No. 2

THE HASHEMITE KINGDOM OF JORDAN
MINISTRY OF PLANNING

# FEASIBILITY STUDY ON AGRICULTURAL DEVELOPMENT FOR THE KARAK - TAFILA DEVELOPMENT REGION

## ANNEX

A: Meteo-hydrology
B: Socio-economy
C: Land Use Plan
D: Agriculture
E: Facilities Development Plan
F: Organization and Management
G: Project Evaluation

OCTOBER 1990

JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO, JAPAN

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FOR
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# ANNEX

## CONTENTS

## ABBREVIATIONS AND MEASURES

Weight

| | | |
|---|---|---|
| kg | : | kilo gram |
| ton or t | : | metric ton |

Volume

| | | |
|---|---|---|
| l or lit | : | liter |
| $m^3$ | : | cubic meter |
| MCM | : | million cubic meters |

Length

| | | |
|---|---|---|
| mm | : | millimeter |
| cm | : | centimeter |
| m | : | meter |
| km | : | kilometer |

Area

| | | |
|---|---|---|
| $cm^2$ | : | square centimeter |
| $m^2$ | : | square meter |
| $km^2$ | : | square kilometer |
| ha | : | hectare |
| dunum | : | 0.1 ha |

Time

| | | |
|---|---|---|
| s or sec | : | second |
| min | : | minute |
| hr | : | hour |

Other

| | | |
|---|---|---|
| % | : | per cent |
| $^{o}C$ | : | degree centigrade |
| EC | : | electrical conductivity |
| El. | : | elevation |
| AD | : | Aqaba datum |

Derived Measure

| | | |
|---|---|---|
| l/s or lit/sec | : | liter per second |
| mS/cm or mmho/cm | : | milli-Siemen per centimeter |
| ton/hour | : | ton per hour |
| cum/sec | : | cubic meter per second |

Money

| | | |
|---|---|---|
| JD | : | Jordan Dinar |
| Fil | : | 1/1000 JD |
| US$ | : | U.S. dollar (US$ 1.00 = JD 0.680 as of November 1989) |

Organizations

| | | |
|---|---|---|
| MOP | : | Ministry of Planning |
| MOA | : | Ministry of Agriculture |
| MOS | : | Ministry of Supply |
| DOS | : | Department of Statistics |
| WAJ | : | Water Authority of Jordan |
| JVA | : | Jordan Valley Authority |
| ACC | : | Agricultural Credit Corporation |
| JCO | : | Jordan Cooperative Organization |
| JVFA | : | Jordan Valley Farmers' Association |
| AMO | : | Agricultural Marketing Organization |
| AMPCO | : | Agricultural Marketing and Processing Company |
| APC | : | Arab Potash Company |
| NRA | : | National Resources Authority |
| FAO | : | Food and Agricultural Organization of the United State |
| JICA | : | Japan International Cooperation Agency |

Others

| | | |
|---|---|---|
| GDP | : | Gross Domestic Products |
| RGDP | : | Gross Regional Domestic Products |
| GNP | : | Gross National Products |
| ETo | : | Potential Evaporation |
| CUW | : | Consumptive Use of Water |
| kc | : | Crop Coefficient |
| TDS | : | Total Dissolved Solids |

*ANNEX - A*

*METEO-HYDROLOGY*

ANNEX-A METEO-HYDROLOGY

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# PREFACE

This annex describes the result of meteorological and hydrological study for " the Agricultural Development Project for the Karak-Tafila Development Region " carried out during the period from October 1989 to July 1990.

The purpose of the meteorological study is to clarify the meteorological circumstances, which are important for agriculture.

The purpose of the hydrological study is two fold. Namely, one is the water harvesting scheme, in which rainfall directly fallen on the ground surface is utilized. Rainfall based on statistical analyses must be clarified. Another is the winter irrigation scheme, in which surface water flowing into wadis from catchment area as runoff is to be stored tentatively at small scale weirs and be utilized for irrigation. In this case estimation of runoff volume at each weir as well as rainfall is required.

# 1. DATA COLLECTION AND REVIEW

## 1.1 Data Collection

The following data were collected in the meteo-hydrological study.

(1) Climatological data

Precipitation, air temperatures (average, and absolute maximum and minimum ), relative humidity, wind velocity and direction, sunshine hours, evaporation, solar radiation.
The data sources are Jordan Climatological Data Handbook and data sheets obtained from WAJ.

(2)Hydrological data

Annual rainfall, daily rainfall, daily discharge record of flood and base flows at Hassa Tannour.
The data sources are Rainfall Data in Jordan. Technical Paper No.52 and data sheets prepared by WAJ.

(3)Others

Sediment load data, water quality

## 1.2 Review of Climatological Data

The climatological data such as precipitation, air temperatures, relative humidity, wind velocity or run and wind direction, sunshine hours and solar radiation and evaporation are observed by meteorological stations.

There are five meteorological stations in and around the priority areas, of which the data can be utilized for the present purpose. They are Wadi Wala, Er-Rabah, Tafila, Siwaqa and Hasa Evaporation stations.

The observation of fundamental meteorological features was commenced from 1961 at Er-Rabah, 1962 at Wadi Wala, 1973 at Al-Hassan Tafila by Meteorological Department of Ministry of Transport, and from 1982 at Siwaqa Evaporation station, 1977 at Hasa Evaporation station by WAJ or antecedent agency. All the meteorological data were shown as monthly-based values for the following items.

Mean monthly and yearly rainfall, Maximum daily rainfall, Maximum monthly and seasonal rainfall , Mean monthly and yearly wind run (km/day) or mean monthly (m/sec), Wind direction in degree clock wise from the north or points of the compass, Sunshine hours, Daily evaporation by class A pan method, Total evaporation, and Solar radiation.

## 1.3 Review of Rainfall Data

### (1) Annual Rainfall Data

There exist about 51 raingauge stations within the study area and at neighboring localities. All the data of stations within the study area were referred, even if recording periods are short. As for stations outside of the study area the stations necessary for preparing map of rainfall distribution maps were referred.

All the rainfall stations have been registered and named by the agencies concerned in accordance with the drainage system. Name, code number, location in palestine grid, altitude, established date and type of gauging, and closed date are shown in Table A.1.1. Rainfall data of each station from start of recording up to 1988/89 winter year or up to the closed date was collected. Although the earliest observation of rainfall commenced 1934, data available were from that of 1937/38 hydroyear.

The types of gauging are daily reading, totalizer and automatic recording. Totalizer are installed mainly in desert area. Many of the rainfall stations were installed in 1960's. The availability of the data is shown also in Table A.1.1.

The data sources are (a)Rainfall in Jordan for the years 1976-1980, Technical Paper No.50, (b)Rainfall Data in Jordan, 1980-1985, technical Paper No.52, and (c)computer output obtained from WAJ.

### (2) Daily Rainfall Data

Daily rainfall data of stations near the proposed weir sites and the priority areas, have been collected.

The data sources are the same as for the annual rainfall.

## 1.4 Review of Runoff Data

The proposed sites are located within or in the vicinity of the Hasa Tannour Basin. Therefore it is considered to be most effective to utilize discharge data at Hasa Tannour gauging station, which consist of daily mean, flood flow and base flow discharge from 1968/69 winter year to 1988/89. Hourly flood volume recorded in "Discharge computation sheet (type 2)" were collected from WAJ. All the data were checked with WAJ staffs.

## 1.5 Review of Sediment Load and Water Quality

There are few new information on these items for the study area. Therefore the study results of some reports on the subjects were referred.

## 2. CLIMATE

### 2.1 General

The climatic characteristics of the study area are divided into two well defined seasons : hot and dry summer ,and relatively wet and cold winter.

As for atmospheric conditions, Mediterranean depression known as Cyprus low are formed repeatedly during rainfall occurs within winter season due to active cold fronts stretching from the depressions. On the contrary, in spring season mainly from the middle of March to the middle of May Khamsinic depression rapidly spread from the west causing heavy showers for short period of time. During the rest of the year high pressures prevail throughout the country, which account for the absence of rainfall practically from June to September.

The mean annual rainfall in the study area ranges from 350 mm in a restricted area around Karak, to less than 100 mm in the desert area along the Desert Highway. The average rainfall of the study area is approximately 200 mm.

The Mean daily temperature ranges from 22 degree centigrade in the western area alongside the Jordan Valley, to 16 degree centigrade in the southern area around Tafila as shown in Fig. A.2.1. Most of the study area falls between 16 degree to 18 degrees centigrade.

The climate of the study area is classified as mediterranean to desert according to the climatic regional division by Koppen as shown below and in Fig.A.2.2.

- Warm temperate rainy climate : Mediterranean (Csa)
- Cool steppe climate (BSK)
- Cool desert climate (BWK)

Csa region which is another subdivision of the Mediterranean climate, is distributed as a narrow belt zone from Rabba to Tafila extending north to south (hereafter, described as the western zone). BSK region surrounds the Csa belt narrowly. This semi-arid climate is characterized by rainfall less than 300 mm and average annual temperature less than 18 degrees centigrade. BWK region is distributed on the eastern side of the BSK region along the Desert Highway. This climate is distinguished from the warm desert climate by its moderate temperature, of which average annual temperature is less than 18 degrees centigrade.

As a bioclimatic classification, Emberger's climatic region is well known. According to the classification the study area is divided into arid-mild, semi arid-mild, very arid-mild and semi arid-cold in descending order of area.

## 2.2 Climatological Features

There are five stations in the study area, of which two Er-Rabah and Al-Hassan/Tafial stations are located in the western part of the study area and are considered as representative stations of the western zone. Siwaqa and Hasa Evaporation stations are located along the Desert Highway, which are representative of the desert area. Wadi Wala station is installed near the wadi floor.

The climatological features here dealt with are absolute daily and yearly maximum and minimum temperatures, mean monthly and yearly temperatures, mean daily and yearly maximum and minimum temperatures, mean monthly and yearly relative humidity, so on, as shown in Table A.2.1.

### 2.2.1 Precipitation

Monthly changes in monthly total precipitation of the five stations are illustrated in Fig A.2.3.

Precipitation occurs from October until May in general, and there is no rainfall from June to September practically. Precipitation in the western zone is much bigger in comparison with that in the desert area. Precipitation at Siwaqa Evaporation station is bigger than that at the Hasa Evaporation station.

### 2.2.2 Temperature

Monthly changes in daily mean, maximum and minimum, as well as monthly maximum and minimum temperatures of the five stations are illustrated in Fig A.2.4.

(1) Mean Temperature

Monthly averages of daily mean temperatures of the five stations range from 7 degrees in winter to 26 degrees centigrade in summer. At the beginning of February, mean temperature in the desert and inside the large wadi reaches more than 10 degrees centigrade. On the other hand, in the western zone it is early March when daily mean temperatures reach more than 10 degrees centigrade. Although there is no marked areal difference, monthly average temperatures at Hasa Evaporation and Wadi Wala stations are slightly higher than the other stations. The higher temperatures occurs in July in the desert and in July and August in the western zone and in the wadi.

(2) Maximum Temperature

Monthly averages of daily maximum temperatures of the five stations range from 11 degrees in winter to 34 degrees centigrade in summer. Maximum temperature of more than 30 degrees centigrade continue for more than four months in summer in the desert and in the wadi. To the contrary, it does not exceed 30 degrees centigrade throughout summer in the western zone.

(3) Minimum Temperature

Monthly averages of daily minimum temperatures of the five stations range from 3 degrees in winter to 19 degrees centigrade in summer. The areal difference among the five stations is little.

(4) Others

Daily change in air temperature, i.e. the difference between the maximum and minimum temperature, is larger in the desert than in the western zone. It is noteworthy that the daily change at Siwaqa station is the largest among them.

### 2.2.3 Relative Humidity

*Monthly changes in daily mean relative humidity for the five* stations are illustrated in Fig.A.2.5.

Monthly averages of the five stations range from 40 % to 74 %. The lowest relative humidity occurs in May, and low relative humidity lasts during summer. It increases gradually from November to January, then decrease rather rapidly to May.

Relative humidity tends to be slightly higher in the desert than in the western zone, however its areal difference is small.

### 2.2.4 Evaporation

Monthly changes in daily evaporation of the five stations and evapotranspiration at Er-Rabah are illustrated in Fig.A.2.6.

Monthly averages of daily evaporation of the five stations range from 2.5 to 16.8 mm/day. Seasonal variation in evaporation in the desert is more obvious than in the western zone. Its difference is approximately 10 - 13 mm/day in the desert and 8-9 mm/day in the western zone. Areal difference is not marked in winter, but obvious in summer. It is noteworthy that evaporation at Wadi Wala is as low as at Tafila.

### 2.2.5 Wind

(1) Wind run

Monthly changes in daily wind run for the five stations are illustrated in Fig.A.2.7.

Monthly averages of daily wind run of the five stations range from 100 km/day to 450 km/day. The areal difference surpasses the seasonal variation except Hasa Evaporation station. The wind run at Wadi Wala station is conspicuously small and change only slightly throughout year from 70 km/day to 130 km/day. On the contrary, the wind run at Hasa Evaporation station varies from 250 km/day in November to 450 km/day in July.

(2) Wind Direction

Monthly changes of monthly average of daily total wind run for Er-Rabah are illustrated in Fig.A.2.8.

Wind direction is observed only at Er-Rabah. The predominant wind direction is west. And relation between wind direction and monthly average of daily wind run in each month is also shown in Fig.A.2.8.

### 2.2.6 Solar Radiation

Monthly changes in daily solar radiation in the three stations are illustrated in Fig.A.2.9.

Monthly averages of daily solar radiation of the three stations range from 0.28 to 0.93 kcal/cm$^2$/day. Solar radiation is *low in winter and high in summer at all stations.* *Seasonal* difference is 0.4 -0.5 kcal/cm$^2$/day. Solar radiation at Hasa Evaporation station is strongest of the three and is weakest at Er-Rabah. However, the solàr radiation measured at Swaqa and Hasa stations contains extraordinary high figures, which must be checked

## 3. RAINFALL ANALYSIS

### 3.1 General

Annual rainfall in the region varies from 50 mm to 350 mm, and its distribution is markedly biased to the western part as described above.

Annual rainfall of the 51 stations in the study area and related surrounding areas are shown in Table A.3.1.

Annual rainfall in the study area varies from 793 mm recorded at Khanzira station (CA 2) in 1964/65 winter year to 16 mm at Hasa Police Post (CF 5) in 1969/70. Average annual rainfall ranges from 355 mm at Karak (CF 4) to 64 mm at Jurf Ed-Darawish (CF 3).

### 3.2 Rainfall Analysis

#### 3.2.1 Rainfall Distribution - Long Term Average, 5 Years and 10 Years Drought Return Period.

(1) Long Term Average

Average annual rainfall of each station was calculated as shown in Table A.3.1. A rainfall distribution map based on these long term average values was prepared and illustrated in Fig. A.3.1.

Areas with rainfall more than 300 mm/y are found around Karak (CE 4) and Qasr (CD 23), and areas with comparatively much rainfall but less than 300 mm/y are found along King's Highway. Rainfall decreases sharply from these areas westward to the Jordan Valley where annual rainfall is less than 100 mm/y, and gently decreases eastward to the Desert Highway where rainfall of 50 - 100 mm/y prevails. Rainfall along large wadi courses treading east-west is markedly lower than surrounding high lands as stated before.

It is known that coefficient of variation (CV) of annual rainfall decreases in proportion to the amount of rainfall as shown in bold line in Fig.A.3.2, which is the case of the Middle East and United States of America. However, the coefficients of variation increase only slightly as compared to the decrease in rainfall in this region. It indicates that there exists relatively stable rainfall even in the desert area.

(2) Return Period of 5 Years Drought

Annual rainfall with a return period of 5 years drought in the related stations in and around the priority areas was obtained with statistic calculation using the Log-Pearson method. Isohyetal maps showing a return period of 5 years drought in the three priority areas are illustrated in Fig.A.3.3.

In Dhiban area, isohyetal lines of 100 and 150 mm/y exist. There are no isohyetal lines of 200 and 250 mm/y. In Abyad area, isohyetal lines of 100 and 150 mm/y exist. In Tafila area, isohyetal lines of 100 and 150 mm/y are distributed. Isohyetal lines of 200, 250, 300 and 350 mm/y are not present in the map. These indicate that basin rainfall of return period of 5 years drought is much smaller than that of long term average as described later.

(3) Return Period of 10 years Drought

Annual rainfall of return period of 10 years drought was obtained in the same way with that of 5 years return period. Isohyetal maps of return period of 10 years drought for the three priority areas are illustrated in Fig.A.3.4.

In Dhiban area, only isohyetal line of 100 mm/y are distributed in the western area, and there is no isohyetal lines of 150 mm/y and 50 mm/y. In Abyad area, isohyetal lines of 100 and 50 mm/y exist, and in Tafila area, isohyetal line of 100 mm/y is distributed. Isohyetal line of 50 mm/y is observed at the eastern edge of the area.

These differences in distribution of the isohyetal lines indicates that basin rainfall of dry year return period of 10 years decreases fairly.

The basin rainfall based on each rainfall distribution map for the three priority areas was obtained by are as follows.

<u>Area Rainfall in the Priority Areas</u>

| Priority Area ( $Km^2$ ) | Long Term Average Basin Rainfall(mcm) Rainfall depth(mm) | Return Period (Drought) 5 Years | 10 Years |
|---|---|---|---|
| Dhiban | 75.1 | 42.1 | 38.8 |
| (431) | 174 | 97 | 90 |
| Abyad | 45.8 | 30.1 | 26 |
| (357) | 128 | 84 | 73 |
| Tafila | 111.4 | 69.1 | 54.1 |
| (570) | 195 | 121 | 95 |

3.2.2 Rainfall Intensity - Duration

For designing the proposed weirs for the winter irrigation scheme, analysis of the relation between rainfall intensity and duration with various return periods is required. Fortunately, some analysis of this matter have been published already in Professional Paper No. 3 of WAJ.

The relation between rainfall intensity and duration with various return periods at Tafila (DB1) ,Rashadia (DC2) and Mazar (CD13), are referred and shown in Fig A.3.5., which is adopted for the present study.

### 3.2.3 Rainfall Variation in the Priority Areas

(1) Pattern of Rainfall Distribution within Rainy Season

Monthly average rainfalls in the nine stations in and around the three priority areas were summarized for 1976/77 to 1987/88 as shown in Table A.3.2. The stations in the Dhiban area are Dhiban (CD7), Um El-Risas (CD-17), and Dhaba's Nursery (CD17), in the Abyad area Mazar (CD13), Muhai (CA6) and Hasa Evaporation Station(CF7), in the Tafila area Tafila (DB1), Prince Hasan Nursery (DB2) Buseira (DC1) and Jurf Ed-Darawish (CF3). Accumulative curve of monthly rainfall of the nine stations are shown in Fig.A.3.6.

Although average annual rainfall (shown in parentheses in the figures) is different from station to station,the accumulated curves resemble each other. The pattern of the curves are characterized by low gradients both from October to November and from March to May, and high gradient from November to January.

These indicate that the large part of rainfall concentrate in the middle of the rainy season.

The average dates of the first rainfall, 10 and 20 percentage of annual rainfall during these about 10 years are summarized as follows.

Average Date of Rainfall Occurrence

| Station | Date of Rainfall Occurrence | | |
|---|---|---|---|
| | First Rain | 10 percentage *1 | 20 percentage |
| Dhiban (CD7) | Nov.12 | Dec. 6 | Dec.17 |
| Um El-Risas (CD17) | Nov.20 | Dec.10 | Dec.23 |
| Dahab'a Nursery (CD15) | Nov. 5 | Nov.29 | Dec.13 |
| Mazar (CD13) | Nov.16 | Dec.11 | Dec.29 |
| Muhai (CA6) | Nov.19 | Dec.10 | Jan. 1 |
| Hasa Evap Sta. (CF7) | Nov.16 | Dec.12 | Dec.19 |
| Tafila (DB1) | Nov.12 | Dec. 7 | Dec.24 |
| Prince Hasan Nursery (DC1) | Nov. 7 | Dec.13 | Dec.26 |
| Buseira (DC1) | Nov.10 | Dec.12 | Dec.26 |
| Jurf Ed-Darawi (CF3) | Nov.18 | Dec.12 | Dec.17 |

*accumulated 10 and 20 percentage of annual rainfall

The first rainfall includes trace rainfall from Nov. 5 to

Nov. 20. The dates when the accumulated rainfall exceed 10 % of the total rainfall range from Nov. 29 to Dec. 13 to Dec. 26. The time when accumulated rainfall exceeds 50 percentage of annual rainfall is around early to middle Jannuary in most stations.

(2) Rainfall Distribution for 10 Years in the Priority Areas.

Annual rainfall distributions from 1976/1977 to 1987/1988 for the seven representative stations inside the three priority areas and in neighboring areas are illustrated in Fig A.3.7 to overview rainfall variations. Each data are total of rainfall of consecutive three days except the last day of some months with 31 days and 28 or 29 days.

These figures show that annual rainfall distributions are quite erratic.

# 4 RUNOFF ANALYSIS

## 4.1 General

Running water in a wadi is dependent on capricious storms over its drainage basin. Flush flood flows directly down to the Jordan Valley within a few days after a storm, leaving a small amount of base flow only after a good amount of rainfall and flood flows during winter.

There is no runoff data of small wadis in the study area nor in the country. There are runoff records of the large wadi named Hasa Tannour measured at Hasa Gauging Station for more than 18 years, which run through the middle part of the study area. It would be better to make good use of the data for runoff analysis.

According to the runoff records at Hasa Tannour Gauging station, duration of floods ranges from within a day to several days. Most of them are a few days. The longest of them is the flood that lasted from January 14 to January 25 in 1974. The largest flood occurred in December 6 to 8 in 1979, with the volume of 22.62 MCM. Normal runoff volume of a flood ranges between 0.02 to 2 MCM. Annual total runoff volume is within a range of 0.75 MCM to 38.46 MCM and its average is 8.53 MCM. The peak discharge varies from 0.2 $m^3$/sec to 420 $m^3$/sec.

The proposed sites are located in the southwestern part of the Wadi Hasa basin, where low mountains are developed. Catchment areas of all weir sites are small. In the present study the acquisition of first hand observational data of rainfall and runoff were attempted as much as possible. The observations were carried out at the experimental weir and the rain gauge station in the Abyad area throughout the present study period, but to our regret rainfall was too scarce.

## 4.2 Runoff Coefficient

### 4.2.1 Runoff Coefficient

(1) Basin Rainfall

The basin rainfall was calculated by Thiessen polygon method using the five stations located inside the basin or at neighboring localities, namely they are CF8 (Hasa Gauging Station), CA6 (Muhai) DB1 (Tafila), CF3(Jurf Ed Darawish) and CD33 (Jabel Sakhriyat).

(2) Runoff Volume of the Hasa Tannour

Runoffs of the Wadi Hasa basin have been measured at the middle of the Wadi Hasa, at Hasa Tannour gauging station as described before. The runoff records of the station are shown in Table A.4.1.

The catchment of the wadi has diverse hydrological characteristics such as flat deserts with scarce rainfall and low mountains with higher rainfalls. Therefore, runoff coefficient obtained from hydrological analysis for the whole basin is not appropriate for the runoff analysis of the proposed weir sites which have low mountains and higher rainfalls.

The rainfall distribution and ground surface conditions of the upper Hasa Tannour sub-basin which has flat land and low rainfall can be represented with the Qatrana and Sultani sub-basins. The runoff coefficient of Qatrana and Sultani sub-basins was applied to the upper Hasa basin, which is estimated at 1.8 percentage according to the Master Plan.

Consequently the runoff volume from the upper Hasa basin is excluded from the Hasa Tannour runoff volume to determine the runoff volume of the Hasa Tannour sub-basin where proposed weir sites exist.

(3) Runoff Coefficient

Table A.4.2 and Fig.A.4.1 show the annual runoff coefficients of the whole Hasa basin. The annual runoff coefficients vary from 0.7% to 15.6%, and its average is 5.6%. The annual runoff coefficients excluding the upper Hasa sub-basin fall between 0.2% and 25.3%. Its average value was 7.9%. It is generally acknowledged that runoff coefficients increase in proportion to rainfall. Its tendency, however, is not so evident as expected. Because there is large variation in runoff coefficients and the proportional tendency is not so marked, as far as basin annual rainfalls between 50 and 150 mm/y is concerned. In the present runoff study this average value i.e 7.9 % was adopted.

## 4.3 Runoff Survey at an Experimental Weir

### 4.3.1 Preparation, and Rainfall and Runoff Observation

Runoff observations to estimate runoff coefficients of a very small catchment area were carried out from October 1989 to March 1990 in the following way.

- Construction of a small scale weir
- Installation of automatic rain gauge
- Topo survey of the reservoir of the small scale weir
- Observation of rainfall and runoff

(1) Site Selection of Runoff Observation

a) Tafila area

Based on a reconnaissance survey, an observatory small scale weir site was selected on Wadi Lavan about 6 km east of Tafila, and an automatic rain gauge was to be installed at the pumping station of Tafila Governorate in Al Hazir about 3 km up stream of the weir site. The working plan and schedule of the runoff observation was prepared. Land ownership of the site was identified by the Land and Survey Department.

In the Tafila Governorate Office, the JICA study Team met with both a proposed contractor and the land owner, and explained the plan and the specifications to the contractor on November 13,

1989. However, the land owner requested to construct wire fences around the reservoir. Besides, the contractor's construction cost presented to the team was too high to be accepted. Afterwards, JICA Study Team negotiated with other two contractors but in vain.

b) Abyad area

The construction of the small scale weir had to be started as soon as possible during the present investigation period. The Study Team endeavored to search for an alternative site and finally found out an appropriate place from viewpoints of land owner ship and contraction cost. The site of the small scale weir was changed to Wadi Sukur near the proposed Abyad weir site for the Winter Irrigation Scheme.

(2) Construction of the Small Scale Weir

Based on the reconnaissance survey in the Wadi Abyad basin, the small scale weir site was selected on the Wadi Sukun, a tributary of the Wadi Abyad, about 2.5 km east of the Muhai village in Karak Governorate.

The construction of the weir financed by JICA was entrusted to the Karak Municipality Office by the Study Team. The contract was signed for the construction work on November 6, 1989.

The crest gauges for measuring water level were installed inside the reservoir on December 13, 1989. The principal features of the weir are as follows, and the plan and profile of the weir are shown in Fig.A.4.2 and A.4.3.

a) Reservoir

| | | |
|---|---|---|
| Catchment area | : | 12 $km^2$ |
| Storage capacity | : | 4,000 $m^3$ |
| Water level | : | EL 936.7 m |
| High water level | : | EL 937.4 m |
| Reservoir area | : | 5,000 $m^2$ |

b) Weir

| | | |
|---|---|---|
| Weir type | : | Homogeneous earthfill type |
| Crest level | : | EL. 937.5 m |
| Crest length | : | 42 m |
| Weir height | : | 3.5 m from Wadi bed level (EL.934.0 m) |
| Weir slope | : | Upstream 1:2    Downstream 1:2 |
| Weir volume | : | 440 $m^3$ |

c) Spillway

| | | |
|---|---|---|
| Design flow capacity | : | 14 $m^3/s$ |
| Type | : | Non-gated side overflow type |
| Overflow crest length | : | 12 m |
| Overflow crest level | : | EL.936.7 m |

(3) Installation of the Automatic Rain Gauge

The automatic rain gauge brought by the JICA Study Team consists of measuring and recording parts. The automatic rain gauge station for the runoff observation was installed at the Muhai Secondary School for boys in the Muhai, in which the daily rainfall station (called No. CA6 MUHAI) has been established by the Water Authority of Jordan (WAJ). The station by the Study Team can record automatically for a week continuously. The site is located upstream in the catchment area of the weir and about 2.5 km west from it. The observation was commenced on December 13, 1989. Location map is shown in Fig.A.4.4.

(4) Topo Survey of the Reservoir of the Weir

The topo survey of the reservoir of the Weir was carried out for the measurement of the storage capacity on December 13, 1989. The topo surveyed map of a scale of 1/1,000 with one meter of contour line interval was prepared.

The water level-storage curve was prepared by using the above-mentioned topo surveyed map. The topo surveyed map and the water level-storage curve are shown in Figs.A.4.5 and A.4.6.

(5) Observation of Rainfall and Runoff

As mentioned above, the observation was started by the present JICA Study Team on December 13, 1989 and finished on March 3, 1990.

a) Result of rainfall observation

The first rainfall after it started to observe rainfall was recorded by the rain gauge from 1:00 a.m. to 3:00 p.m. January 4,1990. At that time, the rainfall amounted to 24 mm. Rainfall occurred 10 times during the whole investigation period, and its accumulated rainfall is 43.5 mm. Record papers of rainfall from December 13, 1989 to March 3, 1990 are shown in Fig.A.4.7.

b) Result of the runoff observation

The reservoir was filled with water by the rainfall on January 4, 1990. The runoff was recorded only once during this whole investigation period. Other rainfalls were too little to make runoff.

The volume of runoff in the reservoir was confirmed at the very high water level (HWL), storage capacity of 4000 $m^3$ at 9:30 a.m. January 4, 1990. After that, runoff began to overflow the spillway.

The maximum height of the flood marks in the reservoir was measured to estimate the runoff volume which overflowed the spillway. The maximum water depth at the spillway was about 0.19 m. The confirmed water level and the crest elevation of the spillway are as follows;

Crest elevation of spillway; EL.936.67 m
Flood mark at spillway; EL.936.86 m

c) Measurement of the water level in the reservoir

The water level in the reservoir was measured to estimate evaporation from water surface and/or infiltration into ground by the crest gauges. A water level recorder of water pressure type which was borrowed from the Surface Water Section of WAJ was installed to measure continuously the water level of the reservoir on January 25, 1990. The water level had been observed continuously in anticipation of next runoff until the end of the field work.

The storage water in the reservoir disappeared by evaporation and/or infiltration in early February, as shown in Fig.A.4.8.

### 4.3.2 Study of Runoff

#### (1) Result of Runoff Observations

Hourly rainfalls on Jan.4, 1990 were as follows;

a) Rainfall

| Time(h) | Rainfall(mm) | Time(h) | Rainfall(mm) |
|---|---|---|---|
| 1 Jan.4,'90 | 0 | 9 | 2 |
| 2 | 4 | 10 | 3 |
| 3 | 3.5 | 11 | 2 |
| 4 | 0.5 | 12 | 0.5 |
| 5 | 0.5 | 13 | 1.5 |
| 6 | 0 | 14 | 2 |
| 7 | 2 | 15 | 0.5 |
| 8 | 2 | 16 | 0 |
| | Total | | 24.0 |

b) Runoff

The actual runoff volumes were checked at the following two points. Firstly the volume of the discharge is about 4,000 $m^3$ at HWL of the reservoir at 9:00 a.m. on January 4, 1990, and secondly the maximum flood mark in the reservoir is as high as 0.19 m above the crest level of spillway, which is evidence of the overflow water depth.

#### (2) Estimation of the Runoff Volume

The overflowing of stored water through the spillway was observed after the water level rose up to the crest of the spillway. It is necessary to calculate the total discharge volume and to estimate the runoff coefficient.

For the estimation of the total volume of the runoff, the time from the start until the end of the discharge was presumed by using Nakayasu's Synthetic Unit Hydrograph Method, as shown in Fig.A.4.9.

The calculation of the unit hydrograph at the weir is as follows;

a) Unit hydrograph by Nakayasu's Synthetic Unit Hydrograph Method

$$Qmax=\frac{1}{3.6}ARo/(0.3T_1+T_{0.3})$$

- tg ; time lag

$$tg = 0.26Lm^{0.7} = 0.235(LmxL)^{0.35}$$

$$tg = 0.26Lm^{0.7} = 0.26\ 4.2^{0.7} = 0.710 = 0.71 \text{ or}$$

$$tg = 0.21L^{0.7} = 0.21\ 5.7^{0.7} = 0.710 = 0.71 \text{ or}$$

$$tg = 0.235(LmL)^{0.35}$$

$$= 0.235(4.2x5.7)^{0.35} = 0.714 = 0.71$$

- $T_{0.3}$ ; Time required until the discharge recesses to 0.3 times of the maximum discharge.

$$T_{0.3} = 1.5tg = 1.5 X 0.71 = 1.07$$

- $T_1$ ; Time of occurrence of peak discharge

$$T_1 = tg + 0.8tr = 0.71+0.8 = 1.51$$

| | | |
|---|---|---|
| A ; | Catchment area | 12 $km^3$ |
| L ; | Maximum length of watercourse | 5.7 km |
| Lm; | Length of watercourse from the furthest point in the zone with the maximum width of the catchment | 4.2 km |
| Ro; | Rainfall (1 mm ) | |

- $Q_{max}$ ; Maximum discharge of unit hydrograph

$$Qmax=\frac{ARo}{3.6(0.3T_1+T_{0.3})}=\frac{12x1}{3.6(0.3x1.51+1.07)}=2.19m^3/s$$

b) Calculation of Unit hydrograph

The calculation of unit hydrograph is shown below.

| Time (hr) | Qmax ($m^3/s$) | K | Unit discharge Qd($m^3/s$) | |
|---|---|---|---|---|
| 0 | 2.19 | 0 | 0 | For rising part of hydro. curve with $0<t<T_1; K=(t/T_1)^{2.4}$ |
| 0.5 | 2.19 | 0.0705 | 0.15 | |
| 1.0 | 2.19 | 0.3719 | 0.81 | |
| 1.51 | 2.19 | 1.0000 | 2.19 | |
| 2.0 | 2.19 | 0.5762 | 1.26 | $K=0.3^{(t-T1)/T0.3}$ |
| 2.5 | 2.19 | 0.3283 | 0.72 | |
| (2.58) | 2.19 | 0.3000 | 0.66 | |
| 3 | 2.19 | 0.2189 | 0.48 | $K=0.3^{((t-T1+0.5T0.3)/1.5T_{0.3})}$ |
| 3.5 | 2.19 | 0.1505 | 0.33 | |
| 4 | 2.19 | 0.1034 | 0.23 | |
| (4.19) | 2.19 | 0.0900 | 0.20 | |
| 5 | 2.19 | 0.0569 | 0.12 | $K=0.09x0.3^{((t-T1-2.5T_{0.3})/2T_{0.3})}$ |
| 6 | 2.19 | 0.0324 | 0.07 | |
| 7 | 2.19 | 0.0185 | 0.04 | |
| 8 | 2.19 | 0.0105 | 0.02 | |

The unit hydrograph thus obtained is illustrated in Fig.A. 4.10(a). However,the calculated accumulated volume at 9:00 Jan. 4 was too large compared with the actual volume of 4,000 tons. Therefore, the following trial and error method was applied to make a unit hydrograph fit to the catchment of the experimental weir. As the preconditions for its calculation, the following 3 points are taken into consideration. Firstly, the time length from the start of runoff until the finish is to be about eight hours judging from the catchment characteristic values by this method. Secondly, the beginning time of runoff is 6:00 a.m. It means consequently that total rainfall of about 10 mm before that time was considered as storm loss. Thirdly, the accumulated volume at 9:00 a.m. was 4,000 tons.

The relation between time (hr) and discharge ($m^3/s$) for the revised unit hydrograph is as follows. And its hydrograph is illustrated in Fig.A.4.10(b).

| Time(hr) | Unit discharge($m^3/s$) |
|---|---|
| 0 | 0 |
| 1 | 0.08 |
| 1.51 | 0.228 |
| 2 | 0.13 |
| 3 | 0.05 |
| 4 | 0.02 |
| 5 | 0.01 |
| 6 | 0.007 |

The calculation table by Nakayasu's synthetic unit hydrograph method and the runoff volume thus obtained is shown in the following table.

CALUCULATION OF DISCHARGE VOLUME BY NAKAYASU'S SYNTHETIC UNIT HYDROGRAPH

| Day & | r | R | Vertical distance of Unit hydrograph | | | | | | Q | Qmean | Volume | Acc. V. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | (mm/h) | (mm/h) | 0.08 | 0.23 | 0.05 | 0.02 | 0.01 | 0.007 | (m3/s) | (m3/s) | (m3) | (m3) |
| 4/1 | 0 | | | | | | | | | | | |
| 2 | 4 | | | | | | | | | | | |
| 3 | 3.5 | | | | | | | | | | | |
| 4 | 0.5 | | | | | | | | | | | |
| 5 | 0.5 | | | | | | | | | | | |
| 6 | 0 | 0 | | | | | | | 0 | 0 | 0 | 0 |
| 7 | 2 | 2 | 0.16 | | | | | | 0.16 | 0.08 | 288 | 288 |
| 8 | 2 | 2 | 0.16 | 0.46 | | | | | 0.62 | 0.39 | 1,404 | 1,692 |
| 9 | 2 | 2 | 0.16 | 0.46 | 0.10 | | | | 0.72 | 0.67 | 2,412 | 4,104 |
| 10 | 3 | 3 | 0.24 | 0.46 | 0.10 | 0.04 | | | 0.84 | 0.78 | 2,808 | 6,912 |
| 11 | 2 | 2 | 0.16 | 0.69 | 0.10 | 0.04 | 0.02 | | 1.01 | 0.93 | 3,330 | 10,242 |
| 12 | 0.5 | 0.5 | 0.04 | 0.46 | 0.15 | 0.04 | 0.02 | 0.01 | 0.72 | 0.87 | 3,114 | 13,356 |
| 13 | 1.5 | 1.5 | 0.12 | 0.12 | 0.10 | 0.06 | 0.02 | 0.01 | 0.43 | 0.58 | 2,070 | 15,426 |
| 14 | 2 | 2 | 0.16 | 0.35 | 0.03 | 0.04 | 0.03 | 0.01 | 0.62 | 0.53 | 1,890 | 17,316 |
| 15 | 0.5 | 0.5 | 0.04 | 0.46 | 0.08 | 0.01 | 0.02 | 0.02 | 0.63 | 0.63 | 2,250 | 19,566 |
| 16 | | | | 0.12 | 0.10 | 0.03 | 0.01 | 0.01 | 0.27 | 0.45 | 1,620 | 21,186 |
| 17 | | | | | 0.03 | 0.04 | 0.02 | 0 | 0.09 | 0.18 | 648 | 21,834 |
| 18 | | | | | | 0.01 | 0.02 | 0.01 | 0.04 | 0.07 | 234 | 22,068 |
| 19 | | | | | | | 0.01 | 0.01 | 0.02 | 0.03 | 108 | 22,176 |
| 20 | | | | | | | | 0 | 0 | 0.01 | 36 | 22,212 |
| | | | | | | | | | Total Volume= | | 22,212 | |

r ; Recorded rainfall Volume ; Volume of discharge

R ; Effective rainfall Acc.V. ; Accumulated volume of discharge

Q ; discharge

(3) Review of Outflow Depth on the Spillway

After the flood, the maximum flood marks in the reservoir was measured to confirm the overflow water depth at the spillway.

| | |
|---|---|
| Crest elevation of spillway | EL.936.67m |
| Flood mark of spillway | EL.936.86m |

The reservoir routing study was carried out to estimate the maximum flood water level in the reservoir and maximum discharge through the spillway.

a) Discharge rating curve of spillway

Discharge volume which had overflowed by the spillway was estimated by the following equation.

$$Q = CBH^{3/2}$$

where, Q ; discharge in $m^3/s$
C ; coefficient of discharge by spillway 2.1
B ; width of spillway 12m
H ; overflow depth on the crest, in meter

| H(m) | $H^{3/2}$ | B(m) | $Q(m^3/s)$ | WL(m) |
|---|---|---|---|---|
| 0 | 0 | 12 | 0 | 936.67 |
| 0.05 | 0.0112 | 12 | 0.13 | 936.72 |
| 0.10 | 0.0316 | 12 | 0.38 | 936.77 |
| 0.15 | 0.0581 | 12 | 0.70 | 936.82 |
| 0.20 | 0.0894 | 12 | 1.07 | 936.87 |
| 0.25 | 0.1250 | 12 | 1.50 | 936.92 |

b) and curves

$\psi = (V/3,500) - O/2$ , $\phi = (V/3,600) + O/2$

where; $\psi$, $\phi$ ; functions of overflow depth
V ; reservoir capacity $(m^3)$
O ; discharge of spillway $(m^3/s)$

| H (m) | V (m3) | V/3,600 $(m^3/s)$ | O/2 $(m^3/s)$ | $\phi$ | $\psi$ |
|---|---|---|---|---|---|
| 0 | 3,800 | 1.09 | 0 | 1.09 | 1.09 |
| 0.05 | 4,050 | 1.13 | 0.07 | 1.20 | 1.06 |
| 0.10 | 4,300 | 1.19 | 0.19 | 1.38 | 1.00 |
| 0.15 | 4,560 | 1.27 | 0.35 | 1.62 | 0.92 |
| 0.20 | 4,840 | 1.34 | 0.54 | 1.88 | 0.80 |
| 0.25 | 5,120 | 1.42 | 0.75 | 2.17 | 0.67 |

c) Calculation of the reservoir routing of the estimated runoff

| Date | Hour | I ($m^3/s$) | Im ($m^3/s$) | H (m) | $\psi$ | $\phi$=Im+ $\psi$ | O ($m^3/s$) |
|---|---|---|---|---|---|---|---|
| 4 | 9 | 0.72 | 0 | 0 | | | 0 |
| | 10 | 0.84 | 0.78 | 0.16 | 0.89 | | 0.78 |
| | 11 | 1.01 | 0.93 | 0.19 | 0.83 | 1.82 | 0.99 |
| | 12 | 0.72 | 0.87 | 0.17 | 0.88 | 1.70 | 0.82 |
| | 13 | 0.43 | 0.68 | 0.14 | 0.94 | 1.56 | 0.63 |
| | 14 | 0.62 | 0.53 | 0.12 | 0.97 | 1.47 | 0.50 |
| | 15 | 0.63 | 0.63 | 0.15 | 0.92 | 1.60 | 0.68 |
| | 16 | 0.27 | 0.45 | 0.10 | 1.01 | 1.37 | 0.36 |
| | 17 | 0.09 | 0.18 | 0.05 | 1.06 | 1.19 | 0.12 |
| | 18 | 0.04 | 0.07 | 0.03 | 1.06 | 1.13 | 0.05 |
| | 19 | 0.02 | 0.03 | 0.01 | 1.06 | 1.09 | 0.02 |
| | 20 | 0 | 0.01 | 0.0 | 1.06 | 1.07 | 0.01 |
| | 21 | | 0 | | | 1.06 | 0 |

where ,

I ; inflow
H ; overflow depth
Im ; 1/2(In + In+1)   O ; outflow discharge

note ; H, and O are taken out from Fig.A.4.11

The procedure of calculation is as follows;

The start of the outflow discharge (O) is at 10:00 a.m. January 4. At this time, the mean inflow (Im), 0.78m $^3$/s, is equal to 0.078 $m^3/s$. H, 0.16 m and $\psi$, 0.89 $m^3/s$ are able to be read from Fig.A.4.11. $\phi$ (at 11:00 a.m.) is given by adding $\psi$, 0.89 $m^3/s$ (at 10:00 a.m.) to Im, 0.93 $m^3/s$ (at 11:00 a.m.). H, $\psi$ and O (at 11:00 a.m.) are taken out from 1.82$m^3/s$ on $\phi$ curve in Fig.A.4.11, and so the process is repeated until 21:00 (9:00 p.m.).

Results of the reservoir routing study are presented in Fig.A.4.12 and summarized below,

| | | |
|---|---|---|
| (a) | Initial reservoir water level | ; El. 936.67 m |
| (b) | Maximum reservoir water level | ; El. 936.67 m |
| (c) | Maximum inflow | ; 1.01 $m^3/s$ |
| (d) | Maximum outflow | ; 0.99 $m^3/s$ |
| (e) | Total volume of inflow | ; 22,320 $m^3$ |
| (f) | Total volume of outflow | ; 17,900 $m^3$ |
| (g) | Reservoir capacity | ; 4,000 $m^3$ |

(4) Estimation of Runoff Volume

The runoff and total volume of discharge at the Muhai experimental weir during the rainfall were estimated by applying Nakayasu's synthetic unit hydrograph method.

The main points of the estimated runoff are as follows;

- Recorded rainfall is 24.0 mm in total from 1:00 a.m. to 3:00 p.m. January 4, 1990.

- The effective rainfall for the calculation is as much as 15.5 mm between 6:00 a.m. and 3:00 p.m.

- The discharge seems to continue from 6:00 a.m.to 8:00 p.m., for 14 hours in total.

- The volume of the runoff discharge is estimated to be about 22,300 $m^3$ in total, of which the volume of 4,000 $m^3$ at the full reservoir capacity was confirmed at 9:00 a.m.

- The runoff coefficient for this flood was calculated to be 7.8%, which is coincidentally the same as that of the Hasa Tannour sub-basin. This value is calculated by the following equations.

$$q = V/A$$
$$f = q/r$$

where,

| | | | |
|---|---|---|---|
| q | ; | depth of direct runoff in mm | |
| V | ; | runoff volume | 22,320 $m^3$ |
| A | ; | catchment area | 12 $km^2$ |
| f | ; | runoff coefficient | |
| r | ; | recorded rainfall | 24.0 mm |

$$q = 22,320 / 12,000,000 = 0.00186m = 1.86mm$$
$$f = 1.86 / 24 = 0.0775 = 7.75\%$$

It is too early to obtain a conclusion by this experimental work at present. Further study of the same purpose will be desired. It is of vital importance to obtain runoff coefficients under various rainfall conditions, which will allow appropriate design of weir of the winter irrigation scheme as well as check dams which are also recommendable method of agricultural development in this Abyad area.

### 4.3.3 Study of Evaporation and Permeability

#### (1) Data of Water level Observation

The water level in the reservoir was measured for the evaporation evaluation since the runoff occurred on January 4, 1990.

The result of water level in the reservoir is as follows,

| Date | WL (m) | Receded WL (m) | Rainfall (mm) |
|---|---|---|---|
| Jan. 4 | 936.86 | 0 | 24.0 |
| 5 | 936.67 | 0.19 | - |
| 8 | 936.39 | 0.28 | - |
| 15 | 936.05 | 0.34 | - |
| 16 | | | 2.5 |
| 17 | | | 1.0 |
| 22 | 935.78 | 0.27 | - |
| 24 | 935.71 | 0.07 | - |
| 25 | 935.66 | 0.05 | - |
| 26 | 935.62 | 0.04 | 4.0 |
| 27 | 935.59 | 0.03 | 0.5 |
| 28 | 935.55 | 0.04 | - |
| 29 | 935.51 | 0.04 | - |
| 30 | 935.48 | 0.03 | - |
| 31 | 935.44 | 0.04 | - |
| Feb. 1 | 935.39 | 0.05 | 4.5 |
| 2 | 935.37 | 0.02 | - |
| 6 | - | | 0.5 |
| 18 | | | 2.0 |
| 24 | | | 0.5 |
| Mar. 1 | | | 4.0 |

The water level changes in the reservoir is shown in Fig.A.4.8.

(2) Study of Water Loss from Reservoir

The water decrease from the reservoir due to evaporation and infiltration was studied based on the above-mentioned data by using the reservoir capacity curve in Fig.A.4.6.

The result of the study is shown in table A.4.3.

Average daily decrease water in the reservoir is calculated 30 mm/day which is about ten times as high as mean daily evaporation of 2.7 mm/day in January.

According to Jordan Climatological Data Handbook (reference 6), the evaporation at Al Hassan/Tafila station which is nearest to the experimental site is given as follows, and data on evaporation at the site are roughly read from the figures and summarized as follows based on National Atlas of Jordan, Part 11, Hydrology and Agrohydrology (reference 7).

- class A pan Evaporation of
  - January daily (ref.6) ; 2.7 mm/day
  - January monthly (ref.7) ; 100 mm/month
- potential evapotranspiration of
  - Mean Annual (ref.7) ; 1,700 mm/year
  - January (ref.7) ; 60 mm/month

Wet period or season (ref.7) ;500-600 mm/period

If the water loss is wholly attributed to evaporation, the average daily decrease of water in the reservoir is too large in comparison with the above mentioned data. Therefore, it is supposed that most of the vanished water had infiltrated into the underground of the reservoir. This phenomenon is well understood if it is taken into consideration that well stratified bed rocks with open cracks and joints are exposed in the wadi floor.

## 4.4 Hydrological Conditions for the Four Proposed Weirs

### 4.4.1 Annual Rainfall

(1) Annual Rainfall of the Weir Site Basin

For the purpose of determination of annual runoff volume at the weir sites, five (5) stations were selected among fifty one (51) rainfall stations located in and around the study area.

Annual rainfall data of these stations is shown in Table A.3.1. Annual mean rainfall of each weir site were calculated by the Thiessen polygon method.

The result of the annual mean rainfall at each weir site basin are summarized as follows:

| Weir | Wadi | Place | Catchment area ($km^2$) | Annual rainfall (mm/yr) | Runoff coefficient (%) |
|---|---|---|---|---|---|
| D-2 | W.Laban | Tafila | 34.8 | 219 | 7.9 |
| E-1 | W.Zabda | Tafila | 9.5 | 227 | 7.9 |
| J-1 | W.Sallam | Qadisiyya | 16.7 | 204 | 7.9 |
| Abyad | W.Abyad | Muhai | 116.5 | 172 | 7.9 |

(2) Annual Runoff at the Hasa Tannour Gauging Station

The annual runoff volume of various return periods at the Hasa Tannour G.S. were obtained by a statistic method i.e. Log-Pearson type III method. The results are shown in Table A.4.4. And the results by Log-Pearson type III are summarized as follows:

| Return Period (years) | Runoff Volume (MCM/yr) |
|---|---|
| 1.01 | 0.16 |
| 1.25 | 1.56 |
| 2 | 4.64 |
| 5 | 11.88 |
| 10 | 18.36 |
| 25 | 28.03 |
| 50 | 36.06 |
| 100 | 44.63 |

(3) Annual Runoff at the Proposed Weir Site

Annual runoff volume at each weir site was estimated based on the above-mentioned annual runoff of various return periods at the Hasa Tannour G.S., annual mean rainfall, and runoff coefficients by using the following equation :

$$Dw = Dt \times (Rw/Rt) \times (Cw/Ct)$$

Where;

Dw: Runoff depth at a weir site (mm)
Dt: Runoff depth at Hasa Tannour (mm)
Rw: Annual mean rainfall at a weir site (mm)
Rt: Annual mean rainfall at Hasa Tannour (mm)
Cw: Mean runoff coefficient at a weir site
Ct: Mean runoff coefficient at Hasa Tannour

In the present study mean runoff coefficient of weir site is considered to be 7.9 % which was the same as that of Hasa Tannour sub-basin representing the ground surface conditions of the western highlands .

The result of the estimation is shown in Table A.4.5 is summarized as follows:

<u>Annual Runoff Volume at Each Weir Site</u>

(unit: MCM/yr)

| Weir | Wadi | Catchment ($km^2$) | Return Period (year) 1.01 | 1.25 | 2 | 5 | 10 | 25 | 50 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|
| E-1 | Zabda | 9.5 | 0.004 | 0.03 | 0.10 | 0.24 | 0.37 | 0.57 | 0.74 | 0.91 |
| D-2 | Laban | 34.8 | 0.020 | 0.12 | 0.34 | 0.86 | 1.36 | 2.03 | 2.61 | 3.22 |
| J-1 | Sallam | 16.7 | 0.007 | 0.05 | 0.15 | 0.38 | 0.59 | 0.91 | 1.17 | 1.44 |
| Abyad | Abyad | 116.5 | 0.040 | 0.31 | 0.90 | 2.26 | 3.47 | 5.34 | 6.86 | 8.46 |

Available water for irrigation is estimated at 30 % of the annual runoff as estimated in the JICA Master Plan.

### 4.4.2 Maximum Flood Discharge

In order to estimate the flood runoff rainfall intensity in the basin was determined by using the time lag of peak discharge defined by the following characteristic values of "Nakayasu's Synthetic Unit Hydrograph Method".

(1) Nakayasu's Synthetic Unit Hydorograph Method

It often occurs that the volume of runoff has to be estimated for basins where hydrological data have not yet been obtained. Nakayasu has given the characteristic values of the unit hydorograph as shown in Fig.A.4.9.

Nakayasu defined the unit hydrograph and concluded that $T_1$ and $T_{0.3}$ can be expressed as a function of the catchment characteristics as follows. If the time lag is t and maximum length of the watercourse is L;

For $L < 15$ km
$$tg = 0.26\ Lm^{0.7} = 0.21\ L^{0.7} = 0.235(Lm.L)^{0.35}$$

For $L > 15$ km
$$tg = 0.4 + 0.077\ Lm = 0.4 + 0.058L$$

Time of occurrence of peak discharge
$$T_1 = tg + 0.8tr$$

Where;
tr: Duration of unit rainfall to be used.

Calculation of time lag, tg for each weir site is summarized as follows:

For L < 15 km

| Weir Site | Catchment Area ($km^2$) | L (km) | Lm (km) | tg: $0.26Lm^{0.7}$ | tg: $0.21L^{0.7}$ | tg: $0.235(Lm.L)^{0.35}$ | tg |
|---|---|---|---|---|---|---|---|
| D-2 | 34.8 | 13.4 | 6.7 | 0.98 | 1.29 | 1.13 | 1.13 |
| E-1 | 9.6 | 6.6 | 3.3 | 0.6 | 0.79 | 0.69 | 0.69 |
| J-1 | 16.7 | 6.6 | 3.3 | 0.6 | 0.79 | 0.69 | 0.69 |

For L > 15 km

| Weir Site | Catchment Area ($km^2$) | L (km) | Lm (km) | tg: 0.4+0.077Lm | tg: 0.4+0.058L | tg |
|---|---|---|---|---|---|---|
| Abyad | 116.5 | 25.0 | 12.5 | 1.36 | 1.85 | 1.6 |

(2) Data of Rainfall Intensity - Duration

In order to estimate peak discharge, the data of rainfall intensity - duration at each Tafila, Rashadia and Mazar Rainfall station are adopted for D-2, J-1 and Abyad respectively, as already mentioned in 3.2.2.

As for the E-1, the calculation was made by using the annual maximum daily rainfall at the station of Prince Hassan Nursery (Abur) DB2.

The result of the rainfall intensity for each site is as follows:

| Probability Year (T) | D-2 (mm/h) | J-1 (mm/h) | Abyad (mm/h) | E-1 (mm/h) |
|---|---|---|---|---|
| 2 | 8.8 | 7.3 | 8 | 5.5 |
| 5 | 11.0 | 10.2 | 12.0 | 9.3 |
| 10 | 12.2 | 12.1 | 14.5 | 12.3 |
| 25 | 14.0 | 14.7 | 17.5 | 16.8 |
| 50 | 15.2 | 16.5 | 19.5 | 20.5 |
| 100 | 17.0 | 18.1 | 21.8 | 24.6 |

(3) Maximum Flood Discharge at the Proposed Weir Site

Maximum flood discharge at the proposed weir sites was calculated by the following rational formula:

$$Qp = \frac{1}{3.6} fRA$$

Where;

Qp: Maximum flood discharge ($m^3/s$),
f : Runoff coefficient,
R : Intensity of rainfall within the time of flood concentration (mm/h).
A : Catchment area ($km^2$).
Remark : Runoff coefficient for each weir site is derived from $T_1$; time from the start of runoff to maximum discharge and $T_{0.3}$; time required until the discharge recesses to 0.3 times of the maximum discharge.

$T_1 = tg + 0.8r$
$T_{0.3} = 0.47(A.L)^{0.25}$
$f = 1/(0.3\ T_1 + T_{0.3})$
$r$ =unit time

Results of the runoff coefficient are as follows:

| Weir Site | A ($km^2$) | L (km) | tg (h) | $T_1$ (h) | $0.3T_1$ (h) | $T_{0.3}$ (h) | f |
|---|---|---|---|---|---|---|---|
| D-2 | 34.8 | 13.4 | 1.13 | 1.93 | 0.579 | 2.186 | 0.36 |
| E-1 | 9.6 | 6.6 | 0.69 | 1.49 | 0.447 | 1.325 | 0.56 |
| J-1 | 16.7 | 6.6 | 0.69 | 1.49 | 0.447 | 1.523 | 0.51 |
| Abyad | 116.5 | 25.0 | 1.60 | 2.4 | 0.720 | 3.455 | 0.24 |

Result of the maximum flood discharge are as follows:

| Weir Site | f | R(mm/h) | | A ($km^2$) | Qp ($m^3/s$) | |
|---|---|---|---|---|---|---|
| | | T=10 | T=25 | | T=10yr | T=25yr |
| D-2 | 0.36 | 12.2 | 14.0 | 34.8 | 42.5 | 48.7 |
| E-1 | 0.56 | 12.3 | 16.8 | 9.6 | 18.4 | 25.1 |
| J-1 | 0.51 | 12.1 | 14.7 | 16.7 | 28.6 | 34.8 |
| Abyad | 0.24 | 14.5 | 17.5 | 116.5 | 112.6 | 135.9 |

For designing the spillway of weir, the maximum discharge of 10-year return period was adopted.

### 4.4.3 Runoff Analysis by SCS Method

(1) SCS Method

The Soil Conservation Service developed a method for calculating runoff from storm rainfall. The characteristic aspects of the method are taking the following points into consideration.

- antecedent moisture conditions (AMC)
- initial abstraction of rainfall
- land use

The general equation relating the accumulated runoff to accumulated rainfall is expressed as follows.

$$Q = (P - Ia)^2 / (P - Ia + S) \quad \text{(Reference 5)}$$

where,

Q is the accumulated depth of runoff in inches
P is the accumulated depth of storm rainfall in inches
Ia is the depth of initial abstraction in inches
S is the depth of the potential abstraction in inches

Ia and S are related to the soil cover conditions. Also the relation between initial abstraction (Ia) and potential abstraction (S) was derived from the studies of different watersheds in The United States of America as,

$$Ia = 0.2\ S$$

Thus the above equation for the accumulated runoff is formulated as,

$$Q = ( P - 0.2 S )^2 / ( P + 0.8 S )$$

Also the relationship between the Curve Number (CN) and S was established as,

$$S = 1000 / CN - 10$$

This SCS method was also applied to estimate runoff volume in the present study for reference.

(2) Model Year Selection

Annual rainfall with dry year return periods of 2, 5, and 10 years were calculated by the Thiessen Polygon method and Log-Pearson III type statistic method, as shown in the numbers in parentheses of the following table. Model years were selected among the years, which gave the nearest annual rainfall to these values.

Return Period (Drought) and Model Year

| Site | 2 years | 5 years | 10 years |
|---|---|---|---|
| D-2 | 1976/77,78/79 (197) | 1986/87 (146) | 1984/85 (126) |
| E-1 | 1976/77,85/86 (196) | 1977/78 (144) | 1972/73 (125) |
| J-1 | 1978/79 (210) | 1986/87 (135) | 1984/85 (105) |
| ABYAD | 1976/77,84/85 (159) | 1983/84 (113) | 1972/73 (97) |

(3) Determination of Curve Number of Each Site Basin

Through the field investigation of the sites, the following curve numbers were adopted. It needs deep experience for the method to determine the curve number appropriate to the study area. The assistance by WAJ staff was indispensable in determining the numbers.

Curve Number

| Site | Curve Number | S | Storm loss |
|---|---|---|---|
| D-2 | 75 | 3.33 | 17.0 |
| E-1 | 75 | 3.33 | 17.0 |
| J-1 | 75 | 3.33 | 17.0 |
| ABYAD | 84 | 1.9 | 9.7 |

S; Potential abstraction

(4) Result

The result of calculation by the method is shown in Table A.4.6, and summary of the results is as follows.

Total Flood Runoff Volume by SCS Method (MCM)

| Site | 2 Year | 5 Year | 10 Year |
|---|---|---|---|
| D-2 | 0.60, 0.56 | 0.05 | 0.33 |
| E-1 | 0.17, 0.31 | 0.10 | 0.31 |
| J-1 | 0.33 | 0.11 | 0.02 |
| ABYAD | 2.09,2.59 | 2.81 | 2.07 |

There is a weak tendency that total volumes of flood runoff of each site decrease, as the return period of drought increase. The volume of return period of 10 years drought exceeds that of 5 years in two cases. It seems to be caused by large rainfall of one time, which leads to more runoff after storm loss. If, in spite of lager annual rainfall, it consists of series of rainfall nearly equal to or smaller than storm loss or effective rainfall, runoff volume results in small ones or zero. The results of this method teaches us that annual runoff volume should not be estimated by only total annual rainfall.

The curve number of each site was determined by experiences at other areas in Jordan at present. If data on the relations between rainfall and runoff accumulates at the experimental weir, and the curve number is determined more precisely on these data, this SCS method will be one of easy and reliable methods to estimate runoff volume.

# 5.SEDIMENT ANALYSIS

## 5.1 General

Suspended load transported by flood flow is known to increase as its magnitude. In the study area, there developed no wadi with base flow even during the wet season except large wadis such as Hasa Tannour, Wadi Wala etc. Therefore, suspended loads in small wadis in the study area occurs only during flood flow, of which the data of suspended load has not been studied.

The data of water quality here dealt are from reference studies.

## 5.2 Sediment Analysis

### 5.2.1 Review Study

Relation between suspended sediment load and water discharge is logarithmically represented by an equation as follows.

$$Qs = KQ^n$$

where, Qs ; Suspended load(kg/sec)
Q ; Discharge ($m^3$/sec)
k,n; Constants

According to the study on suspended load carried out for hydrological study of the Mujib drainage basin ( JICA Mujib Watershed study,1987 ) based on the data from 1964 to 1976, the following results are obtained.

| Station | K value | n value |
|---|---|---|
| Wala gauging station (at Kings Highway & the weir) | $4.095 \times 10^{-3}$ | 1.055 |
| Siwaqa gauging station | $3.814 \times 10^{-3}$ | 1.300 |
| Mujib gauging station | $3.397 \times 10^{-3}$ | 1.299 |

As for Sultani dam, its reservoir had been filled with sediment up to 75% of its full capacity, of which the volume reaches 0.9MCM. It is equivalent to 1.4% of the total inflow volume of 64 MCM. It is analyzed that accumulated suspended load is 0.3MCM and bed load transport accounts for the rest 0.6MCM. However, these data are evaluated as too large, such excess volume of suspended load and bed load transport had been largely affected by outflow of slime from the Sultani phosphate mine.

### 5.2.2 Estimation of Suspended Load

Suspended load at the four weir sites are calculated as rough estimation by applying the above-mentioned equation and the observed constants.

Suspended Load

| Weir Site | Area ($Km^2$) | Q ($m^3/s$) | Qs;suspended load(ton) (1) | (2) |
|---|---|---|---|---|
| D-2 | 34.8 | 0.03 | 0.66 | 0.75 |
| E-1 | 9.6 | 0.008 | 0.11 | 0.14 |
| J-1 | 16.7 | 0.014 | 0.23 | 0.28 |
| ABYAD | 116.5 | 0.082 | 2.3 | 2.5 |

(1) and (2) ; constants of Siwaqa and Mujib gauging stations are used respectively.

$$Q = frA$$

where, r ; basin rainfall based on long term average
f ; runoff coefficient = 7.9%
A ; Catchment area of weir

## 5.3 Water Quality

Data on water quality of flood water is not reported in the study area.

In the Master Plan water quality of springs in the study area is reviewed. Total dissolved solid (T.D.S.) exhibits good correlation with electric conductivity (E.C.; T.D.S. = 0.63 x E.C.) and is used for a major indicator of salinity of water. Other data are taken from reference 2). The results are summarized as follows.

Water Quality

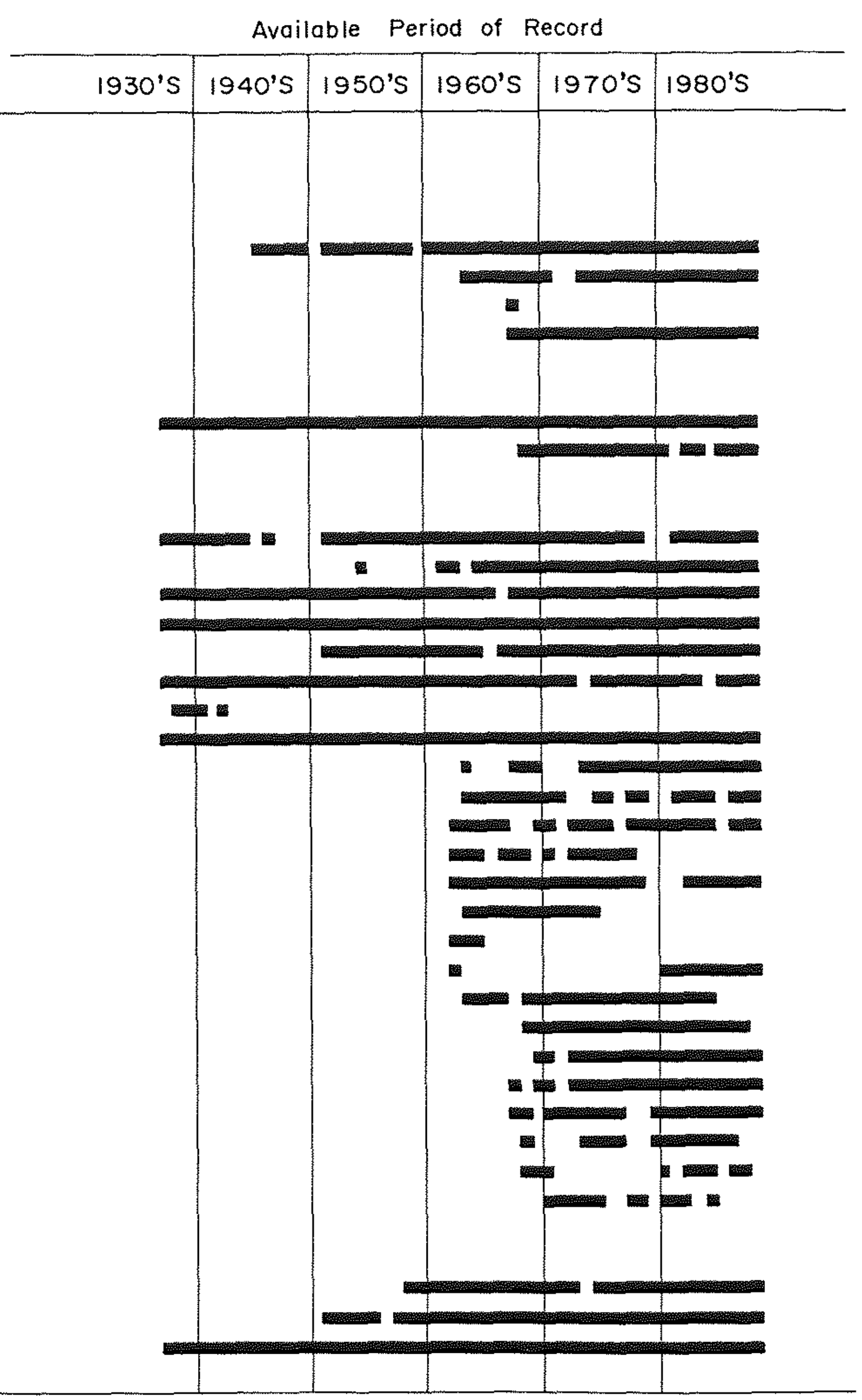
| | pH | Salinity(ppm) | T.D.S |
|---|---|---|---|
| Spring water 1) | 7.1 - 8.8<br>7.5 - 8.0 | 270 - 2300<br>350 - 800 | |
| Ground water 2) | | | 500 - 1250 |
| Wadi Mujib 2) | | | 1250 - 1280 |
| Qatrana dam 2) | | | 365 |

1),2);Reference number, T.D.S ; Total Dissolved Solid (mg/l)

These data indicate that the water quality of Qatrana dam contains the least T.D.S. The water quality of flood runoff which will be stored for irrigation, is supposed to be similar to that of Qatrana dam. It is well known that pH of rainfall is around 6 or so and it increases as the reaction between infiltrated water and surrounding bed rocks proceeds. Because pH of spring waters seems to be not so high, pH of rainfall is supposed to be normal values. In the study area, for ground water with more T.D.S. is utilized for both municipal water and irrigation, there will be no problem to use runoff water in the reservoir for irrigation purpose.

Table A.1.1 (1/2) RAINFALL STATIONS AND AVAILABILITY OF DATA

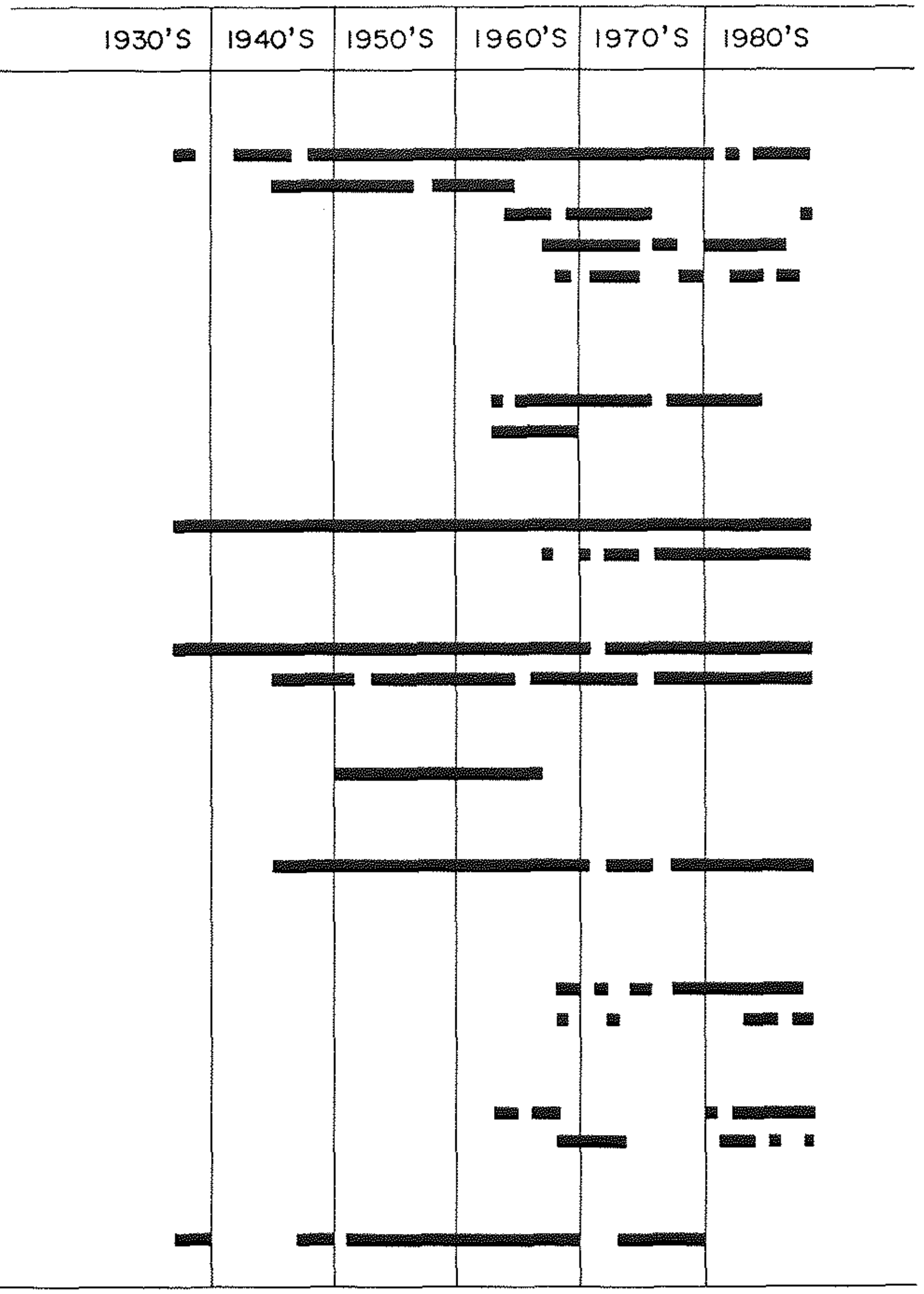
| DRAINAGE AREAS / Sub-Drainage Areas / Station Name | Sta. Code No. | Location: Palestine Grid North | Location: Palestine Grid East | Equip. Alt. (EL. m) | Date Established and Type of Gauging: Daily Reading | Date Established and Type of Gauging: Totalizer | Date Established and Type of Gauging: Automatic Recording | Date Closed |
|---|---|---|---|---|---|---|---|---|
| DEAD SEA | C | | | | | | | |
| Small Drainage Areas East Side | CA | | | | | | | |
| Khanzira | CA 2 | 51.800 | 207.300 | 1000 | 9/1945 | | | |
| Aiy | CA 4 | 60.300 | 211.000 | 900 | 5/1963 | | 10/1973 | |
| Al-Aina | CA 5 | 42.200 | 224.000 | 775 | 10/1967 | | | 10/1986 |
| Muhai | CA 6 | 44.500 | 231.800 | 1000 | 10/1967 | | | |
| Wadi Zarqa Main | CC | | | | | | | |
| Madaba | CC 1 | 125.000 | 225.500 | 785 | 1/1934 | 11/1962 | 10/1970 | |
| Ma'in | CC 2 | 120.800 | 219.900 | 810 | 10/1967 | | 10/1973 | |
| Wadi Mujib | CD | | | | | | | |
| Jiza | CD 5 | 123.000 | 241.000 | 705 | 1/1938 | 11/1962 | 10/1970 | |
| Wadi Wala | CD 6 | 107.500 | 223.000 | 350 | 10/1954 | | 10/1970 | |
| Dhiban | CD 7 | 100.800 | 224.000 | 745 | 1/1938 | 10/1968 | | |
| Hemud | CD 9 | 78.000 | 226.000 | 890 | 10/1943 | 11/1962 | | |
| Rabba | CD10 | 75.500 | 220.500 | 970 | 10/1951 | | | |
| Qatrana Police Post | CD11 | 72.500 | 249.500 | 770 | 1/1938 | 11/1962 | 10/1967 | |
| Bir Hafira | CD12 | | | | 10/1938 | | | 10/1943 |
| Mazar | CD13 | 52.000 | 216.500 | 1140 | 10/1934 | 12/1962 | 10/1963 | |
| Dhab'a Nursery | CD15 | 111.600 | 250.500 | 750 | 11/1962 | | 10/1967 | |
| Judayda | CD16 | 105.000 | 211.500 | 725 | 11/1962 | 11/1962 | | |
| Um El-Risas | CD17 | 101.000 | 237.500 | 750 | 10/1962 | | | |
| Khan Ez-zabeeb | CD18 | 97.800 | 255.000 | 775 | 11/1962 | | | |
| Jad'a | CD19 | 89.500 | 222.000 | 900 | 11/1962 | | | |
| Siwaqa Evap. St. | CD20 | 86.800 | 253.700 | 775 | 11/1962 | 11/1965 | 10/1968 | 10/1975 |
| Manzil | CD21 | 51.500 | 247.000 | 825 | 1/1963 | | | |
| Qasr El-Musheish | CD22 | 38.000 | 254.000 | 850 | | 12/1962 | | 10/1963 |
| Qasr Evap.St. | CD23 | 80.900 | 221.000 | 900 | 5/1963 | 10/1968 | 10/1968 | |
| Zeituna Evap. St. | CD26 | 129.700 | 235.700 | 765 | 10/1968 | 10/1968 | 10/1968 | |
| Muleih | CD28 | 110.900 | 228.000 | 630 | 10/1967 | | | |
| Sirfa | CD29 | 81.600 | 212.500 | 900 | 10/1967 | | | |
| Jabel Abu Hallufa | CD30 | 86.000 | 272.900 | 950 | | 9/1967 | | |
| Wadi El-Jinz | CD31 | 54.500 | 276.000 | 825 | | 9/1967 | | |
| Jabel Sakhriyat | CD33 | 26.600 | 274.000 | 910 | 10/1968 | | | |
| Qatrana Evap.St. | CD34 | 73.600 | 249.500 | 730 | 3/1970 | 3/1970 | 3/1970 | |
| Wadi El-Kerak | CE | | | | | | | |
| Rakin | CE 1 | 70.000 | 217.500 | 1050 | 10/1958 | | | 10/1983 |
| Ain Bisas | CE 2 | 67.800 | 213.500 | 700 | 10/1951 | | 10/1973 | |
| Karak | CE 4 | 66.000 | 217.000 | 1050 | 1/1938 | | 10/1970 | 10/1957 |



## Table A.1.1 (2/2) RAINFALL STATIONS AND AVAILABILITY OF DATA

| DRAINAGE AREAS<br>Sub-Drainage Areas<br>Station Name | Sta. Code No. | Location (Palestine Grid) North | Location (Palestine Grid) East | Equip. Alt. (EL. m) | Date Established and Type of Gauging: Daily Reading | Totalizer | Automatic Recording | Date Closed |
|---|---|---|---|---|---|---|---|---|
| Wadi El-Hasa | CF | | | | | | | |
| Jurf Ed-Darawish | CF 3 | 11.800 | 233.000 | 940 | 1/1938 | 11/1962 | 10/1970 | |
| La'aban | CF 4 | 35.000 | 217.000 | 700 | | 10/1945 | | 10/1965 |
| Hasa police Post | CF 5 | 25.800 | 243.000 | 825 | 11/1962 | 11/1962 | | |
| Hasa Evap. Sta. | CF 7 | 30.600 | 243.600 | 900 | 10/1967 | 10/1967 | 10/1967 | |
| Hasa Gauging Sta. | CF 8 | 41.600 | 220.400 | 380 | 10/1968 | | 10/1966 | |
| WADI ARABA DRAINING NORTH | D | | | | | | | |
| Small Drainage Areas | DA | | | | | | | |
| Ifjeij | DA 4 | 994.000 | 209.000 | | 1/1963 | | | |
| Uneiza Railway Station | DA 5 | 989.000 | 226.500 | | 1/1963 | | 10/1967 | |
| Wadi Feifa Basin | DB | | | | | | | |
| Tafila | DB 1 | 27.500 | 208.000 | 1000 | 1/1938 | 1/1963 | 10/1965 | |
| Prince Hasan Nursery | DB 2 | 23.300 | 218.200 | 1220 | 10/1967 | | 10/1976 | |
| Wadi Khuneizira | DC | | | | | | | |
| Buseira | DC 1 | 17.000 | 208.000 | 1100 | 12/1934 | | 10/1973 | |
| Rashadiya | DC 2 | 12.500 | 210.000 | 1500 | 10/1969 | 10/1945 | 10/1973 | |
| Wadi Dahl | DD | | | | | | | |
| Ain Lahdha | DD 1 | 12.800 | 207.300 | 1420 | 10/1950 | | | 10/1970 |
| Wadi El-Fidan | DE | | | | | | | |
| Dhana | DE 1 | 9.500 | 208.300 | 1230 | 9/1945 | | 10/1973 | |
| AZRAQ BASIN | F | | | | | | | |
| Qasr Tuba | F 12 | 83.000 | 300.000 | | | 9/1968 | | |
| Jabel Mudaysisat | F 19 | 119.200 | 268.000 | | | 9/1968 | | |
| JAFR BASIN | G | | | | | | | |
| Jabel Quzemeh | G 11 | 995.500 | 284.300 | 920 | | 9/1967 | | |
| Qabr Es-Saww | G 12 | 984.000 | 247.000 | 945 | | 9/1967 | | |
| SOUTH EAST DESERT BASIN | | | | | | | | |
| Bayir Evap. Sta. | J 1 | 20.000 | 310.500 | 902 | 10/1947 | OLD | 10/1965 | |

Available Period of Record



## Table A.2.1 (1/5) CLIMATOLOGICAL DATA

Station Name: Wadi Wala
Agency in-charge : Meteorological Dep.
Latitude : 31 33'

Elevation ( m ) : 450
Longitude : 35 47'

| Month | Temperature | | | | | Average Relative Humidity | Precipitation | | | Average | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Absolute | | Average | | | | Average | Max. Daily | Max. Monthly | Wind Run | Wind Direction | Sunshine Hours | Daily Evaporat. | Total Evaporat. | Radia-tion(cal/cm2/day) |
| | Max. (oC) | Min. (oC) | Mean (oC) | Max. (oC) | Min. (oC) | (%) | (mm) | (mm) | (mm) | (km/day) | (Degree) | | (mm/day) | | |
| Jan | 28.3 | -5.0 | 10.3 | 15.6 | 4.7 | 66.0 | 64.3 | | | 110.6 | | | 9.0 | | |
| Feb | 29.5 | -1.5 | 11.2 | 17.3 | 5.5 | 63.0 | 44.7 | | | 120.5 | | | 2.8 | | |
| Mar | 35.5 | -0.2 | 13.7 | 20.3 | 7.1 | 57.0 | 46.1 | | | 103.4 | | | 3.8 | | |
| Apr | 38.5 | 2.0 | 17.7 | 25.1 | 10.3 | 51.0 | 23.8 | | | 111.4 | | | 6.0 | | |
| May | 42.4 | 5.5 | 21.1 | 29.6 | 13.3 | 39.0 | 2.0 | | | 107.9 | | | 8.2 | | |
| Jun | 43.4 | 8.0 | 24.5 | 32.7 | 16.2 | 39.0 | 0.0 | | | 123.1 | | | 10.3 | | |
| Jul | 42.6 | 10.0 | 25.3 | 33.2 | 17.4 | 42.0 | 0.0 | | | 119.0 | | | 10.5 | | |
| Aug | 43.5 | 12.0 | 25.6 | 33.6 | 17.6 | 44.0 | 0.0 | | | 138.0 | | | 9.7 | | |
| Sep | 43.3 | 7.0 | 24.3 | 32.1 | 16.4 | 48.0 | 0.0 | | | 101.2 | | | 7.7 | | |
| Oct | 39.0 | 6.0 | 21.3 | 29.2 | 13.4 | 49.0 | 5.4 | | | 72.1 | | | 6.1 | | |
| Nov | 34.0 | 0.0 | 16.5 | 23.4 | 9.4 | 54.0 | 25.5 | | | 82.7 | | | 3.5 | | |
| Dec | 29.5 | -3.0 | 11.7 | 17.3 | 6.1 | 64.0 | 54.1 | | | 83.5 | | | 2.3 | | |
| Yearly | 43.5 | -5.0 | 18.6 | 25.8 | 11.5 | 51.0 | 265.9 | | | 106.1 | | | 6.7 | | |
| Period | 1962<br>1987 | 1962<br>1987 | 1962<br>1987 | 1962<br>1987 | 1962<br>1987 | 1962<br>1987 | 1962<br>1987 | | | 1972<br>1985 | | | 1966<br>1987 | | |

Table A.2.1 (2/5) CLIMATOLOGICAL DATA

Station Name : Er-Rabah
Agency in-charge : Meteorological Dep.
Latitude : 31 16'

Elevation ( m ) : 920
Longitude : 35 45'

| Month | Temperature | | | | | Average | Precipitation | | | Average | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Absolute | | Average | | | Relative | Average | Max. | Max. | Wind Run | Wind | Sunshine | Daily | Total | Radia- |
| | Max. (oC) | Min. (oC) | Mean (oC) | Max. (oC) | Min. (oC) | Humidity (%) | (mm) | Daily (mm) | Monthly (mm) | (km/day) | Direction (Degree) | Hours | Evaporat. (mm/day) | Evaporat. | tion(cal/ cm2/day) |
| Jan | 26.4 | -5.1 | 7.9 | 12.0 | 3.7 | 69.0 | 74.8 | | | 189.0 | 251.0 | 6.0 | 4.0 | 1.51 | 288.0 |
| Feb | 28.0 | -3.0 | 8.8 | 13.4 | 4.2 | 66.0 | 66.1 | | | 198.4 | 261.0 | 6.2 | 5.1 | 2.14 | 353.0 |
| Mar | 32.0 | -3.5 | 11.2 | 16.4 | 6.1 | 60.0 | 61.8 | | | 196.9 | 263.0 | 7.1 | 6.4 | 3.20 | 450.0 |
| Apr | 33.8 | 0.6 | 15.0 | 21.0 | 8.8 | 50.0 | 20.9 | | | 189.9 | 269.0 | 8.6 | 8.1 | 4.57 | 550.0 |
| May | 39.0 | 3.0 | 18.8 | 25.6 | 11.9 | 42.0 | 3.1 | | | 171.7 | 272.0 | 10.2 | 10.7 | 5.62 | 615.0 |
| Jun | 38.7 | 6.5 | 21.8 | 28.6 | 14.9 | 41.0 | 0.0 | | | 198.8 | 281.0 | 11.8 | 12.1 | 6.56 | 686.0 |
| Jul | 39.0 | 10.9 | 23.3 | 29.7 | 16.8 | 43.0 | 0.0 | | | 221.9 | 279.0 | 11.8 | 12.8 | 6.73 | 673.0 |
| Aug | 40.4 | 10.0 | 23.3 | 29.6 | 16.9 | 46.0 | 0.0 | | | 203.8 | 282.0 | 11.2 | 11.8 | 6.20 | 642.0 |
| Sep | 38.5 | 8.0 | 21.8 | 28.1 | 15.5 | 50.0 | 0.0 | | | 167.5 | 282.0 | 10.1 | 10.5 | 4.94 | 559.0 |
| Oct | 36.0 | 3.5 | 19.1 | 25.4 | 12.9 | 49.0 | 4.2 | | | 137.1 | 265.0 | 8.8 | 8.5 | 3.69 | 449.0 |
| Nov | 30.4 | 0.1 | 14.2 | 19.4 | 9.0 | 58.0 | 32.2 | | | 139.6 | 244.0 | 7.4 | 5.2 | 2.24 | 339.0 |
| Dec | 25.5 | -4.8 | 9.4 | 13.5 | 5.2 | 67.0 | 63.4 | | | 147.4 | 255.0 | 5.8 | 4.1 | 1.47 | 273.0 |
| Yearly | 40.4 | -5.1 | 16.2 | 21.9 | 10.5 | 53 | 326.5 | | | 180.2 | 271.0 | 8.8 | 8.3 | 4.07 | 490 |
| Period | 1961 1987 | 1961 1987 | 1961 1987 | 1961 1987 | 1961 1987 | 1961 1987 | 1952 1987 | | | 1976 1985 | 1983 1987 | 1974 1987 | 1967 1987 | 1974 1987 | 1974 1987 |

## Table A.2.1 (3/5) CLIMATOLOGICAL DATA

Station Name : Al-Hassan/Tafila
Agency in-charge : Meteorological Dep.
Latitude : 30 47'

Elevation ( m ) : 1200
Longitude : 35 43'

| Month | Temperature | | | | | Average | Precipitation | | | Average | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Absolute | | Average | | | Relative Humidity | Average | Max. Daily | Max. Monthly | Wind Run | Wind Direction | Sunshine Hours | Daily Evaporat. | Total Evaporat. | Radiation(cal/cm2/day) |
| | Max. (oC) | Min. (oC) | Mean (oC) | Max. (oC) | Min. (oC) | (%) | (mm) | (mm) | (mm) | (km/day) | (Degree) | | (mm/day) | | |
| Jan | 24.4 | -6.8 | 6.6 | 11.0 | 2.1 | 64.0 | 65.8 | | | 328.2 | 249.0 | 6.8 | 2.7 | | |
| Feb | 25.3 | -5.5 | 7.9 | 12.8 | 3.1 | 62.0 | 53.2 | | | 330.6 | 259.0 | 7.4 | 3.3 | | |
| Mar | 29.4 | -6.5 | 10.2 | 15.7 | 4.7 | 56.0 | 35.9 | | | 312.4 | 256.0 | 8.2 | 4.5 | | |
| Apr | 33.0 | 0.0 | 14.5 | 21.1 | 8.2 | 45.0 | 16.4 | | | 322.4 | 262.0 | 9.1 | 6.8 | | |
| May | 35.8 | 2.8 | 18.1 | 25.1 | 11.7 | 39.0 | 1.9 | | | 283.3 | 265.0 | 10.7 | 9.1 | | |
| Jun | 36.5 | 6.3 | 21.3 | 28.0 | 14.6 | 39.0 | 0.0 | | | 297.1 | 273.0 | 12.1 | 10.1 | | |
| Jul | 41.0 | 10.3 | 23.2 | 29.5 | 16.9 | 39.0 | 0.0 | | | 339.3 | 271.0 | 12.4 | 11.3 | | |
| Aug | 38.6 | 11.0 | 23.2 | 29.7 | 16.6 | 41.0 | 0.0 | | | 308.9 | 272.0 | 11.7 | 10.4 | | |
| Sep | 36.4 | 8.4 | 21.6 | 28.3 | 14.7 | 44.0 | 0.0 | | | 240.6 | 270.0 | 10.5 | 8.4 | | |
| Oct | 34.0 | 4.7 | 18.2 | 24.5 | 11.8 | 46.0 | 3.6 | | | 230.4 | 285.0 | 9.4 | 6.9 | | |
| Nov | 28.0 | -3.5 | 12.5 | 17.8 | 7.1 | 56.0 | 17.9 | | | 248.2 | 243.0 | 8.0 | 4.5 | | |
| Dec | 24.9 | -3.0 | 8.1 | 12.7 | 3.4 | 64.0 | 55.5 | | | 268.2 | 257.0 | 6.0 | 3.0 | | |
| Yearly | 41.0 | -6.8 | 15.5 | 21.4 | 9.6 | 49 | 250.2 | | | 292.5 | 261.0 | 9.4 | 6.8 | | |
| Period | 1973<br>1987 | 1973<br>1987 | 1973<br>1987 | 1973<br>1987 | 1973<br>1987 | 1973<br>1987 | 1973<br>1987 | | | 1973<br>1985 | 1983<br>1987 | 1973<br>1987 | 1973<br>1987 | | |

## Table A.2.1 (4/5) CLIMATOLOGICAL DATA

Station Name : Swaqa Evap Station
Agency in-charge : WAJ
Palestine ( North ) Grid : 86.800

Elevation ( m ) : 920
Palestine ( East ) Grid :253.700

| Month | Temperture | | | | | Average | Precipitation | | | Average | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Absolute | | Average | | | Relative | Average | Max. | Max. | Wind Run | Wind | Sunshine | Daily | Total | Radia- |
| | Max. (oC) | Min. (oC) | Mean (oC) | Max. (oC) | Min. (oC) | Humidity (%) | (mm) | Daily (mm) | Monthly (mm) | (m/sec) | Direction (Degree) | Hours | Evaporat. (mm/day) | Evaporat. | tion(cal. /cm2/d.) |
| Jan | 29.0 | -3.0 | 9.0 | 14.1 | 3.0 | 73 | 35.6 | 31.7 | 116.7 | 2.6 | E | 6.9 | 2.6 | | 350.3 |
| Feb | 31.0 | -3.0 | 10.4 | 17.8 | 3.5 | 70 | 15.9 | 36.0 | 80.5 | 2.8 | E | 8.0 | 4.2 | | 474.9 |
| Mar | 34.0 | -2.0 | 13.0 | 19.9 | 5.9 | 65 | 22.3 | 22.0 | 51.0 | 3.4 | E | 7.8 | 6.0 | | 595.9 |
| Apr | 39.9 | 0.0 | 17.1 | 25.2 | 9.3 | 55 | 12.5 | 17.0 | 57.4 | 3.2 | W | 9.2 | 8.2 | | 709.9 |
| May | 42.0 | 1.0 | 20.3 | 29.8 | 11.6 | 49 | 1.7 | 15.0 | 17.0 | 2.7 | W | 10.1 | 11.7 | | 807.1 |
| Jun | 44.2 | 8.0 | 23.3 | 32.3 | 14.3 | 46 | 0.0 | 0.0 | 0.0 | 3.2 | W | 10.2 | 13.0 | | 862.4 |
| Jul | 45.0 | 11.0 | 24.2 | 33.8 | 15.4 | 50 | 0.0 | 0.0 | 0.0 | 3.0 | W | 11.5 | 13.5 | | 868.0 |
| Aug | 41.0 | 11.0 | 23.7 | 33.4 | 14.6 | 53 | 0.0 | 0.0 | 0.0 | 2.4 | W | 11.6 | 13.2 | | 830.0 |
| Sep | 40.0 | 8.0 | 22.5 | 31.9 | 13.5 | 61 | 0.0 | 0.0 | 0.0 | 2.6 | W | 10.0 | 10.4 | | 728.8 |
| Oct | 37.0 | 3.0 | 19.3 | 28.4 | 10.7 | 63 | 24.8 | 13.1 | 24.8 | 2.5 | E | 9.4 | 7.5 | | 576.3 |
| Nov | 31.5 | 1.0 | 14.7 | 21.8 | 7.2 | 68 | 23.9 | 17.3 | 23.9 | 2.2 | E | 8.2 | 4.5 | | 406.2 |
| Dec | 28.5 | -6.0 | 10.2 | 16.8 | 4.0 | 74 | 75.8 | 28.0 | 75.8 | 2.5 | E | 6.6 | 3.2 | | 308.5 |
| Yearly | 45.0 | -6.0 | 17.3 | 25.4 | 9.4 | 61 | 16.1 | 36.0 | 116.7 | 2.8 | | 9.1 | 8.2 | | 623.5 |
| Period | 7 | 7 | 7 | 7 | 7 | 7 | 12 | 12 | 12 | 7 | 7 | 7 | 7 | | 7 |

## Table A.2.1 (5/5) CLIMATOLOGICAL DATA

Station Name : Hasa Evaporation Station
Agency in-charge : WAJ
PG North : 30.600

Elevation ( m ) : 900
PG East : 243.600

| Month | Temperture Absolute Max. (oC) | Temperture Absolute Min. (oC) | Temperture Mean (oC) | Temperture Average Max. (oC) | Temperture Average Min. (oC) | Average Relative Humidity (%) | Precipitation Average (mm) | Precipitation Max. Daily (mm) | Precipitation Max. Monthly (mm) | Average Wind Run (m/sec) | Average Wind Direction (Degree) | Sunshine Hours | Daily Evaporat. (mm/day) | Total Evaporat. | Radia-tion(cal. /cm2/d.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 28.0 | -5.0 | 8.9 | 14.1 | 2.8 | 73 | 12.4 | 20.9 | 33.9 | 3.5 | W | | 4.2 | | 450 |
| Feb | 29.0 | -9.0 | 11.6 | 17.8 | 5.4 | 70 | 9.2 | 28.0 | 43.7 | 3.5 | W | | 5.8 | | 593 |
| Mar | 35.0 | 1.0 | 13.8 | 19.9 | 7.7 | 60 | 10.1 | 18.0 | 24.9 | 4.4 | W | | 8.1 | | 709 |
| Apr | 38.0 | 1.0 | 18.4 | 25.2 | 11.5 | 54 | 3.0 | 12.8 | 18.3 | 4.6 | W | | 11.7 | | 808 |
| May | 42.0 | 7.0 | 22.3 | 29.8 | 14.7 | 45 | 1.1 | 8.0 | 9.2 | 4.5 | W | | 14.9 | | 897 |
| Jun | 41.0 | 11.0 | 24.5 | 32.3 | 16.8 | 46 | 0.0 | 0.0 | 0.0 | 5.2 | W | | 17.1 | | 939 |
| Jul | 45.0 | 7.0 | 26.2 | 33.8 | 18.5 | 47 | 0.0 | 0.0 | 0.0 | 5.1 | W | | 17.1 | | 939 |
| Aug | 44.0 | 11.0 | 25.8 | 33.4 | 18.2 | 50 | 0.0 | 0.0 | 0.0 | 4.7 | W | | 16.3 | | 886 |
| Sep | 40.0 | 10.0 | 24.2 | 31.9 | 16.4 | 59 | 0.0 | 0.0 | 0.0 | 4.1 | W | | 13.2 | | 844 |
| Oct | 38.0 | 3.0 | 21.2 | 28.4 | 14.0 | 61 | 2.4 | 22.4 | 22.7 | 3.2 | W | | 9.0 | | 695 |
| Nov | 33.0 | 1.0 | 15.5 | 21.8 | 9.4 | 65 | 8.2 | 17.2 | 28.6 | 2.8 | W | | 5.4 | | 542 |
| Dec | 31.0 | -6.0 | 11.3 | 16.8 | 5.8 | 73 | 11.5 | 29.8 | 52.0 | 3.1 | W | | 4.3 | | 441 |
| Yearly | 45.0 | -9.0 | 18.6 | 25.4 | 11.8 | 59 | 57.9 | 29.8 | 52.0 | 4.1 | | | 10.6 | | 729 |
| Period | 12 | 12 | 12 | 12 | 12 | 12 | 16 | 16 | 16 | 12 | 12 | | 12 | | 12 |

## Table A.3.1 (1/10) ANNUAL RAINFALL

| Hydro-year | Khan-zira CA2 | Aiy CA4 | Al-Aina CA5 | Muhai CA6 | Madaba CC1 | Ma'in CC2 | Sahab CD1 | Jiza CD5 | Wadi Wala CD6 | Dhiban CD7 | W. Mujib Gaug. St. CD8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1937 / 38 | - | - | - | - | 397.0 | - | - | 145.0 | - | 310.0 | - |
| 1938 / 39 | - | - | - | - | 397.0 | - | - | 302.0 | - | 246.0 | - |
| 1939 / 40 | - | - | - | - | 448.0 | - | - | 174.0 | - | 355.0 | - |
| 1940 / 41 | - | - | - | - | 257.0 | - | - | 710.0 | - | 203.0 | - |
| 1941 / 42 | - | - | - | - | 550.0 | - | - | 268.0 | - | 463.0 | - |
| 1942 / 43 | - | - | - | - | 452.0 | - | - | 205.0 | - | 314.0 | - |
| 1943 / 44 | - | - | - | - | 295.0 | - | - | 128.0 | - | 295.0 | - |
| 1944 / 45 | - | - | - | - | 616.0 | - | - | 393.0 | - | 480.0 | - |
| 1945 / 46 | 489.0 | - | - | - | 350.0 | - | - | - | - | 263.0 | - |
| 1946 / 47 | 189.0 | - | - | - | 170.0 | - | - | 59.0 | - | 104.0 | - |
| 1947 / 48 | 279.0 | - | - | - | 350.0 | - | - | - | - | 243.0 | - |
| 1948 / 49 | 406.0 | - | - | - | 500.0 | - | - | - | - | 468.0 | - |
| 1949 / 50 | 313.0 | - | - | - | 640.0 | - | - | - | - | 370.0 | - |
| 1950 / 51 | - | - | - | - | 204.0 | - | - | - | - | 172.0 | - |
| 1951 / 52 | 419.0 | - | - | - | 472.0 | - | - | 308.0 | - | 490.0 | - |
| 1952 / 53 | 209.0 | - | - | - | 309.0 | - | - | 94.0 | - | 194.0 | 77.0 |
| 1953 / 54 | 485.0 | - | - | - | 415.0 | - | - | 360.0 | - | 352.0 | 143.0 |
| 1954 / 55 | 292.0 | - | - | - | 221.0 | - | - | 203.0 | 103.0 | 173.0 | 108.0 |
| 1955 / 56 | 370.0 | - | - | - | 417.0 | - | - | 170.0 | - | 334.0 | 232.0 |
| 1956 / 57 | 540.0 | - | - | - | 518.0 | - | - | 310.0 | - | 363.0 | 263.0 |
| 1957 / 58 | 138.0 | - | - | - | 158.0 | - | 157.0 | 117.0 | - | 102.0 | 75.0 |
| 1958 / 59 | 382.0 | - | - | - | 268.0 | - | 226.0 | 220.0 | - | 247.0 | 144.0 |
| 1959 / 60 | - | - | - | - | 141.0 | - | - | 99.0 | - | 130.0 | 56.0 |
| 1960 / 61 | 331.0 | - | - | - | 324.0 | - | 212.0 | 258.0 | - | 244.0 | 168.0 |
| 1961 / 62 | 265.0 | - | - | - | 336.0 | - | 290.0 | 223.0 | 196.0 | 200.0 | 138.0 |
| 1962 / 63 | 118.0 | - | - | - | 136.0 | - | 137.0 | 105.0 | 107.0 | 114.0 | 77.0 |
| 1963 / 64 | 553.0 | 447.0 | - | - | 513.0 | - | 364.0 | 249.0 | - | 286.0 | 261.0 |
| 1964 / 65 | 793.0 | 641.0 | - | - | 452.0 | - | 314.0 | 273.0 | 317.0 | 338.0 | 267.0 |
| 1965 / 66 | 326.0 | 364.0 | - | - | 226.0 | - | 218.0 | 188.0 | 151.0 | 130.0 | 109.0 |
| 1966 / 67 | 400.0 | 322.0 | - | - | 447.0 | - | 520.0 | 335.0 | 340.0 | - | - |
| 1967 / 68 | 231.0 | 303.0 | 210.0 | 122.0 | 351.0 | - | 234.0 | 154.0 | 243.0 | 292.0 | - |
| 1968 / 69 | 234.0 | 337.0 | - | 119.0 | 475.0 | 587.0 | 419.0 | 239.0 | 338.0 | 354.0 | 217.0 |
| 1969 / 70 | 174.0 | 243.0 | - | 78.0 | 225.0 | 270.0 | 152.0 | 108.0 | 161.0 | 171.0 | 99.0 |
| 1970 / 71 | 281.0 | 320.0 | - | 130.0 | 311.0 | 379.0 | - | 256.0 | 377.0 | 347.0 | 204.0 |
| 1971 / 72 | 387.0 | - | - | 179.0 | 352.0 | 502.0 | 250.0 | 210.0 | 364.0 | 399.0 | 270.0 |
| 1972 / 73 | 114.0 | - | - | 84.0 | 143.0 | 245.0 | 141.0 | 104.0 | 150.0 | 150.0 | 74.0 |
| 1973 / 74 | 336.0 | 469.0 | - | 239.0 | 339.0 | 575.0 | 379.0 | 256.0 | 450.0 | 446.0 | - |
| 1974 / 75 | 283.0 | 356.0 | - | 190.0 | 190.0 | 337.0 | 192.0 | 142.0 | 243.0 | 263.0 | - |
| 1975 / 76 | 153.0 | 175.0 | - | 65.0 | 190.0 | 172.0 | 240.0 | 102.0 | 130.0 | 133.0 | - |
| 1976 / 77 | 141.5 | 184.6 | - | 139.7 | 284.3 | 162.5 | 198.5 | 82.0 | 205.8 | 232.4 | - |
| 1977 / 78 | 195.4 | 233.8 | - | 121.8 | 265.4 | 231.6 | - | 126.5 | 237.1 | 247.0 | - |
| 1978 / 79 | 196.7 | 145.7 | - | 83.6 | 136.5 | 201.0 | - | 104.5 | 179.5 | 193.9 | - |
| 1979 / 80 | 286.3 | 384.8 | - | 242.8 | 514.0 | 527.6 | - | - | 440.8 | 412.1 | - |

Table A.3.1 (2/10) ANNUAL RAINFALL

| Hydro-year | Khan-zira CA2 | Aiy CA4 | Al-Aina CA5 | Muhai CA6 | Madaba CC1 | Ma'in CC2 | Sahab CD1 | Jiza CD5 | Wadi Wala CD6 | Dhiban CD7 | W. Mujib Gaug. St. CD8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1980 / 81 | 180.6 | 314.5 | - | 53.4 | 388.0 | 96.6 | - | - | 268.6 | 113.5 | - |
| 1981 / 82 | 369.8 | 196.0 | - | 91.8 | 55.9 | - | - | 57.0 | 184.5 | 213.0 | - |
| 1982 / 83 | 467.0 | 478.2 | - | 211.6 | 330.0 | 242.3 | - | 157.0 | 388.8 | 304.0 | - |
| 1983 / 84 | 132.0 | 144.0 | - | 99.4 | 111.8 | 110.0 | - | 100.0 | 151.0 | 174.3 | - |
| 1984 / 85 | 275.3 | 311.1 | - | 110.2 | 351.0 | - | - | 28.0 | 335.0 | 242.0 | - |
| 1985 / 86 | 262.8 | 162.7 | - | 84.6 | 182.1 | 123.0 | - | 54.0 | 137.0 | 110.3 | - |
| 1986 / 87 | 238.5 | 227.3 | - | 94.9 | 331.7 | 271.6 | - | 111.1 | 246.0 | 206.6 | - |
| 1987 / 88 | 460.9 | 456.6 | - | 230.4 | 440.7 | 419.7 | - | 193.0 | 330.1 | 455.3 | - |
| 1988 / 89 | 254.6 | 278.9 | - | 187.1 | 252.9 | 310.5 | - | 73.5 | 248.4 | 331.3 | - |
| Data Nos. | 42 | 24 | 1 | 22 | 52 | 19 | 18 | 45 | 28 | 51 | 19 |
| Max. | 793.0 | 641.0 | - | 242.8 | 640.0 | 587.0 | 520.0 | 710.0 | 450.0 | 490.0 | 270.0 |
| Min. | 114.0 | 144.0 | - | 53.4 | 55.9 | 96.6 | 137.0 | 28.0 | 103.0 | 102.0 | 56.0 |
| Ann.Avg. | 308.4 | 312.3 | 210.0 | 134.4 | 330.8 | 303.3 | 258.0 | 190.1 | 250.8 | 270.1 | 156.9 |
| Std.Dev. | 138.8 | 121.8 | 0.0 | 57.9 | 135.6 | 152.0 | 102.2 | 118.4 | 100.0 | 109.3 | 73.9 |
| Vari. Coef | 0.45 | 0.39 | | 0.43 | 0.41 | 0.50 | 0.40 | 0.62 | 0.40 | 0.40 | 0.47 |

## Table A.3.1 (3/10) ANNUAL RAINFALL

| Hydro-year | Hemud CD9 | Rabba CD10 | Qatrana P. Post CD11 | Bir Hafira CD12 | Mazar CD13 | Dhab'a Nursery CD15 | Judayda CD16 | Um El-Risas CD17 | Khan Ez Zabeeb CD18 | Jad'A CD19 | Siwaqa Evap.St CD20 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1937 / 38 | 316.0 | - | 101.0 | | 414.0 | - | - | - | - | - | - |
| 1938 / 39 | 326.0 | - | 106.0 | 83.0 | 477.0 | - | - | - | - | - | - |
| 1939 / 40 | 383.0 | - | 168.0 | 116.0 | 440.0 | - | - | - | - | - | - |
| 1940 / 41 | 271.0 | - | 81.0 | 57.0 | 363.0 | - | - | - | - | - | - |
| 1941 / 42 | 493.0 | - | 102.0 | - | 491.0 | - | - | - | - | - | - |
| 1942 / 43 | 323.0 | - | 98.0 | 44.0 | 440.0 | - | - | - | - | - | - |
| 1943 / 44 | 335.0 | - | 125.0 | - | 441.0 | - | - | - | - | - | - |
| 1944 / 45 | 390.0 | - | 142.0 | - | 483.0 | - | - | - | - | - | - |
| 1945 / 46 | 307.0 | - | 99.0 | - | 426.0 | - | - | - | - | - | - |
| 1946 / 47 | 171.0 | - | 32.0 | - | 171.0 | - | - | - | - | - | - |
| 1947 / 48 | 266.0 | - | 103.0 | - | 454.0 | - | - | - | - | - | - |
| 1948 / 49 | 446.0 | - | 122.0 | - | 382.0 | - | - | - | - | - | - |
| 1949 / 50 | 333.0 | - | 142.0 | - | 232.0 | - | - | - | - | - | - |
| 1950 / 51 | 170.0 | - | 67.0 | - | 278.0 | - | - | - | - | - | - |
| 1951 / 52 | 434.0 | 478.0 | 135.0 | - | 457.0 | - | - | - | - | - | - |
| 1952 / 53 | 159.0 | 206.0 | 90.0 | - | 228.0 | - | - | - | - | - | - |
| 1953 / 54 | 245.0 | 341.0 | 80.0 | - | 396.0 | - | - | - | - | - | - |
| 1954 / 55 | 188.0 | 241.0 | 94.0 | - | 267.0 | - | - | - | - | - | - |
| 1955 / 56 | 367.0 | 481.0 | 120.0 | - | 289.0 | - | - | - | - | - | - |
| 1956 / 57 | 420.0 | 486.0 | 190.0 | - | | - | - | - | - | - | - |
| 1957 / 58 | 134.0 | 191.0 | 88.0 | - | 138.0 | - | - | - | - | - | - |
| 1958 / 59 | 287.0 | 320.0 | 72.0 | - | 260.0 | - | - | - | - | - | - |
| 1959 / 60 | 131.0 | 136.0 | 47.0 | - | 198.0 | - | - | - | - | - | - |
| 1960 / 61 | 262.0 | 329.0 | 115.0 | - | 328.0 | - | - | - | - | - | - |
| 1961 / 62 | 190.0 | 218.0 | 97.0 | - | 244.0 | - | - | - | - | - | - |
| 1962 / 63 | 122.0 | 152.0 | 54.0 | - | 120.0 | | - | 82.0 | 58.0 | 156.0 | - |
| 1963 / 64 | 687.0 | 440.0 | 224.0 | - | 461.0 | 176.0 | 513.0 | 225.0 | 138.0 | 454.0 | 127.0 |
| 1964 / 65 | 688.0 | 618.0 | 158.0 | - | 610.0 | - | 364.0 | 448.0 | 233.0 | 570.0 | 147.0 |
| 1965 / 66 | 228.0 | - | 67.0 | - | 243.0 | - | 185.0 | 87.0 | - | 103.0 | 90.0 |
| 1966 / 67 | 263.0 | 362.0 | 78.0 | - | 359.0 | - | 301.0 | 263.0 | 180.0 | 442.0 | 147.0 |
| 1967 / 68 | 327.0 | 378.0 | 102.0 | - | 268.0 | 215.0 | 204.0 | - | 205.0 | 263.0 | 111.0 |
| 1968 / 69 | 267.0 | 247.0 | 86.0 | - | 247.0 | 235.0 | 348.0 | - | 192.0 | 374.0 | 121.0 |
| 1969 / 70 | 206.0 | 271.0 | 56.0 | - | 202.0 | 140.0 | 222.0 | 95.0 | - | 204.0 | 72.0 |
| 1970 / 71 | 331.0 | 377.0 | 116.0 | - | 314.0 | - | 325.0 | 189.0 | 132.0 | 410.0 | 111.0 |
| 1971 / 72 | 405.0 | 463.0 | 139.0 | - | 426.0 | - | 426.0 | - | - | 485.0 | 180.0 |
| 1972 / 73 | 181.0 | 214.0 | 23.0 | - | 136.0 | - | - | 59.0 | 55.0 | 131.0 | 60.0 |
| 1973 / 74 | 518.0 | 515.0 | - | - | 353.0 | 280.0 | - | 239.0 | 263.0 | 481.0 | 187.0 |
| 1974 / 75 | 306.0 | 311.0 | 151.0 | - | 307.0 | 165.0 | 320.0 | 156.0 | 154.0 | 291.0 | 134.0 |
| 1975 / 76 | 178.0 | 256.0 | 83.0 | - | 162.0 | 100.0 | 146.0 | 85.0 | 106.0 | 178.0 | - |
| 1976 / 77 | 196.7 | 276.4 | 47.3 | - | 215.6 | 117.1 | - | - | 87.0 | 289.4 | - |
| 1977 / 78 | 241.1 | 258.7 | 86.8 | - | 188.8 | 128.5 | 188.4 | 238.0 | 104.1 | 329.0 | - |
| 1978 / 79 | 204.3 | 240.1 | 56.8 | - | 300.0 | 76.8 | 190.0 | 99.7 | - | 203.6 | - |
| 1979 / 80 | 534.2 | 580.0 | 59.3 | - | 382.3 | 224.9 | - | 373.8 | - | - | - |

Table A.3.1 (4/10) ANNUAL RAINFALL

| Hydro-year | Hemud CD9 | Rabba CD10 | Qatrana P. Post CD11 | Bir Hafira CD12 | Mazar CD13 | Dhab'a Nursery CD15 | Judayda CD16 | Um El-Risas CD17 | Khan Ez Zabeeb CD18 | Jad'A CD19 | Siwaqa Evap. St CD20 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1980 / 81 | 237.5 | 76.9 | 98.2 | - | 463.3 | 119.7 | - | 167.4 | - | - | - |
| 1981 / 82 | 132.3 | 253.3 | 29.1 | - | 167.4 | 116.3 | 198.0 | 37.1 | - | - | - |
| 1982 / 83 | 369.7 | 480.4 | 105.8 | - | 249.2 | 180.5 | 219.0 | 287.0 | - | 284.5 | - |
| 1983 / 84 | 131.8 | 113.7 | 52.0 | - | 152.9 | 74.5 | 139.2 | 147.0 | - | 169.0 | - |
| 1984 / 85 | 312.6 | 345.3 | - | - | 309.9 | 191.6 | 120.3 | 211.0 | - | 340.8 | - |
| 1985 / 86 | 156.5 | 195.4 | 64.5 | - | 171.7 | 82.4 | - | - | - | 135.0 | - |
| 1986 / 87 | 225.3 | 291.6 | 122.8 | - | 212.7 | 145.4 | 133.2 | 221.7 | - | 305.9 | - |
| 1987 / 88 | 312.0 | 430.1 | 124.1 | - | 512.5 | 186.5 | 318.0 | 138.0 | - | 345.8 | - |
| 1988 / 89 | 295.0 | 372.7 | 114.4 | - | 375.0 | 113.7 | 228.5 | 129.5 | - | 343.2 | - |
| Data Nos. | 52 | 37 | 50 | 4 | 51 | 20 | 20 | 22 | 13 | 24 | 12 |
| Max. | 688.0 | 618.0 | 224.0 | 116.0 | 610.0 | 280.0 | 513.0 | 448.0 | 263.0 | 570.0 | 187.0 |
| Min. | 122.0 | 76.9 | 23.0 | 44.0 | 120.0 | 74.5 | 120.3 | 37.1 | 55.0 | 103.0 | 60.0 |
| Ann. Avg. | 296.2 | 322.9 | 98.3 | 75.0 | 317.8 | 153.4 | 254.4 | 180.8 | 146.7 | 303.7 | 123.9 |
| Std. Dev. | 128.7 | 129.8 | 40.3 | 27.5 | 118.9 | 55.6 | 103.0 | 100.3 | 62.8 | 125.0 | 37.2 |
| Vari. Coef | 0.43 | 0.40 | 0.41 | 0.37 | 0.37 | 0.36 | 0.40 | 0.55 | 0.43 | 0.41 | 0.30 |

## Table A.3.1 (5/10) ANNUAL RAINFALL

| Hydro-year | Manzil . CD21 | Qasr El-Musheish CD22 | Qasr Evap.St. CD23 | Zeituna Evap.St. CD26 | Muleih CD28 | Sirfa CD29 | J. Abu Hilufa CD30 | Wadi El-Jinz CD31 | J.Sak-hriyat CD33 | Qatrana Evap.St. CD34 | Rakin CE1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1937 / 38 | - | - | - | - | - | - | - | - | - | - | - |
| 1938 / 39 | - | - | - | - | - | - | - | - | - | - | - |
| 1939 / 40 | - | - | - | - | - | - | - | - | - | - | - |
| 1940 / 41 | - | - | - | - | - | - | - | - | - | - | - |
| 1941 / 42 | - | - | - | - | - | - | - | - | - | - | - |
| 1942 / 43 | - | - | - | - | - | - | - | - | - | - | - |
| 1943 / 44 | - | - | - | - | - | - | - | - | - | - | - |
| 1944 / 45 | - | - | - | - | - | - | - | - | - | - | - |
| 1945 / 46 | - | - | - | - | - | - | - | - | - | - | - |
| 1946 / 47 | - | - | - | - | - | - | - | - | - | - | - |
| 1947 / 48 | - | - | - | - | - | - | - | - | - | - | - |
| 1948 / 49 | - | - | - | - | - | - | - | - | - | - | - |
| 1949 / 50 | - | - | - | - | - | - | - | - | - | - | - |
| 1950 / 51 | - | - | - | - | - | - | - | - | - | - | - |
| 1951 / 52 | - | - | - | - | - | - | - | - | - | - | - |
| 1952 / 53 | - | - | - | - | - | - | - | - | - | - | - |
| 1953 / 54 | - | - | - | - | - | - | - | - | - | - | - |
| 1954 / 55 | - | - | - | - | - | - | - | - | - | - | - |
| 1955 / 56 | - | - | - | - | - | - | - | - | - | - | - |
| 1956 / 57 | - | - | - | - | - | - | - | - | - | - | - |
| 1957 / 58 | - | - | - | - | - | - | - | - | - | - | - |
| 1958 / 59 | - | - | - | - | - | - | - | - | - | - | 239.0 |
| 1959 / 60 | - | - | - | - | - | - | - | - | - | - | 85.0 |
| 1960 / 61 | - | - | - | - | - | - | - | - | - | - | 251.0 |
| 1961 / 62 | - | - | - | - | - | - | - | - | - | - | 221.0 |
| 1962 / 63 | 46.0 | 48.0 | | - | - | - | - | - | - | - | 99.0 |
| 1963 / 64 | 78.0 | - | 445.0 | - | - | - | - | - | - | - | 490.0 |
| 1964 / 65 | 139.0 | - | 444.0 | - | - | - | - | - | - | - | 557.0 |
| 1965 / 66 | - | - | 200.0 | - | - | - | - | - | - | - | 257.0 |
| 1966 / 67 | - | - | 308.0 | - | - | - | - | - | - | - | 386.0 |
| 1967 / 68 | - | - | - | - | - | 285.0 | 55.0 | - | - | - | 364.0 |
| 1968 / 69 | - | - | 307.0 | 330.0 | - | - | 58.0 | 4.0 | 36.0 | - | 309.0 |
| 1969 / 70 | - | - | 267.0 | 188.0 | 134.0 | 195.0 | - | - | 15.0 | - | 267.0 |
| 1970 / 71 | - | - | 421.0 | 305.0 | 371.0 | 424.0 | 68.0 | - | 55.0 | 88.0 | 376.0 |
| 1971 / 72 | - | - | 504.0 | 293.0 | | | 119.0 | - | - | 167.0 | 532.0 |
| 1972 / 73 | - | - | 193.0 | 152.0 | 134.0 | 172.0 | 42.0 | - | - | 31.0 | 150.0 |
| 1973 / 74 | - | - | 504.0 | 383.0 | 446.0 | 661.0 | 95.0 | 79.0 | - | 163.0 | - |
| 1974 / 75 | - | - | 343.0 | 208.0 | 206.0 | 313.0 | 120.0 | 98.0 | - | 121.0 | 316.0 |
| 1975 / 76 | - | - | 236.0 | 162.0 | 103.0 | 200.0 | 58.0 | 55.0 | - | - | 207.0 |
| 1976 / 77 | - | - | 282.4 | 195.7 | 194.0 | 240.3 | 36.4 | 29.0 | - | - | 217.4 |
| 1977 / 78 | - | - | 249.4 | 188.7 | 183.9 | 326.1 | - | - | - | 99.0 | 270.5 |
| 1978 / 79 | - | - | 219.1 | 132.5 | 158.0 | 280.7 | - | - | - | 56.7 | 273.5 |
| 1979 / 80 | - | - | 636.9 | 475.9 | 386.8 | 646.8 | 51.8 | 153.8 | - | - | 486.1 |

Table A.3.1 (6/10) ANNUAL RAINFALL

| Hydro-year | Manzil . CD21 | Qasr El-Musheish CD22 | Qasr Evap.St. CD23 | Zeituna Evap.St. CD26 | Muleih CD28 | Sirfa CD29 | J. Abu Hllufa CD30 | Wadi El-Jinz CD31 | J.Sak-hriyat CD33 | Qatrana Evap.St. CD34 | Rakin CE1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1980 / 81 | - | 168.0 | 349.7 | 247.7 | 222.8 | 339.8 | 82.8 | 86.0 | 72.6 | 110.0 | 233.3 |
| 1981 / 82 | - | 108.5 | 308.2 | 69.2 | 113.4 | 208.9 | 97.8 | 66.4 | - | 32.5 | 175.2 |
| 1982 / 83 | - | 161.1 | 512.8 | 352.3 | 190.0 | 477.3 | 67.2 | 63.4 | 73.8 | 75.7 | 469.3 |
| 1983 / 84 | - | 129.5 | 224.2 | 149.2 | 153.6 | 160.6 | 43.8 | 9.0 | 10.6 | - | 133.9 |
| 1984 / 85 | - | 143.9 | 317.2 | 34.4 | 257.2 | 286.8 | 47.0 | 43.4 | 41.8 | 69.7 | 330.9 |
| 1985 / 86 | - | 41.4 | - | 237.0 | 87.1 | 172.9 | 67.2 | 56.6 | - | closed | 101.3 |
| 1986 / 87 | - | 34.6 | - | 356.1 | 147.3 | 320.0 | 77.4 | 24.0 | 33.4 | - | 221.7 |
| 1987 / 88 | - | 64.6 | - | 464.0 | 305.9 | 431.9 | 122.6 | - | 95.6 | - | 315.8 |
| 1988 / 89 | - | 47.8 | - | - | 256.6 | 400.8 | 96.4 | - | - | - | 189.9 |
| Data Nos. | 3 | 10 | 21 | 20 | 19 | 20 | 19 | 13 | 9 | 11 | 30 |
| Max. | 139.0 | 168.0 | 636.9 | 475.9 | 446.0 | 661.0 | 122.6 | 153.8 | 95.6 | 167.0 | 557.0 |
| Min. | 46.0 | 34.6 | 193.0 | 34.4 | 87.1 | 160.6 | 36.4 | 4.0 | 10.6 | 31.0 | 85.0 |
| Ann.Avg. | 87.7 | 94.7 | 346.3 | 246.2 | 213.2 | 327.1 | 74.0 | 59.0 | 48.2 | 92.1 | 284.2 |
| Std.Dev. | 38.6 | 50.3 | 119.5 | 118.4 | 98.7 | 141.2 | 26.8 | 38.9 | 26.8 | 43.9 | 126.1 |
| Vari. Coef | 0.44 | 0.53 | 0.35 | 0.48 | 0.46 | 0.43 | 0.36 | 0.66 | 0.56 | 0.48 | 0.44 |

## Table A.3.1 (7/10) ANNUAL RAINFALL

| Hydro-year | Ain Bisas CE2 | Karak CE4 | Jurf Ed-Darawish CF3 | La'aban CF4 | Hasa P. Post CF5 | Hasa E. Station CF7 | Hasa G. Station CF8 | Ifjeij DA4 | Uneiza Rw. Sta. DA5 | Tafila DB1 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1937 / 38 | - | 408.0 | 102.0 | - | - | - | - | - | - | 354.0 |
| 1938 / 39 | - | 424.0 | 82.0 | - | - | - | - | - | - | 325.0 |
| 1939 / 40 | - | 522.0 | - | - | - | - | - | - | - | 327.0 |
| 1940 / 41 | - | 398.0 | - | - | - | - | - | - | - | 209.0 |
| 1941 / 42 | - | 541.0 | - | - | - | - | - | - | - | 306.0 |
| 1942 / 43 | - | 447.0 | 61.0 | - | - | - | - | - | - | 323.0 |
| 1943 / 44 | - | 403.0 | 90.0 | - | - | - | - | - | - | 346.0 |
| 1944 / 45 | - | 524.0 | 103.0 | - | - | - | - | - | - | 464.0 |
| 1945 / 46 | - | 358.0 | 53.0 | 150.0 | - | - | - | - | - | 324.0 |
| 1946 / 47 | - | 123.0 | 26.0 | 59.0 | - | - | - | - | - | 131.0 |
| 1947 / 48 | - | 293.0 | - | 134.0 | - | - | - | - | - | 267.0 |
| 1948 / 49 | - | 464.0 | 41.0 | 64.0 | - | - | - | - | - | 268.0 |
| 1949 / 50 | - | 280.0 | 142.0 | 149.0 | - | - | - | - | - | 380.0 |
| 1950 / 51 | - | 215.0 | 109.0 | 117.0 | - | - | - | - | - | 269.0 |
| 1951 / 52 | 455.0 | 500.0 | 57.0 | 138.0 | - | - | - | - | - | 304.0 |
| 1952 / 53 | 207.0 | 215.0 | 57.0 | 30.0 | - | - | - | - | - | 106.0 |
| 1953 / 54 | 290.0 | 360.0 | 36.0 | 58.0 | - | - | - | - | - | 301.0 |
| 1954 / 55 | 308.0 | 230.0 | 48.0 | 78.0 | - | - | - | - | - | 150.0 |
| 1955 / 56 | 486.0 | 452.0 | 88.0 | 165.0 | - | - | - | - | - | 215.0 |
| 1956 / 57 | | 414.0 | 116.0 | 112.0 | - | - | - | - | - | 263.0 |
| 1957 / 58 | 164.0 | 156.0 | 34.0 | - | - | - | - | - | - | 89.0 |
| 1958 / 59 | 283.0 | 282.0 | 43.0 | 97.0 | - | - | - | - | - | 384.0 |
| 1959 / 60 | 147.0 | 145.0 | 48.0 | 50.0 | - | - | - | - | - | 87.0 |
| 1960 / 61 | 333.0 | 273.0 | 32.0 | 104.0 | - | - | - | - | - | 204.0 |
| 1961 / 62 | 225.0 | 210.0 | 79.0 | 242.0 | - | - | - | - | - | 136.0 |
| 1962 / 63 | 115.0 | 102.0 | 51.0 | 34.0 | - | - | - | - | - | 84.0 |
| 1963 / 64 | 498.0 | 496.0 | 55.0 | 180.0 | - | - | - | 441.0 | 157.0 | 617.0 |
| 1964 / 65 | 643.0 | 661.0 | 99.0 | 225.0 | 87.0 | - | - | - | 164.0 | 751.0 |
| 1965 / 66 | 275.0 | 321.0 | 67.0 | - | 28.0 | - | - | 119.0 | 87.0 | 167.0 |
| 1966 / 67 | 372.0 | 438.0 | 59.0 | - | 79.0 | - | - | 277.0 | 110.0 | 343.0 |
| 1967 / 68 | 357.0 | 387.0 | 64.0 | - | 106.0 | 105.0 | - | 190.0 | 55.0 | 282.0 |
| 1968 / 69 | 336.0 | 359.0 | 49.0 | - | - | 26.0 | 146.0 | 201.0 | 113.0 | 295.0 |
| 1969 / 70 | 232.0 | 291.0 | 43.0 | - | 16.0 | 33.0 | 82.0 | 121.0 | 18.0 | 132.0 |
| 1970 / 71 | 314.0 | 357.0 | 46.0 | - | 50.0 | 53.0 | - | 239.0 | - | 257.0 |
| 1971 / 72 | 588.0 | 606.0 | 75.0 | - | 93.0 | 159.0 | 312.0 | 290.0 | - | 439.0 |
| 1972 / 73 | 166.0 | 187.0 | 11.0 | - | 27.0 | 23.0 | 84.0 | 80.0 | - | 82.0 |
| 1973 / 74 | 509.0 | 509.0 | 57.0 | - | 69.0 | 61.0 | 226.0 | 256.0 | - | 403.0 |
| 1974 / 75 | 337.0 | 364.0 | 65.0 | - | 76.0 | 82.0 | 186.0 | 192.0 | - | 339.0 |
| 1975 / 76 | 180.0 | 202.0 | 30.0 | - | 51.0 | - | - | 94.0 | - | 139.0 |
| 1976 / 77 | 202.0 | 255.5 | 30.3 | - | - | 28.8 | - | - | - | 243.6 |
| 1977 / 78 | 243.1 | 302.0 | 53.0 | - | - | 62.7 | - | 124.9 | - | 168.9 |
| 1978 / 79 | 231.7 | 325.5 | 37.0 | - | - | - | 93.7 | 140.9 | - | 188.5 |
| 1979 / 80 | 478.1 | 619.4 | 89.3 | - | - | - | 237.5 | 173.0 | - | 366.7 |

## Table A.3.1 (8/10) ANNUAL RAINFALL

| Hydro-year | Ain Bisas CE2 | Karak CE4 | Jurf Ed-Darawish CF3 | La'aban CF4 | Hasa P. Post CF5 | Hasa E. Station CF7 | Hasa G. Station CF8 | Ifjeij DA4 | Uneiza Rw. Sta. DA5 | Tafila DB1 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1980 / 81 | 280.5 | 425.7 | 59.7 | - | - | 58.6 | - | 172.2 | - | 316.4 |
| 1981 / 82 | 141.0 | 195.7 | - | - | - | 60.3 | - | 159.4 | - | 175.1 |
| 1982 / 83 | 498.7 | 528.4 | 55.8 | - | - | 83.2 | 205.9 | 212.3 | - | 353.0 |
| 1983 / 84 | 187.9 | 201.1 | - | - | - | 28.5 | 98.7 | 58.3 | - | 94.7 |
| 1984 / 85 | 258.9 | 327.2 | 38.8 | - | - | 50.3 | 97.9 | 111.1 | - | 201.7 |
| 1985 / 86 | 156.4 | 232.9 | 65.7 | - | - | 71.3 | - | - | - | 228.0 |
| 1986 / 87 | 298.4 | 356.9 | 15.3 | - | - | 57.5 | 101.2 | - | - | 211.2 |
| 1987 / 88 | 389.6 | 452.0 | 106.9 | - | - | - | 221.6 | - | - | 370.3 |
| 1988 / 89 | 295.3 | 331.4 | 156.7 | - | 238.4 | - | - | - | - | 263.4 |
| Data Nos. | 37 | 52 | 46 | 19 | 12 | 17 | 13 | 20 | 7 | 52 |
| Max. | 643.0 | 661.0 | 156.7 | 242.0 | 238.4 | 159.0 | 312.0 | 441.0 | 164.0 | 751.0 |
| Min. | 115.0 | 102.0 | 11.0 | 30.0 | 16.0 | 23.0 | 82.0 | 58.3 | 18.0 | 82.0 |
| Ann.Avg. | 310.3 | 355.2 | 63.6 | 115.1 | 76.7 | 61.4 | 161.0 | 182.6 | 100.6 | 270.1 |
| Std.Dev. | 131.1 | 132.6 | 31.0 | 59.4 | 55.8 | 32.8 | 72.1 | 86.5 | 48.6 | 129.2 |
| Vari. Coef | 0.42 | 0.37 | 0.49 | 0.52 | 0.73 | 0.54 | 0.45 | 0.47 | 0.48 | 0.48 |

## Table A.3.1 (9/10) ANNUAL RAINFALL

| Hydro-year | Prince Nursery DB2 | Buseira DC1 | Rasha-diya DC2 | Ain Lahban DD1 | Dhana DE1 | Qasr Tuba F12 | J. Mud-aysisat F19 | Jabel Quzemeh G11 | Qabr Es-Saww G12 | Bayir Evap. S J1 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1937 / 38 | - | 408.0 | - | - | - | - | - | - | - | 23.0 |
| 1938 / 39 | - | 328.0 | - | - | - | - | - | - | - | 82.0 |
| 1939 / 40 | - | 358.0 | - | - | - | - | - | - | - | 48.0 |
| 1940 / 41 | - | 230.0 | - | - | - | - | - | - | - | - |
| 1941 / 42 | - | 401.0 | - | - | - | - | - | - | - | - |
| 1942 / 43 | - | 340.0 | - | - | - | - | - | - | - | - |
| 1943 / 44 | - | 327.0 | - | - | - | - | - | - | - | - |
| 1944 / 45 | - | 416.0 | - | - | - | - | - | - | - | - |
| 1945 / 46 | - | 274.0 | 264.0 | - | 344.0 | - | - | - | - | - |
| 1946 / 47 | - | 149.0 | 168.0 | - | 179.0 | - | - | - | - | - |
| 1947 / 48 | - | 249.0 | 244.0 | - | 263.0 | - | - | - | - | 5.0 |
| 1948 / 49 | - | 269.0 | 127.0 | - | 230.0 | - | - | - | - | 2.0 |
| 1949 / 50 | - | 358.0 | 352.0 | - | 360.0 | - | - | - | - | 38.0 |
| 1950 / 51 | - | 270.0 | 277.0 | 358.0 | 223.0 | - | - | - | - | - |
| 1951 / 52 | - | 293.0 | 263.0 | 421.0 | 402.0 | - | - | - | - | 223.0 |
| 1952 / 53 | - | 132.0 | - | 155.0 | 101.0 | - | - | - | - | 61.0 |
| 1953 / 54 | - | 311.0 | 288.0 | 429.0 | 310.0 | - | - | - | - | 53.0 |
| 1954 / 55 | - | 260.0 | 240.0 | 313.0 | 221.0 | - | - | - | - | 70.0 |
| 1955 / 56 | - | 282.0 | 295.0 | 334.0 | 258.0 | - | - | - | - | 28.0 |
| 1956 / 57 | - | 346.0 | 339.0 | 387.0 | 282.0 | - | - | - | - | 34.0 |
| 1957 / 58 | - | 98.0 | 163.0 | 126.0 | 60.0 | - | - | - | - | 16.0 |
| 1958 / 59 | - | 264.0 | 286.0 | 301.0 | 281.0 | - | - | - | - | 16.0 |
| 1959 / 60 | - | 161.0 | 136.0 | 172.0 | 126.0 | - | - | - | - | 8.0 |
| 1960 / 61 | - | 237.0 | 244.0 | 278.0 | 188.0 | - | - | - | - | 42.0 |
| 1961 / 62 | - | 217.0 | 211.0 | 240.0 | 133.0 | - | - | - | - | 58.0 |
| 1962 / 63 | - | 84.0 | 93.0 | 90.0 | 56.0 | - | - | - | - | 77.0 |
| 1963 / 64 | - | 577.0 | 638.0 | 655.0 | 580.0 | - | - | - | - | 32.0 |
| 1964 / 65 | - | 730.0 | 485.0 | 560.0 | 520.0 | - | - | - | - | 41.0 |
| 1965 / 66 | - | 162.0 | - | 196.0 | 163.0 | - | - | - | - | 67.0 |
| 1966 / 67 | - | 336.0 | 350.0 | 361.0 | 277.0 | - | - | - | - | 82.0 |
| 1967 / 68 | 127.0 | 315.0 | 100.0 | closed | 283.0 | - | - | - | - | 33.0 |
| 1968 / 69 | - | 214.0 | 150.0 | - | 302.0 | 33.0 | 145.0 | - | 17.0 | 21.0 |
| 1969 / 70 | - | 125.0 | 103.0 | - | 121.0 | 28.0 | - | - | 4.0 | 17.0 |
| 1970 / 71 | 143.0 | 253.0 | 252.0 | - | 269.0 | - | - | - | 45.0 | - |
| 1971 / 72 | - | - | 215.0 | - | - | 108.0 | - | - | 41.0 | - |
| 1972 / 73 | 128.0 | 124.0 | 150.0 | - | 102.0 | - | 72.0 | - | 51.0 | - |
| 1973 / 74 | 435.0 | 285.0 | 302.0 | - | 357.0 | - | - | 56.0 | 33.0 | 67.0 |
| 1974 / 75 | 410.0 | 285.0 | 311.0 | - | 313.0 | 101.0 | - | 92.0 | - | 78.0 |
| 1975 / 76 | - | 125.0 | - | - | 135.0 | 56.2 | - | x | - | 50.0 |
| 1976 / 77 | 183.2 | 225.5 | 223.5 | - | - | - | - | 20.4 | - | 22.0 |
| 1977 / 78 | 152.4 | 156.2 | 179.7 | - | 186.7 | 37.6 | - | 21.6 | - | 24.0 |
| 1978 / 79 | 166.3 | 253.4 | 197.2 | - | 270.7 | 23.0 | - | x | - | 23.1 |
| 1979 / 80 | 350.5 | 223.7 | 240.6 | - | 360.1 | 112.2 | - | x | - | 78.0 |

Table A.3.1 (10/10) ANNUAL RAINFALL

| Hydro-year | Prince Nursery DB2 | Buseira DC1 | Rasha-diya DC2 | Ain Lah ban DD1 | Dhana DE1 | Qasr Tuba F12 | J. Mud-aysisat F19 | Jabel Quzemeh G11 | Qabr Es-Saww G12 | Bayir Evap. S J1 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1980 / 81 | 276.3 | 285.5 | 179.6 | - | 336.0 | 61.7 | - | 45.2 | - | - |
| 1981 / 82 | 183.1 | 143.2 | 44.5 | - | 206.7 | 78.3 | - | x | 55.0 | - |
| 1982 / 83 | 272.9 | 339.5 | 393.8 | - | 269.3 | 41.1 | - | 32.4 | 23.0 | - |
| 1983 / 84 | 162.1 | 77.5 | 55.3 | - | 102.4 | 10.0 | 75.8 | 20.0 | 5.6 | - |
| 1984 / 85 | 168.6 | 205.4 | 98.0 | - | 193.0 | 59.2 | 171.6 | 26.8 | - | - |
| 1985 / 86 | 207.1 | 236.3 | 191.6 | - | 263.4 | 54.0 | 58.8 | 98.6 | 72.2 | - |
| 1986 / 87 | 163.0 | 168.8 | 128.2 | - | 154.1 | 36.2 | - | 12.6 | - | - |
| 1987 / 88 | 289.8 | 357.0 | 406.2 | - | 326.2 | 78.4 | 58.2 | 50.6 | - | - |
| 1988 / 89 | 166.6 | 154.4 | 200.2 | - | 262.0 | - | 131.6 | 25.2 | 20.0 | - |
| Data Nos. | 18 | 51 | 41 | 17 | 42 | 16 | 7 | 12 | 11 | 32 |
| Max. | 435.0 | 730.0 | 638.0 | 655.0 | 580.0 | 112.2 | 171.6 | 98.6 | 72.2 | 223.0 |
| Min. | 127.0 | 77.5 | 44.5 | 90.0 | 56.0 | 10.0 | 58.2 | 12.6 | 4.0 | 2.0 |
| Ann.Avg. | 221.4 | 263.1 | 233.8 | 316.2 | 246.9 | 57.4 | 101.9 | 41.8 | 33.3 | 47.5 |
| Std.Dev. | 93.0 | 117.9 | 116.1 | 146.1 | 110.6 | 30.0 | 43.0 | 27.1 | 20.6 | 39.6 |
| Vari. Coef | 0.42 | 0.45 | 0.50 | 0.46 | 0.45 | 0.52 | 0.42 | 0.65 | 0.62 | 0.83 |

Table A.3.2 (1/4) MONTHLY RAINFALL IN THE PRIORITY AREA ( DHIBAN )

CD7 Dhiban

| | OCT. | NOV. | DEC. | JAN. | FEB. | MAR. | APR. | MAY | Total | First Rainfall | 10% of Rainfall | 20% of Rainfall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 /77 | 0 | 16 | 3 | 102 | 16 | 14 | 82 | 0 | 232 | nov 27 58 | jan 3 95 | jan 5 97 |
| 1977 /78 | 0 | 26 | 57 | 70 | 21 | 59 | 14 | 0 | 247 | nov 11 42 | nov 11 42 | dec 14 75 |
| 1978 /79 | 0 | 0 | 52 | 78 | 11 | 41 | 0 | 12 | 194 | dec 2 63 | dec 8 69 | dec 12 73 |
| 1979 /80 | 5 | 89 | 115 | 52 | 60 | 88 | 3 | 0 | 412 | oct 21 21 | nov 29 60 | nov 30 61 |
| 1980 /81 | 5 | 0 | 40 | 32 | 14 | 23 | 0 | 0 | 114 | oct 31 31 | dec 26 87 | dec 26 87 |
| 1981 /82 | 0 | 78 | 25 | 20 | 56 | 16 | 19 | 0 | 213 | nov 7 38 | nov 8 39 | nov 9 40 |
| 1982 /83 | 0 | 78 | 19 | 65 | 78 | 63 | 3 | 0 | 304 | nov 7 38 | nov 8 39 | nov 9 40 |
| 1983 /84 | 0 | 12 | 0 | 55 | 13 | 94 | 0 | 0 | 174 | nov 12 43 | jan 2 94 | jan 18 110 |
| 1984 /85 | 0 | 14 | 28 | 2 | 154 | 44 | 0 | 0 | 242 | nov 17 48 | dec 13 74 | feb 5 128 |
| 1985 /86 | 0 | 5 | 19 | 34 | 51 | 0 | 0 | 2 | 110 | nov 3 34 | dec 18 79 | dec 19 80 |
| 1986 /87 | 0 | 78 | 70 | 16 | 6 | 38 | 0 | 0 | 207 | nov 2 33 | nov 8 39 | nov 9 40 |
| 1987 /88 | 0 | 0 | 68 | 114 | 172 | 93 | 9 | 0 | 455 | dec 5 66 | dec 22 83 | jan 15 107 |
| 1988 /89 | | | | | | | | | | | | |
| Ave. Rain | 0.8 | 33.0 | 41.2 | 53.2 | 54.2 | 47.6 | 10.8 | 1.2 | | nov 12 43 | dec 6 67 | dec 17 78 |
| Acc. Rain | 0.8 | 33.8 | 75.0 | 128.2 | 182.4 | 230.0 | 240.8 | 242.0 | | | | |
| Acc. P.(%) | 0.3 | 14.0 | 31.0 | 53.0 | 75.4 | 95.0 | 99.5 | 100.0 | | | | |

CD17 Um El-Risas

| | OCT. | NOV. | DEC. | JAN. | FEB. | MAR. | APR. | MAY | Total | First Rainfall | 10% of Rainfall | 20% of Rainfall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 /77 | * | * | * | * | * | * | * | * | 0 | | | |
| 1977 /78 | 0 | 3 | 68 | 55 | 39 | 67 | 6 | 0 | 238 | nov 11 42 | dec 15 76 | dec 22 83 |
| 1978 /79 | 3 | 0 | 12 | 52 | 11 | 10 | 0 | 12 | 100 | oct 31 31 | dec 12 73 | jan 9 101 |
| 1979 /80 | 5 | 88 | 70 | 40 | 108 | 59 | 4 | 0 | 374 | nov 11 42 | nov 29 60 | nov 30 61 |
| 1980 /81 | 0 | 0 | 140 | 0 | 7 | 21 | 0 | 0 | 167 | dec 12 73 | dec 12 73 | dec 12 73 |
| 1981 /82 | 0 | 6 | 0 | 4 | 13 | 15 | 0 | 0 | 37 | nov 13 44 | nov 29 60 | jan 15 107 |
| 1982 /83 | 0 | 28 | 0 | 90 | 105 | 64 | 0 | 0 | 287 | nov 10 41 | jan 2 94 | jan 20 112 |
| 1983 /84 | 0 | 0 | 0 | 28 | 12 | 107 | 0 | 0 | 147 | jan 17 109 | jan 27 119 | feb 12 135 |
| 1984 /85 | 70 | 8 | 35 | 7 | 70 | 11 | 10 | 0 | 211 | oct 16 16 | oct 18 18 | oct 18 18 |
| 1985 /86 | * | * | * | * | * | * | * | * | 0 | | | |
| 1986 /87 | 0 | 77 | 34 | 42 | 18 | 51 | 0 | 0 | 222 | nov 3 34 | nov 9 40 | nov 9 40 |
| 1987 /88 | 0 | 0 | 4 | 64 | 35 | 29 | 6 | 0 | 138 | dec 20 81 | jan 6 98 | jan 16 108 |
| 1988 /89 | | | | | | | | | | | | |
| Ave. Rain | 7.8 | 21.0 | 36.3 | 38.2 | 41.8 | 43.3 | 2.6 | 1.2 | | nov 20 51 | dec 10 71 | dec 23 84 |
| Acc. Rain | 7.8 | 28.8 | 65.0 | 103.2 | 145.0 | 188.3 | 190.9 | 192.1 | | | | |
| Acc. P.(%) | 4.1 | 15.0 | 33.9 | 53.7 | 75.5 | 98.0 | 99.4 | 100.0 | | | | |

CD15 Dhab'a Nursery

| | OCT. | NOV. | DEC. | JAN. | FEB. | MAR. | APR. | MAY | Total | First Rainfall | 10% of Rainfall | 20% of Rainfall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 /77 | 6 | 6 | 4 | 50 | 9 | 11 | 33 | 0 | 117 | oct 24 24 | dec 29 90 | jan 4 96 |
| 1977 /78 | 4 | 9 | 50 | 20 | 14 | 30 | 1 | 0 | 129 | oct 16 16 | nov 11 42 | dec 12 73 |
| 1978 /79 | 3 | 0 | 17 | 31 | 12 | 15 | 0 | 0 | 77 | oct 31 31 | dec 2 63 | dec 3 64 |
| 1979 /80 | 0 | 44 | 71 | 36 | 39 | 35 | 0 | 0 | 225 | nov 29 60 | nov 30 61 | dec 6 67 |
| 1980 /81 | 5 | 0 | 73 | 25 | 7 | 9 | 1 | 0 | 120 | oct 30 30 | dec 10 71 | dec 10 71 |
| 1981 /82 | 0 | 2 | 3 | 34 | 45 | 31 | 0 | 3 | 116 | nov 28 59 | jan 5 97 | jan 26 118 |
| 1982 /83 | 0 | 43 | 13 | 57 | 44 | 23 | 0 | 0 | 181 | oct 25 25 | nov 9 40 | nov 23 54 |
| 1983 /84 | 0 | 4 | 5 | 16 | 6 | 44 | 0 | 0 | 75 | nov 12 43 | dec 31 92 | jan 18 110 |
| 1984 /85 | 24 | 15 | 17 | 13 | 73 | 44 | 4 | 2 | 192 | oct 16 16 | oct 18 18 | nov 17 48 |
| 1985 /86 | 0 | 0 | 33 | 12 | 34 | 3 | 0 | 0 | 82 | dec 13 74 | dec 17 78 | dec 17 78 |
| 1986 /87 | 0 | 47 | 12 | 24 | 14 | 49 | 0 | 0 | 145 | nov 1 32 | nov 6 37 | nov 8 39 |
| 1987 /88 | 20 | 3 | 31 | 61 | 29 | 39 | 5 | 0 | 187 | oct 16 16 | oct 28 28 | dec 12 73 |
| 1988 /89 | | | | | | | | | | | | |
| Ave. Rain | 5.1 | 14.3 | 27.5 | 31.5 | 26.9 | 27.7 | 3.7 | 0.4 | | nov 5 36 | nov 29 60 | dec 13 74 |
| Acc. Rain | 5.1 | 19.4 | 46.9 | 78.4 | 105.3 | 133.0 | 136.6 | 137.0 | | | | |
| Acc. P.(%) | 3.7 | 14.2 | 34.2 | 57.2 | 76.8 | 97.0 | 99.7 | 100.0 | | | | |

## Table A.3.2 (2/4) MONTHLY RAINFALL IN THE PRIORITY AREA ( ABYAD )

CD13 Mazar

| | OCT. | NOV. | DEC. | JAN. | FEB. | MAR. | APR. | MAY | Total | First Rainfall | 10% of Rainfall | 20% of Rainfall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 /77 | 0 | 12 | 7 | 88 | 15 | 17 | 78 | 0 | 216 | nov 24 55 | jan 3 95 | jan 4 96 |
| 1977 /78 | 0 | 18 | 72 | 26 | 15 | 56 | 3 | 0 | 189 | nov 11 42 | dec 12 73 | dec 12 73 |
| 1978 /79 | 0 | 0 | 53 | 85 | 47 | 116 | 0 | 0 | 300 | dec 2 63 | dec 12 73 | jan 8 100 |
| 1979 /80 | 0 | 56 | 141 | 72 | 94 | 11 | 9 | 0 | 383 | nov 29 60 | nov 29 60 | jan 22 114 |
| 1980 /81 | 3 | 0 | 231 | 13 | 114 | 84 | 19 | 0 | 463 | oct 30 30 | dec 10 71 | dec 10 71 |
| 1981 /82 | 0 | 16 | 0 | 46 | 55 | 33 | 0 | 18 | 167 | nov 13 44 | jan 5 97 | jan 6 98 |
| 1982 /83 | 0 | 46 | 66 | 20 | 106 | 11 | 0 | 0 | 249 | nov 8 39 | nov 10 41 | dec 6 67 |
| 1983 /84 | 1 | 3 | * | 22 | 19 | 109 | 0 | 0 | 153 | oct 16 16 | | |
| 1984 /85 | 0 | 3 | 43 | 3 | 166 | 43 | 52 | 0 | 310 | nov 17 48 | dec 13 74 | feb 3 126 |
| 1985 /86 | 0 | 0 | 64 | 39 | 33 | 5 | 27 | 4 | 172 | dec 3 64 | dec 18 79 | dec 18 79 |
| 1986 /87 | 0 | 32 | 30 | 13 | 31 | 107 | 0 | 0 | 213 | nov 1 32 | nov 28 59 | dec 19 80 |
| 1987 /88 | 0 | 0 | 104 | 130 | 148 | 131 | 0 | 0 | 513 | dec 5 66 | dec 6 67 | dec 23 84 |
| 1988 /89 | | | | | | | | | | | | |
| Ave. Rain | 0.3 | 18.6 | 81.0 | 55.5 | 84.3 | 72.0 | 18.8 | 2.2 | | nov 16 47 | dec 11 72 | dec 29 90 |
| Acc. Rain | 0.3 | 18.9 | 99.8 | 155.3 | 239.7 | 311.7 | 330.5 | 332.7 | | | | |
| Acc. P.(%) | 0.2 | 9.8 | 52.0 | 80.9 | 124.8 | 162.3 | 172.1 | 173.2 | | | | |

CA6 Muhai

| | OCT. | NOV. | DEC. | JAN. | FEB. | MAR. | APR. | MAY | Total | First Rainfall | 10% of Rainfall | 20% of Rainfall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 /77 | 0 | 7 | 0 | 46 | 19 | 9 | 59 | 0 | 140 | nov 28 59 | jan 3 95 | jan 4 96 |
| 1977 /78 | 0 | 15 | 53 | 13 | 16 | 26 | 0 | 0 | 122 | nov 11 42 | nov 11 42 | dec 12 73 |
| 1978 /79 | 0 | 0 | 14 | 45 | 12 | 12 | 0 | 0 | 84 | dec 11 72 | dec 12 73 | jan 8 100 |
| 1979 /80 | 0 | 33 | 90 | 17 | 78 | 16 | 9 | 0 | 243 | nov 2 33 | nov 29 60 | dec 6 67 |
| 1980 /81 | 0 | 0 | 0 | 9 | 16 | 28 | 0 | 0 | 53 | jan 13 105 | jan 26 118 | feb 24 147 |
| 1981 /82 | 0 | 4 | 0 | 39 | 22 | 28 | 0 | 0 | 92 | nov 28 59 | jan 2 94 | jan 14 106 |
| 1982 /83 | 5 | 34 | 24 | 55 | 25 | 35 | 35 | 0 | 212 | oct 23 23 | nov 11 42 | dec 5 66 |
| 1983 /84 | 0 | 1 | 0 | 24 | 1 | 73 | 0 | 0 | 99 | nov 15 46 | jan 26 118 | jan 26 118 |
| 1984 /85 | 20 | 0 | 12 | 2 | 51 | 15 | 11 | 0 | 111 | oct 17 17 | oct 28 28 | dec 4 65 |
| 1985 /86 | 3 | 3 | 6 | 10 | 32 | 1 | 25 | 5 | 85 | ? | dec 3 64 | jan 19 111 |
| 1986 /87 | 0 | 37 | 7 | 5 | 12 | 33 | 0 | 0 | 95 | nov 1 32 | nov 8 39 | nov 28 59 |
| 1987 /88 | 0 | 0 | 27 | 47 | 71 | 83 | 2 | 0 | 230 | dec 5 66 | dec 21 82 | jan 12 104 |
| 1988 /89 | | | | | | | | | | | | |
| Ave. Rain | 2.3 | 11.0 | 19.4 | 26.0 | 29.7 | 29.9 | 11.8 | 0.4 | | nov 19 50 | dec 10 71 | jan 1 93 |
| Acc. Rain | 2.3 | 13.3 | 32.7 | 58.7 | 88.3 | 118.2 | 130.0 | 130.4 | | | | |
| Acc. P.(%) | 1.8 | 10.2 | 25.0 | 45.0 | 67.7 | 90.6 | 99.7 | 100.0 | | | | |

CF7 Hasa Evap.Sta.

| | OCT. | NOV. | DEC. | JAN. | FEB. | MAR. | APR. | MAY | Total | First Rainfall | 10% of Rainfall | 20% of Rainfall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 /77 | 1 | 0 | 0 | 27 | 0 | 0 | 0 | 0 | 29 | oct 23 23 | jan 5 97 | jan 5 97 |
| 1977 /78 | 0 | 0 | 4 | 9 | 22 | 25 | 3 | 0 | 63 | dec 12 73 | jan 10 102 | jan 10 102 |
| 1978 /79 | 0 | 0 | 0 | 7 | 9 | * | * | * | 16 | jan 8 100 | | |
| 1979 /80 | 0 | * | * | * | * | 23 | * | 0 | 23 | | | |
| 1980 /81 | 1 | 6 | 52 | 0 | 0 | 0 | 0 | 0 | 59 | oct 31 31 | nov 5 36 | dec 13 74 |
| 1981 /82 | 0 | 23 | 0 | 14 | 13 | 10 | 0 | 0 | 60 | nov 8 39 | nov 9 40 | nov 10 41 |
| 1982 /83 | 0 | 24 | 6 | 20 | 14 | 18 | 0 | 0 | 83 | nov 8 39 | nov 9 40 | nov 11 42 |
| 1983 /84 | 0 | 0 | 2 | 19 | 0 | 8 | 0 | 0 | 29 | dec 7 68 | jan 1 93 | jan 1 93 |
| 1984 /85 | 1 | 2 | 0 | 0 | 11 | 22 | 6 | 9 | 50 | oct 29 29 | feb 15 138 | feb 25 148 |
| 1985 /86 | 0 | 1 | 47 | 1 | 5 | 0 | 17 | 1 | 71 | nov 2 33 | dec 3 64 | dec 17 78 |
| 1986 /87 | 0 | 32 | 2 | 9 | 6 | 8 | 0 | 0 | 58 | nov 3 34 | nov 12 43 | nov 12 43 |
| 1987 /88 | * | * | * | * | * | * | * | * | 0 | | | |
| 1988 /89 | | | | | | | | | | | | |
| Ave. Rain | 0.2 | 8.9 | 11.3 | 10.6 | 7.9 | 11.4 | 2.9 | 1.0 | | nov 16 47 | dec 12 73 | dec 19 80 |
| Acc. Rain | 0.2 | 9.2 | 20.5 | 31.2 | 39.1 | 50.5 | 53.3 | 54.3 | | | | |
| Acc. P.(%) | 0.5 | 16.9 | 37.8 | 57.4 | 72.0 | 92.9 | 98.2 | 100.0 | | | | |

## Table A.3.2 (3/4) MONTHLY RAINFALL IN THE PRIORITY AREA ( TAFILA )

DB1 Tafila

| | OCT. | NOV. | DEC. | JAN. | FEB. | MAR. | APR. | MAY | Total | First Rainfall | 10% of Rainfall | 20% of Rainfall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 /77 | 4 | 9 | 4 | 86 | 14 | 4 | 125 | 0 | 244 | oct 23 23 | jan 3 95 | jan 5 97 |
| 1977 /78 | 0 | 16 | 95 | 21 | 4 | 29 | 5 | 0 | 169 | nov 11 42 | dec 8 69 | dec 12 77 |
| 1978 /79 | 0 | 0 | 26 | 75 | 44 | 41 | 0 | 4 | 189 | dec 3 64 | dec 12 73 | jan 8 100 |
| 1979 /80 | 2 | 59 | 122 | 41 | 82 | 45 | 18 | 0 | 367 | oct 20 20 | nov 30 61 | dec 5 66 |
| 1980 /81 | 2 | 1 | 189 | 10 | 64 | 42 | 9 | 0 | 316 | oct 31 31 | dec 13 74 | dec 13 74 |
| 1981 /82 | 0 | 18 | 0 | 51 | 64 | 41 | 2 | 0 | 175 | nov 11 42 | nov 29 60 | jan 15 107 |
| 1982 /83 | 0 | 35 | 46 | 160 | 43 | 70 | 0 | 0 | 353 | nov 6 37 | nov 6 37 | nov 9 40 |
| 1983 /84 | 0 | 0 | 10 | 20 | 10 | 55 | 0 | 0 | 95 | dec 25 86 | dec 26 87 | jan 18 110 |
| 1984 /85 | 19 | 0 | 8 | 3 | 122 | 44 | 7 | 0 | 202 | oct 18 18 | dec 9 70 | feb 5 127 |
| 1985 /86 | 0 | 9 | 97 | 19 | 32 | 1 | 59 | 12 | 228 | nov 17 48 | dec 17 78 | dec 17 78 |
| 1986 /87 | 0 | 76 | 15 | 3 | 28 | 90 | 0 | 0 | 211 | nov 7 38 | nov 8 39 | nov 12 43 |
| 1987 /88 | 0 | 0 | 70 | 87 | 91 | 123 | 0 | 0 | 370 | dec 7 68 | dec 14 75 | jan 5 97 |
| 1988 /89 | 3 | 0 | 110 | 71 | 47 | 44 | 0 | 0 | 274 | | | |
| Ave. Rain | 2.2 | 16.9 | 60.7 | 49.6 | 49.4 | 48.2 | 17.2 | 1.2 | | nov 12 43 | dec 7 68 | dec 24 85 |
| Acc. Rain | 2.2 | 19.2 | 79.9 | 129.5 | 178.9 | 227.1 | 244.4 | 245.6 | | | | |
| Acc. P.(%) | 0.9 | 7.8 | 32.5 | 52.7 | 72.8 | 92.5 | 99.5 | 100.0 | | | | |

DB2 Prince Hasan Nursery

| | OCT. | NOV. | DEC. | JAN. | FEB. | MAR. | APR. | MAY | Total | First Rainfall | 10% of Rainfall | 20% of Rainfall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 /77 | 6 | 5 | 2 | 56 | 14 | 5 | 95 | 0 | 183 | oct 23 23 | jan 3 95 | jan 4 96 |
| 1977 /78 | 0 | 11 | 76 | 6 | 11 | 44 | 5 | 0 | 152 | nov 11 42 | dec 12 73 | dec 14 75 |
| 1978 /79 | 0 | 0 | 11 | 78 | 28 | 44 | 0 | 5 | 166 | dec 11 72 | jan 8 100 | jan 8 100 |
| 1979 /80 | 1 | 63 | 114 | 34 | 83 | 45 | 12 | 0 | 351 | oct 20 20 | nov 29 60 | dec 5 66 |
| 1980 /81 | 6 | 0 | 162 | 16 | 48 | 36 | 8 | 0 | 276 | oct 30 30 | dec 11 72 | dec 11 72 |
| 1981 /82 | 0 | 11 | 0 | 53 | 56 | 52 | 2 | 10 | 183 | nov 5 36 | jan 4 96 | jan 25 117 |
| 1982 /83 | 0 | 29 | 40 | 97 | 32 | 73 | 2 | 0 | 273 | nov 7 38 | nov 23 54 | dec 5 66 |
| 1983 /84 | 0 | 0 | 2 | 38 | 14 | 105 | 4 | 0 | 162 | dec 8 69 | jan 19 111 | jan 28 120 |
| 1984 /85 | 22 | 1 | 23 | 5 | 50 | 36 | 32 | 0 | 169 | oct 13 13 | oct 18 18 | dec 13 74 |
| 1985 /86 | 4 | 4 | 97 | 27 | 49 | 0 | 24 | 3 | 207 | oct 31 31 | dec 17 78 | dec 17 78 |
| 1986 /87 | 0 | 23 | 55 | 22 | 19 | 44 | 0 | 0 | 163 | nov 2 33 | nov 9 40 | dec 19 80 |
| 1987 /88 | 0 | 0 | 28 | 51 | 82 | 128 | 2 | 0 | 290 | dec 12 73 | jan 4 96 | jan 13 105 |
| 1988 /89 | | | | | | | | | | | | |
| Ave. Rain | 3.3 | 12.2 | 50.7 | 40.1 | 40.4 | 50.9 | 15.5 | 1.5 | | nov 9 40 | dec 13 74 | dec 26 87 |
| Acc. Rain | 3.3 | 15.5 | 66.2 | 106.3 | 146.8 | 197.7 | 213.1 | 214.6 | | | | |
| Acc. P.(%) | 1.5 | 7.2 | 30.9 | 49.5 | 68.4 | 92.1 | 99.3 | 100.0 | | | | |

DC1 Buseira

| | OCT. | NOV. | DEC. | JAN. | FEB. | MAR. | APR. | MAY | Total | First Rainfall | 10% of Rainfall | 20% of Rainfall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 /77 | 2 | 8 | 0 | 67 | 19 | 4 | 126 | 0 | 226 | oct 23 23 | jan 4 96 | jan 5 97 |
| 1977 /78 | 0 | 17 | 94 | 18 | 5 | 21 | 1 | 0 | 156 | nov 11 42 | nov 11 42 | dec 14 75 |
| 1978 /79 | 0 | 0 | 41 | 113 | 59 | 35 | 0 | 5 | 253 | dec 3 64 | dec 11 72 | jan 9 101 |
| 1979 /80 | 2 | 53 | 118 | 34 | 155 | 44 | 19 | 0 | 424 | oct 20 20 | nov 30 61 | dec 6 67 |
| 1980 /81 | 2 | 0 | 129 | 6 | 62 | 69 | 18 | 0 | 286 | oct 31 31 | dec 10 71 | dec 10 71 |
| 1981 /82 | 0 | 0 | 0 | 0 | 83 | 51 | 3 | 7 | 143 | feb 2 125 | feb 4 127 | feb 20 143 |
| 1982 /83 | 0 | 66 | 54 | 115 | 45 | 60 | 0 | 0 | 340 | nov 8 39 | nov 10 41 | dec 5 67 |
| 1983 /84 | 0 | 2 | 4 | 28 | 3 | 41 | 0 | 0 | 78 | nov 15 46 | jan 2 94 | jan 18 110 |
| 1984 /85 | 14 | 0 | 30 | 2 | 99 | 33 | 27 | 0 | 205 | oct 18 18 | dec 9 70 | dec 13 74 |
| 1985 /86 | 1 | 4 | 112 | 19 | 34 | 6 | 51 | 9 | 236 | oct 31 31 | dec 17 78 | dec 18 79 |
| 1986 /87 | 0 | 54 | 9 | 3 | 32 | 71 | 0 | 0 | 169 | nov 2 33 | nov 8 39 | nov 28 59 |
| 1987 /88 | 3 | 0 | 63 | 90 | 89 | 112 | 0 | 0 | 357 | oct 21 21 | dec 20 81 | jan 5 97 |
| 1988 /89 | | | 69 | 17 | 39 | 28 | 0 | 0 | 154 | | | |
| Ave. Rain | 2.0 | 17.0 | 55.6 | 39.4 | 55.6 | 44.3 | 18.9 | 1.6 | | nov 10 41 | dec 12 73 | dec 26 87 |
| Acc. Rain | 2.0 | 18.9 | 74.5 | 113.9 | 169.5 | 213.8 | 232.6 | 234.3 | | | | |
| Acc. P.(%) | 0.9 | 8.1 | 31.8 | 48.6 | 72.4 | 91.3 | 99.3 | 100.0 | | | | |

Table A.3.2 (4/4) MONTHLY RAINFALL IN THE PRIORITY AREA ( TAFIAL )

CF3 Jurf Ed-Darawish

| | OCT. | NOV. | DEC. | JAN. | FEB. | MAR. | APR. | MAY | Total | First Rainfall | 10% of Rainfall | 20% of Rainfall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 /77 | 0 | 0 | 0 | 8 | 4 | 8 | 11 | 0 | 30 | jan 4 96 | jan 4 96 | jan 7 99 |
| 1977 /78 | 0 | 2 | 43 | 0 | 7 | 2 | 0 | 0 | 53 | nov 11 42 | dec 12 73 | dec 12 73 |
| 1978 /79 | * | 0 | 8 | 17 | 6 | 2 | 0 | 4 | 37 | dec 12 73 | dec 12 73 | dec 12 73 |
| 1979 /80 | 0 | 12 | 26 | 11 | 14 | 27 | 0 | 0 | 89 | nov 28 59 | nov 28 59 | dec 7 68 |
| 1980 /81 | 0 | 4 | 54 | 2 | 0 | 0 | 0 | 0 | 60 | nov 7 38 | dec 10 71 | dec 11 72 |
| 1981 /82 | * | * | * | * | * | * | * | * | 0 | | | |
| 1982 /83 | 0 | 6 | 2 | 28 | 5 | 16 | 0 | 0 | 56 | nov 9 40 | nov 23 54 | dec 15 76 |
| 1983 /84 | * | * | * | * | * | * | * | * | 0 | | | |
| 1984 /85 | 8 | 6 | * | * | * | 22 | 4 | * | 39 | oct 28 28 | | |
| 1985 /86 | 0 | 6 | 39 | 0 | 7 | 0 | 15 | 0 | 66 | nov 5 36 | dec 3 64 | dec 17 78 |
| 1986 /87 | 0 | 3 | 3 | 0 | 1 | 8 | 0 | 0 | 15 | nov 29 60 | nov 29 60 | nov 29 60 |
| 1987 /88 | 2 | 0 | 1 | 23 | 25 | 55 | 2 | 0 | 107 | oct 16 16 | jan 15 107 | jan 15 107 |
| 1988 /89 | 1 | 0 | 63 | 22 | 35 | 36 | 0 | 0 | 157 | | | |
| Ave. Rain | 1.1 | 3.9 | 26.4 | 12.3 | 11.5 | 17.3 | 3.1 | 0.5 | | nov 18 49 | dec 12 73 | dec 17 78 |
| Acc. Rain | 1.1 | 5.0 | 31.4 | 43.6 | 55.1 | 72.4 | 75.6 | 76.0 | | | | |
| Acc. P. (%) | 1.5 | 6.6 | 41.3 | 57.4 | 72.5 | 95.3 | 99.4 | 100.0 | | | | |

Table A.4.1 (1/5) RUNOFF RECORD AT HASA TANNOUR GAUGING SATATION

| Water Year | NO. | Date Year | Month | Day | D.M.Q. (m3/sec.) | Volume (MCM) | Vol. of each Fl. (MCM) | Annual Total (MCM) |
|---|---|---|---|---|---|---|---|---|
| 68/69 | 1 | 1968 | 11 | 24 | 4.33 | 0.374 | | |
| | 2 | | | 25 | 2.89 | 0.250 | | |
| | 3 | | | 26 | 4.10 | 0.354 | | |
| | 4 | | | 27 | 0.71 | 0.061 | | |
| | 5 | | | 28 | 0.45 | 0.039 | 1.078 | |
| | 6 | 1968 | 12 | 8 | 0.74 | 0.064 | | |
| | 7 | | | 9 | 0.28 | 0.024 | 0.088 | |
| | 8 | | | 26 | 1.15 | 0.099 | 0.099 | |
| | 9 | 1969 | 3 | 21 | 5.14 | 0.444 | | |
| | 10 | | | 22 | 1.19 | 0.103 | | |
| | 11 | | | 23 | 4.65 | 0.402 | | |
| | 12 | | | 24 | 1.15 | 0.099 | | |
| | 13 | | | 25 | 0.05 | 0.004 | | |
| | 14 | | | 26 | 0.03 | 0.003 | 1.055 | 2.32 |
| | 15 | 1970 | 1 | 11 | 45.00 | 3.888 | | |
| | 16 | | | 12 | 18.40 | 1.590 | | |
| | 17 | | | 13 | 0.79 | 0.068 | 5.546 | |
| 69/70 | 18 | | 1 | 27 | 0.33 | 0.029 | 0.029 | |
| | 19 | 1970 | 2 | 11 | 0.02 | 0.002 | | |
| | 20 | | | 12 | 1.07 | 0.092 | | |
| | 21 | | | 13 | 0.03 | 0.003 | 0.097 | |
| | 22 | | | 23 | 2.06 | 0.178 | | |
| | 23 | | | 24 | 0.02 | 0.002 | 0.180 | 5.85 |
| 70/71 | 24 | 1970 | 12 | 1 | 0.01 | 0.001 | 0.001 | |
| | 25 | | | 8 | 0.01 | 0.001 | 0.002 | |
| | 26 | | | 13 | 0.09 | 0.008 | 0.008 | |
| | 27 | 1971 | 1 | 11 | 45.00 | 3.888 | | |
| | 28 | | | 12 | 18.40 | 1.590 | | |
| | 29 | | | 13 | 0.79 | 0.068 | | |
| | 30 | | | 14 | 0.16 | 0.014 | | |
| | 31 | | | 15 | 0.12 | 0.010 | | |
| | 32 | | | 16 | 0.14 | 0.012 | | |
| | 33 | | | 17 | 0.08 | 0.007 | 5.589 | |
| | 34 | 1971 | 3 | 30 | 0.40 | 0.035 | 0.035 | |
| | 35 | 1971 | 4 | 12 | 0.19 | 0.016 | | |
| | 36 | | | 13 | 48.50 | 4.190 | | |
| | 37 | | | 14 | 23.52 | 2.032 | | |
| | 38 | | | 15 | 2.40 | 0.207 | | |
| | 39 | | | 16 | 0.64 | 0.055 | | |
| | 40 | | | 17 | 0.22 | 0.019 | | |
| | 41 | | | 18 | 0.07 | 0.006 | | |
| | 42 | | | 19 | 0.05 | 0.004 | | |
| | 43 | | | 20 | 0.03 | 0.003 | | |
| | 44 | | | 21 | 0.03 | 0.003 | 6.536 | |
| | 45 | | | 24 | 1.11 | 0.096 | 0.096 | 12.26 |
| 71/72 | 46 | 1971 | 11 | 18 | 0.24 | 0.021 | 0.021 | |
| | 47 | 1971 | 12 | 7 | 9.27 | 0.801 | | |
| | 48 | | | 8 | 0.17 | 0.015 | 0.816 | |

Table A.4.1 (2/5) RUNOFF RECORD AT HASA TANNOUR GAUGING SATATION

| Water Year | NO. | Date Year | Month | Day | D.M.Q. (m3/sec.) | Volume (MCM) | Vol.of each Fl. (MCM) | Annual Total (MCM) |
|---|---|---|---|---|---|---|---|---|
| | 49 | | | 23 | 0.24 | 0.021 | 0.021 | |
| | 50 | | | 27 | 17.60 | 1.521 | | |
| | 51 | | | 28 | 13.00 | 1.123 | | |
| | 52 | | | 29 | 3.75 | 0.324 | | |
| | 53 | | | 30 | 0.20 | 0.017 | 2.985 | |
| | 54 | 1972 | 2 | 6 | 0.55 | 0.048 | | |
| | 55 | | | 7 | 8.84 | 0.764 | | |
| | 56 | | | 8 | 1.74 | 0.150 | | |
| | 57 | | | 9 | 0.19 | 0.016 | 0.978 | |
| | 58 | 1972 | 3 | 16 | 3.18 | 0.275 | | |
| | 59 | | | 17 | 9.26 | 0.800 | 1.075 | |
| | 60 | | | 21 | 0.28 | 0.024 | | |
| | 61 | | | 22 | 0.22 | 0.019 | 0.043 | |
| | 62 | 1972 | 4 | 29 | 0.24 | 0.021 | | |
| | 63 | | | 30 | 7.64 | 0.660 | 0.681 | |
| | 64 | 1972 | 5 | 1 | 4.36 | 0.377 | 0.377 | 7.00 |
| 72/73 | 65 | 1972 | 11 | 25 | 16.60 | 1.434 | | |
| | 66 | | | 26 | 0.23 | 0.020 | 1.454 | |
| | 67 | 1973 | 1 | 13 | 0.35 | 0.030 | 0.030 | |
| | 68 | | 1 | 15 | 0.76 | 0.066 | 0.066 | 1.55 |
| 73/74 | 69 | 1973 | 11 | 11 | 1.45 | 0.125 | | |
| | 70 | | | 12 | 2.35 | 0.203 | | |
| | 71 | | | 13 | 0.47 | 0.041 | 0.369 | |
| | 72 | | 11 | 23 | 0.24 | 0.021 | 0.021 | |
| | 73 | 1973 | 12 | 17 | 0.14 | 0.012 | 0.012 | |
| | 74 | | 1 | 17 | 0.67 | 0.058 | | |
| | 75 | | | 18 | 2.40 | 0.207 | 0.265 | |
| | 76 | | 1 | 20 | 1.81 | 0.156 | | |
| | 77 | | | 21 | 0.53 | 0.046 | | |
| | 78 | | | 22 | 2.11 | 0.182 | | |
| | 79 | | | 23 | 0.97 | 0.084 | 0.468 | |
| | 80 | | 1 | 31 | 2.18 | 0.188 | 0.188 | |
| | 81 | 1974 | 2 | 1 | 6.10 | 0.527 | 0.527 | |
| | 82 | | | 11 | 15.80 | 1.365 | | |
| | 83 | | | 12 | 10.10 | 0.873 | 2.238 | |
| | 84 | 1974 | 3 | 18 | 2.40 | 0.207 | | |
| | 85 | | | 19 | 1.21 | 0.105 | | |
| | 86 | | | 20 | 1.89 | 0.163 | | |
| | 87 | | | 21 | 3.34 | 0.289 | | |
| | 88 | | | 22 | 3.73 | 0.322 | 1.086 | 5.17 |
| 74/75 | 89 | 1974 | 11 | 22 | 3.01 | 0.260 | | |
| | 90 | | | 23 | 8.12 | 0.702 | 0.962 | |
| | 91 | 1974 | 12 | 5 | 0.16 | 0.014 | | |
| | 92 | | | 6 | 0.52 | 0.045 | 0.059 | |
| | 93 | | 12 | 11 | 0.43 | 0.037 | 0.037 | |
| | 94 | 1975 | 2 | 10 | 0.20 | 0.017 | | |
| | 95 | | | 11 | 0.49 | 0.042 | 0.060 | |
| | 96 | | 2 | 20 | 7.10 | 0.613 | | |

Table A.4.1 (3/5) RUNOFF RECORD AT HASA TANNOUR GAUGING SATATION

| Water Year | NO. | Date Year | Month | Day | D.M.Q. (m3/sec.) | Volume (MCM) | Vol. of each Fl. (MCM) | Annual Total (MCM) |
|---|---|---|---|---|---|---|---|---|
| | 97 | | | 21 | 79.70 | 6.886 | | |
| | 98 | | | 22 | 10.70 | 0.924 | | |
| | 99 | | | 23 | 0.80 | 0.069 | 8.493 | 9.61 |
| | 100 | | 4 | 6 | 0.3 | 0.026 | | |
| 76/77 | 101 | 1977 | 4 | 7 | 0.06 | 0.005 | 0.031 | |
| | 102 | | 4 | 13 | 2.52 | 0.218 | 0.218 | 0.25 |
| 77/78 | 103 | 1977 | 12 | 12 | 0.15 | 0.013 | | |
| | 104 | | | 13 | 3.09 | 0.267 | | |
| | 105 | | | 14 | 0.58 | 0.050 | | |
| | 106 | | | 15 | 0.75 | 0.065 | 0.395 | |
| | 107 | | | 23 | 0.15 | 0.013 | | |
| | 108 | | | 24 | 0.33 | 0.029 | 0.041 | |
| | 109 | 1978 | 3 | 14 | 0.62 | 0.054 | 0.054 | 0.49 |
| 78/79 | 110 | 1979 | 1 | 8 | 0.09 | 0.008 | | |
| | 111 | | | 9 | 17.94 | 1.550 | | |
| | 112 | | | 10 | 0.25 | 0.022 | | |
| | 113 | | | 11 | 0.8 | 0.069 | 1.648 | |
| | 114 | | | 26 | 0.61 | 0.053 | | |
| | 115 | | | 27 | 0.95 | 0.082 | | |
| | 116 | | | 28 | 0.05 | 0.004 | 0.139 | 1.79 |
| 79/80 | 117 | 1979 | 11 | 3 | 15.66 | 1.353 | 1.353 | |
| | 118 | | | 27 | 13.30 | 1.149 | | |
| | 119 | | | 28 | 1.80 | 0.156 | | |
| | 120 | | | 29 | 0.66 | 0.057 | 1.362 | |
| | 121 | 1979 | 12 | 6 | 31.00 | 2.678 | | |
| | 122 | | | 7 | 214.41 | 18.525 | | |
| | 123 | | | 8 | 16.40 | 1.417 | 22.620 | |
| | 124 | | | 14 | 23.85 | 2.061 | | |
| | 125 | | | 15 | 5.03 | 0.435 | 2.495 | |
| | 126 | 1980 | 2 | 24 | 45.80 | 3.957 | | |
| | 127 | | | 25 | 43.95 | 3.797 | | |
| | 128 | | | 26 | 3.06 | 0.264 | | |
| | 129 | | | 27 | 0.43 | 0.037 | 8.056 | |
| | 130 | 1980 | 3 | 1 | 0.83 | 0.072 | | |
| | 131 | | | 2 | 1.95 | 0.168 | | |
| | 132 | | | 3 | 9.65 | 0.834 | | |
| | 133 | | | 4 | 3.60 | 0.311 | 1.385 | 37.27 |
| 80/81 | 134 | 1980 | 12 | 11 | 15.24 | 1.317 | | |
| | 135 | | | 12 | 8.40 | 0.726 | | |
| | 136 | | | 13 | 3.88 | 0.335 | | |
| | 137 | | | 14 | 1.45 | 0.125 | | |
| | 138 | | | 15 | 1.11 | 0.096 | 2.599 | |
| | 139 | | | 27 | 77.45 | 6.692 | | |
| | 140 | | | 28 | 34.68 | 2.996 | | |
| | 141 | | | 29 | 13.02 | 1.125 | | |
| | 142 | | | 30 | 5.15 | 0.445 | 11.258 | 13.86 |
| 81/82 | 143 | 1982 | 2 | 4 | 0.84 | 0.072 | | |
| | 144 | | | 5 | 0.75 | 0.065 | | |

Table A.4.1 (4/5) RUNOFF RECORD AT HASA TANNOUR GAUGING SATATION

| Water Year | NO. | Date | | | D.M.Q. | Volume | Vol.of each Fl. | Annual Total |
|---|---|---|---|---|---|---|---|---|
| | | Year | Month | Day | (m3/sec.) | (MCM) | (MCM) | (MCM) |
| | 145 | | | 6 | | 0.000 | 0.137 | |
| | 146 | 1982 | 4 | 15 | 16.80 | 1.452 | | |
| | 147 | | | 16 | 1.84 | 0.159 | | |
| | 148 | | | 17 | | 0.000 | 1.610 | |
| | 149 | 1982 | 5 | 11 | | 0.000 | | |
| | 150 | | | 12 | 8.21 | 0.709 | | |
| | 151 | | | 13 | 20.07 | 1.734 | | |
| | 152 | | | 14 | 5.56 | 0.480 | | |
| | 153 | | | 15 | 1.25 | 0.108 | 3.032 | 4.78 |
| 82/83 | 154 | 1982 | 11 | 7 | 8.13 | 0.702 | | |
| | 155 | | | 8 | 2.00 | 0.173 | 0.875 | |
| | 156 | 1982 | 11 | 22 | 15.00 | 1.296 | | |
| | 157 | | | 23 | 9.75 | 0.842 | | |
| | 158 | | | 24 | 4.21 | 0.364 | | |
| | 159 | | | 25 | 1.16 | 0.100 | | |
| | 160 | | | 26 | 1.15 | 0.099 | 2.702 | 3.58 |
| 83/84 | 161 | 1984 | 1 | 28 | 0.70 | 0.060 | 0.060 | |
| | 162 | 1984 | 3 | 14 | 1.03 | 0.089 | | |
| | 163 | | | 15 | 0.10 | 0.008 | 0.097 | 0.16 |
| 84/85 | 164 | 1984 | 10 | 18 | 1.08 | 0.093 | | |
| | 165 | | | 19 | 0.35 | 0.030 | 0.123 | |
| | 166 | | | 31 | 3.10 | 0.268 | 0.268 | |
| | 167 | 1984 | 11 | 1 | 4.34 | 0.375 | | |
| | 168 | | | 2 | 1.78 | 0.154 | 0.529 | |
| | 169 | 1985 | 2 | 15 | 17.01 | 1.470 | | |
| | 170 | | | 16 | 4.59 | 0.397 | 1.866 | |
| | 171 | | | 16 | | 0.000 | | |
| | 172 | 1985 | 3 | 22 | | 0.000 | 0.000 | |
| | 173 | | | 24 | 9.02 | 0.779 | 0.779 | |
| | 174 | 1985 | 4 | 22 | 1.90 | 0.164 | | |
| | 175 | | | 23 | 0.27 | 0.023 | 0.187 | 3.75 |
| 85/86 | 176 | 1985 | 12 | 17 | 1.27 | 0.110 | | |
| | 177 | | | 18 | 35.30 | 3.050 | | |
| | 178 | | | 19 | 66.80 | 5.772 | | |
| | 179 | | | 20 | 38.90 | 3.361 | | |
| | 180 | | | 21 | 4.95 | 0.428 | 12.720 | |
| | 181 | 1986 | 1 | 19 | 0.28 | 0.024 | | |
| | 182 | | | 20 | 0.10 | 0.009 | 0.033 | |
| | 183 | 1986 | 2 | 5 | 0.46 | 0.040 | | |
| | 184 | | | 6 | 0.71 | 0.061 | 0.101 | |
| | 185 | | | 9 | 1.00 | 0.086 | 0.086 | |
| | 186 | | | 13 | 0.13 | 0.011 | | |
| | 187 | | | 14 | 0.50 | 0.043 | | |
| | 188 | | | 15 | | 0.000 | 0.054 | |
| | 189 | | | 24 | 0.88 | 0.076 | | |
| | 190 | | | 25 | 0.71 | 0.061 | 0.137 | |
| | 191 | 1986 | 3 | 22 | 22.34 | 1.930 | 1.930 | |
| | 192 | 1986 | 4 | 8 | 11.65 | 1.007 | | |

Table A.4.1 (5/5) RUNOFF RECORD AT HASA TANNOUR GAUGING SATATION

| Water Year | NO. | Date Year | Month | Day | D.M.Q. (m3/sec.) | Volume (MCM) | Vol. of each Fl. (MCM) | Annual Total (MCM) |
|---|---|---|---|---|---|---|---|---|
| | 193 | | | 9 | 56.89 | 4.915 | | |
| | 194 | | | 10 | 9.62 | 0.831 | | |
| | 195 | | | 11 | 1.44 | 0.124 | 6.877 | 21.94 |
| 86/87 | 196 | 1986 | 10 | 30 | 6.52 | 0.563 | 0.563 | |
| | 197 | 1986 | 11 | 12 | 14.64 | 1.265 | | |
| | 198 | | | 13 | 3.40 | 0.294 | 1.559 | |
| | 199 | 1987 | 3 | 5 | 0.08 | 0.007 | 0.007 | |
| | 200 | 1987 | | 19 | 0.60 | 0.052 | | |
| | 201 | | | 20 | 0.04 | 0.003 | 0.055 | 2.18 |
| 87/88 | 202 | 1987 | 10 | 16 | 11.71 | 1.012 | | |
| | 203 | | | 17 | 1.39 | 0.120 | | |
| | 204 | | | 18 | 4.00 | 0.346 | | |
| | 205 | | | 19 | 1.06 | 0.092 | 1.569 | |
| | 206 | 1988 | 1 | 6 | 0.27 | 0.023 | 0.023 | |
| | 207 | | | 15 | 0.61 | 0.053 | | |
| | 208 | | | 16 | 1.71 | 0.148 | | |
| | 209 | | | 17 | 5.11 | 0.442 | | |
| | 210 | | | 18 | 1.29 | 0.111 | 0.553 | |
| | 211 | 1988 | 3 | 4 | 110.02 | 9.506 | | |
| | 212 | | | 5 | 65.74 | 5.680 | 15.186 | 17.33 |
| 88/89 | 213 | 1988 | 12 | 27 | 7.59 | 0.656 | | |
| | 214 | | | 28 | 1.50 | 0.130 | 0.785 | 0.79 |

Table A.4.2 ANNUAL RUNOFF COEFFICIENT OF THE WADI HASA BASIN

| Year | Annual Rainfall (mm/y) Station code | | | | | Case No. | Basin Rainfall | | | | Runoff | | Runoff Coefficient | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CF8 | CA6 | DB1 | CF3 | CD33 | | R1 (mm/y) | R2 (MCM) | R3 (mm/y) | R4 (MCM) | Meas. (Q)(MCM) | Rev. (Q)(MCM) | Q/R | Q/R' |
| 1968 /69 | 146.0 | 119.0 | 295.0 | 49.0 | 36.0 | 1 | 64.2 | 131.6 | 88.4 | 89.3 | 2.51 | 1.75 | 1.9% | 2.0% |
| 69 /70 | 82.0 | 78.0 | 132.0 | 43.0 | 15.0 | 1 | 41.9 | 85.9 | 59.3 | 59.9 | 6.00 | 5.53 | 7.0% | 9.2% |
| 70 /71 | 128.5 | 130.0 | 257.0 | 46.0 | 55.0 | 1 | 67.8 | 139.0 | 84.2 | 85.1 | 13.28 | 12.31 | 9.6% | 14.5% |
| 71 /72 | 311.6 | 179.0 | 439.0 | 75.0 | - | 2 | 109.5 | 224.4 | 144.8 | 146.4 | 9.36 | 7.95 | 4.2% | 5.4% |
| 72 /73 | 84.0 | 84.0 | 82.0 | 11.0 | - | 2 | 24.1 | 49.4 | 37.5 | 37.9 | 2.18 | 1.97 | 4.4% | 5.2% |
| 73 /74 | 226.0 | 239.0 | 403.0 | 57.0 | - | 2 | 93.9 | 192.5 | 131.7 | 133.2 | 6.96 | 5.89 | 3.6% | 4.4% |
| 74 /75 | 186.0 | 190.0 | 339.0 | 65.0 | - | 2 | 91.7 | 188.0 | 119.1 | 120.4 | 10.40 | 9.18 | 5.5% | 7.6% |
| 75 /76 | - | 65.0 | 139.0 | 30.0 | - | 3 | | 80.5 | | 49.3 | | | | |
| 76 /77 | - | - | 244.0 | 30.3 | - | 4 | 51.7 | 105.9 | 73.6 | 74.4 | 0.75 | 0.18 | 0.7% | 0.2% |
| 77 /78 | - | 121.8 | 169.0 | 53.0 | - | 3 | 67.3 | 137.9 | 81.8 | 82.7 | 1.30 | 0.31 | 0.9% | 0.4% |
| 78 /79 | 93.7 | 83.6 | 189.0 | 37.0 | - | 2 | 49.2 | 100.8 | 61.6 | 62.3 | 2.00 | 1.31 | 2.0% | 2.1% |
| 79 /80 | 237.5 | 242.8 | 367.0 | 89.3 | - | 2 | 120.3 | 246.7 | 152.1 | 153.7 | 38.46 | 36.79 | 15.6% | 23.9% |
| 80 /81 | - | 53.4 | 316.4 | 59.7 | - | 3 | 69.1 | 141.6 | 78.6 | 79.5 | 14.80 | 13.68 | 10.5% | 17.2% |
| 81 /82 | - | 91.8 | 175.1 | - | - | 6 | | | | | 7.23 | 7.23 | | |
| 82 /83 | 205.9 | 211.6 | 353.0 | 55.8 | - | 2 | 87.7 | 179.9 | 120.5 | 121.8 | 4.98 | 3.93 | 2.8% | 3.2% |
| 83 /84 | 98.7 | 99.4 | 94.7 | - | - | | | | | | 3.17 | 3.17 | | |
| 84 /85 | 97.9 | 110.2 | 201.7 | 38.8 | - | 2 | 53.7 | 110.0 | 68.9 | 69.6 | 4.63 | 3.90 | 4.2% | 5.6% |
| 85 /86 | - | 84.6 | 228.0 | 65.7 | - | 3 | 74.8 | 153.4 | 84.1 | 85.0 | 22.76 | 21.53 | 14.8% | 25.3% |
| 86 /87 | 101.2 | 94.9 | 211.2 | 15.3 | - | 2 | 33.5 | 68.7 | 52.2 | 52.7 | 2.77 | 2.48 | 4.0% | 4.7% |
| 87 /88 | 221.6 | 230.4 | 370.3 | 106.9 | - | 2 | 132.8 | 272.2 | 159.2 | 161.0 | 8.44 | 6.44 | 3.1% | 4.0% |
| 88 /89 | - | 187.1 | 263.4 | 156.7 | - | 3 | | 338.7 | | 175.6 | | | | |
| | | | | | Average | | 72.5 | 144.9 | 94.0 | 92.5 | 8.53 | 7.66 | 5.6% | 7.9% |

R1: Average annual basin raindepth of Hasa basin
R2: Average annual basin rainfall of Hasa basin
R3: Average annual basin raindepth of Hasa Tannour sub-basin
R4: Average annual basin rainfall of Hasa Tannour sub-basin
Q/R: Runoff coefficient of hasa basin
Q/R' : Runoff coefficient of Hasa Tannour sub-basin

Table A.4.3 WATER LEVEL AND VOLUME CHANGES IN THE WEIR RESERVOIR

| Date 1990 | Rain-fall (mm) | Water Level (m) | Δ H (m) | 0 Area (m2) | 0 Capacity (m3) | Δ V (m3) | Evap.+ Infil. (mm/m2/day) |
|---|---|---|---|---|---|---|---|
| Jan. 4 | 24.0 | 936.86 | | | | | |
| 5 | | 936.67 | -0.19 | 4800 | 3750 | | |
| 6 | | | | | | | |
| 7 | | | | | | | |
| 8 | | 936.39 | -0.28 | 3700 | 2550 | -1200 | 71 |
| 9 | | | | | | | |
| 10 | | | | | | | |
| 11 | | | | | | | |
| 12 | | | | | | | |
| 13 | | | | | | | |
| 14 | | | | | | | |
| 15 | | 936.05 | -0.34 | 2400 | 1400 | -1150 | 54 |
| 16 | 2.5 | | | | | | |
| 17 | 1.0 | | | | | | |
| 18 | | | | | | | |
| 19 | | | | | | | |
| 20 | | | | | | | |
| 21 | | | | | | | |
| 22 | | 935.78 | -0.27 | 1600 | 850 | -650 | 39 |
| 23 | | | | | | | |
| 24 | | 935.71 | -0.07 | 1400 | 750 | -100 | 33 |
| 25 | | 935.66 | -0.05 | 1200 | 680 | -70 | 54 |
| 26 | 4.0 | 935.62 | -0.04 | 1150 | 635 | -45 | 38 |
| 27 | 0.5 | 935.59 | -0.03 | 1100 | 600 | -35 | 31 |
| 28 | | 935.55 | -0.04 | 1030 | 560 | -40 | 38 |
| 29 | | 935.51 | -0.04 | 990 | 520 | -40 | 40 |
| 30 | | 935.48 | -0.03 | 900 | 490 | -30 | 32 |
| 31 | | 935.44 | -0.04 | 850 | 450 | -40 | 46 |
| Feb. 1 | 4.5 | 935.39 | -0.05 | 750 | 415 | -35 | 44 |
| 2 | | 935.37 | -0.02 | 740 | 400 | -15 | 20 |
| 3 | | | | | 390 | -10 | 14 |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | 0.5 | | | | | | |
| 7 | | | | | | | |
| 8 | | | | | | | |
| 9 | | | | | | | |
| 10 | | | | | | | |
| 17 | | | | | | | |
| 18 | 2.0 | | | | | | |
| 19 | | | | | | | |
| 20 | | | | | | | |
| 21 | | | | | | | |
| 22 | | | | | | | |
| 23 | | | | | | | |
| 24 | 0.5 | | | | | | |
| 25 | | | | | | | |
| 26 | | | | | | | |
| 27 | | | | | | | |
| 28 | | | | | | | |
| Mar. 1 | 4.0 | | | | | | |
| 2 | | | | | | | |

Table A.4.4 ANNUAL RUNOFF VOLUME OF VARIOUS RETURN PERIODS

HASA TANNOUR ANNUAL RUNOFF VOLUME
(LOG-PEARSON TYPE III METHOD )

| WINTER YEAR | Runoff(MCM) Flood | Base | X (MCM) | LogX | (LogX-$\overline{LogX}$) | (LogX-$\overline{LogX}$)$^2$ | (LogX-$\overline{LogX}$)$^3$ |
|---|---|---|---|---|---|---|---|
| 1968 / 69 | 2.32 | 0.19 | 2.32 | 0.37 | -0.256 | 0.068 | -0.018 |
| 69 / 70 | 5.76 | 0.24 | 5.76 | 0.76 | 0.139 | 0.020 | 0.003 |
| 70 / 71 | 12.26 | 1.02 | 12.26 | 1.09 | 0.467 | 0.221 | 0.104 |
| 71 / 72 | 7.00 | 2.36 | 7.00 | 0.85 | 0.224 | 0.048 | 0.011 |
| 72 / 73 | 1.55 | 0.63 | 1.55 | 0.19 | -0.431 | 0.185 | -0.080 |
| 73 / 74 | 5.17 | 1.79 | 5.17 | 0.71 | 0.092 | 0.008 | 0.001 |
| 74 / 75 | 9.61 | 0.79 | 9.61 | 0.98 | 0.362 | 0.130 | 0.047 |
| 75 / 76 | - | - | - | | | | |
| 76 / 77 | 0.25 | 0.50 | 0.25 | -0.60 | -1.223 | 1.488 | -1.816 |
| 77 / 78 | 0.49 | 0.81 | 0.49 | -0.31 | -0.931 | 0.865 | -0.804 |
| 78 / 79 | 1.79 | 0.21 | 1.79 | 0.25 | -0.368 | 0.137 | -0.051 |
| 79 / 80 | 37.27 | 1.19 | 37.27 | 1.57 | 0.950 | 0.903 | 0.857 |
| 80 / 81 | 13.86 | 0.94 | 13.86 | 1.14 | 0.521 | 0.270 | 0.141 |
| 81 / 82 | 4.78 | 2.45 | 4.78 | 0.68 | 0.058 | 0.004 | 0.000 |
| 82 / 83 | 3.58 | 1.40 | 3.58 | 0.55 | -0.067 | 0.005 | 0.000 |
| 83 / 84 | 2.68 | 0.49 | 2.68 | 0.43 | -0.193 | 0.036 | -0.007 |
| 84 / 85 | 3.75 | 0.88 | 3.75 | 0.57 | -0.047 | 0.003 | 0.000 |
| 85 / 86 | 21.94 | 0.82 | 21.94 | 1.34 | 0.720 | 0.518 | 0.373 |
| 86 / 87 | 2.18 | 0.59 | 2.18 | 0.34 | -0.283 | 0.078 | -0.022 |
| 87 / 88 | 7.58 | 0.86 | 7.58 | 0.88 | 0.259 | 0.068 | 0.018 |
| 88 / 89 | | | | | | | |
| Sum. | | | SUM1= 143.82 | SUM2= 11.79 | SUM3= -0.003 | SUM4= 5.054 | SUM5= -1.244 |

| | |
|---|---|
| number of data = | 19 |
| mean of logX = | 0.621 * |
| std.dev.of logX = | 0.530 * |
| skew coef. = | -0.519 |

ANNUAL RUNOFF VOLUME OF VARIOUS RETURN PERIODS (LOG - PEARSON III TYPE METHOD)

| Return Period (Years) | K | log x | x (MCM) |
|---|---|---|---|
| 1.0101 | -2.699 | -0.81 | 0.16 |
| 1.0526 | -1.778 | -0.32 | 0.48 |
| 1.1111 | -1.324 | -0.08 | 0.83 |
| 1.25 | -0.806 | 0.19 | 1.56 |
| 2 | 0.086 | 0.67 | 4.64 |
| 5 | 0.856 | 1.07 | 11.88 |
| 10 | 1.213 | 1.26 | 18.36 |
| 25 | 1.560 | 1.45 | 28.03 |
| 50 | 1.766 | 1.56 | 36.06 |
| 100 | 1.941 | 1.65 | 44.63 |

Note;
1) lologx = logX + K* (sigma logX)
2) logX = 0.621
3) sigma logX = 0.53
4) Skew Coefficient : g = -0.52

## Table A.4.5 (1/4) ANNUAL RUNOFF VOLUME AT D-2 SITE

Wadi: Harir
Place: Tafila

Catchment area: 34.8 km2
Annual rainfall: 219.0 mm/yr
Runoff coefficient: 7.9 %

| Item | Return Period (year) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1.01 | 1.25 | 2 | 5 | 10 | 25 | 50 | 100 |
| Runoff depth (mm/yr) | 0.43 | 3.4 | 9.8 | 24.7 | 37.9 | 58.4 | 75.0 | 92.5 |
| Runoff volume (MCM/yr) | 0.015 | 0.12 | 0.34 | 0.86 | 1.32 | 2.03 | 2.61 | 3.22 |

| Tannour on Wadi Hasa | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Runoff Volume (MCM/yr) | 0.16 | 1.56 | 4.64 | 11.88 | 18.36 | 28.03 | 36.06 | 44.63 |
| Runoff depth (mm/yr) | 0.1 | 0.8 | 2.3 | 5.8 | 8.9 | 13.7 | 17.6 | 21.7 |

Catchment area: 2,052 km2
Mean rainfall: 72.5 mm/y
Mean runoff coefficient: 5.6 %

## Table A.4.5 (2/4) ANNUAL RUNOFF VOLUME AT E-1 SITE

Wadi: Zabda
Place: Tafila

Catchment area: 9.5 km2
Annual rainfall: 227 mm/yr
Runoff coefficient: 7.9 %

| Item | Return Period (year) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1.01 | 1.25 | 2 | 5 | 10 | 25 | 50 | 100 |
| Runoff depth (mm/yr) | 0.044 | 3.53 | 10.2 | 25.6 | 39.3 | 60.5 | 77.7 | 95.8 |
| Runoff volume (MCM/yr) | 0.004 | 0.03 | 0.10 | 0.24 | 0.37 | 0.57 | 0.74 | 0.91 |

| Tannour on Wadi Hasa | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Runoff Volume (MCM/yr) | 0.16 | 1.56 | 4.64 | 11.88 | 18.36 | 28.03 | 36.06 | 44.63 |
| Runoff depth (mm/yr) | 0.1 | 0.8 | 2.3 | 5.8 | 8.9 | 13.7 | 17.6 | 21.7 |

Catchment area: 2,052 km2
Mean rainfall: 72.5 mm/y
Mean runoff coefficient: 5.6 %

Table A.4.5 (3/4) ANNUAL RUNOFF VOLUME AT J-1 SITE

Wadi: Sallam
Place: Rashadia

Catchment area: 16.7 km2
Annual rainfall: 204 mm/yr
Runoff coefficient: 7.9 %

| Item | Return Period (year) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1.01 | 1.25 | 2 | 5 | 10 | 25 | 50 | 100 |
| Runoff depth (mm/yr) | 0.4 | 3.18 | 9.13 | 23.02 | 35.33 | 54.38 | 69.9 | 86.1 |
| Runoff volume (MCM/yr) | 0.007 | 0.05 | 0.15 | 0.38 | 0.59 | 0.91 | 1.17 | 1.44 |
| Tannour on Wadi Hasa | | | | | | | | |
| Runoff Volume (MCM/yr) | 0.16 | 1.56 | 4.64 | 11.88 | 18.36 | 28.03 | 36.06 | 44.63 |
| Runoff depth (mm/yr) | 0.1 | 0.8 | 2.3 | 5.8 | 8.9 | 13.7 | 17.6 | 21.7 |

Catchment area: 2,052 km2
Mean rainfall: 72.5 mm/y
Mean runoff coefficient: 5.6%

Table A.4.5 (4/4) ANNUAL RUNOFF VOLUME AT ABYAD SITE

Wadi: Abyad
Place: Muhai

Catchment area: 116.5 km2
Annual rainfall: 172. mm/yr
Runoff coefficient: 7.9 %

| Item | Return Period (year) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1.01 | 1.25 | 2 | 5 | 10 | 25 | 50 | 100 |
| Runoff depth (mm/yr) | 0.33 | 2.68 | 7.70 | 19.41 | 29.79 | 45.85 | 58.9 | 72.6 |
| Runoff volume (MCM/yr) | 0.038 | 0.31 | 0.90 | 2.26 | 3.47 | 5.34 | 6.86 | 8.46 |
| Tannour on Wadi Hasa | | | | | | | | |
| Runoff Volume (MCM/yr) | 0.16 | 1.56 | 4.64 | 11.88 | 18.36 | 28.03 | 36.06 | 44.63 |
| Runoff depth (mm/yr) | 0.1 | 0.8 | 2.3 | 5.8 | 8.9 | 13.7 | 17.6 | 21.7 |

Catchment area: 2,052 km2
Mean rainfall: 72.5 mm/y
Mean runoff coefficient: 5.6 %

Table A.4.6 (1/2) RUNOFF VOLUME BY SCS METHOD

## D2 Site

2 YEARS RETURN PERIOD: Model Year 1976/77 and 1978/79

| Period of Rainfall | Basin Rainfall mm | Basin Rainfall inch | Runoff inch | Runoff mm | Disch. Vol. ( MCM ) | Total Disch. | Runoff Coef. | Annual Run. Coef. |
|---|---|---|---|---|---|---|---|---|
| 77 Jan. 3-7 | 43.90 | 1.73 | 0.26 | 6.60 | 0.23 | | 15.0 | |
| 77 Feb. 4-8 | 18.00 | 0.71 | 0.00 | 0.00 | 0.00 | | 0.0 | |
| 77 Apr. 4-6 | 23.40 | 0.92 | 0.02 | 0.50 | 0.02 | | 2.1 | |
| 77 Apr. 12-14 | 47.80 | 1.88 | 0.32 | 8.10 | 0.28 | | 16.9 | |
| 77 Apr. 22-24 | 31.20 | 1.23 | 0.08 | 2.00 | 0.07 | 0.60 | 6.4 | 8.6 |
| 78 Dec. 11-12 | 19.90 | 0.78 | 0.00 | 0.10 | 0.00 | | 0.5 | |
| 79 Jan. 8-9 | 52.70 | 2.07 | 0.42 | 10.70 | 0.37 | | 20.3 | |
| 79 Jan. 21-23 | 25.40 | 1.00 | 0.03 | 0.80 | 0.03 | | 3.1 | |
| 79 Feb. 7-10 | 36.40 | 1.43 | 0.14 | 3.60 | 0.13 | | 9.9 | |
| 79 Mar. 8-9 | 26.60 | 1.05 | 0.04 | 1.00 | 0.03 | 0.56 | 3.8 | 8.5 |

5 YEARS RETURN PERIOD: Model Year 1986/87

| Period of Rainfall | Basin Rainfall mm | Basin Rainfall inch | Runoff inch | Runoff mm | Disch. Vol. ( MCM ) | Total Disch. | Runoff Coef. | Annual Run. Coef. |
|---|---|---|---|---|---|---|---|---|
| 86 Nov. 7-11 | 22.70 | 0.89 | 0.01 | 0.30 | 0.01 | | 1.3 | |
| 86 Nov.28-Dc.2 | 20.10 | 0.79 | 0.00 | 0.10 | 0.00 | | 0.5 | |
| 86 Dec. 19-20 | 24.90 | 0.98 | 0.03 | 0.80 | 0.03 | | 3.2 | |
| 87 Mar. 18-19 | 22.50 | 0.89 | 0.01 | 0.30 | 0.01 | 0.05 | 1.3 | 1.0 |

10 YEARS RETURN PERIOD: Model Year 1983/84

| Period of Rainfall | Basin Rainfall mm | Basin Rainfall inch | Runoff inch | Runoff mm | Disch. Vol. ( MCM ) | Total Disch. | Runoff Coef. | Annual Run. Coef. |
|---|---|---|---|---|---|---|---|---|
| 84 Mar. 13-15 | 29.90 | 1.18 | 0.07 | 1.80 | 0.06 | | 6.0 | |
| 84 Mar. 24-29 | 47.00 | 1.85 | 0.31 | 7.90 | 0.27 | 0.33 | 16.8 | 8.1 |

## E1 Site

2 YEARS RETURN PERIOD: Model Year 1976/77 and 1985/86

| Period of Rainfall | Basin Rainfall mm | Basin Rainfall inch | Runoff inch | Runoff mm | Disch. Vol. ( MCM ) | Total Disch. | Runoff Coef. | Annual Run. Coef. |
|---|---|---|---|---|---|---|---|---|
| 77 Jan. 3-7 | 36.40 | 1.43 | 0.14 | 3.60 | 0.03 | | 9.9 | |
| 77 Apr. 12-14 | 57.60 | 2.27 | 0.52 | 13.20 | 0.13 | | 22.9 | |
| 77 Apr. 23-24 | 24.20 | 0.95 | 0.02 | 0.50 | 0.01 | 0.17 | 2.1 | 9.4 |
| 85 Dec. 17-19 | 85.20 | 3.35 | 1.20 | 30.50 | 0.29 | | 35.8 | |
| 86 Jan. 16-19 | 24.00 | 0.94 | 0.02 | 0.50 | 0.01 | | 2.1 | |
| 86 Feb. 3-5 | 28.50 | 1.12 | 0.05 | 1.30 | 0.01 | 0.31 | 4.6 | 15.6 |

5 YEARS RETURN PERIOD: Model Year 1977/78

| Period of Rainfall | Basin Rainfall mm | Basin Rainfall inch | Runoff inch | Runoff mm | Disch. Vol. ( MCM ) | Total Disch. | Runoff Coef. | Annual Run. Coef. |
|---|---|---|---|---|---|---|---|---|
| 77 Dec. 12-15 | 35.30 | 1.39 | 0.13 | 3.30 | 0.03 | | 9.3 | |
| 77 Dec. 21-23 | 39.30 | 1.55 | 0.19 | 4.80 | 0.05 | | 12.2 | |
| 78 Mar. 11-14 | 32.10 | 1.26 | 0.09 | 2.30 | 0.02 | 0.10 | 7.2 | 6.8 |

10 YEARS RETURN PERIOD: Model Year 1972/73

| Period of Rainfall | Basin Rainfall mm | Basin Rainfall inch | Runoff inch | Runoff mm | Disch. Vol. ( MCM ) | Total Disch. | Runoff Coef. | Annual Run. Coef. |
|---|---|---|---|---|---|---|---|---|
| 73 Jan. 12-14 | 88.00 | 3.46 | 1.27 | 32.30 | 0.31 | 0.31 | 36.7 | 25.2 |

Total Disch.; Annual total volume of discharge.
Runoff Coef.; Runoff coefficient of each flood.
Annual Run. Coef.; Percentage of total discharge to annual basin rainfall.

Table A.4.6 (2/2) RUNOFF VOLUME BY SCS METHOD

J1 Site

2 YEARS RETURN PERIOD: Model Year 1978/79

| Period of Rainfall | Basin Rainfall mm | Basin Rainfall inch | Runoff inch | Runoff mm | Disch. Vol. ( MCM ) | Total Disch. | Runoff Coef. | Annual Run. Coef. |
|---|---|---|---|---|---|---|---|---|
| 78 Dec. 11-12 | 35.90 | 1.41 | 0.14 | 3.60 | 0.06 | | 10.0 | |
| 79 Jan. 21-23 | 44.20 | 1.74 | 0.26 | 6.60 | 0.11 | | 14.9 | |
| 79 Feb. 8-10 | 44.80 | 1.76 | 0.27 | 6.90 | 0.12 | | 15.4 | |
| 79 Mar. 7-9 | 33.00 | 1.30 | 0.10 | 2.50 | 0.04 | 0.33 | 7.6 | 9.6 |

5 YEARS RETURN PERIOD: Model Year 1986/87

| Period of Rainfall | Basin Rainfall mm | Basin Rainfall inch | Runoff inch | Runoff mm | Disch. Vol. ( MCM ) | Total Disch. | Runoff Coef. | Annual Run. Coef. |
|---|---|---|---|---|---|---|---|---|
| 86 Nov. 7-12 | 20.30 | 0.80 | 0.01 | 0.10 | 0.00 | | 0.5 | |
| 86 Nov.27-Dc.2 | 42.40 | 1.67 | 0.23 | 5.80 | 0.10 | | 13.7 | |
| 87 Feb. 9 | 17.40 | 0.69 | 0.00 | 0.10 | 0.00 | | 0.6 | |
| 87 Mar. 18-19 | 21.00 | 0.83 | 0.01 | 0.20 | 0.00 | 0.11 | 1.0 | 4.7 |

10 YEARS RETURN PERIOD: Model Year 1984/85

| Period of Rainfall | Basin Rainfall mm | Basin Rainfall inch | Runoff inch | Runoff mm | Disch. Vol. ( MCM ) | Total Disch. | Runoff Coef. | Annual Run. Coef. |
|---|---|---|---|---|---|---|---|---|
| 85 Apr. 21-22 | 28.20 | 1.11 | 0.05 | 1.30 | 0.02 | 0.02 | 4.6 | 1.2 |

ABYAD Site

2 YEARS RETURN PERIOD: Model Year 1976/77 and 1984/85

| Period of Rainfall | Basin Rainfall mm | Basin Rainfall inch | Runoff inch | Runoff mm | Disch. Vol. ( MCM ) | Total Disch. | Runoff Coef. | Annual Run. Coef. |
|---|---|---|---|---|---|---|---|---|
| 77 Jan. 3-7 | 31.00 | 1.22 | 0.26 | 6.60 | 0.77 | | 21.3 | |
| 77 Feb. 4-9 | 18.20 | 0.72 | 0.05 | 1.30 | 0.15 | | 7.1 | |
| 77 Apr. 12-14 | 35.10 | 1.38 | 0.34 | 8.60 | 1.00 | | 24.5 | |
| 77 Apr. 23-24 | 18.80 | 0.74 | 0.06 | 1.50 | 0.17 | 2.09 | 8.0 | 11.3 |
| 84 Dec. 12-14 | 14.20 | 0.56 | 0.02 | 0.50 | 0.06 | | 3.5 | |
| 85 Feb. 1-4 | 17.60 | 0.69 | 0.04 | 1.00 | 0.12 | | 5.7 | |
| 85 Feb. 14-17 | 48.20 | 1.90 | 0.68 | 17.30 | 2.02 | | 35.9 | |
| 85 Feb. 24-25 | 11.80 | 0.46 | 0.00 | 0.10 | 0.01 | | 0.8 | |
| 85 Mar. 22 | 15.90 | 0.63 | 0.03 | 0.80 | 0.09 | | 5.0 | |
| 85 Apr. 21-23 | 21.90 | 0.86 | 0.10 | 2.50 | 0.29 | 2.59 | 11.4 | 13.7 |

5 YEARS RETURN PERIOD: Model Year 1983/84

| Period of Rainfall | Basin Rainfall mm | Basin Rainfall inch | Runoff inch | Runoff mm | Disch. Vol. ( MCM ) | Total Disch. | Runoff Coef. | Annual Run. Coef. |
|---|---|---|---|---|---|---|---|---|
| 84 Jan. 26 | 17.60 | 0.69 | 0.04 | 1.00 | 0.12 | | 5.7 | |
| 84 Mar. 12-19 | 47.50 | 1.87 | 0.65 | 16.50 | 1.92 | | 34.7 | |
| 84 Mar. 22-25 | 30.90 | 1.22 | 0.26 | 6.60 | 0.77 | 2.81 | 21.4 | 21.3 |

10 YEARS RETURN PERIOD: Model Year 1972/73

| Period of Rainfall | Basin Rainfall mm | Basin Rainfall inch | Runoff inch | Runoff mm | Disch. Vol. ( MCM ) | Total Disch. | Runoff Coef. | Annual Run. Coef. |
|---|---|---|---|---|---|---|---|---|
| 72 Nov. 24 | 11.90 | 0.47 | 0.00 | 0.10 | 0.01 | | 0.8 | |
| 73 Jan. 12-16 | 49.00 | 1.93 | 0.70 | 17.80 | 20.70 | 20.71 | 36.3 | 18.4 |

Total Disch.; Annual total volume of discharge(MCM.).
Runoff Coef.; Runoff coefficient of each flood(%).
Annual Run. Coef.; Percentage of total discharge to annual basin rainfall.

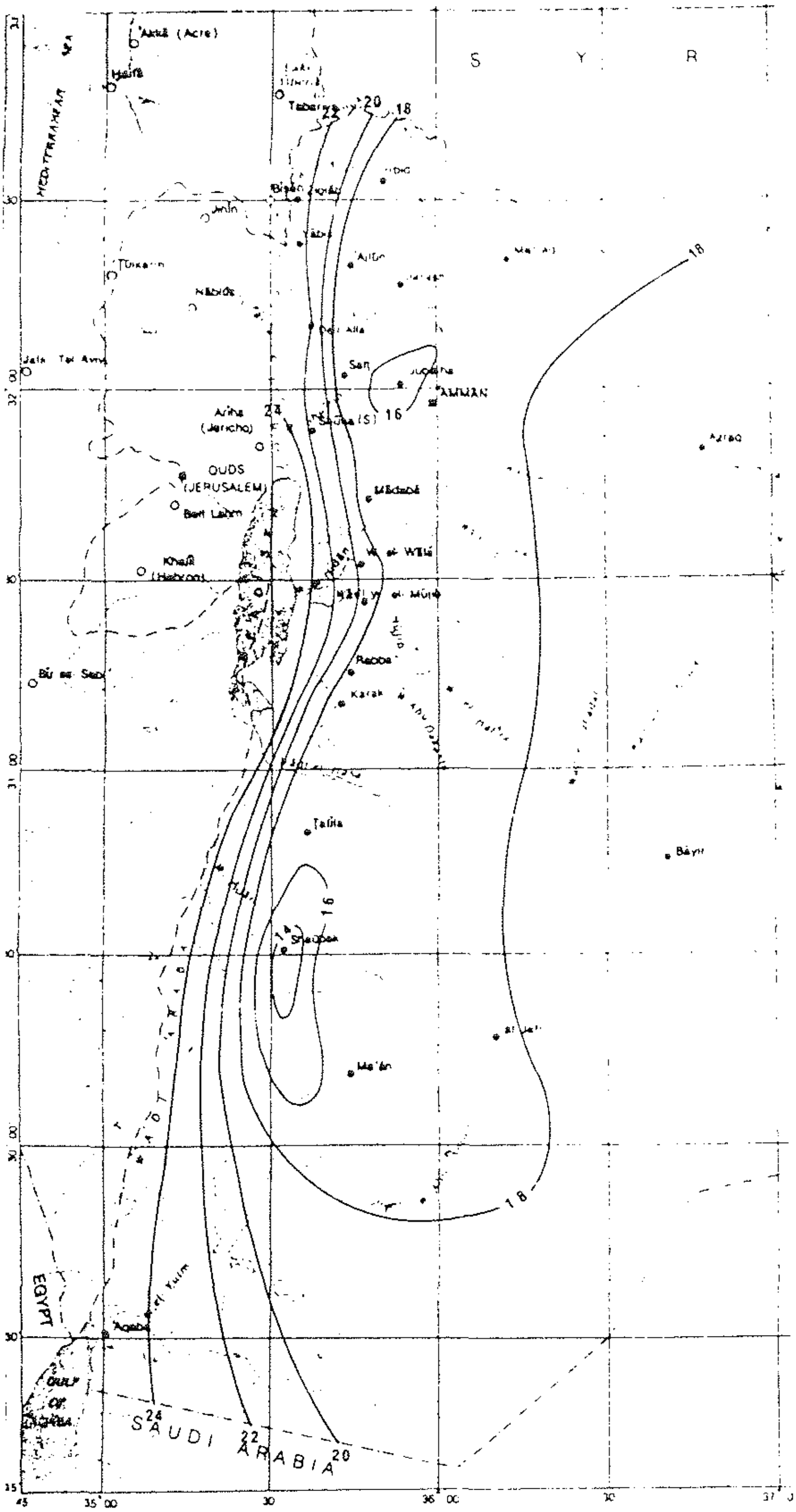


Fig.A.2.1 Mean Daily Temperature - Annual

THE HASHEMITE KINGDOM OF JORDAN

FEASIBILITY STUDY ON AGRICULTURAL DEVELOPMENT FOR THE KARAK-TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY

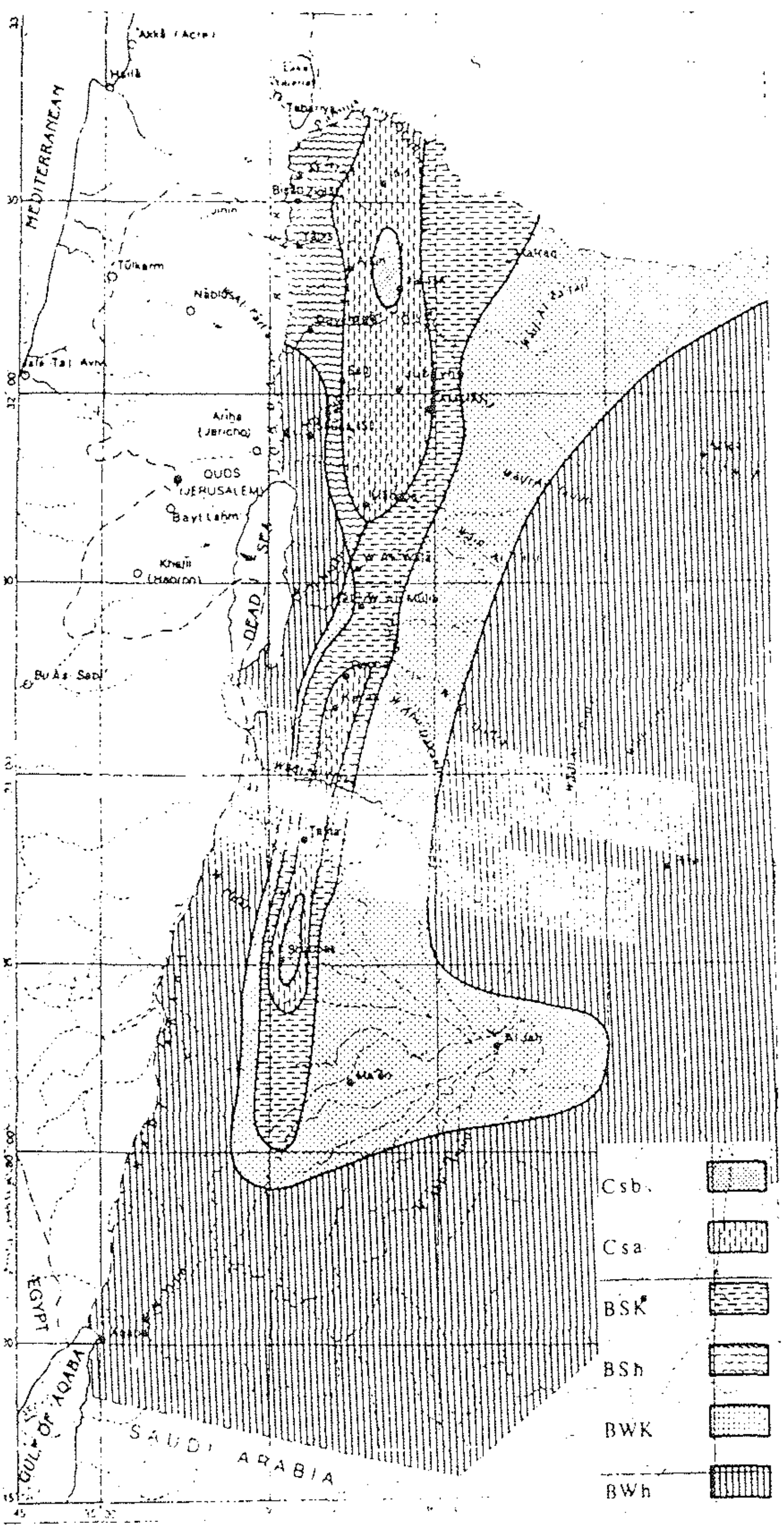



Fig.A.2.2

The Climate Regions of Koppen

| THE HASHEMITE KINGDOM OF JORDAN |
|---|
| FEASIBILITY STUDY ON AGRICULTURAL DEVELOPMENT FOR THE KARAK-TAFILA DEVELOPMENT REGION |
| JAPAN INTERNATIONAL COOPERATION AGENCY |

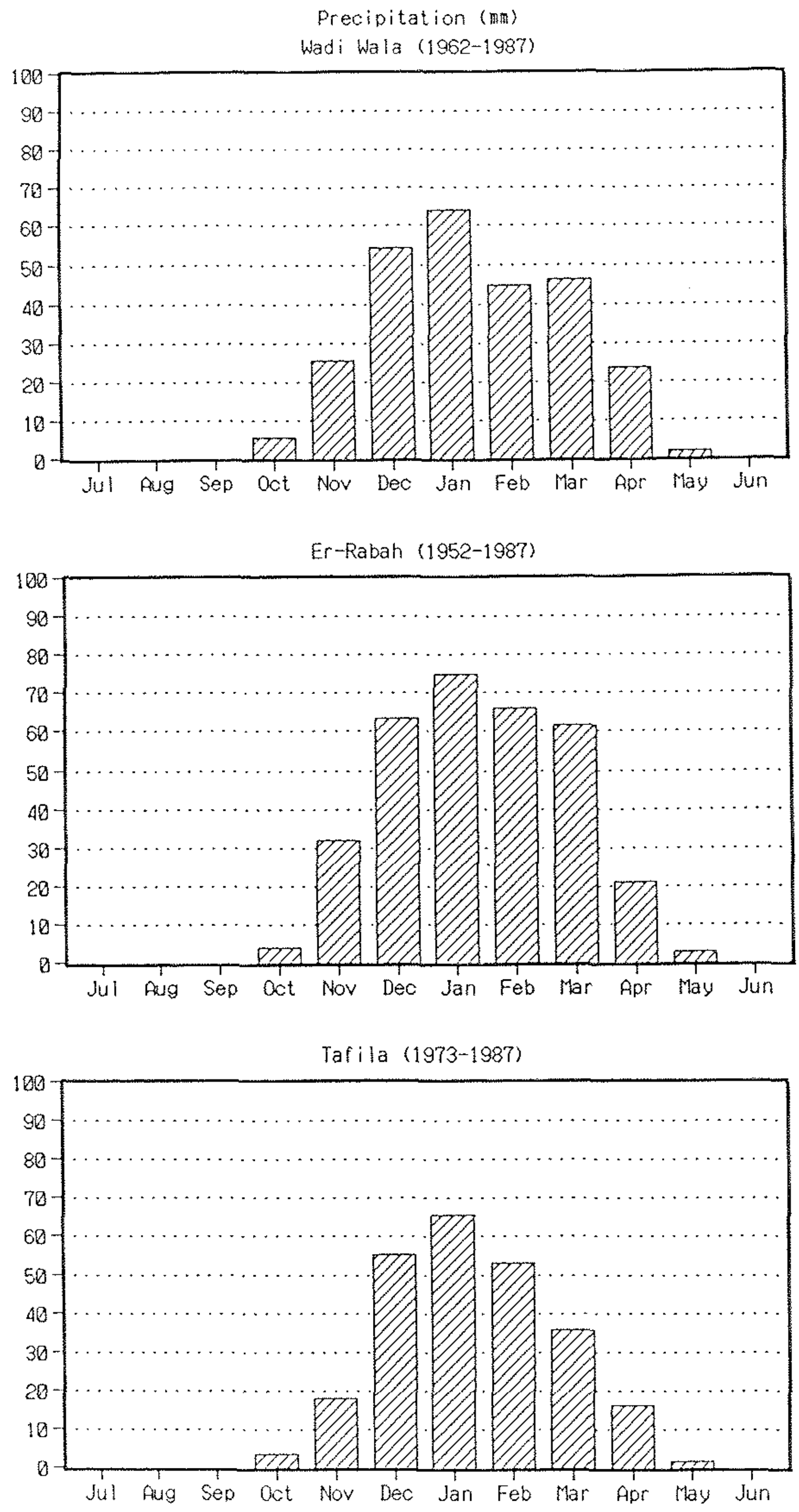
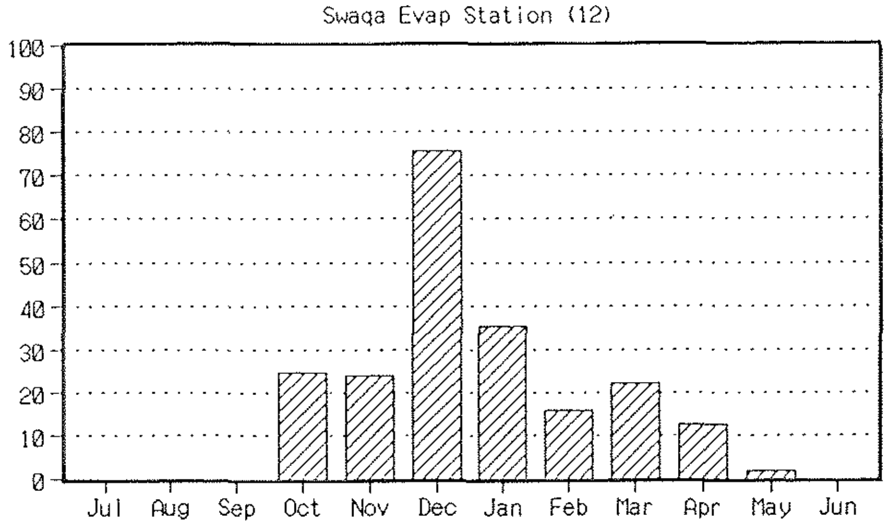



Fig.A.2.3(1/2)Precipitation Total
Monthly Change

THE HASHEMITE KINGDOM OF JORDAN

FEASIBILITY STUDY ON AGRICULTURAL DEVELOPMENT
FOR THE KARAK-TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY



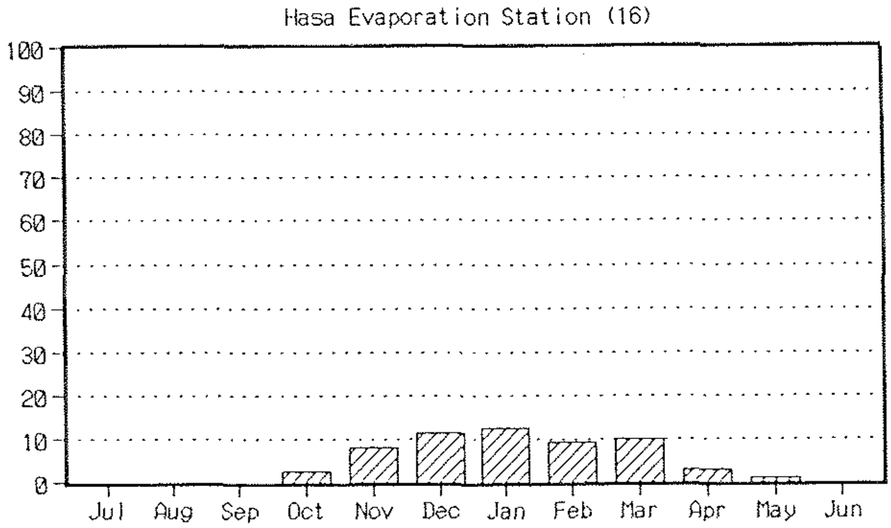




Fig.A.2.3(2/2)Precipitation Total Monthly Change

THE HASHEMITE KINGDOM OF JORDAN

FEASIBILITY STUDY ON AGRICULTURAL DEVELOPMENT FOR THE KARAK-TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY

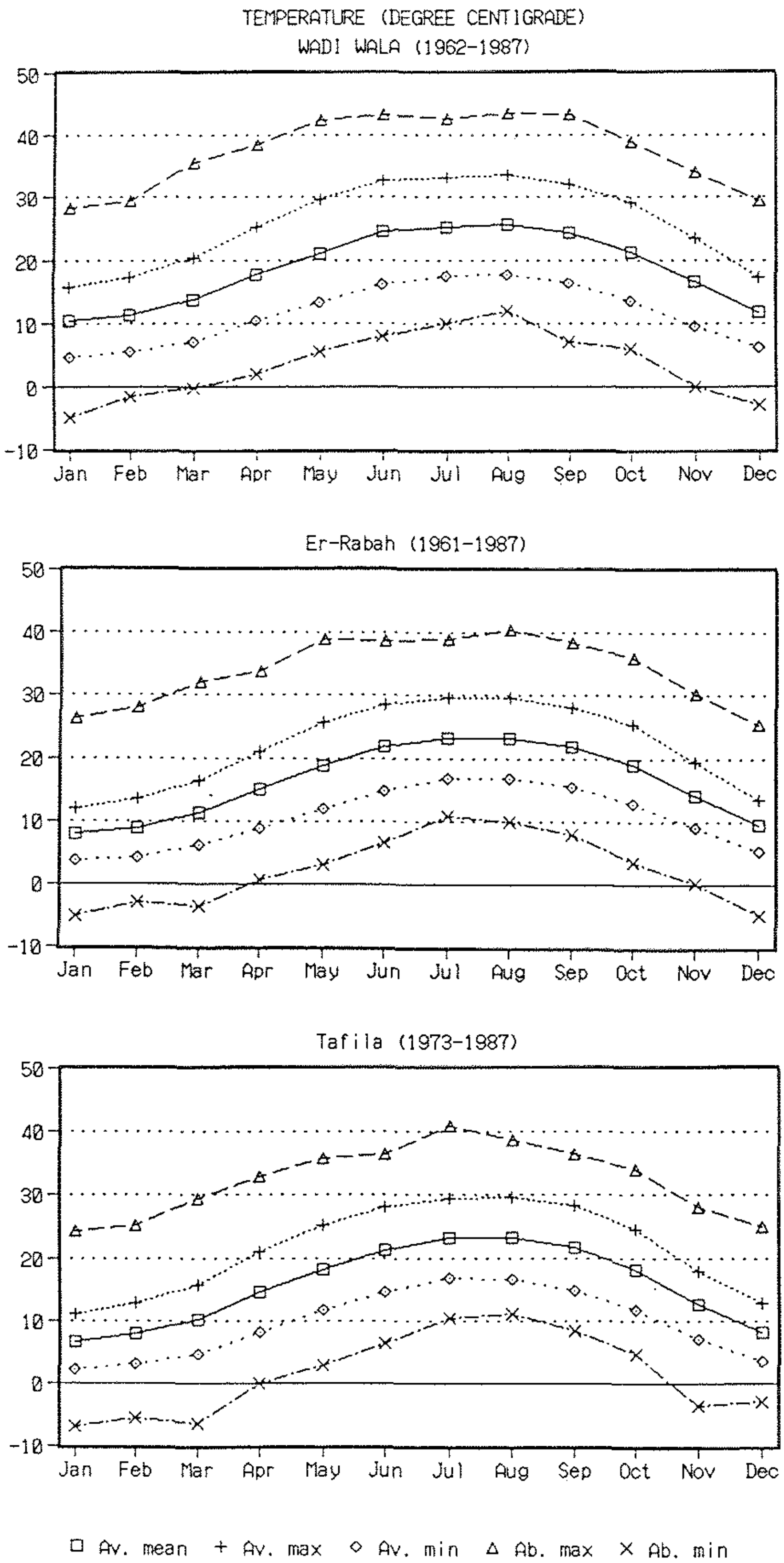
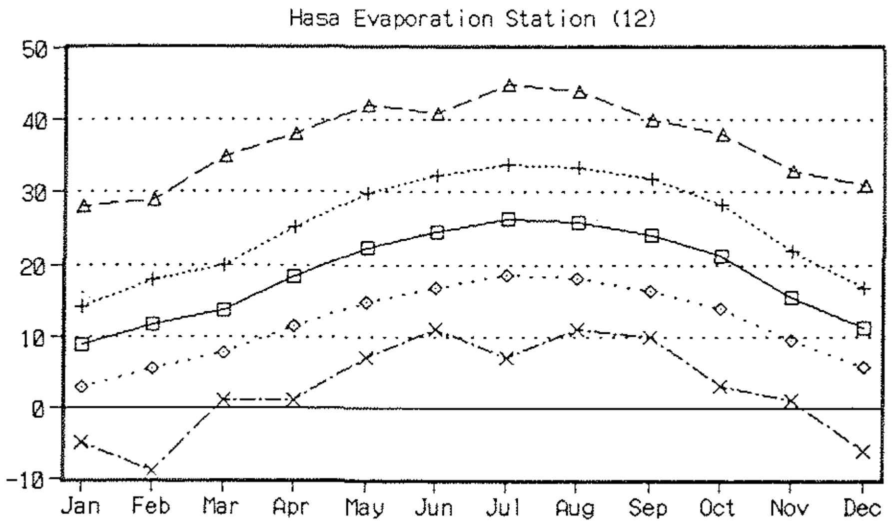



Fig.A.2.4(1/2) Temperature Mean Daily Monthly Change (1/5)~(5/5)

THE HASHEMITE KINGDOM OF JORDAN

FEASIBILITY STUDY ON AGRICULTURAL DEVELOPMENT FOR THE KARAK-TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY



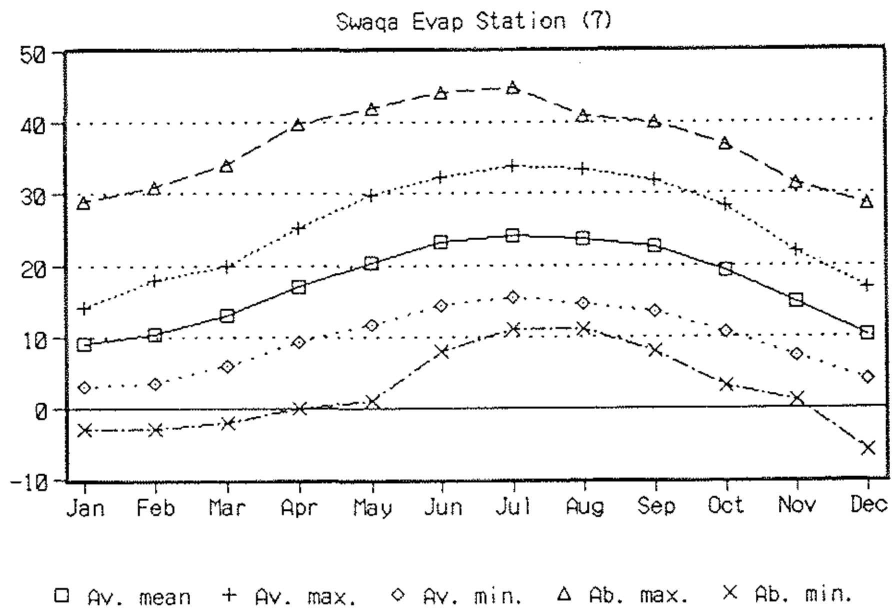
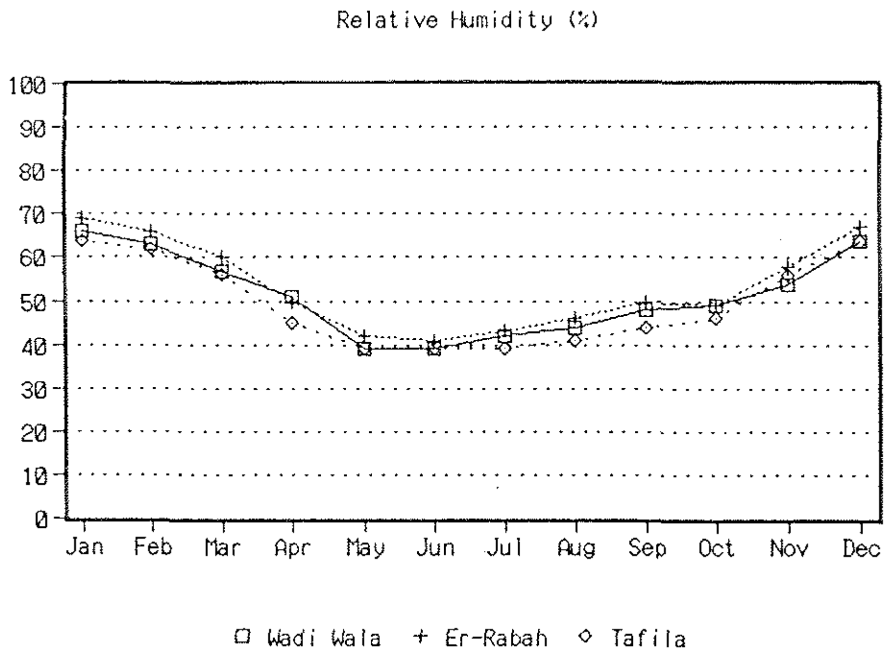




Fig.A.2.4(2/2) Temperature Mean Daily Monthly Change (1/5)~(5/5)

THE HASHEMITE KINGDOM OF JORDAN

FEASIBILITY STUDY ON AGRICULTURAL DEVELOPMENT FOR THE KARAK-TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY



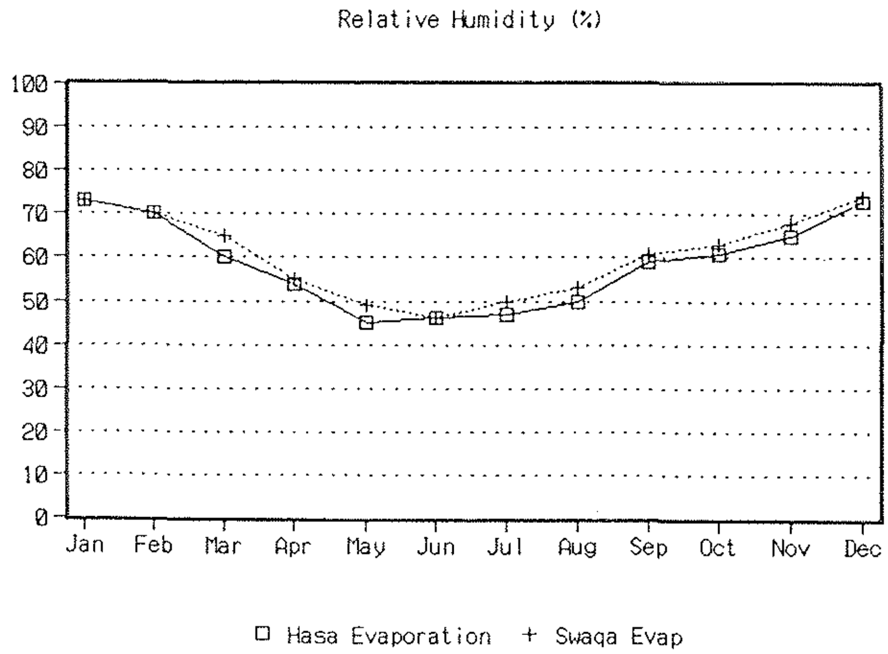




Fig.A.2.5 Relative Humidity Mean Daily Monthly Change

THE HASHEMITE KINGDOM OF JORDAN

FEASIBILITY STUDY ON AGRICULTURAL DEVELOPMENT FOR THE KARAK-TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY

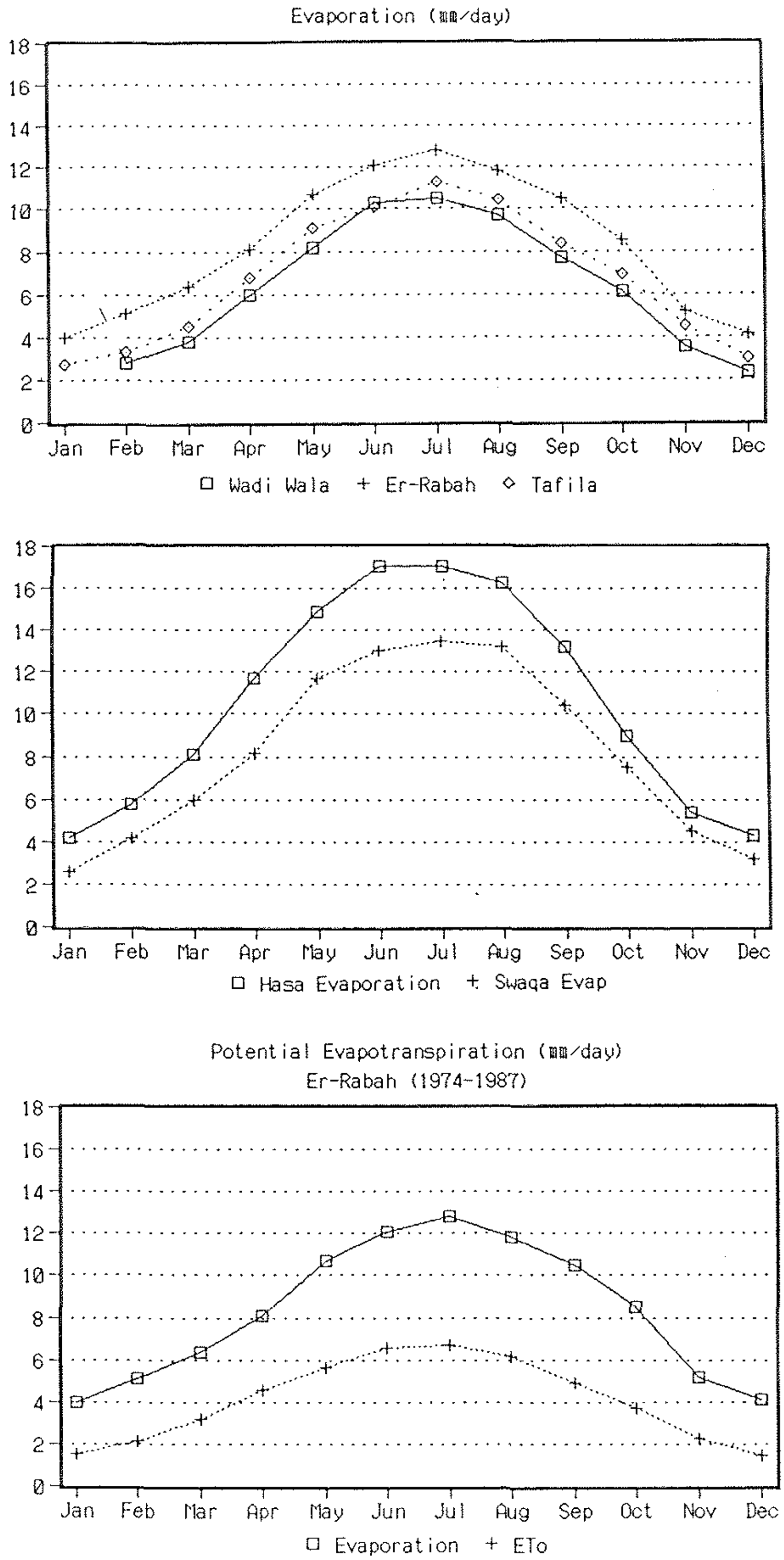



Fig.A.2.6 Evaporation and Potential Evaporation Daily Monthly Change

THE HASHEMITE KINGDOM OF JORDAN

FEASIBILITY STUDY ON AGRICULTURAL DEVELOPMENT FOR THE KARAK-TAFILA DEVELOPMENT REGION

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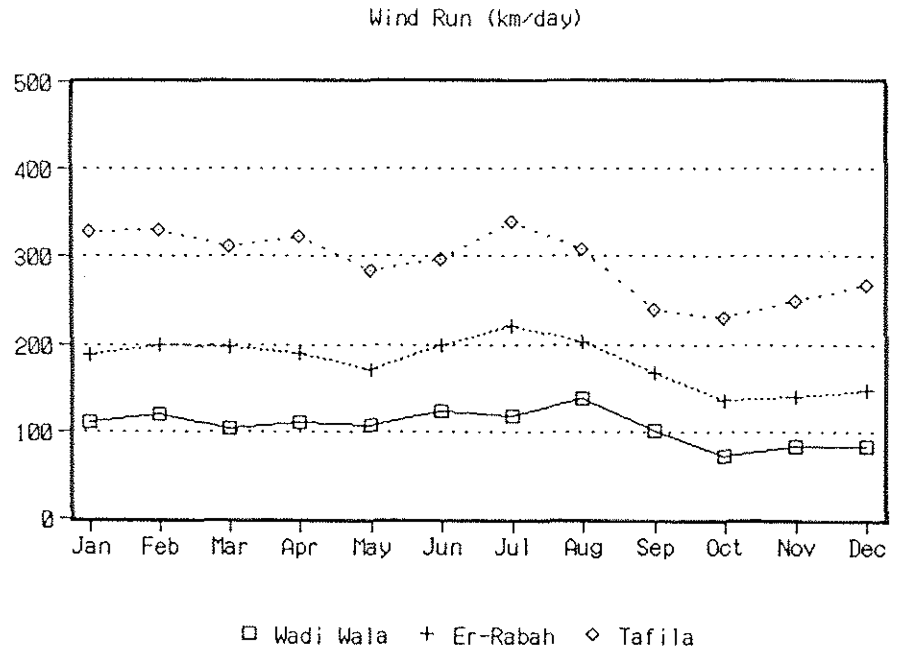


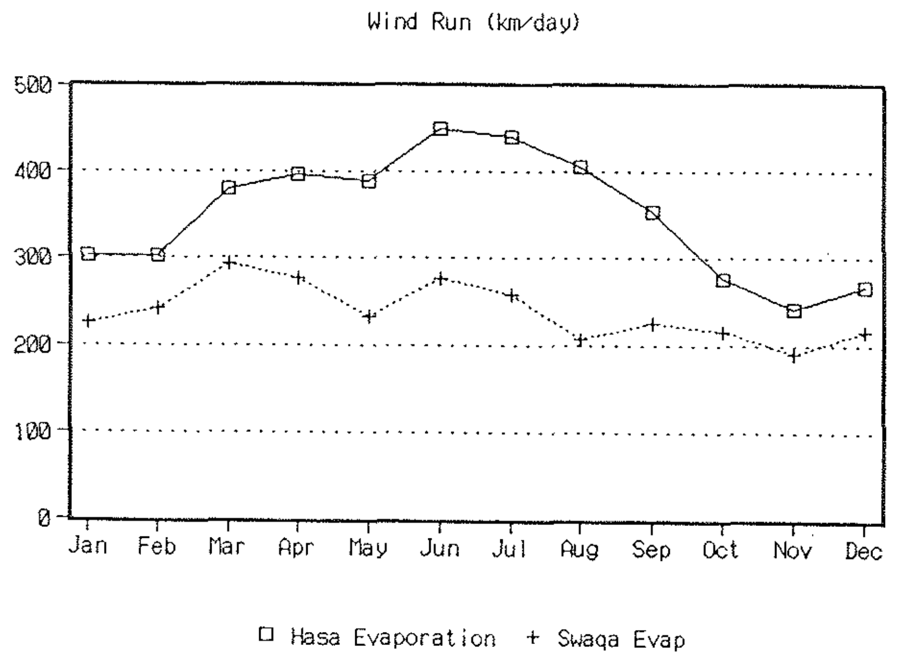
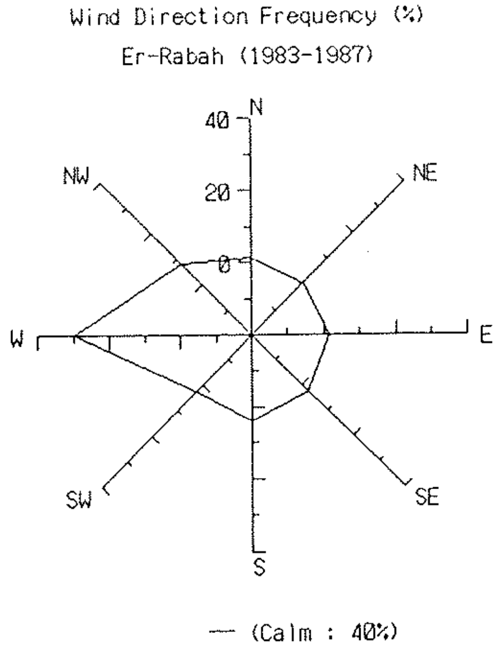




Fig.A.2.7 Wind Run Total Daily Monthly Change

THE HASHEMITE KINGDOM OF JORDAN

FEASIBILITY STUDY ON AGRICULTURAL DEVELOPMENT FOR THE KARAK-TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY



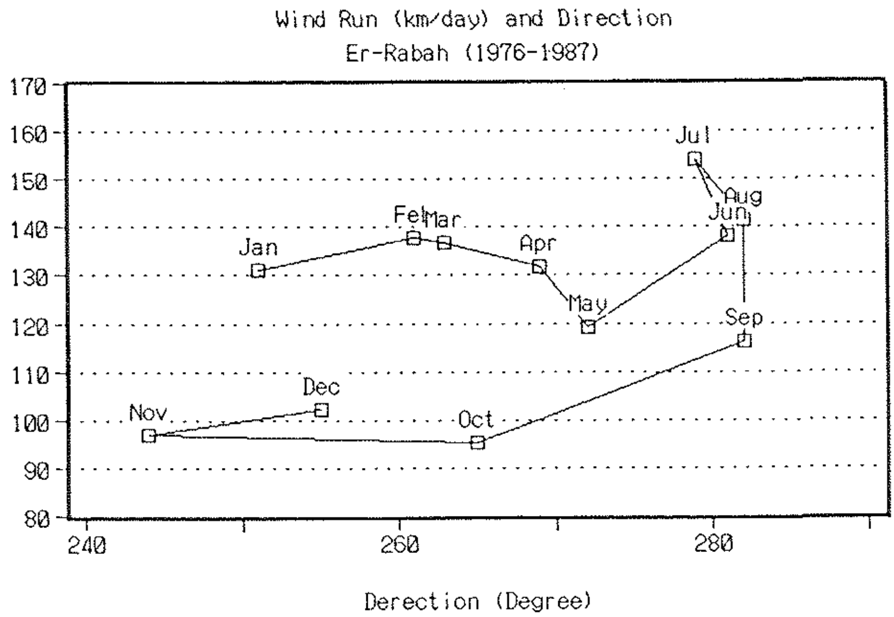




Fig.A.2.8 Wind Direction at Er-Rabah

THE HASHEMITE KINGDOM OF JORDAN

FEASIBILITY STUDY ON AGRICULTURAL DEVELOPMENT FOR THE KARAK-TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY

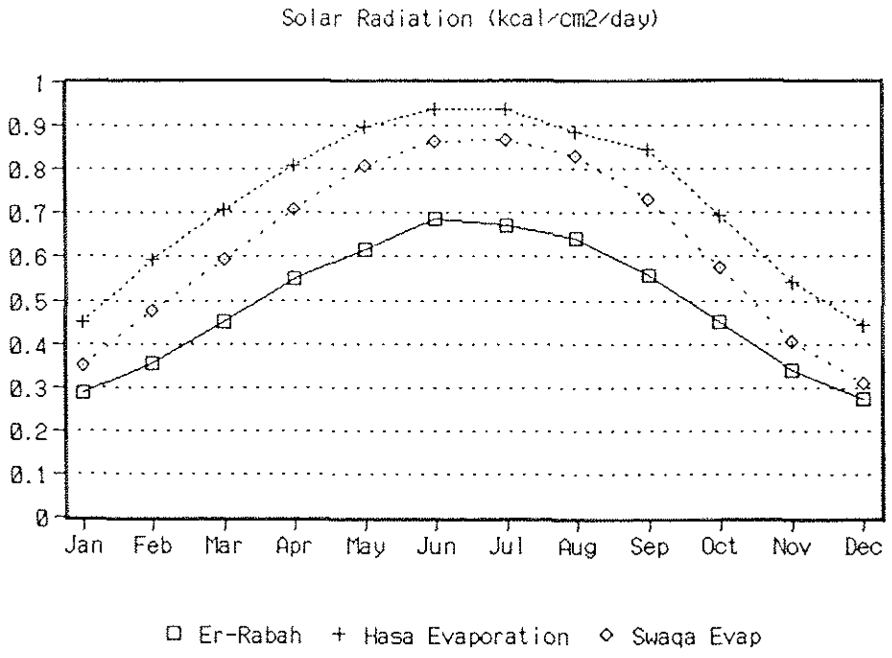



Fig.A.2.9 Solar Radiation

THE HASHEMITE KINGDOM OF JORDAN

FEASIBILITY STUDY ON AGRICULTURAL DEVELOPMENT FOR THE KARAK-TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY

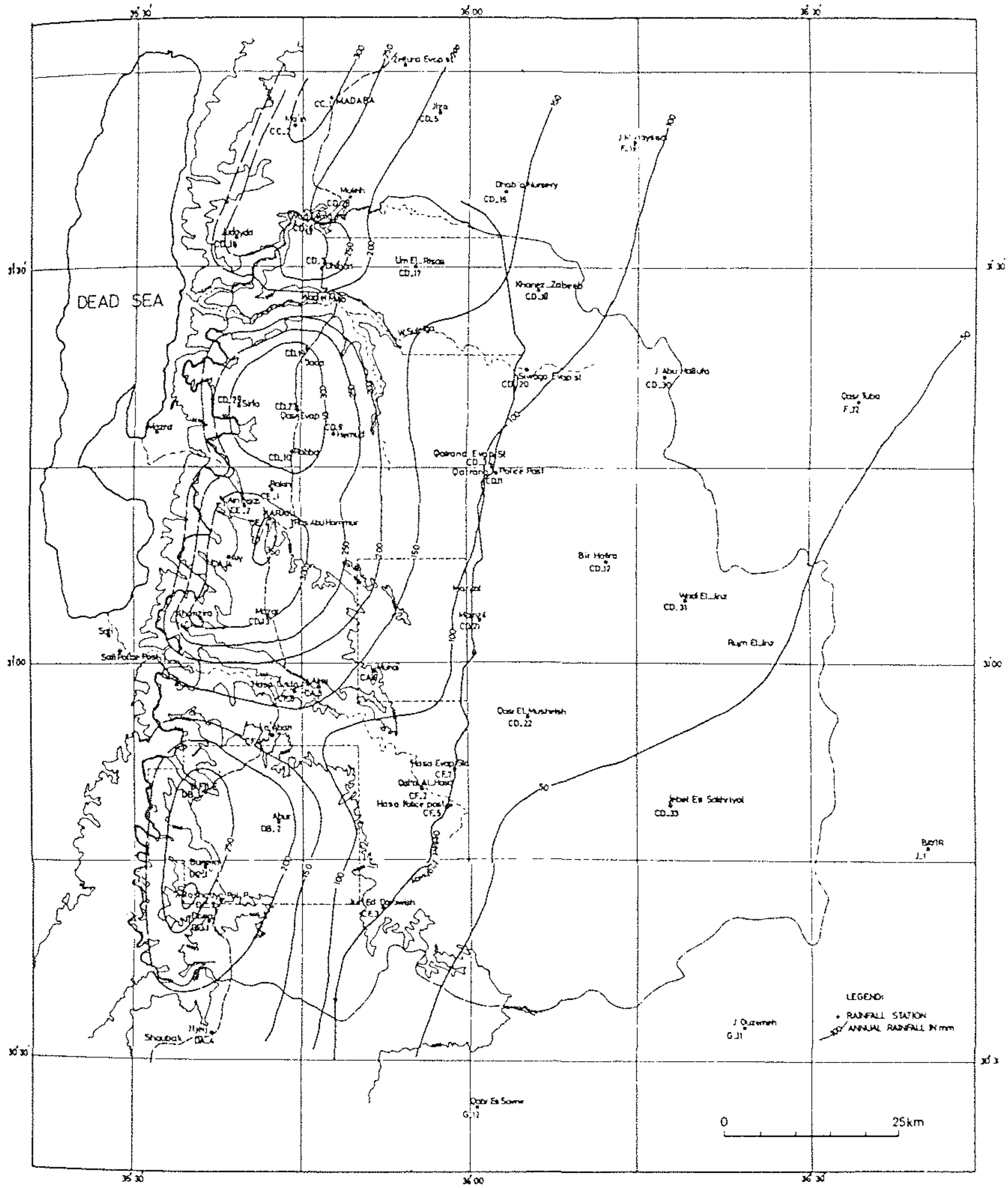



Fig.A.3.1 Rainfall Distribution Isohyets : Long Term Average

THE HASHEMITE KINGDOM OF JORDAN

FEASIBILITY STUDY ON AGRICULTURAL DEVELOPMENT FOR THE KARAK-TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY

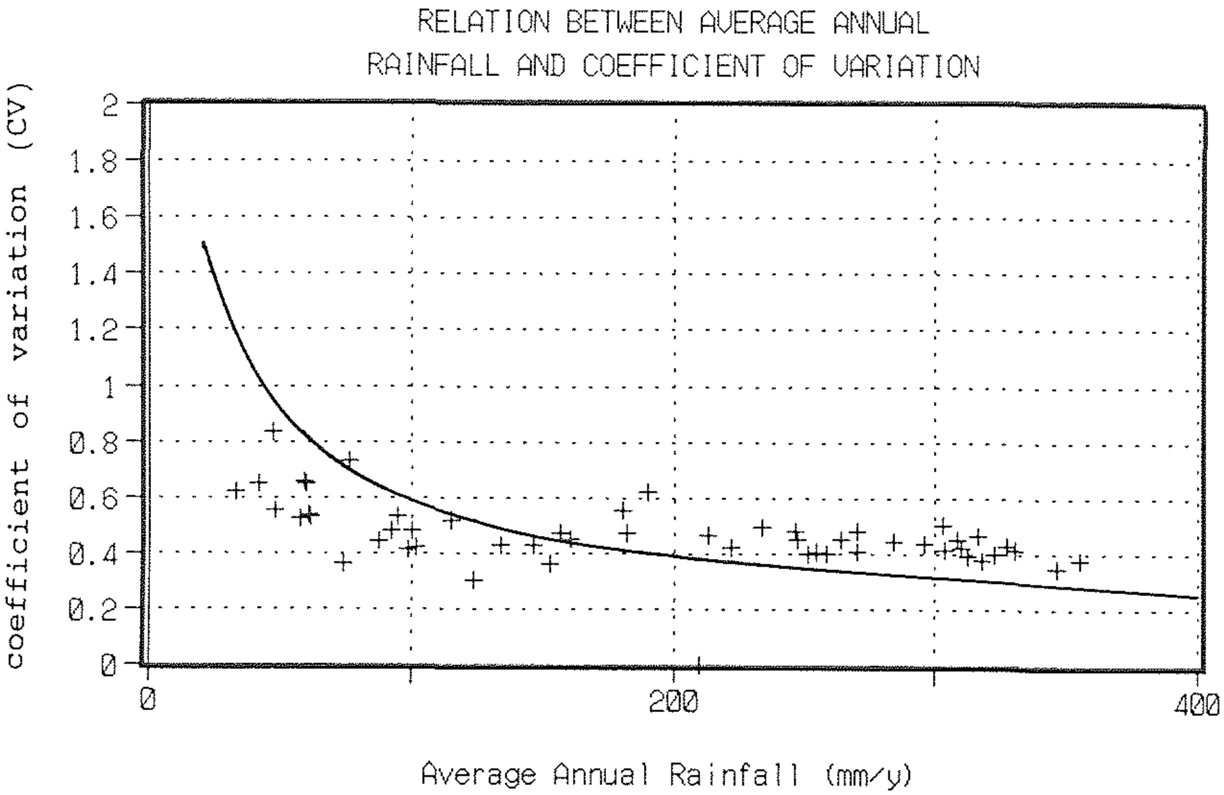



Fig.A.3.2

Relation between Annual Average Rainfall and Variation Coefficient

THE HASHEMITE KINGDOM OF JORDAN

FEASIBILITY STUDY ON AGRICULTURAL DEVELOPMENT FOR THE KARAK-TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY

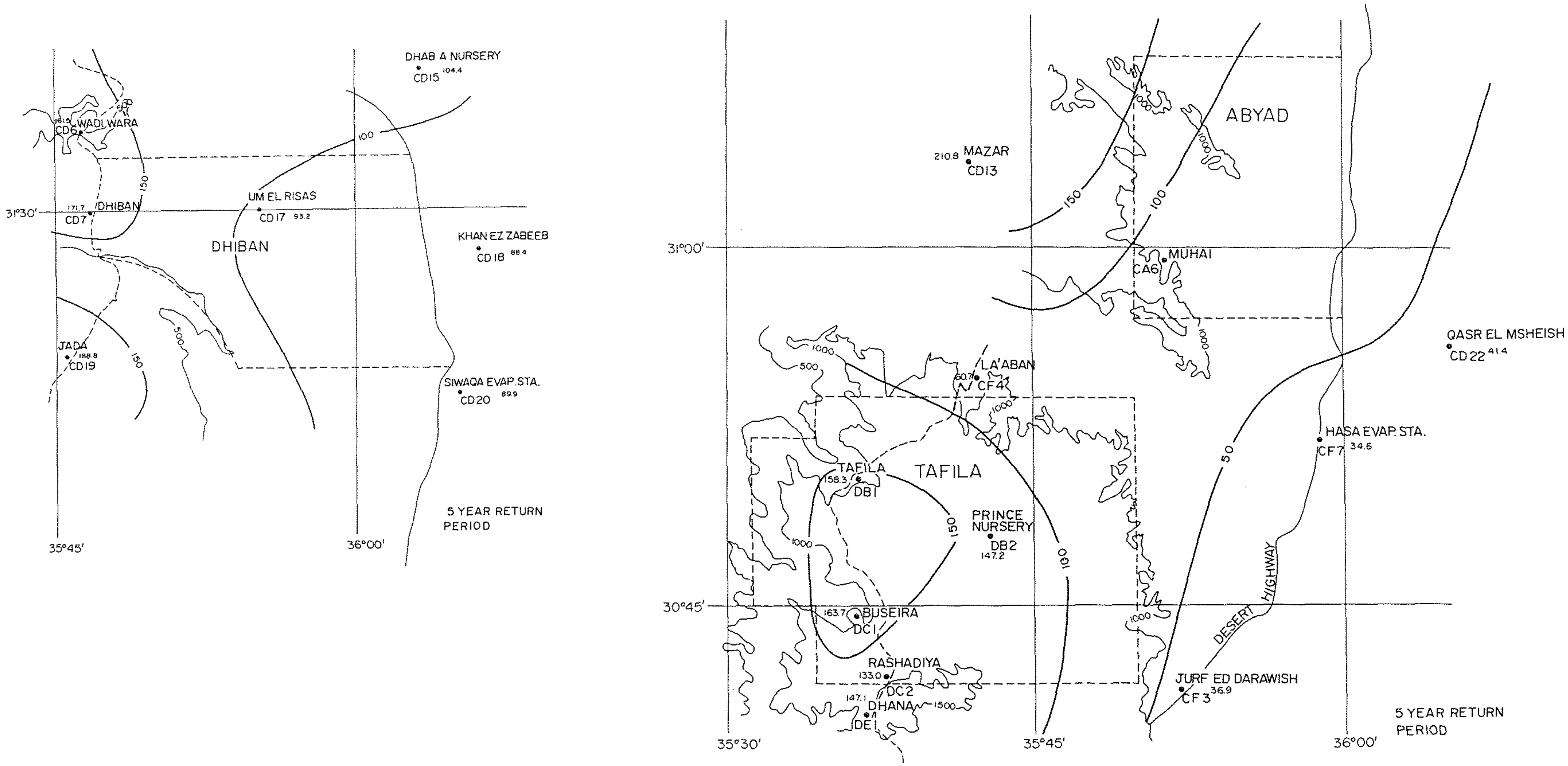
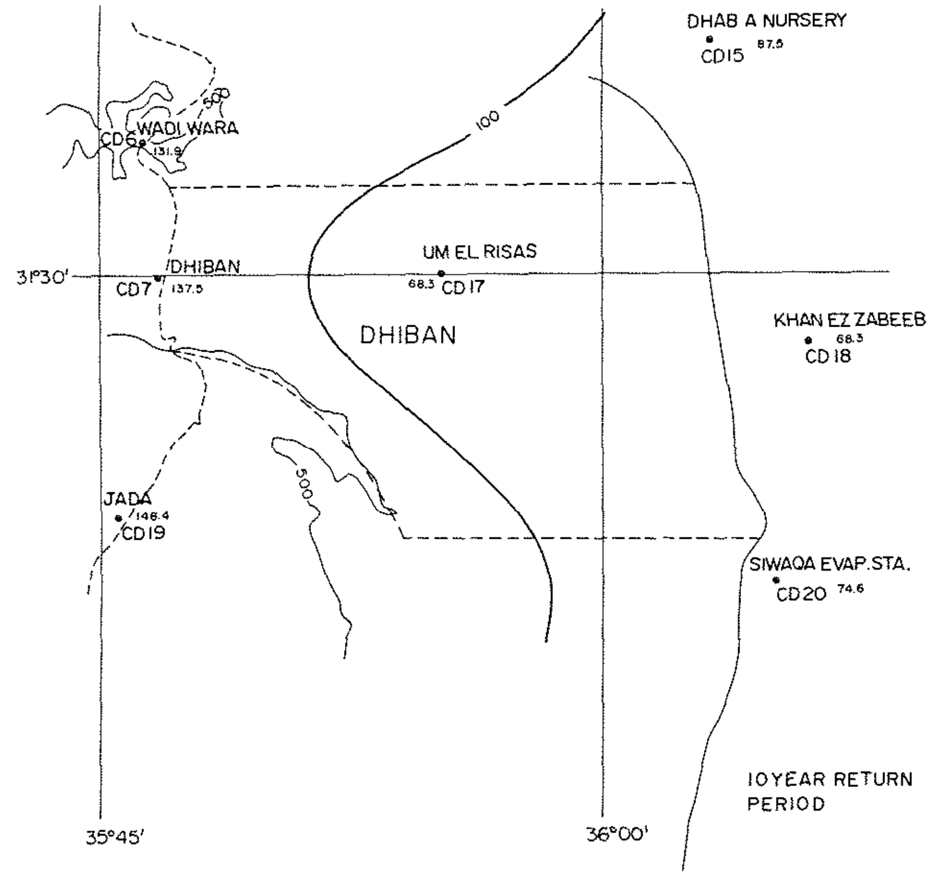



Fig.A.3.3 Rainfall Distribution Isohyets : Return Period of 5 Years Draught

THE HASHEMITE KINGDOM OF JORDAN

FEASIBILITY STUDY ON AGRICULTURAL DEVELOPMENT FOR THE KARAK - TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY



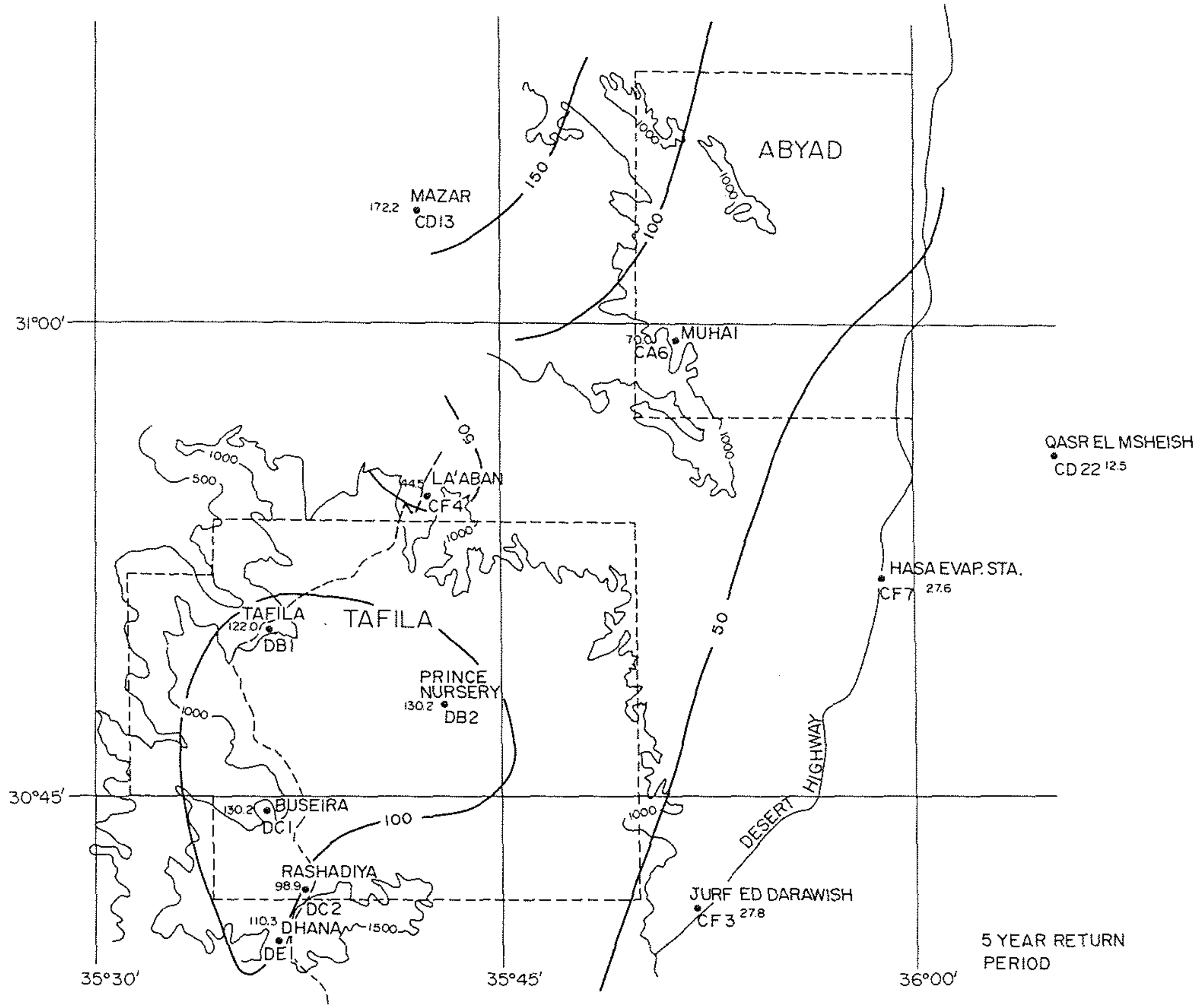




Fig.A.3.4 Rainfall Distribution Isohyets : Return Period of 10 Years Draught

THE HASHEMITE KINGDOM OF JORDAN
FEASIBILITY STUDY ON AGRICULTURAL DEVELOPMENT FOR THE KARAK-TAFILA DEVELOPMENT REGION
JAPAN INTERNATIONAL COOPERATION AGENCY

**WATER AUTHORITY OF JORDAN**
**WATER RESOURCES DEPARTMENT**

RAINFALL INTENSITY - DURATION - FREQUENCY

INTENSITIES ( MM/HR )

STATION NAME : TAFIELEH
LONGITUDE : 35°36'
LATITUDE : 30°50'
ALTITUDE : 1000 m.

DURATION OF RECORD:
PALESTINE GRID E:
N: 27.5

| DURATION / RETURN PERIODS YEARS | MINUTES | | | | | | HOURS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 30 | 60 | 2 | 3 | 6 | 24 |
| 2 | 46.8 | 28.3 | 21.3 | 17.7 | 13.8 | 9.3 | 6.9 | 6.0 | 4.6 | 2.1 |
| 5 | 63.0 | 35.5 | 26.2 | 21.4 | 16.7 | 11.4 | 8.8 | 7.9 | 6.3 | 3.15 |
| 10 | 73.7 | 40.3 | 29.4 | 23.8 | 18.7 | 12.8 | 10.1 | 9.1 | 7.5 | 3.9 |
| 25 | 87.3 | 46.3 | 33.5 | 26.9 | 21.2 | 14.5 | 11.6 | 10.7 | 8.9 | 4.8 |
| 50 | 97.3 | 50.8 | 36.6 | 29.2 | 23.0 | 15.9 | 12.8 | 11.9 | 10.0 | 5.4 |
| 100 | 107.3 | 55.2 | 39.6 | 31.5 | 24.8 | 17.1 | 14.0 | 13.0 | 11.1 | 6.1 |
| 200 | 117.3 | 59.6 | 42.6 | 33.8 | 26.7 | 18.4 | 15.2 | 14.2 | .2.2 | 6.8 |
| 500 | 130.4 | 65.4 | 46.6 | 36.8 | 29.1 | 20.1 | 16.7 | 15.7 | 13.6 | 7.7 |

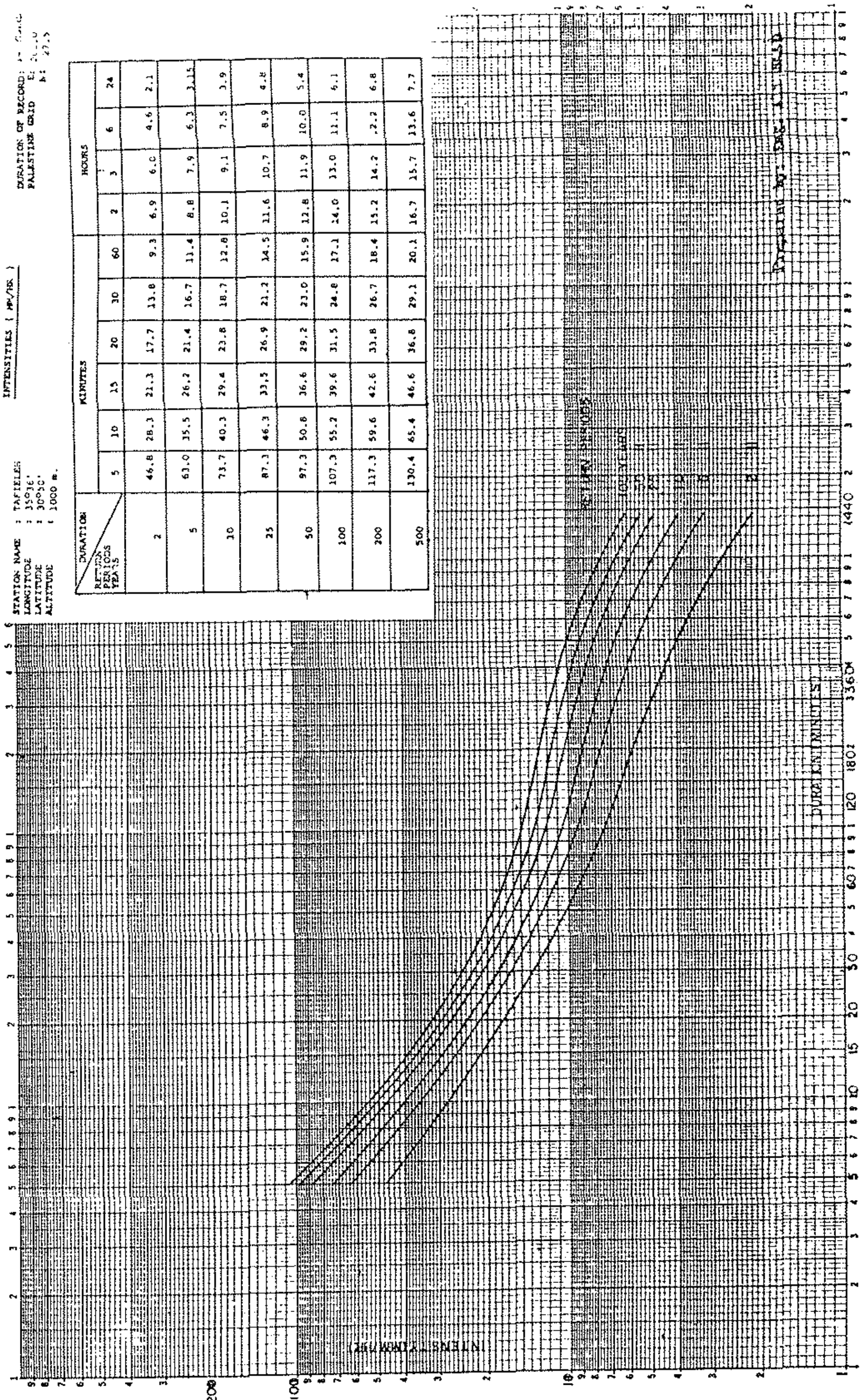



Fig. No. " 32 "

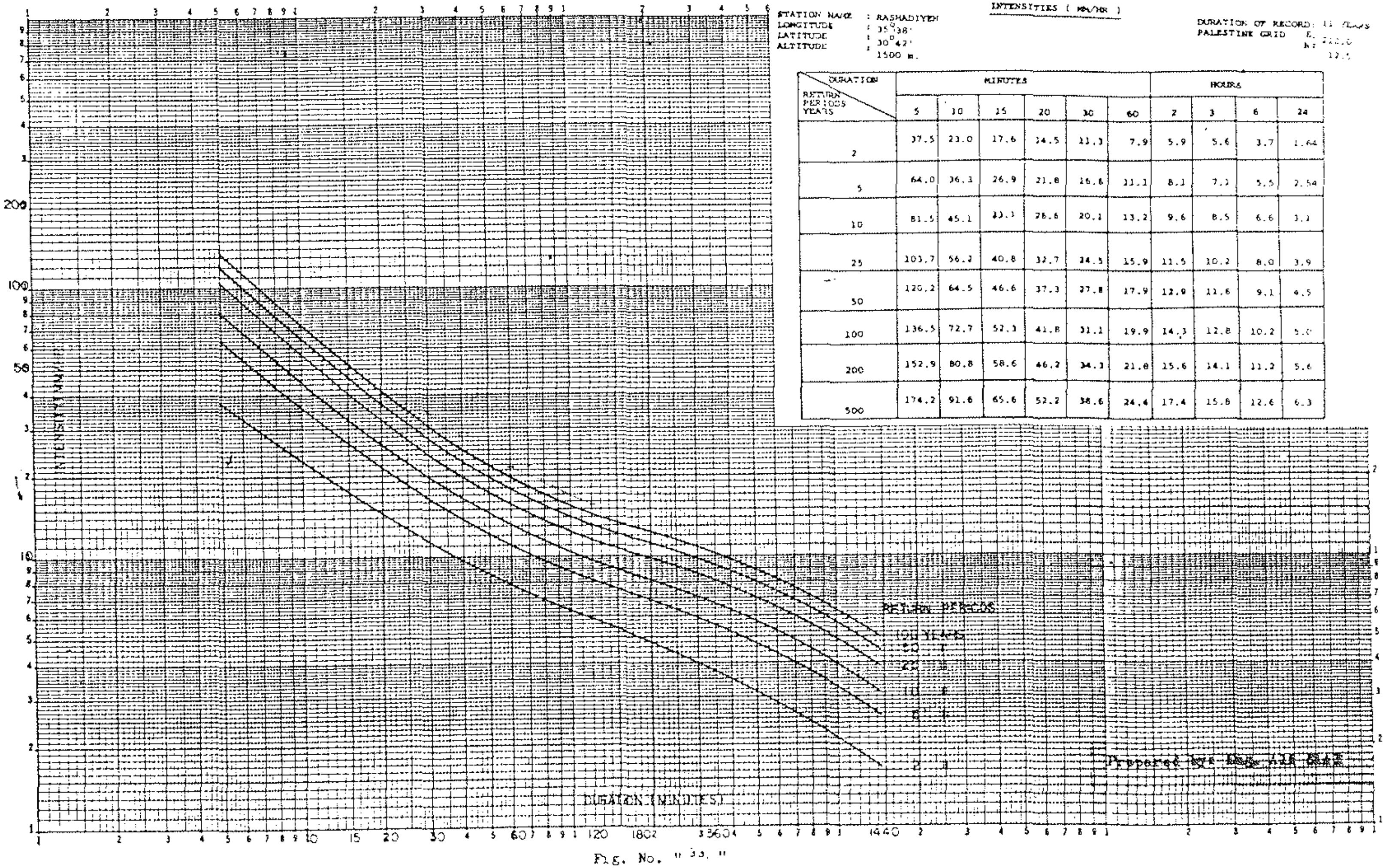
Fig.A.3.5(1/3) Rainfall Strength - Duration Curve at Tafila

THE HASHEMITE KINGDOM OF JORDAN

FEASIBILITY STUDY ON AGRICULTURAL DEVELOPMENT FOR THE KARAK-TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY

WATER AUTHORITY OF JORDAN
WATER RESOURCES DEPARTMENT




RAINFALL INTENSITY - DURATION - FREQUENCY

INTENSITIES ( MM/HR )

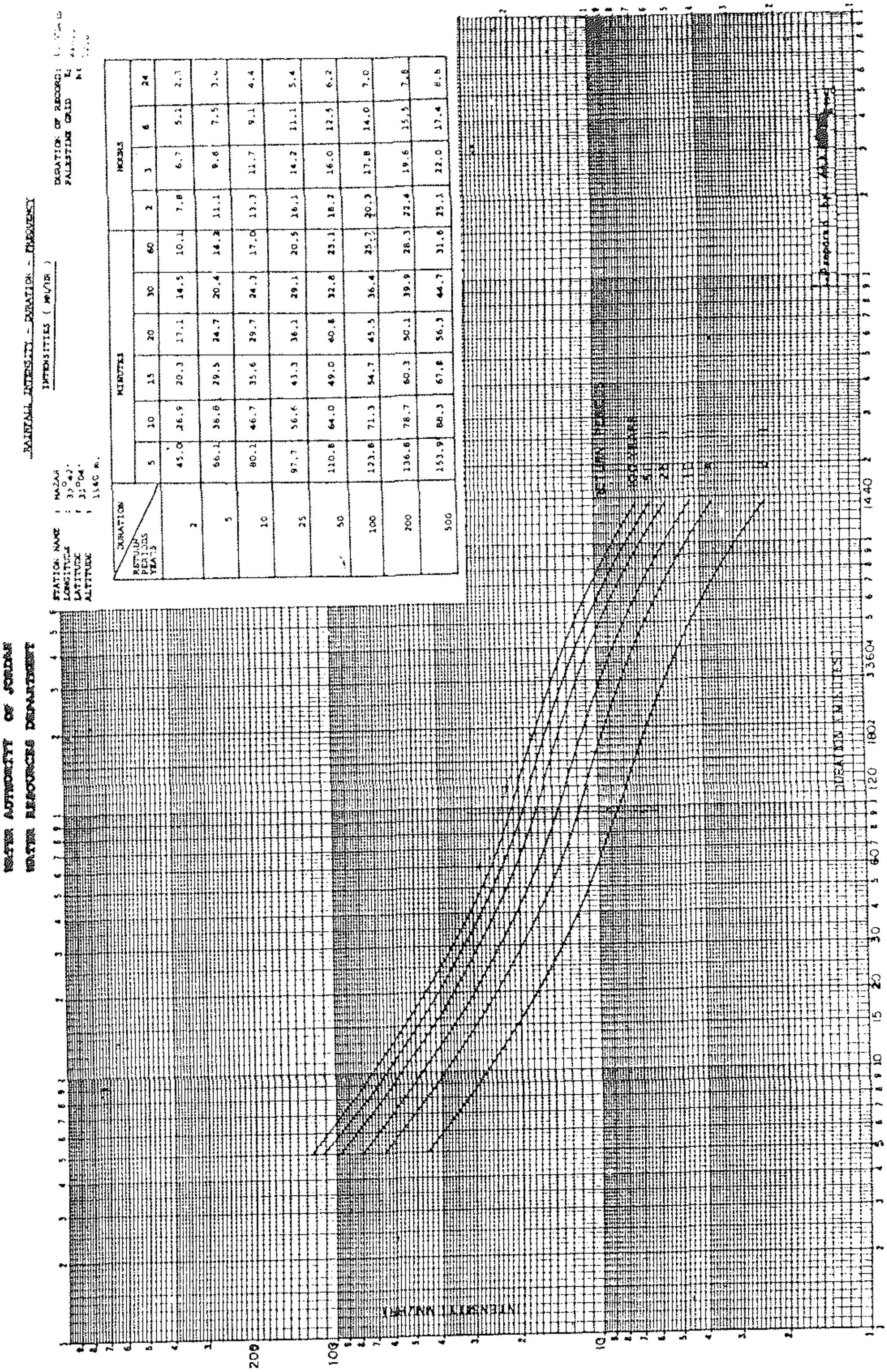
STATION NAME : RASHADIYEH
LONGITUDE : 35°38'
LATITUDE : 30°42'
ALTITUDE : 1500 m.

DURATION OF RECORD: 11 YEARS
PALESTINE GRID

| DURATION / RETURN PERIODS YEARS | MINUTES | | | | | | HOURS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 30 | 60 | 2 | 3 | 6 | 24 |
| 2 | 37.5 | 23.0 | 17.6 | 14.5 | 11.3 | 7.9 | 5.9 | 5.6 | 3.7 | 1.64 |
| 5 | 64.0 | 36.3 | 26.9 | 21.8 | 16.6 | 11.1 | 8.1 | 7.3 | 5.5 | 2.54 |
| 10 | 81.5 | 45.1 | 33.3 | 26.6 | 20.1 | 13.2 | 9.6 | 8.5 | 6.6 | 3.3 |
| 25 | 103.7 | 56.2 | 40.8 | 32.7 | 24.5 | 15.9 | 11.5 | 10.2 | 8.0 | 3.9 |
| 50 | 120.2 | 64.5 | 46.6 | 37.3 | 27.8 | 17.9 | 12.9 | 11.6 | 9.1 | 4.5 |
| 100 | 136.5 | 72.7 | 52.3 | 41.8 | 31.1 | 19.9 | 14.3 | 12.8 | 10.2 | 5.0 |
| 200 | 152.9 | 80.8 | 58.6 | 46.2 | 34.3 | 21.8 | 15.6 | 14.1 | 11.2 | 5.6 |
| 500 | 174.2 | 91.6 | 65.6 | 52.2 | 38.6 | 24.4 | 17.4 | 15.6 | 12.6 | 6.3 |

Fig.A.3.5(2/3) Rainfall Strength - Duration Curve at Rashadia

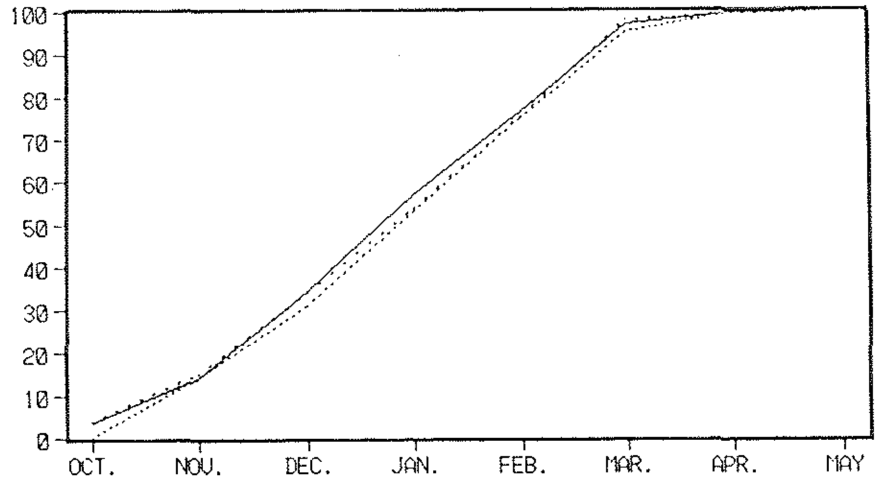
THE HASHEMITE KINGDOM OF JORDAN
FEASIBILITY STUDY ON AGRICULTURAL DEVELOPMENT FOR THE KARAK-TAFILA DEVELOPMENT REGION
JAPAN INTERNATIONAL COOPERATION AGENCY




| DURATION / RETURN PERIODS YEARS | MINUTES | | | | | | HOURS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 30 | 60 | 2 | 3 | 6 | 24 |
| 2 | 45.0 | 26.9 | 20.3 | 17.1 | 14.5 | 10.1 | 7.8 | 6.7 | 5.1 | 2.3 |
| 5 | 66.1 | 38.8 | 29.5 | 24.7 | 20.4 | 14.2 | 11.1 | 9.8 | 7.5 | 3.6 |
| 10 | 80.1 | 46.7 | 35.6 | 29.7 | 24.3 | 17.0 | 13.3 | 11.7 | 9.1 | 4.4 |
| 25 | 97.7 | 56.6 | 43.3 | 36.1 | 29.1 | 20.5 | 16.1 | 14.2 | 11.1 | 5.4 |
| 50 | 110.8 | 64.0 | 49.0 | 40.8 | 32.8 | 23.1 | 18.3 | 16.0 | 12.5 | 6.2 |
| 100 | 123.8 | 71.3 | 54.7 | 45.5 | 36.4 | 25.7 | 20.3 | 17.8 | 14.0 | 7.0 |
| 200 | 136.8 | 78.7 | 60.3 | 50.1 | 39.9 | 28.3 | 22.4 | 19.6 | 15.5 | 7.8 |
| 500 | 153.9 | 88.3 | 67.8 | 56.3 | 44.7 | 31.6 | 25.1 | 22.0 | 17.4 | 8.6 |

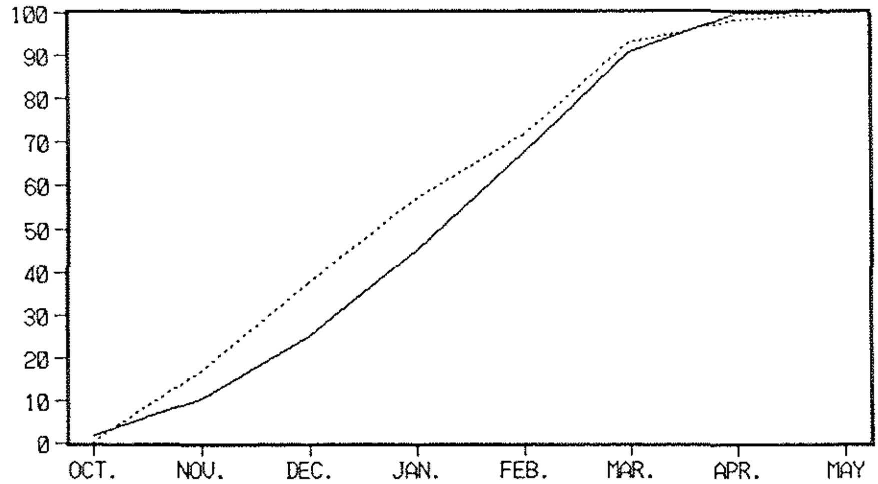
Fig.A.3.5(3/3) Rainfall Strength - Duration Curve at Mazar

| THE HASHEMITE KINGDOM OF JORDAN |
|---|
| FEASIBILITY STUDY ON AGRICULTURAL DEVELOPMENT FOR THE KARAK-TAFILA DEVELOPMENT REGION |
| JAPAN INTERNATIONAL COOPERATION AGENCY |



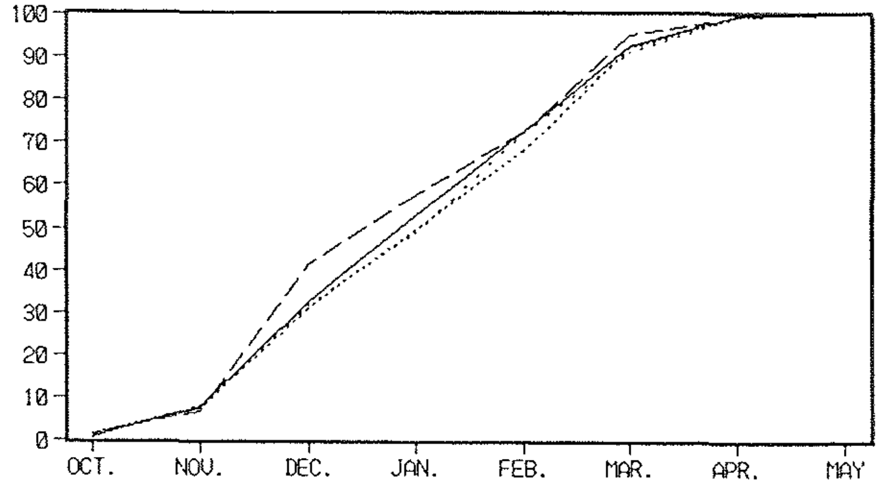

Mass Curve in Dhiban Area

— CD15 (=137.0) ····· CD7 (=242.0) · · · CD17 (=192.0)




Mass Curve in Abyad Area

— CA6 (=130.3) ····· CF7 (=54.31)




Mass Curve in Tafila Area

— DB1 (=245.5) ····· DB2 (=214.6) · · · DC1 (=234.2) -- CF3 (=76.02)

Fig.A.3.6 Accumulative Curve of Rainfall

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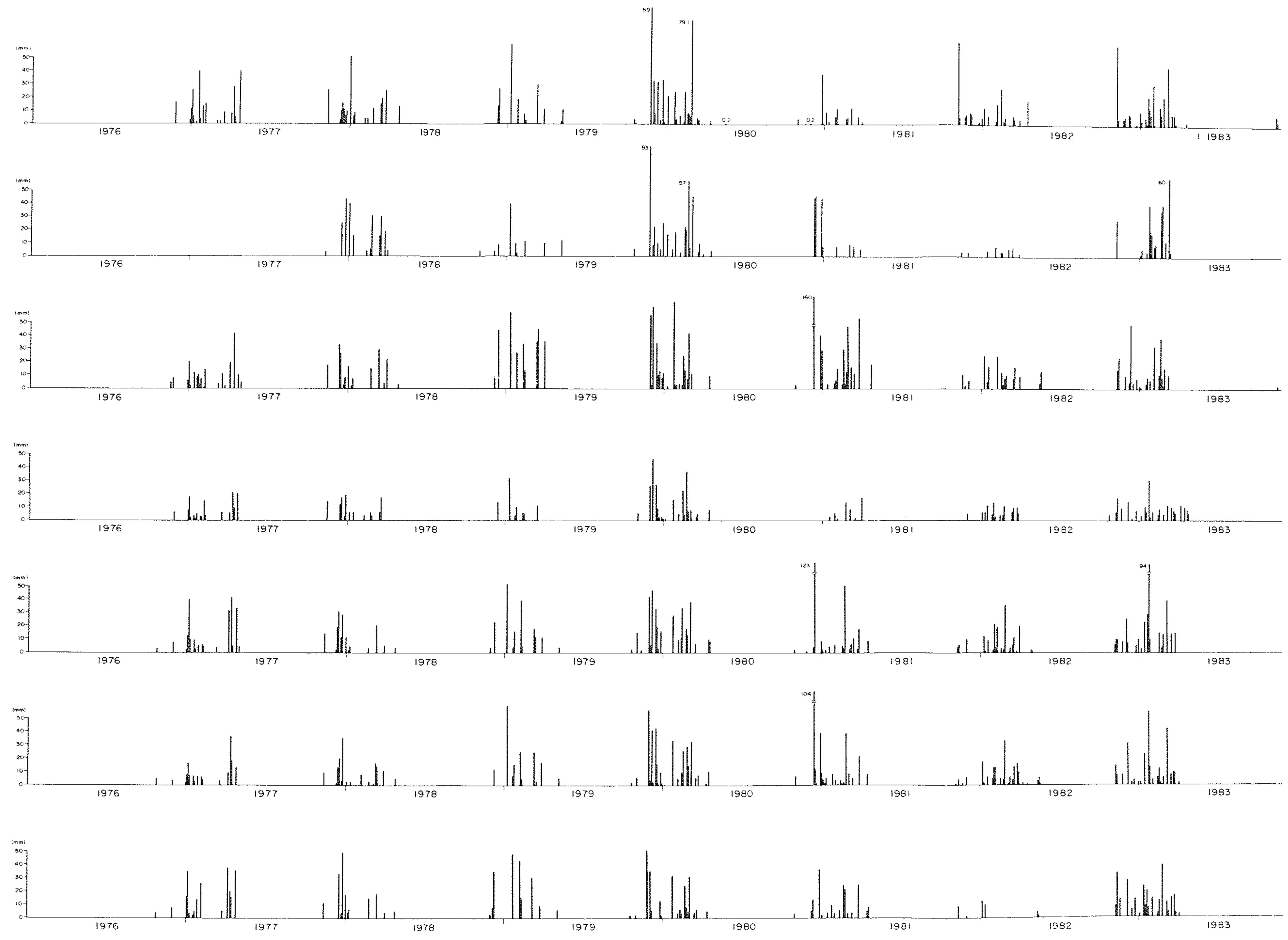

(mm)
0
10
20
30
40
50
1976
1977
1978
1979
1980
1981
1982
1983
89
79.1
0.2
83
57
60
160
123
94
104

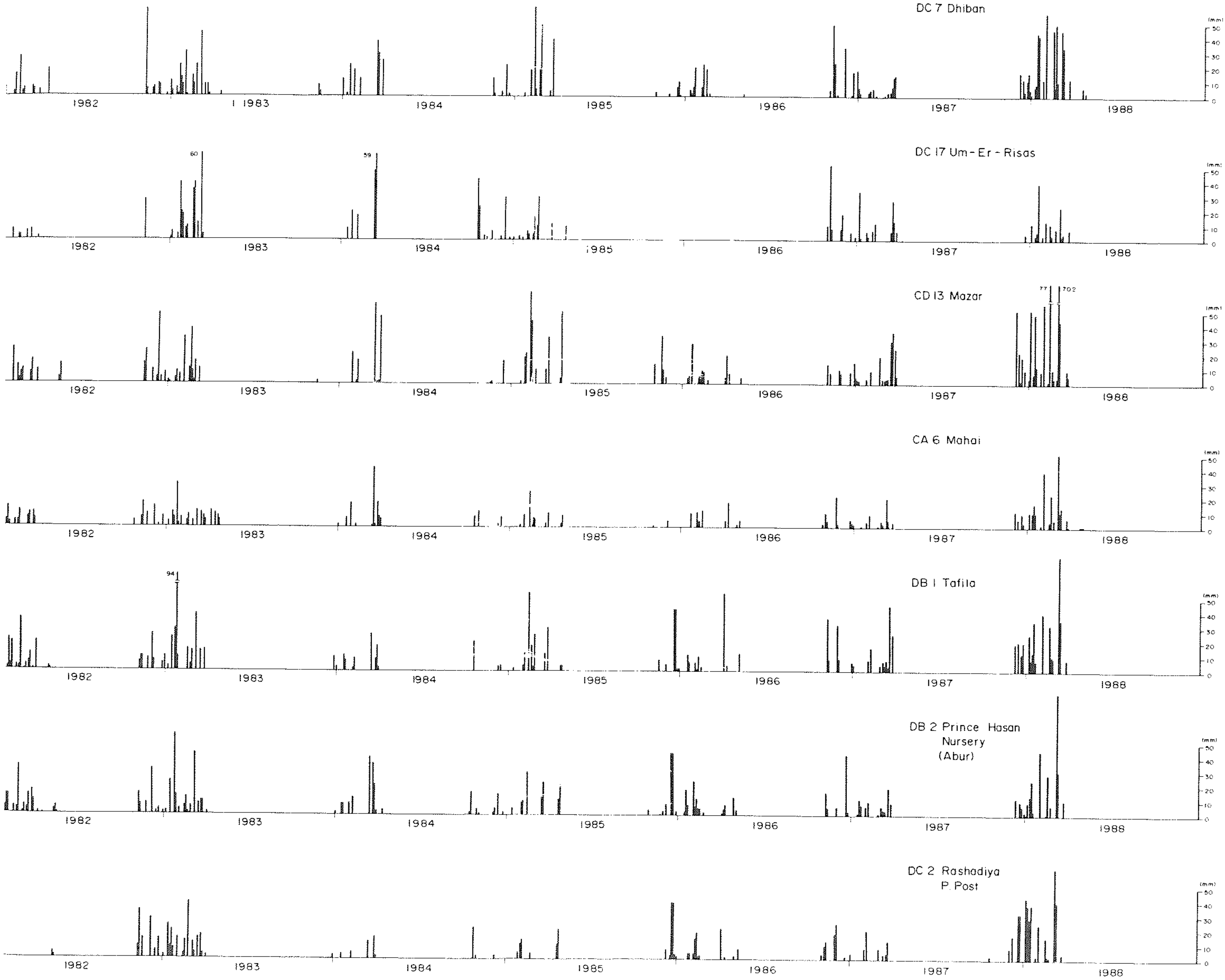


Fig.A.3.7

Rainfall Distribution in Time Series in Priority Areas

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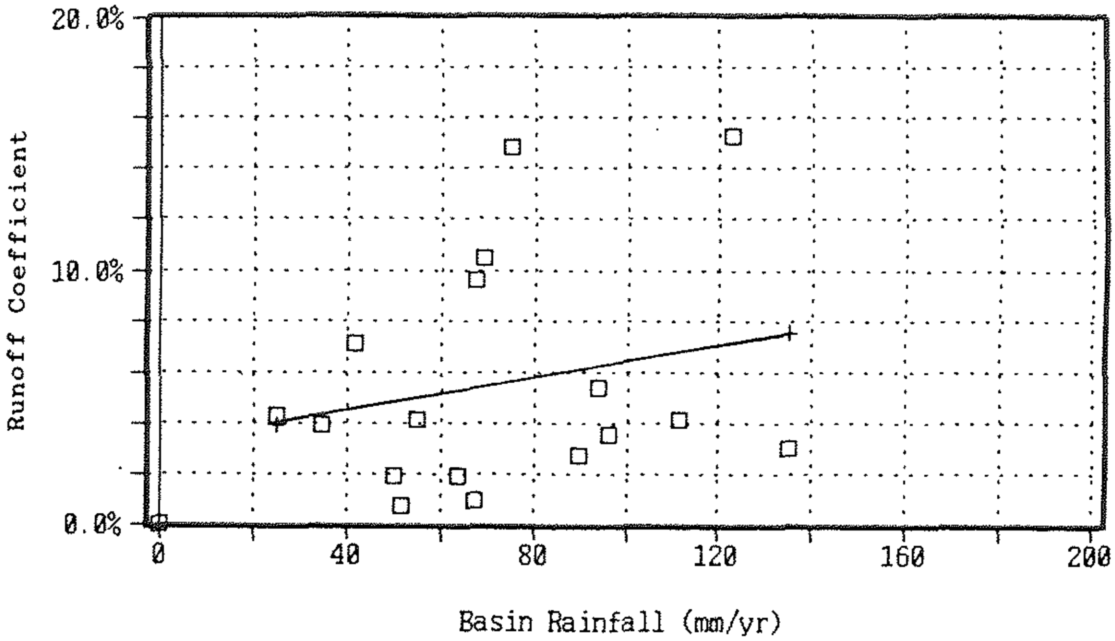
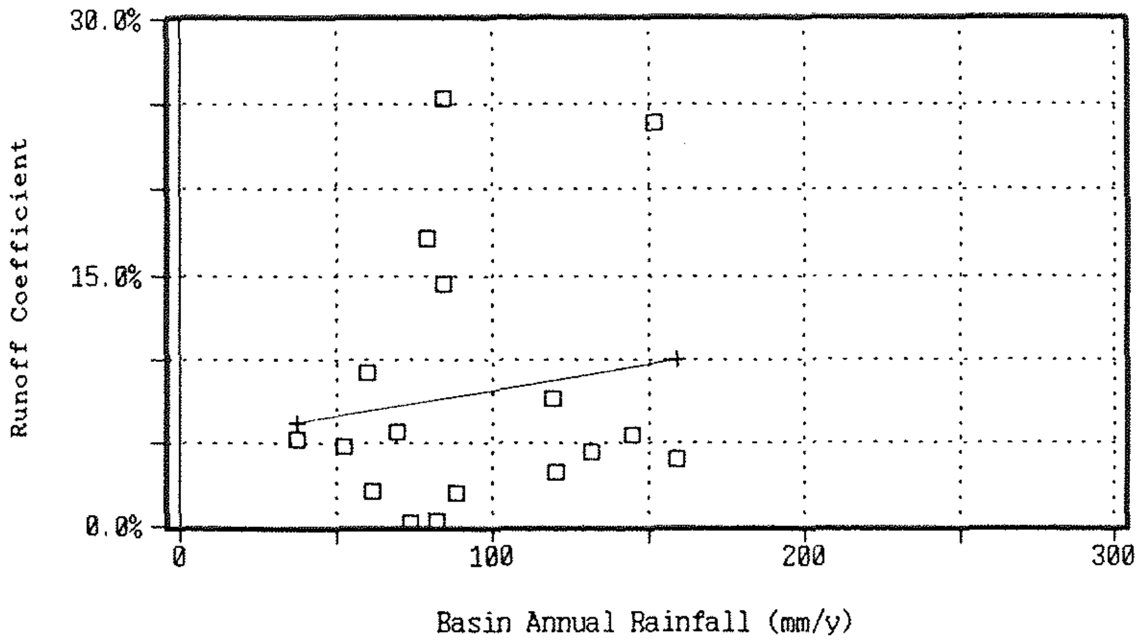



Hasa Tannour Basin (a),




Hasa Tannour Sub-Basin (b)

Fig.A.4.1

Relation between Annual Rainfall and Runoff Coefcient of Hasa Tannour Basin (a), and of Hasa Tannour Sub-Basin (b)

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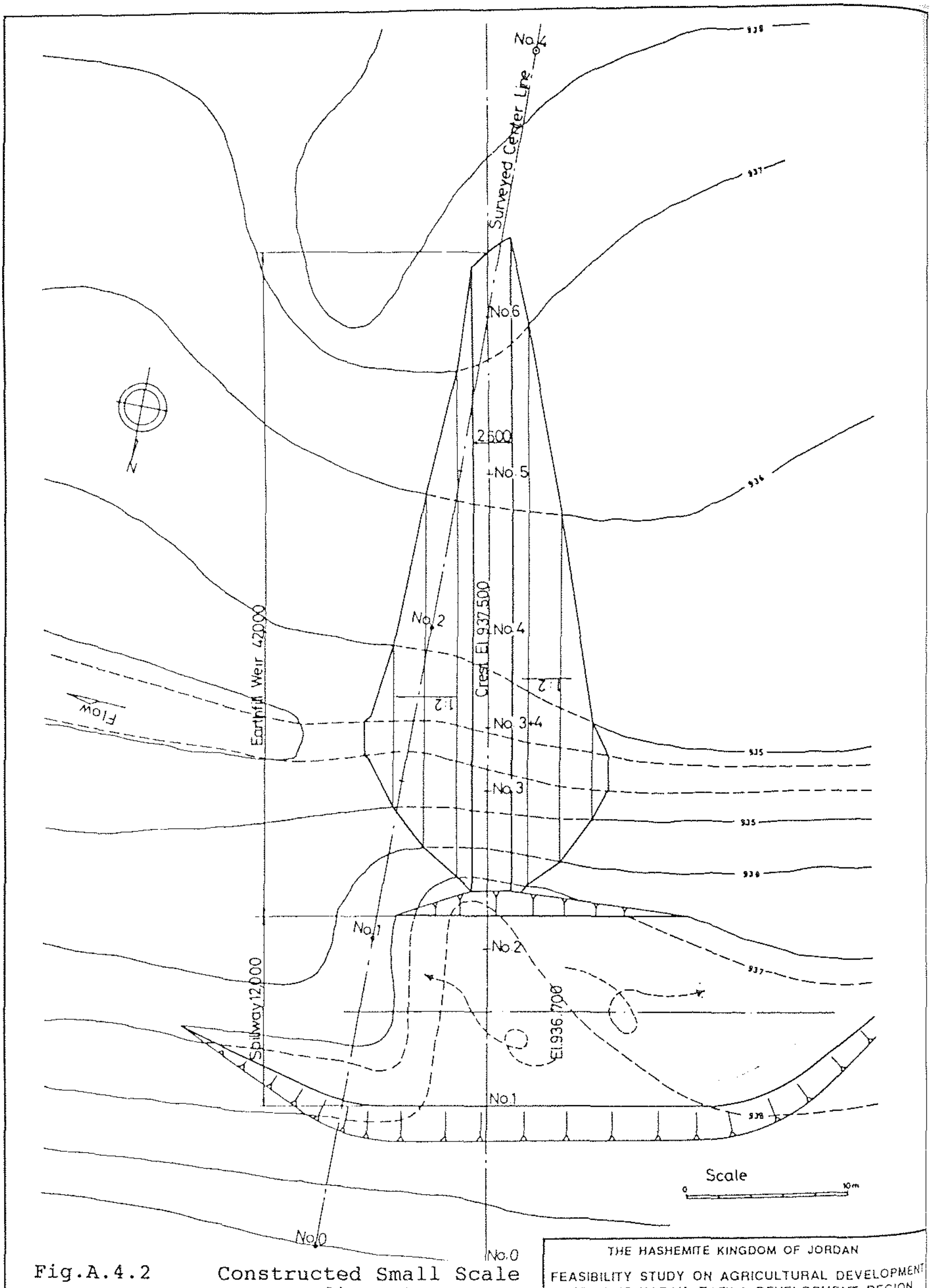


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Fig.A.4.2 Constructed Small Scale Weir Small Scale Weir Site on W.SUKUR

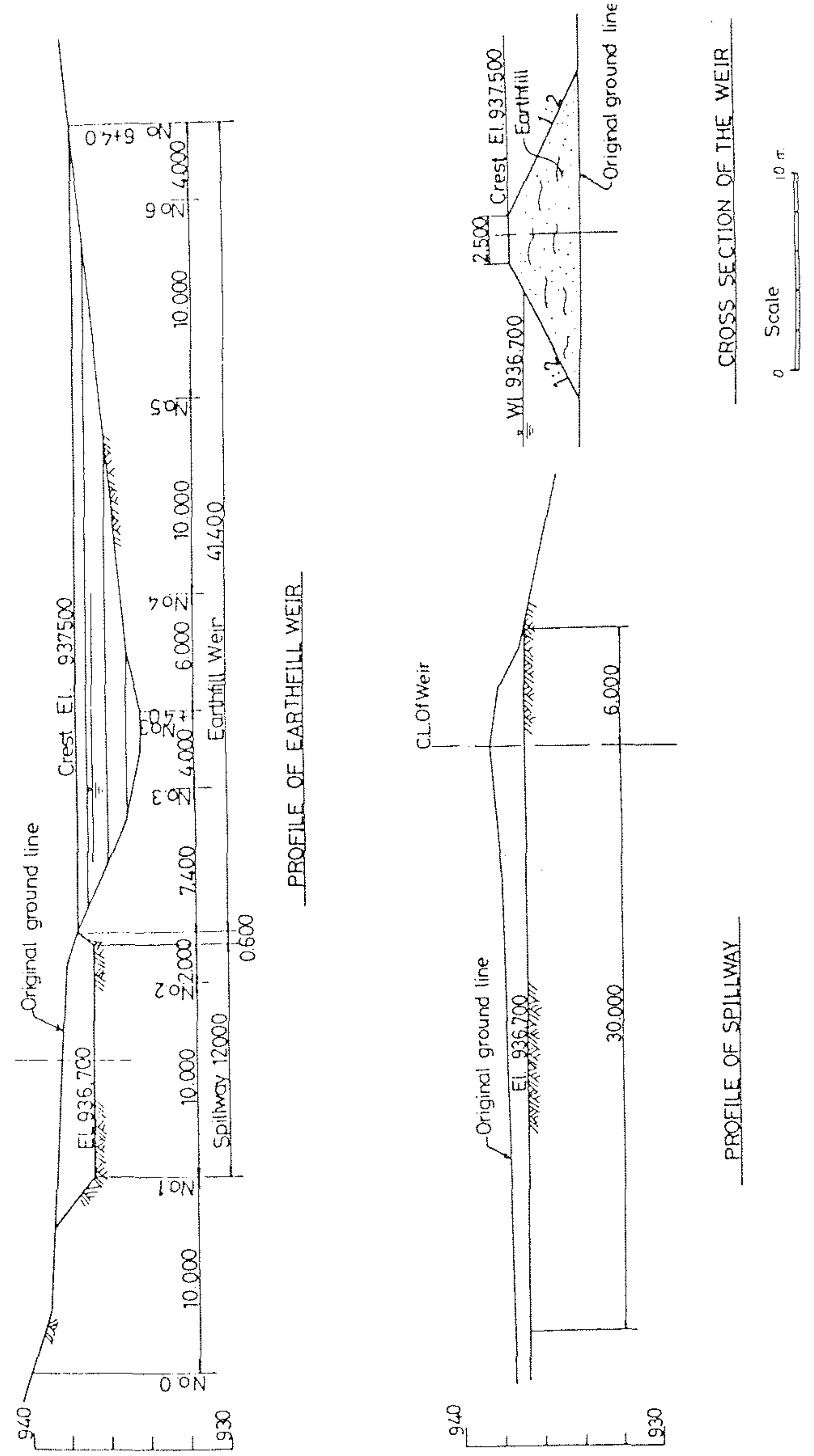


Fig.A.4.3 Cross Section of the Constructed Small Scale Weir

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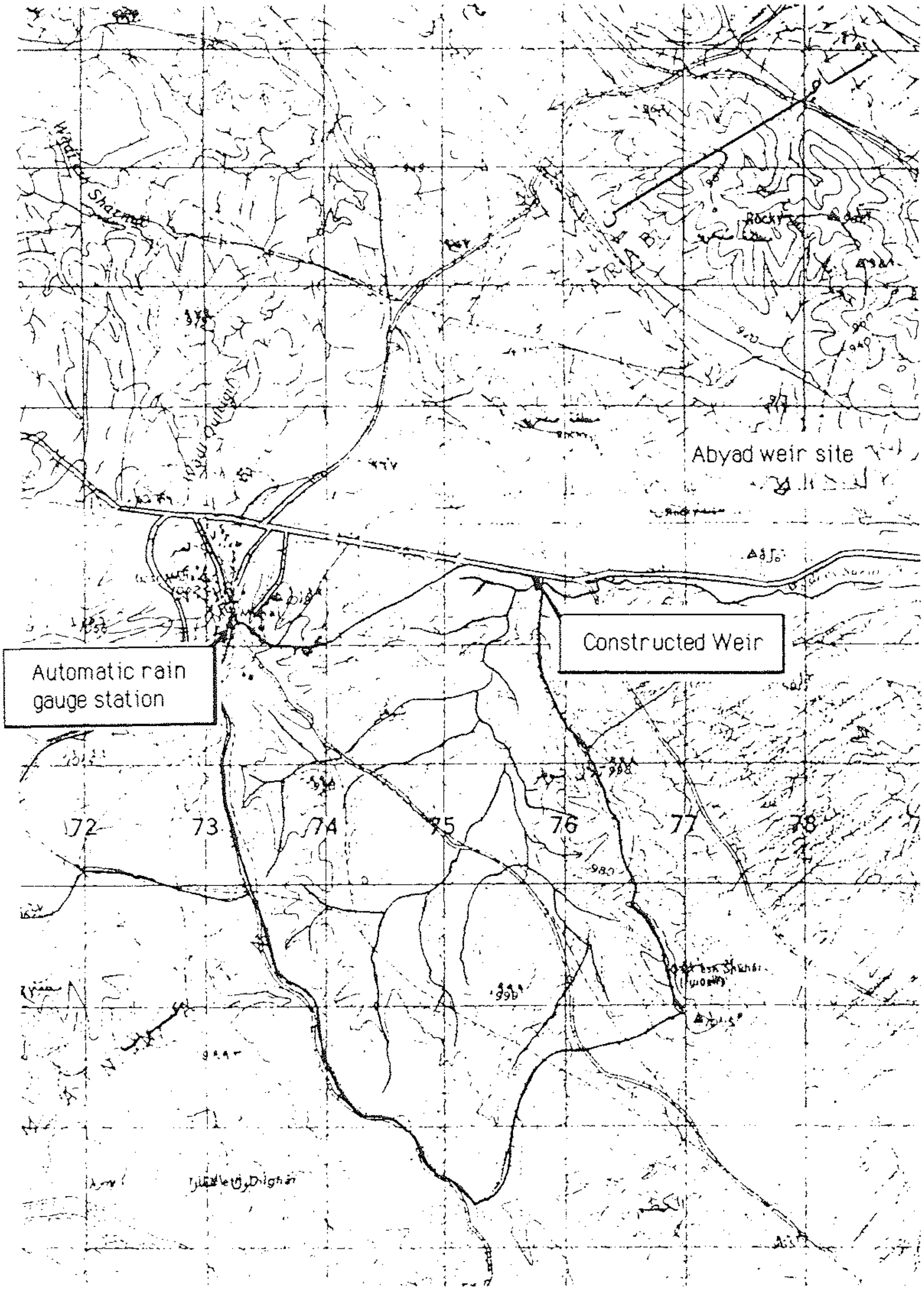


Fig.A.4.4 Location Map of the Constructed Weir and Automatic Rain Gauge Station

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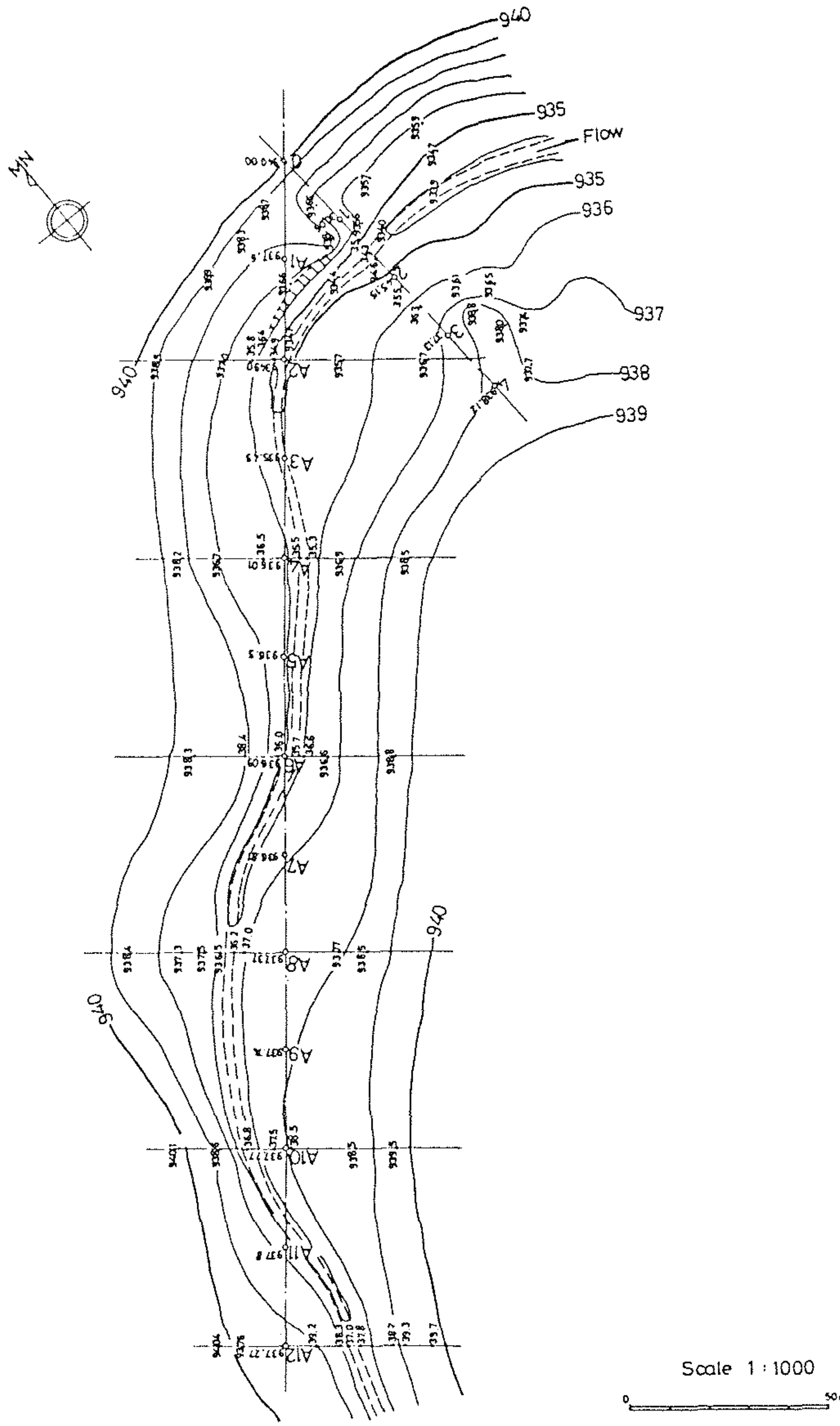


Fig.A.4.5 Topo-Surveyed Map

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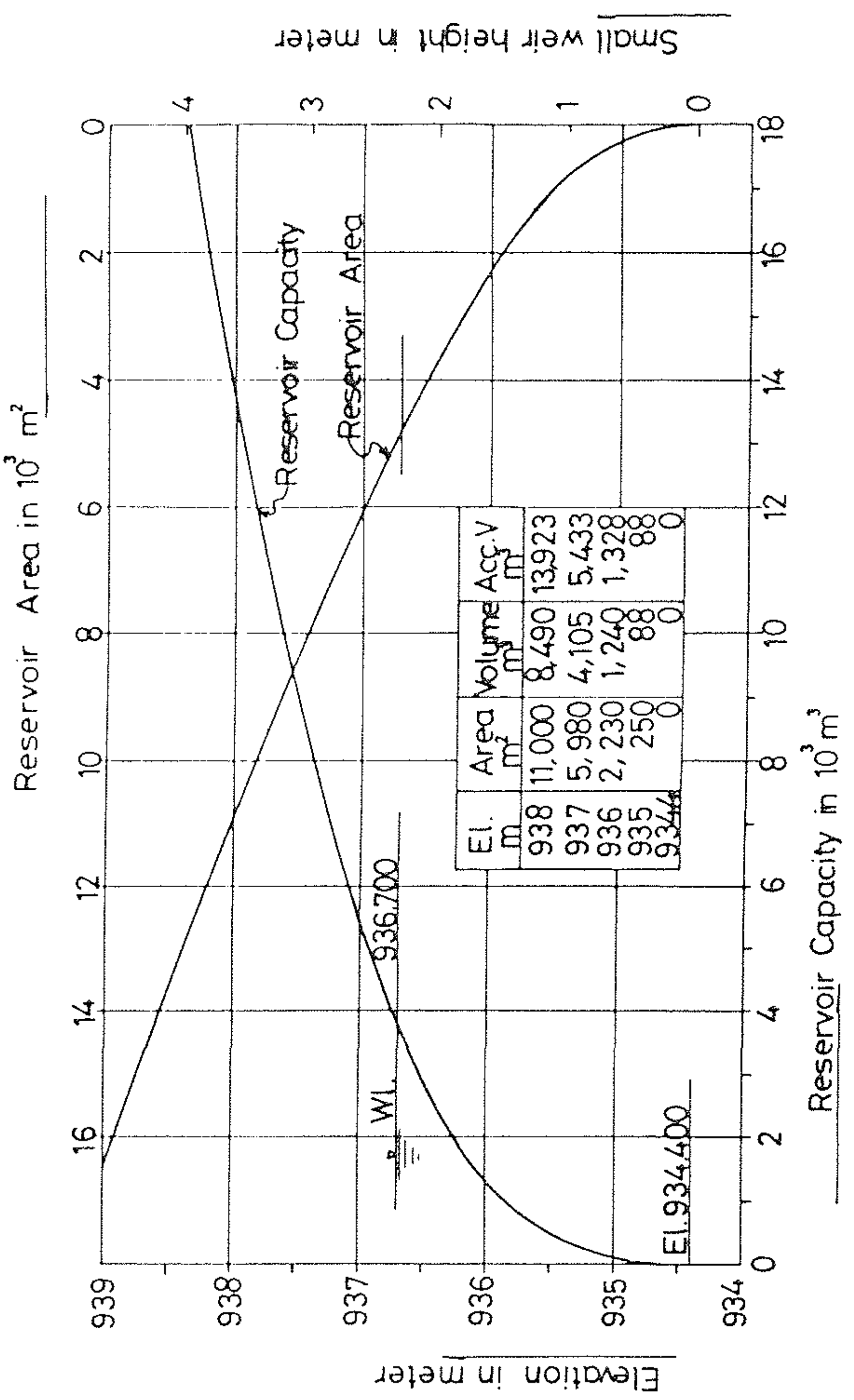


| El. m | Area m² | Volume m³ | Acc.V m³ |
|---|---|---|---|
| 938 | 11,000 | 8,490 | 13,923 |
| 937 | 5,980 | 4,105 | 5,433 |
| 936 | 2,230 | 1,240 | 1,328 |
| 935 | 250 | 88 | 88 |
| 934.4 | 0 | 0 | 0 |

Fig.A.4.6 Reservoir Capacity Curve of Small Scale Weir

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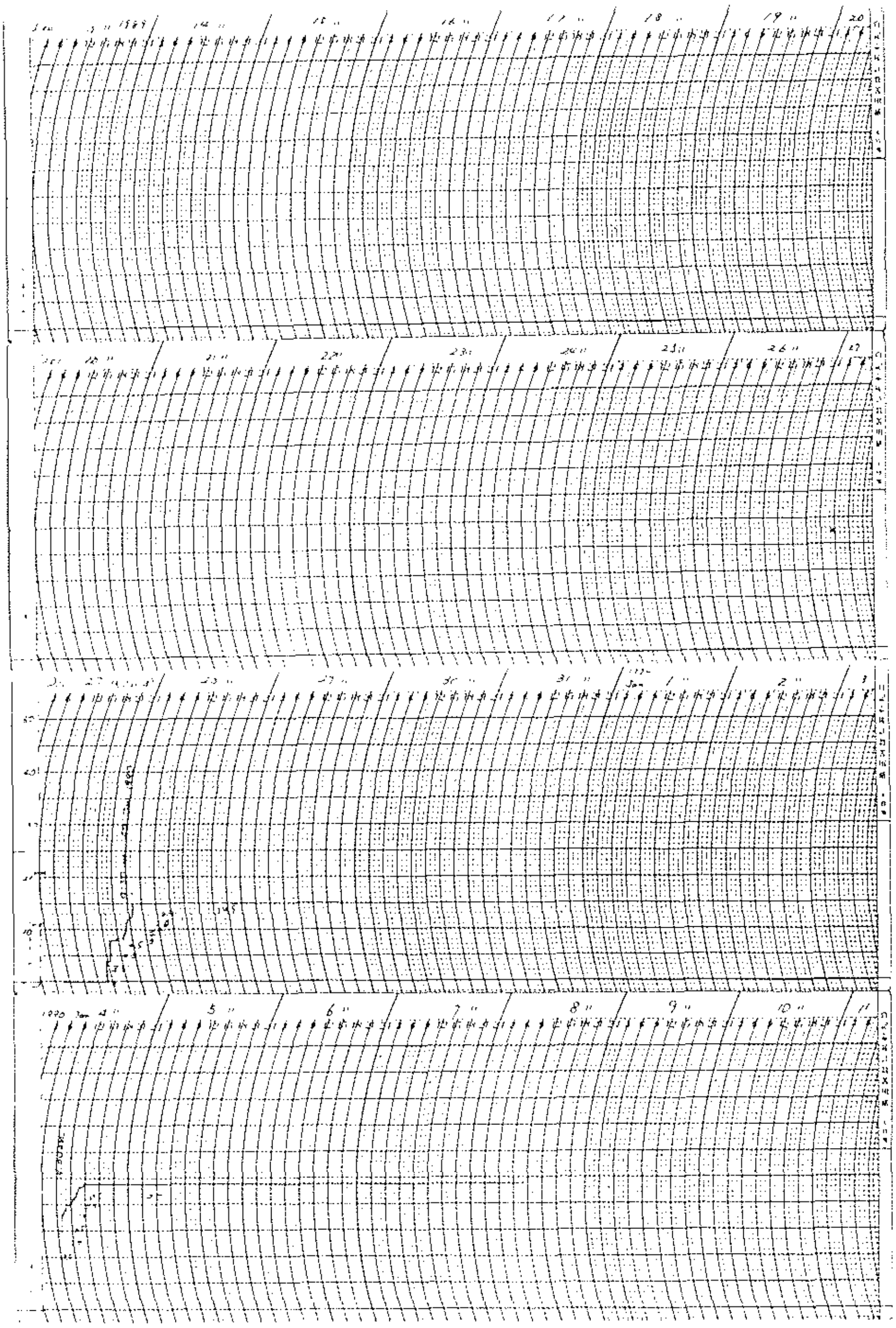

Fig.A.4.7 (1/3) Record Charts of Rainfall Observation

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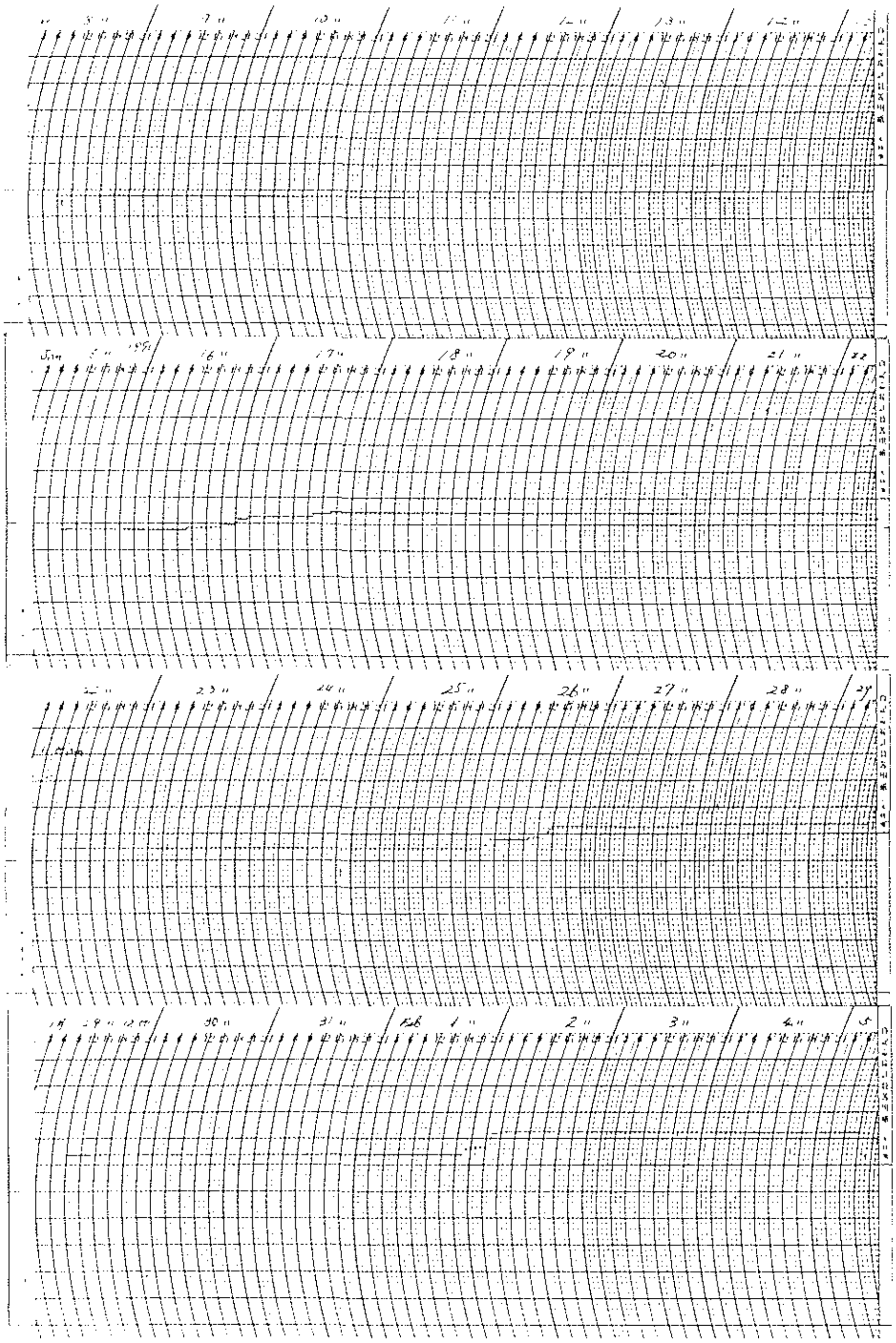

Fig.A.4.7 (2/3) Record Charts of Rainfall Observation

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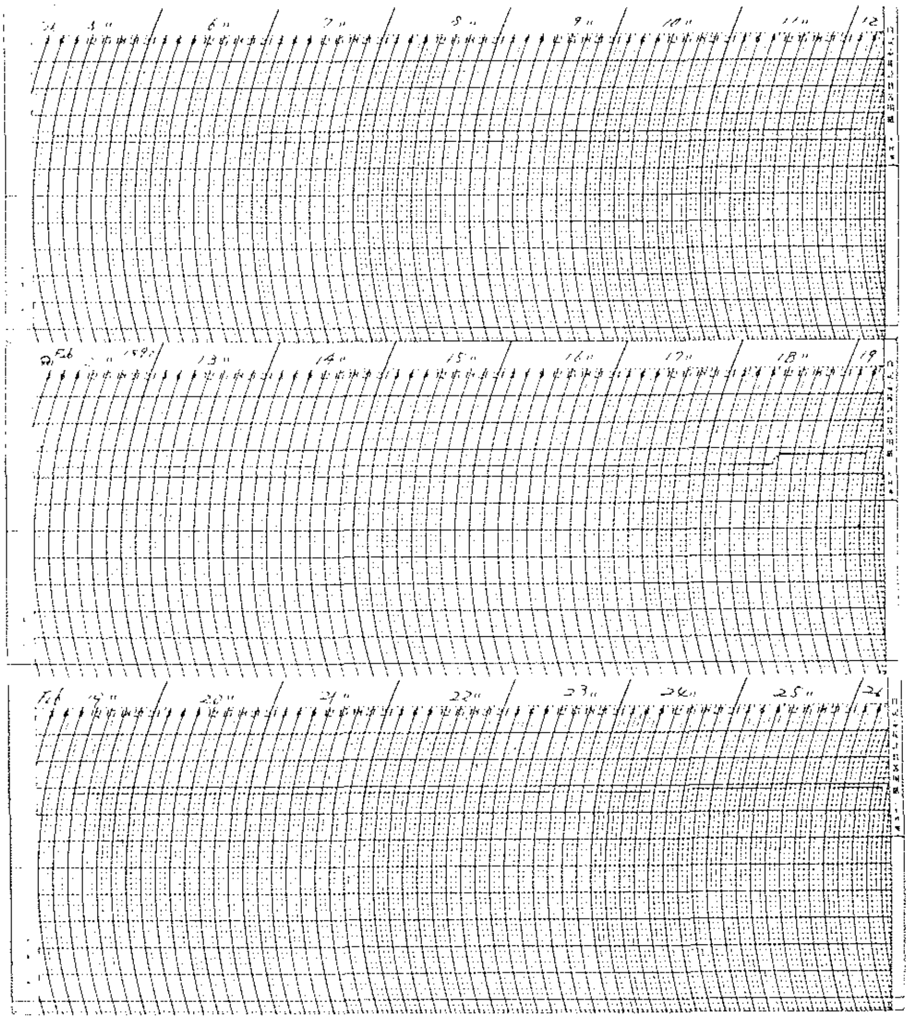

Fig.A.4.7 (3/3) Record Charts of Rainfall Observation

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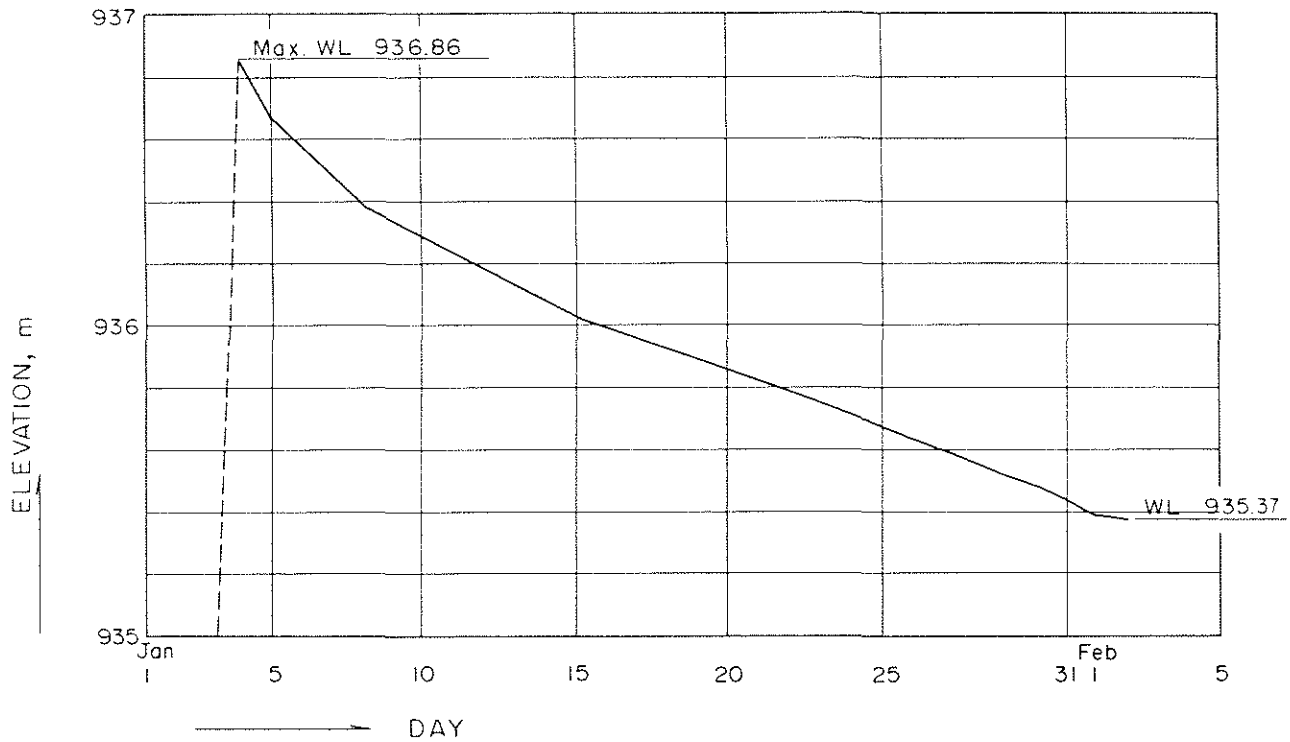


Fig.A.4.8 Result of Water Level Measurment in the Experimental Weir

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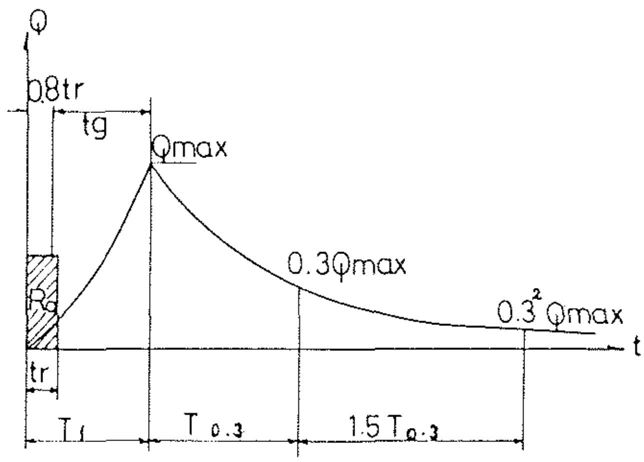


$$Q_{max} = \frac{1}{3.6} AR_o / (0.3T_1 + T_{0.3})$$

For rising unit hydrograph curves with $0 < t < T_1$

$$\frac{Q_a}{Q_{max}} = \left(\frac{t}{T_1}\right)^{2.4}$$

For falling unit hydrograph curves of

with $1 > \frac{Q_d}{Q_{max}} > 0.3$ : $\frac{Q_d}{Q_{max}} = 0.3^{(t-T_1)/T_{0.3}}$

with $0.3 > \frac{Q_d}{Q_{max}} > 0.3^2$ : $\frac{Q_d}{Q_{max}} = 0.3^{(t-T_1+0.5T_{0.3})1.5T_{0.3}}$

Where:

$Q_{max}$ ; Maximum discharge of unit hydrograph ($m^3/S$)

$Q_a$, $Q_d$ ; Discharge at the time of rising and falling limb of unit hydrograph ($m^3/S$)

A ; Catchment area ($Km^2$)

$R_o$ ; Unit rainfall (mm)

T1 ; Time from the start of run-off to maximum discharge

$T_{0.3}$ ; Time required unit the discharge recesses to 0.3 Times the maximum discharge

Fig.A.4.9 Definition Sketch of Nakayasu's Synthetic Unit Hydrograph

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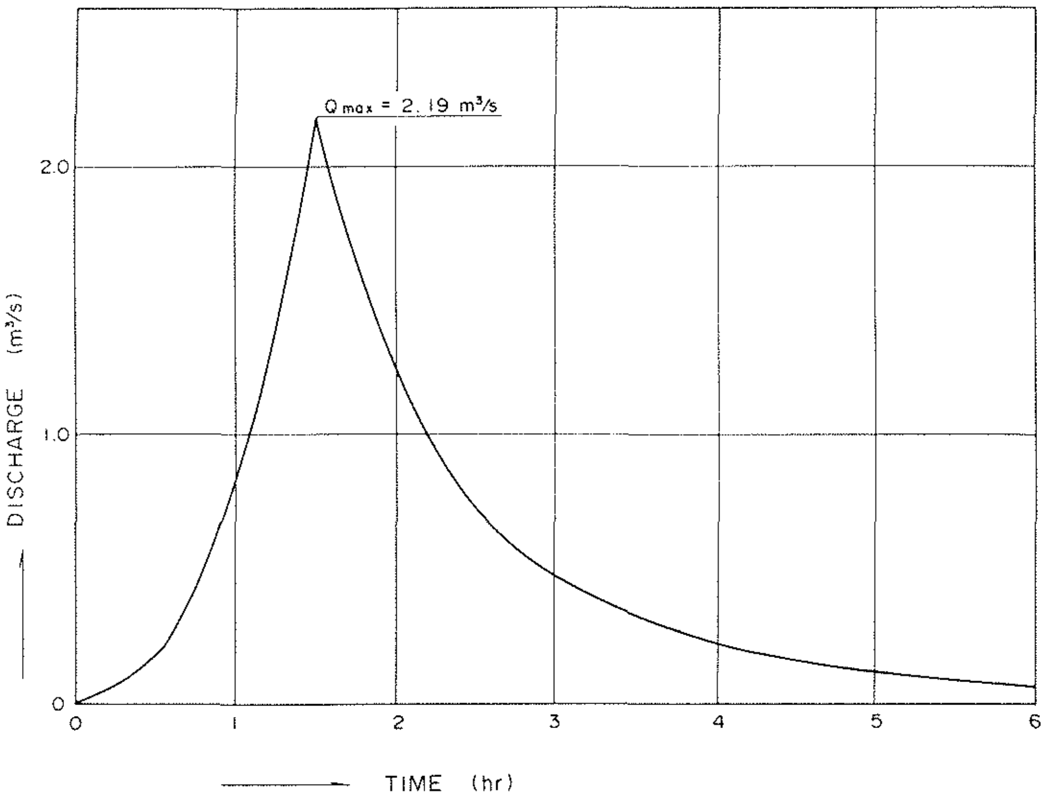
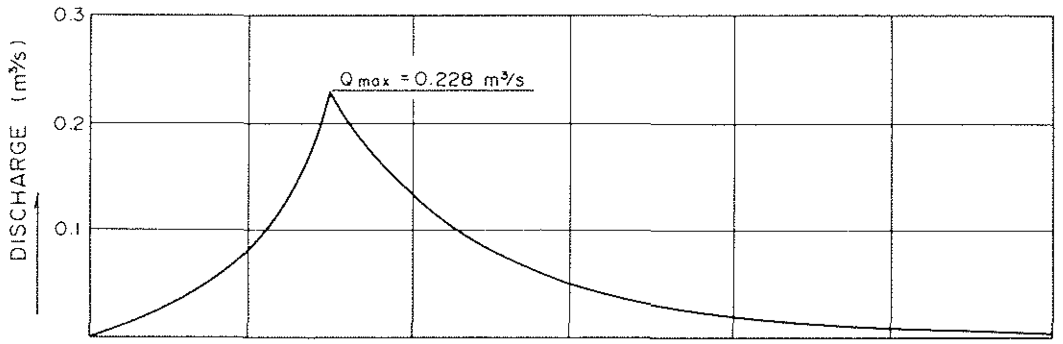



Unit Hydrograph (a)




Revised Unit Hydrograph

Fig.A.4.10 Unit Hydrograph (a) and Revised Unit Hydrograph of Muhai Experimental Weir

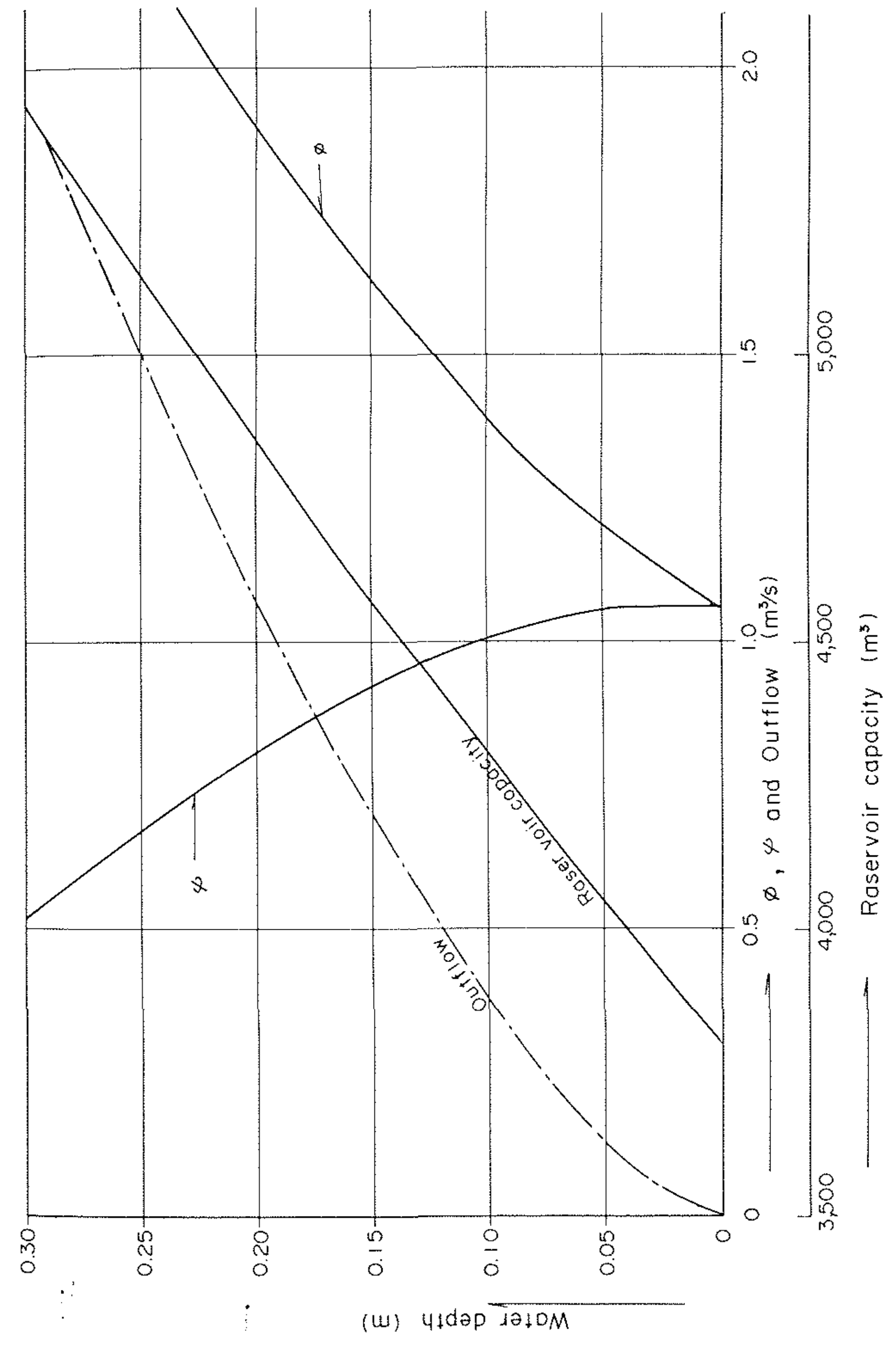



Fig.A.4.11

φ , ψ Curve and Rating Curve of Spillway

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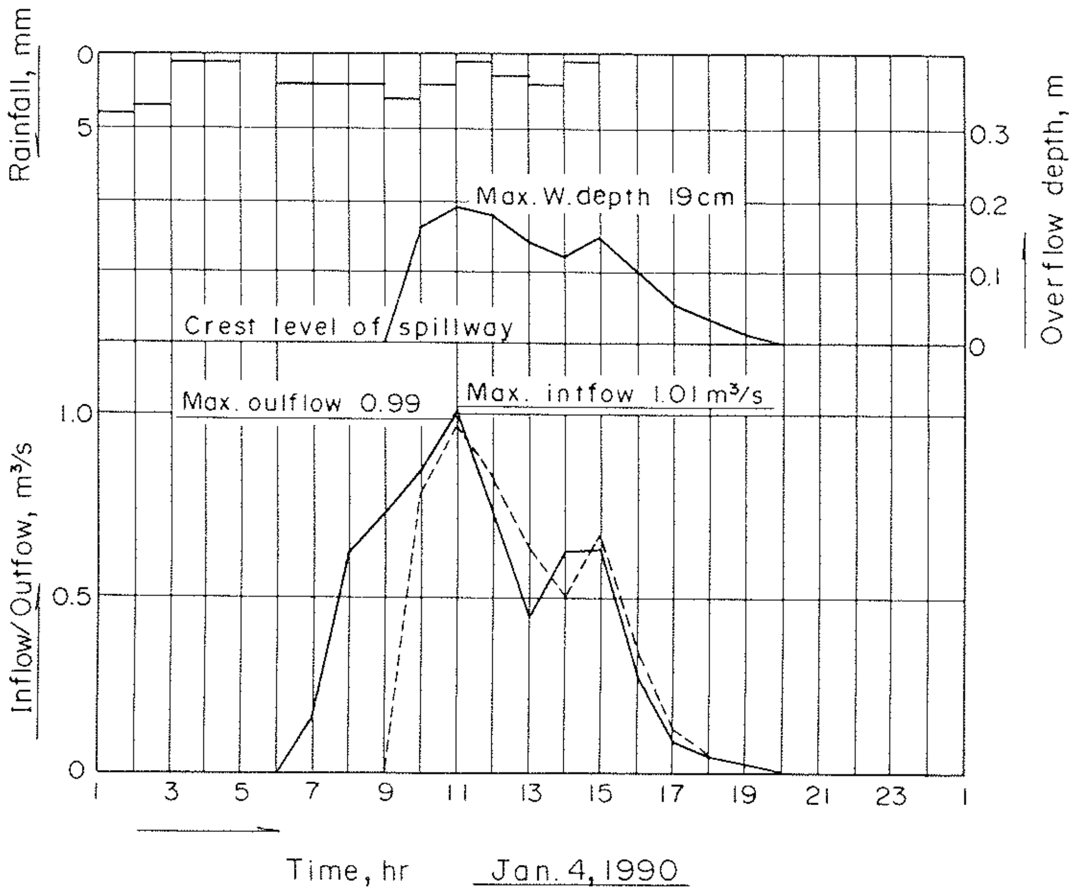


Fig.A.4.12

Reservoir Routing of Muhai Experimental Weir..................................

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