TR 120

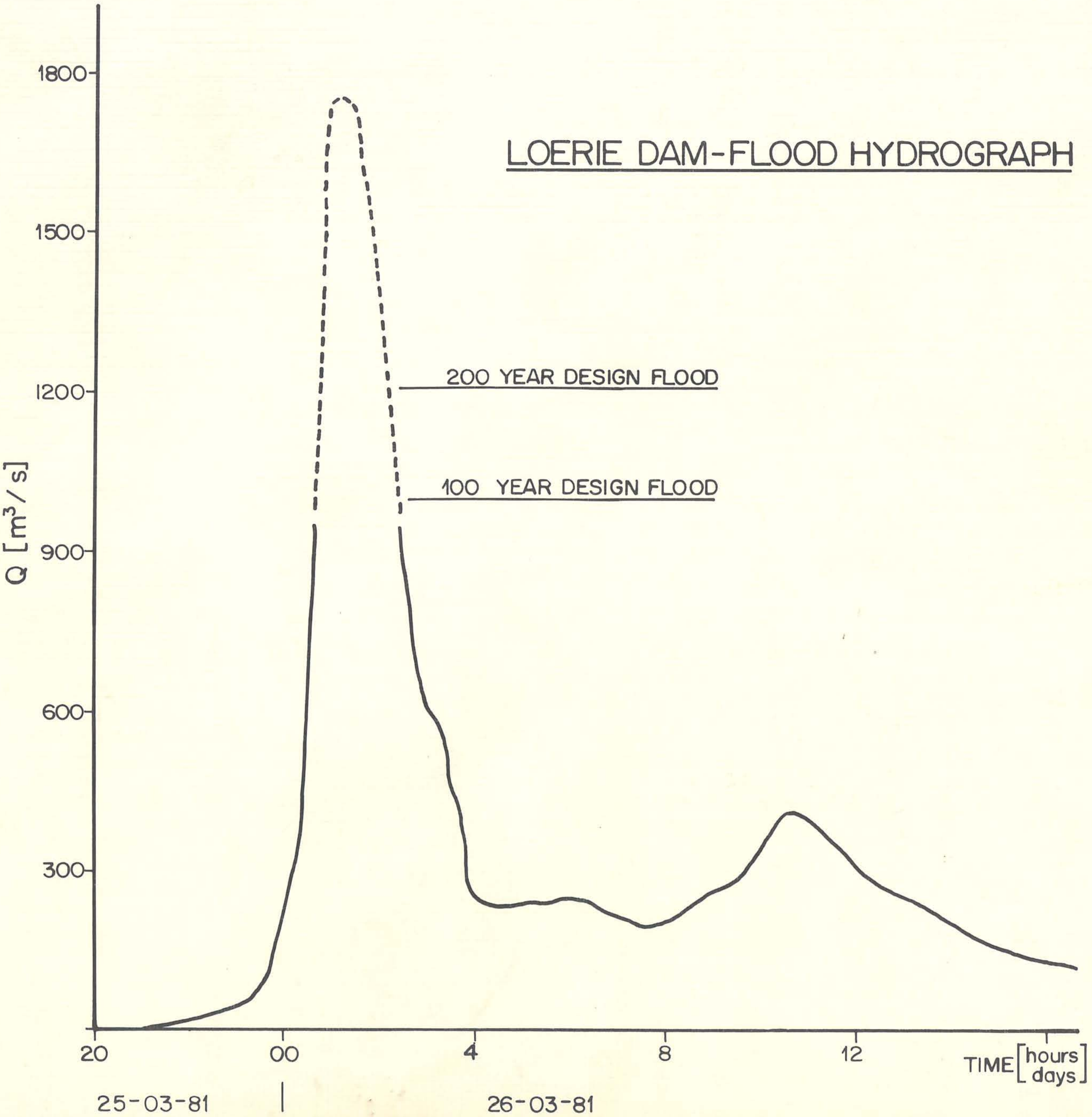
Gerhard Boayn

REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS

Documentation of the March-May 1981 floods in the South Eastern Cape

D B Du Plessis



DEPARTMENT OF WATER AFFAIRS

DIVISION OF HYDROLOGY

Technical Report TR 120

DOCUMENTATION OF THE MARCH - MAY 1981 FLOODS IN THE SOUTH EASTERN CAPE

Compiled by

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1. INTRODUCTION

The Southern parts of the Cape Province had four big storms during January - May 1981. The January event has been described in (1). This report describes the March, April and May 1981 storms. As the January event these later storms caused deaths and serious flooding to farmlands and structures in various areas. (Figure 1.1)

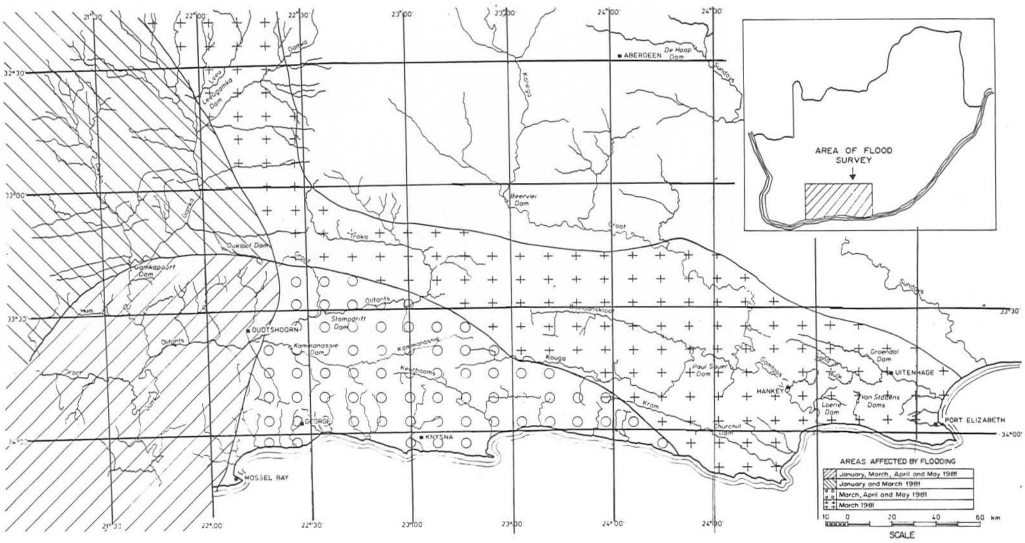


FIGURE 1.1 APPROXIMATE BOUNDARIES OF AREAS AFFECTED BY FLOODING IN JANUARY – MAY 1981

The March storm was the most destructive of the later storms and covered by far the largest area. During this storm at least 14 people lost their lives and 195 had to be moved to safety by helicopter.

The main purpose of this report is to make hydrological flood information available for future use in technical or scientific problems. This report also discusses the meteorological conditions that caused the high rainfall, the flood survey, peak discharges, hydrographs and return periods of flood peaks and rainfall. The extraordinary floods in the Loerie Dam catchment are briefly reviewed in a separate chapter.

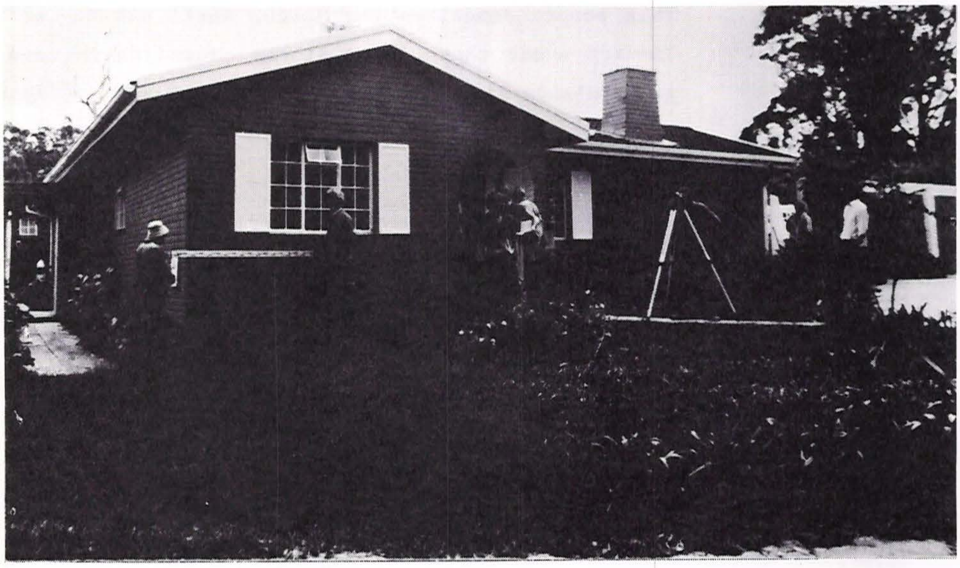


Figure 1.2 House on the bank of the Bakens river: The staff indicates the high water level (site 52).

2. HYDROLOGICAL PERSPECTIVE

The various drainage regions and distribution of some of the hydro-meteorological stations are shown in Fig 2.1 (3).

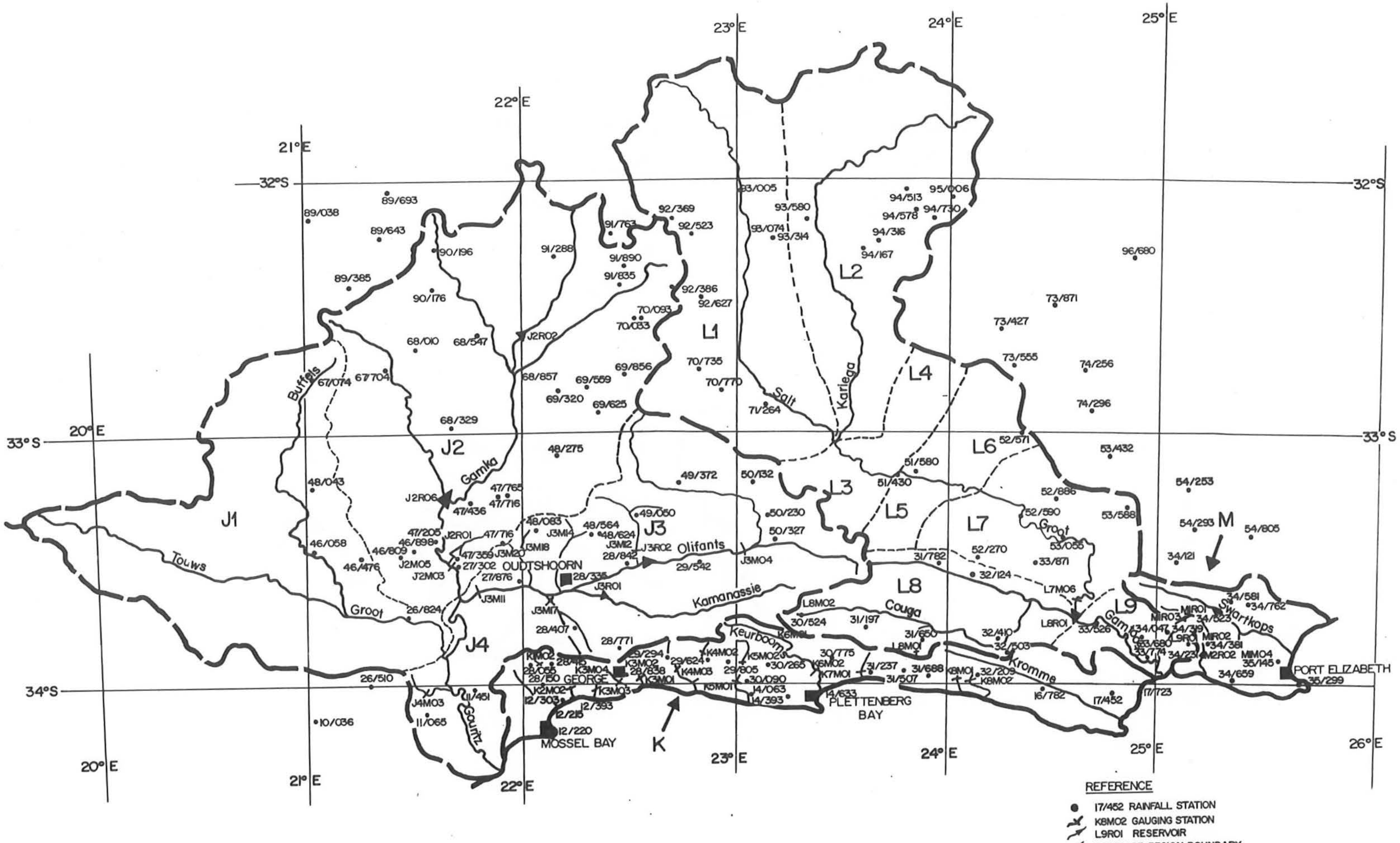


FIG. 2.1 DRAINAGE REGIONS J K L M - DISTRIBUTION OF HYDRO-METEOROLOGICAL STATIONS.

2.1 Climate

The climate of the flooded area varies from humid in the eastern and coastal regions in the south to semi-arid further inland. (2)

The mean annual rainfall can be seen in Fig. 2.2

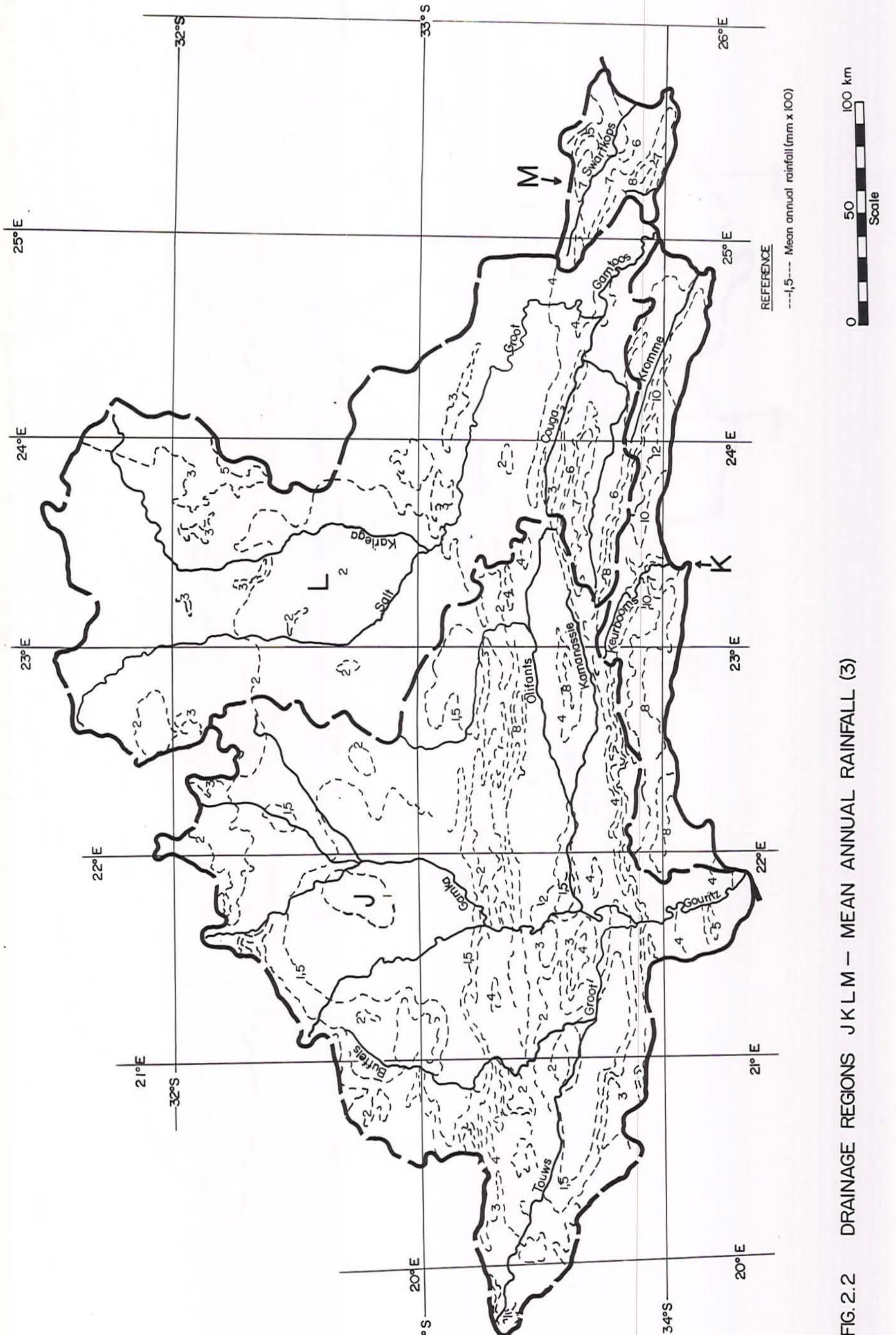


FIG. 2.2 DRAINAGE REGIONS J K L M – MEAN ANNUAL RAINFALL (3)

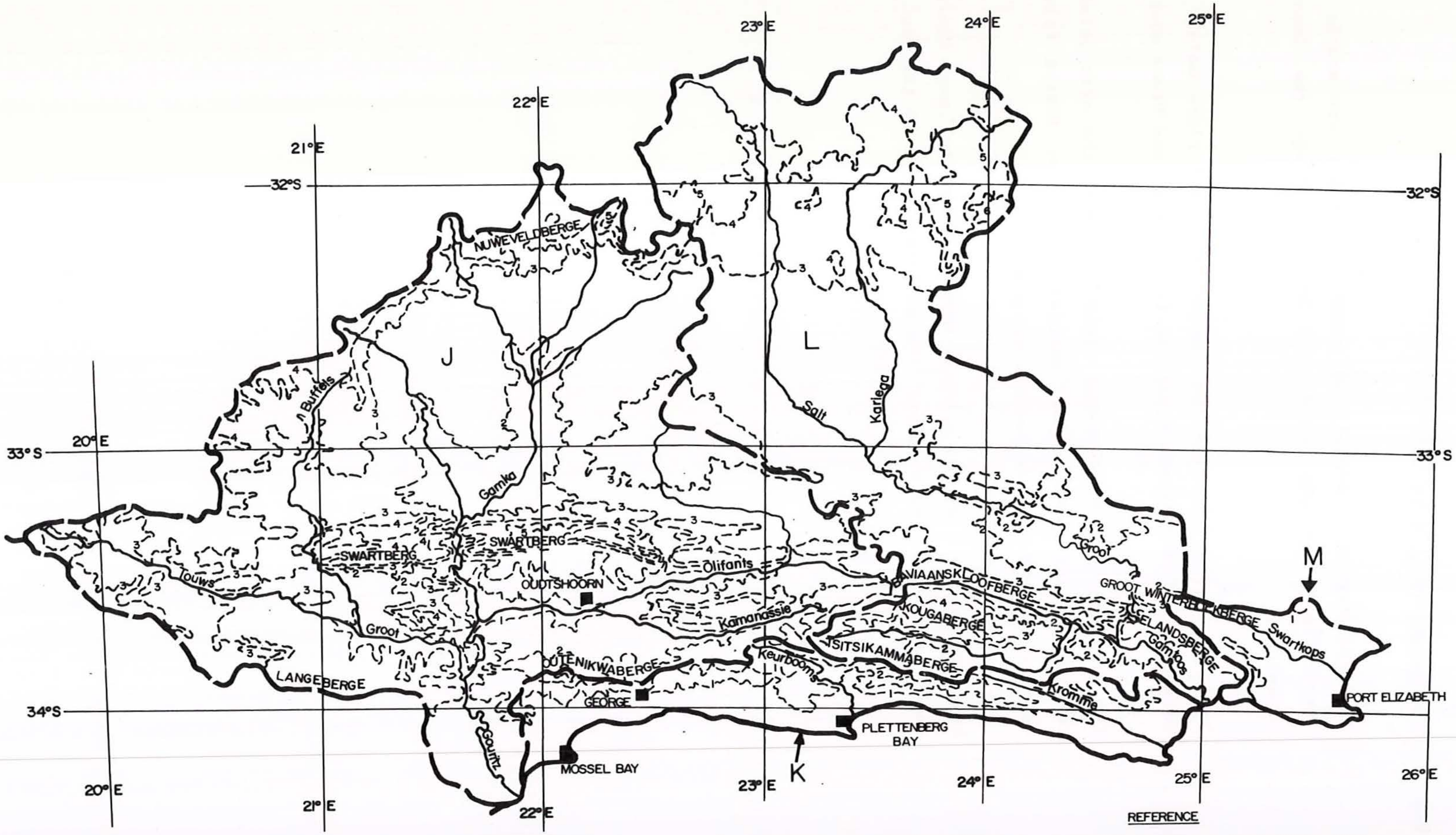
2.2 Topography (Fig. 2.3)

Drainage region J drains the interior plateau and starts in the Nuweveldberge in the north and breaks through the Swart- and Langeberge.

Drainage region K drains the coastal area and rises mainly in the Outenikwa and Tsitsikamma mountains in the north and flows south.

The southern part of drainage region L drains the area between the Tsitsikamma and Baviaanskloof mountains . These rivers follow the mountain range eastwards towards the sea.

Drainage region M drains a small area between the Groot Winterhoek- and Elandsberge. These rivers flow south-eastwards to the sea.



REFERENCE

-4- GROUND CONTOURS (10^3 FEET ABOVE SEA LEVEL)

0 50 100 km
Scale

FIG. 2.3 DRAINAGE REGIONS J K L M – TOPOGRAPHY (3)

2.3 Geology and Soil Types

Fine sediments of the Karoo System dominate the northern part of drainage region J. The rest of the flooded area has a broken relief, and the rocks are mainly coarse and fine sedimentary with some unconsolidated sandy deposits near the coast.

Figure 2.4: Soil erosion in drainage region L9.

As can be seen in Fig. 2.5 lithosols dominate the whole area with some arenosols near the coastline.

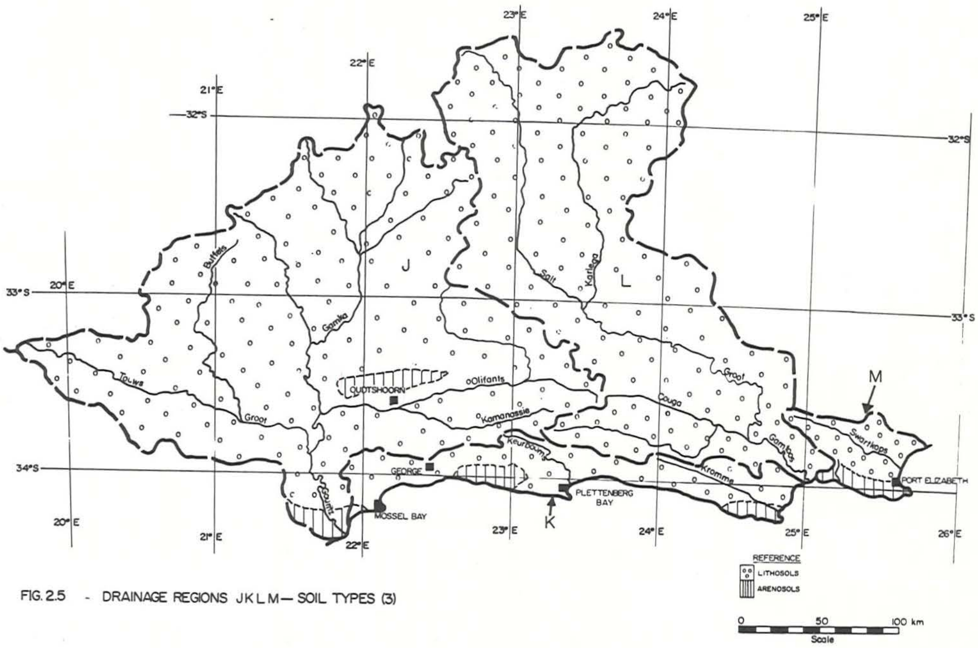


FIG. 2.5 - DRAINAGE REGIONS JKLM— SOIL TYPES (3)

2.4 Veld Types (4)

The vegetation of the flooded area is listed in Table 2.1. (4)

TABLE 2.1: VEGETATION OF THE FLOODED AREA

Drainage Region	Sites	Veld Types
J2 Upper part	1 - 9	Karroid Broken Veld
J2 Lower part		False Macchia Succulent Mountain Scrub Succulent Karroo
J3	10 - 18	Succulent Mountain Scrub False Macchia Karroid Broken Veld
J4	19	Coastal Macchia
K1	20	Coastal Renosterbosveld False Macchia
K4	21 - 37	Knysna Forest
L7	38	False Macchia Succulent Mountain Scrub Valley Bushveld Karroid Broken Veld Succulent Karoo
L8	36, 37, 39	False Macchia Succulent Mountain Scrub
L9, M	40 - 53	Valley Bushveld dominates the lower areas with some False Macchia on the mountains

2.5 Historic Rainfall

Adamson's analysis (5) of historic rainfall was used to plot Figure 2.6 and determine the return period of the storm rainfall. Only the 3 day storm rainfall in the Loerie dam area exceeded the 3 day 100 year rainfall.

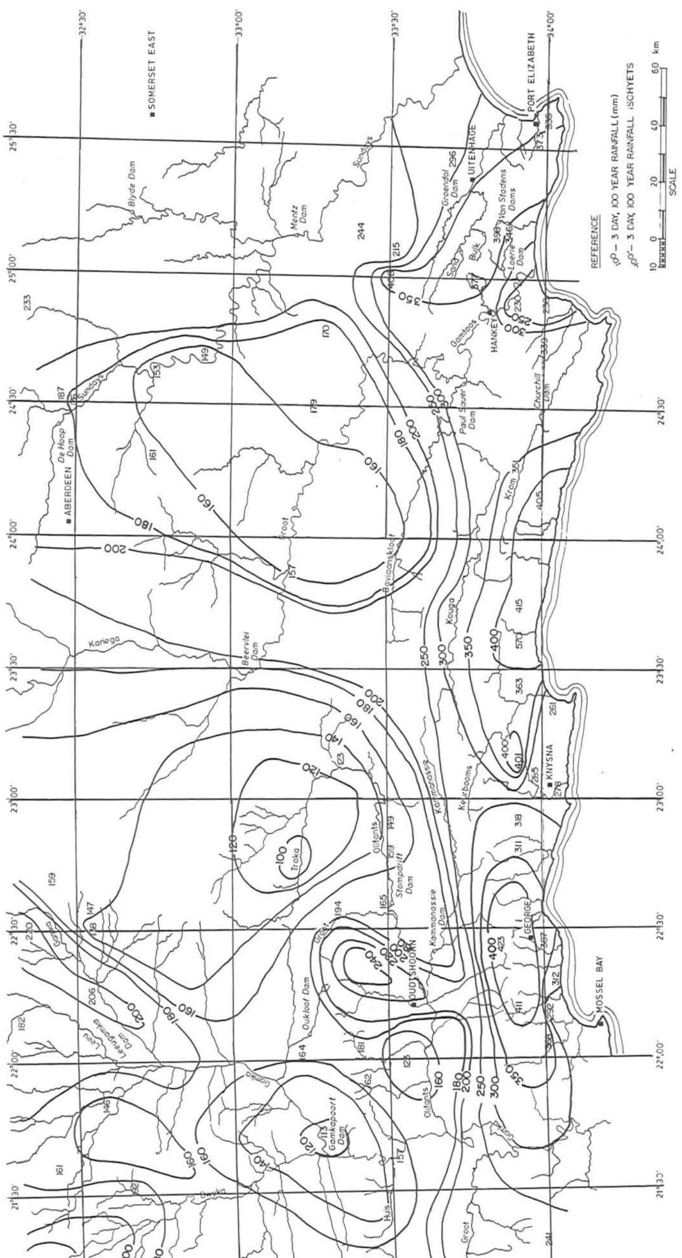


FIG. 2.6 3 DAY 100 YEAR RAINFALL IN MILLIMETRES (based on ref. 5)

3. THE STORMS

In this section the weather pattern for March - May 1981 is compared with the long term average, the synoptic situation leading up to each storm is described, and antecedent conditions and storm rainfall are reconstructed.

The purpose of reconstructing the storm was to determine the depth and return period of rainfall for each catchment and to compare that with the volume of runoff and return period of the flood peak.

The approximate areas covered by various storm rainfall depths for the three storms are listed in Table 3.1. (Daily rainfall from 11 Weather Bureau rainfall stations for the period March - May are listed in Table 3.2.)

TABLE 3.1 APPROXIMATE AREAS IN km^2 THAT EXPERIENCED RAINFALL DEPTHS OF 50 - 250 mm

Date of flood	Rainfall depth in mm				
	> 50	> 100	> 150	> 200	> 250
March 1981	65 000	23 700	10 600	4 800	2 000
April 1981	14 900	7 000	140	-	-
May 1981	32 500	9 200	4 800	950	140

Table 3.2: Daily rainfall at 11 Weather Bureau rainfall stations

W.P. Station	Calitsdorp Dam 47/359			Oudtshoorn 28/335			George 28/838			Harkerville Bos 14/393			Stompdrift Dam 49/060			Joubertina 31/650		
Date	Mar	Apr	May	Mar	Apr	May	Mar	Apr	May	Mar	Apr	May	Mar	Apr	May	Mar	Apr	May
1							5,0	1,0	6,5									0,9
2							3,0		1,5	20,0		2,5				0,3		
3							0,5	2,0		12,0								
4						0,5		0,5	20,0			5,5						
5						1,0		1,5	13,5			13,0						4,5
6								1,2			14,0	3,5						1,1
7								1,5	0,2	3,0								
8						0,5	0,7		0,5									0,8
9																		
10																		
11			2,5			2,5			4,5			5,5			16,5			9,1
12			3,5			2,0			11,5			17,5			8,5			29,7
13																		1,6
14										8,0						0,9		
15							7,5											
16								5,5										
17																	0,7	
18																		
19																		
20							0,6											1,8
21									5,0									
22				8,5			11,6			14,0	9,0					12,0		
23	7,0						3,0	12,0		8,0	4,0						3,7	
24	43,0			3,5	1,0		11,0	12,0		10,5			12,0			16,0		
25	60,0	7,0		37,3	8,0		120,5	2,0	0,2	108,5	56,0	9,0	60,0			107,0		
26		9,0		4,0	29,0		2,0	63,0	5,5	22,0	72,0	3,0		47,5	1,5	12,2	30,6	
27		15,0	34,0		6,5			66,5	2,5								22,6	
28		3,0	14,0			26,0		2,0	78,0			100,0			12,5		3,6	48,6
29						29,5			104,0	2,0		95,0			35,0			107,5
30									2,2									8,2
31							1,5											0,1

W.P. Station	The Island Bos 34/659			Hankey 33/680			Port Elizabeth 35/299			Groendal Bos 34/523			Longmore Bos 34/231		
Month / Day	Mar	Apr	May	Mar	Apr	May	Mar	Apr	May	Mar	Apr	May	Mar	Apr	May
1			7,1	1,5						12,0		2,0			
2				0,3		6,0			7,0			0,9			
3															
4			9,5			3,0			6,5			3,5			
5			12,5			0,8			11,0			17,0			
6		7,0	0,5									3,5			
7															
8	15,0						1,0	0,7							
9				3,0		0,2						1,5			
10															
11			1,8			8,5			19,5			12,5			
12			19,7			0,2			4,2						
13			4,5						1,6						
14													3,0		
15	18,0	21,0		1,0			38,0			15,5				x	
16					0,7			10,0			6,5			10,5	
17															
18												1,0			
19															
20				1,2		0,2									
21				5,0											
22															
23	19,0			3,0										x	
24	26,5	2,8		25,0			16,1	3,5	0,1	23,0	7,5		32,0	x	
25	258,0	5,5		153,0		0,4	139,1		0,1	274,5	5,0	1,0	318,0	x	
26	35,5	13,2	4,5	13,0	2,2	2,0	40,0	x	2,2	19,0	1,5	6,0	111,0	15,0	2,7
27	12,0	2,7	9,5	2,8	3,8	0,2		11,0	3,7	3,5	0,9	40,5		4,5	x
28		1,5	8,0		1,0	24,5			8,7			15,0		5,1	x
29	5,8		17,5			9,5		1,5	8,5						x
30			8,9			2,0			20,0			3,0			x
31															48,6

x - Day is part of an accumulation period.

3.1 March 1981

3.1.1 Weather Pattern

The March rainfall over the flooded area was 200% - 300% higher than the long term average. (Figure 3.1 (6)) Most of this rainfall fell on the 25 March and caused flooding.

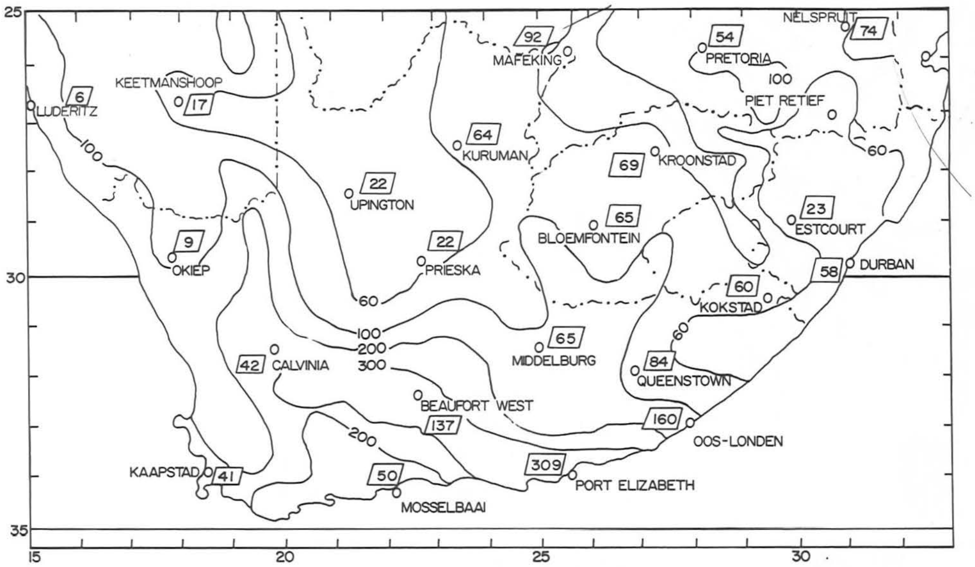
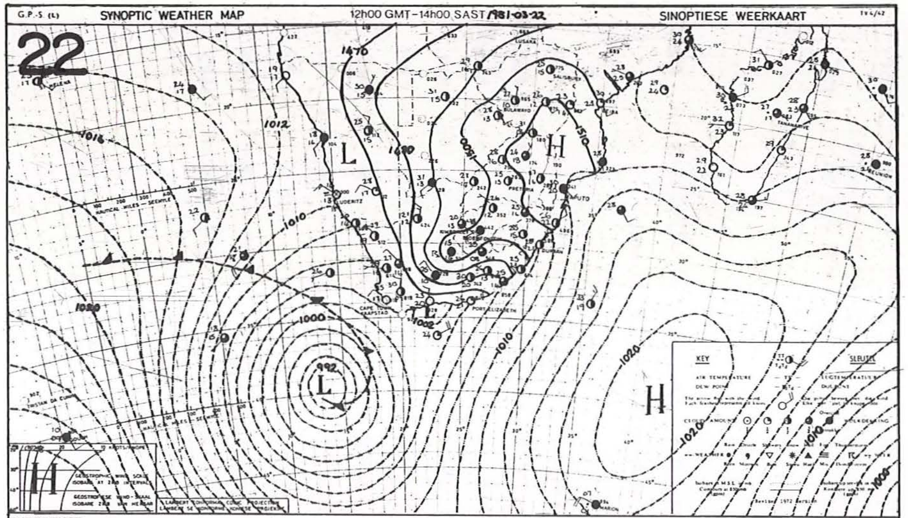


FIGURE 3.1 RAINFALL FOR MARCH 1981 AS A PERCENTAGE OF THE NORMAL. FIGURES IN BLOCKS ARE THE TOTAL RAINFALL (mm) FOR THE MONTH. (6)

3.1.2 Synoptic Situation (Figure 3.2)

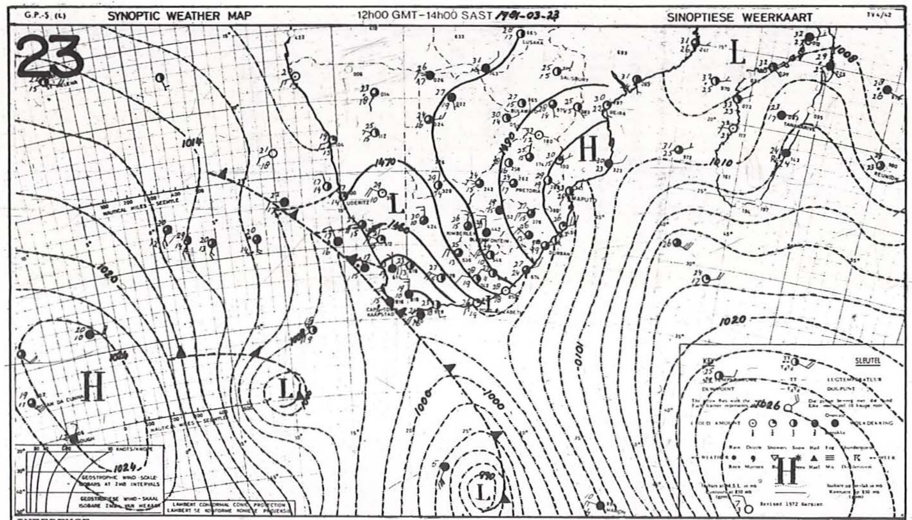
The sequence of synoptic events for the period 22-25 March as described by S.J. Quinn (6) can be summarised as follows:

A low pressure system and cold front developed on the 22nd, south west of Cape Town. The cold front reached Cape Town on the 23rd and the cell moved in the direction of Marion Island. It rained over the South West Cape. A trough of low pressure was situated at the west coast on the 23rd. A second cell developed behind the front on the 23rd and moved towards the west coast on the 24th. A cut-off low developed at all levels south west of Cape Town. The surface low moved eastwards and was situated at Somerset East on the 25th with the coastal low situated just east of the country. An Atlantic high pressure cell ridged into the low pressure system and caused heavy rains on the east coast and surrounding areas.



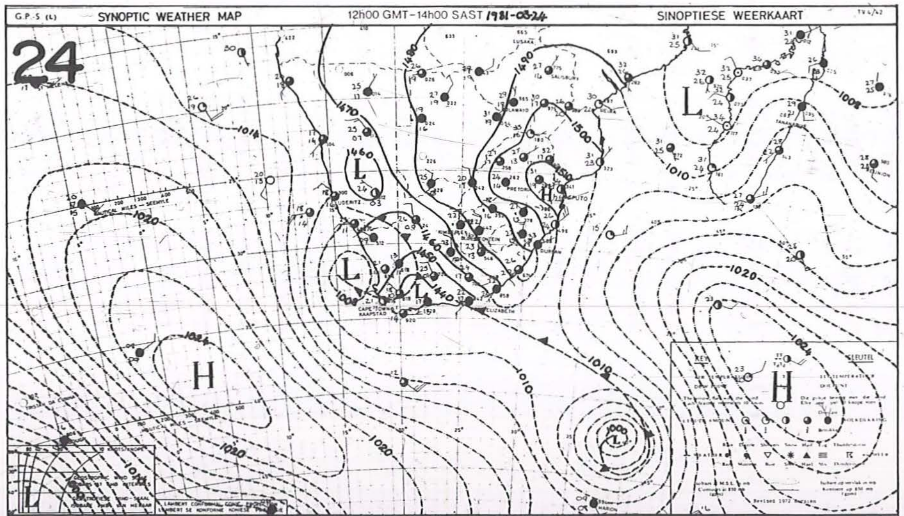
INFERENCE.

A trough is situated over the western parts of the country and scattered thundershowers will occur over the central and eastern parts. The cold front will move in over the southwestern parts of the country and it will become cloudy and colder over these areas with rain.



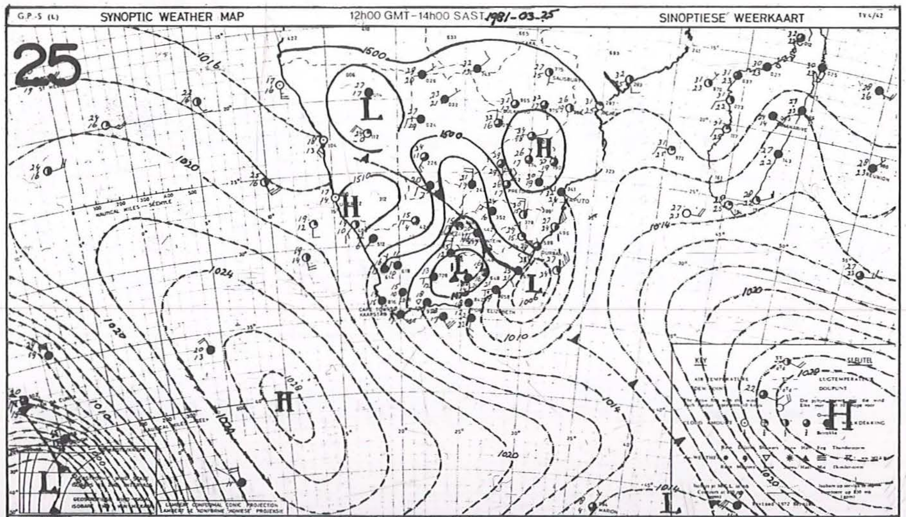
INFERENCE

The cold front at Cape Town will move eastwards and it will become cloudy and cold with rain over the southwestern parts of Cape province. The air in circulation over the eastern half and northern parts of the country is moist and scattered thundershowers are expected over these regions.



INFERENCE.

The low-pressure system along the western Cape coast will move in over the country and the high south-west of the country will ridge further eastwards. Scattered rain and showers will occur over most parts of the country. Cold weather with intermittent rain will spread eastwards over the Cape Province.



INFERENCE.

A cut off low-pressure system in the upper air is situated over Western Cape and the high southwest of the country is ridging eastwards and intensifying. General rain will occur over the southern parts of the Cape Province, with heavy falls over Eastern Cape. Thundershowers will also occur over Natal, Free State and Transvaal.

FIG. 3.2 SYNOPTIC WEATHER CHARTS AT 12h00 GMT ON 22-25 MARCH 1981

3.1.3 Antecedent Conditions

The rainfall for the 15 day period preceding the first day of the storm is indicated in Figure 3.4. Table 3.1 indicates that most of the antecedent rainfall fell just before the main storm.

3.1.4 The storm rainfall

The area affected by this storm can be seen in Figure 1.1 and Table 3.1.

The storm rainfall started approximately at 08h00 on 25.3.81 and lasted for ± 24 hours (see Fig. 3.3). The rainfall intensity for this 24 hour period at W.B. Station 35/179 in Port Elizabeth was 11,0 mm/hour.

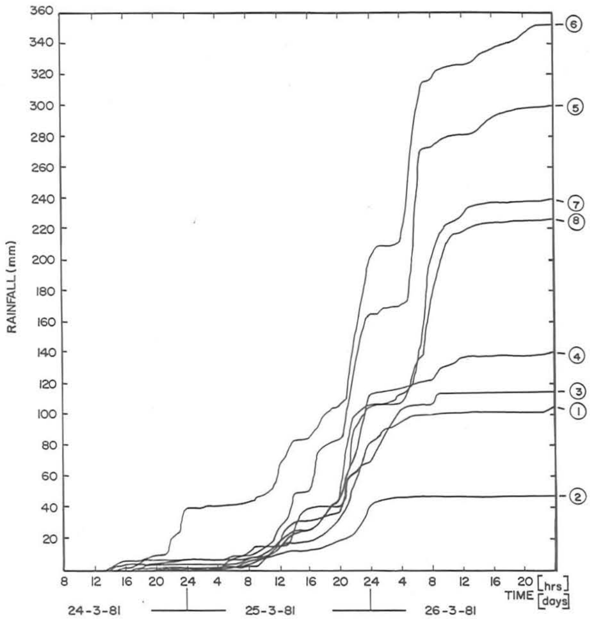


FIGURE 3.3. ACCUMULATED RAINFALL FOR 08h00 24th MARCH 1981 TO 24 h00 26th MARCH 1981 AT :

(1) GEORGE WEATHER BEREAU STATION NO. 28/690
(2) OUDTSHOORN " " " " 28/336
(3) WILLOWMORE " " " " 50/887
(4) UITENHAGE " " " " 37/769
(5) PORT ELIZABETH " " " " 35/179
(6) " MUNICIPALITY STATION 3 AT CHELSEA RADIO STATION
(7) " " " 9 " BETHELSDORP RENT OFFICE
(8) " " " 12 " MUNICIPAL MARKET_MARKMAN

Rainfall figures from 145 Weather Bureau rainfall stations (140 daily and 5 autographic) and 9 autographic rainfall stations run by the municipality of Port Elizabeth were used to reconstruct the storm (see Fig. 3.4).

As the rainfall duration was not the same at all the rainfall stations a total storm rainfall was used instead of a fixed period rainfall. The total storm rainfall is the sum of all rainfall of 5 mm or more that fell on successive days. At rainfall stations receiving 10 mm or more rain in the two days before the main storm, this amount of rain was also included in the storm rainfall.

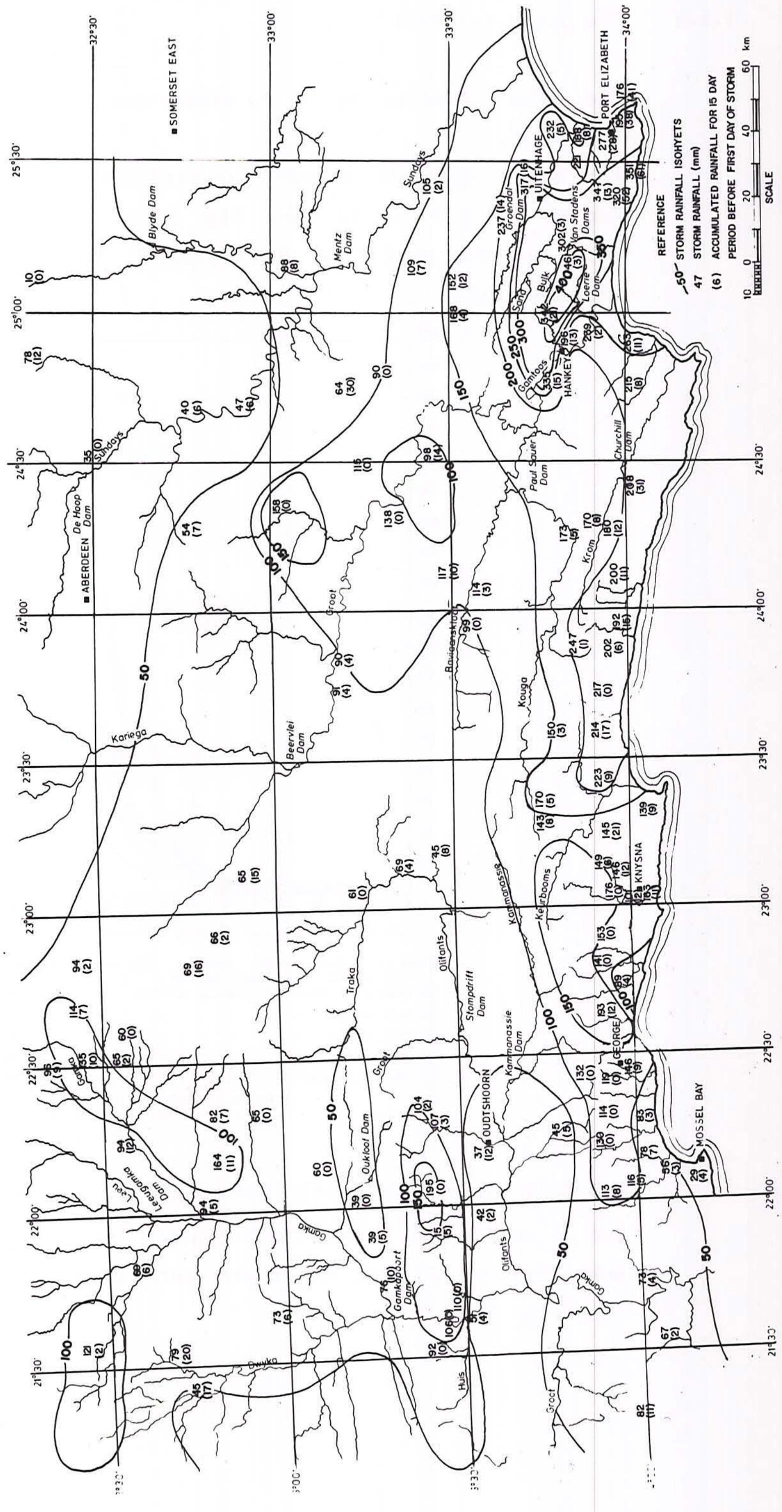


FIG.3.4 STORM RAINFALL ISOHYETS MARCH 1981

The catchment rainfall depths were calculated by plotting all the storm rainfall figures, drawing isohyets and measuring the areas between the isohyets with a planimeter. Storm rainfall depths can be seen in column 4 and column 14 of Appendix I.

Isohyetal maps similar to the one shown in Fig. 2.6 were plotted for the 2 and 3 days: 5, 20 and 100 year rainfall (5). The mean point rainfall over each catchment was determined from these maps. The mean areal rainfall was obtained by multiplying the mean point rainfall on each catchment by the areal reduction factors from Fig. 3.5.

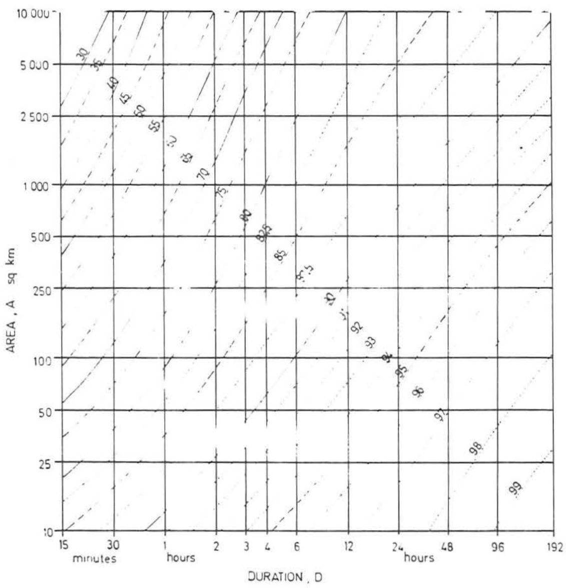


FIG.3.5 AREAL REDUCTION FACTORS (13)

The mean areal rainfall for each catchment with return periods of 5, 20 and 100 years were plotted on log-normal probability paper and the return period of the storm rainfall for each catchment was determined by interpolation or extrapolation between the known values.

Point rainfalls as high as 224 mm and 372 mm were recorded at Port Elizabeth and Loerie dam on the morning of the 26th March, 1981. The South African maximum one day rainfall is 590 mm and was recorded on the 5th of May 1940 at Eshowe (5).

3.2 April 1981

3.2.1 Weather pattern (Figure 3.6)

April was a dry month over most of the country except over the Southern Cape Province where more than 200% of the normal rainfall fell. This rain fell mainly on the 26th and 27th and caused flooding in that area (7).

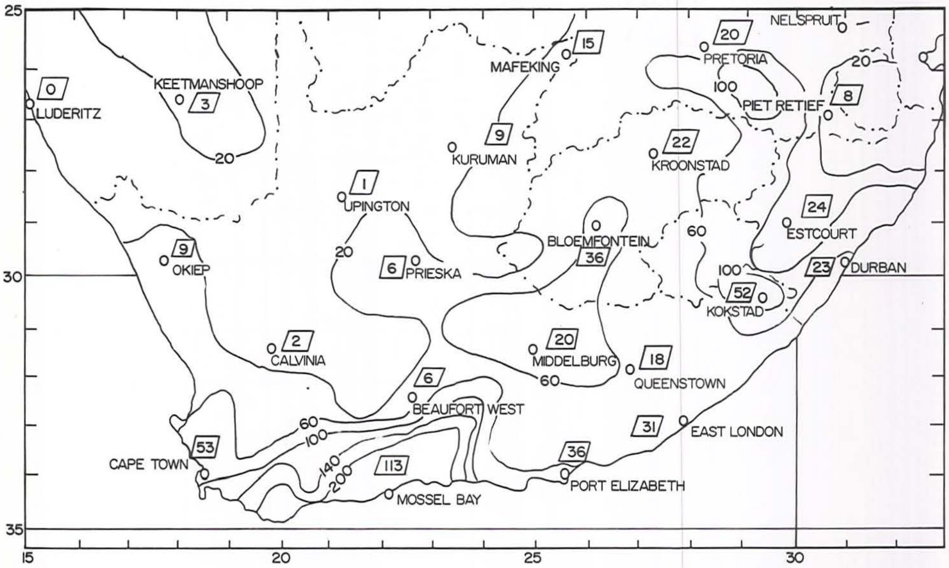


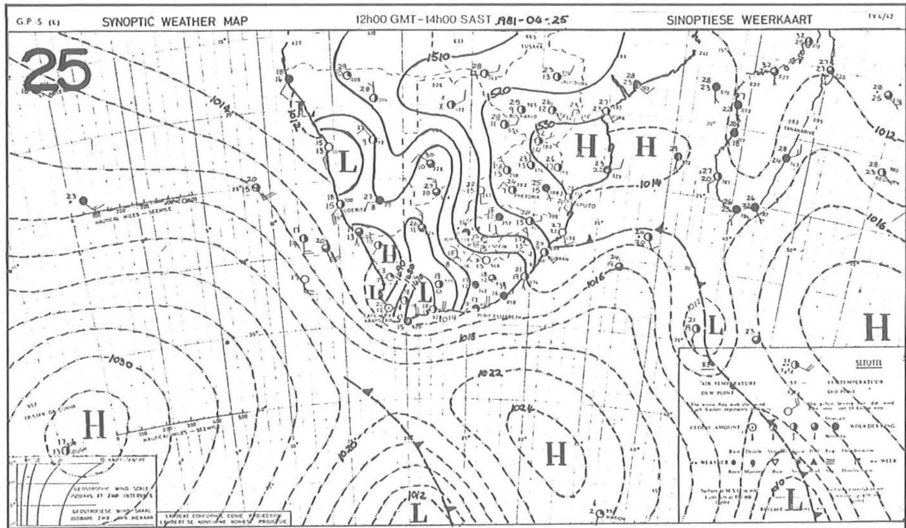
FIGURE 3.6 RAINFALL FOR APRIL 1981 AS A PERCENTAGE OF THE NORMAL. FIGURES IN BLOCKS ARE THE TOTAL RAINFALL (mm) FOR THE MONTH. (7)

3.2.2 Synoptic situation (Fig.3.7)

C. Keyworth (7) described the sequence of synoptic events for the period 23rd to the 27th of April as follows:

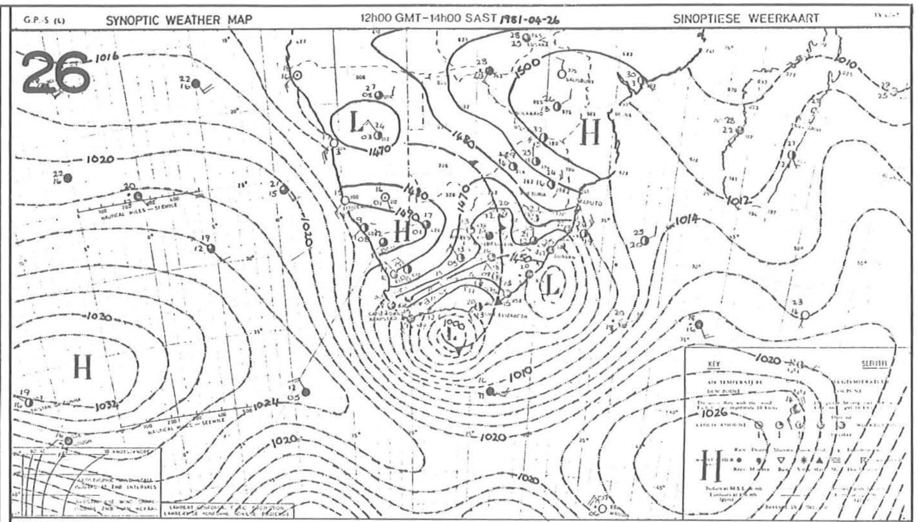
"A weak cold front which passed through Cape Town on the 23rd led to light rain along the south-western coast as well as over the Southern and Eastern Cape. A strong ridge of the Atlantic High then developed behind the front causing colder weather to spread over the southern regions of the Republic. A weak low-pressure area formed over the central regions and isolated showers and thundershowers fell over the Northern and Eastern Cape, Natal and the Free State. On the 25th a pronounced trough developed over the South-Western Cape and fairly

19



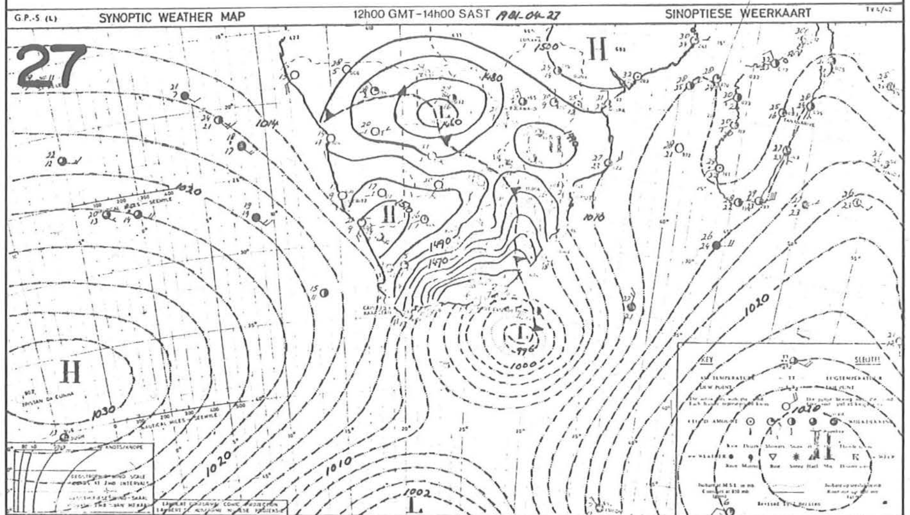
INFERENCE.

The low over Southwestern Cape will intensify and will move slowly southeastwards. Further rain and showers will occur over Free State, Natal, Southern parts of the Free State and the southern and eastern parts of the Cape Province.



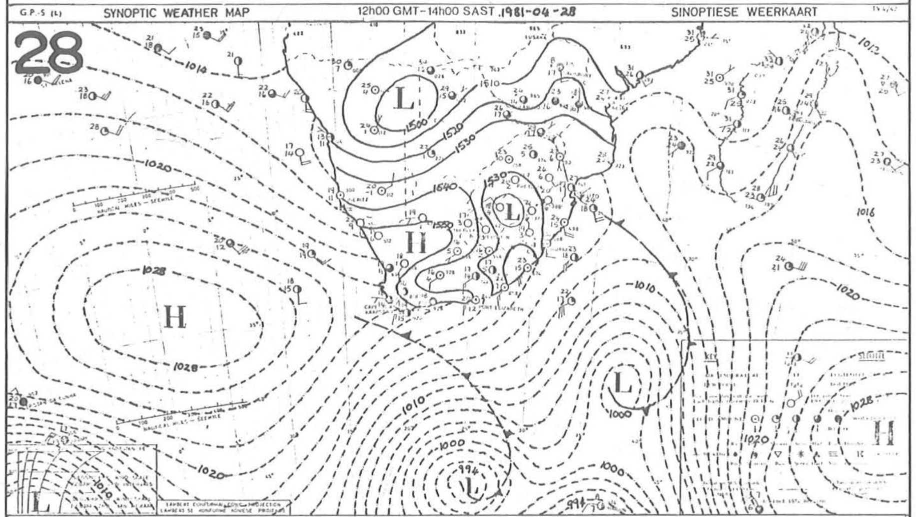
INFERENCE.

The frontal system over the country is moving eastwards. It will be cloudy and cold over most parts of the Republic with rain and showers. Snow falls will occur over the mountains. These conditions will gradually clear from the west.



INFERENCE.

The cold front is moving eastwards and the rainy conditions over the eastern and southern parts will clear. It will therefore be fine and cold over most parts of the country tomorrow.



INFERENCE.

A high is ridging in behind the cold front south of the country and cloudy cooler weather with light showers will spread along the southern and southeastern coastal regions. Over the interior it will be fine and somewhat warmer tomorrow.

FIG. 3.7 SYNOPTIC WEATHER CHARTS AT 12h00 GMT ON 25-28 APRIL 1981 widespread precipitation occurred again over all these regions, as well as the Southern Cape. By the following day the trough had deepened considerably, forming a well-defined low south of the continent. Cold air moved in over the whole of the western and central regions of the country with moderate to heavy rainfalls over the South-Western and Southern Cape. However, in the warm air in advance of the front, some heavy thundershowers developed over the Southern and Central Transvaal, the Northern and North-Eastern Free State and over Natal. Reports of hail were also received. Further light rain occurred on the 27th over the south-western and eastern regions of the Cape Province but over the Southern Cape heavy downpours caused local flooding. It gradually cleared over the central interior and over Natal, while colder rainy weather spread to the Northern and Eastern Transvaal as the front moved eastwards. Light snowfalls occurred over some of the higher mountain peaks in the South-Western Cape and the Malutis."

3.2.3 Antecedent conditions

The rainfall for the 15 day period preceding the first day of the storm is indicated on Fig. 3.9. As can be seen in Fig. 3.9 and Table 3.1 little rain fell before the main storm on 26-27 April 1981.

3.2.4 The storm rainfall

The area affected by the storm can be seen in Figures 1.1 and 3.9. Figure 3.8 shows the accumulative rainfall at three autographic Weather Bureau raingauges. From Fig. 3.8 it can be seen that the main storm started at approximately 00h00 on 27 of April and lasted approximately 12 hours.

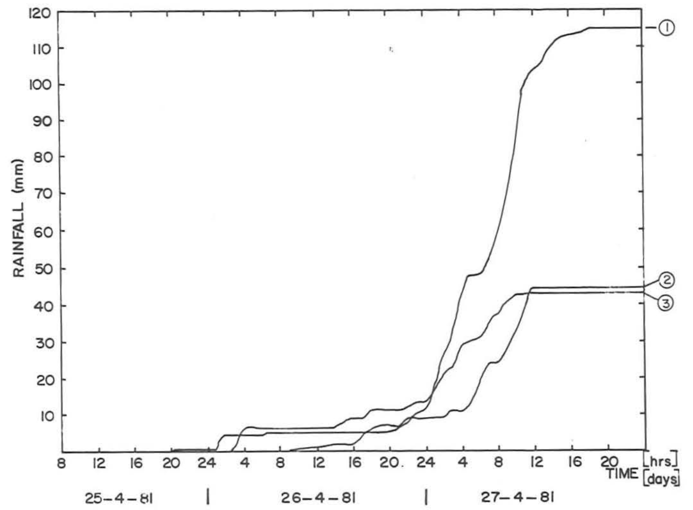


FIG. 3.8 ACCUMULATED RAINFALL FOR 08h00 25th APRIL 1981 TO 24h00 27th APRIL 1981 AT:

① GEORGE W.B. STATION NO. 28/690
② OUDTSHOORN W.B. " " 28/336
③ WILLOWMORE " " " 50/887

The rainfall depth was obtained by using 68 daily and 3 autographic Weather Bureau rainfall stations. The depth and return period of the rainfall on each catchment was calculated as described in 3.1.4.

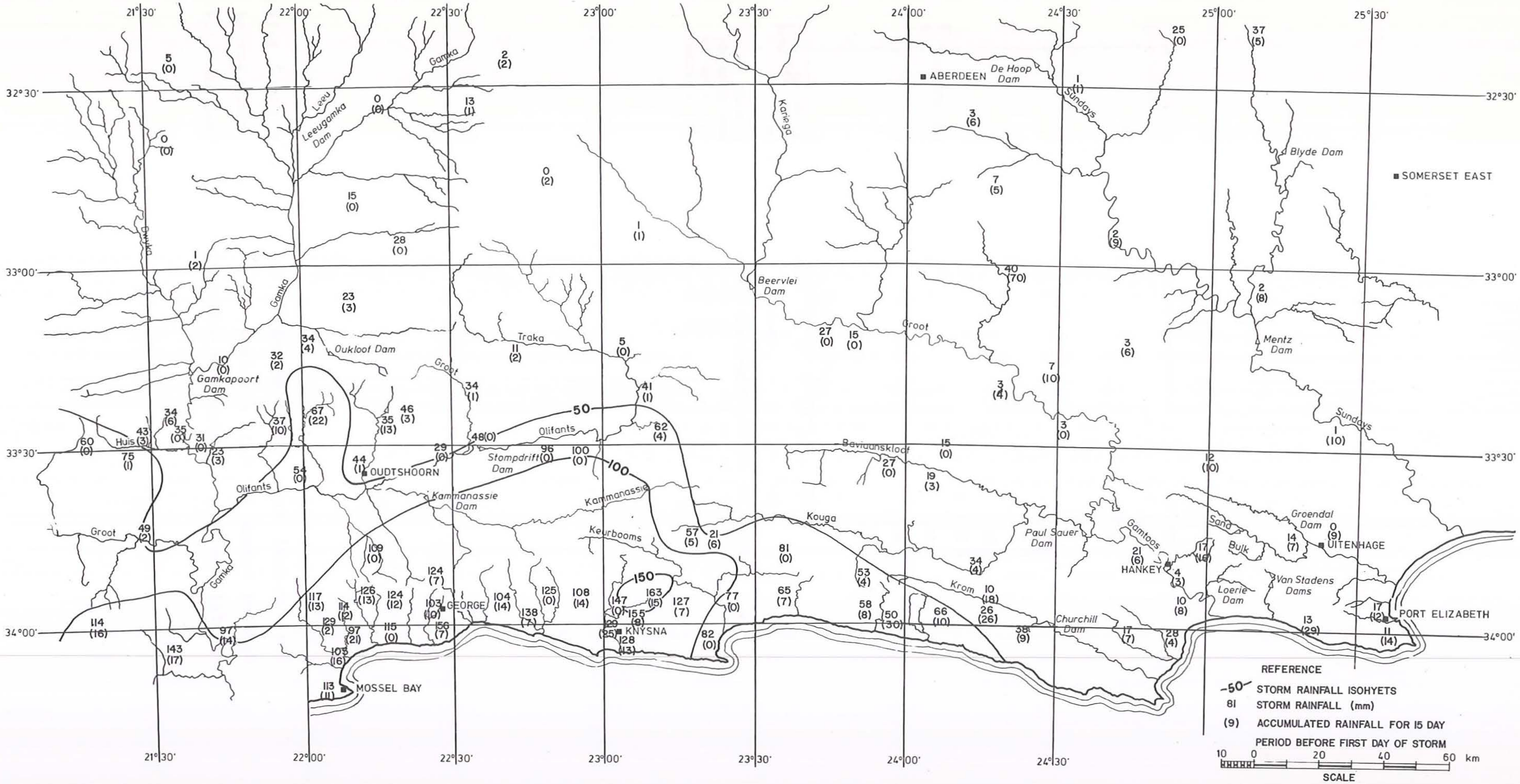


FIG. 3.9 STORM RAINFALL ISOHYETS APRIL 1981

3.3 May 1981

3.3.1 Weather pattern

The George-Knysna area that was most affected by flooding received more than 200% of the normal rainfall for May as shown by Figure 3.10 (8). Most of this rainfall occurred during the last few days of May.

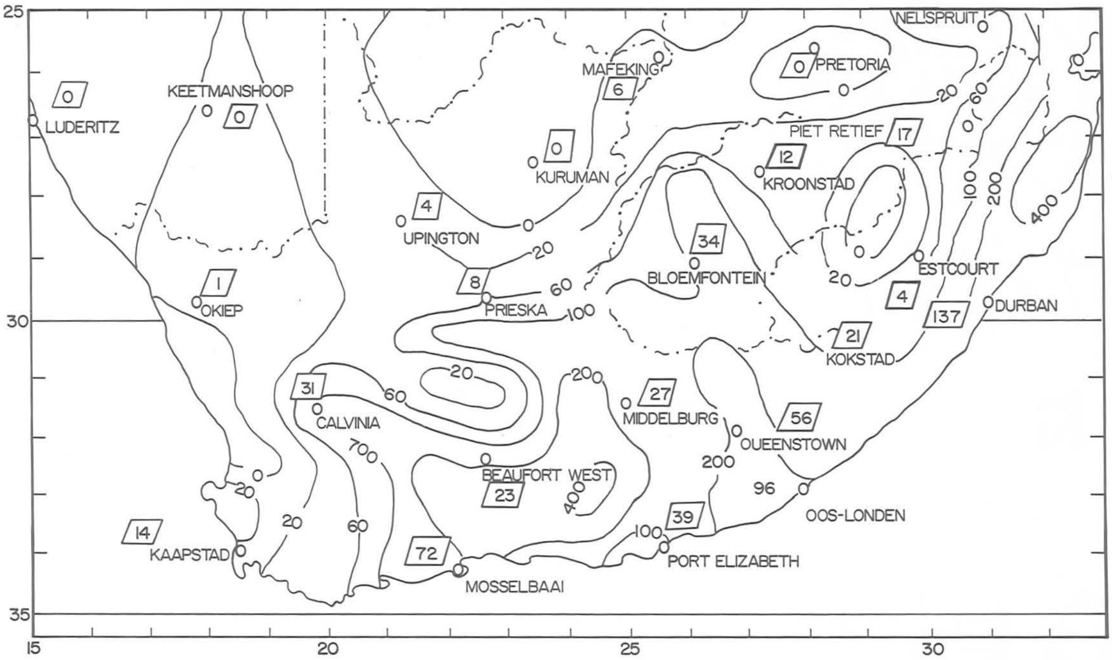
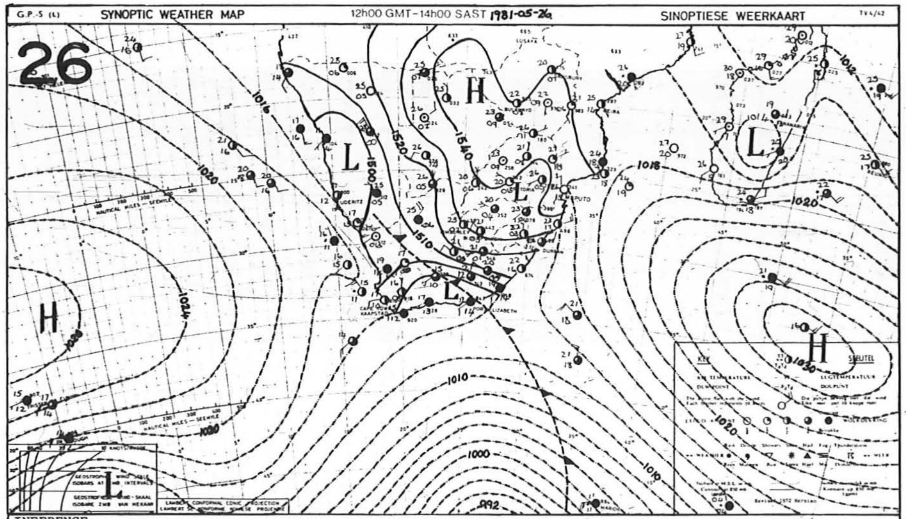


FIGURE 3.10 RAINFALL IN MAY 1981 AS A PERCENTAGE OF THE NORMAL. FIGURES IN BLOCKS ARE TOTAL RAINFALL (mm) FOR THE MONTH.

3.3.2 Synoptic situation (Fig. 3.11)

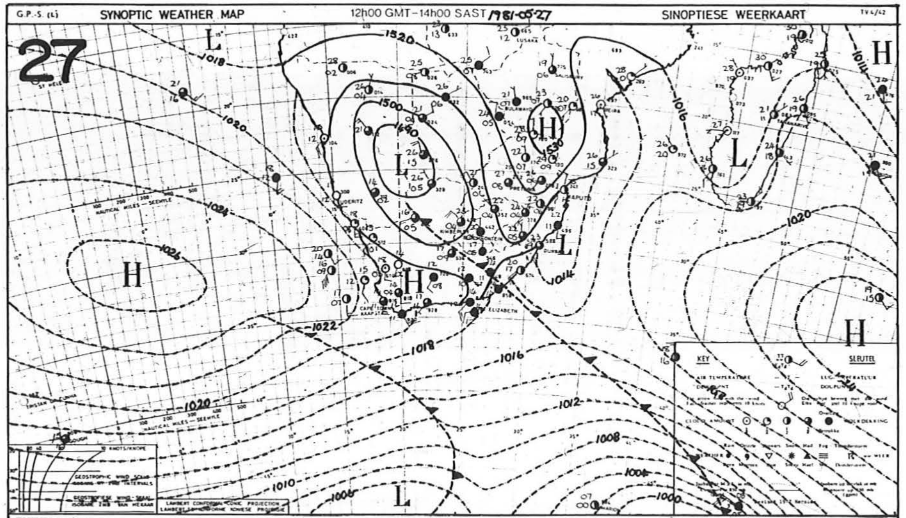
The sequence of synoptic events for the period 25th to 29th of May as described by K.J. Moir (8) can be summarised as follows:

A cut off low was situated south of Cape Town on the 25th and a west coast trough developed. A little rain occured over the south western Cape. The west coast trough deepened and a deep low pressure system was situated over S.W.A. on the 27th, the high pressure system over the South Atlantic ocean ridged in south of the land and formed a Black South Easter pattern. The centre of the system was situated over the George-Plettenberg Bay area. A rainfall of 156 mm was recorded at Joubertina for the 28-29th of May.



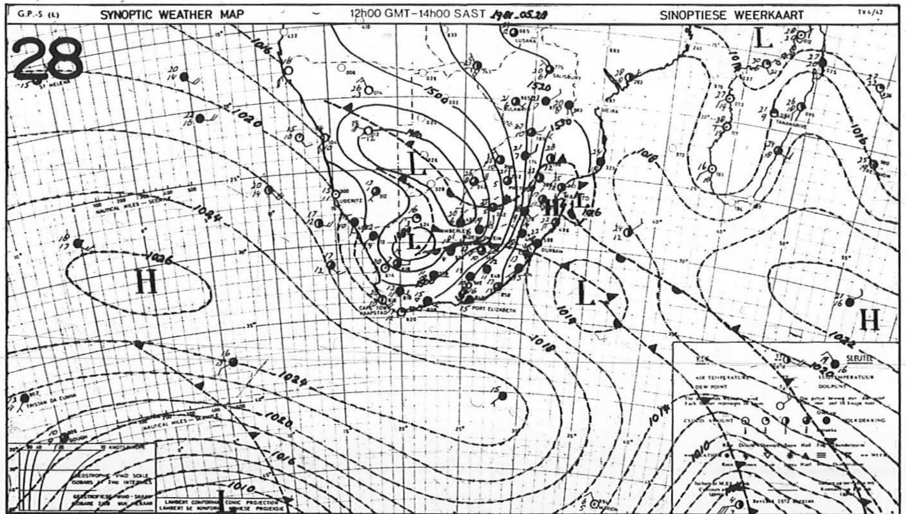
INFERENCE.

The cold front will move eastwards over the southern parts of the country and it will be cloudy and cold over these areas with light rain at places. These conditions will clear gradually from the west tomorrow.



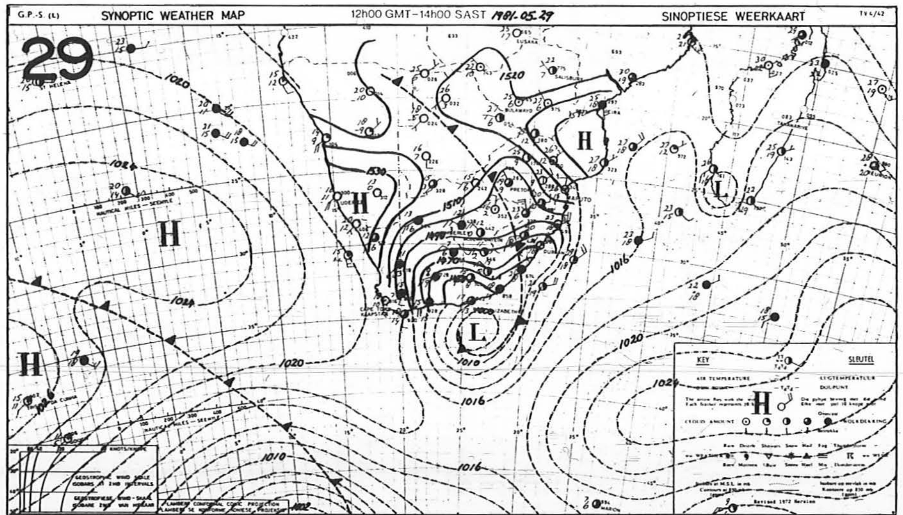
INFERENCE.

The cold front over the interior is moving slowly eastwards and colder weather will spread to the Free State and Natal. Thundershowers will develop over the central parts while rain or showers will fall over the southern and eastern regions.



INFERENCE.

A deep low-pressure system over the Western Cape associated with a strong ridge of high pressure south of the continent is causing an inflow of moist air over the southern, central and eastern regions of the country. Over these areas it will therefore be cloudy and cold with rain and showers.



INFERENCE.

The low pressure system at Port Elizabeth will move northeastwards and the cloudy conditions with rain over the central and eastern parts of the Cape Province will clear partially. The cold front will move eastwards and it will also become cold over Natal and the southern half of Transvaal.

FIG. 3.11 SYNOPTIC WEATHER CHARTS AT 12h00 GMT ON 26-29 MAY 1981

3.3.3 Antecedent Conditions

The May-flood was the third of successive monthly floods. Fig. 3.13 indicates that the accumulative antecedent rainfall over the flooded area for the 15 day period preceding the storm was more than 10 mm. Table 3.1 shows the area received some rain in the beginning of May and some just before the storm.

3.3.4 The Storm Rainfall

The area affected by the flood event can be seen in Figures 1.1 and 3.13. Figure 3.12 shows that the rainfall intensity at George was 3,75 mm/hour and the duration of the storm was ± 30 hours.

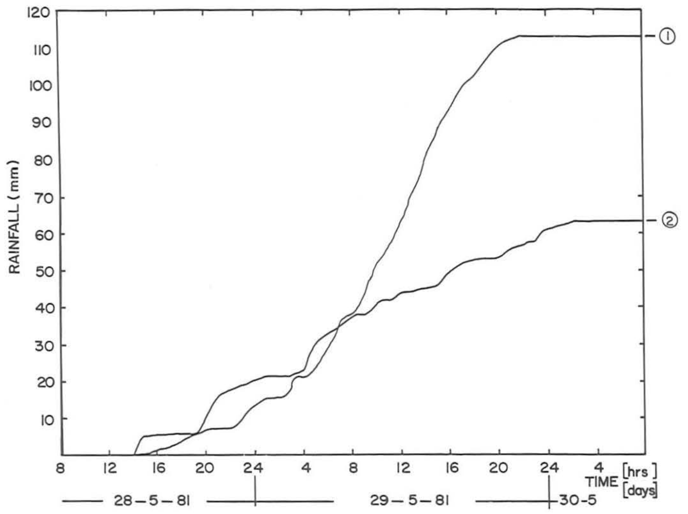


FIG. 3.12
ACCUMULATED RAINFALL FOR 08h00 28th MAY 1981 – 08h00 30th MAY 1981 AT :
① GEORGE - WEATHER BUREAU STATION NO. 28/690.
② WILLOWMORE – " " " " 50/887.

The rainfall depth in each catchment was calculated from figures obtained from 98 daily and 2 autographic Weather Bureau raingauges. Storm rainfall depth and return periods were calculated as described in section 3.1.4.

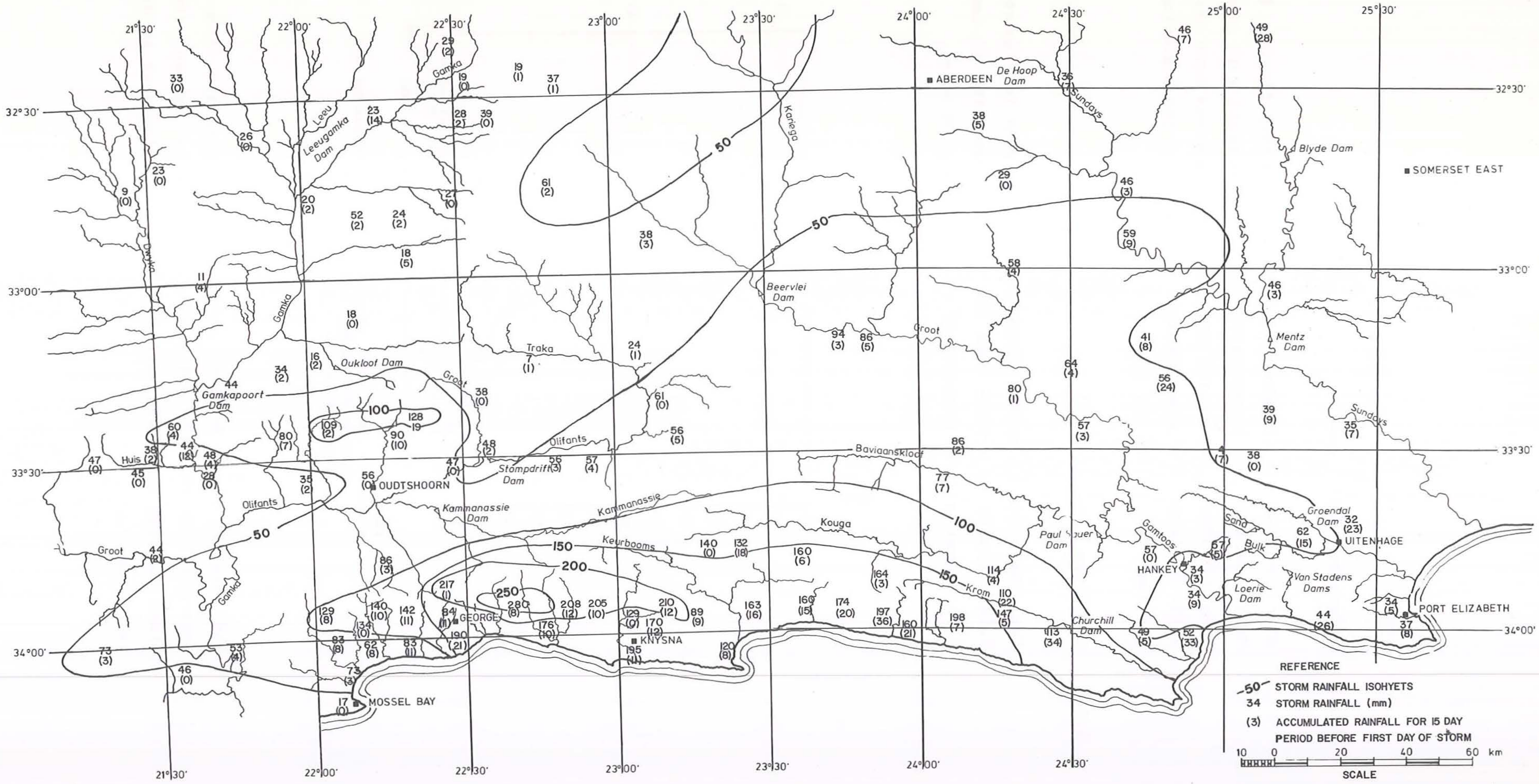


FIG.3.13 STORM RAINFALL ISOHYETS MAY 1981

4. THE FIELD SURVEY

The various areas covered by the three floods are shown in Figure 1.1. The sites where flood measurements have been taken are shown in Figure 4.1.

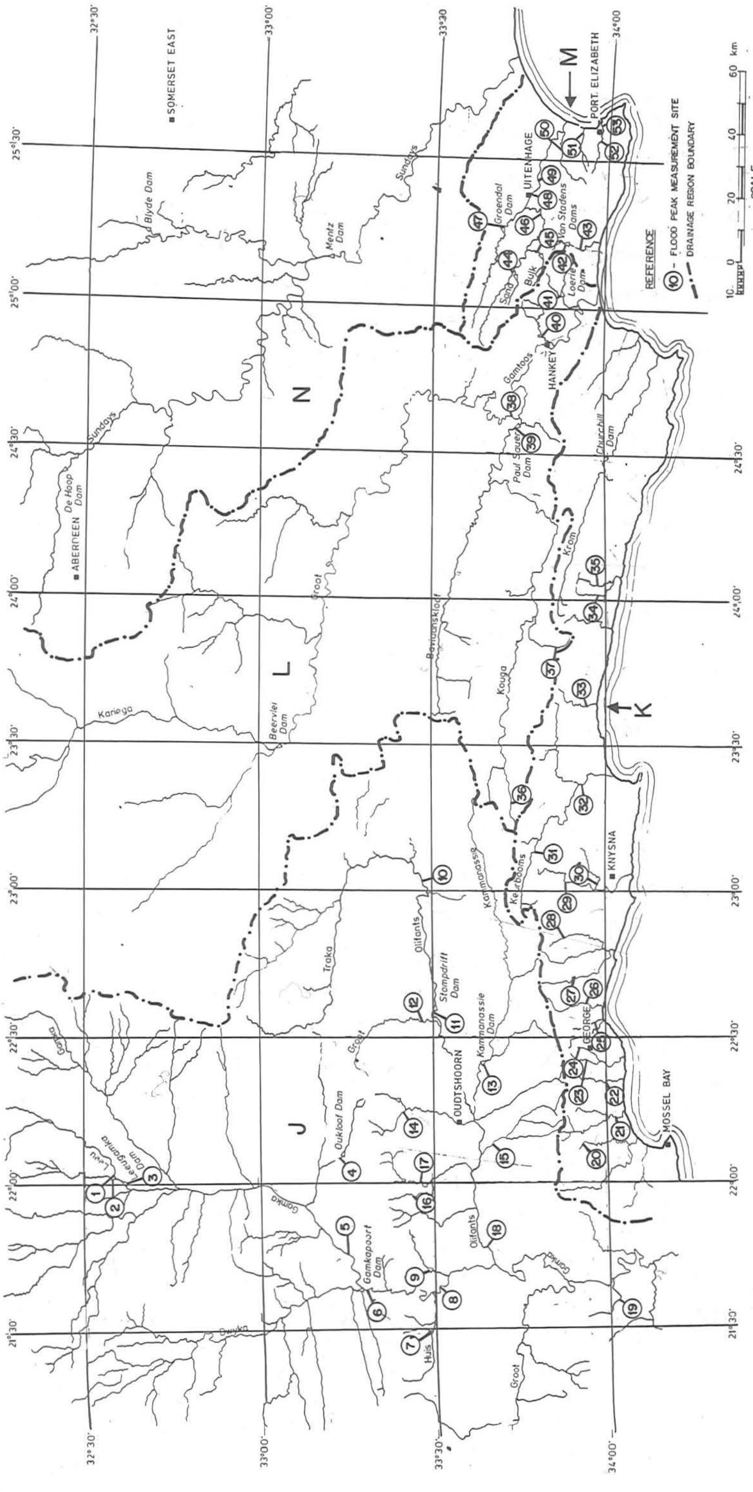


FIG. 4.1 FLOOD PEAK MEASUREMENT SITES.

These sites were selected on the basis of storm isohyetal maps and a ground inspection of the flooded area. The ground survey was completed after the floods as soon as it was possible to reach the sites. The field work consisted of slope-area surveys and surveys at bridges, dams and gauging stations.

4.1 Slope area Surveys (SA)

Total number: March - 12
April - 0
May - 5

The slope-area surveys were done as described in (14). These surveys were done at sites which had experienced a fairly high peak flow. Where possible the surveys were done at gauging stations for calibration purposes.

Statistics that describe the surveyed data are listed in Table 4.1.

TABLE 4.1: STATISTICS OF SURVEYED DATA

Site No.	No. of cross sections	Length of reach (m)	Top width of sections (m)	No. of flood marks	No. of surveyed points/section	Date of flood
1	3	332	83	6	25	March 81
2	3	214	102	11	33	March 81
5	3	1 219	436	17	26	March 81
10	3	394	139	14	11	March 81
12	3	215	43	12	18	March 81
12	3	215	46	15	18	May 81
17	2	67	44	10	14	March 81
18	3	46	118	7	16	May 81
26	2	37	42	9	14	May 81
31	3	60	40	14	12	May 81
32	2	124	187	6	19	May 81

Site No.	No. of cross sec- tions	Length of reach (m)	Top width of sec- tions (m)	No. of flood marks	No. of sur- veyed points/ section	Date of flood
38	4	443	81	38	16	March 81
40	4	406	118	21	15	March 81
43	4	587	85	38	13	March 81
46	4	272	91	18	12	March 81
51	2	114	69	2	16	March 81
53	4	122	49	19	10	March 81
Mean	3,1	286	104	15	17	-

As can be seen in Table 4.1 the average slope-area station complies with the set standards described in (14). However, at certain sites cross sections were taken too close to each other (site 18, 31) At site 18 only the Chézy method was used to calculate the flow.

4.2 Bridge Contractions (B)

Total number: 4 (March flood)

These surveys were carried out at sites where relatively high flood peaks were assumed.

Bridges over rivers with deep sandy beds were avoided because it is impossible to determine the true section at the bridge during the flood.

Reference 14 explains the field work and calculations involved in a bridge survey.

4.3 River gauging stations (G)

Total number: March - 25
April - 22
May - 23

At five of these 70 sites slope area surveys were done to check or calibrate the gauging structure in the flood region. Field work at a gauging station involves the removal of the recorder chart and at some sites the recorded flood levels were checked with a survey of flood marks in the vicinity of the gauging structure.

4.4 Dams (D)

Total number: March - 12
April - 2
May - 2

Surveys at dams were the same as at gauging stations. If no recorder was available, the high flood level was found by surveying (site 44).

5. FLOOD PEAKS AND HYDROGRAPHS

The calculation of flood peaks serves to:

- supply data for statistical flood frequency analysis
- help with the calibration of gauging stations in the high flow region
- the calculation of extraordinary peaks provides, in addition, data for maximum design discharge determination

Many ordinary small flood peaks were also included to check on the behaviour of catchments under a variety of circumstances. Hydrographs were calculated at all sites where the recorder charts were available.

5.1 Methods of flood peak calculation

5.1.1 Slope-area method (SA)

This method was applied as described in (1) and (14). Hydraulic parameters at the slope-area sites (Table 5.1) show the following:

- the flow approaches supercritical conditions in most of the small catchments
- the velocity distribution coefficient (or energy coefficient) is much greater than unity and consequently, should not be ignored in flow calculations
- the mean velocity varied between 1,40 - 4,1 m/s
- the median roughness of the main channel of all 17 slope-area sites was between 0,5 and 0,6 m. Figures 5.1 - 5.3 show sites with main channel roughness that varies from 0,4 m - 1,2 m.

BLE 5.1 HYDRAULIC PARAMETERS AT 17 SLOPE-AREA STATIONS

No. of cross sections	Represen- titive peak flow (m^3/s)	Slope: Water (survey) (SW)	Slope: 1/50000 map (SB)	Catchment area ($km)^2$	Rough- ness of main channel (m)	Mean cross- section area (m^2)	Mean depth of cross- sections hm(m)	Mean velo- city (m/s)	Energy coefficient	Froude No.
2	2	4	5	6	7	8	9	10	11	12
3	215	0,00248	0,00260	1 741	0,4	137	1,65	1,57	1,36	0,47
3	239	0,00217	0,00185	336	0,45	150	1,47	1,58	1,64	0,53
3	2 230	0,00141	0,00240	13 087	0,57	1 586	3,64	1,41	1,49	0,29
3	914	0,00390	0,00277	4 305	0,53	350	2,51	2,61	1,42	0,63
3	70	0,01200	0,00730	688	0,85	39,6	0,91	1,77	2,09	0,86
3	109	0,01450	0,00730	688	0,87	54,8	1,20	1,99	2,21	0,86
2	150	0,00900	0,01610	137	0,50	69,7	1,57	2,15	2,41	0,85
3	1 300	0,00190	0,00190	10 927	0,60	535	4,5	2,43	1,33	0,42
2	400	0,01110	0,01110	78	1,1	113	2,71	3,54	1,89	0,94
3	294	0,01430	0,00769	165	1,0	105	2,63	2,81	1,68	0,72
2	1 070	0,00249	0,00205	764	2,0	641	3,44	1,67	1,74	0,38
4	808	0,00160	0,00160	29 232	0,47	328	4,07	2,46	1,25	0,44
4	987	0,00373	0,00280	170	0,53	340	2,88	2,90	1,54	0,68
4	1 110	0,00974	0,02020	74	1,1	271	3,17	4,10	1,45	0,89
4	1 800	0,00538	0,00290	400	1,7	530	5,82	3,40	1,53	0,56
2	555	0,00600	0,00600	39	0,01	121	1,75	4,59	1,55	1,38
4	500	0,00847	0,00590	69	0,58	128	2,62	3,91	1,39	0,91

Fig. 5.1 Main channel roughness~0,4 m (site 2)

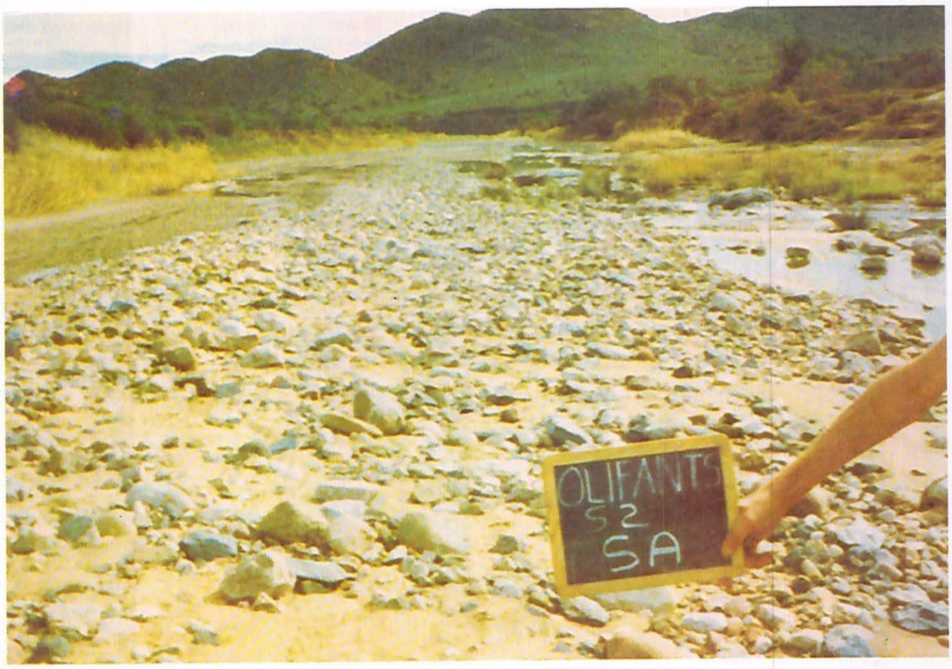


Fig. 5.2 Main channel roughness ~ 0,6 m (site 10)

Fig. 5.3 Main channel roughness ~ 1,1 m (site 43)

5.1.2 Bridge contractions (B)

The calculations were done as described in (14). During the March flood three bridges and one culvert were surveyed. All bridges had a small contraction ratio, more than 0,5 m drop over the constriction and the flow type belonged to types 1(a) and 1(b). For flow types consult (14).

The United States Geological Survey, D'Aubuisson and broad crested weir formulae were used to calculate the flow at the bridges.

5.1.3 Gauging stations

At gauging stations the flood peak and volume was calculated from the recorded water level. At many sites the high flood level was higher than the calibration limit of the gauging station. A bar above the waterdepth in column 7 of Appendix I indicates these sites. At these sites the limit of the discharge table was extended by a combination of the existing weir calibration and the calibration of the river cross section at the weir from estimated roughness and average slope taken from 1/50000 maps.

5.1.4 Dams

At dams where the recorder chart was available level pool routing was used to calculate the peak inflow and flood volume. At those dams without recorders the surveyed height above the spillway was used to calculate the peak outflow.

As indicated by (1) and (9) the measured water level at dams during floods can be higher than the true water level because of surges that were superimposed on the inflow. Reference 9 uses the dimensionless parameter QI.V/g.FSC as an indicator for surge generation by inflow. Table 5.2 shows typical values for the surge parameter and possible surge wave heights for the March 1981 flood.

TABLE 5.2: TYPICAL VALUES FOR THE SURGE PARAMETER AND POSSIBLE SURGE WAVE HEIGHTS

SITE No.	Peak flow Q (m^3/s)	Full supply capacity ($10^6 m^3$)	Length of dam (km)	$\frac{Q.V.}{g.FSC}$ (10^{-6})	Estimated surge wave height h+ (m)
6	I:5700	154,3	10,8	12,1	1,00
11	I:847	61,2	9,2	0,18	0,15
41	I:1750	3,92	2,1	43	0,80
42	Ø:690	0,322	0,72	337	1,2
44	Ø:600	2,67	1,4	7,2	0,30
45	Ø:550	0,821	1,8	82,4	1,0
47	Ø:625	11,8	4,2	1,2	0,25

NOTE

I - Inflow

Ø - Outflow

V - Mean velocity of flow in dam

FSC - Full supply capacity of dam

$$h^{+} = \frac{Q - Q_o}{(V_o + \sqrt{gh_o})\,T}$$

h^{+}	height of estimated surge
Q	peak flow (correctly, it should always be peak inflow)
Q_o	flow before flood inflow
V_o	flow velocity before flood inflow
g	the acceleration of gravity
h_o	mean depth of dam - at FSC level
T	mean surface width of dam - at FSC level

All calculated flood peaks are shown in column 9 of Appendix I.

5.2 Return Periods of Peak Discharges

The ratio of the flood peak to the regional maximum flood (RMF) calculated by the Francou-Rodier equation (10) was used to establish return period classes. Table 5.3 (12) shows the return period classes and ratio's that were used.

Table 5.3 (12)

Return period (Yr)	Flood peak/RMF	
	MAP < 400 mm	MAP > 400 m
<10	<0,10	<0,15
10 - 50	0,10 - 0,35	0,15 - 0,50
50 - 200	0,35 - 0,50	0,5 - 0,65
>200	0,50 - 0,90	0,65 - 0,95
~RMF	>0,90	>0,95

NOTE:

MAP - mean annual precipitation

The calculated return periods are shown in column 10 and the Francou-Rodier K in column 11 of Appendix I.

5.3 Evaluation of results

The evaluation of results was carried out as described in (1). The rating symbols have the following meaning:

Rating		Error in peak discharge
1	less than	± 10%
2	less than	± 30%
u		unknown

The accuracy rating for each site is shown in column 12 of Appendix I.

A comparison of the return period of the flood peak and the rainfall depth give a good indication of the reliability of the calculations. Table 5.4 shows the comparison of the return period of the flood peak and the rainfall depth for various catchment sizes. The agreement between the return period of the flood peak (TQ) and the return period of the rainfall (Tp) is good especially in the larger catchments.

TABLE 5.4

Catchment area (km^2)	No. of sites			
	Total	TQ<Tp	TQ ~ Tp	TQ > Tp
< 100	47	6	34	7
100 - 500	32	7	21	4
500 - 5000	15	3	11	1
> 5000	10	1	8	1
Totals	104	17	74	13

TABLE 5.5 THE ELEVEN HIGHEST FLOOD PEAKS RECORDED IN MAXIMUM FLOOD PEAK REGION 1.

River	Station or drainage region	A (km^2)	Q (m^3/s)	FRANCOU RODIER K	Date of peak (Y M D)	Site No. or source
1	2	3	4	5	6	7
Loerie	L9R01	147	1 750	5,27	81 03 26	41
Van Stadens	M2	74	1 110	5,18	81 03 26	43
Hluhluwe	W3R01	734	3 060	5,10	63 07 04	Ref.10
Van Stadens (Lower)	M2R02	36	690	5,09	81 03 26	42
Nahoon	R3R01	473	2 266	5,03	70 08 28	Ref.10
Loerie	L9R01	147	1 250	5,02	77 05 08	Ref.10
Blyde	N3	130	1 165	5,02	22 01 11	Ref.10
Bulk	M1R02	34	550	4,96	81 03 26	Ref.10
Buffalo	R2R03	1 176	3 258	4,95	70 08 28	Ref.10
Papenkuils	M2	39	555	4,92	81 03 26	51
Elands	M1M04	400	1 800	4,92	81 03 26	46

Table 5.5 indicates the uniqueness of the March 1981 flood event. Six of the 11 highest flood peaks that have ever been recorded in flood region 1 were recorded during the March 1981 flood. The flood peak at Loerie dam (site 41) was even higher than the regional maximum flood established in (10).

Figure 5.5 shows all flood peaks with a Francou-Rodier K value of 4,5 or more and confirmes the realistic nature of the Francou-Rodier envelope curve. The next general review of the countrywide maximum flood peak catalogue may warrant a slight rise in the vlaue of the envelope 'K'. Eleven of the 37 plotted flood peaks were recorded during the March 1981 flood.

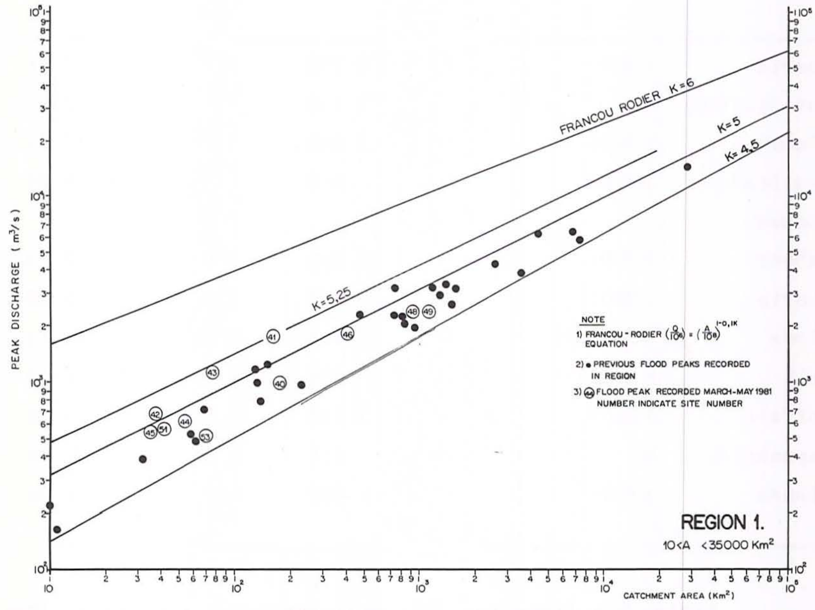


FIG. 5.5 MAXIMUM PEAK DISCHARGES WITH FRANCOU-RODIER K ≥ 4,5

5.4 Flood hydrographs

Eighty two hydrographs at 34 sites were reconstructed for the March-May storms. The January 1981 flood hydrographs were also included if available at these 34 sites (1). These hydrographs can be used to determine the response of the various catchments to rainfall. Information on these hydrographs is listed in Appendix II.

5.4.1 Flood volume and runoff percentage

The flood volume is the area under the flood hydrograph. The duration of the hydrograph starts at the sudden increase in flow and ends where the flow reaches a certain low value.

The sudden increase in flow is easy to spot but it is difficult to know when to terminate the duration of the flood hydrograph. Four rules as explained in Table 5.6 and Figure 5.6 were used to define the duration of the falling limb (T_L) of the hydrograph.

TABLE 5.6 ALTERNATIVE DURATIONS OF FALLING LIMB (T_L)

Method	Duration	Minimum duration	Maximum duration
1	2Tp	Point of max. curvature T_A	when flow drops to the greater of Q_o or 0,1 Q m
2	2tc	"	"
3	0,1 Q m	-	"
4	parabola rule	-	-

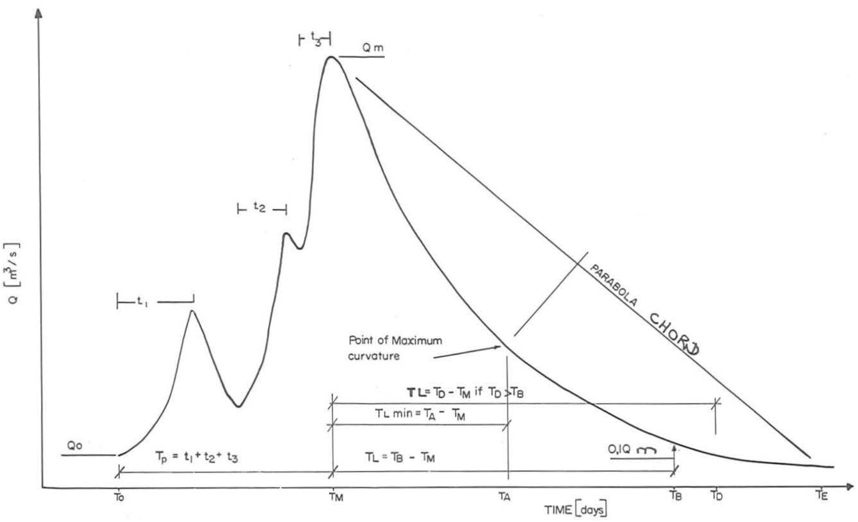


FIG. 5.6 ALTERNATIVE DEFINITION OF THE DURATION OF A FLOOD HYDROGRAPH

LIST OF SYMBOLS

t_c	-	time of concentration
To	-	'0' time
T_A	-	time of max curvature
T_B	-	time when the flow reaches a value equal to ten percent of the last peak flow
T_D	-	time when the flow reaches a value equal to Qo
T_E	-	time when the parabola line cuts the hydrograph
T_M	-	time of peak flow
T_p	-	duration of total net rise of a multi-peaked hydrograph = Σt

The calculated flood volumes showed that it is not important which method is used to calculate the duration of the recession limb as long as there is a realistic minimum and maximum limit to the duration of T_L. Because of this insensitivity of the flood volume to the duration of T_L the flood volume was taken as the volume between the sudden increase in flow in the river and the time when the discharge in the river has returned to 10% of the last peak flow. At sites with relatively small floods the length of the receding limb of the hydrograph was terminated when the flow reached a steady value even if it was bigger than 10% of the peak flow.

With the inclusion of the January flood 87 hydrographs were available. Twenty four of these corresponded to floods larger than the 10 year event. Figures 5.7 to 5.24 show 18 of these 24 hydrographs.

The runoff % was calculated by dividing the flood volume by the rainfall volume. Runoff percentage versus storm rainfall is plotted in Figures 5.25 and 5.26. Figure 5.25 shows all 87 sites and Figure 5.26 all sites in region J for the January-May storms. These two figures show that at least 5 mm of rain is needed to produce runoff and in certain instances, mainly in small catchments with plantations, up to 80 mm of rain was necessary to establish surface runoff.

The flood volume was also compared to the mean annual runoff (M.A.R.). Appendix II shows that the mean runoff volume for the 87 storms is 52% of the M.A.R. The runoff volume from the 24 biggest recorded floods was 86% of the M.A.R. and the mean storm rainfall 25% of the mean annual precipitation (M.A.P.). This underlines the great importance of having flow gauging stations calibrated for high flows (M.A.R. and M.A.P. values were obtained from (3)).

5.4.2 Time to peak (Tp)

The time to peak (see column 7 of Appendix II) is the duration of the rising limb of the hydrograph (In cases of multiple peaks Tp was taken as the sum of the rising limbs.)

The time to peak/time of concentration (Tp/tc) ratio gives an indication of whether the whole catchment has contributed to the runoff. If the ratio is less than one it either rained only over a part of the catchment or the duration of the storm was less than the time of concentration (t_c) of the catchment. If the ratio is larger than one then the duration of the storm was longer than the time of concentration of the catchment.

The median T_p (see column 8 of Appendix II) for all 87 hydrographs is 2 - 3 times the time of concentration. In region J where the catchments are larger the median T_p was 1 - 2 times t_c (The United States Bureau of Reclamation formula was used to calculate t_c).

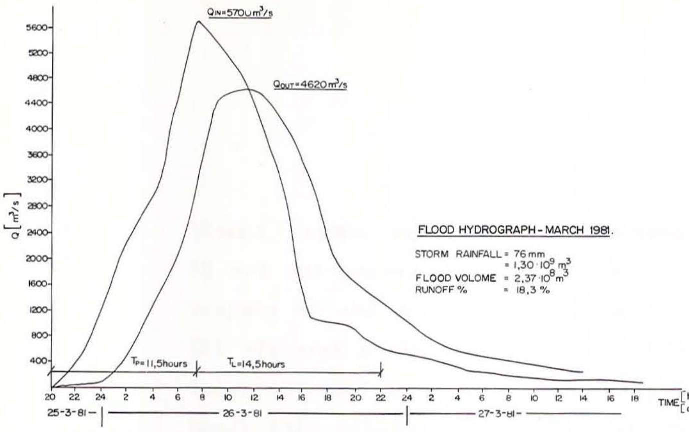


Fig. 5.7 GAMKAPOORT DAM (J2R06) - SITE 6

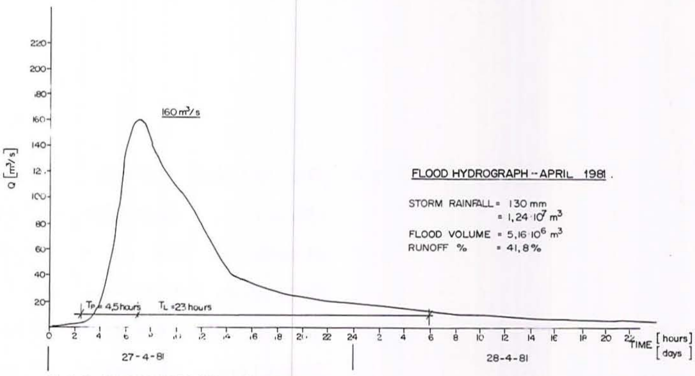


Fig. 5.8. WEYERS RIVER AT J4M03 - SITE 19.

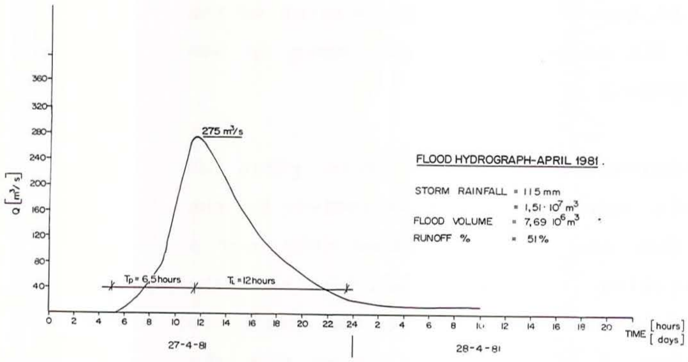


Fig. 5.9. GROOT BRAK RIVER AT K2M02-SITE 21.

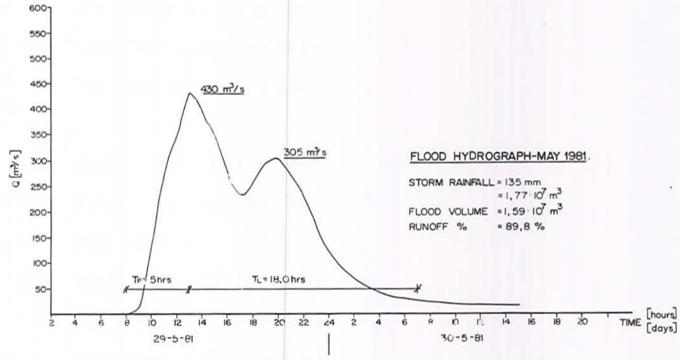


Fig. 5.10. GROOT BRAK RIVER AT K2M02-SITE 21

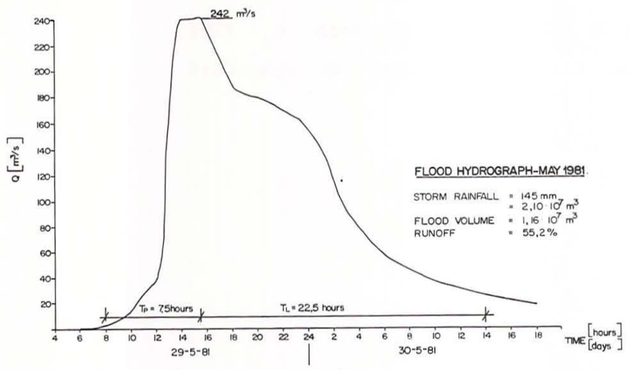


Fig. 5.11. MALGATE RIVER AT K3M03-SITE 22.

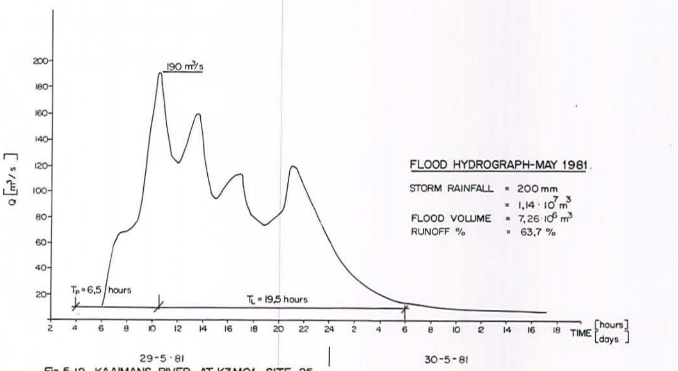


Fig. 5.12. KAAIMANS RIVER AT K3M01-SITE 25

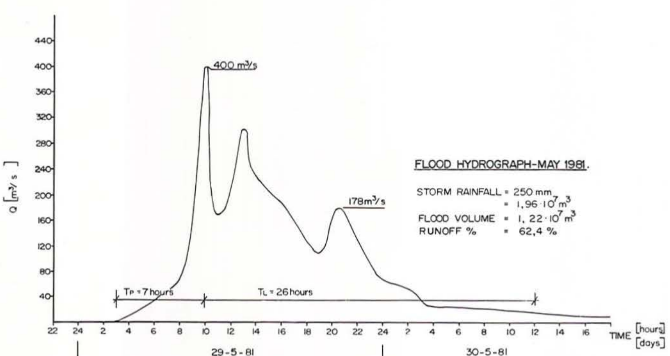


Fig. 5.13. TOUWS RIVER A K3M05-SITE 26.

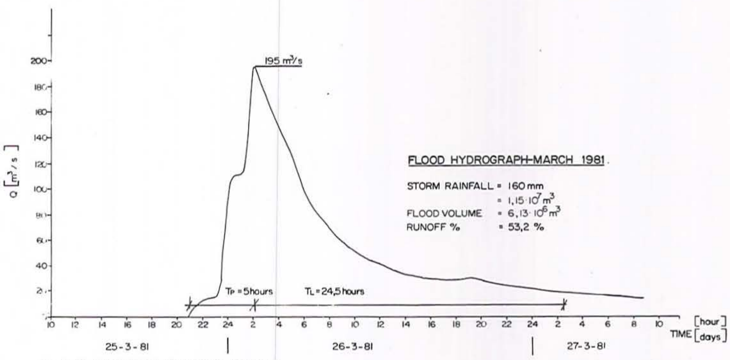


Fig. 5.14. DIEP RIVER AT K4M03-SITE 27.

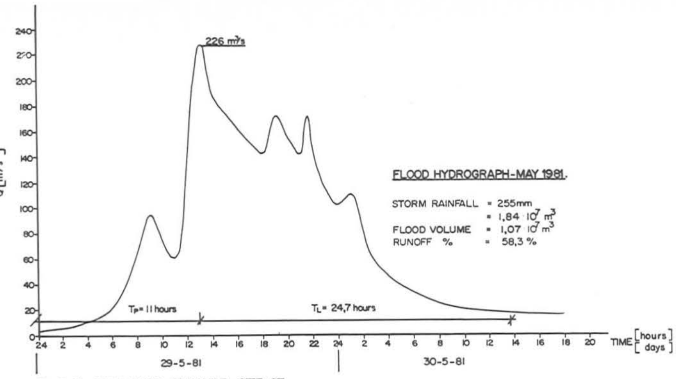


Fig. 5.15 DIEP RIVER AT K4M03 - SITE 27.

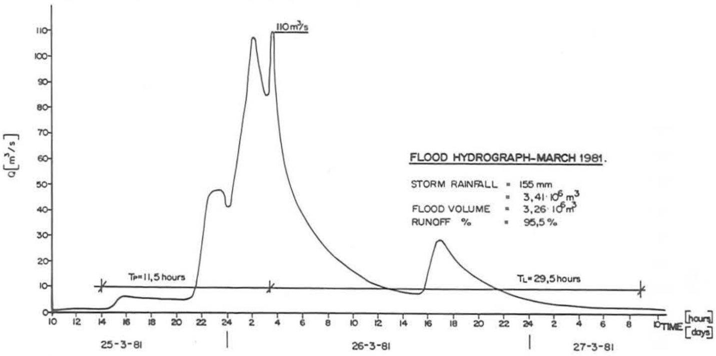


Fig. 5.16 KARATARA RIVER AT K4M02 - SITE 28.

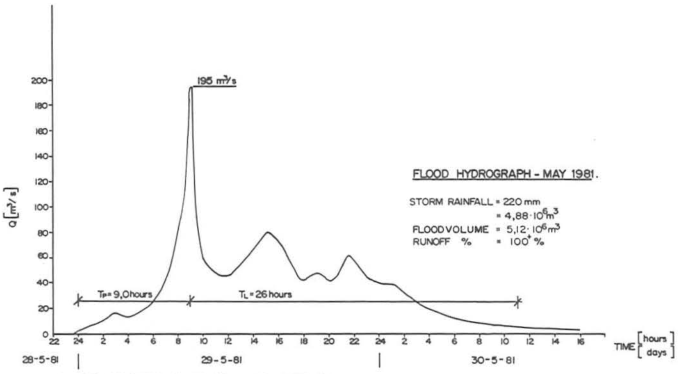


Fig. 5.17. KARATARA RIVER AT K4M02 - SITE 28.

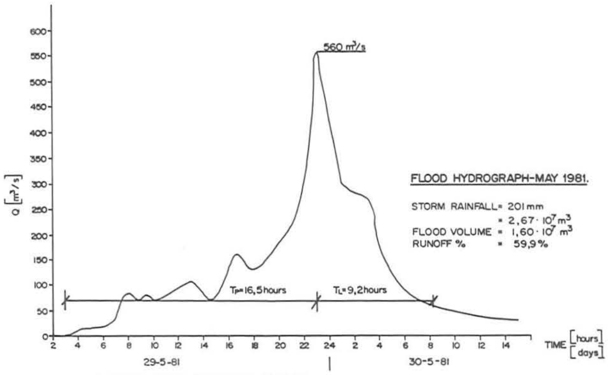


Fig. 5.18. KNYSNA RIVER AT K5M02 - SITE 29.

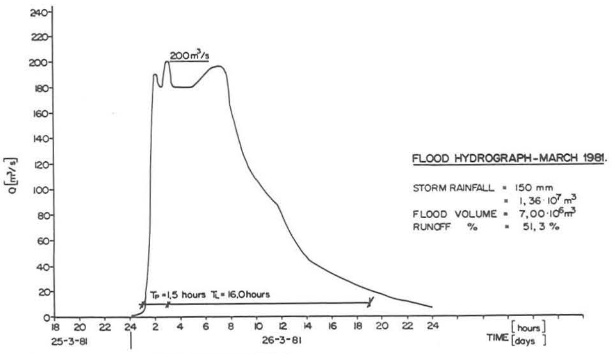


Fig. 5.19. GOUNA RIVER AT K5M01 - SITE 30.

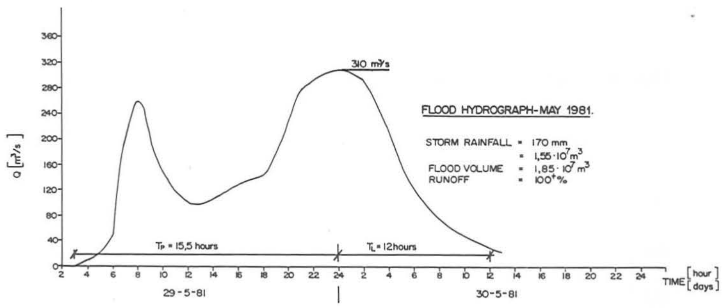


Fig. 5.20. GOUNA RIVER AT K5M01 - SITE 30.

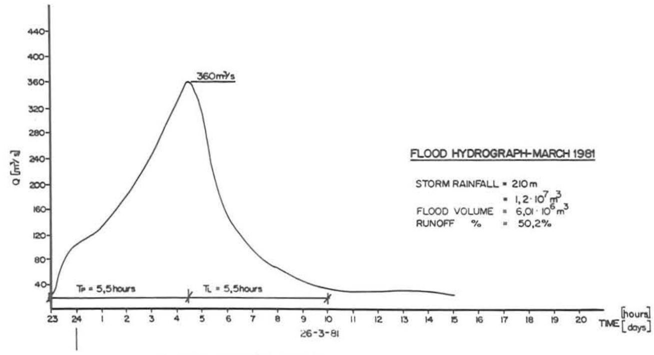


Fig. 5.21. BLOUKRANS RIVER AT K7M01 - SITE 33

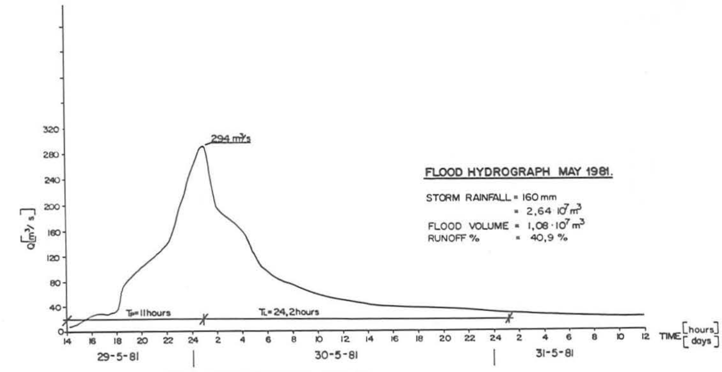


Fig. 5.22 KEURBOOMS RIVER AT K6M01 - SITE 31.

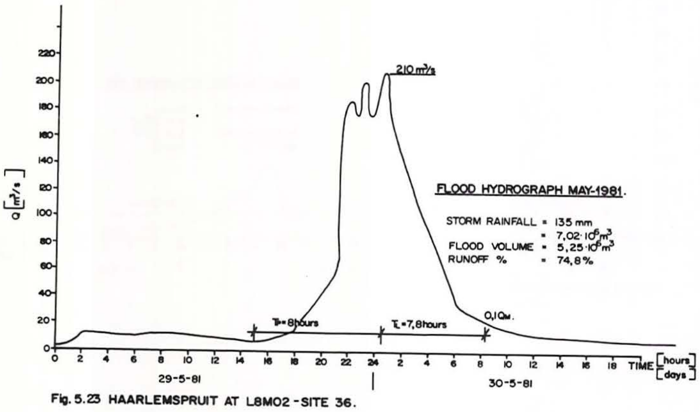


Fig. 5.23 HAARLEMSPRUIT AT L8M02 - SITE 36.

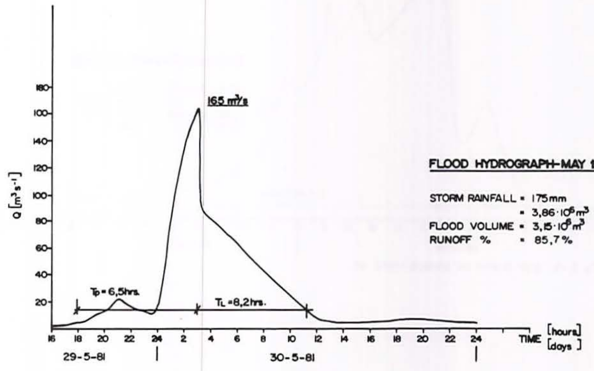


Fig. 5.24 WABOOMS RIVER AT L8M01 - SITE 37.

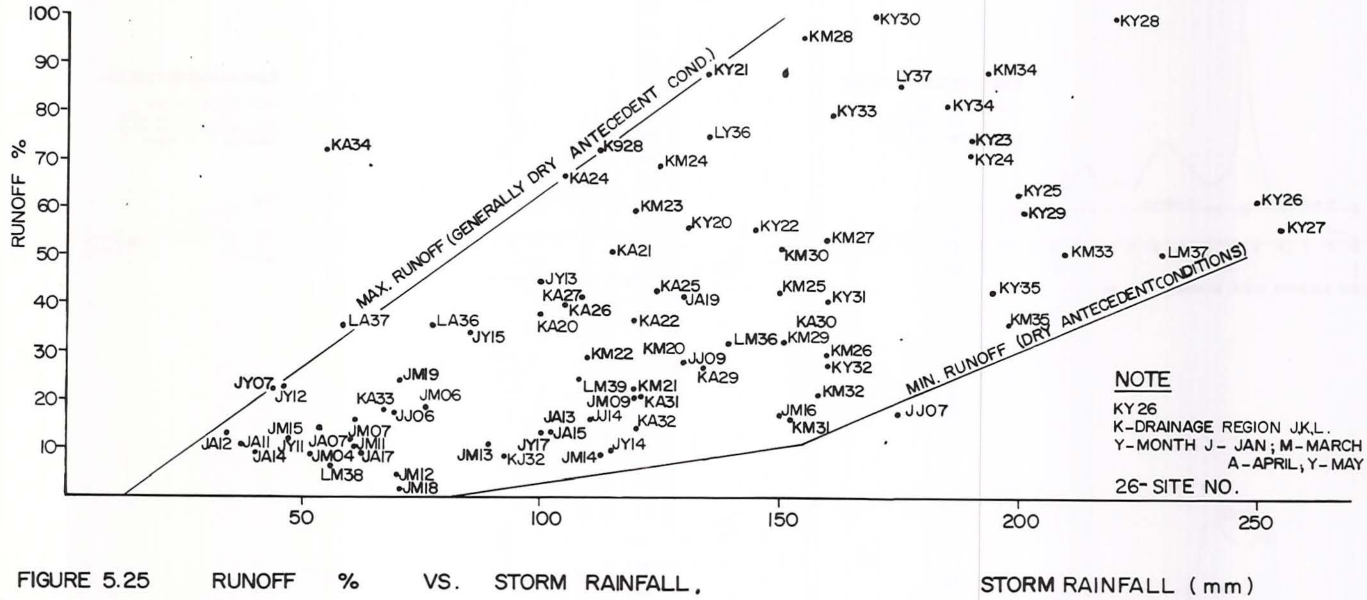


FIGURE 5.25 RUNOFF % VS. STORM RAINFALL.

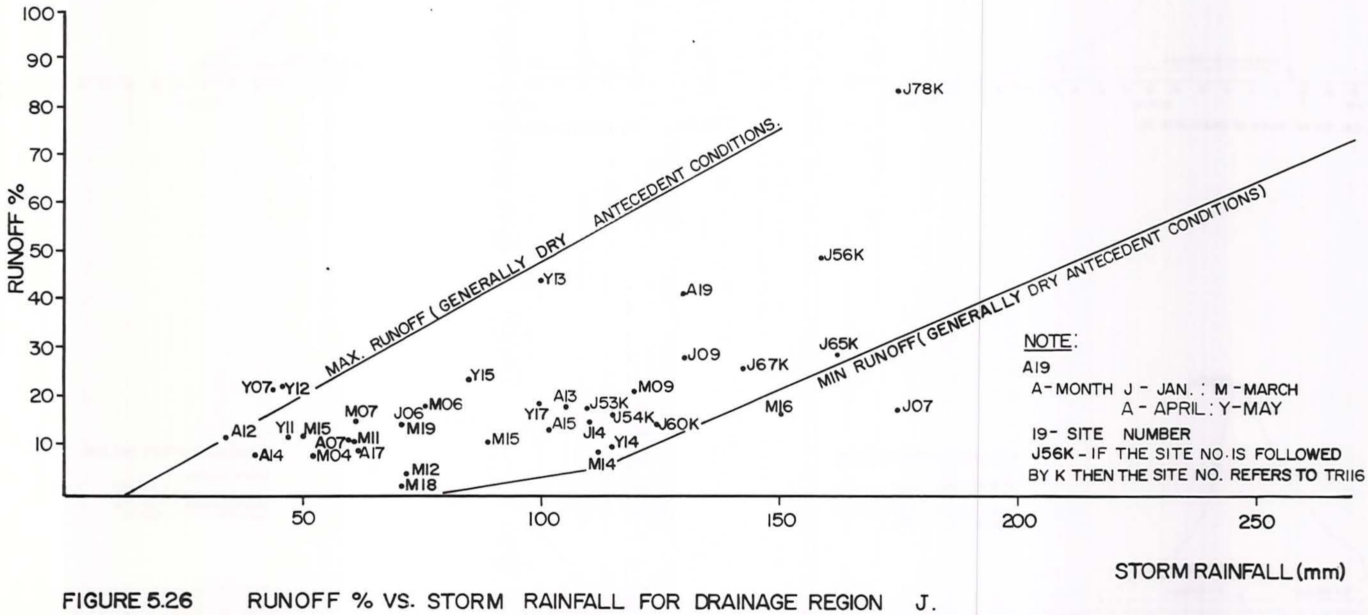


FIGURE 5.26 RUNOFF % VS. STORM RAINFALL FOR DRAINAGE REGION J.

6. COMPARISON OF THE MAY 1977 AND MARCH 1981 FLOODS AT LOERIE DAM

The Loerie Dam (Figure 6.1) was completed in 1971 and since then the dam has experienced two floods that exceeded the design capacity of the side spillway. On both occations water flowed over the non-overspill earth embankment and caused damage to the earth embankment (Figure 6.2).

The dam is situated near the coast at the confluence of the Geelhoutboom and Berg rivers. The May 1977 and March 1981 floods were caused by clyclonic type of rainfall. Figures 6.5-6 and Table 6.1 shows the rainfall situation before and during the 1977 and 1981 floods.

TABLE 6.1

Date of flood	Rainfall (mm)				Return period of (3) (year)
	16 day antece-dent (1)	On day before the peak (2)	On day of the peak (3)	Total storm (4)	
May 1977	75	15	181	215	50
March 1981	35	25	315	415	400

It is seen that the 1977 storm occured after a wetter antecedent period but the 1981 storm rainfall was much higher. In May 1977 the peak outflow was 1250 m^3/s and the inflow was obtained by means of level pool routing to be 1360 m^3/s.

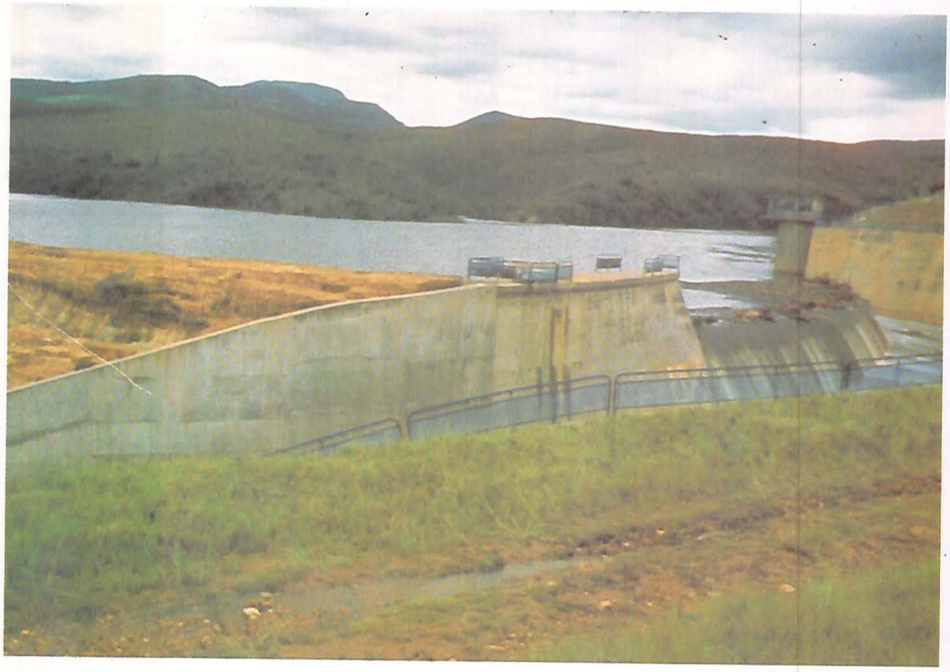


Fig. 6.1 Loerie Dam. General layout

Fig. 6.2 Loerie Dam. Damage to earth embankment

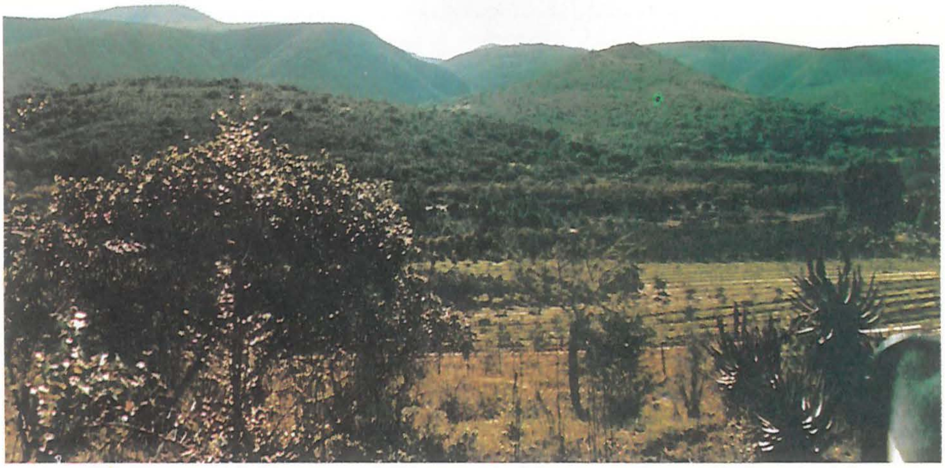


Fig. 6.3 Loerie Dam Catchment

The accurate calculation of the peak outflow from the dam during March 1981 was impossible because the recorder got stuck 1,29 m below the surveyed high water level and a part of the non-overspill wall washed away during the flood peak. Therefore the inflow peak was calculated (1) with the Rational-method and (2) by comparing the characteristics of neighbouring catchments, with a known flood peak and rainfall depth, to that of the Loerie catchment.

The real storm data was used as input into the Rational method. The time of concentration for the Loerie dam catchment is 3 hours. An analysis on 11 autographic rainfall recorders in the Port Elizabeth area showed that 40% of the 24 hour rainfall on the 25th March 1981 fell in 3 hours, see Figure 3.3. The same ratio of 3 hour to 24 hour rainfall was used to calculate the flood peak at Loerie dam. The rainfall intensity averaged over the area was 42 mm/hour and the runoff coefficient was taken as 1,0 because approximately 50% of the 24 hour rainfall fell earlier during the day. The flood peak was calculated as 1720 m^3/s.

Table 6.2 shows flood peaks at Loerie Dam deduced from data of six surrounding catchments. Figure 6.4 shows a plan of the region.

Table 6.2 DEDUCED FLOOD PEAKS AT LOERIE DAM

Site	A (km^2)	Catchment steepness (%)	Rainfall on 81.03.25 (mm)	Calculated flood peak (m^3/s)	Runoff coefficient C	Deduced flood peaks at Loerie Dam (m^3/s)
1	2	3	4	5	6	7
40	170	28	220	987	0,75	1 230
41	147	20	315	-	0,70	-
42	36	25	235	690*	0,73	1 730*
43	74	18	273	1 110	0,69	1 800
44	51	25	220	600*	0,73	1 362*
45	34	20	230	550*	0,70	1 510*
46	400	20	225	1 800	0,70	1 566

NOTE: * outflow from dam
Site 41: Loerie Dam

Sites 41, 42 and 45 - the content of these dams played a minor role because the dams was fairly full or very small.

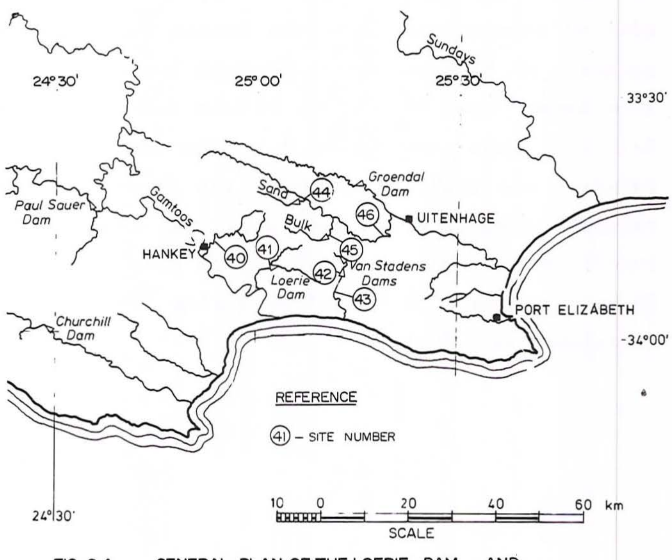


FIG. 6.4 GENERAL PLAN OF THE LOERIE DAM - AND SURROUNDING CATCHMENTS

In this comparison the runoff coefficient for the permeability of the soil and vegetation was taken as the maximum value from the Rational-method because approximately 50% of the 24 hour rainfall fell earlier during the day. The flows in column 7 of Table 6.2 were obtained by comparing the area, mean catchment steepness, rainfall and flood peak of the various catchments to that of the Loerie catchment. Sites 42, 44 and 45 indicate that the outflow peak at Loerie dam was in the order of 1 580 m^3/s and with the low value of site 40 excluded, site 43 and 46 indicate that the inflow peak was in the order of 1 680 m^3/s.

Example of flood peak calculation:

Comparison of sites 43 and 41:

$$\frac{Q41}{Q43} = \frac{C41}{C43} \cdot \frac{P41}{P43} \cdot \left(\frac{A41}{A43}\right)^{1-0,1(K)}$$

$$\therefore Q41 = 1\ 110 \cdot \frac{0,7}{0,69} \cdot \frac{315}{273} \cdot \left(\frac{147}{74}\right)^{1-0,1(5,25)}$$

$$= 1800\ m^3/s$$

Q - flow

C - rational method runoff coefficient

P - rainfall on 84.3.25

A - catchment area

K - Francou-Rodier regional envelope coefficient

Based on the Rational-method and catchment comparison methods the inflow peak was conservatively estimated to be 1 750 m^3/s.

Even with the estimated known inflow peak the outflow peak was still impossible to calculate accurately because of the unknown true water level. Based on the inflow peak of 1 750 m^3/s it was estimated in (9) that a surge wave of 0,77 m could have been formed by the inflow and wind waves (11) as high as 0,9 m could have been responsible for the surveyed high flood level. The magnitude of these waves is of such an order that they should be taken into account in the hydraulic design for maximum flood conditions, in the reducion of outflow peaks calculated from observed maximum dam levels during extraordinary floods in dams characterised by high $\frac{Q.V.}{g.FSC}$ factors. Because of these uncertainties (water level, damaged wall) the outflow peak could have been as high or higher than the inflow peak.

Table 6.3 summarises the hydrological data of the 1977 & 1981 floods. Dam contents were at 101% of the full supply capacity at the beginning of each flood.

Table 6.3 HYDROLOGICAL DATA

Year of flood	I (m^3/s)	Ø (m^3/s)	T_p (hours)	Rain volume ($10^6 m^3$	Runoff volume ($10^6 m^3$)	Run-off %	Frequency of QI
1977	1 360	1 250	3	31,6	11,6	37	>200 yr
1981	1 750	1 580*	3	61,0	31,5	52	RMF

*very rough estimate

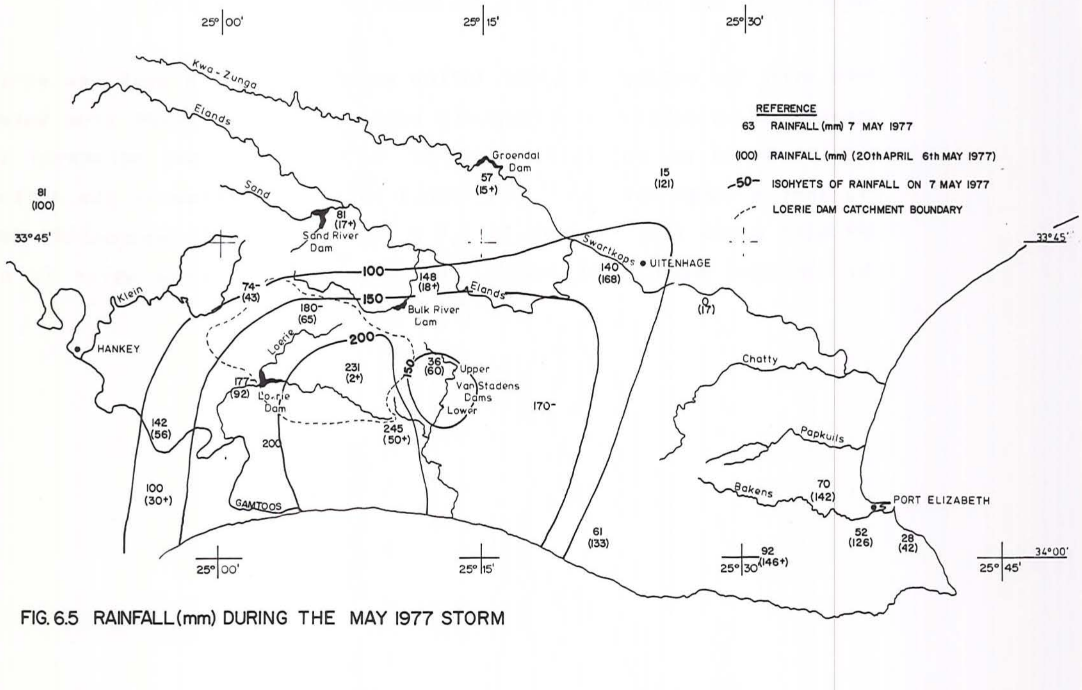


FIG. 6.5 RAINFALL (mm) DURING THE MAY 1977 STORM

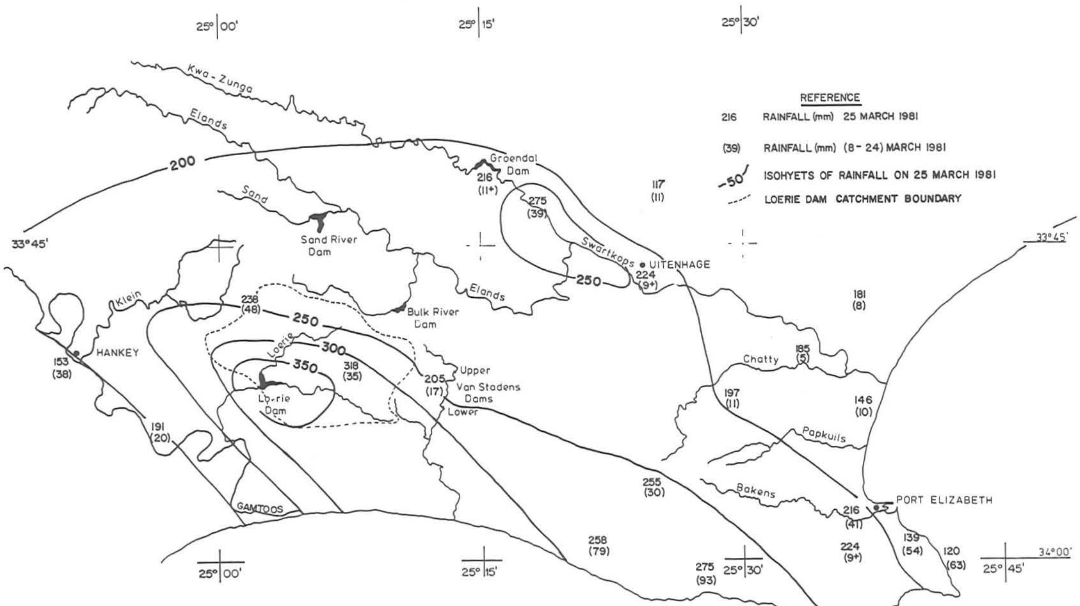


FIG.6.6 RAINFALL (mm) DURING THE MARCH 1981 STORM

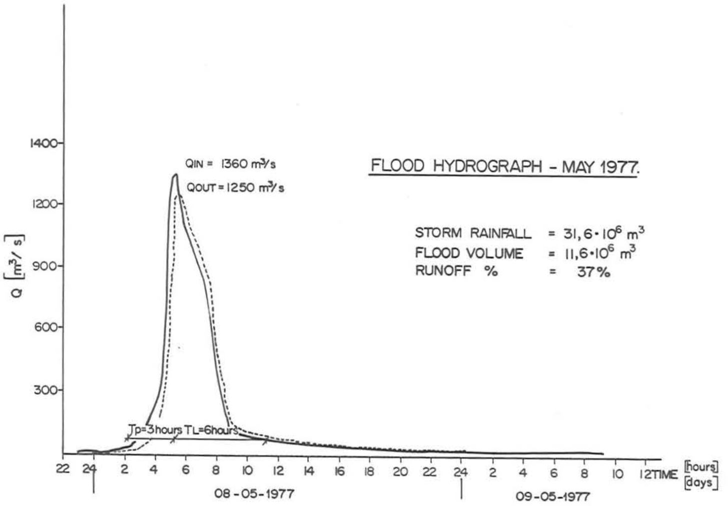


FIG. 6.7 LOERIE DAM (L9R01 - SITE 41)

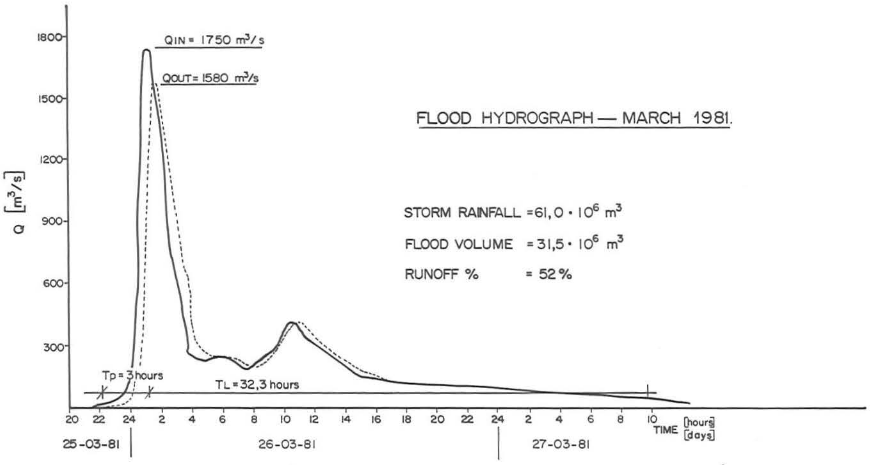


FIG.6.8 LOERIE DAM (L9R01)-SITE 41

Some conclusions

1. The large return period of the flood peaks and relative small return period of the one day rainfall indicate that floods of this magnitude are not uncommon at the Loerie dam site.

2. The fan-shaped catchment is a decisive factor in the generation of very high flood peaks.

3. The runoff factors are fairly low. This could partly be due to a low accuracy in calculated mean storm rainfalls.

4. The critical storm duration is equal to the time of concentration.

7. SUMMARY

1. A total of 105 flood peaks were recorded at 53 sites.

2. The March 1981 flood covered by far the largest area of the three floods and at 23 sites a greater than 10 year flood was recorded. This flood was caused by a cut-off low pressure system and 200 - 300% of the normal rainfall for March was recorded.

3. The April 1981 flood covered the smallest area and was caused by a frontal system.

4. A typical black south easter system caused the May 1981 flood and more than 200% of the normal rainfall for May was recorded. The recorded flood peak was greater than the 10 year event at 13 sites.

5. Indirect methods (slope-area, bridge contraction) were used to calculate 28% of the flood peaks.

6. The recorded flood level exceeded the calibration limit of the gauging and dam stations at 73% of the sites.

7. Fourty percent of the calculated flood peaks exceeded the 10 year event. Seven flood peaks were associated with a Francou-Rodier K > 4,8.

8. At 70% of the sites the return period of the flood was approximately equal to the return period of the rainfall.

9. The runoff/rainfall ratio approached unity in some catchments.

10. Twenty four of the 82 recorded hydrographs corresponded to floods larger than the 10 year event. On the average, the runoff volume at these 24 sites was 86% of the mean annual runoff.

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DOCUMENTATION OF THE MARCH - MAY 1981

FLOODS IN THE SOUTH EASTERN CAPE

TECHNICAL REPORT 120

E R R A T A

Position		Error	Correction
Appendix I, Column 10			
Site No.	Date of flood		
10	March	10	± 10
17	March	10	± 10
19	April	10	± 10
22	May	10	± 10
28	March	10	± 10
30	March	10	± 10
31	May	10	± 10
39	March	10	± 10
All other sites		10	<10
Sites 42, 43, 45 and 46		200	>200
Appendix I, Site 52			
Column 3		33°58' 25°35¾'	33°57½' 25°31'
" 8		67	36
" 11		4,25	4,49
Appendix II, Site 52		67	36

APPENDIX I: SUMMARY OF RAINFALL AND FLOOD DATA

SITE NO	DRAINAGE REGION OR STATION	GEOGRAPHIC POSITION LAT.	GEOGRAPHIC POSITION LONG.	RIVER	PLACE (FARM, ROAD BRIDGE, DAM)	METHOD OF MEASUREMENT	MAX. GAUGE HEIGHT OR (MEAN DEPTH) (m)	CATCH-MENT AREA A (km²)	FLOOD PEAK: PEAK DISCHARGE Q(m³/s)	FLOOD PEAK: RETURN PERIOD (YR)	FLOOD PEAK: FRANCOU RODIER K	FLOOD PEAK: ACCURACY RATING	FLOOD PEAK: TIME M.DDHHMM	STORM RAINFALL OVER CATCHMENT: DEPTH (mm)	STORM RAINFALL OVER CATCHMENT: RETURN PE-RIOD (YR)	REMARKS
1	2	3		4	5	6	7	8	9	10	11	12	13	14	15	16
1	J2	32° 35¼'	22° 02'	Leeu	Vlagfontein	SA	(2,3)	1 741	215	10	2,29	2	3.26	74	9	
2	J2	32° 34¾'	22° 01'	Klein Hotten-tots	Vlagfontein	SA	(2,5)	336	237	10	3,38	2	3.26	70	9	
3	J2R02	32° 37½'	22° 00½'	Leeu	Leeugamka	D	1,0	2 088	Ø: 340	10	2,59	1	3.26	73	10	
4	J2R03	33° 14^{3}'	22° 05½'	Cordiers	Oukloof	D	-	141	I:14,8	10	1,75	1	3.260815			
									Ø: 0					52	4	
5	J2	33° 15½'	21° 45½'	Gamka	Weltevreden	SA	(7,1)	13 087	2 230	10-50	3,17	2	3.26	81	16	
6	J2R06	33° 18½'	21° 38'	Gamka	Gamkapoort	D		17 076	I: 3700	10-50	3,55	1	1.260700			From
							5,86		Ø: 3110					69	12	TR116(1)
	J2R06	33° 18½'	21° 38'	Gamka	Gamkapoort	D		17 076	I: 5700	50	4,04		3.260700			
							7,32		Ø: 4620				3.26	76	14	
7	J2M05	33° 29½'	21° 28½'	Huis	Zoar	SA	2,5	253	236	±10	3,52	2	1.25	175	257	From TR116(1)
						G	1,13	253	35,2	10	2,04	1	3.260300	61	6	
						G	0,97	"	24,0	10	1,75	1	4.271000	60	7	
						G	0,88	"	19,2	10	1,57	1	5.291845	44	3	
8	J2M03	33° 31½'	21° 38¾'	Gamka	Kleinberg	G	5,21	17 815	3740	10-50	3,53	2	3.26	76	16	
9	J2R01	33° 29¼'	21° 42¼'	Nels	Calitzdorp	D		170	I:127	10	3,25		1.252000			From TR116(1)
							0,59		Ø: 72			2		130	60	
									I:126	10	3,24		3.260730	120	42	
							1,02		Ø: 118		3,24	2				

SITE NO	DRAINAGE REGION OR STATION	GEOGRAPHIC POSITION LAT.	GEOGRAPHIC POSITION LONG.	RIVER	PLACE (FARM, ROAD BRIDGE, DAM)	METHOD OF MEASUREMENT	MAX. GAUGE HEIGHT OR (MEAN DEPTH) (m)	CATCH-MENT AREA A (km²)	FLOOD PEAK: PEAK DISCHARGE Q(m³/s)	FLOOD PEAK: RETURN PERIOD (YR)	FLOOD PEAK: FRANCOU RODIER K	FLOOD PEAK: ACCURACY RATING	FLOOD PEAK: TIME M.DDHHMM	STORM RAINFALL OVER CATCHMENT: DEPTH (mm)	STORM RAINFALL OVER CATCHMENT: RETURN PERIOD (YR)	REMARKS
1	2	3		4	5	6	7	8	9	10	11	12	13	14	15	16
10	J3M04	33° 28¾'	23° 01¾'	Olifants	Kromlaagte	SA	4	4 305	914	10	3,04	2	3.26	60	14	
11	J3R02	33° 30¾'	22° 35¼	Olifants	Stompdrift	D	-	5 235	I: 847	10	2,82		3.261000			
									Ø: 0			1		61	30	
									I: 430	10	2,14		4.271600	37	3	
							0,76		Ø: 100			1				
									I: 414	10	2,10		5.300700			
							1,54		Ø: 304			1		47	6	
12	J3M12	33° 28¾'	22° 32¾'	Groot	De Rust	SA		688	70	10			3.260730	72	9	
						G	1,68	688	61	10	1,84	1	3.260730	72	9	
						G	1,98		92	10	2,18	1	4.271500	34	3	
						G	2,08		109	10	2,32	1	5.300330	46	3	
13	J3R01	33° 38½'	22° 24½'	Kammanassie	Kammanassie	D	-	1 505	I: 205	10	2,35	1	3.261300	89	7	
									Ø: 0							
									I: 267	10	2,59	1	4.280100	105	10	
							0,76		Ø:200							
									I: 806	10-50	3,58					
							2,2		Ø: 756			2	5.292100	100	9	

SITE NO	DRAINAGE REGION OR STATION	GEOGRAPHIC POSITION LAT.	GEOGRAPHIC POSITION LONG.	RIVER	PLACE (FARM, ROAD BRIDGE, DAM)	METHOD OF MEASUREMENT	MAX. GAUGE HEIGHT OR (MEAN DEPTH) (m)	CATCH-MENT AREA A (km²)	FLOOD PEAK: PEAK DISCHARGE Q(m³/s)	FLOOD PEAK: RETURN PERIOD (YR)	FLOOD PEAK: FRANCOU RODIER K	FLOOD PEAK: ACCURACY RATING	FLOOD PEAK: TIME M.DDHHMM	STORM RAINFALL OVER CATCHMENT: DEPTH (mm)	STORM RAINFALL OVER CATCHMENT: RETURN PERIOD (YR)	REMARKS
1	2	3		4	5	6	7	8	9	10	11	12	13	14	15	16
14	J3M14	33° 25¼'	22° 14½'	Grobbelaars	Kombuys	G	$\overline{1,59}$	151	52	10	2,64	2	1.251500	110	11	From TR116(1)
						G	$\overline{1,63}$		53	10	2,65	2	3.260100	112	14	
						G	0,43		4,49	10	0,81	1	4.271100	40	2	
						G	1,11		21,0	10	1,96	1	5.292230	114	15	
15	J3M17	33° 40¾'	22° 08'	Kandelaars	Geo Q 7A-30	G	$\overline{3,25}$	348	105	10	2,71	U	3.260600	50	2	
						G	$\overline{3,2}$		100	10	2,67	U	4.271630	102	8	
						G	$\overline{4,55}$		200	10	3,22	U	5.292300	85	6	
16	J3M20	33° 27½'	21° 57¾'	Meul	Vogelfontein	G	$\overline{3,08}$	35	27	10	2,92	U	3.260030	150	70	
17	J3M18	33° 28'	22° 00'	Wynands	Koetzerskraal	SA	$\overline{3,8}$	137	160	10	3,53	2	3.260800	163	84	
						G	1,0		7,2	10	1,23	1	4.271200	62	8	
						G	$\overline{2,68}$		45	10	2,59	2	5.292200	100	18	
18	J3M11	33° 39½'	21° 46½'	Olifants	Warm Water	SA	$\overline{2,0}$	10 927	105	10	0	U	1.	49	2	From TR116(1)
						SA	$\overline{2,61}$		211	10	0,72	U	3.261330	71	6	
						SA	($\overline{3,85}$)		535	10	1,74	U	4.27	56	3	
						SA	($\overline{6,8}$)		1 300	10	2,71		5.29	70	6	Reach too short
19	J4M03	34° 02'	21° 35¼'	Weyers	Weyersrivier	G	0,56	95	10,9	10	1,76	1	3.261500	71	2	
						G	$\overline{2,2}$		160	10	3,70	U	4.270700	130	10	
20	K1M02	33° 56'	22° 08'	Beneke	Pine Grove Forest	G	0,76	3,8	5,45	10	2,91	1	3.260020	122	4	
						G	0,65		4,0	10	2,73	1	4.271000	100	3	
						G	0,85		7,0	10	3,05	1	5.282030	131	6	

SITE NO	DRAINAGE REGION OR STATION	GEOGRAPHIC POSITION LAT.	GEOGRAPHIC POSITION LONG.	RIVER	PLACE (FARM, ROAD BRIDGE, DAM)	METHOD OF MEASUREMENT	MAX. GAUGE HEIGHT OR (MEAN DEPTH) (m)	CATCHMENT AREA A (km²)	FLOOD PEAK: PEAK DISCHARGE Q(m³/s)	FLOOD PEAK: RETURN PERIOD (YR)	FLOOD PEAK: FRANCOU RODIER K	FLOOD PEAK: ACCURACY RATING	FLOOD PEAK: TIME M.DDHHMM	STORM RAINFALL OVER CATCHMENT: DEPTH (mm)	STORM RAINFALL OVER CATCHMENT: RETURN PERIOD (YR)	REMARKS
1	2	3		4	5	6	7	8	9	10	11	12	13	14	15	16
21	K2M02	34° 01¾'	22° 13¼'	Groot-Brak	Wolvedans	G	1,99	131	131	10	3,40	1	3.260600	120	5	
						G	3,02		275	10-50	3,95	1	4.271130	115	6	
						G	$\overline{3,80}$		430	10-50	4,28	2	5.291300	135	10	
22	K3M03	34° 00¼	22° 21'	Maalgate	Buffelsdrift	G	2,4	145	53,1	10	2,68	1	3.261230	110	3	
						G	$\overline{4,18}$		180	10	3,59	2	4.271400	120	4	
						G	$\overline{4,72}$		242	10	3,81	U	5.291530	145	10	
23	K3M04	33° 57'	22° 25¼'	Malgas	Blanco	G	$\overline{2,26}$	34	94	10	3,77	U	3.260000	120	4	
						G	$\overline{2,3}$		101	10	3,82	U	5.291300	190	25	
24	K3M02	33° 56'	22° 27¾'	Rooi	George	G	0,81	1,04	2,3	10	2,94	1	3.260000	125	4	
						G	0,69		1,7	10	2,77	1	4.271130	105	3	
						G	0,78		2,1	10	2,89	1	5.291300	190	23	
25	K3M01	33° 58¼'	22° 33'	Kaaimans	Upper Babiers Kraal	G	$\overline{2,35}$	57	120	10	3,72	2	3.252330	150	5	
						G	$\overline{2,0}$		82	10	3,46	2	4.271200	124	4	
						G	$\overline{2,78}$		190	10-50	4,04	U	5.291030	200	25	
26	K3M05	33° 56¾'	22° 36¾'	Touws	Geo F12-8	G	$\overline{2,85}$	78	138	10	3,68	U	3.260400	160	6	
						G	$\overline{2,15}$		71	10	3,21	U	4.271300	105	3	
						G+SA	$\overline{3,97}$		400	10-50	4,44	U	5.291000	250	23	Reach too short

SITE NO	DRAINAGE REGION OR STATION	GEOGRAPHIC POSITION LAT.	GEOGRAPHIC POSITION LONG.	RIVER	PLACE (FARM, ROAD BRIDGE, DAM)	METHOD OF MEASUREMENT	MAX. GAUGE HEIGHT OR (MEAN DEPTH) (m)	CATCH-MENT AREA A (km²)	FLOOD PEAK: PEAK DISCHARGE Q(m³/s)	FLOOD PEAK: RETURN PERIOD (YR)	FLOOD PEAK: FRANCOU RODIER K	FLOOD PEAK: ACCURACY RATING	FLOOD PEAK: TIME M.DDHHMM	STORM RAINFALL OVER CATCHMENT: DEPTH (mm)	STORM RAINFALL OVER CATCHMENT: RETURN PERIOD (YR)	REMARKS
1	2	3		4	5	6	7	8	9	10	11	12	13	14	15	16
27	K4M03	33° 54¾'	22° 42½'	Diep	Woodville Bosreservaat	G	$\overline{2,34}$	72	195	10-50	3,96	U	3.260200	160	6	
						G	1,0	36		10	2,77	1	4.271500	108	3	
						G	$\overline{2,55}$		226	10-50	4,06	U	5.291300	255	27	
28	K4M02	33° 52¾'	22° 50¼'	Karatara	Karatara Bosreservaat	G	$\overline{2,2}$	22	110	10	4,05	U	3.260330	155	8	
						G	$\overline{1,5}$		42	10	3,43	2	4.271200	112	3	
						G	$\overline{2,65}$		195	10-50	4,43	U	5.290900	220	35	
29	K5M02	33° 53½'	23° 01¾'	Knysna	Laer Streepbos	G	$\overline{3,26}$	133	180	10	3,63	U	3.260330	151	7	
						G	$\overline{2,5}$		104	10	3,22	2	4.271400	134	4	
						G	$\overline{4,84}$		560	10-50	4,47	U	5.292330	201	26	
30	K5M01	33° 59½'	23° 02½'	Gouna	Concordia Plantation	G	1,99	91	200	10	3,88	1	3.260300	150	4	
						G	1,84		130	10	3,57	1	4.271400	154	9	
						G	$\overline{2,41}$		310	10-50	4,19	2	5.291330	170	13	
31	K6M01	33° 48'	23° 08'	Keurbooms	Peters River	G	$\overline{2,08}$	165	117	10	3,20	2	3.260500	152	14	
						G	$\overline{1,88}$		95	10	3,04	2	4.271500	121	5	
						SA+G	$\overline{2,86}$		294	10	3,89	2	5.300100	160	17	

SITE NO	DRAINAGE REGION OR STATION	GEOGRAPHIC POSITION LAT.	GEOGRAPHIC POSITION LONG.	RIVER	PLACE (FARM, ROAD BRIDGE, DAM)	METHOD OF MEASUREMENT	MAX. GAUGE HEIGHT OR (MEAN DEPTH) (m)	CATCH-MENT AREA A (km^2)	FLOOD PEAK: PEAK DISCHARGE Q(m^3/s)	FLOOD PEAK: RETURN PERIOD (YR)	FLOOD PEAK: FRANCOU RODIER K	FLOOD PEAK: ACCURACY RATING	FLOOD PEAK: TIME M.DDHHMM	STORM RAINFALL OVER CATCHMENT: DEPTH (mm)	STORM RAINFALL OVER CATCHMENT: RETURN PERIOD (YR)	REMARKS
1	2	3		4	5	6	7	8	9	10	11	12	13	14	15	16
32	K6M02	33° 56¼'	23° 22'	Keurbooms	Newlands	G	1,2	764	28,5	10	1,12	1	1.280800	93	2	
						G	$\overline{5,21}$		710	10-50	3,85	U	3.260600	158	11	
						G	$\overline{2,44}$		135	10	2,44	U	4.271930	120	5	
						SA+G	$\overline{6,12}$		1 070	10-50	4,19	U	5.292330	160	14	Reach too short
33	K7M01	33° 57¼'	23° 38¼'	Bloukrans	Blaauw Krantz	G	$\overline{4,2}$	57	360	10-50	4,48	U	3.260430	210	12	
						G	0,87		10	10	1,99	1	4.270930	63	1	
						G	$\overline{2,70}$		135	10	3,80	2	5.300200	161	7	
34	K8M01	33° 59'	24° 01¾'	Kruis	Pineview	G	$\overline{1,6}$	26	86	10	3,83	2	3.260300	193	8	
						G	0,62		11,8	10	2,52	1	4.272300	55	1	
						G	$\overline{1,55}$		80	10	3,78	2	5.300330	185	8	
35	K8M02	33° 59'	24° 03'	Elands	Witelsbos Bosreservaat	G	1,06	35	20,5	10	2,74	1	3.261800	198	9	
						G	1,13		23,2	10	2,82		5.301200	195	12	
36	L8M02	33° 44½'	23° 18¼'	Haarlemspruit	Welgelegen	G	1,5	52	88	10	3,55	1	3.260500	140	11	
						G	1,09		39	10	2,98	1	4.271300	77	3	
						G	$\overline{2,13}$		210	10-50	4,15	2	5.300030	135	10	
37	L8M01	33° 52'	23° 50¼'	Wabooms	Diepkloof	G	$\overline{1,85}$	21	75	10	3,82	U	3.260400	230	13	
						G	0,82		9,7	10	2,49	1	4.272100	59	1	
						G	$\overline{2,72}$		165	10-50	4,34	U	5.300300	175	10	

SITE NO	DRAINAGE REGION OR STATION	GEOGRAPHIC POSITION		RIVER	PLACE (FARM, ROAD BRIDGE, DAM)	METHOD OF MEASUREMENT	MAX. GAUGE HEIGHT OR (MEAN DEPTH) (m)	CATCH-MENT AREA A (km²)	FLOOD PEAK					STORM RAINFALL OVER CATCHMENT		REMARKS
		LAT.	LONG.						PEAK DISCHARGE Q(m³/s)	RETURN PERIOD (YR)	FRANCOU RODIER K	ACCURACY RATING	TIME M.DDHHMM	DEPTH (mm)	RETURN PE-RIOD (YR)	
1	2	3		4	5	6	7	8	9	10	11	12	13	14	15	16
38	L7M06	33° 43¾'	24° 37'	Groot	H.Q.10-24	SA	$\overline{4,78}$	29 232	808	10	1,25	2	3.261400	56	4	
39	L8R01	33° 44½'	24° 35¼'	Koega	Paul Sauer	D		3 887	I: 1098	10	3,29	1	3.261100	109	9	
							2,47		Ø: 826							
40	L9	33° 48½'	24° 54'	Klein	Hankey	SA	(6,2)	170	987	50-200	4,79	2	3.26	360	158	
41	L9R01	33° 51¾'	25° 02½'	Loerie	Loerie	D		147	I: 1750	RMF	5,27		3.260108	415	250	
							$\overline{5,64}$		Ø: 1580			2				
42	M2R02	33° 53'	25° 12¾'	Van Stadens	Van Stadens (Dam (Lower)	D	$\overline{3,77}$	36	Ø: 690	200	5,09	2	3.26	350	114	
43	M2	33° 55'	25°11 2/3	Van Stadens	Van Stadens Pass	SA	(4,3)	74	1 110	200	5,18	2	3.26	360	145	
44	M1R03	33° 43¾'	25° 06½'	Sand	Sand River	D	$\overline{2,87}$	51	600	50-200	4,88	2	3.26	325	90	
45	M1R02	33° 48'	25° 10½'	Bulk	Bulk River	D	$\overline{3,2}$	34	Ø: 550	200	4,96	2	3.26	345	75	
46	M1M04	33° 47¾'	25° 18½'	Elands	Longhill	SA	(7,1)	400	1800	200	4,92	2	3.26	320	77	
47	M1R01	33° 41½'	25° 16'	Swartskops	Groendal	D	2,13	261	Ø: 625	10-50	4,26	1	3.26	200	17	
48	M1	33° 46 1/3	25° 23¼'	Swartskops	Nivens	B		900	2130	50-200	4,71	2	3.26	300	72	
49	M1	33° 47½'	25° 25½'	Swartskops	Frans Claassens	B		1080	2300	50-200	4,69	2	3.26	300	58	
50	M1	33° 51'	25° 32'	Chatty	R333	B		127	410	10-50	4,26	2	3.26	230	26	
51	M2	33° 54¾'	25° 35¼'	Papenkuils	Everite	SA	(2,0)	39	555	50-200	4,92	2	3.25	261	37	

SITE NO	DRAINAGE REGION OR STATION	GEOGRAPHIC POSITION LAT.	GEOGRAPHIC POSITION LONG.	RIVER	PLACE (FARM, ROAD BRIDGE, DAM)	METHOD OF MEASUREMENT	MAX. GAUGE HEIGHT OR (MEAN DEPTH) (m)	CATCH-MENT AREA A (km²)	FLOOD PEAK: PEAK DISCHARGE Q(m³/s)	FLOOD PEAK: RETURN PERIOD (YR)	FLOOD PEAK: FRANCOU RODIER K	FLOOD PEAK: ACCURACY RATING	FLOOD PEAK: TIME M.DDHHMM	STORM RAINFALL OVER CATCHMENT: DEPTH (mm)	STORM RAINFALL OVER CATCHMENT: RETURN PERIOD (YR)	REMARKS
1	2	3		4	5	6	7	8	9	10	11	12	13	14	15	16
52	M2	33° 58'	25° 35¾'	Bakens	Kragakama	B		67	280	10-50	4,25	2	3.25	280	44	
53	M2	33° 58'	25° 37¼'	Bakens	Targetkloof	SA	(2,6)	69	500	10-50	4,64	2	3.25	280	46	

NOTES:

Col. 6: G = River gauging station: D= Dam: SA = Slope-area: B = Bridge contraction

Col. 7: 2,3 = Guage height at peak flow: (2,3) = mean water depth in main channel from slope area survey

$\overline{2,3}$ = Bar indicates water level was higher than calibration limit of gauging station

Col. 9: I = Inflow into dam: Ø = Outflow from dam

Col. 12: 1 = error less than ± 10%: 2 = error less than ± 30% U = unknown accuracy

APPENDIX II SUMMARY OF RAINFALL AND RUN-OFF DATA

SITE NO.	A (km^2)	MONTH OF FLOOD	STORM RAINFALL (SP) TOTAL SP (mm)	MAX 1 DAY SP / TOTAL SP	DURATION (DAYS)	$\frac{SP}{MAP}$ %	FLOOD HYDROGRAPH T_p (hr)	T_p/t_c	VOLUME (m^3)	VOLUME (mm)	VOLUME $\frac{VOL}{MAR}$ %	RUNOFF %	REMARKS
1	1 741	March	74	0,81	2	34,4	-	-	-	-	-	-	
2	336	March	70	0,86	2	34,8	-	-	-	-	-	-	
3	2 088	March	73	0,82	2	34,8	-	-	-	-	-	-	
4	141	March	52	0,94	2	11,4	13,5	3,84	6,05E5	4,3	17,1	8,3	
5	13 087	March	81	0,86	2	41,3	-	-	-	-	-	-	
6	17 076	Jan.	69	0,5	3	35,4	14,5	0,41	2,06E8	12,1	109	17,5	
		March	76	0,79	2	39,0	11,5	0,32	2,37E8	13,9	126	18,3	
7	253	Jan.	175	0,53	3	36,2	12,6	3,59	7,55E6	29,8	112	17,1	
		March	61	0,82	3	12,6	5,90	1,68	2,35E6	9,27	34,7	15,2	
		April	60	0,92	2	12,4	8,21	2,34	1,73E6	6,85	25,6	11,4	
		May	44	0,59	2	9,1	14,2	4,05	2,51E6	9,92	37,1	22,6	
8	17 815	March	76	0,87	2	37,2	-	-	-	-	-	-	
9	170	Jan.	130	0,45	3	29,2	19	5,04	6,30E6	37,0	92,7	28,5	
		March	120	0,67	3	26,9	12	3,18	4,38E6	25,8	64,4	21,5	
10	4 305	March	60	0,97	1	24,9	-	-	-	-	-	-	
11	5 235	March	61	0,95	1	22,9	7,5	0,35	3,58E7	6,8	84,4	11,2	
		April	37	0,90	2,5	13,8	9	0,41	2,09E7	4,0	49,3	10,8	
		May	47	0,79	2	17,5	17,5	0,81	2,98E7	5,7	70,3	12,1	
12	688	March	72	0,92	2	19,2	6,5	0,81	1,96E6	2,8	13,3	3,9	
		April	34	1	1	9,07	5,5	0,75	2,90E6	4,2	19,7	12,4	
		May	46	0,92	2	12,3	12,0	1,49	7,13E6	10,4	48,5	22,5	
13	1 505	March	89	0,79	2	18,9	5,0	0,24	1,40E7	9,3	34,3	10,5	
		April	105	0,77	2	22,3	15	0,73	2,98E7	19,8	73,0	18,9	
		May	100	0,80	2	21,3	11	0,54	6,67E7	44,3	163	44,3	

SITE NO.	A (km^2)	MONTH OF FLOOD	STORM RAINFALL (SP) TOTAL SP (mm)	MAX-DAY SP	DURATION (DAYS)	SP/MAP %	FLOOD HYDROGRAPH T_p (hr)	T_p/t_c	VOLUME (m^3)	(mm)	VOL/MAR %	RUNOFF %	REMARKS
14	151	Jan.	110	0,49	3	26,4	27	8,94	2,60E6	17,2	79,8	15,6	
		March	112	0,79	2	26,9	5	1,66	1,44E6	9,5	44,2	8,5	
		April	40	0,63	2	9,6	6	1,99	5,36E5	3,5	16,4	8,8	
		May	114	0,69	2	27,4	12	3,97	1,61E6	10,7	49,4	9,4	
15	348	March	50	0,76	2	11,3	3	0,54	2,12E6	6,09	15,3	12,2	
		April	102	0,83	2	23,0	11	1,97	4,78E6	13,7	34,4	13,5	
		May	85	0,71	2	19,1	9	1,62	1,01E7	29,0	72,7	34,1	
16	35	March	150	0,61	3	39,9	6,5	4,74	8,94E5	25,5	191	17,0	
17	137	March	163	0,67	3	43,4	-	-	-	-	-	-	
		April	62	1	1	16,5	12,8	3,27	8,03E5	5,9	43,9	9,5	
		May	100	0,65	2	26,6	18	4,59	2,52E6	18,4	138	18,4	
18	10 927	Jan.	49	0,73	3	14,4	-	-	-	-	-	-	
		March	71	0,85	2	20,9	4,5	0,12	1,38E7	1,26	8,36	1,78	
		April	56	0,71	2	16,5	-	-	-	-	-	-	
		May	70	0,71	2	20,6	-	-	-	-	-	-	
19	95	March	71	0,63	4	12,2	33	16,4	1,65E6	17,4	31,9	24,5	
		April	130	0,65	2	22,4	4,5	2,24	5,16E6	54,3	99,6	41,8	
20	3,8	March	122	0,72	4	16,9	7,0	18,9	1,35E5	35,5	19,0	29,1	
		April	100	0,80	3	13,8	10	27,0	1,44E5	37,9	20,3	37,9	
		May	131	0,61	2	18,1	4,5	12,2	2,83E5	74,5	39,9	56,9	
21	131	March	120	0,64	3	15,5	4	1,23	3,28E6	25,0	17,2	20,9	
		April	115	0,70	2	14,8	6,5	2,01	7,69E6	58,5	40,3	51,0	
		May	135	0,56	2	17,4	5	1,54	1,59E7	121	83,3	89,8	
22	145	March	110	0,73	4	15,7	17	5,59	4,57E6	31,5	17,6	28,6	
		April	120	0,83	2	17,1	5,5	1,81	6,39E6	44,1	24,6	36,8	
		May	145	0,68	2	20,7	7,5	2,47	1,16E7	80,0	44,6	55,2	
23	34	March	120	0,82	5	13,6	6,5	4,81	2,42E6	71,2	14,8	59,3	
		May	190	0,66	2	21,5	13	9,63	4,49E6	141	27,4	74,2	

SITE NO.	A (km^2)	MONTH OF FLOOD	STORM RAINFALL (SP) TOTAL SP (mm)	MAX 1 DAY SP	DURATION (DAYS)	SP/MAP %	FLOOD HYDROGRAPH T_p (hr)	T_p/t_c	VOLUME (m^3)	VOLUME (mm)	VOL/MAR %	RUNOFF %	REMARKS
24	1,04	March	125	0,84	5	15,1	8	7,69	9,06E4	87,1	37,1	69,7	
		April	105	0,57	3	12,7	9	8,65	7,28E4	70,0	29,8	66,7	
		May	190	0,66	2	22,9	13,5	13,0	1,41E5	136	57,8	71,6	
25	57	March	150	0,83	5	14,0	2,5	0,81	3,60E6	63,2	19,9	41,1	
		April	124	0,52	3	11,6	4,	1,30	3,03E6	53,2	16,7	42,7	
		May	200	0,63	2	18,7	6,5	2,12	7,26E6	127	40,1	63,7	
26	78	March	160	0,82	5	17,5	7	2,7	3,63E6	46,5	18,5	29,1	
		April	105	0,57	3	11,5	4,5	1,74	3,26E6	41,8	16,6	39,8	
		May	250	0,56	3	27,3	7	2,7	1,22E7	156	62,2	62,4	
27	72	March	160	0,84	4	16,6	5	2,19	6,13E6	85,1	52,8	53,2	
		April	108	0,51	3	11,2	11	4,82	3,21E6	44,6	27,6	41,3	
		May	255	0,51	3	26,4	11	4,82	1,07E7	149	92,1	58,3	
28	22	March	155	0,61	5	19,8	4	3,77	3,26E6	148	88,4	95,5	
		April	112	0,58	4	15,5	7	6,6	1,78E6	80,9	48,2	72,2	
		May	220	0,45	3	28,0	8	7,55	5,12E6	233	139	105	Much rain fell after the flood peak has occurred
29	133	March	151	0,73	5	16,3	3	0,79	6,50E6	48,9	19,3	32,4	
		April	134	0,52	3	14,4	8	2,10	4,94E6	37,1	14,7	27,7	
		May	201	0,50	2	21,7	18,5	4,86	1,60E7	120	47,5	59,9	
30	91	March	150	0,74	5	16,2	1,5	0,44	7,00E6	76,9	43,7	51,3	
		April	154	0,52	2	16,6	7	2,05	4,78E6	52,5	29,8	34,1	
		May	170	0,71	2	18,3	5	1,46	1,85E6	203	115	119	Rainfall depth could have been higher
31	165	March	152	0,58	2	23,4	5,5	1,33	4,22E6	25,6	41,8	16,8	
		April	121	0,54	3	18,6	4	0,97	4,18E6	25,3	41,4	20,9	
		May	160	0,53	2	24,6	11	2,66	1,08E7	65,5	107	40,9	
32	764	Jan	93	0,52	4	11,5	34	3,05	6,35E6	8,3	7,09	8,9	
		March	158	0,85	3	19,5	5,5	0,49	2,64E7	34,6	29,5	21,9	
		April	120	0,46	3	14,8	11,5	1,03	1,28E7	16,8	14,3	14,0	
		May	160	0,56	2	19,8	11	0,99	3,64E7	47,6	40,6	27,8	

SITE NO.	A (km^2)	MONTH OF FLOOD	STORM RAINFALL (SP): TOTAL SP (mm)	STORM RAINFALL (SP): MAX 1 DAY SP	STORM RAINFALL (SP): DURATION (DAYS)	SP / MAP %	FLOOD HYDROGRAPH: T_p (hr)	FLOOD HYDROGRAPH: T_p/t_c	VOLUME (m^3)	VOLUME (mm)	VOLUME: VOL / MAR %	RUNOFF %	REMARKS
33	57	March	210	0,81	3	19,1	11	5,16	6,01E6	105	30,7	50,2	
		April	63	0,48	5	5,74	1,5	0,7	6,65E5	11,7	3,39	18,6	
		May	161	0,75	2	14,7	7,5	3,52	7,33E6	128	37,4	79,5	
34	26	March	193	0,67	4	16,1	8,5	5,25	4,43E6	170	21,5	88,1	
		April	55	0,45	4	4,58	30	18,5	1,03E6	39,6	5,0	72,0	Wet antecedent conditions
		May	185	0,54	3	15,4	2,5	1,54	3,93E6	151	19,1	81,6	
35	35	March	198	0,66	4	17,2	24	15,2	2,51E6	71,7	14,2	36,2	
		May	195	0,51	2	16,9	23	14,6	2,93E6	83,7	16,6	42,9	
36	52	March	140	0,71	2	20,5	5	1,93	2,33E6	44,8	43,4	32,0	
		April	77	0,45	3	11,3	5,5	2,12	1,42E6	27,3	26,4	35,5	
		May	135	0,70	2	19,8	8,5	3,28	5,25E6	101	97,8	74,8	
37	21	March	230	0,55	4	32,1	7,5	8,33	2,45E6	117	88,5	50,9	
		April	59	0,51	2	8,23	9,5	10,6	4,36E5	20,8	15,7	35,3	
		May	175	0,60	2	24,4	6,5	7,22	3,15E6	150	114	85,7	
38	29 232	March	56	0,88	3	22,1	8	0,1	1,01E8	3,5	46,5	6,2	
39	3 887	March	109	0,92	2	19,6	13	0,38	8,97E7	23,1	51,0	21,2	
40	170	March	360	0,65	4	55,3	-	-	-	-	-	-	
41	147	March	415	0,76	3	60,9	3	1	3,15E7	214	260	51,6	RMF
42	36	March	350	0,60	3	49,5	-						
43	74	March	360	0,69	3	50,9	-						
44	51	March	325	0,65	3	46,0	-						
45	34	March	345	0,80	3	48,9	-						
46	400	March	320	0,78	3	45,3	-						
47	261	March	200	0,80	3	30,6	-						
48	900	March	300	0,58	3	44,4	-						
49	1 080	March	300	0,58	3	45,9	-						
50	127	March	230	0,83	3	42,0	-						
51	39	March	261	0,75	3	36,9	-						
52	67	March	280	0,82	3	39,6	-						
53	69	March	280	0,79	3	39,6	-						