CHAPTER 4 ANALYSIS OF RAINFALL

4.1 Rainfall Mechanism

4.1.1 Characteristics of Rainfall

Monthly rainfall and rain-days observed at the rain gauges installed by the project (Table B-1-3, Fig. B-1-1) during June, 1983 to July, 1985 are shown in Table B-4-1. Daily rainfall is shown in Fig. B-4-1. The data of the rain gauges installed after 1984, are excluded from the figure. The rain gauges in the upper part on this figure -- from RA3 to RK6 -- are in the mountain area, in the middle part -- from RA2 to RM4 -- are on and around the boundary between the mountain and the marginal wadi plain area, and in the lower part -- from RA1 to RM2 -- are in the marginal wadi plain and the gravel plain area. Monthly mean rainfall and rain-days in the mountain and in the gravel plain are shown in Fig. B-4-2.

The characteristics of rainfall in the project area, suggested from those figures, are described below.

- There was no rain in the gravel plain in summer (June to September) except one rainfall on August 10 - 11, 1983.
- Rainfall was observed at a few rain gauges on the same days, in summer except one rainfall on August 10 - 11, 1983
- Although rain-days are not many in winter, rainfall was observed at many rain gauges on same days.

Three representative rainfalls (on August 10 - 11, 1983, on August 25, 1984, and during December 28, 1984 to January 1, 1985) are analyzed and the results are described below.

1) The rainfall on August 10 - 11, 1983

The distribution of the rainfall on the weather chart is shown in Fig. B-4-3, and the distribution in comparison with NOAA data is shown in Supporting Report (F). Time series of hourly rainfall at each gauge is shown in Fig. B-4-4.

The tropical cyclones, originating in the Arabian Sea and migrating westerly to Mashirah Island in southeast of Oman, brought rainfall over the project area. The rainfall moved from east to west.

It brought heavy rainfall to the mountains and light rainfall to the gravel plain; no rainfall was observed at Saham on the coast of Wadi Ahin. The rainfall continued intermittently during more than 24 hours. The heaviest rainfall was observed at RF1, 88.5 mm.

2) The rainfall on August 25, 1984

The distibution of the rainfall on the weather chart is shown in Fig. B-4-5 and time series of hourly rainfall in shown in Fig. B-4-6. Though the low pressure spreads to Northwest India and Arabian Peninsula, this is the typical weather chart in summer. Even though rainfall continued less than an hour in a very small area, the intensity was very high.

3) The rainfall during December 28, 1984 to January 1, 1985

The distribution of rainfall on the weather chart is shown in Fig. B-4-7, and the distribution in comparison with NOAA data is shown in Supporting Report (F).

The cold front, stretching from the cyclone, moved east over Oman and brought the rainfall. Time series of hourly rainfall on December 29, 1985 when the front passed, are shown in Fig. B-4-8. Although much rain came on the coastal area, the rainfall occured over the whole project area except for a part of the mountain. As the cold front was passing easterly, the rainfall was also moving from west to east.

The maximum rainfall intensity observed at each rain gauge is shown in Table B-4-2. Although all the rainfall in the mountain on the figure is in summer, almost of all rainfall in the gravel plain and the marginal wadi plain (RAI, RG1, RG2, RF4, RM1, RM2) are in winter. The strong rainfall for long periods in the mountain were caused by the tropical cyclone on August 10 - 11, 1983. On the other hand, the strong rainfall during a short period in the mountain was recorded on each of the days.

As the result of the analysis, the rainfalls in the project area can be divided into three types: rainfall caused by tropical cyclones, rainfall in summer caused by other phenomena, and rainfalls caused by synoptic disturbances in winter.

The second type of rainfall have strong intensity. Seventy percent of the rainfalls lasted less than one hour, and almost all rainfall came during one hour even when that rainfall continued more than one hour.

The correlation of the summer daily rainfalls between RF1 and RF2, which are the nearest rain gauges in the mountain, is shown in Fig. B-4-9. Although those are only 4 km apart, both of them experienced only six rainfalls out of twenty-four rainfalls which were either observed. Consequently, the rainfall area is narrow. These characteristics (narrow are a, intense and short rainfalls) suggest that rainfalls are caused by cumulus and cumulonimbus clouds formed under strong ascending air current.

The distribution of occurence time of the summer rainfall is shown in Fig. B-4-10. It shows that 85% of the rainfalls comes during one to six in the afternoon, when the sea breeze circulation grows strongly. Consequently, the cause of the rainfall can be considered as the sea breeze circulation.

In summary, there are three clear causes of the rainfalls in the project area: tropical cyclones, sea breeze circulations, synoptic disturbances.

Table B-4-1 Monthly Rainfall and Rain-day (June 1983-July 1985)

Unit: Number, mm

Station	1983							1984												1985						
	JUN	JUL	AUG	SEP	OCT	NOB	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL
RA 1	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(1) 26.0	(0)	(0)	(1) 0.5	(0)	(0)	(0)	(0)
RA 2	(x)	(0)	(2) 20.0	(0)	(0)	(0)	(0)	(1) 0.5	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(1) 3.0	(0)	(0)	(1) 3.5	(0)	(0)	(0)	(0)	(0)	(0)	(0)
RA 3	(x)	(0)	(3) 64.0	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(1) 2.5	(0)	(3) 18.0	(1) 2.5	(4) 11.0	(0) 0.0	(0)	(1) 2.0	(0)	(0)	(1) 0.5	(1) 10.0	(0)	(0)	(1) 1.0
RA 4	(x)	(x)	(x)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(1) 0.5	(0)	(0)	(2) 8.5	(0)	(2) 4.5	(0)	(0)	(2) 1.0	(0)	(0)	(0)	(0)	(0)	(0)	(0)
RA 5	(x)	(x)	(3) 12.0	(1) 6.0	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(1) 0.5	(0)	(4) 36.5	(0)	(0)	(2) 3.5	(0)	(0)	(1) 2.5	(0)	(0)	(0)	(2) 17.0
RA 6	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(3) 18.5	(0)	(0)	(0)	(0)	(0)	(0)	(0)
RG 1	(0)	(0)	(1) 1.5	(0)	(0)	(0)	(0)	(1) 4.5	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(1) 28.0	(0)	(0)	(0)	(0)	(0)	(0)	(0)
RG 2	(0)	(0)	(1) 7.0	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(1) 18.5	(1) 0.5	(0)	(1) 1.5	(0)	(0)	(0)	(0)
RG 3	(0)	(0)	(x)	(1) 16.5	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(1) 2.5	(0)	(0)	(0)	(0)	(2) 3.5	(0)	(0)	(1) 0.5	(2) 5.0	(0)	(0)	(0)
RG 4	(0)	(1) 13.5	(3) 47.5	(1) 1.0	(0) 0.0	(0) 0.0	(1) 3.0	(1) 1.0	(0)	(0)	(2) 11.0	(0)	(1) 2.5	(4) 13.5	(x) +	(x) +	(x) +	(0)	(1) 9.0	(0)	(0)	(1) 5.0	(0)	(0)	(0)	(0)
RG 5	(0)	(1) 7.5	(3) 41.0	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(2) 2.5	(0)	(1) 1.0	(4) 5.0	(2) 9.5	(1) 3.5	(0)	(0)	(2) 1.0	(0)	(0)	(2) 3.0	(0)	(0)	(2) 27.0	(0)
RF 1	(0)	(1) 1.0	(3) 93.5	(1) 7.0	(0)	(0)	(0)	(0)	(0)	(0)	(2) 24.5	(0)	(0)	(3) 26.0	(1) 0.5	(2) 7.5	(0)	(0)	(0)	(1) 1.5	(0)	(2) 6.5	(0)	(1) 0.5	(1) 9.5	(0)
RF 2	(0)	(2) 14.5	(4) 59.5	(3) 20.5	(0)	(0)	(0)	(0)	(0)	(1) 5.5	(2) 2.0	(0)	(0)	(5) 45.0	(4) 27.0	(5) 41.5	(0)	(0)	(0)	(1) 3.0	(0)	(2) 17.5	(0)	(2) 10.5	(1) 26.5	(2) 15.5
RF 3	(0)	(2) 18.0*	(3) 29.0*	(0)	(0)	(0)	(0)	(0)	(0)	(1) 3.0	(2) 26.5	(1) 1.0	(x) x	(x) x	(2) 3.0	(3) 8.0	(0)	(0)	(0)	(2) 7.0	(0)	(3) 15.5	(0)	(1) 5.0	(1) 0.5	(4) 11.0
RF 4	(0)	(0)	(1) 4.5	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(1) 15.5	(0)	(0)	(0)	(0)	(0)	(0)	(0)
MF 1	(x)	(x)	(1) 6.5	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(1) 9.0	(1) 0.5	(0)	(1) 1.0	(0)	(0)	(0)	(0)
MF 2	(0)	(0)	(8) 45.0	(3) 13.6	(0)	(0)	(2) 0.4	(2) 0.4	(1) 0.2	(x)	(x)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(3) 13.5	(0)	(0)	(1) 3.0	(0)	(0)	(0)	(0)
RK 1	(0)	(0)	(1) 7.5	(1) 2.0	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(1) 20.5	(0)	(0)	(1) 8.0	(0)	(0)	(2) 4.5	(0)	(0)	(0)	(0)
RK 2	(0)	(0)	(3) 10.5	(1) 3.5	(0)	(0)	(0)	(0)	(0)	(0)	(1) 10.5	(0)	(0)	(1) 2.5	(3) 30.5	(5) 18.0	(0)	(0)	(3) 6.0	(0)	(0)	(1) 4.0	(0)	(1) 0.5	(1) 11.5	(1) 9.5
RK 3	(0)	(0)	(3) 49.0	(1) 2.5	(0)	(0)	(0)	(0)	(0)	(x)	(x)	(1) 2.5	(0)	(3) 6.5	(5) 59.5	(6) 16.5	(0)	(0)	(0)	(1) 4.5	(0)	(2) 9.0	(1) 6.5	(1) 11.5	(2) 10.0	(2) 1.0
RK 4	(0)	(1) 11.0	(8) 51.5	(0)	(0)	(0)	(0)	(0)	(0)	(1) 3.0	(2) 7.5	(1) 4.0	(0)	(3) 4.0	(5) 32.5	(3) 11.5	(0)	(0)	(0)	(1) 2.0	(0)	(2) 10.5	(0)	(1) 5.0	(1) 18.0	(3) 24.0
RK 5	(0)	(0)	(4) 19.5	(2) 35.5	(0)	(0)	(0)	(0)	(0)	(0)	(2) 2.0	(0)	(0)	(2) 5.5	(0)	(1) 3.0	(0)	(0)	(x) ++	(x) ++	(x) ++	(1) 1.5	(0)	(1) 2.0	(1) 0.5	(0)
RK 6	(0)	(5) 31.0	(4) 76.5	(2) 16.0	(0)	(0)	(0)	(0)	(0)	(1) 3.0	(2) 14.0	(0)	(0)	(4) 14.5	(5) 22.0	(5) 23.0	(0)	(0)	(1) 2.0	(0)	(0)	(2) 13.5	(2) 6.5	(2) 10.0	(0)	(5) 52.0
RK 7	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(0)	(0)	(0)	(0)
RM 1	(0)	(0)	(1) 4.0	(0)	(0)	(0)	(0)	(1) 0.5	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(1) 38.5	(0)	(0)	(1) 1.5	(0)	(0)	(0)	(0)
RM 2	(0)	(0)	(1) 1.5	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(1) 7.0	(0)	(0)	(0)	(0)	(0)	(0)	(0)
RM 3	(0)	(0)	(1) 11.5	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(1) 11.5	(0)	(0)	(1) 4.0	(1) 1.0	(0)	(0)	(0)
RM 4	(0)	(x)	(x)	(x)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(1) 0.5	(0)	(0)	(2) 1.0	(1) 1.0	(0)	(2) 23.5	(0)	(0)	(0)	(0)

Note: -: Before installed of rain gauge
x: No record
*: Recorded partly and total rainfall in July and August is 60.0mm
+: Total rainfall in August September and October is 3.0mm
++: Total rainfall in December 1984 and January, February 1985 is 3.0mm

Table B-4-2 Maximum Rainfall Intensity (June 1983-July 1985)

Rain gauge		Duration							
		15 min.	30 min.	60 min.	120 min.	6 hr.	12 hr.	24 hr.	48 hr.
WADI AHIN	RA1	8.5 (29/12/84)	9.0 (29/12/84)	15.5 (29/12/84)	17.0 (29/12/84)	26.0 (29/12/84)			
	RA2	3.5 (10/8/83)	4.0 (10/8/83)	4.0 (10/8/83)	7.5 (10/8/83)	11.5 (10/8/83)	18.5 (10,11/8/83)	20.0 (10,11/8/83)	
	RA3	9.0 (29/8/83)	12.5 (29/8/83)	13.0 (29/8/83)	15.0 (10/8/83)	29.5 (10/8/83)	41.5 (10,11/8/83)	48.0 (10,11/8/83)	49.5 (10,11/8/83)
	RA4	5.0 (15/7/84)	5.0 (15/7/84)	7.5 (15/7/84)	8.0 (15/7/84)				
	RA5	10.0 (5/9/84)	19.0 (5/9/84)	20.5 (5/9/84)					
WADI BANI GHAFIR	RG1	19.5 (29/12/84)	19.5 (29/12/84)	20.5 (29/12/84)	24.0 (29/12/84)	26.0 (29/12/84)	26.0 (29/12/84)	28.0 (29/12/84)	
	RG2	12.5 (29/12/84)	12.5 (29/12/84)	16.0 (29/12/84)	16.0 (29/12/84)	18.5 (29/12/84)			
	RG3	10.0 (15/9/83)	14.0 (15/9/83)	16.0 (15/9/83)	16.5 (15/9/83)				
	RG4	13.0 (28/7/83)	13.5 (28/7/83)	13.5 (28/7/83)	13.5 (28/7/83)	28.0 (28/7/83)	37.0 (10/8/83)		
	RG5	10.0 (10/8/83)	16.5 (10/8/83)	17.5 (10/8/83)	18.0 (10/8/83)	30.0 (10/8/83)	32.5 (10/8/83)	37.0 (10/8/83)	
WADI AL-FARA'	RF1	13.5 (10/7/84)	14.5 (10/7/84)	23.0 (10/8/83)	34.5 (10/8/83)	61.5 (10/8/83)	88.5 (10/8/83)		
	RF2	19.5 (22/6/85)	26.0 (22/6/85)	26.5 (22/6/85)	39.0 (10/8/83)	53.0 (10/8/83)	54.0 (10/8/83)		
	RF3	12.5 (10/7/83)	14.0 (11/4/84)	14.0 (11/4/84)	14.0 (11/4/84)	15.0 (10/8/83)	18.5 (10/8/83)	19.5 (10,11/8/83)	
	RF4	12.0 (29/12/84)	12.5 (29/12/84)	12.5 (29/12/84)	12.5 (29/12/84)	15.5 (29/12/84)			
	MF1	3.0 (29/12/84)	5.0 (29/12/84)	7.0 (29/12/84)	9.0 (29/12/84)				
	MF2	6.4 (28/8/83)	11.0 (28/8/83)	17.6 (28/8/83)	19.0 (28/8/83)	19.0 (28/8/83)	20.4 (10/8/83)	21.0 (10/8/83)	21.2 (10,11/8/83)
WADI BANI KHARUS	RK1	15.0 (8/9/84)	20.0 (8/9/84)	20.5 (8/9/84)					
	RK2	14.0 (24/8/84)	18.0 (24/8/84)	19.0 (24/8/84)					
	RK3	18.0 (25/8/84)	35.0 (25/8/84)	43.0 (25/8/84)					
	RK4	15.0 (15/6/85)	18.0 (15/6/85)	19.5 (10/8/83)	20.0 (10/8/83)	25.0 (10/8/83)	25.5 (10/8/83)		
	RK5	16.0 (15/9/83)	18.5 (15/9/83)	19.5 (15/9/83)					
	RK6	15.5 (3/9/84)	15.5 (3/9/84)	23.0 (25/7/83)	23.0 (25/7/83)	33.5 (10/8/83)	39.5 (10/8/83)	72.0 (10,11/8/83)	
WADI AL-MA'AWIL	RM1	27.0 (29/12/84)	29.5 (29/12/84)	29.5 (29/12/84)	37.5 (29/12/84)	38.5 (29/12/84)			
	RM2	4.5 (29/12/84)	4.5 (29/12/84)	4.5 (29/12/84)	5.0 (29/12/84)	7.0 (29/12/84)			
	RM3	2.5 (10/8/83)	2.5 (10/8/83)	4.5 (10/8/83)	5.5 (10/8/83)	10.0 (10/8/83)	11.5 (10/8/83)		
	RM4	18.5 (18/4/85)	18.5 (18/4/85)	18.5 (18/4/85)	18.5 (18/4/85)	18.5 (18/4/85)	18.5 (18/4/85)	18.5 (18/4/85)	23.5 (18,19/4/85)

upper row: Rainfall (mm)
lower row: (date)

Fig. B-4-1 Daily Rainfall Time Series

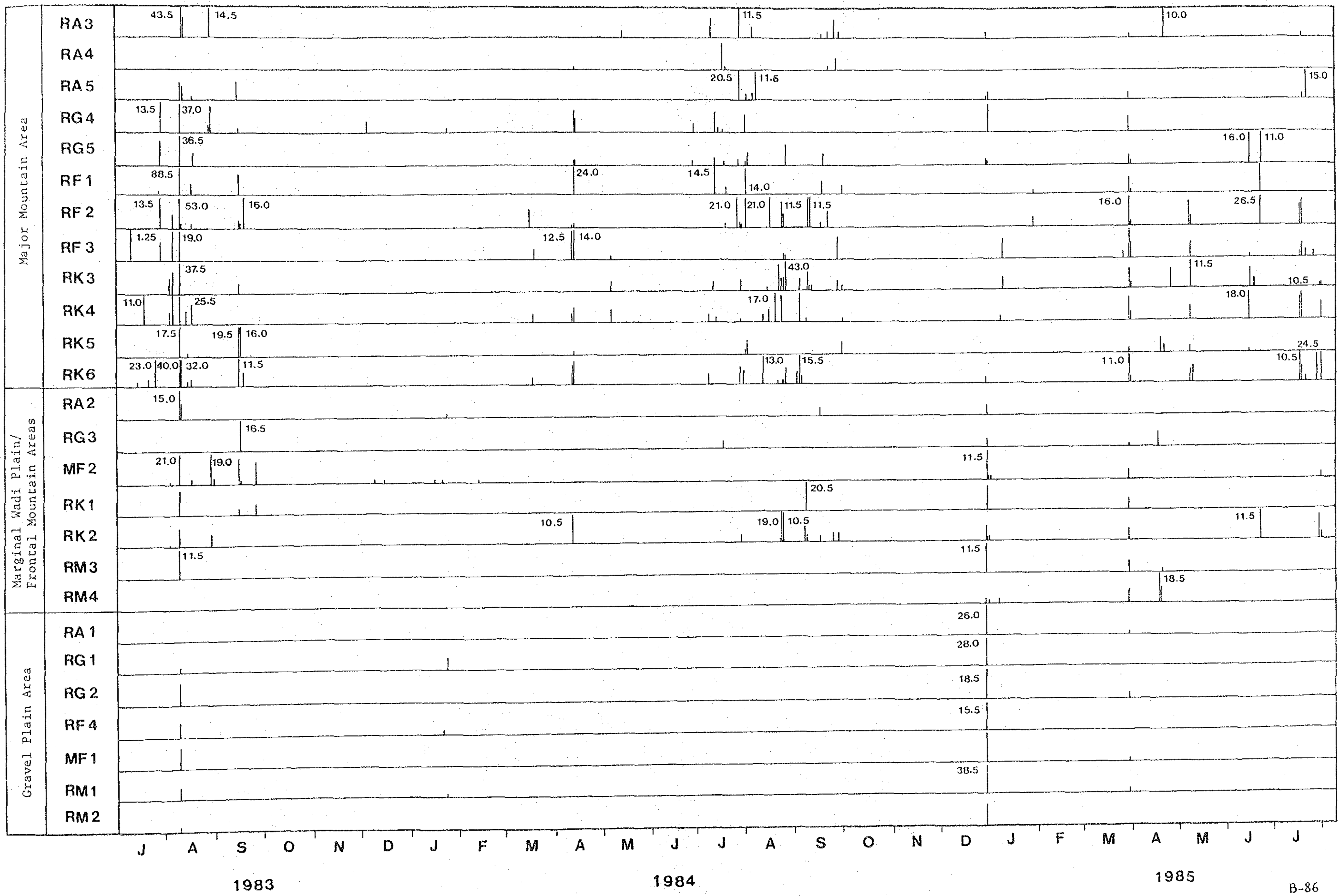


Fig. B-4-2 Comparison of Regional Rainfall in Mountain and in Marginal Wadi Plain and Gravel Plain

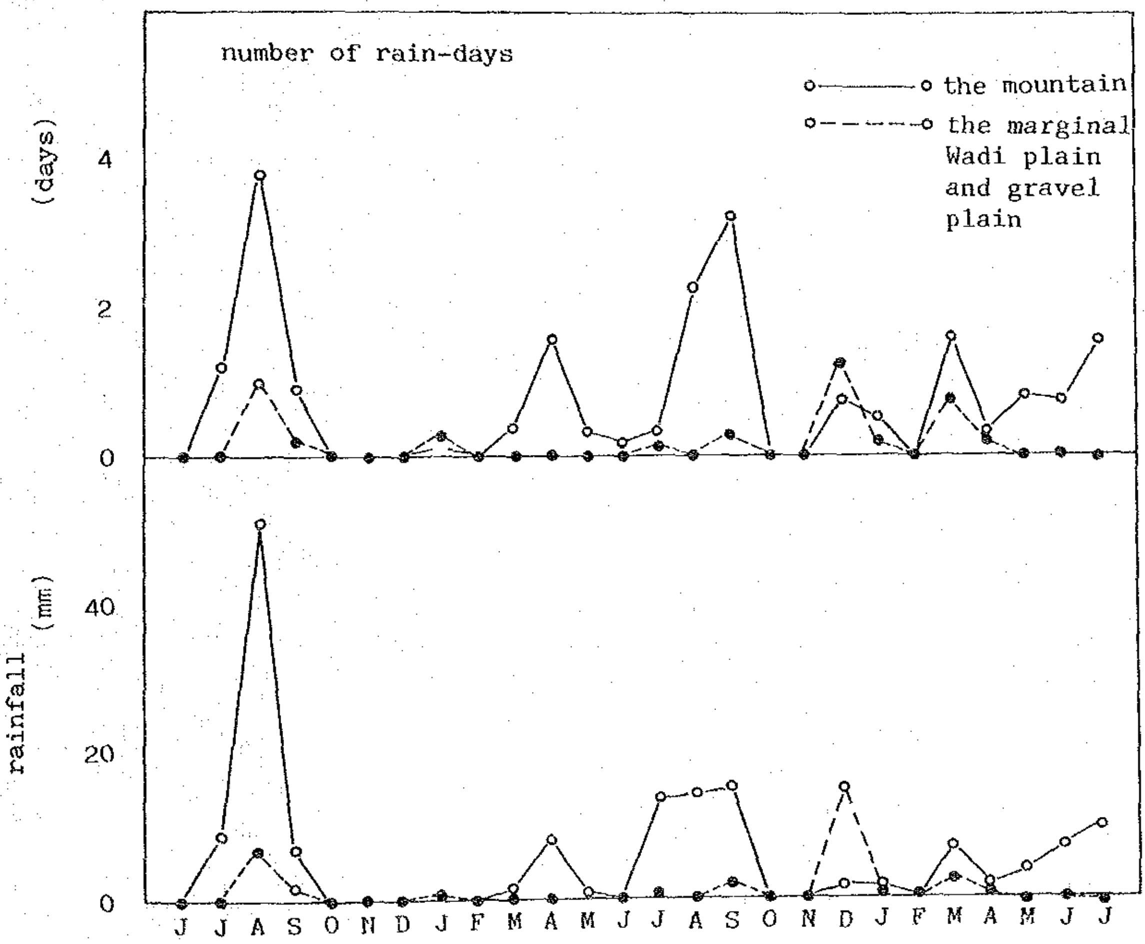
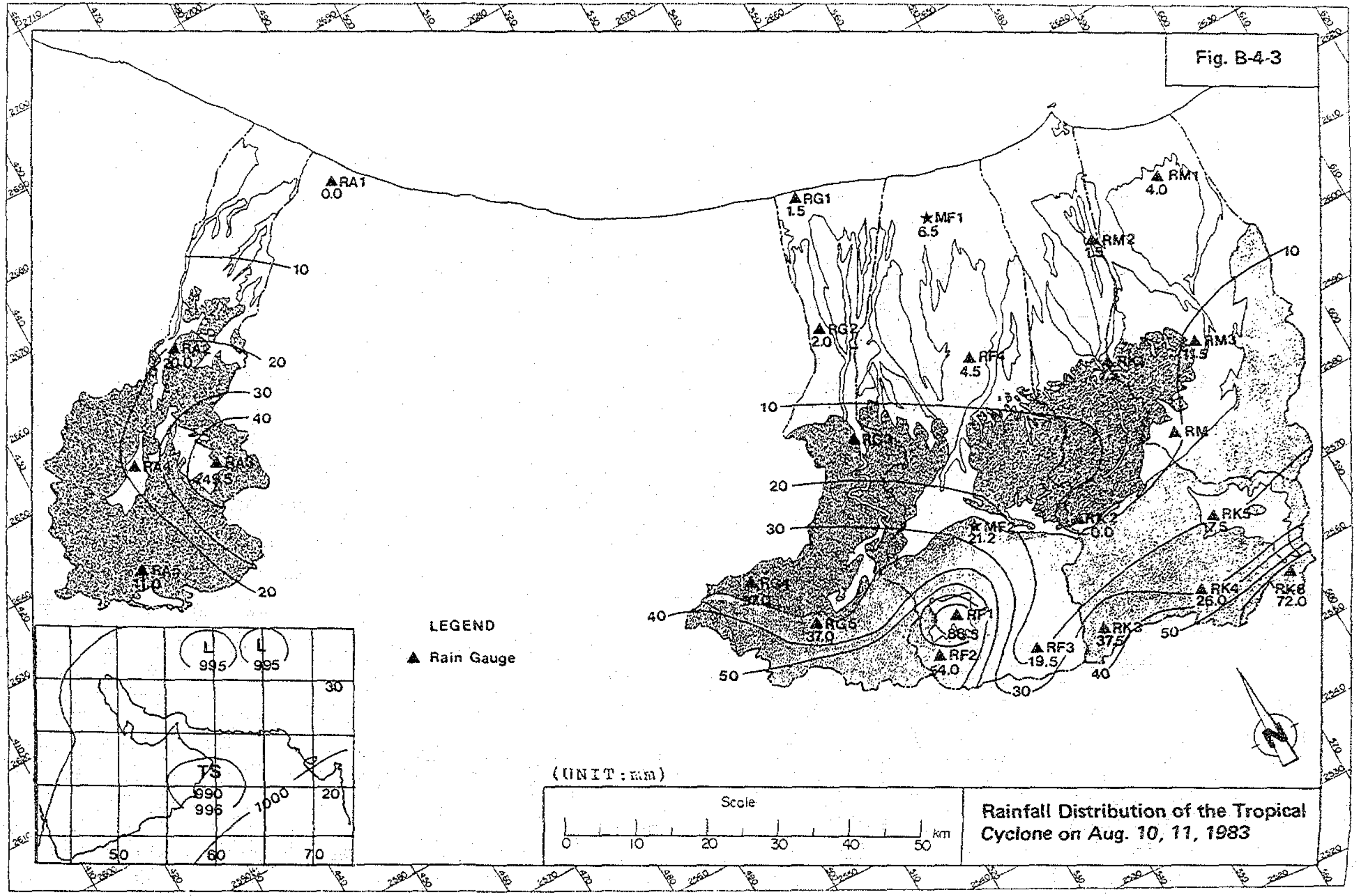


Fig. B-4-3



Rainfall Distribution of the Tropical Cyclone on Aug. 10, 11, 1983

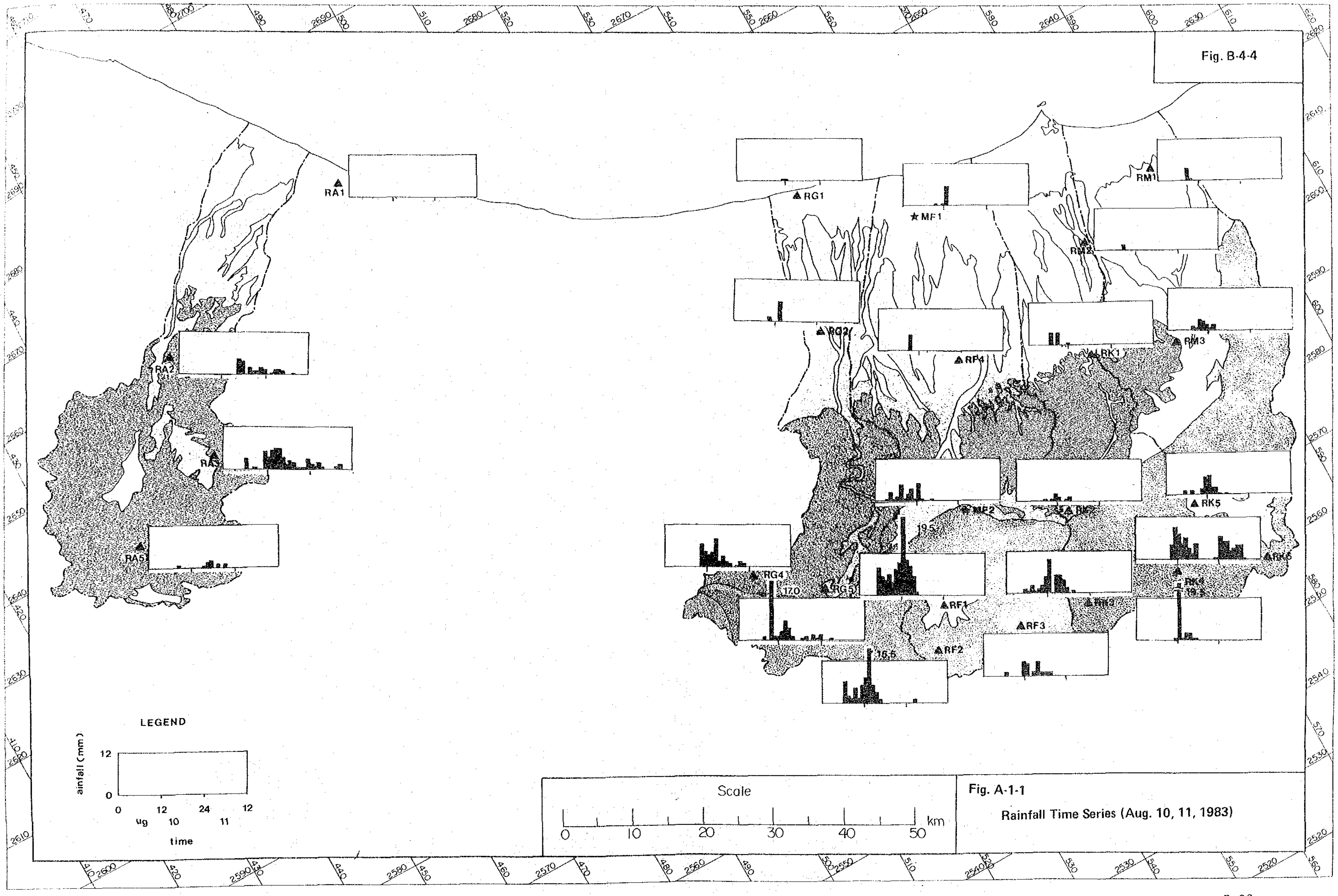
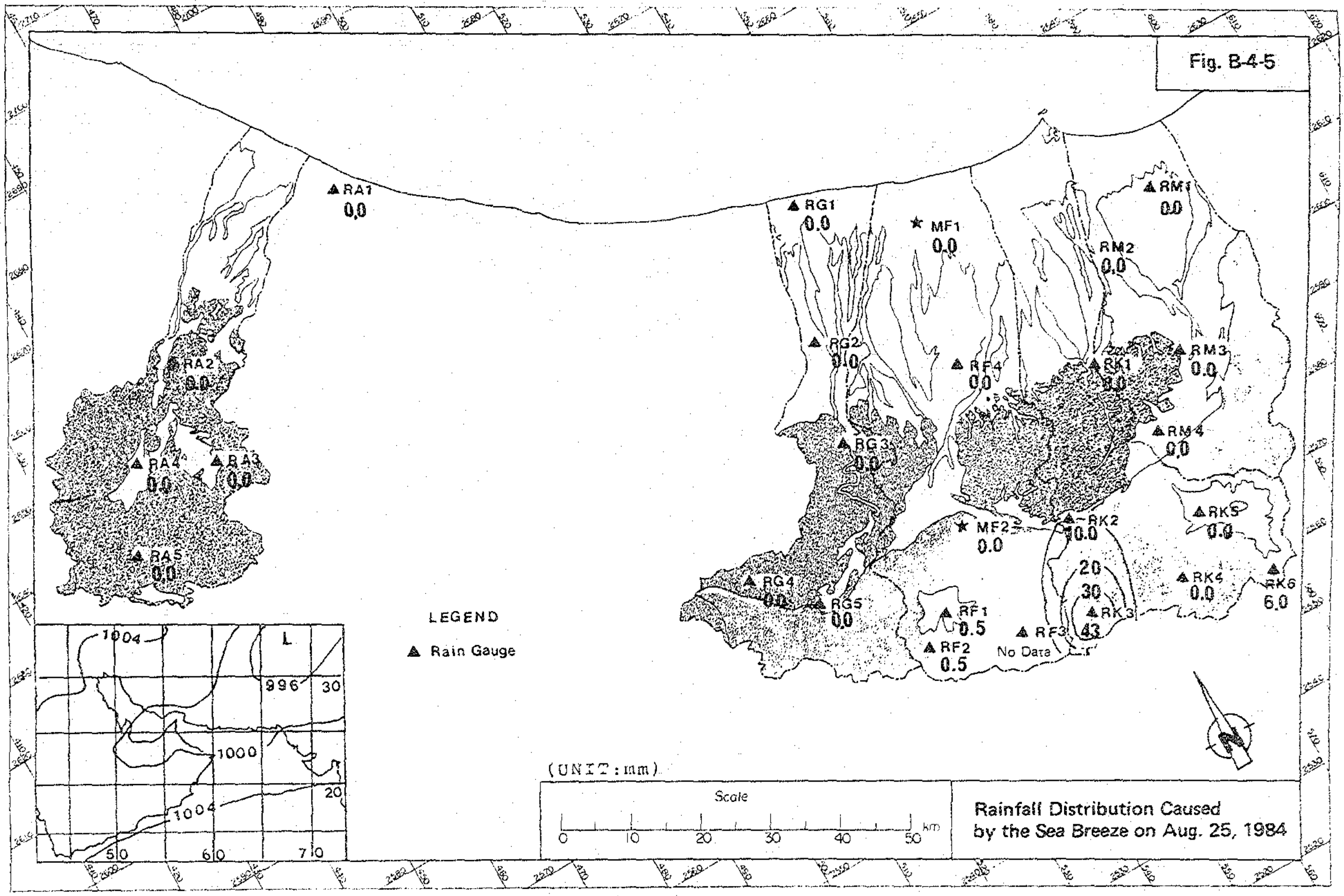


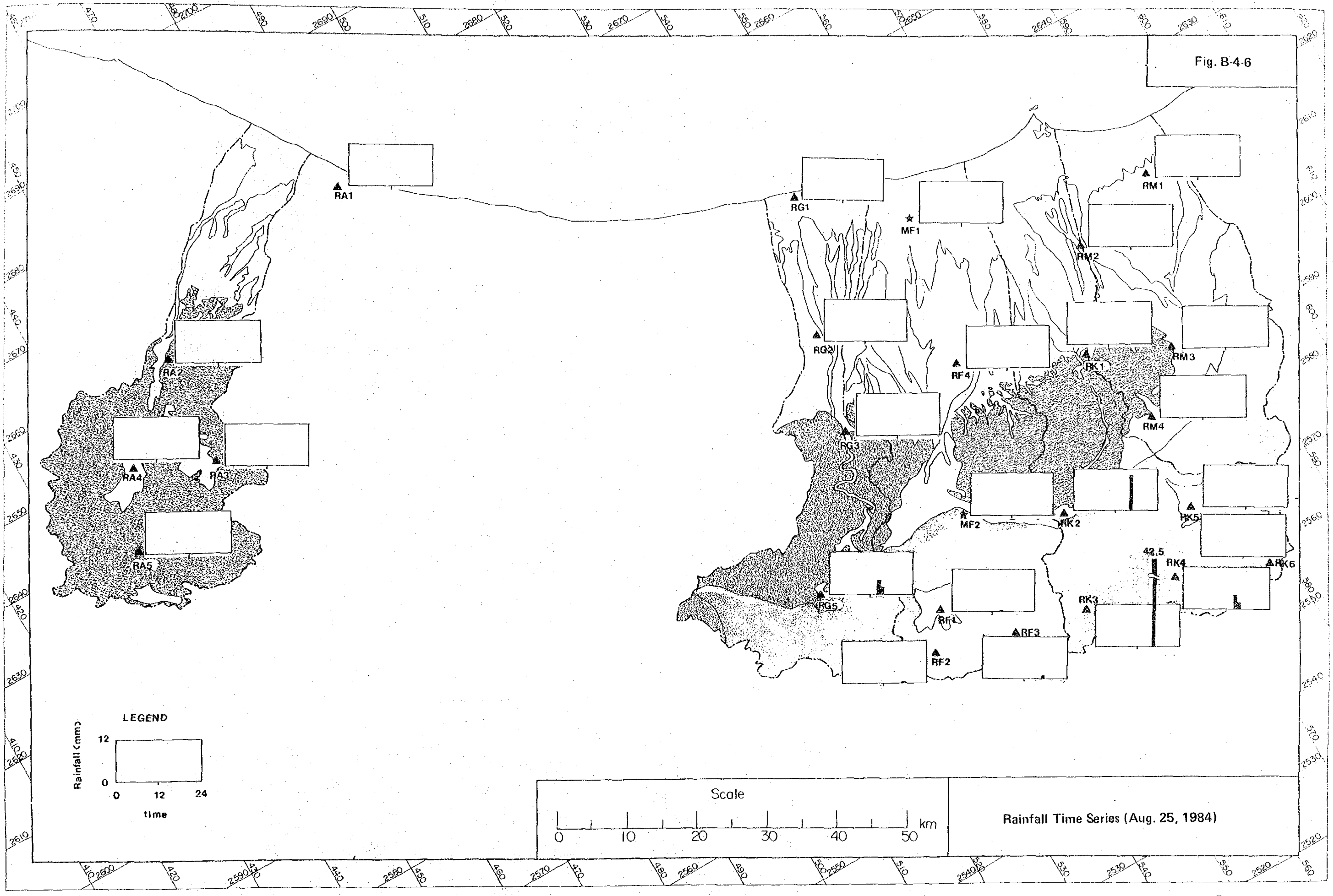
Fig. A-1-1

Rainfall Time Series (Aug. 10, 11, 1983)

Fig. B-4-5

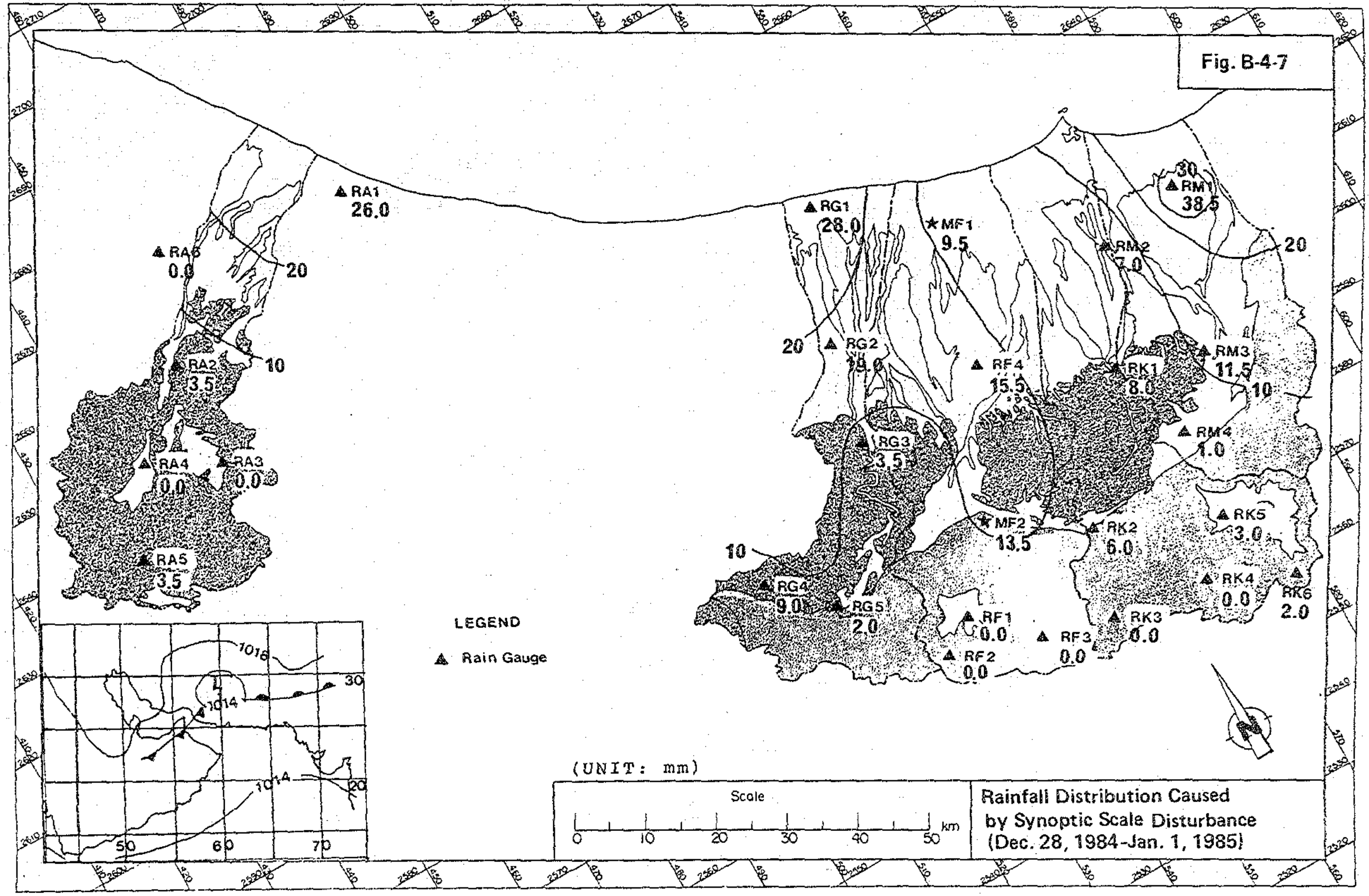


Rainfall Distribution Caused by the Sea Breeze on Aug. 25, 1984

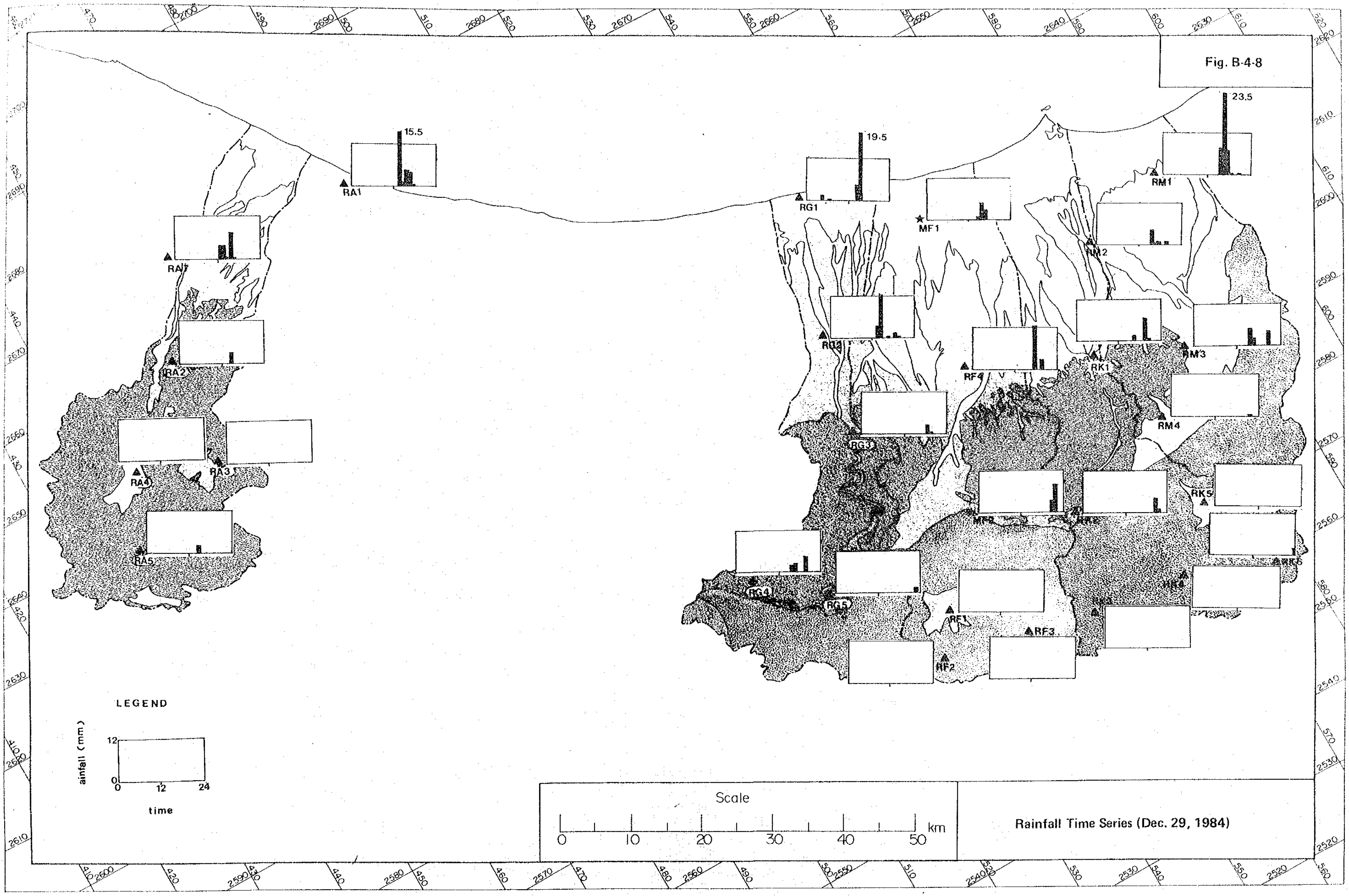


Rainfall Time Series (Aug. 25, 1984)

Fig. B-4-7



Rainfall Distribution Caused by Synoptic Scale Disturbance (Dec. 28, 1984-Jan. 1, 1985)



Rainfall Time Series (Dec. 29, 1984)

Fig. B-4-9 Correlation of Summer Rainfall between Adjacent Rain Gauges

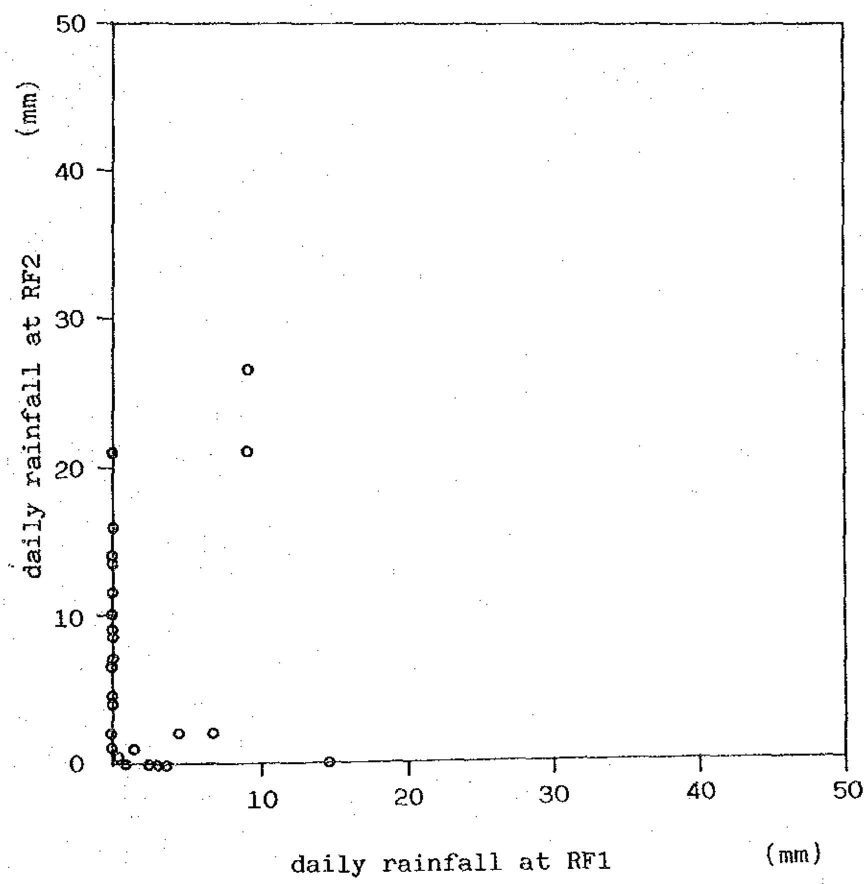
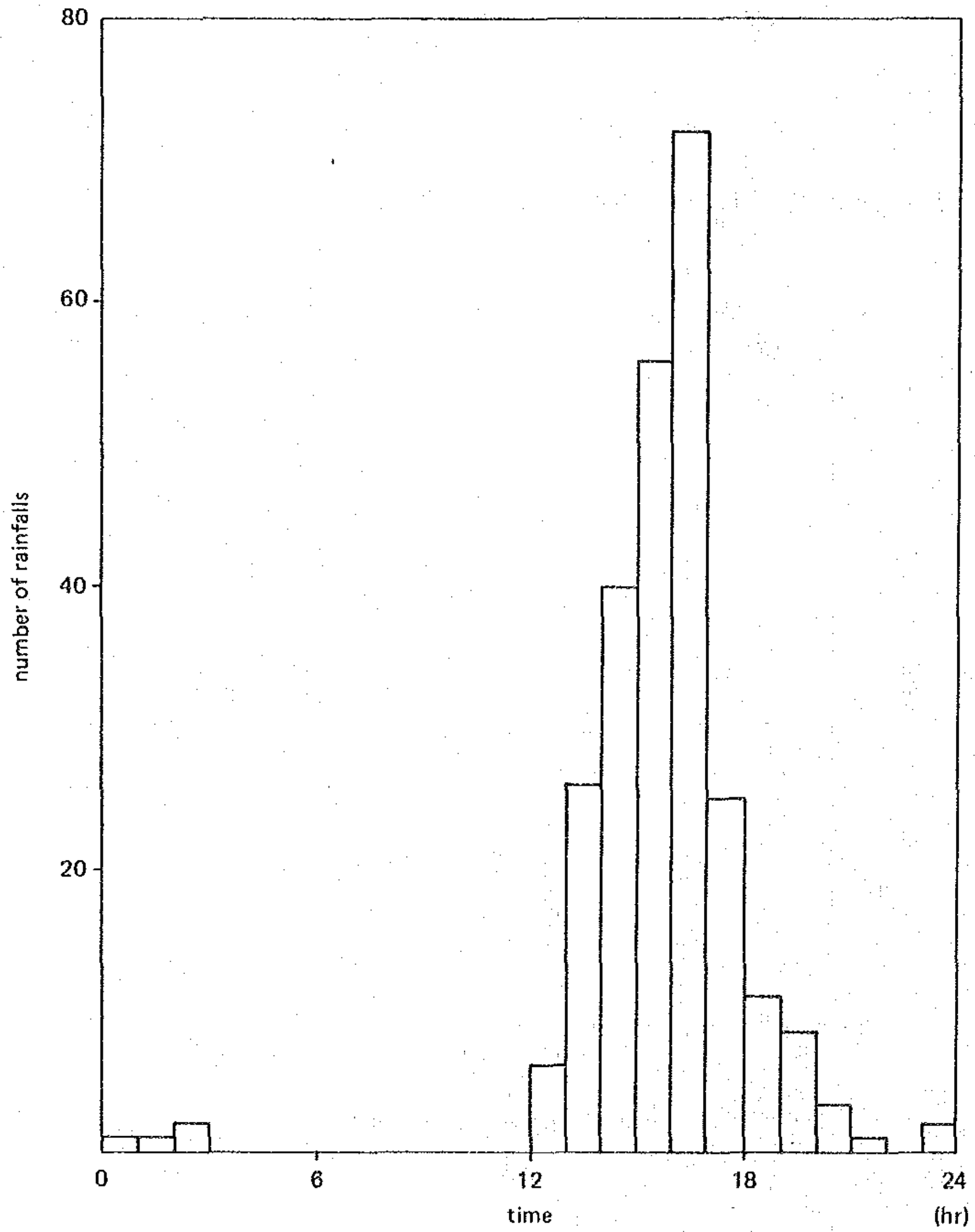


Fig. B-4-10 Occurrence Time Distribution of Summer Rainfall



4.1.2 Rainfalls Caused by Tropical Cyclone

The largest rainfall observed during the project, was brought by the tropical cyclone. However, according to D.E. Pedgley who summarized the record of the cyclones in the Arabian Sea (Cyclones along the Arabian Coast, Weather, London, Volume 24, 1969, pp.456-468), tropical cyclones that bring more than 10 mm rainfall on Mashirah Island or at Salalah come once in more than five years. As Mashirah Island and Salalah are on the Arabian Coast, they are considered under stronger influence of tropical cyclones than Muscat.

According to Renardet Sauti Ice (Water Resources Survey in North-East Oman, Annex A Climatology, March 1975) tropical cyclones bringing more than 10 mm rainfall at Muscat come once in more than 50 years. Renardet Sauti Ice also reported more than 300 mm rain came on June 5, 1890 from a tropical cyclone. This amount of rain is very rare.

4.1.3 Rainfall Caused by Sea Breeze

The mechanism of rain formation by sea breeze is shown in Fig. B-4-11. The sea breeze transports humid air masses from Gulf of Oman to Hajar Mountain. The air mass is lifted by the sea breeze circulation joined with valley wind circulation. Then it is transformed to cumulus or cummulonimbus clouds where rainfall is formed.

The relation between elevation and rain-days and rainfalls caused by the sea breeze circulation is shown in Fig. B-4-12. All of the data was observed during June to September of 1983, 1984 and in June and July of 1985. As elevation increases, the rainfall and the rain-days increase. No rain was observed from the rain gauge below 150 m a.s.l.

The total number of the rainfalls during the period was 202. The frequency distribution of the rainfalls on normal probability paper is shown in Fig. B-4-13. On this figure, the X-axis is daily rainfall using a cube root scale, and the Y-axis is cumulative frequency. The cube root of rainfalls generally form a normal distribution. The distribution of the rainfalls caused by sea breeze circulation fits the normal curve well.

The characteristics of rainfall caused by the sea breeze circulation are summarized below.

- The rainfall increases, as elevation increases.
- The rainfall probably does not occur at lower elevation.
- The rainfall occurs mainly in the afternoon.
- The rainfall continues for a short time and almost all of it stops in less than one hour.
- The rainfall area is narrow.

Fig. B-4-11 Sea Breeze Circulation in the Batinah Coast

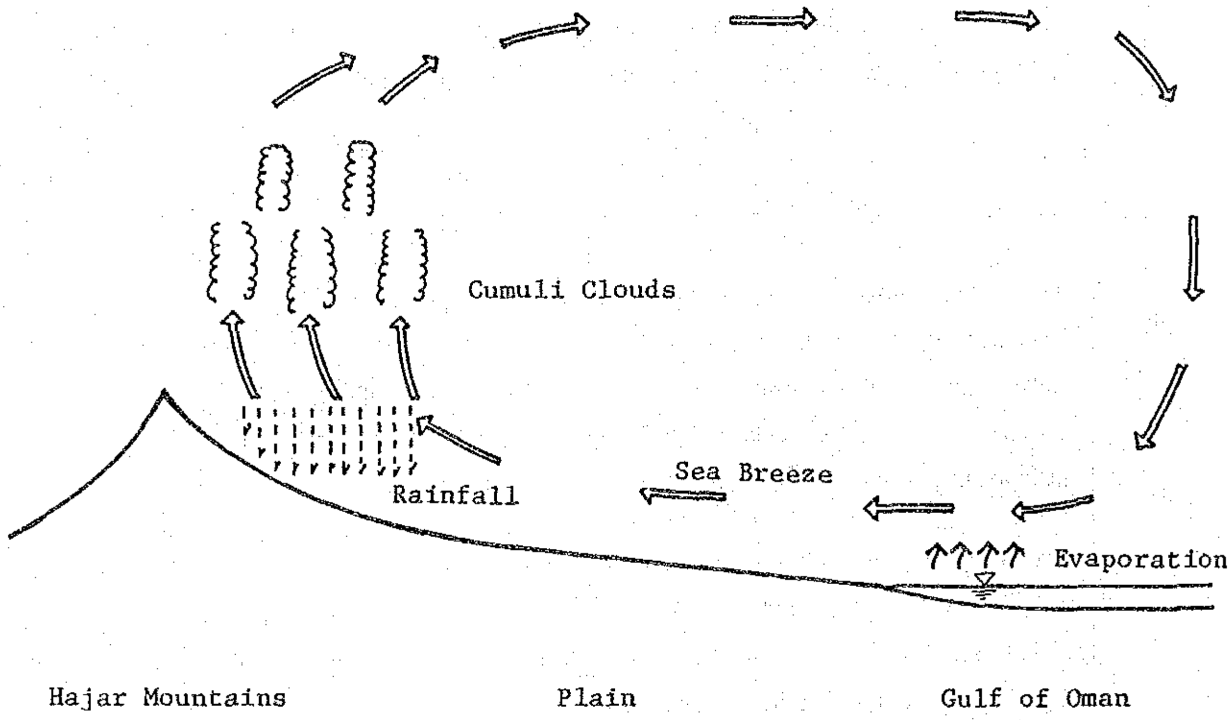


Fig. B-4-12 Relation between Elevation and Rainfall and Rain-days Caused by the Sea Breeze Circulation

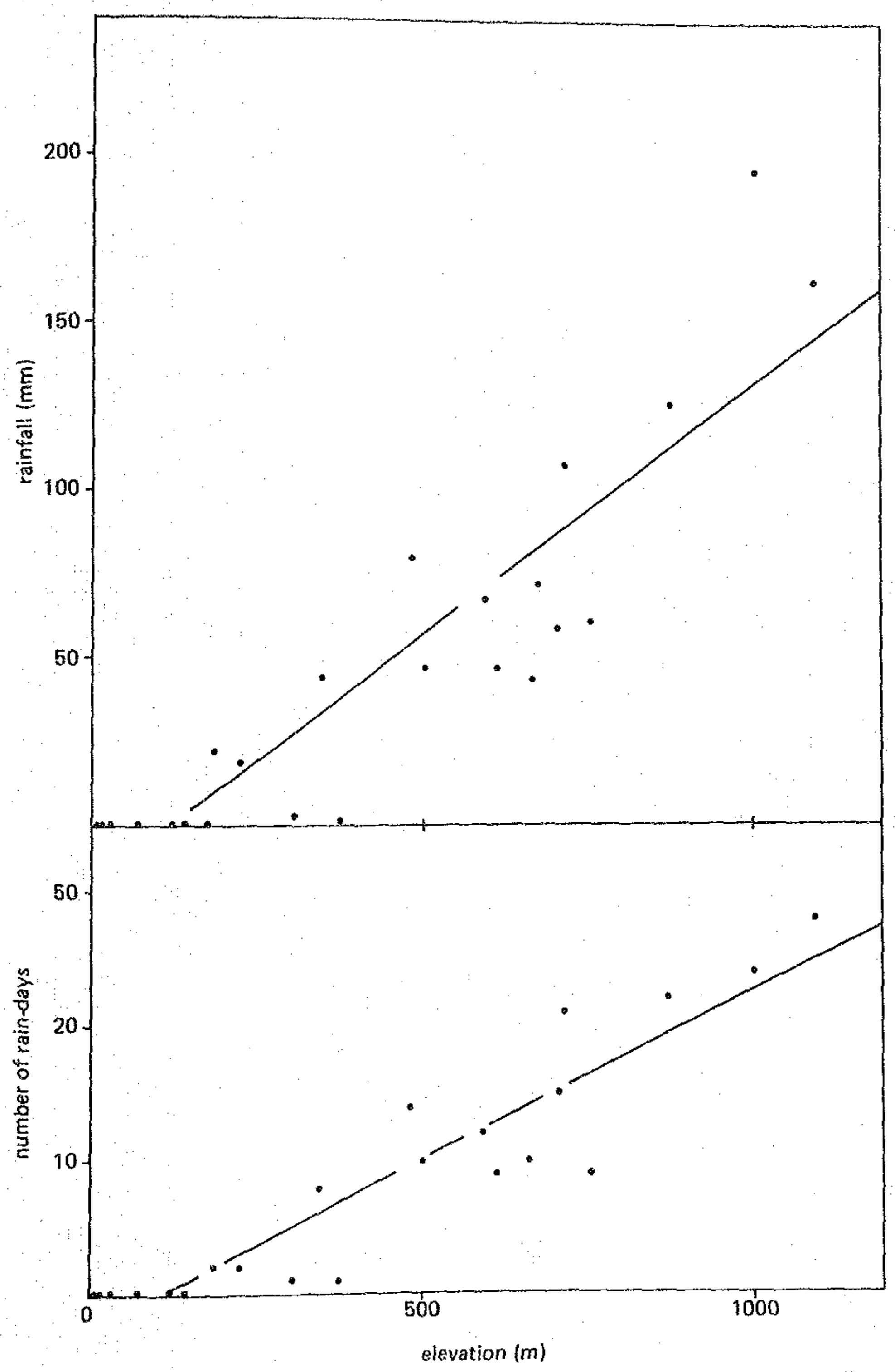
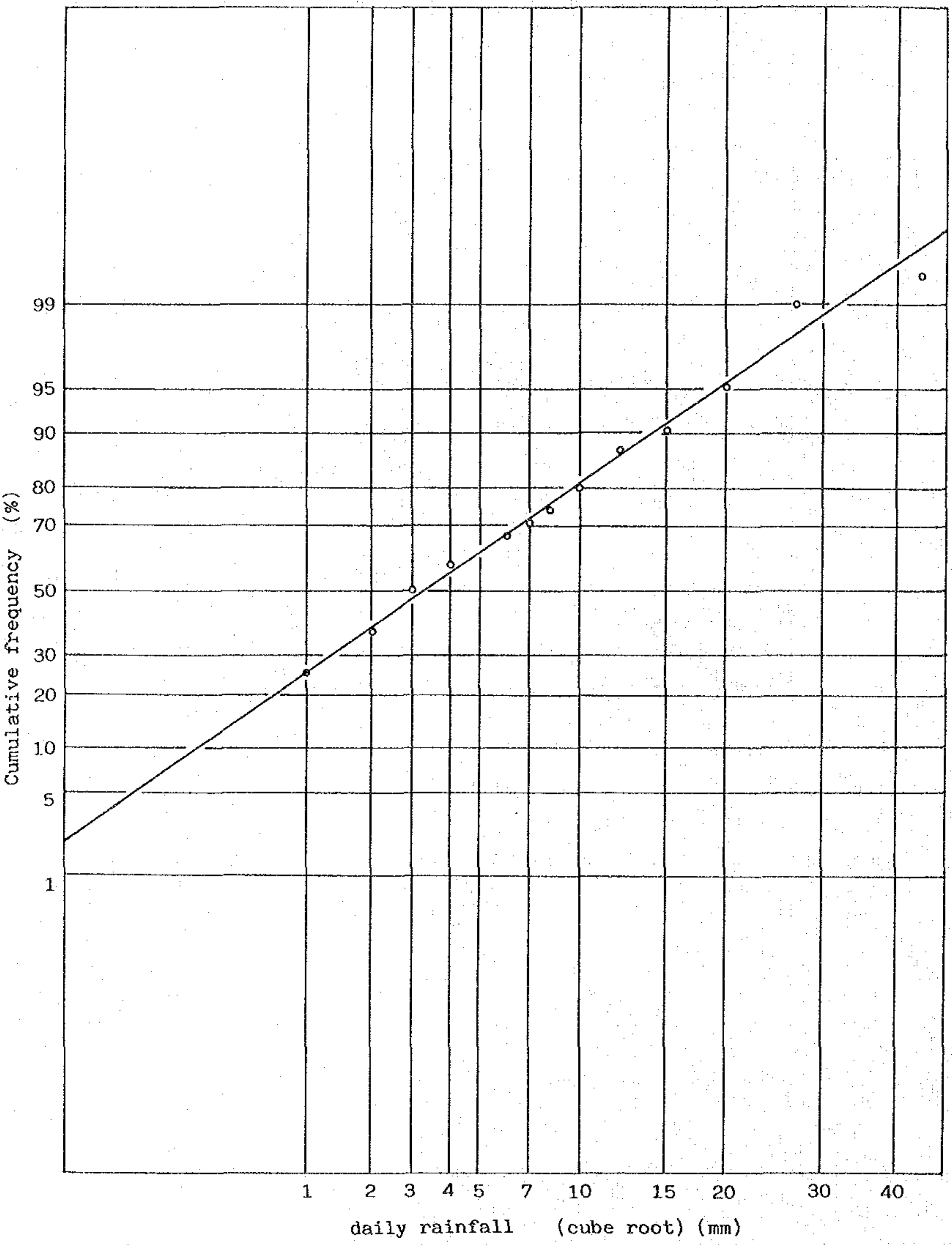


Fig. B-4-13 Cumulative Frequency of Summer Rainfall (Normal Curve)



4.1.4 Rainfall Caused by Synoptic Disturbance

Although the rainfall caused by synoptic disturbance occures mainly in winter, only a few rainfalls were observed in winter of 1983-84 and 1984-85. Therefore, the characteristics are summarized below from past data.

- The rainfall occurs mainly in winter.
- The rainfall occurs over a broad area.

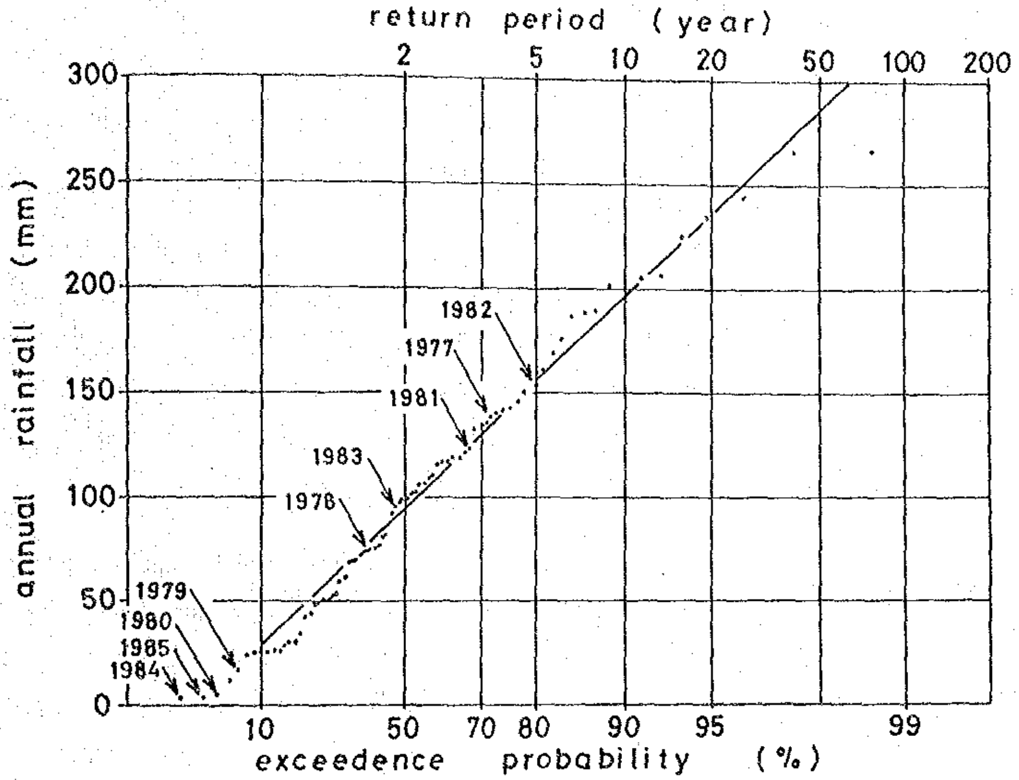
4.2 Probability of Occurence

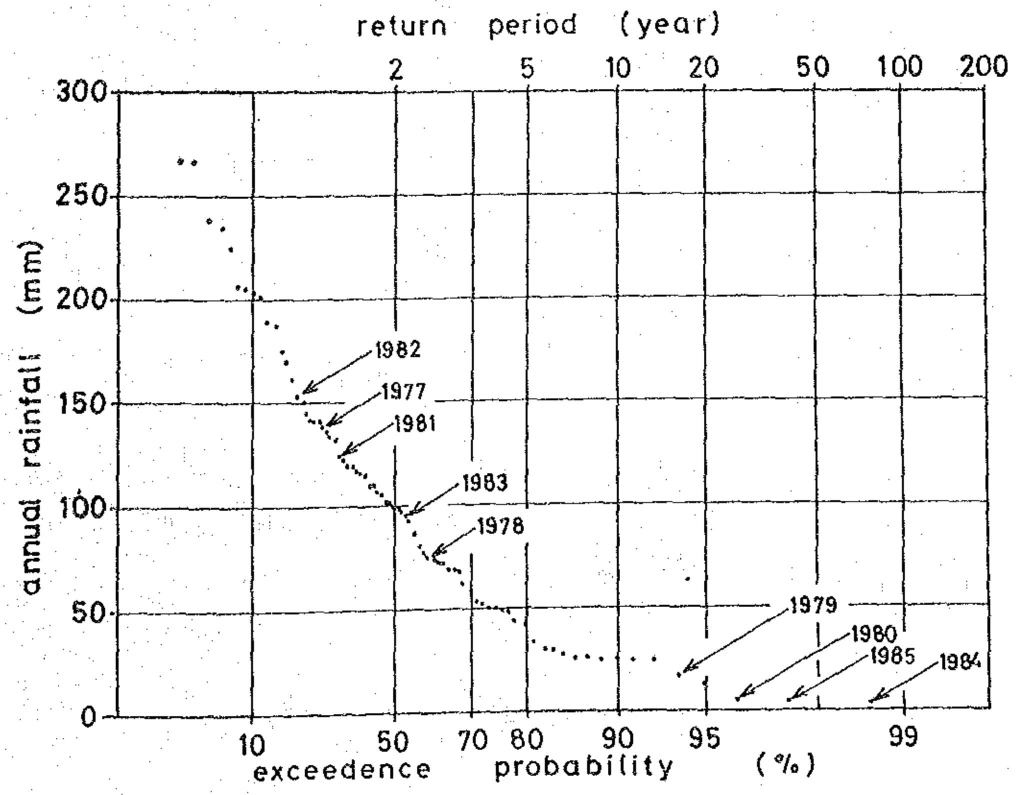
Muscat alone could supply rainfall data for a long period in and around the project area. The data is for seventy-three years intermitently from 1872. They are plotted on probability paper (Fig. B-4-14). They fit double exponential type distribution well. It shows that annual rainfall more than 100 mm occurrs once in two years; more than 200 mm once in ten years; and more than 300 mm once in a hundred years. The numbers on the figure indicate rainfall after the year 1977. In years where there was no data at Muscat, the rainfall at Darsite or Ruwi (MAF) neighbouring Muscat are indicated.

The annual rainfall is 2.5 mm at Ruwi in 1984 and 3.5 mm in 1985. Those are less than any other data observed at Muscat. The total rainfall in two years, after the observation network was installed by the project, is only 22 mm; consequently, the duration was very dry. Although the rainfall probability at Muscat can apply to the project area, even though the rainfall caused by sea breeze circulation may not occur, it is clear that during the observation period it was very dry.

Fig. B-4-14 Annual Rainfall Frequency at Muscat

return period (year)





4.3 Estimation of Rainfall over Each Basin

4.3.1 Outline of Estimation Method

The long duration rainfalls are estimated by the use of the rainfall data of MAF network. Examination of rainfalls lasting for a long period are necessary in order to evaluate the water resources, but this project could get data only during dry years.

The rainfalls should be estimated daily, because daily rainfall are necessary in the calculation process of water balance, which are calculated in chapter five. The period for the estimation is after June of 1976, because daily rainfall observation started on that day at all of the MAF network shown in Table B-1-3.

Interpolation or extrapolation of rainfall observed by MAF cannot apply to the estimation of winter rainfall. However, it can not apply to the estimation of summer rainfall, because summer rainfall covers a smaller rain area than winter rainfall. Accordingly, different methods are applied to rainfall of each season. Since there were no summer rains anywhere in the project area, it was assumed that sea breeze circulation brought all of summer rainfall during June to September. It was also assumed that synoptic disturbance brought all of winter rainfall during October to May.

After the estimation of rainfall at each rain gauge, rainfall over each basin was calculated by the use of the Thiessen method.

4.3.2 Rainfall in Summer

Rainfall caused by sea breeze is estimated by the probability model created in the project.

The dependence of the rain days on elevation is made clear in Fig. B-4-12. Together with the rainfall data observed at Al-Saiq (2000 m a.s.l), the relation between elevation (a) and rain-days in summer (n) is expressed as follows:

$n = 0.02190a-2.87.$

Accordingly, the relation between rain-days at Al-Saiq in summer (ns) and the rain-days at a m a.s.l. (na) is expressed as follows:

na = (a-131).ns/(2000-131).

This expression can be used to estimate the rain-days at a m a.s.l. with the use of the rain-days at Al-Saiq (ns).

According to daily rainfall, the cube roots are distributed on a normal curve (Fig. B-4-13). The probability model which produces the rainfall along the normal curve was created and the daily rainfall at each rain gauge was estimated using the model. Annual summer rainfall, the sum of daily rainfall, is shown in Table B-4-3. The values after 1983 on the table are not estimated ones, but rather observed data.

Table B-4-3 Estimated Summer Rainfall

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985 (June-July)	Mean (1976-1984)
RA 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1.1	22.2	5.5	11.0	3.7	0.5	10.3	20.0	3.0	0.0	8.6
3	17.9	12.9	18.1	9.1	22.6	3.6	16.7	64.0	31.5	1.0	21.8
4	44.9	13.4	62.2	32.1	19.9	26.4	11.2	8.9	13.0	0.0	25.8
5	52.9	20.1	56.6	20.4	28.7	19.8	29.9	18.0	37.0	17.0	31.5
RG 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.2
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	0.0	0.8
3	8.9	7.4	0.5	1.2	10.2	0.0	0.5	16.5	2.5	0.0	5.3
4	65.2	11.0	54.9	20.5	13.2	5.5	5.4	62.0	19.0	0.0	28.5
5	46.0	13.9	64.7	26.0	32.8	16.9	25.3	48.5	19.0	27.0	32.6
RF 1	27.4	32.1	49.2	7.7	21.4	1.5	12.8	101.5	34.0	9.5	32.0
2	41.6	41.5	74.9	36.4	73.8	38.3	76.6	94.5	113.5	42.0	65.7
3	45.3	11.7	25.2	12.4	30.6	19.9	8.6	60.0	20.5	11.5	26.1
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.5
MF 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5	0.0	0.0	0.7
2	42.1	3.8	16.4	15.4	17.7	0.5	3.0	58.6	5.0	1.5	18.1
RK 1	13.3	0.0	9.4	0.0	0.0	0.0	0.0	9.5	20.5	0.0	5.9
2	29.9	6.9	20.8	11.2	13.7	22.9	24.5	14.0	51.0	21.0	21.7
3	57.0	36.9	28.0	22.0	62.8	11.9	14.7	51.5	82.5	11.0	40.8
4	48.9	71.9	75.6	20.3	47.5	59.1	11.0	62.5	48.0	42.0	49.4
5	29.7	31.3	17.0	31.4	5.6	49.6	18.4	55.0	8.5	0.5	27.4
6	38.9	100.8	69.7	56.8	29.7	21.9	16.4	123.5	59.5	52.0	57.5
RM 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.4
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.2
3	0.0	0.0	4.4	0.0	0.0	0.0	0.0	11.5	0.0	0.0	1.8
	4	12.2	1.6	5.1	1.1	1.0	12.3	13.0	7.2	0.0	0.0

* The values before 1982 are estimated, and the values after 1983 are observed.

4.3.3 Rainfall in Winter

The rainfall in winter can be estimated directly from the daily data observed by MAF, because such rainfall covers a broad area.

The general method for estimating rainfall at non-observed points was used. As shown in Fig. B-4-15, non-observed points were plotted at origin and observed points A, B, C were plotted against the X-Y-axes. If the observed rainfall r_A, r_B, r_C are plotted in Z-direction, one plane including r_A, r_B, r_C is determined. The intersection of the plane and Z-axis r_O is assumed to be the estimated rainfall. This method can be used, even if the intersection is outside the triangle $r_A\ r_B\ r_C$.

This method can be expressed as follows:

$$r_o = \begin{vmatrix} r_A & r_B & r_C \\ X_A & X_B & X_C \\ Y_A & Y_B & Y_C \end{vmatrix} \Bigg/ \begin{vmatrix} 1 & 1 & 1 \\ X_A & X_B & X_C \\ Y_A & Y_B & Y_C \end{vmatrix}$$

Because it is clear that the rainfall in winter also depends on elevation (Fig. B-2-2), one of the coordinates chosen should be elevation and the other longitude. Latitude was taken into consideration when A,B,C were chosen from the rain gauges of MAF network.

In case A,B,C are located nearly on a line or fan from the origin, this method produces inadequate values. Since estimation of the rainfall in Wadi Ahin is this type of case, latitude is included in the expression as follows:

$$r_o = \begin{vmatrix} r_A & r_B & r_C & r_D \\ X_A & X_B & X_C & X_D \\ Y_A & Y_B & Y_C & Y_D \\ Z_A & Z_B & Z_C & Z_D \end{vmatrix} \Bigg/ \begin{vmatrix} 1 & 1 & 1 & 1 \\ X_A & X_B & X_C & X_D \\ Y_A & Y_B & Y_C & Y_D \\ Z_A & Z_B & Z_C & Z_D \end{vmatrix}$$

Annual winter rainfall and the sum of daily rainfall are shown in Table B-4-4. The values after October 1984 on the table are not estimated ones, but actually observed ones.

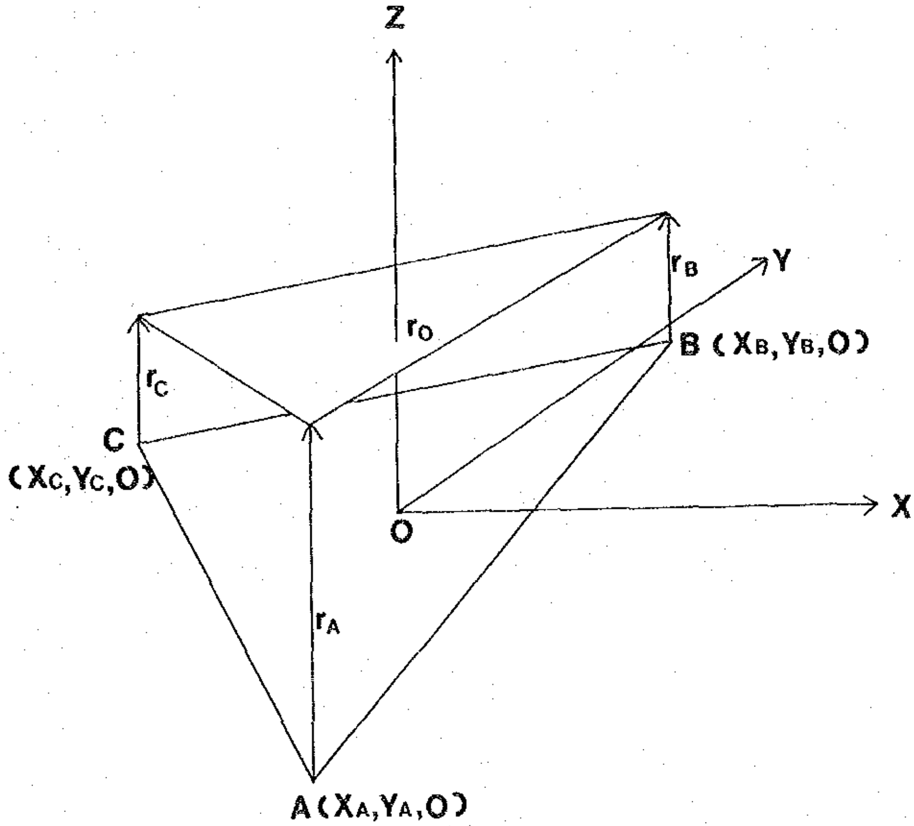
Table B-4-4 Estimated Winter Rainfall

(mm/season)

Rain-gauge		1976 (Oct.-Dec.)	1977	1978	1979	1980	1981	1982	1983	1984	1985 (Jan.-May)	Mean
RA	1	15.2	120.2	59.9	116.8	1.2	49.4	117.1	76.9	26.0	0.5	64.8
	2	25.9	104.4	43.1	89.5	34.4	63.1	152.4	142.0	4.0	0.0	73.2
	3	47.2	146.3	71.3	71.4	28.3	75.8	236.0	102.5	4.5	10.5	88.2
	4	31.2	114.2	46.6	67.5	25.0	31.2	193.8	128.6	1.5	0.0	71.1
	5	58.9	172.7	75.6	110.0	37.1	63.9	281.2	163.1	3.5	2.5	107.6
RG	1	9.8	94.2	37.8	82.3	4.4	62.2	146.4	86.3	32.5	0.0	61.8
	2	41.2	168.7	30.4	107.3	64.1	68.5	230.4	102.9	18.5	2.0	92.7
	3	71.1	240.1	22.0	130.0	122.0	76.0	314.0	120.0	3.5	5.5	122.7
	4	55.2	179.6	73.6	90.3	68.1	95.6	345.4	110.2	21.0	5.0	116.0
	5	56.8	182.4	72.4	94.0	72.5	96.7	357.7	103.1	3.5	3.0	115.8
RF	1	58.5	191.3	73.6	98.1	82.7	102.2	385.7	106.3	24.5	8.5	125.7
	2	53.7	203.7	85.4	87.9	89.1	113.8	399.7	145.0	7.5	31.0	135.2
	3	60.5	193.8	71.9	102.6	87.2	103.0	398.6	100.2	30.5	27.5	130.6
	4	30.8	122.3	42.2	87.8	33.9	74.4	241.2	76.8	15.5	0.0	80.5
MF	1	13.6	94.3	33.9	75.8	11.8	66.8	172.8	85.8	9.0	1.5	62.8
MF	2	65.2	178.8	59.1	112.5	78.2	89.5	377.6	59.0	14.1	3.0	115.2
RK	1	8.6	198.4	93.2	94.5	17.2	101.2	289.8	118.8	8.0	4.5	103.8
	2	47.2	188.9	72.4	99.2	68.3	100.3	364.9	96.2	16.5	4.5	117.6
	3	55.8	199.2	75.5	100.7	87.2	107.4	403.3	110.1	2.5	31.5	130.4
	4	37.1	210.5	89.8	86.7	77.6	119.2	391.7	150.8	14.5	17.5	132.8
	5	25.1	199.3	87.4	83.6	54.1	111.9	344.6	138.0	5.0	4.0	117.0
	6	24.7	233.5	106.4	79.6	78.7	136.1	402.8	198.2	19.0	30.0	145.4
RM	1	6.2	82.5	25.3	55.3	8.7	74.3	180.8	95.4	39.0	1.5	63.2
	2	7.3	115.9	46.3	69.2	10.1	79.1	200.1	99.0	7.0	0.0	70.4
	3	6.5	180.0	82.5	79.5	16.0	99.0	267.7	114.0	11.5	5.0	95.7
	4	21.1	187.7	81.7	85.1	39.0	103.1	312.3	117.1	1.0	24.5	108.1

* The values before May 1983 are estimated, and the values after Oct. 1983 are observed.

Fig. B-4-15 Coordinate System of Rain Gauges



4.3.4 Calculation of Rainfall over Each Basin.

Seasonal and annual mean of estimated rainfalls at each rain gauge are shown in Table B-4-5. The rainfalls for each basin were calculated by the use of Thiessen method and the estimated rainfalls at each rain gauge. The results, mean rainfalls over each basin, are shown in Table B-4-6. Comparing the rainfall on each basin, rainfall on Wadi Bani Kharus is the greatest with Wadi Bani Ghafir, Wadi Al-Fara, Wadi Ahin and Wadi Al-Ma'awil following Wadi Bani Kharus in turn.

Table B-4-5 Annual Mean Rainfall

(1976 ∿ 1985)

Rain Gauge Station	Winter	Summer	Annual
RA 1	64.8	0.0	64.8
2	73.2	8.6	81.8
3	88.2	21.8	110.0
4	71.1	25.8	96.9
5	107.6	31.5	139.1
RG 1	61.8	0.2	61.8
2	92.7	0.8	93.5
3	122.7	5.3	128.0
4	116.0	28.5	144.5
5	115.8	32.6	148.4
RF 1	125.7	32.0	157.7
2	135.2	65.7	200.9
3	130.6	26.1	156.7
4	80.5	0.5	81.0
MF 1	62.8	0.7	63.5
2	115.2	18.1	133.3
RK 1	103.8	5.9	109.7
2	117.6	21.7	139.3
3	130.4	40.8	171.2
4	132.8	49.4	182.2
5	117.0	27.4	144.4
6	145.4	57.5	202.9
RM 1	63.2	0.4	63.6
2	70.4	0.2	70.6
3	95.7	1.8	97.5
4	108.1	5.9	114.0

Table B-4-6 Mean Rainfall of Wadi Basin (Seasonal & Annual)

UNIT : MM

YEAR	SEASON	W.AHIN UPPER	W.AHIN LOWER	W.AHIN BAISN	W.B.GHAFIR UPPER	W.B.GHAFIR LOWER	W.B.GHAFIR BAISN	W.AL-FARA' UPPER	W.AL-FARA' LOWER	W.AL-FARA' BAISN	W.B.KHARUS UPPER	W.B.KHARUS LOWER	W.B.KHARUS BAISN	W.AL-MA'AWIL UPPER	W.AL-MA'AWIL LOWER	W.AL-MA'AWIL BAISN
77	SUMMER	16.8	11.6	15.2*	16.4	.2	11.5*	16.8	2.3	10.4*	41.6	3.3	29.2*	10.8	4.1	7.0
	WINTER	142.1	111.8	132.5*	194.5	136.6	177.0*	187.5	119.3	157.1*	197.6	140.0	179.0*	181.8	127.3	150.5
	ANNUAL	159.0	123.4	147.7*	210.9	136.8	188.5*	204.4	121.6	167.4*	239.2	143.3	208.2*	192.6	131.5	157.5
78	SUMMER	44.0	2.9	31.0*	47.3	0.0	33.0*	28.0	0.0	15.5*	34.5	3.2	24.4*	7.0	2.2	4.2
	WINTER	62.4	51.1	58.8*	61.7	33.1	53.1*	64.0	37.2	52.0*	84.9	61.2	77.2*	83.1	53.4	66.0
	ANNUAL	106.4	54.0	89.8*	109.0	33.1	86.1*	91.9	37.2	67.5*	119.4	64.4	101.6*	90.0	55.6	70.2
79	SUMMER	20.8	5.7	16.0*	19.2	0.0	13.4*	13.0	0.0	7.2*	22.5	0.0	15.2*	5.8	0.0	2.5
	WINTER	87.1	102.4	91.9*	101.2	95.8	99.6*	104.5	86.4	96.4*	90.1	79.3	86.6*	82.7	69.1	74.9
	ANNUAL	107.8	108.2	107.9*	120.4	95.9	113.0*	117.5	86.4	103.6*	112.6	79.3	101.8*	88.5	69.1	77.4
80	SUMMER	22.2	1.9	15.8*	25.3	.2	17.7*	24.7	.3	13.8*	25.0	0.0	16.9*	1.4	0.0	.6
	WINTER	31.4	18.5	27.3*	84.2	38.9	70.5*	82.3	31.1	59.4*	65.4	13.9	48.8*	31.3	12.0	20.2
	ANNUAL	53.5	20.4	43.1*	109.5	39.1	88.2*	106.9	31.4	73.2*	90.4	13.9	65.7*	32.6	12.0	20.8
81	SUMMER	16.6	.3	11.4*	11.2	0.0	7.8*	10.6	0.0	5.9*	30.8	0.0	20.9*	13.1	0.0	5.6
	WINTER	56.1	56.5	56.2*	93.1	64.8	84.5*	96.1	70.7	84.8*	111.5	85.5	103.1*	102.8	85.4	92.8
	ANNUAL	72.7	56.8	67.6*	104.3	64.8	92.4*	106.7	70.7	90.7*	142.3	85.5	123.9*	115.9	85.4	98.4
82	SUMMER	19.5	5.4	15.0*	17.8	0.0	12.5*	15.0	0.0	8.3*	16.0	0.0	10.8*	8.0	0.0	3.4
	WINTER	231.8	135.3	201.3*	348.5	196.4	302.5*	369.7	215.4	300.9*	366.1	230.6	322.2*	298.0	221.2	254.0
	ANNUAL	251.3	140.7	216.3*	366.4	196.5	315.0*	384.7	215.4	309.2*	382.1	230.6	333.1*	306.0	221.2	257.4
83	SUMMER	30.1	10.5	23.9*	53.8	5.7	39.2*	58.5	6.5	35.3*	49.1	4.8	34.8*	18.5	6.3	11.5
	WINTER	138.2	110.8	129.5*	111.2	95.7	106.5*	94.9	84.7	90.3*	128.8	103.7	120.7*	119.3	104.0	110.5
	ANNUAL	168.4	121.3	153.5*	164.9	101.3	145.7*	153.5	91.2	125.7*	177.9	108.5	155.4*	137.8	110.3	122.0
84	SUMMER	3.1	.2	2.2*	2.6	0.0	1.8*	3.5	0.0	1.9*	5.1	.9	3.7*	.3	.2	.2
	WINTER	.4	1.8	.8*	1.1	2.8	1.6*	2.1	1.6	1.9*	1.3	1.0	1.2*	.8	2.7	1.9
	ANNUAL	3.5	2.0	3.0*	3.7	2.8	3.4*	5.6	1.6	3.8*	6.4	1.9	4.9*	1.1	2.9	2.1
	SUMMER	24.4	5.0	18.2*	26.4	.8	18.7*	24.3	1.2	14.0*	32.5	2.3	22.8*	8.4	1.8	4.6
	WINTER	94.0	75.1	88.0*	125.4	85.5	113.4*	127.0	82.2	107.0*	131.8	90.3	118.4*	113.2	86.7	98.0
	ANNUAL	118.4	80.1	106.3*	151.9	86.3	132.0*	151.3	83.4	121.0*	164.4	92.6	141.1*	121.5	88.5	102.6

CHAPTER 5 ANALYSIS OF INFILTRATION CAPACITY AND EVAPOTRANSPIRATION

5.1 Experiment on Infiltration Capacity

5.1.1 Experimental Sites

A series of experiments for infiltration capacity of surface soil were carried out at five sites within the project area. The sites and their surface soil characteristics are as follows:

1) Sand ———— Al-Muladdah
2) Silt ———— Ab-Abari
3) Unconsolidated sand and gravel ———— South of Tarif
4) Semi-consolidated sand and gravel ———— North of Jamma
5) Semi-consolidated sand and gravel ———— West of Al-Rustaq

No rainfall was recorded at any of the sites six monthes before the experiments.

5.1.2 Method and procedure of experiments

The method and procedure of the experiments are as follows;

1) Set up a block of area (1 x 1 m^2) at flat ground without vegetation, and surround it with a small mound of soil and gravel.

2) Sprinkling water uniformly on the ground by watering device at a constant sprinkling intensity (mm/h) determined beforehand.

3) Keep sprinkling water and watching whether all the water infiltrates or not into soil without any remaining on the ground surface.

4) Check time and cumulative water amount when 30%, 50% and 70% of the block (1 m^2) are covered with water remaining on the surface.

5) Take soil samples at different depths with soil sampler, right after the end of water sprinkling to determine the water content of the soil.

6) Repeat taking soil samples after a few days interval.

7) Measure the water content of all the soil samples.

The procedure above was carried out for all sites. In addition, the following measurement was performed for some of the sites.

8) Observe the features of lowering wet front during water pouring.

9) Measure the grain size of soil samples.

10) Measure the density of dehydrated soil samples.

The dehydration of major soil samples and weight measurement of dehydrated samples were carried out at Rumeis Laboratory, MAF.

Some samples were brought to Japan and measurement was done there.

5.1.3 Experiment results on infiltration capacity

Experiment conditions and results are summarized in Table B-5-1. The soil stratification of the two sites is shown in Fig. B-5-1.

The relationships between cumulative water amount and infiltration capacity, are shown in Fig. B-5-2. A great difference in capacity is revealed between surface soil materials. Sand has the highest capacity. Semi-consolidated sand and gravel has the lowest capacity.

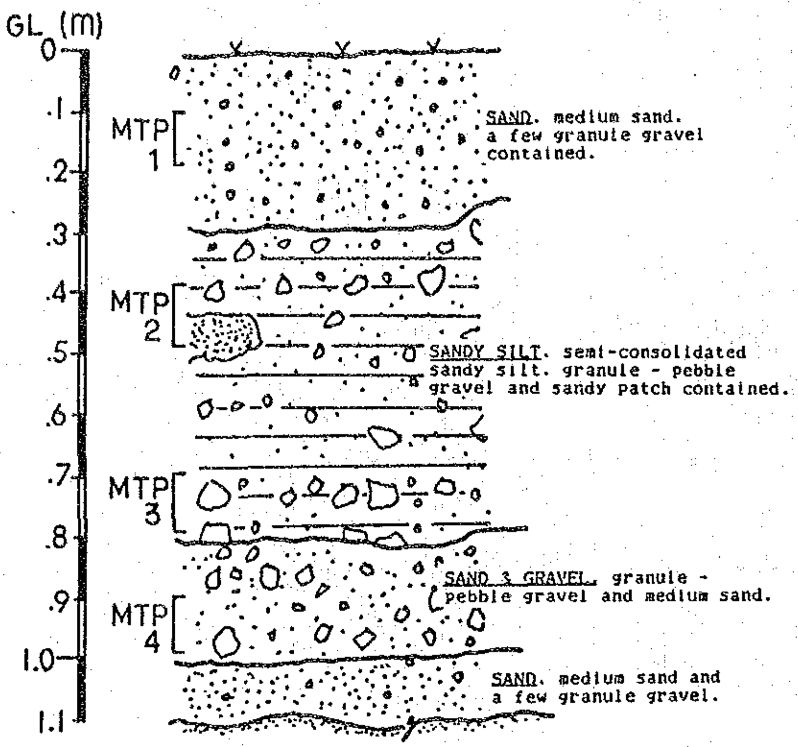
Regarding the depth of wet front in case of 120 mm/h on sand, its change with time as shown in Table B-5-2 and Fig. B-5-3 is uniform. The descending speed of the front is speed almost constant, 9.2 mm/min., as shown in Fig. B-5-4. The average volume water content of the transmission zone was 22%.

Table B-5-1 Experiment Results of Infiltration

Location of experiment site		Al-Muladdah		Ab-Abari			South of Tarif			North of Jamma		West of Al-Rustaq			
Surface soil		Sand		Silt			Un-consolidated sand and gravel			Semi-consolidated sand and gravel		Semi-consolidated sand and gravel			
Date of experiment		13/7/'85	15/7/'85	15/7/'85			18/7/'85			17/7/'85		21/7/'85			
Experiment site No.		M-1	M-2	A-1	A-2	A-3	T-1	T-2	T-3	J-1	J-2	R-1	R-2	R-3	R-4
Water sprinkling intensity (mm/h)		60	120	40	60	120	20	30	60	10	60	10	15	20	30
30% surface covered with water film	time (min)	62.5	22.5	26	10	8	21	6	-	25	2.5	18	10	9	4
	cumulative water amount (mm)	62.5	11.0	17.5	10	16	17	3	-	4.2	2.5	3.5	2.5	3.0	2.0
50% surface covered with water film	time (min)	75.0	45	31	19	10	120	10	-	30	-	24	12	12	6
	cumulative water amount (mm)	75.0	22.5	21	19	20	40	5	-	5.0	-	4.0	3.5	4.0	3.0
70% surface covered with water film	time (min)	-	117.5	50	-	18	-	13	5	35	5	27	18	13.5	8
	cumulative water amount (mm)	-	59.0	34	-	36	-	6.5	5	5.8	5.0	4.5	4.5	4.5	4.0
Cumulative water amount at the end of water sprinkling		92.5	125	54	25.5	42	40	11	6.5	6.7	7.5	4.5	5.0	5.0	4.5
Depth of wet front at the end of water sprinkling(cm)		32	-	28	8	11	-	10	10	5	6	1.3	1.3	1.5	1.0

Fig. B-5-1 Stratification of Infiltration Experiment Sites

(a) Al-Muladdah



(b) Ab-Abari

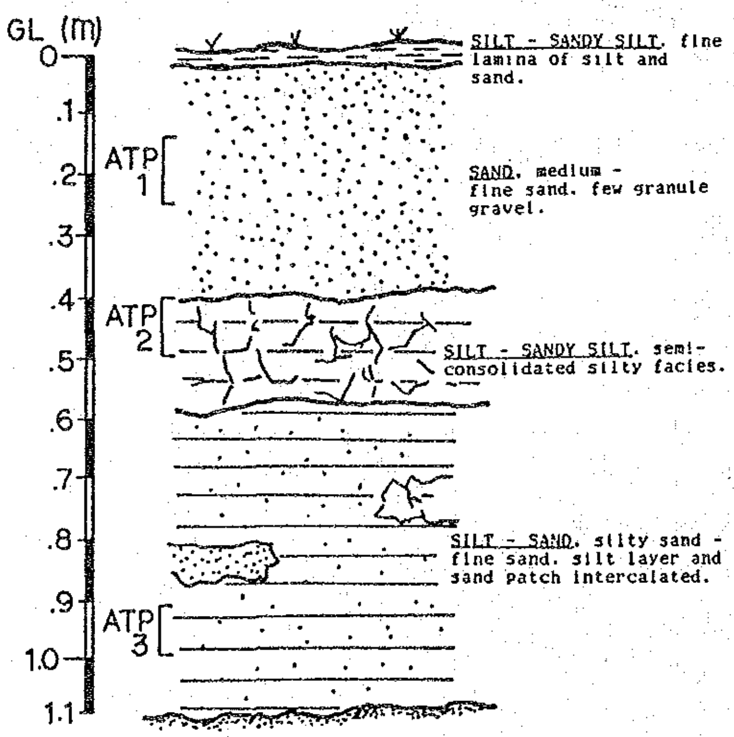


Fig. B-5-2 Experiment Results of Infiltration

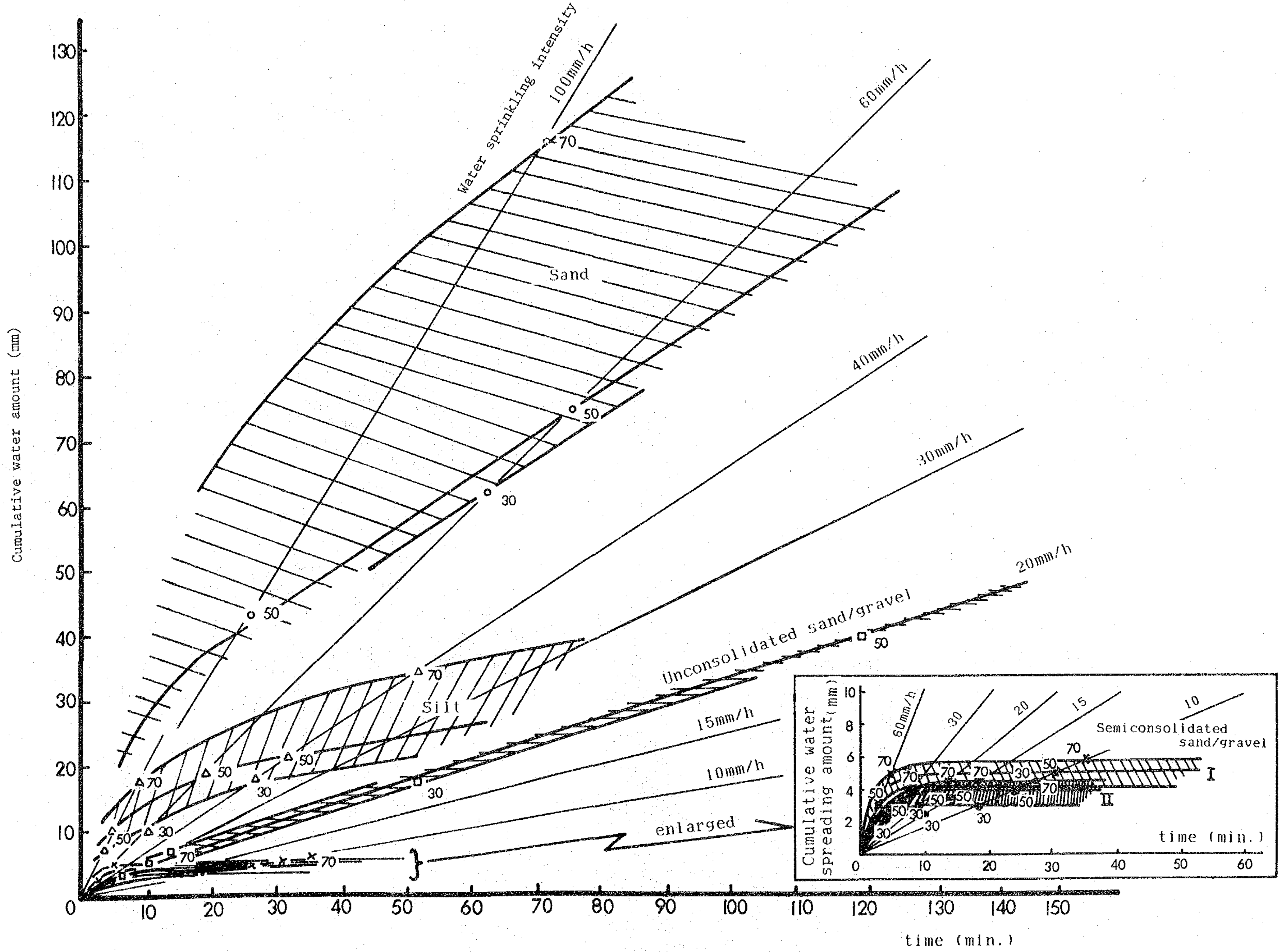


Table B-5-2 Depth of Wet Front in Sand in Case of Water Sprinkling Intensity 120mm/h

Al-Muladdah (M-2)

A: Time after starting water sprinkling
B: Cumulative sprinkling water amount
C: Depth of wet front

A (min.)	B (mm)	C (cm)
0	0	0
1.5	3.0	1
2.8	5.6	3
4.0	8.0	5
5.3	10.6	8
6.2	12.4	9
7.4	14.8	9.5
8.8	17.6	10
10.0	20.0	11
11.1	22.2	12.5
12.5	25.0	14
13.7	27.4	16
14.7	29.4	16.5
16.0	32.0	17
17.4	34.8	18
18.5	37.0	18.5
20.0	40.0	19
21.1	42.2	20.5
25.4	50.8	23
27.5	55.0	24
29.0	58.0	25
30.0	60.0	26
31.2	62.4	-
32.5	65.0	28.5

A (min.)	B (mm)	C (cm)
33.8	67.6	29.5
35.0	70.0	-
36.2	72.4	32
37.5	75.0	32.5
39.0	78.0	35
4.04	80.8	-
42.0	84.0	38
43.0	86.0	-
44.4	88.8	-
45.5	91.0	-
46.8	93.6	-
48.2	96.4	-
49.5	99.0	-
50.0	100.0	-
51.1	102.2	-
52.2	104.4	-
54.5	109.0	-
55.6	111.2	-
57.0	114.0	-
58.0	116.0	-
59.5	119.0	-
60.0	120.0	-
62.0	124.0	-
63.0	126.0	-

Fig. B-5-3 Depth and Shape of Wet Front in Sand in Case of Water Sprinkling Intensity, 120mm/h

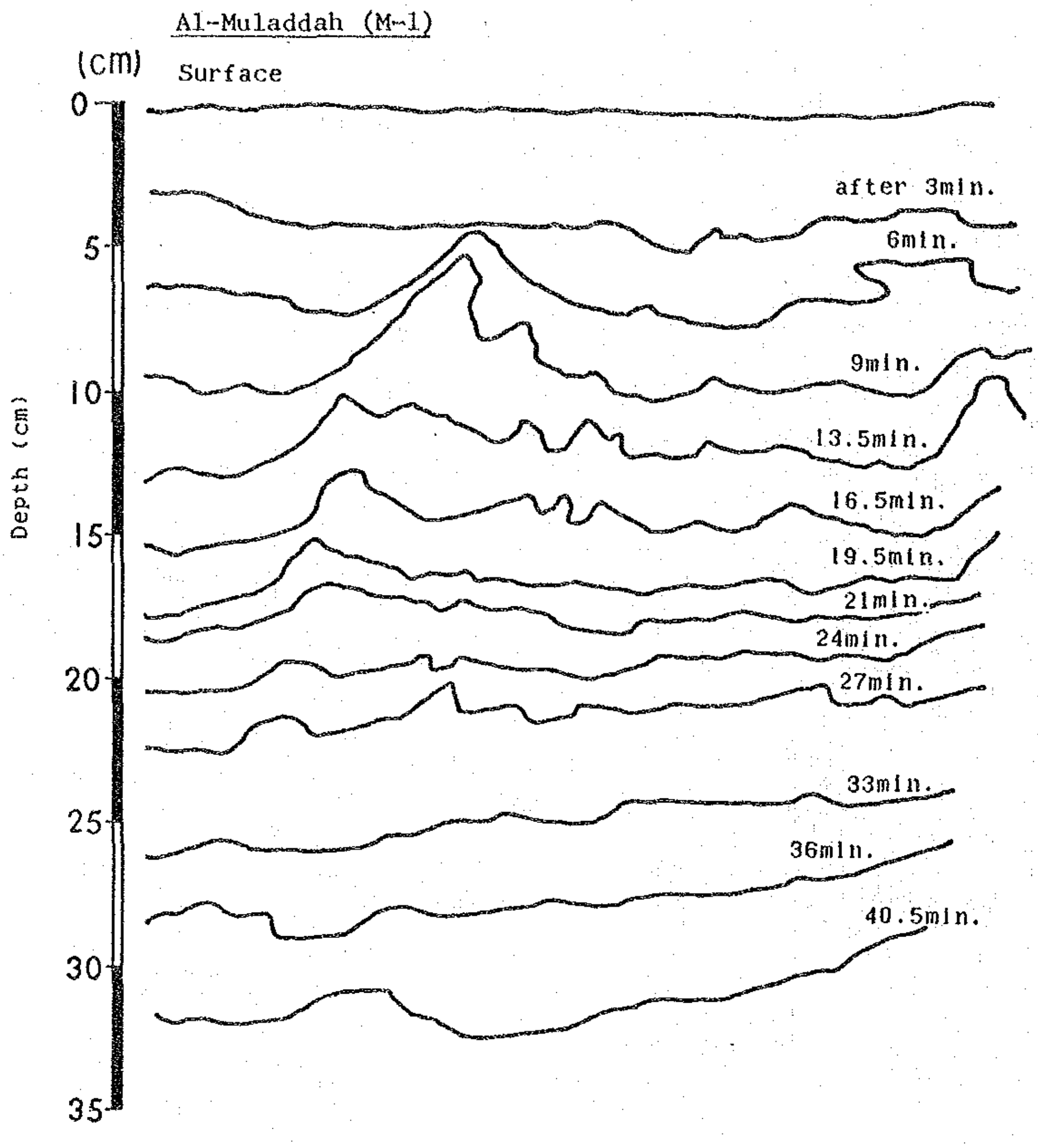
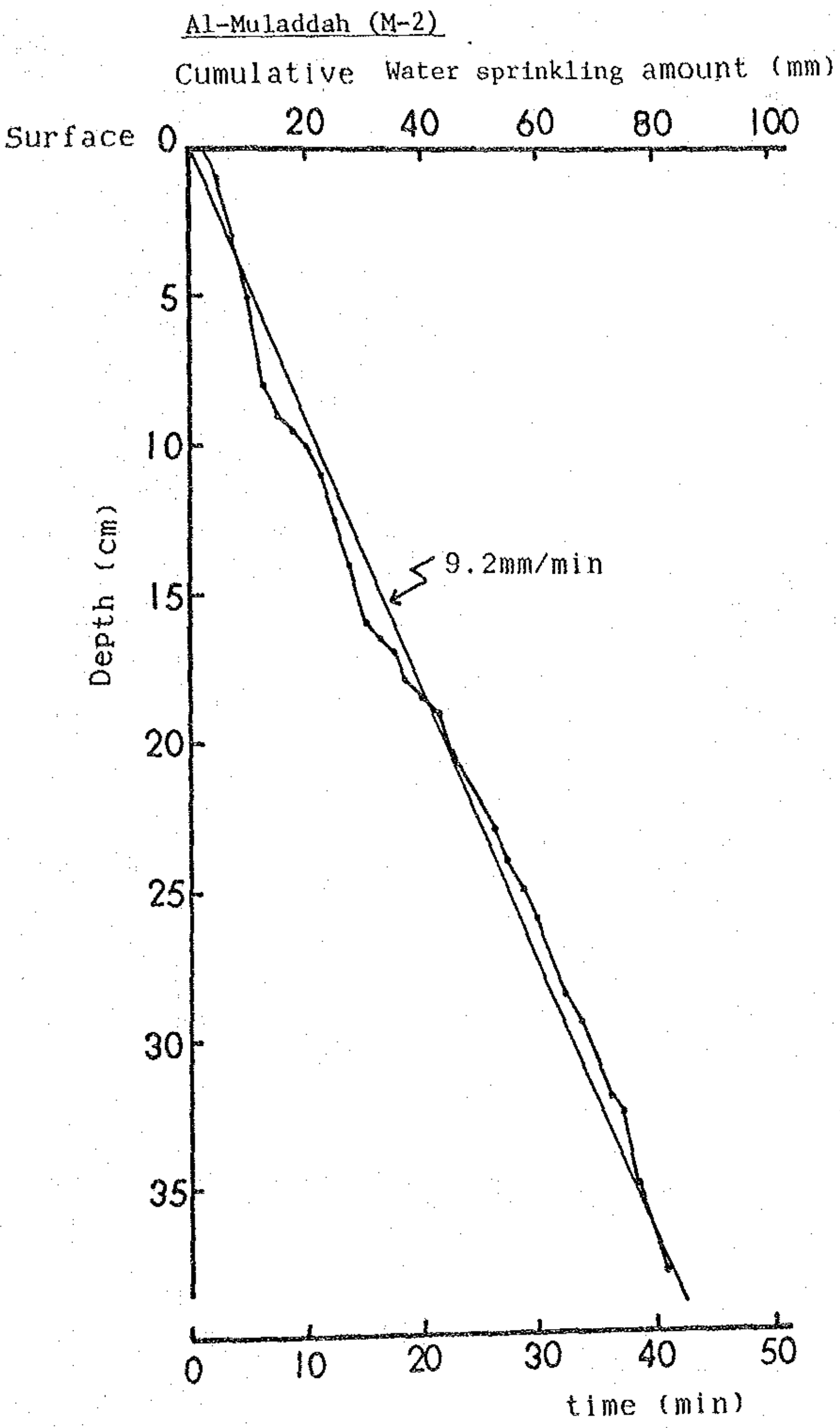


Fig. B-5-4 Descending Speed of Wet Front in Sand in Case of Water Sprinkling Intensity, 120mm/h



5.1.4 Experiment Results on Soil Water Content

All the measured results of the experiment are summarized in Table B-5-3.

The sand and silt which were taken with the soil sampler display a similar tendency in the change of water content with time, as shown in Fig. B-5-5 and Fig. B-5-6.

Regarding the other sites, quick evaporation within 24 hours was confirmed.

Table B-5-3(1) Soil Water Contents after Water Sprinkling (1/4)

Site: Experimental site No. (cf. tableB-5-1)
Date: Sampling date
Time: Sampling time
V_s: Volume of soil sample
W_s: Weight of dry soil sample
W_w: Weight of soil water
ω: Water content $(W_w/W_s)\times100$
θ: Volume water content $(W_w/V_s)\times100$
ρ: Density of dry soil sample (W_s/V_s)

Site	Date	Time	Depth	V_s	W_s	W_w	ω	θ	ρ
			cm	cm^3	g	g	%	%	g/cm^3
M-1	Jul.13	10pm	0~5	-	118.3	21.1	17.8	-	-
			1~6	100	138.9	35.0	25.2	35.0	1.39
			23~28	100	156.0	26.5	17.0	26.5	1.56
			32~	-	-	-	dry	dry	-
	Jul.14	5am	2~7	100	151.8	14.5	9.6	14.5	1.52
			2~7	100	153.1	15.4	10.0	15.4	1.53
			11~16	100	153.2	16.0	10.4	16.0	1.53
			19~24	100	154.2	20.7	13.4	20.7	1.54
	Jul.15	5am	2~7	100	143.2	10.5	7.3	10.5	1.43
			8~13	100	153.8	13.0	8.4	13.0	1.54
			10~15	100	160.1	13.6	8.5	13.6	1.60
			17~22	100	149 0	12.5	8.5	12.5	1.49
			22~27	100	152.0	13.1	8.6	13.1	1.52
	Jul.16	6am	0~5	100	145.5	6.0	4.2	6.0	1.46
			7~12	100	156.2	11.8	7.6	11.8	1.56
			13.5~18.5	100	158.9	13.5	8.5	13.5	1.59
			21.5~26.5	100	153.8	12.0	7.8	12.0	1.54
			29~34	100	158.3	12.7	8.0	12.7	1.58
			35~40	100	147.2	10.6	7.2	10.6	1.47
			43~48	100	134.9	12.0	8.9	12.0	1.35

Table B-5-3(2) Soil Water Contents after Water Sprinkling (2/4)

Site	Date	Time	Depth	V_s	W_s	W_w	ω	θ	ρ
			cm	cm^3	g	g	%	%	g/cm^3
M-1	Jul.17	6am	0~1	-	145.3	1.0	0.7	-	-
			1~6	100	144.8	6.7	4.6	6.7	1.45
			8.5~13.5	100	141.0	9.9	7.0	9.9	1.41
			15~20	100	155.5	10.4	7.4	10.4	1.56
	Jul.18	6am	0~5	100	134.3	3.8	2.8	3.8	1.34
			6~11	100	146.1	8.7	6.0	8.7	1.46
			13.5~18.5	100	150.4	9.3	6.2	9.3	1.50
			22~27	100	150.2	9.1	6.0	9.1	1.50
			28.5~33.5	100	146.3	8.4	5.7	8.4	1.46
			35.5~40.5	100	139.6	8.3	6.0	8.3	1.40
			42.5~48.5	100	129.4	9.6	7.4	9.6	1.29
			49~54	100	116.3	11.1	9.6	11.1	1.16
			55~58	-	62.2	4.8	7.7	-	-
	Jul.21	8am	0~5	100	146.9	4.0	2.7	4.0	1.47
			5.5~10.5	100	146.0	7.9	5.4	7.9	1.46
			11~16	100	164.3	9.9	6.0	9.9	1.64
			23~28	100	140.5	7.7	5.5	7.7	1.41
			30~35	100	147.9	7.5	5.1	7.5	1.48
			37~42	100	131.5	12.9	9.8	12.9	1.32
			44~49	100	134.6	9.1	6.7	9.1	1.35
	Jul.24	6pm	0~5	100	141.4	1.2	0.8	1.2	1.41
			8~13	100	154.4	7.2	4.7	7.2	1.54
			13.5~18.5	100	162.7	8.3	5.1	8.3	1.63
			19~24	100	153.4	7.6	5.1	7.6	1.53
			30.5~35.5	100	157.3	6.5	4.1	6.5	1.57
			37.5~42.5	100	146.0	7.1	4.8	7.1	1.46

Table B-5-3(3) Soil Water Contents after Water Sprinkling (3/4)

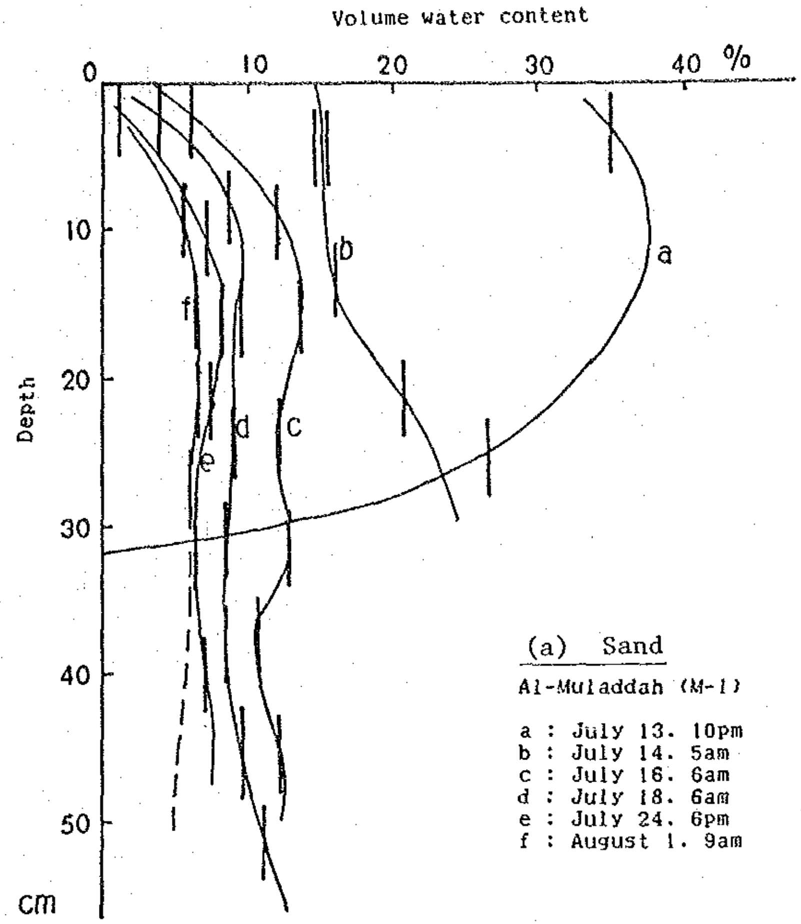
Site	Date	Time	Depth	V_s	W_s	W_w	ω	θ	ρ
			cm	cm^3	g	g	%	%	g/cm^3
M-1	Aug.1	10am	7~12	100	150.9	5.6	3.7	5.6	1.51
			13~18	100	152.8	6.3	4.2	6.3	1.53
			19~24	100	144.4	6.4	4.4	6.4	1.44
			25~30	100	150.6	5.9	3.9	5.9	1.51
			30~34	-	128.6	4.3	3.4	-	-
			36~40	-	156.1	8.8	5.6	-	-
	Aug.11	10am	(0~10)	-	(201.3)	(1.34)	(0.7)	-	-
			10~18	-	182.8	6.3	3.4	-	-
			40~48	-	157.9	15.0	9.5	-	-
			70~78	-	190.7	8.8	4.6	-	-
			90~98	-	171.9	11.6	6.7	-	-
A-1	Jul.20	9pm	1.5~6.5	100	153.8	25.7	16.7	25.7	1.54
			7.5~12.5	100	152.4	21.4	14.0	21.4	1.52
			14~19	100	153.1	21.9	14.3	21.9	1.53
			21~26	100	153.6	18.5	12.0	18.5	1.54
			28~	-	-	-	dry	dry	-
A-2	Jul.20	6pm	1~6	100	141.2	22.2	15.8	22.2	-
			8~	-	-	-	dry	dry	-
	Jul.22	1pm	0~5	100	127.9	3.8	3.0	3.8	1.28
			6~11	100	146.0	7.7	5.2	7.7	1.46
			15.5~20.5	100	142.2	7.5	5.2	7.5	1.42
			25~	-	-	-	dry	dry	-
	Jul.24	2pm	0~5.5	-	152.9	3.2	2.1	-	-
			7~12	100	148.4	5.0	3.4	5.0	1.48
			15~20	100	148.2	8.2	5.5	8.2	1.48
			22~27	100	146.6	8.4	5.7	8.4	1.47
			30~	-	-	-	dry	dry	-

Table B-5-3 (4) Soil Water Contents after Water Sprinkling (4/4)

Site	Date	Time	Depth	V_s	W_s	W_w	ω	θ	ρ
			cm	cm^3	g	g	%	%	g/cm^3
A-2	Jul.29	2pm	0~4	-	151.4	1.7	1.1	-	-
			4.5~9.5	100	148.3	4.1	2.7	4.1	1.48
			11.5~16	-	139.4	5.2	3.8	-	-
			17~22	100	149.7	5.2	3.5	5.2	1.50
			23~28	100	126.5	7.1	5.6	7.1	1.27
			29~30	-	47.6	2.0	4.1	-	-
	Aug.1	7am	0~3	-	187.0	1.8	1.0	-	-
			3~6	-	112.8	1.8	1.6	-	-
			8~12	-	102.2	3.0	3.0	-	-
			14~19	100	141.0	4.4	3.1	4.4	1.41
			20~25	100	139.5	5.8	4.1	5.8	1.40
			26~30	-	137.3	8.6	6.3	-	-
	Aug.11	11am	(0~8)	-	(186.1)	(1.9)	(1.0)	-	-
			15~23	-	162.6	4.6	2.8	-	-
			40~48	-	151.2	9.6	6.4	-	-
			90~98	-	141.8	11.6	8.2	-	-
A-3	Jul.20	6pm	0.5~5.5	100	136.5	23.4	17.2	23.4	1.37
			11~	-	-	-	dry	dry	-
T-3	Jul.18	9pm	0~2	-	1429.8	41.4	2.9	-	-
			10~	-	-	-	dry	dry	-
J-1	Jul.17	7pm	0~3	-	318.4	16.7	5.2	-	-
			0~5	-	773.6	54.1	7.0	-	-
			5~	-	-	-	dry	dry	-
	Jul.20	2pm	0~	-	-	-	dry	dry	-
J-2	Jul.17	7pm	2~5	-	684.1	56.4	8.2	-	-
			6~	-	-	-	dry	dry	-
	Jul.20	2pm	0~	-	-	-	dry	dry	-

( ): sample taken outside the water spreading sites

Fig. B-5-5 Change of Volume Water Content in Sand and Silt with Time after Water Sprinkling



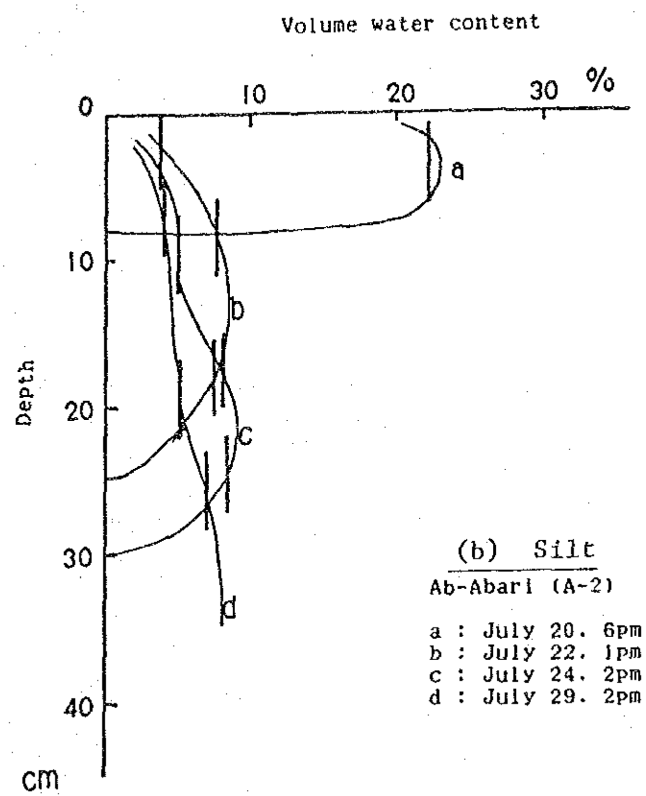
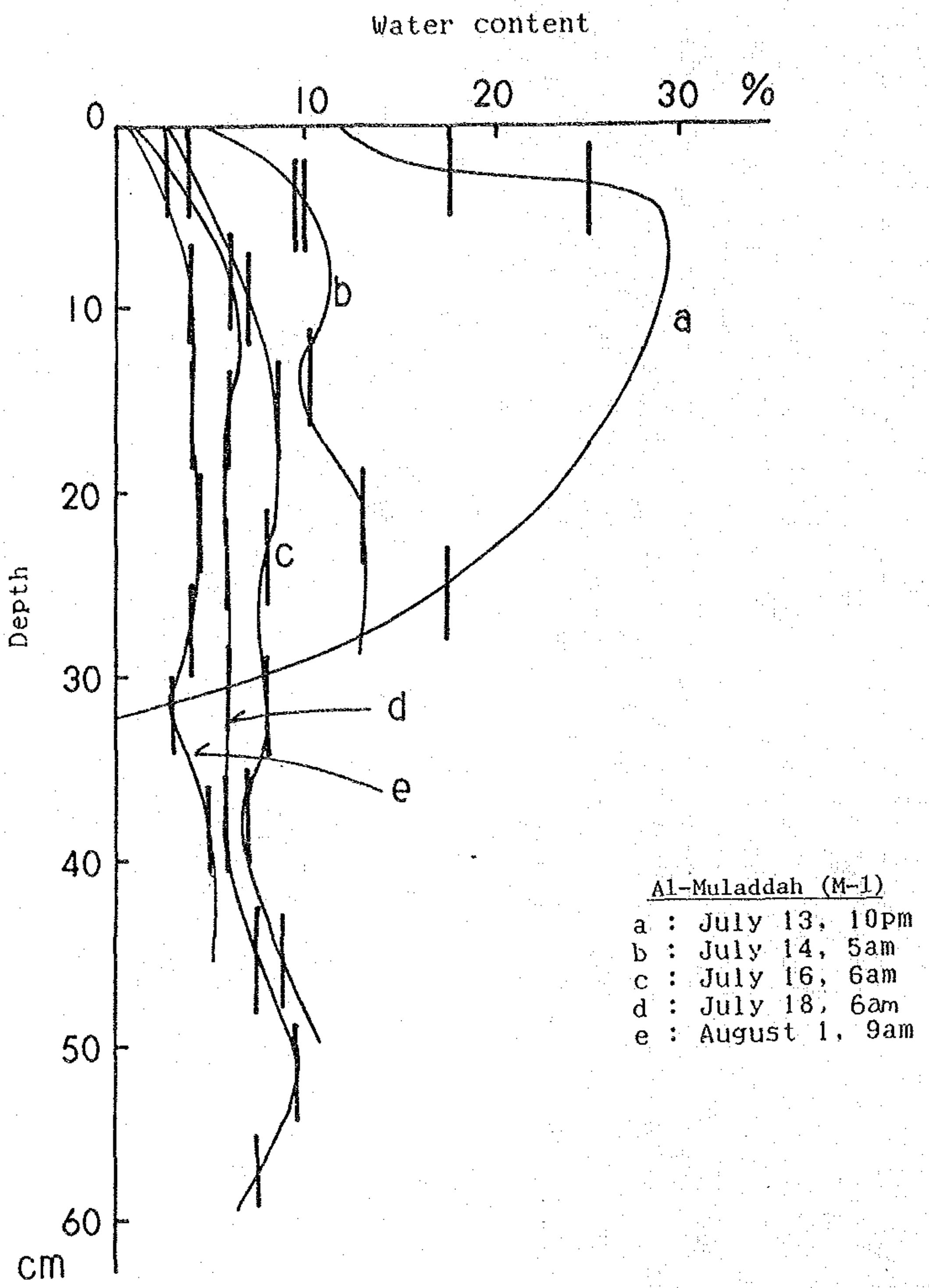


Fig. B-5-6 Change of Water Content in Sand with Time after Water Sprinkling



5.2 Areal Distribution of Infiltration Capacity

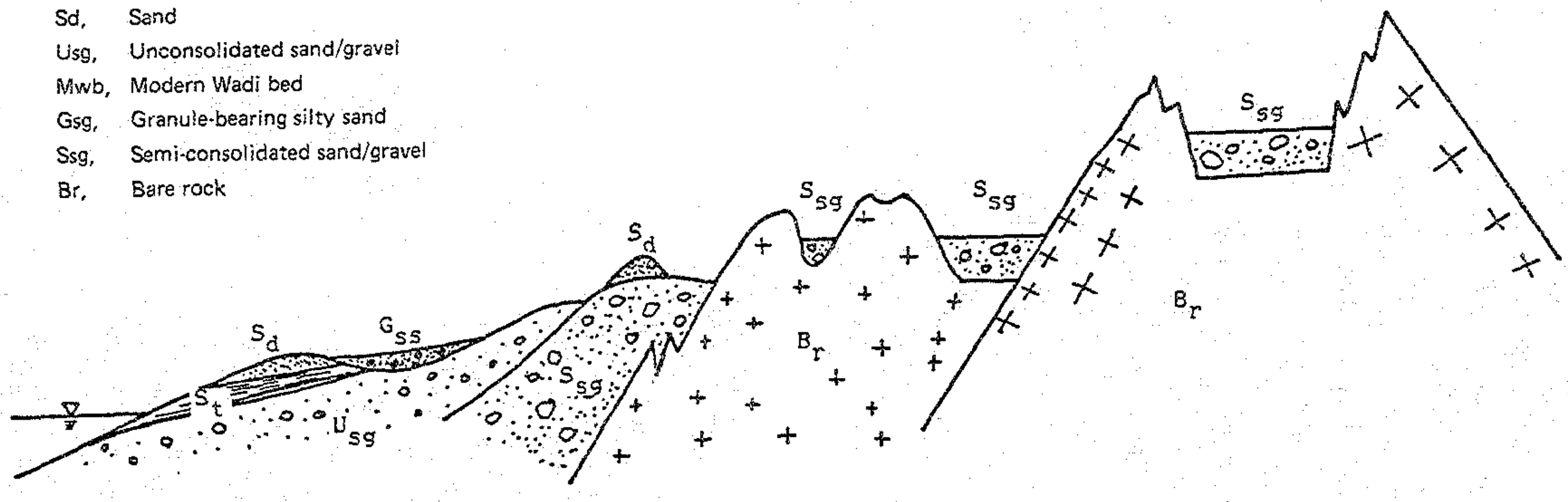
As shown in the schematic longitudinal section in Fig. B-5-7, silt, sand, unconsolidated sand/gravel and semi-consolidated sand/gravel distribute in the Batinah plain roughly in that order from the coast. This section is based on the topographic and geologic maps and also on the satellite imagies of LANDSAT and NOAA. A surface soil distribution map was drawn and is shown in Fig. B-5-8.

The foregoing experiment sites were selected to represent each type of soil surface in this map. The map exhibits the distribution of infiltration capacity. The area of each surface soil is compiled in Table B-5-4.

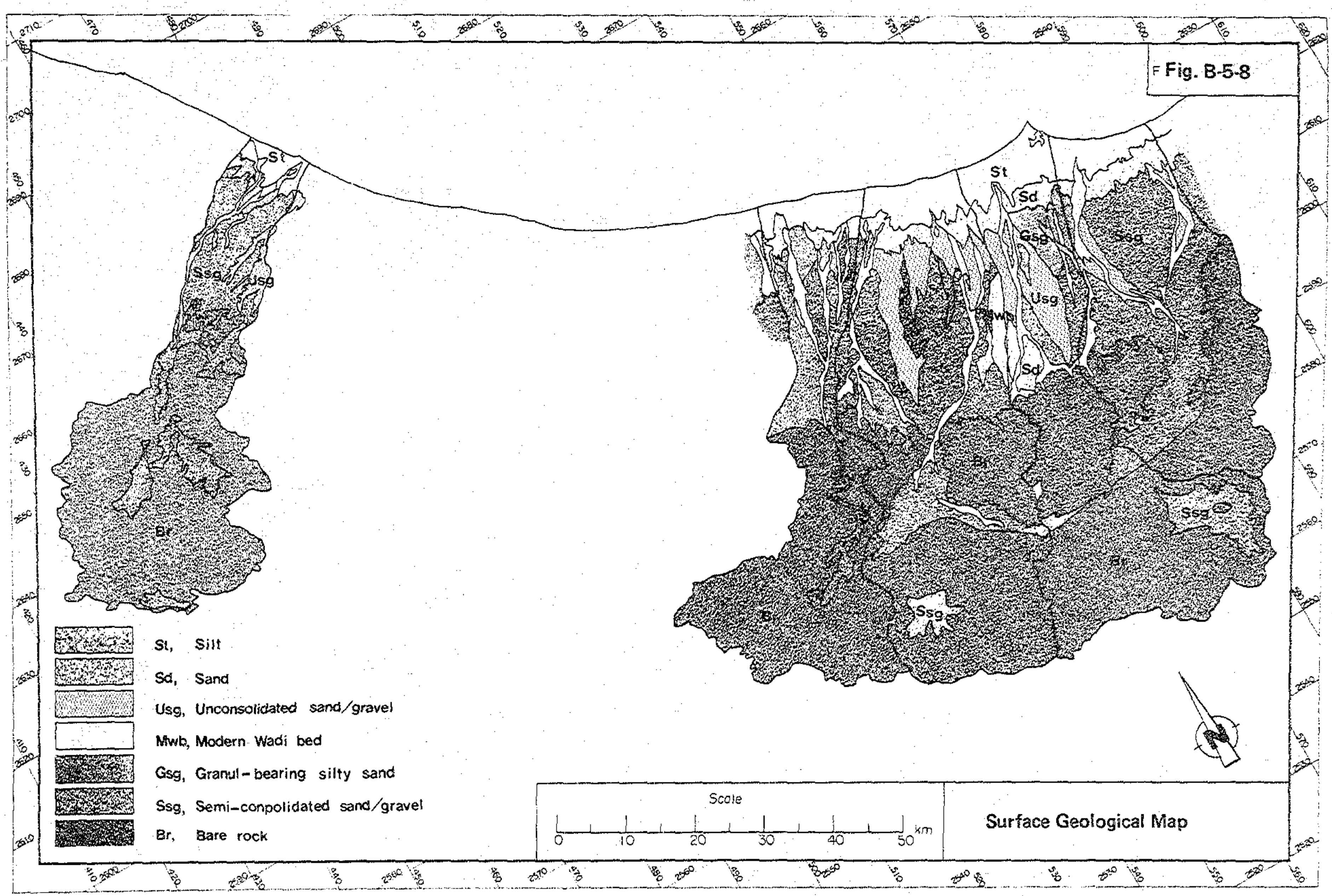
Fig. B-5-7 Schematic Longitudinal Section Showing the Occurrence of Surface Soil in Relation with Geologic Structure

LEGEND

St, Silt
Sd, Sand
Usg, Unconsolidated sand/gravel
Mwb, Modern Wadi bed
Gsg, Granule-bearing silty sand
Ssg, Semi-consolidated sand/gravel
Br, Bare rock



F Fig. B-5-8



Surface Geological Map

Table B-5-4 Areal Classification of Surface Geologic Coverage

area	soil \ wadi (km², %)	Areal extent (km²)					Areal percentage (%)				
		Ahin	Bani Ghafir	Al-Fara'	Bani Kharus	Al-Ma'awil	Ahin	Bani Ghafir	Al-Fara'	Bani Kharus	Al-Ma'awil
Coastal area (A)	St	6.611	17.694	18.800	34.399	17.343	.586	1.859	1.215	2.662	1.684
	Sd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Usg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Mwb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Gss	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Ssg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Br	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Total	6.611	17.694	18.800	34.399	17.343	.586	1.859	1.215	2.662	1.684
Sand/gravel plain (B)	St	18.216	35.474	35.891	31.231	17.736	1.616	3.727	2.320	2.417	1.722
	Sd	8.741	20.443	40.608	59.444	26.323	.775	2.148	2.625	4.600	2.556
	Usg	34.890	0.000	86.959	66.987	19.532	3.094	0.000	5.622	5.184	1.897
	Mwb	11.973	19.068	44.983	31.080	31.936	1.062	2.003	2.908	2.405	3.101
	Gss	5.950	35.474	28.576	45.714	5.276	.528	3.727	1.847	3.537	.512
	Ssg	140.368	5.583	228.609	40.208	207.329	12.450	.587	14.779	3.111	20.133
	Br	47.744	0.000	0.000	24.441	112.533	4.235	0.000	0.000	1.891	10.928
	Total	267.882	116.042	465.626	299.105	420.664	23.759	12.191	30.103	23.145	40.849
(A)+(B)	St	24.827	53.168	54.691	65.630	35.079	2.202	5.585	3.536	5.079	3.406
	Sd	8.741	20.443	40.608	59.444	26.323	.775	2.148	2.625	4.600	2.556
	Usg	34.890	0.000	86.959	66.987	19.532	3.094	0.000	5.622	5.184	1.897
	Mwb	11.973	19.068	44.983	31.080	31.936	1.062	2.003	2.908	2.405	3.101
	Gss	5.950	35.474	28.576	45.714	5.276	.528	3.727	1.847	3.537	.512
	Ssg	140.368	5.583	228.609	40.208	207.329	12.450	.587	14.779	3.111	20.133
	Br	47.744	0.000	0.000	24.441	112.533	4.235	0.000	0.000	1.891	10.928
	Total	274.493	133.737	484.426	333.504	438.007	24.345	14.049	31.318	25.807	42.533
Mountain area (C)	St	24.827	53.168	54.691	65.630	35.079	2.202	5.585	3.536	5.079	3.406
	Sd	8.741	21.989	40.608	59.444	26.323	.775	2.310	2.625	4.600	2.556
	Usg	34.890	0.000	86.959	66.987	19.532	3.094	0.000	5.622	5.184	1.897
	Mwb	11.973	33.327	53.461	31.080	33.283	1.062	3.501	3.456	2.405	3.232
	Gss	5.950	40.456	28.576	45.714	5.276	.528	4.250	1.847	3.537	.512
	Ssg	207.578	133.994	349.613	114.814	237.301	18.410	14.077	22.602	8.884	23.043
	Br	559.049	535.230	448.467	575.127	235.000	49.583	56.227	28.993	44.504	22.820
	Total	853.007	818.163	1062.374	958.796	591.793	75.655	85.951	68.682	74.193	57.467
(A)+(B)+(C)	St	49.654	106.336	109.382	131.259	70.158	4.404	11.171	7.072	10.157	6.813
	Sd	17.482	42.431	81.216	118.888	52.646	1.550	4.458	5.251	9.200	5.112
	Usg	69.780	0.000	173.918	133.975	39.064	6.189	0.000	11.244	10.367	3.793
	Mwb	23.946	52.395	98.444	62.160	65.218	2.124	5.504	6.364	4.810	6.333
	Gss	11.899	75.930	57.152	91.429	10.552	1.055	7.977	3.695	7.075	1.025
	Ssg	347.946	139.577	578.221	155.022	444.630	30.860	14.663	37.382	11.996	43.176
	Br	606.793	535.230	448.467	599.568	347.532	53.818	56.227	28.993	46.395	33.748
	Total	1127.500	951.900	1546.800	1292.300	1029.800	100.000	100.000	100.000	100.000	100.000

5.3 Infiltration Capacity and Surface Runoff

Some rainfall infiltrates into soil, and the rest flows on surface as surface runoff. For a single rainfall,

$$p = m + f$$

where p, m and f are the amounts of rainfall, infiltration and surface runoff, respectively.

Based on the experiment results in Fig. B-5-2, the interpolation and extrapolation of measured 50% values were calculated and the cumulative infiltration amount verses time is shown in Fig. B-5-9. The infiltration-rate with time derived from the figure above was drawn and is shown in Fig. B-5-10. The initial and final infiltrabilities of each soil thus obtained are tabulated in Table B-5-5, where intial infiltration is defined as the value at 0 hour of the extrapolated straight line.

The actual relationship between p, m and f applied to the rainfall on Aug. 10, 1983 is exhibited in Fig. B-5-11.

Table B-5-5 Initial Infiltration Loss and Final Infiltration Rate

	St	Sd	Gss	Usq	Ssq	Br	Mwb
Initial infiltration loss (mm)	15	25	15*	3	5	2*	—
Final infiltration rate (mm/h)	10	40	25*	20	0	0*	—

*Estimation value

Fig. B-5-9 Proposed Curve of Cumulative Intiltration Amount with Time

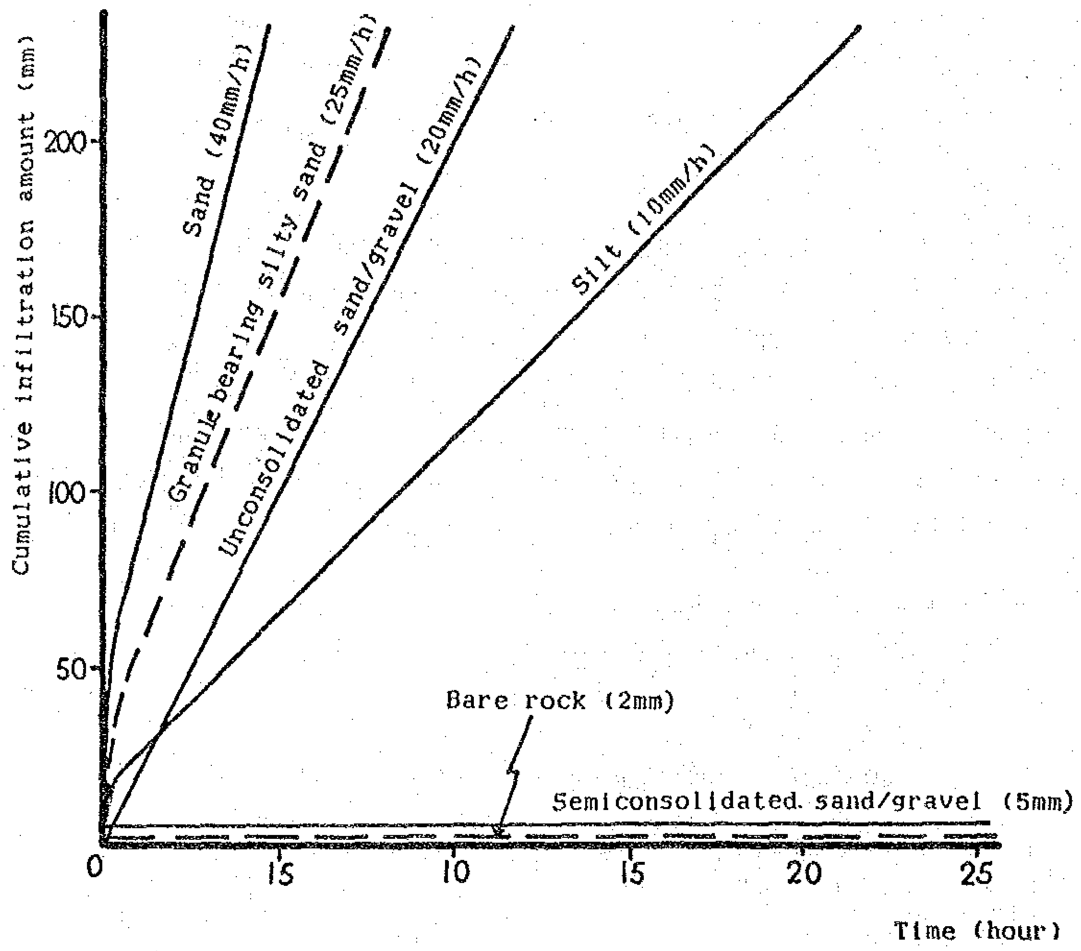
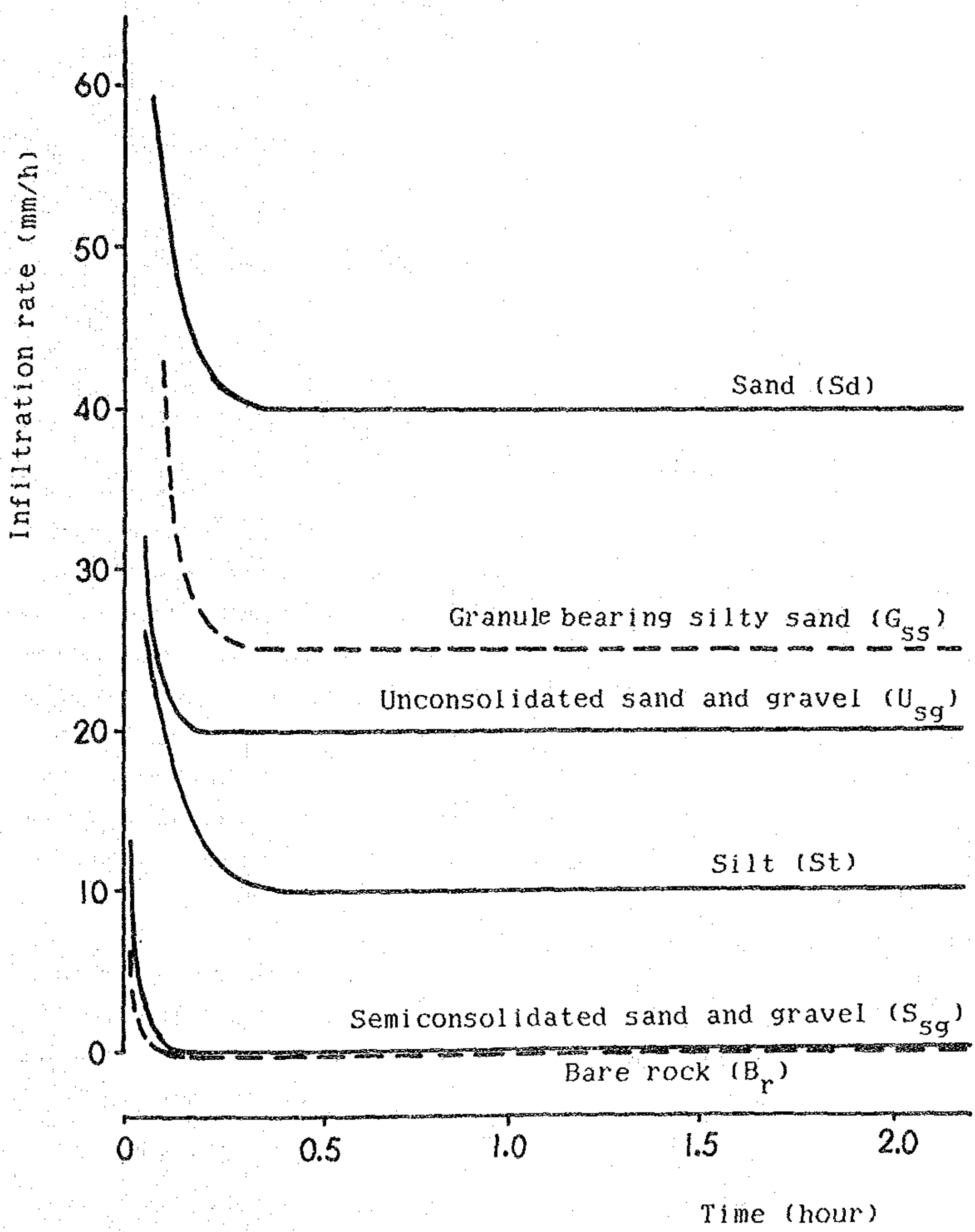


Fig. B-5-10 Proposed Infiltration Rate Curve



5.4 Infiltration Capacity and Evapotranspiration

The majority of water which infiltrates into soil is later lost due to evaportranspiration. The balance percolates down to the groundwater zone. For a single rainfall,

$$m = e^* + r$$

where m, e* and r are the amount of infiltration, evapotranspiration and ground water recharge due to percolation.

In the region of semi-consolidated sand/gravel and bare rock, the final infiltration rate is zero (cf. Table B-5-5), then

$$m = e^*$$

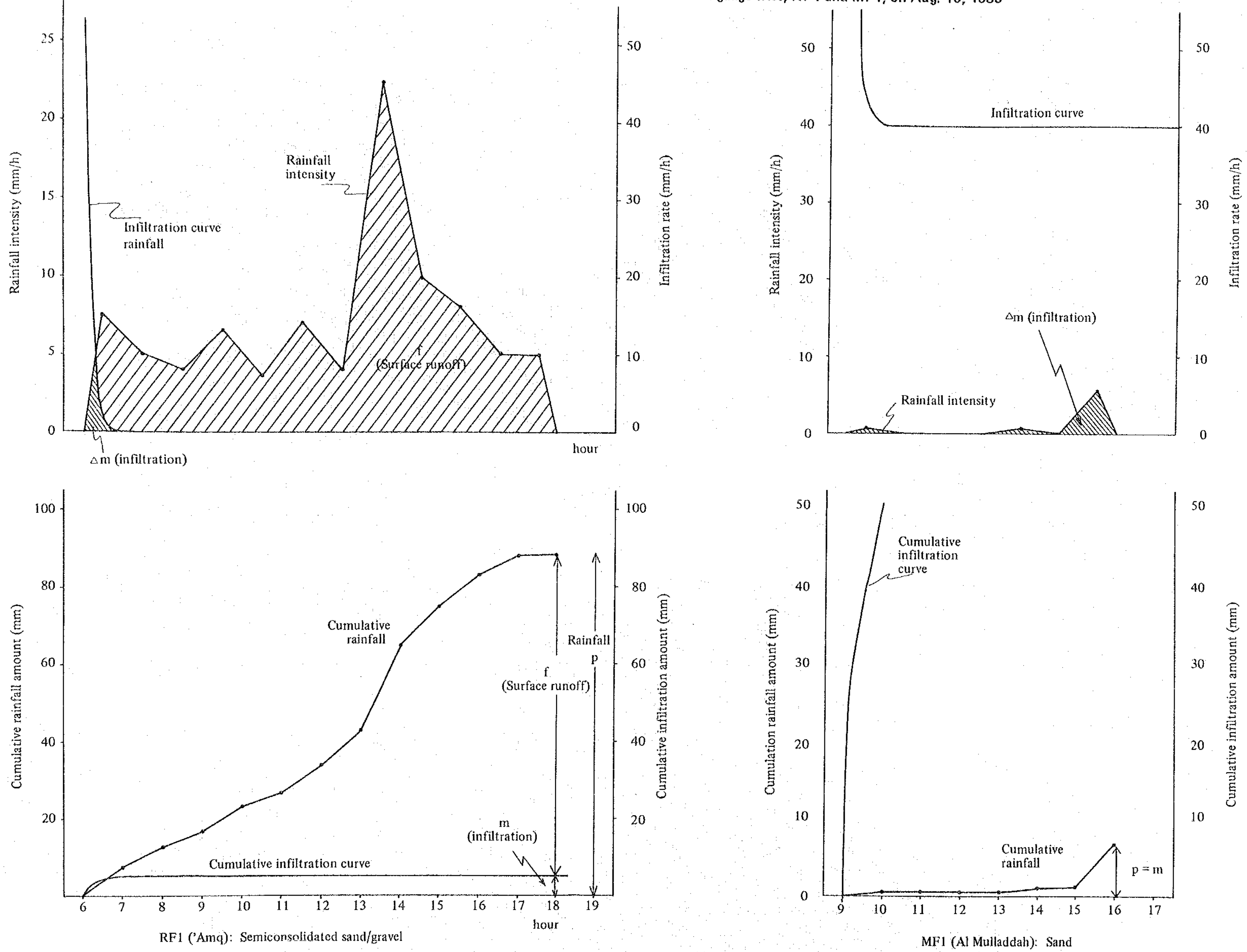
The region of high final infiltration-rate extends along the coastline where rainfall is rare, and then only in small amounts.

When rainfall is small, m is also small and the resultant r becomes very small. Fig. B-5-12 shows the depth of infiltration observed at the Al-Muladdah Agro-meteorological station for the next day after rainfall of 6.5 mm. The average infiltration depth is 8.7 cm, and the average volume water content in wet layer is 7.4%. It is routhly equal to the field capacity of 6% approx. obtained through the experiment (cf. Fig. B-5-4). This fact implies that tens of mm of rainfall do not percolate down to groundwater zone but stay in the surface soil layer within a few meters. A similar situation may hold true for the other soils. The percolation down to groundwater zone should be negligible for all soils, that is, $r \doteqdot 0$.

The bare rock and semi-consolidated sand/gravel contain the smallest volume of water among all soils and it may evaporate within 24 hours after rainfall. The other soils take several days or weeks until they return to the initial soil moisture conditions before rainfall. Evapotranspiration takes place during these days.

What is mentioned above corresponds with the analytical results of NOAA images. The surface soil distribution in the coastal plain corresponds especially well with the final NOAA images obtained for the aerial change on soil water content after rainfall (cf. Supporting Report (F)).

Fig. B-5-11 Examples, Showing the Actual Relation between Rainfall, Surface Runoff and Infiltration measured at two rain gauge sites, RF1 and MF1, on Aug. 10, 1983



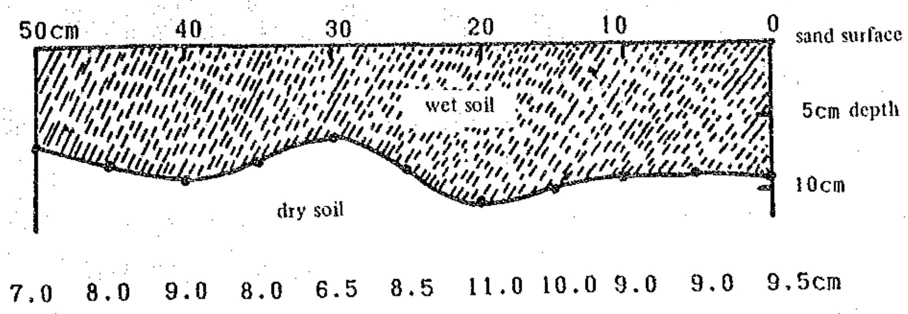
LEGEND

P : Rainfall

f : Surface Runoff

m : Infiltration

Fig. B-5-12 Infiltration Depth of Rain at Al-Muladdah on Dec. 29, 1984, Measured at 14:30 on Dec. 30, 1984



5.5 Estimation of Actual Evaporation After Rainfall

The equilibrium equation for energy at soil surface level can be expressed:

$$LeE + H + Qn + G = O,$$

where Le is latent heat of evaporation, E is rate of actual evaporation, H is specific flux of sensible heat into atmosphere, Qn is specific flux of net radiation, and G is specific flux of heat conducted into the earth. The Bowen ratio Bo, which is the ratio between latent heat and sensible heat, is defined by:

$$Bo = H/LeE$$

Derived from two equations above is the actual evaporation E, namely:

$$E = \frac{-Qn - G}{(1+Bo)Le}$$

Bo, Bowen ratio, can be determined by:

$$Bo = \frac{Cp\,(T_1 - T_2)}{Le\,(q_1 - q_2)}$$

where o_p is specific heat under constant pressure, T_1 and T_2 are air temperature at two different heights, and q_1 and q_2 are specific humidity at two different heights.

A items except E observed at Al-Muladda, Agrometeorological Station.

By using the equations above, the daily amount of actual evaporation E, was calculated for the period before and after the rainfall on August 10, 1983, the results shown in Fig. B-5-13.

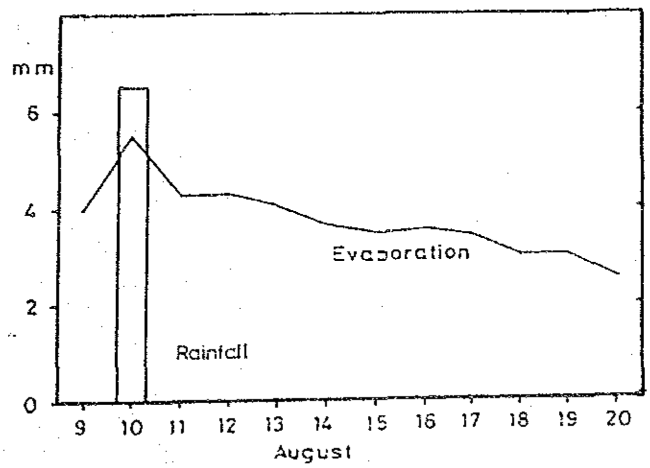
A clear tendency can be seen on daily change of calculated amount. However the calculated actual evaporation exceeds the total rainfall . One of the reasons of the excess is unsuitable observation height of the thermometer. Therefore, the height of the thermometer were adjusted in November 1983. The data observed after that time are considered to be more appropriate for estimation of actual evaporation.

5.6 Estimation of Dew

The same method which is used in estimation of actual evaporation normally can be applied to the estimation of dew. However, the daily value of dew is less than the actual daily evaporation after rainfall and the method has the same problem mentioned in paragraph 5.3 above. Accordingly, the estimated dew cannot be evaluated quantatively. However, the results of estimation suggest dew will probably occur in summer, in August and September especially. This coincides with personal experience.

Dew on tree leaves is greater than that on the ground because the temperature of leaves is lower than that of the ground at night.

Fig. B-5-13 Actual Evaporation Calculated Using the Bowen Ratio



CHAPTER 6 STUDY OF SURFACE RUNNOFF

6.1 Observed Surface Runoff

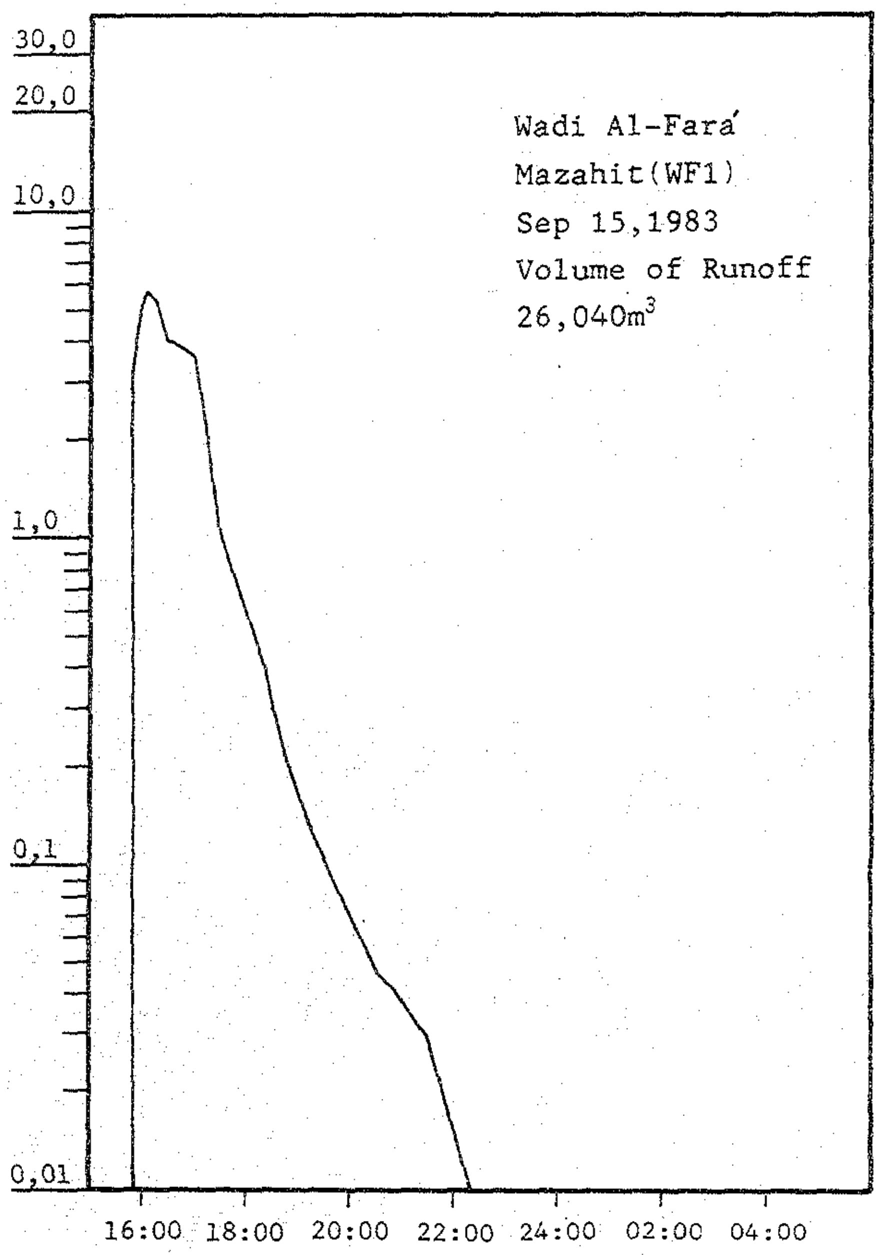
During the survey period, surface runoffs were observed eight times at the six wadi gauges installed by the Project. However, large floods which reach the sea did not occur in the project period as expected. The survey period was an extremely dry one. Further investigation will be required for studying the relationship between the precipitation and topographic structures. Eight flood dischanges recorded during the survey period are summarized in Table B-6-1, B-6-2(1) - (8) and FiG. B-6-1(1) - (8).

Manning's equation was used to estimate outflow from the water level data, given the geometry of wadi channel found by surveying. The roughness coefficient was assumed as 0.040 according to the wadi situation and the previous studies. The ground surveys such as longitudinal profile and cross-section leveling surveys were executed at all the gauge sites during the survey period. The results of survey are shown in Fig. B-1-7 (1) (15).

Table B-6-1 Observed Flood during Survey Period

Wadi Basin	Discharge Site	Date	Duration	Outflow (m^3)	Peak Discharge (m^3/sec)
Wadi Al-Fara'	WF1 (Mazahit)	Sep.15,'83	15:50-00:02	26,040	5.8
Wadi Bani Ghafir	WG1 (Al-Houqain)	Sep.15'83	13:46-20:57	1,263	0.9
Wadi Al-Fara'	WF4 (Tabaqah)	Apr.12,'84	14:55-16:15	815	0.7
Wadi Al-Fara'	WF1 (Mazahit)	Jul.30'84	18:00-22:01	65,017	13.0
Wadi Ahin	WA1 (Al-Heil)	Sep.15,'84	17:00-18:08	2,036	1.6
Wadi Ahin	WA1 (Al-Heil)	Sep.16'84	19:25-22:52	8,376	1.7
Wadi Al-Ma'awil	WM2 (Afi)	Apr.18,'85	16:10 - 20:07	41,891	19.1
Wadi Bani Kharus	WK1 (Al-Abiyad)	Apr.19,'85	16:20 06:51	127,658	44.1

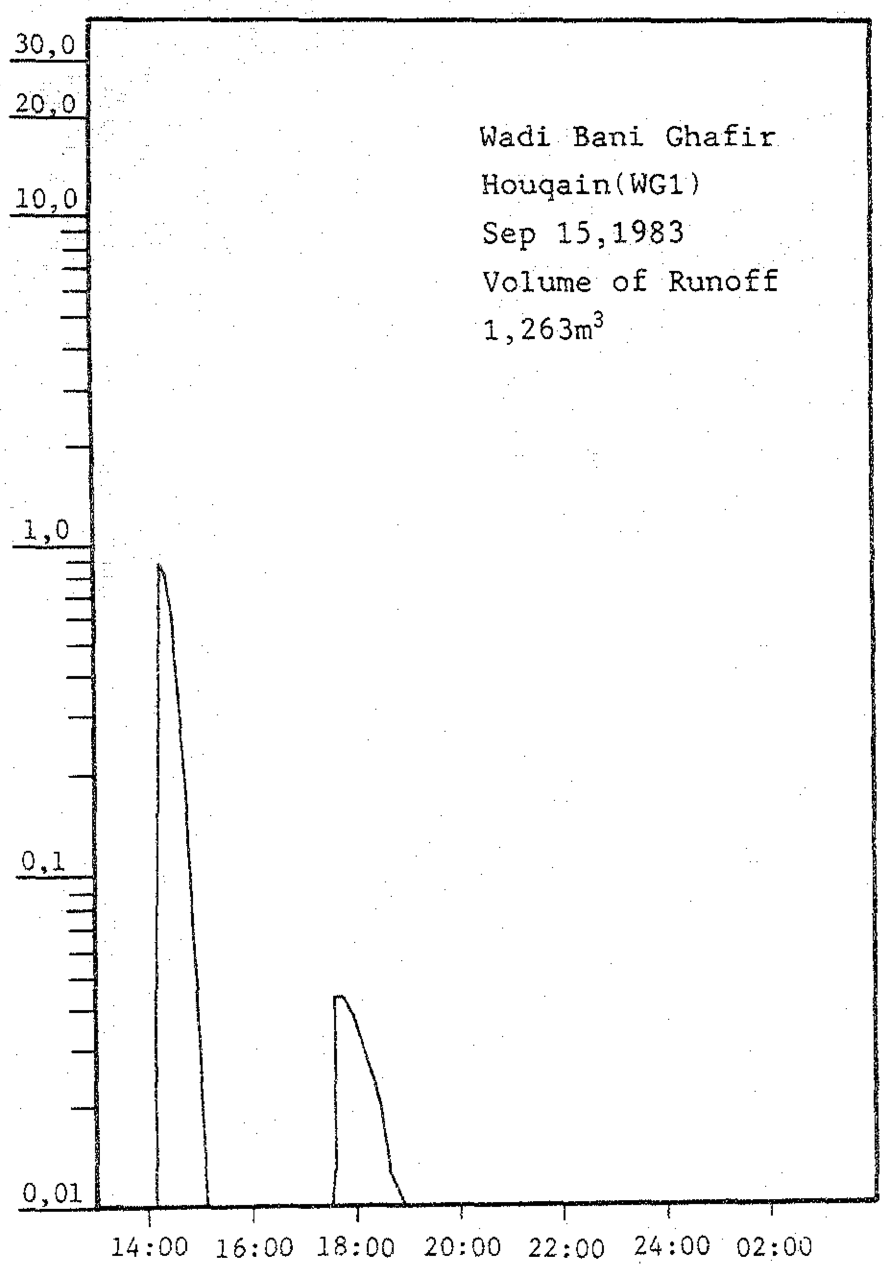
Fig. B-6-1(1) Observed Runoff Hydrograph WF1, Sep. 15, 1983



** CALCULATED RUNOFF VOL.(EVERY ONE MINUTES) **
SITE: MAZAHIT DATE: SEP. 15 UNIT:M3/SEC.

	15	16	17	18	19	20	21	22	23
0	0.000	5.188	3.657	0.607	0.165	0.072	0.038	0.016	0.003
1	0.000	5.247	3.527	0.597	0.163	0.071	0.038	0.016	0.003
2	0.000	5.307	3.400	0.588	0.160	0.071	0.037	0.016	0.003
3	0.000	5.366	3.276	0.579	0.158	0.070	0.037	0.015	0.003
4	0.000	5.426	3.155	0.569	0.156	0.069	0.037	0.015	0.003
5	0.000	5.487	3.037	0.557	0.153	0.068	0.036	0.015	0.002
6	0.000	5.547	2.923	0.545	0.151	0.067	0.036	0.014	0.002
7	0.000	5.608	2.811	0.534	0.149	0.066	0.036	0.014	0.002
8	0.000	5.670	2.703	0.523	0.147	0.065	0.035	0.014	0.002
9	0.000	5.731	2.597	0.511	0.145	0.064	0.035	0.013	0.002
10	0.000	5.793	2.495	0.500	0.143	0.064	0.035	0.013	0.002
11	0.000	5.731	2.395	0.489	0.140	0.063	0.035	0.013	0.002
12	0.000	5.670	2.299	0.479	0.138	0.062	0.034	0.012	0.002
13	0.000	5.608	2.205	0.468	0.136	0.061	0.034	0.012	0.002
14	0.000	5.547	2.114	0.458	0.134	0.060	0.034	0.012	0.002
15	0.000	5.487	2.026	0.447	0.132	0.059	0.033	0.011	0.002
16	0.000	5.426	1.941	0.437	0.130	0.059	0.033	0.011	0.002
17	0.000	5.366	1.858	0.427	0.128	0.058	0.033	0.011	0.002
18	0.000	5.306	1.778	0.417	0.126	0.057	0.033	0.011	0.002
19	0.000	5.247	1.701	0.407	0.124	0.056	0.032	0.010	0.002
20	0.000	5.188	1.626	0.398	0.122	0.055	0.032	0.010	0.002
21	0.000	5.070	1.554	0.388	0.120	0.055	0.032	0.010	0.002
22	0.000	4.954	1.484	0.379	0.118	0.054	0.032	0.010	0.002
23	0.000	4.838	1.417	0.370	0.116	0.053	0.031	0.009	0.002
24	0.000	4.724	1.353	0.361	0.115	0.052	0.031	0.009	0.002
25	0.000	4.611	1.290	0.352	0.113	0.052	0.031	0.009	0.002
26	0.000	4.499	1.230	0.343	0.111	0.051	0.030	0.009	0.002
27	0.000	4.388	1.173	0.335	0.109	0.050	0.030	0.008	0.001
28	0.000	4.279	1.118	0.326	0.107	0.049	0.030	0.008	0.001
29	0.000	4.170	1.065	0.318	0.106	0.049	0.030	0.008	0.001
30	0.000	4.069	1.014	0.310	0.104	0.048	0.029	0.008	0.001
31	0.000	4.054	0.997	0.304	0.103	0.048	0.029	0.007	0.001
32	0.000	4.040	0.980	0.298	0.101	0.047	0.028	0.007	0.001
33	0.000	4.026	0.963	0.293	0.100	0.047	0.028	0.007	0.001
34	0.000	4.012	0.947	0.287	0.099	0.046	0.027	0.007	0.001
35	0.000	3.998	0.930	0.282	0.098	0.046	0.027	0.007	0.001
36	0.000	3.984	0.915	0.276	0.097	0.046	0.026	0.006	0.001
37	0.000	3.970	0.899	0.271	0.096	0.045	0.026	0.006	0.001
38	0.000	3.956	0.883	0.265	0.095	0.045	0.025	0.006	0.001
39	0.000	3.942	0.868	0.260	0.094	0.045	0.025	0.006	0.001
40	0.000	3.928	0.853	0.255	0.093	0.044	0.024	0.006	0.001
41	0.000	3.914	0.839	0.250	0.091	0.044	0.024	0.005	0.001
42	0.000	3.900	0.824	0.245	0.090	0.044	0.024	0.005	0.001
43	0.000	3.887	0.810	0.240	0.089	0.043	0.023	0.005	0.001
44	0.000	3.873	0.796	0.235	0.088	0.043	0.023	0.005	0.001
45	0.000	3.859	0.783	0.230	0.087	0.043	0.022	0.005	0.001
46	0.000	3.846	0.769	0.225	0.086	0.042	0.022	0.005	0.001
47	0.000	3.832	0.756	0.221	0.085	0.042	0.021	0.004	0.001
48	0.000	3.818	0.743	0.216	0.084	0.042	0.021	0.004	0.001
49	0.000	3.805	0.731	0.211	0.083	0.041	0.020	0.004	0.001
50	3.276	3.791	0.718	0.207	0.082	0.041	0.020	0.004	0.001
51	3.425	3.778	0.706	0.202	0.081	0.041	0.020	0.004	0.001
52	3.579	3.764	0.694	0.198	0.080	0.040	0.019	0.004	0.001
53	3.737	3.751	0.683	0.194	0.079	0.040	0.019	0.004	0.001
54	3.900	3.737	0.671	0.189	0.078	0.040	0.018	0.003	0.001
55	4.069	3.724	0.660	0.185	0.077	0.039	0.018	0.003	0.001
56	4.279	3.710	0.649	0.181	0.076	0.039	0.018	0.003	0.001
57	4.499	3.697	0.638	0.177	0.075	0.039	0.017	0.003	0.001
58	4.724	3.684	0.628	0.173	0.074	0.039	0.017	0.003	0.001
59	4.954	3.671	0.617	0.169	0.073	0.038	0.017	0.003	0.001

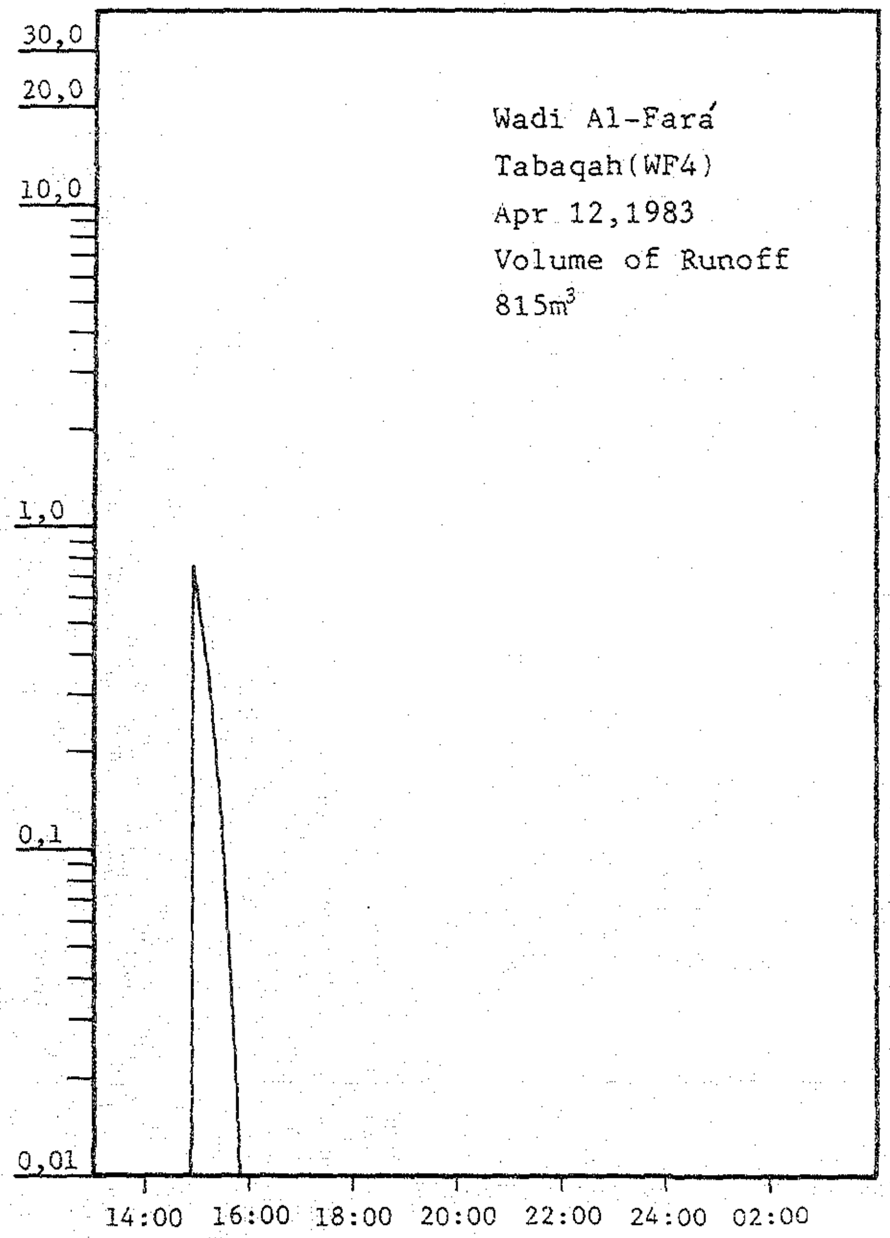
Fig. B-6-1 (2) Observed Runoff Hydrograph WG1, Sep. 15, 1983



** CALCULATED RUNOFF VOL. (EVERY ONE MINUTES) ** 3 /3
SITE; HOUQEN DATE; SEP. 15 UNIT;M3/SEC.

	13	14	15	16	17	18	19	20
0	0.000	0.002	0.037	0.000	0.000	0.037	0.009	0.002
1	0.000	0.003	0.032	0.000	0.000	0.036	0.009	0.002
2	0.000	0.005	0.029	0.000	0.000	0.035	0.008	0.002
3	0.000	0.008	0.025	0.000	0.000	0.034	0.008	0.002
4	0.000	0.011	0.022	0.000	0.000	0.034	0.008	0.002
5	0.000	0.015	0.019	0.000	0.000	0.033	0.008	0.002
6	0.000	0.020	0.017	0.000	0.000	0.032	0.008	0.002
7	0.000	0.026	0.014	0.000	0.000	0.032	0.008	0.002
8	0.000	0.034	0.012	0.000	0.000	0.031	0.007	0.002
9	0.000	0.043	0.010	0.000	0.000	0.030	0.007	0.002
10	0.000	0.053	0.009	0.000	0.000	0.030	0.007	0.002
11	0.000	0.079	0.008	0.000	0.000	0.029	0.007	0.002
12	0.000	0.114	0.008	0.000	0.000	0.029	0.007	0.002
13	0.000	0.158	0.007	0.000	0.000	0.028	0.007	0.002
14	0.000	0.214	0.007	0.000	0.000	0.027	0.007	0.002
15	0.000	0.283	0.006	0.000	0.000	0.027	0.006	0.001
16	0.000	0.367	0.006	0.000	0.000	0.026	0.006	0.001
17	0.000	0.469	0.006	0.000	0.000	0.025	0.006	0.001
18	0.000	0.590	0.005	0.000	0.000	0.025	0.006	0.001
19	0.000	0.734	0.005	0.000	0.000	0.025	0.006	0.001
20	0.000	0.903	0.005	0.000	0.000	0.024	0.006	0.001
21	0.000	0.873	0.004	0.000	0.000	0.024	0.006	0.001
22	0.000	0.843	0.004	0.000	0.000	0.023	0.005	0.001
23	0.000	0.815	0.004	0.000	0.000	0.023	0.005	0.001
24	0.000	0.787	0.003	0.000	0.000	0.022	0.005	0.001
25	0.000	0.760	0.003	0.000	0.000	0.022	0.005	0.001
26	0.000	0.734	0.003	0.000	0.000	0.021	0.005	0.001
27	0.000	0.708	0.003	0.000	0.000	0.021	0.005	0.001
28	0.000	0.683	0.002	0.000	0.000	0.020	0.005	0.001
29	0.000	0.659	0.002	0.000	0.000	0.020	0.005	0.001
30	0.000	0.635	0.002	0.000	0.000	0.019	0.005	0.001
31	0.000	0.590	0.002	0.000	0.000	0.019	0.004	0.001
32	0.000	0.547	0.002	0.000	0.000	0.018	0.004	0.001
33	0.000	0.507	0.002	0.000	0.001	0.018	0.004	0.001
34	0.000	0.469	0.002	0.000	0.002	0.017	0.004	0.001
35	0.000	0.433	0.001	0.000	0.004	0.017	0.004	0.001
36	0.000	0.399	0.001	0.000	0.007	0.017	0.004	0.001
37	0.000	0.367	0.001	0.000	0.013	0.016	0.004	0.001
38	0.000	0.337	0.001	0.000	0.020	0.016	0.004	0.001
39	0.000	0.309	0.001	0.000	0.030	0.015	0.004	0.001
40	0.000	0.283	0.001	0.000	0.044	0.015	0.004	0.001
41	0.000	0.258	0.001	0.000	0.044	0.015	0.003	0.001
42	0.000	0.235	0.001	0.000	0.044	0.014	0.003	0.001
43	0.000	0.214	0.001	0.000	0.044	0.014	0.003	0.001
44	0.000	0.194	0.001	0.000	0.044	0.014	0.003	0.001
45	0.000	0.175	0.001	0.000	0.044	0.013	0.003	0.001
46	0.001	0.158	0.001	0.000	0.044	0.013	0.003	0.001
47	0.001	0.142	0.001	0.000	0.044	0.013	0.003	0.001
48	0.001	0.127	0.001	0.000	0.044	0.012	0.003	0.001
49	0.001	0.114	0.001	0.000	0.044	0.012	0.003	0.001
50	0.001	0.101	0.000	0.000	0.044	0.012	0.003	0.001
51	0.001	0.092	0.000	0.000	0.043	0.011	0.003	0.001
52	0.001	0.084	0.000	0.000	0.043	0.011	0.003	0.001
53	0.001	0.077	0.000	0.000	0.042	0.011	0.003	0.001
54	0.001	0.070	0.000	0.000	0.041	0.010	0.002	0.001
55	0.001	0.063	0.000	0.000	0.040	0.010	0.002	0.001
56	0.001	0.057	0.000	0.000	0.039	0.010	0.002	0.001
57	0.002	0.051	0.000	0.000	0.039	0.010	0.002	0.001
58	0.002	0.046	0.000	0.000	0.038	0.009	0.002	0.000
59	0.002	0.041	0.000	0.000	0.037	0.009	0.002	0.000

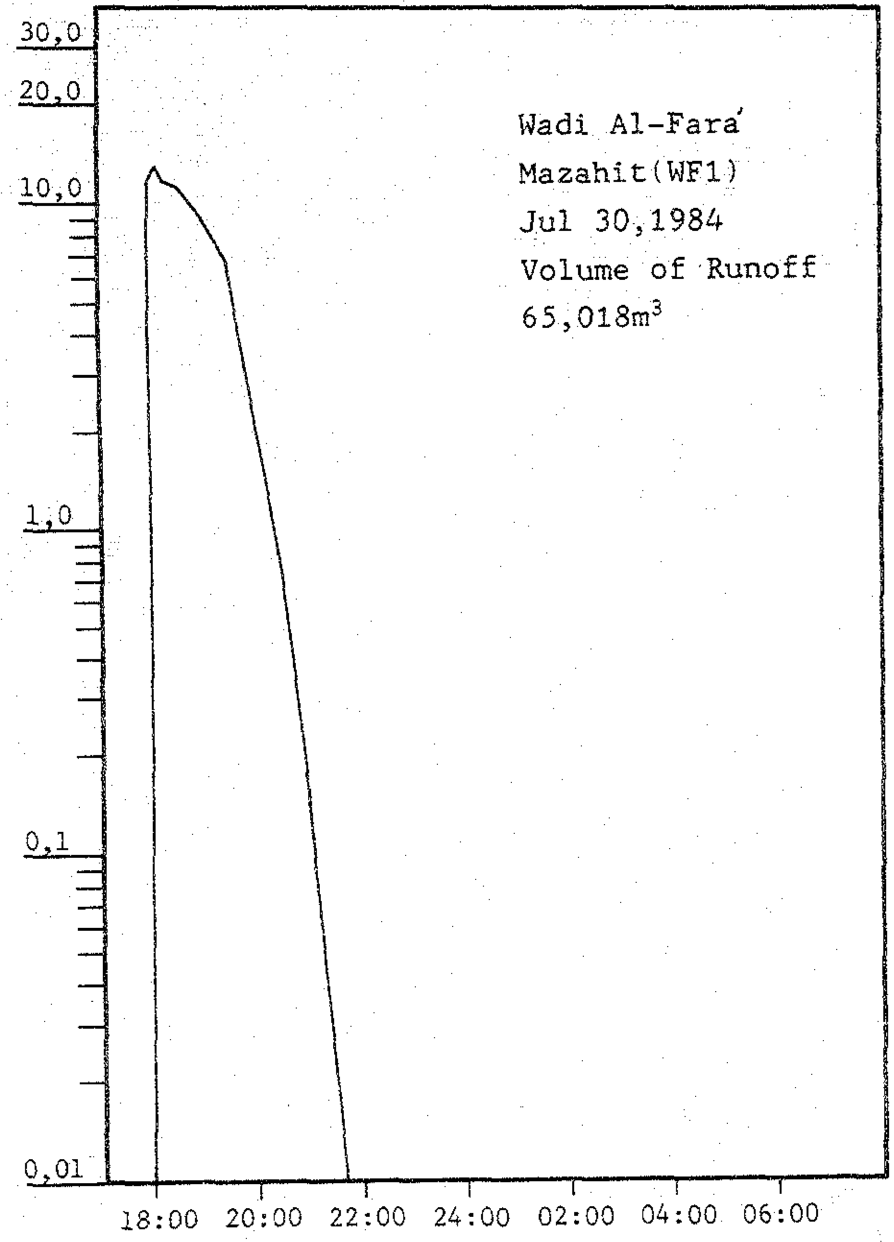
Fig. 8-6-1 (3) Observed Runoff Hydrograph WF4, Apr. 12, 1983



** CALCULATED RUNOFF VOL. (EVERY ONE MINUTES) ** 2/3

	9	10	11	12	13	14	15	16
0	0.000	0.000	0.000	0.000	0.000	0.000	.568	.003
1	0.000	0.000	0.000	0.000	0.000	0.000	.546	.002
2	0.000	0.000	0.000	0.000	0.000	0.000	.524	.002
3	0.000	0.000	0.000	0.000	0.000	0.000	.503	.002
4	0.000	0.000	0.000	0.000	0.000	0.000	.483	.002
5	0.000	0.000	0.000	0.000	0.000	0.000	.462	.002
6	0.000	0.000	0.000	0.000	0.000	0.000	.443	.001
7	0.000	0.000	0.000	0.000	0.000	0.000	.423	.001
8	0.000	0.000	0.000	0.000	0.000	0.000	.404	.001
9	0.000	0.000	0.000	0.000	0.000	0.000	.385	.001
10	0.000	0.000	0.000	0.000	0.000	0.000	.367	.001
11	0.000	0.000	0.000	0.000	0.000	0.000	.349	.001
12	0.000	0.000	0.000	0.000	0.000	0.000	.332	.001
13	0.000	0.000	0.000	0.000	0.000	0.000	.315	.001
14	0.000	0.000	0.000	0.000	0.000	0.000	.298	.001
15	0.000	0.000	0.000	0.000	0.000	0.000	.282	.001
16	0.000	0.000	0.000	0.000	0.000	0.000	.266	0.000
17	0.000	0.000	0.000	0.000	0.000	0.000	.251	0.000
18	0.000	0.000	0.000	0.000	0.000	0.000	.236	0.000
19	0.000	0.000	0.000	0.000	0.000	0.000	.221	0.000
20	0.000	0.000	0.000	0.000	0.000	0.000	.207	0.000
21	0.000	0.000	0.000	0.000	0.000	0.000	.194	0.000
22	0.000	0.000	0.000	0.000	0.000	0.000	.180	0.000
23	0.000	0.000	0.000	0.000	0.000	0.000	.167	0.000
24	0.000	0.000	0.000	0.000	0.000	0.000	.155	0.000
25	0.000	0.000	0.000	0.000	0.000	0.000	.143	0.000
26	0.000	0.000	0.000	0.000	0.000	0.000	.131	0.000
27	0.000	0.000	0.000	0.000	0.000	0.000	.120	0.000
28	0.000	0.000	0.000	0.000	0.000	0.000	.109	0.000
29	0.000	0.000	0.000	0.000	0.000	0.000	.100	0.000
30	0.000	0.000	0.000	0.000	0.000	0.000	.092	0.000
31	0.000	0.000	0.000	0.000	0.000	0.000	.086	0.000
32	0.000	0.000	0.000	0.000	0.000	0.000	.080	0.000
33	0.000	0.000	0.000	0.000	0.000	0.000	.075	0.000
34	0.000	0.000	0.000	0.000	0.000	0.000	.069	0.000
35	0.000	0.000	0.000	0.000	0.000	0.000	.064	0.000
36	0.000	0.000	0.000	0.000	0.000	0.000	.059	0.000
37	0.000	0.000	0.000	0.000	0.000	0.000	.055	0.000
38	0.000	0.000	0.000	0.000	0.000	0.000	.051	0.000
39	0.000	0.000	0.000	0.000	0.000	0.000	.046	0.000
40	0.000	0.000	0.000	0.000	0.000	0.000	.043	0.000
41	0.000	0.000	0.000	0.000	0.000	0.000	.039	0.000
42	0.000	0.000	0.000	0.000	0.000	0.000	.035	0.000
43	0.000	0.000	0.000	0.000	0.000	0.000	.032	0.000
44	0.000	0.000	0.000	0.000	0.000	0.000	.029	0.000
45	0.000	0.000	0.000	0.000	0.000	0.000	.026	0.000
46	0.000	0.000	0.000	0.000	0.000	0.000	.024	0.000
47	0.000	0.000	0.000	0.000	0.000	0.000	.021	0.000
48	0.000	0.000	0.000	0.000	0.000	0.000	.019	0.000
49	0.000	0.000	0.000	0.000	0.000	0.000	.017	0.000
50	0.000	0.000	0.000	0.000	0.000	0.000	.015	0.000
51	0.000	0.000	0.000	0.000	0.000	0.000	.013	0.000
52	0.000	0.000	0.000	0.000	0.000	0.000	.011	0.000
53	0.000	0.000	0.000	0.000	0.000	0.000	.010	0.000
54	0.000	0.000	0.000	0.000	0.000	0.000	.008	0.000
55	0.000	0.000	0.000	0.000	0.000	.745	.007	0.000
56	0.000	0.000	0.000	0.000	0.000	.708	.006	0.000
57	0.000	0.000	0.000	0.000	0.000	.671	.005	0.000
58	0.000	0.000	0.000	0.000	0.000	.636	.004	0.000
59	0.000	0.000	0.000	0.000	0.000	.601	.003	0.000

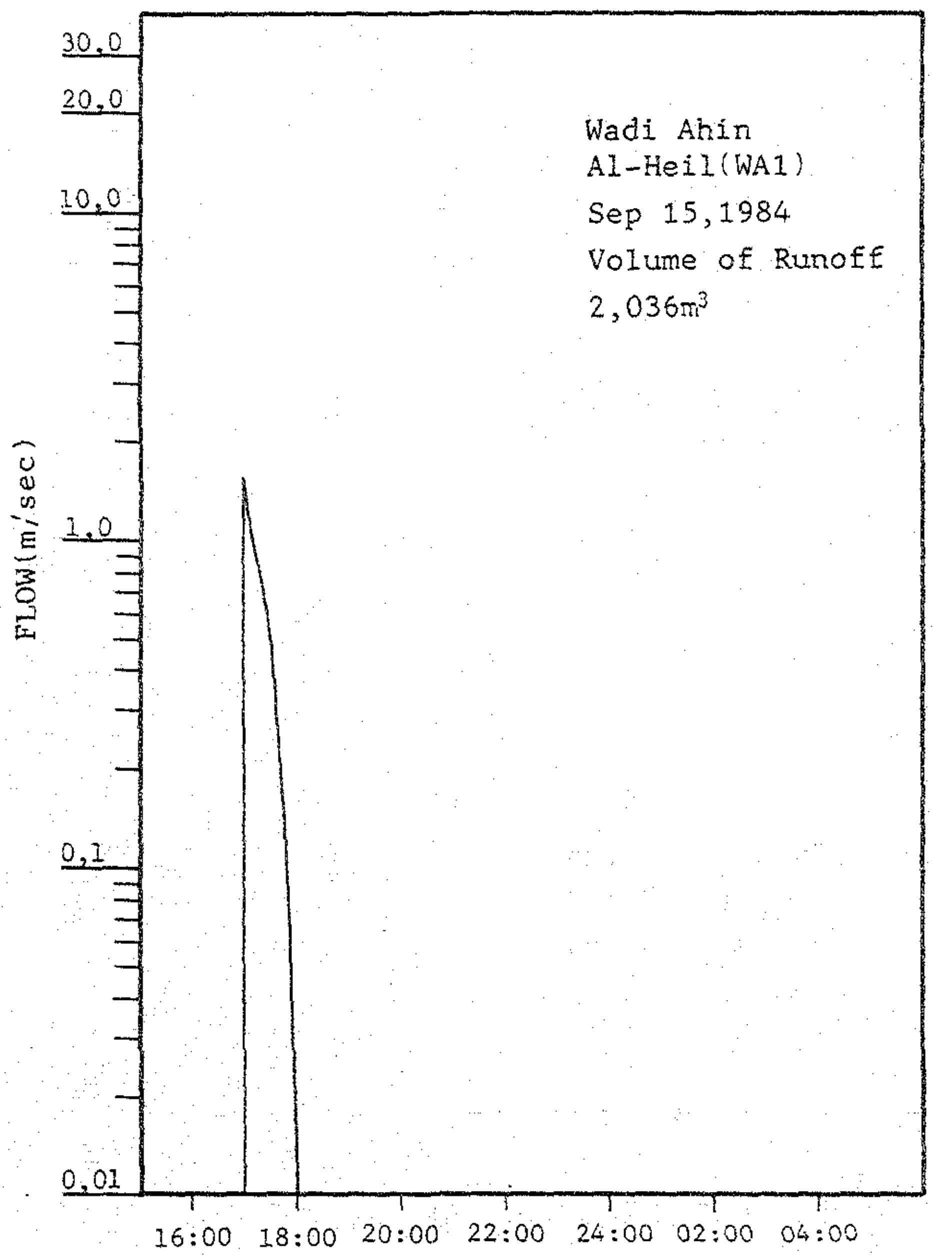
Fig. B-6-1 (4) Observed Runoff Hydrograph WF1, Jul. 30, 1984



** CALCULATED RUNOFF VOL.(EVERY ONE MINUTES) **

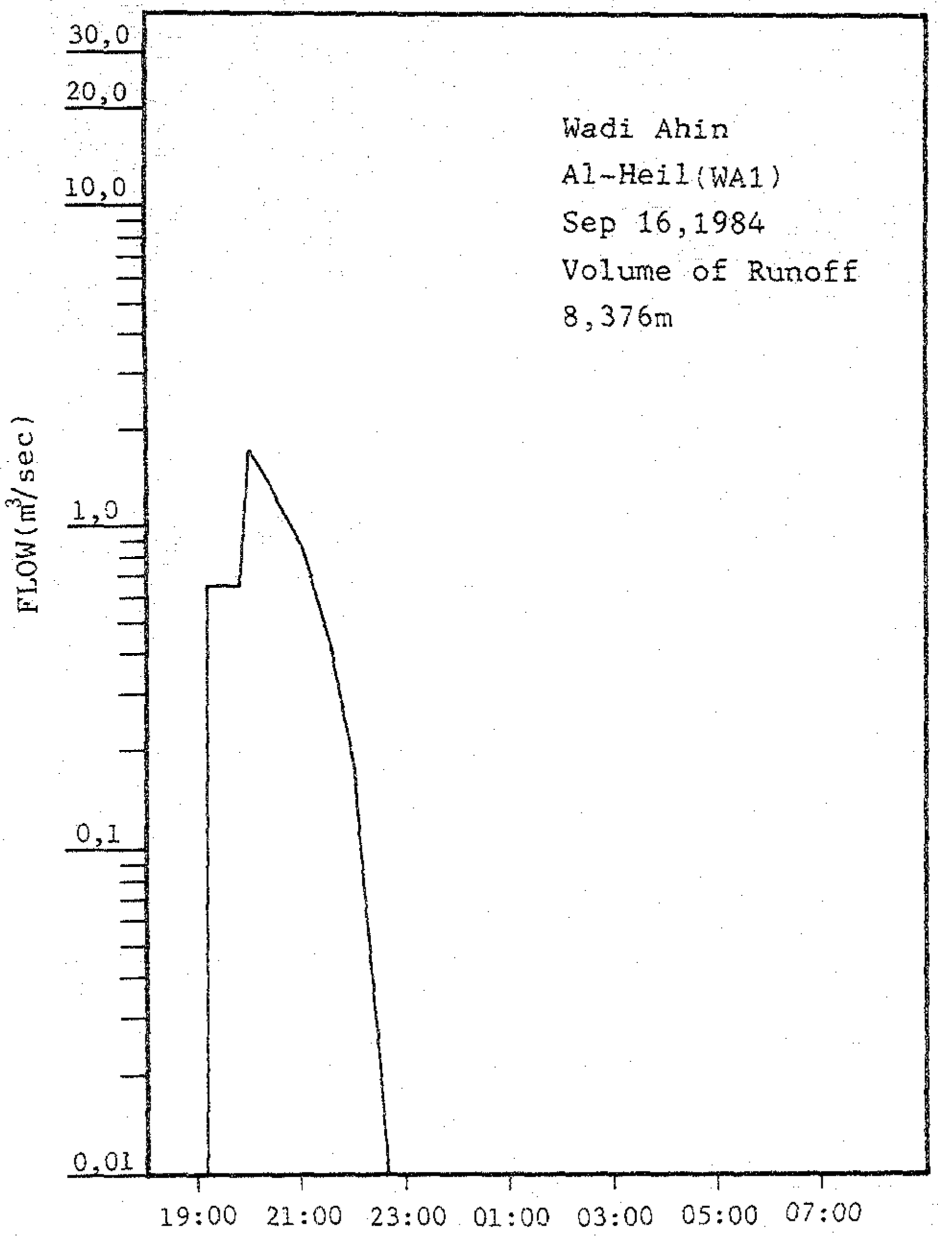
	16	17	18	19	20	21	22	23
0	0.000	0.000	11.703	8.987	2.052	.147	.001	0.000
1	0.000	0.000	11.956	8.901	1.966	.140	.001	0.000
2	0.000	0.000	12.211	8.816	1.883	.133	0.000	0.000
3	0.000	0.000	12.468	8.732	1.802	.126	0.000	0.000
4	0.000	0.000	12.727	8.648	1.724	.120	0.000	0.000
5	0.000	0.000	12.989	8.564	1.648	.113	0.000	0.000
6	0.000	0.000	12.858	8.481	1.575	.107	0.000	0.000
7	0.000	0.000	12.727	8.397	1.505	.101	0.000	0.000
8	0.000	0.000	12.597	8.315	1.437	.096	0.000	0.000
9	0.000	0.000	12.468	8.232	1.372	.090	0.000	0.000
10	0.000	0.000	12.339	8.150	1.309	.085	0.000	0.000
11	0.000	0.000	12.211	8.069	1.248	.080	0.000	0.000
12	0.000	0.000	12.083	7.987	1.190	.075	0.000	0.000
13	0.000	0.000	11.956	7.906	1.134	.071	0.000	0.000
14	0.000	0.000	11.829	7.826	1.080	.066	0.000	0.000
15	0.000	0.000	11.703	7.745	1.029	.062	0.000	0.000
16	0.000	0.000	11.703	7.666	1.004	.058	0.000	0.000
17	0.000	0.000	11.703	7.586	.980	.054	0.000	0.000
18	0.000	0.000	11.703	7.507	.956	.050	0.000	0.000
19	0.000	0.000	11.703	7.428	.933	.046	0.000	0.000
20	0.000	0.000	11.703	7.349	.910	.043	0.000	0.000
21	0.000	0.000	11.703	7.271	.888	.040	0.000	0.000
22	0.000	0.000	11.703	7.193	.866	.037	0.000	0.000
23	0.000	0.000	11.703	7.116	.845	.034	0.000	0.000
24	0.000	0.000	11.703	7.039	.824	.031	0.000	0.000
25	0.000	0.000	11.703	6.962	.804	.028	0.000	0.000
26	0.000	0.000	11.703	6.886	.785	.026	0.000	0.000
27	0.000	0.000	11.703	6.810	.766	.024	0.000	0.000
28	0.000	0.000	11.703	6.734	.747	.021	0.000	0.000
29	0.000	0.000	11.703	6.659	.729	.019	0.000	0.000
30	0.000	0.000	11.703	6.584	.711	.017	0.000	0.000
31	0.000	0.000	11.608	6.510	.683	.016	0.000	0.000
32	0.000	0.000	11.513	6.435	.657	.015	0.000	0.000
33	0.000	0.000	11.419	6.362	.631	.014	0.000	0.000
34	0.000	0.000	11.323	6.288	.607	.013	0.000	0.000
35	0.000	0.000	11.229	6.215	.584	.012	0.000	0.000
36	0.000	0.000	11.135	6.142	.560	.011	0.000	0.000
37	0.000	0.000	11.042	6.070	.533	.011	0.000	0.000
38	0.000	0.000	10.949	5.998	.507	.010	0.000	0.000
39	0.000	0.000	10.856	5.926	.481	.009	0.000	0.000
40	0.000	0.000	10.763	5.855	.456	.008	0.000	0.000
41	0.000	0.000	10.671	5.366	.432	.008	0.000	0.000
42	0.000	0.000	10.579	4.896	.409	.007	0.000	0.000
43	0.000	0.000	10.488	4.444	.386	.006	0.000	0.000
44	0.000	0.000	10.397	4.026	.365	.006	0.000	0.000
45	0.000	0.000	10.306	3.697	.344	.005	0.000	0.000
46	0.000	0.000	10.216	3.566	.324	.005	0.000	0.000
47	0.000	0.000	10.126	3.437	.305	.004	0.000	0.000
48	0.000	0.000	10.036	3.312	.286	.004	0.000	0.000
49	0.000	0.000	9.947	3.191	.268	.003	0.000	0.000
50	0.000	0.000	9.858	3.072	.251	.003	0.000	0.000
51	0.000	0.000	9.769	2.957	.239	.003	0.000	0.000
52	0.000	0.000	9.681	2.844	.227	.002	0.000	0.000
53	0.000	0.000	9.593	2.735	.216	.002	0.000	0.000
54	0.000	0.000	9.505	2.629	.205	.002	0.000	0.000
55	0.000	0.000	9.418	2.525	.195	.002	0.000	0.000
56	0.000	0.000	9.331	2.425	.184	.001	0.000	0.000
57	0.000	0.000	9.244	2.328	.174	.001	0.000	0.000
58	0.000	0.000	9.158	2.233	.165	.001	0.000	0.000
59	0.000	0.000	9.072	2.141	.156	.001	0.000	0.000

Fig. B-6-1 (5) Observed Runoff Hydrograph WA1, Sep. 15, 1984



	16	17	18	19	20	21	22	23
0	0.000	1.570	.021	0.000	0.000	0.000	0.000	0.000
1	0.000	1.489	.016	0.000	0.000	0.000	0.000	0.000
2	0.000	1.410	.012	0.000	0.000	0.000	0.000	0.000
3	0.000	1.333	.009	0.000	0.000	0.000	0.000	0.000
4	0.000	1.259	.006	0.000	0.000	0.000	0.000	0.000
5	0.000	1.186	.004	0.000	0.000	0.000	0.000	0.000
6	0.000	1.151	.002	0.000	0.000	0.000	0.000	0.000
7	0.000	1.116	.001	0.000	0.000	0.000	0.000	0.000
8	0.000	1.081	.001	0.000	0.000	0.000	0.000	0.000
9	0.000	1.047	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	1.014	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	.981	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	.949	0.000	0.000	0.000	0.000	0.000	0.000
13	0.000	.917	0.000	0.000	0.000	0.000	0.000	0.000
14	0.000	.886	0.000	0.000	0.000	0.000	0.000	0.000
15	0.000	.855	0.000	0.000	0.000	0.000	0.000	0.000
16	0.000	.828	0.000	0.000	0.000	0.000	0.000	0.000
17	0.000	.801	0.000	0.000	0.000	0.000	0.000	0.000
18	0.000	.775	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	.750	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	.724	0.000	0.000	0.000	0.000	0.000	0.000
21	0.000	.700	0.000	0.000	0.000	0.000	0.000	0.000
22	0.000	.675	0.000	0.000	0.000	0.000	0.000	0.000
23	0.000	.651	0.000	0.000	0.000	0.000	0.000	0.000
24	0.000	.628	0.000	0.000	0.000	0.000	0.000	0.000
25	0.000	.604	0.000	0.000	0.000	0.000	0.000	0.000
26	0.000	.582	0.000	0.000	0.000	0.000	0.000	0.000
27	0.000	.559	0.000	0.000	0.000	0.000	0.000	0.000
28	0.000	.537	0.000	0.000	0.000	0.000	0.000	0.000
29	0.000	.516	0.000	0.000	0.000	0.000	0.000	0.000
30	0.000	.495	0.000	0.000	0.000	0.000	0.000	0.000
31	0.000	.469	0.000	0.000	0.000	0.000	0.000	0.000
32	0.000	.444	0.000	0.000	0.000	0.000	0.000	0.000
33	0.000	.419	0.000	0.000	0.000	0.000	0.000	0.000
34	0.000	.395	0.000	0.000	0.000	0.000	0.000	0.000
35	0.000	.372	0.000	0.000	0.000	0.000	0.000	0.000
36	0.000	.349	0.000	0.000	0.000	0.000	0.000	0.000
37	0.000	.327	0.000	0.000	0.000	0.000	0.000	0.000
38	0.000	.306	0.000	0.000	0.000	0.000	0.000	0.000
39	0.000	.285	0.000	0.000	0.000	0.000	0.000	0.000
40	0.000	.265	0.000	0.000	0.000	0.000	0.000	0.000
41	0.000	.246	0.000	0.000	0.000	0.000	0.000	0.000
42	0.000	.227	0.000	0.000	0.000	0.000	0.000	0.000
43	0.000	.209	0.000	0.000	0.000	0.000	0.000	0.000
44	0.000	.192	0.000	0.000	0.000	0.000	0.000	0.000
45	0.000	.175	0.000	0.000	0.000	0.000	0.000	0.000
46	0.000	.159	0.000	0.000	0.000	0.000	0.000	0.000
47	0.000	.144	0.000	0.000	0.000	0.000	0.000	0.000
48	0.000	.129	0.000	0.000	0.000	0.000	0.000	0.000
49	0.000	.115	0.000	0.000	0.000	0.000	0.000	0.000
50	0.000	.102	0.000	0.000	0.000	0.000	0.000	0.000
51	0.000	.089	0.000	0.000	0.000	0.000	0.000	0.000
52	0.000	.077	0.000	0.000	0.000	0.000	0.000	0.000
53	0.000	.067	0.000	0.000	0.000	0.000	0.000	0.000
54	0.000	.058	0.000	0.000	0.000	0.000	0.000	0.000
55	0.000	.050	0.000	0.000	0.000	0.000	0.000	0.000
56	0.000	.043	0.000	0.000	0.000	0.000	0.000	0.000
57	0.000	.037	0.000	0.000	0.000	0.000	0.000	0.000
58	0.000	.031	0.000	0.000	0.000	0.000	0.000	0.000
59	0.000	.026	0.000	0.000	0.000	0.000	0.000	0.000

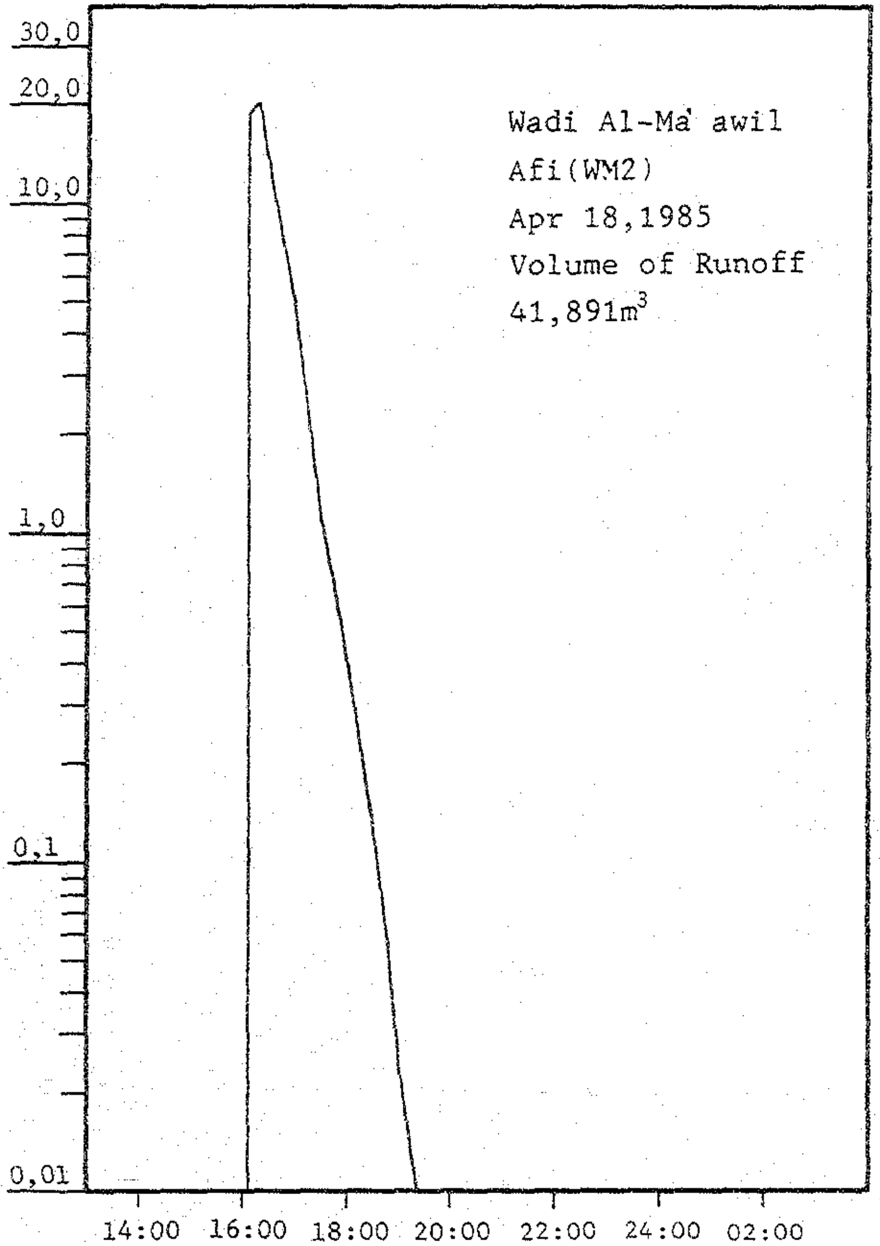
Fig. B-6-1 (6) Observed Runoff Hydrograph WA1, Sep. 16, 1984



** CALCULATED RUNOFF VOL.(EVERY ONE MINUTES) **

	16	17	18	19	20	21	22	23
0	0.000	0.000	0.000	0.000	1.711	.855	.164	0.000
1	0.000	0.000	0.000	0.000	1.703	.839	.157	0.000
2	0.000	0.000	0.000	0.000	1.696	.824	.149	0.000
3	0.000	0.000	0.000	0.000	1.689	.808	.142	0.000
4	0.000	0.000	0.000	0.000	1.682	.793	.136	0.000
5	0.000	0.000	0.000	0.000	1.675	.778	.129	0.000
6	0.000	0.000	0.000	0.000	1.668	.763	.122	0.000
7	0.000	0.000	0.000	0.000	1.661	.749	.116	0.000
8	0.000	0.000	0.000	0.000	1.654	.734	.110	0.000
9	0.000	0.000	0.000	0.000	1.647	.720	.104	0.000
10	0.000	0.000	0.000	0.000	1.640	.705	.098	0.000
11	0.000	0.000	0.000	0.000	1.633	.691	.092	0.000
12	0.000	0.000	0.000	0.000	1.626	.677	.086	0.000
13	0.000	0.000	0.000	0.000	1.619	.663	.081	0.000
14	0.000	0.000	0.000	0.000	1.612	.649	.075	0.000
15	0.000	0.000	0.000	0.000	1.605	.636	.070	0.000
16	0.000	0.000	0.000	0.000	1.598	.622	.066	0.000
17	0.000	0.000	0.000	0.000	1.591	.609	.062	0.000
18	0.000	0.000	0.000	0.000	1.584	.596	.058	0.000
19	0.000	0.000	0.000	0.000	1.577	.582	.055	0.000
20	0.000	0.000	0.000	0.000	1.570	.569	.051	0.000
21	0.000	0.000	0.000	0.000	1.550	.557	.048	0.000
22	0.000	0.000	0.000	0.000	1.530	.544	.044	0.000
23	0.000	0.000	0.000	0.000	1.509	.531	.041	0.000
24	0.000	0.000	0.000	0.000	1.489	.519	.038	0.000
25	0.000	0.000	0.000	.663	1.469	.507	.035	0.000
26	0.000	0.000	0.000	.663	1.450	.495	.033	0.000
27	0.000	0.000	0.000	.663	1.430	.483	.030	0.000
28	0.000	0.000	0.000	.663	1.410	.471	.028	0.000
29	0.000	0.000	0.000	.663	1.391	.459	.025	0.000
30	0.000	0.000	0.000	.663	1.372	.447	.023	0.000
31	0.000	0.000	0.000	.663	1.352	.436	.021	0.000
32	0.000	0.000	0.000	.663	1.333	.425	.019	0.000
33	0.000	0.000	0.000	.663	1.315	.413	.017	0.000
34	0.000	0.000	0.000	.663	1.296	.402	.015	0.000
35	0.000	0.000	0.000	.663	1.277	.391	.014	0.000
36	0.000	0.000	0.000	.663	1.259	.381	.012	0.000
37	0.000	0.000	0.000	.663	1.240	.370	.011	0.000
38	0.000	0.000	0.000	.663	1.222	.360	.010	0.000
39	0.000	0.000	0.000	.663	1.204	.349	.009	0.000
40	0.000	0.000	0.000	.663	1.186	.339	.007	0.000
41	0.000	0.000	0.000	.663	1.168	.329	.006	0.000
42	0.000	0.000	0.000	.663	1.151	.319	.006	0.000
43	0.000	0.000	0.000	.663	1.133	.309	.005	0.000
44	0.000	0.000	0.000	.663	1.116	.299	.004	0.000
45	0.000	0.000	0.000	.663	1.098	.290	.003	0.000
46	0.000	0.000	0.000	.663	1.081	.281	.003	0.000
47	0.000	0.000	0.000	.663	1.064	.271	.002	0.000
48	0.000	0.000	0.000	.663	1.047	.262	.002	0.000
49	0.000	0.000	0.000	.663	1.030	.253	.001	0.000
50	0.000	0.000	0.000	.663	1.014	.244	.001	0.000
51	0.000	0.000	0.000	.746	.997	.236	.001	0.000
52	0.000	0.000	0.000	.835	.981	.227	.001	0.000
53	0.000	0.000	0.000	.927	.965	.219	0.000	0.000
54	0.000	0.000	0.000	1.025	.949	.210	0.000	0.000
55	0.000	0.000	0.000	1.127	.933	.202	0.000	0.000
56	0.000	0.000	0.000	1.234	.917	.194	0.000	0.000
57	0.000	0.000	0.000	1.346	.901	.186	0.000	0.000
58	0.000	0.000	0.000	1.463	.886	.179	0.000	0.000
59	0.000	0.000	0.000	1.584	.870	.171	0.000	0.000

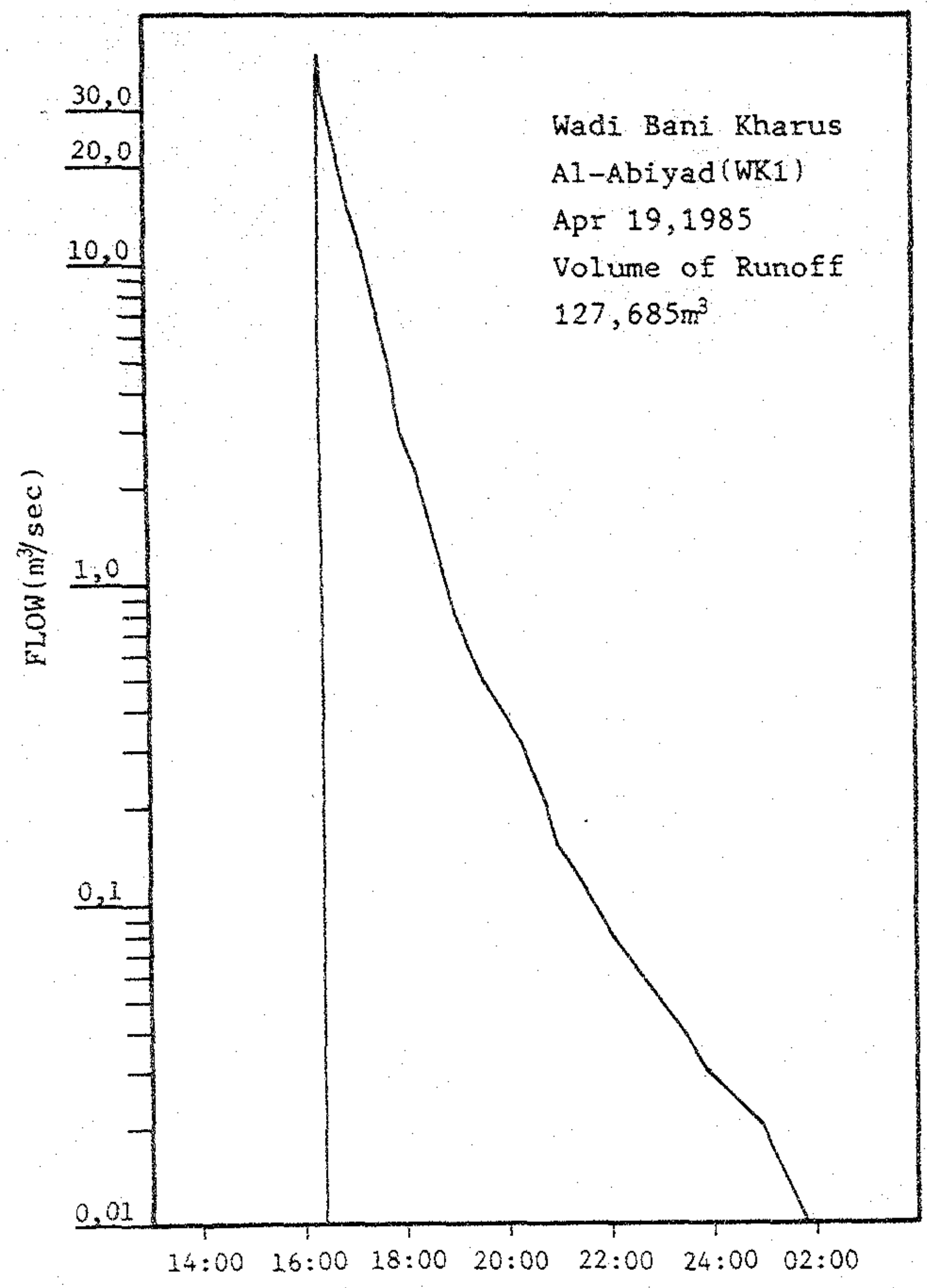
Fig. B-6-1(7) Observed Runoff Hydrograph WM2, Apr. 18, 1985



** CALCULATED RUNOFF VOL.(EVERY ONE MINUTES) ** 3 /3
SITE: AFI DATE: APR. 18 UNIT;M3/SEC.

	15	17	18	19	20.	21	22	23
0	0.000	4.575	0.428	0.027	0.001	0.000	0.000	0.000
1	0.000	4.391	0.415	0.026	0.001	0.000	0.000	0.000
2	0.000	4.213	0.402	0.025	0.001	0.000	0.000	0.000
3	0.000	4.040	0.389	0.024	0.001	0.000	0.000	0.000
4	0.000	3.873	0.377	0.024	0.001	0.000	0.000	0.000
5	0.000	3.712	0.364	0.023	0.001	0.000	0.000	0.000
6	0.000	3.556	0.352	0.022	0.001	0.000	0.000	0.000
7	0.000	3.405	0.341	0.021	0.001	0.000	0.000	0.000
8	0.000	3.260	0.329	0.020	0.000	0.000	0.000	0.000
9	0.000	3.119	0.318	0.019	0.000	0.000	0.000	0.000
10	17.654	2.984	0.307	0.019	0.000	0.000	0.000	0.000
11	17.798	2.853	0.295	0.018	0.000	0.000	0.000	0.000
12	17.943	2.727	0.286	0.017	0.000	0.000	0.000	0.000
13	18.088	2.606	0.276	0.016	0.000	0.000	0.000	0.000
14	18.234	2.489	0.266	0.016	0.000	0.000	0.000	0.000
15	18.380	2.377	0.256	0.015	0.000	0.000	0.000	0.000
16	18.527	2.269	0.246	0.014	0.000	0.000	0.000	0.000
17	18.675	2.165	0.237	0.014	0.000	0.000	0.000	0.000
18	18.823	2.066	0.228	0.013	0.000	0.000	0.000	0.000
19	18.972	1.970	0.219	0.013	0.000	0.000	0.000	0.000
20	19.122	1.878	0.211	0.012	0.000	0.000	0.000	0.000
21	18.380	1.790	0.202	0.011	0.000	0.000	0.000	0.000
22	17.654	1.706	0.194	0.011	0.000	0.000	0.000	0.000
23	16.943	1.625	0.186	0.010	0.000	0.000	0.000	0.000
24	16.247	1.547	0.178	0.010	0.000	0.000	0.000	0.000
25	15.567	1.473	0.171	0.009	0.000	0.000	0.000	0.000
26	14.902	1.402	0.164	0.009	0.000	0.000	0.000	0.000
27	14.252	1.333	0.156	0.008	0.000	0.000	0.000	0.000
28	13.618	1.267	0.150	0.008	0.000	0.000	0.000	0.000
29	12.998	1.203	0.143	0.007	0.000	0.000	0.000	0.000
30	12.394	1.142	0.136	0.007	0.000	0.000	0.000	0.000
31	12.039	1.110	0.131	0.007	0.000	0.000	0.000	0.000
32	11.689	1.078	0.125	0.006	0.000	0.000	0.000	0.000
33	11.345	1.047	0.120	0.006	0.000	0.000	0.000	0.000
34	11.006	1.016	0.115	0.006	0.000	0.000	0.000	0.000
35	10.673	0.986	0.110	0.006	0.000	0.000	0.000	0.000
36	10.345	0.957	0.105	0.005	0.000	0.000	0.000	0.000
37	10.022	0.929	0.100	0.005	0.000	0.000	0.000	0.000
38	9.705	0.901	0.096	0.005	0.000	0.000	0.000	0.000
39	9.394	0.874	0.091	0.005	0.000	0.000	0.000	0.000
40	9.119	0.847	0.087	0.004	0.000	0.000	0.000	0.000
41	8.838	0.821	0.083	0.004	0.000	0.000	0.000	0.000
42	8.563	0.796	0.079	0.004	0.000	0.000	0.000	0.000
43	8.294	0.771	0.075	0.004	0.000	0.000	0.000	0.000
44	8.030	0.747	0.071	0.003	0.000	0.000	0.000	0.000
45	7.771	0.723	0.068	0.003	0.000	0.000	0.000	0.000
46	7.518	0.700	0.064	0.003	0.000	0.000	0.000	0.000
47	7.270	0.678	0.061	0.003	0.000	0.000	0.000	0.000
48	7.028	0.656	0.058	0.003	0.000	0.000	0.000	0.000
49	6.791	0.634	0.055	0.003	0.000	0.000	0.000	0.000
50	6.559	0.613	0.052	0.002	0.000	0.000	0.000	0.000
51	6.333	0.593	0.049	0.002	0.000	0.000	0.000	0.000
52	6.111	0.573	0.046	0.002	0.000	0.000	0.000	0.000
53	5.895	0.553	0.043	0.002	0.000	0.000	0.000	0.000
54	5.684	0.534	0.041	0.002	0.000	0.000	0.000	0.000
55	5.478	0.515	0.038	0.002	0.000	0.000	0.000	0.000
56	5.276	0.497	0.036	0.002	0.000	0.000	0.000	0.000
57	5.101	0.479	0.033	0.001	0.000	0.000	0.000	0.000
58	4.921	0.462	0.031	0.001	0.000	0.000	0.000	0.000
59	4.745	0.445	0.029	0.001	0.000	0.000	0.000	0.000

Fig. B-6-1(8) Observed Runoff Hydrograph WK1, Apr. 19, 1985 (1/2)



** CALCULATED RUNOFF VOL.(EVERY ONE MINUTES) **
SITE; AL-ABIYAD DATE; APR. 19 1985 UNIT;M3/SEC.

	16	17	18	19	20	21	22	23
0	0.000	15.052	2.979	0.820	0.383	0.158	0.084	0.052
1	0.000	14.819	2.929	0.809	0.380	0.156	0.084	0.051
2	0.000	14.578	2.880	0.798	0.378	0.155	0.083	0.051
3	0.000	14.325	2.831	0.787	0.375	0.153	0.082	0.050
4	0.000	14.064	2.782	0.776	0.373	0.152	0.082	0.050
5	0.000	13.804	2.734	0.765	0.371	0.150	0.081	0.049
6	0.000	13.545	2.686	0.754	0.369	0.149	0.081	0.049
7	0.000	13.289	2.639	0.743	0.367	0.147	0.080	0.048
8	0.000	13.035	2.592	0.733	0.365	0.146	0.079	0.048
9	0.000	12.783	2.545	0.723	0.364	0.145	0.079	0.048
10	0.000	12.534	2.499	0.712	0.363	0.143	0.078	0.047
11	0.000	12.286	2.453	0.702	0.358	0.142	0.078	0.047
12	0.000	12.040	2.408	0.693	0.352	0.140	0.077	0.046
13	0.000	11.797	2.363	0.683	0.347	0.139	0.076	0.046
14	0.000	11.556	2.319	0.673	0.342	0.138	0.076	0.045
15	0.000	11.317	2.275	0.664	0.337	0.136	0.075	0.045
16	0.000	11.080	2.231	0.655	0.332	0.135	0.075	0.045
17	0.000	10.845	2.188	0.645	0.327	0.134	0.074	0.044
18	0.000	10.612	2.145	0.636	0.322	0.132	0.073	0.044
19	0.000	10.381	2.102	0.627	0.317	0.131	0.073	0.043
20	44.062	10.153	2.060	0.619	0.312	0.130	0.072	0.043
21	42.977	9.927	2.018	0.610	0.308	0.128	0.072	0.043
22	41.889	9.703	1.977	0.602	0.303	0.127	0.071	0.042
23	40.817	9.481	1.936	0.593	0.298	0.125	0.071	0.042
24	39.761	9.261	1.895	0.585	0.294	0.124	0.070	0.041
25	38.720	9.043	1.855	0.577	0.289	0.123	0.069	0.041
26	37.695	8.828	1.816	0.569	0.284	0.122	0.069	0.041
27	36.685	8.615	1.777	0.561	0.280	0.121	0.068	0.040
28	35.693	8.404	1.738	0.554	0.276	0.119	0.068	0.040
29	34.715	8.195	1.699	0.546	0.271	0.118	0.067	0.039
30	33.752	7.989	1.661	0.539	0.267	0.117	0.067	0.039
31	32.888	7.785	1.624	0.532	0.263	0.116	0.066	0.039
32	31.997	7.582	1.587	0.525	0.258	0.115	0.066	0.038
33	31.139	7.383	1.550	0.518	0.254	0.113	0.065	0.038
34	30.294	7.185	1.513	0.511	0.250	0.112	0.064	0.037
35	29.462	6.990	1.477	0.504	0.246	0.111	0.064	0.037
36	28.644	6.797	1.442	0.498	0.242	0.110	0.063	0.037
37	27.838	6.606	1.406	0.491	0.238	0.109	0.063	0.036
38	27.045	6.417	1.371	0.485	0.234	0.108	0.062	0.036
39	26.265	6.231	1.337	0.479	0.230	0.106	0.062	0.036
40	25.498	6.047	1.303	0.473	0.226	0.105	0.061	0.035
41	24.743	5.865	1.269	0.467	0.222	0.104	0.061	0.035
42	24.001	5.686	5.333	0.461	0.218	0.103	0.060	0.035
43	23.272	5.509	1.210	0.456	0.215	0.102	0.060	0.034
44	22.555	5.335	1.183	0.450	0.211	0.101	0.059	0.034
45	21.850	5.162	1.157	0.445	0.207	0.100	0.059	0.033
46	21.155	4.992	1.132	0.440	0.204	0.099	0.058	0.033
47	20.855	4.825	1.107	0.435	0.200	0.098	0.058	0.033
48	20.382	4.650	1.082	0.430	0.197	0.097	0.057	0.032
49	19.905	4.497	1.058	0.425	0.193	0.095	0.057	0.032
50	19.434	4.337	1.034	0.421	0.190	0.094	0.055	0.032
51	18.970	4.179	1.011	0.416	0.186	0.093	0.056	0.031
52	18.511	4.023	0.988	0.412	0.183	0.092	0.055	0.031
53	18.059	3.878	0.965	0.408	0.180	0.091	0.055	0.031
54	17.613	3.742	0.943	0.404	0.176	0.090	0.054	0.030
55	17.173	3.509	0.922	0.400	0.173	0.089	0.054	0.030
56	16.739	3.476	0.901	0.398	0.170	0.088	0.053	0.030
57	16.311	3.350	0.880	0.393	0.167	0.087	0.053	0.029
58	15.889	3.224	0.860	0.389	0.164	0.086	0.053	0.029
59	15.473	3.100	0.840	0.386	0.161	0.085	0.052	0.029

Fig. B-6-1 (8) Observed Runoff Hydrograph, WK1, Apr. 19, 1985 (2/2)

** CALCULATED RUNOFF VOL.(EVERY ONE MINUTES) **
SITE: AL-ASIYAD DATE: APR. 20 1985 UNIT:M3/SEC.

	0	1	2	3	4	5	6	7
0	0.026	0.020	0.008	0.008	0.004	0.002	0.001	0.000
1	0.026	0.020	0.008	0.008	0.004	0.002	0.001	0.000
2	0.026	0.019	0.008	0.008	0.004	0.002	0.001	0.000
3	0.026	0.019	0.008	0.008	0.004	0.002	0.001	0.000
4	0.026	0.019	0.008	0.008	0.004	0.002	0.001	0.000
5	0.026	0.019	0.008	0.008	0.004	0.002	0.001	0.000
6	0.026	0.018	0.008	0.008	0.004	0.002	0.001	0.000
7	0.027	0.018	0.008	0.008	0.004	0.002	0.001	0.000
8	0.027	0.018	0.008	0.008	0.004	0.002	0.001	0.000
9	0.027	0.018	0.008	0.007	0.004	0.002	0.001	0.000
10	0.027	0.018	0.008	0.007	0.004	0.002	0.001	0.000
11	0.027	0.017	0.008	0.007	0.004	0.002	0.001	0.000
12	0.027	0.017	0.008	0.007	0.004	0.002	0.001	0.000
13	0.026	0.017	0.008	0.007	0.004	0.002	0.001	0.000
14	0.026	0.017	0.008	0.007	0.004	0.002	0.001	0.000
15	0.026	0.016	0.008	0.007	0.004	0.002	0.001	0.000
16	0.026	0.016	0.008	0.007	0.004	0.002	0.001	0.000
17	0.026	0.016	0.008	0.007	0.004	0.002	0.001	0.000
18	0.026	0.016	0.008	0.007	0.004	0.002	0.001	0.000
19	0.026	0.015	0.008	0.007	0.004	0.002	0.001	0.000
20	0.025	0.015	0.008	0.007	0.004	0.002	0.001	0.000
21	0.025	0.015	0.008	0.007	0.004	0.002	0.001	0.000
22	0.025	0.015	0.008	0.007	0.003	0.002	0.001	0.000
23	0.025	0.015	0.008	0.007	0.003	0.002	0.001	0.000
24	0.025	0.014	0.008	0.007	0.003	0.002	0.001	0.000
25	0.025	0.014	0.008	0.006	0.003	0.002	0.001	0.000
26	0.025	0.014	0.008	0.006	0.003	0.002	0.001	0.000
27	0.024	0.014	0.008	0.006	0.003	0.002	0.001	0.000
28	0.024	0.014	0.008	0.006	0.003	0.002	0.001	0.000
29	0.024	0.013	0.008	0.006	0.003	0.002	0.001	0.000
30	0.024	0.013	0.008	0.006	0.003	0.002	0.001	0.000
31	0.024	0.013	0.008	0.006	0.003	0.002	0.001	0.000
32	0.024	0.013	0.008	0.006	0.003	0.001	0.001	0.000
33	0.024	0.013	0.008	0.006	0.003	0.001	0.001	0.000
34	0.023	0.012	0.008	0.006	0.003	0.001	0.001	0.000
35	0.023	0.012	0.008	0.006	0.003	0.001	0.001	0.000
36	0.023	0.012	0.008	0.006	0.003	0.001	0.001	0.000
37	0.023	0.012	0.008	0.006	0.003	0.001	0.001	0.000
38	0.023	0.012	0.008	0.006	0.003	0.001	0.001	0.000
39	0.023	0.012	0.008	0.006	0.003	0.001	0.001	0.000
40	0.023	0.011	0.008	0.006	0.003	0.001	0.001	0.000
41	0.022	0.011	0.008	0.005	0.003	0.001	0.001	0.000
42	0.022	0.011	0.008	0.005	0.003	0.001	0.001	0.000
43	0.022	0.011	0.008	0.005	0.003	0.001	0.001	0.000
44	0.022	0.011	0.008	0.005	0.003	0.001	0.001	0.000
45	0.022	0.010	0.008	0.005	0.003	0.001	0.001	0.000
46	0.022	0.010	0.008	0.005	0.003	0.001	0.001	0.000
47	0.022	0.010	0.008	0.005	0.003	0.001	0.001	0.000
48	0.021	0.010	0.008	0.005	0.002	0.001	0.001	0.000
49	0.021	0.010	0.008	0.005	0.002	0.001	0.001	0.000
50	0.021	0.010	0.008	0.005	0.002	0.001	0.001	0.000
51	0.021	0.009	0.008	0.005	0.002	0.001	0.001	0.000
52	0.021	0.009	0.008	0.005	0.002	0.001	0.000	0.000
53	0.021	0.009	0.008	0.005	0.002	0.001	0.000	0.000
54	0.021	0.009	0.008	0.005	0.002	0.001	0.000	0.000
55	0.021	0.009	0.008	0.005	0.002	0.001	0.000	0.000
56	0.020	0.009	0.008	0.005	0.002	0.001	0.000	0.000
57	0.020	0.009	0.008	0.005	0.002	0.001	0.000	0.000
58	0.020	0.008	0.008	0.005	0.002	0.001	0.000	0.000
59	0.020	0.008	0.008	0.005	0.002	0.001	0.000	0.000

6.2 Surface Runoff Features

It was observed that the rainfalls which caused the runoff observed at the wadi gauges, were not recorded at the rain-gauges in located in the basins of the wadi gauges, because of their small coverage. The density of the rain gauges might be reviewed after several years observation for water resources development purposes. Although only a small amount of data was obtained during the Project, the general relationship between rainfall and runoff are described based on this observation data and previous studies. (ILACO and GIBB, 1977).

1. Short duration of runoff

   The minimum duration of runoff was about 1 hour and the maximum was about 24 hours in both of mountain and coastal area. Hence, runoff is usually of very short duration.

2. Rapid runoff in the mountain area

   The Project area belongs to the semi-arid zone and the major mountain area, which are covered with steep bare rocks and sparce vegetation so that the flood reaches the wadi bed rapidly. Wadi gradients in the mountain area are as steep as 1/75 -1/145. These basin conditions are the cause of rapid runoffs in the mountain areas.

3. Great infiltration capacity of the wadi-bed

   Fewer observed runoff events comparing the number of rainfall imply that the wadi-beds have a large infiltration capacity. There are many cases of the rainfall which were recorded at the rain-gauges in the mountain area, however no discharges were recorded at the wadi gauges downstream.

4. Floods of the coastal area occur mainly in winter

   The number of the floods in winter is greater than the ones in summer in the coastal area. This tendency suggests that there is a relationship between the rainfall intensity and the infiltration capacity of the gravel plain.

   As the area which has infiltration capacity exist only along wadi beds in the gravel plain (about 18%), the other area (about 82%) is classified as non-permiable.

6.3 Flood Discharge to the Sea

Flood discharge to the sea was not observed during the observation period (Sep. '83 to Aug. '84). Flood discharges to the sea which had been observed in previos studies are summarized in Table B-6-2. Those 7 floods occurred in the winters from 1974 to 1976. The year of 1976 had heavy rainfall according to the rainfall data of Muscat (See Table B-6-3). From the previous studies and our observation, flood discharge to the sea is rare for the following reasons:

1. The coastal area which is composed mainly of sand and silt seems to have a large storage infiltration capacity. Consequently, most of the rainfalls was captured along the wadi bed.

2. The Gravel plain area spreads out from about 10 km upstream of the seaside for about 35 km to the interior. The surface of the Maginal wadi plain area is cemented hard which will easily convey surface runoff to the wadi bed rapidly. However, the wadi beds have a large infiltration capacity, which will accelerate the depletion of the discharge into the ground. Thus, the average annual rainfall would be about 100 mm/year and each rainfall would be small scale.

3. Mountain area and runoff

   Mountain area, is mainly covered with bare rocks and sparce vegetation. Surface runoffs occur easily, but the wadi-beds are covered with gravels where the surface flow can easily infiltrate. Accordingly, surface runoff to the sea occurs only under the following conditions;

   a) Heavy rainfall over the whole water-shed.

   b) Rainfall with strog rainfall intensity in the coastal area.

      Regarding the water resources in the Batinah area, Horn (1979) and Credew (1980) reported that the average runoff to the sea is about 20-23 MCM/year (Table B-6-4). The estimations by Horn and Credew are very similar except for the discharge from Wadi Bani Kharus.

Table B-6-2 Enumeration of Observed Floods

Wadi Basin	Wadi Gauge	Topological Location	Observation Date	Season	Observation time	Duration	Peak Discharge m³/s	Runoff Volume m³	Observer
W. Ahin	WA1	Mountain	Sept.15,'84	Summer	17:00 - 18:08	1.1 hrs	1.6	2,036	JICA
	WA1	Mountain	Sept.16,'84	Summer	19:25 - 22:52	2.5 hrs	1.7	8,376	JICA
W.B.Ghafir	N7	Mountain	Feb.12,'75	Winter	18:00 - 18:00	24 hrs	90.9	738,360	Gibb
	N7	Mountain	May 13,'75	Winter	15:20 - 17:30	2.2 hrs	16.9	26,520	Gibb
	WG1	Mountain	Sept.15,'83	Summer	13:46 - 20:57	7.2 hrs	0.9	1,263	JICA
W. Al-Fara	N9	Mountain	Jul.7,'74	Summer	16:00 - 18:06	2.0 hrs	1.5	9,630	Gibb
	N9	Mountain	Feb.2,'76	Winter	18:25 - 03:00	8.6 hrs	3.3	24,237	Gibb
	N9	Mountain	Feb.6,'76	Winter	06:00 - 02:50	20.8 hrs	2.9	31,470	Gibb
	N9	Mountain	Jul.29,'76	Summer	13:00 - 23:00	10.0 hrs	59.0	177,810	Gibb
	WF1	Mountain	Sept.15,'83	Summer	15:50 - 00:02	8.2 hrs	5.8	26,040	JICA
	WF1	Mountain	Jul.30,'84	Summer	18:00 - 22:01	4.0 hrs	13.0	65,017	JICA
	WF4	Mountain	Apr.12,'84	Winter	14:55 - 16:15	1.3 hrs	0.7	815	JICA
W.B.Kharus	N3	Mountain	Mar.25,'76	Winter	17:30 - 20:30	3.0 hrs	7.3	41,925	Gibb
	N4	Coastal	May 14,'75	Winter	17:45 - 02:00	8.3 hrs	3.4	74,506	Gibb
	N4	Coastal	Feb.3,'76	Winter	00:00 - 05:00	5.0 hrs	4.6	29,715	Gibb
	N4	Coastal	Mar.26,'76	Winter	02:00 - 03:30	1.5 hrs	1.2	6,720	Gibb
	N4	Coastal	Mar.30,'76	Winter	23:00 - 07:00	8.0 hrs	1.9	23,640	Gibb
	N4	Coastal	Apr.9,'76	Winter	02:30 - 06:00	3.5 hrs	6.9	51,900	Gibb
	N5	Mountain	Oct.,2'74	Winter	15:00 - 22:45	7.8 hrs	5.9	37,800	Gibb
	N5	Mountain	Oct.4,'74	Winter	15:00 - 18:12	3.2 hrs	77.7	244,080	Gibb
	N5	Mountain	Oct.6,'74	Winter	16:00 - 17:36	1.5 hrs	2.0	5,040	Gibb
	N5	Mountain	Dec.27,'74	Winter	20:00 - 23:20	3.3 hrs	8.2	38,160	Gibb
	N5	Mountain	May 12,'75	Winter	15:20 - 16:40	1.3 hrs	40.3	68,040	Gibb
	N5	Mountain	Aug.16,'75	Summer	18:00 - 13:50	19.8 hrs	71.2	295,459	Gibb
	N5	Mountain	Aug.17,'75	Summer	14:40 - 04:40	14 hrs	69.5	635,463	Gibb
	N5	Mountain	Mar.30,'76	Winter	17:00 - 00:40	7.7 hrs	5.1	47,175	Gibb
	N5	Mountain	Apr.8'76	Winter	19:00 - 05:50	10.8 hrs	85.6	672,270	Gibb
	N5	Mountain	Sept.15,'76	Summer	16:15 - 09:30	17.3 hrs	107.3	781,065	Gibb
	N6	Mountain	May 22,'74	Winter	21:50 - 05:20	7.5 hrs	1.5	20,565	Gibb
	N6	Mountain	Oct.1,'74	Winter	19:00 - 10:55	16.0 hrs	7.9	43,305	Gibb
	N6	Mountain	Oct.2,'74	Winter	17:45 - 24:00	6.3 hrs	9.6	60,930	Gibb
	WK1	Mountain	Apr.19,'85	Winter	16:20 - 06:51	13.5 hrs	44.1	127,658	JICA
W. Al-Maawil	WM2	Mountain	Apr.18,'85	Winter	16:10 - 20:07	4.0 hrs	19.1	41,891	JICA

Table B-6-3 Observed Flood Discharge to the Sea during Previous Survey Period

Wadi Basin	Name of Place (Name of gauge)	Runoff date	Runoff duration	Peak flow m^3/sec.	Amount of Runoff m^3
Wadi *1) Ahin	Khishdah	Feb.15,'74	No data	1.2	12,000
		Feb.15,'74	No data	1.4	20,000
Wadi *2) Bani Kharus	Al-Sawadi (N4)	May 14,'75	17:45 - 02:00	3.4	74,506
		Feb.02,'76	00:00 - 05:00	4.6	29,715
		Mar.25,'76	02:00 - 03:30	1.2	6,720
		Mar.30,'76	23:00 - 07:00	1.9	23,640
		Apr.09,'76	02:30 - 06:00	6.9	51,900

*1) ILACO Jul. 1975
"WATER RESOURCES DEVELOMENT PROJECT NORTHERN OMAN"

*2) SIR ALEXANDER GIBB AND PARTNERS JUN. 1976
"WATER RESOURCES SURVEY OF NORTHERN OMAN"

Table B-6-4 Annual Rainfall at Muscat during Previous and JICA Survey Period

Year of Survey Period	Annual Rainfall (mm/year)
1974	3.7
1975	80.0
1976	203.3
1983	123.0
1984	18.5
Mean *	105.0

*) Mean of rainfall data from 1951 to 1984

Table B-6-5 Estimated Flood Discharge to the Sea for the Median Year

(unit = mcm/year)

Reorters	Wadi Ahin	Wadi B. Ghafir	Wadi Al-Fara'	Wadi B. Kharus	Wadi Al-Ma'awil	Total
ILACO *1	2.58	-	-	-	-	2.58
GIBB *2	-	21.2	13.9	27.7	7.0	69.8
HORN *3	5.5	4.5	4.1	5.4	0.4	19.9
CARDEW *4	4.8	3.8	3.6	10.9	0.3	23.4

*1 ILACO JUL. 1975
"WATER RESOURCES DEVELOPMENT PROJECT NORTHERN OMAN"

*2 SIR ALEXANDER GIBB AND PARTINERS JUNE 1976
"WATER RESOURCES SURVEY OF NORTHERN OMAN"

*3 P.M. HORN-F.A.O. FEB. 1979
"WATER RESOURCES OF THE BATINAH"

*4 PRECCE CARDEW AND RIDER/SIR M MACDONALD AND PARTNERS SEP. 1980
"POWER AND URBAN WATER SUPPLY STUDY: PHASE II, WATER DEVELOPMENT PROGRAME"

Fig. B-6-2 Observed Runoff to the Sea during Previous Survey Period