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Ministry of Agriculture, Fisheries, Petroleum & Minerals.

Directorate of Agriculture.

Water Resources Department.

RAINFALL IN DHOFAR (SALALAH AREA)  
TO 1977 INCLUSIVE.

F.A.O. Project OMA/77/001.  
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Food & Agriculture Organization  
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RAINFALL IN DHOFAR (SALALAH) TO 1977.

F.M. Horn F.A.C.

This paper was produced as a part of the work of the Water Resources Department, of the Ministry of Agriculture, Fisheries, Petroleum and Minerals.

Data collection by the Water Resources Department in Salalah Area, was initiated early in 1977, under the supervision of Mr. E.D. Larsen (FAO). Besides the operation of new and current stations, W.R.D. staff have endeavoured to assemble all previous rainfall data.

This work has mainly been carried out by Mr. Majid Bil Arab of the W.R.D.

Grateful thanks are due to the following persons for assistance in locating old and current record.

- |                    |                          |
|--------------------|--------------------------|
| Mr. Aslam Mohamed, | Water Supply Department. |
| Mr. J. Mc Inerery, | R.A.F. Salalah           |
| Mr. P. Huncar      | PANAM, D.G.C.A.          |
| Mr. Littlejohn     | T.W.T. & Partners        |
| Mr. M. Kenney      | Previously W.S.D.        |

This document has been produced under some urgency, because of immediate development needs in Salalah. Many of the descriptions and interpretations are inevitably tentative, pending the acquisition of better record.

This Field Document has yet to receive the endorsement of the Food and Agriculture Organization of the United Nations, and does not necessarily present the opinions or recommendations of that organization.

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1. AVAILABLE RECORD

1.1. General:

Rainfall record for Salalah Airport has been maintained by the R.A.F. since late 1942. In March 1977 the station was taken over by Government, and is currently operated by PANAM on behalf of the D.G.C.A.

Apart from this, some fragmentary record for Midway (Thamrait), and the Masirah Island record, there is no other data available prior to 1973.

During 1973, several stations were established by Sir William Halcrow and Partners, as a part of their Land and Water Development surveys. However, operations were extremely difficult at that time because of the war conditions then prevailing. In their report of August 1975, fifteen sites are listed, but with the comment that, due to the above mentioned difficulties, reliable records were obtained from five stations only. Subsequently, fragmentary data for two other sites, not included in this list, have also been found.

On the completion of the survey, operation of the stations, and copies of records, were transferred to the Water Supply Department, Southern Region.

Early in 1977, Water Resources Department were able to establish an office in Salalah and a few additional stations have been installed. Equally, the W.R.D. have co-ordinated and assisted the W.S.D. in the operation and control of the surviving "Halcrow" stations especially Medinat Al Haq and Robot.

At the same time, the Water Resources Department have tried to collect and research all previous record. There have been two main sources for these:-

- (a) Data published in the second "Halcrow" report (June 1977). Only monthly or seasonal record, for selected stations, is quoted in these reports.
- (b) Photocopies (and subsequently, originals) of daily rainfall records, with the Water Supply Department. By comparison with source (a), these earlier photocopies are not complete. Recent data for Salalah Airport is direct from station records, with the kind assistance of the Meteorologist i/c (Mr. J. Mc Inerey, and now Mr. Bob Hunter). Record for a temporary private raingauge at Zeak, has kindly been made available by Taylor-Woodrow-Towell.

1.2. Available Record, individual stations: with notes on quality

- (a) No record has been found for any of the following stations, listed in the "First Halcrow" Report.

Ashinhaib BE 092085  
Yasmin 2 AB 915030  
Yasmin 6 AD 950975  
Makinat-Shihan (No co-ords)  
Marbat BD 341800  
Mugsayl AO 961691  
Reef No coords

Also, there is no rainfall record for Thumrayt, during the present decade: some wind and temperature records are taken by the Forces during times of aircraft operation.

- (b) Stations not listed in "First Halcrow".

Diana 3. Monthly total for August 1973, in "Second Halcrow". Co-ords unknown.  
Taqah Co ords 2224-18855  
Daily rainfall, late June 73 thru Jan 1974.

- (c) Other Defunct stations

Jibjat BE 344095. Partial annual totals, 1973-1975 in "Second Halcrow". Daily record November 1974 through February 1976, with gaps. Totals are so low as to be incredible: data is not reliable and has not been published.

Tawi Atair BD 405937  
Seasonal total, July-August 1975, "Second Halcrow".

- (d) Current stations: see also Table DFR/1

Raysut (Five inch daily, read by W.S.D.)  
Daily record from 1/8/73, with gaps in some dry seasons: these are shown as "Nil rainfall" in "Second Halcrow". Low rainfall of 1975 looks doubtful.

Salalah Airport

(Five inch, read twice daily by Met Dept) complete daily record:

- Robat (Dynes recorder: five inch rim. Now read by W.R.D. Daily gauge to be added, 1978). Daily record from February 1974, with some gaps, especially monsoon 1976. "Second Halcrow" gives monthly record from June 1973, and lower values for 1974. Record for 1974 and 1975 is consistently rather high: it is known that there were problems in the supply of charts, and there may have been some systematic error here. Minor rainfalls in the dry seasons were possibly omitted - as also for Raysut and Arzat - but the error is minor.
- Arzat (Five inch daily, read for W.S.D.) Daily record from 24/6/73, with some minor gaps as shown in tables.
- Raqbat (SIAP monthly recorder, installed 1/4/77: run from W.R.D. office with cross checks of catch in bucket).
- Eidas (Five inch gauge, used as totalizer) Temporary installation for most of monsoon season, 1976: regular observations since Feb 1977. (Gauge damaged in June) Read about twice monthly during dry periods, and frequently whenever rainfall occurs.
- Qairoon Heriti (150cm<sup>2</sup> fibreglass, used as totalizer) Installed 11/6/77; read at same frequency as Eidas. Record for an earlier installation at this site (total for July - October 1974) quoted in "Second Halcrow".
- Zeak Gauge operated privately by Taylor Woodrow Towell at construction site: available record from 27/7/76 through 18/10/76, and April 1977 through 13/9/77. Now closed. W.R.D. plan to instal new gauge, spring 1978. Record seems high compared to nearby stations and possibility of systematic error may be suspected.
- Medinat al Haq (White City). (5 inch daily, resident observer) Daily record from Sept. 1974; with gaps Monthly record from June 1973 inclusive, from "Second Halcrow".

1.3. Summary of available record

Particulars of current stations, are shown in table DFR/1. Tables DFR/2 a/c, list all available monthly record, derived from the two sources described above. Where there are differences between the two versions, that based on the more detailed record has been accepted: except Robot for 1974 where "Halcrow" is preferred.

It is probable that certain of the "Nil" rainfall records are not literally correct: e.g. for the period Jan/May 1975 when there were some very minor showers, as shown in the Salalah airport record. However, this is of no practical significance.

As also mentioned in Halcrows reports, many of the gaps in record are for low rainfall periods, which may be estimated without introducing any noticeable error. This has been done for subsequent interpretation. However, tables DFR/2 have been restricted to the actual data available, as a factual basis for future work. Record for Jibjat, and Zeak, has been exclude

Copies of daily rainfall figures are on file, and available for study, in the Water Resources offices at Salalah, and Ruwi.

Rainfall record for Salalah is shown in tables DFR/3.

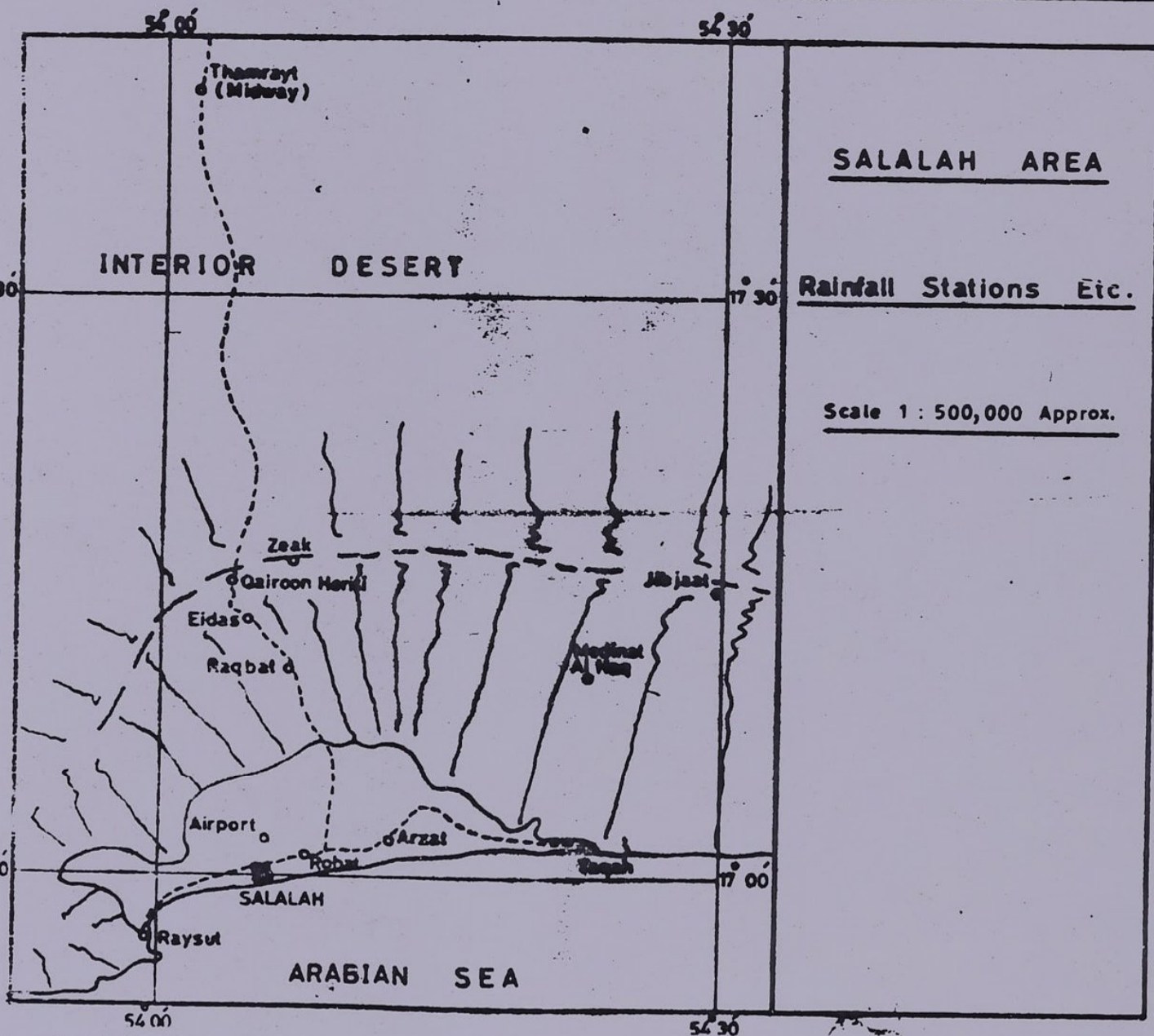
Table DFR/1

Particulars of active rainfall stations in Salalah area (end 1977)

Name	Lat.	Longe	Approx Alt. (meters)	Record Started	Agency	Notes
Raysut	16° 57'	53° 55'	10	8/73 ?	W.S.D.	
Salalah Airport	17° 02'	54° 06'	20	9/42	D.G.C.A.	Met.Dept: previously RAF.
Robat	17° 01'	54° 07'	15	6/73	W.R.D.	Dynesrecorder, daily to be added 1978.
Arzat	17° 03'	54° 13'	15	6/73	W.S.D.	
Medinat Al Haq	17° 09'	54° 23'	700	6/73	W.R.D.	
Zeak	17° 16'	54° 09'	830	7/76	x	Now lapsed, to be replaced 1978
Qairoon Heriti	17 <sup>8</sup> 15'	54° 06'	(890)	6/77	W.R.D.	Some previous record. 1974
Eidas	17° 14'	54° 05'	680	7/76	W.R.D.	
Raqbat	17° 10'	54° 07'	480	3/77	W.R.D.	
Thamrayt	17° 38'	54° 01'	(450)	x	D.G.C.A.	Non operational through 1977. D.G.C.A. hope to instal station in 1978.

Note: There are gaps in many records.





SALALAH AREA

Rainfall Stations Etc.

Scale 1 : 500,000 Approx.

TABLE DFR/2a

	J	F	M	A	M	J	J	A	S	O	N	D		
	1973													
Bayut	Installed 1/8/73 ?							23.7	T	-	(-)	-		a
Salalah Airport	T	T	T	T	T	4.5	29.9	30.2	4.5	T	-	-		69.2
Sohat						0.5	14.4	17.4	0.6	-	-	-		(33.9)
Azzat						5	12.6	13.2	4.0	-	-	-		(31.9)
Tarsh						5	21.1	19.1	1.7	-	-	-		(32.9)
Madinat al Haq						8.2	106.1	52.4	6.6	x	-	x		(173.7)
Alwadi								185.1	x	x	x	x		n
	1974													
Bayut	x	-	-	-	-	1.9	7.3	6.9	-	-	-	-		10.6
Salalah Airport	T	T	-	-	T	4.6	8.2	8.2	T	-	-	T		21.2
Sohat	-	-	-	-	-	-	7.0	8.9	-	-	-	-		15.9 (1)
Azzat	-	-	-	-	-	1.9	6.3	6.1	0.2	-	-	-		14.4
Madinat al Haq	-	-	-	-	0.9	15.2	45.2	57.6	3.0	x	x	T		(122.7)
Alwadi								66.9			x	x		a

(1) Haloway Report; daily values higher

DHOFAR/SALALAH

TABLE DFR/2b

MONTHLY RAINFALL

1975 & 1976

	J	F	M	A	M	J	J	A	S	O	N	D	
	1975												
Raysut	-	-	-	-	-	T	3.5	(1.2.)	(-)	(-)	-	-	Doubt
Salalah Airport	1.4	0.2	T	-	0.1	1.1	14.2	7.6	11.0	T	-	6.0	41.6
Robat	-	-	-	-	-	T	20.0	21.0	22.0	-	-	-	63.0
Arat	-	-	(-)	(-)	(-)	T	11.0	12.1	7.7	-	-	-	31.6
Madinat al Hac	-	-	-	-	-	35.0	91.2	42.2	53.3	-	-	-	222.8
Total Atair							157.4	x	x	x	x		a
	1976												
Raysut	-	T	-	29.0	-	-	38.2	12.4	x	x	x	x	(81.2) (1)
Salalah Airport	-	1.8	-	26.0	-	0.2	51.7	10.8	1.7	-	-	-	74.2
Robat	-	5.0	-	37.1	-	-	x	x	x	x	x	x	s
Arat	-	-	(-)	75.0	2.0	T	22.3	10.2	x	x	x	x	(115.7) (1)
Eldas							65.4	(81.8)	16x1	x	x	x	a
Madinat al Hac	-	-	1.5	52.2	-	-	171.5	60.1	x	x	x	x	(286.3)

(1) Includes estimated rain for September.



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دائرة موارد المياه

SALALAH AIRPORT

DFR/3a

Monthly Rainfall

1942 - 1959

	J	F	M	A	M	J	J	A	S	O	N	D		
1942	x	x	x	x	x	x	x	x	x	-	-	T	8	
1943	T	T	-	-	-	3	27	15.5	10	-	T	25.5	82	
1944	-	T	T	T	1.5	4	30	16.5	-	-	T	61	112.5	
1945	T	T	-	T	-	0.5	31	30	6	45	45	-	83	
1946	-	-	-	-	-	T	18	34	T	-	-	-	52	
1947	1	-	-	-	0.5	4	27	48.5	4	-	7	-	92	
1948	4	T	-	T	T	T	16	27	2	157	-	-	206	
1949	2	-	-	-	0.5	2	26	30	2	-	-	-	63	
1950	2.5	1.5	-	-	-	1	49	7	1	-	-	T	61	
1951	-	-	22	-	-	1	23	10	6	-	-	4	66	
1952	2	-	-	-	-	4	29	40	-	1	-	-	76	
1953	5	-	-	-	-	34	13	37	2	-	-	5	96	
1954	1	17	-	5	-	-	48	23	3	-	-	5	102	
1955	1	-	2	14	-	29	43	55	15	-	-	3	162	
1956	-	-	-	-	-	1	31	21	1	9	-	-	63	
1957	1	-	-	17	-	2	31	35	1	-	-	-	87	
1958	1	-	-	-	-	4	34	13	8	-	-	5	65	
1959	-	-	-	-	121	-	33	41	6	-	-	-	201	



## 2. GENERAL DESCRIPTION OF RAINFALL

### 2.1. Main Rainfall types

Previous reports have identified two main types of rainfall. These are

- 1) The Monsoon; locally famous as the Kharif: this is the most reliable season, normally starting between late June and mid July, and ending early in September.

The onset of the moist southwest monsoon, combined with a cold offshore current at this season, produce the typical Kharif weather: extensive cloud and thick mists. Rainfall is frequent, but of very low quantity and intensity.

In Salalah, for the two months of July and August, there were an average of 33 raindays (and an additional 16 days with trace rainfalls) but the highest daily total was less than 5mm (Period 1973 - 1977 inclusive). On the Jebel, the pattern is similar: but the daily rainfalls are each somewhat higher, and there can also be some days with moderate to heavy rain. For 1975-77 inclusive, there were a total of six days with rainfall exceeding 15mm (max 26.6) for this season.

- ii) Cyclones and cyclonic storms. These generate over the Indian Ocean and Arabian Sea, and sometimes track in toward Salalah. Probable frequencies have been assessed as about 1 in 3, not all producing rainfall: for heavy storms the frequency is about 1 in 5. When such storms do occur, they are of extremely heavy intensity. In the recent past, there has been infrequent occurrence: prior to the recent cyclone of June 1977 the last previous cyclone had been those of May 1963, and November 1966.

The cyclone season is normally accepted as being May/June and Oct/November.

- iii) Recent experience and data has allowed the identification of a third type of rainfall; which, in terms of groundwater resources, may be of equal importance. This appears to derive from temporary synoptic situations, of frontal or cyclonic type, favourable to rainfall generation. The rainfall period may last for a few days, to a week; and will include one or two heavy daily falls. Recent examples include the rains of April, May, and October 1977; and April 1976: there were probably no other examples through 1973 inclusive..

## 2.2. Spatial distribution of rainfall:

This depends very much upon the three different types of rainfall, described immediately above.

For the monsoon period, orography and possibly aspect, will be of major importance, with the southwest facing massifs likely to enjoy a more favourable situation: That is, that the eastern rim to the Salalah plain may be wetter than the west. (This would be consistent with the apparent lower rainfall of Raysut). It appears also that for many locations, rainfall may be higher on the middle slopes than on the crest itself. This is certainly apparent in the 1977 record, and was also observed by Mr. L. Fallon when he was frequently travelling the main road, during the monsoon of 1976.

Certainly, rainfall drops off extremely rapidly inland of the watershed: the countryside reverting to aridity within a few kilometers of the crest.

Examination of the distribution and density of natural vegetation, as shown on air photos and the maps derived therefrom could be extremely helpful in determining the spatial distribution. For example, this implies that the headwaters of both the wadis Adawnib and Ashawq, immediately to the west of Salalah plain, lie in a comparative rainshadow behind the higher crest of Jebel Kahmah to the south, whose seaward slopes are densely vegetated. Local tradition also considers wadi Ashawq as being rather out of the Kharif influence.

For cyclonic storms, orography is probably of lesser influence: the determining factor being the track of the storm itself. This is dramatically illustrated by the most recent cyclone, of June 1977, which centred disastrously over Masirah Island; and apparently, inland into the desert between Dhofar and North Oman.

Salalah itself lay just on the fringes of the rainfall activity associated with the cyclone: to the extent that Raysut at the extreme west of the Salalah plain, received less than twenty millimeters. Further east, all the stations along the axis of the Salalah - Thamrayt road (approx centre of the plain and Jebel) enjoyed good but not calamitous rainfall of around one hundred millimeters, the bulk over two days. Slightly further east again, Medinat al Haq received over four times this amount, and the eastern plain, Mirbat and points east experienced major and damaging floods.

The third type of rain seems also, to be determined by the behaviour of major airmasses, rather than orographic influences. This rainfall appears to be generally widespread, but with some sharp local variations probably resulting from higher activity of certain convective cells.



2.3. Variation of rainfall with time.

The only long term record is for Salalah Airport. Various reports have commented to the effect that this is not "indicative" of the general rainfall. Insofar as quantity is concerned, this is certainly so: but there seems no reason why it should not be indicative of variation over time: especially both for the occurrence or non occurrence of cyclones, and for the monsoon season. For this latter, the parameters deciding the rainfall are the duration of the season, and the moisture of the air mass relative the temperature: variations in these to give a greater or lesser years rain in Salalah, should equally produce a (proportionally higher but) greater or lesser rainfall in the Jebel. This is illustrated in the table following.

Comparative Monsoon Rainfalls, 1973 - 1977

(Totals for July and August only)

<u>Year</u>	<u>Plain</u>		<u>Jebel</u>	
	<u>Stations</u>	<u>Average</u>	<u>Average</u>	<u>Statio:</u>
1973	Airport, Robat, Arzat	39.6	158.5	Medina
1974	" " "	14.6	102.8	"
1975	Airport, Arzat	22.8	133.5	"
1976	" "	41.5	231.6	"
1977	Airport, Robat, Arzat	53.2	278.2	Eidas, Raqbat.

The data from which this table is derived is considered too scrappy to justify detail analysis: but it seems clear that a positive relationship exists, which may be better defined when further data is accrued.

Even in qualitative terms, it is clear that, until 1977, recent rainfall has been poor: both 1974 and 1975 were very poor years, and even 1976 rather below average. This is further evidenced by the failure of usually reliable waterholes in the Jebel wadis during that period.

Indeed, it seems very probable that throughout the late sixties and early seventies, the Salalah area was suffering a similar shortage of rainfall to that experienced in sub Saharan Africa, the Jizan region of Saudi Arabia, and the Sanaa area of North Yemen, all lying in the same belt of latitude.

This hypothesis is supported by the evidence of the record for Salalah Airport. Over the whole 35 years (1943-1977 inclusive) the mean annual rainfall is 109mm: but whereas the average for the first twenty five years was 117mm, that for the recent nine years 1968-1976 inclusive, was only 54mm. This latter period included three of the five lowest rainfall years, including the worst so far recorded (21.6mm in 1974).

Even more significant, are similar averages for the two monsoon months of July and August only, which are as follows:-

Salalah Airport, Average Monsoon Rainfalls (July & August)

<u>Period</u>	<u>No. of years</u>	<u>Average Rain (mm)</u>
1943 - 1977	35	51.1
1943 - 1967	25	57.6
1968 - 1977	10	35.0

The period 1968 - 1977 also includes all six of the lowest values during the period of record: the worst being 1972 (9.0mm) and 1974 (16.4mm).

These trends are very clearly illustrated by the 5 year and 10 year moving averages.

The longest successive period of below average monsoon has been the 3 years 1960 - 1962 inclusive: but this was probably less severe than the three pairs of very poor years, 1968 - 69, 1971 - 72, and 1974 - 75, each interspersed with a single good year.

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DHOFAR/SALALAH

TABLE DFR/4

ANNUAL RAINFALL  
(millimeters)

	1973	1974	1975	1976	1977
Raysut	(54)	17	D	(85)	268
Salalah Airport	69	21	42	74	394
Robat	(35)	16	(65)	a	370
Arzet	(33)	14	(33)	(116)	263
Raqbat	x	x	x	x	698
Eidas	x	x	x	(200)	(600)
Qaroon Heriti	x	(90)	x	x	(500)
Medinat al Haq	(190)	125	223	(300)	(1,100)
1)	For base data, see tables DFR/2				
2)	Gaps in record estimated				
3)	Rainfall for Medinat al Haq in 1977 includes 480mm during the cyclone				
4)	Decimals rounded to nearest whole millimeter.				

### 3. RAINFALL QUANTITIES.

#### 3.1. Rainfall on the Jebel

At the present time, mean annual rainfall over the Jebel may be estimated in two ways; either by using the available record, or by extrapolation of the Salalah data.

Annual record since 1973 inclusive is shown in Table DFR/4. To complete this table, various gaps in the record have been synthesized: reference should be made to tables DFR/2. Even aside from this, there must be doubts as to how valid a sample this short record is: it is known to include infrequent extremes of both maximum and minimum, in 1977 and 1974 respectively.

Alternatively, monsoon rainfall (on the wettest parts of the Jebel) may be estimated from the relationship with Salalah, tentatively described in Section 2:3. The quantity of cyclone rainfall may be expected to be similar: the "synoptic" rainfall of the Jebel may exceed that of the plain by a factor of about 1.5 or 2. From these, the following rainfall expectations may be derived:-

Rainfall Type	Plain		Jebel	
	%	Amount	Amount	%
Monsoon	50	56	300	75
Cyclone	25	26	30	8
Synoptic	20	21	40	10
Other minor rains	5	6	30	7
Total:	100	109	400	100

(Monsoon rainfall for plain includes late June, and early September)

Fortitiously, this calculation is in fairly close agreement with the average of the values for Medinat al Haq, in table DFR/4. It is also consistent with the ecological evidence: the vegetation cover would be unlikely if rainfall were below 300mm, and could be expected to be denser if greater than 500mm.

Tentatively, pending further data mean rainfall on the wettest parts of the Jebel is estimated at about 400mm/year: falling to about 250-300mm on the drier parts of the Jebel catchment. Average mean annual rainfall over the whole catchment might be between 300 to 350 mm. However, as is very apparent from table DFR/4, this "mean" is itself somewhat of a statistical concept with extreme individual values varying almost by the order of 10.

### 3.2. Rainfall intensities

There are as yet, few values for short periods of less than one day. However, some notable daily values have been recorded. Record for the main Salalah cyclones is as follows

<u>Month</u>	<u>12 hour</u>	<u>24 hour</u>	<u>Period total</u>
Oct. 1948	x	156.8	156.8
May 1959	x	117.2	121.0
May 1963	134.0	174.0	226.0
Nov. 1966	178.1	194.3	202.7
March 1967	x	x	91.1
June 1977	x	70.3	124.0

Note that for the June cyclone, three consecutive days rainfall of 171.5, 160.0 and 111.8 were recorded at Medinat al Haq: at Masirah island, the 24 hour total for 13/6/77 was 430.6 millimeters.

### 3.3. Recent rainfall

It is worth emphasizing that recent rainfall, over the past few years, has been exceptional, swinging from one extreme to the other

1974 was the lowest total for the 35 years since record began at Salalah Airport, and the end of 1976 (i.e. the first three months of 1977) marked the end of the most prolonged below average period, in the record.

This was immediately followed by an extremely wet year. In terms of numerical annual total, 1977 was the second wettest year since 1943, and the wettest since 1963. However, since a large part of the 1963 total was provided in a single days cyclone, 1977 may be about equal to 1963 in terms of effective rainfall.

#### 4. FUTURE MEASURING PROGRAMME

Present Water Resources Staff in Salalah is restricted to one man, with a local assistant under training, and limited logistic support. This team is also responsible for spring flow gauging and groundwater (well) records, and numerous other duties of a non-hydrometric nature.

There is therefore no present possibility of early expansion of the network, desirable though this may be. Instead, the Department is following the realistic policy of trying to assure reliable and continuous record from a minimum sample of stations. Ease of access, for control of the stations, has to be a major consideration: also it is preferred to "group" the stations, for purposes of quality control and for interpolation of gaps if necessary.

#### 5. SUMMARY

- (a) Data presently available is extremely limited. Many interpretations in this paper are therefore highly tentative, and subject to revision when better record is available.

At the same time, it is of the utmost importance that the present measuring programme shall not be interrupted, but rather, should receive more support.

- (b) Average mean annual rainfall, over the whole Jebel catchment, of Salalah plain, is tentatively estimated to lie between 300mm and 350mm: but varying widely within individual years. Mean annual rainfall over the wetter parts of the Jebel, probably reaches about 400mm/year.
- (c) The end of 1976, and early 1977, probably represented the most adverse conditions to be expected within a generation. In contrast, 1977 was an exceptionally favourable year.

**SALALAH AIRPORT — MONSOON RAINFALL**

**( July & August only )**

