Rainfall Data and Analysis of Auja Al -Timsah Catchment and Relation with Springs Discharge

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The findings , interpretations and the conclusions expressed in this study don't necessarily express the views of Birzeit University, the views of the individual members of the MSc committee or the views of their representative employers.

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ABSTRACT

Hydrology of Auja al Timsah Catchment was the main issue studied in this research, in terms of rainfall and springs discharge.

Auja al Timsah Catchment was chosen specifically for this study since it forms the main recharge area for the western aquifer basin , also there are more than 150 Palestinian communities depends directly on rainfall, or depends on groundwater wells and springs to get their needs from fresh water for drinking and irrigation purposes.

The main goal of this study is to screen, estimate and analyze the rainfall data and find the relationship with spring's discharges. The screened and analyzed data will be the main input for groundwater, surface water, and recharge models used to estimate water budget and estimate yields of aquifers.

First, the research started by collecting data from different water institutions, second by screening the data using different tests like time series, tabular comparison, spatial homogeneity, double mass curve, t-test, f-test and trend analysis tests applied for daily, monthly and annual data sets. Computer programs were utilized and modified to screen the data and estimate the missing. The data sets were analyzed to evaluate the adequacy of rainfall network and to analyze the water quantities in terms of areal rainfall, wet and dry days, rainfall depth, frequency analysis and extreme analyses, k-analysis, seasonal analysis, temporal and spatial and trend analysis. Finally springs data were analyzed in the major springs in terms of discharge quantities and relationship with rainfall data.

The results of the study indicate that the quality of rainfall data is poor in terms of measurements, instrumentations, network distribution, spatial and temporal coverage. The rainfall quantities is affected spatially by topography features, geographical location and distance from the coast, the spatial variety is high and caused by small, intense and convective storms. On the other hand the temporal trend of rainfall shows changes in the annual and seasonal patterns. Also the results of the study show a strong relationship between rainfall and spring discharges, where the effect of rainfall in recharging the aquifer starts to appear after two months.

Finally, in order to conduct the hydrological and modeling studies, the data screening and analysis techniques applied in this study can be applied in other catchments, also other further detailed studies are recommended.

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ACRONYMS and ABBREVIATIONS

Number	Title
amsl	Above Mean Sea Level
ARIJ	Applied Research Institute of Jerusalem
ARIMA	Auto Regressive Integrated Moving Average
C	Celiuse
DB	Data Base
DD	Dry Day
DFID	Department for International Development
EXACT	Executive Action Team
IHS	Israeli Hydrology Services
IRC	International Research Center
km	kilometer
L.B.K	Lower Beit Kahil
L.C	Lower Cenomanian
l/s	Liter per second
m	meter
m3/hr	Cubic Meter per Hour
mcm	Million cubic meter
MD	Meteorological Department
mg/l	Milligram per liter
mm	milimeter
PCBS	Palestinian Central Beruea of Statistics
PHG	Palestinian hydrology Group
PNA	Palestinian National Authority
PWA	Palestinian Water Authority
QA/QC	Quality Assurance and Quality Control
U.C	Upper Cenomanian
UK	United Kingdom
USGS	United States Geological Survey
WAB	Western aquifer Basin
WB	West Bank
WBWD	West Bank Water department
WD	Wet Day
WS	Wet Season

CHAPTER 1
INTRODUCTION

1.1 Background.

The study area is part of the Occupied Palestinian Territories (The West Bank), which is characterized by semi-arid to arid climate with scarce rainfall.

The water resources are generally scarce and limited and have been under stress quantitatively and qualitatively during the last few decades. This stress is due to the population growth and rapid urban development, which resulted from huge mass transfers and demographic changes.

Occupied Palestinian Territories have even been more suffering from scarcity of water resources since 1967. Since then the Israeli Authorities took control over almost all of the available water resources and restrained Palestinians from using their water rights. The Israeli Settlements constructed in the Palestinian Territories after 1967 have added more stress on water resources.

The sole water resources utilized by the Palestinians, is limited to abstractions from groundwater wells mainly tapping the shallow aquifer in addition to some flowing springs. The area lacks rivers and major perennial streams. Surface runoff is limited to intermittent streams that flow only after rainstorms.

Since 1993 (Oslo agreement), several attempts have been made to investigate the water resources in the Palestinian Territories where a few projects have been conducted and some others are in progress.

However, research is still needed to investigate the parameters of the different catchments including rainfall, runoff, infiltration and

other parameters of the water balance. This requires analysis and evaluation of the available hydrological data.
The present study attempts to investigate the hydrology of one of the catchment areas in the West Bank and to analyze and evaluate the existing rainfall data as well as the discharge of the springs located within the area. This will help in the estimation of the surface runoff in the study area, as there are no measurements been or being carried out. Such estimation can be used in hydrological modeling of the area that is necessary for water resources evaluation and management.

1.2 Aims and Objectives.

The main objective of the present study is to investigate the hydrological parameters of the study catchment with concentration on the analysis of rainfall data that can lead to the estimation of surface runoff. Attempts to correlate rainfall data with the discharges of the springs within the area will be made. The investigation will cover the following:

1. Study the adequacy of existing rainfall network.
2. Carry out the necessary quality control procedures to clean the data.
3. Analyze the rainfall data through applying the statistical and hydrological methods and models.
4. Run correlation between rainfall and spring discharges.

CHAPTER TWO

LITERATURE REVIEW

2.1 Definition of Precipitation

Precipitation is defined as any form of water particle, liquid or solid, that falls from atmosphere and reaches the ground. It is not fog, dew, rime or frost because it must fall. It is not cloud or fog because it must reach the ground. Precipitation includes the following forms: rain, drizzle, freezing rain/drizzle, hail, occasionally snow.(Ward and Robinson, 2000).

2.2 Formation of Precipitation

Precipitation takes place when a body of moist air is cooled sufficiently for it to become saturated, and if condensation nuclei are present. The most important cooling mechanism is due to the uplifting of the air masses under dynamic cooling conditions (WMO, 1994). Four types of formation of perception due to airlifting can be distinguished and summarized:

1. Frontal Precipitation: the existence of an area with low pressure causes surrounding air to move into the depression, displacing low pressure air upwards.
2. Cyclonic Precipitation (Tropical Depression): These are active depressions which gain energy while moving over warm ocean water and which dissipate energy while moving over land or cold water.
3. Convectional Precipitation: The rainfall results when heating of the ground surface causes warming of the air, and locally strong vertical air motions occur. If the air is thermally unstable, it continues to rise and the resulting cooling, condensation and cloud formation may lead to locally intense precipitation but of limited duration.

4. Orographic precipitation: this happens when air passes over a barrier like a mountain or island; the air is then forced to rise which may cause rainfall on the windward slope. Typically more rain falls on windward than leeward slopes.

2.3 Sitting of the Raingauge

The location of the site should be selected in such a way that the observations are representative on a scale required from the station; a station in the synoptic network should make observations to meet synoptic scale requirements, a rainfall station should measure the impact of local orography on the rainfall amount, as far it is possible, stations in the synoptic and climatological networks meet the following requirements for site location (Meteorological Office, 1982):

- The site should be representative of an area of several tens of km from the station
- The instruments should be installed on level ground
- There should be no steeply sloping ground in the vicinity and the site should not be in a hollow
- The site should be well away from the trees or any other large obstructions. The distance of any such object should not be less than twice the height of the object, and preferably four times the height
- The site should be adequately protected to exclude entry by unauthorized persons
- The site must be possible to meet the exposure of the raingauge.

Raingauge site should be examined occasionally to note any possible changes in the exposure of the instrument. Removal of neighboring trees or the growth of the adjacent plants are modifications of the natural surroundings that could affect the raingauge record. Observers should be encouraged to report any major structural changes to buildings near the gauge because they could result in changing wind patterns in the vicinity of the instrument which also could also affect the homogeneity of the catch record.

2.4 Calibration, Maintenance and Inspection

Most measurements are made with full traceability to national or international standards; this practice ensures a uniformity of measurement over time. Instruments are calibrated after receipt from the manufacturer and in some cases at intervals after that. Some of the other checks performed to ensure properly functioning observing system are as follows (WMO, 1994)

- Observers perform basic routine checks of equipment quality as part of normal observing practice.
- Observations and the observing practice are checked.
- Observations are monitored routinely on receipt and technicians are called where faults occur
- Regular maintenance is performed on all instrumentation
- Regular inspections are carried out. Checks are made of equipment, exposure and observing practice. Check readings are taken.
- Quality control is performed on all data.

2.5 Precipitation Measurement

It is necessary to review the different means of measuring and recording precipitation, and discuss their problems and limitations before dealing and analyzing rainfall variation in time and space, and aspects of magnitude and frequency. (WMO, 1994).

The measurement of rainfall comprises two aspects: first, the point measurement of rainfall at a gauge or a recorder, second the using of catches to estimate areal rainfall

2.5.1 Point Measurement and Instruments

A storage raingauge is basically is an open container to catch falling drops over a known area bounded by the raingauge rim. The amount of rain collected may be measured by manually emptying a storage raingauge usually at daily or greater intervals. The size of the rim and the height varies between countries but is usually standardized within each country. The major problem of accuracy is due to wind turbulence around the gauge, and sensitivity to change in the immediate environment surrounding the gauge, which usually results in underestimates. This may be due to both exposures of the site and to the type of raingauge. (Meteorological Office,1982).

Recording gauges which are numerous instruments automatically registers the intensity, or rate of accumulation have been invented due to the needs for the continuous recording of precipitation arose from the need to know not only how much rain has fallen but also when it fell and over what period. There are three different types of recording gauges: the weighting type, the tilting bucket type and the float type. The weighting type observes precipitation directly when it falls by recording the weight of the reservoir with a pen on a chart. With the float type, the rain is collected in a float champer, the vertical movement of the float is recorded by pen on a chart. The tilting or tipping bucket type is a very simple recording raingauge. Rain is led down a funnel into a wedge-shaped bucket of fixed capacity. When full, the bucket tips, to empty and a twin adjoining bucket begins to fill. At each tip, a magnet attached to the connecting pivot closes circuit and the ensuing pulse is recorded on a counter. The main disadvantage of using automatic recorders is the performance of the instruments, rather than wind effects. Rainfall amounts may exceed the capacity of storage gauges, causing water to overflow and be lost. High intensity rainfall can cause recording gauge mechanism to jam, or to lose accuracy due to the finite time taken for the float gauges for emptying the gauge or for tipping buckets to tip. (Meteorological Office,1982). Figure 2.1 shows a standard storage raingauges while Figure 2.2 shows principles of tipping-bucket mechanism

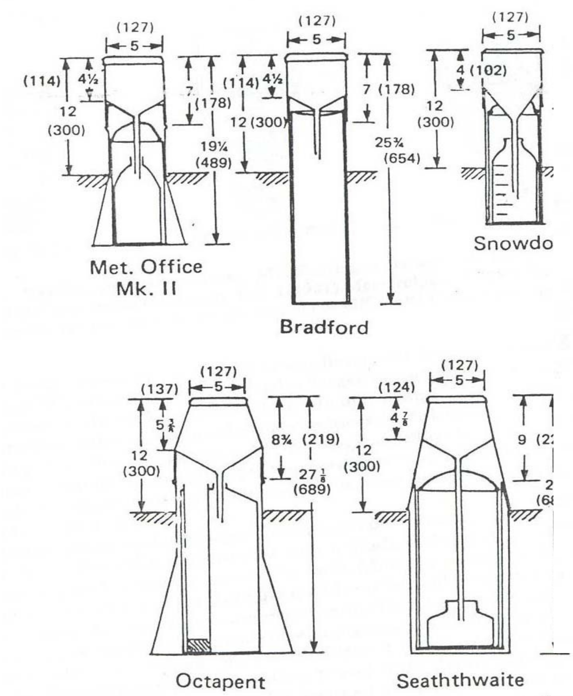


Figure 2.1:Standard Storage raingauges (Dimensions in Inches and Milimeters (Source: Shaw,1988)

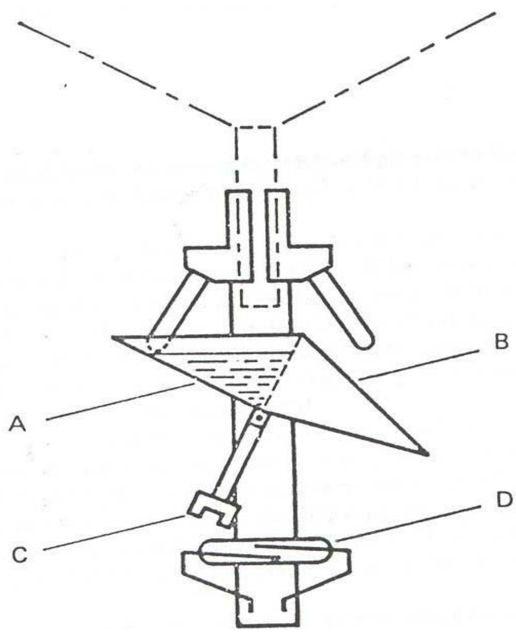


Figure 2.2: Principle of tipping-Bucket Mechanism (Source Shaw,1988)

2.5.2 Areal Measurement

Radar and satellite measurements of rainfall can be used to measure rainfall particularly in remote areas or in area where increased spatial or time resolution is required. Radar works on the basis on radar echo or reflectivity transmitted by radar. The relation between radar reflectivity and rainfall rate is not constant, but depends on number of factors including the concentration of drops, their size distribution and the vertical wind velocity.

The major advance enabling radar to be used for quantitative precipitation estimates came from the use if measured rainfall rates for real time data (Morin J, etal, 1995).

Since radar and raingauges coverage are inadequate over much of the Earth's surface, comprising the oceans, desserts and semi desserts regions, most mountainous regions and most humid regions in the tropics, so satellites techniques are the only systematic means in those areas of monitoring the movement of weather systems and to provide estimates of likely rainfall patterns. Satellites can provide spatially continuous information and can provide complete global coverage over a period of time.

The major disadvantage of using satellite is that satellite provides observations of clouds, not rainfall, and so can't measure rainfall directly, so the accuracy is not accurate as raingauges and radar. In both radar and satellite, however, surface rainfall measurements are necessary for calibration and checking purposes.

2.6 Previous Studies.

Because the study area is shared groundwater resources, there exists both Israeli and Palestinian literature. Husary etal (1995), provide an analysis for the rainfall data from the northern West Bank. Procedures of quality control for time series of rainfall data were applied for 29 manual gauges on daily, monthly, and annually. Screening of the daily data through using spatial homogeneity test reveals that 17% of the rainfall records does not meet the relative criterion of spatial homogeneity test. The results of the double mass curve method for the monthly data show that the monthly rainfall data of the most rainguages do not deviate considerably from the expected average of rainfall of the neighbouring stations. Screening techniques of f-test and t-test show that the mean and variance of the annual time series are independent of time and they are trend-free. Therefore, the time series are considered to be stationary.

Another study conducted by (Ben Gai, etal, 1999) studied and analyzed the daily maximum and minimum temperature and rainfall from 40 stations in Israel to detect long-term trends and changes in temporal and spatial distribution pattern during the second half of the 20^{th} Century. The trend analysis reveals a rather complex changing pattern, with a significant decreasing of both the daily maximum and minimum temperature, during the cool season, and increasing trend during the warm season. On an annual basis, there seems to be almost no temporal trend in minimum and maximum temperature since the changes in winter and summer show an opposite tendency. In another study (Steinberger and Gazit,1996) revealed that rainfall amounts have also decreased in the area to the north of Tel Aviv. They also showed that in the coastal area south of Tel Aviv and western slopes of the West Bank mountains the rainfall increased.

CHAPTER 3
STUDY AREA AND METHODOLOGY

3.1 Study Area

3.1.1 Location and population.

The study area is located between 138,000 to 180,000 North, and 145,000 to 185,000 East. It forms the eastern part of Auja Al-Timsah Catchment (1804 Km^2). The study covers the part within the West Bank only (Figure3.1). This area covers about 1100 km^2 forming the central part of what is known as the western aquifer basin.

The study area extends through large parts of Ramallah Governorate, whole of Salfit Governorate, large parts of Nablus and Qalqilya Governorates. The total population of the study area for 1997 is (326472) inhabitants distributed among 152 Palestinian localities, the largest are Qalqilya, Salfit and Bidya (PCBS, 1998). In addition, there are about 85 Israeli settlements; the largest are Araiel, which is a city of more than 40,000 settlers (PCBS,2004). Figure 3.2 shows the Palestinian communities and Israeli settlements.

3.1.2 Climate.

The study area is part of the West Bank which is highly influenced by the Mediterranean climate, which is characterized by long, hot, dry summers and short, cool, rainy winters.

Average annual rainfall in the study area is about 600 mm, Rainfall is limited to the winter and spring months mostly between November and April. Summer is completely dry. Snow and hail are uncommon, although hail, associated with thunderstorms, can

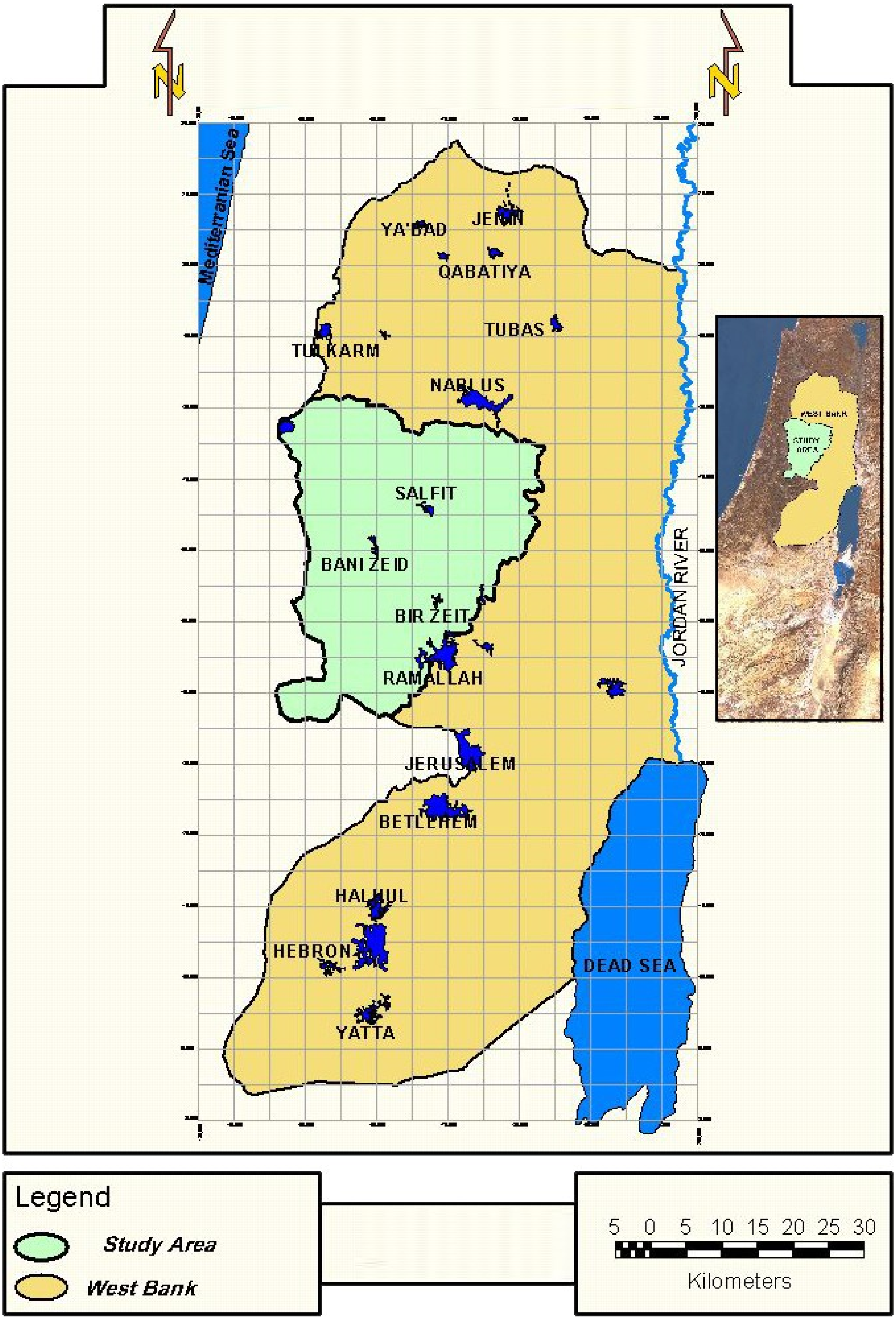


Figure 3.1: Location Map of the Study Area

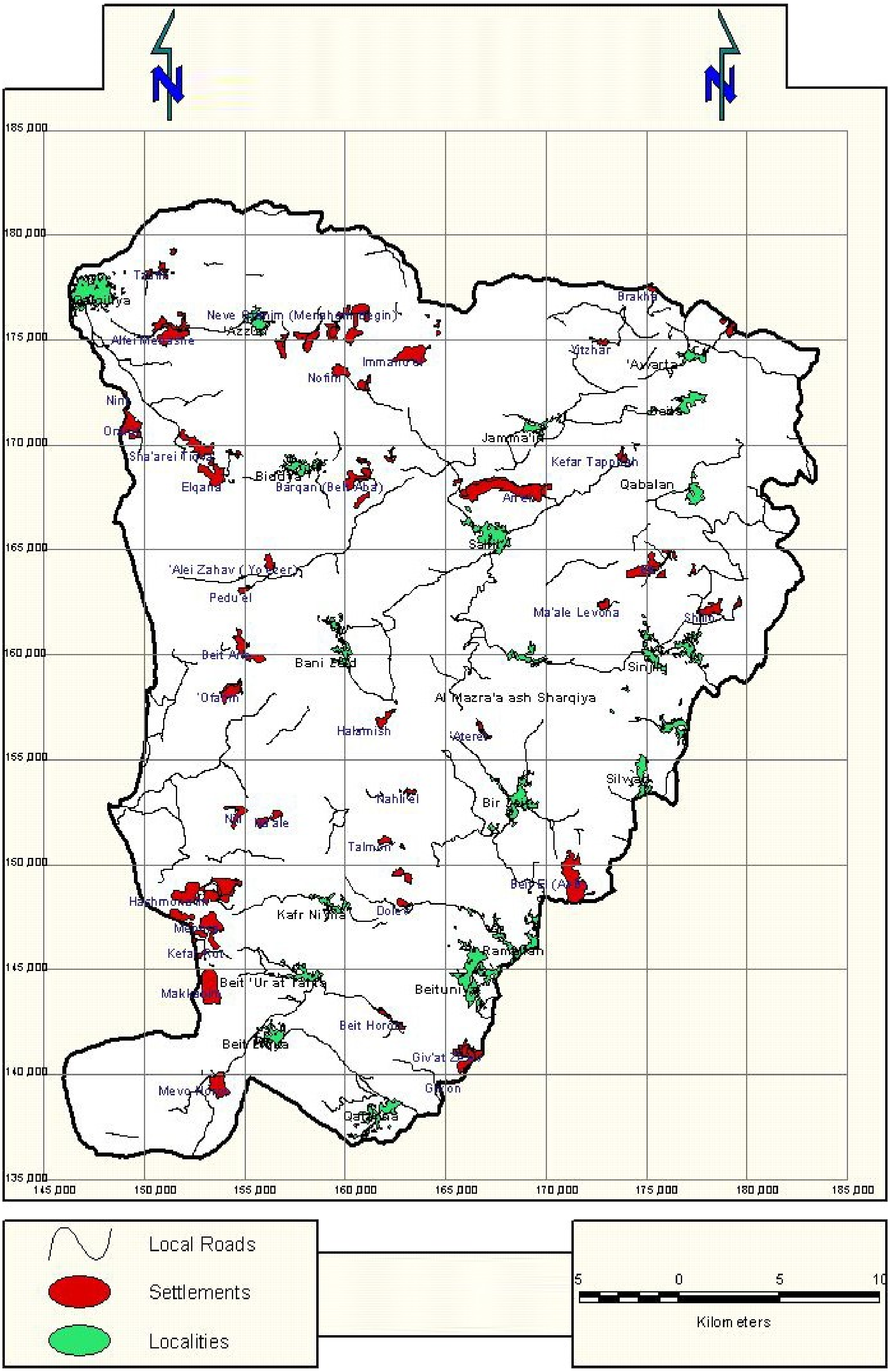


Figure 3.2: Palestinian Communities and Israeli settlement in the Study Area

occur anywhere in the area and snow is possible over the highlands.
Summer conditions are ruled by a high pressure belt over the Mediterranean and the continental low pressure area to the east and the south, which creates a strong pressure gradient across the country with a corresponding wind movement of relatively cooler air from the Mediterranean. The reduction of the pressure gradient at night, when the land areas are cooler, causes diurnal fluctuation in wind speeds (Rofe and Rafety, 1965).
Temperatures vary according to geographical position, altitude, and exposure to marine influences. The mean annual temperature variation in Nablus and Ramallah ranges between 15 °C-20 °C, the temperature for the coldest month (January) is 6-13 °C, while for the hottest month (August) ranges between 22-25 °C. The hottest days of the year occur in August. The average monthly maximum temperature Nablus is 29.4°C. Because of the moderating influence of the marine breezes in the low-lying Tulkarem District, the average maximum temperature reaches 29.6 °C (ARIJ, 1996a).

The mean Relative humidity ranges from 60%-65%. The maximum reaches its highest point in the winter (December) when the average humidity is 76.7% in Ramallah, 67.2% in Nablus, and 66.5% in Tulkarem, The annual minimum relative humidity occur in May and reaches to 57% in Ramallah and 50% in Nablus (ARIJ,1996b).

Evaporation is particularly strong in summer as a result of high temperatures, intensive sunshine and low humidity. The mean monthly evaporation rate in summer (from June to August) is 227

mm/month, while the mean monthly evaporation rate in winter (from December to February) is 55 mm/month (ARIJ, 1996a).
The annual total evaporation rates reach 1,681 mm/year in Nablus, the mountainous area, In Nablus Mountains; rainfall exceeds evaporation in only four months of the year which are December, January, February, and March (ARIJ, 1996a).

3.1.3 Topography

The study area extends over an area of about 1128 km^2, in which the elevation ranges from 50 m in Qalqilya up to 850 m above sea level in the Al Bireh (Figure 3.3).

3.2 Geology of the study area:

The outcropping formations in the study area consist mainly of limestone, dolomite, chert, chalk, and ranging in age from Albian to Recent. Figure 3.4 shows the Geological outcrops of the study area. These rocks are primarily outcrops of upper cretaceous carbonate rocks of Albian, Cenomanian, Turonian, and Senonian age. Younger, Eocene rocks are also present, but outcropping in small areas. In addition Unconsolidated, Quaternary alluvial sediments overlie the major rock formations.

3.2.1 Lithostratigraphy

The geological formations and the rock sequences of the study area were studied by (Goldsmith, 1947) and Rofe and Raffety, 1963), as well as many recent Israeli and Palestinian studies. The following is description of the geological formations in the study area:

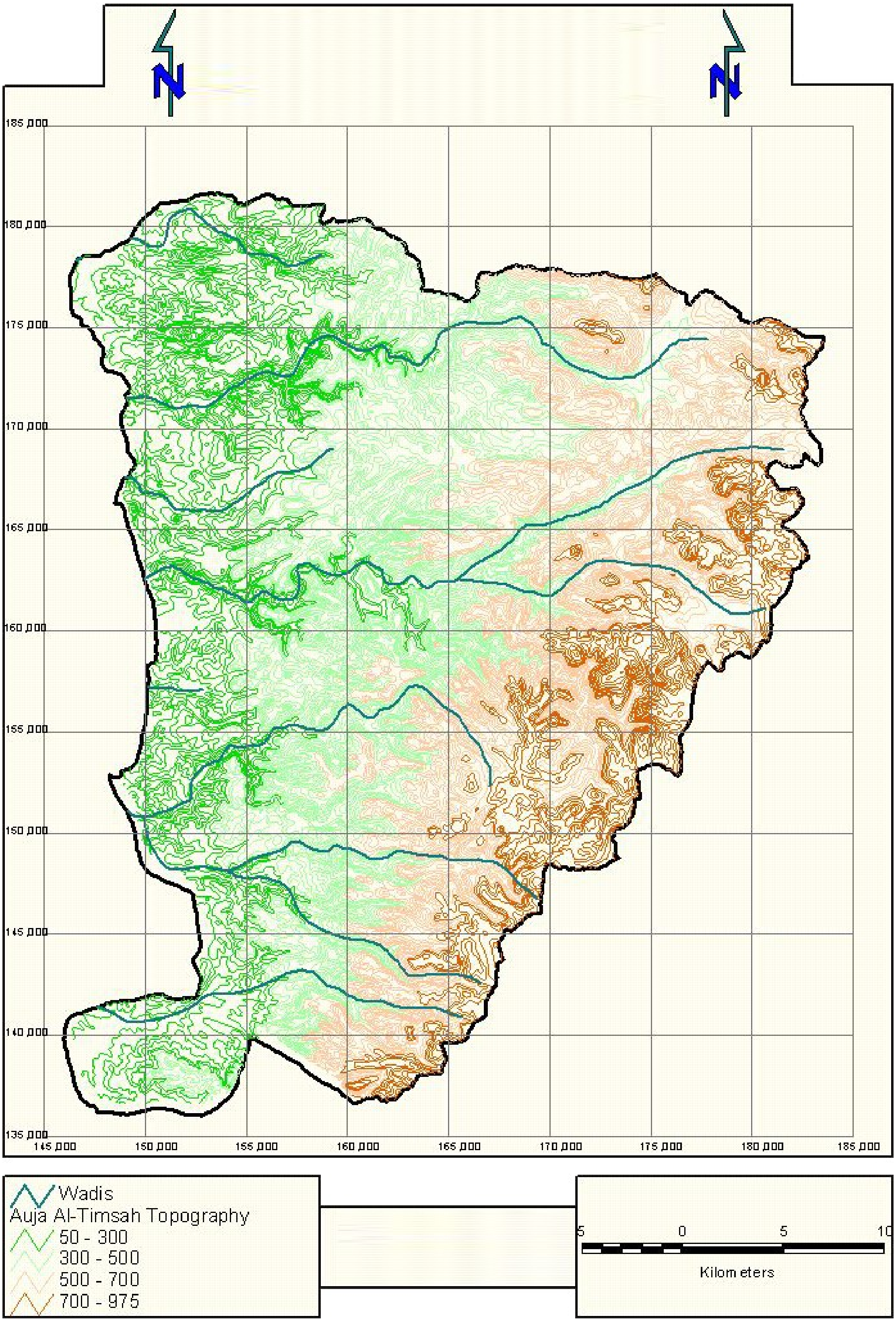


Figure 3.3: Topographical Zones of the Study Area

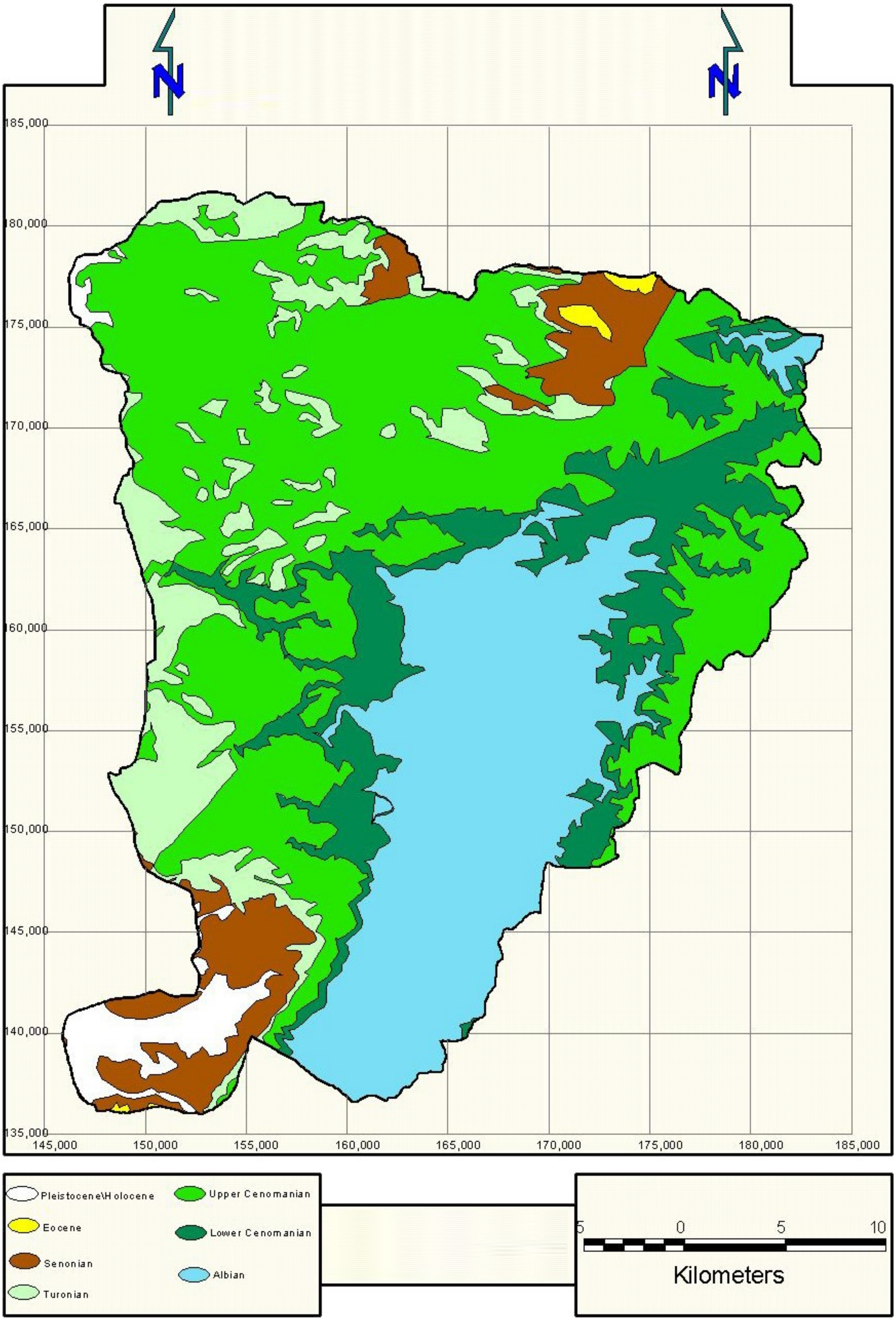


Figure 3.4: Geological Outcrops of the Study Area

(1) Kobar Formation).

Two units of Albian and Aptian age and an overall thickness of 190 m consisting this formation. The upper Albian was reported to contain sandstone, marl, clay and limestone.

(2) The Lower Beit Kahil Formation (Albian to Lower Cenomanian)

Limestone conditions were developed in Ramallah area (Rofe and Raffety,1965). The Lower Beit Kahil outcrops is massively bedded at base and becomes increasing thin bedded towards the top. Its thickness ranges from 170m to about 280m.

(3) The Upper Beit Kahil Formation (Albian to Lower Cenomanian)

The most common rock in this formation is dolomite and dolomitic limestone. It is massively and thinly bedded, usually coarse crystalline, sometimes chalky. The formation becomes increasingly karstified upwards. Its thickness is 120-220m.

(4) Yatta Formation (Lower Cenomanian).

Yatta outcrops in the south of Salfit. The characteristic lithology is marly limestone interbedded with dolomistic limestone or dolomite. The dolomite and limestone usually appears in yellowish or brown colors, with a non-sugary grain fabric. Minor chert content, either nodular, lensoid or disseminated, is recorded in some locations.

(5) Hebron Formation (Upper Cenomanian).

The formation is more uniform than Yatta but undergoes laterally a considerable facies change. The main lithologic component is dolomite and dolomitc limestone. On the flanks of the anticline the lithology is more limeys. Hebron consists almost entirely of dolomite. The rock is hard, massive and poorly bedded. It shows sugary texture, by this a high secondary porosity and a well developed karst in many parts of the formation.

(6) Bethlehem Formation (Upper Cenomanian to Turonian).

Dolomite and limestone - massively bedded with a well-developed karst. Some parts with thin-bedded limestone are used for floor tiles. The dolomite forms a rugged morphology on general slopes.

(7) Jerusalem Formation (Turonian).

The main body of formation is thinly bedded limestone, fine grained and uniform, sometimes dolomitic. It has a well-developed karst and forms a cliff morphology. Towards the top, chalk beds with occasional chert bands are common, and the formation is transitional to the facies above.

(8) Abu Dis Formation (Senonian).

The Abu Dis Formation consists of white chalk. A prominent twin band of chert marks the base of the lower part of Mishash Formation.

(9) Eocene.

Chalk-massive to finely bedded with some chert and limestone. Limestones are most common to the west along the Anabta anticline.

(10) Quaternary.

Quaternary Alluvial deposits are mainly found in Wadi beds and terraces, but also occur as fans and piedmont cones. The Nari weathering crust is a prominent feature on the carbonate rocks of almost all formations within Ramallah area.

3.2.2 Karstification.

The dominance of carbonate rocks in the West Bank suggests the possible existence of karst caves. The development of

Karstification begins after the percolation of rainfall down along the fractures and dissociation and displacement of carbonate materials. A great number of huge caverns are observed in Hebron formation. Few sink holes are located after a heavily periods of rainfall (Rofe and Raffety, 1965).

3.3 Hydrogeology of the Study Area.

3.3.1 Aquifer System.

The study area is located within the system of the Western aquifer Basin. The whole western surface drainage is considered as one unit, namely Auja Al-Timsah catchment. Hydrogeologically, the study area is composed of two main aquifers. (Table 3.1) shows the stratigraphy and aquifer system of the study area.

(1) The Upper Aquifer

The Upper Aquifer consists of the (Bethlehem and Hebron formations of (Cenomanian age) and (Jerusalem formation of Turonian).

<u>Cenomanian Aquifer</u>

The Cenomanian aquifer is composed of Bethlehem and Hebron formations. It consists mainly of interbedded dolomites and chalky limestone. The aquifer is an important source of water supply for both domestic use and irrigation purposes. It is heavily exploited in the study area, where the aquifer is shallow near Qalqilya because the recharge is large (Bachmatt,1995). Thickness of the aquifer approximately ranges from 100 to 150 m. The well yields range from 40-400 m^3/hr. The well depths in general are less than 400 m. The depth to water is rarely more than 200 m below ground surface. The Aquifer has high recharge values and its water quality is generally good (30-100 mg/1 of chloride). The apparent transmisivity (T) values ranges from 353 m^2/day in Qalqilya

Muncipality well No.1 to about 1210 m^2/day in Azzun Municipal well, while the horizontal hydraulic conductivity (K) values are relatively high and ranges from 150 m/day to 500 m/day, (PWA DataBase).

Table3.1: Stratigraphy and Aquifer system in the Study area

Period		Age	Lithology	Palestinian Formation Terminology		Hydrostratig-raphy	Typical Thickness (m)
Quaternary		Pleistocene/ Holocene		Alluvial		Aquifer	0-100
Tertiary	Paleogene	Eocene	Marl, Clay, chalk, limestone and chert	Jenin Subseries	J	Aquifer	200-250
				Abu dis	AD	Aquitard	
Cretacious	Upper	Senonian					
		Turonian	Limestone, marl, chalk, chert	jerusalem	J	Aquifer	200-250
				Bethlehem	BL		
		Upper cenomainian		Hebron	HB		
	&		Limestone, marl, chalk, chert	Yatta	Y	Aquitard	100-150
		Lower cenomanian		Upper Beit Kahil	UBK	Aquifer	300-400
		Albian		Lower Beit Kahil	LBK		
	Lower			Kobar	K	Aquitard	

Turonian Aquifer

The formation of this aquifer is Jerusalem, which consists of massive and thick limestone and dolomites with crystalline limestone and dolomitic limestone with well-developed karst features. The Turonian aquifer is part of the Upper Aquifer. The aquifer is of good thickness generally from 200m to 250m, and extent in the Tulkarm area (approximately 130 m thick). The aquifer is considered fairly good aquifer especially where the saturation thickness is in tens of meters. The water quality of this aquifer is generally good but in some area there is an evidence of deterioration because of sewage and agro-chemicals pollution.

(2) The Lower Aquifer.

Part of the Lower Cenomanian Yatta formation hydraulically separates the Upper and Lower Aquifers across the study area as most of the West Bank, the presence of the Yatta limestone gives rise to minor springs and seepage. Water levels (heads) in the Upper Aquifer are generally higher than in the Lower Aquifer.

The Lower Beit Kahil and Upper Beit Kahil formations and at places also the lower part of Yatta formation form the Lower Aquifer, strongly confined aquifer. It is an excellent source of water, due to its large thickness of 300-400m. Individual well yields across the study area range from 150-450 m^3/hr. Well depths vary from 500 to 850 m. The high water bearing capacity and productivity is owed to the great thickness of the carbonates, mainly dolomitic limestone and limestone. Water quality is generally good with chloride values in the range of 20-50 mg/l, (PWA,2001).

3.3.3 Drainage System

The main drainage system in the Study Area runs to the west through such wadis as Wadi Sarida, Wadi el-Shamiyah, Wadi el-Dulb, Wadi Qana and Wadi Ein Arik (Figure 3.3). All the drainage systems in the Study area originate from the inland escarpment and are largely controlled by a few streams flowing westwards, some of which have cut deeply into the highlands with their numerous main streams. The potential runoff is estimated to be 49.7 mcm/year (PWA,2000). Table 3.2 shows the major wadis in the catchment.

Table 3.2: Major Wadis and Potential Runoff (PWA,2000).

Name	Total Catchment area km^2	Potential Runoff MCM/y	Catchment area Inside Palestine Km^2	Potential Runoff Inside Palestine MCM/y	Percentage of Palestinian area to total catchment area %	Percentage of Palestinian Flow to total Flow %
Auja-Tamaseeh Yarkon-taninim	1804	49.7	1256	36.4	69.6	22
Wadi Qana			188	5.2		
Wadi Sarida			331	6.3		
Wadi Dilib			111	4.9		
Wadi Ein Arik				2.5		

3.2.4 Recharge.

Annual precipitation over Judea Group outcrops in the mountains of Judea and Samaria is the dominant natural of replenishment to The Yarkon-Taninim Basin. The estimated mean of the annual recharge of the entire aquifer as 360 MCM. 230 MCM flow into the upper subaquifer and 130 MCM into the lower sub-aquifer. (Weinberger etal, 1994). In the study area, more than 90% of the outcrops of the study area is considered to be very good recharge area as it appears in Figure 3.4. The average annual rainfall exceeds 600 mm (Guttman and Zukerman,1995).

3.3 Data collection.

Data collection for the study area included the available field data of rainfall measurements and springs discharge. Data was compiled in a database and manipulated using Arc View Software for preparing the maps. The available data were collected from the following institutions:

- The Palestinian Meteorological Department which is the main responsible body to collect and store all rainfall data.
- Palestinian Water Authority.
- Palestinian Hydrology Group.

- Palestinian Central Beureu of Statistics.

3.4 Data assessment and screening.

There has been no access to all sources of data on the water resources of the West Bank since its occupation by the Israeli troops in 1967. Oslo Agreement in 1994 made a sort of accessibility to hydrological data for the Palestinians and since then some data on the water sector including rainfall data, became available. Most of the rainguages are located in schools and measured by school staffs, who are in many cases not properly trained for such work, and this allows for personal errors. Also instrumental errors are expected to affect the total quantities of rainfall depth. A procedure for quality assurance, quality control (QA/QC) will be followed to screen and evaluate the data. The following parameters were investigated

- Daily rainfall.
- Monthly rainfall.
- Yearly rainfall.
- Spring discharges.

3.5 Data analysis and interpretation:

All screened data after making the suitable QA/QC were analyzed. The analysis included the followings:

- Descriptive statistics (tabular).
- Time series Analysis.
- Extreme analysis.
- Trend Analysis.
- Estimation.

3.6 Expected results or output.

The following results are expected after applying the study:

- Assessment of the current rainguages network.
- Suggestions for improvement if required.
- Isohetal maps for the study area.
- Assessment of volumes of rainfall water.
- Time series graphs to show the history of rainfall amount in the study area.
- Comparison tables and graphs showing relationship between the rainfall and discharge of springs.
- Assessment of total volume of spring water.

CHAPTER 4:
MONITORING NETWORK AND QUALITATIVE DATA

4.1 Rainfall Monitoring System.

Rainfall monitoring network was installed during the Jordanian administration for the West Bank. Most of the raingauges were installed in the rainy year 1953/1954. Most of those raingauges were located in different schools all over West Bank. Rainfall data measurements are made by volunteer teachers every 24 hours. So the quality of gathered data depends on the volunteers training and the technical experience with the measuring devices.

The monitoring system in the study area consists of Manual Raingauges. There are about 26 daily raingauges distributed among different schools, measured by schools, operated and maintained by the Palestinian Meteorological Department. Because lack of maintenance, some of those raingauges are not functioning since many years, and few of them were completely destroyed. Figure 4.1 shows the distribution of the raingauges in the study area.

4.2 Availability of the Data.

There are 26 rainguages in the study area. Table 4.1 shows these rainguages and the available related data and their characteristics Referring to the table below, it can be easily noted that, in most of the stations, there are a lot missing years of records, and the available data ranges from less than 10 years as in Sinjil and Rantis to more than 28 years like in Hajja and Jinsafut. Appendix A shows the available data in all stations in the study area.

Table (4.1) : Data Availability in Study Area

Station ID	Station Name	First Year	Last Year	Available Date (year)			Annual Average Rainfall (m)	
				68/77	78/87	88/97	Average all period	Average 68-97
0000001	Bassam Al Shak'ah	1968	1997	6	8	1	600	600
0000003	Bir Zeit	1972	2002	6	10	2	522	557
0000004	Al Salam	1960	2002	9	9	8	597	600
0000008	WBWD	1975	2002	3	10	10	691	709
0000011	Qibya	1968	1993	7	6	3	590	590
0241030	Kafr Qadum	1963	2002	9	9	9	649	639
0241140	Hajja	1964	2002	9	10	10	654	641
0241170	Burin	1964	2002	3	2	7	563	548
0241200	Jinsafut	1954	2002	9	10	10	640	677
0241250	Azuun	1954	2002	7	10	8	588	586
0241270	Awarta	1973	1997	5	9	9	572	572
0241300	Deir Istya	1954	2002	9	10	10	641	646
0241350	Aqraba	1964	2002	7	10	8	535	529
0241400	Buiddya	1968	2002	3	9	9	628	617
0241450	Salfit	1954	2002	8	10	9	668	711
0241470	Qarut	1954	2002	9	10	9	563	566
0241500	Deir Ghassaneh	1968	1997	5	7	3	634	634
0241550	Sinjil	1968	1995	0	5	0	623	623
0241599	Rantis	1968	1992	4	2	1	590	590
0241630	Attarah	1962	1997	9	10	9	699	695
0241650	Al Mizra'ah Al Sharqiya	1968	1997	7	9	6	568	568
0241900	Al Mizra'ah Al Qibliya	1968	2002	5	7	4	493	493
0242151	Saffa	1969	1993	5	9	3	551	551
0242230	Al Hashimiya	1968	1997	8	10	6	625	625
0242400	Beitunya	1954	2002				616	648
0242935	Al Malik Ghazi	1968	1997	6	10	2	625	625

4.3 Quality of the Measured Rainfall Data.

During the period (1967 till 1994), the Palestinian haven’t the access to rainfall data like all other water related data. After Establishment of Palestinian National Authority (PNA) in 1994, and Palestinian Water Authority (PWA) in 1996, all the water data including also rainfall data were gathered and compiled in one Data Base (DB). All the rainfall data was digitized in the database as it found in the original files without doing the necessary Quality Assurance (QA) and Quality Control (QC). Also, the Meteorological Department (MD), which is the responsible institution for rainfall network installation, maintenance started recently to collect all historical data of rainfall and installed new rain gauges.

As mentioned previously, the raingauges were distributed among schools, and have poor quality data and a lot of errors due to the following:

- The quality of the measured data is affected mainly by the lack of the technical experience of teachers either in measuring or recording. In addition to this, different measurements are taken by different teachers at the same station, so that the accuracy of the data depends on the person who does the measurement.
- The political situation plays another important factor in the quality of the data. Closures and curfews imposed by Israeli army specially in the years of first Intifada specially during the period (1988 and 1992) prevented recording of data on daily basis, and therefore, many of the readings were recorded for several days, or some times do not have any records because of damaging the gauges.
- Most of the rain gauges located at schools where there are holiday in Fridays, and winter holiday in January. Therefore, all rainfall in Thursdays was added to rainfall in Fridays. Also, all rainfall in the winter holiday is often registered as one record.

There is no enough documentation that describes status of the rainfall like intensity, wind speed, start, end and duration of storm etc...

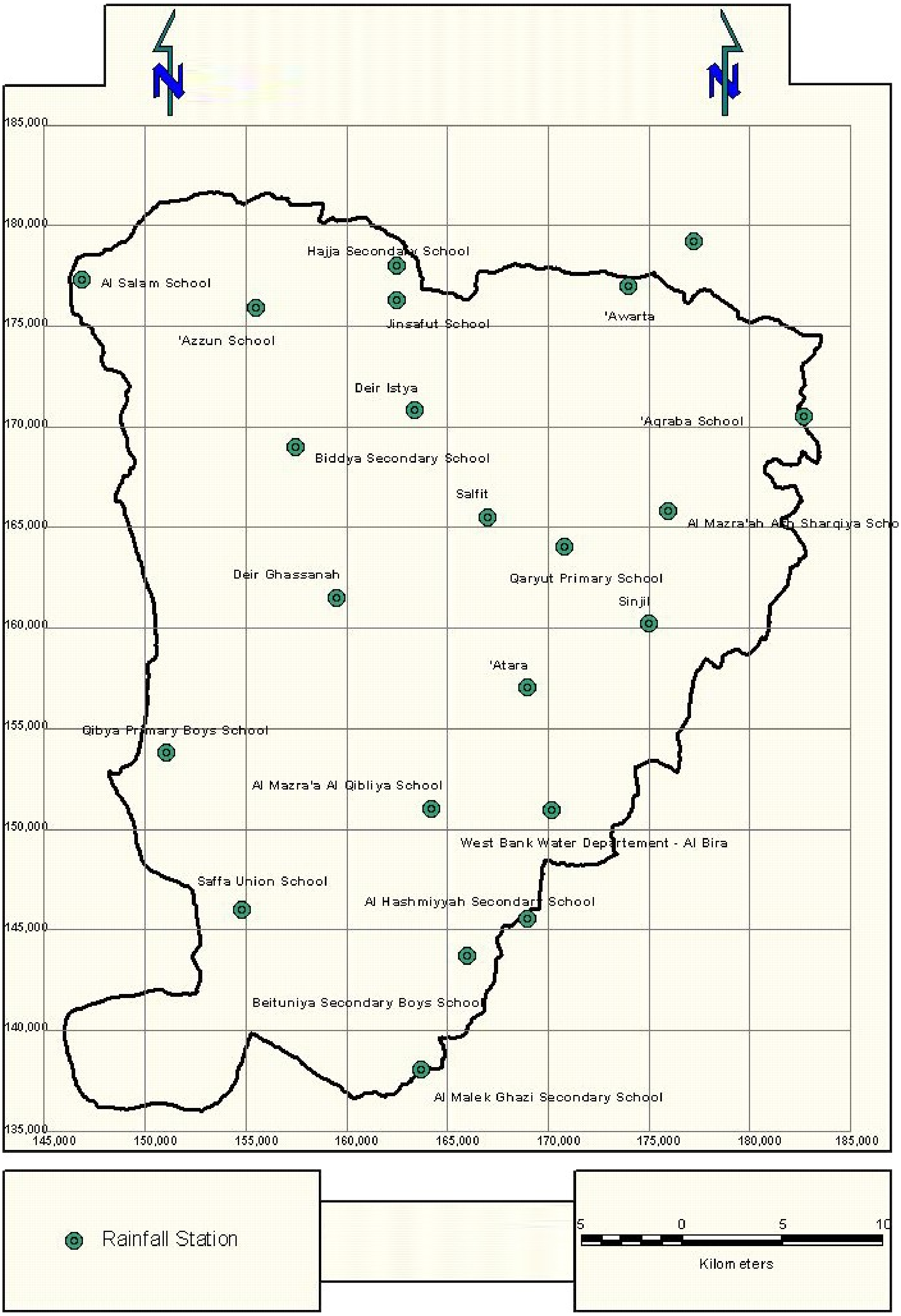


Figure 4.1: Rainfall Stations Network in the Study Area

- There isn't any information about the station instruments like type, diameter, location, altitude, surrounding conditions, maintenance etc.
- There is no documentation about the missing records; sometimes you find total monthly or annually rainfall without any explanation for those figures, and how it was accumulated.
- There is no estimation for snow falling in some years, especially in those stations of altitude more than 500 m, where the snow falling is considerable. Sometimes it documented, there is a falling snow without clarifying weather it was added to rainfall or not, or if added, no methods of calculations are mentioned.
- Times of measurement always not mentioned and suppose to be at 08:00 am. But in fact, the measurements are delayed till the storm is ended. This mean in many times, the measurements are not exactly 24 hours. This will necessarily affect the values and specially the extremes.
- The geographic locations of the station (longitude, latitude and altitude) are often estimated from maps of large scales, and sometimes, no coordinates are found. Naturally, this will affect the data, especially when comparing the amount of rainfall with altitude (elevation).

Also, through reviewing the data itself, the following facts were noticed:

- There is inconsistency in daily measurements. Sometimes it is clear that the date of measurement recorded for day of measurements not for day of rainfall (the previous day). This will affect the special homogeneity.

- The total rain values for whole year recorded as one value, often in the first of October, which will affect number of rainy days and the extremes.
- The total rain amounts of the whole month are recorded as one value, often at the first or last day of the month. This also affects the extremes, number of rainy days.
- The rainfall amounts for several days are recorded as one value. So the distinguish between the accumulated and missing data are almost difficult through comparison and estimation.
- It is noticed that the observer sometimes forgot to empty the gauge. This was clear from repeating the same value for the next day, or accumulates it. This was expected through comparison with the adjacent gauges. This affects the amounts of rainfall, special homogeneity.
- There are shifting in recording for consequence of rainy days. It is expected that the observer used to write the rainfall amounts on external paper, and make mistakes during transferring data to the rainfall copybook.
- There are sometimes contradiction between the registered of monthly rainfall at lower part of the rainfall copybook pages and the calculated rainfall of rainy days. This mean there should be an error either in daily amounts or in the monthly totals.
- Sometimes, it is difficult to distinct if there a decimal or not. Because figures are written unclearly. So it can’t be distinguished between 1.5 and 15.

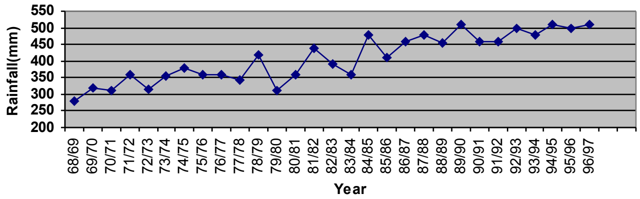
4.4 Rainfall Data Screening and Processing

Advances in scientific hydrology and in the practice of engineering hydrology are dependent on good, reliable and continuous measurements of hydrological variables. The worth of rainfall data depends primarily on the instruments, its installation, its site characteristics and its operation by a responsible observer. The measurements are recorded by a wide range of methods, from the manual writing by observer to the invisible marking of electronic impulses on a magnetic tape. So that data processing and quality control techniques should be used to ensure homogeneous, accurate and comparable data.

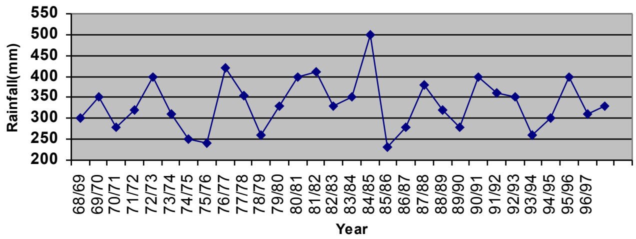
Effective quality assurance and quality control (QA/QC) procedures are essential to ensure the validity of hydrologic data including rainfall and ultimately the decisions utilizing hydrologic data. QA/QC procedures commonly apply to sample collection, measurements, control and analysis. QC refers to specific procedures used to achieve prescribed standards of performance. QA is an integrated planning process for assuring the reliability of the hydrologic data so that it can be used with some definable degree of confidence. Quality assurance components commonly include:

- Outlining intended use of the data such as to support permit insurance or revisions, to verify compliance with performance standards, or to verify self-monitoring data.
- Identifying factors that influence the design of the monitoring system such as the homogeneity.
- Selecting the parameters to be monitored and the frequency of monitoring.
- Identifying quality control procedures to document whether these requirements are being met.

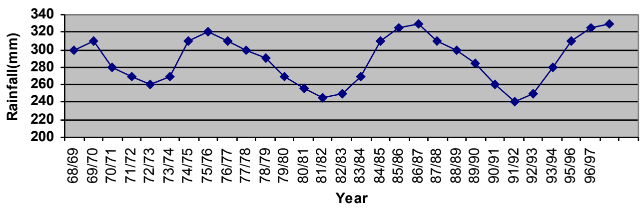
Data screening is used to spot doubtful records resulted from human mistakes or instruments errors. Generally rainfall data is available as daily data and expressed as time series. For statistical analysis, time series should be stationary (the statistical properties like average and standard deviation are independent on the choice of the origin of the series and do not change with the absolute time. In the contrary case they are non-stationary. If the mean of the time series is a constant over the time series is said to be stationary in the mean of the first-order stationary. Non stationary usually occurs in the form of jumps or trends or periodic components.. Figure 4.2 shows the characteristics of time series data.



(a) stationary Series



(b) Non-Stationaty series with a trend



(c) Non-stationary series with seasonal Fluctuations

Figure 4.2 Three Characteristic Rainfall Time Series (Source: after (Zhou,1996).

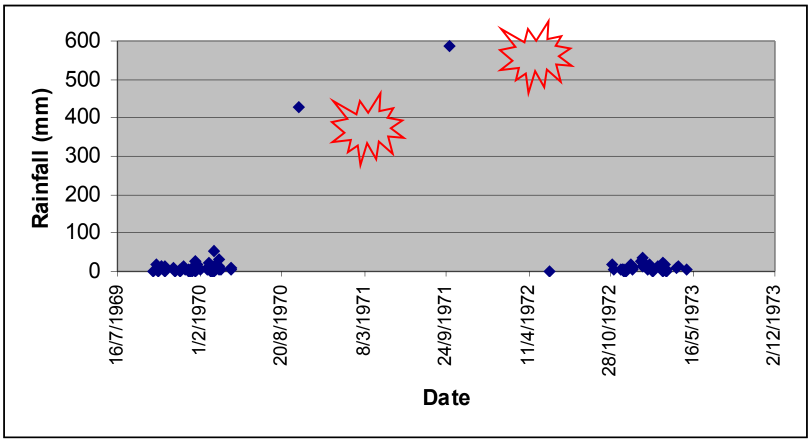
Daily, monthly and yearly screening (QAlQC) procedures will be applied for all above stations, outliers will be flagged and removed, and missing data will be estimated and filled.

- For daily intensity analysis, extreme analysis, daily estimation, only the gauges with complete daily series are considered and the stations of annual-only records and monthly-only records are dropped.
- For seasonal analysis, monthly records are required, so the total monthly amounts are considered without taken into consideration the daily amounts or number of rainy days. In this case, the stations of annual-only records are dropped.
- For special mapping of annual rainfall, records with more than 10 years of recorded annual total are required. In this case, the total annual amount are considered without taking into consideration the daily or monthly amounts or number of rainy days.
- For trend analysis, only records with more than 20 years of data were considered.

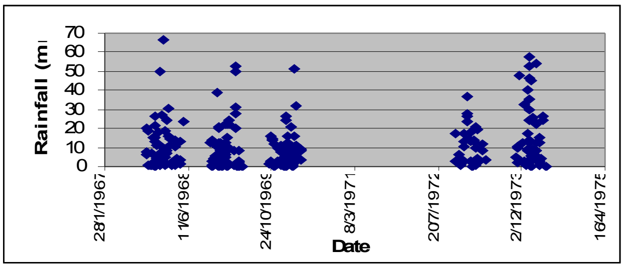
4.4.1 Daily Rainfall Data Screening.

Four types of data screening are used for daily rainfall which is time series plot, spatial homogeneity test, UK meteorological Office for Quality control program, and tabular comparison.

i. Time series: this is a powerful graphical tool, where a doubtful data can be easily marked through plotting the date versus the rainfall depth. Time series can be plotted for the same station as shown in Figure (4.3) which represents the time series data for Al Mazr'a Al Sharqiya station as example.



a: Time Series Daily Data as Recorded



b: Time Series Daily Data without Suspicious Values

Figure 4.3: Time Series Data Al Mazr'a Al Sharqiya

Quickly, two suspicious values can be marked in Figure 4.3a. After referring to the original data, it is discovered that those values are the sum of annual rainfall, and recorded as one value in first of October (start of the hydrological year), while the other rainy days in the same year are kept blanks. So when computing number of rainy days for this station at year 1970/1971, it is found only one day. But when comparing amounts of the annual rainfall, it is acceptable value comparing to average of adjacent stations. This mean, this suspicious value will be deleted when screening the daily data and plotted in Figure 4.3b, and kept as correct annual value.

Another example of using time series is to plot two or more adjacent station for the same period of time to compare the behavior of the data, and easily guess weather the largest values are incorrect or express a heavy storm as shown in Figure (4.4) where the rainfall at Al Hashimiya station is compared with the rainfall in WBWD station (2.5 km apart and with the same elevation(825m amsl).

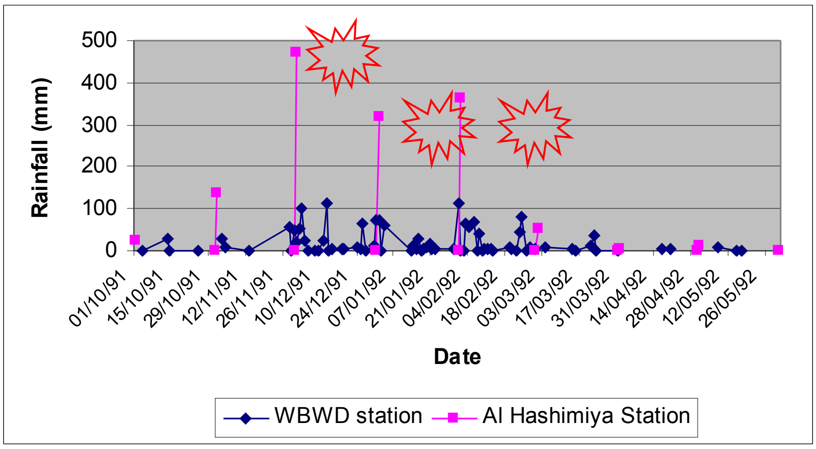


Figure 4.4: Time Series Data Comparison between Two Adjacent Stations

In Figure 4.4, there are clear suspicious records. Where those flagged records are in fact the annual rainfall in Al Hashimiya station.

Another example of screening using time series is shown in Figure 4.5, Which compares the rainfall in Kafr Qadum station with the rainfall in Hajja (3.2 km apart) and Jinsafut station(4.8 km away) and approximately the same elevation (375 to 400 amsl).

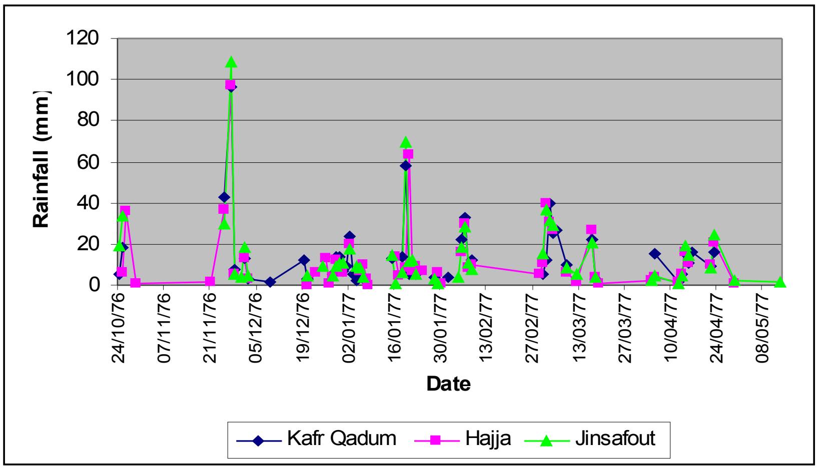


Figure 4.5: Comparison Among Three Adjacent Stations

In Figure 4.5, there are no clear suspicious records. This does not mean that all data for the three stations are always correct, since those flagged are in fact records for Thursday and Friday as documented in the original files and recorded in one value. This type of screening is powerful only to check the maximum values. So it is not enough to use this test alone to screen the data. And other types of screening are necessary like spatial homogeneity test.

ii. **Spatial Homogeneity Test.**

Spatial homogeneity test is another tool of data screening, where data of base station are related to number of surrounding stations. It can be carried out if there is already some indication of a correlation of data between adjacent stations. The aim of this test is to investigate the reliability of recorded rainfall data ((DE Latt and Savenije, 1999b). when two rainfall stations are closely together, data from these stations show a good correlation. The correlation is better if the period of observation is larger. Statistically, the correlation between two variables is defined by correlation coefficient ρ. ρ value ranges from ($-1< \rho <1$). As the value closes to zero, it means there is no correlation, while as the absolute value closes to 1; it means there is perfect correlation. This coefficient depends on the distance between the stations, and will be stronger as the distance is shorter.

If r is defined as the distance between stations, then the correlation between stations at a distance r apart is often described by Kagan's formula (De latt, 1999b): which can be expressed by a negative exponential function

$$\rho(r) = \rho_0 \exp(-r/r_0) \qquad 4.1$$

where

$\rho(r)$ = correlation at distance r

ρ_0 = correlation at distance 0

r = distance between stations

r_0 = coefficient

a maximum distance r_{max} between the base station and neighboring stations is defined as the limit where correlation becomes insignificant. To investigate the reliability of point observations, the measurements, $pi_{s(t)}$, of one station compared with estimated values, $p_{est(t)}$, based on a weighted calculation using the rainfall at neighboring stations. Only stations with a correlation distance smaller than r_{max} are taken into consideration. The weights are inversely proportional to some power of the distance between the base station and the neighboring stations (De Latt, 1999b).

the estimated daily rainfall is calculated with

$$P_{est(t)} = \frac{\Sigma\, p_{i(t)}/D_i^b}{\Sigma\, 1/D_i^b} \qquad 4.2$$

Where

$P_{est(t):}$ estimated rainfall at base at time t

$p_{i(t):}$ measured rainfall at neighbouring station at time t

$D_{i\,:}$ distance to neighboring station

b: power of distance (usually b = 2)

i: 1,2 .., number of the adjacent station

the difference between the observed value and the estimated value is considered (in this study) to be insignificant if the following condition are met

1. Absolute criterium

$$|p_{meas(t)} - P_{est(t)}| \leq 30 \qquad 4.3$$

2. relative Criterium

$$2 \leq P_{est(t)}/\,p_{meas(t)} \leq 0.5 \qquad 4.4$$

the above procedure was implemented for all stations in study area from the hydrological year 1967/1968 through 1996/1997. Before implementing the above procedure the following steps were done:

- All rainfall records below 0.5 mm were canceled. The rainy day is considered to be equal or greater than 0.5 mm.
- In relating the base station to the adjacent station three factors were considered respectively (distance, average annual rainfall, and altitude). The results are presented in Table 4.2. The figures in brackets below name of adjacent station express distance, average rainfall, and altitude respectively.

Table 4.2: Base and surrounding Stations Used in Spatial Homogeneity Test

Base Station	Surrounding stations			
Bassam Al Sha'kah		Burin	'Awarta	'Aqraba
(0,600,-)		(3.5,563,675)	(5.9,600,-)	(10.9,572,630)
Al Salam	‘Azzun	Kafr Zeibad		
(0,600,150	(8.7,586,260			
‘Azzun	Al Salam	Jinsafut	Deir Istya	Biddya
(0,586,260)	(8.7, 600,150)	(7,640,430)	(9.4,646,430)	7.2,617,315)
Kafr Qadum	Jinsafut	Hajja		
(0,639,400)	(1.7,640,430)	(3.2,641.350)		
Hajja	Kafr Qadum	Jinsafut		
(0,641,350)	(3.2,639,400)	(1.7,640,430)		
Burin	Bassam al Shak'ah	'Awarta	'Aqraba	
(0,563,675)	(3.5,600,-)	(3.3,572,500)	(11.1,529,630)	
Jinsafut	Kafr Qadum	Hajja	Deir Istya	‘Azzun
(0,640,430)	(4.8,639,400)	(1.7,641,350)	(5.6,646,430	(7,586,260)
‘Awarta	Bassam Al Shak’a	‘Aqraba	Burin	
(0,572,500)	(5.9,600,-)	(10.9,529,630)	(3.3,563,675)	
Deir Istya	Jinsafut	‘Azzun	Biddya	Salfit
(0,646,430	(5.6,640,430)	(9.4,586,260)	(6.2,617,315)	(6.4,668,520)
‘Aqraba	Bassam Al Shak’a	‘Awarta	Burin	Qaryut
(0,529,630	(10.3,600,-)	(10.9,572,500)	(11.1,563,675)	(7.9,566,790)
Bidyya	Deir Istya	Salfit	‘Azzun	Deir Gassanah
(0,617,315)	(6.2,646,430	(10.1,668,520)	(7.2,586,260)	(7.8,634,460)
Salfit	Bidyya	Deir Istya	Qaryut	Deir Gassanah
(0,668,520)	(10.1,617,315	(6.4,646,430)	(11.1,566,790)	(8.5,634,460)

Table 4.2: Base and surrounding Stations Used in Spatial Homogeneity Test

Base Station	Surrounding stations			
Qaryut (0,566,790)	Salfit (11.1,668,520)	‘Aqraba (7.9,529,630)	Sinjil (4.9,623,775)	Al Mazra’ah ash Sharqiya (8,568,835)
Al Mazra’ah ash Sharqiya (0,568,835)		Qaryut (8,566,790	Sinjil (3.9,623,775)	Deir Dibwan* (9.4,493,850)
Deir Gassanah (0,634,460)		Salfit (8.5,668,520)	Bidyya (7.8,617,315)	Qibya (11.4,590,-)
Sinjil (0,623,775)	‘Attara (6.4,695,500)	Qaryut (4.9,566,790)	Al Mazra’ah ash Sharqiya (3.9,568,835)	
‘Attara (0,695,500)	WBWD (6.4,691,820)	Sinjil (6.9,623,775)		
Qibya (0,590,-)	Al Mazra’ah Al Qibliya (13.4,537,600)		Saffa (8.6,551,325	Deir Gassanah (11.4,634,460)
Al Mazra’ah Al Qibliya (0,537,600)		Saffa (10.6,551,325)	Qibya (13.4,590,-)	
WBWD (0,691,850)	‘Attara (6.4,695,500)	Al Hashimiya (4.6,636,875)	Beituniya (7.6,648,810)	
Saffa	Al Mazra’ah Al Qibliya (10.6,537		Qibya (8.6,590,-)	
Al Hashimiya (0,636,875)	WBWD (4.6,691,850)	Beituniya (3.5,648,810	Al malek Ghazi 9.2,625	
Beituniya (0,648,810)	WBWD (7.6,691,850	Al Hashimiya (3.5,625,875	Al malek Ghazi (6.1,625,-)	
Al malek Ghazi (0,625,-)		Al Hashimiya (9.2, 625,875	Beituniya (6.1,648,810	

- Because the large number of records (more than 28,000) and stations (26), a program using Microsoft Access was designed to calculate the estimated values. This program take into consideration the expected missing values, so it is normally to find that number of estimated records will be more than measured records. Table 4.3 shows an example of screening the daily data using spatial homogeneity test. Those records marked in red do not satisfy one or both criteria used as an indicator to check the reliability of the observed data.

Table 4.3: Screening of Rainfall Data Using Spatial Homogeneity Test on Daily Basis

Date	Jinsafut	Kafr Qadum	Hajja	Azzun	Deir Istya	etimated	Criterium1	Criterium2
12/10/1996	15.0	12.5	9.0	11.0		17.3	2.3	1.16
13/10/1996	1.0	2.6	5.0	2.0		2.0	1.0	2.00
14/10/1996	2.2	0.5				0.0	-2.2	0.00
25/10/1996	11.5	10.0	12.5	12.5		9.1	-2.4	0.79
28/10/1996	17.8	1.2	1.5	2.0		2.0	-15.8	0.11
29/10/1996	12.5	23.1	14.6	16.2		19.4	6.9	1.56
05/11/1996	13.0	3.4	8.0	16.6		12.9	-0.1	1.00
06/11/1996	5.6	3.7	7.9	6.1		6.3	0.7	1.13
03/12/1996	5.6	1.1		0.5		0.5	-5.1	0.09
05/12/1996	8.1	3.4	10.0	6.5		6.5	-1.6	0.80
07/12/1996	1.0			2.8		2.8	1.8	2.80
08/12/1996	3.0	0.8	4.6	4.3		7.4	4.4	2.46
12/12/1996	16.2	18.3	14.4	20.6	20.0	19.5	3.3	1.20
13/12/1996	57.9	45.7	46.6	45.0	10.0	23.8	-34.1	0.41
22/12/1996	13.0	0.4		7.7	10.0	9.6	-3.4	0.74
13/01/1997	9.4	6.1	7.0	7.3		7.4	-2.0	0.79
14/01/1997	10.2	7.6	2.5	1.0		6.3	-3.9	0.62
15/01/1997	45.6	55.7	42.7	57.0		41.2	-4.4	0.90
16/01/1997	33.4	8.3	16.1	9.0	77.0	45.5	12.1	1.36
22/01/1997	84.7	80.7	86.0	92.0	55.0	67.3	-17.4	0.79
23/01/1997	5.6	1.2	1.7	0.6		2.0	-3.6	0.35
26/01/1997	2.4	3.6	3.4	2.9		4.6	2.2	1.92
30/01/1997	12.9	10.7		12.5		14.3	1.4	1.11
02/02/1997	26.6	25.1	25.0	27.2	25.0	25.2	-1.4	0.95
03/02/1997	27.8	30.5	29.0	25.8	35.0	28.6	0.8	1.03
04/02/1997	8.1	11.9	10.0	5.7	16.0	11.7	3.6	1.45
20/02/1997	9.3	17.2	13.5	8.2		14.5	5.2	1.56
21/02/1997	65.7	74.7	61.2	80.0	40.0	55.3	-10.4	0.84
22/02/1997	81.4	76.5	79.2	99.6	30.0	62.6	-18.8	0.77
23/02/1997	11.9	10.6	6.2	12.5	105.0	57.0	45.1	4.79
24/02/1997	12.7	10.8		15.3		13.5	0.8	1.06
26/02/1997	5.9	6.4	6.2			6.1	0.2	1.02
02/03/1997	18.5	14.2	20.0	10.0	14.0	11.8	-6.7	0.64
03/03/1997	7.7	10.8	11.2	14.2	8.0	9.5	1.8	1.23
05/03/1997	2.9	1.2	2.3	2.2		2.7	-0.2	0.93
06/03/1997	5.7	3.4	4.2	6.5		7.4	1.7	1.29
13/03/1997	1.6	6.4	6.1	8.0		9.3	7.7	5.82
14/03/1997	9.8	9.8	10.1	5.0	20.0	13.5	3.7	1.38
15/03/1997	53.9	77.3	77.2	60.7	22.0	40.4	-13.5	0.75
16/03/1997	28.4	23.4	27.5	23.0	46.0	34.2	5.8	1.20
17/03/1997	24.6	21.1	33.5	27.8	50.0	34.0	9.4	1.38
18/03/1997	20.6	25.3	21.5	13.1	28.0	18.8	-1.8	0.91
22/03/1997	11.5	13.2	21.5	18.6	15.0	18.9	7.4	1.65
23/03/1997	13.8	14.5	6.2	6.3	15.0	10.5	-3.3	0.76
24/03/1997	10.3	9.0	9.0	10.2		12.2	1.9	1.18
04/04/1997	1.2	2.4	2.6	3.5		3.5	2.3	2.92
07/04/1997	3.6	3.9	4.1	3.5		3.4	-0.2	0.94
08/04/1997	2.1	2.7	3.2	1.4		1.6	-0.5	0.77
03/05/1997	9.0	28.1	21.0	10.5		10.5	1.5	1.17
04/05/1997	20.2	13.8	7.2	3.5		3.5	-16.7	0.17

iii. **UK Meteorological Office Quality Control Program (Shaw,1988)**

This program used by the meteorological Office in UK, and it is similar in the idea to spatial homogeneity test suggested by De Laat, in comparing the daily rainfall data with surrounding stations, but this method use different approach through checking the daily data by relating them to the average annual rainfall thus making allowances for variation in site and altitude in the following steps:

A. The area daily rainfall means as percentage of the area annual average using all the area stations, (M_d), and the standard deviation (S_d) are calculated.

B. All the daily values are converted to percentage of station annual average (D_p) and checked against the mean percentage for the area (M_d):

If D_p-$(M_d$+$2S_d)/D_p > 0.25$ 4.5

Then daily value is too high

If $D_p < (M_d - 2S_d)$, 4.6

Then daily value is too low

Table 4.4 shows an example of screening the daily data using Uk Meteorological Office. Those records marked in red do not satisfy one or both criteria used as an indicator to check the reliability of the observed data in the base station compared to surrounding stations. Compare the results of screening data using spatial homogeneity test and UK meteorological office procedure, it is easy to reveal that sometimes both methods gave the same results as example in the records observed in 20/10/1996 and 23/01/1997, while in another observed records they gave different results. This is due to that UK meteorological office procedure depends on the percentage of the value compared to the total sum of the rainfall.

Table 4.4: Screening of Daily Rainfall Using Meteorological Office Procedure

Date	Jinsafut	Dp	Kafr Qadum	Hajja	Azzun	Deir Istya	Avg surrounding	Md	Md – 2sd	re
12/10/1996	15.0	1.7	12.5	9.0	11.0		10.8	1.3	-2.3	-3.1
13/10/1996	1.0	0.1	2.6	5.0	2.0		3.2	0.4	-41.1	-4.0
14/10/1996	2.2	0.2	0.5				0.5	0.1	-16.9	-4.3
25/10/1996	11.5	1.3	10.0	12.5	12.5		11.7	1.4	-3.4	-3.0
28/10/1996	**17.8**	**2.0**	**1.2**	**1.5**	**2.0**		**1.6**	**0.2**	**-1.3**	**-4.2**
29/10/1996	12.5	1.4	23.1	14.6	16.2		18.0	2.1	-3.6	-2.3
05/11/1996	13.0	1.5	3.4	8.0	16.6		9.3	1.1	-2.7	-3.3
06/11/1996	5.6	0.6	3.7	7.9	6.1		5.9	0.7	-7.0	-3.7
03/12/1996	5.6	0.6	1.1		0.5		0.8	0.1	-6.1	-4.3
05/12/1996	8.1	0.9	3.4	10.0	6.5		6.6	0.8	-4.6	-3.6
07/12/1996	1.0	0.1			2.8		2.8	0.3	-40.7	-4.1
08/12/1996	3.0	0.3	0.8	4.6	4.3		3.2	0.4	-13.1	-4.0
12/12/1996	16.2	1.8	18.3	14.4	20.6	20.0	18.3	2.1	-2.6	-2.3
13/12/1996	57.9	6.6	45.7	46.6	45.0	10.0	36.8	4.3	-0.3	-0.1
22/12/1996	**13.0**	**1.5**	**0.4**		**7.7**	**10.0**	**6.0**	**0.7**	**-2.5**	**-3.7**
13/01/1997	9.4	1.1	6.1	7.0	7.3		6.8	0.8	-3.9	-3.6
14/01/1997	**10.2**	**1.2**	**7.6**	**2.5**	**1.0**		**3.7**	**0.4**	**-3.2**	**-4.0**
15/01/1997	45.6	5.2	55.7	42.7	57.0		51.8	6.0	-1.0	1.6
16/01/1997	33.4	3.8	8.3	16.1	9.0	77.0	27.6	3.2	-1.0	-1.2
22/01/1997	84.7	9.6	80.7	86.0	92.0	55.0	78.4	9.2	-0.4	4.8
23/01/1997	**5.6**	**0.6**	**1.2**	**1.7**	**0.6**		**1.2**	**0.1**	**-6.1**	**-4.3**
26/01/1997	2.4	0.3	3.6	3.4	2.9		3.3	0.4	-16.6	-4.0
30/01/1997	12.9	1.5	10.7		12.5		11.6	1.4	-2.9	-3.0
02/02/1997	26.6	3.0	25.1	25.0	27.2	25.0	25.6	3.0	-1.5	-1.4
03/02/1997	27.8	3.2	30.5	29.0	25.8	35.0	30.1	3.5	-1.5	-0.9
04/02/1997	8.1	0.9	11.9	10.0	5.7	16.0	10.9	1.3	-5.2	-3.1
20/02/1997	9.3	1.1	17.2	13.5	8.2		13.0	1.5	-4.6	-2.9
21/02/1997	65.7	7.4	74.7	61.2	80.0	40.0	64.0	7.5	-0.6	3.1
22/02/1997	81.4	9.2	76.5	79.2	99.6	30.0	71.3	8.3	-0.4	3.9
23/02/1997	11.9	1.3	10.6	6.2	12.5	105.0	33.6	3.9	-5.2	-0.5
24/02/1997	12.7	1.4	10.8		15.3		13.1	1.5	-3.1	-2.9
26/02/1997	5.9	0.7	6.4	6.2			6.3	0.7	-6.7	-3.7
02/03/1997	18.5	2.1	14.2	20.0	10.0	14.0	14.5	1.7	-1.9	-2.7
03/03/1997	7.7	0.9	10.8	11.2	14.2	8.0	11.0	1.3	-5.5	-3.1
05/03/1997	2.9	0.3	1.2	2.3	2.2		1.9	0.2	-13.1	-4.2
06/03/1997	5.7	0.6	3.4	4.2	6.5		4.7	0.5	-6.7	-3.9
13/03/1997	1.6	0.2	6.4	6.1	8.0		6.8	0.8	-27.7	-3.6
14/03/1997	9.8	1.1	9.8	10.1	5.0	20.0	11.2	1.3	-4.1	-3.1
15/03/1997	53.9	6.1	77.3	77.2	60.7	22.0	59.3	6.9	-0.9	2.5
16/03/1997	28.4	3.2	23.4	27.5	23.0	46.0	30.0	3.5	-1.5	-0.9
17/03/1997	24.6	2.8	21.1	33.5	27.8	50.0	33.1	3.9	-2.0	-0.5
18/03/1997	20.6	2.3	25.3	21.5	13.1	28.0	22.0	2.6	-2.0	-1.8
22/03/1997	11.5	1.3	13.2	21.5	18.6	15.0	17.1	2.0	-3.9	-2.4
23/03/1997	13.8	1.6	14.5	6.2	6.3	15.0	10.5	1.2	-2.6	-3.2
24/03/1997	10.3	1.2	9.0	9.0	10.2		9.4	1.1	-3.7	-3.3
04/04/1997	1.2	0.1	2.4	2.6	3.5		2.8	0.3	-33.8	-4.1
07/04/1997	3.6	0.4	3.9	4.1	3.5		3.8	0.4	-10.9	-4.0
08/04/1997	2.1	0.2	2.7	3.2	1.4		2.4	0.3	-18.7	-4.1
03/05/1997	**9.0**	**1.0**	**28.1**	**21.0**	**10.5**		**19.9**	**2.3**	**-5.6**	**-2.1**
04/05/1997	20.2	2.3	13.8	7.2	3.5		8.2	1.0	-1.3	-3.4

iv. **Tabular Comparison (Statistical Description Table).**

Through applying both time series plotting and spatial homogeneity test, there was a need to compare the recorded daily rain in the base station to all surrounding stations (not necessarily those used in the spatial homogeneity test). This table compares the data that being recorded day by day. In addition to the tabulated data, the following parameters were calculated:

- Minimum and maximum: to compare the difference
- Mean, Median and standard Deviation: to check the skewness
- Number of stations that have recorded rainfall: to check missing values and consistency of recording.

Table 4.5 shows an example of using tabular comparison table to screen the daily data

Table 4.5:Representative Tabular Comparison Table.

Date	WBWD	AlHash-imiya	Beitunya	Al Malik Ghazi	Min	Max	Avg	STDV	Count
2/5/1980	24.0	30.0	30.0	14.0	14.0	30.0	24.5	7.5	4
2/6/1980	0.5			1.2	0.5	1.2	0.9	0.5	2
2/9/1980	2.8	3.0	1.0	1.5	1.0	3.0	2.1	1.0	4
2/10/1980				2.3	2.3	2.3	2.3		1
2/11/1980	**0.1**	**0.6**	**1.0**	**141.6**	**0.1**	**141.6**	**35.8**	**70.5**	**4**
2/13/1980	12.0	9.1	11.0		9.1	12.0	10.7	1.5	3
2/14/1980	20.6	18.5	10.5		10.5	20.6	16.5	5.3	3
2/15/1980	0.0	0.4	8.0		0.0	8.0	2.8	4.5	3
2/16/1980	16.1	14.0	12.0		12.0	16.1	14.0	2.1	3
2/17/1980	40.0	32.0	36.0		32.0	40.0	36.0	4.0	3
2/18/1980	3.8	4.0	5.0		3.8	5.0	4.3	0.6	3
2/19/1980	0.4	1.0			0.4	1.0	0.7	0.4	2
2/20/1980	2.6				2.6	2.6	2.6		1
2/23/1980	5.5	6.5	5.0		5.0	6.5	5.7	0.8	3
2/24/1980	7.5	6.5			6.5	7.5	7.0	0.7	2

From the tabular table above, it was easy to reveal that the value recorded in Al Malek Ghazi in 11/02/1980 represent accumulated value of rainfall for several days. This, of course, will affect number of rainy days, spatial homogeneity, and will affect the estimation.

By using the tabular comparison, it was easy to mark the errors and fixed those expected to be correct reading and wrong days. Spatial homogeneity test was recalculated again. Table 4.6 compares the percentages of those records achieves equations 4.3 and 4.4 before and after processing and fixing errors.

Table 4.6: Results in percentage of processed Daily Data

Station ID	Station Name	Number of records	Before processing	After processing
0000001	Bassam Al Shak'ah	791	69%	80%
0000003	Bir Zeit	750	70%	78%
0000004	Al Salam	1462	71%	79%
0000008	WBWD	964	71%	81%
0000011	Qibya	606	69%	78%
0241030	Kafr Qadum	1423	74%	86%
0241140	Hajja	1459	74%	91%
0241170	Burin	854	71%	79%
0241200	Jinsafut	1932	80%	87%
0241250	Azuun	1853	77%	83%
0241270	Awarta	1089	74%	81%
0241300	Deir Istya	1899	79%	85%
0241350	Aqraba	1396	74%	82%
0241400	Buiddya	1070	79%	83%
0241450	Salfit	1784	78%	85%
0241470	Qarut	1384	73%	84%
0241500	Deir Ghassaneh	673	73%	79%
0241550	Sinjil	321	72%	87%
0241599	Rantis	368	66%	79%
0241630	Attarah	1421	69%	81%
0241650	Al Mizra'ah Al Sharqiya	958	71%	82%
0241900	Al Mizra'ah Al Qibliya	531	67%	78%
0242151	Saffa	672	72%	79%
0242230	Al Hashimiya	1074	73%	81%
0242400	Beitunya	959	65%	73%
0242935	Al Malik Ghazi	743	70%	76%
Averages		**28436**	**73%**	**82%**

4.4.2 Screening of Monthly Rainfall Records

The monthly rainfall totals were determined from the processed daily rainfall data and from those stations have records on only monthly bases. The results show that the rainfall often starts in October and ends in May which express the wet season, while the other months from June to September express the dry season.

The methods used for monthly rainfall records were time series, spatial homogeneity, UK meteorological office program, tabular comparison and double mass curve. The principles of the first three methods were explained in screening of the daily data, and only the double mass analysis and Uk meteorological office methods will be explained in the following paragraphs:

i. Double Mass Analysis

The principle of the double mass analysis is to plot the accumulated values of the base station against accumulated values of another adjacent station, or the average of the surrounding stations over the same period of time (Chow etal, 1988).

Accumulated monthly values of the base station and the average of surrounding station as defined in Table 4.2 were used. Figure 4.6 shows comparison between the base station (Hajja) and the average of surrounding stations (Kafr Qadum and Jinsafut).

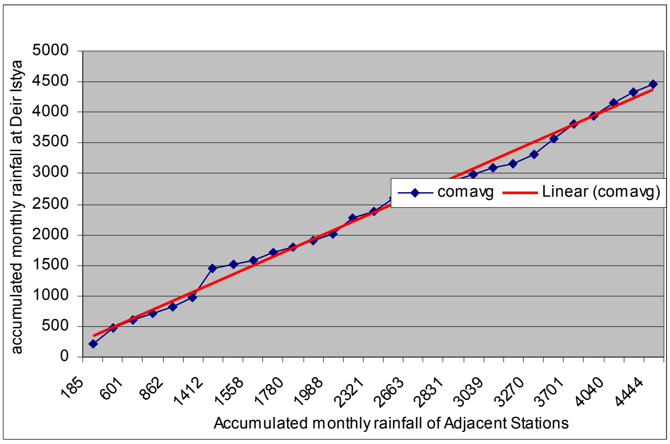


Figure 4.6: Double Mass Analysis for Hajja stations in January

Another Way to look at results of the double mass curve of the data can be interpreted through plotting the residual mass curve. It is defined as a curve of accumulative departures from the mean. When comparing two stations x and Y the residual mass is defined using the following procedure (De Latt,1999b)

$$\text{Mi} = \sum_{1}^{i} Yj - \frac{\sum Y}{\sum X} \cdot \sum_{1}^{i} Xj \,, \qquad 4.7$$

where:

Mi: Residual Mass in Year I of station Y

X_i : Monthly rainfall in year J of station X

Yj: Monthly rainfall in year J of station Y

$\sum X$: The accumulated rainfall of station X over the entired period.

$\sum Y$: The accumulated rainfall of station Y over the entired period.

I and j, …, n where in is the total number of years considered

If the second term on the right side of this Eq. 4.7 is plotted against the accumulative X values, an average linear relation is obtained. This linear relation is included in the graphs for January presented in Figure 4.6. the result is explained clearly in Figure 4.7 .The interpretation of the double mass curves can be explained as follows:

- An upward deviation from the average straight line (the red bold line in Figure 4.6) indicates relative high values of rainfall for the base station compared to the surrounding stations.
- A parallel line indicates a constant relation between the base station and the surrounding stations.
- A downward deviation from the average straight line indicates relatively low values for the base station compared to the surrounding stations.

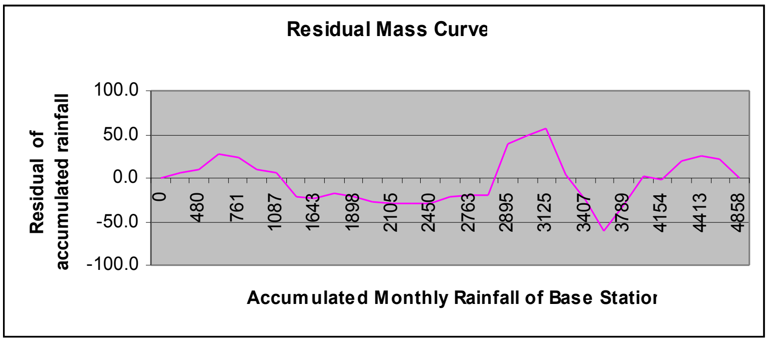


Figure 4.7: Residual mass Curve for Hajja stations in January

From Figure 4.7, through comparing Hajja station with the surrounding stations, it can be deduced the rainfall data of Hajja station do not deviate considerably from the expected average data expressed by Eq. 4.7. this mean that the observed data for hajja station in January indicates some low values and some high values compared to surrounding stations but relatively accepted.

Through applying double mass curve, and reviewing those data outside the limits, the following concluded:

- a lot of missing data that make the total monthly is so small compared to estimated values.
- Sometimes, several months recorded as one value especially in years 1989, 1990 and 1991 when the schools were closed by the Israeli army.

ii. **UK Meteorological Office (Monthly Data)**

The principle of this method is similar to daily data but using different equations in calculations:

a. Monthly totals are checked by obtaining their percentage of the station average annual rainfalls (M_p) and comparing them with surrounding stations (means percentage (M_m) and the standard deviation (S_m).

The monthly totals are unacceptable if the control factors lies outside designated limits:

$+1.5 < M_p\text{-}M_m/S_m < -1.5$ 4.8

if S_m is small, a further check excludes data when:

$0.85 >= M_p/M_m >= 1.15$ 4.9

Table 4.7 shows an example of screening the daily data using Uk Meteorological Office. Those records marked in red do not satisfy equations 4.8 and 4.9 used as an indicator to check the reliability of the observed data in the base station compared to surrounding stations.

Table 4.7: Screening of Monthly Rainfall Using Meteorological Office Procedure

Mont/Year	Jinsafut Station	mp	Kafr Qadum	Hajja	Azzun	Deir Istya	avg	mm	mp-mm	result	mp/mm
10/1996	**60.5**	**6.9**	**53.3**	**43.0**	**44.2**	**0.0**	**35.1**	**4.3**	**2.6**	**0.2**	**1.60**
11/1996	18.6	2.1	12.6	20.4	27.1	4.5	16.2	2.0	0.1	0.0	1.07
12/1996	**104.8**	**11.9**	**72.0**	**74.6**	**88.4**	**53.0**	**72.0**	**8.8**	**3.1**	**0.3**	**1.35**
1/1997	204.2	23.1	175.8	172.2	183.9	132.0	166.0	20.2	2.9	0.2	1.14
2/1997	249.4	28.2	264.9	230.8	274.7	251.0	255.4	31.1	-2.9	-0.2	0.91
3/1997	209.3	23.7	234.1	251.3	208.3	242.5	234.1	28.5	-4.8	-0.4	0.85
4/1997	**6.9**	**0.8**	**19.4**	**16.8**	**16.2**	**33.0**	**21.3**	**2.6**	**-1.8**	**-0.1**	**0.30**
5/1997	**29.2**	**3.3**	**41.9**	**28.5**	**14.0**	**0.0**	**21.1**	**2.6**	**0.7**	**0.1**	**1.29**

Through applying double mass curve and UK meteorological office monthly, and reviewing those data outside the limits, the following concluded:

A lot of missing data that make the total monthly is so small compared to estimated values.

- Sometimes, several months recorded as one value especially in years 1989 and 1990 when the schools were closed by the Israeli army.

3.4.3 Screening of Yearly Data.

The annual rainfall totals were determined from the processed monthly rainfall data and from those stations have records registered on only annual bases. The calculation of the annual data was calculated as a hydrological year which starts at October of a specific year (first month of the wet season) and ends at September of the next year (last month of the dry season). The annual rainfall for each station tends to vary from year to year, but does not deviate greatly from the mean value where the data fluctuated it except for few years like 1992, where it was heavy rainfall exceeded approximately two times the mean.

The methods used in annual data screening are t-test to check the stability of the mean, f-test to check the stability of the variance, and trend. The main aim of applying these methods is to inconsistencies and non-homogeneities of time series data. Inconsistencies result from changes in the amount of systematic errors that arising from change in instrumentation or observational practices. Non-homogeneity is defined as a change in the statistics of the data which caused by natural human affects like change in water use, land use, climate change, etc.

i. **Student's t-test for Stability of the Mean.**

The total annual data was checked for the stability of the mean which gives and indication about the characteristics of the time series through dividing the time series into two equal halves and comparing the significant difference between the mean of the first half of the series with the second half. The following equation was applied to calculate t (De Laat, 1999a).

$$t = \frac{x1 - x2}{\left\{(n1-1)S1^2 + (n2-1)S2^2\left\{\frac{1}{n1} + \frac{1}{n2}\right\}\right\}} \qquad 4.10$$

Where

$n1$ is the number of data in the subset

x1 is the mean of subset i

S1 is the variance of subset i

The mean of the time series is stable if

$$\{-\infty, t(v, 2.5\%) \square \{t(v, 97.5\%)\}, +\infty\} \qquad 4.11$$

where, v is the number of degrees of freedom, v = n1+n2 -2

the result are shown in the Table 4.5 which indicates that the time series data in all station are stable around the mean.

ii. **f-test for the Stability of the Variance**

This method is used to investigate the stability of the variance of two non-overlapping subsets of series. the idea of this test is similar to T-test by dividing the time series data into two equal halves and comparing the significant difference between the variance of the two halves. The distribution of the variance ratio is known as Fisher Distribution. Number of records should be at least 20 years to apply the test in the following equation

$$Ft = \frac{s1^2}{s2^2} \qquad 4.12$$

Where

Ft is the test value

$S1^2$ and $S2^2$ are the variance of the first and second halves of the time series respectively.

The variance is stable if

$$f\{v1, v2, 2.5\%\} < ft < f\{v1, v2, 97.5\%\}$$

4.13

The results are shown in table 4.5 which indicates that in all stations, the variance is stable.

iii. **Trend Analysis (Spearman's Rank Correlation Method)**

The aim of this test is to identify the presence of a trend in a time series. The trend in the series assumed if there is no obvious shift in the sample mean over a period of records. To apply this test the following procedure was carried out for each station as the following:

1. the data(observed) was ranked in ascending order by the year, and then kx is determined.
2. the data for each station was ranked in ascending order by value, then Ky is determined.
3. n (number of the samples) is then determined.
4. difference between Kx and Ky (Di) is determined.
5. the Speraman rank correlation coefficient (Rsp) is calculated

$$Rsp = 1 - \frac{6\sum Di^2}{n(n^2-1)} \qquad 4.14$$

6. the test statistics t is calculated

$$t = Rsp\sqrt{\frac{n-2}{1-R^2_{sp}}} \qquad 4.15$$

the time series has no trend for v = n-2 and significance of 5 percent if

$$t\{v,2.5\%\} \le t \le t\{v,97.5\%\} \qquad 4.16$$

The results shown in table 4.8 indicate no evidence of trend in time series data.

Based on the results of yearly data screening for all station in the study area, which is shown it Table 4.8, the time series has no trend that causes inconsistencies. The variance and the mean for all stations are stable, the data series is stationary (not a function of time or the length of records), which means that the statistical theories can be applied.

Table 4.8: Annual Data Screening by Using trend, t-test, and f-test

Station ID	Trend			t-test			f-test	
	pearson correlation	t stat	t c(+-)	rsp	t	tcr(+-)	f	F critical
0241300	-0.2145	-0.3293	2.1448	-0.0118	-0.0624	2.12	0.5208	0.1173
0241630	-0.2593	0.3967	2.1448	-0.1657	-0.8893	2.13	0.5198	0.1166
0000008	-0.1609	-1.2389	2.1448	0.2067	1.1177	2.14	0.3258	0.0221
0242935	-0.1035	-0.0273	2.1448	-0.1715	-0.9213	2.15	0.3585	0.0324
0242400	-0.0950	-0.1910	2.1448	-0.0536	-0.2841	2.16	0.3887	0.0440
0242230	-0.1802	-0.1348	2.1448	-0.0852	-0.4525	2.17	0.2989	0.0155
0242151	-0.2289	-0.5337	2.1448	0.0705	0.3741	2.18	0.3402	0.0264
0241900	-0.2146.	0.3243	2.1448	-0.1150	-0.6127	2.19	0.4841	0.0935
0241650	-0.2119	-0.1383	2.1448	-0.0389	-0.2062	2.20	0.5516	0.1389
0241599	-0.2777	-0.6523	2.1448	0.0710	0.4384	2.21	0.2334	0.0051
0241550	-0.0484	-0.4113	2.1448	-0.1631	-0.8746	2.22	0.9293	0.4464
0241500	-0.1118	-0.3859	2.1448	-0.2002	-0.0130	2.23	0.4506	0.0740
0241470	-0.2176	-1.1211	2.1448	0.1577	0.8452	2.24	0.5022	0.1050
0241450	-0.15061	0.1971	2.1448	-0.1449	-0.7749	2.25	0.5717	0.1536
0241400	-0.1953	-0.2025	2.1448	-0.0051	-0.0271	2.26	0.4765	0.0889
0241350	-0.1961	0.6417	2.1448	0.0492	0.2605	2.27	0.5138	0.1126
0241270	0.0860	0.7508	2.1448	0.1061	0.5647	2.28	0.5863	0.1647
0241250	-0.2291	-1.1494	2.1448	0.2089	1.1303	2.29	0.3642	0.0344
0241200	-0.0853	-0.8596	2.1448	0.1760	1.0258	2.30	0.4301	0.0632
0241170	0.1024	-0.6931	2.1448	0.1057	0.5623	2.31	0.6388	0.2060
0241140	-0.1063	-0.7639	2.1448	0.0794	0.4216	2.32	0.3205	0.0207
0241030	-0.0681	-0.3699	2.1448	0.1012	0.5384	2.33	0.3487	0.0291
0000011	-0.2471	-0.5230	2.1448	0.0638	0.3385	2.34	0.3238	0.0216
0000004	-0.0926	-0.7704	2.1448	0.0923	0.4906	2.35	0.2725	0.0103
0000003	-0.1518	-0.1742	2.1448	-0.0661	-0.3504	2.36	0.5360	0.1277
0000001	-0.0863	-0.3493	2.1448	0.0228	0.1472	2.37	0.3939	0.0465

4.6 Data Completion and Estimation.

As mentioned before, and as noticed from the tests used to screen the data on daily and monthly basis, there are a lot of records were failed to achieve any of tests used. This was expected result because the poor quality of the recorded data. The reasons were mentioned in the last section about the quality of the recorded data like inconsistency of recording and missing data.

In order to make the necessary analysis of the data, those marked records must be deleted and replaced by estimated values. One of the most popular methods is linear regression.

4.6.1 Data Completion through Spatial Homogeneity on Daily Basis.

For all recorded daily data, the spatial homogeneity test was applied. Comparing the recorded values and estimated values, there were sometimes a huge difference exceeds 20 times or less by 10 times was obtained. This is due to also to poor quality of recording daily data, where it was very difficult to distinguish between missing and accumulated data. The results also checked when aggregating the data to annual totals, the estimated values always is greater than the registered values, and sometimes the estimated is 1.5 times the registered. So that data estimation on daily basis will not give good results for the reasons mentioned before and also for the big variance among the daily rainfall.

4.6.2 Data Completion through Linear Regression on Monthly Basis.

Spatial homogeneity test was applies on monthly totals. Those records of suspicious or missing values were firstly cancelled. Through comparing the estimated values with actual recorded values, often there were good correlations (p2 > 0.7) which are statistically accepted. The estimated values from spatial homogeneity test and actual values aggregated from daily data are used to find the mathematical relation between the base station and the surrounding station. This is known as linear regression model of the form:

$$Y = b + aX \qquad 4.17$$

Y: series of monthly values of base station (dependent variable).

X: average y values of surrounding stations (independent variable).

a: the equation's coefficient.

b: the equation constant for rainfall equal Zero.

Also, the simplest method of analyzing the relationship of two variables is the correlation analysis. Correlation is defined as the association of two variables. The correlation coefficient R, is used to explain the degree of this association as a linear dependence. There are several types of correlation coefficients used in statistics. The most commonly used correlation coefficient, R, is defined between two variables x and y(Zhou,1996) as:

$$R = \frac{\sum_{j=1}^{n}\left(x_j - \bar{x}\right)\left(y_j - \bar{y}\right)}{\sqrt{\sum_{j=1}^{n}\left(x_j - \bar{x}\right)^2}\sqrt{\sum_{j=1}^{n}\left(y_j - \bar{y}\right)^2}} \qquad 4.18$$

where, n is the total number of observations, xj and yj are j'th observation of variables x and y, x, y are mean values of variable x and y.

The value of correlation coefficient ranges from -1 to +1. When the correlation coefficient is larger than zero, two variables are said to be positively correlated, and negatively correlated if the correlation coefficient is smaller than zero, and no correlation if R equal zero.

The correlation coefficient is actually a measure of how close the cloud of points lies near a straight line on a scatterplot. When correlation coefficient equals -1 or +1, the scatter plot of (x,y) will be straight line with a positive or negative slope. The correlation between two variable is said to be perfect as the coefficient closes to absolute 1.

Through applying the single linear regression represented in Equation 4.17, and using the data in Table 4.2, and monthly data, the equations used in estimation are summarized in Table 4.9.

Table 4.9: Data Completion Using Linear Regression

Base Station (Y)	Equation	ρ^2	Surrounding Stations (X)
Bassam al Shak'ah	Y=1.00X	0.94	,Aqraba, 'Awarta
Bir Zeit	Y=0.98X	0.95	'Attarah, Al Mazra'a ash Sharqiya, Al Mazra'a al Qibliya
Qalqilya	Y =0.99X	0.92	'Azzun, Kafr Zeibad

Base Station (Y)	Equation	ρ^2	Surrounding Stations (X)
Jinsafut	Y=1.02X	0.97	Qafr Qadum,Deir Istya,Azzun,Hajja
Azzun	Y=0.94X	0.93	Qalqilya,Jinsafut,Deir Istya, Biddya
'Awarta	Y=1.01X	0.93	Bassam AlShak'ah, 'Aqraba,Burin
Deir Istiya	Y=0.99X	0.97	Jinsafut, Azzun, Biddya, Salfit
Biddya	Y=1.0X	0.97	Deir Istya, Salfit, Azzun, Deir Ghassaneh
Salfit	Y=1.01X	0.96	Biddya, Deir Istya, Qaryut, Deir Ghasaneh
Deir Ghasaneh	Y=0.99X	0.93	Salfit, Biddya, Qibya
Sinjil	Y=0.97X	0.97	'Attarah, Qaryut, Al Mazra'a ash Sharqiya
'Atara	Y=0.99X	0.95	WBWD, Sinjil, BirZeit
Al Mazra'a ash Sharqiya	Y=1.01X	0.94	Qarut, Sinjil, Deir Dibwan
Al Mazra'a al Qibliya	Y=0.97X	0.94	Saffa, Qibya
Saffa	Y=0.99X	0.94	Qibya, Al Mazra'a al Qibliya
Beituniya	Y=0.94	0.93	WBWD, AlMalek Ghazi, Al Hashimiya
Al Malek Ghazi	Y=1.01X	0.93	Beituniya, Al Hashimiya
Qibya	Y=0.96	0.91	Saffa, Al Mazra'a al Qibliya, Deir Ghasaneh
WBWD	Y=0.94X	0.57	Beituniya, Al Hashimiya, 'Attara
Hajja	Y=0.98X	0.95	Kafr Qadum,Jinsafut
Qaryut	Y=0.98	0.94	Salfit, Sinjil, 'Aqraba, Al Mazra'a ash Sharqiya

In Table 4.6, the coefficients of the equations range from 0.94 to 1.02, the correlation coefficient (p^2) ranges from 0.91 to 0.97 (except in WBWD station). This means that the surrounding stations were selected correctly, and there is a strong relation with adjacent stations.

The completed monthly data are shown in Appendix B, where there are monthly data for 8 months in the year (October to May), the data was completed for 30 yea (1967/1968 to 1996/1997).

4.6: Discussion of Results.

The rainfall data was screened through applying different techniques for QA/QC. The missing data was estimated and completed through applying the linear regression method. Figure 4.7 compares between the recorded data and estimated data at Bir Zeit station, where the available data was only for 18 years while the completed and estimated data was for 30 years. The same procedure was applied for the 26 stations in the study area. Comparing the estimated data with the recorded data shows the importance of estimating and screening the data. To make the statistical analysis with incomplete data like summation, averages, and extremes give sometimes- especially in case of a lot of missing- unacceptable

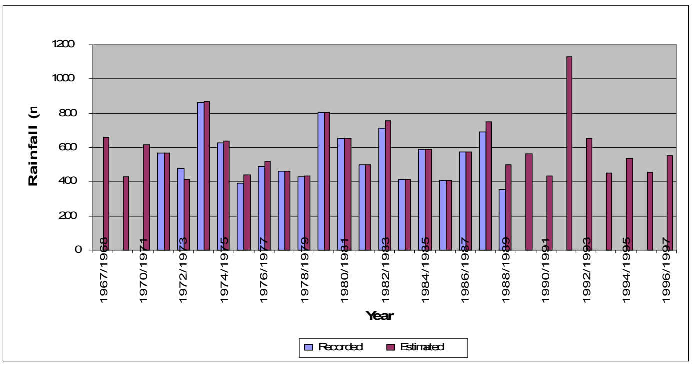


Figure 4.7: comparison between Recorded and Estimated Data (Bir Zeit Station)

results, while through using the estimated and completed data, it is acceptable to make all the statistical analysis.

CHAPTER 5

Monitoring Network Design and Rainfall Analysis

This chapter discusses and evaluates the existing network design, rainfall analysis on daily (extreme, depth and k-analysis), monthly (frequency and Seasonality) and yearly (Areal, Spatial and Temporal trend) basis.

5.1 Network Analysis.

The existing raingauges network consists of 21 manual daily raingauges located completely inside the catchment, while another 5 manual raingauges located around the boundary and contribute partially. Those gauges located inside the catchment were taken into consideration to evaluate the existing design from different aspects like instrumentations, spatial and temporal distribution.

5.1.1 Instrumentations.

The entire network is manual daily gauges with time measurements of at least 24-hours. There are no Autographic charts or tipping bucket instruments to measure the intensity on the real time scale like every 15 minutes or on hourly basis, which is the most important in engineering and hydraulic design. Also the gauges were installed before 40 years or more, some gauges stopped measurements due to lack of maintenance like destroying the gauges or tube breaking.

4.1.2 Spatial Distribution.

The total catchment area is about 1128 km^2 with 21 gauges, which mean a high density reaches to 54 km^2/station which is higher than the minimum density in the mountainous areas recommended by World Meteorologaical Organization which ranges from 100 to 250km^2 covered by 1 gauge. (Shaw, 1988).

5.1.2.1 Geographical Distribution

Despite the large number of gauges but it is not fairly distributed if the catchment is divided into areas of equal quadrant (10X10km), Figure 5.1 indicates that in some quadrants, there are 4 gauges, while there are no gauges in others.

5.1.2.2 Topographical Distribution

The existing network is not fairly distributed to cover the topographical variations within the catchment. If the topography is divided for equal intervals (Table 5.1), it indicates that the density rainges from 16 km^2 /station in the interval of contours (800-1000) to 116 km^2/station in the interval of contours less than 200m.

Table 5.1: Rainfall Stations Density by Topographic Zones.

Topo. Contour(m)	Area (km^2)	No. of stations	Density (km^2/station)
<200	116	1	116
200-400	416	7	59
400-600	308	4	77
600-800	257	7	37
800-1000	31	2	16
Total	**1128**	**21**	**54**

5.1.2.3 Geological and Outcrops Distribution.

The existing network does not cover fairly geological and outcrops of the catchment as shown in Table 5.3. The quaternary is not covered, while in the lower aquifer, the density is 71 km^2 per station.

Table 5.2: Rainfall Stations Density by Outcrop

Outcrops	Area (km^2)	No. of stations	Density (km^2/station)
Upper Aquifer	585	13	45
Lower Aquifer	427	6	71
Eocene	4	1	4
Quaternary	33	0	
Aquitard	77	1	77
Total	**1126**	**21**	**54**

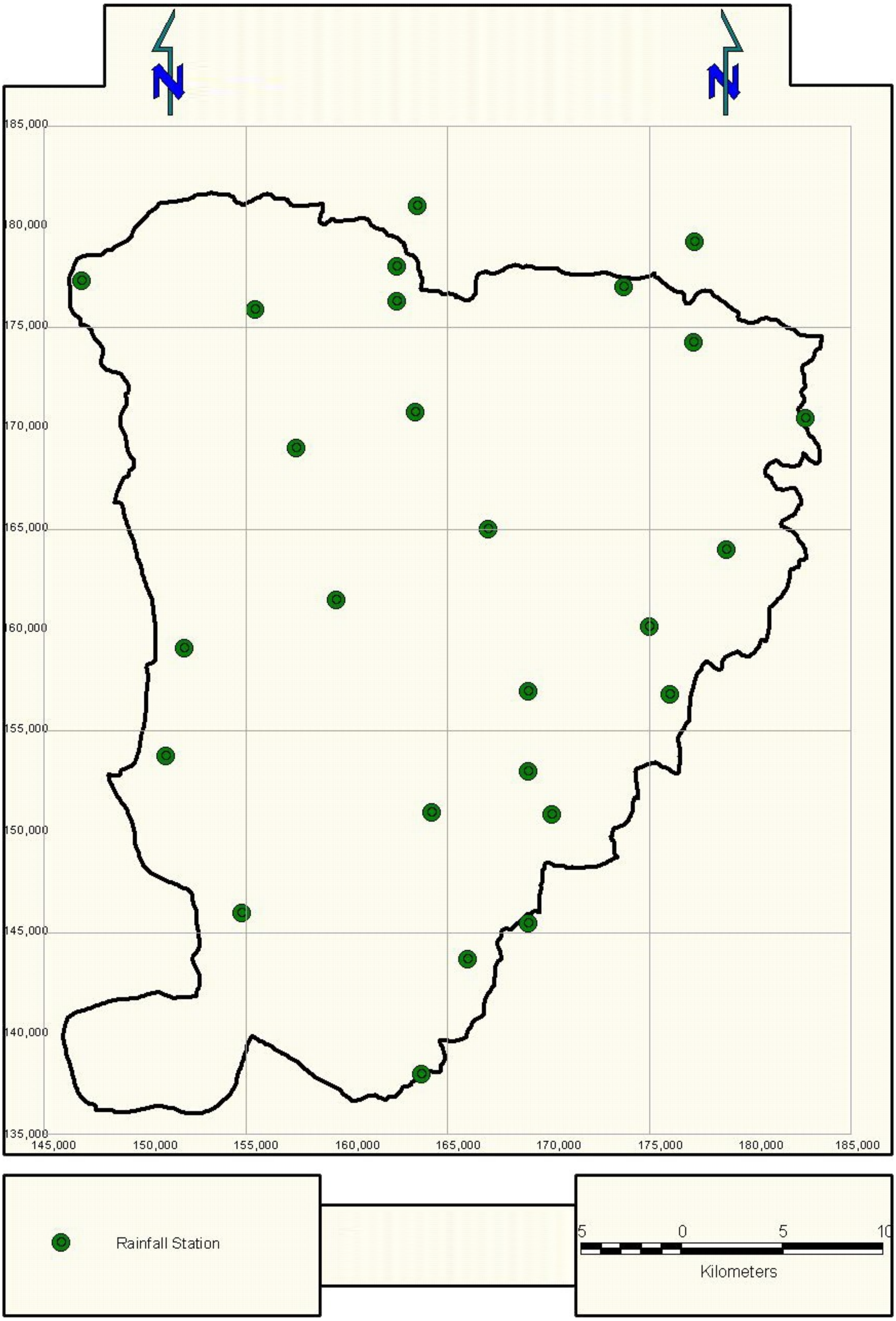


Figure 5.1: Geographical Distribution of Rainfall Network

5.1.2.4 Precipitation Zones Distribution.

The existing network does not cover fairly the different precipitation zones. If the catchment is divided into equal precipitation zones of 200mm intervals (Table 5.3), it is easy to reveal that the zone of 500-550 mm is not covered, while the zone of 550-600 mm has less density to reach 77 km^2 per gauge.

Table 5.3: Rainfall Stations Density by Precipitation Zone

Precipitation Zone (mm)	Area (km^2)	No. of stations	Density (km^2/station)
500-550	70	0	45
550-600	366	9	41
600-650	384	5	77
650-700	308	7	44
Total	**1128**	**21**	**54**

5.1.2.5 Distribution according to location above ground level

None of the existing gauges were located on the ground level as recommended by WMO. All stations located on the roof top of the schools with different levels ranges from 4 m to about 12 m above the ground level. As example WBWD station are located on the third floor of about 11 m from the ground level, while in Beitunya station, like most of the stations, it located on the roof top of the second floor of about 8 m above the ground level. This situation affect directly the measured quantities where the measurements decreases as the height above the ground level increases.

5.1.3 Time Coverage.

The existing gauges were installed in different periods some are since 50 years, some since less than 10 years, and some only for 1 year; so the time coverage is different. Also a lot of months and years are missing, so the available data is not always equal the period of installation, (Table 3.2) shows the availability of data and time coverage for each station.

5.1.4 Evaluation of the existing network.

The existing network does not satisfy the needs to conduct the hydrological and modeling studies in types of instruments, spatial distribution, and time coverage as the quality of the recorded data. So it is recommended to upgrade the network through installing new stations with different types to measure the intensity, distributed uniformly to cover the topographical, geographical, geological, and rainfall distribution. Also the system of measurements and recordings should be modified and documented.

5.2 Rainfall Analysis

The purpose of rainfall analysis is to present the data in such way that make it is easy for researchers to conduct the hydrological studies. Different types of rainfall analysis based on the screened data are presented in sections 5.2.1 to 5.2.7 .

5.2.1 Determination of Areal Rainfall

Areal Rainfall is to evaluate or estimate the quantity of water falling on the catchment. It is called sometimes the general or average rainfall over an area. This is expressed as a volume (m^3) for a specific time period, but more usually as an average depth (mm) over the catchment area.

The accuracy of estimation the areal rainfall depends on many factors:

- Design of the raingauges network, in general, the accuracy of the estimation will increase as the density of the gauging network increases.
- Number of measurements, it is the most important factor. To estimate the areal rainfall it is required to have a lot of historical measurements to assess the spatial variation.
- Type of topography and climate characteristics, errors will occur due to the random nature of storms and their paths relative to gauges.

The accuracy then depends on the spatial variability of precipitation, thus more gauges would be required in slopes.

- Total number of raingauges and their spatial distribution, raingauges may be sited within a classification of domain representing classes with different raingauges of geographical and topographical characteristics such as altitude, distance to the sea, ground slope and aspect. So the accuracy of areal rainfall estimation will increase as the total number of raingauges with good spatial distribution increase.

There are various methods to estimate the average areal precipitation over a catchment. Some of them are well known and were applied in this study

i. **Depth Method (The Arithmetic Mean).**

This is the simplest method of calculating the average rainfall over an area. The simultaneous measurements are summed for a specific period of time and divided by the number of gauges as the following equation

$$\sum_{i} \frac{Ri}{n} \qquad 5.1$$

Where Ri are the rainfall measurements, and n is number of stations

The arithmetic mean gives very satisfactory measure of areal rainfall under the following conditions:

a: the study area is sampled by uniformly spaced raingauges.

b: the study area of relatively uniform rain.

c: the study area has no marked diversity in surface characteristics, so the range in altitude is small and hence variation in rainfall amounts is minimal. So it is used mostly in monthly and annual rainfall totals, not for the small duration's events.

ii. The Thiessan Polygon

This method was derived by Thiessan, 1911. It is an objective method. The rainfall measurement is first weighted by the fraction of the area represented by the gauge. To determine the average areal rainfall, the rainfall amount in each station is multiplied by the area of its polygon and then the sum of the products is divided by the total area. The catchment area is divided into polygons with lines that are equidistant between pairs of adjacent stations including those just outside the area (Gold, 1989).

Thiessan polygon Middle of West Bank is shown in figure 5.2, for all stations that have at least 20 years of screened measurements.

The areal rainfall R is given by

$$\sum_{n} \frac{Riai}{A} \qquad 5.2$$

Where, Ri is the rainfall measurements at n raingauges and A is the total area of the catchment, ai is the area represented by station.

The coefficient ai / A is called the Thiessan coefficient once they have been determined for a stable raingauges network, the areal rainfall is quickly computed for any set of measurements.

The Thiessan method is adopted as a better method for calculating areal rainfall than the arithmetic mean because it allows for non-uniform distribution of gauges by assigning weights to the measured depths at each gauge according to the proportion of the catchment area that is nearest to the gauge. But this method is not particularly good for mountainous areas, since altitudinal effects are not allowed for by the areal coefficients, nor is it useful for deriving areal rainfall from the intense local storms.

iii. The Isohytal Method

This is considered to be the most accurate method, but it is subjective and dependent on the experience and skills of the analyst who should have a good knowledge of the rainfall characteristics of the region that containing the study area of the catchment.

Rainfall amounts for considered period of time are plotted on a map, and contours of equal precipitation depth (isohyets) are drawn as showed in Figure 5.3. the other isohytal maps are shown in Appendix C, where it represent the isohytal map for the average annual of all historical measurements in the Catchment. To determine the average areal rainfall, the average precipitations between the isohyets are multiplied by representing area, and then by dividing the sum of these products by the total area.

From table 5.4, it is noticed that the three methods have approximately the same results. This result was expected because of the following reasons:

- Small area
- Dense network ,
- Accuracy of the isohytal maps.

Thiessan method was used in areal rainfall calculation because of its simplicity, stability of the network, and the gradual changes in topography. Table 5.4 shows the annual average areal rainfall inn the catchment for the period 1967/1968 to 1996/1997 by the above three methods.

Table 5.4: Areal Rainfall by Different Methods

Period	Arithmetic Mean (mm)	Thiessan (mm)	Isohytal (mm)
1668/1977	597	609	593
1678/1987	588	599	589
1988/1997	647	645	644
1968/1997	611	609	623

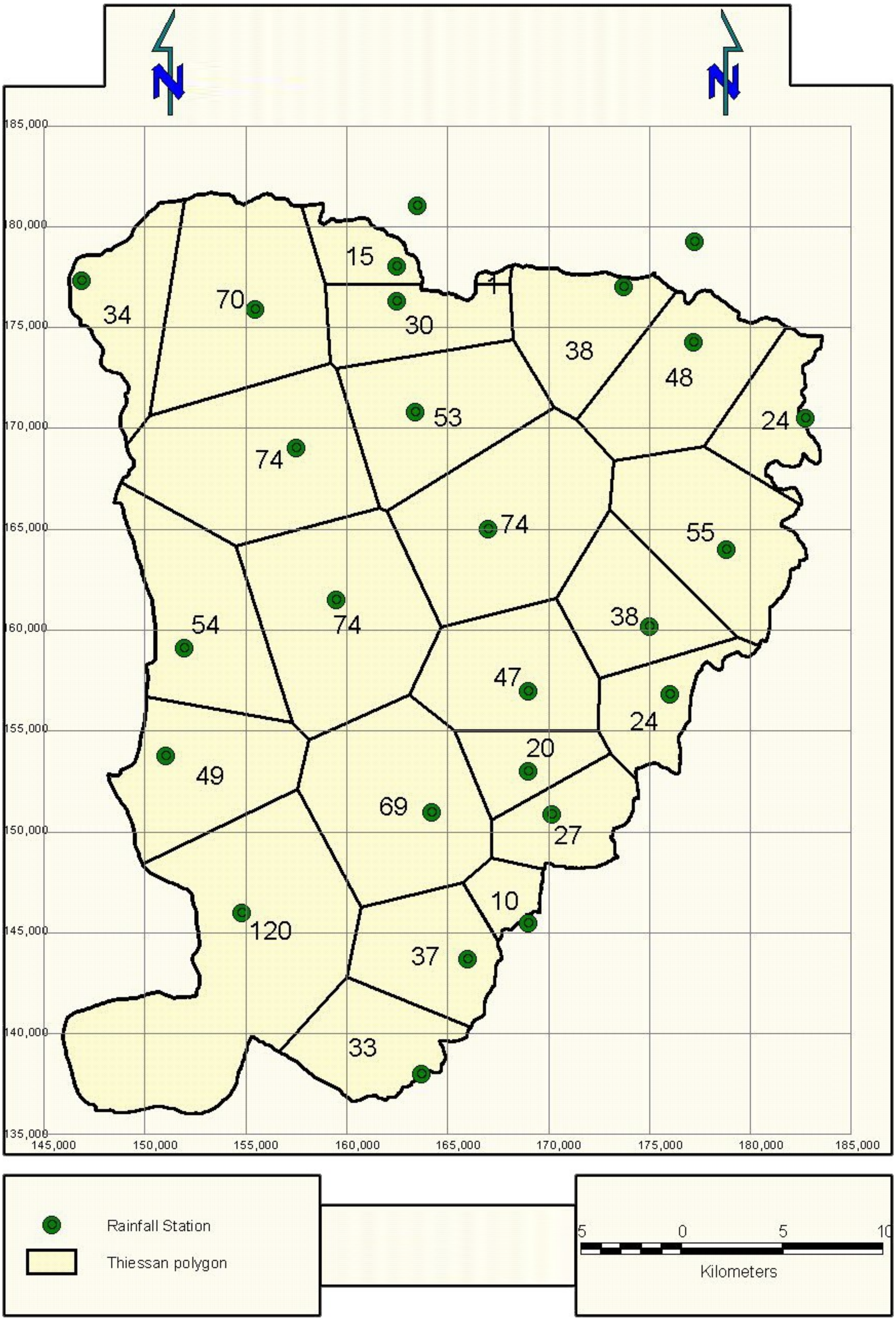


Figure 5.2: Thiessan Area Distribution in the Study Area

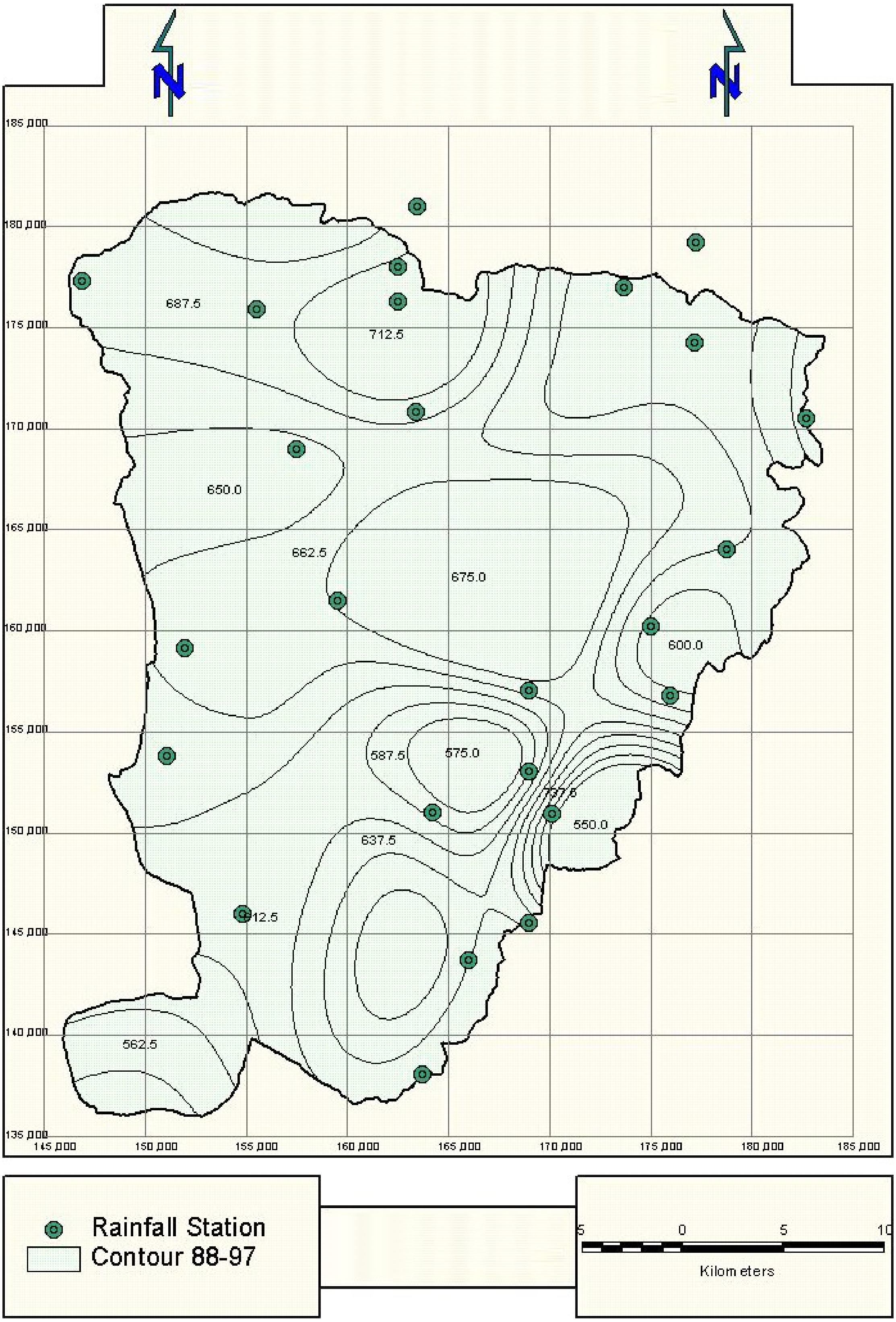


Figure 5.3: Isohytal Map of the Study Area (1988-1997)

4.2.2 Wet And Dry Days.

The wet day is considered to be one in which rainfall is equal to or greater than 0.5 mm, while the wet season is considered to start from first of October till end of May,. This means that the wet season is 243 days. Based on definition of wet day and wet season, the average number of wet and dry day is presented in Table 5.5. From table 5.5, the average of rainy days is 43 per year. The wet days in the year ranges from 35 days in al Mazra'ah al Al Qibliya to 49 days in Deir Istya. From this table, in general, the number of wet days decreases as going from north to south, where the least wet days located in Al Mazra'ah Al Qibliya, Saffa, Qibya. Also, the ratio of wet day to wet season ranges from 14.6% to 20.1% which mean that the storms occur intensively over short periods of time.

Table 5.5: Average Wet and Dry Days

Name	Wet Days	Dry Days	WD/DD	WD/WS
Bassam Al Shak'ah	42	323	12.8%	17.1%
Bir Zeit	41	324	12.5%	16.7%
Al Salam	45	320	14.1%	18.6%
Al Bira	46	319	14.5%	19.0%
Qibya	38	327	11.7%	15.7%
Kafr Qaddum	45	320	14.0%	18.4%
Hajja	46	319	14.4%	18.9%
Burin	42	323	13.0%	17.3%
Jinsafut	48	317	15.3%	19.9%
Azzun	47	318	14.9%	19.5%
'Awarta	47	318	14.7%	19.2%
Deir Istiya	49	316	15.4%	20.1%
Aqraba	46	319	14.3%	18.7%
Biddya	45	320	14.0%	18.4%
Salfit	47	318	14.9%	19.4%
Qaryut	46	319	14.5%	19.1%
Deir Ghassanah	40	325	12.3%	16.5%
Sinjil	38	327	11.5%	15.5%
Rantis	37	328	11.3%	15.2%
'Atara	45	320	14.1%	18.5%
Al Mazra'a ash Sharqiya	41	324	12.8%	17.1%
Al Mazra'a al Qibliya	35	330	10.7%	14.6%
Saffa	38	327	11.7%	15.7%
'Al Hashmiyyah School	47	318	14.7%	19.2%
Beituniya	43	322	13.3%	17.7%
Al Malek Ghazi	41	324	12.8%	17.0%
Average	**43**	**322**	**13.4%**	**17.7%**

5.2.3 Rainfall Depth.

After screening the daily data, removing the monthly and annual totals and estimation of the missing, it was easy to categorize the rainfall depth into groups according to rainfall depth. Table 5.6 shows those categories and number of records in each one. The total number of records is 32416, 18713 records (57.7%) have rainfall less than 10 mm/day , and 25523 records (78.7%) have rainfall less than 20 mm/day. While only 545 records (1.7%) have rainfall greater than 60 mm/day. These results mean that most of the rainfall in the study area occurs in light or flash storms (less than 20 mm/day) since the daily rainfall may represent one or more than one storm.

Table 5.6: Depth of Daily Rainfall (mm)

Station	<=10mm	10-20	20-40	40-60	60-80	80-100	>100 mm	Total
Bassam Al Shak'ah	555	182	130	37	9	1	3	917
Bir Zeit	500	177	109	29	7	0	1	823
Al Salam	991	338	223	59	21	7	2	1641
WBWD	664	201	183	62	19	6	5	1140
Al Hashmiyyah	620	247	183	50	12	4	2	1118
Al Qubeiba	482	208	129	57	12	2		890
Al Mazra'a ash Sharqiya	667	238	167	51	11	1	3	1138
Al Mazra'a al Qibliya	428	180	137	35	6	3		789
Aqraba	899	294	209	65	15	1	1	1484
'Atara	770	342	294	90	18	3	2	1519
'Awarta	718	219	153	38	19	1	2	1150
Azzun	1128	385	268	85	23	9	1	1899
Beituniya	942	391	314	85	9	3	5	1749
Biddya	645	241	154	51	14	2	3	1110
Burin	631	194	115	33	8	1	1	983
Deir Ghassanah	383	159	134	33	11	2		722
Deir Istiya	1181	389	273	89	26	5	3	1966
Hajja	844	334	249	72	27	6	2	1534
Jinsafut	1139	427	298	93	34	9	2	2002
Kafr Qaddum	906	332	222	64	22	8	3	1557
Qaryut	1135	363	278	71	12	5	1	1865
Qibya	360	177	115	38	10	4	1	705

Station	<=10mm	10-20	20-40	40-60	60-80	80-100	>100 mm	Total
Rantis	212	96	62	11	9	3	1	394
Saffa	482	208	129	44	9	2	1	875
Salfit	1221	429	302	119	30	10	3	2114
Sinjil	210	59	43	14	4	1	1	332
Totals	**18713**	**6810**	**4873**	**1475**	**397**	**99**	**49**	**32416**

5.2.4 Frequency Analysis of Extremes and Exceedence

Hydrologic systems are usually impacted by extreme events such as severe storms, flood and drought. The magnitude of an extreme is inversely related to its frequency of occurrence, very severe events less frequently than more moderate events.

The objective of frequency analysis of rainfall data is to relate the magnitude of extreme events to their frequency of occurrence through use of the probability distributions. The data is assumed to be independent and identically distributed, the hydrologic system is considered to be stochastic, space and time independent. The data should be carefully selected to satisfy the conditions. This is often achieved by selecting the annual maximum of variable (rainfall) analyzed.

All the screened available data will be used to determine the maximum recorded daily rainfall. The results are presented in table 5.7, which shows the maximum records of the average daily rainfall in the catchment. Analyzing the maximums records in the catchment presented in table 5.8 shows the maximum value of rainfall in the catchment was 142 mm and recorded in WBWD station at 10/12/1980.there are 28 extremes occurred in 7 dates, 13 of them measured at 28/11/1979, 7 of them measured at 15/12/1992, and 4 of them measured at 10/12/1980. These results prove that most of stations in the catchment are affected by the same storm. It is noticeable also that most of the extremes occurred in the second decade, despite it is the lowest annual average rainfall; this

Table 5.7 The Maximum Average Daily Extremes Recorded in the Catchment

Average Rainfall (mm)	Date	Decade
112	11/28/1979	Second
93.6	12/15/1992	Third
85.9	4/12/1971	First
83.2	12/10/1980	Second
73.2	11/8/1986	Second
70.9	02/24/1992	Third

indicates increase in the intensities and decrease in total amounts of rainfall.

The maximum daily extreme rainfall events are available for all stations with at least 20 years of records. In this study, the following two methods were used in the analysis.

Table 5.8 : Maximum Daily Extremes Recorded in Each Station

Station Name	Max.(mm)	Date	Decade
WBWD/ Al Bireh	142	10/12/1980	Second
'Atara	141.1	28/11/1979	Second
Salfit	138	15/12/1992	Third
Bir Zeit	135	28/11/1979	Second
'Al Hashmiyyah School	135	28/11/1979	Second
Aqraba	132	15/12/1992	Third
Qibya	127.5	15/12/1992	Third
Bassam Al Shak'ah	124 124	12/15/1992, 28/11/1979	Third Second
Jinsafut	123	28/11/1979	Second
Sinjil	120	10/12/1980	Second
Saffa	120	28/11/1979	Second
Beituniya	120	28/11/1979	Second
'Awarta	118	28/11/1979	Second
Hajja	117.5	28/11/1979	Second
Al Salam	116	24/2/1992	Second
Qaryut	115	15/12/1992	Third
Deir Istiya	112	15/12/1992	Third
Biddya	112	28/11/1979	Second
Rantis	110	28/11/1979	Second
Al Mazra'a ash Sharqiya	106.3	10/12/1980	Second
Burin	105	15/12/1992	Third
Azzun	99.6	22/2/1997	Second
Al Malek Ghazi	97 97	10/12/1980, 28/11/1979	Second Second
Deir Ghassanah	96.5	8/11/1986	Second
Al Mazra'a al Qibliya	87	2/12/1978	Second

- **Analysis of Extremes (Annual Series).**

This method was first developed by Gumbel, 1941. the method has been used successfully in many hydrological events. The fundamental theorem was applied according to the following steps :(De Laat,1999B

If X1, X2, X3, ….XN are independent extreme values observed in N samples of equal size n (e.g years), and if X is unlimited exponentially-distributed variable, then as n and N approach infinity, the commutative probability q that any of the extremes will be less than a given value Xi is given by:

$$q = \exp(-\exp(-y)) \qquad 5.3$$

where q is the probability of non excedence, y is the reduced variate.

If the total probability equal one, then the probabilitity of exceedence(p) for X I is

$$P = 1-q \qquad 5.4$$

Then equation 4.3 can be written as

$$y = -\ln(-\ln(1-p)) \qquad 5.5$$

if T is the return period measured in sample n, then

$$T = 1/p \qquad 5.6$$

So equation 4.5 can be written as

$$y = -\ln(-\ln(1-1/T)) \qquad 5.7$$

since the theory is based on best fit, then Gumbel assumes there is a linear relation between X and y

$$y = aX+b \qquad 5.8$$

where a is the dispersion, and y is the mode.

For finite series of N observations, a and b can be computed

$$a = \frac{\sigma}{S_{ext}} \qquad 5.9$$

$$b= X_{ext}- S_{ex} \frac{y_n}{\sigma} \qquad 5.10$$

where X_{ext} is the mean of X, S_{ext} is the standard deviation of the sample. y_n (the mean of reduced variate y, σ_N (the standard deviation of the reduced variate are tabulated as a function of observations (N). equation 4.8 is thus modified to

$$X = Xext + \frac{S_{ex}}{\sigma_N}(y - y_{N)}) \qquad 5.11$$

Equation 5.11 yields a straight line since it is modified from the linear relation in 5.8. To plot the data points on the horizontal axis a (called plotting position or estimator) of the probability of non exceedence q is required. There are several formulas used as plotting position, the most famous formulas are

Weilbull formula (Shaw, 1998)

$$q = 1 - p = 1 - \frac{m}{N+1} \qquad 5.12$$

where m is the rank number of the maximum occurrences in decreasing order and N is the total number of years of observations. It is more widely used; it is easier to be calculated. But it is not a good estimator when N is not large.

So another suitable formula for analysis will be used. This formula is known as Gringorten Formula (shaw,1988)

$$P(X) = \frac{r - 0.44}{n + 0.12} \qquad 5.13$$

Where p(x) is the probability of exceedence, r is the rank number, n is the total number of recorded years (r is m, n is N in equation 5.12).

In this study, Gringorten Formula (Eq. 5.13) is used since N is not large (24 years in the example) which mean that m/N is not good estimator.

All the annual maximum daily rainfall were determined for all stations, and ranked in descending order. Gumbel distribution was applied to all stations in the study area, Table 5.9 shows an example of WBWD station, where there are 24 of years available, where Xext is the recorded extreme, X-Gumbel is the calculated extreme using Annual series Analysis, Xexc is the Gumbel extreme using Partial Series Analysis.

Table 5.9 Annual and partial Series Analysis

Xext	Rank	p(x)	f(x)	T	y	logT	y	X-gumbel	Xexc
142.0	1	0.02	1.0	43.1	3.8	1.6	3.75	147.1	142
113.8	2	0.06	0.9	15.5	2.7	1.2	2.71	123.8	113.8
102.7	3	0.11	0.9	9.4	2.2	1.0	2.19	112.3	113.6
101.4	4	0.15	0.9	6.8	1.8	0.8	1.83	104.4	102.7
96.8	5	0.19	0.8	5.3	1.6	0.7	1.56	98.3	101.4
92.0	6	0.23	0.8	4.3	1.3	0.6	1.34	93.3	99
87.0	7	0.27	0.7	3.7	1.1	0.6	1.15	89.1	96.8
82.0	8	0.31	0.7	3.2	1.0	0.5	0.98	85.3	92
79.1	9	0.35	0.6	2.8	0.8	0.4	0.82	81.9	87
78.5	10	0.40	0.6	2.5	0.7	0.4	0.68	78.7	82
74.9	11	0.44	0.6	2.3	0.6	0.4	0.55	75.8	81.5
73.1	12	0.48	0.5	2.1	0.4	0.3	0.43	73.0	79.1
69.3	13	0.52	0.5	1.9	0.3	0.3	0.31	70.3	79
66.2	14	0.56	0.4	1.8	0.2	0.3	0.19	67.7	78.5
66.0	15	0.60	0.4	1.7	0.1	0.2	0.08	65.2	74.9
65.7	16	0.65	0.4	1.6	0.0	0.2	-0.04	62.7	73.1
62.4	17	0.69	0.3	1.5	-0.1	0.2	-0.15	60.2	72.6
59.5	18	0.73	0.3	1.4	-0.3	0.1	-0.26	57.6	72.3
55.0	19	0.77	0.2	1.3	-0.4	0.1	-0.38	54.9	70.7
54.6	20	0.81	0.2	1.2	-0.5	0.1	-0.51	52.1	69.3
54.0	21	0.85	0.1	1.2	-0.6	0.1	-0.65	49.0	66.2
53.0	22	0.89	0.1	1.1	-0.8	0.0	-0.81	45.5	66
43.1	23	0.94	0.1	1.1	-1.0	0.0	-1.01	41.0	65.7
34.8	24	0.98	0.0	1.0	-1.3	0.0	-1.33	33.9	65.5

- **Analysis of Exceedences (partial duration series)**

This method is different from the first one. This method taking all values, exceeding certain value of daily rainfall occurring, regardless the number of occurances in the year. Since this method is independent from the year of occurring (may two or more maximum in the same year) so it is more accurate where all maximum are included. There is greater risk that the extremes values are independent from each other. To apply this in the same example of annual series, the maximum 24 records for WBWD station (the same number of N) are added to table 4.7 in the last column under the title Xexc. Extreme and exceedence in addition to Gumbel extreme are all plotted in the same graph (Fig 5.4)

Since the values of Xexc are the largest records regardless the year of occurrence, so it is always found that Xexc/Xext is greater than 1 and approximately approaches 1 for larger return period. There is a relation exists between the previous two methods as shown by Langbein (De Laat, 1999a)

$$1/T = 1\text{-}\exp^{(1/Tp)} \qquad 5.14$$

where T is the retutn period of annual extremes, and Tp is return period of exceedences.

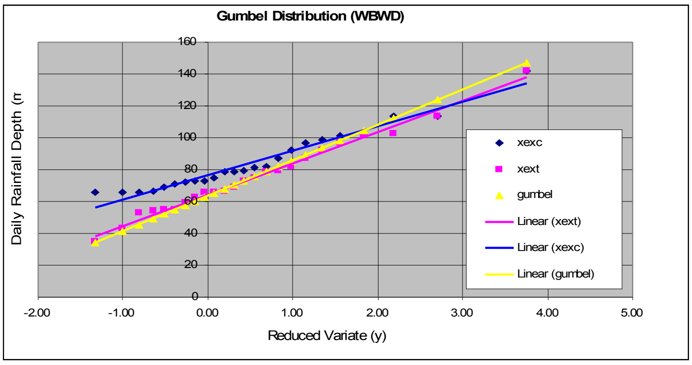


Figure 5.4: Extremes analysis comparing full and Partial extremes with Measured data.

In order to check weather Gumbel distribution fits the measured data or not, the square value of the correlation coefficient (p^2) is determined. for this station, p^2 is equal to 0.99 which is close to 1. this mean that Gumbel distribution shows good fits. Another test was used to check the fitness, which is the Exponential Distribution Function according to the following equation:

$$X = a_e \exp(b_e(F(x))) \qquad 5.15$$

Where a is the equation coefficient, b is the intercept. a and b can be found from the from fitting Xext values against F(X) values using exponential trend. For the same station using Microsoft Excel, the square of the correlation factor computed to be 0.94. The test was applied also for all stations, the values were tabulated in table 5.10.

Table 5.10: Comparison between Gumbel and Exponential Distributions

Name	(p^2)Gumbel	(p^2)Exponential
Bassam Al Shak'ah	0.92	0.85
Bir Zeit	0.86	0.72
Al Salam	0.94	0.96
Al Bira	0.99	0.94
Qibya	0.98	0.94
Kafr Qaddum	0.99	0.90
Hajja	0.99	0.96
Burin	0.97	0.94
Jinsafut	0.99	0.94
Azzun	0.94	0.85
'Awarta	0.98	0.90
Deir Istiya	0.97	0.85
Aqraba	0.94	0.81
Biddya	0.95	0.92
Salfit	0.99	0.92
Qaryut	0.99	0.92
Deir Ghassanah	0.97	0.96
'Atara	0.94	0.83
Al Mazra'a ash Sharqiya	0.95	0.90
Al Mazra'a al Qibliya	0.96	0.96
Saffa	0.98	0.94
'Al Hashmiyyah School	0.97	0.90
Beituniya	0.96	0.88
Al Malek Ghazi	0.95	0.86

Comparing the results of both tests in Table 4.10 prove that both Gumbel and the exponential distributions show good fits, where the correlation coefficient (p^2) always greater than 0.8 in both of them, but Gumbel distribution is suitable to be used more than Exponential distribution since always p^2(Gumbel) is greater than p^2(Exponential).

5.2.5 K- Analysis of Rainfall Data.

This test is used for rainfall-runoff analysis. For the purposes of design, it is important to observe the amount of rainfall over several consequence days. K–days rainfall values refer to the sum of the rainfall over the previous k-days, including the days of observation. K can be any period, but often it is 1, 2 ,5, or 10 days.

In the study area, WBWD station will be analyzed as representative station for the whole catchment (no missing data). The analysis will be done for the whole period of measurements at this station (1974/1975-1996/1997). Number of occurrences of certain rainfall amounts within class limits (e.g rainfall is greater than 10mm (not including the upper class limit which equal to 20) are computed during one, two, five, and ten days as shown in Table 5.11.

Table 4.11 shows that 8401 records (23years*365.25 days) are greater than or equal to zero which are all days for the whole period of records. Also it is easy to determine that there is only 6 days grater than or equal to 100 mm, while there are any day greater than 150mm. But for k=2, there are 29 values exceeding 100 mm, and for k=5, there are 14 values exceeding 200mm, and for k=10, there are 4 values exceeding 300mm.

So it is clear that the skew is less when the (k) is taken longer as shown in Figure 5.5 which shows the frequency distribution for different (k).

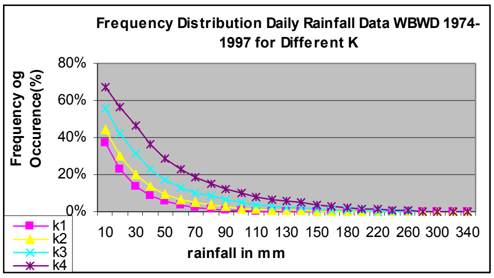


Figure 5.5: Frequency Distribution for different (K)

Table 5.11 Totals of K-day periods for k = 1,2,5 and 10 days.

Class Interval(mm)	K=1	K=2	K=5	K=10
0	8401	8400	8396	8391
0-10	435	775	1623	2625
10-20	267	521	1212	2187
20-30	156	349	920	1795
30-40	103	237	670	1426
40-50	66	165	494	1117
50-60	40	117	383	896
60-70	25	82	290	711
70-80	16	60	240	592
80-90	12	45	181	471
90-100	6	29	143	383
100-110	3	22	103	310
110-120	1	15	81	257
120-130	1	9	69	218
130-140	1	8	54	184
140-150	0	5	42	140
150-160	0	1	28	109
160-180	0	1	21	80
180-200	0	1	14	69
200-220	0	1	7	49
220-240	0	1	2	26
240-260			0	15
260-280				13
280-300				4
300-320				2
320-340				2

To derive Intensity- Duration-Frequency curves (IDF) by frequency analysis, it requires many records to yield reliable results, mostly more than 20 years. So the above station is useful to derive like IDF curves as the following procedure

1. From Table 4.10, the cumulative frequency curves for different durations (K=1,2,5 and 10) were plotted as in figure 5.6 .
2. From figure 5.6, with return period equal one year, it shows that for durations 1, 2, 5, and 10 days, the rainfall equal or exceeds (70, 110, 180, and 280 mm respectively). Those values are plotted in figure 5.7 to yield the Depth-Duration curve of

frequency one year (T=1). Similarly the curves for T=10 and the extrapolated curve T=100 are constructed.

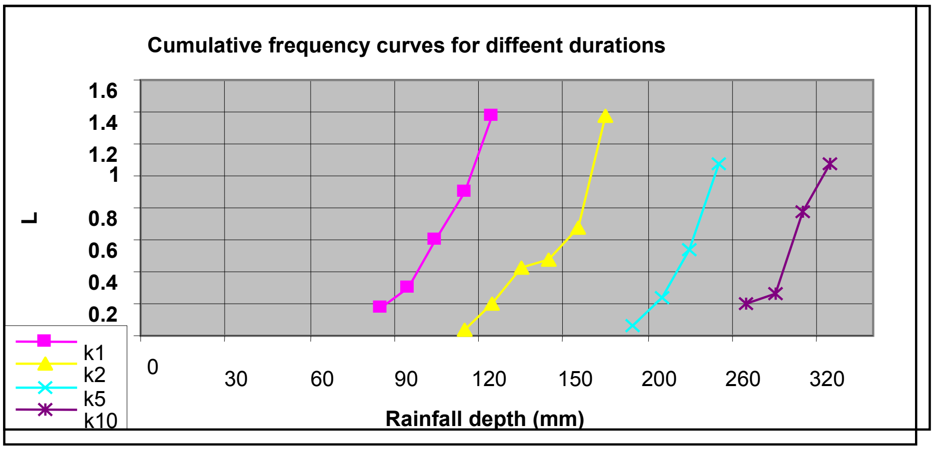
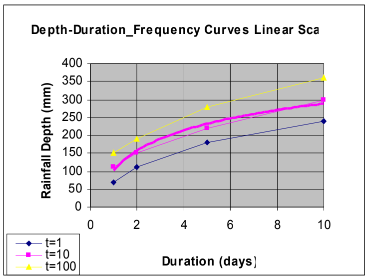


Figure 5.6: Cumulative Frequency Curves for Different Durations

Those values are plotted in double logarithmic paper to form approximately straight lines as shown in figure 5.8.



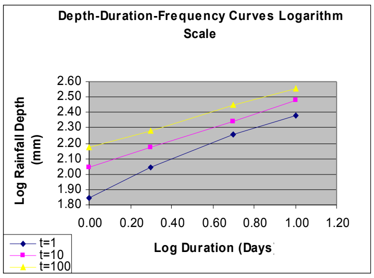
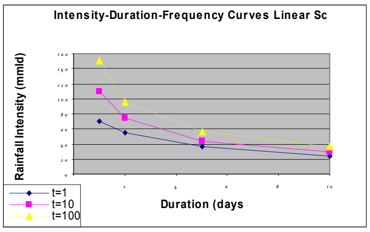


Figure 5.7 Depth-Duration-Frequency Frequency (linear scale Curves)

Figure 5.8 Depth-Duration-(Log Scale curve).

3. From figures 5.7, 5.8, dividing the rainfall depth by the duration, and log rainfall depth by log duration yield the average intensity curve. By this procedure the DDF curves are converted to IDF curves as shown in figure 5.9 and 5.10.
4. The above analysis was carried out for the whole available data (full time series data), and can also be carried out for partial series duration like those values exceeds certain values like all events exceeds 30 mm.



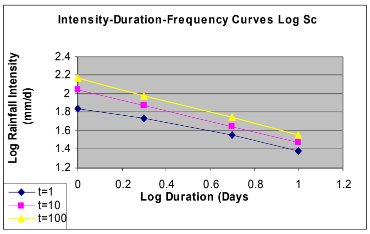


Figure 5.9 Intensity-Duration –Frequency Curve (Linear Scale)

Figure 5.10 Intensity- Frequency Curve (Double Log scale)

5.2.6 Monthly Rainfall Analysis

- **Maximum Recorded Monthly Rainfall**

In General, the maximum monthly rainfall occurs in December, January and February. The maximum average recorded monthly rainfall in the catchment exceeded 430 mm in January/1974 as shown in table 5.11

Table 5.12 The average monthy Rainfall (Extreme values)

Month	Hydrological Year	Average Rainfall (mm)
January	1973/1974	432
December	1991/1992	407
February	1991/1992	339
December	1992/1993	310

From the total data of all stations, as an average, the maximum monthly rainfall occurs in January for all stations, but the maximum monthly rainfall varies from year to year. In some years, the maximum occurs in December or in February as noticed in the above table. The sequence of extreme recorded months differs among the stations as shown in table 5.13, where, as example, the first maximum recorded monthly value in Bassam al Skak'ah station occurred in Feb/1992, while the same month is the second maximum value in 'Awarta and the third in Birzeit .

From table 5.13, it is noticed that in all stations, most of the monthly extremes occur in the same months with different sequence like the extremes month in table 5.12.

Table 5.13: Maximum Monthly Rainfall in the catchment

Name	1st Max	month/y	2nd Max	Month/y	3rd max	month/y
Bassam Al Shak'ah	420.7	Feb-92	390.6	Jan-74	370	Dec-92
Bir Zeit	445.5	Jan-74	414.7	Dec-92	321	Feb-92
Al Salam	503.2	Dec-92	356.4	Jan-74	336.7	Feb-92
WBWD/ Al Bireh	508.1	Dec-92	454.4	Jan-74	388.7	Feb-92
Qibya	480.5	Jan-74	415.5	Dec-92	371	Dec-93
Kafr Qaddum	485.5	Dec-92	466.1	Jan-74	338.4	Feb-92
Hajja	508.1	Dec-92	414	Jan-74	313.2	Feb-92
Burin	451.4	Jan-74	404	Dec-92	306.1	Feb-92
Jinsafut	479.1	Jan-74	460.7	Dec-92	412.3	Dec-93
Azzun	446.8	Dec-92	446.5	Jan-74	359.4	Dec-93
'Awarta	456.4	Jan-74	360	Feb-92	330.9	Dec-92
Deir Istiya	482	Jan-74	431.4	Dec-92	364.4	Dec-93
Aqraba	421.1	Jan-74	311.4	Dec-92	289.9	Dec-93
Biddya	446.8	Jan-74	421.3	Dec-92	385.6	Dec-93
Salfit	358.4	Jan-74	345	Dec-92	319.3	Dec-93
Qaryut	457.3	Dec-92	413.6	Jan-74	345.7	Feb-92
Deir Ghassanah	485.4	Jan-74	435.8	Dec-92	389	Feb-92
Sinjil	415.4	Jan-74	351.9	Feb-92	328.4	Dec-92
Rantis	458.3	Jan-74	441.7	Dec-92	433	Feb-92
'Atara	437.1	Jan-74	370	Dec-92	361	Feb-92
Al Mazra'a ash Sharqiya	431.4	Jan-74	417.5	Dec-92	346.5	Feb-92
Al Mazra'a al Qibliya	417.6	Jan-74	342.3	Dec-92	283.8	Feb-92
Saffa	440	Jan-74	406.5	Dec-92	315.1	Feb-92
'Al Hashmiyyah	470	Dec-92	449.2	Jan-74	364.4	Feb-92
Beituniya	482.1	Jan-74	452.3	Dec-92	388.5	Feb-92
Al Malek Ghazi	482.5	Jan-74	465	Dec-92	388	Feb-92

- **Analysis of trend in seasonal rainfall pattern (Temporal Trend).**

Analysis of monthly rainfall in the catchment has marked a seasonality, with the annual total falling in the wet months (October to May) and the wettest months being January and December (Figure 5.12 shows the seasonal pattern of rainfall. Downward and upward trend can be observed by inspecting the seasonal pattern of rainfall for different decades. It can be seen that the maximum average monthly rainfall in the first decade is 160 mm, while in the second decade has decreased to 118 mm, and then increased to 154 mm in the third decade.

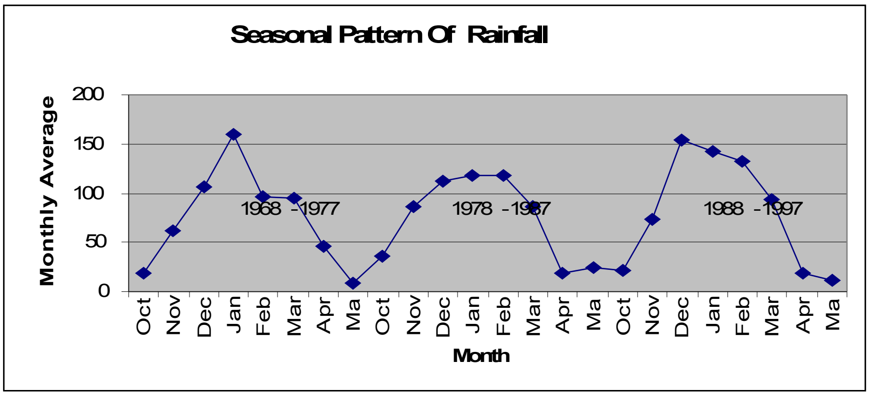


Figure 5.11 Seasonal Pattern of rainfall

- **Proportion of wet days and intensity analysis**

The proportion of wet days (rainfall grater than 0.5 mm) was also analyzed, in order to investigate the change in intensity of daily rainfall. The results are shown in figure 5.12.

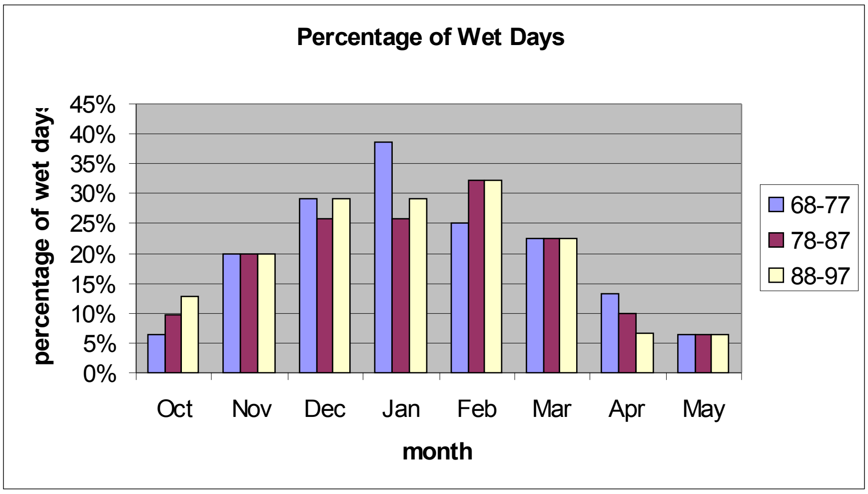


Figure 5.12: Proportion of wet days for the last three decades

The figure indicates that, overall, the proportion of wet days is consistently decreased from the first decade to the third decade. It is also noticeable that the month of the highest proportion of wet (January) in the first decade is moved to February for the second and third decades.

Further analysis was performed using all the daily records to establish the existence of trends in intensity, by calculating and comparing for the recent decades:

- Average daily rainfall;
- Mean wet day rainfall amount.
- Proportion of days with rainfall greater than 10 mm.

Figures 5.13, 5.14, and 5.15 show the frequency analysis of monthly data

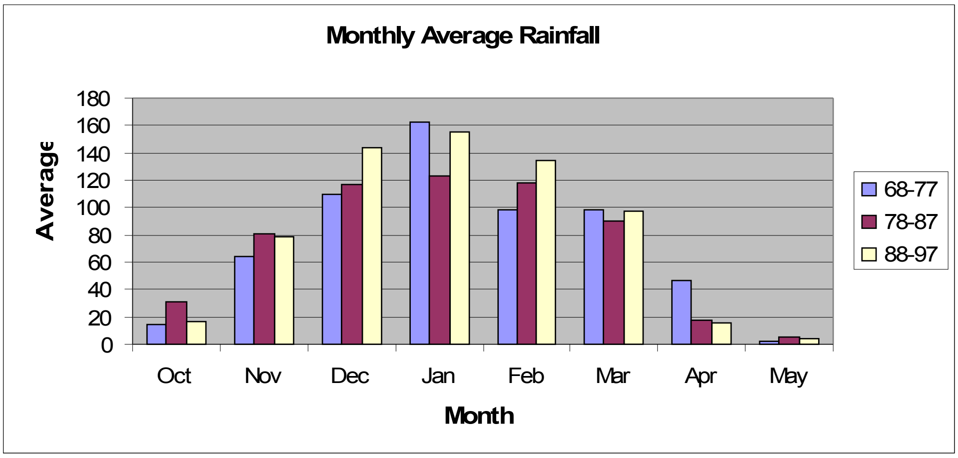


Figure 5.13: Monthly Average Rainfall for the last three decades

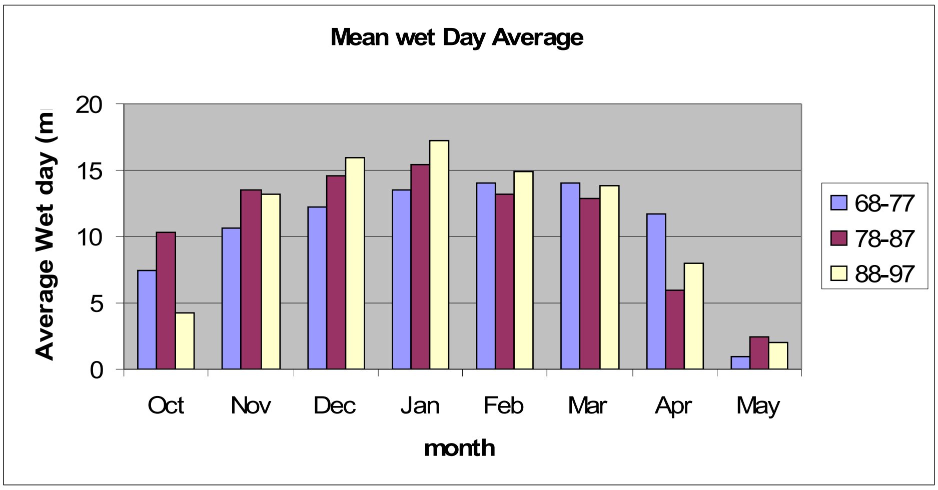


Figure 5.14: Mean Wet Day Average

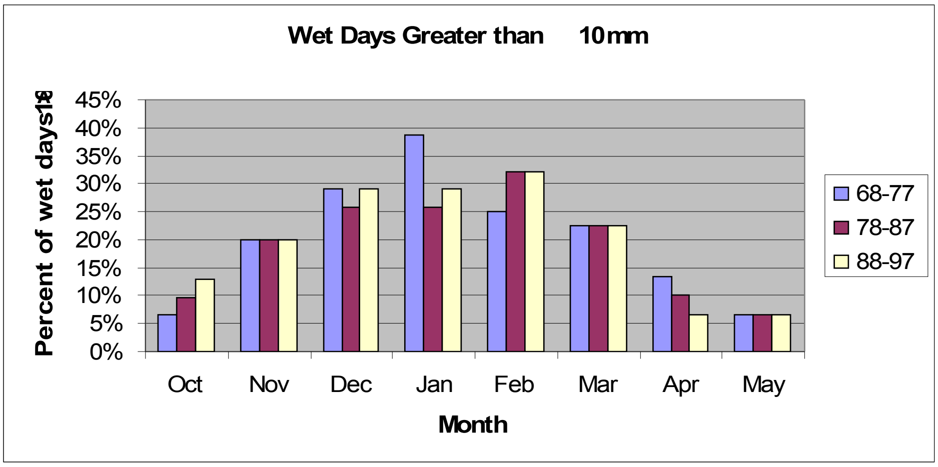


Figure 5.15 Proportion of wet days with rainfall greater than 10 mm

Figure 5.13, 5.14, and 5.15 that there are changes in seasonal pattern, with a general trend towards more intense rainfall in the season in the recent decades.

To investigate temporal variations in the quantities of average daily rainfall and mean wet day rainfall further, Figure 5.15 shows monthly time series of proportion of wet days (pw) and proportion of days with rainfall greater than 10 mm for the wet period (October to May) for each month individually. These figures show that there is considerable inter-annual variation, and there is no consistent trend apparent.

5.2.7 Yearly Rainfall Analysis

- **Annual Rainfall Variation**

The average annual rainfall in the catchment is about 600 mm, but there is wide variation of rainfall from year to year. The average annual rainfall in the hydrological year 1991/1992 was approximately twice than the annual average.(Fig 5.16).

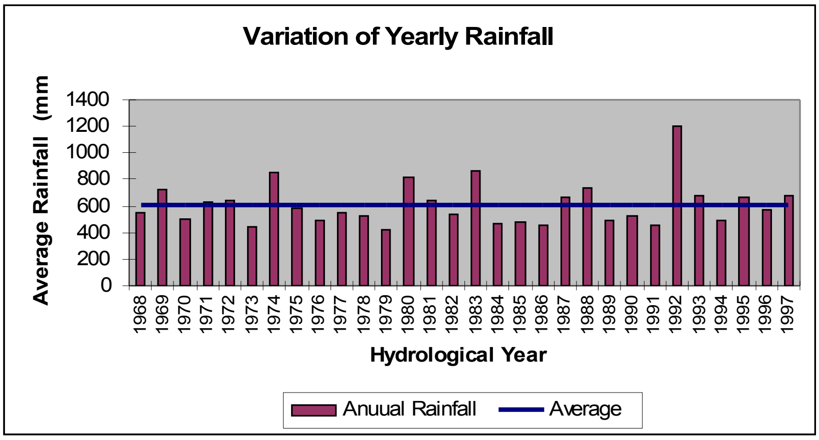


Figure 5.16 Variation of Yearly Rainfall

Most of the annual rainfall in the catchment ranges from 450mm to 750 mm. Figure 5.17 shows that 80% of the average annual rainfall are located within this range, 43% are ranged 450 mm to 550 mm.

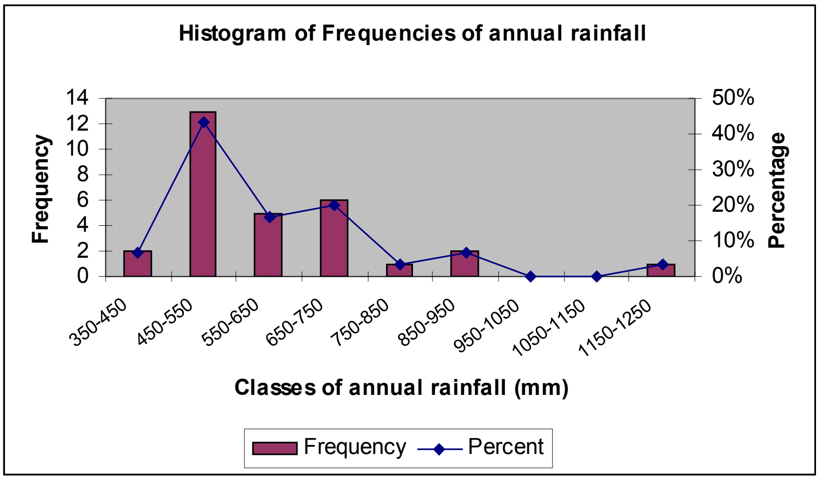


Figure 5 .17 Frequencies of Annual Rainfall

- **Spatial Annual Rainfall Pattern.**

In general, the annual rainfall in the catchment is affected by latitude, distance from the coast, and elevation.

Rainfall gradient with latitude is usually explained by the variation in frequency of the main cyclonic weather systems originating over the Mediterranean. The effect of elevation on the other hand is well-known phenomenon of orographic enhancement of rainfall, where winward (west) facing mountain slopes receive higher rainfall amounts. Conversely, leeward (eastern) facing slopes receive lower rainfall amounts. The effect of distance from the coast may be explained by the progressive reduction in atmospheric moisture moving away from its principal source, the Mediterranean Sea. The effect is complicated by a relative increase due to orographic effects over the mountains. However, overall, these effects are dominated by the rainfall gradient with Latitude.

- **Annual Trend Analysis**

From the available data for 30 years, the average was selected and analyzed to detect any long-term trends in the annual rainfall. The deviation from the mean was calculated using Cumulative Departure Method (CDM) Formula

$$\text{CDM} = \sum_{i=1}^{k} (Xi - X)/X \qquad 5.16$$

Where X_i is the annual rainfall (mm), X is the overall mean, $I \leq k \leq n$.

Then a linear least-squares trend line fitted (Figure 5.18).

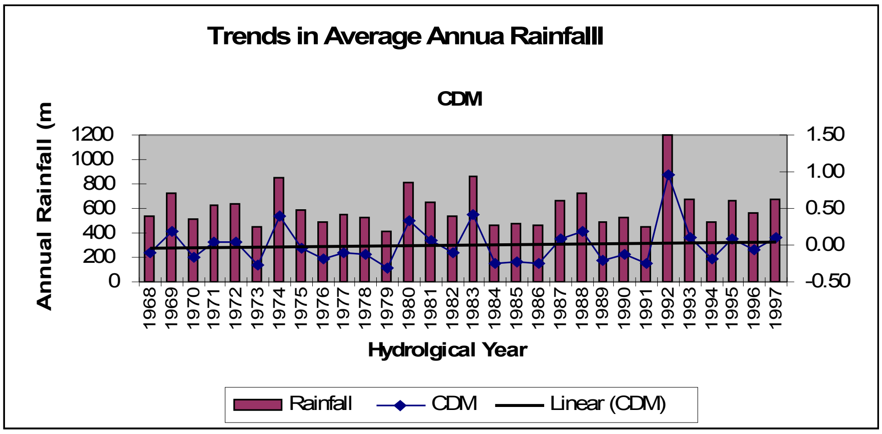


Figure 5.18 Trends in Annual Rainfall Using (CDM)

It is apparent from the analysis in Figure 5.18, that there is no considerable trend in rainfall amount and intensity. A spatial analysis of trends performed that any station within the catchment subject to change over a recent decade. But if trends are plotted for each decade separately, some minor negative trends are seen the first and second decades, and this is consistent with the time series plots for individual stations described in Appendix A.

5.3 Discussion of Results.

The installed rainfall monitoring network was not fit with the necessary conditions. It does no valid to satisfy the hydrological monitoring needs in aspects of types, instrumentations, distribution, and recordings. So that it is needed to be improved, the followings are suggested:

- 5 climatological stations (telemetry) fully automated should be installed to cover the study area in geographical and topographical aspects, 1 station in each zone categorized in tables 5.1, 5.2 and 5.3. In year 2002, 2 stations were installed in WBWD and Salfit.
- 10 tipping buckets (semi automatic) should be installed to overcome the troubles resulted from manual recordings. 2 stations in each zone categorized in tables 5.1, 5.2 and 5.3. in year 1998, 2 stations were installed in Farkha and Al Nabi Saleh.
- 3 tipping bucket should be installed much closed to manual gauges for double checking. Those will be used to compare the collected rainfall to be sure that both of them are in suitable places.
- Comprehensive maintenance should be done for all manual gauges. The maintenance should be periodically and at least one time per year (suggested being in September, before starting the rainfall). The maintenance should include cleaning the gauges, replacing the broken, and stabilizing the raingauges against the wind.
- Note book should be provided to document all the changes related to the raingauges like maintenance, surrounding conditions, shifting the gauge, etc.. Figure 5.19 shows the suggested monitoring network in the study area. The suggested network are

designed and improved to fit the hydrological needs which are necessary in hydrological studies.

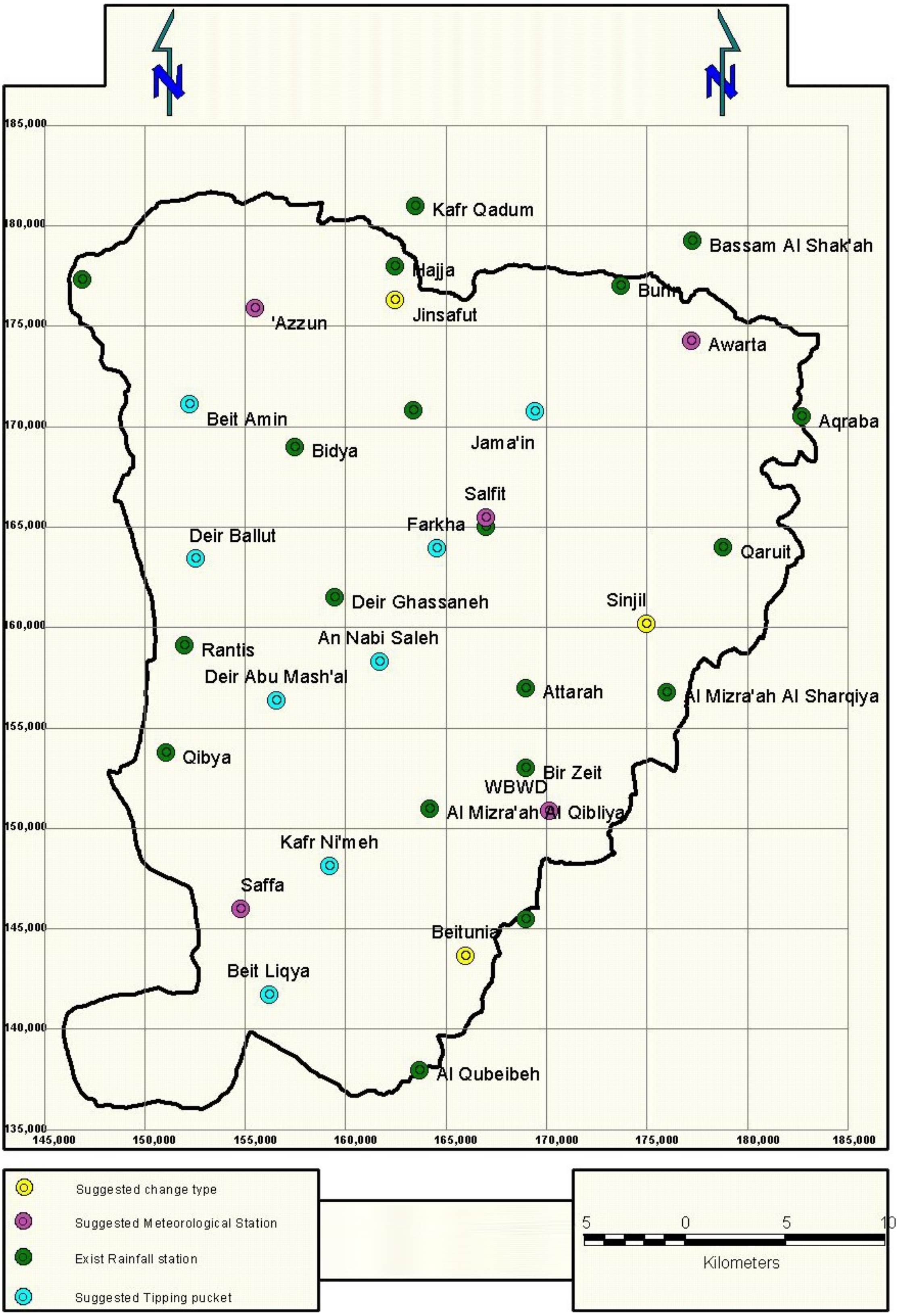


Figure 5.19: Suggested Rainfall Network

CHAPTER 6

SPRINGS DISCHARGES AND RELATION WITH RAINFALL

This chapter studies the springs monitoring network, classification of springs, the quantities of discharge, and relation between spring discharge and rainfall

6.1 Springs and Monitoring Network

Springs are found in mountainous or hilly terrain, they are defined as a place where a natural out drain of ground water occurs. Springs water fed from a sandy gravel water-bearing ground formation (aquifer), or a water flow through fissured rock. When solid or clay layers block the under ground flow of water, it is forced upward in order to come to surface.

Springs water is an essential source of water for both domestic and agriculture use in some of the Palestinian Communities in the study area, like Ein Arik, Ein Qinya, Bettilu and Salfit.

There are more than 94 springs monitored in the study area by PWA, 50 of them still under continuous monitoring. There are more than 200 springs and seeps according surveys done by PCBS (PCBS,1998). Figure 5.1 shows the main springs with average discharges exceeding 0.1 litre per second (PWA,2001).

Appendix E shows all the general data about the springs in the study area. These springs have different physical characteristics according to the geological formation and tapping aquifer, where most of them

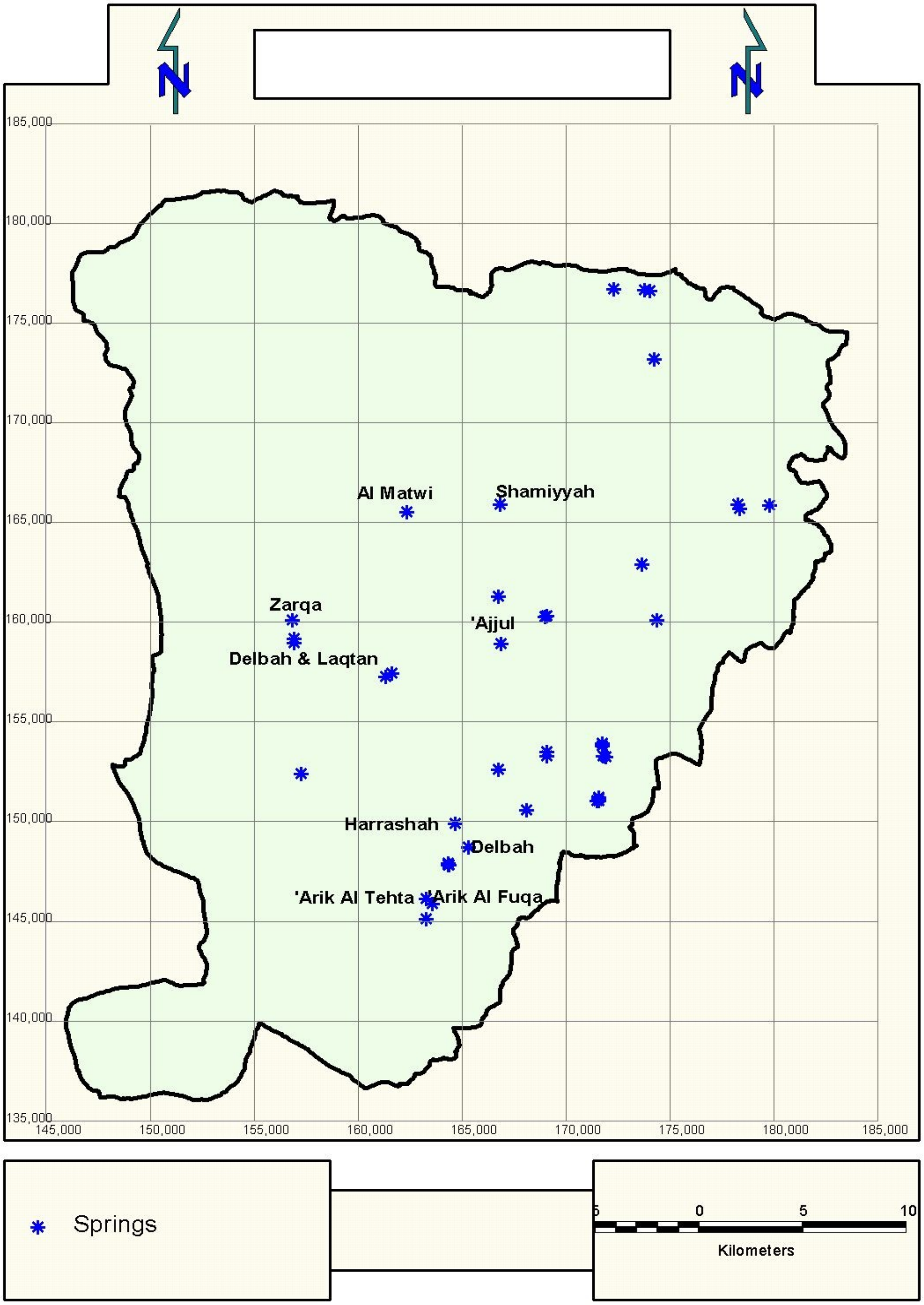


Figure 6.1: Springs in the Study Area

tapping from the lower and upper aquifer, while few of them tapping from the Eocene.

Rofe and Raffety (1965) classified these springs hydrogeologically into the following groups:

Ein Qinya and Ein Arik Group.

They are fed from the lower Beit Kahil Formation aquifer. Ein Qinya springs (Dilba, Al Balad, Um al Rumman, Um Al E'nein, Um Issa) Issues from within the Kobar Formation close to the so called Aptian-Albian unconformity, whereas the Two Ein Arik springs (Al Fauqa and Al Tehata) are at the contact. Many of the smaller springs and seepages also issue from the same formation and vicinity. Data measurements are available for these springs since 1955. The maximum discharge of these two springs is 32.5 l/s in March, and declined gradually to 3.6 l/s in September, October, and November. Ein Qinia has a very high winter flow which rises and falls quickly in the period December to April, while from June to November there is a gradual decline from 4.4 to 1.5 liter per second.

It is significant that at both Ein Qinia and Ein Arik, the spring outflow appears to be against the dip of the rocks (Roff and Raffety, 1965). They could therefore be overflows from much larger groundwater storage.

Salfit Group.

The group includes Ein Salfit north of the town and a number of springs and seepage (Matwi, Shamiyya, Al 'Adas and Al Shallal) in the wadi system to the west.

Ein Salfit occurs in an anomalous position at the southern edge of a northerly dipping outcrop of Hebron Formation. The dip is shallow and the Hebron outcrop rises steeply above the spring eye, which is in Yatta Formation above the wadi floor. The groundwater flow in the aquifer is thought to be in southerly direction, aided by topographic steepness, against the shallow dip.

West of Salfit a number of springs and seepages occur in the floor of Wadi Matwi where Yatta Formation outcrops. The Hebron Formation occurs south of the springs in this area and the groundwater movement is expected to be northward.

Qana Group.

A number of small springs and seepages, associated with the base of Hebron Formation, issue from Yatta outcrop in the floor of wadi Qana. The dip in Hebron is very variable and the springs are probably caused by faulting, rather than any local folding, which permit the drainage of groundwater from the limestone, sometimes against the dip, to the base level of the wadi floor. The remainder are small, many little more than seepages, not all are perennial and most are at high level in areas of high rainfall. They issue from many formations for both structural and stratigraphical reasons.

6.2 Measurements of Springs

Those springs are monitored by PWA either monthly or every two months or three or four times per year according to spring discharge. Measuring methods are either by volumetric or by current meter. Small springs and seeps are measured through filling the flowing water into a bowl of specified volume and measuring the time it takes to be filled completely, the unit of measurement is liter per second. For those large springs that flowing in open channel, the current meter is used to measure the velocity of flowing water and then computing the discharge in meter per seconds.

6.3 Quantity Analysis of Springs Discharge.

6.3.1 Annual Springs Flow Variation.

The average total flow of all springs in the study area are about (1.75 MCM) per year. Figure 6.2 shows the total annual discharge for those springs, where there is a wide variation in the annual discharge and ranges from 860 thousand cubic meters in 1986 to 4630 thousand cubic meters in 1992.

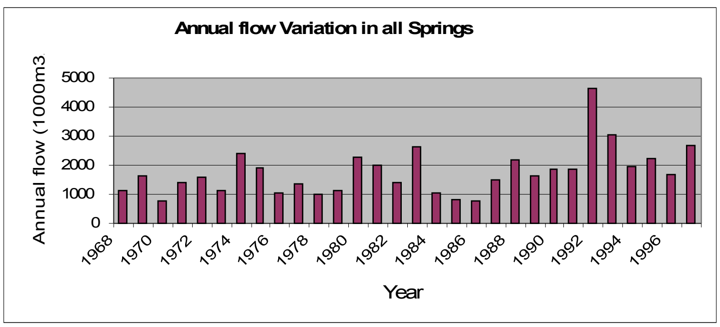


Figure 6.2: Annual Average Flow of Springs

6.3.2 Monthly Springs Flow Variations.

The monthly averages of 30 years were taken for analysis for all monitored springs by PWA. It is clear that the maximum monthly discharge occurs in March, February and April respectively, and forms about 44.8% of the total discharge, which indicates a strong relation with months of strong rainfall. Figure 6.3 shows distribution of average monthly discharge in the study area.

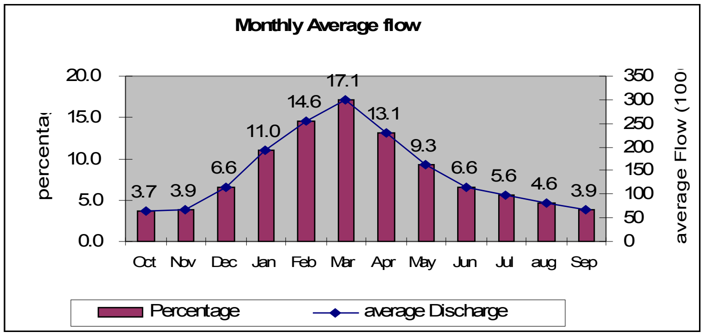


Figure 6.3: Spring's Monthly Flow Variation and Percentages

Also, there is a wide variation of flow within the same month in different years, as example in January; the minimum flow is about 46 thousand cubic meters in 1986, while the maximum flow is about 646 thousand cubic meters in 1992. Figure 6.4 shows the variation in flow of January in different years.

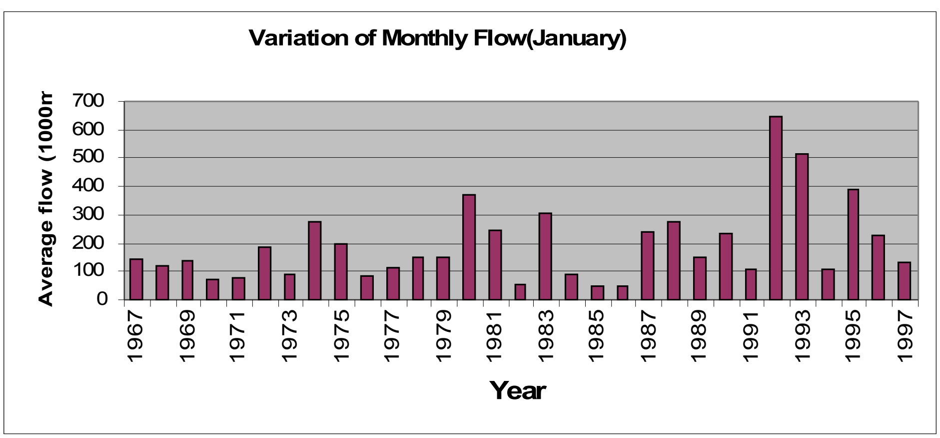


Figure 6.4: Variation of January Flow in Different Years

The same behavior of flow occurs strongly in months of spring and winter which indicate strong effect by rainfall variation.

6.4 Major springs.

In the study area, the measurements are available for more than 94 springs, 80 % of the total discharge flows from 9 major springs. So those springs will be used for analysis because those are the largest, and the flow is more stable where the error in measurements will be less than for small springs. Table 6.1 shows the physical characteristics and the geological information for the major springs in the study area.

Table 6.1: Geologiac Characteristics of the Major Springs

Spring ID.	Name	Emergent formation	Probable Aquifer	Cause	Aquifer Type
BA/085	Al Shamiya	Yatta	U.C	Lithology	Unconfined
Ba/085A	Al Matwi	Yatta	U.C	Lithology	Unconfined
BA/111	Ajjul	L.C	L.C	Lithology	Unconfined
BA/120	Delba,Legetan	Hebron	U.C	Lithology	Unconfined
BA/121	Zerqa	Hebron	U.C	Lithology	Unconfined
BA/153	Harrasheh	L.B.K	L.C	Lithology	Unconfined
BA/164	Dilba	Kobar	L.C	Lithology	Unconfined
BA/170	Arik Fauqa	L.B.K	L.C	Lithology	Unconfined
BA/171	Arik Tehta	L.B.K	L.C	Lithology	Unconfined

Table 6.1 indicates that the major springs in the study area are flowing from phreatic aquifers (Gravity depression springs). Gravity springs usually have a small yield and further reduction is likely to occur when dry season conditions or nearby groundwater withdrawals occur (IRC,1988).

The spring discharges are usually affected by seasonal precipitation in the recharge region and by the storage capacity of the aquifer system as shown in Table 6.2 where in all of springs (except Harrasheh), the highest flow occurs in March and lowest flow occurs in November and October. Annual flow of these major springs is similar, where the maximum and the minimum occur approximately in the same time. The maximum flow in all of these springs occurred in 1992, while the minimum occurred in 1986 and 1970 as shown in Table 6.3.

Table 6.2: Maximum and Minimum Monthly Flow in the Major Springs

Spring ID.	Name	Highest flow	Percent (%)	Lowest Flow	Percent (%)
BA/085	Al Shamiya	March	12	November	5.8
Ba/085A	Al Matwi	March	13.5	November	3.7
BA/111	Ajjul	March	14.5	November	5.4
BA/120	Delba,Legetan	March	12.8	November	5.3
BA/121	Zerqa	March	14.5	November	4.4
BA/153	Harrasheh	February	22.4	October	1.7
BA/164	Dilba	March	23.8	October	1.5
BA/170	Arik Fauqa	March	21.2	October	2..4
BA/171	Arik Tehta	March	20.0	October	2.15

Table 6.3: Maximimum and Minimum Yearly and Monthly Flow

Spring ID.	Name	Maximum year	Minimum year	Maximum month/year
BA/085	Al Shamiya	1992	1970	Feb/1983
Ba/085A	Al Matwi	1992	1970	Feb/1983
BA/111	Ajjul	1992	1986	Feb/1992
BA/120	Delba,Legetan	1992	1986	Feb/1992
BA/121	Zerqa	1992	1986	Feb/1992
BA/153	Harrasheh	1992	1970	Feb/1992
BA/164	Dilba	1992	1986	Feb/1993
BA/170	Arik Fauqa	1992	1970	Feb/1992
BA/171	Arik Tehta	1992	1970	Feb/1993

The maximum monthly flow occurs usually in February for all springs but in different years. Monitoring discharge every two months or more make it so difficult to reveal when the peak really occurs, so that the peaks will be considered as the largest available measurements. The real peak only can be known if data loggers are installed on these springs.

6.5 Rainfall –Flow relation

Identifying the relationship between rainfall and flow quantities is a useful tool to observe the effect of rain on the natural recharge and storage capacity of the aquifers, which gives good indications about the spring system, discharge patterns and quantities.

In order to check the relationship between the rainfall and the springs discharge, the total amount of the annual springs flow was plotted against the average annual rainfall as shown in Figure 6.5.

From Figure 6.5, it was easy to reveal the proportional variation of springs flow according to variation of rainfall. The correlation coefficient was calculated to be 0.83 which is strong relation from statistical point of view.

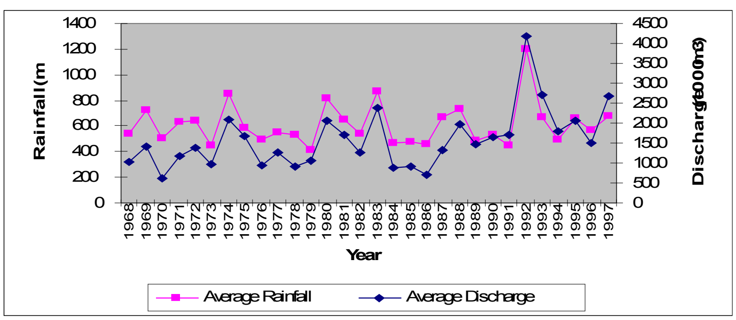


Figure 6.5: Rainfall – Discharge Relationship

6.5.1 Relationship between Spring Discharges and Rainfall on Annual Scale.

Since the springs tapping from different outcrops, so the relationship between the discharges of springs will be compared with rainfall in stations located in same outcrops In the upper aquifer, the total annual flow of both Al Shamiyya and Al Matwi, were plotted against the average flow of Biddya and Salfit stations located in the same outcrop as shown in figure 6.6, which shows a strong correlation between quantities of rainfall and flow, where the correlation coefficient (p^2) equal to 88%.

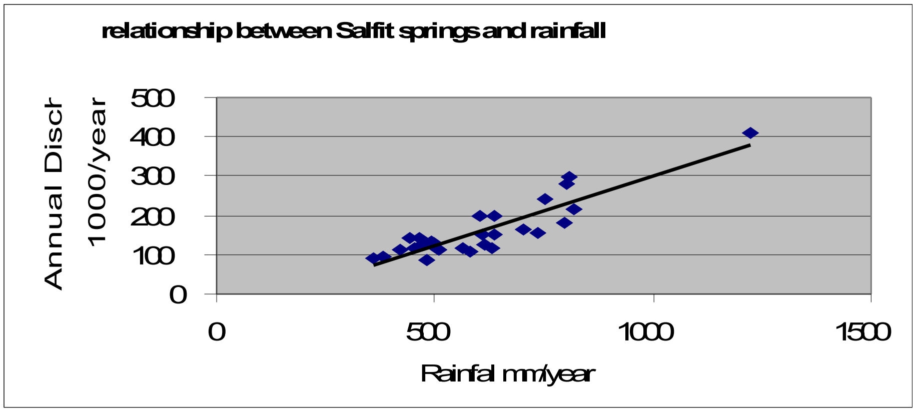


Figure 6.6: Relationship between Rainfall and Discharge (Upper Aquifer)

The same procedure was applied for Harrasheh spring located in the lower aquifer and compared with al Mazr'ah Al Qibliya station located in the same aquifer and plotted in Figure 6.7, where the correlation coefficient (p^2) is 87%.

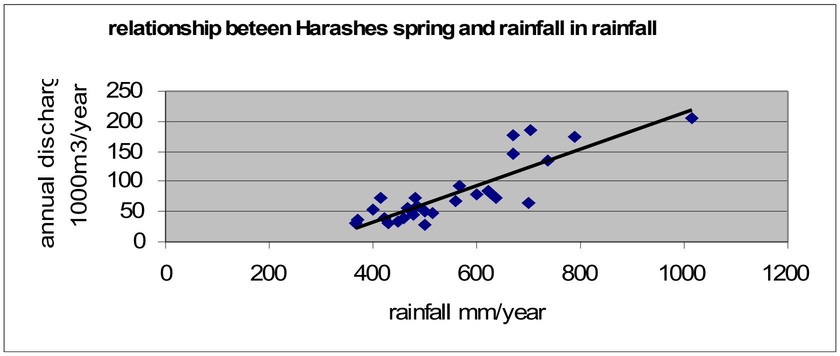


Figure 6.7: Relationship between Rainfall and Discharge (Lower Aquifer)

6.5.2 Relationship between discharge and rainfall on monthly scale.

Comparing the average monthly rainfall with the total monthly flow in both Upper and lower aquifer (Table 6.4), it is easy to reveal that the maximum discharge occurs after two month of maximum rainfall. From rainfall analysis results presented in chapter 4 the maximum rainfall occurs in January, December, and February respectively, while the maximum discharge presented in the same table shows the maximum discharge occurs in March, February, and April respectively. This means that the recharge time is approximately two months after rainfall starting.

In the summer months, from June to August, there is no rainfall, the total quantities starts to decrease gradually. It seems that the discharge in November is greater than October because the direct infiltration starts to occur after starting raining in October and in some few years in September.

Table 6.4 (Relationship between Rainfall and Discharge on Monthly Scale

Average Rainfall (%)	Month	Average Discharge (%)	Month	Lag time (month)
23.7	January	17.1	March	2
20.9	December	14.6	February	2
19.4	Febtuary	13.1	April	2
15.5	March	11	May	2
12.3	November	9.3	January	2
4.2	April	6.6	June	2
3.4	October	6.6	December	2
0.6	May	5.6	July	2
0	June	4.6	August	2
0	July	3.9	September	2
0	August	3.9	Noveber	3
0	September	3.7	October	1
100		100		

6.5 Discussion of Results.

There is a strong relationship between the rainfall and the total discharge the study area with a correlation coefficient reaches to 0.83. This relationship appears to be greater if the study area are divided into according to tapping aquifers. The correlation coefficient in the upper aquifer is greater than the coefficient in the lower aquifer. This mean that the response of the upper aquifer to recharge from rainfall is faster than the lower aquifer and this is due to the distance of the aquifer from the ground surface.

In general there are three parameters affecting recharge in both upper and lower aquifer, which are:

1. The average annual rainfall. The total springs flow is proportionally affected by variation of the average annual rainfall. The total springs flow increase as the rainfall increase and vise versa, this was indicated easily from Figure 6.5.
2. The intensity of the rainfall. Runoff is directly proportional to the rainfall intensity, where the runoff increases as the intensity increases, the possibility for recharge decreases, and then the springs flow decreases. As example, the discharge in 1979 was very low because of the high rainfall intensity occurred in several storms in this year.
3. Number of storms (number of rainy days). The possibility for recharge increases as a result of increasing number of the storms and the rainy days. Through analysis, it is noticed that the discharge increase as number of rainy days increase comparing the same quantities of annual rainfall.

4. Distribution of rainfall along the wet season. The possibility for recharge is also affected by as the period of rainy season, It is noticed that in the year of long rainy season (from October to May) the quantities of discharge is grater than in those short rainy season (December to February) comparing the same quantities of annual rainfall.

CHAPTER 7
CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

Auja Al Timsah catchment is very important to be studied since it forms the main recharge area for the Western Aquifer Basin, where more than 93% of the outcrops feeds the upper and lower aquifer, which is the main source of water supply for domestic and agricultural use for Palestinian communities in the study area.

The rainfall is the only source of recharge, so adequate design of precipitation network is very important to estimate the quantities of rainfall, and then estimation of recharge.

The current monitoring network, despite it is dense geographically, but it is poor and inadequate for type, space and time. The current network consists of manual daily raingauges only, and there are no autographic charts or tipping bucket to measure the rainfall intensity which is the most important factor for recharge and hydraulic design. Also there are no full automatic weather stations to measure the parameters important for the hydrological and modeling studies like evaporation. Spatially, the network is poorly distributed and does not cover fairly the topographic variations, geological outcrops, precipitation zones and the geographic areas. For time series data, although there is long historical data exceeding 40 years in some stations, there are a lot of missing months and years that make it is difficult to calculate the monthly and annual totals.

The quality of rainfall measurements is influenced by many factors like

- Lack of experience technicians for measuring and recording the rainfall because all the raingauges located at schools and measured by non-trained teachers.
- Closure of schools imposed by Israeli Army, where the schools were closed for several months.
- Number of holidays and vacations within the rainy season, where it causes either to accumulate the rain or miss-reading it.

Quality assurance and Quality Control of data and data screening are very necessary through cleaning the data from the suspicious records and estimating missing data.

Different techniques were applied to screen daily, monthly and yearly data like time series analysis, double mass analysis and spatial homogeneity test. Using these tests indicated that the records were not always done on daily basis, several days were recorded as one value. So that it was not easy to distinguish between accumulated and missing records. So estimating of daily data by spatial homogeneity test didn't give good results while estimating monthly and yearly data gave more reliable results.

All the stations within the catchment were analyzed (26 stations) for areal rainfall, extreme analysis, K-day analysis, rainfall depth analysis and frequency analysis, the results were the followings:

- For areal rainfall: Average depth method, Thiessan method, and Isohytal method were used in calculations and have approximately similar results around 600 mm/year.
- For extreme analysis: Gumbel distribution and exponential distribution were applied and both show good fits to recorded rainfall, where the correlation coefficients exceeds 90% at most stations.

- For daily Analysis, average number of rainy days is 43 day, and ranges from 35 days in Al Mazra'ah Al Qibliya to 49 days in Deir Istya. More than 78 % of the daily rainfall is less than 20 mm, which means that most of rainfall occurs in small storms.
- For monthly analysis: the wet season starts in October and ends in May. The maximum rainfall occurs in January, December, and February respectively. While the summer months from June till September is completely dry. Also the quantities of rainfall vary greatly for the same month in different years.
- For annual analysis: average annual rainfall varies from year to year, sometimes by two time the average like 1991/1992 or half the average like 1979.Isohytal maps for different periods were generated for periods 1968-1977, 1978-1987, 1988-1997, and 1968-1997. The volume of water was computed and compared with Thiessan polygons drawn for the same purpose. Thieissan method is the most appropriate and easiest method.
- Rainfall regime has be shown to be highly variable in a number of aspects. Much of the rainfall occurs in intense rainstorms-the frequency of short duration intense rainfall is high
- Spatial patterns exist caused by distance from the coast, topography and latitude. it is complex to find which is the most causing factor affecting in rainfall patterns because the area is small, the variation in annual rainfall is also small.
- Inter-annual variability of rainfall is high-the long term mean is not a good guide to expected rainfall amounts.

- Spatial variability is very high, caused by small, intense, convective rain storms so correlation falls off rabidly with distance.
- Temporal trends shows changes in the annual and seasonal rainfall and intensity have occurred through last 30 years. These have occurred particulary in the period 1987-1988 when decrease in the annual rainfall and increases in intensity are apparent.
- There is a strong relationship between the amounts of rainfall and quantities of spring discharges. The lag time is about only two month.

7.2 Recommendations

1. The existing network of rainfall stations is needed to be rehabilitated and developed. Where there are a lot of non functioning raingauges because lack of maintenance. Also new type of intensity instruments like autographic charts and tipping bucket should be placed and take into consideration the variation in topography, geological characteristics, precipitation zones, in addition to the geographic location.
2. Historical data has poor quality of both measurements and recordings. It is recommended to train those personnel who do the measurements with the necessary training to overcome the problems of measurements. A unified form of data recording should be prepared that includes description of the data and comments of the observer about the status of the station.
3. To serve the engineering design purposes and hydrological studies, the data should be recorded as short intensities like every 15 minutes or on hourly basis. The current data is

available for shortest length of at least 24 hours, and this requires new type of instruments.

4. Historical data should be used carefully especially on daily and monthly basis. Clear and written procedures for data screening should be applied for all historical rainfall data before using it. Also comparing the data collected by different types of instruments like comparing data of manual gauges with tipping pucket or autographic charts should be used.

5. Springs discharges monitoring network should be upgraded. Data loggers should be installed on the major springs to measure the real-time data that is necessary to assess the relationship between rainfall and flow, and then the capacity of the aquifer.

6. In order to conduct the hydrogeological and modeling studies, surface runoff network should be placed to measure the runoff in major wadis in each catchment. This is very important for rainfall-runoff studies. Most of the studies till now deal with old figures found in Rofe and Raffety, 1965 or from Israeli literature.

CHAPTER 8
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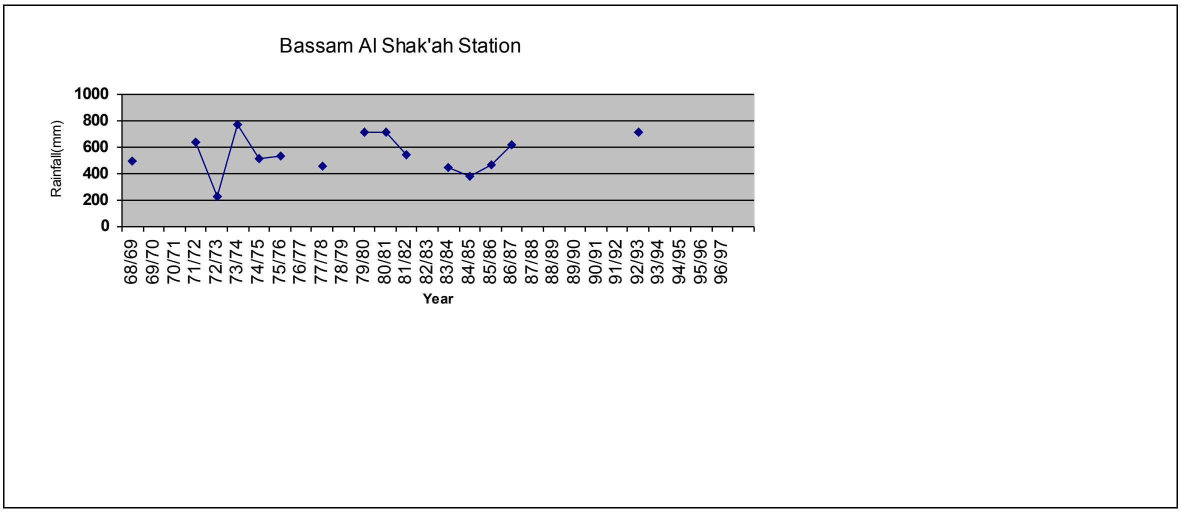
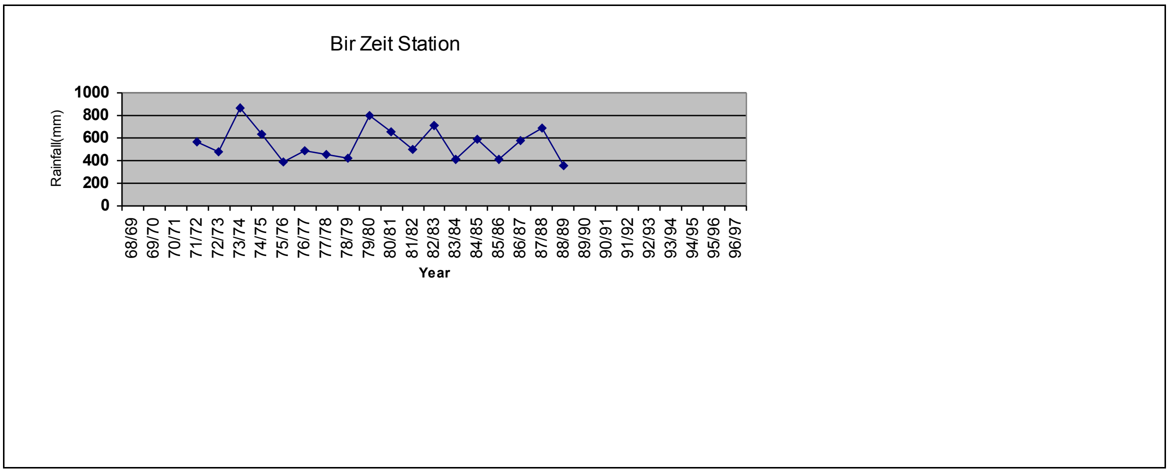
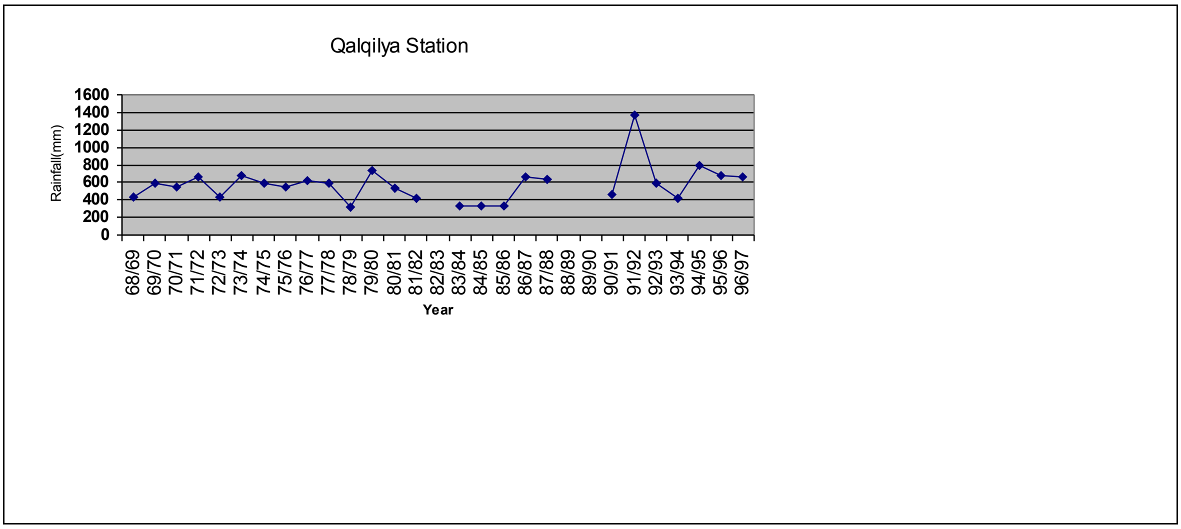
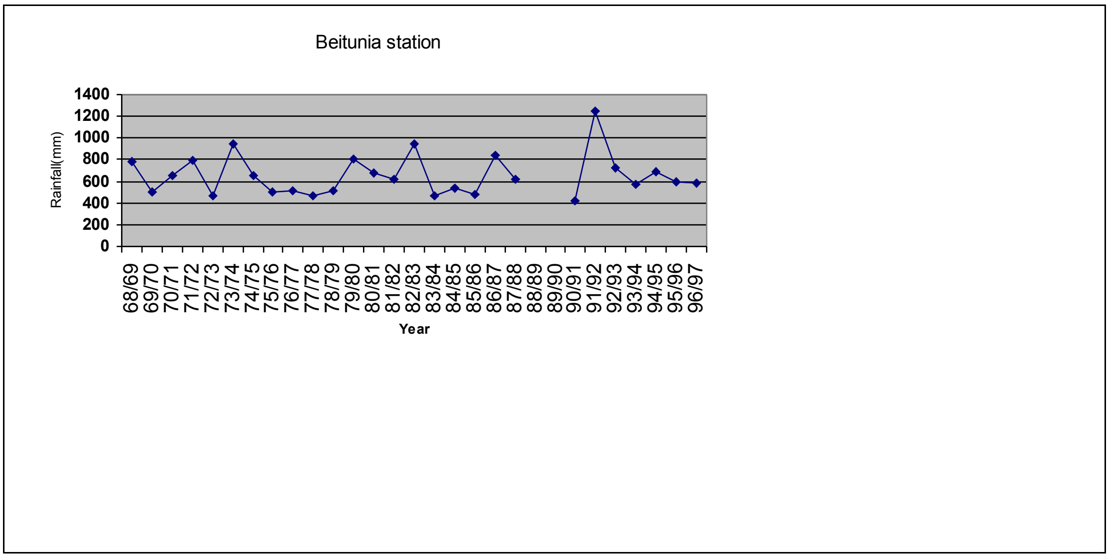
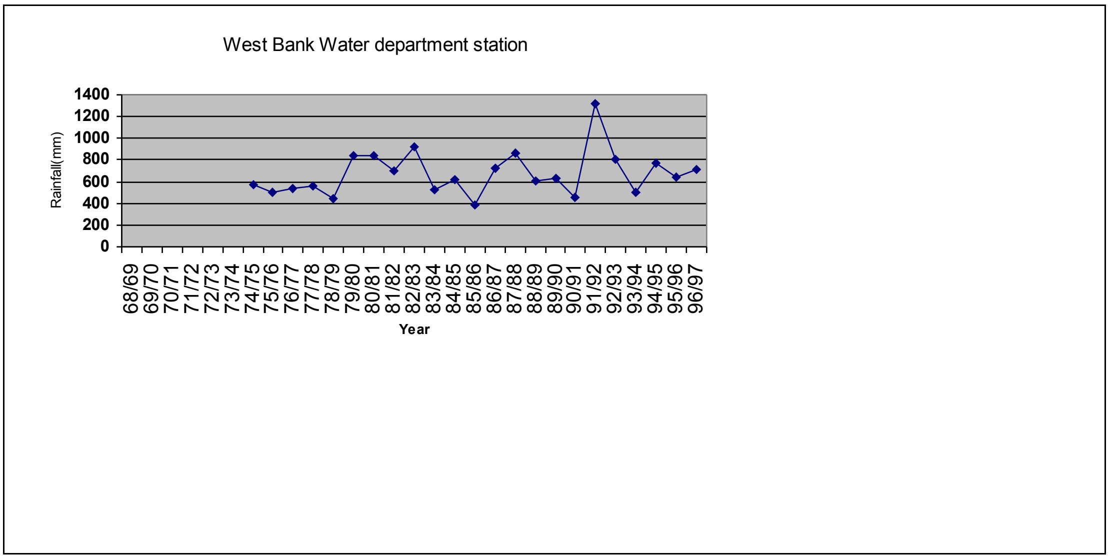
APPENDIX A: Recorded Annual Data

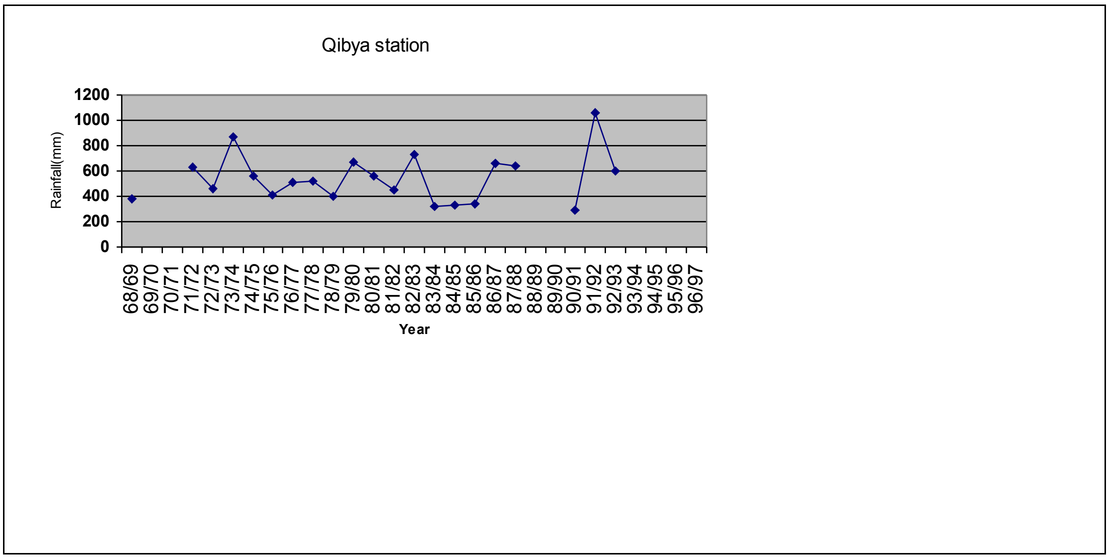


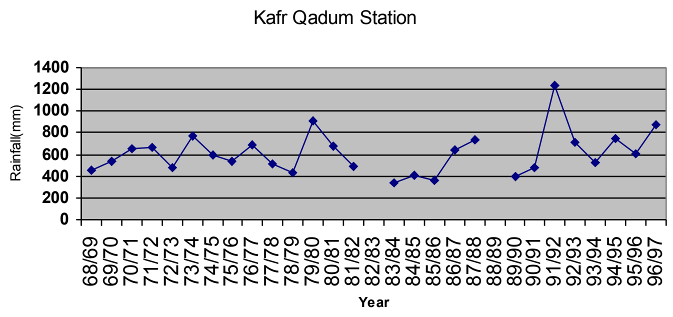


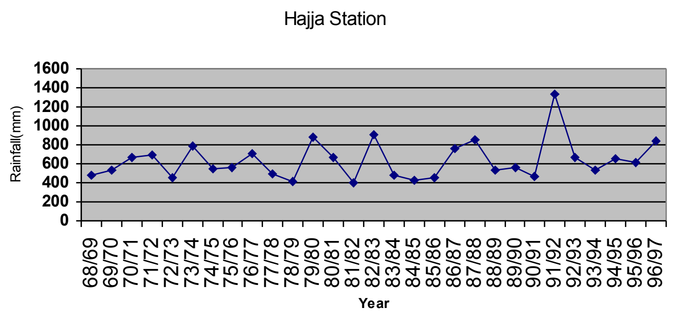


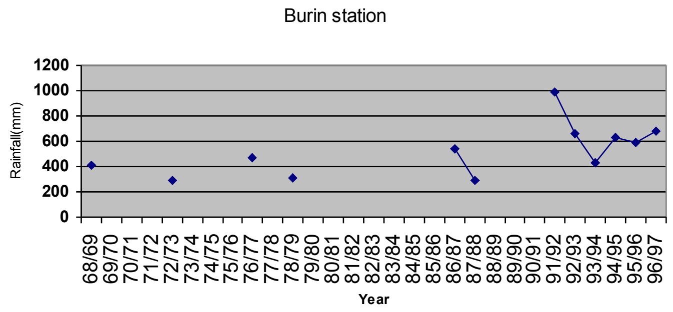

Beitunia station
Rainfall(mm)
Year

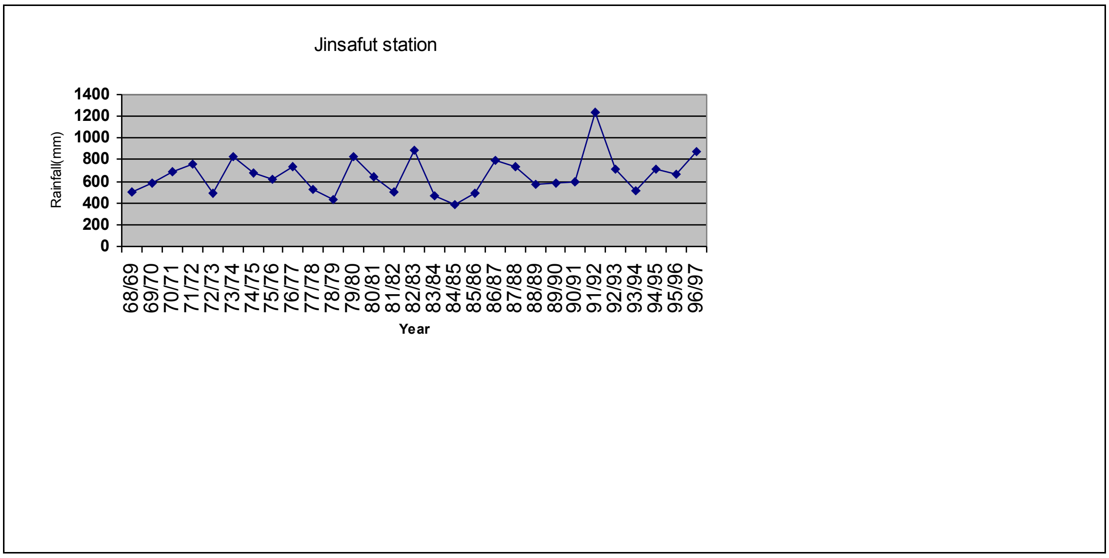

West Bank Water department station
Rainfall(mm)
Year

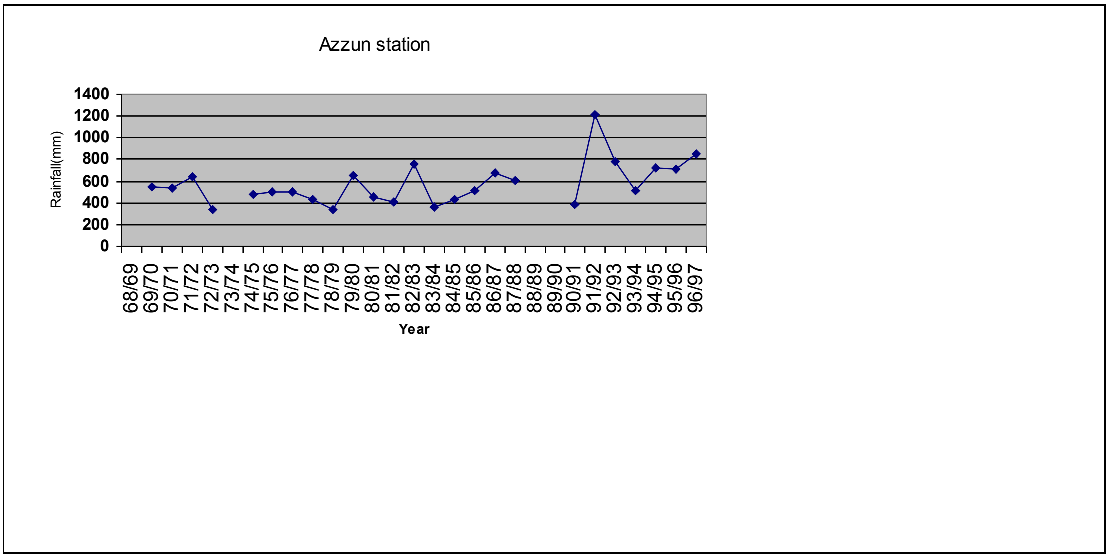

Qibya station
Rainfall(mm)
Year

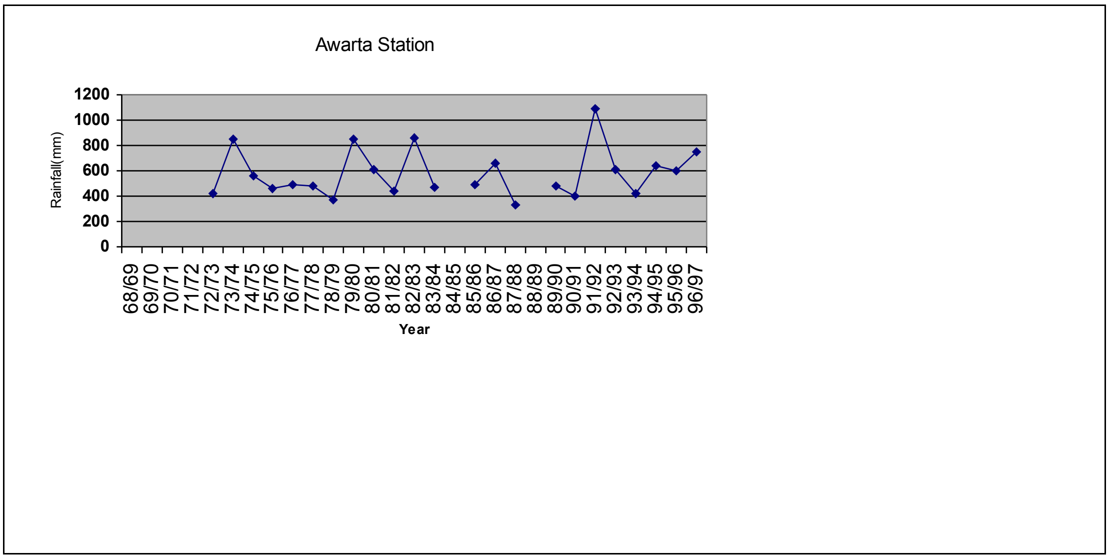

Kafr Qadum Station
Rainfall(mm)
1400
1200
1000
800
600
400
200
0
68/69 69/70 70/71 71/72 72/73 73/74 74/75 75/76 76/77 77/78 78/79 79/80 80/81 81/82 82/83 83/84 84/85 85/86 86/87 87/88 88/89 89/90 90/91 91/92 92/93 93/94 94/95 95/96 96/97
Year

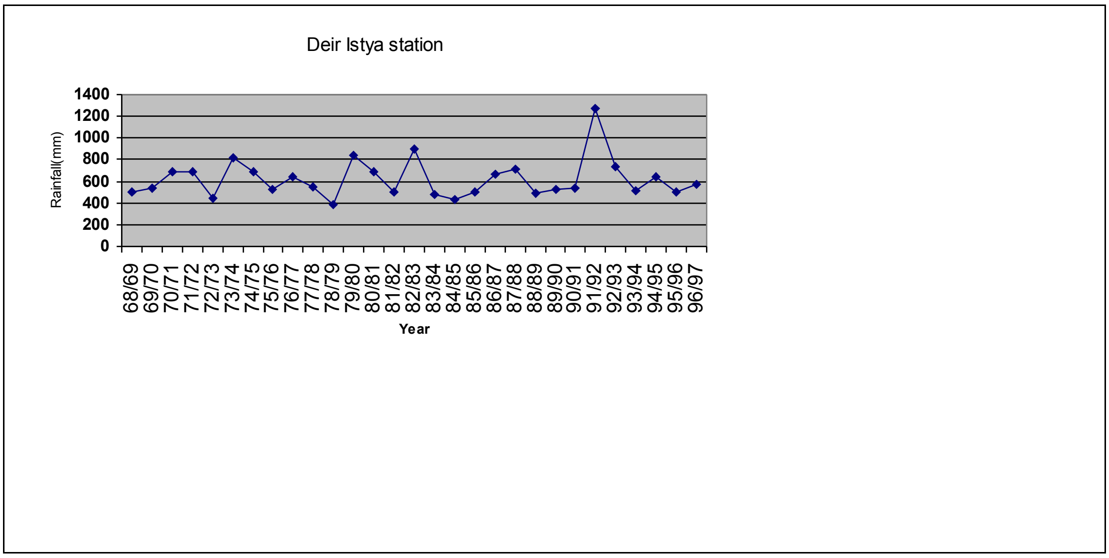

Hajja Station
Rainfall(mm)
1600
1400
1200
1000
800
600
400
200
0
68/69 69/70 70/71 71/72 72/73 73/74 74/75 75/76 76/77 77/78 78/79 79/80 80/81 81/82 82/83 83/84 84/85 85/86 86/87 87/88 88/89 89/90 90/91 91/92 92/93 93/94 94/95 95/96 96/97
Year

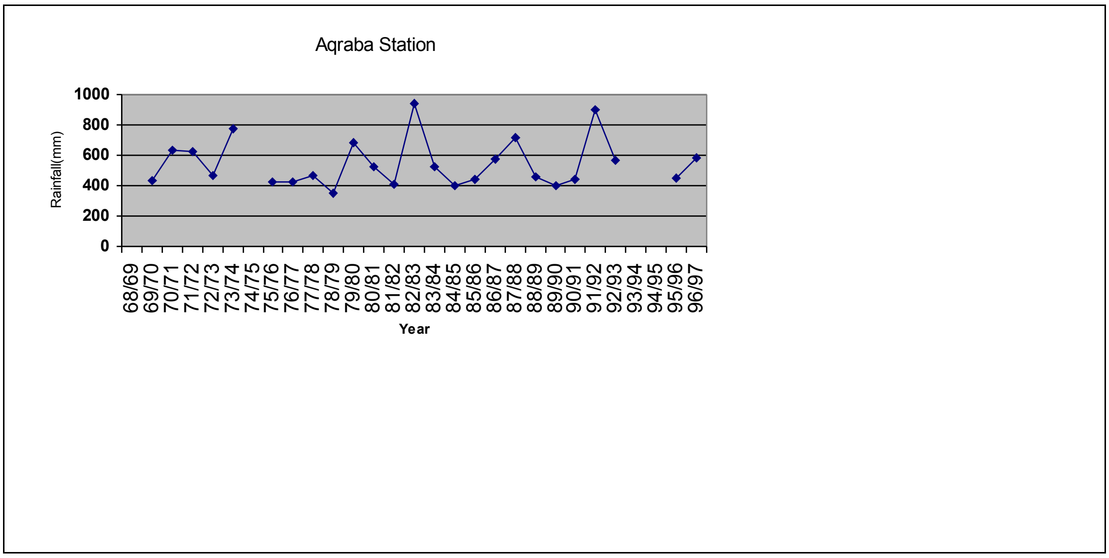

Burin station
Rainfall(mm)
1200
1000
800
600
400
200
0
68/69 69/70 70/71 71/72 72/73 73/74 74/75 75/76 76/77 77/78 78/79 79/80 80/81 81/82 82/83 83/84 84/85 85/86 86/87 87/88 88/89 89/90 90/91 91/92 92/93 93/94 94/95 95/96 96/97
Year

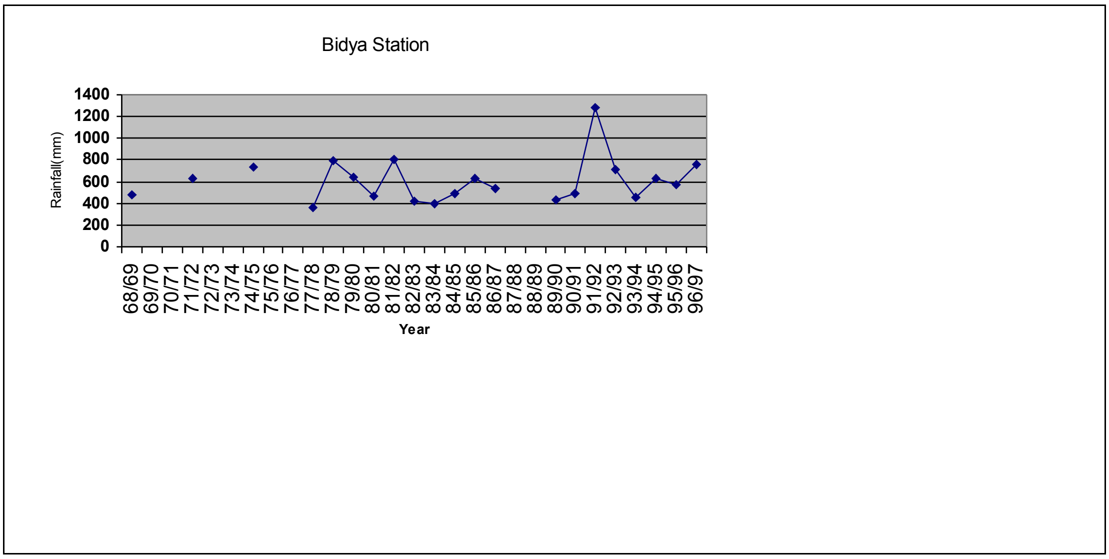

Jinsafut station
Rainfall(mm)
1400
1200
1000
800
600
400
200
0
68/69
69/70
70/71
71/72
72/73
73/74
74/75
75/76
76/77
77/78
78/79
79/80
80/81
81/82
82/83
83/84
84/85
85/86
86/87
87/88
88/89
89/90
90/91
91/92
92/93
93/94
94/95
95/96
96/97
Year

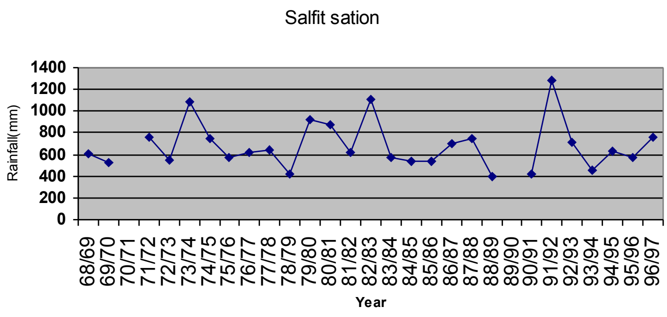

Azzun station
Rainfall(mm)
1400
1200
1000
800
600
400
200
0
68/69
69/70
70/71
71/72
72/73
73/74
74/75
75/76
76/77
77/78
78/79
79/80
80/81
81/82
82/83
83/84
84/85
85/86
86/87
87/88
88/89
89/90
90/91
91/92
92/93
93/94
94/95
95/96
96/97
Year

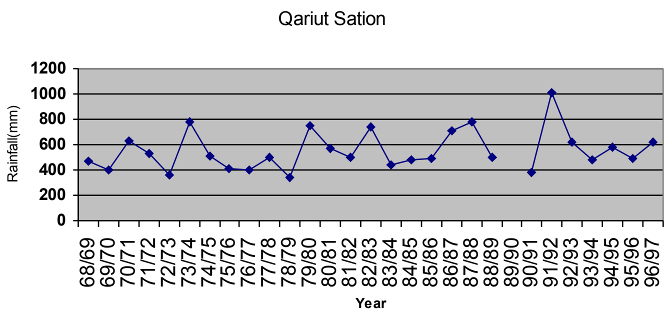

Awarta Station
Rainfall(mm)
1200
1000
800
600
400
200
0
68/69
69/70
70/71
71/72
72/73
73/74
74/75
75/76
76/77
77/78
78/79
79/80
80/81
81/82
82/83
83/84
84/85
85/86
86/87
87/88
88/89
89/90
90/91
91/92
92/93
93/94
94/95
95/96
96/97
Year

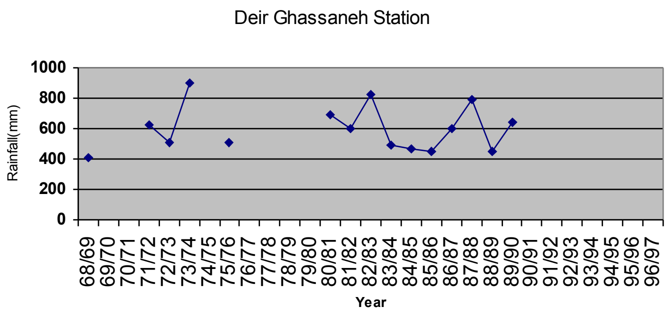

Deir Istya station
Rainfall(mm)
0
200
400
600
800
1000
1200
1400
68/69
69/70
70/71
71/72
72/73
73/74
74/75
75/76
76/77
77/78
78/79
79/80
80/81
81/82
82/83
83/84
84/85
85/86
86/87
87/88
88/89
89/90
90/91
91/92
92/93
93/94
94/95
95/96
96/97
Year

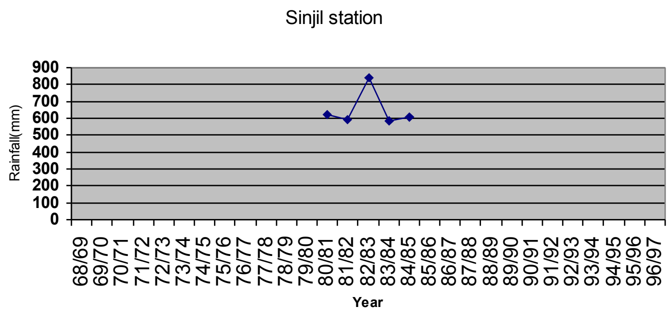

Aqraba Station
Rainfall(mm)
0
200
400
600
800
1000
68/69
69/70
70/71
71/72
72/73
73/74
74/75
75/76
76/77
77/78
78/79
79/80
80/81
81/82
82/83
83/84
84/85
85/86
86/87
87/88
88/89
89/90
90/91
91/92
92/93
93/94
94/95
95/96
96/97
Year

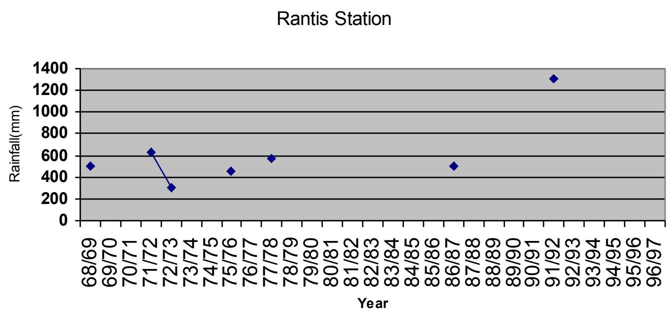

Bidya Station
Rainfall(mm)
0
200
400
600
800
1000
1200
1400
68/69
69/70
70/71
71/72
72/73
73/74
74/75
75/76
76/77
77/78
78/79
79/80
80/81
81/82
82/83
83/84
84/85
85/86
86/87
87/88
88/89
89/90
90/91
91/92
92/93
93/94
94/95
95/96
96/97
Year

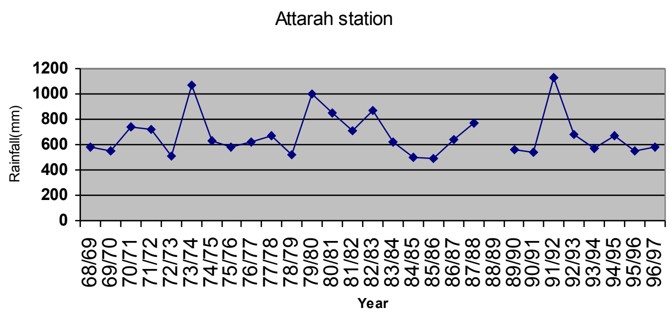

Salfit sation
Rainfall(mm)
1400
1200
1000
800
600
400
200
0
68/69
69/70
70/71
71/72
72/73
73/74
74/75
75/76
76/77
77/78
78/79
79/80
80/81
81/82
82/83
83/84
84/85
85/86
86/87
87/88
88/89
89/90
90/91
91/92
92/93
93/94
94/95
95/96
96/97
Year

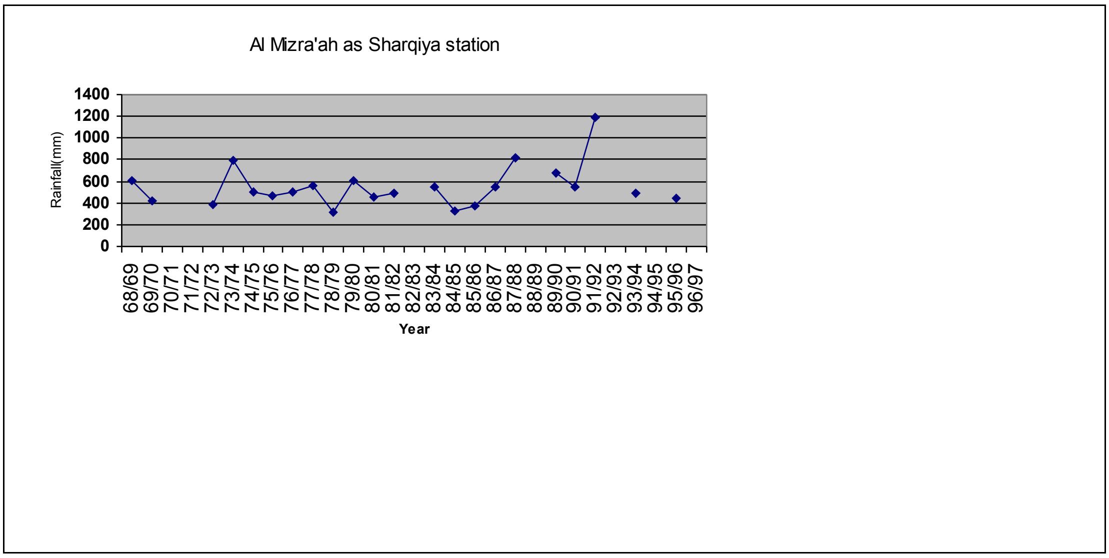

Qariut Sation
Rainfall(mm)
1200
1000
800
600
400
200
0
68/69
69/70
70/71
71/72
72/73
73/74
74/75
75/76
76/77
77/78
78/79
79/80
80/81
81/82
82/83
83/84
84/85
85/86
86/87
87/88
88/89
89/90
90/91
91/92
92/93
93/94
94/95
95/96
96/97
Year

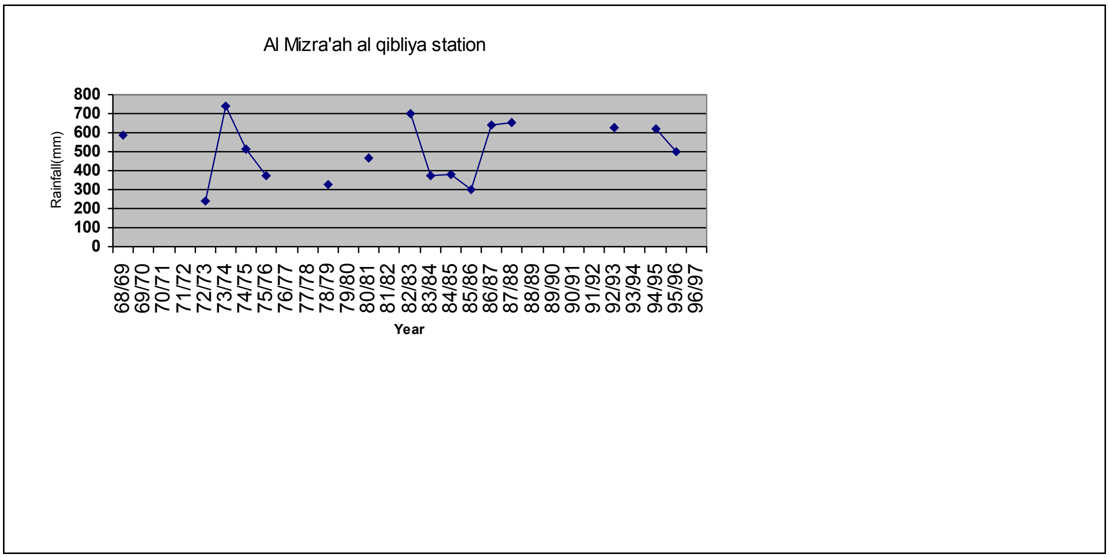

Deir Ghassaneh Station
Rainfall(mm)
1000
800
600
400
200
0
68/69
69/70
70/71
71/72
72/73
73/74
74/75
75/76
76/77
77/78
78/79
79/80
80/81
81/82
82/83
83/84
84/85
85/86
86/87
87/88
88/89
89/90
90/91
91/92
92/93
93/94
94/95
95/96
96/97
Year

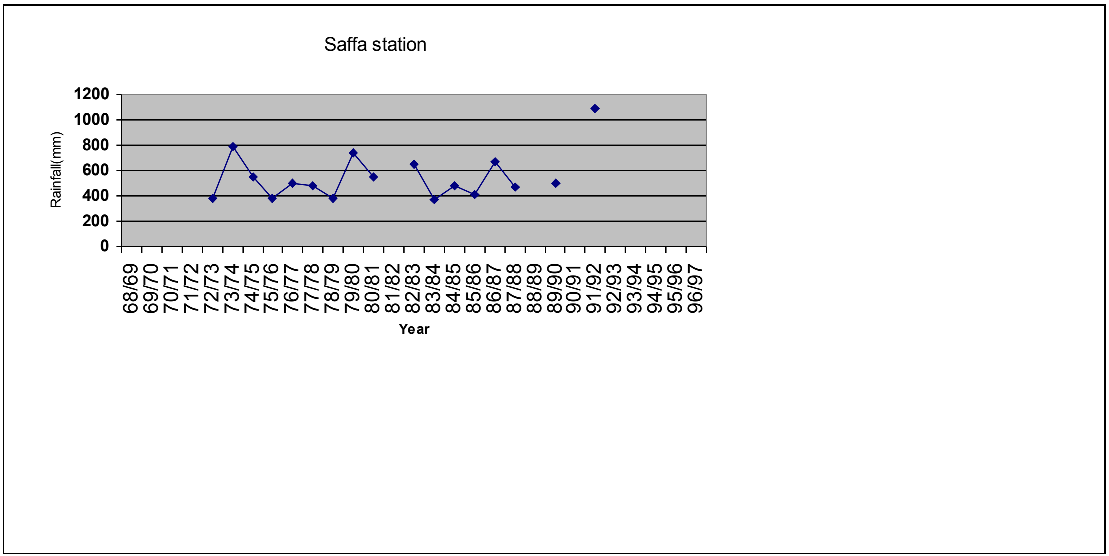

Sinjil station
Rainfall(mm)
Year

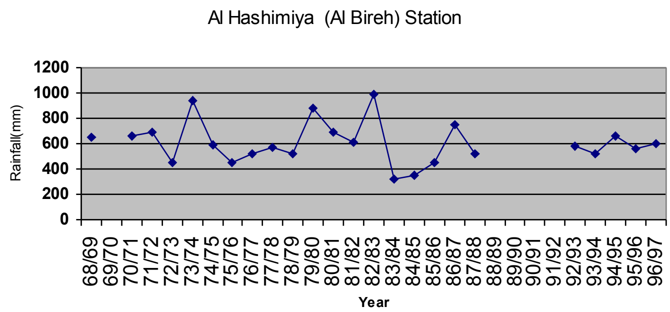

Rantis Station
Rainfall(mm)
Year

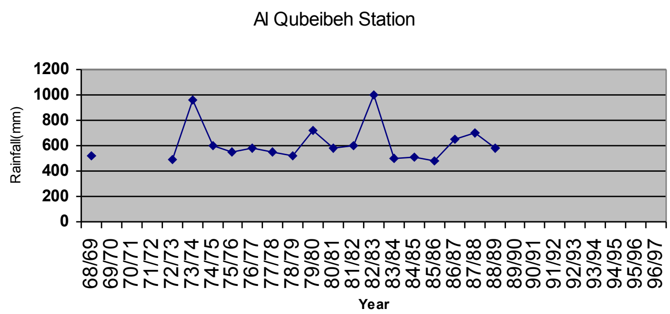

Attarah station
Rainfall(mm)
Year


Al Mizra'ah as Sharqiya station
Rainfall(mm)
1400
1200
1000
800
600
400
200
0
68/69 69/70 70/71 71/72 72/73 73/74 74/75 75/76 76/77 77/78 78/79 79/80 80/81 81/82 82/83 83/84 84/85 85/86 86/87 87/88 88/89 89/90 90/91 91/92 92/93 93/94 94/95 95/96 96/97
Year


Al Mizra'ah al qibliya station
Rainfall(mm)
800
700
600
500
400
300
200
100
0
68/69 69/70 70/71 71/72 72/73 73/74 74/75 75/76 76/77 77/78 78/79 79/80 80/81 81/82 82/83 83/84 84/85 85/86 86/87 87/88 88/89 89/90 90/91 91/92 92/93 93/94 94/95 95/96 96/97
Year


Saffa station
Rainfall(mm)
1200
1000
800
600
400
200
0
68/69 69/70 70/71 71/72 72/73 73/74 74/75 75/76 76/77 77/78 78/79 79/80 80/81 81/82 82/83 83/84 84/85 85/86 86/87 87/88 88/89 89/90 90/91 91/92 92/93 93/94 94/95 95/96 96/97
Year


Al Hashimiya (Al Bireh) Station
Rainfall(mm)
1200
1000
800
600
400
200
0
68/69 69/70 70/71 71/72 72/73 73/74 74/75 75/76 76/77 77/78 78/79 79/80 80/81 81/82 82/83 83/84 84/85 85/86 86/87 87/88 88/89 89/90 90/91 91/92 92/93 93/94 94/95 95/96 96/97
Year


Al Qubeibeh Station
Rainfall(mm)
1200
1000
800
600
400
200
0
68/69 69/70 70/71 71/72 72/73 73/74 74/75 75/76 76/77 77/78 78/79 79/80 80/81 81/82 82/83 83/84 84/85 85/86 86/87 87/88 88/89 89/90 90/91 91/92 92/93 93/94 94/95 95/96 96/97
Year

APPENDIX B: Montly Rainfall Data (Corrected and Estimated)
Bassam Al Shaka'ah Station

code	year	October	November	December	January	Febuary	March	April	May	Sum
0000001	1968	29.1	79.3	75.0	242.1	58.7	26.9	19.5	8.3	539
0000001	1969	12.1	40.3	193.0	198.0	38.6	163.2	15.9	0.7	662
0000001	1970	23.5*	33.1*	44.4*	132.3*	31.3*	141.7*	24.5*	0.0	431
0000001	1971	22.0*	5.0*	98.0*	78.9*	107.8*	97.7*	204.1*	0.0	614
0000001	1972	0.0*	61.0	185.1	128.3	151.3	84.4	29.0	0.0	639
0000001	1973	5.4	40.0*	59.3*	165.1	48.6*	105.7	29.0	6.0	459
0000001	1974	17.0	105.1	65.7	390.6	108.5	62.2*	43.6*	0.0*	793
0000001	1975	0.0	53.6	144.8	49.5	191.7	72.2	5.2	0.0	517
0000001	1976	0.7	49.2	99.0	62.1*	128.7	139.6	20.0	8.4	508
0000001	1977	39.8	81.2	41.5	121.5	65.3	115.8*	63.6*	0.7	529
0000001	1978	74.4	2.0	171.1	70.5	56.6	71.7	7.3	0.0	454
0000001	1979	26.4*	15.5*	110.9*	103.6*	25.8*	68.2*	11.0*	0.0	361
0000001	1980	46.0	197.8	224.2*	114.4	188.6	134.0*	20.0	0.0	925
0000001	1981	32.3	8.2	235.5	220.0	141.0	75.5	18.7*	0.0	731
0000001	1982	0.0	132.1	10.0	90.1	179.2	110.7*	0.0	0.0	522
0000001	1983	33.3*	106.9*	111.2*	195.4*	248.2*	161.3*	8.6*	0.0	865
0000001	1984	3.0	59.2	19.1	127.5	65.0	134.6	42.2	0.0	451
0000001	1985	20.3	22.2	46.1	33.9	227.5	14.9	52.0	0.0	417
0000001	1986	14.3	41.4	34.4	74.0	135.5	40.8	49.9	58.2	449
0000001	1987	48.3	207.3	119.0	104.5	47.0	90.9	2.0	0.0	619
0000001	1988	42.3	18.0	177.0	94.0*	245.0*	94.0*	13.0*	0.0*	683
0000001	1989	0.0	38.7*	219.8*	50.7*	33.3*	74.0*	0.0*	0.0*	416
0000001	1990	13.8*	71.4*	40.7*	124.2*	61.8*	79.5*	31.6*	0.0*	423
0000001	1991	9.5	29.5*	4.5*	180.0*	76.1*	81.5*	20.6*	0.0*	402
0000001	1992	10.8	145.0	370.0	257.3	420.7	78.0	4.0	25.7	1312
0000001	1993	0.0	68.9	321.1	131.2	102.3	55.2	4.3	17.0	700
0000001	1994	12.5	18.6	22.1	165.8	97.0*	131.8	17.2	0.0	465
0000001	1995	9.1*	252.9*	180.6*	35.5*	76.4*	45.3*	19.7*	0.0*	619
0000001	1996*	0.0*	93.0*	58.4*	207.7*	43.3*	155.8*	21.3*	0.0*	580
0000001	1997	31.8*	15.0*	95.0	154.8*	177.0	181.6*	22.2*	2.8*	680
Average		19.3	69.7	119.2	136.8	119.3	96.3	27.3	4.3	592

* means estimated

Bir Zeit Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0000003	1968	31.0	115.7	91.4	184.3	90.2	27.3	20.4	16.5	577
0000003	1969	31.0	28.8	169.9	174.0	43.1	191.8	18.2	0.0	657
0000003	1970	21.0	52.9	46.4	108.1	43.0	137.0	21.0	0.0	429
0000003	1971	14.0	26.8	132.4	75.3	95.6	63.9	206.4	0.0	614
0000003	1972	0.0	50.0	197.6	75.1	131.4	80.0	29.0	2.0	565
0000003	1973	0.0	50.0	62.0	151.7	50.0	86.5	11.0	4.0	415
0000003	1974	8.0	84.5	54.0	445.5	153.5	72.0	49.0	0.0	867
0000003	1975	0.0	102.0	159.5	66.0	226.0	71.0	10.0	0.0	635
0000003	1976	14.2	58.0	84.5	52.0	135.7	69.0	24.0	0.0	437
0000003	1977	12.0	57.2	52.5	157.0	37.0	143.5	59.5	0.5	519
0000003	1978	68.5	4.0	165.5	57.0	77.0	75.0	15.0	0.0	462
0000003	1979	62.0	14.0	133.0	103.0	38.0	76.0	6.0	0.0	432
0000003	1980	42.0	218.0	193.5	125.0	137.0	80.0	7.0	0.0	803
0000003	1981	15.0	4.5	206.0	207.0	85.0	122.7	11.0	0.0	651
0000003	1982	0.0	129.0	20.5	113.5	131.5	106.7	0.0	0.0	501
0000003	1983	0.6	119.6	87.6	159.9	221.8	155.3	6.5	4.0	755
0000003	1984	2.0	41.3	30.8	137.3	52.0	126.2	22.8	0.0	412
0000003	1985	25.0	51.4	62.1	70.2	300.3	21.3	40.9	2.0	573
0000003	1986	28.5	14.0	64.7	91.0	126.5	31.5	19.0	32.0	407
0000003	1987	41.5	219.0	84.5	98.0	27.5	101.0	3.0	0.0	575
0000003	1988	40.0	21.0	215.0	105.0	260.0	89.6	20.3	0.0	751
0000003	1989	0.0	87.8	161.3	72.7	73.5	100.5	0.0	0.0	496
0000003	1990	8.4	116.5	96.5	173.5	49.0	69.5	46.5	0.0	560
0000003	1991	13.0	37.9	6.0	164.5	90.5	105.1	15.1	0.0	432
0000003	1992	10.0	112.8	414.7	194.0	321.0	65.4	0.0	10.0	1128
0000003	1993	0.0	92.2	311.0	128.4	74.7	30.0	0.0	20.2	656
0000003	1994	17.7	27.0	24.4	169.0	101.5	101.2	11.0	0.0	452
0000003	1995	11.6	190.9	160.8	26.0	96.0	30.3	19.9	0.0	535
0000003	1996	0.0	75.0	31.4	162.8	34.9	130.6	20.4	0.0	455
0000003	1997	18.6	13.0	60.2	134.4	162.1	148.5	6.8	6.5	550
Average		17.9	73.8	119.3	132.7	115.5	90.3	24.0	3.3	577

* means estimated

Qalqilya Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0000004	1968	18.4	106.8	91.1	163.9	45.3	27.9	27.9	0.0	481
0000004	1969	45.6	87.5	238.0	262.0	23.4	140.9	24.3	0.0	822
0000004	1970	48.8	60.2	60.7	190.5	37.5	141.7	29.1	1.7	570
0000004	1971	6.9	16.4	98.3	114.6	107.4	38.9	153.8	0.0	536
0000004	1972	2.5	66.5	187.0	130.5	181.7	76.6	16.3	0.0	661
0000004	1973	3.9	65.7	93.6	122.4	23.3	78.0	13.0	17.0	417
0000004	1974	5.5	112.0	56.1	356.4	86.7	44.9	42.0	0.0	704
0000004	1975	0.0	110.1	180.3	67.8	204.2	60.2	0.9	0.0	624
0000004	1976	16.4	63.5*	116.8*	74.8	116.4	105.2	10.4	1.5	505
0000004	1977	41.0	81.5*	61.2	148.3	64.4	106.4	64.5	0.3	568
0000004	1978	133.2	0.0	235.1	74.7*	61.8	71.9	3.2	0.0	580
0000004	1979	13.4	10.2	137.9	102.8	24.5	61.9*	1.9	0.4	353
0000004	1980	39.3	144.5*	276.0	70.4	136.9	94.4	7.1	0.0	769
0000004	1981	34.1	3.1	167.6	218.6	87.1*	26.7	19.9*	0.0	557
0000004	1982	0.0	146.7	9.5	86.6*	111.8	114.2	2.0	3.7	474
0000004	1983	7.9*	97.5	100.2	189.6*	208.6*	121.1*	6.0*	0.0	731*
0000004	1984	0.0	52.1	23.8	123.9*	52.5	96.5*	50.0*	0.0	399
0000004	1985	32.5	29.0	49.3	56.1*	215.9*	4.8	41.6	0.0	429
0000004	1986	15.3*	25.0*	79.2	117.6*	166.2*	19.3	14.0	28.3	465
0000004	1987	59.4	239.0	137.4*	82.7	32.9*	64.1	0.0	0.0	615
0000004	1988	78.5	4.0	239.6	117.6	181.0	61.8	12.2	0.0	695
0000004	1989	15.5	79.7	196.5*	71.8*	49.5*	76.5*	0.0	0.0	489
0000004	1990	15.0*	89.3*	90.6*	133.4*	47.4*	61.3*	39.7*	0.0	477
0000004	1991	3.0	31.9*	17.1	184.5	101.7*	107.9	21.7	2.5	470
0000004	1992	9.3	151.6*	503.2	272.8	336.7	35.8	2.5	5.0	1317
0000004	1993	0.0	64.8	271.5	118.9	94.4	42.1	0.3	3.0	595
0000004	1994	13.3	20.3	14.0	188.4	77.0	102.0	0.3	0.9	416
0000004	1995	39.5	292.8	203.8	66.0*	127.4	37.5*	23.5	0.0	790
0000004	1996	0.0	103.6*	62.9*	284.8	22.5	194.0	9.4	0.0	677
0000004	1997	73.5	29.0	106.7	169.7*	274.0	237.2	8.5	3.0	902
Average		25.7	79.5	136.8	145.4	110.0	81.7	21.5	2.2	603

* means estimated

West Bank Water Department Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0000008	1968	25.5	125.6	104.7	211.6	95.4	33.4	23.2	0.0	619
0000008	1969	34.0	67.0	195.2	171.7	40.7	247.3	21.2	0.0	777
0000008	1970	31.6	56.1	65.1	149.7	55.5	167.7	21.6	0.0	547
0000008	1971	10.9	27.7	134.3	80.9	89.3	73.5	227.3	0.0	644
0000008	1972	0.0	74.7	242.4	78.7	137.8	102.0	28.1	0.0	664
0000008	1973	0.0	49.3	62.2	214.4	40.2	71.1	12.0	5.0	454
0000008	1974	9.0	96.8	65.7	454.4	165.2	67.1	65.2	0.0	923
0000008	1975	0.0	79.3	123.1	75.8	206.4	62.2	4.9	0.0	552
0000008	1976	0.0	42.7	97.3	86.4	149.1	102.1	19.8	3.2	501
0000008	1977	11.5	74.5	46.1*	161.3	58.2	120.6	90.2	0.7	563
0000008	1978	75.8	4.5*	199.0	51.6	77.1	116.2	22.8	0.0	547
0000008	1979	63.0	17.4	143.3	129.7	20.0	63.8	12.2	0.0	449
0000008	1980	48.0	157.0	206.0	165.3	170.9	128.5	13.5	0.0	889
0000008	1981	42.4	10.0	288.6	235.0	124.0	116.0	15.4	0.0	831
0000008	1982	0.0	129.8	31.3	164.9	206.4	159.0	9.8	0.0	701
0000008	1983	30.9	118.2	118.0	301.2	368.4	217.4	20.1	5.9	1180
0000008	1984	3.1	45.7	30.4	203.2	91.6	154.0	43.2	0.0	571
0000008	1985	47.1	50.0	53.5	66.7	316.1	34.5	46.5	1.2	616
0000008	1986	41.1	13.3	62.6	107.2	150.3	27.5	27.4	29.1	458
0000008	1987	37.3	291.5	109.8	161.8	52.2	110.0	5.8	0.0	768
0000008	1988	55.1	13.2	254.2	152.1	256.7	126.6	7.9	0.0	866
0000008	1989	9.1	77.1	238.9	92.8	62.8	127.1	0.0	0.0	608
0000008	1990	15.8	88.3	74.3	209.9	87.5	98.2	54.7	5.8	634
0000008	1991	0.0	49.4	9.1	207.9	96.0	133.9	14.8	7.5	519
0000008	1992	28.7	143.3	508.1	332.4	388.7	62.5	7.4	8.1	1479
0000008	1993	0.0	119.6	310.0	187.2	129.1	49.7	0.0	13.7	809
0000008	1994	8.9	39.3	33.0	202.7	141.9	142.2	23.3	7.1	598
0000008	1995	17.3	267.2	255.6	39.5	113.5	48.4	31.6	0.0	773
0000008	1996	0.6	92.2	45.2	199.2	58.8	217.6	26.4	0.0	640
0000008	1997	25.4	9.5	103.9*	194.2	185.2	167.6	17.1	9.5	712
Average		22.4	81.0	140.4	169.6	137.8	111.6	30.4	3.2	697

* means estimated

Qibya Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum

0000011	1968	27.70*	97.30	59.30	151.70	49.50	35.83*	33.80	0.00	455
0000011	1969	17.70	42.30*	187.00	171.70	29.50	172.50	8.54*	0.00	629
0000011	1970	35.90	52.50	59.10	157.00	49.30	155.50	29.00	0.00	538
0000011	1971	8.70	24.00	113.90	89.40	108.20	60.70	196.20	0.00	601
0000011	1972	0.00	72.50	203.50	85.70	147.50	89.00	12.80	0.00	611
0000011	1973	0.00	62.90	94.60	165.50	32.50	91.50	10.70	5.50	463
0000011	1974	15.40	98.90	45.90	480.50	110.20	70.80	50.40	0.00	872
0000011	1975	0.00	57.80	193.30	63.60	198.30	65.50	0.00	0.00	579
0000011	1976	0.00	35.40	95.90	66.20*	137.20*	84.00*	15.30	0.00	434
0000011	1977	1.20	63.30	57.70*	165.60	46.60	92.30	58.10	0.00	485
0000011	1978	94.70	0.00	206.60	61.10	77.50	59.50	21.20	0.00	521
0000011	1979	58.00	6.10	145.90	93.00	24.60	71.40	8.00	0.00	407
0000011	1980	48.10	144.40	231.40	75.80	117.40	76.90	7.50	0.00	701
0000011	1981	31.50	6.30*	188.80	205.90	73.10	39.20	18.90*	0.00	564
0000011	1982	0.00	132.50	23.20	115.40	170.10*	134.10	0.00	0.00	575
0000011	1983	15.60*	128.80	101.00	200.20	159.50	132.20*	11.30*	0.00	749
0000011	1984	0.00	51.40*	25.90	153.00*	35.42*	116.00*	29.65*	0.00	411
0000011	1985	42.50	37.20	30.14	55.98	211.53	20.21	45.44	0.00	443
0000011	1986	22.50	8.00	65.10	97.20	139.18*	24.72*	23.56*	45.00*	425
0000011	1987	44.00*	232.00	97.69*	113.90	30.77*	74.50*	0.00	0.00	593
0000011	1988	41.50	8.50	229.93	108.18	233.30	74.90	12.50	0.00	709
0000011	1989	0.00	63.00	185.00	61.00*	52.00*	89.80*	0.00	0.00	451
0000011	1990	8.30*	108.20	62.20*	178.20*	70.80*	77.50*	48.30*	0.00	553
0000011	1991	0.00	38.00	5.00	159.10	93.20	95.70*	19.50*	0.00	411
0000011	1992	15.00	116.50	415.50*	273.50	351.50	32.50	0.00	4.00*	1209
0000011	1993	0.00	62.00	371.00	116.50	103.50	52.00	0.00	14.20	719
0000011	1994	24.60	29.20	25.00	152.40	121.60	96.40	8.10	0.00	457
0000011	1995	22.00	228.30	190.00	53.00	119.90	39.80	24.10	0.00	677
0000011	1996	0.00	73.92	47.00	177.70	35.90	180.80	22.00	0.00	537
0000011	1997	26.50	14.00	85.00	140.10	167.10	165.30	11.10	13.60	623
Average		20.05	69.84	128.05	139.60	109.89	85.70	24.20	2.74	580

* means estimated

Kafr Qadum Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0241030	1968	16.5	101.5	79.8	161.9	52.8	18.4	19.1	0.0	450
0241030	1969	18.6	53.4	217.9	278.5	31.2	121.3	11.3	0.0	732

0241030	1970	34.2	53.8	59.0	153.6	50.0	192.8	18.7	0.0	562
0241030	1971	4.0	22.8	115.5	138.5	133.9	62.5	242.5	0.0	720
0241030	1972	0.0	56.1	174.6	166.3	167.3	80.0	19.0	0.0	663
0241030	1973	1.0	67.0	60.2	164.6	18.5	137.7	32.7	9.0*	491
0241030	1974	5.0	112.3*	61.9*	466.1	130.3	48.5	36.5	0.0	861
0241030	1975	0.0	47.0	216.0	71.8	202.5	62.0	0.0	0.0	599
0241030	1976	1.3	49.8	121.4*	125.8	146.7	155.4	15.8	2.5	619
0241030	1977	23.3	147.0	73.4	156.0	79.0	144.5	89.1	0.0	712
0241030	1978	63.0	0.0	282.0	86.9*	71.5	96.2	7.5	0.0	607
0241030	1979	39.5	15.0	146.5	125.2	14.8	80.5	3.0	0.0	424
0241030	1980	22.5	184.6	298.9	110.3	188.8	119.4*	16.7	0.0	941
0241030	1981	7.5	13.0	219.2	204.0	123.3*	62.0	19.0	0.0	648
0241030	1982	0.0	159.9	15.1	93.7	130.3	121.1*	0.0	0.0	520
0241030	1983	10.0	145.2*	127.4*	206.2	306.3	124.6	11.0*	0.0	931
0241030	1984	0.0	62.7*	20.2	127.3	97.0	118.9	29.9	0.0	456
0241030	1985	33.6*	25.7	47.0	60.0	207.8*	16.8	33.8	0.0	425
0241030	1986	28.0	26.5*	46.6	111.0	146.5	37.5	29.0	43.0*	468
0241030	1987	40.0	265.3	145.7	165.6	40.2	87.2	0.0	0.0	744
0241030	1988	66.6	9.9	210.1	132.4	237.9	74.7	8.0	0.0	740
0241030	1989	1.5	75.5*	171.8	83.6*	36.9	97.4*	0.0	0.0	467
0241030	1990	15.7	93.8	93.0	168.2*	49.9	66.5*	49.6	0.0	537
0241030	1991	7.9	13.6	8.8	184.8*	78.4	99.7	22.0	4.8	420
0241030	1992	10.2	157.1	485.5	239.9	338.4	54.8*	3.1	21.5	1311
0241030	1993	0.0	79.5	316.6	131.2	101.8	46.0*	1.8	10.1	687
0241030	1994	21.3	19.8	25.2	185.2	122.5	144.4	5.9	0.0	524
0241030	1995	23.7	301.2	161.0	76.6	114.5	33.6	37.9	0.0	749
0241030	1996	0.0	110.7	53.1	225.7	21.8	199.7	24.2	0.0	635
0241030	1997	53.3	12.6	72.0	175.8	264.9	234.1	19.4	41.9	874
Average		18.3	82.7	137.5	159.2	123.5	97.9	26.9	4.4	651

* means estimated

Hajja Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0241140	1968	17.3	105.4	83.2	187.3	45.4	18.4	18.2	0.0	475
0241140	1969	27.6	55.4	225.9	278.4	36.0	132.6	14.3	0.0	770
0241140	1970	39.3	52.8	46.0	148.6	58.6	179.2	37.3*	0.0	562
0241140	1971	5.6	22.5	118.7	127.8	109.3	87.4	214.0	0.0	685

0241140	1972	0.0	75.5	177.0	162.6	177.6*	89.0	19.0	0.0	701
0241140	1973	1.7	66.4	75.7	157.4	20.2	113.5	24.7	11.0*	471
0241140	1974	14.1	114.4	64.0	414.0	95.0	46.9	41.8	0.0	790
0241140	1975	0.0	61.5	193.0	69.6	197.8	62.6*	0.0	0.0	585
0241140	1976	0.0	42.0	114.1	107.6	138.1	150.5	15.0	0.0	567
0241140	1977	42.4	141.1	67.0	159.0	63.7	151.1	71.4	0.0	696
0241140	1978	60.3	0.0	234.4	90.8	54.8	77.6*	8.7	0.0	527
0241140	1979	32.4	6.8	135.8	134.1	17.3	81.5	9.3	0.0	417
0241140	1980	28.7	179.1	267.6	109.3	166.6	122.2	8.1	0.0	882
0241140	1981	0.4	13.0	214.0	243.9	132.2	45.0	16.4	0.0	665
0241140	1982	0.0	144.5*	14.0*	73.2	138.4	103.5	2.1*	0.0	476
0241140	1983	7.3*	142.2	128.0	243.2	258.9	128.0	7.3	0.0	915
0241140	1984	0.0	64.6	22.1	123.3	78.8	140.6	55.7	0.0	485
0241140	1985	31.3	31.6	52.6	58.3	204.2	12.5	37.1	0.0	428
0241140	1986	24.4	27.2	47.2	100.8	143.8	43.8	18.9	50.2	456
0241140	1987	43.4	284.8	165.8	130.9	45.9	89.1	2.7	0.0	763
0241140	1988	81.4	14.4	260.8	126.4	296.9	68.3	12.9	0.0	861
0241140	1989	10.2	74.4	237.5	77.4	33.7	99.1	0.0	0.0	532
0241140	1990	15.9	101.7	116.0	166.9	89.4	65.4	38.8	0.0	594
0241140	1991	0.0	17.9	10.3	175.8	122.7	101.6	32.0	0.0	460
0241140	1992	6.5*	174.6	508.1	262.7	313.2	51.5	4.0	18.5	1339
0241140	1993	0.0	74.3	300.1	119.0	96.2	65.1	0.0	8.5	663
0241140	1994	12.2*	27.7	27.2*	224.9	112.3	130.3	3.4	0.0	538
0241140	1995	17.8	250.9	153.6	68.6	97.1	29.7	29.6	0.0	647
0241140	1996	0.0	95.9	59.0	210.2	19.5	202.1	15.3	0.0	602
0241140	1997	43.0	20.4	74.6	172.2	230.8	251.3	16.8	28.5	838
Average		18.8	82.8	139.8	157.5	119.8	98.0	25.8	3.9	646

* means estimated

Burin Station

Code	Year	October	November	December	January	Febuary	March	April	May	Sum
0241170	1968	27.1*	87.2*	79.8	229.2	61.0	16.7	31.0	1.0	533
0241170	1969	6.5	62.7	238.0	167.6	44.5	149.8	17.0	0.0	686
0241170	1970	27.0	39.0	50.8	142.2	31.3	141.7	30.1	0.0	462
0241170	1971	6.5	9.8	102.0	86.7	107.8	97.7	204.1	0.0	615

0241170	1972	0.0	49.5	193.8*	108.0	141.8*	58.0	16.4	0.3	568
0241170	1973	2.6	32.1	60.8*	150.5*	50.5*	112.6*	8.5	5.0	423
0241170	1974	5.9	102.9*	50.5*	451.4*	128.8*	47.8	39.8	0.0	827
0241170	1975	0.0	57.4*	97.8	53.3*	178.1*	69.8	0.0	0.0	456
0241170	1976	0.0	40.8*	70.8	58.0*	123.5*	107.5	16.2	6.4	423
0241170	1977	11.8	71.8*	31.6*	118.3	79.2	118.6*	49.7	0.8	482
0241170	1978	69.0	0.0	204.6	72.2	69.5	88.6	14.5	0.0	518
0241170	1979	20.0*	3.0	112.4*	105.1*	25.7*	75.0	9.4	0.0	351
0241170	1980	49.5	180.6	245.0	108.4	154.9	141.8	4.9	0.0	885
0241170	1981	27.0	4.4	214.7	197.1	100.5	71.0	19.4	0.0	634
0241170	1982	0.0	107.8	15.2	92.9	131.2	119.8	0.0	0.0	467
0241170	1983	37.4	106.7	113.0	191.2	247.5	157.3	9.0	0.0	862
0241170	1984	0.0	56.5	22.5	136.6	64.0	144.4	41.9	0.0	466
0241170	1985	39.2*	34.6*	43.9*	59.0*	212.2*	35.6	33.3	39.2	497
0241170	1986	28.5	49.5	46.8	67.0	172.5	32.8	16.0	48.6	462
0241170	1987	41.4	193.6	87.2	118.2*	37.6	113.0	3.5	0.0	595
0241170	1988	68.1	14.5	159.4	104.0	245.0*	94.0*	11.5*	0.0	696
0241170	1989	0.0	43.1	235.3	51.2	34.7	74.0	0.0	0.0	438
0241170	1990	14.2	80.8	47.1	136.0	70.2	83.5	36.8	0.0	469
0241170	1991	2.0	28.0	8.4	182.8*	78.5*	89.2	31.0	0.0	420
0241170	1992	22.0	147.0	404.0	164.2	306.1	47.0	7.0	10.2*	1107
0241170	1993	0.0	67.3	297.8	118.1	109.2	53.5	1.0	9.3	656
0241170	1994	14.0	24.3	14.0	179.0	83.9	109.5	2.0	0.0	427
0241170	1995	20.2	258.7	159.0	54.5	67.0	54.5	25.5	0.0	639
0241170	1996	0.0	89.0	67.0	221.2	31.3	160.5	23.3	0.0	592
0241170	1997	30.5	6.6	91.6	161.3	195.9	160.6	17.0	21.0	685
Average		19.0	68.3	118.8	136.2	112.8	94.2	24.0	4.7	578

* means estimated

Jinsafut Station

Code	Year	October	November	December	January	Febuary	March	April	May	Sum
0241200	1968	17.3	108.1	77.3	189.9	51.4	24.4	30.4	0.0	499
0241200	1969	31.0	56.4*	216.7	290.1	47.3	143.4	22.6	0.0	807
0241200	1970	52.7	43.2	48.4	141.1	58.1	180.0	36.6*	1.6	562
0241200	1971	7.5	21.0	137.2	139.6	108.4	79.4	196.1	0.0	689

0241200	1972	0.0	95.2	205.4	169.5	182.3	90.4	28.1	0.0	771
0241200	1973	3.6	74.6	87.6	157.2	26.1	114.9	11.7	9.9	486
0241200	1974	12.7*	106.5	56.1	479.1	85.8	42.6	57.1	0.0	840
0241200	1975	0.0	61.7	219.9	76.9	241.9	62.9	1.0	0.0	664
0241200	1976	0.0	66.0	141.7	92.3	163.0	136.8	22.7	0.0	623
0241200	1977	53.1	146.8	71.8	162.4	68.4	150.2	80.3	1.6	735
0241200	1978	86.2	0.0	233.5	76.1	51.3	69.4	5.1	0.0	522
0241200	1979	32.7	12.7	138.9	130.4	24.2	81.8	6.6	0.0	427
0241200	1980	28.2	173.0	248.1	105.6	153.4	111.5	8.5	0.0	828
0241200	1981	8.2	5.6	240.1	239.9	98.7	51.3	21.5	0.0	665
0241200	1982	0.0	137.7	14.6	84.2	134.8	101.1	0.5	0.0	473
0241200	1983	7.3*	155.0	126.1	228.7	240.9	124.3	9.6	0.0	892
0241200	1984	0.0	57.5	23.4	131.8	56.1	130.0	60.8	0.0	460
0241200	1985	40.1	27.5	50.3	56.7*	217.9	17.6	27.5	0.0	438
0241200	1986	35.0	25.5	48.8	103.2	156.3	27.7	39.0	43.5	479
0241200	1987	46.0	315.0	163.0	127.0	39.8	88.7	3.0	0.0	782
0241200	1988	26.2	7.7	242.0	122.9*	280.6	86.1	16.0	0.0	782
0241200	1989	10.9	78.7	228.5	100.7	32.8	112.3	0.0	0.0	564
0241200	1990	28.0	108.4	114.6	172.0	68.7	69.4	48.4	0.0	610
0241200	1991	18.7	18.6	10.3	209.8	134.4	103.5*	20.0*	0.0	515
0241200	1992	5.0	147.7	460.7	219.7	290.6	56.7	3.5	18.8	1203
0241200	1993	0.0	71.7	412.3	145.0	97.1	71.5	0.6	4.0	802
0241200	1994	12.0	32.7	19.9	205.2	115.0	131.1	4.3	0.0	520
0241200	1995	34.3	288.0	167.6	54.0	107.0	41.2	31.5	0.0	724
0241200	1996	101.5	104.2*	67.5	241.1	37.1	237.9	25.1	0.0	814
0241200	1997	60.5	18.6	104.8	204.2	249.4	209.3	6.9	29.2	883
Average		25.3	85.5	145.9	161.9	120.6	98.2	27.5	3.6	669

* means estimated

Azzun Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0241250	1968	29.9*	92.9*	57.2	148.1	45.0*	24.2	28.1	0.0	425
0241250	1969	31.9	70.0	231.8	282.3	27.3	124.3	15.3	0.0	783
0241250	1970	56.9	45.7	51.8	154.3	52.2	145.0	40.3	0.0	546
0241250	1971	9.0	19.8*	109.0	124.7	96.9	49.1	142.1	0.2	551
0241250	1972	0.0	86.3	209.4*	129.9	163.5	72.8	24.2	0.0	686

0241250	1973	63.3	54.4*	69.8	137.2*	28.9*	87.2	6.3	9.3	456
0241250	1974	8.2*	88.7	42.4	446.5*	106.8*	51.9*	44.2	0.0	789
0241250	1975	0.0	73.2*	152.2	69.1	158.4	76.1*	0.0	0.0	529
0241250	1976	5.5	77.2	119.6	72.1	142.2*	99.0	12.4	0.0	528
0241250	1977	26.0	84.5	54.5	134.1	54.4	130.3*	54.1	2.5	540
0241250	1978	71.2	0.0	170.9	56.7	74.2	54.8	3.0	0.0	431
0241250	1979	33.8	2.0	139.5*	108.8	16.8	58.9	10.1*	0.0	370
0241250	1980	39.8	138.7	193.0	94.1*	153.1*	98.2	2.8	0.0	720
0241250	1981	5.7	5.0	203.3*	240.2*	103.0*	29.9	20.5	0.0	608
0241250	1982	0.0	134.7	17.4	85.6*	103.0	135.9*	2.2	0.0	479
0241250	1983	7.7*	146.8	104.8	185.2	207.6	109.9	3.6	1.2	767
0241250	1984	0.6	48.1	32.9*	129.7*	55.0	85.7	56.3	0.0	408
0241250	1985	52.6	18.9	45.8	61.5	209.5	16.4	31.6	0.0	436
0241250	1986	44.5	21.3	62.8	105.8*	157.1	25.0	19.2	42.2	478
0241250	1987	39.0	296.7	151.8	86.7	30.1	69.8	3.7	0.0	678
0241250	1988	66.5	9.2*	194.1	95.9	212.1	68.8*	9.3*	0.0	656
0241250	1989	0.0	60.0	212.7	73.2*	37.3*	90.3*	0.0	0.0	473
0241250	1990	18.1	92.7	86.0	133.2	58.0	61.9	39.2	0.0	489
0241250	1991	0.0	27.8*	3.0	213.4	104.0	105.5	35.9	4.9	495
0241250	1992	0.6	160.1	446.8	206.4*	326.4	53.6	8.0	16.5	1218
0241250	1993	0.0	92.7	359.4	140.5	111.2	63.4	0.9	11.1	779
0241250	1994	17.8	22.1	14.8	219.3	96.1	111.0*	4.5	0.8	486
0241250	1995	18.9	285.8	164.2	72.0	124.2	35.0	30.8	0.0	731
0241250	1996	0.0	112.2	72.7	263.4	35.9	209.7	22.9	0.0	717
0241250	1997	44.2	27.1	88.4	183.9	274.7	208.3	16.2	14.0	857
Average		23.1	79.8	128.7	148.5	112.2	85.1	22.9	3.4	604

* means estimated

Awarta Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0241270	1968	29.0	87.4	75.0	218.5	48.5	33.0	18.5	0.0	510
0241270	1969	30.0	40.3	211.4	199.1	40.0	159.4	16.0	0.0	696
0241270	1970	23.0	32.1	64.4	128.0	35.5	127.1	25.7	0.0	436
0241270	1971	6.5	5.6	101.0	78.9	111.2	87.6	212.6	0.0	603
0241270	1972	0.0	50.1	195.0	109.0	144.1	62.0	16.1	0.0	576
0241270	1973	0.0	37.5	62.8	146.4	53.5	111.6	16.1	4.0*	432

0241270	1974	10.8	103.3	51.1	455.4	130.6	62.2	37.2	0.0	851
0241270	1975	0.0	58.6	129.3	55.3	166.6*	74.4	4.5	0.0	489
0241270	1976	1.6	38.7	78.8	66.2	124.8	113.1	27.0	8.1	458
0241270	1977	99.1	38.4	33.0	108.4	44.8	122.6	63.3	0.5	510
0241270	1978	62.8	4.3	192.3	65.3	69.5	82.4	9.5	0.0	486
0241270	1979	28.7	14.8	109.8	109.2	25.6	65.5	13.5	0.5	368
0241270	1980	50.0	169.3	232.5	99.8	144.5	141.8	12.7	0.7	851
0241270	1981	27.8	2.0	202.0	185.6	101.3	71.0	22.6	0.0	612
0241270	1982	0.0	100.6	17.9	87.6	121.7	111.8	2.9	13.2	456
0241270	1983	21.0	106.7	113.0	191.2	253.0	157.3	19.5	4.0	866
0241270	1984	7.0	56.5	22.5	137.2	64.0	144.4	41.9	0.0	473
0241270	1985	20.1	31.3	50.6	49.9*	211.9*	11.9*	33.7*	0.0	409
0241270	1986	25.0	49.5	40.6	76.0	161.4	33.6	61.1	48.9	496
0241270	1987	30.5	246.4	109.8	120.1	36.3	97.0	6.3	0.0	646
0241270	1988	72.2	15.9	196.1	104.7*	243.0*	91.4*	11.5*	0.0	735
0241270	1989	13.0	38.0	208.6	45.5	34.1*	83.4*	0.0	0.0	423
0241270	1990	19.5	94.5	51.9	137.8	62.8	83.5	31.0	0.0	481
0241270	1991	2.0	28.0	5.6	175.4	80.0	80.0	41.0	2.5	414
0241270	1992	16.3	93.9	330.9	172.8	360.0	72.5	3.5	10.2	1060
0241270	1993	0.0	55.4	274.8	103.1	110.0	58.0	2.0	11.0	614
0241270	1994	11.3	17.6	19.0*	159.9	103.2	85.6	14.0	0.0	411
0241270	1995	8.5	291.7	184.4	40.5	78.1	47.5	20.0	1.0	672
0241270	1996	0.0	95.1	60.5	215.0	58.2	162.8	21.5	0.0	613
0241270	1997	36.0	12.0	83.5	159.8	239.0	186.5	26.5	3.0*	746
Average		21.7	67.2	116.9	133.4	115.2	94.0	27.7	3.6	580

* means estimated

Deir Istya Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0241300	1968	41.2	81.7	97.0	226.3	39.2	33.1	36.8	1.3	557
0241300	1969	45.0	59.5	222.4	245.0	28.9	183.5	17.4	0.0	802
0241300	1970	36.9	47.8	76.0	139.6	56.0	158.2	20.2	0.0	535
0241300	1971	17.8	17.0	113.3	108.4	148.7	59.0	231.8	0.0	696
0241300	1972	1.8	98.7	219.2	112.4	164.2	70.1	16.4	0.0	683
0241300	1973	1.4	65.0	62.1	141.1	36.2	115.3	22.0	7.0	450
0241300	1974	8.2	117.3	60.6	482.0	112.3	63.6	50.1	0.0	894
0241300	1975	0.0	58.4	203.4	66.9	272.2	85.4	1.4	0.0	688

0241300	1976	1.1	61.2	114.9	60.2	145.4	112.3	24.7	5.2	525
0241300	1977	42.5	115.3	59.6	135.8	62.1	141.8	83.9	1.8	643
0241300	1978	98.6	0.0	195.1	88.6	61.4	86.4	16.7	0.0	547
0241300	1979	30.4	4.0	131.4	107.6	20.2	79.2	14.5	0.0	387
0241300	1980	32.1	159.7	241.5	101.0	185.3	130.4	8.7	0.6	859
0241300	1981	26.3	9.7	194.1	253.8	122.5	68.2	21.1	0.0	696
0241300	1982	0.0	109.4	13.5	112.0	141.3	119.9	1.1	0.0	497
0241300	1983	7.3*	104.9	131.6	223.6	249.1	170.1	16.8	0.0	903
0241300	1984	2.4	66.4	41.0	137.3	48.8	125.4	52.9	0.0	474
0241300	1985	38.1	31.6	47.3	53.0	217.1	12.1	27.0	3.2	429
0241300	1986	44.0	34.8	56.3	76.9	182.2	33.4	11.4	55.1	494
0241300	1987	28.5	250.2	144.7	117.6	43.4	89.8	5.3	0.0	679
0241300	1988	116.7	10.5	251.9	98.3	265.5	74.8*	8.2	0.0	826
0241300	1989	2.0	59.1	187.3	81.3	43.7	100.2	40.0	0.0	514
0241300	1990	25.3	91.2	85.5	148.8	63.8	71.3	40.6	0.0	527
0241300	1991	3.3	27.9	7.9	254.1	85.9	124.6	35.5	5.4	545
0241300	1992	11.6	140.4	431.4	235.2	310.6*	53.6	7.4	12.1*	1202
0241300	1993	0.0	73.3	364.4	130.2	97.2	41.3	0.0	30.1	736
0241300	1994	15.3	31.5*	29.1	213.7	125.8	129.3	4.1	2.1	551
0241300	1995	53.4	247.2	178.1	43.8*	94.8*	31.0*	23*.0	0.0	671
0241300	1996	0.0	99.0	71.6	176.0	20.0	132.0	23.4*	0.0	522
0241300	1997	0.0	4.5	75.2*	132.0	251.0	242.5	33.0	0.0	738
Average		24.4	75.9	136.9	150.1	123.2	97.9	29.8	4.1	642

* means estimated

Aqraba Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0241350	1968	30.0*	86.4*	74.4*	189.2	41.8	11.3	41.8	24.7	500
0241350	1969	10.3	43.3	203.5	193.7	35.7	166.1	22.7	0.0	675
0241350	1970	25.0	27.1	46.4	132.3	31.3	143.0	44.5	0.0	450
0241350	1971	12.5	16.2	94.3	79.4	109.3	100.7	210.1	0.0	623
0241350	1972	0.0	69.5	185.0	91.6	124.8	69.3*	29.5	2.1	572
0241350	1973	1.5	45.4	45.4	181.9	28.3	119.8	23.5	11.1	457
0241350	1974	9.9*	100.0	45.5	421.1	115.9	62.3	48.0	0.0	803
0241350	1975	0.0	48.4	99.1	38.0	169.9	70.4	5.1	0.0	431

0241350	1976	3.2	56.9	68.5	45.8	115.4	111.0	9.5	3.8	414
0241350	1977	12.4	88.7	29.3*	102.7	48.5*	88.6	55.0	0.0	425
0241350	1978	52.2	12.5	183.5	55.8	61.5	94.8	10.3	0.0	471
0241350	1979	12.3	20.0	120.5	110.5*	26.8	86.5	9.9	0.0	386
0241350	1980	54.0	134.5	190.8	93.2	120.1	103.4	12.1*	0.0	708
0241350	1981	12.0	15.1	165.2	164.2	100.7	50.9	14.0	0.0	522
0241350	1982	0.0	108.2*	15.5*	90.1	133.8	106.4	6.0	0.0	460
0241350	1983	45.0	116.5	98.6	224.4	267.0	188.3	9.0	0.0	949
0241350	1984	0.0	36.0	24.9*	132.5	58.0	160.5	20.5	0.0	432
0241350	1985	30.7	29.9	46.7	44.5	201.0	21.0	27.5	0.0	401
0241350	1986	26.0	28.8	36.0	62.5	163.0	30.0	63.0	55.0	464
0241350	1987	20.1	223.3	104.5	103.8	30.0	87.5	0.0	0.0	569
0241350	1988	48.5	16.0	182.6	111.5	268.0	94.0	9.0	0.0	730
0241350	1989	12.5	50.0	206.0	90.5	28.9	74.0	0.0	0.0	462
0241350	1990	13.5	60.0	74.0	110.5	57.0	76.0*	28.5	0.0	420
0241350	1991	4.0	43.0	6.5*	239.0	67.0	92.1	11.9	0.0	464
0241350	1992	7.5	75.3	311.4	183.5	270.7	52.5	2.8	4.8	909
0241350	1993	0.0	64.2	289.9	87.9	93.8*	43.1	2.5	11.9	593
0241350	1994	13.8	14.0	18.0	179.9*	89.1*	105.9*	4.6	0.0	425
0241350	1995	8.8	256.5*	153.8	37.6*	66.7	30.8	17.5	0.0	572
0241350	1996	0.0	103.7	54.2*	159.8	32.1	122.1	20.2	0.0	492
0241350	1997	24.1	6.5	65.0	135.0	189.5	151.1	12.4	4.3	588
Average		16.3	66.5	108.0	129.7	104.9	90.4	25.7	3.9	546

* means estimated

Biddya Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0241400	1968	48.8	87.6*	93.5	191.2	40.4	24.9	32.4*	0.0	519
0241400	1969	36.9	76.8	249.2	243.6	33.1*	166.8	26.3	0.0	833
0241400	1970	45.0	46.6	54.1	149.1	54.1	150.5	30.5	0.0	530
0241400	1971	12.0	10.3	107.0	114.9	124.4	57.9	179.8	0.0	606
0241400	1972	0.2	90.7	220.9	129.8	179.1	79.7	15.0*	0.0	715
0241400	1973	3.0	63.7*	76.7*	135.3*	30.6*	104.9*	10.7*	10.0*	435
0241400	1974	7.2*	82.3*	56.1*	446.8	104.8	58.1	45.6*	0.0	801
0241400	1975	0.0	71.4	222.2	63.6	222.9*	93.2	0.0	0.0	673
0241400	1976	0.0	67.1	111.9	65.8	135.1	112.3	17.2	0.0	509

0241400	1977	28.0	117.7	56.8	135.6	56.0	117.9	70.1	0.0	582
0241400	1978	90.0	0.0	200.7	81.8	56.0	65.0	9.9*	0.0	503
0241400	1979	26.2	3.2	145.8	94.0	15.3	62.2	13.2	0.0	360
0241400	1980	31.0	147.6	250.6	92.7	143.2	127.1	4.9	0.0	797
0241400	1981	3.0	12.2	193.8	245.5	120.6	43.4	20.2	0.0	639
0241400	1982	0.0	152.3	7.5	100.6	103.6	124.8	3.7	3.0	496
0241400	1983	1.0	98.2	135.7	189.1	211.3	160.1	12.0	2.0	809
0241400	1984	2.5	72.7	43.1	138.6	50.6*	85.0	43.4	0.0	436
0241400	1985	28.8	28.5*	35.7	49.6	217.5*	10.0	43.0	0.0	413
0241400	1986	42.2	38.0	51.9	94.8	189.2	25.2	11.9	30.5	484
0241400	1987	39.7	252.7	117.1	95.5	38.6	81.9	5.3	0.0	631
0241400	1988	10.0	13.2	208.4	90.5	210.0	63.0	7.0	0.0	602
0241400	1989	0.0	61.7*	171.4*	67.9	45.9	94.0	0.0	0.0	441
0241400	1990	11.4	78.8	88.0	154.3*	48.7	87.6	36.7	2.8	508
0241400	1991	0.0	32.7*	7.5*	211.4*	101.3	138.9	29.7	0.0	522
0241400	1992	12.5	139.4	421.3	223.2	366.6	49.0	7.1*	3.3	1222
0241400	1993	0.0	63.3	385.6	103.3	89.0	32.9	0.0	3.2	677
0241400	1994	26.7	22.4	27.0	187.8	111.3	128.2*	6.4	0.0	510
0241400	1995	18.2	275.9	178.3	38.5	70.0	31.4	21.9	0.0	634
0241400	1996	0.0	101.4	52.7	212.7	26.1	141.9	31.0	0.0	566
0241400	1997	58.1	17.6	61.0	160.2	235.4	195.0	13.2	14.3	755
Average		19.4	77.5	134.4	143.6	114.4	90.4	24.9	2.3	607

* means estimated

Salfit Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0241470	1968	45.0*	114.9	70.2	169.1	54.9	13.9	35.3	46.4	550
0241470	1969	15.2	28.7	189.1	231.5*	40.5	190.2	19.7	0.0	715
0241470	1970	25.9	48.3*	48.5	117.8	42.1	152.1*	26.8	0.0	462
0241470	1971	6.0	18.3	111.3	110.7*	116.4	73.8	216.8	0.0	653
0241470	1972	0.0	64.1	218.9*	81.9	121.4	75.0	28.6	0.0	590
0241470	1973	2.8	40.3	61.0	123.5	44.7	107.6*	16.4	9.6	406
0241470	1974	9.0*	84.6	55.7	358.4	151.7	72.4	57.8	0.0	790
0241470	1975	0.0	94.8	185.7*	64.5*	176.8	84.3	5.3	0.0	611
0241470	1976	1.8	49.2	111.8*	45.3	114.3	101.4	13.9	0.0	438
0241470	1977	12.7	63.3	55.9*	147.1*	62.1*	119.7	50.0	0.8	512
0241470	1978	72.6	15.7	185.9	60.6	61.9	95.2	11.4	0.0	503

0241470	1979	15.1	6.7	140.0*	119.6*	24.7	82.8	6.2	0.0	395
0241470	1980	32.6	144.4	214.3	94.1	138.5	117.6	10.7	0.2	752
0241470	1981	16.5	9.6	171.5	194.6	94.0	80.8	9.7	0.0	577
0241470	1982	0.0	103.0	16.2	113.8	140.7	127.8	5.8	0.0	507
0241470	1983	6.4*	97.4	103.4	182.7	288.7	153.2	12.7	3.2	848
0241470	1984	2.4	39.3	33.1	145.3	50.3	138.9	31.7	0.0	441
0241470	1985	60.0	28.2	42.0	68.0	232.1	26.6	26.5	0.3	484
0241470	1986	42.7	27.1	40.9	92.9	178.1	26.2	35.9	37.1	481
0241470	1987	38.0	276.1	119.6	161.4	31.6	102.6	4.9	0.0	734
0241470	1988	70.5	13.0	195.7	138.4	239.9	94.2	14.1	0.0	766
0241470	1989	13.4*	63.5	182.9	74.4	49.1	104.2	0.0	0.0	487
0241470	1990	16.3	91.3	82.2	139.9	86.0	66.8	40.3	0.0	523
0241470	1991	0.0	32.8*	7.4	183.1	74.6	102.1	16.3	4.3	421
0241470	1992	18.2	91.1	345.0	222.1	267.6	49.3	9.1*	6.4	1009
0241470	1993	0.0	83.6	319.3	112.2	122.7*	31.8	1.2	16.5	687
0241470	1994	47.0	43.6	22.7	215.4	131.8*	114.0	16.2	0.0	591
0241470	1995	63.3	211.8	167.8	26.3	94.5	47.0	22.4	0.0	633
0241470	1996	0.0	83.5	58.5*	162.8	40.4	139.0	33.5	0.0	518
0241470	1997	32.2	9.3	54.0	141.7	194.2	159.9	9.9	2.2	603
Average		22.2	69.3	120.3	136.6	115.5	95.0	26.3	4.2	590

* means estimated

Qariut Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0241470	1968	47.0	114.9	70.2	169.1	54.9	13.9	35.3	46.4	552
0241470	1969	15.2	28.7	189.1	170.7	40.5	190.2	19.7	0.0	654
0241470	1970	25.9	32.2	48.5	117.8	42.1	124.5	26.8	0.0	418
0241470	1971	6.0	18.3	111.3	66.7	116.4	73.8	216.8	0.0	609
0241470	1972	0.0	64.1	163.1	81.9	121.4	75.0	28.6	0.0	534
0241470	1973	2.8	40.3	61.0	123.5	44.7	88.1	16.4	9.6	386
0241470	1974	10.8	84.6	55.7	358.4	151.7	72.4	57.8	0.0	791
0241470	1975	0.0	94.8	97.4	42.5	176.8	84.3	5.3	0.0	501
0241470	1976	1.8	49.2	83.7	45.3	114.3	101.4	13.9	0.0	410
0241470	1977	12.7	63.3	39.3	106.4	48.2	119.7	50.0	0.8	440
0241470	1978	72.6	15.7	185.9	60.6	61.9	95.2	11.4	0.0	503
0241470	1979	15.1	6.7	146.0	104.7	38.4	82.8	6.2	0.0	400

0241470	1980	32.6	144.4	214.3	94.1	138.5	117.6	10.7	0.2	752
0241470	1981	16.5	9.6	171.5	194.6	94.0	80.8	9.7	0.0	577
0241470	1982	0.0	103.0	16.2	113.8	140.7	127.8	5.8	0.0	507
0241470	1983	40.8	97.4	103.4	182.7	288.7	153.2	12.7	3.2	882
0241470	1984	2.4	39.3	33.1	145.3	50.3	138.9	31.7	0.0	441
0241470	1985	60.0	28.2	42.0	68.0	232.1	26.6	26.5	0.3	484
0241470	1986	42.7	27.1	40.9	92.9	178.1	26.2	35.9	37.1	481
0241470	1987	38.0	276.1	119.6	161.4	31.6	102.6	4.9	0.0	734
0241470	1988	70.5	19.0	195.7	138.4	239.9	94.2	14.1	0.0	772
0241470	1989	13.4	63.5	182.9	74.4	49.1	104.2	0.0	0.0	487
0241470	1990	12.2	85.4	85.0	111.8	54.6	60.1	33.7	0.0	443
0241470	1991	0.0	36.9	7.4	183.1	74.6	102.1	16.3	4.3	425
0241470	1992	18.2	91.1	345.0	222.1	267.6	49.3	9.1	6.4	1009
0241470	1993	0.0	83.6	319.3	112.2	59.1	31.8	1.2	16.5	624
0241470	1994	47.0	43.6	22.7	215.4	89.5	114.0	16.2	0.0	548
0241470	1995	63.3	211.8	167.8	26.3	94.5	47.0	22.4	0.0	633
0241470	1996	0.0	83.5	35.0	162.8	40.4	139.0	33.5	0.0	494
0241470	1997	32.2	9.3	54.0	141.7	194.2	159.9	9.9	2.2	603
Average		23.3	68.9	113.6	129.6	111.0	93.2	26.1	4.2	570

* means estimated

Deir Ghassaneh Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0241500	1968	43.0*	84.1*	103.6	185.1	77.6	41.0	14.4*	0.0	549
0241500	1969	33.0*	39.2	187.7	249.0	52.0	162.4	29.0	0.0	752
0241500	1970	46.3	45.1	50.7	178.1	37.5	133.8	45.4	0.0	537
0241500	1971	5.5	18.2	113.0	113.5	105.5	38.9	151.5	0.0	546
0241500	1972	0.0	84.7	224.4	95.4	157.5	88.7	18.0	0.0	669
0241500	1973	22.0	60.9	65.4*	194.0	37.5	118.2	25.4	15.5	539
0241500	1974	5.5	99.3	66.2	485.4	146.3	84.3	73.6	0.0	961
0241500	1975	0.0	73.2	203.0	57.6	247.6	82.4	0.0	0.0	664
0241500	1976	25.3	51.7	112.3	66.1	161.9	121.0	15.0	0.0	553
0241500	1977	8.0	82.0	69.8	163.9	46.3	107.4	87.5	0.0	565
0241500	1978	90.0	0.0	203.5	72.9	86.6	55.1	11.5	0.0	520
0241500	1979	31.6	16.5	145.1	87.2	19.0	62.6	11.1	0.0	373

0241500	1980	42.1*	155.8*	238.7*	95.5*	138.1*	112.9*	7.8*	0.0	791
0241500	1981	47.0	5.0	224.0	248.0	105.1	59.7	21.0	0.0	710
0241500	1982	0.0	131.4	18.4	139.5	179.5	138.5	0.0	0.0	607
0241500	1983	9.6*	104.2	122.4	220.0	237.0	138.6	11.0*	0.0	843
0241500	1984	3.0	45.0	48.4	179.0	47.0	131.5	40.5	0.0	494
0241500	1985	25.2	53.5	32.5	51.5	255.0	18.5*	19.0	0.0	455
0241500	1986	35.5	25.9	55.0	121.0	161.5	28.0	13.0	47.0	487
0241500	1987	3.0	311.0	113.9*	134.0	34.0	79.5	5.0	0.0	680
0241500	1988	49.5	9.5	256.0	115.0	283.6	54.3	20.7	0.0	789
0241500	1989	0.0	62.5	209.0	90.5	59.5	87.5	0.0	0.0	509
0241500	1990	31.6	118.0	97.5	199.5	54.5	89.0	46.5	0.0	637
0241500	1991	0.0	42.9	8.8*	193.0*	105.4*	140.3*	28.4*	0.0	519
0241500	1992	11.5	146.0	435.7	244.2	389.0	44.4	0.0	4.0	1275
0241500	1993	0.0	90.3	337.5*	102.1*	91.2*	33.8*	0.0	7.2*	662
0241500	1994	24.6	17.1	15.3	185.0	117.1	86.9	6.4	0.0	452
0241500	1995	19.4	275.3	164.3	55.0	97.0	27.7	19.2	0.0	658
0241500	1996	0.0	98.0	57.0	217.4	21.9	175.0	27.6	0.0	597
0241500	1997	27.8	18.6	46.0*	147.7	208.9	199.6*	11.3*	15.0*	675
Average		21.3	78.8	134.2	156.2	125.4	91.4	25.3	3.0	636

* means estimated

Sinjil Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0241550	1968	58.7*	137.9	105.6	214.8	87.0	26.7	23.2	13.6	668
0241550	1969	37.5	25.1	182.1	216.0	61.2	198.0	19.6	0.0	740
0241550	1970	25.0	41.3	56.4	101.4	42.7*	117.9	22.0	0.0	407
0241550	1971	4.6	10.1	112.0	77.9	132.4	68.3	231.1	0.0	636
0241550	1972	2.0	71.4	190.5	100.5	126.2*	67.6	19.5	0.0	578
0241550	1973	1.0	44.1	51.4	152.5*	39.1*	72.1	6.7	3.7	371
0241550	1974	7.8	98.2	51.8*	415.4	161.2	88.7	78.6	0.0	902
0241550	1975	0.0	117.7	145.1	61.0	203.4*	90.3	8.4	0.0	626
0241550	1976	4.0	67.7	102.5	63.9	161.7	135.5	19.9*	0.0	555
0241550	1977	17.0	64.3	46.5	153.2	59.7	121.4*	82.4	0.0	545
0241550	1978	78.5	12.1	236.6	93.1	77.7*	96.5*	22.6	0.0	617
0241550	1979	21.0	18.3	168.4	117.7	24.1*	96.5	11.0	0.0	457
0241550	1980	55.9	193.0	243.5	136.5	170.6	119.5	14.5	0.0	934

0241550	1981	16.5	8.5	182.0	196.0*	114.6	114.3	14.4	0.0	646
0241550	1982	0.0	126.9	18.8	140.3	140.7	156.3	9.7	3.0	596
0241550	1983	17.5	121.8	88.2	183.7	242.3	166.0	13.6	2.7	836
0241550	1984	3.0	63.4	29.0	197.8	85.5	152.4	32.2*	0.0	563
0241550	1985	62.3	37.2	63.8	63.1*	313.1	30.3	42.8	0.4	613
0241550	1986	31.3	23.0*	54.4*	93.5	145.8	13.8	33.2*	39.4*	434
0241550	1987	30.1	187.4	69.0	122.4*	27.7	92.3	3.9	0.0	533
0241550	1988	51.6	13.8	141.1	100.3	196.6	74.0	8.9	0.0	586
0241550	1989	0.0	88.2	183.7*	77.6*	66.2	65.5	40.6	0.0	522
0241550	1990	10.7	85.8	71.0	179.1	66.6	66.4	36.5	0.0	516
0241550	1991	23.0	30.0*	7.0	202.0*	12.0	120.1*	17.5*	0.0	412
0241550	1992	12.7*	100.2*	328.4	207.8*	351.9*	41.7	5.1*	5.0	1053
0241550	1993	0.0	84.5	302.0	139.9	72.2	32.6	1.2*	15.5*	648
0241550	1994	39.0	16.6	26.0	195.5	112.3	108.0	19.8	0.0	517
0241550	1995	14.0	231.5	190.4	29.5	96.2	42.3	24.2	0.0	628
0241550	1996	0.0	80.4	36.5*	164.0*	37.4*	138.9*	23.3*	0.0	480
0241550	1997	15.8	6.8	48.8	133.5	178.3	172.7	8.0	3.0	567
Average		21.3	73.6	117.8	144.3	120.2	96.2	29.8	2.9	606

* means estimated

Rantis Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0241599	1968	33.3	94.2*	72.6*	157.1	52.7	17.8	27.5	4.0	459
0241599	1969	47.9	50.3	182.4	223.0	35.4	138.4	7.2	0.0	685
0241599	1970	47.3	44.0	50.7	173.4	37.5	133.8	44.2	0.0	531
0241599	1971	5.4	20.2	115.0	110.5	105.5	53.8	151.5	0.0	562
0241599	1972	0.0	97.8	196.2	111.0	156.8	88.3*	12.3	0.0	662
0241599	1973	0.0	64.1*	77.4*	144.0	61.5	85.0	11.1*	8.0*	451
0241599	1974	11.8	87.2	50.1	458.3	120.2	63.8	45.9	0.0	837
0241599	1975	0.0	56.3	195.3	62.2	192.8	65.0	0.0	0.0	572
0241599	1976	0.1	42.2*	119.6	68.0	140.7	104.1	14.6	0.0	489
0241599	1977	5.5	60.2	58.7	144.3	42.3	94.6	56.3	0.0	462
0241599	1978	127.3	0.0	216.4	65.8*	68.3	70.5	19.1*	0.0	567
0241599	1979	30.0	15.5*	155.3	83.0	25.0*	68.4*	10.0*	0.0	387
0241599	1980	59.0	153.5	230.9*	73.7*	118.7*	78.8*	6.5*	0.0	721
0241599	1981	28.5	8.8	198.8	242.7	81.8	44.8	23.0	0.0	628
0241599	1982	0.0	107.2	19.5	118.2	163.4	128.5	0.0	0.0	537

0241599	1983	8.0*	107.2*	107.8*	203.8	187.2	138.9*	12.0*	0.0	765
0241599	1984	0.0	46.1	31.4	165.8	47.1	122.5	38.9	0.0	452
0241599	1985	26.3	38.7	34.5	49.6	239.8	24.1	41.6	0.0	455
0241599	1986	26.0	13.2	54.0	81.9	161.5	24.6	17.0	45.7	424
0241599	1987	38.5	254.0*	122.8*	117.8*	31.9*	76.5*	0.0	0.0	642
0241599	1988	50.6	8.6	249.6	111.4	262.6	80.0	9.0	0.0	772
0241599	1989	0.0	62.5	166.4	81.0	57.5	82.0	0.0	0.0	449
0241599	1990	8.4	93.9	65.6	167.3	49.0	69.5	44.8	0.0	498
0241599	1991	0.0	38.8	7.1	137.9	90.0	113.7	20.9	0.0	408
0241599	1992	5.0	145.2	441.7	275.9	433.0	62.0	10.4	3.5	1377
0241599	1993	0.0	70.0	310.0	89.3	88.0	44.7	0.0	15.0	617
0241599	1994	13.3	20.3	14.0	188.4	118.3	98.0	9.0	0.0	461
0241599	1995	27.6	274.8	203.8	56.0	119.5	48.8	9.5	0.0	740
0241599	1996	0.0	75.2	47.0	193.4	35.0	175.0	9.1	0.0	535
0241599	1997	26.8	16.8	75.6	146.9	208.5	230.7	12.3	5.0	723
Average		20.9	72.2	129.0	143.4	117.7	87.6	22.1	2.7	596

* means estimated

Attarah Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0241630	1968	52.5	117.3	124.7	158.2	95.6	33.0	26.5	5.0	613
0241630	1969	7.5	51.6	201.4	209.7	57.1	248.1	24.3	0.0	800
0241630	1970	32.0	56.8	66.2	152.0	56.1	169.5	21.8	0.0	554
0241630	1971	9.5	20.8	120.4	79.1*	157.7	83.6	253.2	0.0	724
0241630	1972	1.0	91.9	246.9	106.4	150.9	99.3	36.5	0.0	733
0241630	1973	0.0	49.6	67.3	204.3	43.4	122.0	23.2	9.2	519
0241630	1974	5.7	103.2	77.7	437.1	186.7	68.8*	63.4*	0.0	943
0241630	1975	0.0	95.8	177.2	61.5	239.2	69.4	0.0	0.0	643
0241630	1976	14.2	65.1	112.9	74.6	154.5	103.3*	25.8	0.0	550
0241630	1977	11.1	61.6	55.2	172.5	64.9	123.2*	85.0	0.0	574
0241630	1978	96.1	3.2	224.7	93.8	73.3*	120.6	28.4	0.0	640
0241630	1979	60.5	15.0	153.2	145.3	29.8	72.4*	14.3	0.0	490
0241630	1980	31.8	165.0*	208.2*	136.9	189.2	113.0	14.3	0.0	858
0241630	1981	24.2	8.0	290.6	278.0	115.2*	106.0	15.8*	0.0	838
0241630	1982	0.0	160.7	33.0	121.5*	194.9	147.4	2.5	0.0	660

0241630	1983	6.0	98.2	119.0	195.0	285.8	192.3	7.6	0.0	904
0241630	1984	9.0	58.3	52.1	217.0	81.3	142.7	32.0*	0.0	592
0241630	1985	30.0	52.5	51.3	70.0	246.8	17.0	37.0	0.0	505
0241630	1986	17.0	16.0	82.0	98.0	157.7*	37.0	34.0	36.3*	478
0241630	1987	42.0	271.0	110.9*	116.0	48.0	110.5	0.0	0.0	698
0241630	1988	29.0	20.0	267.0	138.0	241.0	78.0	8.1*	0.0	781
0241630	1989	0.0	69.1	197.1	85.6	44.8	94.2	0.0	0.0	491
0241630	1990	8.2*	107.0	88.0	162.0	105.0	81.0	42.0	0.0	593
0241630	1991	0.0	25.0	11.0	202.0	92.1*	147.0	27.0	0.0	504
0241630	1992	11.0	131.1*	370.0	228.0	361.0	73.0	0.0	6.6*	1181
0241630	1993	0.0	78.0	249.0	137.0	114.0*	57.0	0.0	8.5*	644
0241630	1994	15.2*	32.0	27.0	205.0	126.9*	126.0	10.0*	0.0	542
0241630	1995	18.0	241.0	221.0	38.0	105.0*	51.0	19.0	0.0	693
0241630	1996	0.0	88.8*	44.0	191.0	54.1*	178.0	8.0	0.0	564
0241630	1997	9.0	6.0*	77.0	129.0	189.0	149.0	6.0	6.5*	572
Average		18.0	78.7	137.5	154.8	135.4	107.1	28.9	2.4	663

* means estimated

Al Mazra'ah Al Sharqiyya Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0241650	1968	54.5	116.1	116.4	164.4	82.0*	40.3*	19.6	23.5	617
0241650	1969	26.3	30.7	144.8	163.2	48.3	194.2	16.6	0.2	624
0241650	1970	22.6	53.0	53.4*	110.3	43.2	150.2	21.0	0.0	454
0241650	1971	21.1*	6.3*	111.3*	76.9*	116.4*	72.1*	225.8*	0.0	630
0241650	1972	0.0*	51.4*	180.5*	75.0*	129.1*	77.6*	25.2*	0.0	539
0241650	1973	0.0	39.8	47.9	162.5	32.3	82.3	20.0	3.4	388
0241650	1974	5.0	84.4	48.3	431.4	134.0	81.9	55.0	0.2	840
0241650	1975	0.0	74.0	139.5*	44.1	220.3	67.1	7.2	0.0	552
0241650	1976	0.6	70.4	82.9	67.3	116.4	109.6	27.5	1.5	476
0241650	1977	9.1	60.0*	43.2	147.8	49.7	129.8	73.0	2.0	515
0241650	1978	75.9	10.1	188.8	68.6	90.4*	101.8	27.1	0.0	563
0241650	1979	43.6	5.6	139.8	99.8	20.8	79.0	11.7	0.0	400
0241650	1980	37.3	173.8	217.5	127.5*	159.7*	112.6*	14.0	0.0	842
0241650	1981	14.0	5.7	227.3	195.0	80.0	111.8	16.4	0.0	650
0241650	1982	0.0	142.7	88.5	137.1	160.2	115.2	10.5	0.0	654
0241650	1983	5.0	93.5	84.0	203.5	265.5	146.6	6.4	0.0	805

0241650	1984	7.0	55.0	48.7	160.8	70.0	142.6	35.7*	0.0	520
0241650	1985	34.6	26.0	59.8*	65.1*	295.5*	21.0	27.9	0.0	530
0241650	1986	17.0	21.7	63.1	75.0	143.0*	18.5	22.0*	40.8	401
0241650	1987	31.0	231.2	70.7	96.0	30.9	82.8	1.7	0.0	544
0241650	1988	57.1	18.0*	160.7	107.4*	214.4*	80.0*	12.6*	0.0	650
0241650	1989	0.0	71.0*	201.0	83.5*	48.2*	98.8*	0.0	0.0	502
0241650	1990	11.0*	104.0	76.8	189.5*	61.6*	86.9	43.2	4.8	578
0241650	1991	5.5	47.0	10.5	230.0	92.0	137.5	18.5	1.1	542
0241650	1992	10.0	105.0	417.5	199.0	346.9*	53.3*	12.5	10.0	1154
0241650	1993	0.0	101.5	260.0	156.0	87.3	27.1	0.0	5.4	637
0241650	1994	31.8	21.7	26.8	187.5	102.3	106.0	13.0	0.0	489
0241650	1995	22.0	183.5	151.3	28.4*	95.9*	27.0	21.1*	0.0	529
0241650	1996	0.0	62.5	40.9	143.8	40.5	138.0*	19.5	0.0	445
0241650	1997	18.6	9.6	71.1	113.9	158.3	166.3*	9.9*	2.3*	550
Average		18.7	69.2	119.1	137.0	117.8	95.3	27.2	3.2	587

* means estimated

Al mazra'ah Al Qibliya Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0241900	1968	28.5	108.5	115.6	192.5	87.4	52.6	12.3	1.9	599
0241900	1969	10.4	51.7*	187.8	194.0	40.3	183.9*	17.7	0.0	686
0241900	1970	31.6	56.3	65.0	150.0	52.5	168.2	21.7	0.0	545
0241900	1971	8.6	18.8	124.6	85.1	139.8	85.0	239.6	0.0	702
0241900	1972	0.0	70.4	195.2	67.0	143.2	101.0	22.8	0.0	600
0241900	1973	0.0	62.8*	60.3	159.6	59.3	63.7	5.2	3.0	414
0241900	1974	10.3	80.4*	42.2	417.6	104.8	84.2	51.2*	0.0	791
0241900	1975	0.0	89.6	150.5	61.4	203.3	61.3	0.0	0.0	566
0241900	1976	0.0	42.3	92.4	65.3*	127.2	81.7	15.5*	0.0	424
0241900	1977	4.0*	81.2	69.0	148.6	58.5	99.0*	63.8*	0.0	524
0241900	1978	96.1	0.0	222.8	53.0	66.1*	64.3*	14.0*	0.0	516
0241900	1979	68.0	8.4*	158.2	121.1	25.3*	77.0*	9.0*	0.0	467
0241900	1980	54.6	166.0	196.0	97.7*	146.4	75.9*	10.4*	0.0	747
0241900	1981	12.0	7.6*	226.8	219.0	102.9*	39.2*	14.8*	0.0	622
0241900	1982	0.0	120.1*	27.3	99.0	191.2*	147.2*	0.0	3.5	588
0241900	1983	9.0	103.0	94.0	205.0	180.0	103.0	8.0	0.0	702
0241900	1984	4.5	56.8*	26.5	136.5	57.0	118.0	30.0	0.0	429
0241900	1985	25.0	45.7*	30.0	61.0	198.0	25.0	38.0	0.0	423

0241900	1986	28.0*	6.2*	57.0	98.1*	125.5	25.0	26.0	40.0*	406
0241900	1987	39.0	247.0	96.5	129.0	40.0	82.5	1.5	0.0	636
0241900	1988	36.0	11.0	238.0	127.0	188.5	61.5	8.1	0.0	670
0241900	1989	15.5	73.3*	180.9*	85.1*	45.0*	93.3*	0.0	0.0	493
0241900	1990	8.2*	93.7*	45.0*	162.6*	86.5*	81.0*	44.7*	0.0	522
0241900	1991	0.0	41.2	8.0	100.6	107.9	120.2	22.7	0.0	401
0241900	1992	8.0	132.5	342.3	192.4	283.8	50.0	0.0	4.9	1014
0241900	1993	5.0	98.4	246.0	132.2	110.2	28.7	0.0	6.3	627
0241900	1994	25.0	17.4	21.0	142.5	146.4	116.7	9.6	0.0	479
0241900	1995	10.7	251.2	185.2	42.2*	97.0	31.0	27.3	0.0	645
0241900	1996	0.0	70.4	57.2*	169.0	48.5	132.4	12.3*	0.0	490
0241900	1997	24.5	9.0	71.4	166.6	153.1*	155.8*	6.8	7.1*	594
Average		18.7	74.0	121.1	136.0	113.9	86.9	24.4	2.2	577

* means estimated

Saffa Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0242151	1968	25.0*	84.9*	81.8*	168.1*	52.8	43.1	21.3	0.0	477
0242151	1969	35.0	59.7*	156.1	163.7	33.8*	192.1	19.1	0.0	659
0242151	1970	30.7	55.6	62.2	146.2	54.4	164.9	21.5	0.0	536
0242151	1971	11.3	26.8	135.1	75.3	95.6	63.9	206.4	0.0	614
0242151	1972	0.0	71.6	198.6	68.2	145.7	101.0	22.8	0.0	608
0242151	1973	1.4	62.7	68.0	179.6	43.2*	80.4*	5.0	5.0*	445
0242151	1974	16.5	67.1	45.3	440.0	128.9	76.2*	51.8	0.0	826
0242151	1975	0.0	101.5	153.9	62.7*	163.4	51.9	0.0	0.0	533
0242151	1976	4.4	38.2	79.2	89.9*	130.5	71.6*	16.4	0.0	430
0242151	1977	6.5	67.8	47.0	136.5	51.6	117.5	68.7	0.0	496
0242151	1978	79.1	0.4	204.2	50.6	59.2	74.7	11.1	0.0	479
0242151	1979	38.1*	9.8*	144.7	112.9	28.4	85.7	14.3	0.0	434
0242151	1980	26.9	185.2	216.3	113.3	112.6	77.9	7.6	0.0	740
0242151	1981	26.8	2.8	154.9	211.2*	103.7*	39.9*	14.5*	0.0	554
0242151	1982	0.0	111.2	16.1	108.8*	181.9*	146.6*	0.0*	0.0	565
0242151	1983	14.5*	89.7	96.1	227.7	232.4	124.4*	12.5*	0.0	797
0242151	1984	3.0	49.3	42.2	128.5*	36.5*	99.1*	32.2	0.0	391
0242151	1985	66.0	44.4	37.7	56.7	220.9	22.0	50.5	0.0	498
0242151	1986	36.3	15.4	53.3	98.7	140.7	26.7	24.2	36.2	431
0242151	1987	61.2	296.0	109.3	99.6	29.0	75.0	1.6	0.0	672

0242151	1988	69.3	8.3	232.8	111.9	215.5*	98.3*	9.1*	0.0	745
0242151	1989	0.0	80.7	178.0	75.3*	51.6*	94.3*	0.0	0.0	480
0242151	1990	26.9	83.3	59.6	166.9	50.9	66.5	45.7	0.0	500
0242151	1991	0.0	43.9	6.0*	136.0*	95.5*	104.0*	22.0*	0.0	407
0242151	1992	3.5	152.8	406.5	217.5	315.1	45.0*	0.0	6.0	1146
0242151	1993	0.0	74.0*	262.2	128.2	108.4	35.9*	0.0	20.2*	629
0242151	1994	22.0	23.0	23.0	143.5	122.7	93.6	8.5	0.0	436
0242151	1995	23.0	206.5	185.0	34.4	114.5	43.5	28.6	0.0	636
0242151	1996	0.0	85.0	64.5	175.5*	35.9*	186.1*	23.0*	0.0	570
0242151	1997	32.5	11.0	77.0	138.0	143.0	148.5	12.6	7.8	570
Average		22.0	73.6	119.9	135.5	109.9	88.3	25.0	2.5	577

* means estimated

Al Hashimiyya (Al Bireh) Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0242230	1968	24.4	126.9	110.6	216.7	91.0	35.4	22.6	22.5	650
0242230	1969	32.7	35.4*	192.5	164.3	43.0	243.8	19.9	0.0	732
0242230	1970	84.2	38.3	53.2	147.4	62.8	123.0	36.0	0.0	545
0242230	1971	12.0	31.0	135.0	88.0	97.0	77.0	235.0	0.0	675
0242230	1972	0.0	82.4	265.0	81.0	133.5	113.0	27.4	0.0	702
0242230	1973	0.8	46.6	59.7	225.3	40.5	73.3	7.7	9.0*	463
0242230	1974	20.0	98.5	68.7	449.2	165.4	70.2	64.5	0.0	937
0242230	1975	0.0	77.3	108.9	95.4	230.3	72.0	8.0	0.0	592
0242230	1976	1.2	40.9	99.4	82.9	127.5	109.5	16.5	0.0	478
0242230	1977	6.3	61.2	44.5	146.0	51.5	136.5	89.4	0.0	535
0242230	1978	87.1	15.5	228.5	51.3	74.5	96.6	18.0	0.0	571
0242230	1979	61.8	15.8*	156.0	148.5	31.2	88.5	12.0	0.0	514
0242230	1980	41.8	216.4	208.0	140.5	153.6	117.5	9.5	0.0	887
0242230	1981	17.1*	4.5*	253.5	180.0	111.5	103.5	12.5	0.0	683
0242230	1982	0.0	118.7	28.2	105.0*	168.0	137.0	4.0	0.0	561
0242230	1983	22.0	101.5	105.5	253.0	310.0	176.0	17.5	3.5	989
0242230	1984	0.0	36.0	32.5*	169.9*	65.6*	119.5*	22.0	0.0	446
0242230	1985	33.0	21.0	46.4*	36.8	283.3*	24.7	22.0	0.0	467
0242230	1986	28.0	5.0	54.0	86.0	158.0	28.0	49.0	39.0	447
0242230	1987	45.0	278.0	104.5	146.0	50.5	115.0	5.5	0.0	745
0242230	1988	38.5	14.5	238.0	140.0	205.0	71.0	7.5*	0.0	715

0242230	1989	0.0*	48.5*	182.7*	77.5*	51.0*	96.0*	0.0	0.0	456
0242230	1990	7.5*	85.2*	68.7*	191.6*	83.2*	85.6*	52.1*	0.0	574
0242230	1991	0.0*	30.2*	4.0*	124.0*	138.0*	120.2*	13.8*	0.0	430
0242230	1992	25.0	138.0	470.0	317.0	364.4	53.6	4.2	13.2	1385
0242230	1993	0.0	112.0	264.1	136.0	129.6	41.4	0.0	8.1	691
0242230	1994	8.9	50.2	30.5	163.0	122.0	126.4	16.0	0.0	517
0242230	1995	21.7	229.2	211.5	36.2	89.2	43.0	30.2	0.0	661
0242230	1996	0.0	83.7	42.8	179.0	54.8	184.2	18.9	0.0	563
0242230	1997	27.6	10.3	95.7	152.7	154.2	136.9	16.1	8.0	601
Average		21.6	75.1	132.1	151.0	128.0	100.6	28.6	3.4	640

* means estimated

Beitunya Station

Code	year	October	November	December	January	Febuary	March	April	May	Sum
0242400	1968	21.0*	121.9	106.5	198.1	107.6	41.0	25.0	6.3	627
0242400	1969	41.0	24.3	203.8	194.7	34.4	256.9	26.1	0.0	781
0242400	1970	9.8	48.0	52.2	153.3	60.0	139.4	37.2	0.0	500
0242400	1971	14.3	22.2*	135.1	76.6	104.1	68.6	206.9	0.0	628
0242400	1972	0.0	77.5	268.6	88.2	156.4	98.7	31.5	0.0	721
0242400	1973	0.8	56.7	71.9	213.4	39.4	75.2	7.0	1.0	465
0242400	1974	15.0	93.5	57.5	482.1	169.9	61.7	67.0	0.0	947
0242400	1975	0.0	101.4	133.8	97.5	215.2	92.7	8.9	0.0	649
0242400	1976	0.0	46.8*	109.1	63.5	118.5	98.3	18.2	1.0	455
0242400	1977	15.4	56.7*	34.4	162.2	51.9	142.0	107.2	0.0	570
0242400	1978	91.4	3.5	229.6	54.0	73.2	91.6*	16.0	0.0	559
0242400	1979	66.0	19.2	143.1	146.3	32.9	93.2	13.5	0.0	514
0242400	1980	33.8	184.5	163.0	145.0	157.5	119.7	3.2	0.0	807
0242400	1981	39.0	6.5	244.2	166.5	96.6	110.2	14.5	0.0	677
0242400	1982	0.0	125.7	25.0	133.2	183.1	147.1	3.8	1.0	619
0242400	1983	19.8*	107.9	114.5	249.8	292.5	165.6	10.0	0.0	960
0242400	1984	0.0	53.0	32.1	153.5	55.0	136.7	36.2	0.0	466
0242400	1985	55.5	30.0	44.0	39.0	277.5	35.0	54.0	0.0	535
0242400	1986	48.0	7.5	74.5	106.0	135.5	23.0	55.0	34.0	484
0242400	1987	56.0	290.5	124.0	138.2	42.9	107.3*	2.0	0.0	761
0242400	1988	47.0	10.0	235.1	130.0	191.5	98.3*	9.1*	0.0	721

0242400	1989	0.0	48.6	202.0	89.5	55.0	99.5	0.0	0.0	495
0242400	1990	8.5	82.7	67.5	188.9	77.9	86.5	51.3	0.0	563
0242400	1991	0.0	35.0	5.0	115.0*	126.0*	108.0	14.0	0.0	403
0242400	1992	17.0	102.0	452.3	215.5	388.5	64.0	3.0	11.0	1253
0242400	1993	5.0	96.1	274.0	147.0	88.6*	42.0	3.5	15.2	671
0242400	1994	3.0	53.0	27.5	166.8*	122.6*	149.5	13.1*	0.0	536
0242400	1995	11.5	256.5	205.0	53.0	114.5	43.5	28.6*	0.0	713
0242400	1996	0.0	89.0	35.5	174.5	51.6*	183.0	23.0	0.0	557
0242400	1997	32.5	26.5	93.5	138.0	143.0	148.5	12.6*	7.8*	602
Average		21.7	75.9	132.1	149.3	125.4	104.2	30.0	2.6	641

* means estimated

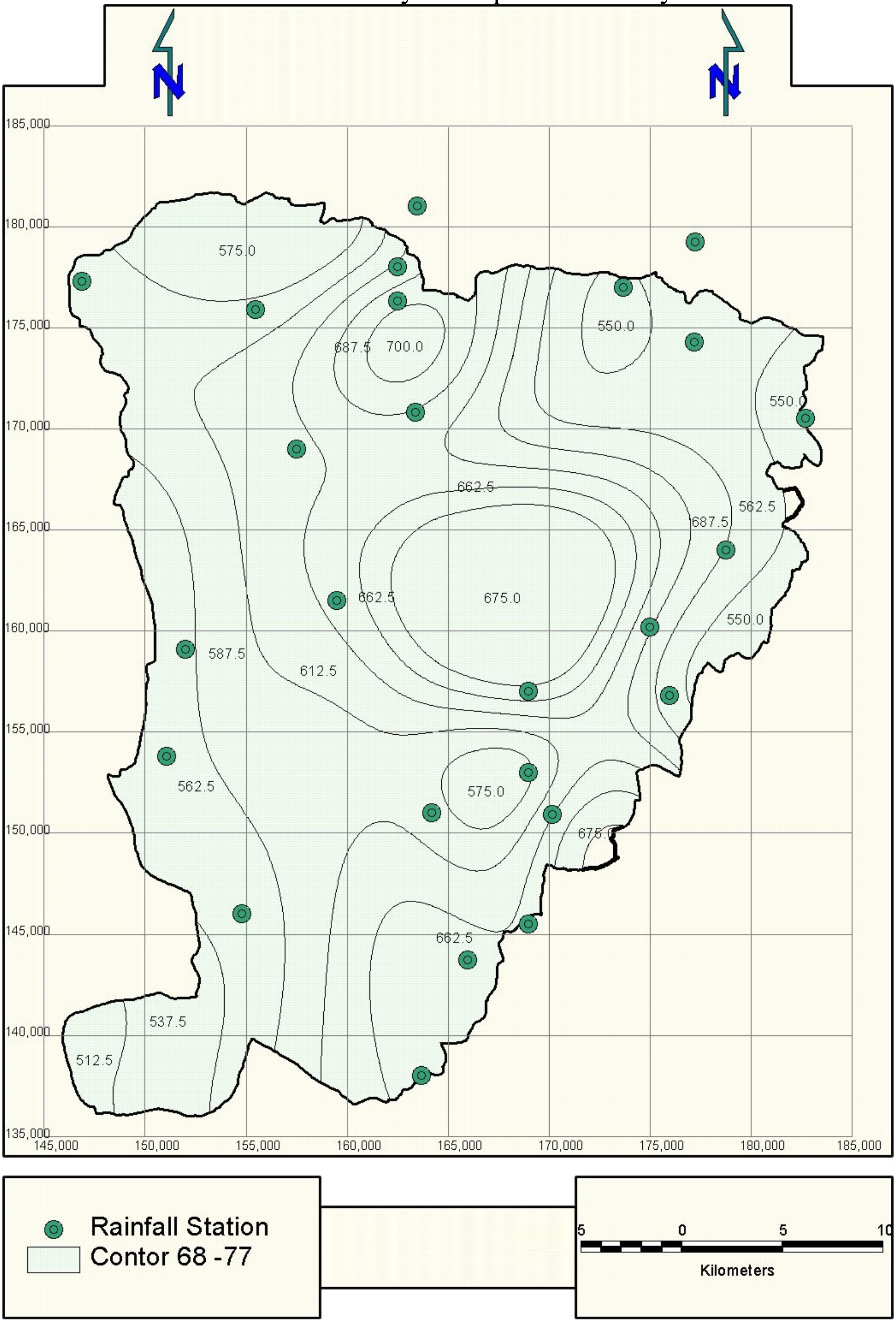
Al Qubeibeh Station

Code	Year	October	November	December	January	Febuary	March	April	May	Sum
0242935	1968	20.0*	123.4*	98.6	203.8*	89.3	26.0	36.0	11.0*	608
0242935	1969	50.0	22.4	151.2	205.2	47.1	219.1	20.7	0.0	716
0242935	1970	31.0	55.7	63.2	147.3	54.7	165.7	21.5	0.0	539
0242935	1971	14.5	27.4	134.8	78.5	92.9	68.0	215.2	0.0	631
0242935	1972	0.0	63.2	257.3	76.7	146.1	99.3	30.0	0.0	673
0242935	1973	0.0	67.8	53.6	219.5	46.1	94.1	4.3	5.2	491
0242935	1974	13.5	112.4	62.5	482.5	151.4	84.0	76.4	0.0	983
0242935	1975	0.0	89.9	131.7	66.1	225.8	72.3	10.0	0.0	596
0242935	1976	2.6	68.3	131.9	73.1	121.3*	99.8	15.7	0.0	513
0242935	1977	4.2	78.5	54.0	155.4	51.8*	134.5	98.6	1.0	578
0242935	1978	59.7	5.6	229.5	61.5	58.9	110.4	10.0	0.0	536
0242935	1979	59.7	17.6	144.7	106.9*	32.9	117.7	6.0	0.0	485
0242935	1980	28.5	180.5	241.8	146.4	164.7	119.0*	15.2	0.0	896
0242935	1981	20.3	5.6	249.9	170.7*	79.7	51.0	21.0	0.0	598
0242935	1982	0.0	117.2	24.4	107.5	171.1	160.3	9.8	0.0	590
0242935	1983	5.6	105.0	122.4	298.0	302.2	159.3	19.7	0.0	1012
0242935	1984	0.0	47.7*	30.0	173.9	66.3	117.6	41.0	0.0	476
0242935	1985	46.5	46.8	42.0	55.3	261.1	28.3	50.0	1.5	532
0242935	1986	36.0	18.8	58.3	97.4	173.5	22.0	30.2	29.5	466
0242935	1987	84.5	289.6	102.2	112.8	44.5	77.1	1.5	0.0	712
0242935	1988	50.5	12.4	210.1	136.3	197.4	92.0	7.5*	0.0	706
0242935	1989	10.0	59.5	191.9	69.0*	64.3	98.6*	0.0	0.0	493
0242935	1990	20.1	83.5*	47.8	189.7*	61.7	86.2*	51.6*	0.0	541

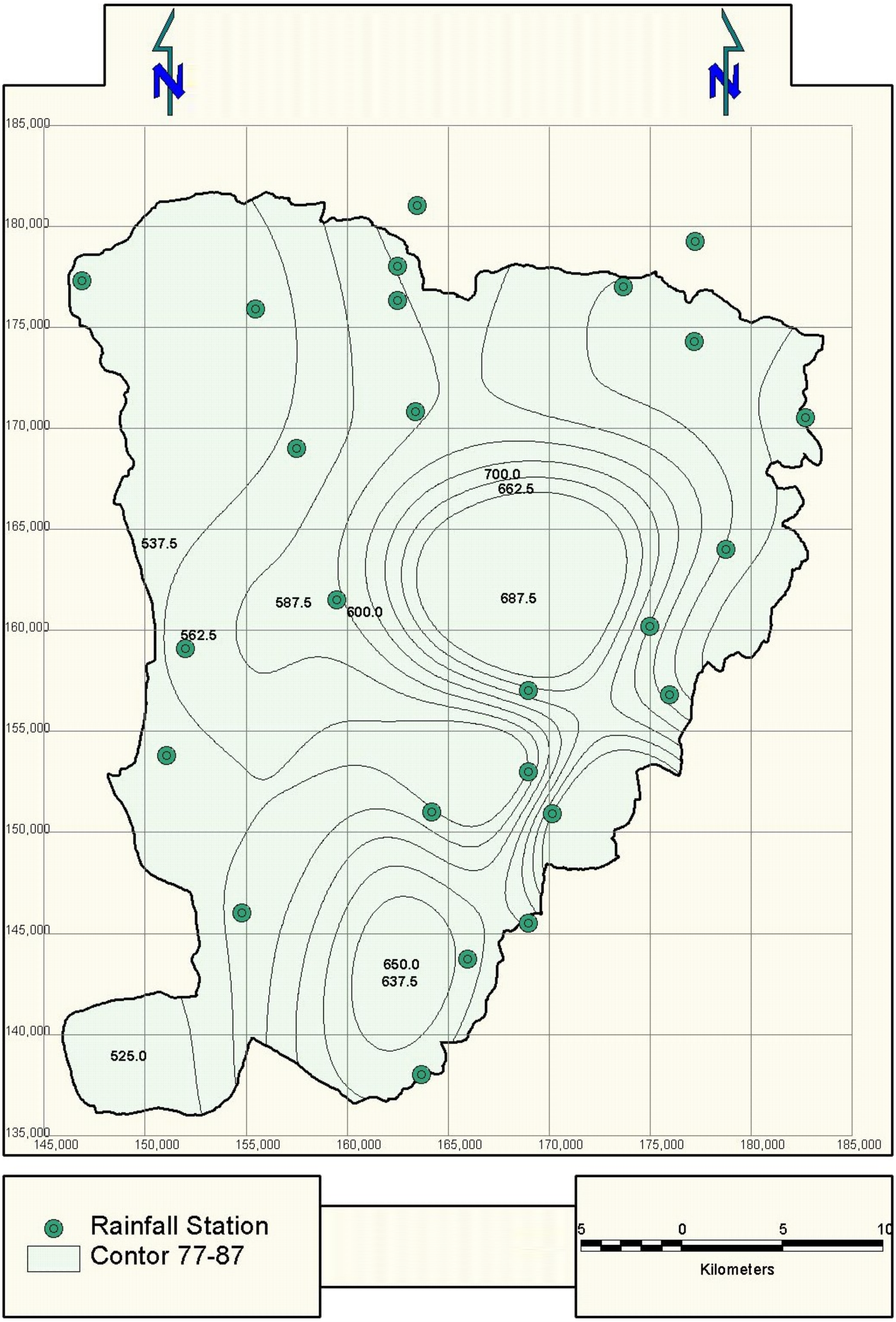
0242935	1991	0.0	28.0	11.0*	99.0*	140.6*	108.0*	5.6	0.0	392
0242935	1992	6.0	125.0	465.0	248.6	388.0	56.6	0.0	9.8	1299
0242935	1993	0.0	69.5	258.0	156.4	94.1	36.6	0.0	16.3	631
0242935	1994	4.7	38.8	25.7	161.3	122.0	102.4	10.0	0.0	465
0242935	1995	14.7	212.5	164.7	36.6	107.7	43.8	30.5	0.0	611
0242935	1996	0.0	73.6	31.3	177.0	40.9	186.4	21.9	0.0	531
0242935	1997	30.5*	14.0	93.3*	118.0	175.0	144.9*	12.9*	7.5*	596
Average		20.4	75.3	129.4	147.7	125.8	99.4	29.1	2.7	630

* means estimated

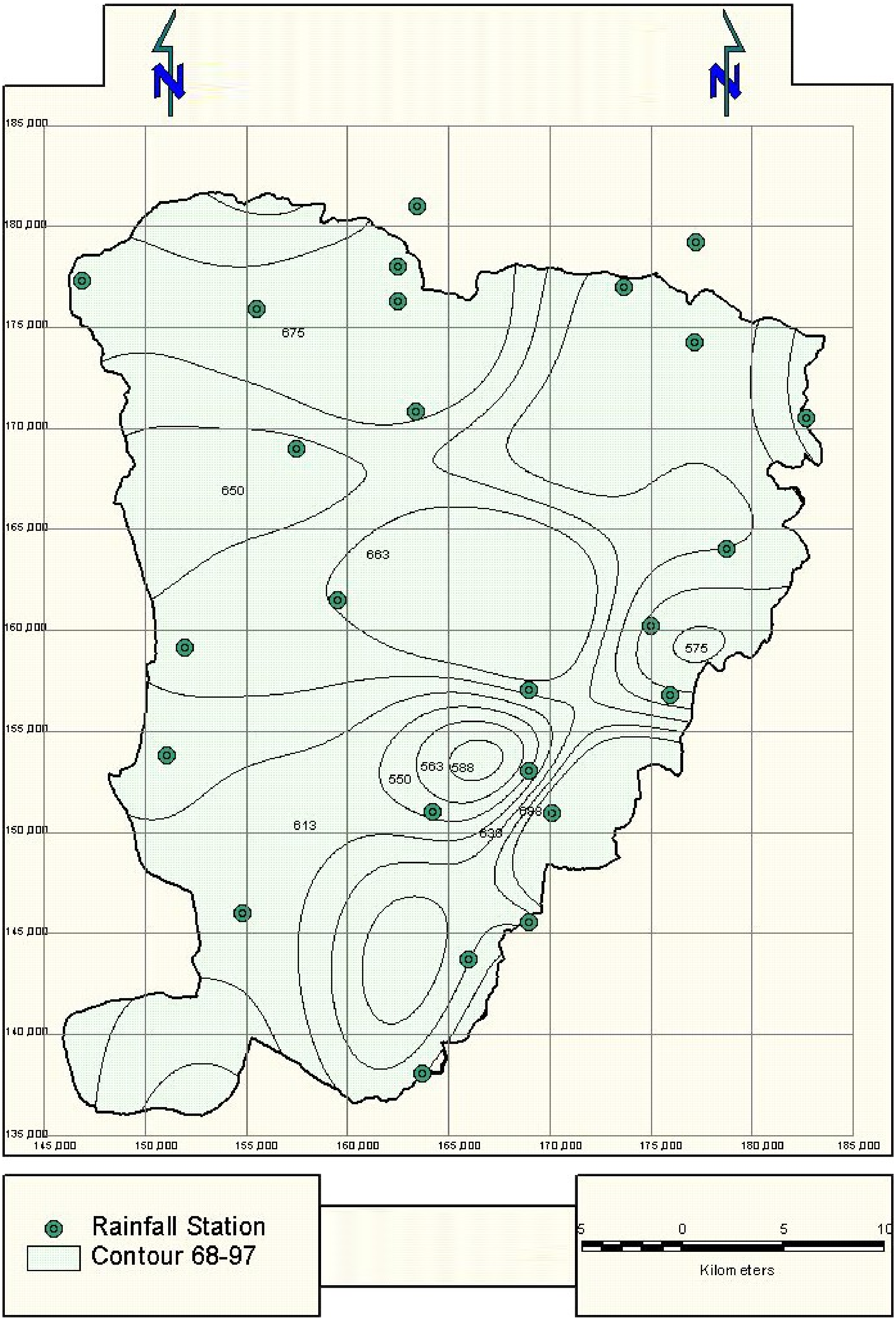
APPENDIX C: Isohytal Maps of the Study Area



Isohytal Map of the Study Area (1968-1977)



Isohytal Map of the Study Area (1978-1987)



Isohytal Map of the Study Area (1968-1997)

APPENDIX D: Springs General Information

Spring ID	X (km)	Y (km)	Z (m)	Name	Location	Governorate
AS/026	172.3	148.4	880	Beitin	Beitin	Ramallah
BA/072	178.00	174.30	590	'Awarta	'Awarta	Nablus
BA/073	173.80	176.65	575	Al Balad	Burin	Nablus
BA/074	174.08	176.62	580	Al Sharqiyyah	Burin	Nablus
BA/075	172.33	176.68	615	Al Sha'ra	Madama	Nablus
BA/076	174.28	173.20	550	Al Balad	Huwwara	Nablus
BA/077	163.6	171		Kaffet 'Udah	Deir Istiya	Salfit
BA/078	160.80	173.90	240	Al Fawwar	Deir Istiya	Salfit
BA/079	161.10	173.80	250	Al Juzah	Deir Istiya	Salfit
BA/080	160.40	173.70	250	Al Bassah	Deir Istiya	Salfit
BA/081	163.6	171		Al Moqodeh	Deir Istiya	Nablus
BA/085	162.40	165.50	375	Al Matwi	Salfit	Salfit
BA/085A	166.86	165.92	470	Shamiyyah	Salfit	Salfit
BA/086	163.40	164.60	390	Al Shallal	Salfit	Salfit
BA/087	167.6	165.5		'Adas	Salfit	Salfit
BA/088	173.70	162.90	500	Al Sha'er	Al Lubban ash Sharqiya	Ramallah
BA/089	172.9	164.3		Al Lubban	Al Lubban ash Sharqiya	Nablus
BA/090	180.03	155.80	740	Jurish	Jurish	Ramallah
BA/091	178	166.1		Momiya	Talfit	Nablus
BA/092	178.30	165.90	800	Al'Eina	Talfit	Nablus
BA/093	178.38	165.70	640	Al Balad	Talfit	Nablus
BA/095	176.80	155.60	690	Seilun	Qaryut	Ramallah
BA/096	179.85	165.85	790	Al Balad	Jalud	Nablus
BA/100	177.6	160.2		Turmus'ayya	Turmus'ayya	Ramallah
BA/101	175.3	160		Al Balad	Sinjil	Ramallah
BA/102	174.40	160.10	790	Um Ghurbah	Sinjil	Ramallah
BA/104	171.8	159.7		Sala'	Jilijliya	Ramallah
BA/106	170.50	155.40		Jilijliya Al Balad	Jilijliya	Ramallah
BA/107	171.8	159.7		Mendam	Jilijliya	Ramallah
BA/108	169.10	160.30	570	Al Balad	Abwein	Ramallah
BA/109	169.05	160.27	550	Al Sufla	Abwein	Ramallah
BA/110	166.8	161.3	525	Al Balad	Arura	Ramallah

Spring ID	X (km)	Y (km)	Z (m)	Name	Location	Governorate
	0	0				
BA/111	166.90	158.90	430	'Ajjul	'Ajjul	Ramallah
BA/111A	167	158.9		Darah	'Ajjul	Ramallah
BA/112	157.30	152.40	460	Daqlah	Umm Safa	Ramallah
BA/113	160.50	159.30		Abu Fayyad	Bani Zaid	Ramallah
BA/114	160.2	160.6		Al Deir	Bani Zaid	Ramallah
BA/115	161.2	161.8		Kafer Ein	Kafr'Ein	Ramallah
BA/116	162.5	162.8		Qarawah	Qarawat Bani Zeid	Ramallah
BA/117	161.35	157.25	485	Riya	Deir Nidham	Ramallah
BA/117A	161.4	156.1		Rayya Al Fuqa	Deir Nidham	Ramallah
BA/118	164.1	160		Qasab	Deir as Sudan	Ramallah
BA/120	156.95	159.18	290	Delbah & Laqtan	'Abud	Ramallah
BA/121	156.88	160.08	255	Zarqa	Bani Zaid	Ramallah
BA/122	156.96	158.96	300	Al Mgharah	'Abud	Ramallah
BA/124	157.7	163.7		Al Fawwara	Kafr ad Dik	Salfit
BA/126	171.60	151.20	750	Al Kabeerah	Dura al Qar'	Ramallah
BA/127	171.60	151.05	760	Al Derrah	Dura al Qar'	Ramallah
BA/128	171.55	151.05	750	Al Mgharah	Dura al Qar'	Ramallah
BA/129	171.60	151.15	740	Al Daraj	Dura al Qar'	Ramallah
BA/130	171.95	153.25	630	Al Sharqiyyah	Ein Siniya	Ramallah
BA/131	171.9	153.4	650	Abu Hamdan	Ein Siniya	Ramallah
BA/132	171.85	153.30	640	Shaikh Husain	Ein Siniya	Ramallah
BA/133	171.9	153.4	675	Al Jarab	Ein Siniya	Ramallah
BA/134	171.9	153.4	675	Al Mezrab	Ein Siniya	Ramallah
BA/135	171.9	153.4	675	Al Jurah	Ein Siniya	Ramallah
BA/135A	170.55	152.20	645	Jifna Al Balad	Jifna	Ramallah
BA/136	168.5	153	725	Al Marj	Bir Zeit	Ramallah
BA/137	161.68	157.42	500	Al Qus	Bir Zeit	Ramallah
BA/138	169.10	153.27	730	Al Hammam	Bir Zeit	Ramallah
BA/139	169.10	153.50	745	Flaiflah	Bir Zeit	Ramallah
BA/140	168.5	153	100	Al Fawwar	Bir Zeit	Ramallah
BA/142	169.8	156.7		Al Balad	'Atara	Ramallah
BA/144	168.15	150.55	730	Majur	Abu Qash	Ramallah
BA/151	164.8	155.3	600	Kobar	Kobar	Ramallah
BA/152	166.80	152.60	670	Al 'Alaq	Abu Shukheidim	Ramallah

Spring ID	X (km)	Y (km)	Z (m)	Name	Location	Governorate
BA/153	164.70	149.90	670	Harrashah	Al Mazra'a al Qibliya	Ramallah
BA/155	157.50	155.30	340	Al Zarqah	Beitillu	Ramallah
BA/155A	152.50	155.30	340	Al Zarqah Al Tehta	Beitillu	Ramallah
BA/156	161.1	154.1	340	Al Qwaiqbah	Beitillu	Ramallah
BA/157	161.1	154.1	350	'Akari	Beitillu	Ramallah
BA/158	161.1	154.1	525	Al Balad	Beitillu	Ramallah
BA/159	161.1	154.1	450	Al Qus	Beitillu	Ramallah
BA/160	159.7	153.2	225	Al Sharqiyyah	Deir 'Ammar	Ramallah
BA/161	159.7	153.2	500	Deir 'Ammar	Deir 'Ammar	Ramallah
BA/162	158.8	153.6		Al Balad	Jammala	Ramallah
BA/163	164.38	147.92	510	Al Balad	'Ein Qinya	Ramallah
BA/164	165.37	148.70	500	Delbah	'Ein Qinya	Ramallah
BA/165	164.37	147.80	560	Um Al 'Enain	'Ein Qinya	Ramallah
BA/166	164.3	148.2	490	Umm 'Issa	'Ein Qinya	Ramallah
BA/167	164.40	147.80	525	Um Al Rumman	'Ein Qinya	Ramallah
BA/170	163.63	145.88	535	'Arik Al Fuqa	'Ein 'Arik	Ramallah
BA/171	163.33	146.12	515	'Arik Al Tehta	'Ein 'Arik	Ramallah
BA/172	163.30	145.10	600	Al Jaryut	Beituniya	Ramallah
BA/178	162.8	141		Beit Duqqu	Beit Duqqu	Jerusalem
BA/180	160.4	137.1		Janan	Qatanna	Jerusalem
NS/004	168.5	153		Al Saqi	Bir Zeit	Ramallah
NS/005	181.6	165.8		Qusra	Qusra	Nablus
BA/181	160.4	137.1		Al Balad	Qatanna	Jerusalem
BA/085B	167.6	165.5		Al Matwi Seeps	Salfit	Salfit
BA/084	173.1	168.8		Al Balad	Yasuf	Salfit
BA/084A	173.1	168.8		Delbah	Yasuf	Salfit
NS/001	167.6	165.5		Yanbou'	Salfit	Salfit
NS/003	177.3	167.8		Qasabeh	Qabalan	Nablus

APPENDIXES

Appendix A: Recorded Annual Data

Appendix B: Monthly Rainfall Data (Corrected and Estimated)

Appendix C: Isohytal Maps of the study Area

Appendix D: Springs General Information

الخلاصة

تم في هذا البحث دراسة هيدرولوجيا حوض العوجا التمساح السطحي وكان التركيز في الدراسة منصبا على تحليل بيانات الامطار والينابيع.

تم اختيار حوض العوجا التمساح لاسباب عديدة منها كونه يشكل منطقة التغذية الرئيسية للحوض الجوفي الغربي، ثاني اكبر الاحواض الجوفية المائية في فلسطين التاريخية، بالاضافة الى وجود اكثر من 150 تجمعا فلسطينيا يزيد عدد سكانها عن 300 الف نسمة يعتمدون مباشرة على استغلال مياه الامطار او مياه الابار الجوفية والينابيع لسد احتياجاتهم من المياه لاغراض الشرب والزراعة.

الهدف الرئيسي من هذه الدراسة يتمثل في دراسة شبكة مراقبة الامطار، تدقيق بيانات الامطار وتحليلها واستكمالها، حيث تبرز اهمية ذلك في كون مياه الامطار تشكل المدخل الرئيسي في النمذجة المائية(التغذية والمياه السطحبة والجوفية) التي تهدف الى حساب الموازنة المائية والطاقة التخزينية للأحواض.

لقد بدأت خطوات هذا البحث في جمع المعلومات والبيانات التاريخية من العديد من المؤسسات ومن ثم تم تدقيق هذه البيانات باستخدام الاساليب الاحصائية المختلفة مثل مقارنة التسلسل الزمني لمحطة القياس نفسها و المقارنة مع المحطات المتجاورة ومقارنة البيانات زمانيا ومكانيا وذلك للقياسات اليومية، الشهرية والسنوية وتقدير البيانات المفقودة باستخدام النمط الخطي الرياضي.
لقد تم دراسة خصائص شبكة المراقبة وتحليل مدى ملائمتها للمواصفات المتبعة عالميا من حيث ادوات القياس، والية التسجيل والتوزيع الجغرافي والتغطية الزمنية. ايضا تم تحليل بيانات الامطار عن طريق حساب الكميات الكلية للامطار الساقطة، الايام الجافة والرطبة، العمق، التكرار ، الشدة، القيم القصوى، التحليل الفصلي والاتجاه السنوي الزماني والمكاني السنوي للمطر. واخيرا تم تحليل البيانات الكمية للينابيع بالتركيز على الينابيع الكبيرة وكيفية تغير هذه الكميات مع الزمن واستخلاص تغير هذه الكميات مع سقوط الأمطار.

وتشير نتائج هذه الدراسة الى رداءة نوعية هذة البيانات من نواحي التسجيل وطريقة القياس والتوثيق. والامر ذاته ينطبق على شبكة المراقبة حيث انها غير ملائمة في التصميم لا من النواحي الجغرافية ولا من نواحي الادوات.
اما نتائج تحليل بيانات الامطار فتشير الى تغير كميات الامطار مكانيا حسب الارتفاع عن مستوى سطح البحر، والبعد عن الساحل بالاضافة الى الموقع الجغرافي، وتتغير زمانيا من سنة الى اخرى وان تبقى تدور حول معدل عام ثابت تقريبا. وتشير نتائج الدراسة الى وجود علاقة طردية وثيقة بين سقوط الامطار وتدفق الينابيع، حيث وجد ان تأثير سقوط الأمطار في تدفق مياه الينابيع يظهر بعد شهرين تقريبا.

وفي النهاية يوصى بتطبيق الوسائل والاساليب الاحصائية المتبعة في هذه الدراسة على جميع بيانات الامطار في جميع الاحواض السطحية وذلك حتى يتم ينقيحها واستخدامها في مختلف الدراسات المائية بالاضافة الى ضرورة القيام بدراسات تفصيلية ولا سيما موضوع شدة الامطار.