FIGURE 5.2** Peak Flow Rates using Different Rainfall Data




(REFER TO TABLES 5,1 AND 5,2 FOR MEANING OF a,b,c etc.)

**FIGURE 5.2** Peak Flow Rates using Different Rainfall Data

1. The lowest peak flowrates (30 to 60% of highest peak flowrate) result from the following storm distributions:

   Computer-generated :
   - Uniform distribution (a).

   User-input :
   - Bimodal triangular distribution (f).
   - Average mass curve of all storms in conjunction with the bimodal triangular distribution DDF (i).
   - Weighted average of all quartile peak flows in conjunction with the bimodal triangular distribution DDF (l).

2. The next highest peak flowrates (30 to 80% of highest peak flowrate) result from the following storm distributions:

   Computer-generated :
   - Triangular distribution (b).
   - Chicago distribution (c).

   User-input :
   - Uniform distribution (d).
   - Average mass curve of all storms in conjunction with the uniform distribution DDF (g).
   - Average mass curve of all storms in conjunction with the triangular distribution DDF (h).
   - Weighted average of all quartile peak flows in conjunction with the uniform distribution DDF (j).

3. The highest peak flowrates (67% to 100% of highest peak flowrate) result from the folowing storm distributions:

   User-input:
   - Triangular distribution (e).
   - Weighted average of all quartile peak flows in conjunction with the triangular distribution DDF (k).

## 5.3 Summary.

The mass curves derived in the previous chapter can be used in two ways. The average mass curve of all storms can be used as input to a hydrological model to generate peak flows or mass curves for each quartile can be used individually and the resultant peak flows weighted according to the relative frequency of each mass curve and then summated. Using three catchments of 1,7 to 54,7 ha. and the hydrological computer model HYDROSIM, both approaches are used in this chapter. In addition other, commonly-used, rainfall distributions are used as input to the model and a variety of DDF relationships are tried.

The resultant peak flowrates are divided into three categories, depending on their magnitude relative to the highest peak flowrate. For each of the three catchments the storm distributions giving both the highest and the lowest peak flowrates are derived from mass curves. Peak flowrates that occur between these limits result from commonly-used storm distributions as well as further storm distributions derived from mass curves.

## 6 CONCLUSIONS

The following conclusions can be drawn from this investigation :

1. Due to factors such as the areal extent of the storm and the amount of storage within the catchment, storm runoff from a small catchment is likely to be particularly sensitive to the rainfall rate. Johannesburg, located as it is on a major watershed, includes a number of small catchments, making it important to model the temporal distribution of storm rainfall as accurately as possible.

2. The spatial distribution of annual rainfall in the Johannesburg region is strongly influenced by topography. Storms tend to move across the region on a south-west to north-east track, with the result that less rain is recorded to the north of the east-west trending ridges than on the southern slopes.

3. Previous rainfall research in Johannesburg has concentrated mainly on deriving suitable parameters for simplified hyetograph shapes. The increasing use of computer models has led to standard distributions (such as the Chicago and Triangular distributions) being built into these models. The user, guided by results of local rainfall studies, selects parameters relating to the depth, duration and frequency of the storm.

4. Some local research resulting in the publication of mass curves of rainfall (for the entire country and for the Pretoria region) was done twenty to twenty-five years ago. However this research is seldom referred to in the literature and it would appear that it has largely been ignored.

5. The mass curves that are more frequently referred to by local researchers are those of Huff (1967), prepared from data collected in Illinois, USA. The first quartile storms have been regarded as most appropriate to the Highveld due to the large number of thunderstorms in the region. However no attempt had been made to quantify this effect before this investigation.

6. First quartile storms dominate the quartile distribution at a raingauge in Norwood, Johannesburg. Analysis of 82 storms in a 26 year period reveals that 56% were first quartile storms, 23% were second quartile, 15% third quartile and 6% fourth quartile. It is considered that these percentages could be used with reasonable confidence since there was very little variation in these values after the first 14 years of record.

7. Although second quartile storms dominate Huff's quartile distribution, they amounted to only 36% of the total number of storms. The majority is thus not as clear as it is for the Norwood results. Although Huff classified 38% of his storms as thunderstorms, it is possible that Norwood experienced an even higher percentage of thunderstorms, causing the distinct preponderence of first quartile storms.

Investigation into the reason for the high percentage of first quartile storms could be the subject of further research. Since the storms have been identified it should be possible to determine the rain producing system by reference to synoptic weather charts for the relevant day.

8. No relationhip between quartile classification and storm duration, as well as between quartile classification and rainfall depth was found to exist. There appears to be a discrepancy between the findings of Huff and those of local researchers regarding the relationship between the shape of the hyetograph and the storm duration.

9. Although years with above-average rainfall had more "severe" storms (i.e. storms selected for analysis) in total, the maximum number of "severe" storms occurring in a year was the same for years of above-average rainfall as it was for years of below-average rainfall. The storm with the highest rainfall occurred in a year with below-average rainfall.

10. The shapes (using values at 25%; 50% and 75% of storm duration) of the average dimensionless mass curve for each of the four quartiles are similar to those of Huff's average curves, particularly so for the first quartile storms.

11. Using the mass curves for rainfall distribution derived in this investigation to generate peak flows from a catchment yields results that are comparable with those of the uniform, triangular and bimodal triangular rainfall distributions.

12. Depth-Duration-Frequency (DDF) curves derived for a bimodal triangular rainfall distribution resulted in some of the lowest peak flows, whether they were used in conjunction with the mass curves for rainfall distribution derived in this investigation or in conjunction with a bimodal triangular rainfall distribution.

Further research into the bimodal triangular distribution as well as the unimodal triangular distributions could be undertaken using the extended record that has resulted from this investigation.

13. DDF curves derived for a specific distribution and used in conjunction with that distribution resulted in higher peak flows than curves derived for a uniform distribution.

DDF curves for different distributions should be incorporated into computer models so that they can be used in deriving computer-generated storms. If this is not done it is unlikely that users will go to the considerable trouble of calculating hyetographs based on these curves and the curves will largely go unused.

14. Peak flowrates resulting from use of the first quartile mass curve in conjunction with the uniform distribution DDF curves were very close to those obtained using a triangular distribution in conjunction with the same DDF curves. The time to peak runoff would however be longer than that calculated using the first quartile distribution alone. So although the use of Huff's first quartile storms, as has been recommended in the past, is not unreasonable for the calculation of peak flowrates, it would not necessarily result in an accurate hydrograph.

APPENDIX A

<u>Selected rainfall distri :tions as mass curves.</u>

1. Uniform-intensity.

1.1 Intensity - Time curve

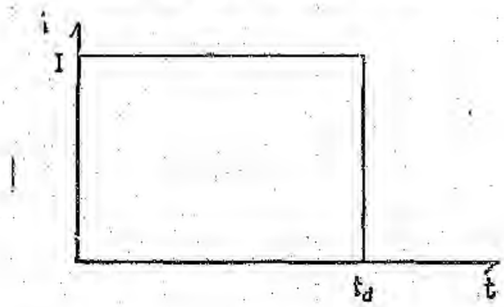



Figure A1 Definition sketch for uniform intensity-time curve.

Intensity:

$i(t) = I$ (Constant)

Precipitation:

$$p(t) = \int_0^{t_d} i(t).dt = It\Big|_0^{t_d}$$

So $p(t) = It$ ...(1)
and $P = It_d$ ...(2)

1.2 Dimensionless mass curve

$p(t)/P = t/t_d$ ...from (1) and (2)

For the case of uniform - intensity precipitation the dimensionless mass curve is thus linear as shown in Figure A2.

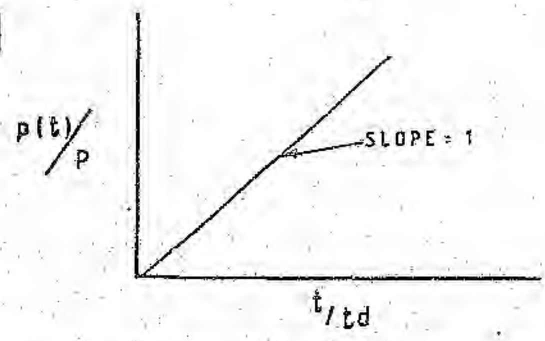



Figure A2 Definition sketch for dimensionless mass curve - uniform intensity distribution.

2. Triangular distribution.

2.1 Intensity - Time curve.

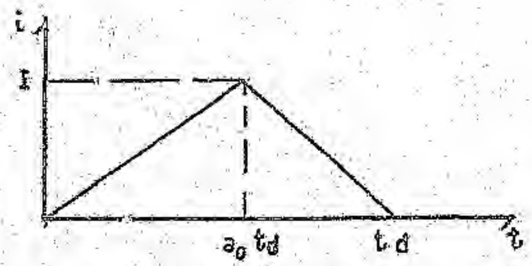



Figure A3 Definition sketch for triangular intensity-time curve.

Intensity:

Peak intensity I occurs at time $t = a_0 t_d$

Before peak :

$$i_b(t) = [I/(a_0 t_d)](t) \qquad ...(3)$$

After peak :

$$i_a(t) = -\{I/[(t_d)(1-a_0)]\}(t) + \{I/[(t_d)(1-a_0)]\}(t_d)$$

$$= \{I/[(t_d)(1-a_0)]\}(t_d-t) \qquad ...(4)$$

Precipitation:

Before peak :

Total precipitation before peak ($P_b$)

$$P_b = \int_0^{a_0 t_d} i(t).dt$$

$$= \int_0^{a_0 t_d} [I/(a_0 t_d)]/t.dt \qquad \text{...(from (3))}$$

$$= [I/(a_0 t_d)][(1/2)(t)^2]\Big|_0^{a_0 t_d}$$

$$= 1/2(I)a_0 t_d \qquad \text{...(5)}$$

As a function of time ($p_b(t)$)

$$p_b(t) = [I/(a_0 t_d)][(1/2)(t)^2] \qquad \text{...(6)}$$

After peak :

Total precipitation after peak ($P_a$)

$$P_a = \int_{a_0 t_d}^{t_d} i(t).dt$$

$$= \int_{a_0 t_d}^{t_d} \{I/[(t_d)(1-a_0)]\}(t_d-t).dt \qquad \text{...from (4)}$$

$$= \{I/[(t_d)(1-a_0)]\}.\int_{a_0 t_d}^{t_d} (t_d-t).dt$$

$$= \{I/[(t_d)(1-a_0)]\}\{(t_d)(t)-[(1/2)(t)^2]\}\Big|_{a_0 t_d}^{t_d}$$

$$= \{I(t)/[(t_d)(1-a_0)]\}\{(t_d)-[(1/2)(t)]\}\Big|_{a_0 t_d}^{t_d}$$

$$= [I(t_d)/(1-a_0)]\{(1/2)-[(a_0)(1-a_0/2)]\}$$

$$= [I(t_d)/2](1-a_0) \qquad \text{...(7)}$$

Total precipitation (P)

$$P = P_a + P_b$$

$$= (1/2)(I)(t_d) \qquad \ldots(8)$$

2.2 Dimensionless mass curve

Before peak :

$p_b(t)/P =$

$$[(1/2)(I)(t^2)/(a_0 t_d)]/[(1/2)(t_d)(I)] \quad \ldots(6)/(8)$$

$$= (t^2)/(a_0)(t_d)^2$$

$$= [1/(a_0)](t/t_d)^2 \qquad \ldots(9)$$

After peak :

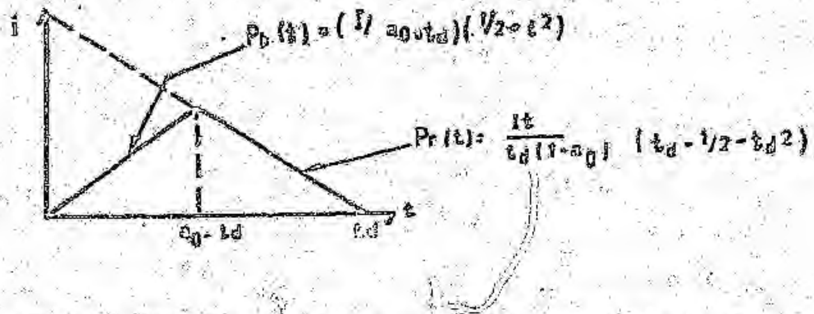



Figure A4 Definition sketch for triangular intensity-time curve - $p_r(t)$

$$p_a(t)/P = [p_b(a_0 t_d)+p_r(t)-p_r(a_0 t_d)]/P$$

$$= [p_r(t)+(p_b(a_0 t_d)-p_r(a_0 t_d))]/P$$

$$= \{[(It(t_d-t/2))/(1-a_0)t_d)]+[(Ia_0 t_d/2$$
$$-(a_0 I(t_d-(a_0 t_d/2)))/(1-a_0)]\}/P$$

$$= \{[(I(t-t^2/2t_d))/(1-a_0)]+[(a_0 I t_d)(1/2$$
$$-(1-(a_0/2)))/(1-a_0)]\}/P$$

$$= [I/(1-a_0)][(t-t^2/2t_d)+a_0 t_d(1/2$$
$$-a_0/2-1+a_0/2)]/P$$

Substitute for P from eqn. (8)

$$p_a(t)/P = [\ 2/(1-a_0)]\ [(t/t_d - 1/2(t/t_d)^2) - a_0 1/2]$$

$$= 1/(1-a_0)[-a_0 + 2(t/t_d) - (t/t_d)^2)] \qquad ..(10)$$

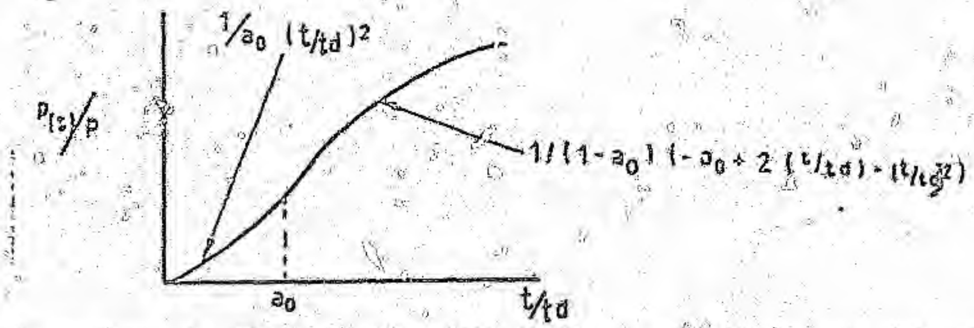



Figure A5 Definition sketch for dimensionless mass curve - triangular intensity distribution

APPENDIX B

## Description and operation of Norwood raingauge.

The Norwood raingauge is a continuous-recording syphon gauge. Precipitation which falls on the area within a sharp-edged aperture ring, is funnelled into a graduated glass measuring cylinder. A float inside the measuring cylinder is connected to a pen, which records the movement of the float on a chart fixed to a rotating drum. Once ten millimetres of precipitation has entered the measuring cylinder, it is automatically syphoned out into a collecting vessel. This causes the float to fall rapidly, leaving a nearly-vertical trace on the chart. Figure B1 shows the gauge with relevant data.

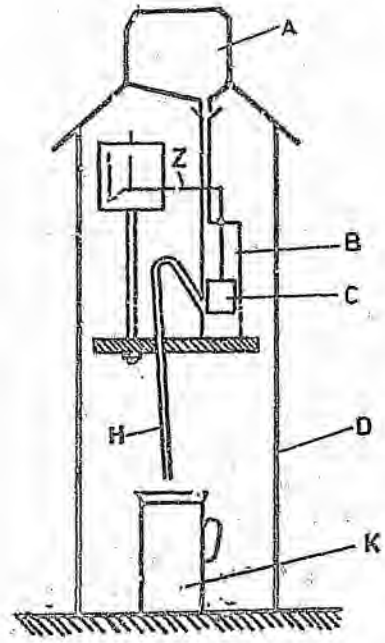
The trace of the pen on the chart is 0,3 to 0,5 mm thick. Assuming that the chart may be read reasonably to a resolution of one millimetre, then rainfall depth can be read to within 0,13 mm and time to within four minutes.

Another factor which may effect accuracy is the speed with which the syphon empties the measuring cylinder. However further investigation shows that the highest recorded 5-minute intensity during the period was approximately 2,5 mm/minute (recorded as 152,4 mm/hour between 15 and 20 minutes from the start of the storm of 26 January 1964) indicating that speed of syphoning is unlikely have a significant effect on accuracy.

The Norwood gauge is included in two inventories of hydrological data:

1. James, A.G. and Fuller H.L.M. (March 1987), Register of Southern African Hydrological Data Sources (2nd. ed.), South African Water Information Centre, p. 55.

2. National Register for Weather Climate and Atmosphere Numeric Data Sources (April 1988, 2nd. ed.), Centre for Information Services, CSIR, Pretoria, South Africa, p. 56.




KEY

A - APERTURE RING  B - FLOAT VESSEL  C - FLOAT
D - CASING  H - SIPHON  K - COLLECTING VESSEL
Z - PEN ARM

## MODEL 95 FUESS RAIN GAUGE

| | | | |
|---|---|---|---|
| AREA of APERTURE RING | $A_A$ | 200 | $cm^2$ |
| VOLUME of FLOAT VESSEL | $V_D$ | 200 | $cm^3$ |
| RAINFALL DEPTH per HEIGHT of RECORDING | $K = V_D / A_A$ | 10 | mm |
| HEIGHT of RECORDING | h | 78 | mm |
| EXAGGERATION of DEPTH | $E = h/R$ | 7.8 | times |
| DRUM DIAMETER | d | 133 | mm |

FIGURE B 1  Diagram of Autographic Raingauge and Relevant Data.

APPENDIX C

## Data from the Norwood Gauge and its analysis.

Table C1, lists total annual rainfall and the number of storms meeting certain criteria.

Table C1 Salient records from Norwood raingauge

| Year | Norwood Annual Rainfall (mm) | Number of storms with 10 mm of rain or more | Number of storms with requisite intensities as well | Number of storms selected |
|---|---|---|---|---|
| 1963/64 | i | 21 | 8 | 7 |
| 64/65 | 642 | 25 | 2 | 1 |
| 65/66 | 544 | 5 | 0 | 0 |
| 66/67 | 1043 | 23 | 5 | 1 |
| 67/68 | 730 | 17 | 3 | 3 |
| 68/69 | 488 | 11 | 0 | 0 |
| 69/70 | 790 | 21 | 8 | 6 |
| 70/71 | 772 | 22 | 3 | 3 |
| 71/72 | 706 | 19 | 5 | 5 |
| 72/73 | 627 | 17 | 7 | 6 |
| 73/74 | 486 | 12 | 4 | 4 |
| 74/75 | 623 | 12 | 3 | 2 |
| 75/76 | 901 | 26 | 5 | 5 |
| 76/77 | 746 | 21 | 3 | 3 |
| 77/78 | 674 | 20 | 3 | 2 |
| 78/79 | 465 | 15 | 2 | 2 |
| 79/80 | 724 | 20 | 4 | 4 |
| 80/81 | 676 | 18 | 3 | 3 |
| 81/82 | 505 | 13 | 2 | 2 |
| 82/83 | 419 | 9 | 2 | 2 |
| 83/84 | 635 | 19 | 2 | 2 |
| 84/85 | 581 | 11 | 4 | 4 |
| 85/86 | 607 | 15 | 3 | 3 |
| 86/87 | 881 | 30 | 6 | 6 |
| 87/88 | 594 | 18 | 3 | 3 |
| 88/89 | i | 7 | 0 | 0 |
| 89/90 | 487 | 12 | 4 | 3 |
| Totals | | 459 | 94 | 82 |
| 1964/65 to 1989/90 | | | | |
| Totals | 16 346 | 431 | 86 | 75 |
| Mean p.a. | 654 | 17,3 | 3,4 | 3 |

Notes :

1. Source : CED rainfall records and Watson (1981).
2. i = incomplete year.
3. Hydrological years shown = 1 October to 30 September.
4. Totals and mean values for 1964/65 to 1989/90 are calculated for a 25-year period i.e. results for the incomplete year 1988/89 have not been taken into account.
5. Storms of 10 mm or more occur on average every 21 days (refer Tyson and Wilcocks average of 28 days).
6. Storms with requisite intensities are only 94/459 (i.e. 20 %) of storms over 10mm on average.
7. The selection of fewer storms than the number meeting the criteria could be due to problems in reading the raingauge charts.

Table C2, relates the number of storms selected to the above- or below-average rainfall during a year.

Table C2 "Wet" and "dry" years and relationship to number of storms selected for analysis

| Year | Annual Rainfall a. Total (mm) | Annual Rainfall b. As percentage of 15-year average | Number of storms during year selected for analysis |
|---|---|---|---|
| 1964/65 | 642 mm | 98 % | 1 |
| 65/66 | 544 | 83 | 0 |
| 66/67 | 1 043 | 159 | 1 |
| 67/68 | 730 | 112 | 3 |
| 68/69 | 488 | 75 | 0 |
| 69/70 | 790 | 121 | 6 |
| 70/71 | 772 | 118 | 3 |
| 71/72 | 706 | 108 | 5 |
| 72/73 | 627 | 96 | 6 |
| 73/74 | 486 | 74 | 4 |
| 74/75 | 623 | 95 | 2 |
| 75/76 | 901 | 138 | 5 |
| 76/77 | 746 | 114 | 3 |
| 77/78 | 674 | 103 | 2 |
| 78/79 | 465 | 71 | 2 |
| 79/80 | 724 | 111 | 4 |
| 80/81 | 676 | 103 | 3 |
| 81/82 | 505 | 77 | 2 |
| 82/83 | 419 | 64 | 2 |
| 83/84 | 635 | 97 | 2 |

Table C2 (ctd.)

| Year | Annual Rainfall a. Total (mm) | b. As percentage of 15-year average | Number of storms during year selected for analysis |
|---|---|---|---|
| 84/85 | 581 | 89 | 4 |
| 85/86 | 607 | 93 | 3 |
| 86/87 | 881 | 135 | 6 |
| 87/88 | 594 | 91 | 3 |
| 88/89 | 1 | | 0 |
| 89/90 | 487 | 74 | 3 |
| Totals | 16 346 | | 75 |
| Range | 419 - 1043 | 64 - 159 | 0 - 6 |

Notes :

1. Twenty five year period contains 11 "wet" years (i.e. above-average annual precipitation) and 14 "dry" years (i.e. below-average annual precipitation).
2. Total number of storms in "wet" years is 41 and in "dry" years is 34.
3. Maximum number of storms in a "wet" year is six (1969/70 with 116 % of average rainfall for period and 1986/87 with 135 %) and in a "dry" year is also six (1972/73 with 96 % of average rainfall for period).
4. Only one storm was selected from "wettest" year (1966/67) whereas two storms were selected from "dryest" year (1982/83).
5. The single storm with the highest rainfall occurred in a "dry" year (on 1/11/85 - year had 93 % of average for period).

Data from Tables C1 and C2 is plotted in the accompanying Figures C1 C2 and C3, showing Annual Precipitation, in millimetres, as a percentage of Mean Annual Precipitation and as a frequency distribution.

Using data from Watson (1981), supplemented by data from this investigation, frequency distributions for the storms in terms of rainfall depth (Figure C4) and storm duration (Figure C5), are plotted to illustrate the amount of rain and length of storm under consideration. (After further work relating to quartile classification is done, rainfall depth and storm duration are plotted against each other in Figure E4).

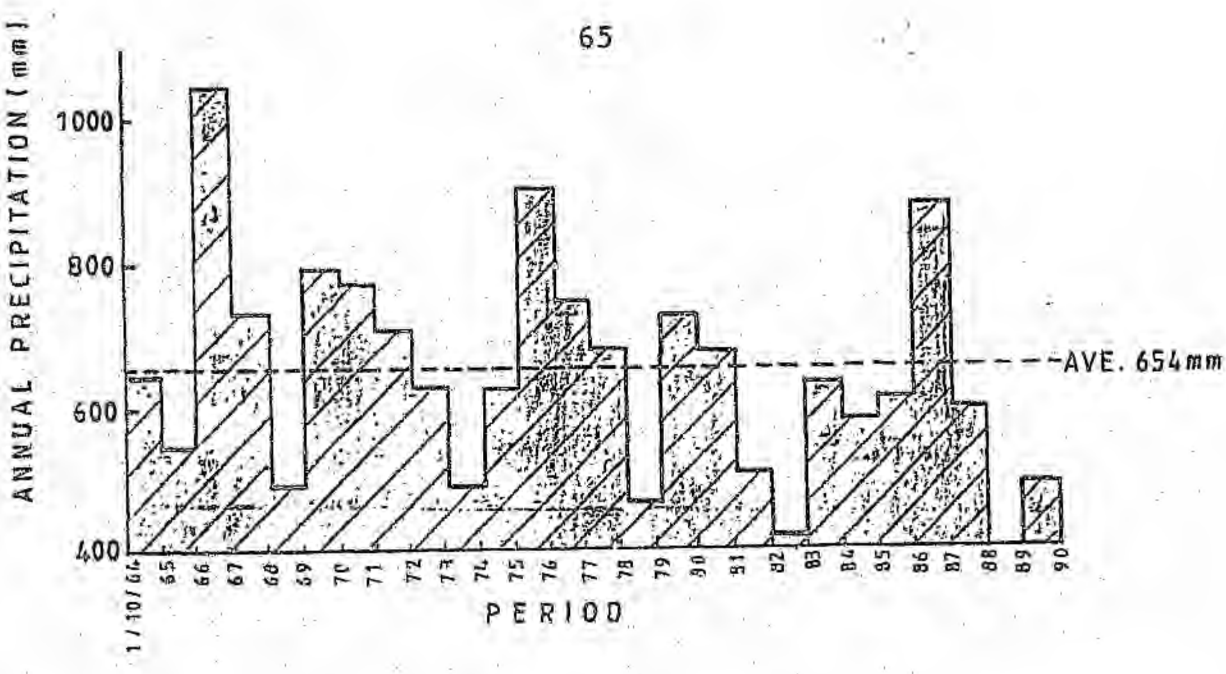



FIGURE C1 Annual Precipitation

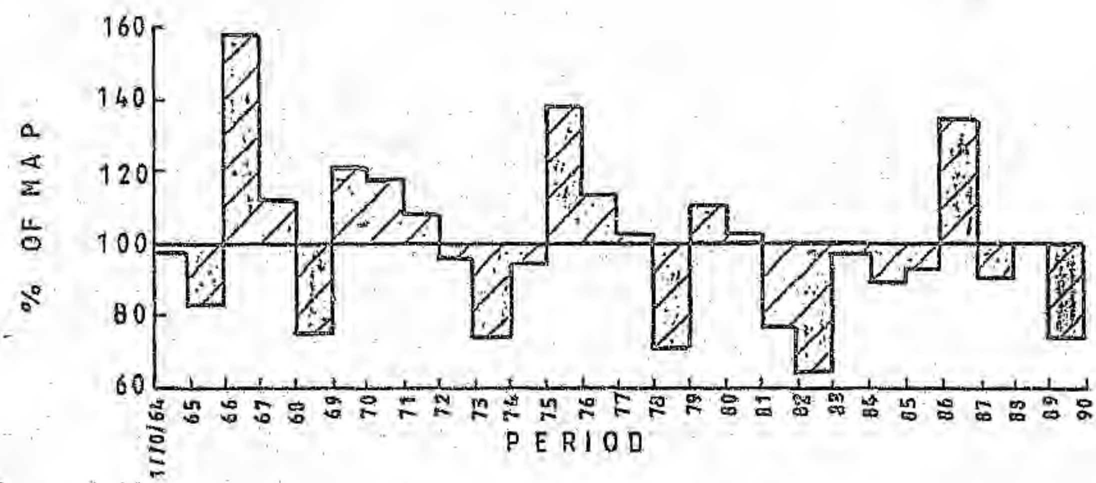



FIGURE C2 Annual Precipitation as Percentage of MAP

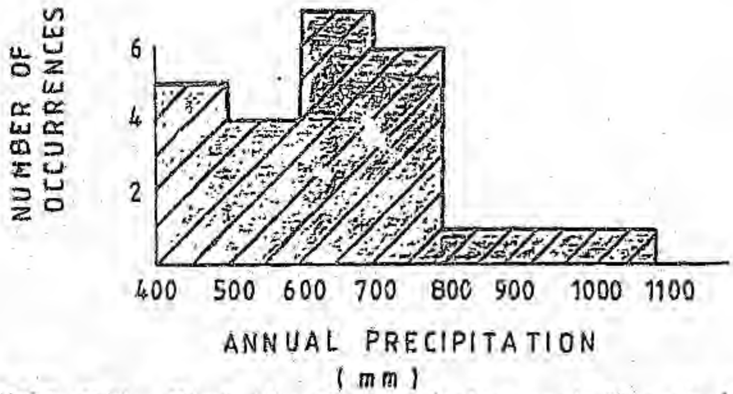



**FIGURE C3** Distribution of Annual Precipitation

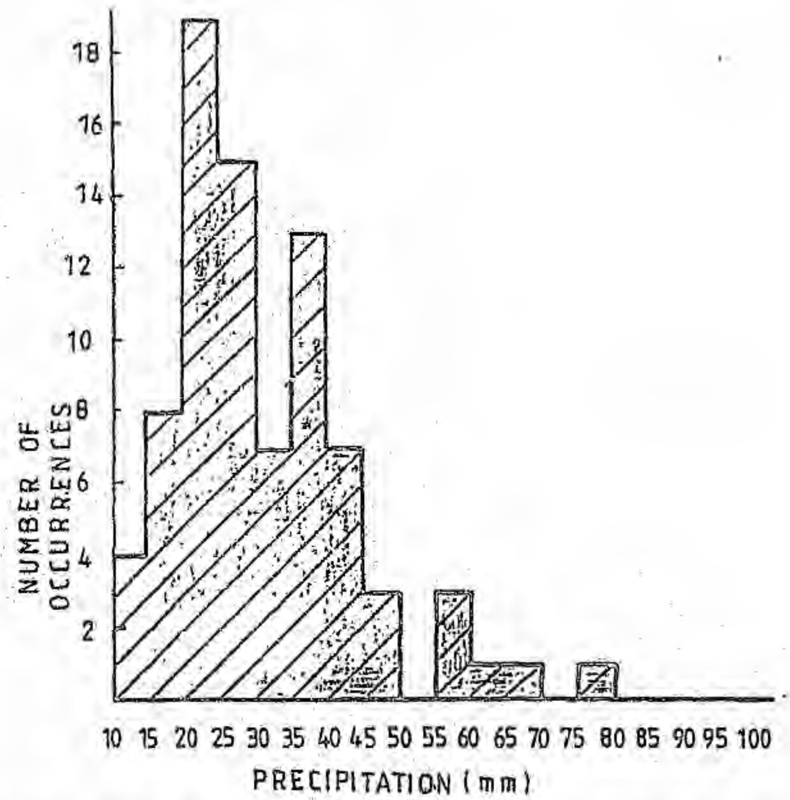



**FIGURE C4** Distribution of Precipitation Depths

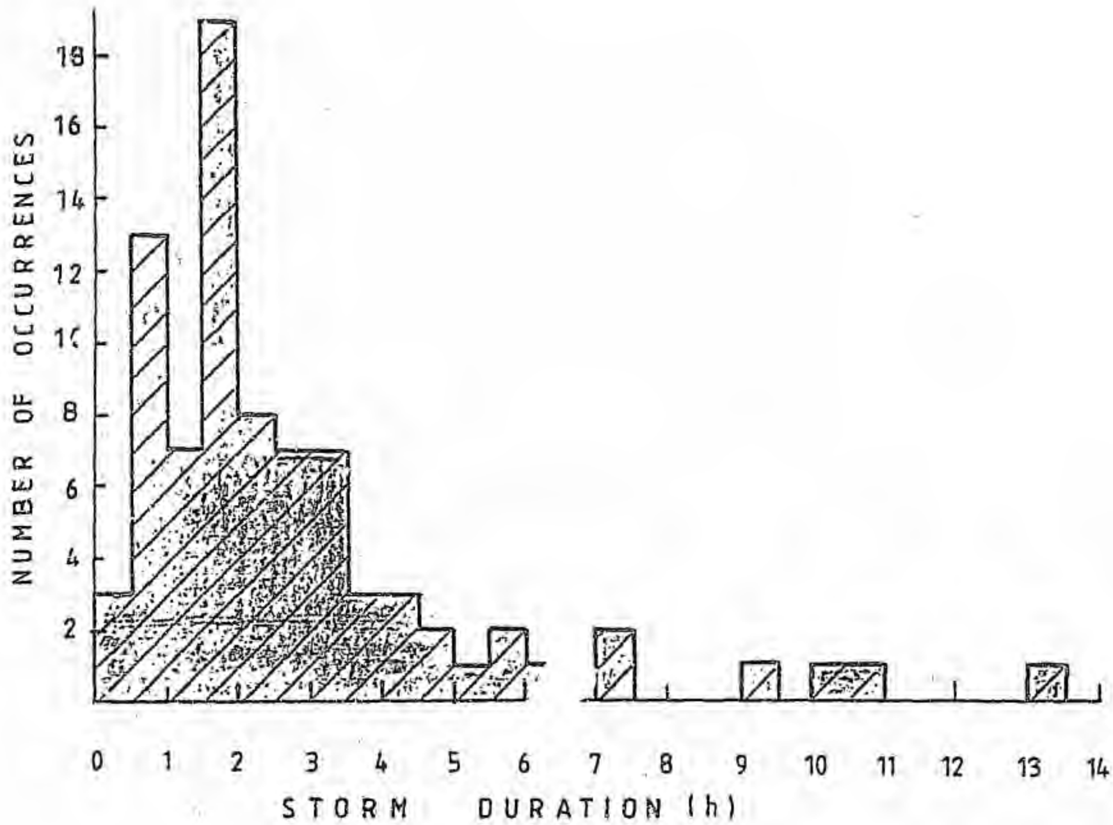



FIGURE C5 Distribution of Storm Duration

APPENDIX D

Listing and output of computer programs to analyse rainfall data.

NORANAL was written to analyse data compiled by Watson. A listing of the program and output in the form of a sample of the detailed data from a single storm and a summary of all storms is contained in this Appendix.

NORMOR is a slight modification of NORANAL in order to extend the length of record by analysing data compiled by the author. The only significant difference between NORMOR and NORANAL is that the data is read in different ways - which affects lines 260 to 320 and 380 to 450 of NORANAL. Because the difference is so slight, a listing of the program is not included in this Appendix

NORMOR output in the form of the detailed data for all storms and a summary of all storms is contained in this Appendix.

```
10    PRINT
20    PRINT "PROGRAM:NORANAL "
30    PRINT
40    !
50    ! Program gives an option of tabulating entire storm precipitation or
60    ! tabulating quartiles only.
70    !
80    DIM T(110,54),P(110,54),Dur(54),Tot(54),R(110),Nval(54),Pt(110,54),Pp(110,
54),Pa(54),Pb(54),Pc(54),P1(54),P2(54),P3(54),P4(54),Q(54)
90    ASSIGN @Filein TO "NORWOOD:HP8290X,700,0"
100   PRINT
110   INPUT "No. of storms to be analysed? (54 max.)",S
120   PRINT
130   INPUT "Table of cumulative values and percentages required?(Y/N)",A$
140   IF A$="Y" THEN 250
150   PRINT
160   PRINT "Storm  Date              Quartile                  Storm       Durn.
  Rain"
170   PRINT " No.                                           Classification  (min)
  (mm)"
180   PRINT "                                                  (Quartile)"
190   PRINT "                      1st     2nd     3rd     4th"
200   PRINT
210   A=0                                      !Counters for no. of quartiles
220   B=0
230   C=0
240   D=0
250   FOR No=1 TO S
260     ENTER @Filein;Number,Date$,Nval(No),Ti     !Begin data input.
270     FOR I=0 TO Nval(No)-1
280       ENTER @Filein;R(I)
290       R(I)=R(I)*5/60
300     NEXT I
310                                            !End data input.
```

```
320      IF A$="N" THEN 380
330      PRINT
340      PRINT "Norwood - Storm No:";No,"Date:";Date$,"No. values:";Nval(No)
350      PRINT
360      PRINT " Time(min)     Rain(mm)       %Time         %Rain"
370      PRINT
380      T(0,No)=0
390      P(0,No)=0
400      FOR I=1 TO Nval(No)-1
410        T(I,No)=T(I-1,No)+Ti                         !Cumulative time.
420        P(I,No)=P(I-1,No)+R(I)                       !Cumulative precipitation.
430      NEXT I
440      Dur(No)=(Nval(No)-2)*Ti                        !Storm duration.
450      Tot(No)=P(Nval(No)-1,No)                       !Total precipitation.
460      J=0                                            !Counter for quartiles.
470      FOR I=0 TO Nval(No)-2
480        Pt(I,No)=T(I,No)/Dur(No)                     !Time as percentage.
490        Pp(I,No)=P(I,No)/Tot(No)                     !Precipitation as percentage.
500        IF A$="Y" THEN PRINT USING "1X,4(DDD.DD,8X,DDD.D,9X,DDD.D,9X,DDD.D)";T
(I,No),P(I,No),100*Pt(I,No),100*Pp(I,No)
510                                                     !% Precipitation in quartiles.
520        IF J=1 THEN 600
530        IF J=2 THEN 650
540        IF J=3 THEN 750
550        IF Pt(I,No)>=.25 THEN
560          IF Pt(I,No)=.25 THEN Pa(No)=100*Pp(I,No)
570          IF Pt(I,No)>.25 THEN Pa(No)=100*(Pp(I-1,No)+((Pp(I,No)-Pp(I-1,No))*(
.25-Pt(I-1,No))/(Pt(I,No)-Pt(I-1,No))))
580          J=J+1
590        END IF
600        IF Pt(I,No)>=.50 THEN
610          IF Pt(I,No)=.50 THEN Pb(No)=100*Pp(I,No)
```

```
620         IF Pt(I,No)>.50 THEN Pb(No)=100*(Pp(I-1,No)+((Pp(I,No)-Pp(I-1,No))*(
.50-Pt(I-1,No))/(Pt(I,No)-Pt(I-1,No))))
630         J=J+1
640       END IF
650       IF Pt(I,No)>=.75 THEN
660         IF Pt(I,No)=.75 THEN Pc(No)=100*Pp(I,No)
670         IF Pt(I,No)>.75 THEN Pc(No)=100*(Pp(I-1,No)+((Pp(I,No)-Pp(I-1,No))*(
.75-Pt(I-1,No))/(Pt(I,No)-Pt(I-1,No))))
680         J=J+1
690       END IF
700                                               !% precipation per quartile.
710       P1(No)=Pa(No)
720       P2(No)=ABS(Pb(No)-Pa(No))
730       P3(No)=ABS(Pc(No)-Pb(No))
740       P4(No)=100-Pc(No)
750       IF I<Nval(No)-2 THEN 760
760     NEXT I
770                                               ! Labelling of storm quartiles
780     IF P1(No)>P2(No) THEN 930
790     IF P2(No)>P3(No) THEN 970
800     IF P3(No)>P4(No) THEN 900
810     Q(No)=4
820     D=D+1
830     GOTO 990
840     Q(No)=1
850     A=A+1
860     GOTO 990
870     Q(No)=2
880     B=B+1
890     GOTO 990
900     Q(No)=3
910     C=C+1
920     GOTO 990
```

```
930    IF P1(No)>P3(No) THEN 950
940    GOTO 800
950    IF P1(No)>P4(No) THEN 840
960    GOTO 810
970    IF P2(No)>P4(No) THEN 870
980    GOTO 810
990    IF A$="Y" THEN 1070
1000   P1(No)=PROUND(P1(No),0)
1010   P2(No)=PROUND(P2(No),0)
1020   P3(No)=PROUND(P3(No),0)
1030   P4(No)=PROUND(P4(No),0)
1040   Dur(No)=PROUND(Dur(No),0)
1050   Tot(No)=PROUND(Tot(No),-1)
1060   IF A$="N" THEN PRINT No;TAB(8);Date$;TAB(20);P1(No);TAB(27);P2(No);TAB(3
4);P3(No);TAB(41);P4(No);TAB(52);Q(No);TAB(61);Dur(No);TAB(71);Tot(No)
1070  NEXT No
1080  PRINT
1090  PRINT "Totals ";TAB(20);A;TAB(27);B;TAB(34);C;TAB(41);D
1100  PRINT
1110  E=PROUND(100*(A/S),0)                    !% Storms in each quartile.
1120  F=PROUND(100*(B/S),0)
1130  G=PROUND(100*(C/S),0)
1140  H=PROUND(100*(D/S),0)
1150  PRINT "Percentages ";TAB(20);E;TAB(27);F;TAB(34);G;TAB(41);H
1160  PRINT
1170  ASSIGN @Filein TO *
1180  PRINT
1190  PRINT "                  ---NORANAL ENDED---  "
1200  END
```

PROGRAM:NORANAL

Norwood - Storm No: 1 Date:16/11/83 No. values: 25

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | 1.3 | 4.3 | 6.8 |
| 10.00 | 3.3 | 8.7 | 17.2 |
| 15.00 | 8.3 | 13.0 | 43.2 |
| 20.00 | 15.0 | 17.4 | 78.1 |
| 25.00 | 17.0 | 21.7 | 88.5 |
| 30.00 | 17.7 | 26.1 | 92.2 |
| 35.00 | 17.9 | 30.4 | 93.2 |
| 40.00 | 18.0 | 34.8 | 93.7 |
| 45.00 | 18.2 | 39.1 | 94.8 |
| 50.00 | 18.4 | 43.5 | 95.8 |
| 55.00 | 18.5 | 47.8 | 96.4 |
| 60.00 | 18.5 | 52.2 | 96.4 |
| 65.00 | 18.5 | 56.5 | 96.4 |
| 70.00 | 18.6 | 60.9 | 96.9 |
| 75.00 | 18.7 | 65.2 | 97.4 |
| 80.00 | 18.8 | 69.6 | 97.9 |
| 85.00 | 18.9 | 73.9 | 98.4 |
| 90.00 | 19.0 | 78.3 | 98.7 |
| 95.00 | 19.0 | 82.6 | 99.0 |
| 100.00 | 19.1 | 87.0 | 99.2 |
| 105.00 | 19.1 | 91.3 | 99.5 |
| 110.00 | 19.2 | 95.7 | 99.7 |
| 115.00 | 19.2 | 100.0 | 100.0 |

Totals 1 0 0

Percentages 100 0 0 0

---NORANAL ENDED---

PROGRAM:NORANAL

| Storm No. | Date | Quartile 1st | 2nd | 3rd | 4th | Storm Classification (Quartile) | Durn. (min) | Rain (mm) |
|---|---|---|---|---|---|---|---|---|
| 1 | 16/11/63 | 91 | 5 | 2 | 1 | 1 | 115 | 19.2 |
| 2 | 23/11/63 | 5 | 0 | 14 | 81 | 4 | 85 | 28.8 |
| 3 | 10/12/63 | 64 | 14 | 12 | 10 | 1 | 240 | 38.3 |
| 4 | 17/1/64 | 82 | 15 | 3 | 0 | 1 | 70 | 26 |
| 5 | 26/1/64 | 88 | 2 | 7 | 2 | 1 | 120 | 28.2 |
| 6 | 21/2/64 | 59 | 32 | 8 | 1 | 1 | 75 | 37.9 |
| 7 | 31/3/64 | 52 | 15 | 31 | 2 | 1 | 350 | 31.2 |
| 8 | 29/12/64 | 29 | 39 | 22 | 10 | 2 | 175 | 26.1 |
| 9 | 20/3/67 | 60 | 9 | 19 | 11 | 1 | 240 | 37 |
| 10 | 26/11/67 | 14 | 39 | 33 | 14 | 2 | 25 | 23.9 |
| 11 | 28/11/67 | 0 | 21 | 72 | 7 | 3 | 100 | 21.9 |
| 12 | 14/4/68 | 94 | 5 | 0 | 1 | 1 | 55 | 16.7 |
| 13 | 18/10/69 | 2 | 5 | 73 | 20 | 3 | 130 | 36.5 |
| 14 | 5/11/69 | 60 | 23 | 11 | 6 | 1 | 55 | 19.6 |
| 15 | 8/12/69 | 52 | 45 | 3 | 0 | 1 | 190 | 33.5 |
| 16 | 29/12/69 | 47 | 47 | 5 | 1 | 2 | 95 | 23.6 |
| 17 | 16/1/70 | 47 | 33 | 15 | 5 | 1 | 295 | 39.7 |
| 18 | 12/2/70 | 64 | 34 | 1 | 1 | 1 | 190 | 43.8 |
| 19 | 17/11/70 | 42 | 32 | 20 | 6 | 1 | 65 | 30.8 |
| 20 | 22/3/71 | 27 | 53 | 14 | 6 | 2 | 110 | 20.4 |
| 21 | 5/4/71 | 77 | 6 | 8 | 9 | 1 | 180 | 24 |
| 22 | 3/11/71 | 48 | 33 | 16 | 3 | 1 | 95 | 22 |
| 23 | 17/1/72 | 69 | 24 | 4 | 3 | 1 | 100 | 30.9 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 24 | 20/1/72 | 43 | 0 | 1 | 56 | 4 | 100 | 22.6 |
| 25 | 22/3/72 | 54 | 36 | 6 | 4 | 1 | 135 | 44.3 |
| 26 | 2/4/72 | 25 | 42 | 27 | 5 | 2 | 45 | 21.7 |
| 27 | 29/11/72 | 8 | 67 | 24 | 1 | 2 | 40 | 22.0 |
| 28 | 10/12/72 | 70 | 20 | 9 | 1 | 1 | 230 | 43.6 |
| 29 | 23/12/72 | 11 | 0 | 78 | 3 | 3 | 40 | 14.6 |
| 30 | 26/12/72 | 63 | 10 | 17 | 10 | 1 | 295 | 56.7 |
| 31 | 5/1/73 | 49 | 26 | 17 | 8 | 1 | 30 | 17.1 |
| 32 | 25/3/73 | 10 | 32 | 25 | 33 | 4 | 135 | 37.0 |
| 33 | 22/10/73 | 30 | 61 | 6 | 3 | 2 | 215 | 57 |
| 34 | 5/1/74 | 51 | 36 | 8 | 5 | 1 | 20 | 18.6 |
| 35 | 19/2/74 | 35 | 47 | 16 | 1 | 2 | 25 | 14.1 |
| 36 | 14/3/74 | 40 | 43 | 14 | 3 | 2 | 45 | 24 |
| 37 | 17/1/75 | 92 | 1 | 5 | 1 | 1 | 165 | 22.4 |
| 38 | 24/1/75 | 21 | 50 | 8 | 21 | 2 | 540 | 67.6 |
| 39 | 11/11/75 | 14 | 24 | 36 | 26 | 3 | 85 | 40 |
| 40 | 22/11/75 | 76 | 9 | 8 | 7 | 1 | 110 | 34.8 |
| 41 | 27/11/75 | 6 | 5 | 30 | 59 | 4 | 130 | 26.8 |
| 42 | 11/1/76 | 78 | 21 | 1 | 0 | 1 | 110 | 46.6 |
| 43 | 12/1/76 | 15 | 19 | 61 | 5 | 3 | 110 | 25 |
| 44 | 25/10/76 | 79 | 20 | 0 | 1 | 1 | 40 | 10.1 |
| 45 | 19/1/77 | 5 | 12 | 42 | 41 | 3 | 35 | 19.8 |
| 46 | 27/9/77 | 2 | 1 | 87 | 10 | 3 | 255 | 47.8 |
| 47 | 25/11/77 | 61 | 33 | 4 | 2 | 1 | 35 | 10.3 |
| 48 | 27/1/78 | 24 | 72 | 3 | 1 | 2 | 235 | 38.7 |
| 49 | 29/1/79 | 3 | 16 | 72 | 9 | 3 | 130 | 18.8 |
| 50 | 15/4/79 | 84 | 8 | 3 | 5 | 1 | 165 | 32.6 |
| 51 | 18/11/79 | 55 | 30 | 15 | 1 | 1 | 115 | 25.3 |
| 52 | 15/1/80 | 18 | 74 | 6 | 3 | 2 | 105 | 40.9 |
| 53 | 12/2/80 | 54 | 28 | 17 | 1 | 1 | 50 | 28.7 |
| 54 | 23/2/80 | 78 | 14 | 4 | 4 | 1 | 120 | 18.5 |
| Totals | | 30 | 12 | 8 | 4 | | | |
| Percentages | | 56 | 22 | 15 | 7 | | | |

---NORANAL ENDED---

PROGRAM:NORMOS

| Storm No. | Date | rtile | | | | Storm Classification (Quartile) | Durn. (min) | Rain (mm) |
|---|---|---|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | 4th | | | |
| 1 | 28/12/80 | 75 | 19 | 4 | 3 | 1 | 50 | 25.6 |
| 2 | 28/02/81 | 48 | 37 | 12 | 3 | 1 | 205 | 39.1 |
| 3 | 01/03/81 | 70 | 13 | 13 | 3 | 1 | 445 | 42.8 |
| 4 | 20/01/82 | 54 | 19 | 27 | 1 | 1 | 110 | 36.7 |
| 5 | 10/02/82 | 13 | 83 | 3 | 1 | 2 | 165 | 23.5 |
| 6 | 10/12/82 | 31 | 20 | 36 | 13 | 3 | 175 | 28.6 |
| 7 | 16/12/82 | 3 | 17 | 79 | 2 | 3 | 95 | 23.4 |
| 8 | 07/11/83 | 30 | 63 | 6 | 0 | 2 | 155 | 27.5 |
| 9 | 02/01/84 | 71 | 11 | 6 | 12 | 1 | 155 | 29 |
| 10 | 17/01/85 | 6 | 37 | 45 | 12 | 3 | 800 | 64.9 |
| 11 | 21/01/85 | 66 | 29 | 4 | 1 | 1 | 105 | 22.1 |
| 12 | 25/02/85 | 51 | 43 | 3 | 2 | 1 | 185 | 23 |
| 13 | 08/03/85 | 52 | 36 | 9 | 3 | 1 | 110 | 21 |
| 14 | 01/11/85 | 6 | 51 | 20 | 22 | 2 | 425 | 76 |
| 15 | 31/12/85 | 67 | 32 | 1 | 1 | 1 | 50 | 22.3 |
| 16 | 07/02/86 | 45 | 14 | 30 | 12 | 1 | 60 | 28.7 |
| 17 | 28/10/86 | 27 | 45 | 25 | 3 | 2 | 640 | 58.7 |
| 18 | 26/11/86 | 34 | 6 | 7 | 53 | 4 | 115 | 29.7 |
| 19 | 07/12/86 | 56 | 35 | 4 | 4 | 1 | 90 | 25.6 |
| 20 | 17/12/86 | 83 | 4 | 9 | 4 | 1 | 625 | 39.5 |
| 21 | 29/12/86 | 1 | 41 | 47 | 11 | 3 | 145 | 30.5 |
| 22 | 21/01/87 | 12 | 67 | 18 | 3 | 2 | 320 | 37.4 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 23 | 27/11/87 | 88 | 5 | 7 | 1 | 1 | 360 | 24.3 |
| 24 | 24/12/87 | 5 | 82 | 8 | 5 | 2 | 345 | 46.4 |
| 25 | 02/03/88 | 20 | 43 | 27 | 10 | 2 | 90 | 42.2 |
| 26 | 24/01/90 | 72 | 22 | 3 | 4 | 1 | 95 | 34.5 |
| 27 | 11/02/90 | 47 | 37 | 11 | 5 | 1 | 60 | 24.4 |
| 28 | 05/04/90 | 44 | 29 | 26 | 1 | 1 | 90 | 30.3 |
| Totals | | 16 | 7 | 4 | 1 | | | |
| Percentages | | 57 | 25 | 14 | 4 | | | |

---NORMOR ENDED---

PROGRAM:NORMOR

Norwood - Storm No: 1 Date:28/12/80 No. Intervals: 10

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | 6.1 | 10.0 | 23.8 |
| 10.00 | 16.1 | 20.0 | 62.9 |
| 15.00 | 22.1 | 30.0 | 86.3 |
| 20.00 | 23.1 | 40.0 | 90.2 |
| 25.00 | 23.9 | 50.0 | 93.4 |
| 30.00 | 24.4 | 60.0 | 95.3 |
| 35.00 | 24.8 | 70.0 | 96.9 |
| 40.00 | 25.1 | 80.0 | 98.0 |
| 45.00 | 25.5 | 90.0 | 99.6 |
| 50.00 | 25.6 | 100.0 | 100.0 |

Norwood - Storm No: 2 Date:28/02/81 No. Intervals: 41

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | 5.0 | 2.4 | 12.8 |
| 10.00 | 8.8 | 4.9 | 22.5 |
| 15.00 | 10.7 | 7.3 | 27.4 |
| 20.00 | 12.7 | 9.8 | 32.5 |
| 25.00 | 14.5 | 12.2 | 37.1 |
| 30.00 | 15.7 | 14.6 | 40.2 |
| 35.00 | 16.3 | 17.1 | 41.7 |
| 40.00 | 17.8 | 19.5 | 45.5 |
| 45.00 | 18.6 | 22.0 | 47.6 |
| 50.00 | 18.7 | 24.4 | 47.8 |
| 55.00 | 18.8 | 26.8 | 48.1 |
| 60.00 | 21.2 | 29.3 | 54.2 |
| 65.00 | 23.5 | 31.7 | 60.1 |
| 70.00 | 23.9 | 34.1 | 61.1 |
| 75.00 | 24.5 | 36.6 | 62.7 |
| 80.00 | 26.1 | 39.0 | 66.8 |
| 85.00 | 28.2 | 41.5 | 72.1 |
| 90.00 | 30.3 | 43.9 | 77.5 |
| 95.00 | 31.5 | 46.3 | 80.6 |
| 100.00 | 32.8 | 48.8 | 83.9 |
| 105.00 | 33.6 | 51.2 | 85.9 |
| 110.00 | 34.9 | 53.7 | [illegible] |

| | | | |
|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] |
| 85.00 | 2[illegible].2 | 41.5 | 72.1 |
| 90.00 | 30.3 | 43.9 | 77.5 |
| 95.00 | 31.5 | 46.3 | 80.6 |
| 100.00 | 32.8 | 48.8 | 83.9 |
| 105.00 | 33.6 | 51.2 | 85.9 |
| 110.00 | 34.9 | 53.7 | 89.3 |
| 115.00 | 35.8 | 56.1 | 91.6 |
| 120.00 | 36.0 | 58.5 | 92.1 |
| 125.00 | 36.2 | 61.0 | 92.6 |
| 130.00 | 36.3 | 63.4 | 92.6 |
| 135.00 | 36.5 | 65.9 | 93.4 |
| 140.00 | 36.7 | 68.3 | 93.9 |
| 145.00 | 36.8 | 70.7 | 94.1 |
| 150.00 | 37.3 | 73.2 | 95.4 |
| 155.00 | 38.0 | 75.6 | 97.2 |
| 160.00 | 38.5 | 78.0 | 98.5 |
| 165.00 | 38.7 | 80.5 | 99.0 |
| 170.00 | 38.8 | 82.9 | 99.2 |
| 175.00 | 38.8 | 85.4 | 99.2 |
| 180.00 | 39.0 | 87.8 | 99.7 |
| 185.00 | 39.0 | 90.2 | 99.7 |
| 190.00 | 39.0 | 92.7 | 99.7 |
| 195.00 | 39.0 | 95.1 | 99.7 |
| 200.00 | 39.0 | 97.6 | 99.7 |
| 205.00 | 39.1 | 100.0 | 100.0 |

Norwood - Storm No: 3 Date:01/03/81 No. Intervals: 89

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .2 | 1.1 | .5 |
| 10.00 | 1.3 | 2.2 | 3.0 |
| 15.00 | 6.1 | 3.4 | 14.3 |
| 20.00 | 9.8 | 4.5 | 22.9 |
| 25.00 | 13.4 | 5.6 | 31.3 |
| 30.00 | 16.5 | 6.7 | 38.6 |
| 35.00 | 19.5 | 7.9 | 45.6 |
| 40.00 | 21.9 | 9.0 | 51.2 |
| 45.00 | 23.5 | 10.1 | 54.9 |
| 50.00 | 25.9 | 11.2 | 60.5 |
| 55.00 | 26.6 | 12.4 | 62.1 |
| 60.00 | 27.3 | 13.5 | 63.9 |
| 65.00 | 27.6 | 14.6 | 64.5 |
| 70.00 | 27.8 | 15.7 | 65.0 |
| 75.00 | 28.1 | 16.9 | 65.7 |
| 80.00 | 28.2 | 18.0 | 65.9 |
| 85.00 | 28.3 | 19.1 | 66.1 |
| 90.00 | 28.6 | 20.2 | 66.8 |
| 95.00 | 29.0 | 21.3 | 67.8 |
| 100.00 | 29.3 | 22.5 | 68.5 |
| 105.00 | 29.5 | 23.6 | 68.9 |
| 110.00 | 30.1 | 24.7 | 70.3 |
| 115.00 | 30.3 | 25.8 | 70.8 |
| 120.00 | 30.6 | 27.0 | 71.5 |
| 125.00 | 31.1 | 28.1 | 72.7 |
| 130.00 | 32.8 | 29.2 | 76.6 |
| 135.00 | 33.6 | 30.3 | 78.5 |
| 140.00 | 34.0 | 31.5 | 79.4 |
| 145.00 | 34.2 | 32.6 | 79.9 |
| 150.00 | 34.5 | 33.7 | 80.6 |
| 155.00 | 34.7 | 34.8 | 81.1 |
| 160.00 | 34.9 | 36.0 | 81.5 |
| 165.00 | 35.1 | 37.1 | 82.0 |
| 170.00 | 35.4 | 38.2 | 82.7 |
| 175.00 | 35.4 | 39.3 | 82.7 |
| 180.00 | 35.5 | 40.4 | 82.9 |
| 185.00 | 35.5 | 41.6 | 82.9 |
| 190.00 | 36.6 | 42. | 85.5 |
| 195.00 | 36.6 | 43.8 | 85.5 |
| 200.00 | [illegible] | [illegible] | |

| | | | |
|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] |
| 175.00 | 35.4 | 39.3 | 82.7 |
| 180.00 | 35.5 | 40.4 | 82.9 |
| 185.00 | 35.5 | 41.6 | 82.9 |
| 190.00 | 36.6 | 42.7 | 85.5 |
| 195.00 | 36.6 | 43.8 | 85.5 |
| 200.00 | 35.7 | 44.9 | 83.4 |
| 205.00 | 35.7 | 46.1 | 83.4 |
| 210.00 | 35.7 | 47.2 | 83.4 |
| 215.00 | 35.8 | 48.3 | 83.6 |
| 220.00 | 35.8 | 49.4 | 83.6 |
| 225.00 | 35.9 | 50.6 | 83.9 |
| 230.00 | 35.9 | 51.7 | 83.9 |
| 235.00 | 35.9 | 52.8 | 83.9 |
| 240.00 | 40.0 | 53.9 | 93.5 |
| 245.00 | 40.0 | 55.1 | 93.5 |
| 250.00 | 40.1 | 56.2 | 93.7 |
| 255.00 | 40.1 | 57.3 | 93.7 |
| 260.00 | 40.2 | 58.4 | 93.9 |
| 265.00 | 40.2 | 59.6 | 93.9 |
| 270.00 | 40.3 | 60.7 | 94.2 |
| 275.00 | 40.3 | 61.8 | 94.2 |
| 280.00 | 40.4 | 62.9 | 94.4 |
| 285.00 | 40.4 | 64.0 | 94.4 |
| 290.00 | 40.5 | 65.2 | 94.6 |
| 295.00 | 40.6 | 66.3 | 94.9 |
| 300.00 | 40.7 | 67.4 | 95.1 |
| 305.00 | 40.8 | 68.5 | 95.3 |
| 310.00 | 40.9 | 69.7 | 95.6 |
| 315.00 | 41.0 | 70.8 | 95.8 |
| 320.00 | 41.2 | 71.9 | 96.3 |
| 325.00 | 41.2 | 73.0 | 96.3 |
| 330.00 | 41.3 | 74.[illegible] | 96.5 |
| 335.00 | 41.4 | 75.[illegible] | 96.7 |
| 340.00 | 41.5 | 76.[illegible] | 97.0 |
| 345.00 | 41.6 | 77.5 | 97.2 |
| 350.00 | 41.5 | 78.7 | 97.2 |
| 355.00 | 41.6 | 79.8 | 97.2 |
| 360.00 | 41.6 | 80.9 | 97.2 |
| 365.00 | 41.7 | 82.0 | 97.4 |
| 370.00 | 41.7 | 83.1 | 97.4 |
| 375.00 | 41.8 | 84.3 | 97.7 |
| 380.00 | 41.8 | 85.4 | 97.7 |
| 385.00 | 41.8 | 86.5 | 97.7 |
| 390.00 | 41.8 | 87.6 | 97.7 |
| 395.00 | 41.9 | 88.8 | 97.9 |
| 400.00 | 41.9 | 89.9 | 97.9 |
| 405.00 | 41.9 | 91.0 | 97.9 |
| 410.00 | 42.0 | 92.1 | 98.1 |
| 415.00 | 42.1 | 93.3 | 98.4 |
| 420.00 | 42.3 | 94.4 | 98.8 |
| 425.00 | 42.5 | 95.5 | 99.3 |
| 430.00 | 42.6 | 96.6 | 99.5 |
| 435.00 | 42.7 | 97.8 | 99.8 |
| 440.00 | 42.7 | 98.9 | 99.8 |
| 445.00 | 42.8 | 100.0 | 100.0 |

Norwood - Storm No: 4    Date:20/01/82    No. Intervals: 22

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .4 | 4.5 | 1.1 |
| 10.00 | 1.2 | 9.1 | 3.3 |
| 15.00 | 5.0 | 13.6 | 13.6 |
| 20.00 | 10.6 | 18.2 | 28.9 |
| 25.00 | 17.6 | 22.7 | 48.0 |
| 30.00 | 21.8 | 27.3 | 59.4 |
| 35.00 | 25.9 | 31.8 | 70.6 |
| 40.00 | 26.4 | 36.4 | 71.9 |
| 45.00 | 26.5 | 40.9 | 72.2 |
| [illegible] | [illegible] | 45.5 | 72.2 |

| | | | |
|---|---|---|---|
| 25.00 | 17.6 | 22.7 | 48.0 |
| 30.00 | 21.8 | 27.3 | 59.4 |
| 35.00 | 25.9 | 31.8 | 70.6 |
| 40.00 | 26.4 | 36.4 | 71.9 |
| 45.00 | 26.5 | 40.9 | 72.2 |
| 50.00 | 26.5 | 45.5 | 72.2 |
| 55.00 | 26.5 | 50.0 | 72.2 |
| 60.00 | 31.2 | 54.5 | 85.0 |
| 65.00 | 34.8 | 59.1 | 94.8 |
| 70.00 | 36.2 | 63.6 | 98.6 |
| 75.00 | 36.5 | 68.2 | 99.5 |
| 80.00 | 36.5 | 72.7 | 99.5 |
| 85.00 | 36.5 | 77.3 | 99.5 |
| 90.00 | 36.5 | 81.8 | 99.5 |
| 95.00 | 36.6 | 86.4 | 99.7 |
| 100.00 | 36.6 | 90.9 | 99.7 |
| 105.00 | 36.6 | 95.5 | 99.7 |
| 110.00 | 36.7 | 100.0 | 100.0 |

Norwood - Storm No: 5 Date:10/02/82 No. Intervals: 33

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .5 | 3.0 | 2.1 |
| 10.00 | 2.2 | 6.1 | 9.4 |
| 15.00 | 2.7 | 9.1 | 11.5 |
| 20.00 | 3.0 | 12.1 | 12.8 |
| 25.00 | 3.1 | 15.2 | 13.2 |
| 30.00 | 3.1 | 18.2 | 13.2 |
| 35.00 | 3.1 | 21.2 | 13.2 |
| 40.00 | 3.1 | 24.2 | 13.2 |
| 45.00 | 3.1 | 27.3 | 13.2 |
| 50.00 | 3.1 | 30.3 | 13.2 |
| 55.00 | 3.1 | 33.3 | 13.2 |
| 60.00 | 4.3 | 36.4 | 18.3 |
| 65.00 | 10.1 | 39.4 | 43.0 |
| 70.00 | 12.7 | 42.4 | 54.0 |
| 75.00 | 18.7 | 45.5 | 79.6 |
| 80.00 | 21.8 | 48.5 | 92.8 |
| 85.00 | 23.3 | 51.5 | 99.1 |
| 90.00 | 23.3 | 54.5 | 99.1 |
| 95.00 | 23.3 | 57.6 | 99.1 |
| 100.00 | 23.3 | 60.6 | 99.1 |
| 105.00 | 23.3 | 63.6 | 99.1 |
| 110.00 | 23.3 | 66.7 | 99.1 |
| 115.00 | 23.3 | 69.7 | 99.1 |
| 120.00 | 23.3 | 72.7 | 99.1 |
| 125.00 | 23.3 | 75.8 | 99.1 |
| 130.00 | 23.3 | 78.8 | 99.1 |
| 135.00 | 23.3 | 81.8 | 99.1 |
| 140.00 | 23.3 | 84.8 | 99.1 |
| 145.00 | 23.3 | 87.9 | 99.1 |
| 150.00 | 23.3 | 90.9 | 99.1 |
| 155.00 | 23.4 | 93.9 | 99.6 |
| 160.00 | 23.4 | 97.0 | 99.6 |
| 165.00 | 23.5 | 100.0 | 100.0 |

Norwood - Storm No: 6 Date:10/12/82 No. Intervals: 35

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .6 | 2.9 | 2.1 |
| 10.00 | 2.1 | 5.7 | 7.3 |
| 15.00 | 3.2 | 8.6 | 11.2 |
| 20.00 | 4.6 | 11.4 | 16.1 |
| 25.00 | 4.8 | 14.3 | 16.8 |
| 30.00 | 5.4 | 17.1 | 18.9 |
| 35.00 | 7.6 | 20.0 | 26.6 |

| | | | |
|---|---|---|---|
| 10.00 | 2.1 | 5.7 | 7.3 |
| 15.00 | 3.2 | 8.6 | 11.2 |
| 20.00 | 4.6 | 11.4 | 16.1 |
| 25.00 | 4.8 | 14.3 | 16.8 |
| 30.00 | 5.4 | 17.1 | 18.9 |
| 35.00 | 7.6 | 20.0 | 26.6 |
| 40.00 | 8.6 | 22.9 | 30.1 |
| 45.00 | 9.0 | 25.7 | 31.5 |
| 50.00 | 9.2 | 28.6 | 32.2 |
| 55.00 | 9.4 | 31.4 | 32.9 |
| 60.00 | 10.0 | 34.3 | 35.0 |
| 65.00 | 11.0 | 37.1 | 38.5 |
| 70.00 | 12.4 | 40.0 | 43.4 |
| 75.00 | 12.5 | 42.9 | 43.7 |
| 80.00 | 12.5 | 45.7 | 43.7 |
| 85.00 | 13.3 | 48.6 | 46.5 |
| 90.00 | 15.8 | 51.4 | 55.2 |
| 95.00 | 17.5 | 54.3 | 61.2 |
| 100.00 | 20.2 | 57.1 | 70.6 |
| 105.00 | 21.3 | 60.0 | 74.5 |
| 110.00 | 22.4 | 62.9 | 78.3 |
| 115.00 | 24.2 | 65.7 | 84.6 |
| 120.00 | 24.7 | 68.6 | 86.4 |
| 125.00 | 24.7 | 71.4 | 86.4 |
| 130.00 | 24.8 | 74.3 | 86.7 |
| 135.00 | 24.9 | 77.1 | 87.1 |
| 140.00 | 25.6 | 80.0 | 89.5 |
| 145.00 | 27.5 | 82.9 | 96.2 |
| 150.00 | 28.1 | 85.7 | 98.3 |
| 155.00 | 28.2 | 88.6 | 98.6 |
| 160.00 | 28.5 | 91.4 | 99.7 |
| 165.00 | 28.5 | 94.3 | 99.7 |
| 170.00 | 28.5 | 97.1 | 99.7 |
| 175.00 | 28.6 | 100.0 | 100.0 |

Norwood - Storm No: 7    Date:18/12/82    No. Intervals: 19

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .2 | 5.3 | .9 |
| 10.00 | .4 | 10.5 | 1.7 |
| 15.00 | .6 | 15.8 | 2.6 |
| 20.00 | .6 | 21.1 | 2.6 |
| 25.00 | .6 | 26.3 | 2.6 |
| 30.00 | .6 | 31.6 | 2.6 |
| 35.00 | .6 | 36.8 | 2.6 |
| 40.00 | .6 | 42.1 | 2.6 |
| 45.00 | 1.2 | 47.4 | 5.1 |
| 50.00 | 8.0 | 52.6 | 34.2 |
| 55.00 | 15.1 | 57.9 | 64.5 |
| 60.00 | 19.8 | 63.2 | 84.6 |
| 65.00 | 22.5 | 68.4 | 96.2 |
| 70.00 | 22.9 | 73.7 | 97.9 |
| 75.00 | 23.2 | 78.9 | 99.1 |
| 80.00 | 23.3 | 84.2 | 99.6 |
| 85.00 | 23.3 | 89.5 | 99.6 |
| 90.00 | 23.3 | 94.7 | 99.6 |
| 95.00 | 23.4 | 100.0 | 100.0 |

Norwood - Storm No: 8    Date:07/11/83    No. Intervals: 31

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .1 | 3.2 | .4 |
| 10.00 | .2 | 6.5 | .7 |
| 15.00 | .4 | 9.7 | 1.5 |
| 20.00 | .5 | 12.9 | 1.[illegible] |

| | | | |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .1 | 3.2 | .4 |
| 10.00 | .2 | 6.5 | .7 |
| 15.00 | .4 | 9.7 | 1.5 |
| 20.00 | .5 | 12.9 | 1.8 |
| 25.00 | 1.0 | 16.1 | 3.6 |
| 30.00 | 2.6 | 19.4 | 9.5 |
| 35.00 | 6.0 | 22.6 | 21.8 |
| 40.00 | 9.1 | 25.8 | 33.1 |
| 45.00 | 10.8 | 29.0 | 39.3 |
| 50.00 | 15.0 | 32.3 | 54.5 |
| 55.00 | 17.9 | 35.5 | 65.1 |
| 60.00 | 20.3 | 38.7 | 73.8 |
| 65.00 | 22.8 | 41.9 | 82.9 |
| 70.00 | 24.3 | 45.2 | 88.4 |
| 75.00 | 25.4 | 48.4 | 92.4 |
| 80.00 | 26.0 | 51.6 | 94.5 |
| 85.00 | 26.4 | 54.8 | 96.0 |
| 90.00 | 26.6 | 58.1 | 96.7 |
| 95.00 | 26.8 | 61.3 | 97.5 |
| 100.00 | 27.0 | 64.5 | 98.2 |
| 105.00 | 27.1 | 67.7 | 98.5 |
| 110.00 | 27.3 | 71.0 | 99.3 |
| 115.00 | 27.4 | 74.2 | 99.6 |
| 120.00 | 27.4 | 77.4 | 99.6 |
| 125.00 | 27.4 | 80.6 | 99.6 |
| 130.00 | 27.4 | 83.9 | 99.6 |
| 135.00 | 27.4 | 87.1 | 99.6 |
| 140.00 | 27.4 | 90.3 | 99.6 |
| 145.00 | 27.4 | 93.5 | 99.6 |
| 150.00 | 27.5 | 96.8 | 100.0 |
| 155.00 | 27.5 | 100.0 | 100.0 |

Norwood - Storm No: 9 Date:02/01/84 No. Intervals: 31

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | 1.8 | 3.2 | 6.6 |
| 10.00 | 6.4 | 6.5 | 22.1 |
| 15.00 | 11.9 | 9.7 | 41.0 |
| 20.00 | 15.4 | 12.9 | 53.1 |
| 25.00 | 18.9 | 16.1 | 65.2 |
| 30.00 | 19.7 | 19.4 | 67.9 |
| 35.00 | 20.1 | 22.6 | 69.3 |
| 40.00 | 20.7 | 25.8 | 71.4 |
| 45.00 | 21.2 | 29.0 | 73.1 |
| 50.00 | 21.7 | 32.3 | 74.8 |
| 55.00 | 22.1 | 35.5 | 76.2 |
| 60.00 | 22.5 | 38.7 | 77.6 |
| 65.00 | 22.9 | 41.9 | 79.0 |
| 70.00 | 23.3 | 45.2 | 80.3 |
| 75.00 | 23.5 | 48.4 | 81.0 |
| 80.00 | 23.7 | 51.6 | 81.7 |
| 85.00 | 24.0 | 54.8 | 82.8 |
| 90.00 | 24.4 | 58.1 | 84.1 |
| 95.00 | 24.5 | 61.3 | 84.5 |
| 100.00 | 24.6 | 64.5 | 84.8 |
| 105.00 | 24.7 | 67.7 | 85.2 |
| 110.00 | 24.8 | 71.0 | 85.5 |
| 115.00 | 25.1 | 74.2 | 86.6 |
| 120.00 | 26.3 | 77.4 | 90.7 |
| 125.00 | 27.0 | 80.6 | 93.1 |
| 130.00 | 27.6 | 83.9 | 95.2 |
| 135.00 | 28.0 | 87.1 | 96.6 |
| 140.00 | 28.2 | 90.3 | 97.2 |
| 145.00 | 28.5 | 93.5 | 98.3 |
| 150.00 | 28.9 | 96.8 | 99.7 |
| 155.00 | 29.0 | 100.0 | 100.0 |

... No: 10 Date:17/01/85 No. Intervals: 160

| | | | |
|---|---|---|---|
| 140.00 | 29.2 | 90.3 | 97.2 |
| 145.00 | 28.5 | 93.5 | 98.3 |
| 150.00 | 28.3 | 96.8 | 99.7 |
| 155.00 | 25.0 | 100.0 | 100.0 |

Norwood - Storm No: 10 Date:17/01/85 No. Intervals: 160

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .2 | .6 | .3 |
| 10.00 | .2 | 1.3 | .3 |
| 15.00 | .3 | 1.9 | .5 |
| 20.00 | .3 | 2.5 | .5 |
| 25.00 | .3 | 3.1 | .5 |
| 30.00 | .3 | 3.8 | .5 |
| 35.00 | .3 | 4.4 | .5 |
| 40.00 | .3 | 5.0 | .5 |
| 45.00 | .3 | 5.6 | .5 |
| 50.00 | .3 | 6.3 | .5 |
| 55.00 | .3 | 6.9 | .5 |
| 60.00 | .3 | 7.5 | .5 |
| 65.00 | .3 | 8.1 | .5 |
| 70.00 | .4 | 8.8 | .6 |
| 75.00 | .4 | 9.4 | .6 |
| 80.00 | .5 | 10.0 | .8 |
| 85.00 | .6 | 10.6 | .9 |
| 90.00 | .7 | 11.3 | 1.1 |
| 95.00 | .7 | 11.9 | 1.1 |
| 100.00 | .7 | 12.5 | 1.1 |
| 105.00 | .7 | 13.1 | 1.1 |
| 110.00 | .7 | 13.8 | 1.1 |
| 115.00 | .7 | 14.4 | 1.1 |
| 120.00 | .7 | 15.0 | 1.1 |
| 125.00 | .7 | 15.6 | 1.1 |
| 130.00 | .7 | 16.3 | 1.1 |
| 135.00 | .7 | 16.9 | 1.1 |
| 140.00 | .7 | 17.5 | 1.1 |
| 145.00 | .7 | 18.1 | 1.1 |
| 150.00 | .7 | 18.8 | 1.1 |
| 155.00 | .7 | 19.4 | 1.1 |
| 160.00 | .8 | 20.0 | 1.2 |
| 165.00 | 1.1 | 20.6 | 1.7 |
| 170.00 | 1.7 | 21.3 | 2.6 |
| 175.00 | 1.8 | 21.9 | 2.8 |
| 180.00 | 2.0 | 22.5 | 3.1 |
| 185.00 | 2.5 | 23.1 | 3.9 |
| 190.00 | 3.0 | 23.8 | 4.6 |
| 195.00 | 3.5 | 24.4 | 5.4 |
| 200.00 | 3.8 | 25.0 | 5.9 |
| 205.00 | 4.1 | 25.6 | 6.3 |
| 210.00 | 4.4 | 26.3 | 6.8 |
| 215.00 | 4.9 | 26.9 | 7.6 |
| 220.00 | 5.6 | 27.5 | 8.5 |
| 225.00 | 6.2 | 28.1 | 9.5 |
| 230.00 | 6.6 | 28.7 | 10.2 |
| 235.00 | [illegible] | 29.4 | 11.4 |
| 240.00 | 7.8 | 30.0 | 12.0 |
| 245.00 | 8.5 | 30.6 | 13.1 |
| 250.00 | 8.9 | 31.3 | 13.7 |
| 255.00 | 9.3 | 31.9 | 14.3 |
| 260.00 | 9.7 | 32.5 | 14.9 |
| 265.00 | 10.0 | 33.1 | 15.4 |
| 270.00 | 10.4 | 33.8 | 16.0 |
| 275.00 | 10.8 | 34.4 | 16.6 |
| 280.00 | 11.8 | 35.0 | 18.2 |
| 285.00 | 12.4 | 35.6 | 19.1 |
| 290.00 | 13.0 | 36.3 | 20.0 |
| 295.00 | 14.0 | 36.9 | 21.6 |
| 300.00 | 14.5 | 37.5 | 22.3 |
| 305.00 | 14.8 | 38.1 | 23.0 |
| 310.00 | 15.3 | 38.8 | 23.6 |

| | | | |
|---|---|---|---|
| 280.00 | 11.8 | 35.0 | 18.2 |
| 285.00 | 12.4 | 35.6 | 19.1 |
| 290.00 | 13.0 | 36.2 | 20.0 |
| 295.00 | 14.0 | 36.9 | 21.6 |
| 300.00 | 14.5 | 37.5 | 22.3 |
| 305.00 | 14.9 | 38.1 | 23.0 |
| 310.00 | 15.3 | 38.8 | 23.6 |
| 315.00 | 15.6 | 39.4 | 24.0 |
| 320.00 | 16.3 | 40.0 | 25.1 |
| 325.00 | 17.4 | 40.6 | 26.8 |
| 330.00 | 18.5 | 41.3 | 28.5 |
| 335.00 | 19.8 | 41.9 | 30.5 |
| 340.00 | 20.5 | 42.5 | 31.6 |
| 345.00 | 20.9 | 43.1 | 32.2 |
| 350.00 | 22.6 | 43.8 | 35.1 |
| 355.00 | 27.0 | 44.4 | 41.6 |
| 360.00 | 27.5 | 45.0 | 42.4 |
| 365.00 | 27.7 | 45.6 | 42.7 |
| 370.00 | 27.8 | 46.3 | 42.8 |
| 375.00 | 27.8 | 46.9 | 42.8 |
| 380.00 | 27.8 | 47.5 | 42.8 |
| 385.00 | 27.8 | 48.1 | 42.8 |
| 390.00 | 27.9 | 48.7 | 43.0 |
| 395.00 | 27.9 | 49.4 | 43.0 |
| 400.00 | 27.9 | 50.0 | 43.0 |
| 405.00 | 28.1 | 50.6 | 43.3 |
| 410.00 | 28.5 | 51.2 | 43.9 |
| 415.00 | 29.1 | 51.9 | 44.8 |
| 420.00 | 29.7 | 52.5 | 45.8 |
| 425.00 | 30.6 | 53.1 | 47.1 |
| 430.00 | 31.7 | 53.7 | 48.8 |
| 435.00 | 32.3 | 54.4 | 49.8 |
| 440.00 | 32.8 | 55.0 | 50.8 |
| 445.00 | 33.6 | 55.6 | 51.8 |
| 450.00 | 33.9 | 56.3 | 52.2 |
| 455.00 | 34.4 | 56.9 | 53.0 |
| 460.00 | 38.0 | 57.5 | 58.6 |
| 465.00 | 44.5 | 58.1 | 68.6 |
| 470.00 | 47.5 | 58.8 | 73.2 |
| 475.00 | 48.8 | 59.4 | 75.3 |
| 480.00 | 49.4 | 60.0 | 76.1 |
| 485.00 | 50.0 | 60.6 | 77.0 |
| 490.00 | 50.6 | 61.3 | 78.0 |
| 495.00 | 50.7 | 61.9 | 78.1 |
| 500.00 | 50.8 | 62.5 | 78.3 |
| 505.00 | 51.0 | 63.1 | 78.6 |
| 510.00 | 51.0 | 63.7 | 78.6 |
| 515.00 | 51.0 | 64.4 | 78.6 |
| 520.00 | 51.6 | 65.0 | 78.5 |
| 525.00 | 51.9 | 65.6 | 80.0 |
| 530.00 | 52.2 | 66.2 | 80.4 |
| 535.00 | 52.5 | 66.9 | 80.9 |
| 540.00 | 52.8 | 67.5 | 81.4 |
| 545.00 | 53.1 | 68.1 | 81.6 |
| 550.00 | 53.3 | [illegible] | 82.4 |
| 555.00 | 53.6 | 69.4 | 82.6 |
| 560.00 | 53.8 | 70.0 | 83.1 |
| 565.00 | 54.4 | 70.6 | 83.6 |
| 570.00 | 54.7 | 71.3 | 84.1 |
| 575.00 | 55.2 | 71.8 | 85.1 |
| 580.00 | 55.7 | 72.5 | 85.8 |
| 585.00 | 56.0 | 73.1 | [illegible] |
| 590.00 | 56.2 | 73.7 | 86.6 |
| 595.00 | 56.4 | 74.4 | 86.3 |
| 600.00 | 56.8 | 75.0 | [illegible] |
| 605.00 | [illegible] | [illegible] | [illegible] |
| 610.00 | 57.4 | 76.2 | [illegible] |
| 615.00 | 57.8 | [illegible] | [illegible] |
| 620.00 | [illegible] | [illegible] | [illegible] |
| 625.00 | [illegible] | 78.1 | [illegible] |
| 630.00 | [illegible] | 78.7 | [illegible] |
| 635.00 | [illegible] | [illegible] | [illegible] |

| | | | |
|---|---|---|---|
| 280.00 | 11.8 | 35.0 | 18.2 |
| 285.00 | 12.4 | 35.6 | 19.1 |
| 290.00 | 13.0 | 36.2 | 20.0 |
| 295.00 | 14.0 | 36.9 | 21.6 |
| 300.00 | 14.6 | 37.5 | 22.3 |
| 305.00 | 14.9 | 38.1 | 23.0 |
| 310.00 | 15.3 | 38.8 | 23.6 |
| 315.00 | 15.6 | 39.4 | 24.0 |
| 320.00 | 16.3 | 40.0 | 25.1 |
| 325.00 | 17.4 | 40.6 | 26.8 |
| 330.00 | 18.5 | 41.3 | 28.5 |
| 335.00 | 19.8 | 41.9 | 30.5 |
| 340.00 | 20.5 | 42.5 | 31.6 |
| 345.00 | 20.9 | 43.1 | 32.2 |
| 350.00 | 22.6 | 43.8 | 35.1 |
| 355.00 | 27.0 | 44.4 | 41.6 |
| 360.00 | 27.5 | 45.0 | 42.4 |
| 365.00 | 27.7 | 45.6 | 42.7 |
| 370.00 | 27.8 | 46.3 | 42.2 |
| 375.00 | 27.8 | 46.9 | 42.8 |
| 380.00 | 27.8 | 47.5 | 42.8 |
| 385.00 | [illegible] | 48.1 | 42.8 |
| 390.00 | 27.9 | 48.7 | 43.0 |
| 395.00 | 27.9 | 49.4 | 43.0 |
| 400.00 | 27.9 | 50.0 | 43.0 |
| 405.00 | 28.1 | 50.6 | 43.3 |
| 410.00 | 28.5 | 51.2 | 43.9 |
| 415.00 | 29.1 | 51.9 | 44.6 |
| 420.00 | 29.7 | 52.5 | 45.8 |
| 425.00 | 30.6 | 53.1 | 47.1 |
| 430.00 | 31.7 | 53.7 | 48.9 |
| 435.00 | 32.3 | 54.4 | 49.6 |
| 440.00 | 33.0 | 55.0 | 50.8 |
| 445.00 | 33.6 | 55.6 | 51.8 |
| 450.00 | 33.9 | 56.3 | 52.2 |
| 455.00 | 34.4 | 56.9 | 53.0 |
| 460.00 | 38.0 | 57.5 | 58.6 |
| 465.00 | 44.5 | 58.1 | 68.6 |
| 470.00 | 47.9 | 58.8 | 73.2 |
| 475.00 | 48.9 | 59.4 | 75.3 |
| 480.00 | 49.4 | 60.0 | 76.1 |
| 485.00 | 50.0 | 60.6 | 77.0 |
| 490.00 | 50.6 | 61.3 | 78.0 |
| 495.00 | [illegible] | 61.9 | 78.1 |
| 500.00 | 50.[illegible] | 62.5 | 76.3 |
| 505.00 | 51.0 | 63.1 | 78.6 |
| 510.00 | 51.0 | 63.7 | 78.6 |
| 515.00 | 51.0 | 64.4 | 78.6 |
| 520.00 | 51.6 | 65.0 | 79.5 |
| 525.00 | 51.9 | 65.6 | 80.0 |
| 530.00 | 52.2 | 66.2 | 80.4 |
| 535.00 | 52.6 | 66.9 | 80.9 |
| 540.00 | 52.8 | 67.5 | 81.4 |
| 545.00 | 53.1 | 68.1 | 81.8 |
| 550.00 | 53.3 | 68.8 | 82.1 |
| 555.00 | 53.6 | 69.4 | 82.6 |
| 560.00 | 53.9 | 70.0 | 83.1 |
| 565.00 | 54.4 | 70.6 | 83.8 |
| 570.00 | 54.7 | 71.3 | 84.3 |
| 575.00 | 55.2 | 71.9 | 85.1 |
| 580.00 | 55.7 | 72.5 | 65.8 |
| 585.00 | 56.0 | 73.1 | 86.3 |
| 590.00 | 56.2 | 73.8 | 86.6 |
| 595.00 | 56.4 | 74.4 | 86.9 |
| 600.00 | 56.9 | 75.0 | 87.7 |
| 605.00 | 57.1 | 75.6 | 88.0 |
| 610.00 | 57.4 | 76.3 | 88.4 |
| 615.00 | 57.6 | 76.9 | 88.8 |
| 620.00 | 57.9 | 77.5 | 89.2 |
| 625.00 | 58.2 | 78.1 | 89.7 |
| 630.00 | 58.4 | 78.7 | [illegible] |

| | | | |
|---|---|---|---|
| 610.00 | 57.4 | 76.3 | 88.4 |
| 615.00 | 57.6 | 76.9 | 88.8 |
| 620.00 | 57.9 | 77.5 | 89.2 |
| 625.00 | 58.2 | 78.1 | 89.7 |
| 630.00 | 58.4 | 78.7 | 90.0 |
| 635.00 | 58.6 | 79.4 | 90.3 |
| 640.00 | 58.7 | 80.0 | 90.4 |
| 645.00 | 58.7 | 80.6 | 90.4 |
| 650.00 | 58.8 | 81.3 | 90.6 |
| 655.00 | 58.8 | 81.9 | 90.6 |
| 660.00 | 59.2 | 82.5 | 91.2 |
| 665.00 | 59.7 | 83.1 | 92.0 |
| 670.00 | 60.1 | 83.8 | 92.6 |
| 675.00 | 60.4 | 84.4 | 93.1 |
| 680.00 | 60.9 | 85.0 | 93.8 |
| 685.00 | 61.2 | 85.6 | 94.3 |
| 690.00 | 61.4 | 86.3 | 94.6 |
| 695.00 | 61.6 | 86.9 | 94.9 |
| 700.00 | 61.8 | 87.5 | 95.2 |
| 705.00 | 62.2 | 88.1 | 95.8 |
| 710.00 | 62.4 | 88.8 | 96.1 |
| 715.00 | 62.9 | 89.4 | 96.9 |
| 720.00 | 63.4 | 90.0 | 97.7 |
| 725.00 | 64.0 | 90.6 | 98.6 |
| 730.00 | 64.6 | 91.2 | 99.5 |
| 735.00 | 64.6 | 91.9 | 99.5 |
| 740.00 | 64.6 | 92.5 | 99.5 |
| 745.00 | 64.6 | 93.1 | 99.5 |
| 750.00 | 64.6 | 93.8 | 99.5 |
| 755.00 | 64.7 | 94.4 | 99.7 |
| 760.00 | 64.7 | 95.0 | 99.7 |
| 765.00 | 64.7 | 95.6 | 99.7 |
| 770.00 | 64.7 | 96.3 | 99.7 |
| 775.00 | 64.8 | 96.9 | 99.8 |
| 780.00 | 64.8 | 97.5 | 99.8 |
| 785.00 | 64.8 | 98.1 | 99.8 |
| 790.00 | 64.8 | 98.8 | 99.8 |
| 795.00 | 64.8 | 99.4 | 99.8 |
| 800.00 | 64.9 | 100.0 | 100.0 |

Norwood - Storm No: 11 Date:21/01/85 No. Intervals: 21

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .5 | 4.8 | 2.3 |
| 10.00 | 1.6 | 9.5 | 7.2 |
| 15.00 | 5.2 | 14.3 | 23.5 |
| 20.00 | 9.5 | 19.0 | 43.0 |
| 25.00 | 14.0 | 23.8 | 63.3 |
| 30.00 | 16.5 | 28.6 | 74.7 |
| 35.00 | 17.7 | 33.3 | 80.1 |
| 40.00 | 18.9 | 38.1 | 85.5 |
| 45.00 | 20.7 | 42.9 | 93.7 |
| 50.00 | 20.9 | 47.6 | 94.6 |
| 55.00 | 21.0 | 52.4 | 95.0 |
| 60.00 | 21.1 | 57.1 | 95.5 |
| 65.00 | 21.1 | 61.9 | 95.5 |
| 70.00 | 21.4 | 66.7 | 96.8 |
| 75.00 | 21.7 | 71.4 | 98.2 |
| 80.00 | 21.8 | 76.2 | 98.6 |
| 85.00 | 21.8 | 81.0 | 98.6 |
| 90.00 | 21.9 | 85.7 | 99.1 |
| 95.00 | 21.9 | 90.5 | 99.1 |
| 100.00 | 22.0 | 95.2 | 99.5 |
| 105.00 | 22.1 | 100.0 | 100.0 |

Norwood - Storm No: 12 Date:25/02/85 No. Intervals: 37

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |

| | | | |
|---|---|---|---|
| 105.00 | 22.1 | 100.0 | 100.0 |

Norwood - Storm No: 12 Date:25/02/85 No. Intervals: 37

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | 1.9 | 2.7 | 8.3 |
| 10.00 | 3.2 | 5.4 | 13.9 |
| 15.00 | 5.1 | 8.1 | 22.2 |
| 20.00 | 6.3 | 10.8 | 27.4 |
| 25.00 | 8.3 | 13.5 | 36.1 |
| 30.00 | 9.0 | 16.2 | 39.1 |
| 35.00 | 9.5 | 18.9 | 41.3 |
| 40.00 | 9.9 | 21.6 | 43.0 |
| 45.00 | 11.2 | 24.3 | 48.7 |
| 50.00 | 13.3 | 27.0 | 57.8 |
| 55.00 | 16.0 | 29.7 | 69.6 |
| 60.00 | 18.6 | 32.4 | 80.9 |
| 65.00 | 21.2 | 35.1 | 92.[illegible] |
| 70.00 | 21.3 | 37.8 | 92.6 |
| 75.00 | 21.4 | 40.5 | 93.0 |
| 80.00 | 21.5 | 43.2 | 93.5 |
| 85.00 | 21.5 | 45.9 | 93.5 |
| 90.00 | 21.7 | 48.6 | 94.3 |
| 95.00 | 21.7 | 51.4 | 94.3 |
| 100.00 | 21.8 | 54.1 | 94.8 |
| 105.00 | 21.9 | 56.8 | 95.2 |
| 110.00 | 22.1 | 59.5 | 96.1 |
| 115.00 | 22.2 | 62.2 | 96.5 |
| 120.00 | 22.2 | 64.9 | 96.5 |
| 125.00 | 22.3 | 67.6 | 97.0 |
| 130.00 | 22.4 | 70.3 | 97.4 |
| 135.00 | 22.5 | 73.0 | 97.8 |
| 140.00 | 22.5 | 75.7 | 97.8 |
| 145.00 | 22.6 | 78.4 | 98.3 |
| 150.00 | 22.7 | 81.1 | 98.7 |
| 155.00 | 22.8 | 83.8 | 99.1 |
| 160.00 | 22.8 | 86.5 | 99.1 |
| 165.00 | 22.8 | 89.2 | 99.1 |
| 170.00 | 22.8 | 91.9 | 99.1 |
| 175.00 | 22.8 | 94.6 | 99.1 |
| 180.00 | 22.9 | 97.3 | 99.6 |
| 185.00 | 23.0 | 100.0 | 100.0 |

Norwood - Storm No: 13 Date:08/03/85 No. Intervals: 22

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .9 | 4.5 | 4.3 |
| 10.00 | 2.8 | 9.1 | 13.3 |
| 15.00 | 6.8 | 13.6 | 32.4 |
| 20.00 | 8.5 | 18.2 | 40.5 |
| 25.00 | 10.3 | 22.7 | 49.0 |
| 30.00 | 11.7 | 27.3 | 55.7 |
| 35.00 | 13.2 | 31.8 | 62.9 |
| 40.00 | 14.6 | 36.4 | 69.5 |
| 45.00 | 16.1 | 40.9 | 76.7 |
| 50.00 | 17.8 | 45.5 | 84.8 |
| 55.00 | 18.6 | 50.0 | 88.6 |
| 60.00 | 19.1 | 54.5 | 91.0 |
| 65.00 | 19.5 | 59.1 | 92.9 |
| 70.00 | 19.9 | 63.6 | 94.8 |
| 75.00 | 20.2 | 68.2 | 96.2 |
| 80.00 | 20.4 | 72.7 | 97.1 |
| 85.00 | 20.5 | 77.3 | 97.6 |

| | | | |
|---|---|---|---|
| 75.00 | 20.2 | 68.2 | 96.2 |
| 80.00 | 20.4 | 72.7 | 97.1 |
| 85.00 | 20.5 | 77.3 | 97.6 |
| 90.00 | 20.6 | 81.8 | 98.1 |
| 95.00 | 20.8 | 86.4 | 99.0 |
| 100.00 | 20.8 | 90.9 | 99.0 |
| 105.00 | 20.9 | 95.5 | 99.5 |
| 110.00 | 21.0 | 100.0 | 100.0 |

Norwood - Storm No: 14    Date:01/11/85    No. Intervals: 85

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .2 | 1.2 | .3 |
| 10.00 | .3 | 2.4 | .4 |
| 15.00 | .4 | 3.5 | .5 |
| 20.00 | .6 | 4.7 | .8 |
| 25.00 | 1.9 | 5.9 | 2.5 |
| 30.00 | 2.9 | 7.1 | 3.8 |
| 35.00 | 3.4 | 8.2 | 4.5 |
| 40.00 | 4.2 | 9.4 | 5.5 |
| 45.00 | 4.5 | 10.6 | 5.9 |
| 50.00 | 4.6 | 11.8 | 6.1 |
| 55.00 | 4.7 | [illegible] | 6.2 |
| 60.00 | 4.7 | 14.1 | [illegible] |
| 65.00 | 4.7 | 15. | [illegible] |
| 70.00 | 4.7 | 16 | |
| 75.00 | 4.7 | 17.6 | |
| 80.00 | 4.7 | 18.8 | |
| 85.00 | 4.7 | 20.0 | |
| 90.00 | 4.7 | 21.2 | [illegible] |
| 95.00 | 4.7 | 22.4 | 6.2 |
| 100.00 | 4.7 | 23.5 | 6.2 |
| 105.00 | 4.7 | 24.7 | 6.2 |
| 110.00 | 5.4 | 25.9 | 7.1 |
| 115.00 | 7.9 | 27.1 | 10.4 |
| 120.00 | 10.5 | 28.2 | 13.8 |
| 125.00 | 14.5 | 29.4 | 19.1 |
| 130.00 | 16.4 | 30.6 | 21.6 |
| 135.00 | 18.8 | 31.8 | 24.7 |
| 140.00 | 26.2 | 32.9 | 34.5 |
| 145.00 | 27.2 | 34.1 | 35.8 |
| 150.00 | 28.3 | 35.3 | 37.2 |
| 155.00 | 29.3 | 36.5 | 38.6 |
| 160.00 | 29.4 | 37.6 | 38.7 |
| 165.00 | 29.6 | 38.8 | 38.9 |
| 170.00 | 29.8 | 40.0 | 39.2 |
| 175.00 | 30.1 | 41.2 | 39.6 |
| 180.00 | 30.2 | 42.4 | 39.7 |
| 185.00 | 30.5 | 43.5 | 40.1 |
| 190.00 | 31.1 | 44.7 | 40.9 |
| 195.00 | 32.5 | 45.9 | 42.8 |
| 200.00 | 34.3 | 47.1 | 45.1 |
| 205.00 | 39.3 | 48.2 | 51.7 |
| 210.00 | 41.7 | 49.4 | 54.9 |
| 215.00 | 45.2 | 50.6 | 59.5 |
| 220.00 | 45.9 | 51.8 | 60.4 |
| 225.00 | 46.6 | 52.9 | 61.3 |
| 230.00 | 46.7 | 54.1 | 61.4 |
| 235.00 | 46.7 | 55.3 | 61.4 |
| 240.00 | 47.0 | 56.5 | 61.8 |
| 245.00 | 47.1 | 57.6 | 62.0 |
| 250.00 | 47.5 | 58.8 | 62.5 |
| 255.00 | 49.5 | 60.0 | 65.1 |
| 260.00 | 51.5 | 61.2 | 67.8 |
| 265.00 | 52.0 | 62.4 | 68.4 |
| 270.00 | 52.9 | 63.5 | 69.6 |
| 275.00 | 53.9 | 64.7 | 70.9 |

| | | | |
|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] |
| 260.00 | 51.5 | 61.2 | 67.3 |
| 265.00 | 52.0 | 62.4 | 68.4 |
| 270.00 | 52.9 | 63.5 | 69.6 |
| 275.00 | 53.9 | 64.7 | 70.9 |
| 280.00 | 54.7 | 65.9 | 72.0 |
| 285.00 | 55.4 | 67.1 | 72.9 |
| 290.00 | 56.2 | 68.2 | 73.9 |
| 295.00 | 58.0 | 69.4 | 76.3 |
| 300.00 | 58.7 | 70.6 | 77.2 |
| 305.00 | 58.9 | 71.8 | 77.5 |
| 310.00 | 59.0 | 72.9 | 77.6 |
| 315.00 | 59.0 | 74.1 | 77.6 |
| 320.00 | 59.0 | 75.3 | 77.6 |
| 325.00 | 59.1 | 76.5 | 77.8 |
| 330.00 | 59.2 | 77.6 | 77.9 |
| 335.00 | 59.7 | 78.8 | 78.0 |
| 340.00 | 61.7 | 80.0 | 81.2 |
| 345.00 | 64.6 | 81.2 | 85.0 |
| 350.00 | 73.7 | 82.4 | 97.0 |
| 355.00 | 74.1 | 83.5 | 97.5 |
| 360.00 | 74.3 | 84.7 | 98.2 |
| 365.00 | 74.9 | 85.9 | 98.6 |
| 370.00 | 75.0 | 87.1 | 98.7 |
| 375.00 | 75.1 | 88.2 | 98.8 |
| 380.00 | 75.4 | 89.4 | 99.2 |
| 385.00 | 75.6 | 90.6 | 99.5 |
| 390.00 | 75.7 | 91.8 | 99.6 |
| 395.00 | 75.8 | 92.9 | 99.7 |
| 400.00 | 75.8 | 94.1 | 99.7 |
| 405.00 | 75.9 | 95.3 | 99.9 |
| 410.00 | 75.9 | 96.5 | 99.9 |
| 415.00 | 75.9 | 97.6 | 99.9 |
| 420.00 | 75.9 | 98.8 | 99.9 |
| 425.00 | 76.0 | 100.0 | 100.0 |

Norwood – Storm No: 15 Date:31/12/85 No. Intervals: 10

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | 4.1 | 10.0 | 18.4 |
| 10.00 | 10.9 | 20.0 | 48.9 |
| 15.00 | 18.8 | 30.0 | 84.3 |
| 20.00 | 20.3 | 40.0 | 91.0 |
| 25.00 | 21.9 | 50.0 | 98.7 |
| 30.00 | 22.1 | 60.0 | 99.1 |
| 35.00 | 22.1 | 70.0 | 99.1 |
| 40.00 | 22.2 | 80.0 | 99.6 |
| 45.00 | 22.2 | 90.0 | 99.6 |
| 50.00 | 22.3 | 100.0 | 100.0 |

Norwood – Storm No: 16 Date 17/02/86 No. Intervals: 12

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | 5.2 | 8.3 | 19.1 |
| 10.00 | 8.2 | 16.7 | 28.6 |
| 15.00 | 12.0 | 25.0 | 44.6 |
| 20.00 | 13.5 | 33.3 | 47.4 |
| 25.00 | 14.4 | 41.7 | 50.2 |
| 30.00 | 15.8 | 50.0 | 58.5 |
| 35.00 | 17.4 | 58.3 | 60.6 |
| 40.00 | 18.3 | 66.7 | 67.[illegible] |
| 45.00 | 25.6 | 75.0 | 96.2 |
| 50.00 | 26.3 | 83.3 | 98.6 |
| 55.00 | 26.5 | 91.7 | 99.3 |
| 60.00 | 26.7 | 100.0 | 100.0 |

| | | | |
|---|---|---|---|
| 45.00 | 26.3 | 75.0 | 86.2 |
| 50.00 | 28.3 | 83.3 | 96.6 |
| 55.00 | 28.5 | 91.7 | 99.3 |
| 60.00 | 28.7 | 100.0 | 100.0 |

Norwood - Storm No: 17 Date:20/10/85 No. Intervals: 1[illegible]

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .3 | .8 | .5 |
| 10.00 | .5 | 1.6 | .9 |
| 15.00 | .7 | 2.3 | 1.2 |
| 20.00 | .8 | 3.1 | 1.4 |
| 25.00 | .8 | 3.9 | 1.4 |
| 30.00 | .8 | 4.7 | 1.4 |
| 35.00 | 1.6 | 5.5 | 2.7 |
| 40.00 | 2.2 | 6.3 | 3.7 |
| 45.00 | 2.8 | 7.0 | 4.8 |
| 50.00 | 3.5 | 7.8 | 6.0 |
| 55.00 | 4.1 | 8.6 | 7.0 |
| 60.00 | 6.8 | 9.4 | 11.6 |
| 65.00 | 9.9 | 10.2 | 16.9 |
| 70.00 | 10.0 | 10.9 | 17.0 |
| 75.00 | 10.2 | 11.7 | 17.4 |
| 80.00 | 10.4 | 12.5 | 17.7 |
| 85.00 | 10.6 | 13.3 | 18.1 |
| 90.00 | 10.7 | 14.1 | 18.2 |
| 95.00 | 10.8 | 14.8 | 18.4 |
| 100.00 | 10.8 | 15.6 | 18.4 |
| 105.00 | 10.8 | 16.4 | 18.4 |
| 110.00 | 10.8 | 17.2 | 18.4 |
| 115.00 | 10.8 | 18.0 | 18.4 |
| 120.00 | 10.8 | 18.8 | 18.4 |
| 125.00 | 10.8 | 19.5 | 18.4 |
| 130.00 | 13.3 | 20.3 | 22.7 |
| 135.00 | 14.2 | 21.1 | 24.2 |
| 140.00 | 14.8 | 21.9 | 25.2 |
| 145.00 | 14.8 | 22.7 | 25.2 |
| 150.00 | 14.8 | 23.4 | 25.2 |
| 155.00 | 14.8 | 24.2 | 25.2 |
| 160.00 | 16.0 | 25.0 | 27.3 |
| 165.00 | 16.7 | 25.8 | 28.4 |
| 170.00 | 17.2 | 26.6 | 29.3 |
| 175.00 | 17.4 | 27.3 | 29.6 |
| 180.00 | 17.5 | 28.1 | 29.8 |
| 185.00 | 18.0 | 28.9 | 30.7 |
| 190.00 | 18.4 | 29.7 | 31.3 |
| 195.00 | 19.0 | 30.5 | 32.4 |
| 200.00 | 20.7 | 31.3 | 35.3 |
| 205.00 | 21.5 | 32.0 | 36.6 |
| 210.00 | 22.1 | 32.8 | 37.6 |
| 215.00 | 22.6 | 33.6 | 38.5 |
| 220.00 | 22.9 | 34.4 | 39.0 |
| 225.00 | 23.6 | 35.2 | 40.2 |
| 230.00 | 24.3 | 35.9 | 41.4 |
| 235.00 | 25.5 | 36.7 | 43.4 |
| 240.00 | 26.4 | 37.5 | 45.0 |
| 245.00 | 28.0 | 38.3 | 47.7 |
| 250.00 | 28.9 | 39.1 | 49.1 |
| 255.00 | 29.6 | 39.8 | 50.4 |
| 260.00 | 30.4 | 40.6 | 51.8 |
| 265.00 | 30.8 | 41.4 | 52.5 |
| 270.00 | 32.2 | 42.2 | 54.9 |
| 275.00 | 34.5 | 43.0 | 58.8 |
| 280.00 | 36.0 | 43.8 | 61.3 |
| 285.00 | 37.3 | 44.5 | 63.5 |
| 290.00 | 38.5 | 45.3 | 65.6 |
| 295.00 | 38.9 | 46.1 | 66.3 |
| 300.00 | 40.0 | 46.9 | 68.1 |
| 305.00 | 40.2 | 47.7 | 68.5 |
| 310.00 | [illegible] | [illegible] | [illegible] |

| | | | |
|---|---|---|---|
| 280.00 | 36.0 | 43.8 | 61.3 |
| 285.00 | 37.3 | 44.5 | 63.5 |
| 290.00 | 38.5 | 45.3 | 65.6 |
| 295.00 | 38.9 | 46.1 | 66.3 |
| 300.00 | 40.0 | 46.9 | 68.1 |
| 305.00 | 40.2 | 47.7 | 68.5 |
| 310.00 | 40.8 | 48.4 | 69.5 |
| 315.00 | 41.3 | 49.2 | 70.4 |
| 320.00 | 42.2 | 50.0 | 71.9 |
| 325.00 | 43.1 | 50.8 | 73.4 |
| 330.00 | 44.1 | 51.6 | 75.1 |
| 335.00 | 44.4 | 52.3 | 75.6 |
| 340.00 | 44.6 | 53.1 | 76.0 |
| 345.00 | 45.0 | 53.9 | 76.7 |
| 350.00 | 45.3 | 54.7 | 77.2 |
| 355.00 | 45.6 | 55.5 | 77.7 |
| 360.00 | 45.7 | 56.3 | 77.9 |
| 365.00 | 45.8 | 57.0 | 78.0 |
| 370.00 | 46.7 | 57.8 | 79.6 |
| 375.00 | 47.0 | 58.6 | 80.1 |
| 380.00 | 47.7 | 59.4 | 81.3 |
| 385.00 | 48.5 | 60.2 | 82.6 |
| 390.00 | 49.5 | 60.9 | 84.3 |
| 395.00 | 50.0 | 61.7 | 85.2 |
| 400.00 | 50.7 | 62.5 | 86.4 |
| 405.00 | 51.5 | 63.3 | 87.7 |
| 410.00 | 52.2 | 64.1 | 88.9 |
| 415.00 | 52.6 | 64.8 | 89.6 |
| 420.00 | 53.1 | 65.6 | 90.5 |
| 425.00 | 53.4 | 66.4 | 91.0 |
| 430.00 | 54.2 | 67.2 | 92.3 |
| 435.00 | 54.7 | 68.0 | 93.2 |
| 440.00 | 55.2 | 68.8 | 94.0 |
| 445.00 | 55.8 | 69.5 | 95.1 |
| 450.00 | 56.2 | 70.3 | 95.7 |
| 455.00 | 56.4 | 71.1 | 96.1 |
| 460.00 | 56.6 | 71.9 | 96.4 |
| 465.00 | 56.6 | 72.7 | 96.4 |
| 470.00 | 56.7 | 73.4 | 96.6 |
| 475.00 | 56.8 | 74.2 | 96.8 |
| 480.00 | 56.8 | 75.0 | 96.8 |
| 485.00 | 56.9 | 75.8 | 96.9 |
| 490.00 | 57.0 | 76.6 | 97.1 |
| 495.00 | 57.4 | 77.3 | 97.8 |
| 500.00 | 57.6 | 78.1 | 98.1 |
| 505.00 | 57.8 | 78.9 | 98.5 |
| 510.00 | 57.9 | 79.7 | 98.6 |
| 515.00 | 57.9 | 80.5 | 98.6 |
| 520.00 | 58.0 | 81.3 | 98.8 |
| 525.00 | 58.1 | 82.0 | 99.0 |
| 530.00 | 58.1 | 82.8 | 99.0 |
| 535.00 | 58.1 | 83.6 | 99.0 |
| 540.00 | 58.1 | 84.4 | 99.0 |
| 545.00 | 58.1 | 85.2 | 99.0 |
| 550.00 | 58.2 | 85.9 | 99.1 |
| 555.00 | 58.2 | 86.7 | 99.1 |
| 560.00 | 58.2 | 87.5 | 99.1 |
| 565.00 | 58.2 | 88.3 | 99.1 |
| 570.00 | 58.2 | 89.1 | 99.1 |
| 575.00 | 58.2 | 89.8 | 99.1 |
| 580.00 | 58.2 | 90.6 | 99.1 |
| 585.00 | 58.2 | 91.4 | 99.1 |
| 590.00 | 58.2 | 92.2 | 99.1 |
| 595.00 | 58.2 | 93.0 | 99.1 |
| 600.00 | 58.2 | 93.8 | 99.1 |
| 605.00 | 58.2 | 94.5 | 99.1 |
| 610.00 | 58.3 | 95.3 | 99.3 |
| 615.00 | 58.3 | 96.1 | 99.3 |
| 620.00 | 58.4 | 96.9 | 99.5 |
| 625.00 | 58.5 | 97.7 | 99.7 |
| 630.00 | 58. | 98.4 | 99.7 |
| 635.00 | [illegible] | 99.2 | 99.8 |
| | | | 100.0 |

| | | | |
|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] |
| 610.00 | 58.3 | 95.3 | 99.3 |
| 615.00 | 58.3 | 96.1 | 99.3 |
| 620.00 | 58.4 | 96.9 | 99.5 |
| 625.00 | 58.5 | 97.7 | 99.7 |
| 630.00 | 58.5 | 98.4 | 99.7 |
| 635.00 | 58.6 | 99.2 | 99.8 |
| 640.00 | 58.7 | 100.0 | 100.0 |

Norwood - Storm No: 18 Date:26/11/86 No. Intervals: 23

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | 1.2 | 4.3 | 4.0 |
| 10.00 | 3.3 | 8.7 | 11.1 |
| 15.00 | 6.2 | 13.0 | 20.9 |
| 20.00 | 7.3 | 17.4 | 24.6 |
| 25.00 | 9.0 | 21.7 | 30.3 |
| 30.00 | 10.6 | 26.1 | 35.7 |
| 35.00 | 11.0 | 30.4 | 37.0 |
| 40.00 | 11.3 | 34.8 | 38.0 |
| 45.00 | 11.3 | 39.1 | 38.0 |
| 50.00 | 11.5 | 43.5 | 38.7 |
| 55.00 | 11.7 | 47.8 | 39.4 |
| 60.00 | 12.0 | 52.2 | 40.4 |
| 65.00 | 12.1 | 56.5 | 40.7 |
| 70.00 | 12.1 | 60.9 | 40.7 |
| 75.00 | 12.1 | 65.2 | 40.7 |
| 80.00 | 12.3 | 69.5 | 41.4 |
| 85.00 | 13.4 | 73.9 | 45.1 |
| 90.00 | 15.1 | 78.3 | 50.8 |
| 95.00 | 16.1 | 82.6 | 54.2 |
| 100.00 | 23.5 | 87.0 | 79.1 |
| 105.00 | 27.3 | 91.3 | 91.9 |
| 110.00 | 29.4 | 95.7 | 99.0 |
| 115.00 | 29.7 | 100.0 | 100.0 |

Norwood - Storm No: 19 Date:07/12/86 No. Intervals: 18

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | 1.4 | 5.6 | 5.5 |
| 10.00 | 2.7 | 11.1 | 10.5 |
| 15.00 | 5.7 | 16.7 | 22.3 |
| 20.00 | 11.1 | 22.2 | 43.4 |
| 25.00 | 17.6 | 27.8 | 68.8 |
| 30.00 | 20.9 | 33.3 | 81.6 |
| 35.00 | 22.3 | 38.9 | 87.1 |
| 40.00 | 23.0 | 44.4 | 89.8 |
| 45.00 | 23.4 | 50.0 | 91.4 |
| 50.00 | 23.6 | 55.6 | 92.2 |
| 55.00 | 23.9 | 61.1 | 93.4 |
| 60.00 | 24.0 | 66.7 | 93.8 |
| 65.00 | 24.3 | 72.2 | 94.9 |
| 70.00 | 24.6 | 77.8 | 96.1 |
| 75.00 | 24.8 | 83.3 | 96.9 |
| 80.00 | 25.0 | 88.9 | 97.7 |
| 85.00 | 25.4 | 94.4 | 99.2 |
| 90.00 | 25.6 | 100.0 | 100.0 |

Norwood - Storm No: 20 Date:17/12/86 No. Intervals: 125

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | [illegible] | .8 | 2.5 |
| [illegible] | [illegible] | 1.6 | 8.8 |

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | 1.0 | .8 | 2.5 |
| 10.00 | 3.9 | 1.6 | 9.9 |
| 15.00 | 4.1 | 2.4 | 10.4 |
| 20.00 | 4.1 | 3.2 | 10.4 |
| 25.00 | 4.1 | 4.0 | 10.4 |
| 30.00 | 4.2 | 4.8 | 10.6 |
| 35.00 | 4.2 | 5.6 | 10.6 |
| 40.00 | 4.3 | 6.4 | 10.9 |
| 45.00 | 4.3 | 7.2 | 10.9 |
| 50.00 | 4.3 | 8.0 | 10.9 |
| 55.00 | 4.3 | 8.8 | 10.9 |
| 60.00 | 4.3 | 9.6 | 10.9 |
| 65.00 | 4.3 | 10.4 | 10.9 |
| 70.00 | 4.3 | 11.2 | 10.9 |
| 75.00 | 5.1 | 12.0 | 12.9 |
| 80.00 | 9.6 | 12.8 | 24.3 |
| 85.00 | 12.6 | 13.6 | 31.9 |
| 90.00 | 17.1 | 14.4 | 43.3 |
| 95.00 | 23.9 | 15.2 | 60.5 |
| 100.00 | 26.7 | 16.0 | 67.6 |
| 105.00 | 27.7 | 16.8 | 70.1 |
| 110.00 | 28.8 | 17.6 | 72.9 |
| 115.00 | 29.9 | 18.4 | 75.7 |
| 120.00 | 30.3 | 19.2 | 75.7 |
| 125.00 | 30.9 | 20.0 | 78.2 |
| 130.00 | 31.1 | 20.8 | 78.7 |
| 135.00 | 31.5 | 21.6 | 79.7 |
| 140.00 | 31.9 | 22.4 | 80.9 |
| 145.00 | 32.2 | 23.2 | 81.5 |
| 150.00 | 32.5 | 24.0 | 82.3 |
| 155.00 | 32.7 | 24.8 | 82.8 |
| 160.00 | 33.1 | 25.6 | 83.8 |
| 165.00 | 33.3 | 26.4 | 84.3 |
| 170.00 | 33.3 | 27.2 | 84.3 |
| 175.00 | 33.3 | 28.0 | 84.3 |
| 180.00 | 33.3 | 28.8 | 84.3 |
| 185.00 | 33.3 | 29.6 | 84.3 |
| 190.00 | 33.3 | 30.4 | 84.3 |
| 195.00 | 33.4 | 31.2 | 84.6 |
| 200.00 | 33.4 | 32.0 | 84.6 |
| 205.00 | 33.4 | 32.8 | 84.6 |
| 210.00 | 33.4 | 33.6 | 84.6 |
| 215.00 | 33.4 | 34.4 | 84.6 |
| 220.00 | 33.4 | 35.2 | 84.6 |
| 225.00 | 33.4 | 36.0 | 84.6 |
| 230.00 | 33.4 | 36.8 | 84.6 |
| 235.00 | 33.4 | 37.6 | 84.6 |
| 240.00 | 33.4 | 38.4 | 84.6 |
| 245.00 | 33.4 | 39.2 | 84.6 |
| 250.00 | 33.4 | 40.0 | 84.6 |
| 255.00 | 33.4 | 40.8 | 84.6 |
| 260.00 | 33.5 | 41.6 | 84.8 |
| 265.00 | 33.5 | 42.4 | 84.8 |
| 270.00 | 33.6 | 43.2 | 85.1 |
| 275.00 | 33.6 | 44.0 | 85.1 |
| 280.00 | 33.6 | 44.8 | 85.1 |
| 285.00 | 33.6 | 45.6 | 85.1 |
| 290.00 | 33.6 | 46.4 | 85.1 |
| 295.00 | 33.6 | 47.2 | 85.1 |
| 300.00 | 33.7 | 48.0 | 85.3 |
| 305.00 | 33.9 | 48.8 | 85.8 |
| 310.00 | 34.2 | 49.6 | 86.6 |
| 315.00 | 34.5 | 50.4 | 87.3 |
| 320.00 | 34.8 | 51.2 | 88.1 |
| 325.00 | 35.0 | 52.0 | 88.6 |
| 330.00 | 35.3 | 52.8 | 89.4 |
| 335.00 | 35.8 | 53.6 | 90.6 |
| 340.00 | 36.0 | 54.4 | 91.1 |

| | | | |
|---|---|---|---|
| 315.00 | [illegible] | [illegible] | [illegible] |
| 320.00 | 34.8 | 51.2 | 88.1 |
| 325.00 | 35.0 | 52.0 | 88.6 |
| 330.00 | 35.3 | 52.8 | 89.4 |
| 335.00 | 35.8 | 53.6 | 90.6 |
| 340.00 | 36.0 | 54.4 | 91.1 |
| 345.00 | 36.1 | 55.2 | 91.4 |
| 350.00 | 36.3 | 56.0 | 91.9 |
| 355.00 | 36.5 | 56.8 | 92.4 |
| 360.00 | 36.6 | 57.6 | 92.7 |
| 365.00 | 36.9 | 58.4 | 93.4 |
| 370.00 | 37.2 | 59.2 | 94.2 |
| 375.00 | 37.3 | 60.0 | 94.4 |
| 380.00 | 37.4 | 60.8 | 94.7 |
| 385.00 | 37.5 | 61.6 | 94.9 |
| 390.00 | 37.6 | 62.4 | 95.2 |
| 395.00 | 37.7 | 63.2 | 95.4 |
| 400.00 | 37.8 | 64.0 | 95.7 |
| 405.00 | 37.8 | 64.8 | 95.7 |
| 410.00 | 37.8 | 65.6 | 95.7 |
| 415.00 | 37.8 | 66.4 | 95.7 |
| 420.00 | 37.8 | 67.2 | 95.7 |
| 425.00 | 37.8 | 68.0 | 95.7 |
| 430.00 | 37.8 | 68.8 | 95.7 |
| 435.00 | 37.8 | 69.6 | 95.7 |
| 440.00 | 37.9 | 70.4 | 95.9 |
| 445.00 | 37.9 | 71.2 | 95.9 |
| 450.00 | 38.0 | 72.0 | 96.2 |
| 455.00 | 38.1 | 72.8 | 96.5 |
| 460.00 | 38.1 | 73.6 | 96.5 |
| 465.00 | 38.1 | 74.4 | 96.5 |
| 470.00 | 38.1 | 75.2 | 96.5 |
| 475.00 | 38.1 | 76.0 | 96.5 |
| 480.00 | 38.1 | 76.8 | 96.5 |
| 485.00 | 38.1 | 77.6 | 96.5 |
| 490.00 | 38.1 | 78.4 | 96.5 |
| 495.00 | 38.1 | 79.2 | 96.5 |
| 500.00 | 38.1 | 80.0 | 96.5 |
| 505.00 | 38.1 | 80.8 | 96.5 |
| 510.00 | 38.1 | 81.6 | 96.5 |
| 515.00 | 38.1 | 82.4 | 96.5 |
| 520.00 | 38.1 | 83.2 | 96.5 |
| 525.00 | 38.1 | 84.0 | 96.5 |
| 530.00 | 38.2 | 84.8 | 96.7 |
| 535.00 | 38.2 | 85.6 | 96.7 |
| 540.00 | 38.2 | 86.4 | 96.7 |
| 545.00 | 38.2 | 87.2 | 96.7 |
| 550.00 | 38.2 | 88.0 | 96.7 |
| 555.00 | 38.3 | 88.8 | 97.0 |
| 560.00 | 38.3 | 89.6 | 97.0 |
| 565.00 | 38.3 | 90.4 | 97.0 |
| 570.00 | 38.3 | 91.2 | 97.0 |
| 575.00 | 38.4 | 92.0 | 97.2 |
| 580.00 | 38.4 | 92.8 | 97.2 |
| 585.00 | 38.5 | 93.6 | 97.5 |
| 590.00 | 38.5 | 94.4 | 97.5 |
| 595.00 | 38.6 | 95.2 | 97.7 |
| 600.00 | 38.7 | 96.0 | 98.0 |
| 605.00 | 39.2 | 96.8 | 99.2 |
| 610.00 | 39.3 | 97.6 | 99.5 |
| 615.00 | 39.4 | 98.4 | 99.7 |
| 620.00 | 39.4 | 99.2 | 99.7 |
| 625.00 | 39.5 | 100.0 | 100.0 |

Norw od - Storm No: 21    Date:29/12/86    No. Intervals: 29

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .3 | 3.4 | 1.0 |
| 10.00 | .3 | 6.9 | 1.0 |
| [illegible] | [illegible] | [illegible] | 1.3 |

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .3 | 3.4 | 1.0 |
| 10.00 | .3 | 6.9 | 1.0 |
| 15.00 | .4 | 10.3 | 1.3 |
| 20.00 | .4 | 13.8 | 1.3 |
| 25.00 | .4 | 17.2 | 1.3 |
| 30.00 | .4 | 20.7 | 1.3 |
| 35.00 | .4 | 24.1 | 1.3 |
| 40.00 | .5 | 27.6 | 1.6 |
| 45.00 | .5 | 31.0 | 1.5 |
| 50.00 | .7 | 34.5 | 2.3 |
| 55.00 | .8 | 37.9 | 2.6 |
| 60.00 | 1.2 | 41.4 | 3.9 |
| 65.00 | 6.6 | 44.8 | 21.6 |
| 70.00 | 12.6 | 48.3 | 41.3 |
| 75.00 | 13.0 | 51.7 | 42.6 |
| 80.00 | 15.6 | 55.2 | 51.1 |
| 85.00 | 19.0 | 58.6 | 62.3 |
| 90.00 | 22.5 | 62.1 | 73.8 |
| 95.00 | 25.6 | 65.5 | 83.9 |
| 100.00 | 26.3 | 69.0 | 86.2 |
| 105.00 | 26.8 | 72.4 | 87.9 |
| 110.00 | 27.2 | 75.9 | 89.2 |
| 115.00 | 27.5 | 79.3 | 90.2 |
| 120.00 | 27.8 | 82.8 | 91.1 |
| 125.00 | 27.9 | 86.2 | 91.5 |
| 130.00 | 30.1 | 84.7 | 98.7 |
| 135.00 | 30.3 | 93.1 | 99.3 |
| 140.00 | 30.4 | 56.6 | 99.7 |
| 145.00 | 30.5 | 100.0 | 100.0 |

Norwood – Storm No: 22 Date:21/01/[illegible] No. Intervals: 64

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | 1.0 | 1.6 | 2.7 |
| 10.00 | 1.5 | 3.1 | 4.0 |
| 15.00 | 2.3 | 4.7 | 6.1 |
| 20.00 | 3.5 | 6.3 | 9.4 |
| 25.00 | 4.2 | 7.8 | 11.2 |
| 30.00 | 4.4 | 9.4 | 11.8 |
| 35.00 | 4.5 | 10.9 | 12.0 |
| 40.00 | 4.5 | 12.5 | 12.0 |
| 45.00 | 4.5 | 14.1 | 12.0 |
| 50.00 | 4.5 | 15.6 | 12.0 |
| 55.00 | 4.5 | 17.2 | 12.0 |
| 60.00 | 4.5 | 18.8 | 12.0 |
| 65.00 | 4.5 | 20.3 | 12.0 |
| 70.00 | 4.5 | 21.9 | 12.0 |
| 75.00 | 4.5 | 23.4 | 12.0 |
| 80.00 | 4.6 | 25.0 | 12.3 |
| 85.00 | 4.6 | 26.6 | 12.3 |
| 90.00 | 4.6 | 28.1 | 12.3 |
| 95.00 | 4.6 | 29.7 | 12.3 |
| 100.00 | 4.6 | [illegible] | 12.3 |
| 105.00 | 4.6 | 32.8 | 12.3 |
| 110.00 | 4.6 | 34.4 | 12.3 |
| 115.00 | 4.6 | 35.9 | 12.3 |
| 120.00 | 4.7 | 37.5 | 12.6 |
| 125.00 | 6.0 | 39.1 | 16.0 |
| 130.00 | 9.0 | 40.6 | 24.1 |
| 135.00 | 9.9 | 42.2 | 26.5 |
| 140.00 | 13.9 | 43.8 | 37.2 |
| 145.00 | 17.9 | 45.3 | 47.9 |
| 150.00 | 21.8 | 46.9 | 58.3 |
| 155.00 | 26.3 | 48.4 | 70.3 |
| 160.00 | 29.6 | 50.0 | 79.1 |

| | | | |
|---|---|---|---|
| 140.00 | 13.9 | 43.8 | 37.2 |
| 145.00 | 17.8 | 45.3 | 47.8 |
| 150.00 | 21.8 | 46.5 | 58.3 |
| 155.00 | 26.3 | 48.4 | 70.3 |
| 160.00 | 29.6 | 50.0 | 79.1 |
| 165.00 | 31.6 | 51.6 | 84.5 |
| 170.00 | 33.6 | 53.1 | 89.8 |
| 175.00 | 35.2 | 54.7 | 94.1 |
| 180.00 | 35.8 | 56.3 | 95.7 |
| 185.00 | 36.1 | 57.8 | 96.5 |
| 190.00 | 36.3 | 59.4 | 97.1 |
| 195.00 | 36.4 | 60.9 | 97.3 |
| 200.00 | 36.4 | 62.5 | 97.3 |
| 205.00 | 36.4 | 64.1 | 97.3 |
| 210.00 | 36.4 | 65.6 | 97.3 |
| 215.00 | 36.4 | 67.2 | 97.3 |
| 220.00 | 36.4 | 68.8 | 97.3 |
| 225.00 | 36.4 | 70.3 | 97.3 |
| 230.00 | 36.4 | 71.9 | 97.3 |
| 235.00 | 36.4 | 73.4 | 97.3 |
| 240.00 | 36.4 | 75.0 | 97.3 |
| 245.00 | 36.4 | 76.6 | 97.3 |
| 250.00 | 36.4 | 78.1 | 97.3 |
| 255.00 | 36.7 | 79.7 | 98.1 |
| 260.00 | 37.1 | 81.3 | 99.2 |
| 265.00 | 37.2 | 82.8 | 99.5 |
| 270.00 | 37.2 | 84.4 | 99.5 |
| 275.00 | 37.2 | 85.9 | 99.5 |
| 280.00 | 37.2 | 87.5 | 99.5 |
| 285.00 | 37.2 | 89.1 | 99.5 |
| 290.00 | 37.2 | 90.6 | 99.5 |
| 295.00 | 37.2 | 92.2 | 99.5 |
| 300.00 | 37.2 | 93.8 | 99.5 |
| 305.00 | 37.2 | 95.3 | 99.5 |
| 310.00 | 37.2 | 96.9 | 99.5 |
| 315.00 | 37.3 | 98.4 | 99.7 |
| 320.00 | 37.4 | 100.0 | 100.0 |

Norwood - Storm No: 23 Date:27/11/87 No. Intervals: 72

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .3 | 1.4 | 1.2 |
| 10.00 | .4 | 2.8 | 1.6 |
| 15.00 | .6 | 4.2 | 2.5 |
| 20.00 | .6 | 5.6 | 2.5 |
| 25.00 | .6 | 6.9 | 2.5 |
| 30.00 | .7 | 8.3 | 2.9 |
| 35.00 | 7.5 | 9.7 | 30.9 |
| 40.00 | 16.0 | 11.1 | 65.8 |
| 45.00 | 18.7 | 12.5 | 77.0 |
| 50.00 | 20.1 | 13.9 | 82.7 |
| 55.00 | 20.3 | 15.3 | 83.5 |
| 60.00 | 20.5 | 16.7 | 84.4 |
| 65.00 | 21.0 | 18.1 | 86.4 |
| 70.00 | 21.1 | 19.4 | 86.8 |
| 75.00 | 21.3 | 20.8 | 87.7 |
| 80.00 | 21.3 | 22.2 | 87.7 |
| 85.00 | 21.4 | 23.6 | 88.1 |
| 90.00 | 21.4 | 25.0 | 88.1 |
| 95.00 | 21.5 | 26.4 | 88.5 |
| 100.00 | 21.5 | 27.8 | 88.5 |
| 105.00 | 21.5 | 29.2 | 88.5 |
| 110.00 | 21.6 | 30.6 | 88.9 |
| 115.00 | 21.7 | 31.9 | 89.3 |
| 120.00 | 21.7 | 33.3 | 89.3 |
| 125.00 | 21.8 | 34.7 | 89.7 |
| 130.00 | 22.0 | 36.1 | 90.5 |
| 135.00 | 22.1 | 37.5 | 90.9 |

| | | | |
|---|---|---|---|
| 115.00 | 21.7 | 31.9 | 89.3 |
| 120.00 | 21.7 | 33.3 | 89.3 |
| 125.00 | 21.8 | 34.7 | 89.7 |
| 130.00 | 22.0 | 36.1 | 90.5 |
| 135.00 | 22.1 | 37.5 | 90.9 |
| 140.00 | 22.1 | 38.9 | 90.9 |
| 145.00 | 22.2 | 40.3 | 91.4 |
| 150.00 | 22.2 | 41.7 | 91.4 |
| 155.00 | 22.2 | 43.1 | 91.4 |
| 160.00 | 22.2 | 44.4 | 91.4 |
| 165.00 | 22.2 | 45.8 | 91.4 |
| 170.00 | 22.2 | 47.2 | 91.4 |
| 175.00 | 22.3 | 48.6 | 91.8 |
| 180.00 | 22.5 | 50.0 | 92.6 |
| 185.00 | 22.7 | 51.4 | 93.4 |
| 190.00 | 22.9 | 52.8 | 94.2 |
| 195.00 | 23.2 | 54.2 | 95.5 |
| 200.00 | 23.3 | 55.6 | 95.9 |
| 205.00 | 23.4 | 56.9 | 96.3 |
| 210.00 | 23.5 | 58.3 | 96.7 |
| 215.00 | 23.6 | 59.7 | 97.1 |
| 220.00 | 23.7 | 61.1 | 97.5 |
| 225.00 | 23.7 | 62.5 | 97.5 |
| 230.00 | 23.7 | 63.9 | 97.5 |
| 235.00 | 23.8 | 65.3 | 97.9 |
| 240.00 | 23.9 | 66.7 | 98.4 |
| 245.00 | 23.9 | 68.1 | 98.4 |
| 250.00 | 24.0 | 69.4 | 98.8 |
| 255.00 | 24.0 | 70.8 | 98.8 |
| 260.00 | 24.0 | 72.2 | 98.8 |
| 265.00 | 24.1 | 73.6 | 99.2 |
| 270.00 | 24.1 | 75.0 | 99.2 |
| 275.00 | 24.1 | 76.4 | 99.2 |
| 280.00 | 24.1 | 77.8 | 99.2 |
| 285.00 | 24.1 | 79.2 | 99.2 |
| 290.00 | 24.1 | 80.6 | 99.2 |
| 295.00 | 24.1 | 81.9 | 99.2 |
| 300.00 | 24.1 | 83.3 | 99.2 |
| 305.00 | 24.1 | 84.7 | 99.2 |
| 310.00 | 24.1 | 86.1 | 99.2 |
| 315.00 | 24.1 | 87.5 | 99.2 |
| 320.00 | 24.1 | 88.9 | 99.2 |
| 325.00 | 24.2 | 90.3 | 99.6 |
| 330.00 | 24.2 | 91.7 | 99.6 |
| 335.00 | 24.2 | 93.1 | 99.6 |
| 340.00 | 24.2 | 94.4 | 99.6 |
| 345.00 | 24.2 | 95.8 | 99.6 |
| 350.00 | 24.2 | 97.2 | 99.6 |
| 355.00 | 24.2 | 98.6 | 99.6 |
| 360.00 | 24.3 | 100.0 | 100.0 |

Norwood - Storm No: 24 Date:24/12/87 No. Intervals: 69

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .6 | 1.4 | 1.3 |
| 10.00 | 1.1 | 2.9 | 2.4 |
| 15.00 | 1.3 | 4.3 | 2.8 |
| 20.00 | 1.5 | 5.8 | 3.2 |
| 25.00 | 1.6 | 7.2 | 3.4 |
| 30.00 | 1.6 | 8.7 | 3.4 |
| 35.00 | 1.7 | 10.1 | 3.7 |
| 40.00 | 1.9 | 11.6 | 4.1 |
| 45.00 | 1.9 | 13.0 | 4.1 |
| 50.00 | 1.9 | 14.5 | 4.1 |
| 55.00 | 1.9 | 15.9 | 4.1 |
| [illegible] | [illegible] | 17.4 | 4.1 |

| | | | |
|---|---|---|---|
| 50.00 | 1.9 | 14.5 | 4.1 |
| 55.00 | 1.9 | 15.9 | 4.1 |
| 60.00 | 1.9 | 17.4 | 4.1 |
| 65.00 | 1.9 | 18.8 | 4.1 |
| 70.00 | 1.9 | 20.3 | 4.1 |
| 75.00 | 1.9 | 21.7 | 4.1 |
| 80.00 | 1.9 | 23.2 | 4.1 |
| 85.00 | 2.1 | 24.6 | 4.5 |
| 90.00 | 2.1 | 26.1 | 4.5 |
| 95.00 | 2.2 | 27.5 | 4.7 |
| 100.00 | 3.3 | 29.0 | 7.1 |
| 105.00 | 5.0 | 30.4 | 10.8 |
| 110.00 | 5.7 | 31.9 | 12.3 |
| 115.00 | 12.0 | 33.3 | 25.9 |
| 120.00 | 14.5 | 34.8 | 31.3 |
| 125.00 | 18.2 | 36.2 | 39.2 |
| 130.00 | 19.5 | 37.7 | 42.0 |
| 135.00 | 20.7 | 39.1 | 44.6 |
| 140.00 | 23.0 | 40.6 | 49.6 |
| 145.00 | 28.1 | 42.0 | 60.6 |
| 150.00 | 31.6 | 43.5 | 68.1 |
| 155.00 | 35.4 | 44.9 | 76.3 |
| 160.00 | 37.4 | 46.4 | 80.6 |
| 165.00 | 38.4 | 47.8 | 82.8 |
| 170.00 | 39.7 | 49.3 | 85.6 |
| 175.00 | 40.9 | 50.7 | 88.1 |
| 180.00 | 42.1 | 52.2 | 90.7 |
| 185.00 | 42.5 | 53.6 | 91.6 |
| 190.00 | 42.6 | [illegible] | 91.8 |
| 195.00 | 42.6 | 56.5 | 91.8 |
| 200.00 | 43.0 | [illegible] | 92.7 |
| 205.00 | 43.7 | 59.4 | 94.2 |
| 210.00 | 43.6 | 60.9 | 94.0 |
| 215.00 | 44.0 | 62.3 | 94.8 |
| 220.00 | 44.1 | 63.8 | 95.0 |
| 225.00 | 44.1 | 65.2 | 95.0 |
| 230.00 | 44.1 | 66.7 | 95.0 |
| 235.00 | 44.1 | 68.1 | 95.0 |
| 240.00 | 44.1 | 69.6 | 95.0 |
| 245.00 | 44.1 | 71.0 | 95.0 |
| 250.00 | 44.1 | 72.5 | 95.0 |
| 255.00 | 44.1 | 73.9 | 95.0 |
| 260.00 | 44.2 | 75.4 | 95.3 |
| 265.00 | 44.2 | 76.8 | 95.3 |
| 270.00 | 44.3 | 78.3 | 95.5 |
| 275.00 | 44.6 | 79.7 | 96.1 |
| 280.00 | 44.9 | 81.2 | 96.8 |
| 285.00 | 45.1 | 82.6 | 97.2 |
| 290.00 | 45.2 | 84.1 | 97.4 |
| 295.00 | 45.3 | 85.5 | 97.6 |
| 300.00 | 45.3 | 87.0 | 97.6 |
| 305.00 | 45.3 | 88.4 | 97.6 |
| 310.00 | 45.3 | 89.9 | 97.6 |
| 315.00 | 45.4 | 91.3 | 97.8 |
| 320.00 | 45.5 | 92.8 | 98.1 |
| 325.00 | 45.8 | 94.2 | 98.7 |
| 330.00 | 46.2 | 95.7 | 99.6 |
| 335.00 | 46.3 | 97.1 | 99.8 |
| 340.00 | 46.3 | 98.6 | 99.8 |
| 345.00 | 46.4 | 100.0 | 100.0 |

Norwood - Storm No: 25    Date:02/03/88    No. Intervals: 18

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .3 | 5.6 | .7 |
| 10.00 | 1.6 | 11.1 | 3.5 |
| 15.00 | 4.4 | 16.7 | 10.4 |

| | | | |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .3 | 5.6 | .7 |
| 10.00 | 1.6 | 11.1 | 3.8 |
| 15.00 | 4.4 | 16.7 | 10.4 |
| 20.00 | 7.2 | 22.2 | 17.1 |
| 25.00 | 9.6 | 27.8 | 22.7 |
| 30.00 | 13.4 | 33.3 | 31.8 |
| 35.00 | 17.1 | 38.9 | 40.5 |
| 40.00 | 23.0 | 44.4 | 54.5 |
| 45.00 | 26.5 | 50.0 | 62.8 |
| 50.00 | 29.2 | 55.6 | 69.2 |
| 55.00 | 30.4 | 61.1 | 72.0 |
| 60.00 | 34.8 | 66.7 | 82.5 |
| 65.00 | 37.4 | 72.2 | 88.6 |
| 70.00 | 38.8 | 77.8 | 91.9 |
| 75.00 | 39.4 | 83.3 | 93.4 |
| 80.00 | 41.0 | 88.9 | 97.2 |
| 85.00 | 42.0 | 94.4 | 99.5 |
| 90.00 | 42.2 | 100.0 | 100.0 |

Norwood - Storm No: 26 Date:24/01/90 No. Intervals: 19

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .8 | 5.3 | 2.3 |
| 10.00 | 5.3 | 10.5 | 15.4 |
| 15.00 | 13.0 | 15.8 | 37.7 |
| 20.00 | 19.2 | 21.1 | 55.7 |
| 25.00 | 26.5 | 26.3 | 76.8 |
| 30.00 | 30.4 | [illegible] | 88.1 |
| 35.00 | 31.4 | 36.8 | 91.0 |
| 40.00 | 31.9 | 42.1 | 92.5 |
| 45.00 | 32.2 | 47.4 | 93.3 |
| 50.00 | 32.3 | 52.6 | 93.6 |
| 55.00 | 32.4 | 57.9 | 93.9 |
| 60.00 | 32.7 | 63.2 | 94.8 |
| 65.00 | 33.1 | 68.4 | 95.9 |
| 70.00 | 33.2 | 73.7 | 96.2 |
| 75.00 | 33.4 | 78.9 | 96.8 |
| 80.00 | 33.5 | 84.2 | 97.1 |
| 85.00 | 34.0 | 89.5 | 98.6 |
| 90.00 | 34.4 | 94.7 | 99.7 |
| 95.00 | 34.5 | 100.0 | 100.0 |

Norwood - Storm No: 27 Date:11/02/90 No. Intervals: 12

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | 2.0 | 8.3 | 8.2 |
| 10.00 | 7.5 | 16.7 | 30.7 |
| 15.00 | 11.5 | 25.0 | 47.1 |
| 20.00 | 16.0 | 33.3 | 65.6 |
| 25.00 | 18.5 | 41.7 | 75.8 |
| 30.00 | 20.5 | 50.0 | 84.0 |
| 35.00 | 22.0 | 58.3 | 90.2 |
| 40.00 | 22.7 | 66.7 | 93.0 |
| 45.00 | 23.3 | 75.0 | 95.5 |
| 50.00 | 23.7 | 83.3 | 97.1 |
| 55.00 | 24.3 | 91.7 | 99.6 |
| 60.00 | 24.4 | 100.0 | 100.0 |

Norwood - Storm No: 28 Date:05/04/90 No. Intervals: 18

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .2 | 5.6 | .7 |
| 10.00 | [illegible] | [illegible] | 4.0 |

Norwood - Storm No: 28  Date:05/04/90  No. Intervals: 18

| Time(min) | Rain(mm) | %Time | %Rain |
|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 0.0 |
| 5.00 | .2 | 5.6 | .7 |
| 10.00 | 1.2 | [illegible] | 4.0 |
| 15.00 | 5.0 | 16.7 | 16.5 |
| 20.00 | 11.5 | 22.2 | 38.0 |
| 25.00 | 15.0 | 27.8 | 49.5 |
| 30.00 | 18.6 | 33.3 | 61.4 |
| 35.00 | 20.6 | 38.9 | 68.0 |
| 40.00 | 21.3 | 44.4 | 70.3 |
| 45.00 | 22.1 | 50.0 | 72.9 |
| 50.00 | 26.7 | 55.6 | 88.1 |
| 55.00 | 29.0 | 61.1 | 95.7 |
| 60.00 | 29.5 | 66.7 | 97.4 |
| 65.00 | 30.0 | 72.2 | 99.0 |
| 70.00 | 30.1 | 77.8 | 99.3 |
| 75.00 | 30.2 | 83.3 | 99.7 |
| 80.00 | 30.2 | 88.9 | 99.7 |
| 85.00 | 30.2 | 94.4 | 99.7 |
| 90.00 | 30.3 | 100.0 | 100.0 |

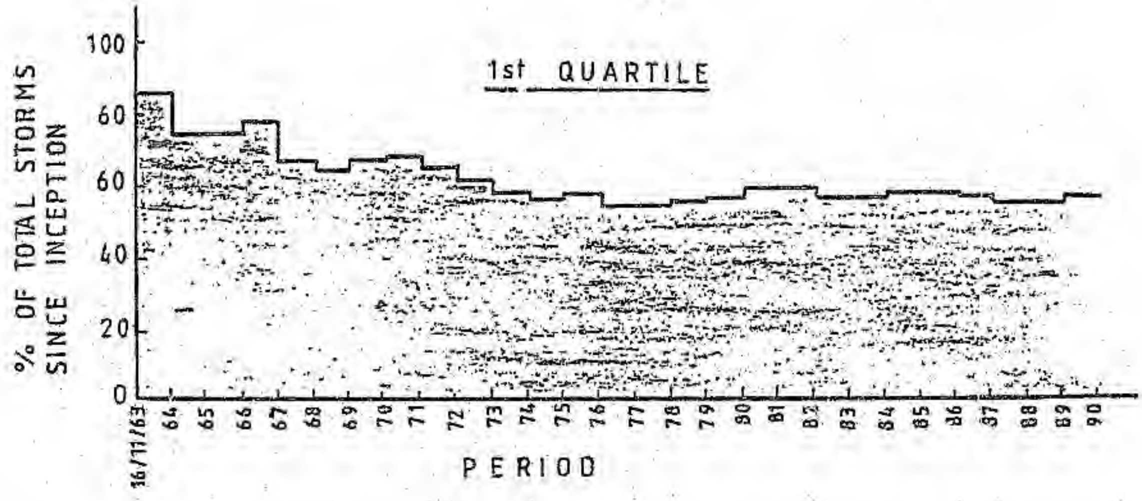
APPENDIX E

## Mass curves of Norwood storms

(Tables and Graphs in this Appendix are synthesised from output from the computer programs NORANAL and NORMOR as described in APPENDIX D.)

FIGURE E1 shows the cumulative relative frequency of each quartile at annual intervals. Since the cumulative relative frequencies are essentailly stable after 14 years, it is concluded from these plots that the length of record is adequate for the purpose of quartile classification.

FIGURE E2 shows the range of rainfall depths for each quartile. Similarly, FIGURE E3 shows the range of storm durations for each quartile. Rainfall depth is plotted against storm duration in FIGURE E4 for all storms. It is concluded that there is no apparent relationship between quartile and either storm duration or rainfall depth.



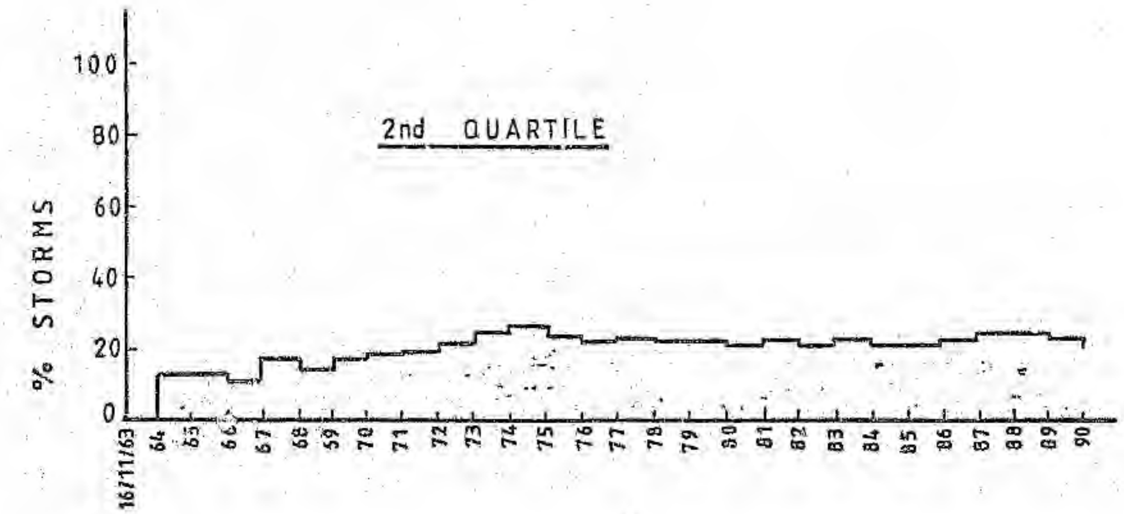




FIGURE E1 Cumulative Relative Frequency of Quartiles

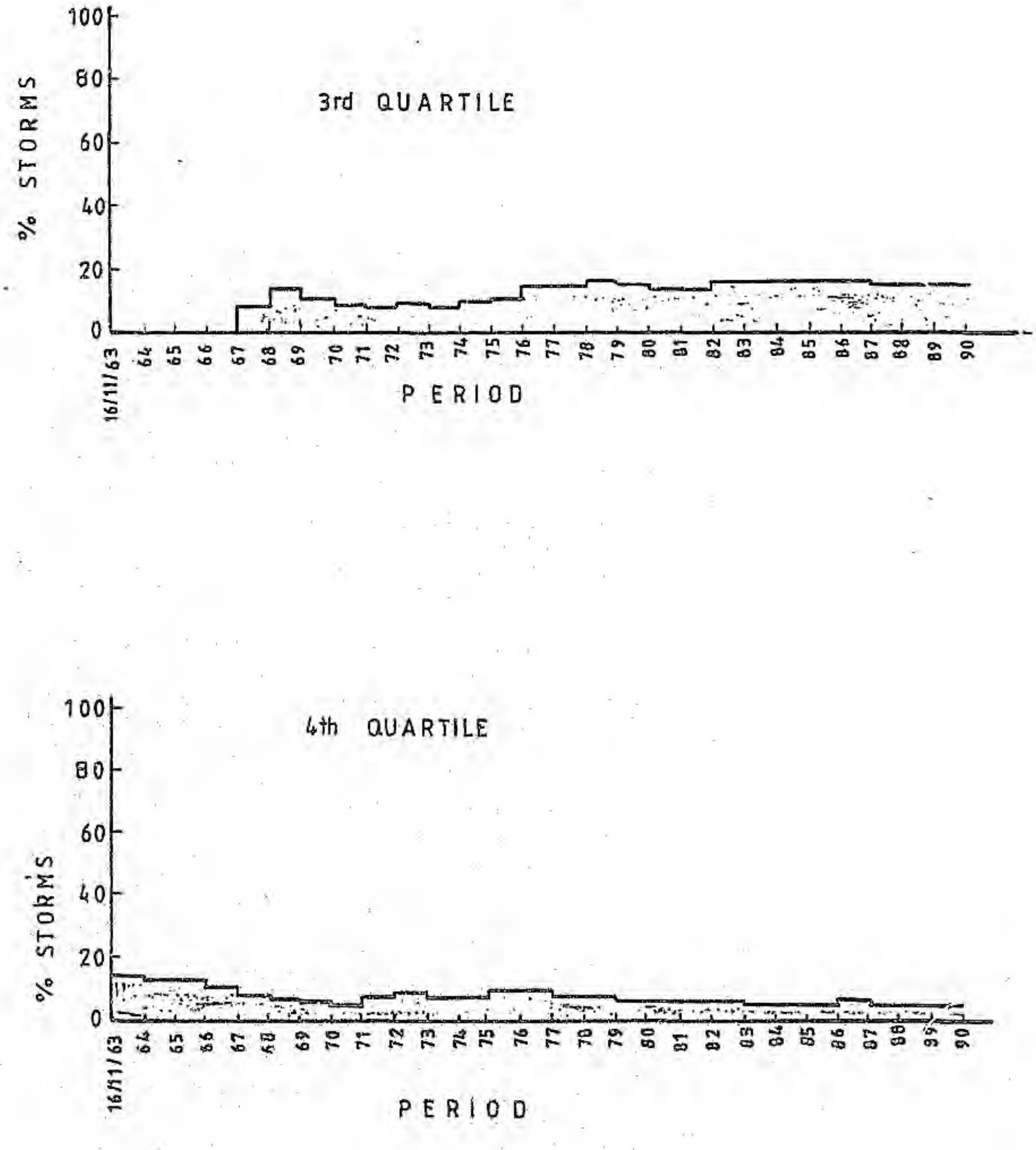



**FIGURE E1** (cont) Cumulative Relative Frequency of Quartiles

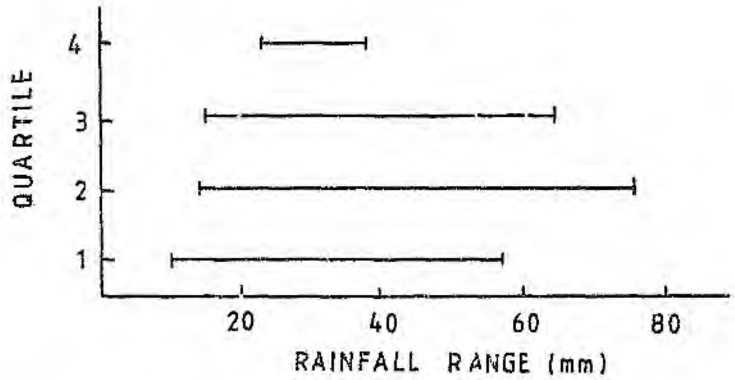



FIGURE E 2 Relationship between Rainfall Depth and Quartile

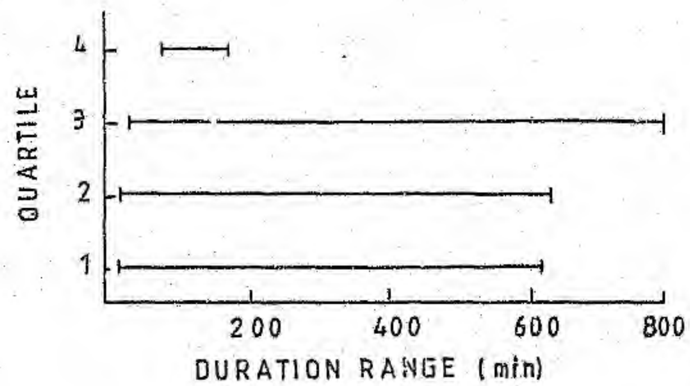



FIGURE E 3 Relationship between Storm Duration and Quartile

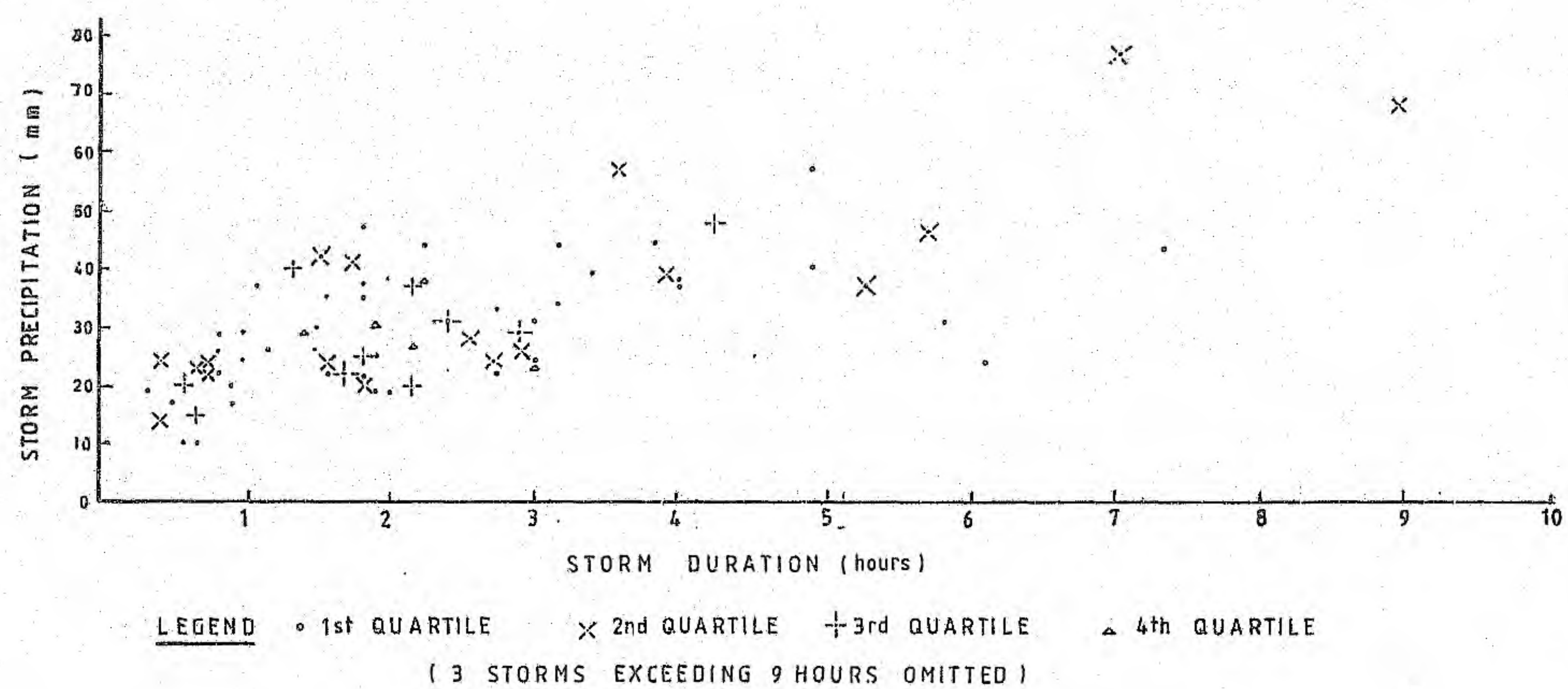



**FIGURE E4 Relationship Between Storm Duration and Precipitation**

Table E1 Quartile values - First quartile storms

| Storm no. | | $P_{25}$ | $P_{50}$ | $P_{75}$ |
|---|---|---|---|---|
| Watson | 1 | 91 | 96 | 99 |
| | 3 | 64 | 78 | 90 |
| | 4 | 82 | 97 | 100 |
| | 5 | 88 | 90 | 98 |
| | 6 | 59 | 91 | 99 |
| | 7 | 52 | 67 | 98 |
| | 9 | 60 | 70 | 89 |
| | 12 | 94 | 99 | 99 |
| | 14 | 60 | 83 | 94 |
| | 15 | 52 | 97 | 100 |
| | 17 | 47 | 80 | 95 |
| | 18 | 64 | 98 | 99 |
| | 19 | 42 | 74 | 94 |
| | 21 | 77 | 83 | 91 |
| | 22 | 48 | 81 | 97 |
| | 23 | 69 | 93 | 97 |
| | 25 | 54 | 90 | 96 |
| | 28 | 90 | 90 | 99 |
| | 30 | 63 | 73 | 90 |
| | 31 | 49 | 75 | 92 |
| | 34 | 51 | 87 | 95 |
| | 37 | 92 | 93 | 99 |
| | 40 | 76 | 85 | 93 |
| | 42 | 79 | 99 | 100 |
| | 44 | 79 | 99 | 99 |
| | 47 | 61 | 94 | 98 |
| | 50 | 84 | 92 | 95 |
| | 51 | 55 | 85 | 99 |
| | 53 | 54 | 82 | 99 |
| | 54 | 78 | 92 | 96 |
| Cross | 1 | 75 | 94 | 98 |
| | 2 | 48 | 85 | 97 |
| | 3 | 70 | 83 | 96 |
| | 4 | 54 | 73 | 100 |
| | 9 | 71 | 82 | 88 |
| | 11 | 66 | 95 | 99 |
| | 12 | 51 | 94 | 97 |
| | 13 | 52 | 88 | 97 |
| | 15 | 67 | 99 | 100 |
| | 16 | 45 | 59 | 89 |
| | 19 | 56 | 91 | 95 |
| | 20 | 83 | 87 | 96 |
| | 23 | 88 | 93 | 100 |

Table E1 (ctd.)

| Storm no. | | $P_{25}$ | $P_{50}$ | $P_{75}$ |
|---|---|---|---|---|
| Cross | 26 | 72 | 94 | 97 |
| | 27 | 47 | 84 | 95 |
| | 28 | 44 | 73 | 99 |
| Total : | | 3003 | 3987 | 4432 |
| Average (46 storms) : | | 65 | 87 | 96 |
| Range : | | 42 - 94 | 59 - 99 | 88 - 100 |

Average, upper limit and lower limit values plotted on Figure E5.

Table E2 Quartile values - Second quartile storms

| Storm no. | | $P_{25}$ | $P_{50}$ | $P_{75}$ |
|---|---|---|---|---|
| Watson | 8 | 29 | 68 | 90 |
| | 10 | 14 | 53 | 86 |
| | 16 | 47 | 94 | 99 |
| | 20 | 27 | 80 | 94 |
| | 26 | 25 | 68 | 95 |
| | 27 | 8 | 75 | 99 |
| | 33 | 30 | 92 | 97 |
| | 35 | 36 | 82 | 99 |
| | 36 | 40 | 83 | 97 |
| | 38 | 21 | 71 | 79 |
| | 48 | 24 | 96 | 99 |
| | 52 | 18 | 92 | 97 |
| Cross | 5 | 13 | 96 | 99 |
| | 8 | 30 | 93 | 99 |
| | 14 | 6 | 57 | 83 |
| | 17 | 27 | 72 | 97 |
| | 22 | 12 | 79 | 97 |
| | 24 | 5 | 87 | 95 |
| | 25 | 20 | 63 | 90 |
| Total : | | 432 | 1501 | 1791 |
| Average (19 storms) : | | 23 | 79 | 94 |
| Range : | | 5 - 47 | 53 - 96 | 79 - 99 |

Average, upper limit and lower limit values plotted on Figure E6.

Table E3 Quartile values - Third quartile storms

| Storm no. | | $P_{25}$ | $P_{50}$ | $P_{75}$ |
|---|---|---|---|---|
| Watson | 11 | 1 | 21 | 93 |
| | 13 | 2 | 7 | 80 |
| | 29 | 11 | 19 | 97 |
| | 39 | 14 | 38 | 74 |
| | 43 | 15 | 34 | 95 |
| | 45 | 5 | 17 | 59 |
| | 46 | 2 | 4 | 90 |
| | 49 | 3 | 19 | 91 |
| Cross | 6 | 31 | 51 | 87 |
| | 7 | 3 | 20 | 99 |
| | 10 | 6 | 43 | 88 |
| | 21 | 1 | 42 | 89 |
| Total : | | 94 | 315 | 1042 |
| Average (12 storms) : | | 8 | 26 | 87 |
| Range : | | 1 - 31 | 4 - 51 | 59 - 99 |

Average, upper limit and lower limit values plotted on Figure E7.

Table E4 Quartile values - Fourth quartile storms

| Storm no. | | $P_{25}$ | $P_{50}$ | $P_{75}$ |
|---|---|---|---|---|
| Watson | 2 | 5 | 5 | 19 |
| | 24 | 43 | 43 | 44 |
| | 32 | 10 | 43 | 67 |
| | 41 | 6 | 11 | 41 |
| Cross | 18 | 34 | 40 | 47 |
| Total : | | 98 | 142 | 218 |
| Average (5 storms) : | | 20 | 28 | 44 |
| Range : | | 5 - 43 | 5 - 43 | 19 - 67 |

Average, upper limit and lower limit values plotted on Figure E8.

Table E5 Quartile values - All storms

| Totals | $P_{25}$ | $P_{50}$ | $P_{75}$ |
|---|---|---|---|
| 1st Quartile | 3003 | 3987 | 4432 |
| 2nd Quartile | 432 | 1501 | 1791 |
| 3rd Quartile | 94 | 315 | 1042 |
| 4th Quartile | 98 | 142 | 218 |
| Total : | 3627 | 5945 | 7483 |
| Average (82 storms) : | 44 | 73 | 91 |
| Range : | 1 - 94 | 4 -99 | 19 -100 |

Notes :

1. Range from Tables E1-E4.
2. Average, upper limit and lower limit values plotted on Figure E9.

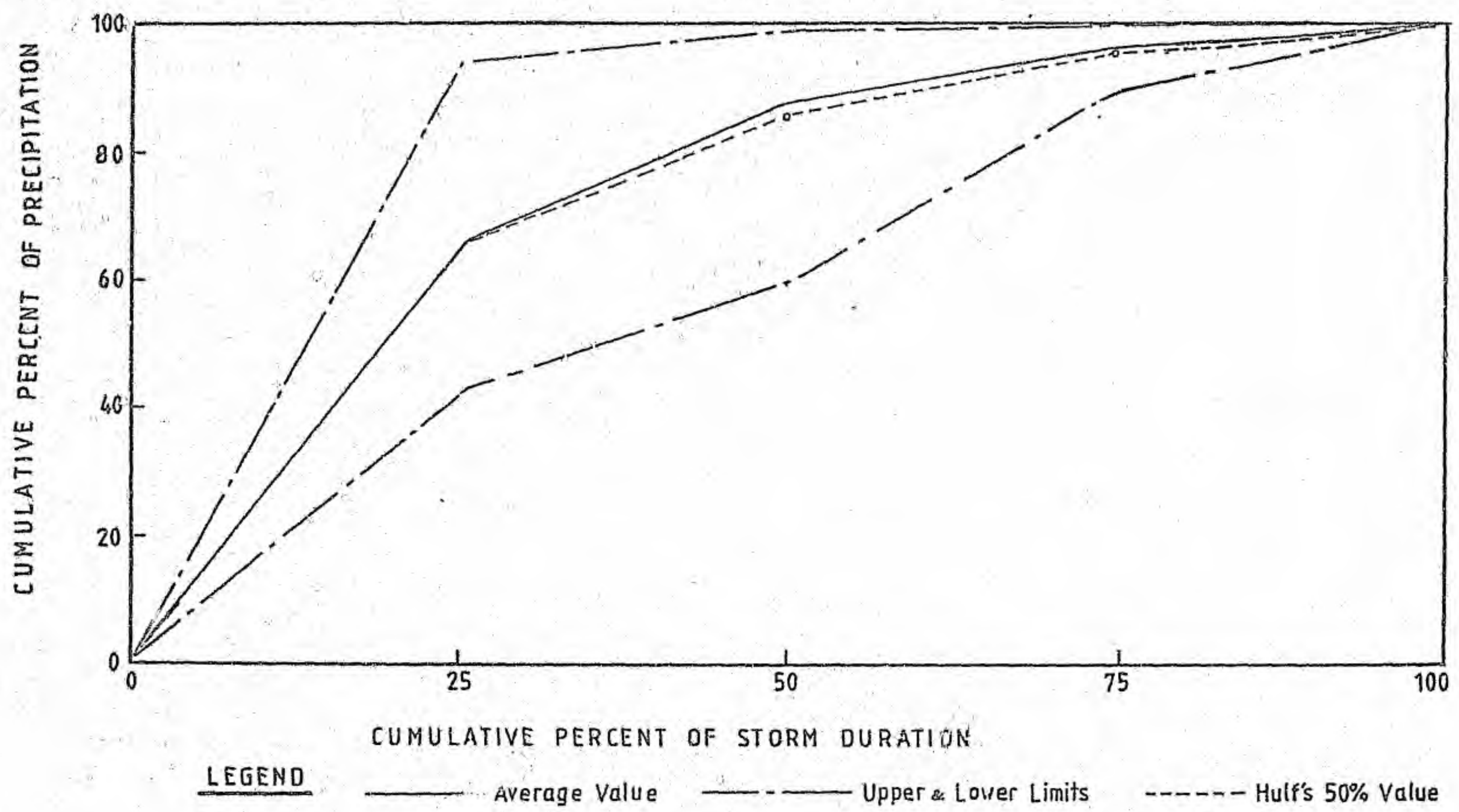
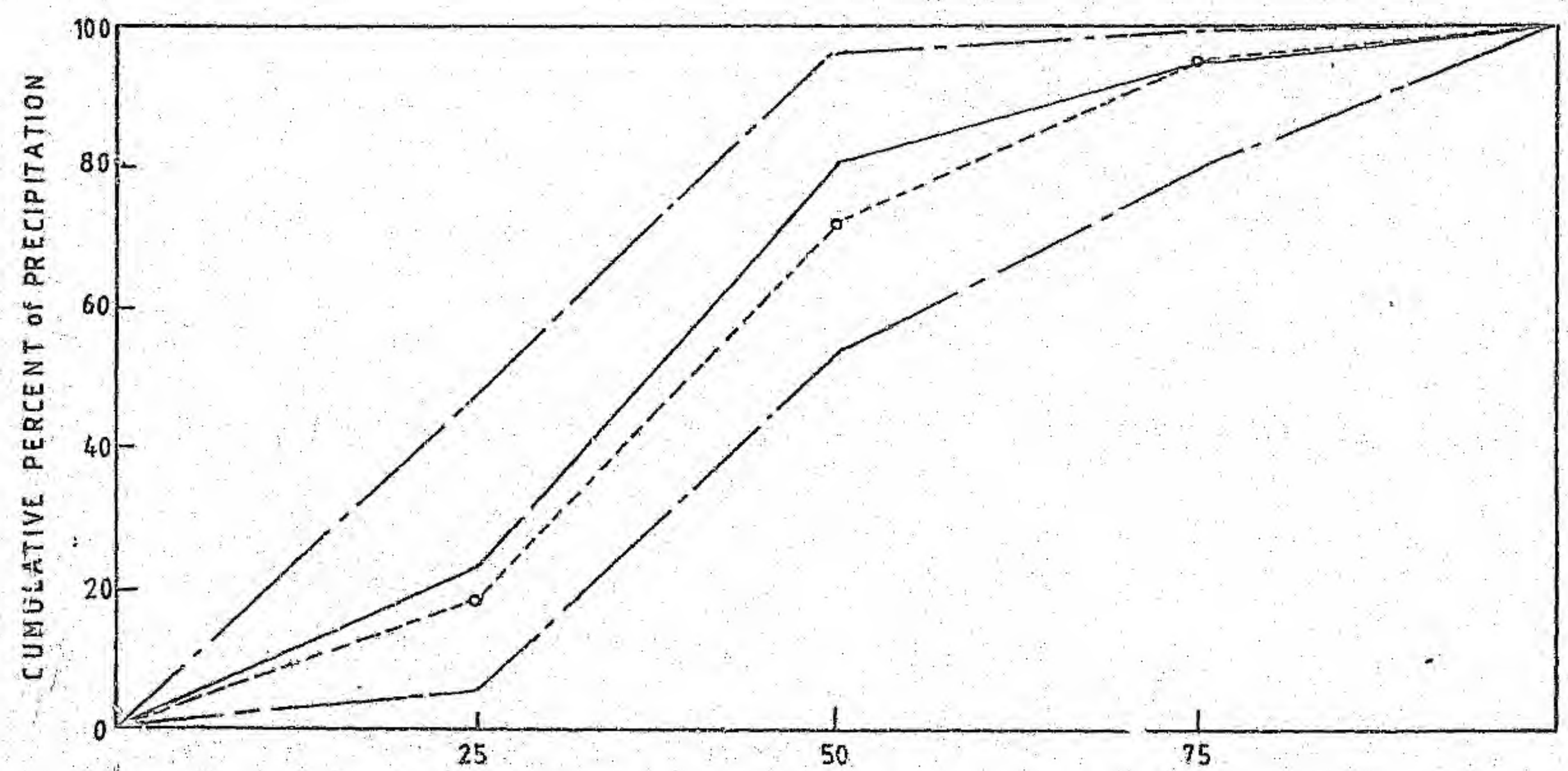



**FIGURE E5** Dimensionless Mass Curve – First Quartile Storms




(Refer FIGURE E5 for LEGEND)

**FIGURE E6** Dimensionless Mass Curve - Second Quartile Sto...s

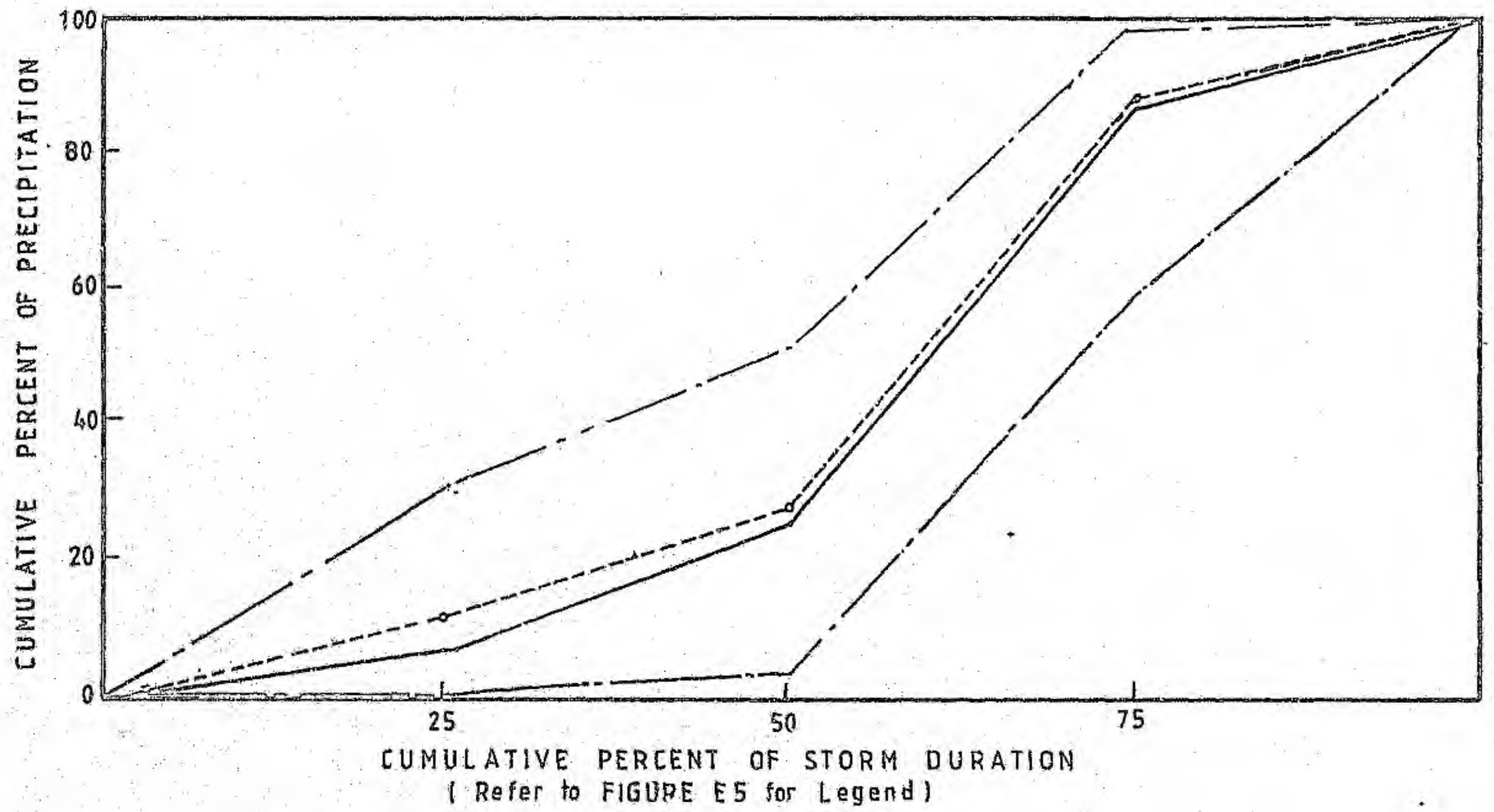



FIGURE E7 Dimensionless Mass Curve — Third Quartile Storms.

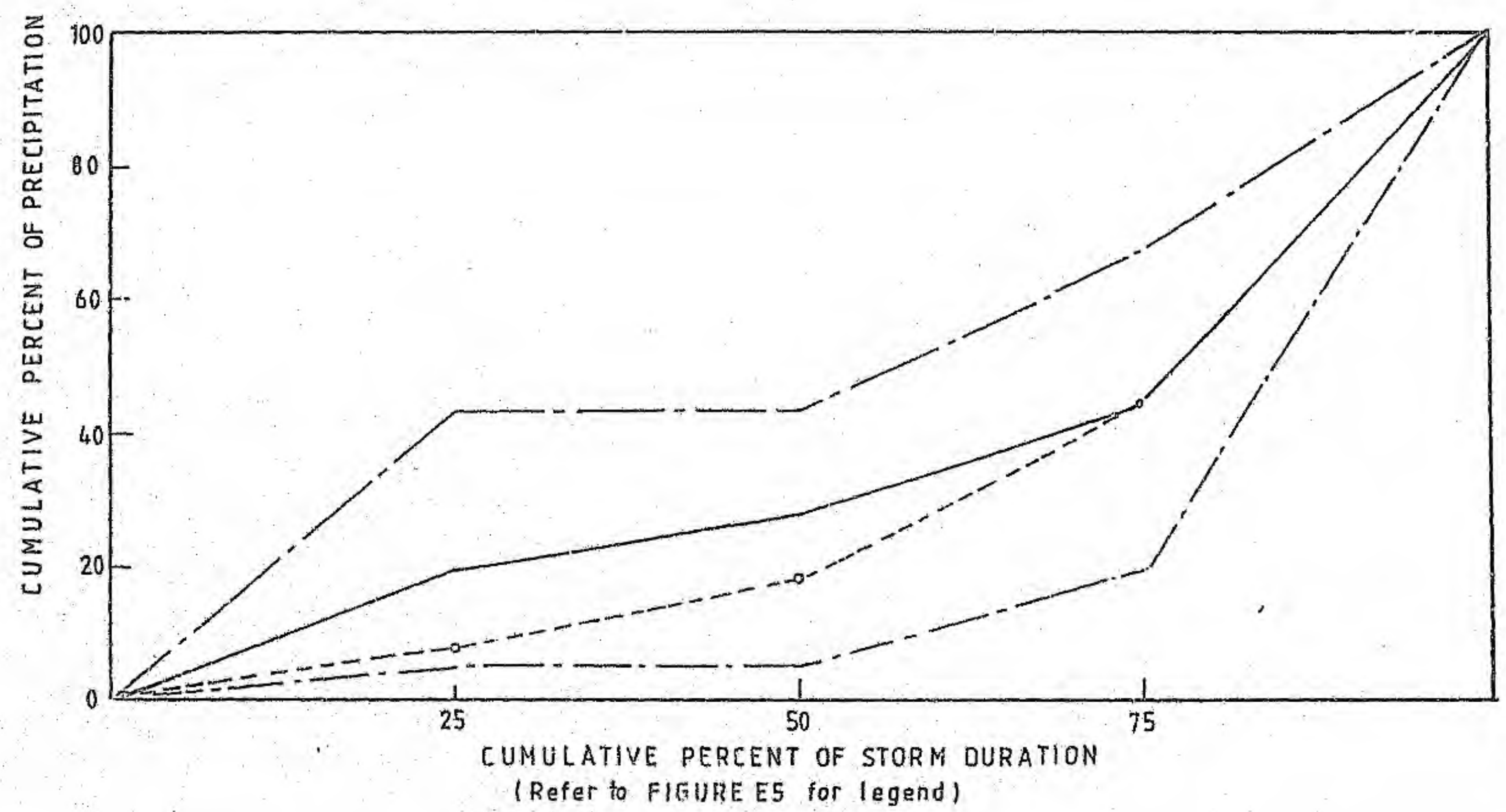



**FIGURE E8** Dimensionless Mass Curve - Fourth Quartile Storms

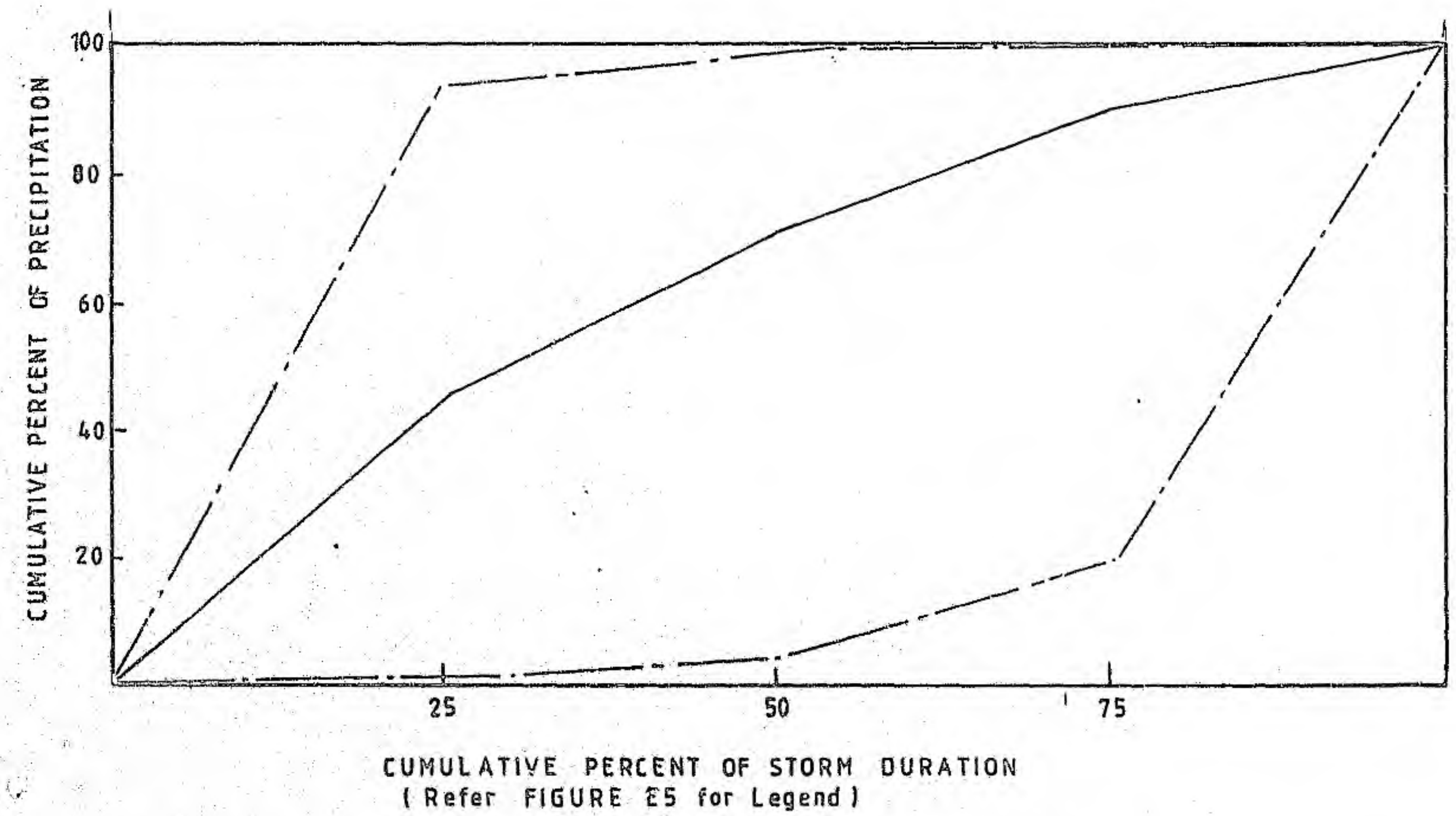



FIGURE E9 Dimensionless Mass Curve - All storms

APPENDIX F

User-input hyetograph data used in HYDROSIM data file

Table F1 Parameters for uniform, triangular and bimodal triangular "user-input" storms

| | Uniform | Triangular | BTD |
|---|---|---|---|
| Duration : | | | |
| Of storm (min) | 20 | 20 | 20 |
| Of first peak as ratio | - | - | 0,56 |
| Storm depth (mm) | 30 | 36 | 24 |
| Max. intensity (mm/h): | | | |
| 1st peak | 91 | 215 | 195 |
| 2nd peak | - | - | 75 |
| Time to peak ratio: | | | |
| 1st peak | - | 0,39 | 0,39 |
| 2nd peak | - | - | 0,43 |

Notes :

1. The triangular distribution above is the "triangular moment" version of Sutherland (1983).

Table F2 Intensity-time pairs for triangular and bimodal triangular storms

| Time (min) | Intensity (mm/h) Triangular | Bimodal triangular |
|---|---|---|
| 1 | 13,5 | 24 |
| 2 | 40,5 | 73 |
| 3 | 67,5 | 121 |
| 4 | 94,5 | 169 |
| 5 | 121,5 | 182 |
| 6 | 148,5 | 154 |
| 7 | 175,5 | 126 |
| 8 | 202,5 | 98 |
| 9 | 207 | 70 |
| 10 | 189 | 42 |
| 11 | 171 | 14 |
| 12 | 153 | 9 |
| 13 | 135 | 27 |
| 14 | 117 | 45 |
| 15 | 99 | 63 |
| 16 | 81 | 68 |
| 17 | 63 | 53 |
| 18 | 45 | 38 |
| 19 | 27 | 23 |
| 20 | 9 | 8 |

Table F3 Intensity-time pairs for locally-derived mass curves

| DDF Relationship : | | Intensity (mm/h) | | |
|---|---|---|---|---|
| | | Uniform | Triangular | BTD |
| Quartile | Time (min) | | | |
| 1 | 5 | 236 | 279 | 185 |
| | 10 | 80 | 94 | 62 |
| | 15 | 32 | 40 | 25 |
| | 20 | 14 | 17 | 12 |
| 2 | 5 | 83 | 99 | 65 |
| | 10 | 204 | 241 | 158 |
| | 15 | 54 | 65 | 43 |
| | 20 | 22 | 25 | 17 |
| 3 | 5 | 29 | 35 | 23 |
| | 10 | 66 | 77 | 52 |
| | 15 | 221 | 262 | 173 |
| | 20 | 47 | 56 | 37 |
| 4 | 5 | 72 | 86 | 56 |
| | 10 | 30 | 34 | 23 |
| | 15 | 58 | 68 | 46 |
| | 20 | 203 | 241 | 160 |
| Average of four quartiles | 5 | 160 | 190 | 125 |
| | 10 | 104 | 124 | 83 |
| | 15 | 66 | 78 | 52 |
| | 20 | 32 | 38 | 25 |

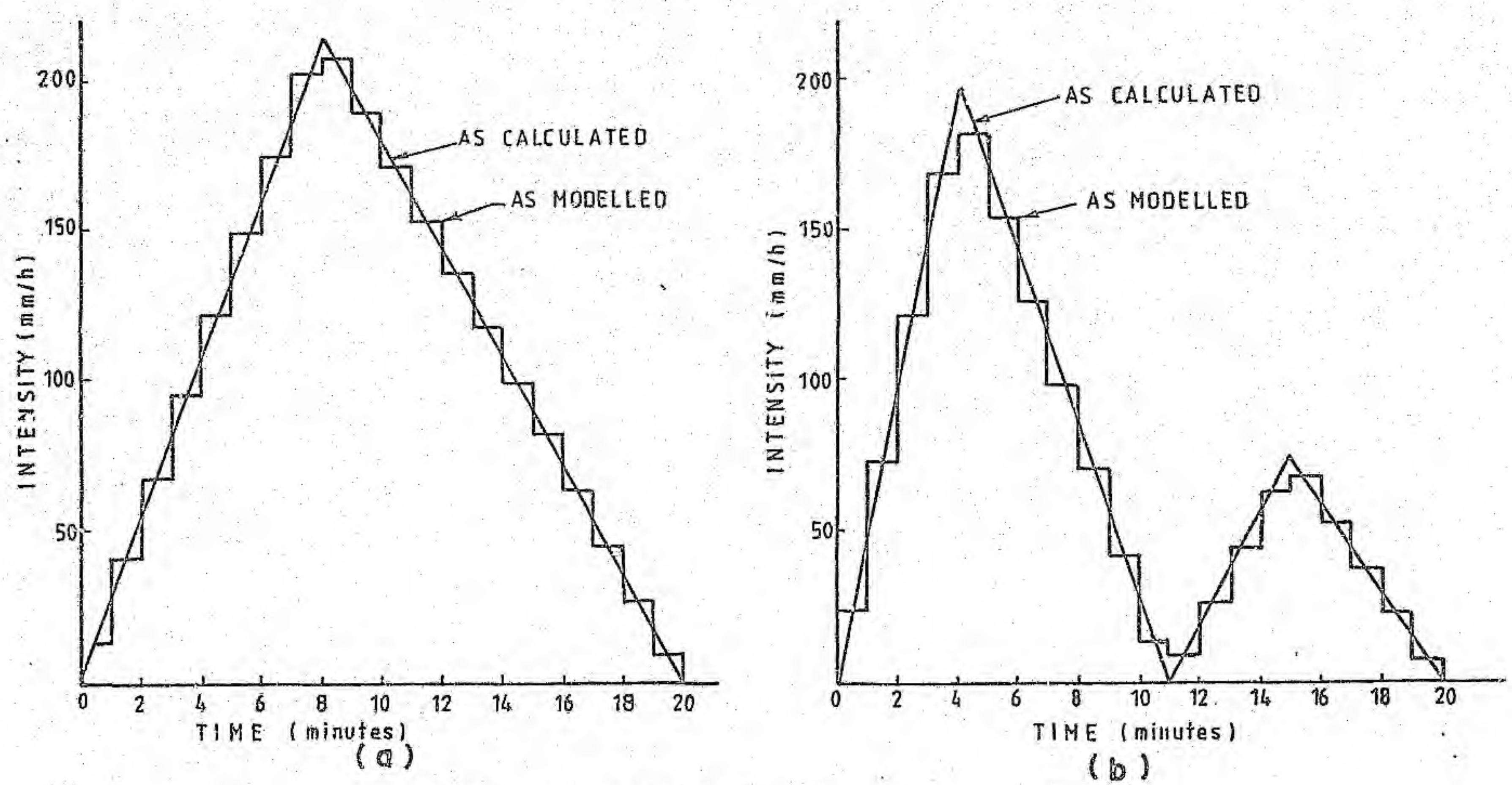



**FIGURE F1** User-input Hyetographs for
a) Triangular distribution
b) Bimodal triangular distribution

APPENDIX G

Listing of typical HYDROSIM data file

## DATA DUMP FACILITY

File name : EMMATEST

Title :

1 - EMMARENTIA CATCHMENT
2 - Effect of different rainfall distributions on
3 - runoff - Average BMD DDF
4 - ------------------------------------

Infiltration routine - SIMPLIFIED
Routing type - TIME-SHIFT

Rainfall

storm type - USER INPUT
storm duration = 20 min.
storm timestep = 5 min.
simulation duration = 60 min.
Rainfall ordinates (mm/hr) ;
128 73 54 29 0 0

Subcatchment data

| No | Node | Area | %Imp | Length | Slope | Dpr Per | Dpr Imp | Inf i | Inf f | 'n'Per | 'n'Imp |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 201 | 1 | 2.38 | 26 | 300 | 0.107 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 202 | 2 | 0.61 | 26 | 180 | 0.161 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 203 | 3 | 0.67 | 26 | 150 | 0.080 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 204 | 4 | 0.86 | 26 | 230 | 0.061 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 205 | 5 | 1.35 | 26 | 230 | 0.074 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 206 | 6 | 0.39 | 70 | 150 | 0.100 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 207 | 7 | 3.87 | 26 | 470 | 0.030 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 208 | 8 | 0.18 | 70 | 100 | 0.100 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 209 | 9 | 3.84 | 26 | 390 | 0.036 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 210 | 10 | 0.37 | 70 | 90 | 0.078 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 211 | 11 | 0.28 | 70 | 106 | 0.075 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 212 | 12 | 4.05 | 26 | 480 | 0.029 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 213 | 13 | 3.30 | 26 | 550 | 0.018 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 214 | 14 | 4.02 | 26 | 480 | 0.013 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 215 | 15 | 0.40 | 70 | 110 | 0.073 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 216 | 16 | 0.23 | 70 | 114 | 0.053 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 217 | 17 | 0.20 | 70 | 104 | 0.058 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 218 | 18 | 0.19 | 70 | 110 | 0.055 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 219 | 19 | 0.20 | 70 | 114 | 0.053 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 220 | 20 | 0.45 | 70 | 210 | 0.048 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 221 | 21 | 0.91 | 26 | 140 | 0.014 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 222 | 22 | 0.26 | 26 | 140 | 0.057 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 223 | 23 | 0.16 | 70 | 100 | 0.058 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 224 | 24 | 0.20 | 70 | 100 | 0.058 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 225 | 25 | 1.00 | 26 | 220 | 0.048 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 226 | 26 | 2.36 | 26 | 450 | 0.020 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 227 | 27 | 1.08 | 26 | 198 | 0.033 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 228 | 28 | 2.20 | 70 | 115 | 0.033 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 229 | 29 | 0.81 | 26 | 184 | 0.033 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 230 | 30 | 0.40 | 26 | 120 | 0.017 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 231 | 31 | 1.97 | 26 | 320 | 0.022 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 232 | 32 | 0.46 | 26 | 140 | 0.043 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 233 | 33 | 0.33 | 26 | 144 | 0.016 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 234 | 34 | 0.39 | 26 | 124 | 0.016 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 235 | 35 | 2.44 | 26 | 460 | 0.024 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 236 | 36 | 0.54 | 26 | 154 | 0.042 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 237 | 37 | 0.78 | 26 | 220 | 0.011 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 238 | 38 | 3.16 | 26 | 460 | 0.033 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 239 | 39 | 0.54 | 70 | 160 | 0.050 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 240 | 40 | 0.50 | 70 | 150 | 0.053 | 3 | 1 | [illegible]5 | 15 | 0.050 | 0.013 |
| 241 | 41 | 3.89 | 26 | 270 | 0.023 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 242 | 42 | 3.21 | 26 | 258 | 0.026 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 243 | 43 | 2.65 | 26 | 230 | 0.030 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 244 | 44 | 2.09 | 26 | 260 | 0.024 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 245 | 45 | 0.95 | 26 | 230 | 0.006 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 246 | 46 | 0.74 | 26 | 230 | 0.016 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 247 | 47 | 1.44 | 26 | 270 | 0.0[illegible]6 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 248 | 48 | 4.08 | 26 | 530 | 0.038 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 249 | 49 | 0.81 | 26 | 150 | 0.047 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 250 | 50 | 0.51 | 26 | 180 | 0.025 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 251 | 51 | 0.34 | 26 | 150 | 0.027 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 252 | 52 | 3.87 | 26 | 510 | 0.041 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 253 | 53 | 1.23 | 26 | 236 | 0.024 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 254 | 54 | 0.26 | 26 | 140 | 0.039 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 255 | 55 | 3.05 | 26 | 390 | 0.044 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 256 | 56 | 1.16 | 26 | 260 | 0.042 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 257 | 57 | 0.86 | 26 | 220 | 0.050 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 258 | 58 | 1.91 | 26 | 330 | 0.027 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 259 | 59 | 1.17 | 26 | 210 | 0.048 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |
| 260 | 60 | 1.66 | 26 | 192 | 0.047 | 3 | 1 | 45 | 15 | 0.050 | 0.013 |

Conduit data

| Type | No | Drain | Overflow | Diam/Width | Height | 'n' | Slope | Length |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 6 | 101 | 0.375 | 0.000 | 0.013 | 0.100 | 130 |
| 1 | 2 | 3 | 102 | 0.300 | 0.000 | 0.013 | 0.083 | 150 |
| 1 | 3 | 4 | 103 | 0.300 | 0.000 | 0.013 | 0.067 | 30 |
| 1 | 4 | 5 | 104 | 0.600 | 0.000 | 0.013 | 0.014 | 144 |
| 1 | 5 | 6 | 105 | 0.825 | 0.000 | 0.013 | 0.005 | 24 |
| 1 | 6 | 8 | 106 | 0.525 | 0.000 | 0.013 | 0.086 | 166 |
| 1 | 7 | 8 | 107 | 0.600 | 0.000 | 0.013 | 0.020 | 24 |
| 1 | 8 | 10 | 108 | 0.675 | 0.000 | 0.013 | 0.077 | 104 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 9 | 10 | 109 | 0.450 | 0.000 | 0.013 | 0.020 | 24 |
| 1 | 10 | 11 | 110 | 0.825 | 0.000 | 0.013 | 0.071 | 84 |
| 1 | 11 | 13 | 111 | 0.750 | 0.000 | 0.013 | 0.020 | 1 |
| 1 | 12 | 13 | 112 | 0.450 | 0.000 | 0.013 | 0.020 | 24 |
| 1 | 13 | 15 | 113 | 0.900 | 0.000 | 0.013 | 0.061 | 114 |
| 1 | 14 | 15 | 114 | 0.525 | 0.000 | 0.013 | 0.005 | 34 |
| 1 | 15 | 16 | 115 | 1.050 | 0.000 | 0.013 | 0.048 | 120 |
| 1 | 16 | 17 | 116 | 1.050 | 0.000 | 0.013 | 0.055 | 108 |
| 1 | 17 | 18 | 117 | 1.050 | 0.000 | 0.013 | 0.055 | 108 |
| 1 | 18 | 19 | 118 | 1.050 | 0.000 | 0.013 | 0.055 | 110 |
| 1 | 19 | 20 | 119 | 1.050 | 0.000 | 0.013 | 0.046 | 214 |
| 2 | 20 | 99 | 120 | 1.000 | 1.000 | 0.013 | 0.020 | 1 |
| 1 | 21 | 22 | 121 | 0.300 | 0.000 | 0.013 | 0.030 | 30 |
| 1 | 22 | 23 | 122 | 0.300 | 0.000 | 0.013 | 0.030 | 80 |
| 1 | 23 | 24 | 123 | 0.300 | 0.000 | 0.013 | 0.059 | 100 |
| 1 | 24 | 25 | 124 | 0.300 | 0.000 | 0.013 | 0.048 | 220 |
| 1 | 25 | 26 | 125 | 0.450 | 0.000 | 0.013 | 0.013 | 30 |
| 1 | 26 | 28 | 126 | 0.600 | 0.000 | 0.013 | 0.008 | 106 |
| 1 | 27 | 28 | 127 | 0.300 | 0.000 | 0.013 | 0.050 | 1 |
| 1 | 28 | 32 | 128 | 0.525 | 0.000 | 0.013 | 0.047 | 116 |
| 1 | 29 | 30 | 129 | 0.300 | 0.000 | 0.013 | 0.017 | 110 |
| 1 | 30 | 31 | 130 | 0.300 | 0.000 | 0.013 | 0.024 | 218 |
| 1 | 31 | 32 | 131 | 0.375 | 0.000 | 0.013 | 0.050 | 1 |
| 1 | 32 | 36 | 132 | 0.600 | 0.000 | 0.013 | 0.048 | 124 |
| 1 | 33 | 34 | 133 | 0.300 | 0.000 | 0.013 | 0.020 | 26 |
| 1 | 34 | 35 | 134 | 0.300 | 0.000 | 0.013 | 0.032 | 282 |
| 1 | 35 | 36 | 135 | 0.375 | 0.000 | 0.013 | 0.050 | 1 |
| 1 | 36 | 39 | 136 | 0.675 | 0.000 | 0.013 | 0.053 | 124 |
| 1 | 37 | 38 | 137 | 0.300 | 0.000 | 0.013 | 0.039 | 282 |
| 1 | 38 | 39 | 138 | 0.375 | 0.000 | 0.013 | 0.050 | 1 |
| 1 | 39 | 40 | 139 | 0.675 | 0.000 | 0.013 | 0.059 | 124 |
| 1 | 40 | 48 | 140 | 0.675 | 0.000 | 0.013 | 0.039 | 22 |
| 1 | 41 | 42 | 141 | 0.600 | 0.000 | 0.013 | 0.061 | 150 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 42 | 43 | 142 | 0.600 | 0.000 | 0.013 | 0.057 | 110 |
| 1 | 43 | 44 | 143 | 0.850 | 0.000 | 0.013 | 0.049 | 150 |
| 1 | 44 | 48 | 144 | 0.600 | 0.000 | 0.013 | 0.050 | 1 |
| 1 | 45 | 46 | 145 | 0.300 | 0.000 | 0.013 | 0.019 | 68 |
| 1 | 46 | 47 | 146 | 0.300 | 0.000 | 0.013 | 0.025 | 24 |
| 1 | 47 | 48 | 147 | 0.375 | 0.000 | 0.013 | 0.045 | 424 |
| 1 | 48 | 49 | 148 | 0.900 | 0.000 | 0.013 | 0.050 | 98 |
| 1 | 49 | 57 | 149 | 1.050 | 0.000 | 0.013 | 0.045 | 14 |
| 1 | 50 | 51 | 150 | 0.300 | 0.000 | 0.013 | 0.025 | 22 |
| 1 | 51 | 52 | 151 | 0.300 | 0.000 | 0.013 | 0.049 | 396 |
| 1 | 52 | 57 | 152 | 0.525 | 0.000 | 0.013 | 0.022 | 70 |
| 1 | 53 | 54 | 153 | 0.300 | 0.000 | 0.013 | 0.025 | 22 |
| 1 | 54 | 55 | 154 | 0.300 | 0.000 | 0.013 | 0.053 | 320 |
| 1 | 55 | 56 | 155 | 0.525 | 0.000 | 0.013 | 0.019 | 126 |
| 1 | 56 | 57 | 156 | 0.525 | 0.000 | 0.013 | 0.019 | 60 |
| 1 | 57 | 59 | 157 | 1.050 | 0.000 | 0.013 | 0.045 | 128 |
| 1 | 58 | 59 | 158 | 0.375 | 0.000 | 0.013 | 0.025 | 16 |
| 2 | 59 | 99 | 159 | 1.000 | 1.131 | 0.013 | 0.020 | 1 |
| 1 | 60 | 99 | 160 | 0.600 | 0.000 | 0.013 | 0.077 | 1 |
| 3 | 101 | 6 | 0 | 2.000 | 9999.000 | 0.018 | 0.010 | 130 |
| 3 | 102 | 3 | 0 | 2.000 | 9999.000 | 0.018 | 0.083 | 150 |
| 3 | 103 | 4 | 0 | 2.000 | 9999.000 | 0.018 | 0.067 | 30 |
| 3 | 104 | 5 | 0 | 2.000 | 9999.000 | 0.018 | 0.014 | 144 |
| 3 | 105 | 6 | 0 | 2.000 | 9999.000 | 0.018 | 0.005 | 24 |
| 3 | 106 | 8 | 0 | 2.000 | 9999.000 | 0.018 | 0.086 | 116 |
| 3 | 107 | 8 | 0 | 2.000 | 9999.000 | 0.018 | 0.020 | 24 |
| 3 | 108 | 10 | 0 | 2.000 | 9999.000 | 0.018 | 0.077 | 104 |
| 3 | 109 | 10 | 0 | 2.000 | 9999.000 | 0.018 | 0.020 | 24 |
| 3 | 110 | 11 | 0 | 2.000 | 9999.000 | 0.018 | 0.071 | 84 |
| 3 | 111 | 13 | 0 | 2.000 | 9999.000 | 0.018 | 0.050 | 1 |
| 3 | 112 | 13 | 0 | 2.000 | 9999.000 | 0.018 | 0.020 | 24 |
| 3 | 113 | 15 | 0 | 2.000 | 9999.000 | 0.018 | 0.061 | 114 |
| 3 | 114 | 15 | 0 | 2.000 | 9999.000 | 0.018 | 0.005 | 34 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3 | 115 | 16 | 0 | 2.000 | 9999.000 | 0.018 | 0.048 | 120 |
| 3 | 116 | 17 | 0 | 2.000 | 9999.000 | 0.018 | 0.055 | 108 |
| 3 | 117 | 18 | 0 | 2.000 | 9999.000 | 0.018 | 0.055 | 108 |
| 3 | 118 | 19 | 0 | 2.000 | 9999.000 | 0.018 | 0.055 | 110 |
| 3 | 119 | 20 | 0 | 2.000 | 9999.000 | 0.018 | 0.046 | 214 |
| 3 | 120 | 99 | 0 | 2.000 | 9999.000 | 0.018 | 0.050 | 1 |
| 3 | 121 | 22 | 0 | 2.000 | 9999.000 | 0.018 | 0.030 | 30 |
| 3 | 122 | 23 | 0 | 2.000 | 9999.000 | 0.018 | 0.030 | 80 |
| 3 | 123 | 24 | 0 | 2.000 | 9999.000 | 0.018 | 0.059 | 100 |
| 3 | 124 | 25 | 0 | 2.000 | 9999.000 | 0.018 | 0.048 | 220 |
| 3 | 125 | 26 | 0 | 2.000 | 9999.000 | 0.018 | 0.013 | 30 |
| 3 | 126 | 28 | 0 | 2.000 | 9999.000 | 0.018 | 0.008 | 106 |
| 3 | 127 | 28 | 0 | 2.000 | 9999.000 | 0.018 | 0.050 | 1 |
| 3 | 128 | 32 | 0 | 2.000 | 9999.000 | 0.018 | 0.047 | 116 |
| 3 | 129 | 30 | 0 | 2.000 | 9999.000 | 0.018 | 0.017 | 110 |
| 3 | 130 | 31 | 0 | 2.000 | 9999.000 | 0.018 | 0.024 | 218 |
| 3 | 131 | 32 | 0 | 2.000 | 9999.000 | 0.018 | 0.050 | 1 |
| 3 | 132 | 36 | 0 | 2.000 | 9999.000 | 0.018 | 0.048 | 124 |
| 3 | 133 | 34 | 0 | 2.000 | 9999.000 | 0.018 | 0.020 | 26 |
| 3 | 134 | 35 | 0 | 2.000 | 9999.000 | 0.018 | 0.032 | 282 |
| 3 | 135 | 36 | 0 | 2.000 | 9999.000 | 0.018 | 0.050 | 1 |
| 3 | 136 | 39 | 0 | 2.000 | 9999.000 | 0.018 | 0.053 | 124 |
| 3 | 137 | 38 | 0 | 2.000 | 9999.000 | 0.018 | 0.039 | 282 |
| 3 | 138 | 39 | 0 | 2.000 | 9999.000 | 0.018 | 0.050 | 1 |
| 3 | 139 | 40 | 0 | 2.000 | 9999.000 | 0.018 | 0.059 | 124 |
| 3 | 140 | 48 | 0 | 2.000 | 9999.000 | 0.018 | 0.059 | 22 |
| 3 | 141 | 42 | 0 | 2.000 | 9999.000 | 0.018 | 0.061 | 150 |
| 3 | 142 | 43 | 0 | 2.000 | 9999.000 | 0.018 | 0.057 | 110 |
| 3 | 143 | 44 | 0 | 2.000 | 9999.000 | 0.018 | 0.049 | 150 |
| 3 | 144 | 48 | 0 | 2.000 | 9999.000 | 0.018 | 0.050 | 1 |
| 3 | 145 | 46 | 0 | 2.000 | 9999.000 | 0.018 | 0.019 | 68 |
| 3 | 146 | 47 | 0 | 2.000 | 9999.000 | 0.018 | 0.025 | 24 |
| 3 | 147 | 48 | 0 | 2.000 | 9999.000 | 0.018 | 0.045 | 424 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3 | 148 | 49 | 0 | 2.000 | 9999.000 | 0.018 | 0.050 | 98 |
| 3 | 149 | 57 | 0 | 2.000 | 9999.000 | 0.018 | 0.045 | 14 |
| 3 | 150 | 51 | 0 | 2.000 | 9999.000 | 0.018 | 0.025 | 22 |
| 3 | 151 | 52 | 0 | 2.000 | 9999.000 | 0.018 | 0.049 | 396 |
| 3 | 152 | 57 | 0 | 2.000 | 9999.000 | 0.018 | 0.022 | 70 |
| 3 | 153 | 54 | 0 | 2.000 | 9999.000 | 0.018 | 0.025 | 22 |
| 3 | 154 | 55 | 0 | 2.000 | 9999.000 | 0.018 | 0.053 | 320 |
| 3 | 155 | 56 | 0 | 2.000 | 9999.000 | 0.018 | 0.019 | 126 |
| 3 | 156 | 57 | 0 | 2.000 | 9999.000 | 0.018 | 0.019 | 60 |
| 3 | 157 | 59 | 0 | 2.000 | 9999.000 | 0.018 | 0.045 | 128 |
| 3 | 158 | 59 | 0 | 2.000 | 9999.000 | 0.018 | 0.025 | 16 |
| 3 | 159 | 99 | 0 | 2.000 | 9999.000 | 0.018 | 0.050 | 1 |
| 3 | 160 | 99 | 0 | 2.000 | 9999.000 | 0.018 | 0.077 | 1 |

(Type:- 1 = pipes 2 = Channels 3 = Overflow channels)

Outfall nodes
-------------
20
59
60

Hydrograph input
----------------
NONE

Output controls
---------------
Full data echo - OFF
Graphics displayed on screen - ON

Connectivity matrix

| Pipe/node | Contributing areas |
|---|---|
| 1 | 201 |
| 2 | 202 |
| 3 | 203 |
| 4 | 204 |
| 5 | 205 |
| 6 | 206 |
| 7 | 207 |
| 8 | 208 |
| 9 | 209 |
| 10 | 210 |
| 11 | 211 |
| 12 | 212 |
| 13 | 213 |
| 14 | 214 |
| 15 | 215 |
| 16 | 216 |
| 17 | 217 |
| 18 | 218 |
| 19 | 219 |
| 20 | 220 |
| 21 | 221 |
| 22 | 222 |
| 23 | 223 |
| 24 | 224 |
| 25 | 225 |
| 26 | 226 |
| 27 | 227 |
| 28 | 228 |
| 29 | 229 |

| | |
|---|---|
| 30 | 230 |
| 31 | 231 |
| 32 | 232 |
| 33 | 233 |
| 34 | 234 |
| 35 | 235 |
| 36 | 236 |
| 37 | 237 |
| 38 | 238 |
| 39 | 239 |
| 40 | 240 |
| 41 | 241 |
| 42 | 242 |
| 43 | 243 |
| 44 | 244 |
| 45 | 245 |
| 46 | 246 |
| 47 | 247 |
| 48 | 248 |
| 49 | 249 |
| 50 | 250 |
| 51 | 251 |
| 52 | 252 |
| 53 | 253 |
| 54 | 254 |
| 55 | 255 |
| 56 | 256 |
| 57 | 257 |
| 58 | 258 |
| 59 | 259 |
| 60 | 260 |

| Pipe/node | Upstream pipes/nodes |
|---|---|
| 6 | 1, 5, 101, 105 |
| 3 | 2, 102 |
| 4 | 3, 103 |
| 5 | 4, 104 |
| 8 | 6, 7, 106, 107 |
| 10 | 8, 9, 108, 109 |
| 11 | 10, 110 |
| 13 | 11, 12, 111, 112 |
| 15 | 13, 14, 113, 114 |
| 16 | 15, 115 |
| 17 | 16, 116 |
| 18 | 17, 117 |
| 19 | 18, 118 |
| 20 | 19, 119 |
| 99 | 20, 59, 60, 120, 159, 160 |
| 22 | 21, 121 |
| 23 | 22, 122 |
| 24 | 23, 123 |
| 25 | 24, 124 |
| 26 | 25, 125 |
| 28 | 26, 27, 126, 127 |
| 32 | 28, 31, 128, 131 |
| 30 | 29, 129 |
| 31 | 30, 130 |
| 36 | 32, 35, 132, 135 |
| 34 | 33, 133 |
| 35 | 34, 134 |
| 39 | 36, 38, 136, 138 |
| 38 | 37, 137 |
| 40 | 39, 139 |
| 48 | 40, 44, 47, 140, 144, 147 |

| | |
|---|---|
| 42 | 41, 141 |
| 43 | 42, 142 |
| 44 | 43, 143 |
| 46 | 45, 145 |
| 47 | 46, 146 |
| 49 | 48, 148 |
| 57 | 49, 52, 56, 149, 152, 156 |
| 51 | 50, 150 |
| 52 | 51, 151 |
| 54 | 53, 153 |
| 55 | 54, 154 |
| 56 | 55, 155 |
| 59 | 57, 58, 157, 158 |

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