FLOOD FORECASTING FOR RESERVOIR OPERATION BY DETERMINISTIC HYDROLOGICAL MODELLING

by

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PREFACE

Report No. 1/78 is a reproduction of a thesis which earned its author, M.S. Basson, the degree of doctor of philosophy in the University of the Witwatersrand in April 1978.

The research on which the thesis is based was conducted over the period January 1976 to December 1977. During the final six months of this period the work formed part of a contract entered into between the University and the Water Research Commission whereby the Unit undertook to study specified aspects of flood hydrology. Research into some of these is still in hand. The Water Research Commission however has been providing substantial financial support to the Unit since 1971 and it is therefore a pleasure to acknowledge this help and the permission of the Commission to publish this report.

Although the subject has been developed with specific reference to Vaaldam, the procedures and computer programs devised can readily be adapted for use with any reservoir system. The report proves in effect that, provided adequate precipitation information can be rapidly communicated to a central computer programmed to operate a simulation model (kept "warmed up" continuously during the flood season), the hydrograph of input to the reservoir can be predicted and the necessary pre-releases (and subsequent operations) can be calculated such as to minimize downstream damage while ensuring that the reservoir will be full after the flood has subsided.

The work has shown that in the case of Vaaldam the benefits in the way of reduced downstream damages would far exceed the cost of establishing and operating the requisite telemetered rainfall observation network and computing system. Research into the economic feasibility of weather-radar monitoring of catchments is proceeding.

I take this opportunity of thanking the officials of the Weather Bureau and of the Department of Water Affairs for their ready co-operation in the abstraction of hydrometeorological data from unpublished records.

D.C. Midgley
Director - Hydrological Research Unit

April 1978

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Severe damage and inconvenience resulting from floods, particularly in recent years, prompted research into the merits of advance warning procedures. The principal aim of this research was to develop a flood forecasting system whereby river response to storm rainfall could be simulated hours or even days in advance, using only rainfall data as basic input.

By initiating the forecast computations with rainfall in preference to streamflow input, warning of floods can be appreciably advanced, with the result that there is more time for evacuation, if necessary, and earlier pre-releases can create greater volumes of storage with much improved flood attenuation capability.

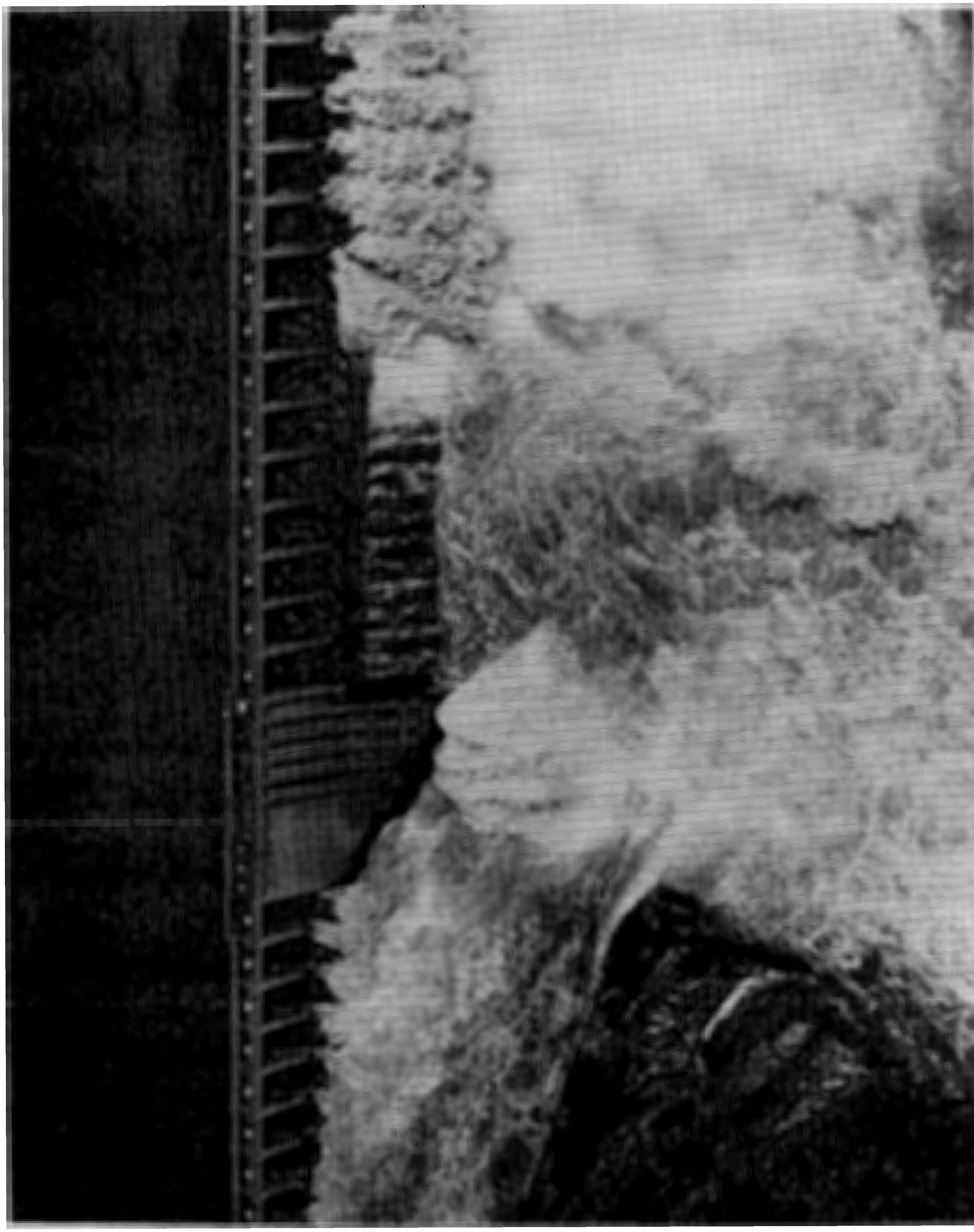
The study was concentrated on Vaaldam, which is perhaps South Africa's most important multi-purpose storage unit but for which there is no storage space officially allocated to flood control. Situated immediately upstream of an important urban and industrial complex, Vaaldam offers all the essential characteristics needed for a study of this type. Reasonably satisfactory data were available for purposes of testing and calibration of the system developed.

River flow responses to storm rainfall were simulated by means of catchment models developed by Dr. W.V. Pitman of the Hydrological Research Unit, the "daily-input" version being employed for initial calibration and warm-up and the "hourly-input" version for simulations during the flood proper. The models were calibrated with some difficulty owing to the paucity of streamflow data in the tributary systems.

Sensitivity of simulated flood flows to variations in the different model parameters was tested and the length of "warm-up" period to achieve stabilization optimized. To establish the optimum number of rainfall stations to be monitored or interrogated, spatial correlations of catchment rainfall were examined. With the object of checking streamflow prediction, should receipt of rainfall records be delayed, observed rainfall was correlated

with weather forecasts. With the appropriate catchment model it is possible, once rainfall has started, to forecast the flood hydrograph at a chosen downstream locality. The forecast can be updated continuously as fresh data become available. The hydrograph of inflow to the reservoir is then routed through storage in a computer program which manipulates the outflow, to the extent possible with the existing outlets, in such a way as to minimize downstream flood damages - subject to the safety of the dam and to other constraints.

It is the development of the routing and gate manipulation program that represents the main burden of the report, which terminates with a socio-economic evaluation. The financial feasibility and average annual benefits revealed provide strong motivation for implementation of the flood forecasting and gate operation system as developed.



VAALDAM DISCHARGING DURING FEBRUARY 1975 FLOOD

FLOODING AT VEREENIGING DURING FEBRUARY 1975 FLOOD

FLOOD FORECASTING FOR RESERVOIR OPERATION BY DETERMINISTIC HYDROLOGICAL MODELLING

CHAPTER 1 INTRODUCTION

1.1 General

Development pressures lead to flood plain encroachment as space for urban and agricultural expansion becomes scarce and land values rise. This is happening all over the world and until administrators appreciate that it pays to introduce flood plain zoning at the earliest stages of development the trauma of flood damage will continue to worsen. To endeavour by engineering means to alleviate flood damage after development has already encroached into the flood plain can seldom be economically justified. In the United States of America, despite the expenditure of some billions of dollars on flood control measures, there has been no net reduction in the average annual cost of flood damages; on the contrary damage costs have continued to soar[1].

During practically every flood season over the past decade some part of South Africa has suffered severe damage and this has served to focus attention on the need to step up floods research. Recent amendments to the Water Act requiring township developers to cause the 50-year and other flood lines to be marked on development proposals presages first steps towards the introduction of flood plain zoning in South Africa.

The Water Research Commission has sponsored researches by the Bureau of Economic Investigations of the University of Stellenbosch (BEI) and the Institute for Social and Economic Research at the University of the Orange Free State (ISER) into damages associated with floods in the Orange and several rivers of the Cape midlands and along the Vaal river. The Commission has also contracted with the Hydrological Research Unit of the University of the Witwatersrand to extend its general flood studies. The current study was undertaken by the author as a member of staff of the Hydrological Research Unit (HRU).

The early storm and flood studies of the HRU culminated in the production of a design flood manual[2] followed by papers[3,4] with the aid of which it is possible to design a storm of specified recurrence interval anywhere in South Africa and to synthesize the resulting flood hydrograph. It has long been a major objective of the HRU to develop a procedure for predicting in real time the stream response to storm rainfall as monitored by weather radar or telemetered from sample recording gauges in the catchment.

By routing the rain, as it were, from the clouds - or at least from its incidence at ground level - through a rainfall-runoff model, it would be possible in relatively large catchments to gain valuable time for flood warning purposes. To take the objective a stage further in catchments commanded by major storage dams, if the hydrograph of inflow can be predicted and routed through storage well in advance of arrival of the flood, operation of the outlets can be calculated to minimize downstream damage. Foreknowledge of the magnitude of the incoming flood is of particular importance where there are dams in the larger tributaries of a river; despatching of floods from reservoirs in such a way as to cause the peaks to coincide at a major confluence may create a situation more severe than would have arisen had there been no dams in the system. Inept handling of the gates of a single dam can create higher rates of outflow than of inflow. For dams equipped with bottom outlets and where the basin characteristics are such as to allow a density or turbidity current to develop, it is of tremendous value to be in a position to vent the early flood flow as a density current and thus preserve storage space against silting. Without foreknowledge that a flood will be sufficient to fill the reservoir it is not easy to take the decision to vent sediment-laden water.

Success at the HRU in developing a workable watershed model[5] made it possible to provide realistic hydrological input for the development of swamp,lake and estuary models[6,7], as well as facilitating a whole range of water resources studies for which long series of monthly flows are required. Improvements to the watershed model (to permit daily[8] and later hourly[9] instead of monthly hydrographs to be synthesized from rainfall and evaporation data) provided realistic data for the development of flood plain management models[10] and opened the way to achieving the early HRU objective of real-time flood forecasting for reservoir operation. In this report the important reservoir at Vaaldam has been selected to demonstrate how this can be done.

Basic to the study is the necessity to generate from given storm rainfall data the corresponding flood hydrograph at entry to Vaaldam. The parameters of the watershed model[5] have been established for the Vaaldam catchment on the basis of monthly rainfall and evaporation but to generate a flood hydrograph it is necessary to operate the model at a shorter time resolution. Because of the paucity of autographic rain gauges in the catchment, however, it was not feasible to adopt a time resolution shorter than one day. The HRU daily model was therefore adopted for performing the hydrograph simulations.

1.2 Vaaldam and its catchment

Situated at the confluence of the Vaal and Wilge rivers about 75 km south of Johannesburg, Vaaldam was constructed during the mid-1930s as the major storage unit of the Vaal River Development Scheme - South Africa's first multi-purpose project. Raised to its present capacity of 2 331 million cubic metres in 1956, Vaaldam regulates the flow of the Vaal river to secure water supplies to the Pretoria-Witwatersrand-Vereeniging-Sasolburg industrial, mining and petro-chemical complex as well as to Far East Reef and Far West Reef gold mining areas, the Orange Free State goldfields, riparian irrigators, the Vaal-Harts government irrigation scheme, the platinum mining areas around Rustenburg, the mineral-rich areas of Sishen-Posmasburg and several towns en route to the confluence of the Vaal with the Orange river near Douglas. As may be gathered the Vaal is the hardest-worked river in the Republic and Vaaldam quite evidently one of the country's most important dams. (See Figure 1.1).

The dam is a mass gravity concrete structure with a long earthen embankment blocking a low saddle at its right flank. Set about 34 m above riverbed level, the 625 m long overspill crest is surmounted by sixty vertical-lift flood gates,

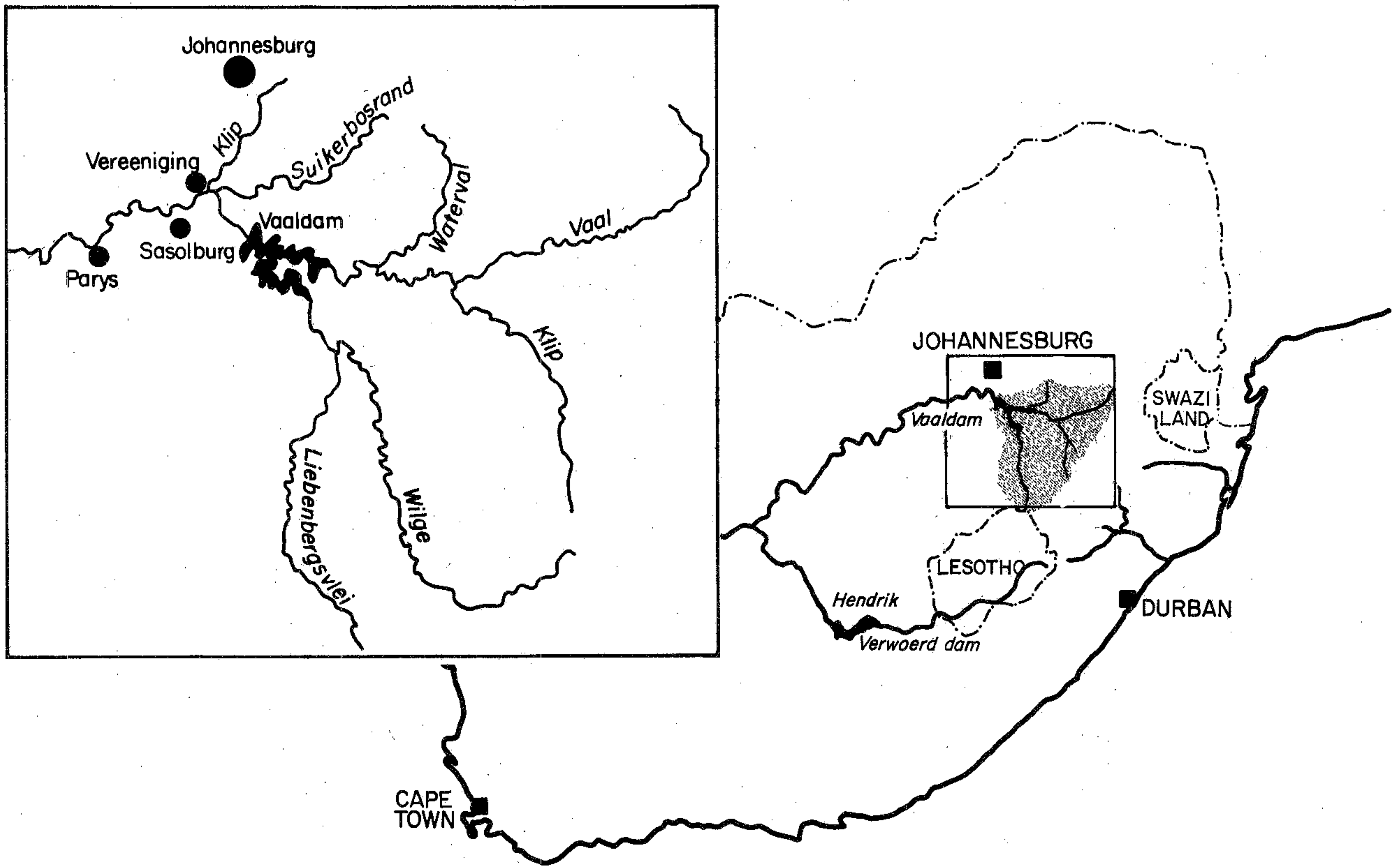


Fig. 1·1 REPUBLIC OF SOUTH AFRICA- *LOCATION OF VAALDAM AND STUDY AREA*

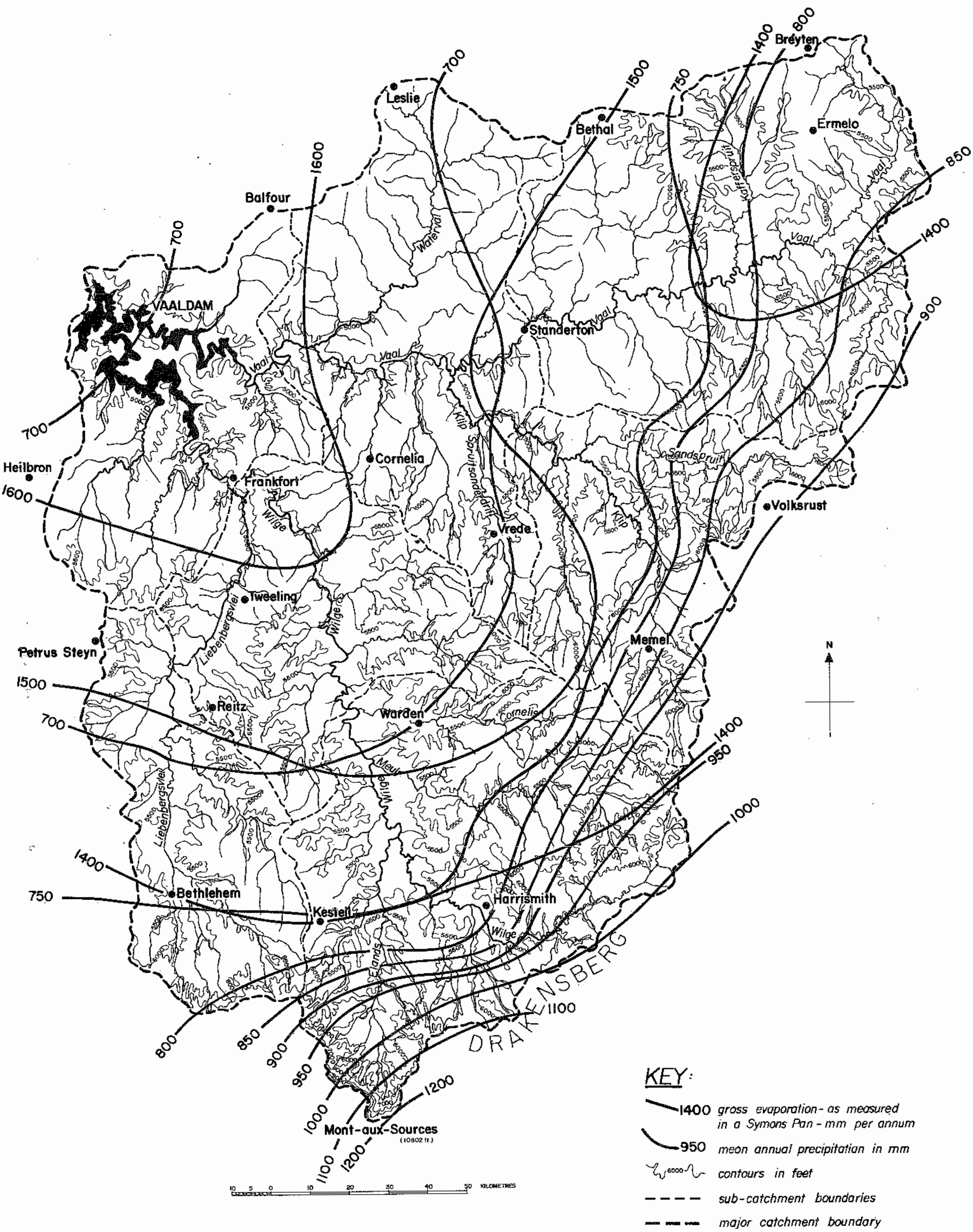


Figure 1·2 VAALDAM CATCHMENT

Physical and Hydrometeorological Features comprises sedimentary rocks of the Karoo system. In the northern half of the catchment Ecca series, shale, sandstone, grits and coal occur; these are the oldest deposits in the catchment. Over most of the southern part of the catchment there are younger deposits of the Beaufort series, namely shale, mudstone and sandstone. A small section in the extreme south belongs to the geologically youngest series, the Stormberg, - mainly sandstone, shale, mudstone - with, along the southernmost border, a small intrusion of yet another sub-series comprising solenetzic soils.

At 125 ton/km^2/year[11] the average silt yield of the catchment is relatively low; significant quantities of sediment are generated mainly from small areas in the upper reaches. Comparable areas of the Orange river catchment upstream of Verwoerd Dam produce sediment at more than twice those in the Vaal, while the silt yield of the Caledon tributary is more than four times as high. The projected silt volume in Vaaldam 50 years after completion - that is, in 1987 - is estimated at 172 x 10^6m^3, or roughly 7% of the reservoir capacity. Silt deposits are thus not expected to have any marked effect on the flood attenuation characteristics of the reservoir for another century or more.

CHAPTER 2 CALIBRATION OF THE MODEL AND SENSITIVITY ANALYSES

2.1 Sub-division of the catchment

As the Hydrological Research Unit daily model is a lumped-parameter model it cannot make provision for the spatial variation of conditions within the catchment, except insofar as infiltration is specified as a range which may change from one sub-catchment to another[8]. Furthermore it cannot take account of the differences in time lags associated with the movement of flood waters from the various parts of a large catchment. Model lag time must in fact be rounded off in multiples of the basic time step of one day. The time taken for floodwaters to reach Vaaldam from the farthest extremities of the catchment can exceed three days and it is therefore necessary, for optimum utilization of the daily model, to sub-divide the catchment into components each with an internal lag of not significantly more than one day.

In sub-dividing the main catchment regard must be had to the location of existing streamgauges, from the points of view not solely of calibrating the model but also of adjusting the simulated flood hydrographs from sub-catchments during real-time operation of the model for flood forecasting. Difficulties arise, however, in that there are few suitable streamgauges within the upper Vaal catchment. The sub-division scheme is shown in Figure 2.1 on which are marked the existing streamgauging and evaporation stations as also the rainfall stations selected for the study. Only those rainfall stations that have good records completely spanning the respective study periods were chosen.

As may be seen, the commanded area was sub-divided into seven sub-catchments. The only reliable long-record fully calibrated streamgauging station in the system, other than at Vaaldam itself, is the Standerton gauge no. C1M01. The Standerton record over the ten-year period October 1965 to September 1975 was used, along with contemporaneous records from 29 rainfall

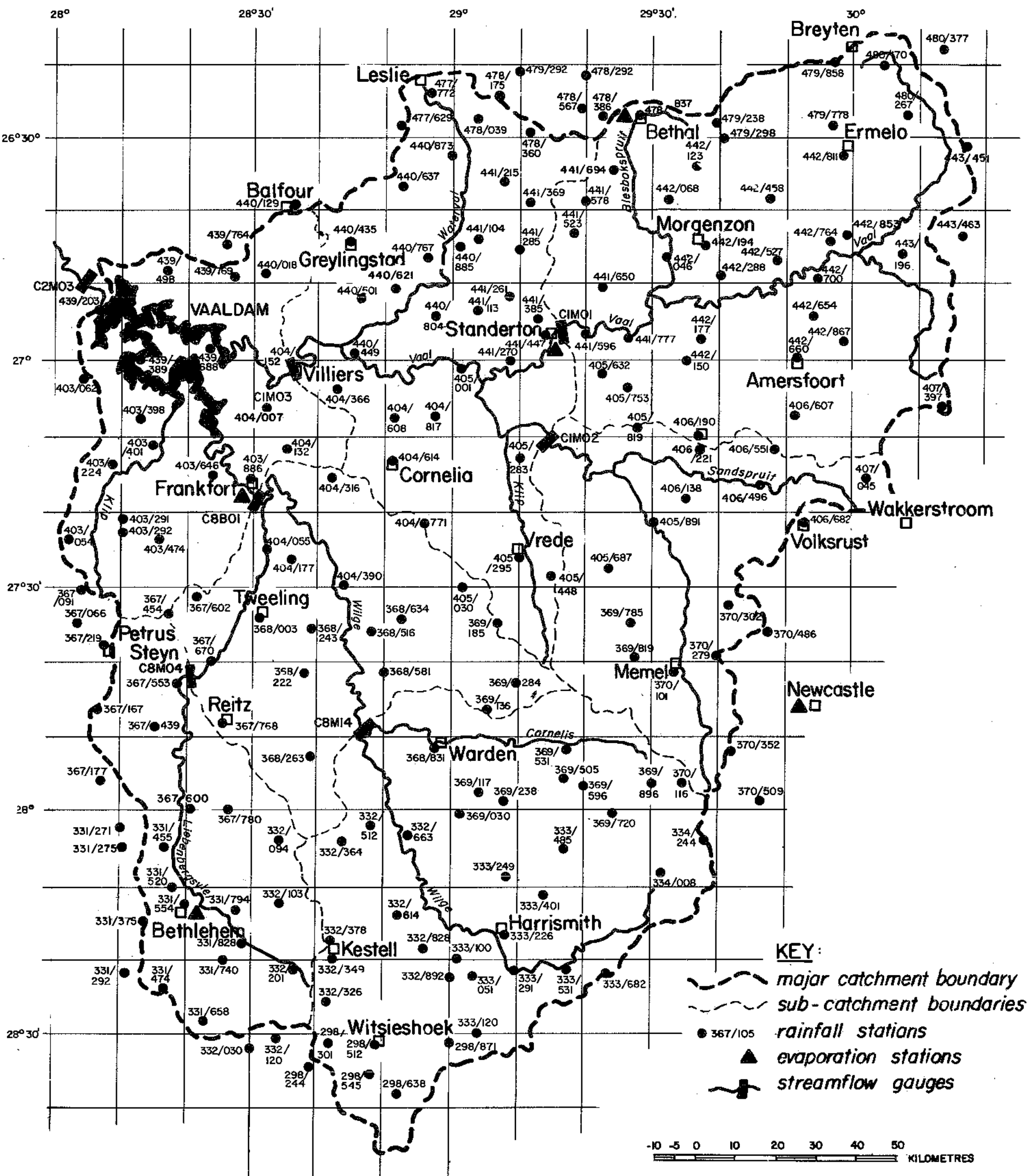


Figure 2·1

VAALDAM CATCHMENT

Hydrometeorological stations and catchment subdivisions stations, to establish the catchment model parameters. Evaporation data were taken from Report 2/73[5]. During the ten-year calibration period there were three significant floods. The resulting calibration was subsequently adjusted after comparison of the simulated with the observed hydrograph of the major flood that occurred during the 1956/57 season.

To generate flood hydrographs as opposed to a monthly flow sequence the watershed model had, as mentioned earlier, to be calibrated on a daily basis. The rainfall input to the model was therefore in daily form but it was not considered necessary to input daily values of potential evaporation. Although actual potential evaporation can vary markedly from the monthly average, the influence of evaporation during the period of a flood is relatively slight and therefore use of monthly average evaporation as input to the model was justified. In an unpublished HRU study the results of streamflow simulation for which actual evaporation values were used as input were compared with those for which average monthly values were used; the differences were found to be negligible and the cost of operating the program was significantly reduced. In any event, operation of the program in real time would be appreciably complicated if actual evaporation values had to be predicted.

As none of the other streamflow gauges shown on Figure 2.1 had records of sufficient accuracy, length or range for purposes of model calibration, the parameters established for the Standerton sub-catchment were, in the first instance, assumed to hold good for the remainder of the Vaaldam catchment. As indicated earlier, hydro-meteorological characteristics are fairly uniform throughout the catchment. Sensitivity analyses were, however, performed in order to check this initial supposition.

Table 2.1 lists the adopted model parameters for the HRU daily model.[8]

Table 2.1 : Adopted parameters[8]

POW	SL mm	ST mm	FT mm/day	AI %	ZMINN mm/h	ZMAXN mm/h	PI mm	TL days	LAG days	GL days	R	DIV
3	0	50	0,1	0	1	5,3	1,5	2,5	1	6	0,5	0

2.2 Warm-up period

The degree of accuracy with which a simulation model can forecast flood events, given the causative precipitation, depends largely upon the accuracy with which it has simulated events immediately prior to the flood event. Antecedent conditions - particularly the state of wetness or dryness of various parts of the catchment as well as the base flows in the streams - largely determine the shape and magnitude of the flood hydrograph that will result from a given rainfall input. It follows that the model must be operated with inputs covering a reasonably long period prior to the flood event of interest so as to ensure that antecedent conditions are correctly simulated. This interval is referred to as the "warm-up" period.

The length of time taken to "home-in" is a characteristic not of the model but of the catchment. The warm-up period for the Vaal catchment was established by operating the model for gradually shortened periods prior to a number of flood events and examining the resulting difference in flood volume as a percentage of that registered for the fully warmed-up operation. As indicated by Figure 2.2, the warm-up period is between 3 and 6 months. Although the percentage variations for short warm-up periods are not great there are strong indications that the model may be unreliable if not adequately warmed up.

2.3 Influence of initial groundwater discharge (QOBS)

A study was undertaken to establish the relationship between one of the important model parameters, viz. initial groundwater discharge (QOBS), from which the model estimates initial catchment conditions and length of warm-up period to be adopted. As is shown by Figure 2.3, unless the warm-up lasts a full season or longer, incorrect estimation of QOBS input to the model can have a marked influence on the accuracy of the simulation. In view of the results of this study it was decided that a warm-up period of 12 months should be adopted.

2.4 Number of rain gauges

Rainfall input to the model is handled on a lumped or average basis. The results of ordinary averaging compare favourably with, for example, those from the Thiessen polygon method, specially for flood studies. The main reason for this is that if records from one or more gauges are missing from those of a network of rain gauges the whole configuration of Thiessen polygons has to be changed, whereas a break in record hardly influences the results of ordinary averaging. For n gauges, 2^n-1 configurations of Thiessen polygons are possible (i.e. $536{,}9 \times 10^6$ possibilities for the 29 gauges in the Standerton catchment alone). Moreover, as the distribution of rainfall between rain gauges is not necessarily linear, the Thiessen method need not be more accurate than averaging, provided the distribution of rain gauges over the catchment is reasonably well balanced.

From an analysis of the records of 55 rain gauges arranged in a grid pattern over 563 km^2, Linsley and Kohler[12] established that the average error in precipitation measurement increased markedly as the number of gauges was reduced but that the percentage error decreased with increasing storm rainfall. Expecting analogous results for larger areas, the author undertook a spatial correlation study of daily rainfall on the Vaaldam catchment. By comparing spatial correlation of daily rainfall on a monthly basis it was found that correlation coefficients during wet Februaries for instance were appreciably higher than those for average or for dry Februaries. This supports the contention that for intermediate-sized catchments

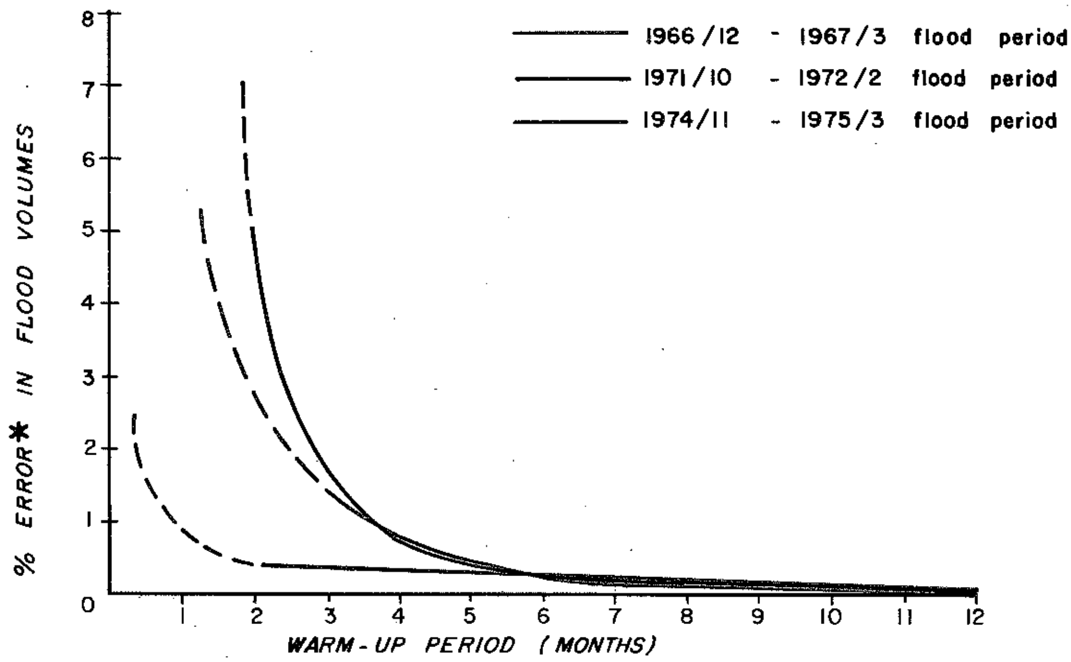


Fig. 2·2 Percentage error* in simulated flood volume as a function of length of warm-up period at gauge CIMOI for different floods.

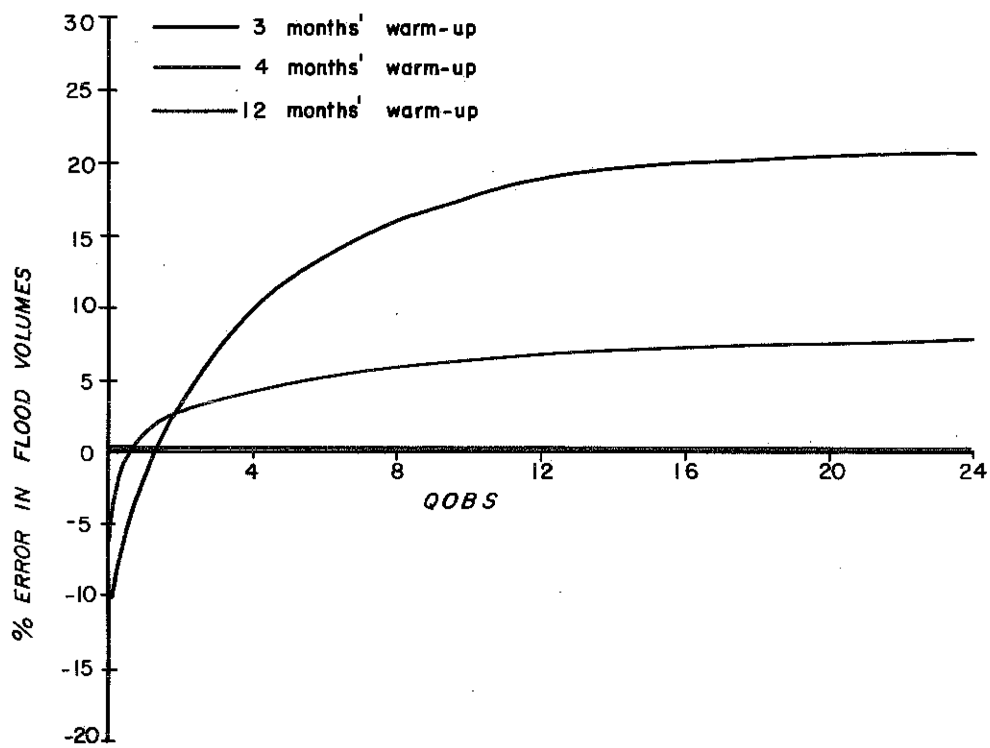


Fig. 2·3 Percentage error* in simulated flood volumes as a function of initial groundwater discharge (QOBS) at gauge CIMOI for different lengths of warm-up period.

** Error based on departure of short warm-up from fully warmed-up simulation.*

the percentage error in rainfall measurement will decrease with increasing catchment rainfall. Referring to Figure 2.4, the continuing fall-off of correlation revealed for wet Februaries beyond the 100 km distance can be largely ascribed to storm movement, which means that the rain under consideration was recorded on different days. With fewer and more randomly distributed rainfall events during average and dry Februaries the effect of storm movement is much less pronounced with the result that the asymptote is reached much sooner than for the wet Februaries. A further explanation is that the accuracy of the graph is poorer for long-distance than for short-distance correlations because of the diminishing numbers of values with distance from the reference station.

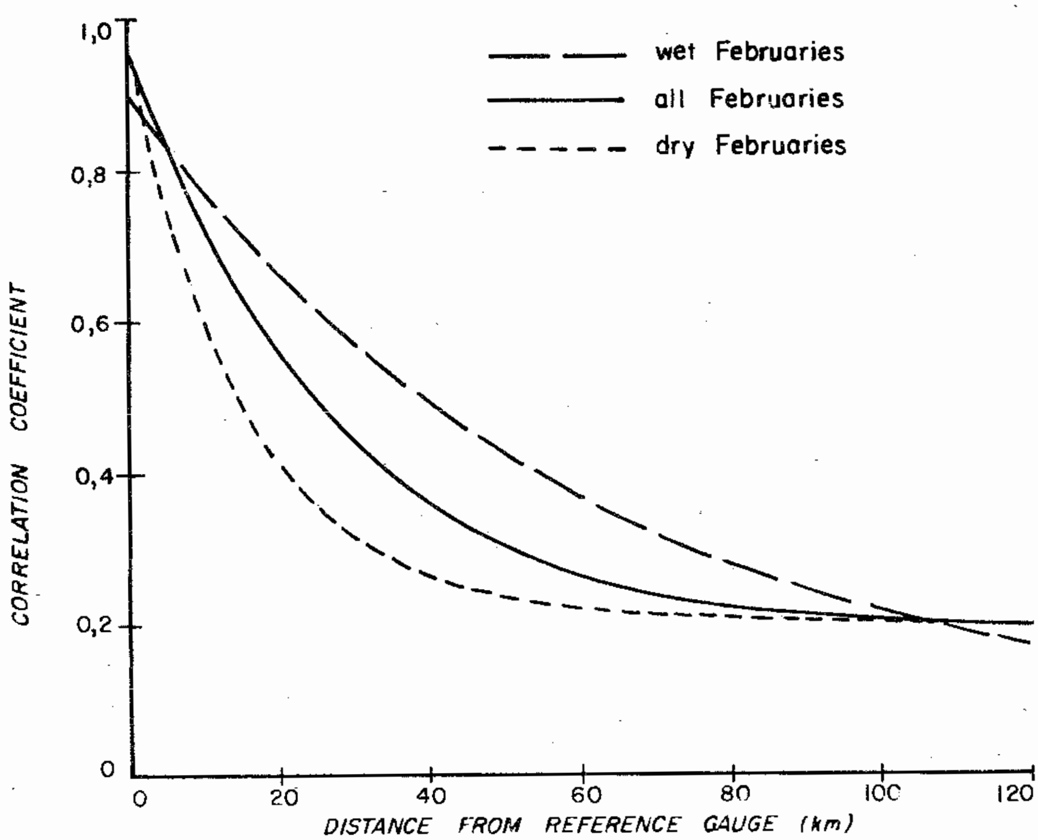


Fig. 2.4 Daily average February rainfall for Vaaldam catchment: Correlation between records at reference gauge and distant gauges as a function of distance from reference gauge.

In flood studies for large catchments one is generally concerned with heavy widespread storms and it follows therefore that the number of gauges providing rainfall input to the model can be reduced without significant loss of accuracy, and with substantial reduction in the cost of operating the data network. In a further study (simulation of flood flow from the Standerton sub-catchment for the period November 1974 to March 1975), the number of rain gauges providing input data was systematically reduced, using random combinations of different numbers of gauges, with the constraint that the combinations would be rejected if extremely poorly distributed. It was found as shown in Figures 2.5 and 2.6 that both simulated flow volume and goodness-of-fit declined rapidly as the number of gauges was reduced below about seven. With more than about seven randomly distributed gauges per sub-catchment, accuracies should be not incommensurate with those generally encountered in hydrology. Moreover, the pattern of scatter in the positive and negative domains of Figure 2.5 indicates that differences may well be balanced out when simulated; flows from all seven sub-catchments are combined.

The U.S. Corps of Engineers[13] suggest a rough guide to the required number of rain gauges for flood forecasting:

$$n = (0{,}39A)^{0{,}35}$$

where n is the number of gauges and A the area (km^2) of the relevant catchment. For the 8192 km^2 Standerton sub-catchment, the suggested number of gauges would thus be seventeen and this checks well with the results shown in Figures 2.5 to 2.7. The number of gauges required for the whole Vaaldam catchment would be twenty-nine according to the Corps of Engineers formula and this was subsequently found to be a reasonable number. Although perhaps weighted too much in favour of small catchments the formula seems to provide a good guide. One should nevertheless take account of the hydrometeorological characteristics of the catchment.

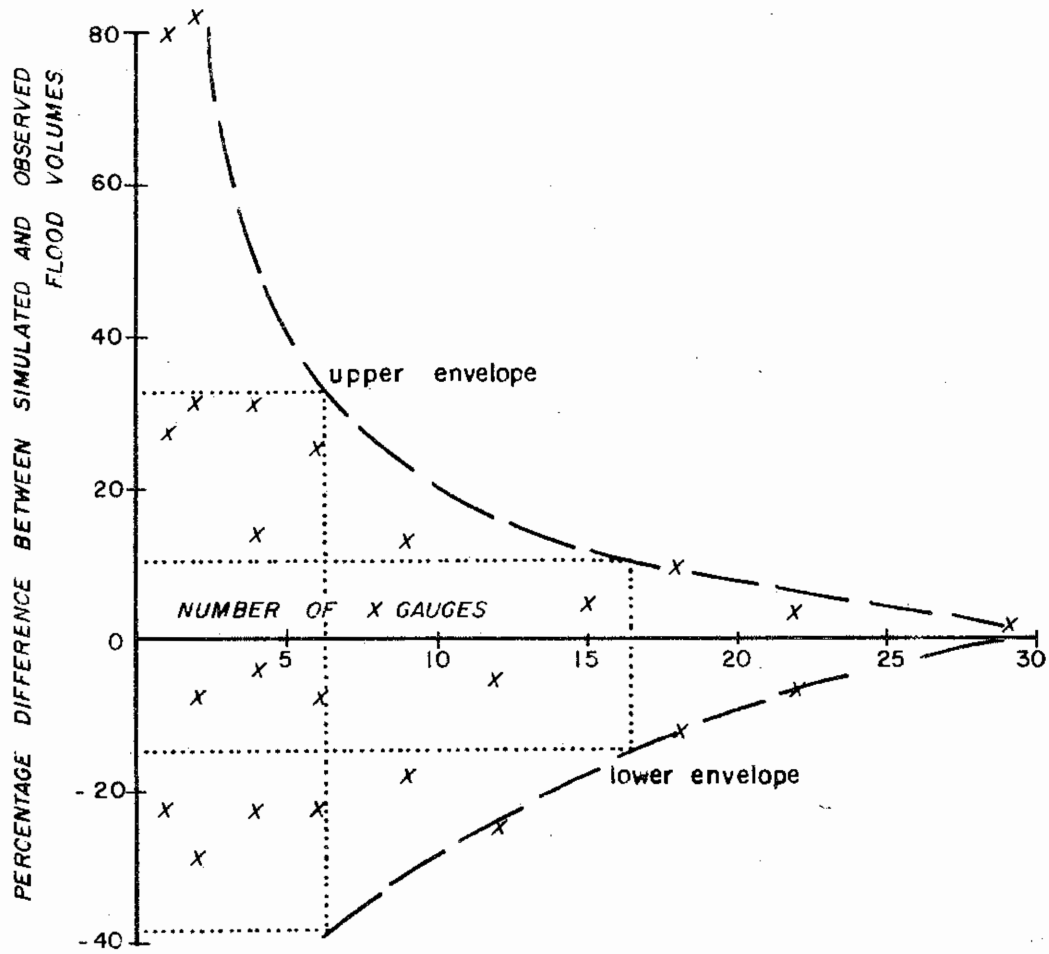


Fig. 2.5 Gauge CIMOI: Error in flood volume as a function of number of rain gauges providing data input.

When different numbers and distributions of rain gauges were tried during recalibration of the daily model, it was found that by keeping ZMAXN (the maximum infiltration rate) constant the calibrated values of ST (maximum soil moisture capacity) became increasingly unstable as the number of gauges was decreased, especially when fewer than about five gauges were employed (Figure 2.7). The same was true for ZMAXN with ST kept constant. This is mainly because the larger the number of gauges the greater the degree to which extremes (whether high or low)

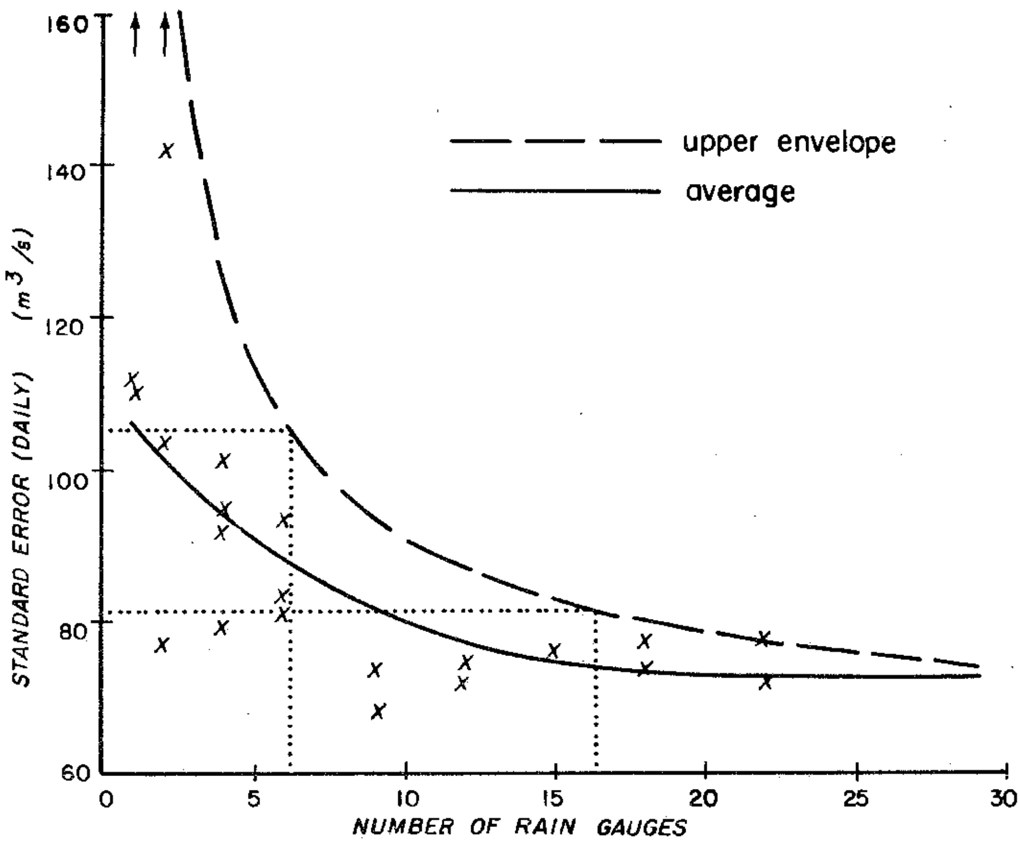


Fig. 2·6 Gauge CIMOI: Standard error of daily discharge as a function of number of rain gauges providing input data.

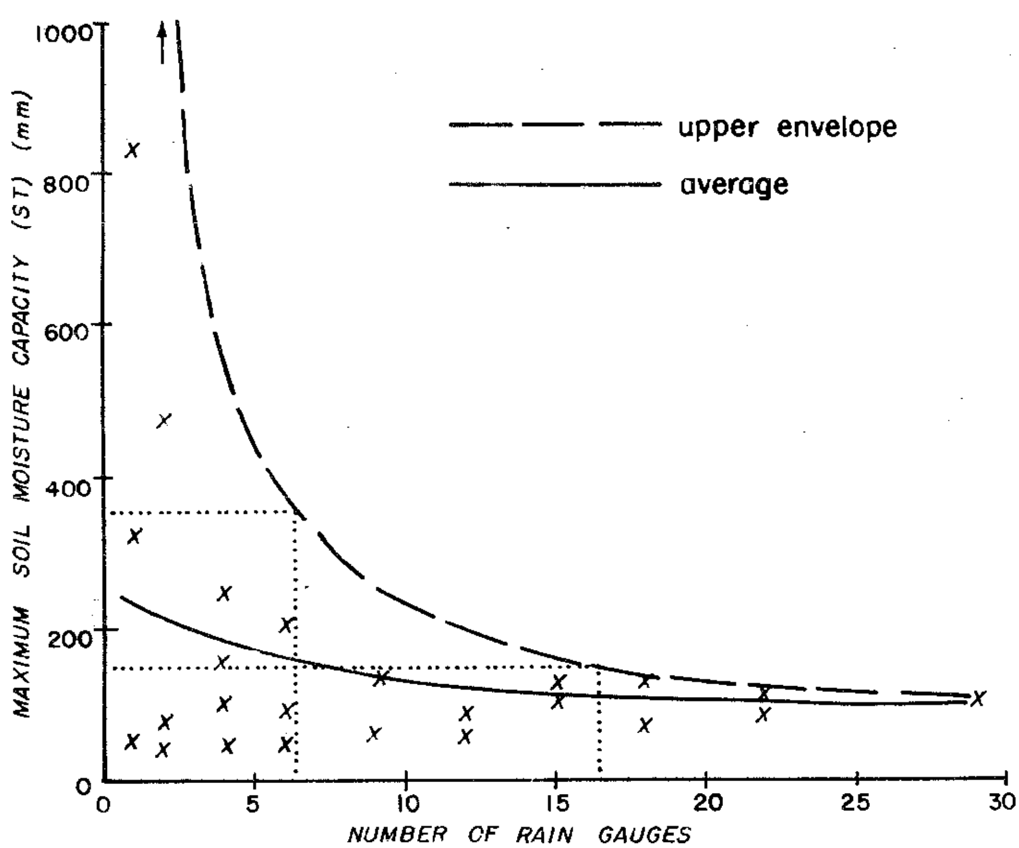


Fig. 2·7 Gauge CIMOI: ST values for best-fit calibration as a function of number of rain gauges providing input data.

recorded by individual gauges were evened out by averaging. It seemed advisable therefore to calibrate the model with the largest number of rain gauges available and only afterwards to examine the effects of reducing the number (see Figures 2.8, 2.10 and 2.12).

2.5 Final calibration of model

As mentioned earlier there is a dearth of reliable streamflow data in the Vaaldam catchment. There was only one other sub-catchment, namely Bavaria (C8M14), against which initial calibration of the model could be checked.

The reliability of the Bethlehem gauge, C8M04, commanding the Liebensbergvlei sub-catchment, was thrown into doubt when model parameters and results of simulations with the daily model were compared with those derived for the Standerton and Bavaria sub-catchments. There seemed to be an order-of-magnitude error in the gaugings. As the record at Bavaria was so short, only the February 1975 flood period could be used for calibration purposes. Even so, the discharge rating table had to be extrapolated for interpretation of high stages. Nevertheless the model parameters for the upper Wilge sub-catchment were found to differ only slightly from those for Standerton. In view of the uniform character of the catchment, as described in Chapter 1, the model parameters derived for the Standerton and Bavaria sub-catchments were adopted for the whole Vaaldam catchment.

To simulate runoff from the whole catchment, the model was run for individual sub-catchments, each with its own data input, lag and other parameters, and the individual hydrographs then combined by program DAYADD to yield the integrated simulated hydrograph for the whole catchment. Thus the lumped models on the micro scale are converted to a distributed model on the macro scale.

Final calibration of the daily model for the Vaaldam catchment was accomplished using input data from a total of 199 daily-read rain gauges for the periods October 1943 to March 1944, October 1956 to October 1957 and October 1973 to September 1975. Because accuracy of simulation of flood hydrographs is of particular importance in this study, emphasis during these final calibrations was laid on the accuracy with which the three distinct flood hydrographs could be simulated. The results of the final calibrations are shown in Figures 2.8, 2.10 and 2.12. Figures 2.9, 2.11 and 2.13 show the respective hydrographs for each of the individual sub-catchments.

A virtually perfect simulation was achieved for the February 1944 flood, which, on a daily basis, was associated with fairly uniform average catchment rainfall. This may have been indicative of relatively uniform intensity of precipitation which in turn is one of the variables that determines the volume of runoff. Uniformity of the hydrographs for the individual sub-catchments (Figure 2.9) is also indicative of uniform spatial distribution of the storm.

For the September-October 1957 flood (Figure 2.10) there is a good fit between the simulated and the observed hydrograph except for an over-estimate of the second peak. For the February 1975 flood (Figure 2.12) the number of rain gauges used for input data had a strong influence on the simulated peak. As the model simulations for all three floods exhibit no bias towards under- or over-estimation it is evident that the differences between simulated and observed flows are less likely to be ascribable to improper calibration (e.g. soil moisture capacity) than to sampling error or inadequate representation of precipitation intensity.

The primary factor influencing runoff is intensity of precipitation and this is not well represented by daily rainfall input values. As precipitation rates vary spatially from storm to storm as well as during the storm itself, and

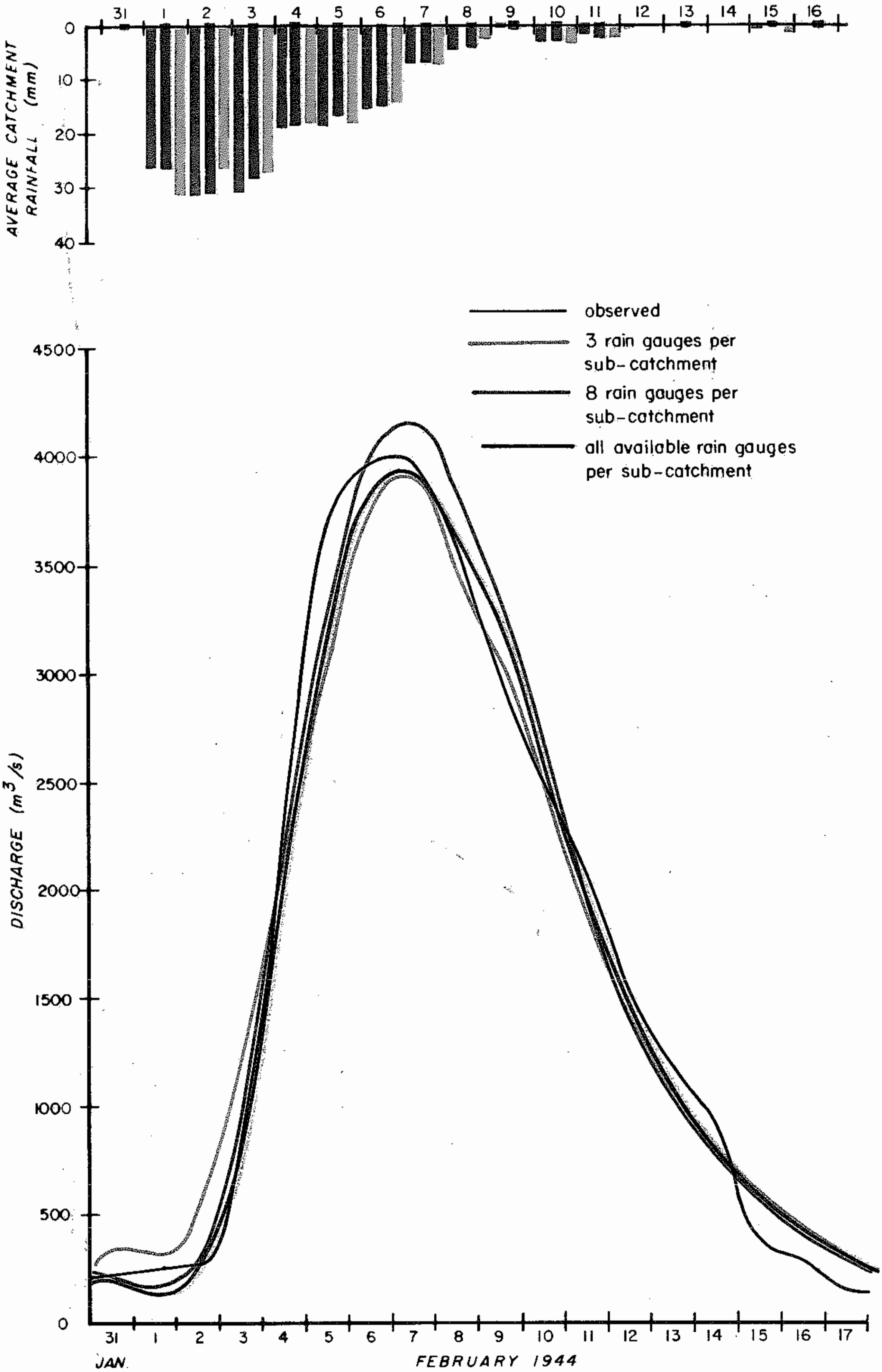


Fig. 2·8 Feb. 1944 discharge hydrographs at Vaaldam.

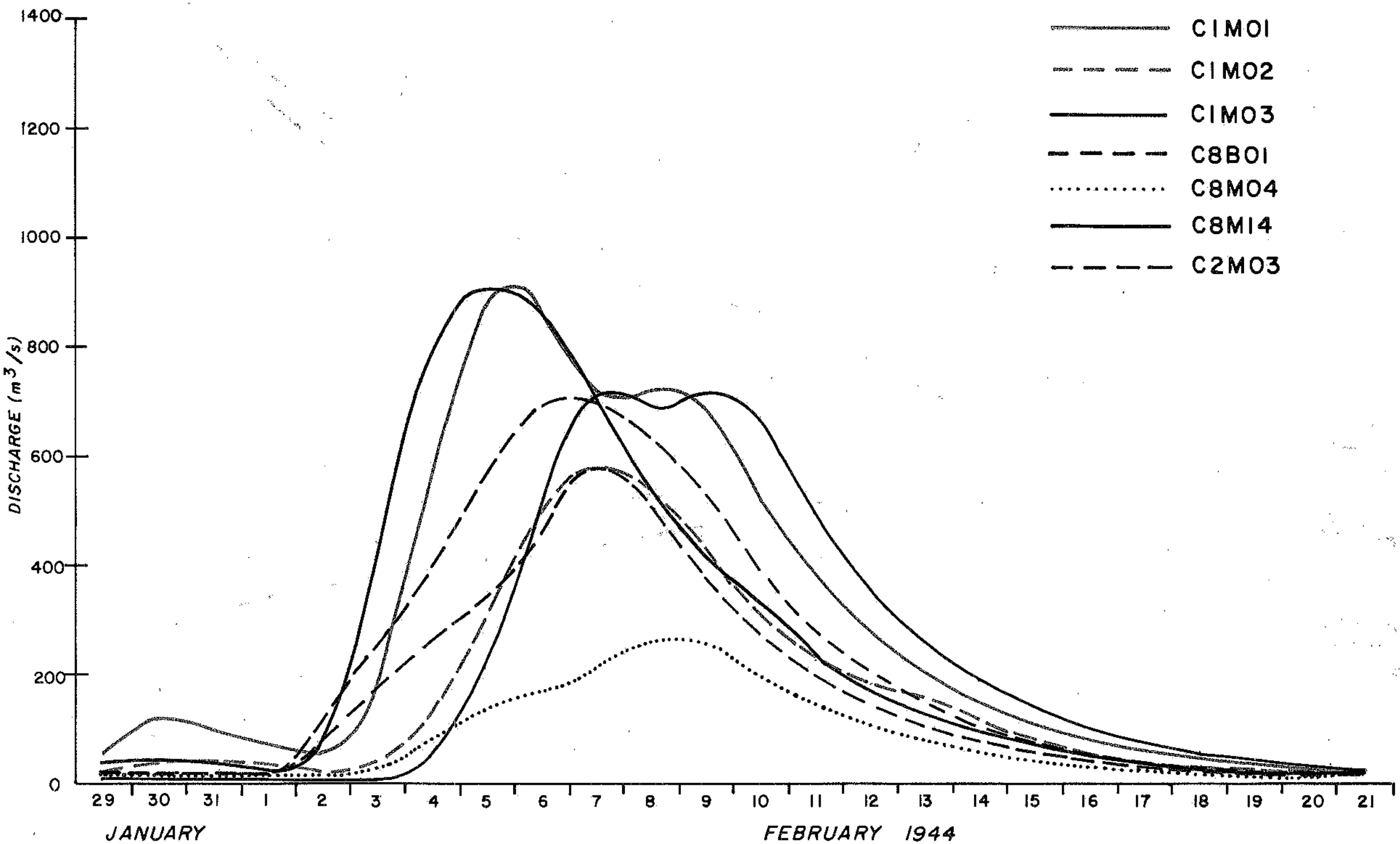


Fig. 2·9 Flood of Feb.1944-Hydrographs of the seven sub-catchments after lagging and routing to Vaaldam.

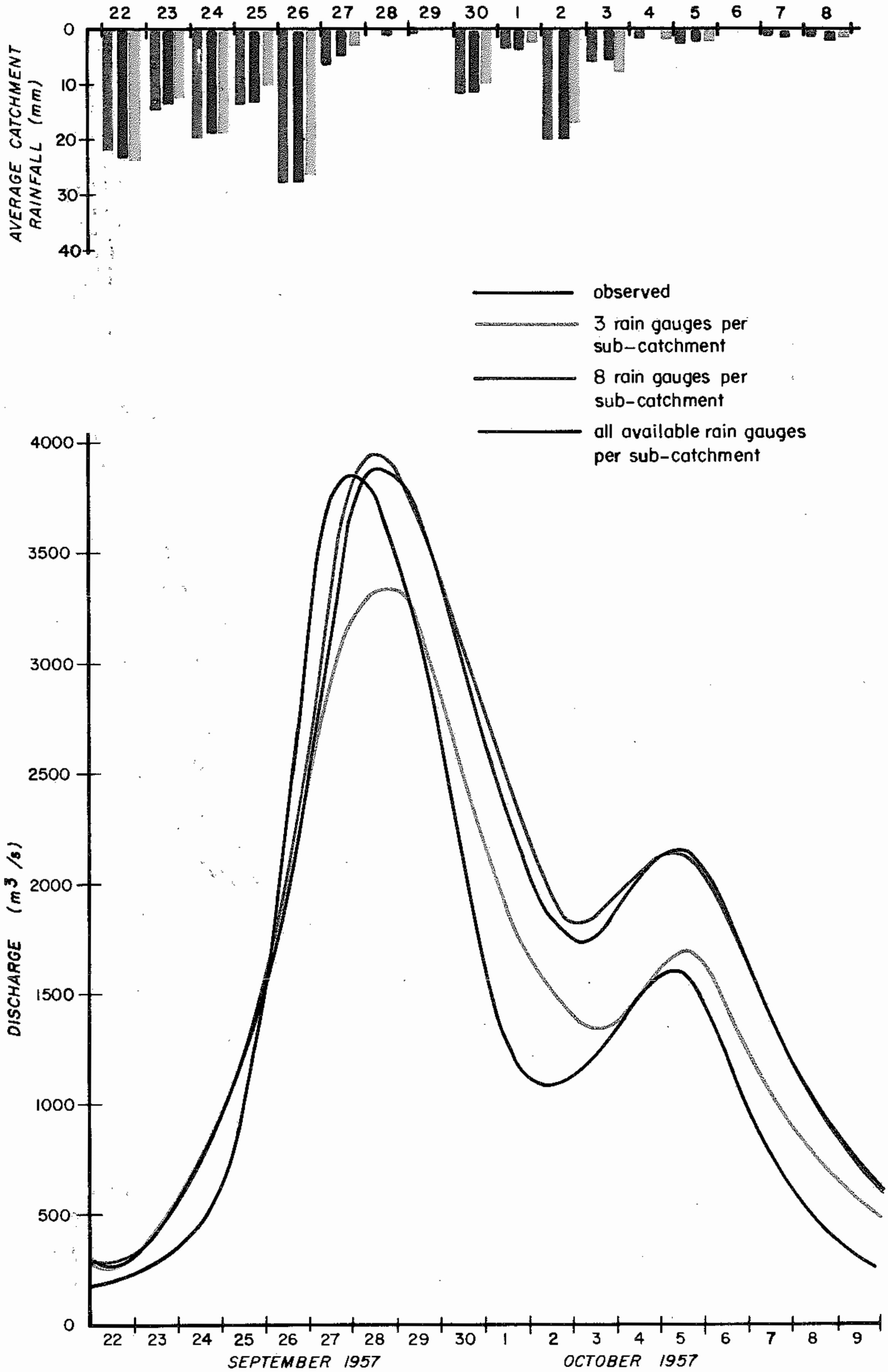


Fig. 2.10 Sept./Oct. 1957 discharge hydrographs at Vaaldam.

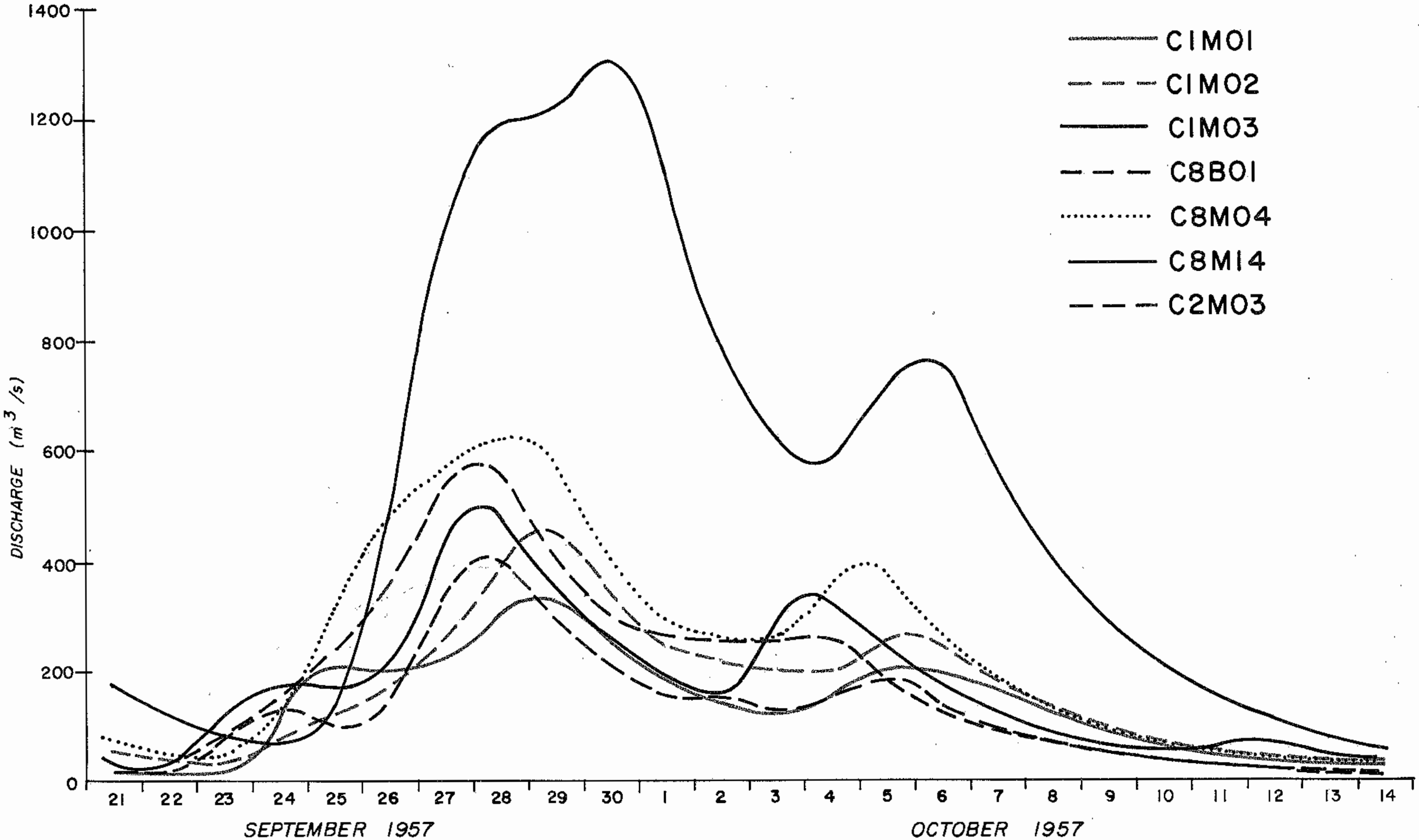


Fig. 2·11 Flood of Sept./Oct. 1957 - Hydrographs of the seven sub-catchments after lagging and routing to Vaaldam.

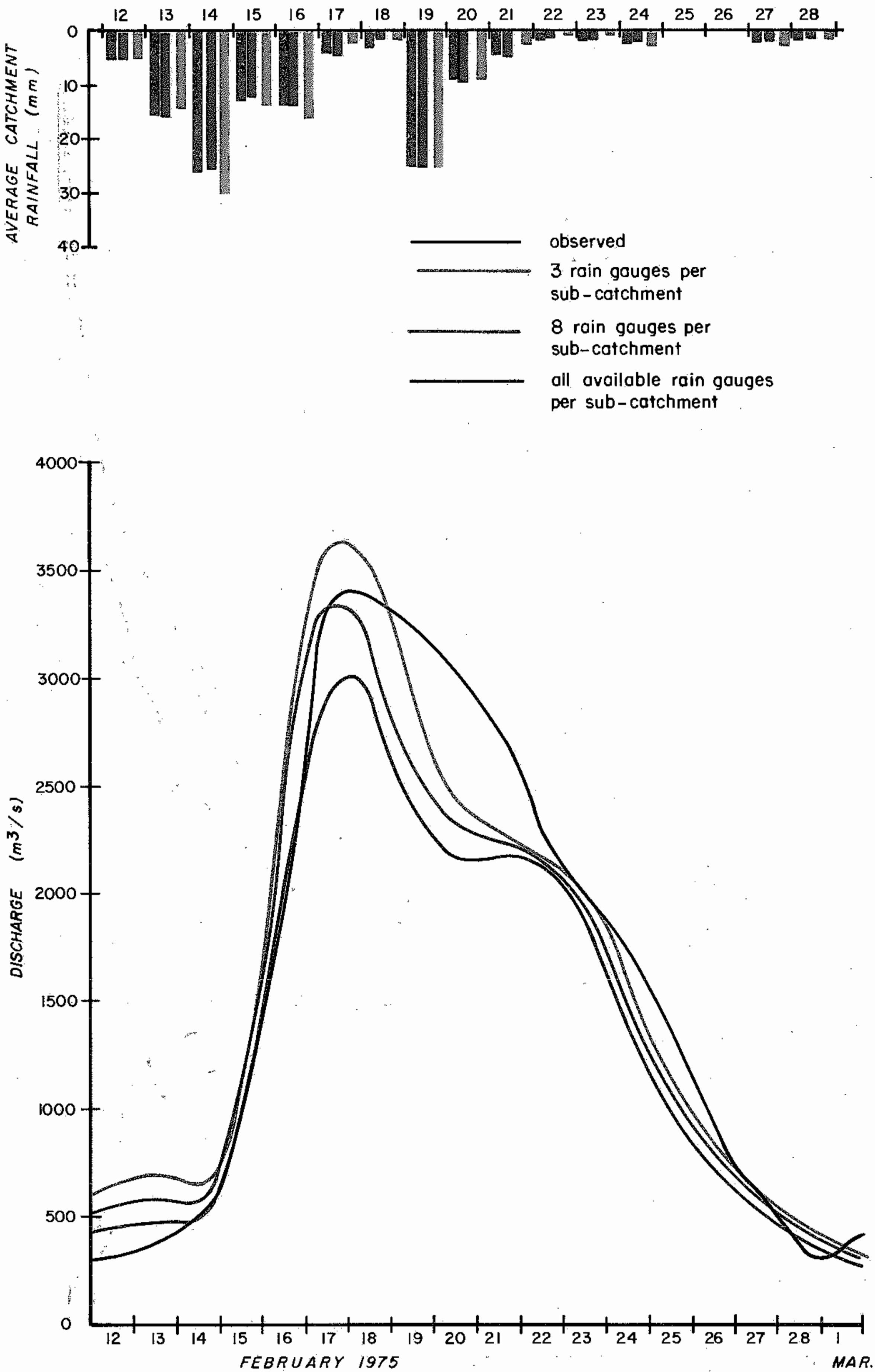


Fig. 2·12 Feb. 1975 discharge hydrographs at Vaaldam.

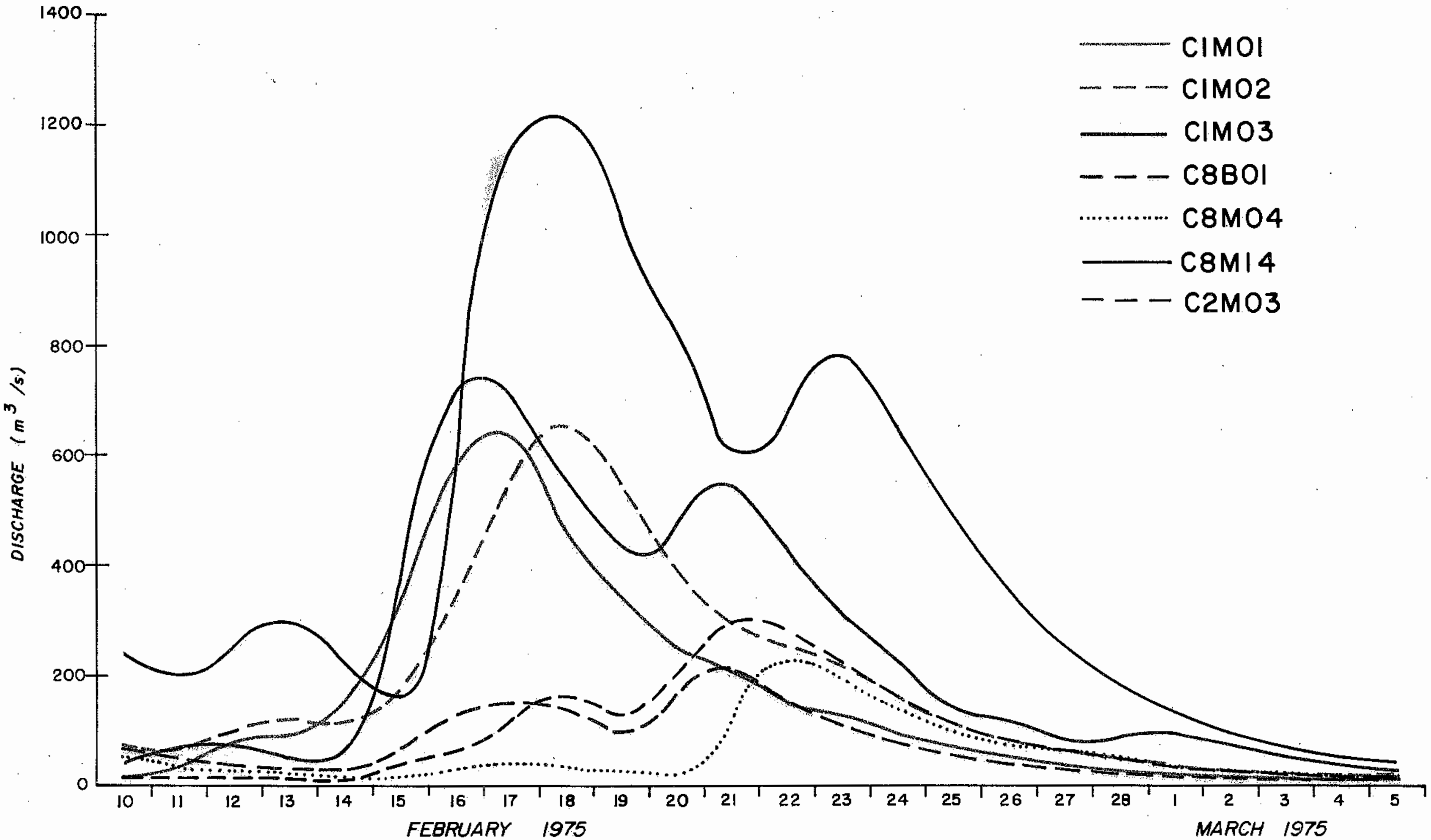


Fig. 2·13 Flood of Feb. 1975- Hydrographs of the seven sub-catchments after lagging and routing to Vaaldam.

also from month to month, as indicated in Table 2.2[14], the sampling errors in the available rainfall data can be highly significant. A system of telemetered rain gauges or radar-monitoring would doubtless reduce such sampling errors.

Table 2.2 : Example of expected maximum falls of rain in mm at Frankfort, for 25- and 50- year recurrence intervals

Month	in 15 min		in 30 min		in 45 min		in 60 min		in 24 hr	
	25 yr	50 yr	25yr	50 yr	25 yr	50 yr	25 yr	50 yr	25 yr	50 yr
Jan	22,0	25,0	28,7	32,3	32,9	37,2	34,7	39,3	55,6	62,9
Feb	28,3	32,9	35,7	41,4	41,2	47,9	44,0	51,2	61,4	70,4
Mar	15,7	18,0	19,5	22,4	23,3	26,9	26,7	20,9	48,1	55,7
Apr	12,8	14,7	17,4	20,0	18,6	21,3	19,8	22,9	44,5	51,0
May	5,2	6,1	7,6	8,9	9,7	11,3	10,3	12,0	28,7	33,8
Jun	3,4	4,1	5,1	6,1	6,5	7,7	7,7	9,2	18,3	21,7
Jul	2,1	2,5	3,1	3,7	4,1	4,9	4,8	5,8	22,8	27,6
Aug	7,5	9,0	10,5	12,6	13,1	15,7	13,9	16,6	25,4	30,3
Sept	8,2	9,7	11,3	13,2	13,7	16,0	14,3	16,7	37,7	44,5
Oct	12,4	14,2	16,7	19,1	17,2	19,5	18,5	20,8	44,6	50,9
Nov	19,6	22,3	25,5	29,0	28,8	32,7	30,3	34,5	50,8	57,3
Dec	21,6	24,7	37,9	43,8	45,4	52,6	48,2	55,7	65,2	73,9

Sensitivity of the model to rainfall input is clearly illustrated in Figures 2.10 and 2.12. From Figure 2.10 it can be seen that, for the period 23 September to 2 October 1957, the average catchment rainfall determined from 3 gauges per sub-catchment was slightly less than that determined from 8 or even from all the available gauges in each sub-catchment; the result is that the simulation based on 3 rain gauges per sub-catchment indicates a much lower runoff than was observed. For the 1975 flood the average catchment rainfall during the period 14 to 17 February based on 3 rain gauges per sub-catchment was higher than that based on all the available rain gauges. The result is a 20%

difference between the respective simulated hydrograph peaks (Figure 2.12).

Bearing in mind this sensitivity of the model to rainfall input, especially during flood periods, it is interesting to note from Figure 2.14 the extent to which average rainfall varied from one sub-catchment to another during the February 1975 flood and the extremes of error that can result from having too few samples from which to determine the spatial distribution of rainfall input. The accuracy of measurement from a network of rain gauges will also differ from storm to storm due to the varying arealdistribution of rainfall, while the catch accuracy of individual gauges can be influenced by differing wind conditions during a storm. Although, as illustrated by Figure 2.14, the differences in rainfall seem to be largely damped out in the average for the catchment as a whole, this will not necessarily be the case for runoff, because of the many non-linear relationships involved; a given percentage difference in rainfall by no means implies the same percentage difference in runoff.

As a final test of the need to subdivide a large catchment, simulation runs of the February 1975 flood were performed for the Vaaldam catchment modelled as a whole with input and parameters lumped. The results, shown in Figure 2.15, indicate that by adopting the same parameters as for the simulations shown in Figures 2.8 to 2.13 surface runoff is grossly underestimated. Even after recalibration for this specific case the best-fit simulated hydrograph still displayed the two very pronounced peaks which were not smoothed out by the effect of differences in respective lag times. The differences among the hydrographs displayed in Figures 2.12 and 2.15 clearly illustrate the advantages of sub-division. One is led to believe that the smaller the sub-catchments the higher the accuracy of simulation. Such a deduction is not necessarily true, however, as the degree of sub-division must conform with the density of the data network, and this in turn should be decided on a benefit-cost basis.

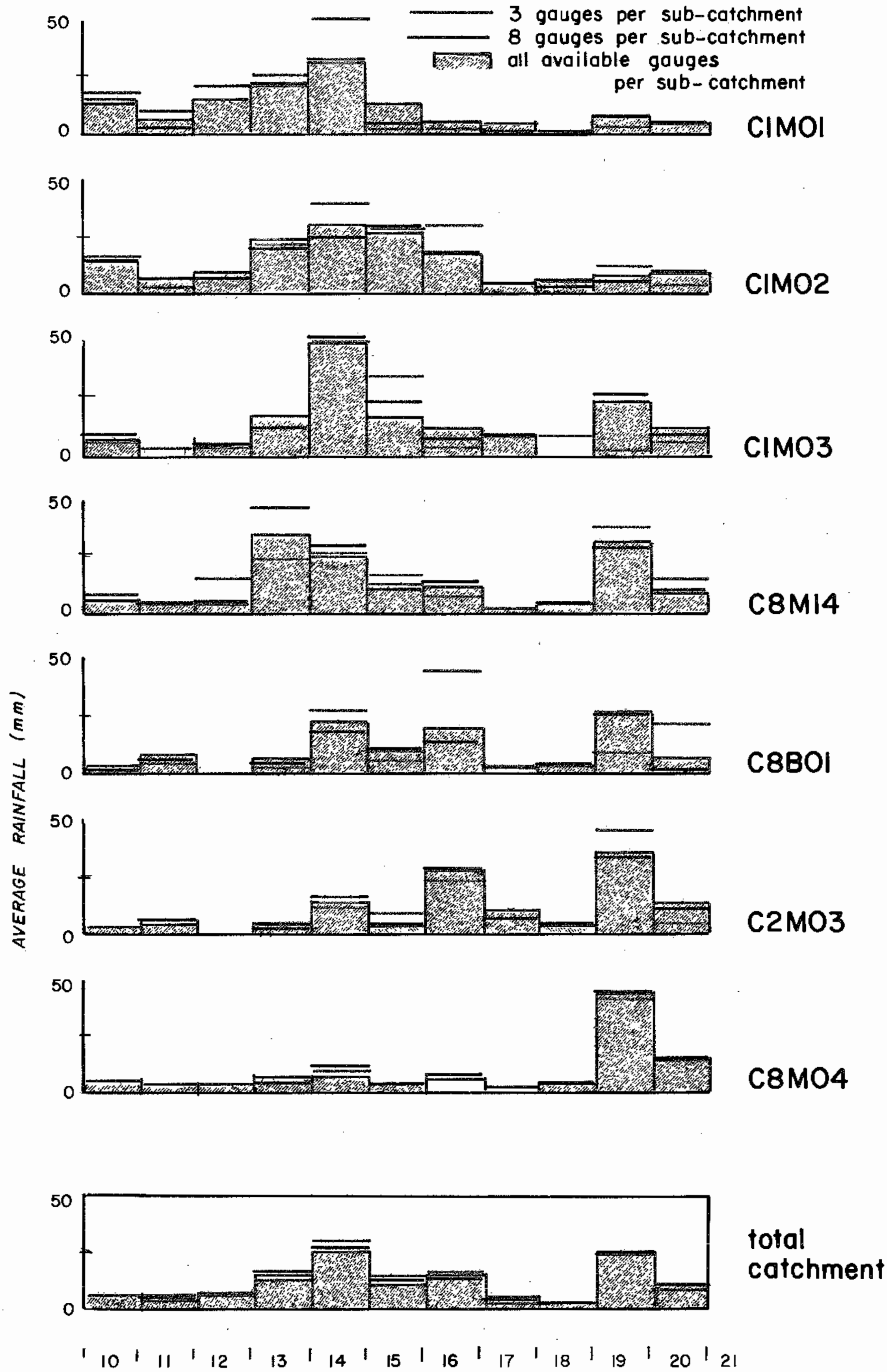


Fig. 2·14 Average rainfall over the individual sub-catchments for the Feb. 1975 flood, as measured by different numbers of gauges.

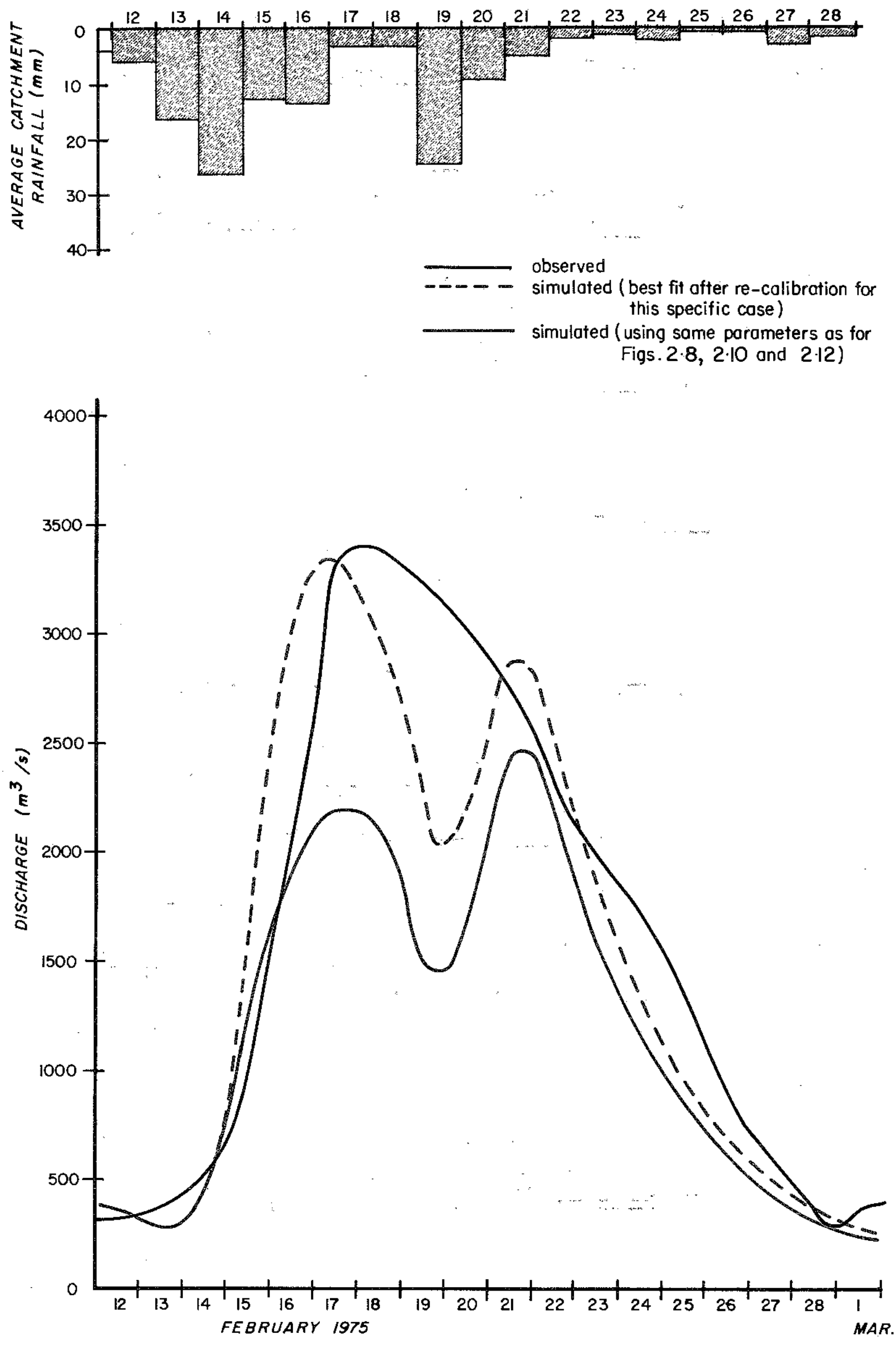


Fig. 2·15 Feb. 1975 simulations for Vaaldam catchment without sub-divisions

2.6 Daily versus hourly simulation

Since the daily model[8] estimates the time distribution of the storm from the depth of precipitation on the basis of a regression equation (with coefficients AA and BB), all storms of given daily precipitation within the same sub-catchment will of necessity be assigned the same time distribution. As the regressions were derived from average time distributions of recorded storms they cannot represent actual time distributions and it follows that inaccuracies in precipitation intensities, infiltration rates and consequently runoff are bound to occur.

Although, as will be shown in Chapter 4, hourly input data can help to improve the accuracy of simulation the chief benefit, for intermediate to large catchments, lies in the rapidity with which action can be taken on the basis of frequent early simulations during the development of the flood.

CHAPTER 3 RESERVOIR ROUTING

3.1 General

The shape of the hydrograph can change appreciably as the flood passes through the reservoir. If the water level at the dam is held constant during a flood, the peak discharge will be attenuated and delayed to an extent that is a function of capacity and topography of the reservoir basin and of the size and configuration of the incoming hydrograph. If one is to optimize release strategies it is essential to have advance knowledge of the magnitude, shape and timing of the incoming hydrograph as well as advance knowledge of the influence of the reservoir storage on these characteristics. The shape of the longitudinal water profile in the reservoir should also be known in order to facilitate the mass balance calculations, as described in Chapter 4.

In the previous section the catchment models were calibrated by seeking best fits between simulated inflow hydrographs to Vaaldam and those derived from mass balance calculations based on observed water elevations, abstractions and spillages at the dam. The degree to which these hydrographs had been attenuated by storage effects, and the relative importance of channel and reservoir routing in determining the values of the routing parameters in the model, were at that stage still unknown and therefore it was not possible to establish in advance the effect of different antecedent reservoir stages on the values of these routing parameters. Unfortunately, the streamgauges on both main rivers entering Vaaldam, namely the Wilge at Frankfort and the Vaal at Villiers (see Figure 3.1), become submerged at high stages and direct observation of the composite inflow hydrograph was therefore not possible. Moreover, it was ascertained only recently in the Department of Water Affairs that high stages at the Frankfort gauge had been underestimated on account of superelevation of the water surface at the side of the weir remote from the recorder well. (This shortcoming has since been rectified but the flow record had not yet been re-processed at the time of writing).

Accordingly, two different methods were employed to establish the

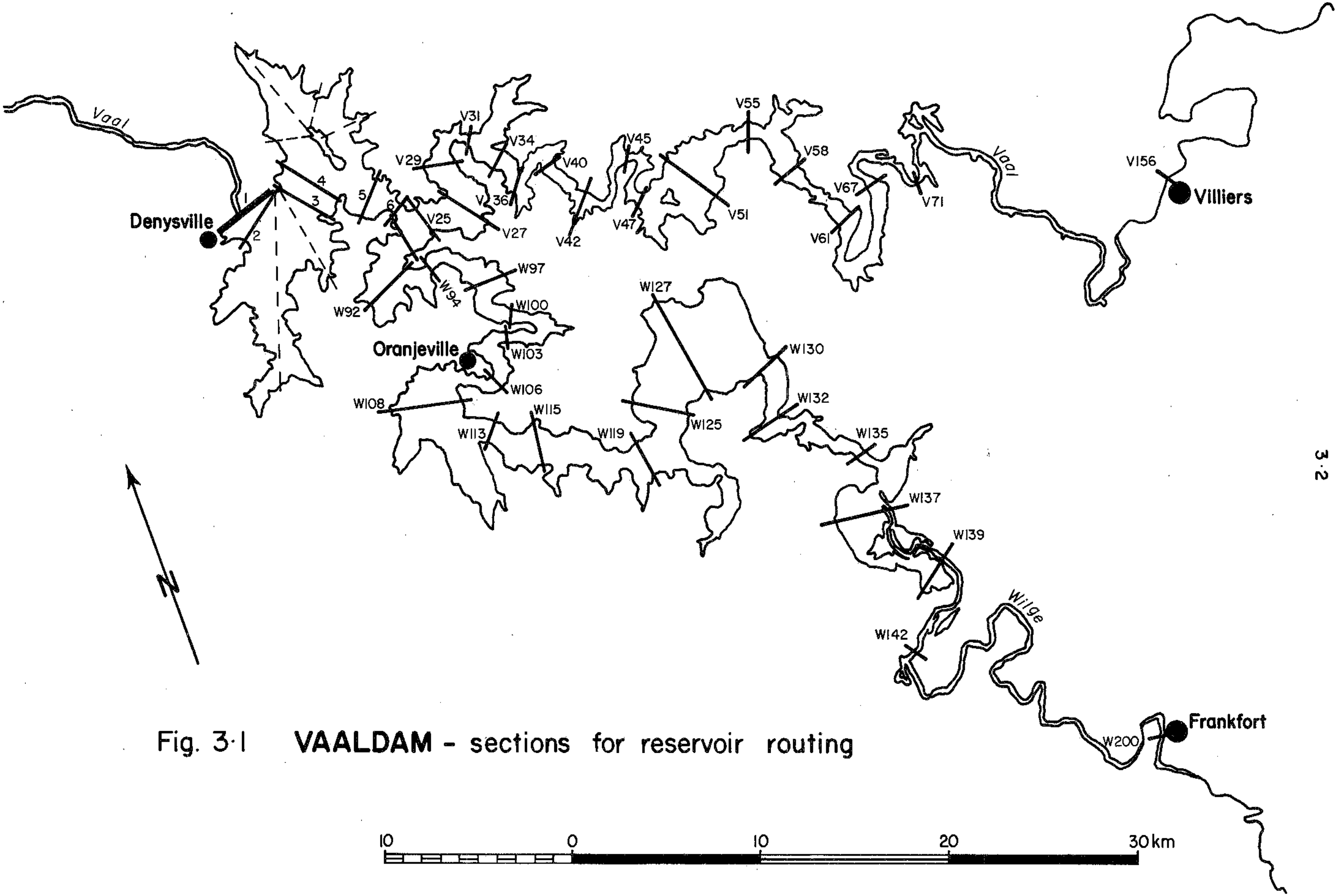


Fig. 3·1 **VAALDAM** - sections for reservoir routing influence of reservoir storage on incoming flood hydrographs. The first was a computer model based on a one-dimensional non-steady flow implicit hydraulic routing program, NSFLOW[15], obtained from the Department of Hydraulic Engineering at the University of California, Berkeley; the other was a quasi-two-dimensional cell-type flood routing model developed in the HRU[10] and referred to as the Weiss model. Identical input data were fed to the two models with the two-fold object of comparing the performance of the models and to some extent of lending confidence to the result, since there was no way of checking against directly observed data.

3.2 Input data

Surveyed cross-sectional profiles of the basin of Vaaldam were abstracted from drawings provided by the Department of Water Affairs. These constitute the topographic input to the routing models. The positions of the cross-sections are shown on Figure 3.1.

Simulated flows from the sub-catchments commanded by gauges C1M01, C1M02 and C1M03 plus an areally weighted proportion of the runoff from the sub-catchment above gauge C2M03 were combined to represent inflow to Vaaldam at Villiers, while simulated flows from sub-catchments C8B01, C8M04, C8M14 and the remainder of C2M03 were taken as inflow at Frankfort. (See Figure 2.1). As the two components of the contribution from the sub-catchment above C2M03 are relatively small proportions of the total and unlikely to influence the water profile, they were assumed to be point inflows at Villiers and Frankfort respectively. Any error resulting from this assumption would amplify the influence of the reservoir, resulting in over-estimation rather than suppression of the backwater and attenuation effects.

The February 1975 flood hydrograph at Vaaldam based on the mass balance calculations was then sub-divided to obtain the same relative proportions between the mean daily discharges at Frankfort and Villiers as was determined for the simulated hydrographs, and advanced by about 12 hours to allow for reservoir lag, i.e.

the time taken for the flood wave to travel from Frankfort or Villiers to Vaaldam. These component hydrographs were assumed to be the "observed" inflows at Frankfort and Villiers respectively and, together with the observed stage values at the wall, provided the input to the routing models. (See Figure 3.2).

3.3 Investigational procedures

In order to achieve the objectives stated in paragraph 3.1, it is first necessary to establish some measure of the accuracy with which the reservoir influence can be modelled. For this purpose the "observed" inflow hydrographs, defining the upstream boundary conditions, and the observed stage hydrograph, defining downstream boundary condition, were used as input to the Weiss model[10]. The outflow hydrograph generated by the model could then be compared with the observed outflow hydrograph, as illustrated in Figure 3.3. Apart from an initial instability in the simulation, the correspondence between the two release hydrographs is remarkably close, especially in view of the relatively poor accuracy and coarse time steps of the input data. It could therefore be concluded that the reliability of the model calculations was satisfactory - a conclusion that is corroborated by the results of subsequent calculations by both models, as discussed presently.

A further fact to be noted is that surface roughness has a negligible influence, the momentum part of the flow equation being more important than the energy component. Accuracy of simulation depends only slightly on correct calibration of roughness values but rather more strongly on model structure and reservoir basin topography. Unfortunately basin structure is not well defined as only relatively sparse cross-sections are available to describe this rather complex basin.

The reason for selecting the Weiss model for this initial simulation rather than the NSFLO program was that, as a one-dimensional model, NSFLO cannot adequately simulate the stage hydrograph in each of the major arms of the reservoir simultaneously. Thus, any change in water level at the wall would activate a

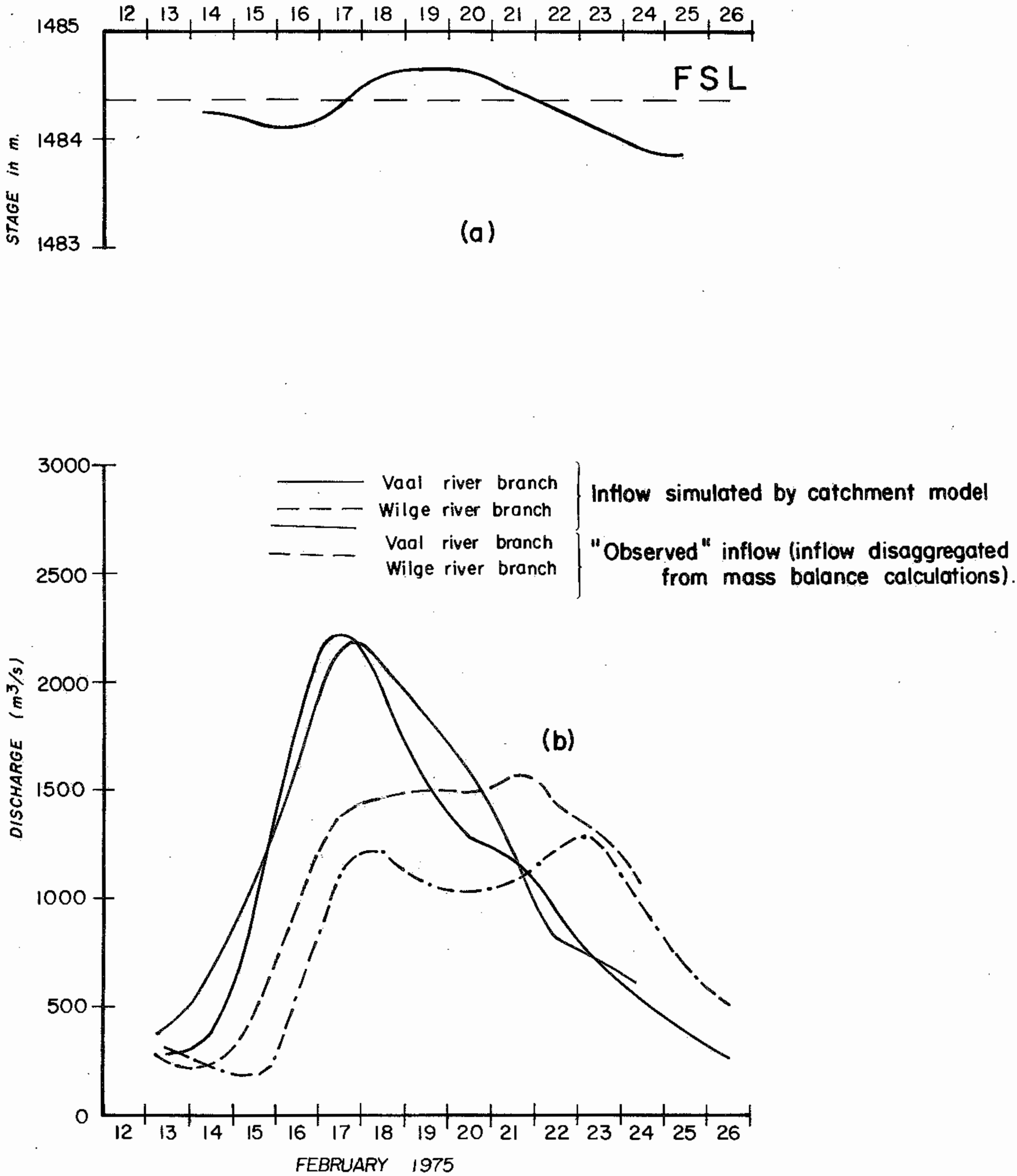


Fig. 3·2 Flood of Feb. 1975:

(a) Stage hydrograph at Vaaldam wall.

(b) Inflow hydrographs to Vaaldam from Vaal and Wilge branches.

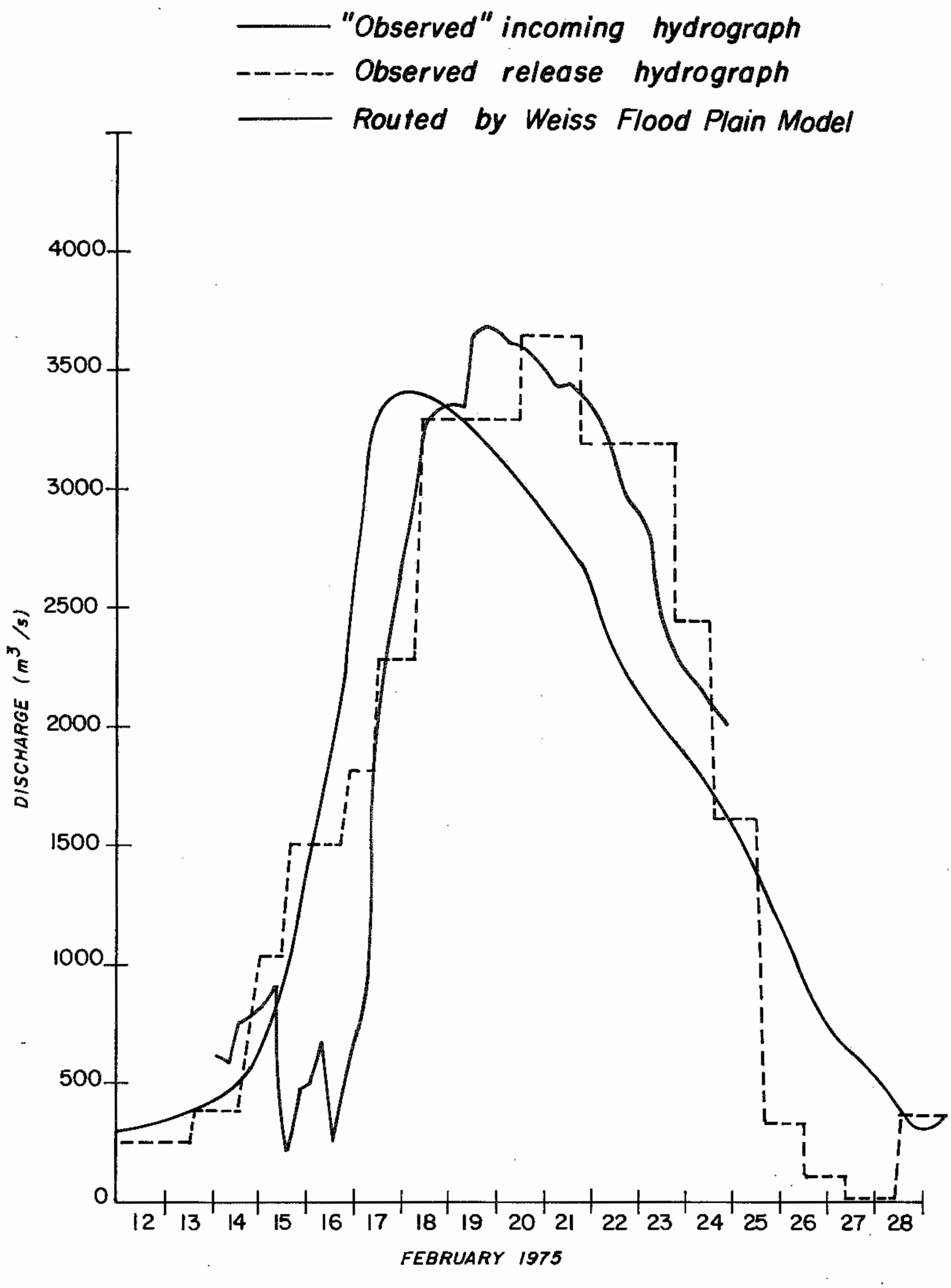


Fig. 3·3 Routing of Feb. 1975 flood through Vaaldam with observed stage hydrograph and "observed" incoming flow hydrographs as input.

corresponding change in storage only in that branch of the reservoir which was being simulated at the time. This could introduce errors of the order of 50% in the change in storage.

As the initial simulation run yielded a good fit with the observed release hydrograph, the Weiss model could be applied with some confidence to establish the inherent attenuation characteristics of the reservoir. This was accomplished by holding the water surface at the wall steady at full supply level (FSL), in order to remove the effects of change of storage, and again using the "observed" hydrographs as upstream input. Any attenuation during such a simulation run would therefore be attributable to backwater storage. The run proved, however, that Vaaldam acts as a level pool at least as far upstream as the confluence of the two major inflows - the Wilge and the Vaal. With the water level at the wall held constant at FSL and Vaaldam acting as a level pool at least up to the confluence, the simulation could now be repeated with program NSFLO. As the arms of the reservoir are modelled separately one at a time, flow to the unmodelled arm could be assumed to be tributary inflow at the point of confluence, and vice versa.

The results of the NSFLO simulation, illustrated in Figure 3.4, reveal that, apart from a distinct time lag, changes in hydrograph shape are negligible. This is consistent with the relatively minor backwater effect shown up in the water surface profiles calculated during the same run and depicted in Figure 3.5. If the backwater elevations are transferred from Figure 3.5 to Figure 3.1 it will be seen that the surface areas and therefore the volumes subjected to significant backwater effects are proportionately small.

3.4 Conclusions

As illustrated by Figure 3.4, attenuation ascribable to backwater storage at full reservoir is small, and would be even less significant at lower stages; it follows that dynamic routing through Vaaldam of the output from the catchment model would be an unwarranted refinement. Moreover, the influence of the reservoir

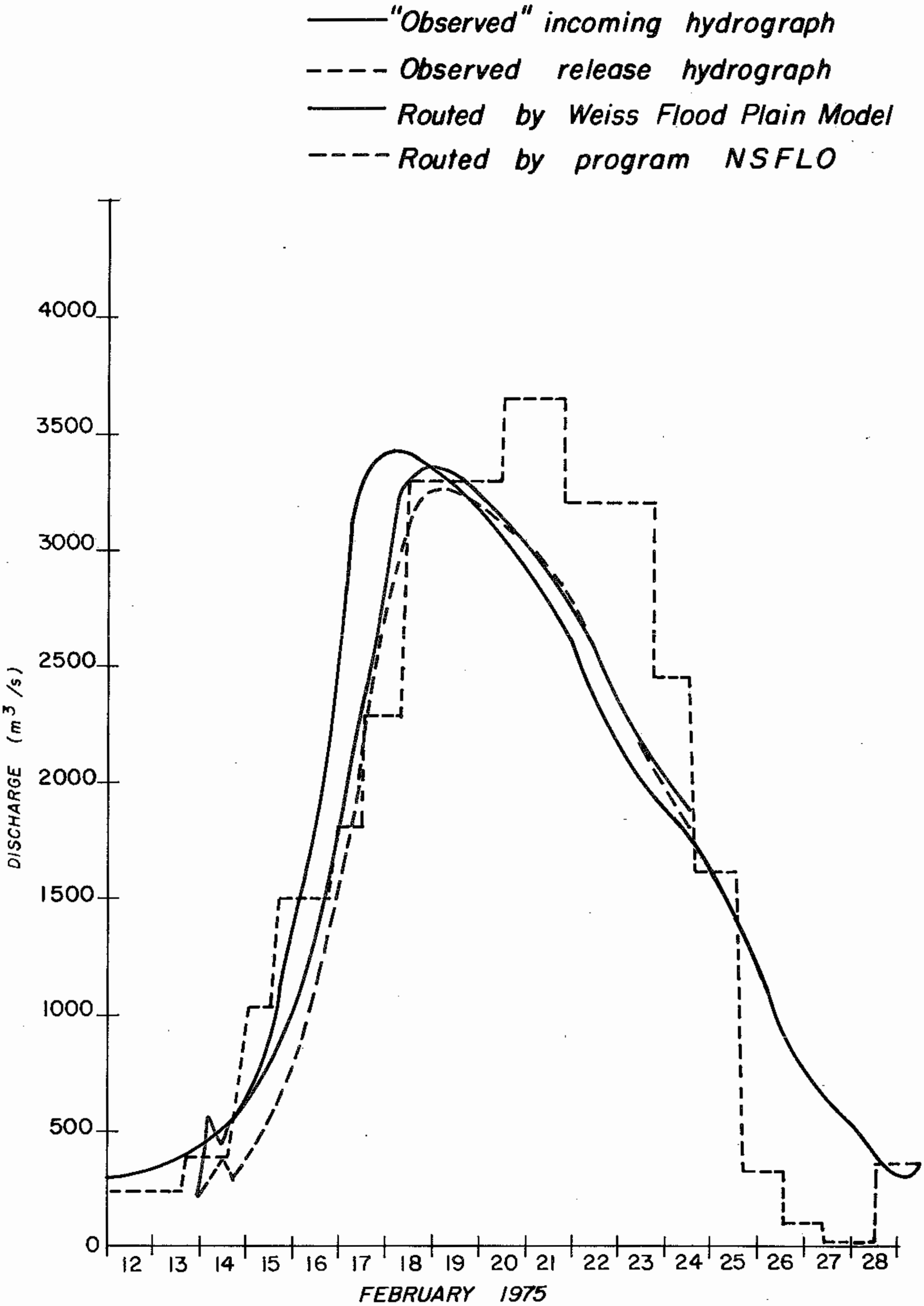


Fig. 3·4 Routing of 1975 flood through Vaaldam with water surface at wall held constant at FSL and "observed" incoming hydrograph as input.

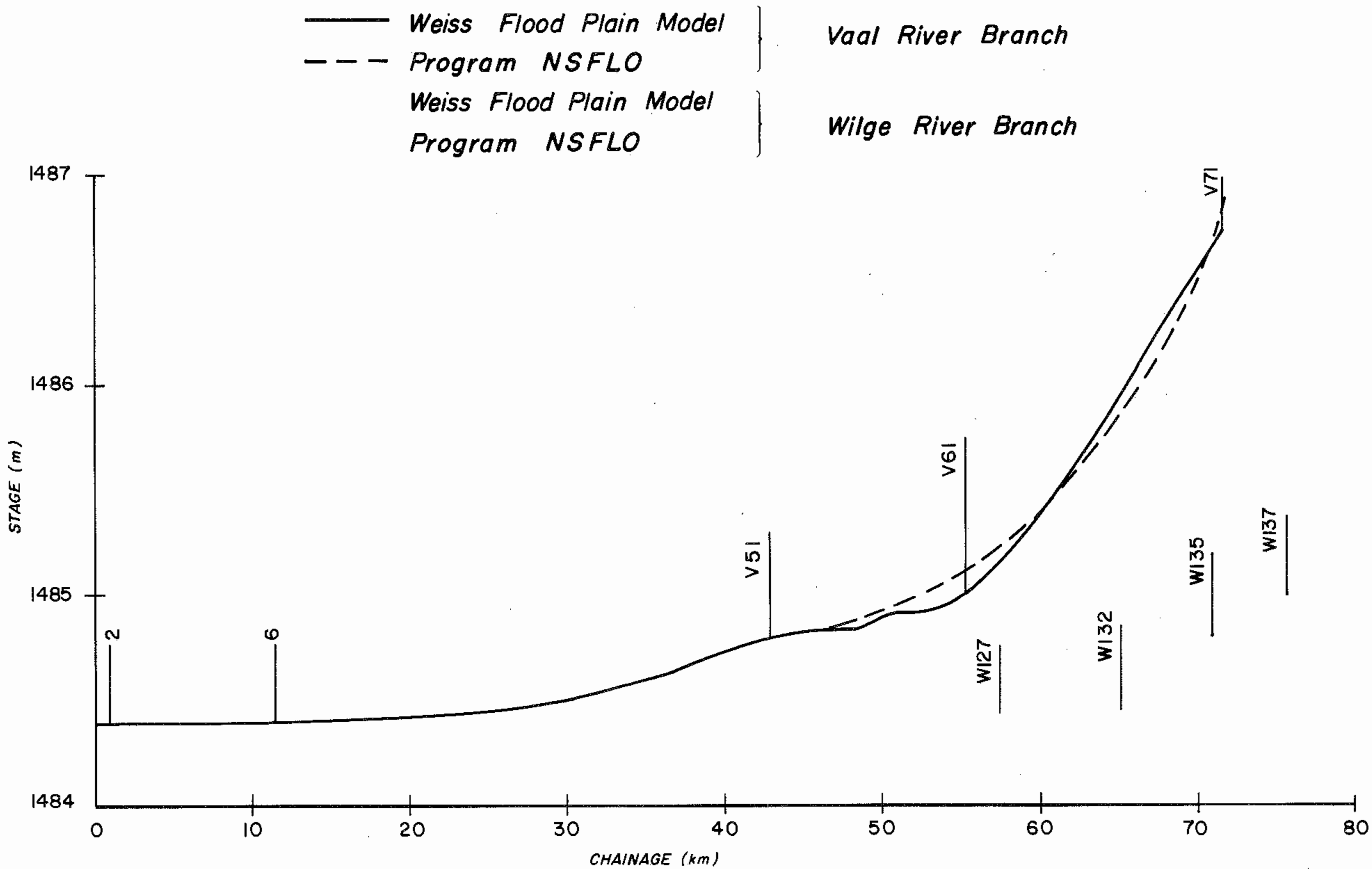


Fig. 3·5 Water surface profile along Vaaldam at peak of flood (18th Feb. 1975) with water level at wall held constant.

on catchment model parameters does not differ significantly from that due to channel attenuation, which is inherent in the catchment model. The influence of reservoir stage on the model parameters can thus safely be assumed to be negligible.

The fact that backwater effects are relatively insignificant at Vaaldam, especially with respect to surface area, as can be seen from Figures 3.1 and 3.5, implies that level pool routing is perfectly acceptable for mass balance purposes, as will be discussed in the next chapter.

CHAPTER 4 RESERVOIR OPERATION FOR FLOOD MITIGATION

4.1 General

The most important problem facing a gate operator seeking (theoretical) optimum control of a flood is the lack of advance knowledge of the magnitude and shape of the incoming flood hydrograph. As was demonstrated in Chapter 2, past flood events have been successfully simulated by conceptual hydrologic modelling. There seems to be no reason why success should not be achieved in application of the same techniques for real-time forecasting of future flood events, given up-to-date causative rainfall.

In the case of the Vaal system the model parameters for each of the seven selected sub-catchments upstream of Vaaldam were lumped and the resulting floods from the sub-catchments were superposed to yield the flood hydrograph at Vaaldam. The basis of lumping and sub-dividing within this infinitely complex system was relatively coarse and, although there is no theoretical limit to the degree of sub-division, there are indeed practical limits to the volume of input and output data that would be needed to evaluate the numerous parameters so that the resulting complex model could be usefully operated. It follows that in the model as developed there are bound to be errors due to lumping both of input and of model parameters.

Kovacs[16] has developed a technique of flood hydrograph prediction for the Vaal catchment based on multi-variate correlations but, because of the wide variety of antecedent conditions, rainfall events and catchment response, his correlograms are bound to display considerable scatter. Whatever the chosen technique it is certain that the forecasting of complete sequences of future events can never be consistently accurate. It follows that, in real time, forecasts must be continuously repeated as fresh information based on transmitted observations comes to hand. The predicted flood hydrographs will therefore grow incrementally as model runs are repeated with fresh data, as illustrated by Figure 4.1. Decision-making based on processing of these predicted hydrographs will also follow step by step; in other words,

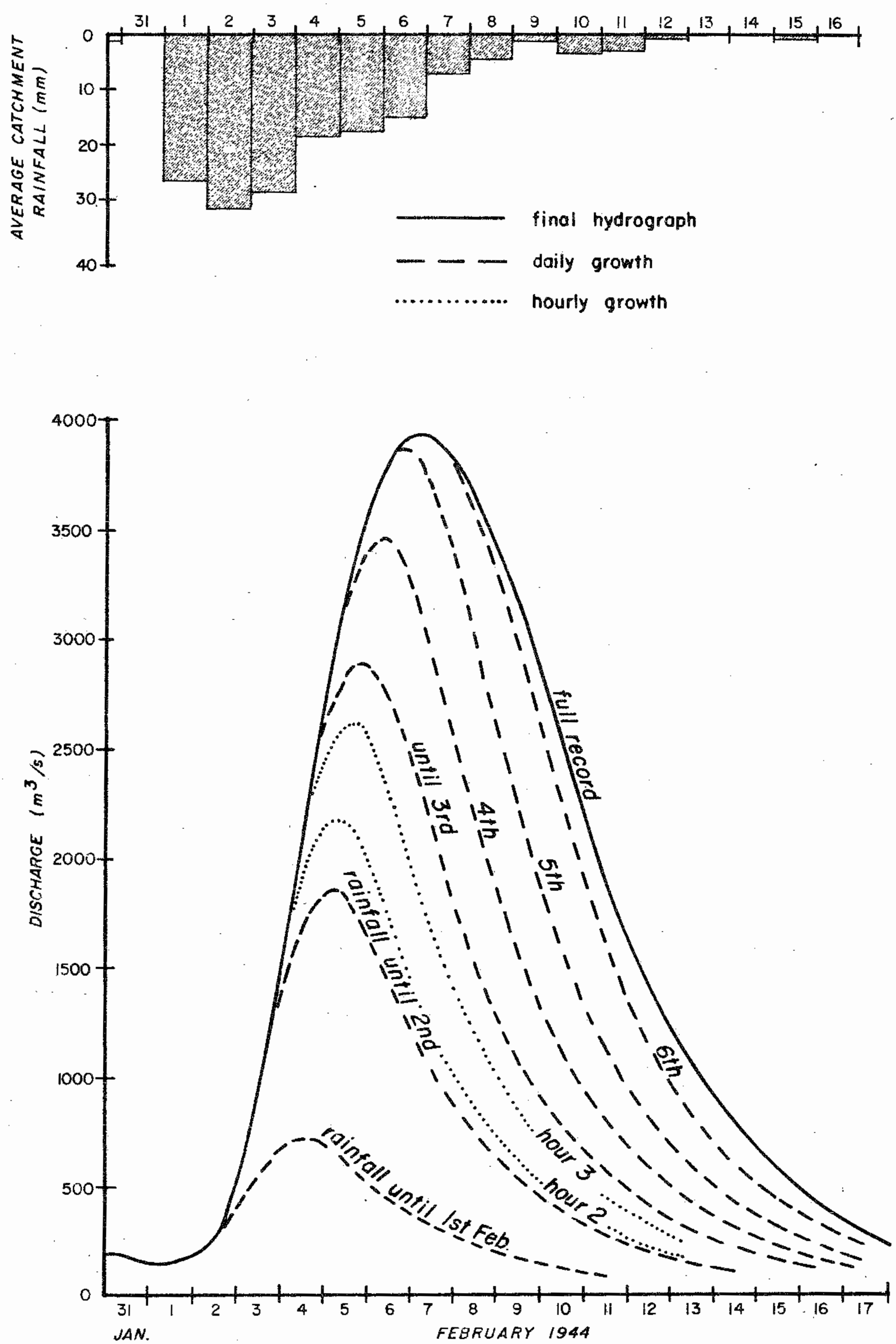


Fig. 4·1 Development of forecast Feb. 1944 flood hydrograph at Vaaldam.

there must be a continuous stream of decisions for action rather than a single action based on a single forecast that can hardly ever be correct.

If one has the power to change the course of events it follows that before action is taken the objective must be clearly defined. An obvious goal would be to minimize flood damage but, where there are conflicting downstream interests, formulation of the objective function offers difficulties. Agricultural interests, for instance, may prefer deeper inundations of shorter duration to shallower long duration flooding of smaller areas. By contrast, damage to residential and industrial areas is, in general, likely to be directly proportional to downstream stage and therefore to extent of area affected.

In some cases it may be economically justifiable to cause minor damages by releasing flows above the damaging stage in order to accommodate a major flood known to be on the way, and thus to avert severe damage that would have been incurred had no action been taken. In any event, it is essential to ensure that minor damage areas are not flooded more frequently or more severely through introduction of a flood control scheme than they would have been without it. Of great importance too is the necessity to institute flood plain zoning and to provide for the maintenance of channel capacity; efficient reservoir operation depends as much on the ability to release flood waters without causing damage as it does on the ability to store surplus water. Unfortunately, reduced frequency of flooding downstream of reservoirs often stimulates the desire to develop the flood plain and dulls the incentive to maintain the channel capacity.

Alternative options are illustrated in Figure 4.2 based on work by Plate and Schultz[17]. In these diagrams, A represents volumes of pre-release, B the volumes by which the damaging part of the hydrograph can be modified by gate manipulation and C the volumes of post-release associated with earlier over-filling of the reservoir or surcharging of the gates. T and Q are respectively the duration and extent of damaging flood discharges.

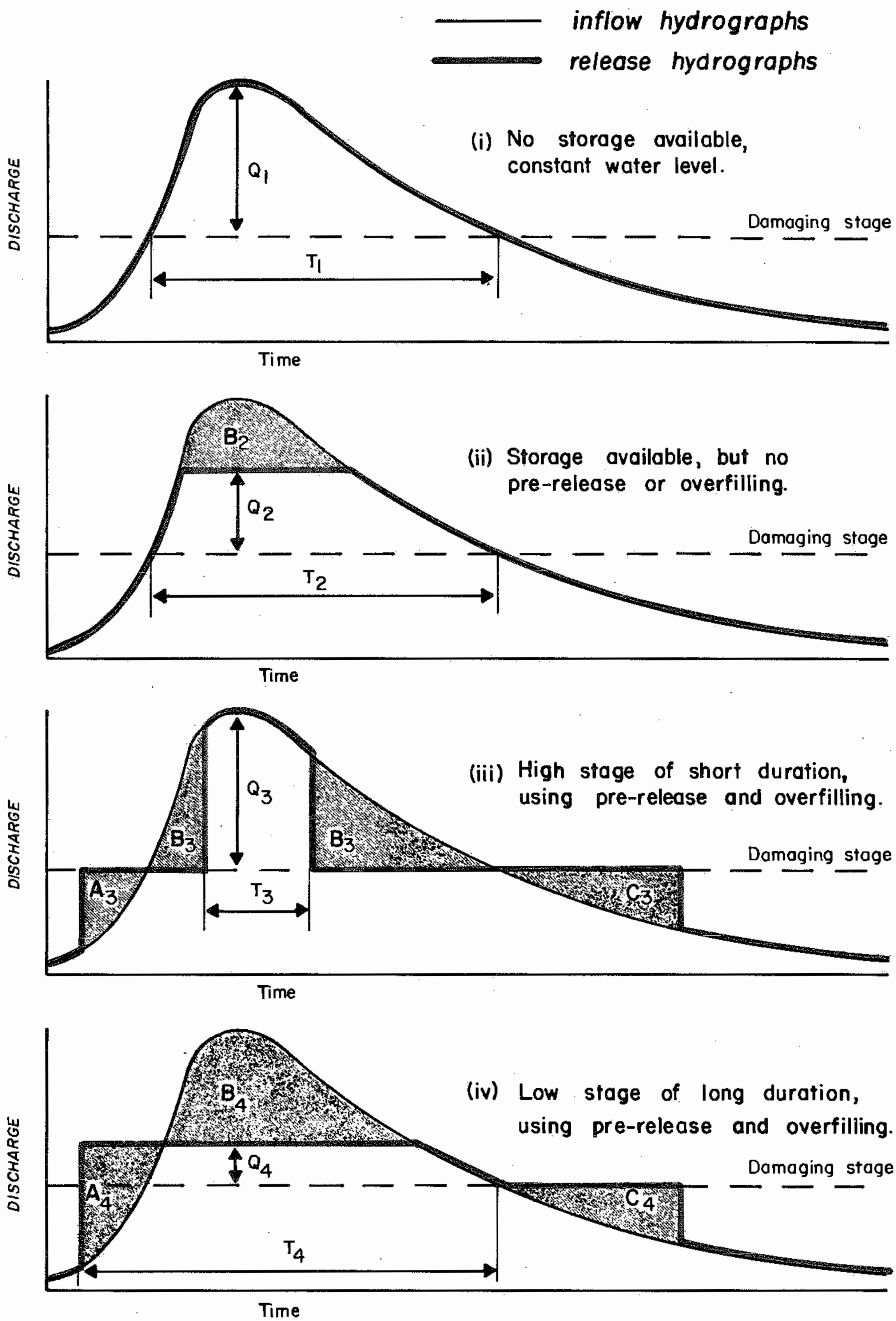


Fig. 4·2 Illustration of basic flood release strategies for a single reservoir.

If no storage space is available at the time of arrival of a flood and no storage above full supply level is permitted (e.g. if reservoir stage is at top-of-gates elevation and overfilling of the reservoir by surcharging the gates is not permitted) the flood hydrograph will pass virtually unchanged through the reservoir, as illustrated by Figure 4.2(i). Any slight attenuation would be that due to backwater storage only (see Chapter 3). If storage B_2 is available at the time of arrival of a flood (i.e. if the reservoir is short of full by amount B_2) the outgoing hydrograph can be modified as shown in Figure 4.2(ii), provided the size and shape of the incoming hydrograph are known in advance. Ever-increasing water demands, however, coupled with the fact that in most countries the best dam sites have already been exploited, have placed a premium on available storage space for purposes of safeguarding water supplies and it therefore becomes more and more difficult to allocate storage volume specifically to flood control.

The foregoing difficulties can be largely overcome if the need to pre-release and to overfill the reservoir is conceded. Figure 4.2(iii) illustrates a control measure aimed at minimizing the duration of damaging inundation without too much concern for the depth or extent of flooding - a measure that might be desirable where the downstream flood plain is largely agricultural. In Figure 4.2(iv), on the other hand, the aim is to minimize the peak discharge - and therefore the extent of areas subjected to inundation - with consequential unavoidable prolongation of the flooding. For every independent flood event, the storage available and the size and shape of incoming hydrograph are fixed, as also is the volume of storage associated with the permissible degree of overfilling of the reservoir. Therefore, in the relevant mass balance equation,

$$B = A + C + S \qquad \text{.................(4.1)}$$

the sole item that can be manipulated is the pre-release volume **A**. In equation 4.1, S is the initial storage available and A, B and C are as previously defined.

The importance of pre-release follows also from the basic hydrologic routing equation:

$$\tfrac{1}{2}(I_1 + I_2)\Delta t - \tfrac{1}{2}(O_1 + O_2)\Delta t = \Delta S \qquad \text{.................(4.2)}$$

Where I and O refer to inflow and outflow rates and S to storage volume. Subscript 1 refers to the beginning and subscript 2 to the end of any time period Δt.

As the allowable change in storage throughout the whole flood period, $\Sigma\Delta S$, is limited to the initial storage available plus the volume of surcharge allowed, the sum over the whole flood period of the left hand side of equation 4.2 must also be limited. If for all time increments the outflows (prior to peak) are constrained to be equal to or smaller than the inflows and if outflow is to reach a constant plateau within the inflow hydrograph, the minimum level of the constant plateau is determined by the initial storage available (B_2 in Figure 4.2(ii))plus any surcharge allowed. The only way the level of the plateau can be lowered is by pre-release, i.e. to allow O to exceed I on the rising limb, thus to create additional storage to accommodate inflows near the peak (see Figure 4.2(iv)).

The volume of storage created by pre-release is defined by the equation:

$$A = \int_{t_o}^{t_A} (O_t - I_t)dt \qquad \text{....................(4.3)}$$

in which the symbols are as previously defined, and t_o refers to the start and t_A to the end of the pre-release. The volume of A is thus dependent both on the length of time between t_o and t_A and on the difference between I_t and O_t, both of which are functions of time. The earliest possible start of pre-release is thus of essence. The maximum rate of release is determined by the acceptable level of risk of flood damage. The volume of water pre-released and therefore the volume of flood attenuation storage one endeavours to create is tempered by the risk of ending up with the reservoir not filled.

4.2 Constraints on reservoir operation at Vaaldam

The constraints on flood control operations at Vaaldam prescribed by the Department of Water Affairs, although nowhere publicly spelled out as far as is known, are understood to be basically as follows:

1) Maximum permissible water level with some gates still closed is 0,3 m above FSL, viz 103,87% of capacity. There can of course be no prescribed level constraint when all gates are open.

2) The reservoir must be 100% full after the main flood wave has passed.

3) The downstream flood peak shall not be higher nor occur earlier than the uncontrolled peak.

4) The maximum rate of increase in discharge should be in the range 50 to 250 $m^3/s/h$, depending upon the rate of release at the time and the anticipated rate of increase in inflow.

5) Increases in rate of release during night time should be avoided.

From points of view of safety of the dam and appurtenant works and the necessity to safeguard water supplies, constraints 1 and 2 must be accepted as inviolable. While there is obviously a need to ensure that the downstream flood peak will not exceed the uncontrolled peak, as stated in constraint 3, there seems to be no valid reason why it should not occur sooner. In the uncontrolled situation, occupants of the downstream flood plain would not necessarily have prior intimation of the arrival of a flood; the rise of the river could come as a complete surprise. It is obviously preferable, however, to have pre-knowledge of both size and timing of an imminent flood, even if it does arrive earlier, than to have it arrive unexpectedly under natural timing. As is demonstrated by Figure 4.2(iv), pre-release of stored water represents the most important contribution to improved flood attenuation and accordingly unnecessary constraints on the timing of pre-release should be avoided.

To set a maximum rate of increase in discharge, as under constraint 4, is basically sound. In the gate operation program presently to be described, the maximum has been set at 75 $m^3/s/h$ - roughly the same as the maximum natural rate of rise of the river at the start of a major flood. Should it be necessary, however, this imposed rate of rise can readily be overridden during real-time operation.

Restrictions on night operation can be regarded as a constraint on the timing of pre-release, which was shown to be most undesirable. Although there may be some advantages to having a constant rate of discharge during the night, this can be beneficial only in the reaches close to the dam. Changes effected during the day are bound to be felt at night some distance downstream because of the lag. In the uncontrolled state, too, the river would sometimes and somewhere have risen at night. Any inconvenience that may result from controlled night-time increases in discharge would as a rule be more than compensated for by the corresponding reduction in flood damages.

4.3 Principles of the gate operation program

The flood plains immediately downstream of Vaaldam are developed mainly as residential and industrial areas, and it is here that the gravest losses have been suffered during past floods. Accordingly, the objective function adopted for the flood routing program was minimization of downstream stage. To meet the objective, mass balance calculations have to be performed regularly as fresh data become available to determine the optimum release rates. The basic equation is :

$$\int_{t_o}^{t_e} I_t dt = \int_{t_o}^{t_e} O_t dt + S_1 + S_2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots(4.4)$$

where I_t = rate of inflow at time t

O_t = rate of release at time t

S_1 = storage available below FSL at start of flood

S_2 = maximum permissible surcharge storage

t_o = time at beginning of flood

t_e = time at end of flood

As inputs and outputs for the daily model are in the form of average daily discharges, the integrals can be changed to summations from d=1, the first day of the flood, to d=ℓ, the last :

$$\sum_{d=1}^{d=\ell} I_d \Delta t = \sum_{d=1}^{d=\ell} O_d \Delta t + S_1 + S_2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.5)$$

where I_d and O_d are average daily values and Δt = one day.

The height to which the release plateau must rise can be minimized by pre-releasing at the maximum rate of increase of discharge permitted under constraint 4. The plateau rate is held until, with the reservoir 100% full, S_1 and S_2 becomes zero at a point on the recession limb of the inflow hydrograph, whereupon outflow is set equal to inflow (Table B4,p.B10). (One of the major problems of prolonging the inundation in order to minimize the depth of flooding is that the banks of the river downstream become saturated and considerable care is needed to avoid rapid curtailment of release and thus minimize sloughing of the river banks with consequent loss of valuable land).

The optimum level of the plateau release rate is determined by an iterative procedure. An initial value is assigned to the constant release O and equation 4.5 is solved. If the left hand side exceeds the right, the release rate is increased, whereas if the left hand side is less than the right it is reduced. The initial setting adopted in the program is 100 m^3/s; this is increased in steps of 100 m^3/s until left < right, whereupon it is reduced in steps of 10 m^3/s until again left > right, when the optimum is assumed to have been reached.

The accuracy to which the plateau release rate is thus established, viz. ± 10 m^3/s, is well within the confidence limits of the forecast. In any event the rate is updated as soon as fresh rainfall data become available with which to repeat the forecast inflow hydrograph.

As the discharge rate through the gates is dependent upon stage in the reservoir and, as this may change quite rapidly during flood control operations, it is evident that the gate settings should be regularly adjusted to follow the discharge plateau. Neglect to adjust continuously may result in failure to achieve maximum flood attenuation.

In operating the program with historical flood events, it was found that, because of the relative coarseness of the daily time step for performing the integrations in equation 4.4, there was instability as the rising limb of the release hydrograph approached the plateau. To overcome this problem the time step was reduced to one hour and it was therefore necessary to convert average daily discharges to average hourly values. This was accomplished with the following Lagrangian interpolation polynomial[18]:-

$$P(I_3,I_4) = L_1Y(I_3-1) + L_2Y(I_3) + L_3Y(I_3+1) + L_4Y(I_3+2) + L_5Y(I_3+3)$$

where P = average hourly discharge

I_3 = indicates which day it is

I_4 = the hour of the day and

L_1 to L_5 are as defined below

$$L_1 = (A_4 - 2A_3 - A_2 + 2A_1)/24$$

$$L_2 = -(A_4 - A_3 - 4A_2 + 4A_1)/6$$

$$L_3 = (A_4 - 5A_2 + 4)/4$$

$$L_4 = -(A_4 + A_3 - 4A_2 - 4A_1)/6$$

$$L_5 = (A_4 + 2A_3 - A_2 - 2A_1)/24$$

further: $A_1 = M$

$A_2 = A_1^2$

$$A_3 = A_1A_2$$

$$A_4 = A_1A_3$$

where $M = (X - X_2)/H$

$X = 24(I_3 - 1) + I_4$

$X_2 = 24I_3$

H = number of interpolations between given values = 24

A computer program, named GOP for "gate operation program",was developed to perform the calculations in accordance with the foregoing discussions, using the Lagrangian interpolation routine. This BASIC (note: BASIC refers to the computer language) program, listed in Appendix B, was developed for use on an HP model 9830A mini-computer and was intended mainly for performing initial test calculations. It can, however, serve the vital purpose of backing-up should the main computer go down during real-time operation. Although updated simulated inflow hydrographs would not be available during a breakdown of the main computer system, program GOP could nevertheless be used to optimize release rates, given inflow hydrographs from field observations, adjusted where necessary on the basis of experience.

4.4 Weather forecasts

In an effort to gain even better advance knowledge of precipitation than that provided by transmitted observations, a study was conducted in which the weather forecasts for the Vaaldam catchment over the period October 1973 to April 1975 were correlated with recorded rainfalls. (The intervening winter of 1974 was excluded as no rainfall forecasts are issued during winter). Daily records from 112 rain gauges were used and there were 313 occasions on which rain was predicted and/or experienced.

Comparison of average catchment rainfall with percentage of gauges that recorded the rain revealed quite a good correlation, as shown in Figure 4.3. Comparison of average catch per gauge that recorded the event with percentage of gauges that recorded

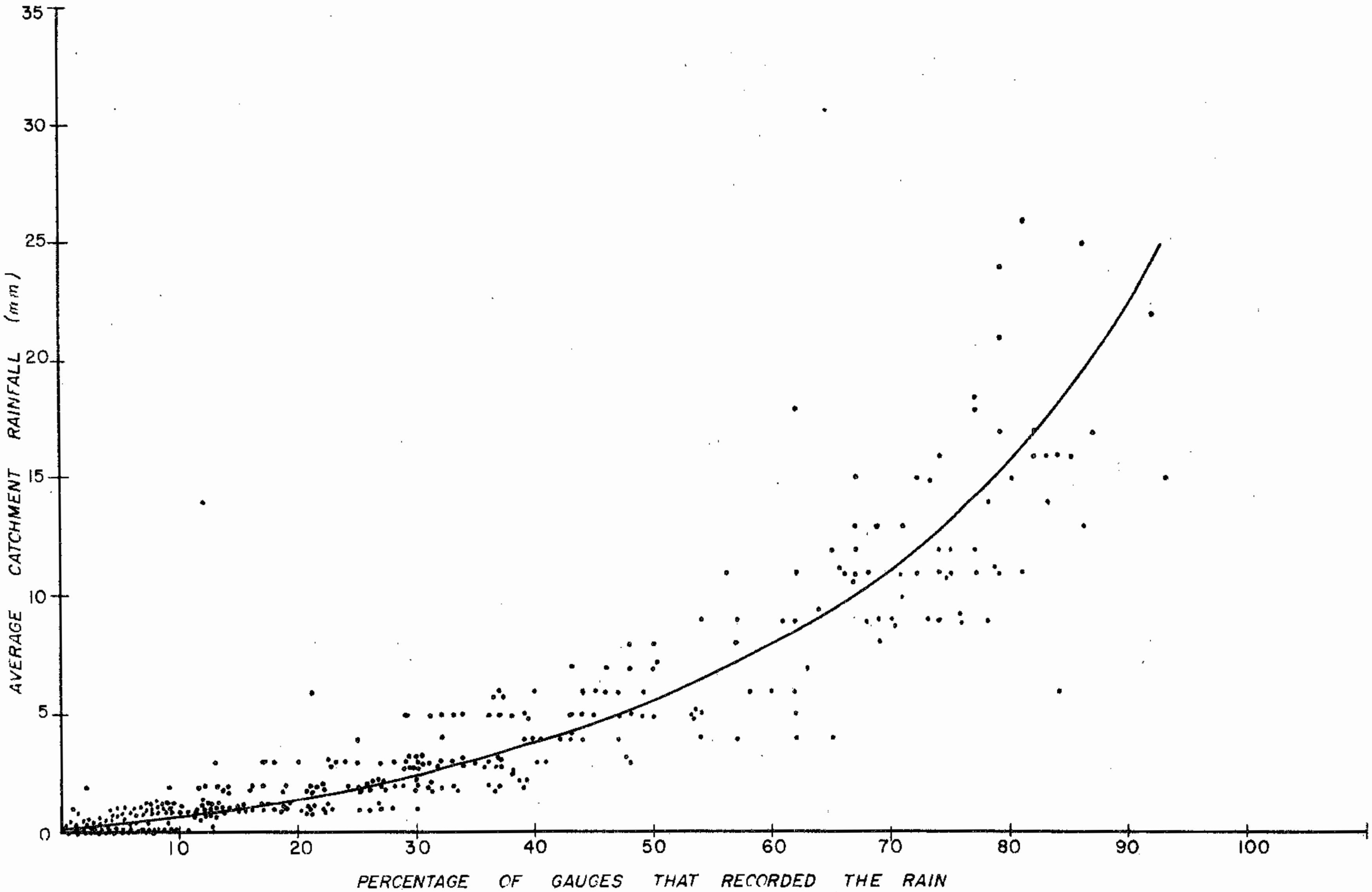


Fig. 4·3 Average rainfall over Vaaldam catchment as a function of spread. 1973/10 – 1975/4 rain, on the other hand,disclosed a wide scatter of values, as shown by Figure 4.4. Nevertheless, a general trend of increasing catch per gauge as the rainfall becomes more widespread can be discerned.

Matching of measured average catchment rainfall with corresponding weather forecast also yielded a promising coarse relationship, as shown in Figure 4.5. The band embracing the upper and lower envelopes is rather too wide to impart a high degree of confidence and so the results shown in Figure 4.5 were not incorporated in the gate operation program. In the absence of or delay in transmission of rainfall data, however, the diagram could prove useful during real-time operation of the model.

A new stationary weather satellite has also recently been taken into service to monitor the southern part of Africa. As this new satellite facilitates scanning of the area at any desired time, as opposed to the regular and relatively infrequent intervals of the previously used orbiting satellite, it could make for greater accuracy in weather forecasting than that shown by Figure 4.5.

4.5 Hourly gate operation program

As has already been emphasized timeous pre-release, if meaningful flood attenuation is to be accomplished, is of utmost importance. The daily model, however, has an inherent lag of up to 24 hours, depending upon the time of the day at which significant rain occurs, and much of the advantage of flood forecasting can therefore be lost. If for instance a heavy storm were to occur just after the gauges have been read for the day, more than 20 hours would elapse before the relevant information reached the computer.

Gate optimizations performed on historical data with program GOP clearly emphasized the need for shorter time steps in the data input to both the flow simulation and the gate operation programs. It was accordingly decided to introduce the HRU hourly catchment model in place of the daily model during the

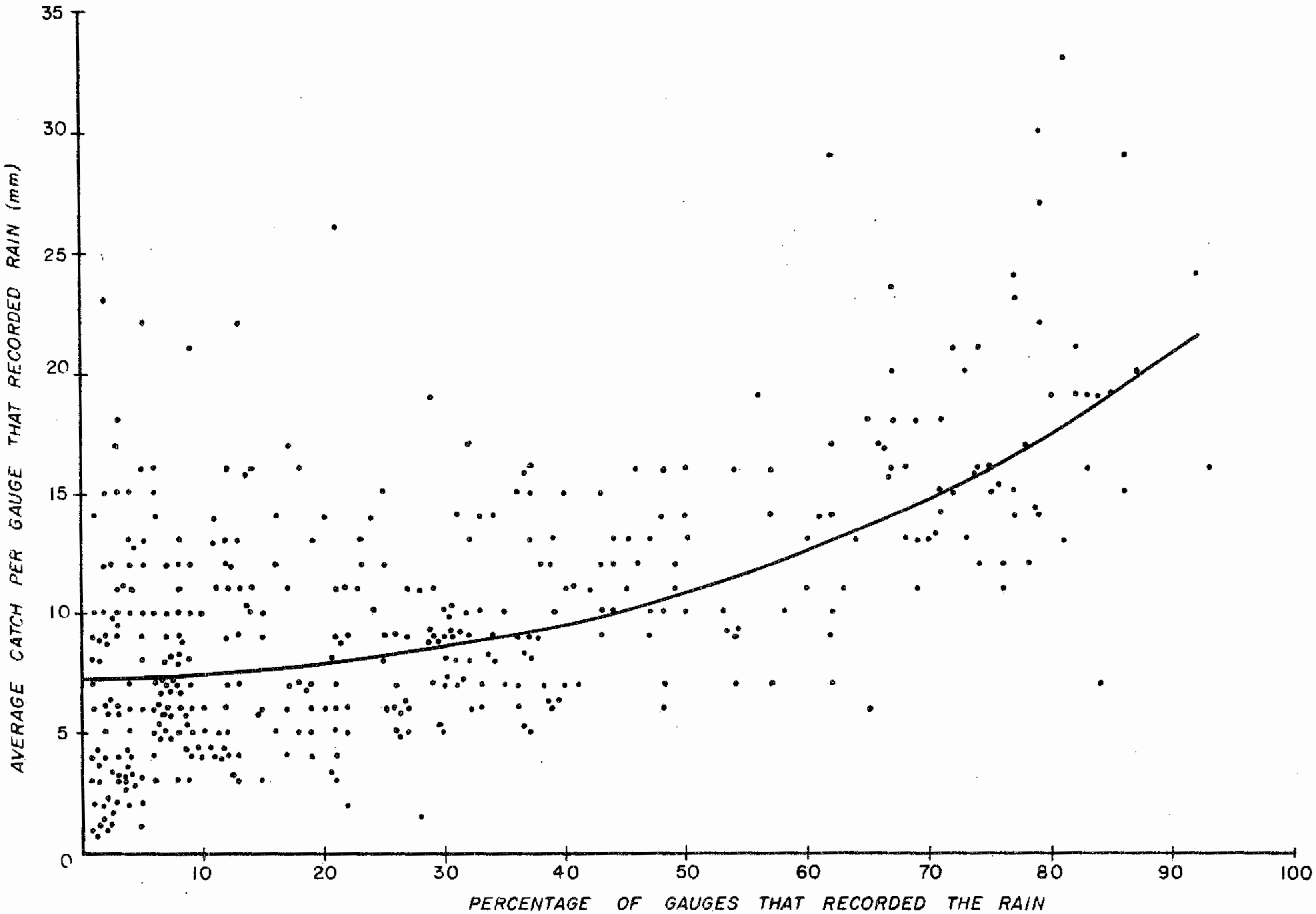


Fig. 4·4 Average catch per gauge that recorded rain (1973/10 - 1975/4) in Vaaldam catchment as a function of spread.

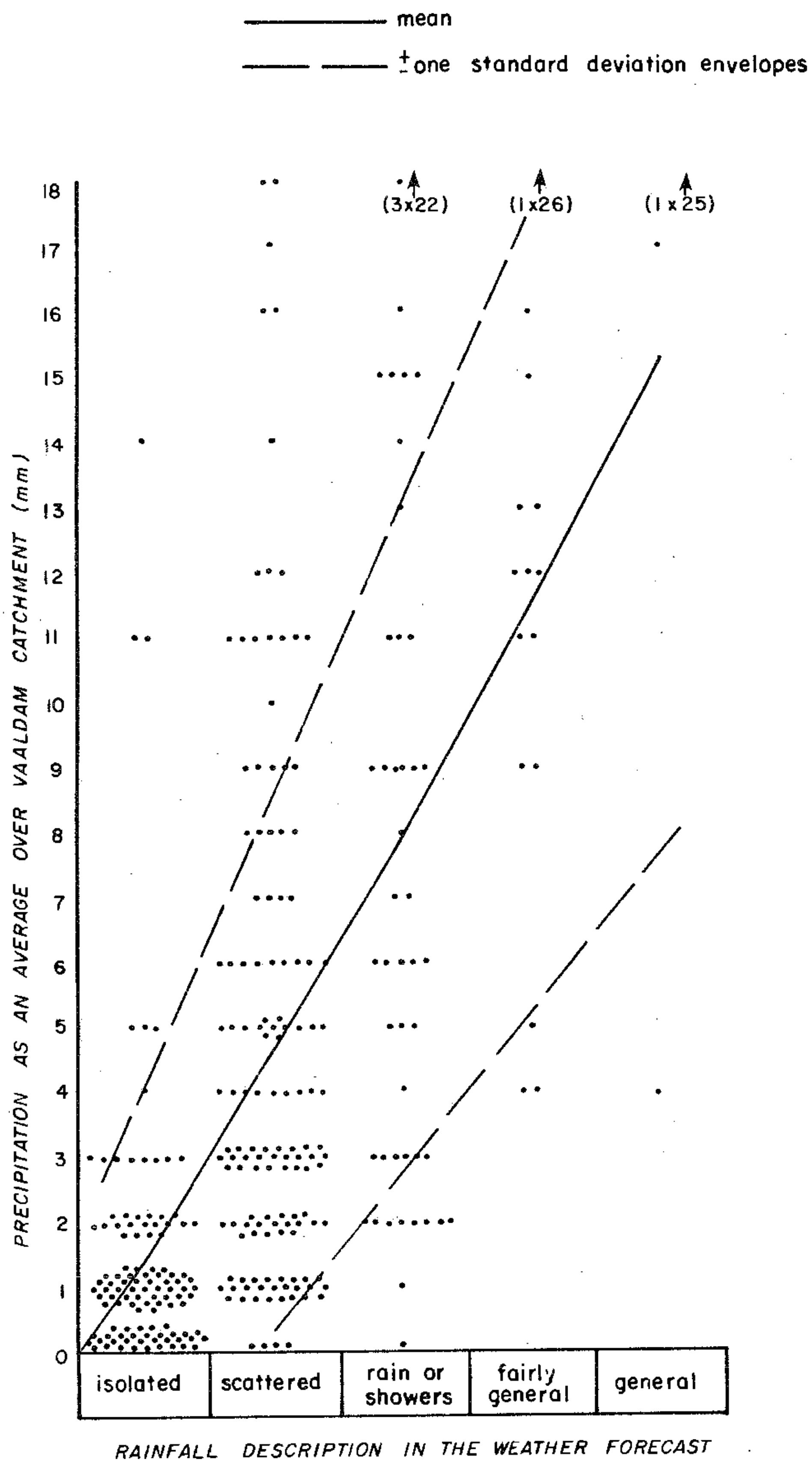


Fig. 4·5 Weather forecast interpreted as average rainfall over Vaaldam catchment.

actual flood period.

The models are basically similar, the major difference lying in the time steps of the calculation. The system is warmed up with the daily model and the values of the internal variables are transferred from the daily to the hourly model immediately prior to the onset of the flood period. As the hourly model is more than an order of magnitude more expensive to operate than the daily model it is essential to limit the time during which operation is on hourly data[9].

To determine reservoir release rates from the output of the hourly model, an Hourly Gate Operation Program (program HRYGOP) was developed from program GOP. This program, listed in Appendix B, was written in FORTRAN to be run on the University of the Witwatersrand IBM 370 system; it accepts directly the output from the hourly hydrograph simulation model as input. Figure 4.6 is a diagram illustrating the flow of data through the various computer programs for real-time flood forecasting and gate operation.

As is illustrated, data covering at least the past season's rainfall are needed for the warm-up run of the daily model. These data must be regularly up-dated so that the input data files can be kept up to date. The daily model should be run a few days after the end of each month during the rainy season to establish the status of the internal variables that have to be transferred to the hourly model. These variables are: interception storage, soil moisture storage, groundwater storage, percolation from soil moisture to groundwater, average daily surface runoff and average daily groundwater discharge[8].

The duration of a flood hydrograph at Vaaldam is of the order of 10 to 15 days, and,as there is always the possibility that this period will span two calendar months, both the hourly model and program HRYGOP are set up to simulate a two-month period at a time. The hourly model requires a few days of warm-up to cancel out the effects of the change in time step

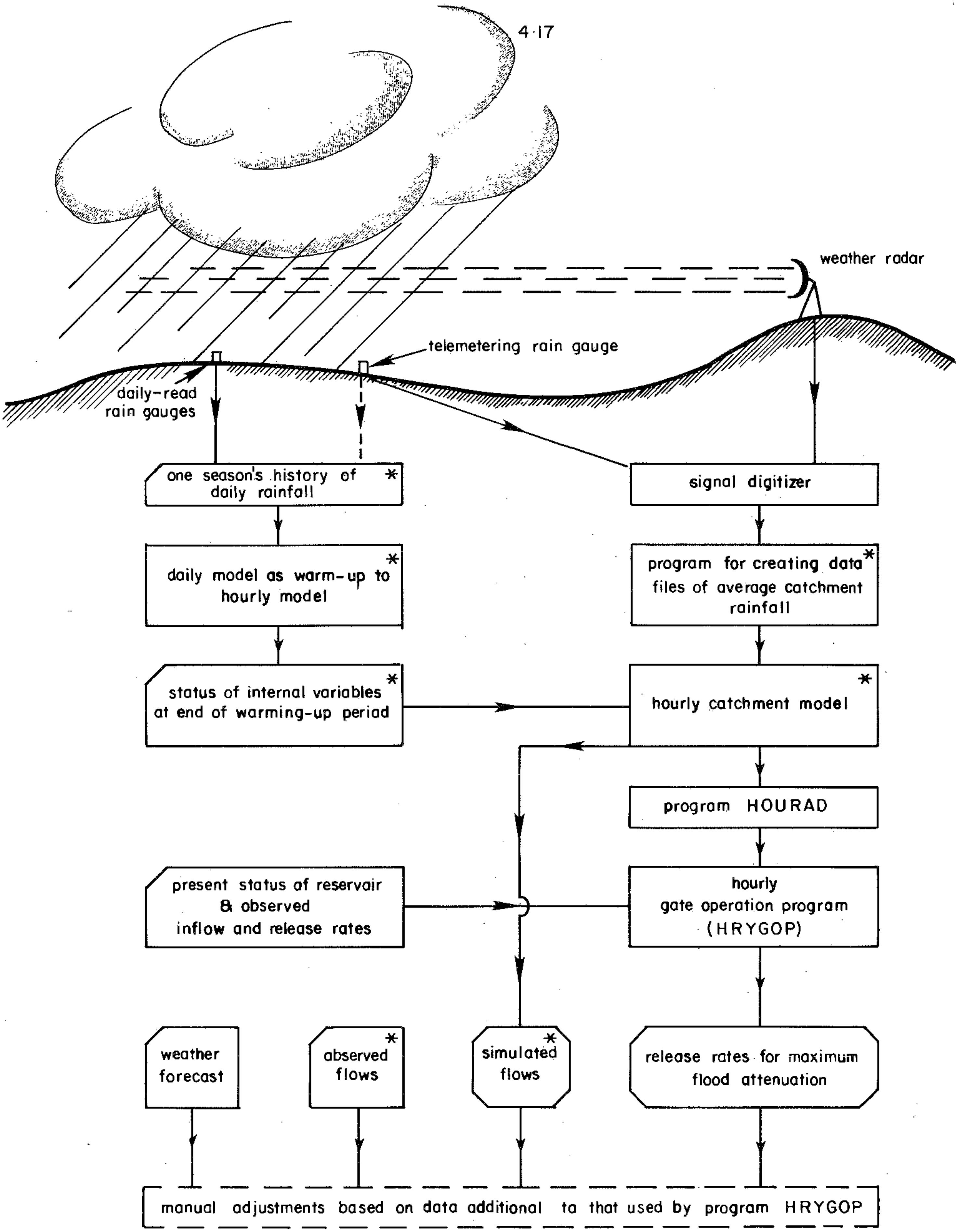


Fig. 4·6 Flow diagram for real-time flood forecasting and gate operation.

between the two models. Warm-up of the daily model should therefore stop before the advent of flood-producing rain. Between 5 and 35 days should be allowed between the switch from the daily to the hourly model and the start of flood-producing rainfall. In other words, the daily model should be run on the 5th of each month, or shortly thereafter, as warm-up to the end of the previous month.

4.6 Adjustment of simulated flows according to observed discharge

Differences between simulated and observed flows are bound to occur, as discussed in Chapter 2, and the need will arise to adjust the simulated flows to accord with observed data. The differences can result from several causes, such as sampling errors in depth or intensity of precipitation, errors in simulating antecedent conditions, incorrect parameter values such as soil moisture capacity and lag, errors due to lumping of catchment characteristics, and so on. Furthermore these differences can appear in many forms so that no generalized adjustment procedure can be prescribed.

In Figures 4.7(i), (ii) and (iii), all have the same simulated hydrographs as well as the same observed hydrographs up to T_R the reference time. If it is assumed that no more rain fell after the reference time, the simulated hydrographs will thereafter remain unchanged. The observed discharges, however, are still unknown beyond the reference time and can assume a variety of shapes, e.g. as shown in sub-figures (i) to (iii). If the observed hydrographs are assumed to be correct, Figure 4.7(i) shows the timing of the simulated hydrograph to be too early. In Figure 4.7(ii) the catchment model overestimated the discharge, possibly as the result of data errors or incorrect calibration of the model. Underestimation of discharge, as in Figure 4.7(iii), could also have been due to any of the above factors.

At reference time T_R it would thus have been quite impossible

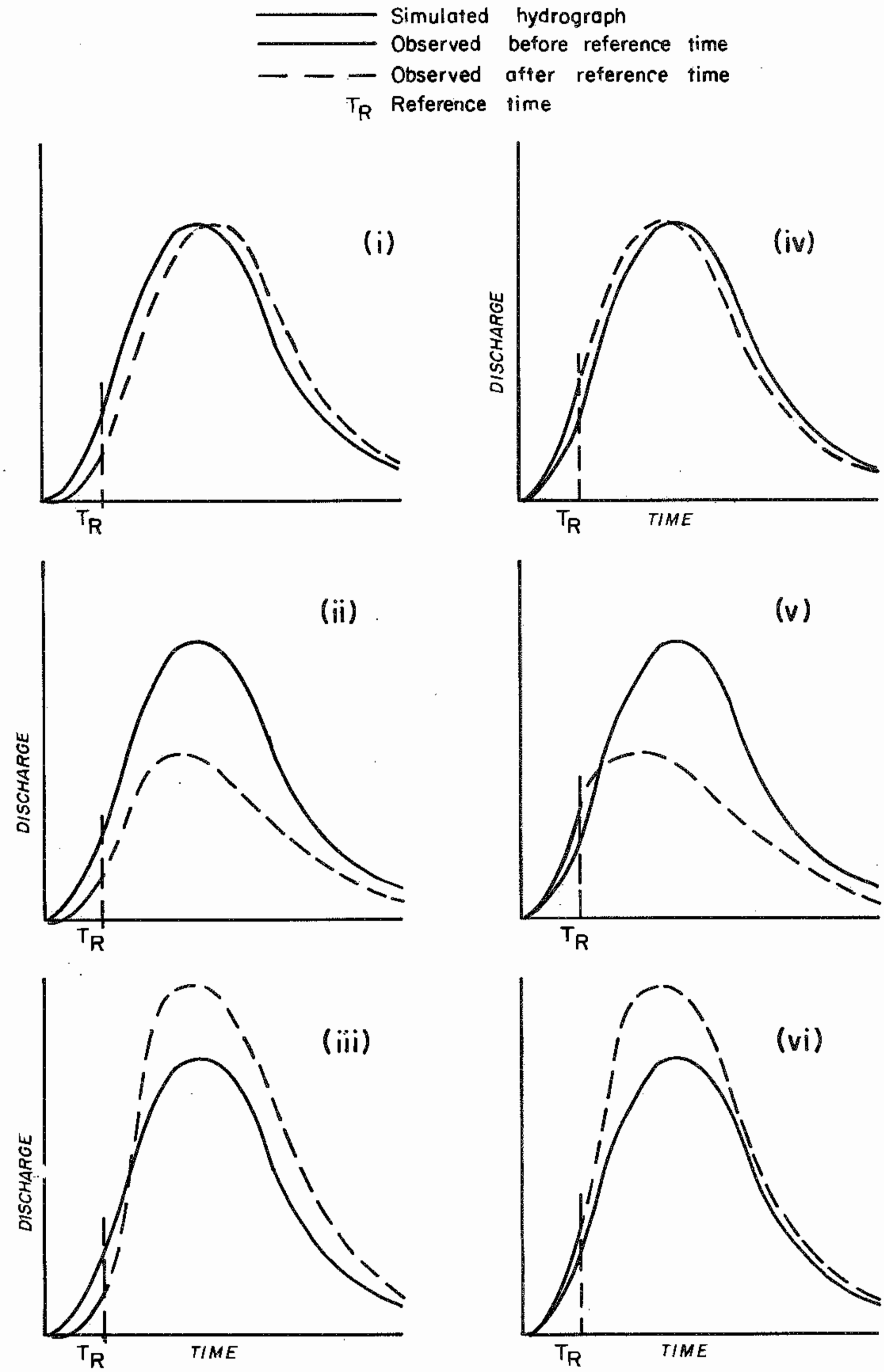


Fig. 4·7 Examples of differences between simulated and observed hydrographs based on two different observations prior to the reference time.

to know whether the difference between the simulated and observed hydrographs was indicative of over- or underestimation of the actual discharge still to come, or whether it was merely due to a timing error. Supposing it were known that an overestimation would result one still would not know whether it was due to a sampling error or incorrect model parameters.

The same argument could apply to sub-figures (iv) to (vi), although the discharge prior to T_R given by the observed hydrograph was higher than that in the simulated hydrograph whereas it was lower in the first group of figures.

Unfortunately these uncertainties are most pronounced at the beginning of the flood hydrograph, which happens to be the crucial time from the point of view of pre-release decisions. As discharge data for sub-catchment gauging stations were severely limited at the time of this study, no attempt was made to adjust the simulated hydrographs at these upstream points. All further attempts at automatic adjustment of total flows at Vaaldam during the rise of the hydrograph were in fact dropped. After the first few trial runs, which revealed the effects of lack of time-scale precision in simulating the rising limb of the hydrograph (Figure 4.7) and in routing flows from the seven different sub-catchments, automatic adjustment was applied only after the peak had been reached.

In the adjustment procedure finally adopted the average daily simulated discharge of the preceding day is compared with the corresponding observed discharge and the difference calculated. Simulated discharges for the day are adjusted on the assumption that the observed discharge is correct. Discharges on subsequent days are adjusted by proportions of the same difference, declining 20% per day for five days whereafter the simulated discharges are assumed to be correct.

These adjustments, after the peak has been reached, are automatically performed by program HRYGOP on the total discharges simulated by program HOURAD from the output of the hourly catchment model. (HOURAD combines the flows from the seven sub-catchments by simple lagging and superposition). Although the procedure is simplistic, performance tests proved it to be satisfactory.

Computer-operated flood control programs are not intended to rule out sound human judgment but must rather be viewed as a powerful aid to final decision-making. Models are only as good as the assumptions on which they are based and the data with which they are fed. Decisions based on the release rates calculated by program HRYGOP should therefore be carefully blended with those based on comparisons between simulated and observed discharges and supplemented by the weather forecasts (see Figure 4.6).

4.7 Verification of hourly gate operation program

In order to test the performance of the flood forecasting system, especially program HRYGOP, the historical floods of February 1944, September/October 1957 and February 1975 were routed through Vaaldam under simulated real-time conditions.

4.7.1 Hourly rainfall data

Hourly rainfall data were practically non-existent and so daily values had to be disaggregated. Rainfalls registered by eight gauges per sub-catchment for the respective flood periods were averaged areally and distributed in time by program DISAGG in the same way as is done internally by the daily model[8]. Values established for the regression coefficients AA and BB were 0,964 and 0,13736 respectively. Although the resulting synthetic hourly rainfalls are not necessarily quite representative of the actual storm events, they are nevertheless completely free of bias and should not therefore favour one part of the system more than another. ("System" here refers to the series of programs employed up to program HRYGOP). On the other hand, the synthetic hourly data are bound to compare poorly with actual data from the point of view of intensity of precipitation (see paragraph 2.5).

The fact that all rainfall events were assumed, as in the daily model, to start at the beginning of the rainfall day (viz. 08h00) could, however, have had a slight effect on overall system performance. For instance, some storms may have been assumed to occur too early, thus activating pre-release too soon. On the other hand, the fact that the permissible rate of discharge increase in program HYRGOP is limited to 75 $m^3/s/h$, compared with the upper limit of 250 $m^3/s/h$ in constraint 4, largely counteracts the advantages of early pre-release. When account is taken of the adverse effect of the synthetic hourly data on the accuracy of simulated flow volumes, the overall influence although not quantifiable, was considered to be more or less neutral and the data were consequently regarded as acceptable for testing purposes.

4.7.2 Verification procedures

To re-enact the past flood events as reliably as possible, observed data were fed to the computer at hourly intervals of historic time. This was achieved by introducing a time pointer into the relevant program such as to cause all observed data beyond a prescribed time to be ignored. Release rates for Vaaldam were consequently determined progressively for the three flood events by making observed data available at one-hour increments for times when rain occurred, and at 6-hour increments when there was no rain. At an average of 10 computer runs per day for say 10 days per flood, the number of runs was roughly three hundred.

In an effort to avoid all possible human bias associated with the fact that what had actually happened was known, the manual adjustment component shown in Figure 4.6 was suppressed. The release rates calculated by program HRYGOP were therefore accepted as correct and acted upon, the only human intervention being to apply the following basic rules:

1) The rate of release should not be reduced as long as the river is rising or the discharge is within the envelope of inflows unless there is an evident risk (indicated by program HRYGOP) that the reservoir will not be full after the flood.

2) Surcharging of the reservoir is allowed only after the release rate has reached 2 500 m^3/s.

The philosophy for introducing rule 1 is that after a certain downstream flood stage has been reached most urban damages associated with that stage have already been incurred and cannot be recalled by lowering the stage. By allowing the higher rate of release to persist, there may be some inconvenience but little further damage. On the other hand, and of much greater importance, is the fact that more buffer storage is created with which to attenuate a possible subsequent flood rise.

The decision to wait for a pre-determined release rate before making use of the surcharge capacity was aimed at ruling out any bias. With no constraint on when surcharge capacity may be utilized, it would be difficult, knowing beforehand what had happened, to resist the temptation to introduce this extra storage at the appropriate moment for it to have maximum attenuation effect. The level of 2 500 m^3/s is arbitrarily chosen as representing the discharge above which severe damage begins to result.

Although all the rules could readily have been incorporated in program HRYGOP, it was considered preferable for real-time operation to allow the computer to print out the required release rates and then to adjust them manually, rather than have the adjusted release rates printed out without any indication of the extent of the adjustments made.

4.7.3 Verification results

The results of automatic routing of three major floods through Vaaldam by means of the flood forecasting and gate operation programs are given in Figures 4.8 to 4.10.

The February 1944 flood occurred before the dam was raised and equipped with flood gates but in order to make use of the data of this event, the inflow hydrograph was routed through the Vaaldam of present capacity and subject to current constraints.

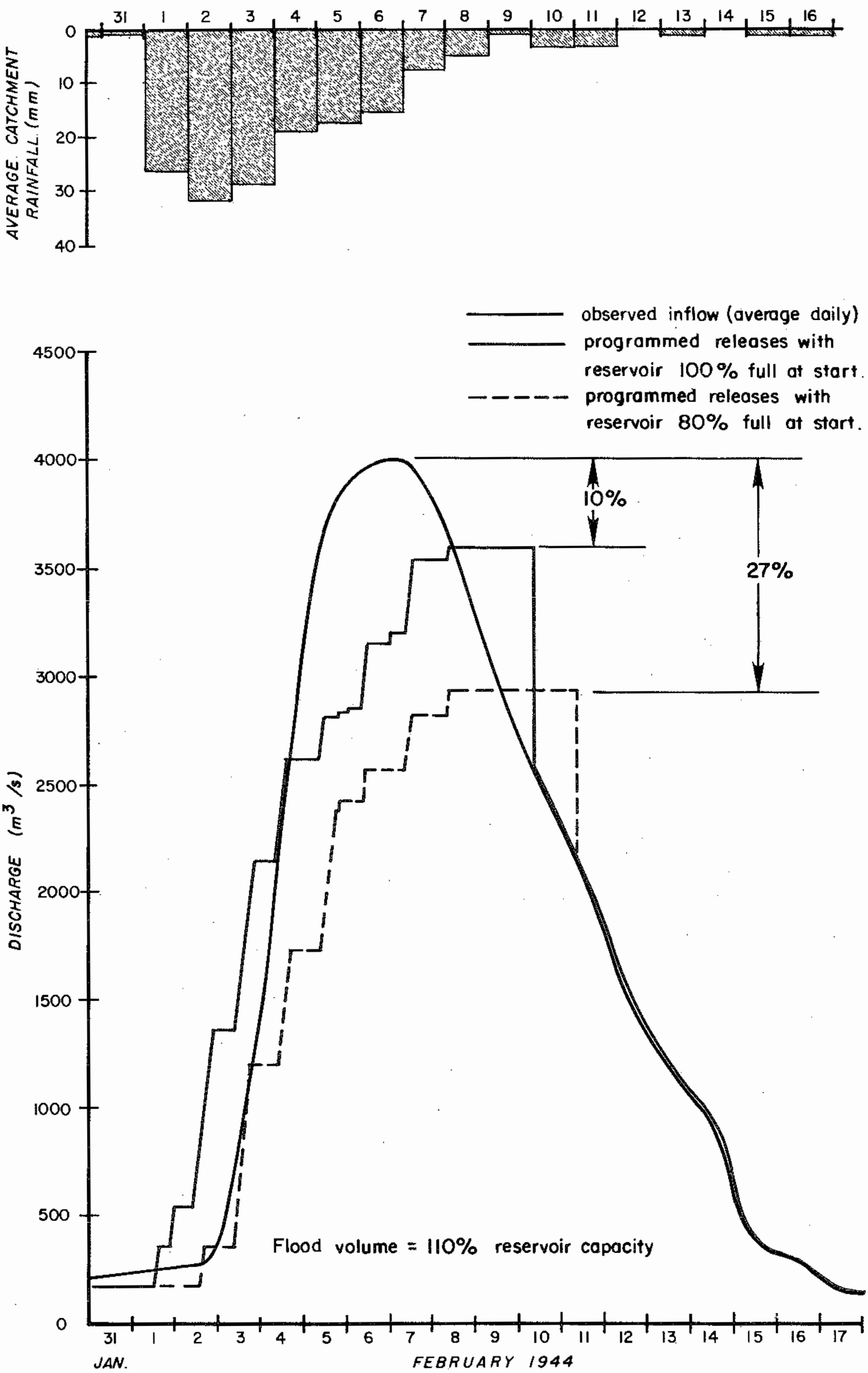


Fig. 4·8 Vaaldam gate operation - flood of Feb. 1944

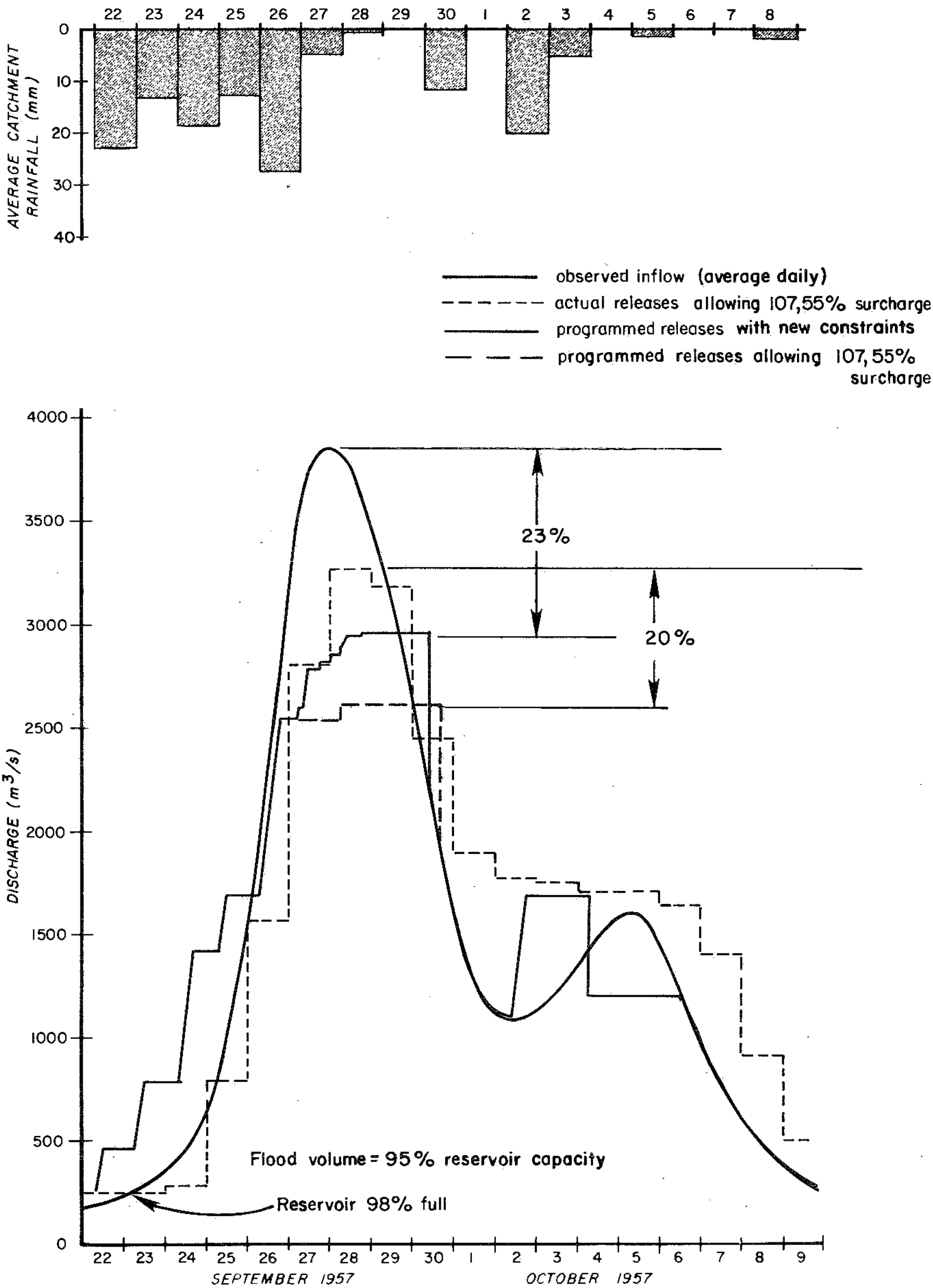


Fig. 4·9 Vaaldam gate operation - flood of Sept./Oct. 1957

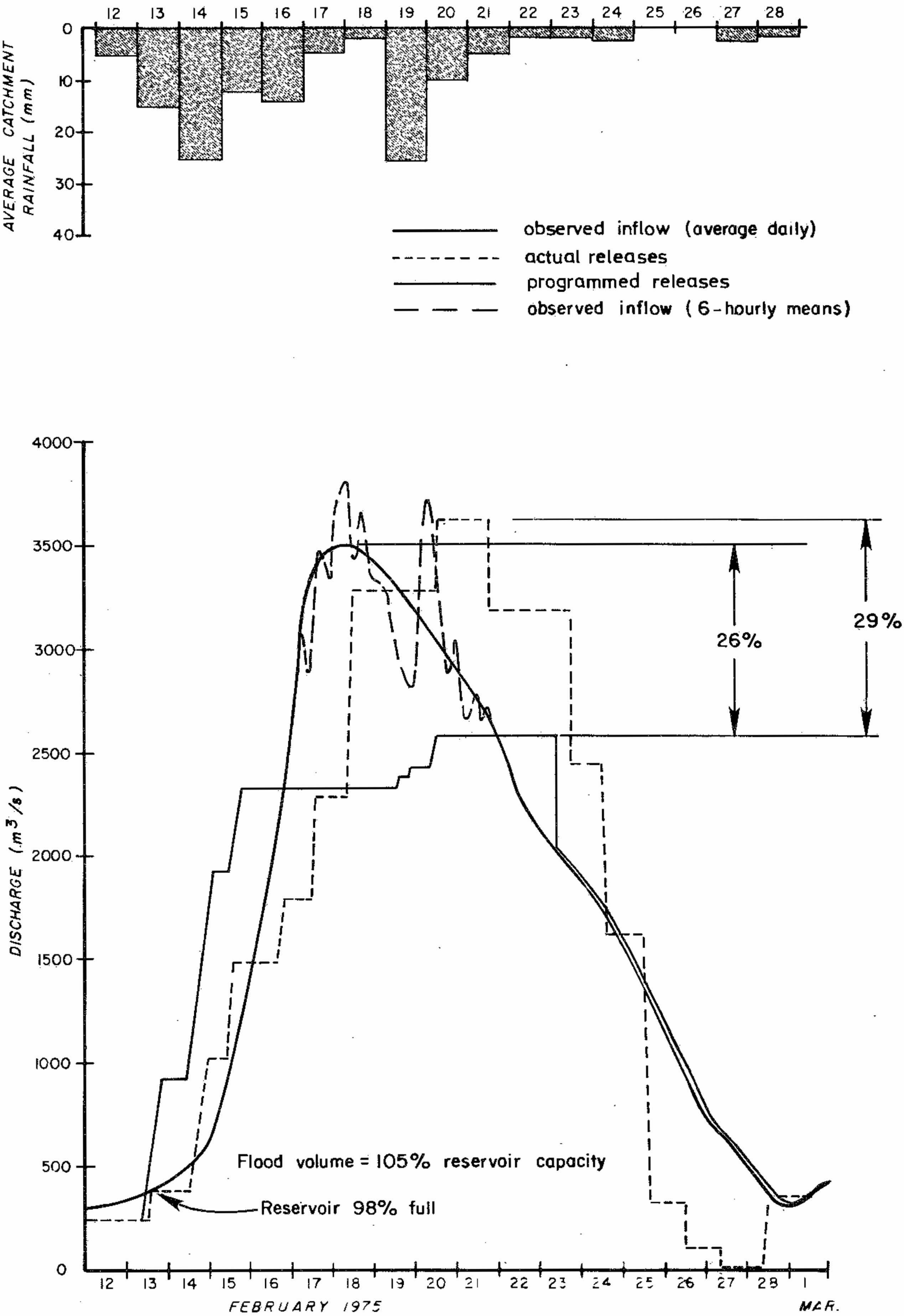


Fig. 4·10 Vaaldam gate operation - flood of Feb.1975

In order to demonstrate the influence of initial buffer storage space on degree of attenuation, routings were performed with initial reservoir storage state at 80% full and at 100% full respectively. Although for the 100% full reservoir situation pre-release started 24 hours earlier than for the 80% full case, attenuation storage equivalent to the 20% difference in starting volume could not be created in time, with the result that the peak discharge was 17% higher than for the partially full case. The attenuation achieved was nevertheless 10% which, together with the benefits associated with advance warning, would represent appreciable savings in flood damage averted. The falls of rain on 6 and 7 February 1944 unfortunately had the effect of widening the body of the hydrograph and this in turn demanded substantially increased releases on these two days in order to satisfy the mass balance.

The September/October 1957 flood occurred after the 1956 raising of Vaaldam and therefore a comparison could be drawn between releases suggested by the model and those actually effected at the time. As may be seen from Figure 4.9, by complying with the stipulated constraints, an attenuation by 23% of the incoming hydrograph was achieved, viz. 10% lower than the peak of the actual release. During the passage of the 1957 flood, however, the reservoir was actually allowed to be surcharged to 107,55% FSL capacity and, as shown in Figure 4.9, when this degree of surcharge was allowed in program HRYGOP, the routed peak release rate was 20% lower than the actual peak release rate. As the hydrograph simulation component of the model overestimated the second peak, as illustrated in Figure 2.10, pre-release for this peak had to be decreased on 4 October 1957 to ensure that the reservoir would be full at the tail of the flood. Nevertheless the programmed release rate was still lower than the actual.

For the February 1975 flood, as illustrated in Figure 4.10, attenuation of the incoming average daily peak was 26%, viz. 29% lower than the actual peak release.

From the foregoing results it is evident that great savings in flood damages can be achieved with the flood simulation and gate operation model, whether comparison is with uncontrolled peaks or with unprogrammed releases. It should be emphasized that the routings illustrated in Figures 4.8 to 4.10 represent programmed releases without human intervention and with limited observational input data (see Figure 4.6). It follows that real-time flood routing by means of the model, supplemented by frequently up-dated rainfall and weather forecasts as well as human intervention where necessary,can without doubt provide considerably improved results.

4.7.4 Routing of February 1977 flood

The benefits of flood forecasting for purposes of routing major floods have been demonstrated. It remains to verify the model - particularly for the more frequent floods of medium severity. It is these that require the most careful handling from the point of view of complete avoidance of both damage and unnecessary spillage. Of particular interest is the verification of program HRYGOP under conditions where the hourly model forecasts the flood volume with poor accuracy. Against this background and in compliance with a request by officials of the Department of Water Affairs (DWA) the flood of February 1977 was selected for model verification purposes.

This flood posed difficult control problems in that average catchment rainfall, as measured by the'DWA' gauges (Table A2), exceeded by more than 15% that which produced the first part of the February 1975 flood (12 to 17 February 1975 - Figure 4.10), and yet the peak discharge generated was only 1 500 m^3/s compared with the 3 400 m^3/s peak of the 1975 flood. The reasons were: first, antecedent conditions were extremely dry in February 1977 and, secondly, the rain was generally of low intensity and long duration. The latter factor can be expected to result in overestimation of simulated discharges unless actual hourly rainfall data can be employed in the modelling. See Figure 4.11.

As shown in Figure 4.11, simulated discharges, based on daily

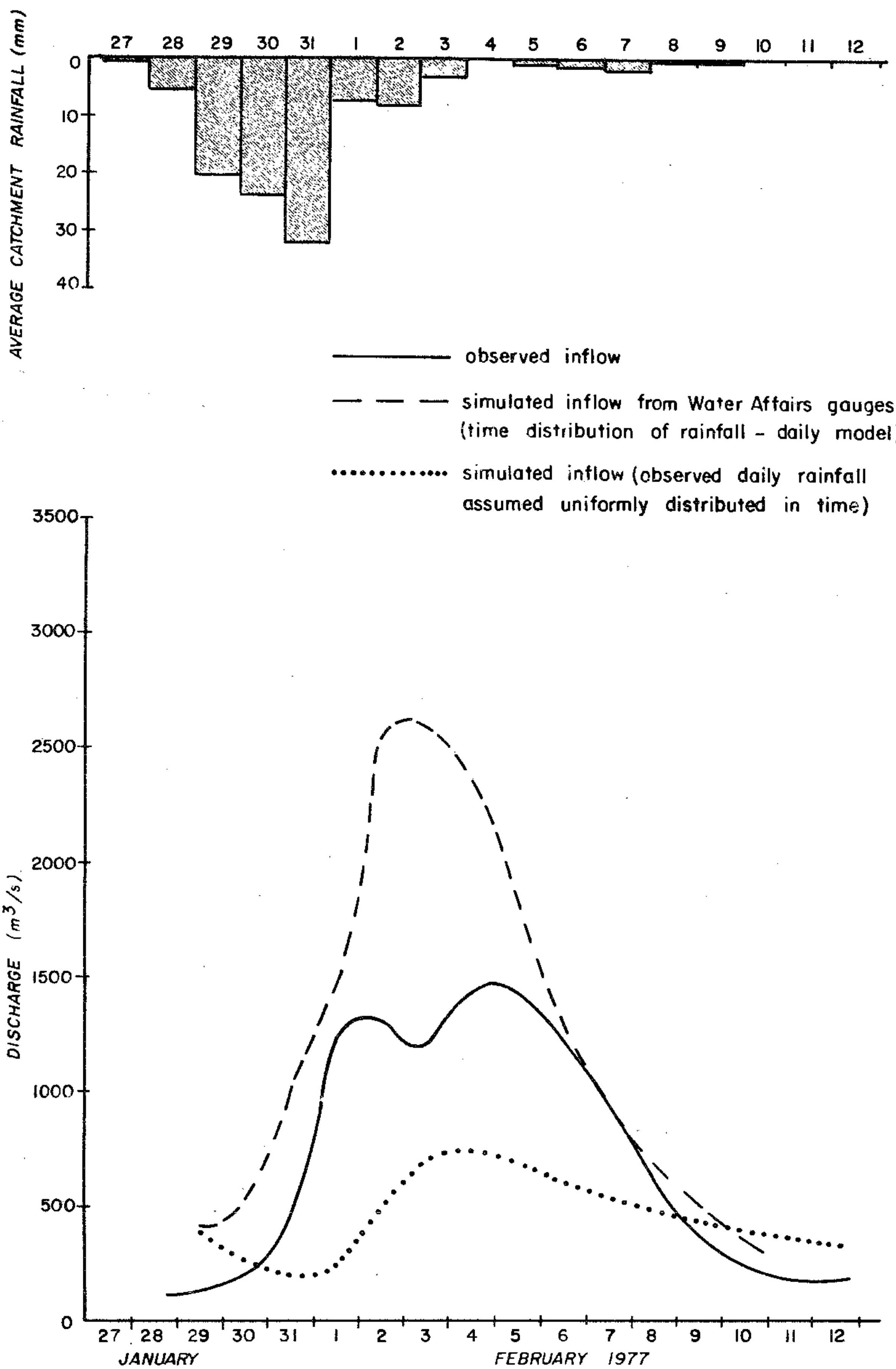


Fig. 4·11 Feb. 1977 discharge hydrographs at Vaaldam rainfall data disaggregated into hourly values according to average time distributions, are in fact much higher than the observed discharges. If, as an extreme, the rainfall for each day is assumed to be distributed uniformly over the 24 hours, the hourly model grossly underestimates the discharge, as shown by Figure 4.11. The observed hydrograph falls roughly halfway between the two simulated hydrographs. Although rainfall uniformly distributed in time is most unlikely ever to occur the result of the assumption clearly illustrates the influence of rainfall intensity on flood runoff. Also illustrated in this exercise is the fact that a sophisticated model fed with inadequate data will often perform less satisfactorily than a simple model demanding less data.

In routing the overestimated simulated hydrograph through Vaaldam, program HRYGOP called for a peak release rate of 1 780 m^3/s, which is about 300 m^3/s higher than the peak of the observed inflow hydrograph but 200 m^3/s lower than the actual peak release rate (Figure 4.12). Thus, even though there was a 50% overestimation by the hourly model of the volume of the inflow hydrograph, the program HRYGOP provided a basis for decision-making that compared favourably with that offered by techniques in use at the time.

Clearly, to improve the accuracy with which flood hydrographs can be simulated, undelayed hourly rainfall input to the model as opposed to disaggregated daily rainfall is essential. This can be achieved by an adequate network of telemetered autographic rain gauges or possibly telemetered weather radar signals.

For real-time operation of the system, finer calibration of the hourly model based on recent flow records for the individual sub-catchments is needed.

4.8 Inflows between Vaaldam and Vereeniging

The Suikerbosrand and Klip rivers enter the Vaal between Vaaldam and Vereeniging as indicated in Figure 1.1. It has been argued that the contributions from these two rivers should be

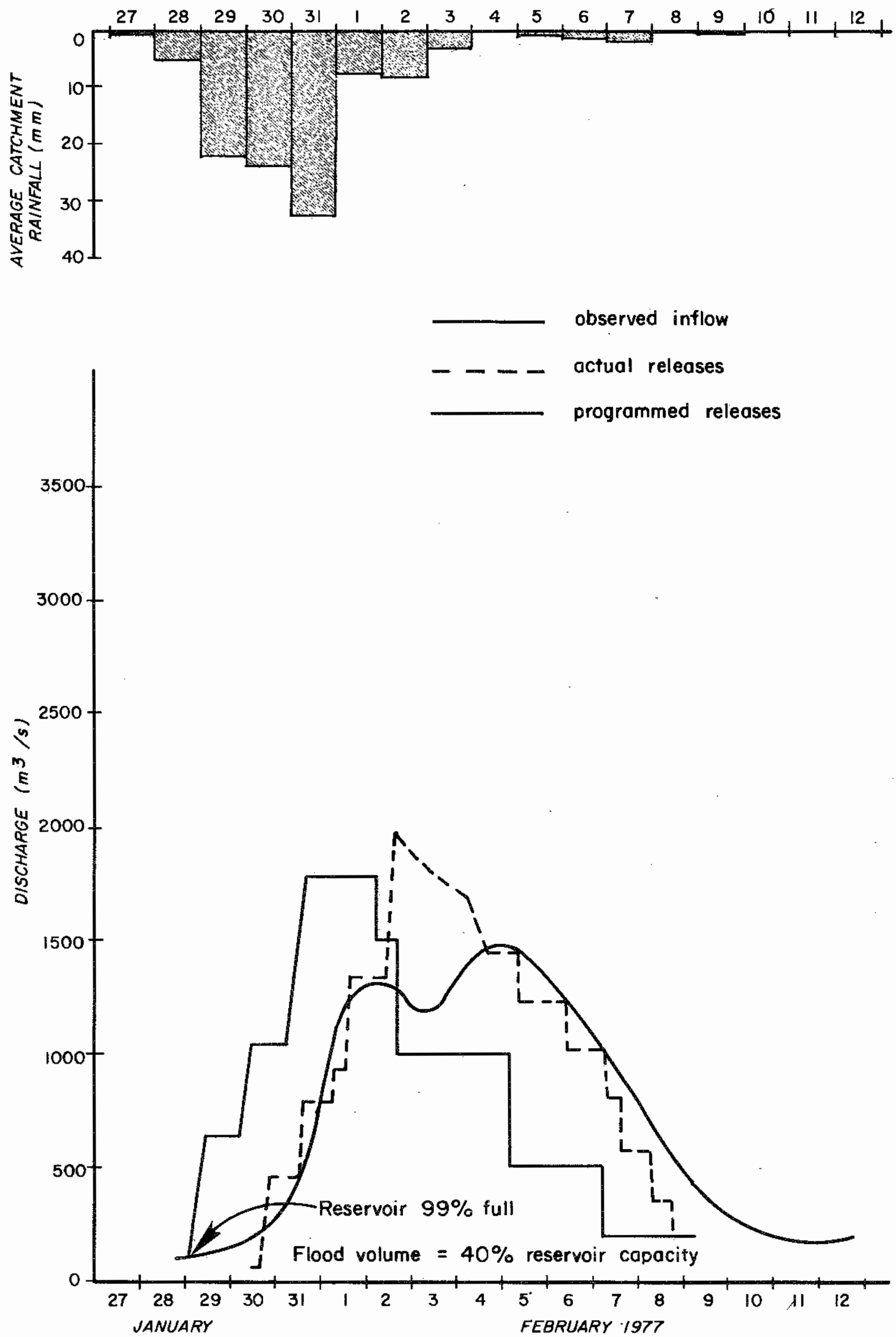


Fig. 4·12 Vaaldam gate operation - flood of Feb. 1977 taken into account when determining the rates of release from Vaaldam. Flood discharges in these two rivers, however, are relatively low compared with damaging discharges in the Vaal. Because of the substantially smaller areas of catchment, floods in these rivers will normally peak at Vereeniging sooner than floodwaters from the Vaal catchment, except in the unlikely event that storm movement is such as to cause runoffs to peak simultaneously.

From an operational point of view it would be extremely unwise to renounce optimum flood control release rates in a major river so as to allow for uncontrolled runoff from relatively minor sources. As one is largely ignorant of the future, it could happen that by postponing release of water from Vaaldam to allow floods from smaller downstream catchments to pass the potential flood damage areas, one might forfeit the opportunity of creating buffer capacity in Vaaldam to handle a really large flood. It is almost axiomatic that the controllable part of a flood should be attenuated to the maximum extent possible while neglecting the discharges from uncontrolled rivers, provided they are relatively small. If both controlled and uncontrolled parts of the problem catchments are of the same order of magnitude it may be necessary to view them as a single system.

CHAPTER 5 SOCIO-ECONOMIC ASPECTS

5.1 General

Described in the foregoing chapters is a system developed for the forecasting of flood hydrographs at Vaaldam with the aid of deterministic catchment models having only precipitation data as basic input. Thus, at a particular point in time, a forecast can be made of the future inflows to Vaaldam expected from rainfall that was observed prior to the reference time. Several forecast hydrographs were routed through Vaaldam reservoir by means of program HRYGOP to establish release rates that would achieve maximum flood attenuation. The degree to which historical floods could be attenuated, by means of buffer storage dictated by the routing program in a reservoir in which no part of the storage capacity has been officially allocated to flood control, was clearly substantial - up to a 29% improvement on unprogrammed releases (see Figures 4.8 to 4.10).

A flood forecasting and reservoir control system should not, however, be aimed merely at minimizing downstream flood levels nor at providing maximum advance warning but rather at seeking the least-cost solution to the many problems associated with flooding. By the same token, data-collection networks for use with forecasting models should be designed to maximize net benefits and not simply to achieve maximum forecasting accuracy.

Although the least-cost solution will normally be expressed in monetary terms, account should also be taken of intangible aspects. Often, too, an engineering solution has to be tempered by political considerations. It is thus necessary to assess all the costs and benefits, both tangible and intangible, associated with flood control systems of varying degrees of sophistication before the optimum can be discerned.

For the areas subject to flood damage downstream of Vaaldam there is unfortunately a serious dearth of information. The Institute for Social and Economic Research (ISER) at the University of the Orange Free State and the Bureau of Economic

Investigation (BEI) at the University of Stellenbosch are currently undertaking a study of flood damages in this area as part of a more extensive floods study on behalf of the Water Research Commission but at the time of writing (February 1978) usable results were not yet available. Although approximate global figures for total damages suffered during historic floods could perhaps be assembled from newspaper, insurance and suchlike sources, there is no reliable way of relating these damages to flood levels and therefore to peak discharges and finally to flood frequencies and risks.

Because of this lack of suitable data, performance of the flood forecasting system that has been developed could not be compared for various degrees of sophistication of the data network. Autographic rainfall stations are extremely sparse and therefore it was not possible to establish with reasonable accuracy the hourly distribution of rainfall on the catchment. A weather radar is operating in the south-eastern part of the catchment for the express purpose of research into rainfall augmentation but the instrument can reliably scan only a relatively small proportion of the contributing area and in any event has not yet produced results meaningful to the purposes of this study.

To evaluate flood control benefits one must be in a position to relate the damage that can be diminished or averted by control measures to features that can be observed, measured or computed in the area of influence of the flood. Such features are (a) depth of inundation, (b) duration of flooding, (c) time of occurrence of flood peak (day/night, season), (d) water velocity, (e) weather conditions and (f) rate of rise of water level. While most of the above have been discussed in some depth in Chapter 4, the controlling feature affecting urban flood damage, provided that sufficient warning precedes any night-time operation, is river stage or depth of inundation.

Because of the lack of performance data for flood forecasting systems of different degrees of sophistication, as well as the shortage of information on flood damages, it was not possible to perform comparative cost-benefit calculations. The processes involved in cost-benefit analysis of hydrological forecasting are dealt with comprehensively by Kuiper[19] and Day[20] but some of the fundamental principles bear repeating here and these are illustrated by actual monetary assessments where appropriate data are available.

The benefits of flood forecasting are twofold : (a) those attributable to reduction of flood peak by manipulation of storage in the system, as discussed in Chapter 4, and (b) those associated with steps that can be taken, such as evacuation of low-lying areas, if adequate advance warnings can be provided.

5.2 Flood attenuation benefits

To evaluate flood attenuation benefits one needs stage versus damage relationships for the reach under study. In order that the relative importance of flood attenuation and advance warning can be established, a distinction should be drawn between cases where advance warning had been given and those where there had been no warning.

For the flood-damaged areas of Vereeniging and Vanderbijlpark, immediately downstream of Vaaldam, the best flood damage data available, although still very incomplete, is for the February 1975 flood. Officials of the Department of Community Development estimated the damages to buildings and furniture to have been in excess of R1,6 million (1975 values). As most of those with private insurance did not request government aid and many were said to have refused to complete the departmental questionnaires, this figure of R1,6 million may be regarded as conservative; it could well have been double. Furthermore, as there was no formal flood warning system operative at that time, these damages may in the absence of better information be assumed to be directly related to river stage.

The figure of R1,6 million can be converted to 1978 value, on the assumption that the inflation rate has been 12% per annum, thus[21] :

$$F = P\left(\frac{f}{p}\right)^{i}_{n}$$

$= R1\ 600\ 000 \times 1{,}405$

$= R2\ 248\ 000$

where F = future value

P = past value

$\frac{f}{p}$ = factor for converting past into future values

$= (1 + i)^n$

i = rate of inflation (interest) per period

n = number of inflation periods.

Officials of the Department of Water Affairs have compiled for their own use a rough tabulation of the number of houses that are flooded at different levels of discharge in the Vaal river and its tributaries joining between Vaaldam and Vereeniging. Figure 5.1 represents a plot of the information used by the Department in connection with flood control operations.

To provide a relationship between Vaal river flood discharges and direct damages in the Vereeniging-Vanderbijlpark area it seemed reasonable to assume that the relationship between Vaal discharge at Vereeniging and houses inundated (and therefore flood damage costs) could be generalized for the area as a whole. Accordingly, at 3 630 m^3/s, the 55 houses flooded on Figure 5.1 could be regarded as equivalent to R2,248 million damage for the area as a whole and the damage at other levels of discharge could be taken proportionally from Figure 5.1 to compile Figure 5.2 - an approximate damage function for the Vereeniging-Vanderbijlpark area.

As may be seen from Figure 4.10, possible attenuation of the February 1975 flood to 2 560 m^3/s would, according to Figure 5.2, have resulted in a present-value saving of about R2,25 million. Figure 5.3 depicts the results of an extreme value analysis of recorded average daily flood peaks in the Vaal at Vaaldam over the period 1925 to 1975. As may be noted there were two other floods that exceeded the damaging level of 3 000 m^3/s, viz.

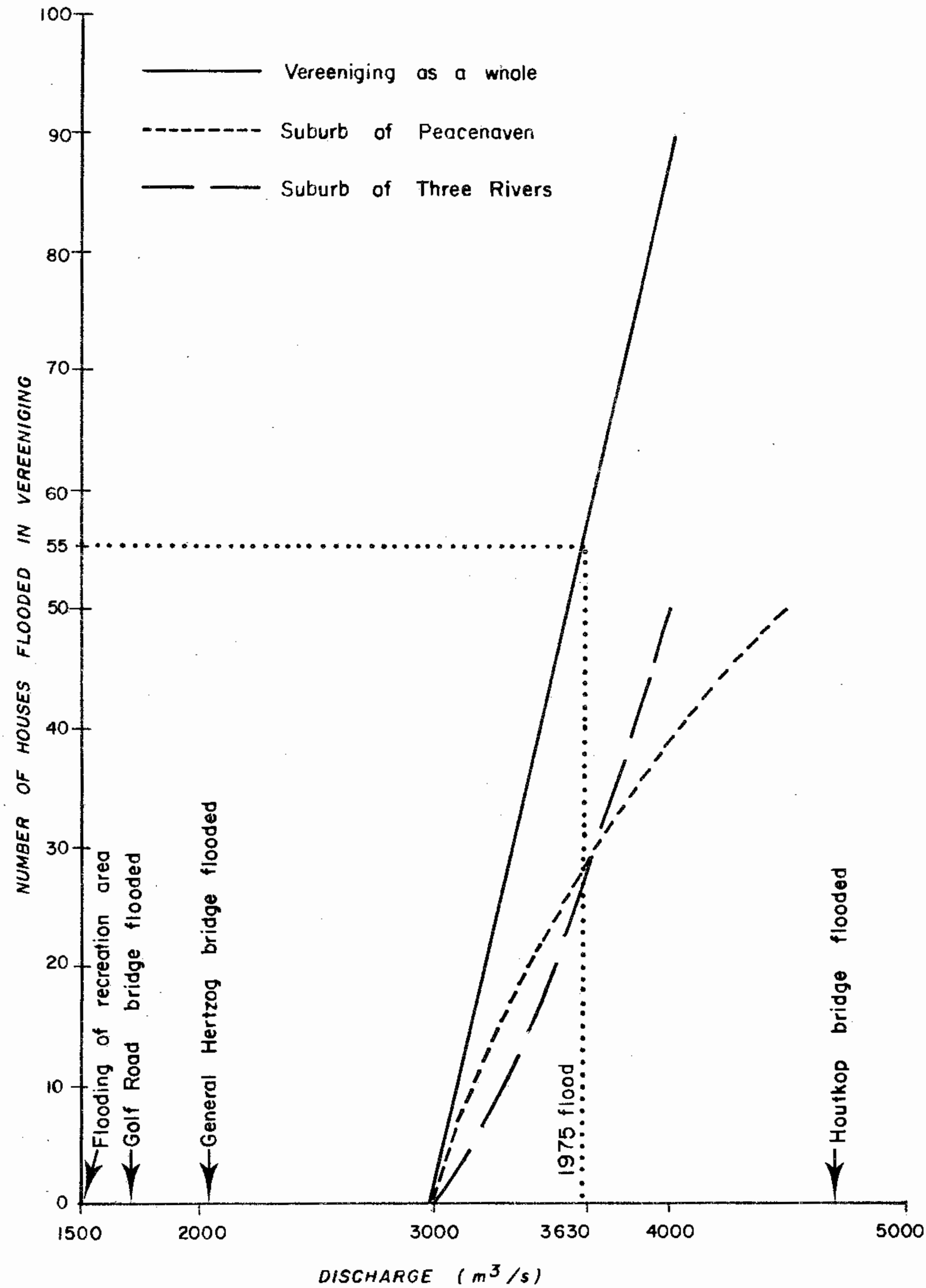


Fig.5·1 Number of houses flooded in Vereeniging versus discharge of Vaal river.

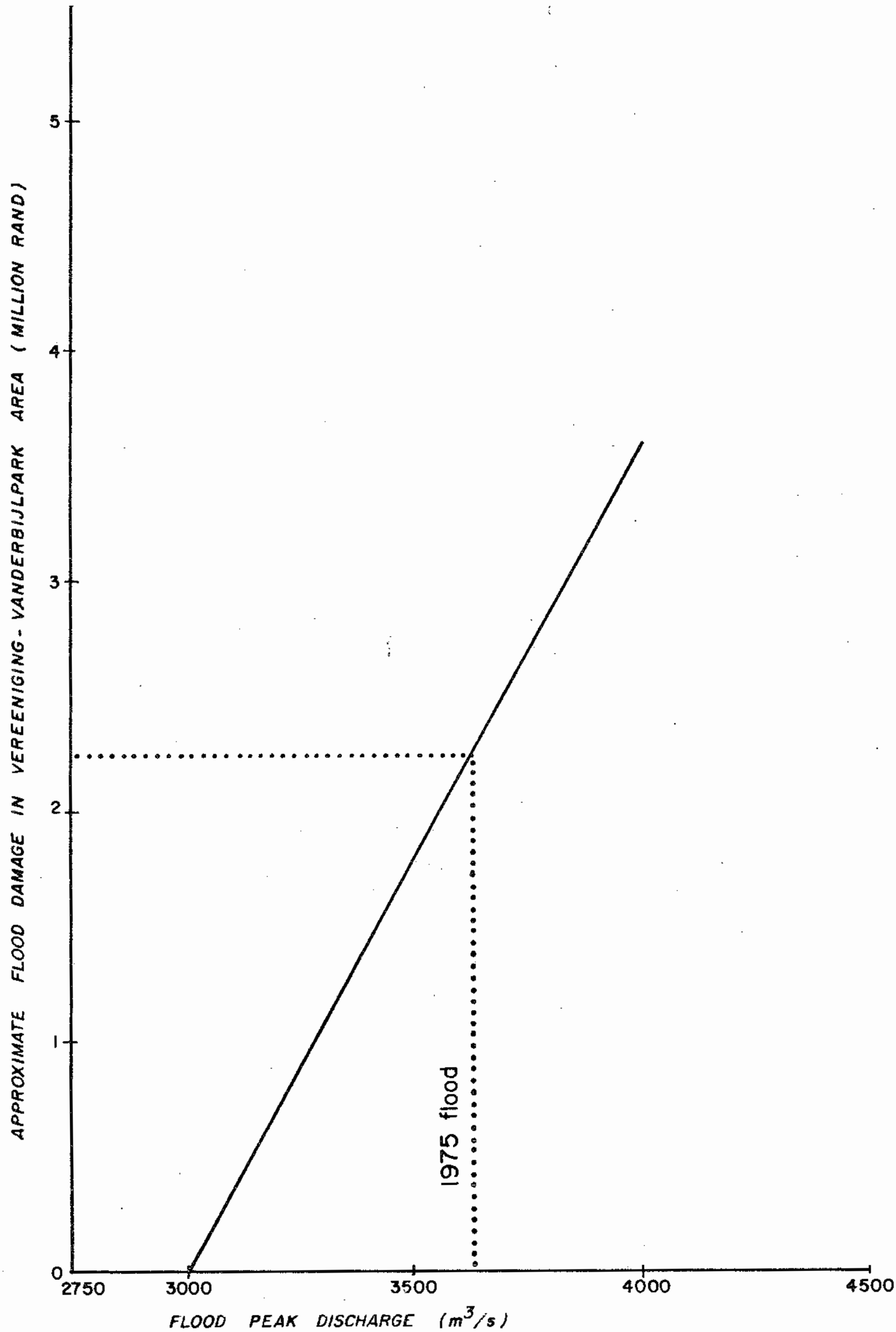


Fig. 5·2 Approximate urban flood damage in Vereeniging - Vanderbijlpark area versus peak discharge of Vaal River.

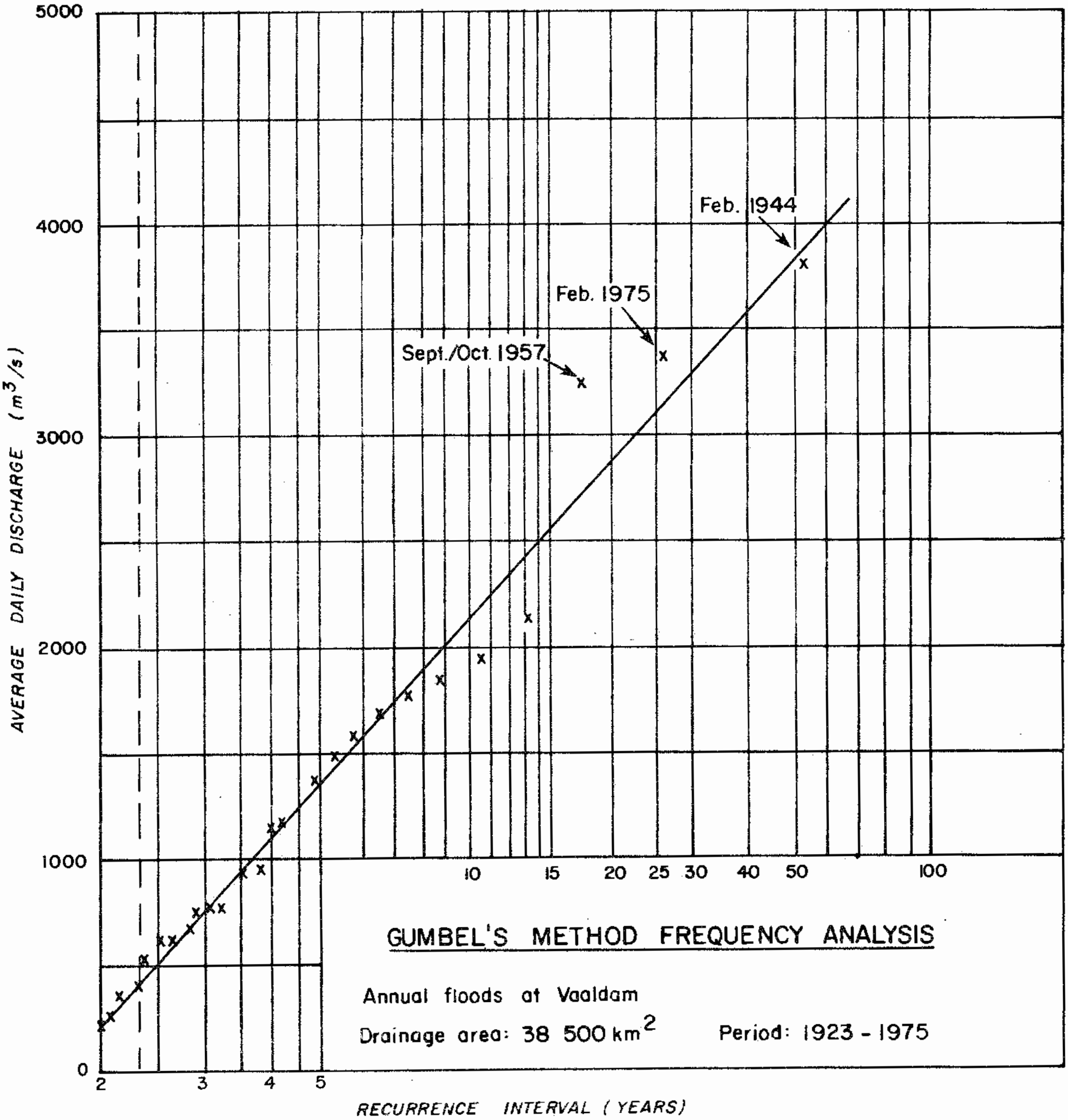


Fig. 5·3 Frequency curve of annual peak daily inflows to Vaaldam.

those of February 1944 and September/October 1957. Had these two floods occurred at the 1975 level of flood plain development, the present-day damages would have been R3,60 million and R3,05 million respectively (Figure 5.2) and the present-day savings that could have been effected by attenuation to 3 600 and 2 950 m^3/s (Figures 4.8 and 4.9) would have been respectively about R1,45 million and R3,05 million.

From the foregoing it may be gathered that the total urban flood damages that could be averted by programmed attenuation over a 50-year period at the 1975 level of development would amount to at least R6,75 million, or an average of R135 000 per annum. If agricultural flood damages, loss of production and inconveniences suffered were to be included the average annual value would be considerably increased. For example, a comprehensive investigation[22] into the flood damages suffered during the February/ March 1974 flood in the lower Orange river has revealed that losses amounted to R42 million. Although the damage relationship for the Orange river cannot be transposed to the Vaal immediately downstream of Vaaldam, the flood forecasting and control system developed for Vaaldam can readily be modified for application to the dams in the Orange river basin. The potential to reduce by a substantial margin damages of R42 million arising from a single event makes introduction of the system highly desirable.

With increasing flood plain development and rising property values the benefits of flood attenuation must become more and more attractive.

5.3 Flood warning benefits

The benefits of flood warning lie mainly in the effects of measures such as evacuation and temporary flood-proofing, the efficiency of which depends on factors such as : (a) length of warning time, (b) extent of reducible damage and (c) degree of public response to flood warnings.

The extent of savings, both of money and of lives, depends to a great extent on the warning given. The longer the time lapse between issuing of the flood warning and rise of the waters to damaging levels the greater the potential saving. For the Vaaldam-Vereeniging area the time interval would normally be a few hours - that required to increase releases at the rate of 50 to 250 m^3/s per hour plus the relatively short travel time of the flood wave from Vaaldam to Vereeniging. For any agricultural areas susceptible to damage along the Vaal downstream of Vaaldam, the warning time will normally be much longer than for the urban/industrial areas near the dam. If warnings are heeded there should be ample time to evacuate livestock and irrigation equipment to high ground.

The extent to which damages can be averted depends greatly upon land use in the flood plain and the relative proportions of movable and immovable property. Family homesteads, for example, may suffer appreciable damages regardless of the warning time or the response to warning and whether or not all movable items can be timeously evacuated.

Response to flood warnings is dependent upon factors such as the efficiency with which the warning is spread, the attitude of persons receiving the warning, the time of day or night when the warning is received, the time that has elapsed since the last flood, and the accuracy of past forecasts. As a rule individuals start planning only after receipt of a flood warning, whereas many organisations have detailed evacuation procedures.

5.4 Cost of flood forecasting systems

A flood forecasting system should have two main components, viz. the data-collection network and the processing unit. Each has its manpower requirements.

For the Vaaldam catchment it has been noted in Chapter 4 that eight rain gauges per sub-catchment were needed for satisfactory simulations. On the basis that say six gauges would be shared by adjacent sub-catchments, i.e. about one per sub-catchment, there would be 50 gauges needed to sample adequately the rainfall over the whole Vaaldam catchment. (This number falls within the optimum range suggested by Grayman and Eagleson[23] viz. one gauge to every 500-1000 km^2).

If the responses of these gauges are to be telemetered the cost would be about R3 000 per gauge[24]. The capital outlay would be about R150 000 for the data network, including the receiver unit. Maintenance could be assumed to cost the equivalent of the salary of one full-time technician - approximately R7 000 per year - plus an equal amount to cover travelling and servicing.

Operation of the simulation models can be handled by a skilled technician in less than 10% of normal working time and this would account for another R700 per annum. At an average of at most four potential flood situations per year and approximately 25 simulation runs per event, the annual processing cost would amount to R2 000, calculated at the current cost of R20 per run on the University computer.

Flood warnings can be issued through the local police and civil defence organisations or over the national broadcasting system. Costs involved would be negligible.

If the capital cost of R150 000 is spread over a 15-year life at 12% interest, the equivalent annual cost would be given by[21]:-

$$A = P \left(\frac{a}{p}\right)_n^{12}$$

$$= R150\ 000 \times 0{,}14682$$

$$= R22\ 023$$

where A = annuity

$$\left(\frac{a}{p}\right)_n^{i} = \frac{i(1+i)^n}{(1+i)^{n-1}}$$

The total annual cost of a flood forecasting and gate operation package would therefore be of the order of R39 000, which is appreciably less than the annual benefits, estimated in paragraph 5.2 to be at least R135 000.

5.5 Radar measured rainfall

Although, as indicated earlier, it was not possible during this study to test the performance of the hourly catchment model with radar-measured rainfall as input, the idea holds great promise for the future and therefore deserves brief discussion here. (Flood forecasting with the aid of data from the CSIR weather radar at Houtkoppen forms the subject of a separate study in flood hydrology within the 4 000 km^2 catchment of Hartbeespoort dam currently being undertaken by the author jointly with Dr. W.V. Pitman of the Hydrological Research Unit).

The chief advantage of radar-measured rainfall, as opposed to point rainfall telemetered from autographic gauges, is the improved depiction of the areal distribution. Anderl et al[25] found streamflow simulations aided by weather radar to be more accurate than those based on continuous measurements by a network of one gauge per 500 km^2 (equivalent to 77 rain gauges over the Vaaldam catchment) and of much the same accuracy as simulations based on the output from a special network having a density of one gauge per 25 km^2. The area of catchment for these studies, however, was only 90 km^2 compared with 38 500 km^2 for the Vaaldam catchment. As the rainfall may also have been of a different type one cannot unconditionally extrapolate to the larger catchment.

An on-line weather radar is potentially much easier to operate in real-time than an extensive network of telemetering gauges hooked to a central processing unit. The radar is also less vulnerable to communications breakdown than a telemetering network, for which telecommunications form the very basis of the system. Power failures, which frequently occur during major storms, can be obviated by provision of an emergency generator.

The capital outlay for weather-radar coverage of the Vaaldam catchment would be from R200 000 upwards[24], depending on the type of system installed. While operating costs could be less than double those associated with a network of telemetering gauges, the overall annual cost of operating an on-line weather radar would be of the same order as that for a telemetering network. A final decision, however, can be reached only after a complete analysis of the costs and benefits associated with both systems. Also to be borne in mind are the not inconsiderable benefits of weather radar other than for rainfall measurement.

CHAPTER 6 SUMMARY AND CONCLUSIONS

The primary objective of this study was to develop and evaluate the performance of a real-time flood forecasting and gate operation package of computer programs, having only current rainfall data as input and providing output by means of which flood damages can be minimized. If input to the computer programs is catchment rainfall (either telemetered from weather radar or from sample recording gauges) rather than telemetered streamflow data, valuable time can be gained, making it possible not only to advance the warning time to occupants of the downstream flood plain but also to pre-release water from the reservoir and thus enhance the flood control capability.

Vaaldam, one of South Africa's most important storage units, was chosen as the practical example upon which to develop and test the package. The HRU daily and hourly catchment models were employed for converting rainfall to stream response. The resulting simulated flood hydrograph provides the input to the optimization program, HRYGOP, for operation of the flood gates. Extensive tests were performed to determine the sensitivity of both the daily and the hourly models to changes in catchment parameters and rainfall data input. Spatial distribution of rainfall over the catchment was also investigated as was the correlation of weather forecasts with recorded rainfalls. The inherent flood attenuation characteristics of the Vaaldam reservoir were investigated in depth in Chapter 3, as was the possible influence of the reservoir on catchment model parameters.

In Chapter 4 it was demonstrated that real-time flood forecasting by deterministic catchment models makes it possible to attenuate the peaks of major floods at Vaaldam by as much as 26 percent. It was also shown that to achieve this, rainfall data must be available at least at hourly intervals so that, where necessary, pre-release can be commenced at the earliest possible moment and so that there can be some precision in the time distribution of rainfall, which is so vital to the accuracy of the simulation.

The annual benefits to be derived from a real-time flood forecasting and reservoir operation system for Vaaldam were assessed at roughly R135 000, while the costs might vary between R39 000 per year for a telemetered rainfall system to upwards of R50 000 per year for a radar-based system. Although the benefit-cost ratios may not be spectacular there are without doubt distinct economic advantages to a system for the control of flood releases from Vaaldam. Needless to say, to attenuate the peak of a major flood by up to 26 percent is highly desirable.

Because of differences in climate, topography, population, land use and level of economic development within the flood plain, benefits to be derived from advance warning and flood attenuation will vary widely from one watershed to another. Transposition of the system to more vulnerable watersheds than the Vaal would yield increased economic gains and facilitate improved flood plain planning.

APPENDIX A

Table A1 : Listing of rain gauges used

√ = used in combinations of all rain gauges

3 = used in combinations of 3 rain gauges per sub-catchment

8 = used in combinations of 8 rain gauges per sub-catchment

Gauge number	Latitude	Longitude	1944 flood	1957 flood	1975 flood
298/244	28°34'	28°39'	√	√	√
298/301	28°31'	28°41'	√	√	
298/512	28°32'	28°48'	3 √ 8	3 √ 8	3 √ 8
298/545	28°35'	28°49'			√
298/638	28°38'	28°52'	√	√	
298/871	28°31'	29°00'	√ 8	√ 8	√ 8
331/271	28°01'	28°10'			√
331/275	28°05'	28°10'	√	√	√
331/292	28°22'	28°10'	√		
331/375	28°15'	28°13'	√	√	
331/455	28°05'	28°16'	3 √ 8	√ 8	√
331/474	28°24'	28°16'	√ 8	√ 8	√
331/520	28°10'	28°18'			√ 8
331/554	28°14'	28°19'			√
331/658	28°28'	28°22'	√		
331/740	28°20'	28°25'	3 √	√	3 √ 8
331/794	28°14'	28°27'	√ 8	√ 8	
331/828	28°18'	28°28'	√	3 √	√
332/030	28°30'	28°31'			√
332/094	28°04'	28°34'	√ 8	√	
332/103	28°13'	28°34'	√	√	√ 8
332/120	28°30'	28°34'	√	√	
332/201	28°21'	28°37'	√ 8	√ 8	
332/210	28°30'	28°37'			√
332/326	28°26'	28°41'	√	√	
332/349	28°19'	28°42'	√ 8		√ 8
332/364	28°04'	28°43'	√		
332/378	28°18'	28°43'		√	
332/512	28°02'	28°48'	√ 8	√ 8	

Gauge number	Latitude	Longitude	1944 flood	1957 flood	1975 flood
332/614	28°14'	28°51'		✓ 8	
332/663	28°03'	28°53'	3 ✓	3 ✓	✓
332/674	28°14'	28°53'			✓
332/828	28°18'	28°58'			✓
332/892	28°22'	29°00'	✓	✓	
333/051	28°21'	29°02'	✓	✓	
333/100	28°10'	29°04'			3 ✓ 8
333/226	28°16	29°08'	✓	✓	✓
333/249	28°09'	29°09'		✓ 8	
333/291	28°21'	29°10'	✓ 8	✓ 8	
333/401	28°11	29°14'	✓ 8		
333/485	28°05	29°17'	✓		
333/531	28°21'	29°18'	✓		
333/682	28°22'	29°23'	✓	✓	✓ 8
334/008	28°08'	29°31'			✓ 8
334/244	28°04'	29°39'	✓		
367/066	27°36'	28°03	✓	✓	✓
367/091	27°31'	28°04'	✓		
367/167	27°47'	28°06	✓ 8		
367/177	27°57'	28°06'	✓	✓ 8	✓ 8
367/219	27°39'	28°08'	✓	3 ✓ 8	3 ✓ 8
367/439	27°49'	28°15'	✓		
367/484	27°34'	28°17'			✓ 8
367/553	27°43	28°19'	3 ✓ 8		
367/600	28°00'	28°20'		3 ✓	✓
367/602	27°32'	28°21'	✓ 8	✓	
367/670	27°40'	28°23'	✓	✓ 8	
367/768	27°48'	28°26'	3 ✓ 8	3 ✓ 8	✓ 8
367/780	28°00'	28°26'	✓ 8	✓ 8	3 ✓ 8
368/003	27°33'	28°31'	✓	✓ 8	✓ 8
368/222	27°42'	28°38'	✓	✓ 8	3 ✓ 8
368/243	27°33'	28°39'	✓ 8	3 ✓	
368/263	27°53'	28°39'	✓ 8		
368/516	27°36'	28°48'	✓		
368/581	27°41'	28°50'	✓ 8		
368/634	27°34'	28°52'	3 ✓	✓	3 ✓ 8
368/831	27°51'	28°58'	✓	✓ 8	✓ 8

Gauge number	Latitude	Longitude	1944 flood	1957 flood	1975 flood
369/030	28°00'	29°01'	✓	✓	✓
369/117	27°57'	29°04'	✓		✓
369/136	27°46'	29°05'	✓ 8	✓ 8	✓ 8
369/185	27°35'	29°07'	✓	✓	
369/238	27°58'	29°08'	✓	✓	✓
369/284	27°44'	29°10'	✓	✓ 8	✓ 8
369/411	27°51'	29°14'			✓
369/505	27°55'	29°17'	✓	✓	3 ✓ 8
369/531	27°51'	29°18'	✓ 8		
369/596	27°56'	29°20'		✓	
369/720	28°00'	29°24'	3 ✓ 8	3 ✓	
369/785	27°35'	29°27'	✓	✓ 8	✓ 8
369/819	27°39'	29°28'	✓ 8	✓ 8	✓
369/896	27°56'	29°30'	✓	✓ 8	
370/101	27°41'	29°34'	3 ✓	3 ✓	3 ✓ 8
370/116	27°56'	29°34'	✓		
370/279	27°39'	29°40'	✓		
370/302	27°32'	29°41'	✓ 8		
370/352	27°52'	29°42'	✓ 8	✓ 8	
370/486	27°36'	29°47'			✓ 8
370/509	27°59'	29°47'			✓
402/827	27°17'	27°58'			✓
402/886	27°26'	27°59'			✓
403/054	27°24'	28°02'	✓ 8	✓	✓ 8
403/062	27°02'	28°03'	✓	✓	✓
403/224	27°14'	28°08'	✓	✓	
403/291	27°21'	28°10'		3 ✓ 8	
403/292	27°22'	28°10'	✓		
403/398	27°08'	28°14'			✓ 8
403/401	27°11'	28°14'	✓ 8	✓ 8	
403/474	27°24'	28°16'	3 ✓ 8	✓	
403/646	27°16'	28°22'	✓ 8	✓ 8	3 ✓ 8
403/886	27°16'	28°30'		✓	✓
404/007	27°07'	28°31'	✓ 8	✓ 8	✓ 8
404/055	27°25'	28°32'	3 ✓	✓	
404/132	27°12'	28°35'	✓	✓	✓

Gauge number	Latitude	Longitude	1944 flood	1957 flood	1975 flood
404/152	27°02'	28°36'	✓	✓	✓
404/177	27°27'	28°36'			3 ✓
404/316	27°16'	28°41'	✓ 8	✓ 8	✓ 8
404/366	27°06'	28°43'		✓ 8	✓
404/390	27°30'	28°43'	✓	✓ 8	✓
404/459	27°09'	28°46'			✓
404/608	27°08'	28°51'	✓ 8		
404/614	27°14'	28°51'	3 ✓		3 ✓ 8
404/771	27°21'	28°56'	✓ 8		
404/817	27°07'	28°58'		✓	✓
405/001	27°01'	29°01'		3 ✓ 8	✓ 8
405/030	27°30'	29°01'	✓ 8	3 ✓ 8	
405/283	27°13'	29°10'		✓ 8	
405/295	27°25'	29°10'		3 ✓ 8	3 ✓ 8
405/448	27°28'	29°15'	✓ 8		
405/632	27°02'	29°22'	✓	✓	✓ 8
405/687	27°27'	29°23'	3 ✓ 8		
405/753	27°03'	29°26'	✓	✓	
405/819	27°09'	29°28'	✓ 8		
405/891	27°21'	29°30'	✓	3 ✓ 8	
406/138	27°18'	29°35'	3 ✓ 8		
406/190	27°10'	29°37'	✓	3 ✓ 8	
406/221	27°11'	29°38'			✓ 8
406/496	27°16'	29°47'	✓ 8		
406/551	27°11'	29°49'		✓	3 ✓ 8
406/607	27°07'	29°51'	✓ 8	✓ 8	✓ 8
406/682	27°22'	29°53'	✓	✓	✓
407/045	27°15'	30°02'		✓ 8	✓ 8
407/397	27°07'	30°14'	✓	✓	✓
439/203	26°53'	28°07'			✓
439/389	26°59'	28°13'	3 ✓ 8	3 ✓ 8	3 ✓ 8
439/498	26°48'	28°17'	✓ 8		
439/688	26°58'	28°23'		✓ 8	✓ 8
439/764	26°44'	28°26'	✓	✓	✓
439/769	26°49'	28°26'	✓	✓ 8	✓
440/018	26°48'	28°31'	3 ✓ 8		3 ✓ 8

Gauge number	Latitude	Longitude	1944 flood	1957 flood	1975 flood
440/129	26°39'	28°35'			✓
440/435	26°45'	28°45'	✓	3 ✓ 8	✓ 8
440/449	26°59'	28°45'	✓ 8	✓	✓ 8
440/501	26°51'	28°47'		✓ 8	✓
440/621	26°51'	28°51'	✓		
440/637	26°37'	28°52'	✓ 8	✓	3 ✓ 8
440/767	26°47'	28°56'		✓	✓
440/804	26°54'	28°57'	✓		
440/873	26°33'	29°00'		✓ 8	
440/885	26°45'	29°00'			✓
441/104	26°44'	29°04'	✓	✓	
441/113	26°53'	29°04'	✓	✓ 8	
441/215	26°35'	29°08'	✓		
441/261	26°51'	29°09'		✓	
441/270	27°00'	29°09'	✓ 8	✓	3 ✓
441/285	26°45'	29°10'	✓ 8		
441/309	26°39'	29°11'		✓ 8	✓ 8
441/385	26°55'	29°13'			✓ 8
441/447	26°57'	29°15'	3 ✓		
441/523	26°43'	29°18'	✓ 8		
441/578	26°39'	29°20'		✓ 8	
441/580	26°40'	29°20'			✓ 8
441/596	26°56'	29°20'		✓	✓
441/650	26°50'	29°22'	✓	✓	
441/694	26°34'	29°24'	✓	✓	
441/777	26°57'	29°26'	✓ 8	✓ 8	✓ 8
442/046	26°46'	29°32'	✓		
442/068	26°38'	29°33'	✓ 8	✓ 8	✓
442/123	26°33'	29°35'	✓		
442/150	27°00'	29°35'		✓	✓
442/177	26°57'	29°36'	✓		
442/194	26°44'	29°37'	3 ✓	3 ✓	3 ✓ 8
442/288	26°48'	29°40'	✓		
442/458	26°38'	29°46'	✓ 8	✓ 8	
442/527	26°47'	29°48'	✓		
442/654	26°54'	29°52'	✓ 8		

Gauge number	Latitude	Longitude	1944 flood	1957 flood	1975 flood
442/660	27°00'	29°52'	3 ✓	3 ✓	3 ✓
442/677	26°49'	29°54'			✓
442/764	26°44'	29°56'	✓		
442/811	26°31'	29°58'	3 ✓	3 ✓	3 ✓ 8
442/853	26°43'	29°59'			✓
442/867	26°57'	29°59'	✓	✓ 8	✓ 8
443/196	26°46'	30°07'	✓ 8	✓ 8	✓ 8
443/451	26°31'	30°16'	✓	✓	✓
443/463	26°43'	30°16'	✓	✓	
443/523	26°43'	30°18'			✓
477/629	26°29'	28°51'	✓		
477/772	26°22'	28°56'	3 ✓	3 ✓	✓
478/039	26°09'	29°02'	✓ 8	✓	
478/292	26°22'	29°10'			✓
478/360	26°30'	29°12'	✓	✓	
478/386	26°26'	29°13'			✓
478/837	26°27'	29°28'	✓		
478/867	26°27'	29°29'			✓
479/238	26°28'	29°38'	✓	✓	✓
479/298	26°28'	29°40'			✓ 8
479/778	26°28'	29°56'		✓	✓
479/858	26°18'	29°59'			✓
480/170	26°20'	30°06'		✓	✓
480/267	26°27'	30°09'	✓ 8	✓ 8	
480/377	26°17'	30°13'			✓

Table A2 : Combinations of the rain gauges reporting daily to DWA, as used for simulation of February 1977 flood

Gauge at:	C1M01	CIM02	CIM03	C8B01	C8M04	C8M14	C2M03
Bethal	✓		✓				
Bethlehem					✓	✓	
Ermelo	2✓						
Frankfort				✓			✓
Harrismith						2✓	
Reitz				✓	✓		
Standerton	✓		✓				
Vaaldam							✓
Villiers							✓
Volksrust	✓	✓					
Vrede		✓	✓	✓			
Warden				✓		✓	

2 = double weight allocated to gauge to compensate for poor spatial distribution

Table A3 : Average daily rainfall (1/10 mm) for the seven sub-catchments from October 1943 to March 1944, as measured by 8 rain gauges per sub-catchment

Data description Year, month, average daily precipitation (1/10mm). (Max. of 31 consecutive values, -1 indicates a non-day)

Table A3.1 Sub-catchment C1MO1

```
43 10  33   0   0   0  23  15  59   8  49  51  13   0  67  31   0   0
  0   8   0   0   0  71  74   2   9  10  58 100  18  73  59
43 11  46  70  34  60   1   0   3   6   0 104  15  10   0  89 174   0
 42  16   3  29  15  37   6   0   0   0   0   0  26  72  -1
43 12   1  24   0   0   0 177  65  15   0  14  69  86  91 146  47  14
  0   5  60  12   0  12  15  75  49 136 218  90  61   0   0
44  1  85 238 118  55 111  67  32  19  37   0   0   4  67 230 115   6
  0   0   0  30  26  40   0  51  63  70 109  70  60   5   0
44  2 293 411 217  73 101 167  71  53  47  10  20   7   4   0   0   0
  2 235  90   4   0   0   4   0  17 101  29  24  64  -1  -1
44  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

Table A3.2 Sub-catchment C1MO2

```
43 10   0   0   0   0   0  13  38   0  76  64  92  66 225  20   0   0
  3   2   0   0   0  20  34   6  79  37 266 133   1  58  34
43 11  26  22   3  12   0  10  19  20   0   0  19  37  78 119 214  46
 44   0   0   0  47  52   0   0   0   0   0   0   0 112  -1
43 12  11   8   0  32   3 149  31   0   0  47 205  71 149   0   1   0
  5   0  75   2  31   0  23   0   8 154 179 119  11   4   0
44  1  18 101 100  51 135  49   0   0   0   0   0   6  46  93  24   0
  0   0   0   0   0   0   9  30  63  45 101  98  32  56   0
44  2 161 265 395 252 169 120  16   6   0  88  48  28   0   0  15   0
  0  72   0   0   0   0  11  65   0 126   0  76  23  16  -1
44  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

Table A3.3 Sub-catchment C1MO3

```
43 10   0   0   0   0   0   0   0  13  78  16  66  25 118  31   0   9
  0   6   1   0   0  92  70  10   0   6 180 195  21  31  64
43 11  94 110   6   9  25   0  13   0   0  21   7  39  52  56 241  58
106  11  26  12 133  90  12  18   0   5   0  31   6  76  -1
43 12   6   5   0  25   5  78 110   2   0  17 200 190 170  36   0   0
  0   0  85   0   0   0   0  32  33 250 109  96   9   0 126
44  1  23  75 122  41  57  56   3   0   0  12   0   8  56  97  40   0
  0   0   0 117   0   0   0   6  41  86  65 128  26  23   6
44  2 179 594 302 191 135  72  47  81   0  27  31   0   0   0  30   0
  5 112  17   0   1   0  61  67   7  42  27  31  37  -1  -1
44  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

Table A3.4 Sub-catchment C8BO1

```
43 10   0   0   0   0   0  81   0   0  67   0 178 180 131   0   0   0
  7  17   0   0   0  41  71   4   0  20 326  64  66 106  37
43 11  66 124  89   0   0   0  27   2  26   5  39 169   9 236  92  63
 88  24   0  13  53  44   0   0   0   0   0  42   0 114  -1
43 12   0   2   0 160   0  35   0   0   0  42 240 177 110 114   0   0
  0   0  77   0   0   0  12   2   0 109  49  28  44   4  25
44  1  64  55  75  38  23 119  19  97   0   0   0  18  89  12   0   0
  0   0   0  14   0  12  12  25   0   0 132 163   0  18  15
44  2 300 202 255 182 303 186  62  23   0  14  10   1   0   0   0   0
  0  16   0   6   7   0   0 150   8   0  11  42  46  -1  -1
44  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

Table A3.5 Sub-catchment C8MO4

43	10	0	0	0	0	0	37	0	0	23	23	160	533	205	6	0	0
5	4	1	0	28	11	37	24	19	139	157	112	37	98	24			
43	11	96	58	115	61	22	22	198	32	50	18	82	349	71	130	220	11
65	93	3	6	47	27	0	0	0	0	38	4	0	239	-1			
43	12	48	18	0	135	1	151	13	0	0	60	222	137	71	206	0	0
4	11	124	1	3	4	9	6	26	93	24	80	3	15	96			
44	1	64	12	34	76	82	34	13	101	0	11	0	67	68	61	0	0
0	0	0	0	0	14	0	54	0	6	108	5	6	0	5			
44	2	218	180	213	110	231	197	82	45	3	54	4	0	0	0	0	0
0	0	0	0	12	0	26	5	34	31	56	80	2	-1	-1			
44	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			

Table A3.6 Sub-catchment C8M14

43	10	0	0	0	0	6	28	21	3	12	11	181	424	323	12	28	0
4	0	0	0	0	22	11	12	0	100	320	157	33	85	9			
43	11	129	68	69	32	0	53	195	120	16	8	84	101	78	114	60	61
32	81	31	6	19	44	0	0	0	0	16	9	1	60	-1			
43	12	65	12	0	4	37	56	45	26	0	78	89	225	49	64	6	0
0	0	101	22	0	0	36	20	21	145	39	110	77	1	70			
44	1	45	18	120	90	96	43	6	24	54	0	0	0	29	135	77	0
0	0	0	0	0	0	0	20	32	2	4	55	36	0	0			
44	2	215	283	382	182	107	164	62	38	4	6	5	6	0	0	0	0
0	6	0	0	0	1	12	57	45	11	21	33	44	-1	-1			
44	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			

Table A3.7 Sub-catchment C2MO3

43	10	0	0	0	0	0	7	0	7	75	48	80	104	81	21	3	0
0	22	0	0	26	129	48	12	0	3	451	144	47	80	130			
43	11	75	3	4	31	13	0	0	6	38	4	17	120	17	99	130	0
55	15	37	0	63	25	45	0	0	0	0	0	0	26	-1			
43	12	0	0	0	16	0	32	0	0	0	43	273	262	77	73	8	0
7	4	17	0	0	0	11	7	6	97	44	41	31	15	0			
44	1	61	40	7	2	40	1	14	119	20	11	0	1	24	7	0	0
0	0	0	54	0	8	0	102	23	24	81	103	29	0	0			
44	2	447	248	379	302	258	143	159	66	0	0	10	0	0	0	0	0
14	3	0	0	0	1	0	216	93	29	0	3	8	-1	-1			
44	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			

Table A4 : Average daily rainfall (1/10mm) for the seven sub-catchments from October 1956 to October 1957, as measured by 8 rain gauges per sub-catchment

Data description Year, month, average daily precipitation (1/10mm) (Max. of 31 consecutive values, -1 indicates a non-day).

Table A4.1 Sub-catchment C1M01

56	10	0	0	0	0	0	0	2	0	0	3	133	76	4	0	21	19
0	39	33	14	49	56	75	5	19	28	38	289	66	188	43			
56	11	22	0	28	7	33	22	20	0	0	0	33	31	7	18	1	25
0	1	4	176	251	68	95	69	18	46	8	0	0	55	-1			
56	12	226	152	44	43	202	51	5	36	35	0	4	37	17	50	5	10
7	68	14	28	118	187	18	0	95	20	6	14	5	1	0			
57	1	0	0	13	7	0	2	116	30	28	58	144	101	7	0	2	1
6	27	24	0	27	24	45	11	13	0	46	1	0	7	25			
57	2	86	11	13	0	10	5	0	92	25	42	19	0	0	0	0	0
3	0	0	0	0	5	105	16	97	130	9	0	-1	-1	-1			
57	3	0	0	34	43	131	15	67	11	28	56	27	0	0	0	83	11
47	0	0	0	47	65	77	14	5	0	0	0	1	0	0			
57	4	25	0	26	93	8	0	0	0	17	99	56	7	57	8	1	30
0	0	0	0	0	0	0	0	0	0	66	28	0	0	-1			
57	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	17	61	34	0	0	0	0	6	0	0	0	0	0	0			
57	6	0	0	0	0	0	0	0	0	0	0	22	1	0	0	0	0
0	0	0	0	0	0	0	0	6	81	50	33	0	0	-1			
57	7	202	211	129	31	16	2	0	10	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
57	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	6	24	12	35	48	17	67	7	0	0	0			
57	9	0	0	0	0	0	0	0	0	17	14	53	176	37	66	68	0
0	0	1	0	0	230	83	83	95	187	62	0	0	66	-1			
57	10	1	146	66	72	6	0	0	6	36	53	34	0	0	0	0	0
3	14	2	33	1	0	10	143	48	49	180	96	24	2	4			

Table A4.2 Sub-catchment C1M02

56	10	0	0	0	0	0	0	0	8	5	0	66	0	0	2	21	13
3	242	11	23	0	56	1	2	91	49	36	135	134	97	95			
56	11	154	4	30	31	7	80	0	0	0	32	133	169	0	0	6	3
30	6	0	205	226	52	93	33	20	22	18	0	1	2	-1			
56	12	79	191	46	0	435	0	28	27	20	0	100	54	37	12	60	17
79	8	10	33	150	260	0	82	227	90	22	0	12	0	0			
57	1	30	0	8	0	29	0	28	0	28	233	141	200	26	46	7	0
0	0	8	17	0	23	36	14	14	3	86	29	11	27	48			
57	2	85	18	0	0	9	24	12	110	15	79	37	21	0	3	0	0
0	0	0	0	0	33	78	92	108	58	6	0	-1	-1	-1			
57	3	0	0	23	86	15	29	35	19	71	88	7	0	0	0	161	2
38	0	0	0	34	41	18	24	0	0	0	0	0	0	0			
57	4	1	19	23	9	7	0	0	0	0	59	25	8	3	0	0	35
11	0	1	0	0	0	0	0	0	4	46	8	0	0	-1			
57	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	8	34	23	0	0	0	0	12	2	0	0	0	0	0			
57	6	0	0	0	0	0	0	0	0	0	19	37	0	0	0	0	0
0	0	0	0	0	0	0	0	0	44	65	0	0	0	-1			
57	7	265	404	106	71	26	25	0	31	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0			
57	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	30	34	34	82	38	50	31	0	0	0	0			
57	9	0	0	0	0	0	0	0	0	13	26	55	384	94	162	1	2
0	0	3	15	4	205	113	214	133	269	61	0	0	159	-1			
57	10	1	158	128	1	56	0	10	2	49	40	0	5	1	27	0	0
58	14	23	0	6	0	0	100	35	311	101	105	44	1	0			

Table A4.3 Sub-catchment C1MO3

56	10	0	0	0	0	0	0	0	0	0	0	69	57	0	4	8	0
3	51	25	15	4	59	0	2	36	60	85	220	59	166	50			
56	11	34	0	6	0	0	32	5	0	0	0	6	81	26	0	2	0
21	4	2	148	226	106	63	71	33	30	17	2	0	2	-1			
56	12	92	169	5	15	276	63	3	0	0	5	23	15	25	20	18	5
22	25	46	5	58	163	41	0	107	57	3	15	0	0	0			
57	1	4	0	33	0	0	5	0	17	49	139	212	179	137	0	2	0
1	10	0	41	49	29	22	13	0	4	20	18	6	27	7			
57	2	43	28	0	12	17	13	0	127	55	16	16	11	0	0	0	0
0	0	0	0	0	8	101	33	99	97	0	0	-1	-1	-1			
57	3	0	0	96	37	26	7	52	39	73	126	9	0	0	0	95	34
30	0	1	0	19	143	46	30	0	0	0	0	0	0	0			
57	4	17	19	18	117	6	0	0	0	0	57	17	26	0	1	16	10
13	0	0	0	0	0	0	0	0	0	11	4	0	0	-1			
57	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	20	30	0	0	0	0	0	0	0	0	0	0	0			
57	6	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0
0	0	0	0	0	0	0	0	0	48	90	17	0	0	-1			
57	7	133	318	163	14	0	12	0	2	3	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
57	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	4	0	10	105	47	35	51	9	0	0	0			
57	9	0	0	0	0	0	0	0	0	10	26	53	219	109	98	29	16
0	0	0	11	0	232	60	139	88	327	45	46	0	57	-1			
57	10	39	204	61	5	8	0	0	35	2	113	0	0	0	6	0	0
56	3	0	4	9	3	0	129	104	325	101	45	22	0	0			

Table A4.4 Sub-catchment C8BO1

56	10	0	0	0	0	0	0	2	0	0	3	17	5	0	30	8	0
0	51	42	20	0	17	5	11	86	78	53	112	60	53	85			
56	11	54	10	31	10	0	3	0	0	0	0	0	270	2	0	0	24
15	5	4	121	160	68	133	50	21	0	0	0	0	0	-1			
56	12	111	124	16	30	183	37	31	32	91	30	80	31	2	72	129	52
45	31	75	149	119	165	26	7	256	55	0	2	0	0	0			
57	1	41	3	17	1	0	0	0	0	0	270	256	264	25	0	0	0
0	12	0	0	40	67	88	12	0	10	0	0	0	5	0			
57	2	29	0	0	2	0	0	0	10	21	53	0	0	0	0	0	0
0	10	18	0	0	36	135	30	126	17	3	1	0	-1	-1			
57	3	1	0	35	28	11	14	36	39	81	141	11	0	0	6	108	70
0	0	0	0	64	73	104	9	25	6	0	0	0	0	0			
57	4	4	0	10	21	0	0	0	0	0	41	0	0	2	0	6	3
0	0	0	0	0	0	0	0	10	17	27	1	0	0	-1			
57	5	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
0	7	15	70	0	0	0	0	0	0	0	0	0	0	0			
57	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	65	115	27	5	14	-1			
57	7	238	411	182	36	12	2	20	21	6	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
57	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	29	4	6	132	41	38	38	0	0	0	0			
57	9	0	0	0	14	0	0	0	0	6	6	92	354	117	85	30	29
9	9	13	9	10	192	89	255	138	299	63	0	0	170	-1			
57	10	21	163	13	0	35	22	0	10	10	26	10	11	6	39	67	2
24	21	19	9	13	0	0	101	101	192	59	16	0	0	0			

Table A4.5 Sub-catchment C8MO4

56	10	0	0	0	0	0	0	0	0	0	1	23	1	0	16	0	0
0	58	82	16	38	97	43	33	76	171	28	55	90	100	250			
56	11	15	12	16	0	0	9	0	0	0	0	8	118	0	0	0	0
23	38	11	40	149	131	19	33	30	7	6	0	0	0	-1			
56	12	43	45	49	0	225	71	102	85	18	11	128	2	6	16	121	66
103	79	75	38	132	102	78	21	224	163	16	0	0	0	0			
57	1	2	1	71	0	0	4	0	0	0	143	151	239	98	0	0	0
30	3	5	3	21	67	24	55	4	3	78	4	2	0	14			
57	2	15	0	0	45	57	5	13	36	18	109	58	0	0	0	0	0
0	84	0	0	0	35	102	5	83	7	0	0	0	-1	-1			
57	3	5	0	71	0	2	10	0	6	105	125	91	0	0	2	75	0
3	5	2	2	36	60	54	3	15	41	0	48	0	0	0			
57	4	1	0	21	33	0	0	0	0	21	118	17	4	5	47	8	2
0	0	0	0	0	0	0	0	13	36	22	15	0	0	-1			
57	5	0	0	6	24	0	0	0	0	0	0	0	0	0	0	0	0
0	1	2	41	0	0	0	6	0	0	0	0	0	0	0			
57	6	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0
0	0	0	0	0	0	0	0	6	119	150	40	13	24	6			
57	7	155	302	100	25	6	8	0	21	0	16	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
57	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	49	5	47	125	40	59	17	0	0	0	0			
57	9	0	0	0	0	0	0	0	0	15	5	104	289	334	185	34	0
0	0	3	0	52	269	270	304	146	307	14	0	0	192	-1			
57	10	55	310	10	0	32	0	15	28	4	50	1	15	0	41	6	0
55	51	169	0	0	0	0	0	225	144	134	46	7	0	0			

Table A4.6 Sub-catchment C8M14

56	10	0	0	0	0	0	0	0	0	0	0	8	0	0	5	0	0
0	76	93	0	25	52	29	27	44	83	37	65	104	90	280			
56	11	203	59	80	0	0	33	0	0	1	0	40	180	0	20	0	38
10	1	0	72	185	43	81	23	76	10	26	0	0	0	-1			
56	12	59	165	47	9	138	104	50	35	29	35	130	77	5	16	80	90
101	51	58	44	147	180	80	52	324	254	54	5	0	1	10			
57	1	42	38	63	21	10	5	6	0	58	215	122	292	40	0	0	17
0	8	0	0	35	25	28	12	0	0	40	7	10	0	0			
57	2	125	17	0	0	0	0	42	160	157	20	1	5	1	1	1	1
1	11	1	1	20	17	48	40	12	62	10	0	-1	-1	-1			
57	3	91	31	46	21	56	36	5	11	151	149	35	0	0	1	67	39
0	0	0	10	41	73	0	3	5	0	0	0	0	5	0			
57	4	0	20	0	16	0	7	1	0	5	118	13	0	0	7	50	34
0	0	5	0	0	0	0	10	3	2	12	14	0	11	-1			
57	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	10	15	1	0	0	0	0	0	0	0	0	0	0			
57	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	133	40	0	21	19	-1			
57	7	141	369	239	18	13	10	0	10	2	0	10	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	1	0	0	0			
57	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	91	23	63	115	21	80	31	4	0	0	0			
57	9	5	0	0	0	0	0	0	0	6	16	103	425	189	161	15	40
0	0	7	0	16	182	346	330	140	237	191	0	14	121	-1			
57	10	117	213	61	26	10	5	0	9	23	15	1	15	0	17	9	1
72	154	90	47	0	7	11	34	146	103	132	83	35	8	0			

Table A4.7 Sub-catchment C2M03

56	10	0	0	0	0	0	0	0	0	0	8	39	0	0	25	9	0
1	19	18	36	1	52	5	0	14	120	39	198	80	100	69			
56	11	35	0	0	0	0	11	0	5	0	0	5	121	0	0	0	0
0	0	39	88	128	40	86	11	42	12	20	7	0	0	-1			
56	12	109	72	54	0	202	60	47	5	0	2	52	27	12	29	40	5
2	68	26	62	72	148	46	16	90	24	0	11	0	0	0			
57	1	14	0	10	0	0	3	0	0	0	371	151	137	56	35	0	0
0	0	25	1	25	99	35	0	11	11	0	0	0	0	10			
57	2	40	36	5	11	0	0	0	61	49	68	82	0	0	0	0	0
0	0	0	0	0	133	52	24	78	49	18	0	-1	-1	-1			
57	3	0	0	26	48	58	18	0	45	140	170	71	0	0	1	15	8
0	10	7	0	58	189	117	7	0	6	0	0	0	0	0			
57	4	1	0	53	83	56	56	0	0	19	49	33	0	0	10	4	22
13	0	0	0	0	0	0	0	0	0	5	0	0	0	-1			
57	5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
0	1	14	6	0	0	0	0	0	0	0	0	0	0	0			
57	6	0	0	0	0	0	0	0	0	0	1	0	3	0	0	0	0
0	0	0	0	0	0	0	0	8	41	107	29	28	0	-1			
57	7	225	309	88	1	107	23	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	5			
57	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	2	7	0	0	114	39	35	50	59	0	0	38			
57	9	0	0	0	0	0	0	0	3	0	19	111	205	164	60	40	4
2	0	0	1	26	233	62	57	216	309	35	0	0	65	-1			
57	10	24	204	53	0	0	0	42	17	6	33	3	0	0	0	0	0
52	1	21	6	0	0	0	57	64	236	80	10	5	0	0			

Table A5 : Average daily rainfall (1/10mm) for the seven sub-catchments from October 1973 to September 1975, as measured by 8 rain gauges per sub-catchment

Data description Year, month, average daily precipitation (1/10mm) (Max. of 31 consecutive values, -1 indicates a non-day).

Table A5.1 Sub-catchment C1M01

73	10	0	0	0	0	0	0	0	0	0	23	51	28	34	10	49	4	0	0	0	0	0	0	0	0	19	98	14	13	9	51	0
73	11	36	59	18	17	0	0	0	69	24	147	0	260	109	48	28	19	0	0	56	203	126	57	27	43	0	142	36	0	0	1	-1
73	12	2	1	0	23	0	30	3	16	165	0	0	0	11	0	29	260	18	193	45	67	0	0	17	96	26	0	0	0	0	0	12
74	1	155	59	7	92	3	39	0	0	0	46	18	28	50	9	5	0	47	99	45	32	91	124	102	222	10	4	0	0	70	5	0
74	2	74	0	0	6	50	88	283	1	0	3	0	0	2	1	0	0	23	3	20	0	0	0	113	2	0	2	0	0	-1	-1	-1
74	3	5	0	0	0	0	0	0	109	5	5	3	17	0	61	11	0	0	0	0	0	0	5	105	6	1	0	1	0	51	21	28
74	4	7	60	134	53	0	3	16	10	15	0	78	22	0	0	12	6	1	0	0	1	1	0	12	79	109	74	0	0	0	0	-1
74	5	0	0	0	0	34	6	9	3	0	0	0	0	0	0	1	0	116	9	8	0	0	0	0	0	0	0	0	0	0	0	0
74	6	49	123	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1
74	7	85	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
74	8	0	0	0	0	0	0	0	0	0	0	0	0	2	9	32	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
74	9	0	0	0	19	24	0	0	0	0	0	0	0	0	100	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1
74	10	0	0	0	0	0	94	51	120	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	3	26	0	1	31	194	71
74	11	0	0	1	0	1	173	59	13	79	115	197	109	0	27	22	4	13	48	539	24	20	24	5	39	0	2	84	35	28	41	-1
74	12	26	99	6	8	0	0	30	171	50	218	214	37	13	0	0	0	39	87	271	0	0	0	25	79	223	36	99	37	37	0	0
75	1	0	10	0	0	0	78	0	43	4	7	4	37	82	0	213	212	156	212	93	0	0	0	0	85	51	29	126	48	62	1	0
75	2	0	0	0	0	7	16	34	22	102	135	26	211	221	322	48	59	9	12	76	51	2	7	6	0	0	10	58	5	-1	-1	-1
75	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A5.2 Sub-catchment C1MO2

73	10	0	0	0	83	25	0	0	0	0	8	53	64	25	8	0	19
0	0	0	0	0	0	2	0	0	113	61	35	13	33	13			
73	11	20	6	16	0	0	0	14	38	10	89	15	96	17	104	24	3
15	0	92	156	200	44	3	23	15	64	5	0	0	0	-1			
73	12	0	0	1	26	0	0	0	0	132	58	3	0	7	20	8	122
109	123	136	42	24	0	69	71	33	12	13	6	0	0	30			
74	1	149	91	118	22	42	0	8	0	0	33	47	4	9	19	0	22
60	88	26	47	59	23	104	161	59	71	0	12	104	50	31			
74	2	15	0	7	0	70	121	217	128	16	38	0	0	0	0	0	0
79	0	19	10	1	0	62	8	0	8	2	0	-1	-1	-1			
74	3	3	8	31	3	0	24	0	119	17	0	0	13	26	56	81	0
0	1	0	0	0	25	30	44	71	1	0	0	111	14	0			
74	4	58	60	107	33	6	0	16	18	0	10	37	20	6	0	10	0
5	0	0	22	0	0	0	85	122	22	8	0	0	0	-1			
74	5	0	0	0	0	11	0	0	7	0	0	0	0	0	5	0	0
89	0	0	0	0	0	0	0	0	26	2	0	0	0	0			
74	6	13	99	31	0	0	0	0	0	23	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1			
74	7	30	8	0	0	0	0	0	5	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
74	8	0	0	0	0	0	0	0	0	0	0	0	0	0	26	26	6
0	0	8	5	0	0	0	0	0	0	0	0	0	0	0			
74	9	0	0	0	0	0	0	0	19	7	0	0	0	0	148	46	60
0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1			
74	10	10	10	11	0	0	35	13	66	82	0	9	0	0	0	0	1
0	0	0	0	0	0	8	1	0	2	0	15	18	28	111			
74	11	21	0	6	6	9	119	152	30	5	71	55	258	0	56	16	7
0	53	235	167	16	26	13	67	0	10	11	54	26	25	-1			
74	12	50	55	36	56	0	10	0	181	10	150	92	77	0	0	0	0
64	34	130	143	47	0	108	54	154	117	70	44	4	81	0			
75	1	10	18	0	0	4	92	33	14	15	0	11	55	101	32	111	60
139	85	91	77	21	0	18	138	168	69	160	47	118	33	0			
75	2	0	0	20	7	53	79	102	33	81	144	76	71	212	251	304	180
49	23	61	111	36	20	3	13	9	1	10	20	-1	-1	-1			
75	3	11	10	0	0	0	17	82	54	0	27	0	0	5	17	14	14
52	57	14	25	0	7	0	3	0	0	1	16	0	0	0			
75	4	1	11	49	41	27	10	0	0	0	12	8	2	128	67	64	21
0	0	5	0	4	2	15	20	3	0	5	0	16	0	-1			
75	5	0	0	15	1	4	0	0	3	18	0	0	0	17	30	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
75	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
75	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
75	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
75	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			

Table A5.3 Sub-catchment C1MO3

73	10	0	0	0	0	0	9	0	0	0	5	18	28	42	4	17	0
14	3	0	0	0	4	1	8	1	65	45	0	0	13	3			
73	11	23	29	0	14	2	0	0	22	19	26	3	193	143	39	18	0
10	0	181	131	192	26	0	48	17	55	11	11	0	5	-1			
73	12	80	6	28	74	0	11	4	11	49	7	0	31	0	20	58	138
154	153	93	40	13	0	124	51	15	36	108	0	0	0	10			
74	1	125	103	77	23	40	50	9	0	7	193	0	38	78	145	0	0
25	114	37	36	85	63	154	169	105	6	0	4	226	116	0			
74	2	4	0	0	7	26	61	129	74	20	0	13	0	8	0	0	0
42	67	31	18	0	0	1	0	0	0	0	0	-1	-1	-1			
74	3	0	0	0	0	0	6	5	46	38	0	0	1	39	72	17	15
5	0	0	0	0	0	52	102	63	23	14	6	16	2	8			
74	4	5	96	166	29	2	3	5	18	0	0	15	6	21	0	0	3
0	0	0	4	0	0	0	44	121	62	0	0	0	0	-1			
74	5	0	0	0	0	37	37	0	0	0	3	0	0	0	0	5	0
95	13	0	0	0	0	0	0	0	0	0	0	0	0	0			
74	6	2	85	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1			
74	7	21	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	2	0	0	0	0	0	0	0	0	0	0	0			
74	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
0	0	15	0	0	0	0	0	0	0	0	0	0	0	0			
74	9	0	0	0	6	13	0	0	0	0	0	0	0	0	60	83	16
25	0	0	0	0	0	0	0	0	0	0	0	0	0	-1			
74	10	0	0	0	0	0	20	15	101	83	0	0	0	0	0	0	0
0	0	0	0	0	0	8	0	0	11	0	11	27	71	48			
74	11	1	43	54	4	0	85	87	90	28	117	81	75	40	0	15	7
14	168	200	38	6	135	113	52	73	0	35	87	168	11	-1			
74	12	86	79	71	0	0	0	1	52	62	124	167	33	0	0	0	0
39	218	56	10	0	0	18	23	309	136	91	56	14	0	0			
75	1	0	2	0	0	0	34	21	0	0	0	0	126	108	62	45	275
160	147	260	13	0	0	0	328	163	44	187	43	50	5	10			
75	2	0	0	20	0	34	3	76	26	118	34	12	40	121	517	230	71
82	0	270	95	45	20	37	19	0	22	90	10	-1	-1	-1			
75	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
75	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
75	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
75	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
75	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
75	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
75	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			

Table A5.4 Sub-catchment C8BO1

73	10	0	0	0	0	0	16	0	0	0	0	5	2	45	6	35	0
0	0	0	0	11	22	5	0	0	68	11	0	0	0	51			
73	11	40	30	3	20	5	0	0	6	46	35	0	61	28	23	2	6
0	0	122	243	176	23	27	0	86	23	0	0	5	7	-1			
73	12	59	0	30	38	0	0	0	40	0	0	0	0	11	60	28	150
33	145	262	0	0	25	198	65	56	0	135	0	0	0	39			
74	1	64	210	55	20	9	6	0	58	0	90	86	15	97	37	0	6
35	48	20	45	188	115	188	152	86	10	7	4	104	50	14			
74	2	4	0	0	71	23	107	183	106	47	36	25	4	0	0	0	0
110	8	27	1	0	0	120	18	0	0	0	0	-1	-1	-1			
74	3	0	0	0	0	0	50	18	18	0	25	31	16	20	43	42	5
0	0	0	0	0	0	0	13	61	11	33	3	11	0	22			
74	4	68	109	53	40	0	6	4	34	7	0	17	10	0	0	0	0
0	0	0	0	0	8	36	95	40	0	0	0	0	0	-1			
74	5	0	0	0	0	16	0	0	0	0	0	0	0	0	0	2	0
4	22	0	0	0	0	0	0	0	0	0	0	0	0	0			
74	6	51	106	21	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1			
74	7	1	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	3	0	0	0			
74	8	0	0	0	0	0	0	0	0	0	2	0	1	8	0	5	0
0	3	25	8	0	0	0	0	0	0	0	0	5	2	0			
74	9	0	0	0	0	0	0	0	0	0	2	7	0	8	86	72	7
0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1			
74	10	0	0	0	0	0	0	0	168	53	0	0	0	0	5	0	16
0	21	0	0	0	0	15	15	61	0	6	30	67	48	155			
74	11	0	6	20	0	0	175	186	31	11	163	48	28	0	64	42	7
3	66	239	37	81	219	40	60	0	0	9	166	99	15	-1			
74	12	177	62	25	14	32	0	0	99	9	155	27	0	0	0	0	0
0	172	0	0	0	0	0	0	247	210	158	74	0	0	0			
75	1	0	0	0	0	0	0	0	0	6	0	8	79	66	0	0	143
195	117	60	0	96	37	0	182	73	130	176	33	33	46	0			
75	2	0	27	14	0	201	41	93	10	51	15	63	1	38	176	103	135
6	41	253	18	42	13	0	0	9	0	11	0	-1	-1	-1			
75	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
75	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
75	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
75	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
75	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
75	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
75	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			

Table A5.5 Sub-catchment C8MO4

73	10	0	0	0	0	0	0	0	0	0	0	0	1	2	0	33	0
0	0	0	3	23	0	25	0	0	80	0	0	0	2	79			
73	11	43	68	5	20	0	0	0	30	49	15	0	44	32	86	7	12
0	0	82	203	245	23	0	4	54	30	0	0	0	42	-1			
73	12	10	6	39	43	0	0	0	53	10	0	0	0	36	0	2	180
0	159	193	2	6	3	131	23	38	22	155	0	0	46	69			
74	1	48	122	19	124	41	8	1	12	1	1	25	33	79	118	9	19
118	41	66	10	425	164	85	20	15	2	0	24	159	0	92			
74	2	2	0	0	55	4	145	79	52	39	20	0	0	0	0	22	0
34	0	9	0	0	5	55	18	0	0	0	0	-1	-1	-1			
74	3	0	1	0	0	2	129	28	23	6	121	103	0	7	1	78	14
9	0	0	0	0	0	0	71	97	0	2	0	5	0	78			
74	4	103	85	26	0	0	11	34	33	1	0	0	3	17	0	0	0
0	0	0	0	0	0	26	124	55	1	0	0	0	0	-1			
74	5	0	0	0	0	35	0	0	0	0	0	0	0	0	0	8	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
74	6	52	119	21	0	0	0	0	0	0	0	12	1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1			
74	7	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
74	8	0	0	0	0	0	0	0	0	0	0	0	0	49	3	0	0
0	0	9	0	1	0	0	0	0	0	0	2	12	0	0			
74	9	0	0	0	1	2	0	0	0	0	2	7	0	1	6	3	7
0	0	14	0	0	0	0	0	0	0	0	0	0	0	-1			
74	10	0	0	0	5	0	0	0	160	0	0	0	0	0	5	1	16
1	13	0	0	0	2	17	64	34	12	6	14	48	43	105			
74	11	0	5	1	30	14	321	199	29	2	99	9	48	0	21	43	4
13	28	193	5	40	284	28	157	0	0	0	102	57	1	-1			
74	12	113	185	3	1	29	0	11	160	31	100	10	0	0	0	0	0
0	89	81	0	0	1	0	0	115	91	175	25	0	0	0			
75	1	0	0	0	0	0	0	0	0	3	0	8	43	9	1	21	139
226	87	24	0	33	0	0	88	177	443	131	46	21	13	0			
75	2	0	1	28	108	157	2	6	12	43	5	15	10	39	106	43	64
5	36	429	146	42	13	8	71	9	0	0	5	-1	-1	-1			
75	3	127	0	11	0	3	7	52	11	0	6	0	5	28	0	0	14
112	114	37	16	14	2	3	3	10	1	0	0	0	0	0			
75	4	0	9	26	0	0	0	0	0	0	15	0	0	150	35	97	13
0	0	0	16	38	18	5	0	0	0	0	0	3	14	-1			
75	5	0	0	216	9	6	1	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
75	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
750	700	0	0	0	0	0	0	0	0	0	0	0	0	0			
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
75	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
75	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			

Table A5.6 Sub-catchment C8M14

73	10	0	0	0	0	0	0	0	0	0	22	8	31	6	10	70	28
		0	0	0	0	0	7	0	12	0	67	41	0	0	18	1	
73	11	75	134	8	20	4	0	0	0	8	31	22	1	23	73	26	14
		9	0	113	159	136	40	20	40	16	74	22	0	0	8	-1	
73	12	1	0	18	9	1	0	0	43	117	38	0	0	9	0	50	190
		35	10	74	28	0	0	106	135	19	95	32	50	0	41	31	
74	1	92	136	48	22	8	10	0	80	0	15	42	42	187	102	0	153
		30	62	30	6	178	197	27	158	105	31	0	8	64	28	58	
74	2	23	71	11	90	108	142	166	102	41	71	22	0	0	0	0	0
		114	0	6	5	0	0	12	12	5	6	7	0	-1	-1	-1	
74	3	0	40	2	0	19	12	0	82	0	3	51	53	36	25	41	0
		11	0	0	0	0	0	3	137	7	0	11	52	77	141	27	
74	4	13	100	81	1	0	0	53	30	0	0	0	0	82	0	12	5
		0	0	0	0	0	0	5	117	51	12	0	0	0	0	-1	
74	5	0	0	0	0	6	7	0	0	0	0	0	0	0	0	0	0
		23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
74	6	58	128	60	0	0	0	0	0	0	0	5	3	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	
74	7	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
74	8	0	0	0	0	0	0	0	0	0	0	0	12	63	5	1	0
		0	0	41	0	0	0	0	0	0	0	0	0	0	0	0	
74	9	0	0	0	0	0	0	0	0	0	0	0	0	6	28	18	1
		1	0	10	1	0	0	0	0	0	0	0	0	0	0	-1	
74	10	0	0	0	4	10	3	16	63	0	11	0	0	0	0	0	11
		0	0	0	2	0	0	0	1	25	18	0	11	45	51	94	
74	11	14	0	13	0	51	298	240	91	9	85	20	261	6	49	0	26
		26	108	198	2	26	140	27	83	0	0	91	116	35	5	-1	
74	12	38	153	31	11	8	0	0	284	0	171	45	10	0	0	0	0
		11	41	173	29	10	1	123	0	80	90	57	32	0	0	0	
75	1	0	0	0	0	0	19	0	5	26	0	0	31	6	1	25	201
		149	51	6	20	74	0	0	99	210	515	98	9	281	10	0	
75	2	0	0	18	182	152	25	77	12	204	50	33	48	461	289	106	129
		9	51	279	99	64	14	7	13	2	0	1	42	-1	-1	-1	
75	3	68	51	0	12	0	36	64	0	0	0	10	2	1	10	0	0
		156	151	25	0	0	0	11	0	0	0	1	0	0	0	0	
75	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
75	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
75	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
75	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
75	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
75	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Table A5.7 Sub-catchment C2M03

73	10	0	0	0	0	0	0	0	0	0	0	40	61	28	0	21	0
		10	7	0	2	0	0	27	4	0	90	28	0	0	1	147	
73	11	56	19	4	20	8	0	0	24	23	15	0	101	70	81	24	0
		0	0	194	263	222	18	3	3	43	24	6	0	3	5	-1	
73	12	43	0	17	80	57	0	2	3	1	0	0	0	5	0	80	292
		59	271	270	31	0	0	188	65	46	48	88	0	0	3	5	
74	1	60	42	61	8	25	20	0	34	18	30	26	9	42	26	13	6
		64	132	67	23	208	121	147	262	116	0	2	18	85	16	0	
74	2	4	0	0	0	59	148	110	109	51	30	8	0	18	0	0	0
		75	10	11	5	0	0	0	18	0	0	0	0	-1	-1	-1	
74	3	10	16	45	0	0	12	0	16	0	0	0	12	38	57	46	21
		3	0	0	3	0	0	0	0	5	16	56	0	0	0	0	
74	4	55	141	68	28	16	0	2	25	0	30	0	0	7	0	0	0
		0	0	0	0	0	0	0	65	80	36	10	0	0	0	-1	
74	5	0	0	0	0	35	21	0	0	0	0	0	0	0	0	0	6
		30	11	0	0	0	0	0	0	0	0	0	0	0	0	0	
74	6	5	2	45	0	0	0	0	0	0	0	0	2	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	
74	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
74	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	11	8	0	0	0	0	0	0	0	0	0	0	0	
74	9	0	0	0	0	6	2	0	0	0	2	7	0	0	36	34	6
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	
74	10	0	0	0	0	0	3	1	132	20	0	0	0	0	5	0	5
		0	13	0	3	1	0	0	10	26	0	6	53	25	61	171	
74	11	15	0	35	0	0	145	103	26	1	139	77	49	0	1	48	21
		0	3	211	0	30	251	44	77	6	0	8	68	91	25	-1	
74	12	122	87	34	0	0	0	0	118	21	25	24	40	0	0	0	5
		0	136	69	5	0	13	0	0	266	130	154	68	25	0	77	
75	1	0	0	0	0	0	0	0	0	0	0	0	12	90	18	13	125
		247	146	166	35	16	0	0	220	154	92	207	43	57	41	0	
75	2	0	0	18	1	72	6	10	20	44	15	58	0	21	168	45	284
		65	53	338	110	91	21	0	4	0	0	22	1	29	-1	-1	
75	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
75	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
75	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
75	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
75	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
75	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
75	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Table A6 : Hourly rainfall for the period Jan/Feb 1944 (1/10mm) as measured by 8 daily-read rain gauges per sub-catchment and disaggregated into hourly falls according to the procedure adopted in the daily model.

Data description Gauge number, year, month, day, 1 = a.m. or 2 = p.m., 12 consecutive values of average hourly precipitation (1/10mm).

Table A6.1 Sub-catchment C1MO1

C1MO1	44	1	1	1	17	68	0	0	0	0	0	0	0	0	0	0
C1MO1	44	1	2	1	24	95	95	24	0	0	0	0	0	0	0	0
C1MO1	44	1	3	1	24	71	24	0	0	0	0	0	0	0	0	0
C1MO1	44	1	4	1	11	44	0	0	0	0	0	0	0	0	0	0
C1MO1	44	1	5	1	22	89	0	0	0	0	0	0	0	0	0	0
C1MO1	44	1	6	1	13	54	0	0	0	0	0	0	0	0	0	0
C1MO1	44	1	7	1	32	0	0	0	0	0	0	0	0	0	0	0
C1MO1	44	1	8	1	19	0	0	0	0	0	0	0	0	0	0	0
C1MO1	44	1	9	1	37	0	0	0	0	0	0	0	0	0	0	0
C1MO1	44	1	12	1	4	0	0	0	0	0	0	0	0	0	0	0
C1MO1	44	1	13	1	13	54	0	0	0	0	0	0	0	0	0	0
C1MO1	44	1	14	1	23	92	92	23	0	0	0	0	0	0	0	0
C1MO1	44	1	15	1	23	69	23	0	0	0	0	0	0	0	0	0
C1MO1	44	1	16	1	6	0	0	0	0	0	0	0	0	0	0	0
C1MO1	44	1	20	1	30	0	0	0	0	0	0	0	0	0	0	0
C1MO1	44	1	21	1	26	0	0	0	0	0	0	0	0	0	0	0
C1MO1	44	1	22	1	8	32	0	0	0	0	0	0	0	0	0	0
C1MO1	44	1	24	1	10	41	0	0	0	0	0	0	0	0	0	0
C1MO1	44	1	25	1	13	50	0	0	0	0	0	0	0	0	0	0
C1MO1	44	1	26	1	14	56	0	0	0	0	0	0	0	0	0	0
C1MO1	44	1	27	1	22	87	0	0	0	0	0	0	0	0	0	0
C1MO1	44	1	28	1	14	56	0	0	0	0	0	0	0	0	0	0
C1MO1	44	1	29	1	12	48	0	0	0	0	0	0	0	0	0	0
C1MO1	44	1	30	1	5	0	0	0	0	0	0	0	0	0	0	0
99																
C1MO1	44	2	1	1	17	73	113	73	17	0	0	0	0	0	0	0
C1MO1	44	2	2	1	11	46	91	115	91	46	11	0	0	0	0	0
C1MO1	44	2	3	1	22	87	87	22	0	0	0	0	0	0	0	0
C1MO1	44	2	4	1	15	58	0	0	0	0	0	0	0	0	0	0
C1MO1	44	2	5	1	20	81	0	0	0	0	0	0	0	0	0	0
C1MO1	44	2	6	1	33	100	33	0	0	0	0	0	0	0	0	0
C1MO1	44	2	7	1	14	57	0	0	0	0	0	0	0	0	0	0
C1MO1	44	2	8	1	11	42	0	0	0	0	0	0	0	0	0	0
C1MO1	44	2	9	1	9	38	0	0	0	0	0	0	0	0	0	0
C1MO1	44	2	10	1	10	0	0	0	0	0	0	0	0	0	0	0
C1MO1	44	2	11	1	20	0	0	0	0	0	0	0	0	0	0	0
C1MO1	44	2	12	1	7	0	0	0	0	0	0	0	0	0	0	0
C1MO1	44	2	13	1	4	0	0	0	0	0	0	0	0	0	0	0
C1MO1	44	2	17	1	2	0	0	0	0	0	0	0	0	0	0	0
C1MO1	44	2	18	1	23	94	94	24	0	0	0	0	0	0	0	0
C1MO1	44	2	19	1	18	72	0	0	0	0	0	0	0	0	0	0
C1MO1	44	2	20	1	4	0	0	0	0	0	0	0	0	0	0	0
C1MO1	44	2	23	1	4	0	0	0	0	0	0	0	0	0	0	0
C1MO1	44	2	25	1	17	0	0	0	0	0	0	0	0	0	0	0
C1MO1	44	2	26	1	20	81	0	0	0	0	0	0	0	0	0	0
C1MO1	44	2	27	1	29	0	0	0	0	0	0	0	0	0	0	0
C1MO1	44	2	28	1	24	0	0	0	0	0	0	0	0	0	0	0
C1MO1	44	2	29	1	13	51	0	0	0	0	0	0	0	0	0	0
99																

Table A6.2 Sub-catchment C1M02

C1M02	44	1	1	1	18	0	0	0	0	0	0	0	0	0	0	0
C1M02	44	1	2	1	20	81	0	0	0	0	0	0	0	0	0	0
C1M02	44	1	3	1	20	80	0	0	0	0	0	0	0	0	0	0
C1M02	44	1	4	1	10	41	0	0	0	0	0	0	0	0	0	0
C1M02	44	1	5	1	27	81	27	0	0	0	0	0	0	0	0	0
C1M02	44	1	6	1	10	39	0	0	0	0	0	0	0	0	0	0
C1M02	44	1	12	1	6	0	0	0	0	0	0	0	0	0	0	0
C1M02	44	1	13	1	9	37	0	0	0	0	0	0	0	0	0	0
C1M02	44	1	14	1	19	74	0	0	0	0	0	0	0	0	0	0
C1M02	44	1	15	1	24	0	0	0	0	0	0	0	0	0	0	0
C1M02	44	1	23	1	9	0	0	0	0	0	0	0	0	0	0	0
C1M02	44	1	24	1	30	0	0	0	0	0	0	0	0	0	0	0
C1M02	44	1	25	1	13	50	0	0	0	0	0	0	0	0	0	0
C1M02	44	1	26	1	9	36	0	0	0	0	0	0	0	0	0	0
C1M02	44	1	27	1	20	81	0	0	0	0	0	0	0	0	0	0
C1M02	44	1	28	1	20	78	0	0	0	0	0	0	0	0	0	0
C1M02	44	1	29	1	32	0	0	0	0	0	0	0	0	0	0	0
C1M02	44	1	30	1	11	45	0	0	0	0	0	0	0	0	0	0
99																0
C1M02	44	2	1	1	32	97	32	0	0	0	0	0	0	0	0	0
C1M02	44	2	2	1	16	66	102	66	16	0	0	0	0	0	0	0
C1M02	44	2	3	1	15	64	119	118	64	15	0	0	0	0	0	0
C1M02	44	2	4	1	25	101	101	25	0	0	0	0	0	0	0	0
C1M02	44	2	5	1	34	101	34	0	0	0	0	0	0	0	0	0
C1M02	44	2	6	1	24	72	24	0	0	0	0	0	0	0	0	0
C1M02	44	2	7	1	16	0	0	0	0	0	0	0	0	0	0	0
C1M02	44	2	8	1	6	0	0	0	0	0	0	0	0	0	0	0
C1M02	44	2	10	1	18	70	0	0	0	0	0	0	0	0	0	0
C1M02	44	2	11	1	10	38	0	0	0	0	0	0	0	0	0	0
C1M02	44	2	12	1	28	0	0	0	0	0	0	0	0	0	0	0
C1M02	44	2	15	1	15	0	0	0	0	0	0	0	0	0	0	0
C1M02	44	2	18	1	14	58	0	0	0	0	0	0	0	0	0	0
C1M02	44	2	23	1	11	0	0	0	0	0	0	0	0	0	0	0
C1M02	44	2	24	1	13	52	0	0	0	0	0	0	0	0	0	0
C1M02	44	2	26	1	25	76	25	0	0	0	0	0	0	0	0	0
C1M02	44	2	28	1	15	61	0	0	0	0	0	0	0	0	0	0
C1M02	44	2	29	1	23	0	0	0	0	0	0	0	0	0	0	0
C1M02	44	2	30	1	16	0	0	0	0	0	0	0	0	0	0	0
99																0

Table A6.3 Sub-catchment C1M03

C1M03	44	1	1	1	23	0	0	0	0	0	0	0	0	0	0	0
C1M03	44	1	2	1	15	60	0	0	0	0	0	0	0	0	0	0
C1M03	44	1	3	1	24	73	24	0	0	0	0	0	0	0	0	0
C1M03	44	1	4	1	8	33	0	0	0	0	0	0	0	0	0	0
C1M03	44	1	5	1	11	46	0	0	0	0	0	0	0	0	0	0
C1M03	44	1	6	1	11	45	0	0	0	0	0	0	0	0	0	0
C1M03	44	1	7	1	3	0	0	0	0	0	0	0	0	0	0	0
C1M03	44	1	10	1	12	0	0	0	0	0	0	0	0	0	0	0
C1M03	44	1	12	1	8	0	0	0	0	0	0	0	0	0	0	0
C1M03	44	1	13	1	11	45	0	0	0	0	0	0	0	0	0	0
C1M03	44	1	14	1	19	78	0	0	0	0	0	0	0	0	0	0
C1M03	44	1	15	1	8	32	0	0	0	0	0	0	0	0	0	0
C1M03	44	1	20	1	23	70	23	0	0	0	0	0	0	0	0	0
C1M03	44	1	24	1	6	0	0	0	0	0	0	0	0	0	0	0
C1M03	44	1	25	1	8	33	0	0	0	0	0	0	0	0	0	0
C1M03	44	1	26	1	17	69	0	0	0	0	0	0	0	0	0	0
C1M03	44	1	27	1	13	52	0	0	0	0	0	0	0	0	0	0
C1M03	44	1	28	1	26	77	26	0	0	0	0	0	0	0	0	0
C1M03	44	1	29	1	26	0	0	0	0	0	0	0	0	0	0	0
C1M03	44	1	30	1	23	0	0	0	0	0	0	0	0	0	0	0
C1M03	44	1	31	1	6	0	0	0	0	0	0	0	0	0	0	0
99																0
C1M03	44	2	1	1	36	107	36	0	0	0	0	0	0	0	0	0
C1M03	44	2	2	1	9	36	74	113	130	113	74	36	9	0	0	0
C1M03	44	2	3	1	18	75	116	75	18	0	0	0	0	0	0	0
C1M03	44	2	4	1	19	76	76	19	0	0	0	0	0	0	0	0
C1M03	44	2	5	1	27	81	27	0	0	0	0	0	0	0	0	0
C1M03	44	2	6	1	14	58	0	0	0	0	0	0	0	0	0	0
C1M03	44	2	7	1	9	38	0	0	0	0	0	0	0	0	0	0
C1M03	44	2	8	1	16	65	0	0	0	0	0	0	0	0	0	0
C1M03	44	2	10	1	27	0	0	0	0	0	0	0	0	0	0	0
C1M03	44	2	11	1	31	0	0	0	0	0	0	0	0	0	0	0
C1M03	44	2	15	1	30	0	0	0	0	0	0	0	0	0	0	0
C1M03	44	2	17	1	5	0	0	0	0	0	0	0	0	0	0	0
C1M03	44	2	18	1	22	67	22	0	0	0	0	0	0	0	0	0
C1M03	44	2	19	1	17	0	0	0	0	0	0	0	0	0	0	0
C1M03	44	2	21	1	1	0	0	0	0	0	0	0	0	0	0	0
C1M03	44	2	23	1	12	49	0	0	0	0	0	0	0	0	0	0
C1M03	44	2	24	1	13	54	0	0	0	0	0	0	0	0	0	0
C1M03	44	2	25	1	7	0	0	0	0	0	0	0	0	0	0	0
C1M03	44	2	26	1	8	34	0	0	0	0	0	0	0	0	0	0
C1M03	44	2	27	1	27	0	0	0	0	0	0	0	0	0	0	0
C1M03	44	2	28	1	31	0	0	0	0	0	0	0	0	0	0	0
C1M03	44	2	29	1	37	0	0	0	0	0	0	0	0	0	0	0
99																0

Table A6.4 Sub-catchment C8B01

C8B01	44	1	1	1	13	51	0	0	0	0	0	0	0	0	0	0
C8B01	44	1	2	1	11	44	0	0	0	0	0	0	0	0	0	0
C8B01	44	1	3	1	15	60	0	0	0	0	0	0	0	0	0	0
C8B01	44	1	4	1	38	0	0	0	0	0	0	0	0	0	0	0
C8B01	44	1	5	1	23	0	0	0	0	0	0	0	0	0	0	0
C8B01	44	1	6	1	24	71	24	0	0	0	0	0	0	0	0	0
C8B01	44	1	7	1	18	0	0	0	0	0	0	0	0	0	0	0
C8B01	44	1	8	1	19	78	0	0	0	0	0	0	0	0	0	0
C8B01	44	1	12	1	18	0	0	0	0	0	0	0	0	0	0	0
C8B01	44	1	13	1	18	71	0	0	0	0	0	0	0	0	0	0
C8B01	44	1	14	1	12	0	0	0	0	0	0	0	0	0	0	0
C8B01	44	1	20	1	14	0	0	0	0	0	0	0	0	0	0	0
C8B01	44	1	22	1	12	0	0	0	0	0	0	0	0	0	0	0
C8B01	44	1	23	1	12	0	0	0	0	0	0	0	0	0	0	0
C8B01	44	1	24	1	25	0	0	0	0	0	0	0	0	0	0	0
C8B01	44	1	27	1	26	79	26	0	0	0	0	0	0	0	0	0
C8B01	44	1	28	1	33	98	33	0	0	0	0	0	0	0	0	0
C8B01	44	1	30	1	18	0	0	0	0	0	0	0	0	0	0	0
C8B01	44	1	31	1	15	0	0	0	0	0	0	0	0	0	0	0
99																0
C8B01	44	2	1	1	18	75	115	75	18	0	0	0	0	0	0	0
C8B01	44	2	2	1	20	81	81	20	0	0	0	0	0	0	0	0
C8B01	44	2	3	1	25	102	102	26	0	0	0	0	0	0	0	0
C8B01	44	2	4	1	36	109	36	0	0	0	0	0	0	0	0	0
C8B01	44	2	5	1	18	75	117	75	18	0	0	0	0	0	0	0
C8B01	44	2	6	1	19	74	74	19	0	0	0	0	0	0	0	0
C8B01	44	2	7	1	12	50	0	0	0	0	0	0	0	0	0	0
C8B01	44	2	8	1	23	0	0	0	0	0	0	0	0	0	0	0
C8B01	44	2	10	1	14	0	0	0	0	0	0	0	0	0	0	0
C8B01	44	2	11	1	10	0	0	0	0	0	0	0	0	0	0	0
C8B01	44	2	12	1	1	0	0	0	0	0	0	0	0	0	0	0
C8B01	44	2	18	1	16	0	0	0	0	0	0	0	0	0	0	0
C8B01	44	2	20	1	6	0	0	0	0	0	0	0	0	0	0	0
C8B01	44	2	21	1	7	0	0	0	0	0	0	0	0	0	0	0
C8B01	44	2	24	1	30	90	30	0	0	0	0	0	0	0	0	0
C8B01	44	2	25	1	8	0	0	0	0	0	0	0	0	0	0	0
C8B01	44	2	27	1	11	0	0	0	0	0	0	0	0	0	0	0
C8B01	44	2	28	1	8	34	0	0	0	0	0	0	0	0	0	0
C8B01	44	2	29	1	9	37	0	0	0	0	0	0	0	0	0	0
99																0

Table A6.5 Sub-catchment C8M04

C8M04	44	1	1	1	13	51	0	0	0	0	0	0	0	0	0	0
C8M04	44	1	2	1	12	0	0	0	0	0	0	0	0	0	0	0
C8M04	44	1	3	1	34	0	0	0	0	0	0	0	0	0	0	0
C8M04	44	1	4	1	15	61	0	0	0	0	0	0	0	0	0	0
C8M04	44	1	5	1	16	66	0	0	0	0	0	0	0	0	0	0
C8M04	44	1	6	1	34	0	0	0	0	0	0	0	0	0	0	0
C8M04	44	1	7	1	13	0	0	0	0	0	0	0	0	0	0	0
C8M04	44	1	8	1	20	81	0	0	0	0	0	0	0	0	0	0
C8M04	44	1	10	1	11	0	0	0	0	0	0	0	0	0	0	0
C8M04	44	1	12	1	13	54	0	0	0	0	0	0	0	0	0	0
C8M04	44	1	13	1	14	54	0	0	0	0	0	0	0	0	0	0
C8M04	44	1	14	1	12	49	0	0	0	0	0	0	0	0	0	0
C8M04	44	1	22	1	14	0	0	0	0	0	0	0	0	0	0	0
C8M04	44	1	24	1	11	43	0	0	0	0	0	0	0	0	0	0
C8M04	44	1	26	1	6	0	0	0	0	0	0	0	0	0	0	0
C8M04	44	1	27	1	22	86	0	0	0	0	0	0	0	0	0	0
C8M04	44	1	28	1	5	0	0	0	0	0	0	0	0	0	0	0
C8M04	44	1	29	1	6	0	0	0	0	0	0	0	0	0	0	0
C8M04	44	1	31	1	5	0	0	0	0	0	0	0	0	0	0	0
99																0
C8M04	44	2	1	1	22	87	87	22	0	0	0	0	0	0	0	0
C8M04	44	2	2	1	36	108	36	0	0	0	0	0	0	0	0	0
C8M04	44	2	3	1	21	85	85	21	0	0	0	0	0	0	0	0
C8M04	44	2	4	1	22	88	0	0	0	0	0	0	0	0	0	0
C8M04	44	2	5	1	23	92	92	23	0	0	0	0	0	0	0	0
C8M04	44	2	6	1	20	79	79	20	0	0	0	0	0	0	0	0
C8M04	44	2	7	1	16	66	0	0	0	0	0	0	0	0	0	0
C8M04	44	2	8	1	9	36	0	0	0	0	0	0	0	0	0	0
C8M04	44	2	9	1	3	0	0	0	0	0	0	0	0	0	0	0
C8M04	44	2	10	1	11	43	0	0	0	0	0	0	0	0	0	0
C8M04	44	2	11	1	4	0	0	0	0	0	0	0	0	0	0	0
C8M04	44	2	21	1	12	0	0	0	0	0	0	0	0	0	0	0
C8M04	44	2	23	1	26	0	0	0	0	0	0	0	0	0	0	0
C8M04	44	2	24	1	5	0	0	0	0	0	0	0	0	0	0	0
C8M04	44	2	25	1	34	0	0	0	0	0	0	0	0	0	0	0
C8M04	44	2	26	1	31	0	0	0	0	0	0	0	0	0	0	0
C8M04	44	2	27	1	11	45	0	0	0	0	0	0	0	0	0	0
C8M04	44	2	28	1	16	64	0	0	0	0	0	0	0	0	0	0
C8M04	44	2	29	1	2	0	0	0	0	0	0	0	0	0	0	0
99																0

Table A6.6 Sub-catchment C8M14

C8M14	44	1	1	1	9	36	0	0	0	0	0	0	0	0	0	0	
C8M14	44	1	2	1	18	0	0	0	0	0	0	0	0	0	0	0	
C8M14	44	1	3	1	24	72	24	0	0	0	0	0	0	0	0	0	
C8M14	44	1	4	1	18	72	0	0	0	0	0	0	0	0	0	0	
C8M14	44	1	5	1	19	77	0	0	0	0	0	0	0	0	0	0	
C8M14	44	1	6	1	9	34	0	0	0	0	0	0	0	0	0	0	
C8M14	44	1	7	1	6	0	0	0	0	0	0	0	0	0	0	0	
C8M14	44	1	8	1	24	0	0	0	0	0	0	0	0	0	0	0	
C8M14	44	1	9	1	11	43	0	0	0	0	0	0	0	0	0	0	
C8M14	44	1	13	1	29	0	0	0	0	0	0	0	0	0	0	0	
C8M14	44	1	14	1	27	81	27	0	0	0	0	0	0	0	0	0	
C8M14	44	1	15	1	15	62	0	0	0	0	0	0	0	0	0	0	
C8M14	44	1	24	1	20	0	0	0	0	0	0	0	0	0	0	0	
C8M14	44	1	25	1	32	0	0	0	0	0	0	0	0	0	0	0	
C8M14	44	1	26	1	2	0	0	0	0	0	0	0	0	0	0	0	
C8M14	44	1	27	1	4	0	0	0	0	0	0	0	0	0	0	0	
C8M14	44	1	28	1	11	44	0	0	0	0	0	0	0	0	0	0	
C8M14	44	1	29	1	36	0	0	0	0	0	0	0	0	0	0	0	
99																	0
C8M14	44	2	1	1	21	86	86	22	0	0	0	0	0	0	0	0	
C8M14	44	2	2	1	17	70	109	70	17	0	0	0	0	0	0	0	
C8M14	44	2	3	1	15	62	115	115	62	15	0	0	0	0	0	0	
C8M14	44	2	4	1	36	109	36	0	0	0	0	0	0	0	0	0	
C8M14	44	2	5	1	21	86	0	0	0	0	0	0	0	0	0	0	
C8M14	44	2	6	1	33	98	33	0	0	0	0	0	0	0	0	0	
C8M14	44	2	7	1	12	50	0	0	0	0	0	0	0	0	0	0	
C8M14	44	2	8	1	38	0	0	0	0	0	0	0	0	0	0	0	
C8M14	44	2	9	1	4	0	0	0	0	0	0	0	0	0	0	0	
C8M14	44	2	10	1	6	0	0	0	0	0	0	0	0	0	0	0	
C8M14	44	2	11	1	5	0	0	0	0	0	0	0	0	0	0	0	
C8M14	44	2	12	1	6	0	0	0	0	0	0	0	0	0	0	0	
C8M14	44	2	18	1	6	0	0	0	0	0	0	0	0	0	0	0	
C8M14	44	2	22	1	1	0	0	0	0	0	0	0	0	0	0	0	
C8M14	44	2	23	1	12	0	0	0	0	0	0	0	0	0	0	0	
C8M14	44	2	24	1	11	46	0	0	0	0	0	0	0	0	0	0	
C8M14	44	2	25	1	9	36	0	0	0	0	0	0	0	0	0	0	
C8M14	44	2	26	1	11	0	0	0	0	0	0	0	0	0	0	0	
C8M14	44	2	27	1	21	0	0	0	0	0	0	0	0	0	0	0	
C8M14	44	2	28	1	33	0	0	0	0	0	0	0	0	0	0	0	
C8M14	44	2	29	1	9	35	0	0	0	0	0	0	0	0	0	0	
99																	0

Table A6.7 Sub-catchment C2M03

C2M03	44	1	1	1	12	49	0	0	0	0	0	0	0	0	0	0	
C2M03	44	1	2	1	8	32	0	0	0	0	0	0	0	0	0	0	
C2M03	44	1	3	1	7	0	0	0	0	0	0	0	0	0	0	0	
C2M03	44	1	4	1	2	0	0	0	0	0	0	0	0	0	0	0	
C2M03	44	1	5	1	8	32	0	0	0	0	0	0	0	0	0	0	
C2M03	44	1	6	1	1	0	0	0	0	0	0	0	0	0	0	0	
C2M03	44	1	7	1	14	0	0	0	0	0	0	0	0	0	0	0	
C2M03	44	1	8	1	24	71	24	0	0	0	0	0	0	0	0	0	
C2M03	44	1	9	1	20	0	0	0	0	0	0	0	0	0	0	0	
C2M03	44	1	10	1	11	0	0	0	0	0	0	0	0	0	0	0	
C2M03	44	1	12	1	1	0	0	0	0	0	0	0	0	0	0	0	
C2M03	44	1	13	1	24	0	0	0	0	0	0	0	0	0	0	0	
C2M03	44	1	14	1	7	0	0	0	0	0	0	0	0	0	0	0	
C2M03	44	1	20	1	11	43	0	0	0	0	0	0	0	0	0	0	
C2M03	44	1	22	1	8	0	0	0	0	0	0	0	0	0	0	0	
C2M03	44	1	24	1	20	82	0	0	0	0	0	0	0	0	0	0	
C2M03	44	1	25	1	23	0	0	0	0	0	0	0	0	0	0	0	
C2M03	44	1	26	1	24	0	0	0	0	0	0	0	0	0	0	0	
C2M03	44	1	27	1	16	65	0	0	0	0	0	0	0	0	0	0	
C2M03	44	1	28	1	21	82	0	0	0	0	0	0	0	0	0	0	
C2M03	44	1	29	1	29	0	0	0	0	0	0	0	0	0	0	0	
99																	0
C2M03	44	2	1	1	12	50	99	125	99	50	12	0	0	0	0	0	
C2M03	44	2	2	1	25	99	99	25	0	0	0	0	0	0	0	0	
C2M03	44	2	3	1	15	61	114	114	61	15	0	0	0	0	0	0	
C2M03	44	2	4	1	18	75	116	75	18	0	0	0	0	0	0	0	
C2M03	44	2	5	1	15	64	99	64	15	0	0	0	0	0	0	0	
C2M03	44	2	6	1	29	86	29	0	0	0	0	0	0	0	0	0	
C2M03	44	2	7	1	32	95	32	0	0	0	0	0	0	0	0	0	
C2M03	44	2	8	1	13	53	0	0	0	0	0	0	0	0	0	0	
C2M03	44	2	11	1	10	0	0	0	0	0	0	0	0	0	0	0	
C2M03	44	2	17	1	14	0	0	0	0	0	0	0	0	0	0	0	
C2M03	44	2	18	1	3	0	0	0	0	0	0	0	0	0	0	0	
C2M03	44	2	22	1	1	0	0	0	0	0	0	0	0	0	0	0	
C2M03	44	2	24	1	22	86	86	22	0	0	0	0	0	0	0	0	
C2M03	44	2	25	1	19	74	0	0	0	0	0	0	0	0	0	0	
C2M03	44	2	26	1	29	0	0	0	0	0	0	0	0	0	0	0	
C2M03	44	2	28	1	3	0	0	0	0	0	0	0	0	0	0	0	
C2M03	44	2	29	1	8	0	0	0	0	0	0	0	0	0	0	0	
99																	0

Table A7 : Hourly rainfall for the period Sept/Oct 1957 (1/10mm) as measured by 8 daily-read rain gauges per sub-catchment, and disaggregated into hourly falls according to the procedure adopted in the daily model.

Data description Gauge number, year, month, day, 1 = a.m. or 2 = p.m., 12 consecutive values of average hourly precipitation (1/10mm).

Table A7.1 Sub-catchment C1M01

C1M01	57	9	9	1	17	0	0	0	0	0	0	0	0	0	0	0
C1M01	57	9	10	1	14	0	0	0	0	0	0	0	0	0	0	0
C1M01	57	9	11	1	11	42	0	0	0	0	0	0	0	0	0	0
C1M01	57	9	12	1	35	106	35	0	0	0	0	0	0	0	0	0
C1M01	57	9	13	1	37	0	0	0	0	0	0	0	0	0	0	0
C1M01	57	9	14	1	13	53	0	0	0	0	0	0	0	0	0	0
C1M01	57	9	15	1	14	54	0	0	0	0	0	0	0	0	0	0
C1M01	57	9	19	1	1	0	0	0	0	0	0	0	0	0	0	0
C1M01	57	9	22	1	23	92	92	23	0	0	0	0	0	0	0	0
C1M01	57	9	23	1	17	66	0	0	0	0	0	0	0	0	0	0
C1M01	57	9	24	1	17	66	0	0	0	0	0	0	0	0	0	0
C1M01	57	9	25	1	19	76	0	0	0	0	0	0	0	0	0	0
C1M01	57	9	26	1	19	75	75	19	0	0	0	0	0	0	0	0
C1M01	57	9	27	1	12	50	0	0	0	0	0	0	0	0	0	0
C1M01	57	9	30	1	13	53	0	0	0	0	0	0	0	0	0	0
99																
C1M01	57	10	1	1	1	0	0	0	0	0	0	0	0	0	0	0
C1M01	57	10	2	1	29	88	29	0	0	0	0	0	0	0	0	0
C1M01	57	10	3	1	13	53	0	0	0	0	0	0	0	0	0	0
C1M01	57	10	4	1	14	58	0	0	0	0	0	0	0	0	0	0
C1M01	57	10	5	1	6	0	0	0	0	0	0	0	0	0	0	0
C1M01	57	10	8	1	6	0	0	0	0	0	0	0	0	0	0	0
C1M01	57	10	9	1	36	0	0	0	0	0	0	0	0	0	0	0
C1M01	57	10	10	1	11	42	0	0	0	0	0	0	0	0	0	0
C1M01	57	10	11	1	34	0	0	0	0	0	0	0	0	0	0	0
C1M01	57	10	17	1	3	0	0	0	0	0	0	0	0	0	0	0
C1M01	57	10	18	1	14	0	0	0	0	0	0	0	0	0	0	0
C1M01	57	10	19	1	2	0	0	0	0	0	0	0	0	0	0	0
C1M01	57	10	20	1	33	0	0	0	0	0	0	0	0	0	0	0
C1M01	57	10	21	1	1	0	0	0	0	0	0	0	0	0	0	0
C1M01	57	10	23	1	10	0	0	0	0	0	0	0	0	0	0	0
C1M01	57	10	24	1	29	86	29	0	0	0	0	0	0	0	0	0
C1M01	57	10	25	1	10	38	0	0	0	0	0	0	0	0	0	0
C1M01	57	10	26	1	10	39	0	0	0	0	0	0	0	0	0	0
C1M01	57	10	27	1	36	108	36	0	0	0	0	0	0	0	0	0
C1M01	57	10	28	1	19	77	0	0	0	0	0	0	0	0	0	0
C1M01	57	10	29	1	24	0	0	0	0	0	0	0	0	0	0	0
C1M01	57	10	30	1	2	0	0	0	0	0	0	0	0	0	0	0
C1M01	57	10	31	1	4	0	0	0	0	0	0	0	0	0	0	0
99																

Table A7.2 Sub-catchment C1MO2

C1M02	57	9	9	1	13	0	0	0	0	0	0	0	0	0	0	0
C1M02	57	9	10	1	26	0	0	0	0	0	0	0	0	0	0	0
C1M02	57	9	11	1	11	44	0	0	0	0	0	0	0	0	0	0
C1M02	57	9	12	1	15	62	115	115	62	15	0	0	0	0	0	0
C1M02	57	9	13	1	19	75	0	0	0	0	0	0	0	0	0	0
C1M02	57	9	14	1	32	97	32	0	0	0	0	0	0	0	0	0
C1M02	57	9	15	1	1	0	0	0	0	0	0	0	0	0	0	0
C1M02	57	9	16	1	2	0	0	0	0	0	0	0	0	0	0	0
C1M02	57	9	19	1	3	0	0	0	0	0	0	0	0	0	0	0
C1M02	57	9	20	1	15	0	0	0	0	0	0	0	0	0	0	0
C1M02	57	9	21	1	4	0	0	0	0	0	0	0	0	0	0	0
C1M02	57	9	22	1	20	82	82	21	0	0	0	0	0	0	0	0
C1M02	57	9	23	1	23	68	23	0	0	0	0	0	0	0	0	0
C1M02	57	9	24	1	21	86	86	21	0	0	0	0	0	0	0	0
C1M02	57	9	25	1	27	80	27	0	0	0	0	0	0	0	0	0
C1M02	57	9	26	1	16	67	103	67	16	0	0	0	0	0	0	0
C1M02	57	9	27	1	12	49	0	0	0	0	0	0	0	0	0	0
C1M02	57	9	30	1	32	95	32	0	0	0	0	0	0	0	0	0
99																
C1M02	57	10	1	1	1	0	0	0	0	0	0	0	0	0	0	0
C1M02	57	10	2	1	32	95	32	0	0	0	0	0	0	0	0	0
C1M02	57	10	3	1	26	77	26	0	0	0	0	0	0	0	0	0
C1M02	57	10	4	1	1	0	0	0	0	0	0	0	0	0	0	0
C1M02	57	10	5	1	11	45	0	0	0	0	0	0	0	0	0	0
C1M02	57	10	7	1	10	0	0	0	0	0	0	0	0	0	0	0
C1M02	57	10	8	1	2	0	0	0	0	0	0	0	0	0	0	0
C1M02	57	10	9	1	10	39	0	0	0	0	0	0	0	0	0	0
C1M02	57	10	10	1	8	32	0	0	0	0	0	0	0	0	0	0
C1M02	57	10	12	1	5	0	0	0	0	0	0	0	0	0	0	0
C1M02	57	10	13	1	1	0	0	0	0	0	0	0	0	0	0	0
C1M02	57	10	14	1	27	0	0	0	0	0	0	0	0	0	0	0
C1M02	57	10	17	1	12	46	0	0	0	0	0	0	0	0	0	0
C1M02	57	10	18	1	14	0	0	0	0	0	0	0	0	0	0	0
C1M02	57	10	19	1	23	0	0	0	0	0	0	0	0	0	0	0
C1M02	57	10	21	1	6	0	0	0	0	0	0	0	0	0	0	0
C1M02	57	10	24	1	20	80	0	0	0	0	0	0	0	0	0	0
C1M02	57	10	25	1	35	0	0	0	0	0	0	0	0	0	0	0
C1M02	57	10	26	1	18	77	120	77	18	0	0	0	0	0	0	0
C1M02	57	10	27	1	20	81	0	0	0	0	0	0	0	0	0	0
C1M02	57	10	28	1	21	84	0	0	0	0	0	0	0	0	0	0
C1M02	57	10	29	1	9	35	0	0	0	0	0	0	0	0	0	0
C1M02	57	10	30	1	1	0	0	0	0	0	0	0	0	0	0	0
99																

Table A7.3 Sub-catchment C1MO3

C1M03	57	9	9	1	10	0	0	0	0	0	0	0	0	0	0	0
C1M03	57	9	10	1	26	0	0	0	0	0	0	0	0	0	0	0
C1M03	57	9	11	1	11	42	0	0	0	0	0	0	0	0	0	0
C1M03	57	9	12	1	22	88	88	22	0	0	0	0	0	0	0	0
C1M03	57	9	13	1	22	87	0	0	0	0	0	0	0	0	0	0
C1M03	57	9	14	1	20	78	0	0	0	0	0	0	0	0	0	0
C1M03	57	9	15	1	29	0	0	0	0	0	0	0	0	0	0	0
C1M03	57	9	15	1	16	0	0	0	0	0	0	0	0	0	0	0
C1M03	57	9	20	1	11	0	0	0	0	0	0	0	0	0	0	0
C1M03	57	9	22	1	23	93	93	23	0	0	0	0	0	0	0	0
C1M03	57	9	23	1	12	48	0	0	0	0	0	0	0	0	0	0
C1M03	57	9	24	1	28	83	28	0	0	0	0	0	0	0	0	0
C1M03	57	9	25	1	18	70	0	0	0	0	0	0	0	0	0	0
C1M03	57	9	26	1	19	81	126	81	19	0	0	0	0	0	0	0
C1M03	57	9	27	1	9	36	0	0	0	0	0	0	0	0	0	0
C1M03	57	9	28	1	9	37	0	0	0	0	0	0	0	0	0	0
C1M03	57	9	30	1	11	46	0	0	0	0	0	0	0	0	0	0
99																
C1M03	57	10	1	1	39	0	0	0	0	0	0	0	0	0	0	0
C1M03	57	10	2	1	20	82	82	20	0	0	0	0	0	0	0	0
C1M03	57	10	3	1	12	49	0	0	0	0	0	0	0	0	0	0
C1M03	57	10	4	1	5	0	0	0	0	0	0	0	0	0	0	0
C1M03	57	10	5	1	8	0	0	0	0	0	0	0	0	0	0	0
C1M03	57	10	8	1	35	0	0	0	0	0	0	0	0	0	0	0
C1M03	57	10	9	1	2	0	0	0	0	0	0	0	0	0	0	0
C1M03	57	10	10	1	23	68	23	0	0	0	0	0	0	0	0	0
C1M03	57	10	14	1	6	0	0	0	0	0	0	0	0	0	0	0
C1M03	57	10	17	1	11	45	0	0	0	0	0	0	0	0	0	0
C1M03	57	10	18	1	3	0	0	0	0	0	0	0	0	0	0	0
C1M03	57	10	20	1	4	0	0	0	0	0	0	0	0	0	0	0
C1M03	57	10	21	1	9	0	0	0	0	0	0	0	0	0	0	0
C1M03	57	10	22	1	3	0	0	0	0	0	0	0	0	0	0	0
C1M03	57	10	24	1	26	77	26	0	0	0	0	0	0	0	0	0
C1M03	57	10	25	1	21	83	0	0	0	0	0	0	0	0	0	0
C1M03	57	10	26	1	19	81	125	81	19	0	0	0	0	0	0	0
C1M03	57	10	27	1	20	81	0	0	0	0	0	0	0	0	0	0
C1M03	57	10	28	1	9	36	0	0	0	0	0	0	0	0	0	0
C1M03	57	10	29	1	22	0	0	0	0	0	0	0	0	0	0	0
99																

Table A7.4 Sub-catchment C8B01

C8B01	57	9	4	1	14	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	9	9	1	6	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	9	10	1	6	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	9	11	1	18	74	0	0	0	0	0	0	0	0	0	0
C8B01	57	9	12	1	14	57	106	106	57	14	0	0	0	0	0	0
C8B01	57	9	13	1	29	88	29	0	0	0	0	0	0	0	0	0
C8B01	57	9	14	1	17	68	0	0	0	0	0	0	0	0	0	0
C8B01	57	9	15	1	30	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	9	16	1	29	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	9	17	1	9	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	9	18	1	9	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	9	19	1	13	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	9	20	1	9	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	9	21	1	10	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	9	22	1	19	77	77	19	0	0	0	0	0	0	0	0
C8B01	57	9	23	1	18	71	0	0	0	0	0	0	0	0	0	0
C8B01	57	9	24	1	25	102	102	26	0	0	0	0	0	0	0	0
C8B01	57	9	25	1	28	83	28	0	0	0	0	0	0	0	0	0
C8B01	57	9	26	1	18	74	115	74	18	0	0	0	0	0	0	0
C8B01	57	9	27	1	13	50	0	0	0	0	0	0	0	0	0	0
C8B01	57	9	30	1	34	102	34	0	0	0	0	0	0	0	0	0
99																
C8B01	57	10	1	1	21	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	2	1	33	98	33	0	0	0	0	0	0	0	0	0
C8B01	57	10	3	1	13	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	5	1	35	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	6	1	22	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	8	1	10	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	9	1	10	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	10	1	26	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	11	1	10	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	12	1	11	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	13	1	6	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	14	1	39	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	15	1	13	54	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	16	1	2	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	17	1	24	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	18	1	21	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	19	1	19	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	20	1	9	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	21	1	13	0	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	24	1	20	81	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	25	1	20	81	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	26	1	19	77	77	19	0	0	0	0	0	0	0	0
C8B01	57	10	27	1	12	47	0	0	0	0	0	0	0	0	0	0
C8B01	57	10	28	1	16	0	0	0	0	0	0	0	0	0	0	0
99																

Table A7.5 Sub-catchment C8M04

C8M04	57	9	9	1	15	0	0	0	0	0	0	0	0	0	0	0
C8M04	57	9	10	1	5	0	0	0	0	0	0	0	0	0	0	0
C8M04	57	9	11	1	21	83	0	0	0	0	0	0	0	0	0	0
C8M04	57	9	12	1	17	72	111	72	17	0	0	0	0	0	0	0
C8M04	57	9	13	1	13	54	100	100	54	13	0	0	0	0	0	0
C8M04	57	9	14	1	18	74	74	19	0	0	0	0	0	0	0	0
C8M04	57	9	15	1	34	0	0	0	0	0	0	0	0	0	0	0
C8M04	57	9	19	1	3	0	0	0	0	0	0	0	0	0	0	0
C8M04	57	9	21	1	10	42	0	0	0	0	0	0	0	0	0	0
C8M04	57	9	22	1	16	67	103	67	16	0	0	0	0	0	0	0
C8M04	57	9	23	1	16	67	104	67	16	0	0	0	0	0	0	0
C8M04	57	9	24	1	18	76	117	76	18	0	0	0	0	0	0	0
C8M04	57	9	25	1	30	89	30	0	0	0	0	0	0	0	0	0
C8M04	57	9	26	1	18	76	118	76	18	0	0	0	0	0	0	0
C8M04	57	9	27	1	14	0	0	0	0	0	0	0	0	0	0	0
C8M04	57	9	30	1	19	77	77	19	0	0	0	0	0	0	0	0
99																
C8M04	57	10	1	1	11	44	0	0	0	0	0	0	0	0	0	0
C8M04	57	10	2	1	18	77	119	77	18	0	0	0	0	0	0	0
C8M04	57	10	3	1	10	0	0	0	0	0	0	0	0	0	0	0
C8M04	57	10	5	1	32	0	0	0	0	0	0	0	0	0	0	0
C8M04	57	10	7	1	15	0	0	0	0	0	0	0	0	0	0	0
C8M04	57	10	8	1	28	0	0	0	0	0	0	0	0	0	0	0
C8M04	57	10	9	1	4	0	0	0	0	0	0	0	0	0	0	0
C8M04	57	10	10	1	10	40	0	0	0	0	0	0	0	0	0	0
C8M04	57	10	11	1	1	0	0	0	0	0	0	0	0	0	0	0
C8M04	57	10	12	1	15	0	0	0	0	0	0	0	0	0	0	0
C8M04	57	10	14	1	8	33	0	0	0	0	0	0	0	0	0	0
C8M04	57	10	15	1	6	0	0	0	0	0	0	0	0	0	0	0
C8M04	57	10	17	1	11	44	0	0	0	0	0	0	0	0	0	0
C8M04	57	10	18	1	10	41	0	0	0	0	0	0	0	0	0	0
C8M04	57	10	19	1	34	101	34	0	0	0	0	0	0	0	0	0
C8M04	57	10	25	1	23	90	90	23	0	0	0	0	0	0	0	0
C8M04	57	10	26	1	29	86	29	0	0	0	0	0	0	0	0	0
C8M04	57	10	27	1	27	80	27	0	0	0	0	0	0	0	0	0
C8M04	57	10	28	1	9	37	0	0	0	0	0	0	0	0	0	0
C8M04	57	10	29	1	7	0	0	0	0	0	0	0	0	0	0	0
99																

Table A7.6 Sub-catchment C8M14

C8M14	57	9	1	1	5	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	9	9	1	6	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	9	10	1	16	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	9	11	1	21	82	0	0	0	0	0	0	0	0	0	0
C8M14	57	9	12	1	11	47	94	119	94	47	11	0	0	0	0	0
C8M14	57	9	13	1	19	76	76	19	0	0	0	0	0	0	0	0
C8M14	57	9	14	1	32	97	32	0	0	0	0	0	0	0	0	0
C8M14	57	9	15	1	15	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	9	16	1	8	32	0	0	0	0	0	0	0	0	0	0
C8M14	57	9	19	1	7	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	9	21	1	16	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	9	22	1	36	109	36	0	0	0	0	0	0	0	0	0
C8M14	57	9	23	1	13	56	104	104	56	13	0	0	0	0	0	0
C8M14	57	9	24	1	19	82	127	82	19	0	0	0	0	0	0	0
C8M14	57	9	25	1	28	84	28	0	0	0	0	0	0	0	0	0
C8M14	57	9	26	1	24	95	95	24	0	0	0	0	0	0	0	0
C8M14	57	9	27	1	19	76	76	19	0	0	0	0	0	0	0	0
C8M14	57	9	29	1	14	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	9	30	1	20	80	0	0	0	0	0	0	0	0	0	0
C8M14	57	9	31	1	21	0	0	0	0	0	0	0	0	0	0	0
99																
C8M14	57	10	1	1	23	70	23	0	0	0	0	0	0	0	0	0
C8M14	57	10	2	1	21	85	85	21	0	0	0	0	0	0	0	0
C8M14	57	10	3	1	12	49	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	4	1	26	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	5	1	10	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	6	1	5	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	8	1	9	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	9	1	23	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	10	1	15	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	11	1	1	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	12	1	15	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	14	1	17	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	15	1	9	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	16	1	1	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	17	1	14	58	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	18	1	31	92	31	0	0	0	0	0	0	0	0	0
C8M14	57	10	19	1	18	72	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	20	1	9	38	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	22	1	7	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	23	1	11	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	24	1	34	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	25	1	29	88	29	0	0	0	0	0	0	0	0	0
C8M14	57	10	26	1	21	82	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	27	1	26	79	26	0	0	0	0	0	0	0	0	0
C8M14	57	10	28	1	17	66	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	29	1	35	0	0	0	0	0	0	0	0	0	0	0
C8M14	57	10	30	1	8	0	0	0	0	0	0	0	0	0	0	0
99																

Table A7.7 Sub-catchment C2M03

C2M03	57	9	8	1	3	0	0	0	0	0	0	0	0	0	0	0
C2M03	57	9	10	1	19	0	0	0	0	0	0	0	0	0	0	0
C2M03	57	9	11	1	22	89	0	0	0	0	0	0	0	0	0	0
C2M03	57	9	12	1	20	82	82	21	0	0	0	0	0	0	0	0
C2M03	57	9	13	1	33	98	33	0	0	0	0	0	0	0	0	0
C2M03	57	9	14	1	12	48	0	0	0	0	0	0	0	0	0	0
C2M03	57	9	15	1	8	32	0	0	0	0	0	0	0	0	0	0
C2M03	57	9	16	1	4	0	0	0	0	0	0	0	0	0	0	0
C2M03	57	9	17	1	2	0	0	0	0	0	0	0	0	0	0	0
C2M03	57	9	20	1	1	0	0	0	0	0	0	0	0	0	0	0
C2M03	57	9	21	1	26	0	0	0	0	0	0	0	0	0	0	0
C2M03	57	9	22	1	23	93	93	23	0	0	0	0	0	0	0	0
C2M03	57	9	23	1	12	50	0	0	0	0	0	0	0	0	0	0
C2M03	57	9	24	1	11	46	0	0	0	0	0	0	0	0	0	0
C2M03	57	9	25	1	22	86	86	22	0	0	0	0	0	0	0	0
C2M03	57	9	26	1	18	77	119	77	18	0	0	0	0	0	0	0
C2M03	57	9	27	1	35	0	0	0	0	0	0	0	0	0	0	0
C2M03	57	9	30	1	13	52	0	0	0	0	0	0	0	0	0	0
99																
C2M03	57	10	1	1	24	0	0	0	0	0	0	0	0	0	0	0
C2M03	57	10	2	1	20	82	82	20	0	0	0	0	0	0	0	0
C2M03	57	10	3	1	11	42	0	0	0	0	0	0	0	0	0	0
C2M03	57	10	7	1	8	34	0	0	0	0	0	0	0	0	0	0
C2M03	57	10	8	1	17	0	0	0	0	0	0	0	0	0	0	0
C2M03	57	10	9	1	6	0	0	0	0	0	0	0	0	0	0	0
C2M03	57	10	10	1	33	0	0	0	0	0	0	0	0	0	0	0
C2M03	57	10	11	1	3	0	0	0	0	0	0	0	0	0	0	0
C2M03	57	10	17	1	10	42	0	0	0	0	0	0	0	0	0	0
C2M03	57	10	18	1	1	0	0	0	0	0	0	0	0	0	0	0
C2M03	57	10	19	1	21	0	0	0	0	0	0	0	0	0	0	0
C2M03	57	10	20	1	6	0	0	0	0	0	0	0	0	0	0	0
C2M03	57	10	24	1	11	46	0	0	0	0	0	0	0	0	0	0
C2M03	57	10	25	1	13	51	0	0	0	0	0	0	0	0	0	0
C2M03	57	10	26	1	24	94	94	24	0	0	0	0	0	0	0	0
C2M03	57	10	27	1	16	64	0	0	0	0	0	0	0	0	0	0
C2M03	57	10	28	1	10	0	0	0	0	0	0	0	0	0	0	0
C2M03	57	10	29	1	5	0	0	0	0	0	0	0	0	0	0	0
99																

Table A8 : Hourly rainfall for the period Jan/Feb 1975 (1/10mm) as measured by 8 daily-read rain gauges per sub-catchment, and disaggregated into hourly falls according to the procedure adopted in the daily model.

Data description Gauge number, year, month, day, 1 = a.m. or 2 = p.m., 12 consecutive values of average hourly precipitation (1/10mm).

Table 8.1 Sub-catchment C1M01

0	C1M01	75	1	2	1	10	0	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	1	6	1	16	62	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	1	8	1	9	34	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	1	9	1	4	0	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	1	10	1	7	0	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	1	11	1	4	0	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	1	12	1	37	0	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	1	13	1	16	66	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	1	15	1	21	85	85	21	0	0	0	0	0	0	0	0
0	C1M01	75	1	16	1	21	85	85	21	0	0	0	0	0	0	0	0
0	C1M01	75	1	17	1	31	94	31	0	0	0	0	0	0	0	0	0
0	C1M01	75	1	18	1	21	85	85	21	0	0	0	0	0	0	0	0
0	C1M01	75	1	19	1	19	74	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	1	24	1	17	68	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	1	25	1	10	41	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	1	26	1	29	0	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	1	27	1	25	76	25	0	0	0	0	0	0	0	0	0
0	C1M01	75	1	28	1	10	38	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	1	29	1	12	50	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	1	30	1	1	0	0	0	0	0	0	0	0	0	0	0
99																	0
0	C1M01	75	2	5	1	7	0	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	2	6	1	16	0	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	2	7	1	34	0	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	2	8	1	22	0	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	2	9	1	20	82	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	2	10	1	27	81	27	0	0	0	0	0	0	0	0	0
0	C1M01	75	2	11	1	26	0	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	2	12	1	21	84	84	21	0	0	0	0	0	0	0	0
0	C1M01	75	2	13	1	22	88	88	22	0	0	0	0	0	0	0	0
0	C1M01	75	2	14	1	19	80	124	80	19	0	0	0	0	0	0	0
0	C1M01	75	2	15	1	10	38	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	2	16	1	12	47	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	2	17	1	9	0	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	2	18	1	12	0	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	2	19	1	15	61	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	2	20	1	10	41	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	2	21	1	2	0	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	2	22	1	7	0	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	2	23	1	6	0	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	2	26	1	10	0	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	2	27	1	12	46	0	0	0	0	0	0	0	0	0	0
0	C1M01	75	2	28	1	5	0	0	0	0	0	0	0	0	0	0	0
99																	0

Table A8.2 Sub-catchment C1MO2

0	C1M02	75	1	1	1	10	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	2	1	18	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	5	1	4	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	6	1	18	74	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	7	1	33	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	8	1	14	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	9	1	15	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	11	1	11	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	12	1	11	44	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	13	1	20	81	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	14	1	32	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	15	1	22	89	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	16	1	12	48	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	17	1	28	83	28	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	18	1	17	68	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	19	1	18	73	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	20	1	15	62	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	21	1	21	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	23	1	18	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	24	1	28	83	28	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	25	1	34	101	34	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	26	1	14	55	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	27	1	32	96	32	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	28	1	9	38	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	29	1	24	71	24	0	0	0	0	0	0	0	0	0
0	C1M02	75	1	30	1	33	0	0	0	0	0	0	0	0	0	0	0
99																	0
0	C1M02	75	2	3	1	20	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	4	1	7	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	5	1	11	42	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	6	1	16	63	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	7	1	20	82	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	8	1	33	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	9	1	16	65	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	10	1	29	86	29	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	11	1	15	61	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	12	1	14	57	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	13	1	21	85	85	21	0	0	0	0	0	0	0	0
0	C1M02	75	2	14	1	25	100	100	25	0	0	0	0	0	0	0	0
0	C1M02	75	2	15	1	18	76	117	76	18	0	0	0	0	0	0	0
0	C1M02	75	2	16	1	36	108	36	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	17	1	10	39	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	18	1	23	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	19	1	12	49	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	20	1	22	89	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	21	1	36	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	22	1	20	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	23	1	3	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	24	1	13	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	25	1	9	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	26	1	1	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	27	1	10	0	0	0	0	0	0	0	0	0	0	0
0	C1M02	75	2	28	1	20	0	0	0	0	0	0	0	0	0	0	0
99																	0

Table A8.3 Sub-catchment C1MO3

0	C1M03	75	1	2	1	2	0	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	1	6	1	34	0	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	1	7	1	21	0	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	1	12	1	25	76	25	0	0	0	0	0	0	0	0	0
0	C1M03	75	1	13	1	22	86	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	1	14	1	12	50	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	1	15	1	9	36	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	1	16	1	16	68	106	68	16	0	0	0	0	0	0	0
0	C1M03	75	1	17	1	32	96	32	0	0	0	0	0	0	0	0	0
0	C1M03	75	1	18	1	29	88	29	0	0	0	0	0	0	0	0	0
0	C1M03	75	1	19	1	15	65	100	65	15	0	0	0	0	0	0	0
0	C1M03	75	1	20	1	13	0	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	1	24	1	19	82	126	82	19	0	0	0	0	0	0	0
0	C1M03	75	1	25	1	33	98	33	0	0	0	0	0	0	0	0	0
0	C1M03	75	1	26	1	9	35	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	1	27	1	19	75	75	19	0	0	0	0	0	0	0	0
0	C1M03	75	1	28	1	9	34	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	1	29	1	10	40	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	1	30	1	5	0	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	1	31	1	10	0	0	0	0	0	0	0	0	0	0	0
99																	0
0	C1M03	75	2	3	1	20	0	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	2	5	1	34	0	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	2	6	1	3	0	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	2	7	1	15	61	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	2	8	1	26	0	C	0	0	0	0	0	0	0	0	0
0	C1M03	75	2	9	1	24	71	24	0	0	0	0	0	0	0	0	0
0	C1M03	75	2	10	1	17	67	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	2	11	1	12	0	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	2	12	1	8	32	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	2	13	1	24	73	24	0	0	0	0	0	0	0	0	0
0	C1M03	75	2	14	1	10	41	85	122	122	85	41	10	0	0	0	0
0	C1M03	75	2	15	1	23	92	92	23	0	0	0	0	0	0	0	0
0	C1M03	75	2	16	1	14	57	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	2	17	1	16	66	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	2	19	1	16	67	104	67	16	0	0	0	0	0	0	0
0	C1M03	75	2	20	1	19	76	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	2	21	1	9	36	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	2	22	1	20	0	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	2	23	1	37	0	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	2	24	1	19	0	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	2	26	1	22	0	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	2	27	1	18	72	0	0	0	0	0	0	0	0	0	0
0	C1M03	75	2	28	1	10	0	0	0	0	0	0	0	0	0	0	0
99																	0

Table A8.4 Sub-catchment C8B01

0	C8B01	75	1	9	1	6	0	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	1	11	1	8	0	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	1	12	1	16	63	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	1	13	1	13	53	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	1	16	1	29	86	29	0	0	0	0	0	0	0	0	0
0	C8B01	75	1	17	1	19	78	78	20	0	0	0	0	0	0	0	0
0	C8B01	75	1	18	1	23	70	23	0	0	0	0	0	0	0	0	0
0	C8B01	75	1	19	1	12	48	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	1	21	1	19	77	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	1	22	1	37	0	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	1	24	1	36	109	36	0	0	0	0	0	0	0	0	0
0	C8B01	75	1	25	1	15	58	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	1	26	1	26	78	26	0	0	0	0	0	0	0	0	0
0	C8B01	75	1	27	1	35	106	35	0	0	0	0	0	0	0	0	0
0	C8B01	75	1	28	1	33	0	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	1	29	1	33	0	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	1	30	1	9	37	0	0	0	0	0	0	0	0	0	0
99																	0
0	C8B01	75	2	2	1	27	0	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	2	3	1	14	0	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	2	5	1	20	80	80	20	0	0	0	0	0	0	0	0
0	C8B01	75	2	6	1	8	33	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	2	7	1	19	74	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	2	8	1	10	0	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	2	9	1	10	41	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	2	10	1	15	0	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	2	11	1	13	50	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	2	12	1	1	0	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	2	13	1	38	0	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	2	14	1	35	106	35	0	0	0	0	0	0	0	0	0
0	C8B01	75	2	15	1	21	82	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	2	16	1	27	81	27	0	0	0	0	0	0	0	0	0
0	C8B01	75	2	17	1	6	0	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	2	18	1	8	33	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	2	19	1	25	101	101	25	0	0	0	0	0	0	0	0
0	C8B01	75	2	20	1	18	0	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	2	21	1	8	34	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	2	22	1	13	0	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	2	25	1	9	0	0	0	0	0	0	0	0	0	0	0
0	C8B01	75	2	27	1	11	0	0	0	0	0	0	0	0	0	0	0
99																	0

Table A8.5 Sub-catchment C8M04

0	C8M04	75	1	9	1	3	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	1	11	1	8	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	1	12	1	9	34	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	1	13	1	9	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	1	14	1	1	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	1	15	1	21	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	1	16	1	28	83	28	0	0	0	0	0	0	0	0	0
0	C8M04	75	1	17	1	23	90	90	23	0	0	0	0	0	0	0	0
0	C8M04	75	1	18	1	17	70	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	1	19	1	24	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	1	21	1	33	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	1	24	1	18	70	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	1	25	1	35	106	35	0	0	0	0	0	0	0	0	0
0	C8M04	75	1	26	1	12	49	98	124	98	49	12	0	0	0	0	0
0	C8M04	75	1	27	1	26	79	26	0	0	0	0	0	0	0	0	0
0	C8M04	75	1	28	1	9	37	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	1	29	1	21	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	1	30	1	13	0	0	0	0	0	0	0	0	0	0	0
99																	0
0	C8M04	75	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	3	1	28	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	4	1	22	86	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	5	1	31	94	31	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	6	1	2	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	7	1	6	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	8	1	12	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	9	1	9	34	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	10	1	5	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	11	1	15	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	12	1	10	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	13	1	39	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	14	1	21	85	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	15	1	9	34	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	16	1	13	51	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	17	1	5	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	18	1	36	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	19	1	12	48	95	120	95	48	12	0	0	0	0	0
0	C8M04	75	2	20	1	29	88	29	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	21	1	8	34	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	22	1	13	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	23	1	8	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	24	1	14	57	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	25	1	9	0	0	0	0	0	0	0	0	0	0	0
0	C8M04	75	2	28	1	5	0	0	0	0	0	0	0	0	0	0	0
99																	0

Table A8.6 Sub-catchment C8M14

0	C8M14	75	1	6	1	19	0	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	1	8	1	5	0	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	1	9	1	26	0	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	1	12	1	31	0	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	1	13	1	6	0	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	1	14	1	1	0	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	1	15	1	25	0	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	1	16	1	20	80	80	20	0	0	0	0	0	0	0	0
0	C8M14	75	1	17	1	30	89	30	0	0	0	0	0	0	0	0	0
0	C8M14	75	1	18	1	10	41	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	1	19	1	6	0	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	1	20	1	20	0	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	1	21	1	15	59	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	1	24	1	20	79	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	1	25	1	21	84	84	21	0	0	0	0	0	0	0	0
0	C8M14	75	1	26	1	10	41	85	121	121	85	41	10	0	0	0	0
0	C8M14	75	1	27	1	20	78	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	1	28	1	9	0	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	1	29	1	17	70	108	70	17	0	0	0	0	0	0	0
0	C8M14	75	1	30	1	10	0	0	0	0	0	0	0	0	0	0	0
99																	0
0	C8M14	75	2	3	1	18	0	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	2	4	1	36	109	36	0	0	0	0	0	0	0	0	0
0	C8M14	75	2	5	1	30	91	30	0	0	0	0	0	0	0	0	0
0	C8M14	75	2	6	1	25	0	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	2	7	1	15	62	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	2	8	1	12	0	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	2	9	1	20	82	82	20	0	0	0	0	0	0	0	0
0	C8M14	75	2	10	1	10	40	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	2	11	1	33	0	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	2	12	1	10	38	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	2	13	1	12	51	102	129	102	51	12	0	0	0	0	0
0	C8M14	75	2	14	1	17	72	111	72	17	0	0	0	0	0	0	0
0	C8M14	75	2	15	1	21	85	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	2	16	1	26	77	26	0	0	0	0	0	0	0	0	0
0	C8M14	75	2	17	1	9	0	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	2	18	1	10	41	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	2	19	1	16	69	107	69	16	0	0	0	0	0	0	0
0	C8M14	75	2	20	1	20	79	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	2	21	1	13	51	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	2	22	1	14	0	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	2	23	1	7	0	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	2	24	1	13	0	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	2	25	1	2	0	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	2	27	1	1	0	0	0	0	0	0	0	0	0	0	0
0	C8M14	75	2	28	1	9	34	0	0	0	0	0	0	0	0	0	0
99																	0

Table 8.7 Sub-catchment C2MO3

0	C2M03	75	1	12	1	12	0	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	1	13	1	18	72	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	1	14	1	18	0	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	1	15	1	13	0	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	1	16	1	25	75	25	0	0	0	0	0	0	0	0	0
0	C2M03	75	1	17	1	25	99	99	25	0	0	0	0	0	0	0	0
0	C2M03	75	1	18	1	29	88	29	0	0	0	0	0	0	0	0	0
0	C2M03	75	1	19	1	33	100	33	0	0	0	0	0	0	0	0	0
0	C2M03	75	1	20	1	35	0	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	1	21	1	16	0	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	1	24	1	22	88	88	22	0	0	0	0	0	0	0	0
0	C2M03	75	1	25	1	31	92	31	0	0	0	0	0	0	0	0	0
0	C2M03	75	1	26	1	18	74	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	1	27	1	21	83	83	21	0	0	0	0	0	0	0	0
0	C2M03	75	1	28	1	9	34	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	1	29	1	11	46	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	1	30	1	8	33	0	0	0	0	0	0	0	0	0	0
99																	0
0	C2M03	75	2	3	1	18	0	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	2	4	1	1	0	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	2	5	1	14	58	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	2	6	1	6	0	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	2	7	1	10	0	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	2	8	1	20	0	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	2	9	1	9	35	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	2	10	1	15	0	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	2	11	1	12	46	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	2	13	1	21	0	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	2	14	1	34	101	34	0	0	0	0	0	0	0	0	0
0	C2M03	75	2	15	1	9	36	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	2	16	1	17	71	109	71	17	0	0	0	0	0	0	0
0	C2M03	75	2	17	1	13	52	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	2	18	1	11	42	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	2	19	1	13	55	101	101	55	13	0	0	0	0	0	0
0	C2M03	75	2	20	1	22	88	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	2	21	1	18	73	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	2	22	1	21	0	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	2	24	1	4	0	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	2	27	1	22	0	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	2	28	1	1	0	0	0	0	0	0	0	0	0	0	0
0	C2M03	75	2	29	1	29	0	0	0	0	0	0	0	0	0	0	0
99																	0

Table A9 : Hourly rainfall (1/10mm) as measured by "DWA" daily-read rain gauges, and disaggregated into hourly falls according to the procedure adopted in the daily model.

Data description as in A6 to A8

Table A9.1 Sub-catchment C1M01

C1M01	77	1	1	1	3	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	7	1	33	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	8	1	2	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	9	1	7	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	10	1	22	88	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	11	1	24	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	12	1	20	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	17	1	13	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	18	1	13	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	19	1	21	85	85	21	0	0	0	0	0	0	0	0
C1M01	77	1	20	1	4	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	22	1	22	89	89	22	0	0	0	0	0	0	0	0
C1M01	77	1	23	1	22	67	22	0	0	0	0	0	0	0	0	0
C1M01	77	1	25	1	25	100	100	25	0	0	0	0	0	0	0	0
C1M01	77	1	26	1	11	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	27	1	2	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	28	1	13	52	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	29	1	25	101	101	25	0	0	0	0	0	0	0	0
C1M01	77	1	30	1	17	72	111	72	17	0	0	0	0	0	0	0
C1M01	77	1	31	1	8	0	0	0	0	0	0	0	0	0	0	0
99																
C1M01	77	2	1	1	20	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	2	2	1	9	35	0	0	0	0	0	0	0	0	0	0
C1M01	77	2	5	1	20	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	2	6	1	10	39	0	0	0	0	0	0	0	0	0	0
C1M01	77	2	7	1	9	34	0	0	0	0	0	0	0	0	0	0
C1M01	77	2	8	1	18	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	2	9	1	18	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	2	14	1	10	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	2	15	1	8	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	2	16	1	6	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	2	18	1	5	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	2	22	1	8	0	0	0	0	0	0	0	0	0	0	0
99																

Table A9.2 Sub-catchment C1M02

C1M02	77	1	1	1	8	0	0	0	0	0	0	0	0	0	0	0
C1M02	77	1	7	1	11	44	0	0	0	0	0	0	0	0	0	0
C1M02	77	1	9	1	18	0	0	0	0	0	0	0	0	0	0	0
C1M02	77	1	10	1	9	36	0	0	0	0	0	0	0	0	0	0
C1M02	77	1	11	1	21	86	86	22	0	0	0	0	0	0	0	0
C1M02	77	1	18	1	11	42	0	0	0	0	0	0	0	0	0	0
C1M02	77	1	19	1	21	86	86	22	0	0	0	0	0	0	0	0
C1M02	77	1	23	1	16	70	108	70	16	0	0	0	0	0	0	0
C1M02	77	1	24	1	29	87	29	0	0	0	0	0	0	0	0	0
C1M02	77	1	25	1	22	89	89	22	0	0	0	0	0	0	0	0
C1M02	77	1	26	1	7	0	0	0	0	0	0	0	0	0	0	0
C1M02	77	1	27	1	5	0	0	0	0	0	0	0	0	0	0	0
C1M02	77	1	29	1	13	56	104	104	56	13	0	0	0	0	0	0
C1M02	77	1	30	1	19	78	78	20	0	0	0	0	0	0	0	0
99																
C1M02	77	2	1	1	31	93	31	0	0	0	0	0	0	0	0	0
C1M02	77	2	2	1	33	100	33	0	0	0	0	0	0	0	0	0
C1M02	77	2	3	1	11	42	0	0	0	0	0	0	0	0	0	0
C1M02	77	2	5	1	10	40	0	0	0	0	0	0	0	0	0	0
C1M02	77	2	6	1	16	64	0	0	0	0	0	0	0	0	0	0
C1M02	77	2	7	1	13	52	0	0	0	0	0	0	0	0	0	0
C1M02	77	2	8	1	3	0	0	0	0	0	0	0	0	0	0	0
C1M02	77	2	14	1	25	0	0	0	0	0	0	0	0	0	0	0
C1M02	77	2	15	1	20	0	0	0	0	0	0	0	0	0	0	0
99																

Table A9.3 Sub-catchment C1M03

C1M03	77	1	7	1	14	0	0	0	0	0	0	0	0	0	0	0
C1M03	77	1	8	1	23	0	0	0	0	0	0	0	0	0	0	0
C1M03	77	1	9	1	3	0	0	0	0	0	0	0	0	0	0	0
C1M03	77	1	10	1	23	69	23	0	0	0	0	0	0	0	0	0
C1M03	77	1	11	1	28	83	28	0	0	0	0	0	0	0	0	0
C1M03	77	1	17	1	16	0	0	0	0	0	0	0	0	0	0	0
C1M03	77	1	18	1	23	0	0	0	0	0	0	0	0	0	0	0
C1M03	77	1	19	1	18	71	0	0	0	0	0	0	0	0	0	0
C1M03	77	1	22	1	9	34	0	0	0	0	0	0	0	0	0	0
C1M03	77	1	23	1	11	44	0	0	0	0	0	0	0	0	0	0
C1M03	77	1	24	1	17	66	0	0	0	0	0	0	0	0	0	0
C1M03	77	1	25	1	23	69	23	0	0	0	0	0	0	0	0	0
C1M03	77	1	28	1	23	68	23	0	0	0	0	0	0	0	0	0
C1M03	77	1	29	1	19	79	122	79	19	0	0	0	0	0	0	0
C1M03	77	1	30	1	22	87	87	22	0	0	0	0	0	0	0	0
C1M03	77	1	31	1	18	74	74	19	0	0	0	0	0	0	0	0
99																
C1M03	77	2	1	1	22	86	0	0	0	0	0	0	0	0	0	0
C1M03	77	2	2	1	28	83	28	0	0	0	0	0	0	0	0	0
C1M03	77	2	3	1	35	0	0	0	0	0	0	0	0	0	0	0
C1M03	77	2	8	1	10	0	0	0	0	0	0	0	0	0	0	0
C1M03	77	2	18	1	16	0	0	0	0	0	0	0	0	0	0	0
99																

Table A9.4 Sub-catchment C8B01 A30

C8B01	77	1	5	1	14	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	9	1	4	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	10	1	21	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	11	1	33	98	33	0	0	0	0	0	0	0	0	0
C8B01	77	1	14	1	19	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	17	1	19	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	18	1	16	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	19	1	20	79	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	20	1	9	36	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	21	1	5	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	22	1	11	42	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	23	1	14	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	24	1	24	73	24	0	0	0	0	0	0	0	0	0
C8B01	77	1	25	1	21	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	26	1	25	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	28	1	38	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	29	1	16	69	107	69	16	0	0	0	0	0	0	0
C8B01	77	1	30	1	15	65	101	65	15	0	0	0	0	0	0	0
C8B01	77	1	31	1	14	60	112	112	60	14	0	0	0	0	0	0
99																
C8B01	77	2	1	1	24	72	24	0	0	0	0	0	0	0	0	0
C8B01	77	2	2	1	25	74	25	0	0	0	0	0	0	0	0	0
C8B01	77	2	3	1	28	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	2	18	1	12	46	0	0	0	0	0	0	0	0	0	0
C8B01	77	2	19	1	14	0	0	0	0	0	0	0	0	0	0	0
99																

Table A9.5 Sub-catchment C8M04

C8M04	77	1	5	1	28	0	0	0	0	0	0	0	0	0	0	0
C8M04	77	1	9	1	8	0	0	0	0	0	0	0	0	0	0	0
C8M04	77	1	10	1	9	34	0	0	0	0	0	0	0	0	0	0
C8M04	77	1	13	1	12	46	0	0	0	0	0	0	0	0	0	0
C8M04	77	1	19	1	38	0	0	0	0	0	0	0	0	0	0	0
C8M04	77	1	20	1	14	56	0	0	0	0	0	0	0	0	0	0
C8M04	77	1	22	1	26	78	26	0	0	0	0	0	0	0	0	0
C8M04	77	1	24	1	11	44	0	0	0	0	0	0	0	0	0	0
C8M04	77	1	25	1	23	68	23	0	0	0	0	0	0	0	0	0
C8M04	77	1	26	1	8	33	0	0	0	0	0	0	0	0	0	0
C8M04	77	1	28	1	15	60	0	0	0	0	0	0	0	0	0	0
C8M04	77	1	29	1	32	95	32	0	0	0	0	0	0	0	0	0
C8M04	77	1	30	1	13	54	101	100	54	13	0	0	0	0	0	0
C8M04	77	1	31	1	9	35	72	109	126	109	72	35	9	0	0	0
99																
C8M04	77	2	1	1	30	0	0	0	0	0	0	0	0	0	0	0
C8M04	77	2	2	1	7	0	0	0	0	0	0	0	0	0	0	0
C8M04	77	2	7	1	28	0	0	0	0	0	0	0	0	0	0	0
C8M04	77	2	13	1	18	70	0	0	0	0	0	0	0	0	0	0
C8M04	77	2	19	1	16	64	0	0	0	0	0	0	0	0	0	0
99																

Table A9.6 Sub-catchment C8M14

C8M14	77	1	8	1	13	0	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	10	1	17	68	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	11	1	11	45	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	18	1	29	0	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	19	1	23	69	23	0	0	0	0	0	0	0	0	0
C8M14	77	1	20	1	16	64	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	22	1	19	76	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	24	1	15	59	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	25	1	22	87	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	26	1	7	0	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	28	1	9	34	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	29	1	22	89	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	30	1	22	89	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	31	1	12	50	99	125	99	50	12	0	0	0	0	0
99																
C8M14	77	2	1	1	13	50	0	0	0	0	0	0	0	0	0	0
C8M14	77	2	2	1	8	34	0	0	0	0	0	0	0	0	0	0
C8M14	77	2	7	1	24	0	0	0	0	0	0	0	0	0	0	0
C8M14	77	2	13	1	9	35	0	0	0	0	0	0	0	0	0	0
C8M14	77	2	18	1	12	46	0	0	0	0	0	0	0	0	0	0
C8M14	77	2	19	1	14	57	0	0	0	0	0	0	0	0	0	0
99																

Table A9.7 Sub-catchment C2M03

C2M03	77	1	8	1	27	0	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	9	1	3	0	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	10	1	12	0	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	14	1	25	0	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	17	1	18	74	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	19	1	20	78	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	21	1	7	0	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	22	1	9	38	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	23	1	18	74	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	24	1	27	0	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	25	1	33	0	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	26	1	32	0	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	28	1	8	34	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	29	1	18	72	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	30	1	15	65	100	65	15	0	0	0	0	0	0	0
C2M03	77	1	31	1	8	32	66	104	131	131	104	66	32	8	0	0
99																
C2M03	77	2	1	1	13	0	0	0	0	0	0	0	0	0	0	0
C2M03	77	2	2	1	11	44	0	0	0	0	0	0	0	0	0	0
C2M03	77	2	3	1	24	72	24	0	0	0	0	0	0	0	0	0
C2M03	77	2	18	1	14	0	0	0	0	0	0	0	0	0	0	0
99																

Table A10 : Hourly rainfall for the period Jan/Feb 1977 (1/10mm) as measured by "DWA"daily rain gauges, and disaggregated into equal hourly rainfalls for the days during the storm (viz. 28/1/77 to 9/2/77).

Data description as in A6 to A8

Table A10.1 Sub-catchment C1M01

C1M01	77	1	1	1	3	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	7	1	33	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	8	1	2	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	9	1	7	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	10	1	22	88	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	11	1	24	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	12	1	20	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	17	1	13	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	18	1	13	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	19	1	21	85	85	21	0	0	0	0	0	0	0	0
C1M01	77	1	20	1	4	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	22	1	22	89	89	22	0	0	0	0	0	0	0	0
C1M01	77	1	23	1	22	67	22	0	0	0	0	0	0	0	0	0
C1M01	77	1	25	1	25	100	100	25	0	0	0	0	0	0	0	0
C1M01	77	1	26	1	11	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	1	28	1	3	3	3	3	3	3	3	3	3	3	3	3
C1M01	77	1	28	2	3	3	3	3	3	3	3	3	3	3	3	3
C1M01	77	1	29	1	10	11	10	11	10	11	10	11	10	11	10	11
C1M01	77	1	29	2	10	11	10	11	10	11	10	11	10	11	10	11
C1M01	77	1	30	1	12	12	12	12	12	12	12	12	12	12	12	12
C1M01	77	1	30	2	12	12	12	12	12	12	12	12	12	12	12	12

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C1M01	77	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
C1M01	77	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1
C1M01	77	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2
C1M01	77	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
C1M01	77	2	5	1	1	1	1	1	1	1	1	1	1	1	1	1
C1M01	77	2	5	2	1	1	1	1	1	1	1	1	1	1	1	1
C1M01	77	2	6	1	2	2	2	2	2	2	2	2	2	2	2	2
C1M01	77	2	6	2	2	2	2	2	2	2	2	2	2	2	2	2
C1M01	77	2	7	1	2	2	2	2	2	2	2	2	2	2	2	2
C1M01	77	2	7	2	2	2	2	2	2	2	2	2	2	2	2	2
C1M01	77	2	8	1	1	1	1	1	1	1	1	1	1	1	1	1
C1M01	77	2	8	2	1	1	1	1	1	1	1	1	1	1	1	1
C1M01	77	2	9	1	1	1	1	1	1	1	1	1	1	1	1	1
C1M01	77	2	9	2	1	1	1	1	1	1	1	1	1	1	1	1
C1M01	77	2	14	1	10	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	2	15	1	8	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	2	16	1	6	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	2	18	1	5	0	0	0	0	0	0	0	0	0	0	0
C1M01	77	2	22	1	8	0	0	0	0	0	0	0	0	0	0	0

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Table A10.2 Sub-catchment C1M02

C1M02	77	1	1	1	8	0	0	0	0	0	0	0	0	0	0	0
C1M02	77	1	7	1	11	44	0	0	0	0	0	0	0	0	0	0
C1M02	77	1	9	1	18	0	0	0	0	0	0	0	0	0	0	0
C1M02	77	1	10	1	9	36	0	0	0	0	0	0	0	0	0	0
C1M02	77	1	11	1	21	86	86	22	0	0	0	0	0	0	0	0
C1M02	77	1	18	1	11	42	0	0	0	0	0	0	0	0	0	0
C1M02	77	1	19	1	21	86	86	22	0	0	0	0	0	0	0	0
C1M02	77	1	23	1	16	70	108	70	16	0	0	0	0	0	0	0
C1M02	77	1	24	1	29	87	29	0	0	0	0	0	0	0	0	0
C1M02	77	1	25	1	22	89	89	22	0	0	0	0	0	0	0	0
C1M02	77	1	26	1	7	0	0	0	0	0	0	0	0	0	0	0
C1M02	77	1	29	1	14	15	14	15	14	15	14	15	14	15	14	15
C1M02	77	1	29	2	14	15	14	15	14	15	14	15	14	15	14	15
C1M02	77	1	30	1	8	8	8	8	8	8	8	8	8	8	8	8
C1M02	77	1	30	2	8	8	8	8	8	8	8	8	8	8	8	8

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C1M02	77	2	1	1	6	6	6	6	6	6	6	6	6	6	6	6
C1M02	77	2	1	2	6	6	6	6	6	6	6	6	6	6	6	6
C1M02	77	2	2	1	7	7	7	7	7	7	7	7	7	7	7	7
C1M02	77	2	2	2	7	7	7	7	7	7	7	7	7	7	7	7
C1M02	77	2	3	1	2	2	2	2	2	2	2	2	2	2	2	2
C1M02	77	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2
C1M02	77	2	5	1	2	2	2	2	2	2	2	2	2	2	2	2
C1M02	77	2	5	2	2	2	2	2	2	2	2	2	2	2	2	2
C1M02	77	2	6	1	3	3	3	3	3	3	3	3	3	3	3	3
C1M02	77	2	6	2	3	3	3	3	3	3	3	3	3	3	3	3
C1M02	77	2	7	1	3	3	3	3	3	3	3	3	3	3	3	3
C1M02	77	2	7	2	3	3	3	3	3	3	3	3	3	3	3	3
C1M02	77	2	14	1	25	0	0	0	0	0	0	0	0	0	0	0
C1M02	77	2	15	1	20	0	0	0	0	0	0	0	0	0	0	0

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Table A10.3 Sub-catchment C1M03

C1M03	77	1	7	1	14	0	0	0	0	0	0	0	0	0	0	0
C1M03	77	1	8	1	23	0	0	0	0	0	0	0	0	0	0	0
C1M03	77	1	9	1	3	0	0	0	0	0	0	0	0	0	0	0
C1M03	77	1	10	1	23	69	23	0	0	0	0	0	0	0	0	0
C1M03	77	1	11	1	28	83	28	0	0	0	0	0	0	0	0	0
C1M03	77	1	17	1	16	0	0	0	0	0	0	0	0	0	0	0
C1M03	77	1	18	1	23	0	0	0	0	0	0	0	0	0	0	0
C1M03	77	1	19	1	18	71	0	0	0	0	0	0	0	0	0	0
C1M03	77	1	22	1	9	34	0	0	0	0	0	0	0	0	0	0
C1M03	77	1	23	1	11	44	0	0	0	0	0	0	0	0	0	0
C1M03	77	1	24	1	17	66	0	0	0	0	0	0	0	0	0	0
C1M03	77	1	25	1	23	69	23	0	0	0	0	0	0	0	0	0
C1M03	77	1	28	1	5	5	5	5	5	5	5	5	5	5	5	5
C1M03	77	1	28	2	5	5	5	5	5	5	5	5	5	5	5	5
C1M03	77	1	29	1	13	13	13	13	13	13	13	13	13	13	13	13
C1M03	77	1	29	2	13	13	13	13	13	13	13	13	13	13	13	13
C1M03	77	1	30	1	9	9	9	9	9	9	9	9	9	9	9	9
C1M03	77	1	30	2	9	9	9	9	9	9	9	9	9	9	9	9
C1M03	77	1	31	1	8	8	8	8	8	8	8	8	8	8	8	8
C1M03	77	1	31	2	8	8	8	8	8	8	8	8	8	8	8	8

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C1M03	77	2	1	1	4	5	4	5	4	5	4	5	4	5	4	5
C1M03	77	2	1	2	4	5	4	5	4	5	4	5	4	5	4	5
C1M03	77	2	2	1	6	6	6	6	6	6	6	6	6	6	6	6
C1M03	77	2	2	2	6	6	6	6	6	6	6	6	6	6	6	6
C1M03	77	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1
C1M03	77	2	3	2	1	1	1	1	1	1	1	1	1	1	1	1
C1M03	77	2	8	1	0	1	0	1	0	1	0	1	0	1	0	1
C1M03	77	2	8	2	0	1	0	1	0	1	0	1	0	1	0	1
C1M03	77	2	18	1	16	0	0	0	0	0	0	0	0	0	0	0

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Table A10.4 Sub-catchment C8B01

C8B01	77	1	5	1	14	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	9	1	4	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	10	1	21	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	11	1	33	98	33	0	0	0	0	0	0	0	0	0
C8B01	77	1	14	1	19	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	17	1	19	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	18	1	16	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	19	1	20	79	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	20	1	9	36	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	21	1	5	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	22	1	11	42	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	23	1	14	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	24	1	24	73	24	0	0	0	0	0	0	0	0	0
C8B01	77	1	25	1	21	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	26	1	25	0	0	0	0	0	0	0	0	0	0	0
C8B01	77	1	28	1	1	2	1	2	1	2	1	2	1	2	1	2
C8B01	77	1	28	2	1	2	1	2	1	2	1	2	1	2	1	2
C8B01	77	1	29	1	11	12	11	12	11	12	11	12	11	12	11	12
C8B01	77	1	29	2	11	12	11	12	11	12	11	12	11	12	11	12
C8B01	77	1	30	1	11	11	11	11	11	11	11	11	11	11	11	11
C8B01	77	1	30	2	11	11	11	11	11	11	11	11	11	11	11	11
C8B01	77	1	31	1	15	16	15	16	15	16	15	16	15	16	15	16
C8B01	77	1	31	2	15	16	15	16	15	16	15	16	15	16	15	16

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C8B01	77	2	1	1	5	5	5	5	5	5	5	5	5	5	5	5
C8B01	77	2	1	2	5	5	5	5	5	5	5	5	5	5	5	5
C8B01	77	2	2	1	5	5	5	5	5	5	5	5	5	5	5	5
C8B01	77	2	2	2	5	5	5	5	5	5	5	5	5	5	5	5
C8B01	77	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1
C8B01	77	2	3	2	1	1	1	1	1	1	1	1	1	1	1	1
C8B01	77	1	29	1	11	12	11	12	11	12	11	12	11	12	11	12
C8B01	77	2	18	1	12	46	0	0	0	0	0	0	0	0	0	0
C8B01	77	2	19	1	14	0	0	0	0	0	0	0	0	0	0	0

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Table A10.5 Sub-catchment C8M04

C8M04	77	1	5	1	28	0	0	0	0	0	0	0	0	0	0	0
C8M04	77	1	9	1	8	0	0	0	0	0	0	0	0	0	0	0
C8M04	77	1	10	1	9	34	0	0	0	0	0	0	0	0	0	0
C8M04	77	1	18	1	12	46	0	0	0	0	0	0	0	0	0	0
C8M04	77	1	19	1	38	0	0	0	0	0	0	0	0	0	0	0
C8M04	77	1	20	1	14	56	0	0	0	0	0	0	0	0	0	0
C8M04	77	1	22	1	26	78	26	0	0	0	0	0	0	0	0	0
C8M04	77	1	24	1	11	44	0	0	0	0	0	0	0	0	0	0
C8M04	77	1	25	1	23	68	23	0	0	0	0	0	0	0	0	0
C8M04	77	1	26	1	8	33	0	0	0	0	0	0	0	0	0	0
C8M04	77	1	28	1	3	3	3	3	3	3	3	3	3	3	3	3
C8M04	77	1	28	2	3	3	3	3	3	3	3	3	3	3	3	3
C8M04	77	1	29	1	7	6	7	6	7	6	7	6	7	6	7	6
C8M04	77	1	29	2	7	6	7	6	7	6	7	6	7	6	7	6
C8M04	77	1	30	1	14	14	14	14	14	14	14	14	14	14	14	14
C8M04	77	1	30	2	14	14	14	14	14	14	14	14	14	14	14	14
C8M04	77	1	31	1	24	24	24	24	24	24	24	24	24	24	24	24
C8M04	77	1	31	2	24	24	24	24	24	24	24	24	24	24	24	24

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C8M04	77	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
C8M04	77	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1
C8M04	77	2	7	1	1	1	1	1	1	1	1	1	1	1	1	1
C8M04	77	2	7	2	1	1	1	1	1	1	1	1	1	1	1	1
C8M04	77	2	13	1	18	70	0	0	0	0	0	0	0	0	0	0
C8M04	77	2	19	1	16	64	0	0	0	0	0	0	0	0	0	0

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Table A10.6 Sub-catchment C8M14

C8M14	77	1	8	1	13	0	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	10	1	17	68	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	11	1	11	45	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	18	1	29	0	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	19	1	23	69	23	0	0	0	0	0	0	0	0	0
C8M14	77	1	20	1	16	64	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	22	1	19	76	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	24	1	15	59	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	25	1	22	87	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	26	1	7	0	0	0	0	0	0	0	0	0	0	0
C8M14	77	1	28	1	2	2	2	2	2	2	2	2	2	2	2	2
C8M14	77	1	28	2	2	2	2	2	2	2	2	2	2	2	2	2
C8M14	77	1	29	1	5	5	5	5	5	5	5	5	5	5	5	5
C8M14	77	1	29	2	5	5	5	5	5	5	5	5	5	5	5	5
C8M14	77	1	30	1	5	5	5	5	5	5	5	5	5	5	5	5
C8M14	77	1	30	2	5	5	5	5	5	5	5	5	5	5	5	5
C8M14	77	1	31	1	19	19	19	19	19	19	19	19	19	19	19	19
C8M14	77	1	31	2	19	19	19	19	19	19	19	19	19	19	19	19
99																
C8M14	77	2	1	1	3	3	3	3	3	3	3	3	3	3	3	3
C8M14	77	2	1	2	3	3	3	3	3	3	3	3	3	3	3	3
C8M14	77	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2
C8M14	77	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
C8M14	77	2	7	1	1	1	1	1	1	1	1	1	1	1	1	1
C8M14	77	2	7	2	1	1	1	1	1	1	1	1	1	1	1	1
C8M14	77	2	13	1	9	35	0	0	0	0	0	0	0	0	0	0
C8M14	77	2	18	1	12	46	0	0	0	0	0	0	0	0	0	0
C8M14	77	2	19	1	14	57	0	0	0	0	0	0	0	0	0	0
99																

Table A10.7 Sub-catchment C2M03

C2M03	77	1	8	1	27	0	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	9	1	3	0	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	10	1	12	0	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	14	1	25	0	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	17	1	18	74	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	19	1	20	78	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	21	1	7	0	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	22	1	9	38	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	23	1	18	74	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	24	1	27	0	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	25	1	33	0	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	26	1	32	0	0	0	0	0	0	0	0	0	0	0
C2M03	77	1	28	1	2	2	2	2	2	2	2	2	2	2	2	2
C2M03	77	1	28	2	2	2	2	2	2	2	2	2	2	2	2	2
C2M03	77	1	29	1	4	4	4	4	4	4	4	4	4	4	4	4
C2M03	77	1	29	2	4	4	4	4	4	4	4	4	4	4	4	4
C2M03	77	1	30	1	11	11	11	11	11	11	11	11	11	11	11	11
C2M03	77	1	30	2	11	11	11	11	11	11	11	11	11	11	11	11
C2M03	77	1	31	1	28	28	28	28	28	28	28	28	28	28	28	28
C2M03	77	1	31	2	28	28	28	28	28	28	28	28	28	28	28	28
99																
C2M03	77	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
C2M03	77	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1
C2M03	77	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2
C2M03	77	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
C2M03	77	2	3	1	5	5	5	5	5	5	5	5	5	5	5	5
C2M03	77	2	3	2	5	5	5	5	5	5	5	5	5	5	5	5
C2M03	77	2	18	1	14	0	0	0	0	0	0	0	0	0	0	0
99																

APPENDIX B

Table B1 : List of catchment characteristics and runoff model parameters as used in simulations

	Sub-catchment						
	C1M01	C1M02	C1M03	C8B01	C8M04	C8M14	C2M03
Area (km^2)	8192	4152	6272	4449	3527	7497	4416
MAP (mm)	780	794	708	708	725	812	700
POW	3	3	3	3	3	3	3
SL (mm)	0	0	0	0	0	0	0
ST (mm)	95	95	95	95	95	95	95
FT (mm/day)	0,1	0,1	0,1	0,1	0,1	0,1	0,1
LAG (days)*	2	2	1	1	2	3	1
LAG(hours)**	46	51	23	26	49	57	19
AI (%)	0	0	0	0	0	0	7
ZMINN(mm/h)	1,0	1,0	1,0	1,0	1,0	1,0	1,0
ZMAXN(mm/h)	5,0	5,0	5,0	5,0	5,0	5,0	5,0
PI (mm)	1,5	1,5	1,5	1,5	1,5	1,5	1,5
TL (days)	3	3	3	3	3	3	3
GL (days)	6	6	6	6	6	6	6
R	0,5	0,5	0,5	0,5	0,5	0,5	0,5
DIV	0	0	0	0	0	0	0
QOBS m^3/s	0,01	0,01	0,01	0,01	0,01	0,01	0,01

* Total internal plus external lag for daily model

** Total internal plus external lag for hourly model

Table B2 : Description of input variables used in program GOP

Symbol	Units	Description
N	day	duration of hydrograph
I	m^3/s	present rate of release
J	$m^3/s/hour$	max. increase in release rate
K	m^3/s	gross basic release rate = pipe releases plus normal flow
S	m^3	present storage available below FSL
T	m^3	max. allowable storage above FSL
W	number	day of peak
Y(I)	m^3/s	average inflow for day I
F	m^3/s	average simulated inflow for day 2
Q	m^3/s	max. discharge rate for plotting

* Day 3 refers to the present day. The inflows for days 1 and 2 are observed inflows while those for days 3 to N are simulated inflows.

Table B3 : Listing of program GOP

```
10 REM   THIS PROGRAM CALCULATES HOURLY RELEASE RATES
11 REM   FOR MAX. ATTENUATION OF DAILY FLOOD
12 REM   HYDROGRAPHS ENTERING A RESERVOIR
13 REM   ------------------------------------------
14 REM
15 DIM Y[23],P[20,24],V[20,24],Z[20,24]
20 REWIND
30 DISP "TOTAL DURATION IN DAYS";
40 INPUT N
45 REM MIN. DURATION = 11 DAYS
50 REM DAY 3 IS TODAY
60 DISP "PRESENT RATE OF RELEASE";
70 INPUT I
80 DISP "MAX HOURLY INCREASE IN RELEASE";
90 INPUT J
100 DISP "BRUTO BASIC RELEASE RATE";
110 INPUT K
120 DISP "PRESENT AVAIL. STOR. BELOW *FWL*";
130 INPUT S
140 DISP "MAX. STORAGE ABOVE *FWL*";
150 INPUT T
160 DISP "ON WHAT DAY IS PEAK";
170 INPUT W
180 FOR I1=1 TO N
190 DISP "INFLOW FOR DAY";I1;
200 INPUT Y[I1]
205 NEXT I1
206 DISP "SIMULATED INFLOW FOR DAY 2";
207 INPUT F
210 IF W>2 THEN 220
213 G=Y[2]-F
214 FOR I1=3 TO 11
215 Y[I1]=Y[I1]+(12-I1)*G/10
216 NEXT I1
220 FOR I3=2 TO N-3
230 X2=I3*24
240 FOR I4=1 TO 24
250 X=(I3-1)*24+I4
260 H=24
270 M=(X-X2)/H
280 A1=M
290 A2=A1*A1
300 A3=A2*A1
310 A4=A3*A1
320 L1=(A4-2*A3-A2+2*A1)/24
330 L2=-(A4-A3-4*A2+4*A1)/6
340 L3=(A4-5*A2+4)/4
350 L4=-(A4+A3-4*A2-4*A1)/6
360 L5=(A4+2*A3-A2-2*A1)/24
370 P[I3,I4]=L1*Y[I3-1]+L2*Y[I3]+L3*Y[I3+1]+L4*Y[I3+2]+L5*Y[I3+3]
380 NEXT I4
390 NEXT I3
395 REM CALCULATE VOL. OF INFLOW = A
400 A=0
410 FOR I3=3 TO N-3
420 FOR I4=1 TO 24
430 A=A+P[I3,I4]
440 NEXT I4
450 NEXT I3
470 REM CALCULATE VOL. OF NET INFLOW = A2
480 A2=(A-(N-5)*K*24)*3600
490 REM CALCULATE OUTFLOW VOLUME = B
500 REM START WITH LIMIT C=100 CUMEC FOR OUTFLOW RATES
```

```
510 I2=1
520 I3=1
530 D=0
540 C=100+100*D
550 B=0
560 T1=0
570 I1=1
580 V[2,24]=I
590 FOR I1=3 TO N-3
600 FOR I4=1 TO 24
610 V[I1,I4]=((I1-3)*24+I4)*J+I
620 IF V[I1,I4] <= C THEN 640
630 V[I1,I4]=C
640 IF I1 <= W THEN 690
650 IF V[I1,I4] <= P[I1,I4] THEN 690
660 T1=T1+(V[I1,I4]-P[I1,I4])*3600
670 IF T >= T1 THEN 690
680 V[I1,I4]=P[I1,I4]
690 B=B+V[I1,I4]
700 NEXT I4
710 NEXT I1
720 REM DETERMINE IF INFLOW = OUTFLOW
730 B=B*3600
740 A1=B+S
750 IF A1<A2 THEN 830
760 IF D=0 THEN 933
770 D=D-0.1
780 I3=2
790 REM ALLOW FOR 50 ITERATIONS TOTAL
800 IF I2>50 THEN 936
810 I2=I2+1
820 GOTO 540
830 IF I3>1 THEN 940
840 D=D+1
850 I3=1
930 GOTO 800
933 PRINT "                    RESERVOIR CANNOT BÉ FILLED."
934 PRINT
935 GOTO 940
936 PRINT "                    MORE THAN 50 ITERATIONS NEEDED."
937 PRINT
940 PRINT "                    *********************************************"
950 PRINT
960 PRINT "          DAY      HOUR      INFLOW    OUTFLOW      STATUS"
970 PRINT "                              CUMEC      CUMEC     PERCENT"
980 PRINT
990 I1=2
991 I4=24
992 Z[I1,I4]=((2330155330-S)/23301553.3)
993 I1=I1+1
994 FOR I4=1 TO 24
995 I6=I1
996 I5=I4-1
997 IF I5<1 THEN 999
998 GOTO 1001
999 I5=24
1000 I6=I1-1
1001 Z[I1,I4]=Z[I6,I5]+(P[I1,I4]-K-V[I1,I4])*1.544961382E-04
1002 NEXT I4
1003 IF I1<N-3 THEN 993
1005 FOR I1=3 TO N-3
1006 FOR I4=1 TO 24
1010 WRITE (15,1020)I1,I4,P[I1,I4],V[I1,I4],Z[I1,I4]
1020 FORMAT 4F10.0,F10.2
1025 NEXT I4
1030 NEXT I1
1040 PRINT
```

```
1050 PRINT "INFLOW (CUB M) =";A;"   OUTFLOW (CUB M) =";B;"ITERATIONS =";I2
1060 PRINT
1070 PRINT
1080 PRINT "      RATE      BASIC        BELOW FWL       ABOVE FWL"
1090 PRINT "   CUMEC/H      CUMEC           CUB M           CUB M"
1100 PRINT
1110 WRITE (15,1120)J,K,S,T
1120 FORMAT 2F10.0,2F15.0
1130 PRINT
1140 PRINT "                    ***********************************************
1150 PRINT
1160 DISP "DO YOU WANT TO PLOT?"
1170 WAIT 3000
1175 REM Q IN MULTIPLES OF 500
1180 DISP "IF YES MAX. Q ?: IF NO PRESS 0";
1190 INPUT Q
1200 IF Q>0 THEN 1230
1210 DISP "PROGRAM TERMINATED!"
1220 STOP
1230 SCALE 25,N*24,0,Q+1000
1240 XAXIS 500,24,72,(N-2)*24
1250 YAXIS 72,500,500,Q+500
1260 FOR I1=3 TO N-3
1270 FOR I4=1 TO 24
1280 X=(I1)*24+I4
1290 PLOT X,P[I1,I4]+500
1300 NEXT I4
1310 NEXT I1
1315 PEN
1320 DISP "CHANGE PEN"
1330 STOP
1340 FOR I1=3 TO N-3
1350 FOR I4=1 TO 24
1360 X=(I1)*24+I4
1370 PLOT X,V[I1,I4]+500
1380 NEXT I4
1390 NEXT I1
1395 PEN
1400 DISP "CHANGE PEN"
1410 STOP
1420 FOR I1=3 TO N-3
1430 FOR I4=1 TO 24
1440 X=(I1)*24+I4
1450 Y=Z[I1,I4]*Q/110+500
1460 PLOT X,Y
1470 NEXT I4
1480 NEXT I1
1485 PEN
1486 YAXIS (N-2)*24,Q/11,500,Q+500
1487 PEN
1488 DISP "CHANGE PEN"
1489 STOP
1490 DEG
1495 LABEL (*,1.5,2,0,7/10)
1500 FOR I1=3 TO N-3
1510 PLOT I1*24,500,1
1520 CPLOT 1.5,-1
1530 LABEL (1540)I1
1540 FORMAT F3.0
1550 NEXT I1
1555 LABEL (*,2.5,2,0,7/10)
1560 PLOT N*12,0,1
1570 CPLOT 0,1
1580 LABEL (*)"DAY"
1585 LABEL (*,1.5,2,0,7/10)
1590 FOR I5=0 TO Q STEP 500
1600 PLOT 72,I5+500,1
```

```
1610 CPLOT -6,-0.3
1620 LABEL (1630)I5
1630 FORMAT F5.0
1640 NEXT I5
1650 FOR I6=0 TO 110 STEP 10
1660 PLOT (N-2)*24,500+I6*Q/110,1
1670 CPLOT 1,-0.3
1680 LABEL (1690)I6
1690 FORMAT F4.0
1700 NEXT I6
1710 LABEL (*,2.5,2,90,7/10)
1720 PLOT (N-1)*24,Q/2
1730 CPLOT -3,-1
1740 LABEL (*)"STATUS IN PERCENT"
1750 PLOT 72,Q/2
1760 CPLOT -3,2.7
1770 LABEL (*)"FLOW IN CUMECS"
1780 LABEL (*,1.5,2,0,7/10)
1790 LETTER
1800 END
```

Table B4 : Sample output from program GOP

****

DAY	HOUR	INFLOW CUMEC	OUTFLOW CUMEC	STATUS PERCENT
3	1	1340	2075	95.59
3	2	1415	2150	95.48
3	3	1491	2225	95.37
3	4	1568	2300	95.25
3	5	1646	2375	95.14
3	6	1724	2450	95.03
3	7	1804	2525	94.92
3	8	1883	2600	94.81
3	9	1963	2600	94.71
3	10	2042	2600	94.62
3	11	2122	2600	94.55
3	12	2201	2600	94.49
3	13	2279	2600	94.44
3	14	2357	2600	94.40
3	15	2434	2600	94.37
3	16	2510	2600	94.36
3	17	2584	2600	94.36
3	18	2658	2600	94.37
3	19	2730	2600	94.39
3	20	2800	2600	94.42

3	21	2869	2600	94.46
3	22	2936	2600	94.51
3	23	3001	2600	94.57
3	24	3064	2600	94.65
4	1	3123	2600	94.73
4	2	3180	2600	94.82
4	3	3235	2600	94.91
4	4	3288	2600	95.02
4	5	3339	2600	95.13
4	6	3387	2600	95.26
4	7	3433	2600	95.38
4	8	3477	2600	95.52
4	9	3518	2600	95.66
4	10	3557	2600	95.81
4	11	3593	2600	95.96
4	12	3627	2600	96.12
4	13	3658	2600	96.29
4	14	3687	2600	96.45
4	15	3713	2600	96.63
4	16	3737	2600	96.80
4	17	3758	2600	96.98
4	18	3777	2600	97.16
4	19	3793	2600	97.35
4	20	3807	2600	97.53
4	21	3818	2600	97.72
4	22	3827	2600	97.91
4	23	3833	2600	98.10
4	24	3837	2600	98.29
5	1	3829	2600	98.48
5	2	3818	2600	98.67
5	3	3807	2600	98.86
5	4	3793	2600	99.04
5	5	3778	2600	99.22
5	6	3762	2600	99.40
5	7	3744	2600	99.58
5	8	3725	2600	99.75
5	9	3706	2600	99.92
5	10	3685	2600	100.09
5	11	3663	2600	100.26
5	12	3641	2600	100.42
5	13	3618	2600	100.57
5	14	3594	2600	100.73
5	15	3570	2600	100.88
5	16	3546	2600	101.02
5	17	3521	2600	101.17
5	18	3496	2600	101.30
5	19	3471	2600	101.44
5	20	3445	2600	101.57
5	21	3419	2600	101.70
5	22	3394	2600	101.82
5	23	3368	2600	101.94
5	24	3342	2600	102.05
6	1	3325	2600	102.16
6	2	3307	2600	102.27
6	3	3289	2600	102.38
6	4	3270	2600	102.48
6	5	3251	2600	102.58
6	6	3231	2600	102.68
6	7	3210	2600	102.78
6	8	3189	2600	102.87
6	9	3168	2600	102.95
6	10	3145	2600	103.04
6	11	3122	2600	103.12
6	12	3098	2600	103.20

6	13	3073	2600	103.27
6	14	3048	2600	103.34
6	15	3021	2600	103.40
6	16	2994	2600	103.46
6	17	2966	2600	103.52
6	18	2937	2600	103.57
6	19	2907	2600	103.62
6	20	2877	2600	103.66
6	21	2845	2600	103.70
6	22	2813	2600	103.73
6	23	2780	2600	103.76
6	24	2746	2600	103.78
7	1	2707	2600	103.80
7	2	2667	2600	103.81
7	3	2626	2600	103.81
7	4	2585	2600	103.81
7	5	2544	2600	103.80
7	6	2502	2600	103.79
7	7	2461	2600	103.77
7	8	2419	2600	103.74
7	9	2377	2600	103.70
7	10	2334	2600	103.66
7	11	2292	2600	103.62
7	12	2250	2600	103.56
7	13	2208	2600	103.50
7	14	2166	2600	103.43
7	15	2124	2600	103.36
7	16	2082	2600	103.28
7	17	2041	2600	103.19
7	18	2000	2600	103.10
7	19	1959	2600	103.00
7	20	1919	2600	102.90
7	21	1879	2600	102.79
7	22	1840	2600	102.67
7	23	1801	2600	102.55
7	24	1763	2600	102.42
8	1	1724	2600	102.28
8	2	1685	2600	102.14
8	3	1647	2600	101.99
8	4	1610	2600	101.84
8	5	1574	2600	101.68
8	6	1539	2600	101.52
8	7	1505	2600	101.35
8	8	1472	2600	101.17
8	9	1440	2600	100.99
8	10	1409	2600	100.81
8	11	1379	2600	100.62
8	12	1351	2600	100.43
8	13	1323	2600	100.23
8	14	1297	2600	100.03
8	15	1273	1273	100.03
8	16	1249	1249	100.03
8	17	1227	1227	100.03
8	18	1206	1206	100.03
8	19	1186	1186	100.03
8	20	1168	1168	100.03
8	21	1151	1151	100.03
8	22	1135	1135	100.03
8	23	1121	1121	100.03
8	24	1108	1108	100.03
9	1	1102	1102	100.03
9	2	1097	1097	100.03
9	3	1092	1092	100.03
9	4	1089	1089	100.03
9	5	1087	1087	100.03
9	6	1085	1085	100.03

9	7	1084	1084	100.03
9	8	1084	1084	100.03
9	9	1084	1084	100.03
9	10	1085	1085	100.03
9	11	1086	1086	100.03
9	12	1088	1088	100.03
9	13	1091	1091	100.03
9	14	1094	1094	100.03
9	15	1097	1097	100.03
9	16	1100	1100	100.03
9	17	1104	1104	100.03
9	18	1109	1109	100.03
9	19	1113	1113	100.03
9	20	1118	1118	100.03
9	21	1122	1122	100.03
9	22	1128	1128	100.03
9	23	1133	1133	100.03
9	24	1138	1138	100.03

INFLOW (CUB M) = 412505 OUTFLOW (CUB M) = 1384322400 ITERATIONS =
37

RATE CUMEC/H	BASIC CUMEC	BELOW FWL CUB M	ABOVE FWL CUB M
75	0	100000000	90000000

****

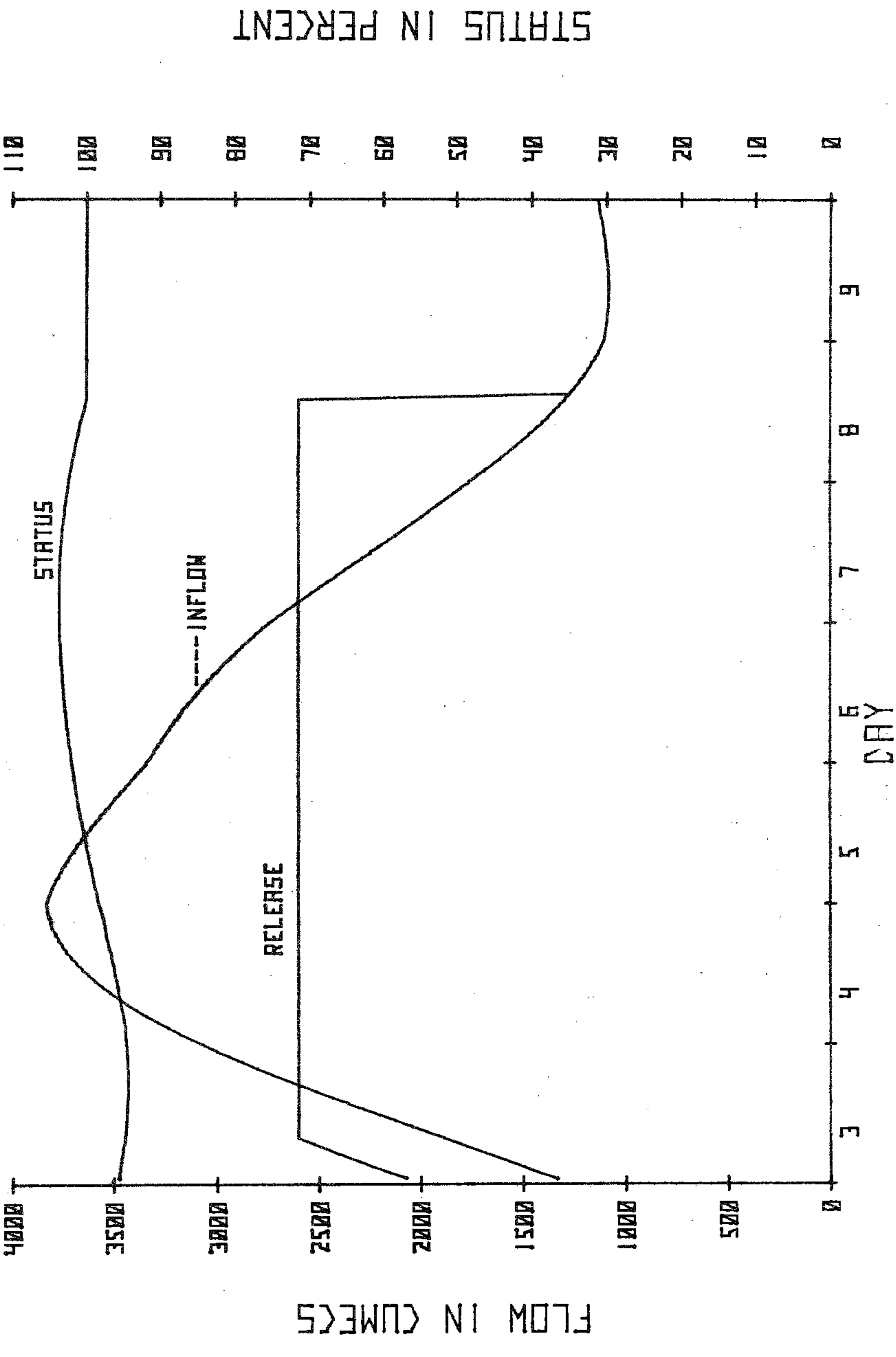
STATUS IN PERCENT
110
100
90
80
70
60
50
40
30
20
10
0
STATUS
INFLOW
RELEASE
3
4
5
6
7
8
9
DAY
4000
3500
3000
2500
2000
1500
1000
500
0
FLOW IN CUMECS

Table B5 : Description of input variables used in program HRYGOP

Symbol	Units	Description	Card	Format
RELRAT	m^3/s	present rate of release	1	free
STOBEL	m^3	present storage available below FSL		free
STOMAX	m^3	max. allowable storage above FSL		free
IYEAR	-	present year		free
MONTH	-	calendar month		free
IDAY	-	present day		free
IHOUR	-	present hour		free
OBSINF	m^3/s	observed average inflow rate for prev. day		free
MDAYS	-	number of days over which mass balance should be performed		free
RELMAX	$m^3/s/h$	max. hourly increase in rate of release		free
-	-	blank card	2*	-
K	-	day in date of flow record	3**	I3
L	-	month in date of flow record		I3
I1	-	year in date of flow record		I5
HOURIN	m^3/s	simulated hourly inflows		24F5.0

* Statement 4900 allows for one line of heading to the output file of the hourly model (see Tables B6 and B7).

**Card 3 is repeated for each day in the two calendar months covering the flood period

Table B6 : Listing of output file from hourly model used as input to program HRYGOP (cards no. 3)

Day, month, year followed by 24 hourly values of discharge (m^3/s)

78 1 28 5 (DATE OF FORECAST) GAUGE: VAALDAM

1	1	1978	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	18.	51.	83.	82.	96.
2	1	1978	154.	210.	216.	213.	210.	208.	205.	202.	200.	197.	193.	191.	188.	187.	184.	182.	179.	177.	174.	172.	193.	215.	228.	226.
3	1	1978	223.	222.	219.	260.	292.	288.	283.	280.	277.	275.	271.	267.	264.	260.	256.	253.	250.	246.	242.	240.	298.	360.	366.	403.
4	1	1978	523.	602.	624.	717.	810.	857.	875.	862.	852.	840.	867.	895.	884.	872.	859.	848.	837.	827.	813.	803.	790.	781.	770.	863.
5	1	1978	956.	946.	957.	966.	954.	939.	927.	916.	903.	889.	929.	1023.	1064.	1050.	1035.	1021.	1007.	994.	981.	967.	954.	942.	927.	916.
6	1	1978	903.	891.	880.	866.	855.	844.	830.	820.	809.	800.	787.	776.	766.	756.	745.	736.	727.	715.	707.	697.	687.	678.	668.	660.
7	1	1978	650.	641.	635.	624.	616.	608.	600.	592.	585.	576.	568.	560.	554.	545.	537.	532.	524.	516.	509.	503.	496.	489.	483.	476.
8	1	1978	469.	465.	457.	452.	445.	440.	432.	428.	421.	416.	411.	404.	401.	394.	389.	385.	378.	373.	368.	365.	359.	353.	350.	345.
9	1	1978	341.	336.	330.	327.	322.	317.	314.	310.	307.	302.	298.	294.	290.	286.	282.	278.	274.	270.	269.	265.	260.	258.	254.	250.
10	1	1978	248.	244.	243.	233.	234.	231.	230.	225.	222.	221.	217.	213.	211.	208.	207.	204.	199.	198.	195.	194.	190.	188.	185.	183.
11	1	1978	182.	180.	173.	173.	172.	170.	168.	166.	164.	161.	159.	159.	156.	153.	151.	150.	147.	146.	144.	143.	140.	139.	137.	135.
12	1	1978	135.	135.	135.	132.	129.	128.	126.	126.	124.	121.	121.	118.	117.	117.	116.	112.	111.	110.	109.	109.	107.	104.	103.	126.
13	1	1978	161.	169.	168.	165.	163.	161.	157.	156.	155.	154.	151.	149.	147.	146.	143.	142.	140.	138.	136.	133.	132.	132.	129.	175.
14	1	1978	272.	320.	324.	326.	321.	317.	313.	310.	305.	300.	299.	298.	294.	290.	286.	282.	278.	275.	270.	267.	264.	260.	258.	253.
15	1	1978	251.	247.	245.	240.	236.	234.	231.	228.	225.	222.	220.	217.	213.	211.	209.	206.	203.	199.	197.	195.	193.	189.	187.	186.
16	1	1978	183.	181.	178.	176.	173.	171.	170.	167.	165.	163.	160.	158.	155.	154.	151.	149.	148.	146.	145.	144.	141.	139.	138.	135.
17	1	1978	134.	133.	132.	130.	128.	127.	125.	123.	120.	119.	118.	117.	116.	114.	113.	111.	110.	108.	107.	106.	104.	103.	101.	99.
18	1	1978	98.	97.	97.	96.	95.	94.	92.	91.	91.	88.	87.	85.	84.	84.	83.	82.	81.	81.	80.	79.	79.	77.	76.	75.
19	1	1978	74.	72.	72.	71.	70.	70.	69.	69.	68.	67.	67.	66.	66.	64.	64.	63.	63.	62.	62.	60.	69.	76.	75.	74.
20	1	1978	74.	72.	72.	82.	108.	120.	119.	118.	116.	114.	112.	112.	111.	109.	108.	106.	105.	105.	103.	102.	124.	144.	142.	150.
21	1	1978	182.	201.	222.	295.	411.	477.	470.	464.	458.	451.	466.	480.	474.	466.	460.	454.	449.	442.	437.	430.	456.	479.	474.	481.
22	1	1978	541.	587.	588.	637.	729.	779.	782.	769.	762.	751.	793.	890.	936.	924.	910.	899.	887.	873.	862.	851.	838.	827.	815.	890.
23	1	1978	965.	953.	957.	961.	956.	949.	939.	924.	910.	900.	886.	874.	862.	852.	840.	827.	817.	806.	794.	784.	783.	782.	770.	758.
24	1	1978	776.	793.	782.	771.	762.	751.	740.	732.	721.	711.	700.	692.	683.	674.	663.	653.	646.	638.	628.	620.	612.	603.	596.	625.
25	1	1978	768.	919.	982.	1016.	1034.	1085.	1142.	1146.	1130.	1115.	1110.	1106.	1091.	1078.	1062.	1047.	1033.	1018.	1007.	992.	982.	972.	960.	949.
26	1	1978	938.	925.	939.	953.	940.	928.	915.	904.	889.	878.	940.	1002.	993.	979.	965.	951.	939.	926.	914.	901.	889.	876.	864.	908.
27	1	1978	947.	937.	937.	941.	928.	915.	904.	891.	879.	866.	855.	844.	832.	820.	809.	798.	788.	776.	767.	756.	752.	801.	898.	956.
28	1	1978	1007.	1101.	1142.	1145.	1146.	1131.	1114.	1100.	1034.	1069.	1058.	1043.	1029.	1015.	1002.	988.	974.	961.	948.	935.	922.	909.	897.	900.
29	1	1978	903.	890.	878.	867.	876.	883.	871.	859.	847.	836.	849.	864.	851.	839.	828.	817.	806.	795.	784.	774.	764.	752.	743.	734.
30	1	1978	726.	716.	707.	697.	710.	723.	715.	706.	695.	686.	677.	667.	658.	651.	640.	632.	624.	615.	606.	599.	591.	582.	577.	566.
31	1	1978	558.	553.	544.	538.	530.	522.	516.	510.	501.	495.	490.	482.	476.	470.	463.	457.	451.	444.	437.	432.	427.	422.	415.	409.
1	2	1978	404.	399.	394.	389.	384.	378.	373.	368.	363.	358.	353.	348.	343.	341.	336.	331.	326.	322.	317.	314.	309.	304.	301.	297.
2	2	1978	294.	289.	286.	281.	277.	274.	270.	267.	263.	261.	255.	255.	250.	246.	243.	240.	237.	233.	230.	227.	226.	222.	218.	216.
3	2	1978	213.	210.	207.	207.	202.	201.	196.	194.	192.	189.	186.	185.	182.	180.	180.	174.	173.	170.	168.	167.	165.	162.	160.	159.
4	2	1978	156.	155.	152.	149.	148.	147.	144.	143.	142.	139.	137.	136.	135.	132.	131.	130.	127.	125.	125.	121.	121.	120.	119.	116.
5	2	1978	116.	113.	113.	111.	109.	107.	106.	106.	104.	102.	101.	100.	98.	98.	98.	95.	94.	93.	93.	93.	91.	88.	88.	86.
6	2	1978	86.	84.	84.	82.	81.	81.	79.	78.	78.	78.	75.	74.	73.	73.	73.	73.	73.	70.	68.	68.	68.	67.	67.	65.
7	2	1978	65.	62.	62.	61.	61.	60.	60.	60.	60.	58.	57.	57.	57.	55.	55.	54.	54.	53.	53.	52.	52.	50.	50.	50.
8	2	1978	49.	49.	49.	48.	48.	47.	46.	46.	46.	45.	45.	44.	44.	44.	41.	41.	40.	40.	39.	39.	39.	39.	39.	39.
9	2	1978	38.	38.	38.	37.	36.	36.	36.	35.	35.	35.	34.	34.	34.	34.	34.	34.	34.	34.	33.	31.	31.	31.	31.	31.
10	2	1978	30.	30.	30.	30.	30.	28.	28.	28.	28.	28.	28.	28.	28.	27.	27.	26.	26.	26.	26.	25.	25.	25.	25.	25.
11	2	1978	25.	25.	25.	25.	25.	25.	25.	25.	24.	24.	24.	24.	22.	21.	21.	21.	21.	20.	20.	20.	20.	20.	20.	20.
12	2	1978	20.	20.	20.	20.	20.	20.	20.	20.	19.	19.	19.	19.	19.	19.	19.	19.	18.	18.	18.	18.	18.	18.	18.	17.
13	2	1978	17.	17.	16.	16.	16.	16.	16.	16.	16.	15.	15.	15.	15.	15.	15.	15.	15.	15.	15.	15.	14.	14.	14.	14.
14	2	1978	14.	14.	14.	14.	14.	14.	14.	14.	14.	14.	14.	14.	14.	14.	14.	14.	14.	14.	14.	14.	14.	14.	14.	14.
15	2	1978	14.	14.	14.	14.	14.	14.	14.	14.	14.	14.	14.	14.	14.	13.	13.	12.	12.	12.	12.	12.	12.	12.	12.	12.
16	2	1978	12.	12.	12.	12.	12.	12.	12.	12.	12.	12.	12.	12.	12.	12.	12.	11.	11.	11.	11.	11.	11.	11.	11.	11.
17	2	1978	11.	11.	11.	11.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.
18	2	1978	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.
19	2	1978	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.
20	2	1978	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.
21	2	1978	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.
22	2	1978	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.
23	2	1978	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.
24	2	1978	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.
25	2	1978	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	8.	8.	8.
26	2	1978	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.
27	2	1978	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.	8.	7.	7.	7.	7.	7.	7.	7.	7.	7.
28	2	1978	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.

Table B7 : Listing of program HRYGOP

```
C
C                 P R O G R A M   H R Y G O P .
C                 ------------------------------
C
C            THIS PROGRAM CALCULATES RELEASE RATES FOR MAX. ATTENUATION
C            OF HOURLY FLOOD HYDROGRAPHS ENTERING A RESERVOIR.
C
C      VARIABLES.
C      ----------
C         RELRAT - PRESENT RATE OF RELEASE (CUMECS).
C         STOBEL - PRESENT STORAGE AVAILABLE. BELOW FULL WATER
C                  LEVEL (M**3).
C         STOMAX - MAXIMUM ALLOWABLE STORAGE ABOVE F.W.L. (M**3).
C         IYEAR  - YEAR    )
C         MONTH  - MONTH   )
C         IDAY   - DAY     ) OF THE PRESENT TIME.
C         IHOUR  - HOUR    )
C         OBSINF - OBSERVED INFLOW RATE FOR THE PREVIOUS DAY,
C                  AS AN AVERAGE FOR THE DAY (CUMECS).
C         HOUREL - HOURLY RELEASE RATES (CUMECS)
C         HOURIN - HOURLY INFLOW RATES (CUMECS)
C         IPREV  - A POINTER SHOWING THE POSITION OF THE PREVIOUS
C                  DAY'S DATA.
C         IPRES  - A POINTER SHOWING THE POSITION OF THE PRESENT
C                  DAY'S DATA.
C         TOTINF - TOTAL INFLOW FOR THE DAY (M**3)
C         MDAYS  - NUMBER OF DAYS OVER WHICH MASS BALANCE
C                  SHOULD BE PERFORMED
C         RELMAX - MAX. HOURLY INCREASE IN RATE OF
C                  RELEASE (CUMECS / HOUR).
C
      DIMENSION HOURIN(24,20),HOUREL(24,20),STATUS(24,20)
      DIMENSION TOTINF(20), JDAYS(12)
      DATA JDAYS / 31,28,31,30,31,30,31,31,30,31,30,31 /
      LOGICAL FLAG
      READ (5,*) RELRAT, STOBEL, STOMAX, IYEAR,  MONTH,  IDAY,
     *          IHOUR,  OBSINF, MDAYS, RELMAX
      WRITE (6,6000) IYEAR, MONTH, IDAY, IHOUR, RELRAT, STOBEL,
     *               STOMAX, OBSINF, MDAYS, RELMAX
 6000 FORMAT (1H1 /// 10X,38HFLOW  RATES  FOR  MAXIMUM  ATTENUATION /
     *          10X,31HOF  HOURLY  FLOOD  HYDROGRAPHS. / 10X,9(4H----),1H- /
     *          // 6X,14HPRESENT DATE: ,I4,1H/,I2,1H/,I2,14X,6HTIME: ,I2,
     *          3HH00
     *          // 6X,25HPRESENT RATE OF RELEASE:-,12X,G11.5,8H(CUMECS)
     *          // 6X,26HPRESENT STORAGE AVAILABLE,
     *           / 6X,23HBELOW FULL WATER LEVEL:,14X,G16.10,6H(M**3)
     *          // 6X,25HMAX. STORAGE ABOVE F.W.L:,12X,G16.10,6H(M**3)
     *          // 6X,32HOBSERVED AVERAGE INFLOW RATE FOR
     *           / 6X,17HTHE PREVIOUS DAY:,20X,G11.5,8H(CUMECS)
     *          // 6X,24HPERIOD FOR MASS BALANCE:,13X,I3,8X,6H(DAYS)
     *          // 6X,37HMAX. HOURLY INCREASE IN RELEASE RATE:
     *             1X,G11.5,13H(CUMECS/HOUR)
     *          // 21X,30HSIMULATED HOURLY INFLOW RATES.
     *           / 21X,7(4H----),2H--
     *          // 5X,10H  DATE   | ,8(8X,1H|) / 5X,2(4H----),2H|-,
     *          8(9H--------|) )
C
C      READ THE SIMULATED HOURLY INFLOWS.
C
      READ (10,4900)
 4900 FORMAT (1H )
 1000 KDAY = IDAY-2
      IF (KDAY.GT. 0) GO TO 1300
      MONTH = MONTH-1
      IF (MONTH.EQ. 0) GO TO 1100
      IF (MONTH.EQ. 2 .AND. IYEAR.EQ.(IYEAR/4)*4) GO TO 1050
      KDAY = KDAY+JDAYS(MONTH)
      GO TO 1300
 1050 KDAY = KDAY+29
      GO TO 1300
 1100 KDAY = KDAY+31
      MONTH = 12
      IYEAR = IYEAR-1
```

```
C
C       SCAN RECORD FOR PRESENT DATE
C
 1300 I2 = 0
 1400 I2 = I2+1
      READ (10,5100) K, L, I1
      IF (I1.LT.IYEAR .OR. L.LT.MONTH .OR. K.LT.KDAY)  GO TO 1400
C
C       DETERMINE LENGTH OF SIMULATED RECORD AVAILABLE
C
      I3 = 59-(MDAYS-1)
      IF (I2.LT. I3) GO TO 1500
      WRITE (6,6200)
 6200 FORMAT (1H-,T10,'***** SIMULATED RECORD TOO SHORT FOR',
     *                  ' ACCEPTABLE ROUTING')
      STOP 1000
C
 1500 I2 = MDAYS
      DO 1600 J=1,I2
      READ (10,5100) K, L, I1, (HOURIN(I,J),I=1,24)
 5100 FORMAT (2I3,I5,24F5.0)
      I1 = I1-((I1/100)*100)
      WRITE (6,6100) I1, L, K, (HOURIN(I,J),I=1,24)
 6100 FORMAT (5X,2(I2,1H/),I2,3(2H| ,8(F7.1,2H |) / 13X),2H|-,
     *        8(9H--------|) )
 1600 CONTINUE
C
C       COMPUTE THE TOTAL SIMULATED INFLOWS, STARTING AT THE
C       PREVIOUS DAY, ENDING MDAYS+1 DAYS LATER.
C
      IPREV = 1
      IPRES = 2
      K = IPRES+MDAYS-1
      DO 1700 J=IPREV,K
      TOTINF(J) = HOURIN(1,J)
      DO 1700 I=2,24
 1700 TOTINF(J) = TOTINF(J)+HOURIN(I,J)
C
C       COMPUTE THE AVERAGE SIM. INFLOW FOR THE PREVIOUS DAY. (CUMECS)
C
      AVERIN = TOTINF(IPREV)/24.0
C
C
C       DETERMINE THE DAY DURING WHICH PEAK OCCURS, FOR THE
C       PERIOD STARTING AT THE PREVIOUS DAY, ENDING MDAYS DAYS
C       LATER.
C
      K = IPRES+9
      FLOMAX = 0.0
      DO 1800 J=IPREV,K
      IF (TOTINF(J).LT.FLOMAX) GO TO 1800
      FLOMAX = TOTINF(J)
      IPEAK = J
 1800 CONTINUE
 1900 IF (IPEAK.GT.IPREV) GO TO 2100
C
C       ADJUST SIMULATED INFLOWS ACCORDING TO THE PREVIOUS
C       DAY'S OBSERVED INFLOW.
C
      L = IPREV+4
      HRINCR = (OBSINF-AVERIN)/5.0
C
      DO 2000 J=IPRES,L
      DO 2000 I=1,24
 2000 HOURIN(I,J) = HOURIN(I,J)+HRINCR*(L+1-J)
C
C
C       CALCULATE THE VOLUME OF INFLOW, OVER MDAYS DAYS.
C
 2100 FLOMDA = 0.0
      J=IHOUR+1
C
      DO 2200 I=J,24
 2200 FLOMDA = FLOMDA+HOURIN(I,IPRES)
C
      K = IPRES+1
      L = IPRES+MDAYS-2
C
      DO 2300 J=K,L
      DO 2300 I=1,24
      FLOMDA =FLOMDA+HOURIN(I,J)
 2300 CONTINUE
      FLOMDA = FLOMDA*3600.0
```

```
C
C     CALCULATE THE OUTFLOW VOLUME. START WITH THE LIMIT
C     FOR OUTFLOW RATES: OUTLIM = 100.0
C
      ITER = 1
      FLAG = .FALSE.
      DELTA = 0.0
 2400 OUTLIM = 100.0*(1.0+DELTA)
      OUTVOL = 0.0
      STORAG = 0.0
      HOUREL(IHOUR,IPRES) = RELRAT
      J = IHOUR+1
C
      DO 2600 I=J,24
      HOUREL(I,IPRES) = AMIN1(OUTLIM,RELRAT+(I-IHOUR)*RELMAX)
      IF (IPRES.LE. IPEAK .OR. HOUREL(I,IPRES).LE.HOURIN(I,IPRES))
     *    GO TO 2500
      STORAG = STORAG+(HOUREL(I,IPRES)-HOURIN(I,IPRES))*3600.0
      IF (STOMAX.LT.STORAG) HOUREL(I,IPRES) = HOURIN(I,IPRES)
 2500 OUTVOL = OUTVOL+HOUREL(I,IPRES)
 2600 CONTINUE
C
C     USE THE VALUES CALCULATED FOR THE PRESENT DAY,
C     TO CALCULATE THE DAYS FOLLOWING.
C
      DO 2800 J=K,L
      DO 2800 I=1,24
      HOUREL(I,J) = HOUREL(24,K-1)+((J-K)*24.0+I)*RELMAX
      HOUREL(I,J) = AMIN1(OUTLIM,HOUREL(I,J))
      IF (J.LE.IPEAK .OR. HOUREL(I,J).LE.HOURIN(I,J)) GO TO 2700
      STORAG = STORAG+(HOUREL(I,J)-HOURIN(I,J))*3600.0
      IF (STOMAX.LT.STORAG) HOUREL(I,J) = HOURIN(I,J)
 2700 OUTVOL = OUTVOL+HOUREL(I,J)
 2800 CONTINUE
C
C     DETERMINE IF THE INFLOW EQUALS THE OUTFLOW PLUS STOBEL.
      OUTVOL = OUTVOL*3600.0
      IF (OUTVOL+STOBEL.LT.FLOMDA) GO TO 3100
C
      IF (DELTA.EQ. 0.0) GO TO 3200
      DELTA = DELTA-0.1
      FLAG = .TRUE.
C
C     TEST FOR 100 ITERATIONS.
C
 2900 IF (ITER.LE. 100.0) GO TO 3000
      WRITE (6,6300)
 6300 FORMAT ('0****  MORE THAN 100 ITERATIONS WILL BE NEEDED' /)
      GO TO 3300
C
 3000 ITER = ITER+1
      GO TO 2400
C
 3100 IF (FLAG) GO TO 3300
      DELTA = DELTA+1.0
      GO TO 2900
C
C
C
 3200 WRITE (6,6400)
 6400 FORMAT ('0****  RESERVOIR WILL NOT BE FILLED' /)
C
 3300 I1 = 2
      STATUS(IHOUR,IPRES) = 100.0-STOBEL/23301553.3
C
      J = IHOUR+1
      DO 3400 I=J,24
 3400 STATUS(I,IPRES) = STATUS(I-1,IPRES)+(HOURIN(I,IPRES)-
     *       HOUREL(I,IPRES))*1.544961382E-04
 3500 I1 = I1+1
      DO 3700 I=1,24
      IF (I.GT. 1) GO TO 3600
      J = 24
      K = I1-1
      GO TO 3700
C
 3600 J = I-1
      K = I1
```

```
C
 3700 STATUS(I,I1) = STATUS(J,K)+(HOURIN(I,I1)-HOUREL(I,I1))*
     *               1.544561382E-04
C
      IF (I1.LT. MDAYS) GO TO 3500
C
C     DETERMINE THE NUMBER OF DAYS IN THE MONTH
C
      IF (IDAY-2.GT. C) GO TO 7000
      MCNTH = MONTH+1
 7000 NDAYS = JDAYS(MONTH)
      IF (MONTH.EQ. 2 .AND. IYEAR.EQ.((IYEAR/4)*4)) NDAYS = 29
      KDAY = IDAY
      K = NDAYS
      I2 = 2
      DO 4100 J=IPRES,K
      I2 = I2+1
      IF (I2.LT. 3) GO TO 3800
      I2 = 1
      WRITE (6,6500)
 6500 FORMAT (1H1 // 19X,18HHOURLY FLOW RATES:
     *        // 19X,6(4H----),2H-- // 18X,23HHOUR    INFLOW    OUTFLOW,
     *           9H    STATUS / 25X,22HCUMECS     CUMECS        % /
     *           25X,22H------     ------       - )
 3800 WRITE (6,6600) IYEAR, MONTH, KDAY
 6600 FORMAT ( 7H DATE: ,I4,1H/,I2,1H/,I2 )
      IF(KDAY.NE.IDAY) GO TO 3900
      WRITE (6,6700) (I,HOURIN(I,J),HOUREL(I,J),STATUS(I,J),
     *           I=IHOUR,24)
      GO TO 4000
 3900 WRITE (6,6700) (I,HOURIN(I,J),HOUREL(I,J),STATUS(I,J),I=1,24)
 6700 FORMAT (19X,I2,2F9.1,F9.2)
 4000 KDAY = KDAY+1
      IF (KDAY.LE.NDAYS) GO TO 4100
      KDAY = 1
      MONTH = MONTH+1
      IF (MONTH.LE. 12) GO TO 4100
      MONTH = 1
      IYEAR = IYEAR+1
 4100 CONTINUE
      WRITE (6,6800) FLOWDA, OUTVOL, STOBEL, ITER
 6800 FORMAT (/ 1H-,18X,'INFLOW  (CUB M)  = ',F16.4
     *          / 19X,'OUTFLOW (CUB M) = ',F16.4
     *          / 19X,'STORAGE (CUB M) = ',F16.4
     *          / 19X,'ITERATIONS = ',I3 // 18X,25(2H *) /)
 9999 STOP
      END
```

FLOW RATES FOR MAXIMUM ATTENUATION
OF HOURLY FLOOD HYDROGRAPHS.

PRESENT DATE: 1978/ 1/28 TIME: 5H00

PRESENT RATE OF RELEASE:- 900.00 (CUMECS)

PRESENT STORAGE AVAILABLE,
BELOW FULL WATER LEVEL: 44950000.0 (M**3)

MAX. STORAGE ABOVE F.W.L: .0 (M**3)

OBSERVED AVERAGE INFLOW RATE FOR
THE PREVIOUS DAY: 960.00 (CUMECS)

PERIOD FOR MASS BALANCE: 10 (DAYS)

MAX. HOURLY INCREASE IN RELEASE RATE: 75.000 (CUMECS/HOUR)

SIMULATED HOURLY INFLOW RATES.

DATE								
78/ 1/27	947.0	937.0	937.0	941.0	928.0	915.0	904.0	891.0
	879.0	866.0	855.0	844.0	832.0	820.0	809.0	798.0
	788.0	776.0	767.0	756.0	752.0	801.0	898.0	956.0
78/ 1/28	1007.0	1101.0	1142.0	1145.0	1146.0	1131.0	1114.0	1100.0
	1084.0	1069.0	1058.0	1043.0	1029.0	1015.0	1002.0	988.0
	974.0	961.0	948.0	935.0	922.0	909.0	897.0	900.0
78/ 1/29	903.0	890.0	878.0	867.0	876.0	883.0	871.0	859.0
	847.0	836.0	849.0	864.0	851.0	839.0	828.0	817.0
	806.0	795.0	784.0	774.0	764.0	752.0	743.0	734.0
78/ 1/30	726.0	716.0	707.0	697.0	710.0	723.0	715.0	706.0
	695.0	686.0	677.0	667.0	658.0	651.0	640.0	632.0
	624.0	615.0	606.0	599.0	591.0	582.0	577.0	566.0
78/ 1/31	558.0	553.0	544.0	538.0	530.0	522.0	516.0	510.0
	501.0	495.0	490.0	482.0	476.0	470.0	463.0	457.0
	451.0	444.0	437.0	432.0	427.0	422.0	415.0	409.0
78/ 2/ 1	404.0	399.0	394.0	389.0	384.0	378.0	373.0	368.0
	363.0	358.0	353.0	348.0	343.0	341.0	336.0	331.0
	326.0	322.0	317.0	314.0	309.0	304.0	301.0	297.0
78/ 2/ 2	294.0	289.0	286.0	281.0	277.0	274.0	270.0	267.0
	263.0	261.0	255.0	255.0	250.0	246.0	243.0	240.0
	237.0	233.0	230.0	227.0	226.0	222.0	218.0	216.0
78/ 2/ 3	213.0	210.0	207.0	207.0	202.0	201.0	196.0	194.0
	192.0	189.0	186.0	185.0	182.0	180.0	180.0	174.0
	173.0	170.0	168.0	167.0	165.0	162.0	160.0	159.0
78/ 2/ 4	156.0	155.0	152.0	149.0	148.0	147.0	144.0	143.0
	142.0	139.0	137.0	136.0	135.0	132.0	131.0	130.0
	127.0	125.0	125.0	121.0	121.0	120.0	119.0	116.0
78/ 2/ 5	116.0	113.0	113.0	111.0	109.0	107.0	106.0	106.0
	104.0	102.0	101.0	100.0	98.0	98.0	98.0	95.0
	94.0	93.0	93.0	93.0	91.0	88.0	88.0	86.0

Table B8 : Sample output from program HRYGOP

HOURLY FLOW RATES:

HOUR	INFLOW CUMECS	OUTFLOW CUMECS	STATUS %
DATE: 1978/ 1/28			
5	1146.0	900.0	98.07
6	1131.0	630.0	98.15
7	1114.0	630.0	98.22
8	1100.0	630.0	98.30
9	1084.0	630.0	98.37
10	1069.0	630.0	98.43
11	1058.0	630.0	98.50
12	1043.0	630.0	98.56
13	1029.0	630.0	98.63
14	1015.0	630.0	98.68
15	1002.0	630.0	98.74
16	988.0	630.0	98.80
17	974.0	630.0	98.85
18	961.0	630.0	98.90
19	948.0	630.0	98.95
20	935.0	630.0	99.00
21	922.0	630.0	99.04
22	909.0	630.0	99.09
23	897.0	630.0	99.13
24	900.0	630.0	99.17
DATE: 1978/ 1/29			
1	903.0	630.0	99.21
2	890.0	630.0	99.25
3	878.0	630.0	99.29
4	867.0	630.0	99.33
5	876.0	630.0	99.36
6	883.0	630.0	99.40
7	871.0	630.0	99.44
8	859.0	630.0	99.48
9	847.0	630.0	99.51
10	836.0	630.0	99.54
11	849.0	630.0	99.58
12	864.0	630.0	99.61
13	851.0	630.0	99.65
14	839.0	630.0	99.68
15	828.0	630.0	99.71
16	817.0	630.0	99.74
17	806.0	630.0	99.76
18	795.0	630.0	99.79
19	784.0	630.0	99.81
20	774.0	630.0	99.84
21	764.0	630.0	99.86
22	752.0	630.0	99.88
23	743.0	630.0	99.89
24	734.0	630.0	99.91

HOURLY FLOW RATES:

	HOUR	INFLOW CUMECS	OUTFLOW CUMECS	STATUS %
DATE: 1978/ 1/30				
	1	726.0	630.0	99.92
	2	716.0	630.0	99.94
	3	707.0	630.0	99.95
	4	697.0	630.0	99.96
	5	710.0	630.0	99.97
	6	723.0	630.0	99.99
	7	715.0	630.0	100.00
	8	706.0	630.0	100.01
	9	695.0	630.0	100.02
	10	686.0	630.0	100.03
	11	677.0	630.0	100.04
	12	667.0	630.0	100.04
	13	658.0	630.0	100.05
	14	651.0	630.0	100.05
	15	640.0	630.0	100.05
	16	632.0	630.0	100.05
	17	624.0	624.0	100.05
	18	615.0	615.0	100.05
	19	606.0	606.0	100.05
	20	599.0	599.0	100.05
	21	591.0	591.0	100.05
	22	582.0	582.0	100.05
	23	577.0	577.0	100.05
	24	566.0	566.0	100.05
DATE: 1978/ 1/31				
	1	558.0	558.0	100.05
	2	553.0	553.0	100.05
	3	544.0	544.0	100.05
	4	538.0	538.0	100.05
	5	530.0	530.0	100.05
	6	522.0	522.0	100.05
	7	516.0	516.0	100.05
	8	510.0	510.0	100.05
	9	501.0	501.0	100.05
	10	495.0	495.0	100.05
	11	490.0	490.0	100.05
	12	482.0	482.0	100.05
	13	476.0	476.0	100.05
	14	470.0	470.0	100.05
	15	463.0	463.0	100.05
	16	457.0	457.0	100.05
	17	451.0	451.0	100.05
	18	444.0	444.0	100.05
	19	437.0	437.0	100.05
	20	432.0	432.0	100.05
	21	427.0	427.0	100.05
	22	422.0	422.0	100.05
	23	415.0	415.0	100.05
	24	409.0	409.0	100.05

HOURLY FLOW RATES:

	HOUR	INFLOW CUMECS	OUTFLOW CUMECS	STATUS %
DATE: 1978/ 2/ 1				
	1	404.0	404.0	100.05
	2	399.0	399.0	100.05
	3	394.0	394.0	100.05
	4	389.0	389.0	100.05
	5	384.0	384.0	100.05
	6	378.0	378.0	100.05
	7	373.0	373.0	100.05
	8	368.0	368.0	100.05
	9	363.0	363.0	100.05
	10	358.0	358.0	100.05
	11	353.0	353.0	100.05
	12	348.0	348.0	100.05
	13	343.0	343.0	100.05
	14	341.0	341.0	100.05
	15	336.0	336.0	100.05
	16	331.0	331.0	100.05
	17	326.0	326.0	100.05
	18	322.0	322.0	100.05
	19	317.0	317.0	100.05
	20	314.0	314.0	100.05
	21	309.0	309.0	100.05
	22	304.0	304.0	100.05
	23	301.0	301.0	100.05
	24	297.0	297.0	100.05
DATE: 1978/ 2/ 2				
	1	294.0	294.0	100.05
	2	289.0	289.0	100.05
	3	286.0	286.0	100.05
	4	281.0	281.0	100.05
	5	277.0	277.0	100.05
	6	274.0	274.0	100.05
	7	270.0	270.0	100.05
	8	267.0	267.0	100.05
	9	263.0	263.0	100.05
	10	261.0	261.0	100.05
	11	255.0	255.0	100.05
	12	255.0	255.0	100.05
	13	250.0	250.0	100.05
	14	246.0	246.0	100.05
	15	243.0	243.0	100.05
	16	240.0	240.0	100.05
	17	237.0	237.0	100.05
	18	233.0	233.0	100.05
	19	230.0	230.0	100.05
	20	227.0	227.0	100.05
	21	226.0	226.0	100.05
	22	222.0	222.0	100.05
	23	218.0	218.0	100.05
	24	216.0	216.0	100.05

HOURLY FLOW RATES:

DATE: 1978/ 2/ 3

HOUR	INFLOW CUMECS	OUTFLOW CUMECS	STATUS %
1	213.0	213.0	100.05
2	210.0	210.0	100.05
3	207.0	207.0	100.05
4	207.0	207.0	100.05
5	202.0	202.0	100.05
6	201.0	201.0	100.05
7	196.0	196.0	100.05
8	194.0	194.0	100.05
9	192.0	192.0	100.05
10	189.0	189.0	100.05
11	186.0	186.0	100.05
12	185.0	185.0	100.05
13	182.0	182.0	100.05
14	180.0	180.0	100.05
15	180.0	180.0	100.05
16	174.0	174.0	100.05
17	173.0	173.0	100.05
18	170.0	170.0	100.05
19	168.0	168.0	100.05
20	167.0	167.0	100.05
21	165.0	165.0	100.05
22	162.0	162.0	100.05
23	160.0	160.0	100.05
24	159.0	159.0	100.05

DATE: 1978/ 2/ 4

HOUR	INFLOW CUMECS	OUTFLOW CUMECS	STATUS %
1	156.0	156.0	100.05
2	155.0	155.0	100.05
3	152.0	152.0	100.05
4	149.0	149.0	100.05
5	148.0	148.0	100.05
6	147.0	147.0	100.05
7	144.0	144.0	100.05
8	143.0	143.0	100.05
9	142.0	142.0	100.05
10	139.0	139.0	100.05
11	137.0	137.0	100.05
12	136.0	136.0	100.05
13	135.0	135.0	100.05
14	132.0	132.0	100.05
15	131.0	131.0	100.05
16	130.0	130.0	100.05
17	127.0	127.0	100.05
18	125.0	125.0	100.05
19	125.0	125.0	100.05
20	121.0	121.0	100.05
21	121.0	121.0	100.05
22	120.0	120.0	100.05
23	119.0	119.0	100.05
24	116.0	116.0	100.05

HOURLY FLOW RATES:

DATE: 1978/ 2/ 5

HOUR	INFLOW CUMECS	OUTFLOW CUMECS	STATUS %
1	116.0	116.0	100.05
2	113.0	113.0	100.05
3	113.0	113.0	100.05
4	111.0	111.0	100.05
5	109.0	109.0	100.05
6	107.0	107.0	100.05
7	106.0	106.0	100.05
8	106.0	106.0	100.05
9	104.0	104.0	100.05
10	102.0	102.0	100.05
11	101.0	101.0	100.05
12	100.0	100.0	100.05
13	98.0	98.0	100.05
14	98.0	98.0	100.05
15	98.0	98.0	100.05
16	95.0	95.0	100.05
17	94.0	94.0	100.05
18	93.0	93.0	100.05
19	93.0	93.0	100.05
20	93.0	93.0	100.05
21	91.0	91.0	100.05
22	88.0	88.0	100.05
23	88.0	88.0	100.05
24	86.0	86.0	100.05

INFLOW (CUB M) = 326822400.
OUTFLOW (CUB M) = 280651264.
STORAGE (CUB M) = 44950000.0
ITERATIONS = 14

* *

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