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Water Studies Institute

Water Resources Assessment for Al-Auja Surface and Sub-Surface Catchments, West Bank, Palestine

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This thesis was defended successfully on (15th of May 2006) and was approved by all members of the Supervision Committee

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Abstract

Water resources assessment in Al Auja study area (Surface and Sub-Surface catchments) was the main issue studied in this research, in terms of rainfall-runoff relation, base flow and recession for the major springs and assessment of the sustainable yield of the Lower Aquifer of Ein Samia well field.

The selection of this study area is based on its significance with respect to population, and because of the critical water supply situation in this central area, more over because it is totally located within the eastern groundwater basin, which is considered the most important for the Palestinians water supply in the central and southern areas.

The studies of Rainfall Runoff analysis in the West Bank suffers from lack of assessment of actual Runoff, and Infiltration from the Rainfall events. Such studies depend on measurements of Wadis flow. Because no comprehensive meteorological system in the study area to measure rainfall events on short periods, but only daily rainfall records were measured, the Soil Conservation Surface method used to measure actual Rainfall Runoff relations and to find the Runoff coefficient, infiltration occurrence in Al Auja surface and Sub-Surface catchments, and to estimate the annual amount of flood occurs in wadi Al Auja. For the comprehensive assessment of water resource in the study area, the Ground water resources were evaluated to assess the impact of the current development on the Aquifer System, after that an analytical modeling approach was used to estimate the optimized ground water abstraction from the Lower Aquifer in Ein Samia well field.

The main objectives of the study are (1) to conduct a comprehensive assessment for Wadi Al-Auja catchment's area which include: an assessment of the surface water resources: rainfall and surface runoff by using Soil Conservation Surface method (SCS), and (2) Assessment of the groundwater resources within Al Auja sub basin: ground water recharge, discharge

occurrence and flow. (3) Assessment of the ground water production from Lower Aquifer in Ein Samia well field, which is located in the study area by using a two dimensional analytical modeling tool (TWODAN).

The study found that the average storm runoff coefficient is 6.7%, and the average annual runoff coefficient is 3.5% of the average annual Rainfall, where the total flood in the Sub-Surface and Surface catchments was 10.27 and 2.70 MCM/yr respectively. The infiltration in the study area was estimated around 30 MCM//yr, which is equal to 11-15% of annual rainfall.

For base flow measurements, which consider one part of the surface water source in the area, recession analysis approach for the major springs are adapted to estimate the potential storage and remaining base flow for each spring, and the result was 42 MCM/yr and 25.7 MCM/yr respectively.

The optimal abstraction was 7800 M^3/ day which equal to 2.84 MCM/yr, that mean a reduction in abstraction from 8900 M^3/day to 7800M^3/day (3.24 to 2.84 MCM/yr).

Finally; an adequate water resources assessment is a corner stone for sustainable management of these important groundwater and surface water resources. Such assessments are required for decision makers and planners to develop the water sector in fordable and sustainable manner.

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Chapter 1

Introduction

1. Background

The Auja Study Area is considered as one of the most important Sub Basin and it is fully representative for the Eastern Aquifer Basin (EAB) which is considered as one of the most important basins in the West Bank that provide the Palestinian with water for the different purposes. Since the Eastern Basin is located entirely in the West Bank, it became the target for the Palestinians to develop their water resources especially after the Oslo II agreement. For this reason, a number of studies and development programs have been carried out to determine the potential of this basin to meet the present and future Palestinian water demand. As a result of these studies and programs, additional wells were suggested to be drilled in the existing and new well fields, such as the new Bani Na'im well field, and the existing Herodian and Ain Samia well fields.

However, during the last two years, the water levels in some of the existing well fields have been observed, which raise the question of the accuracy of the estimates of the aquifer potential, and/or the adequacy of the production program in terms of its rate and pattern.

1.1 Government strategy for Water Resources Development

The decreasing availability of fresh and suitable water resources to the Palestinians, in view of the increasing water demands, combined with the associated political complexity related to these limited, and mostly shared water resources, have urged the -Palestinian Authority- to formulate the main principles of the national water policy, and strategy which, in its turn, forms the basis for efficient water management. The Key elements of the Palestinian water resources management strategy are as follows (PWA, 1998):

1. Secure the Palestinian water rights.
2. Strengthen the national policies, legislations, and regulations.
3. Develop a strong institutional framework and human resources development program.
4. Regulate and coordinate integrated water and wastewater investments and operation.
5. Enforce water pollution control and water resources protection.
6. Promote public awareness.
7. Promote regional and international cooperation.

The main challenge facing the Palestinians is to achieve sovereignty and full control over their surface and ground water resources including their planning, development and management, and to resolve the Palestinian water right issue. Resolving these issues form the base for proper and sustainable water resources development.

1.2 Palestinian Water Resources Status

The main water resources in the West Bank are the renewable groundwater of the mountain aquifers, with an estimated annual recharge of 650 MCM/yr., in addition to about 70 MCM/yr of surface water (Moe, 1998).

The Palestinians total current water use from the ground water resources, in the West Bank, (wells & springs), is estimated at 120 MCM/yr. About 86 MCM is used in irrigation, and the remaining is used in domestic and industrial consumption. Israel is currently controlling 85% of the water resources in the West Bank, (CH2MHILL, 2001)

Palestinians annual share from the Jordan River basin is about 20% of the total annual flow (CH2MHILL, 2001). However, with the extensive upstream storage and diversion projects, the remaining River flow south of Tiberius Lake is too brackish and polluted in quality, and relatively small in quantity, to be of any significant value through direct use for the Palestinian riparian, (CH2MHILL, 2001)

1.3 Role of Water Resources Conservation and Assessment

Assessment of the scale and variability of water resources is basic to many development projects and environmental studies. The scope of an assessment study varies nationally, regionally, and internationally with a wide range of factors.

Water resource conservation and assessment provides engineers, planners, managers, and other decision makers with the basis and foundations for the following:

- Formulation of policies, strategies, plans, and the required legislations for water resources development and management. Such water resources issues are important factors and inputs to the other socio-economic development sectors, such as food production and food security.
- Planning, implementation, regulation, operation and monitoring of water resources and projects
- Decision making on water resources development proposals for the various socio-economic development sectors. This is important for the case of Palestine to assist, encourage, and facilitate donors to provide financial assistance to water and water-related projects.
- Another important role for of water resources assessment to the Palestinians is to provide the technical basis for regional cooperation and peace negotiations on planning and managing shared water resources, and implementation of joint regional water resources projects.
- Promote data communication and exchange at the national, regional, and international levels.
- Identifying water resources areas where further research and development are needed.

1.4 The Scope of the Current Study

The scope of the current water resources assessment study will include the following:

1- A comprehensive assessment study for Wadi Al-Auja catchment area to include:

- An assessment of the surface water resources: rainfall VS surface Runoff and Direct recharge from each rainfall events;
- An assessment of the groundwater resources within this area: ground water recharge, occurrence and flow.

2- An Optimization of the ground water production from Lower Aquifer in Ein Samia well field, which is located in the study area.

Chapter 2

Study Area (Al-Auja)

2.1 General

The main study area consists of the eastern part of Ramallah Governorate, extended eastward to the Jordan Valley main fault (Rift), (figure 2.1), and westward to the major groundwater divide separating the eastern and western basins. The northern and southern boundaries of this area have been determined along the groundwater flow lines, which can be considered as no flow boundaries which surround the Auja surface Catchment's area. The study area is therefore located in the eastern groundwater basin, and therefore the direction of the ground water flow is towards the east. Its boundaries are approximately along the northern grid lines 143,000 & 160,000, and the eastern gridlines 170,000 and 195,000, (Palestine grid), (Figure 2.2).

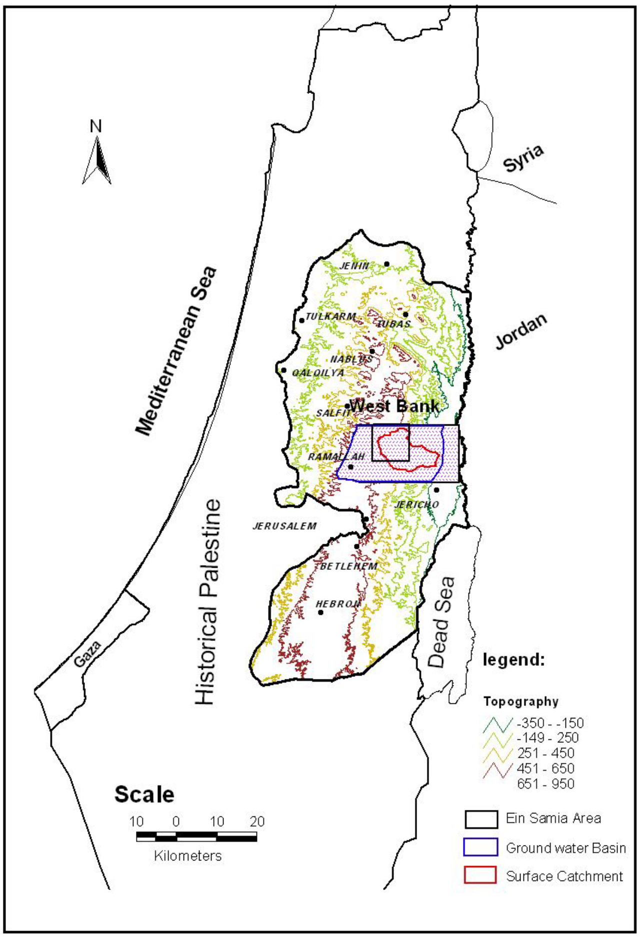

Figure 2.1: Location Map of the study areas

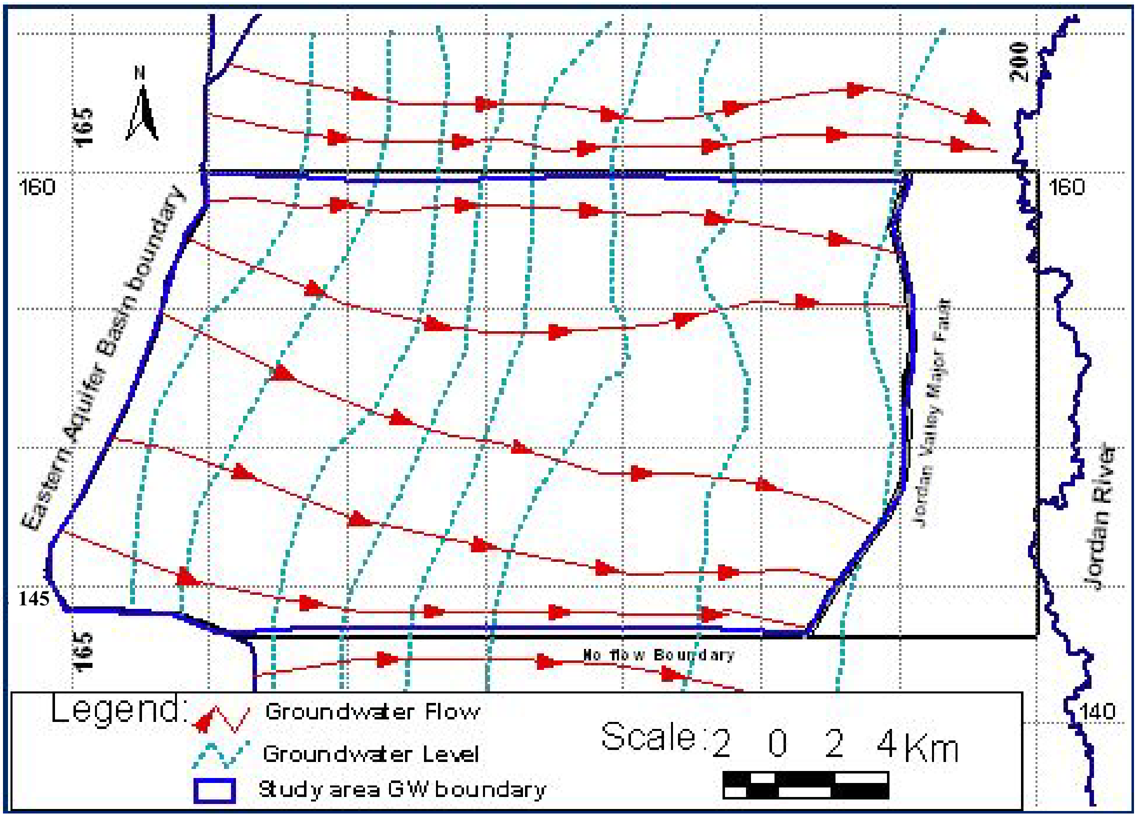

Figure 2.2: Boundary condition of the Al-Auja study area.

The study area may be considered as one Hydrogeological unit with distinct Hydrogeological boundaries. However from the surface water hydrology point of view, it consists of more than surface water catchment, of which Wadi Al Auja catchment, the largest, has also been selected for more detailed hydrological analysis.

The study area consists of the following topographical regions, listed from east to west:

- The Jordan Rift Valley, with elevations ranging from 400 meters below sea level, at the Jordan valley costal line, to 200 meters below sea level at foothills of eastern mountains.
- The eastern escarpment (Central sloping Area), ranging from the minus 200 meters level to an elevation of 500 meters above sea level and the
- Mountains area of Ramallah rising to an elevation of 950 meters above sea level.

The topography, hydrology, and the hydrogeology of the region have been largely affected by the major and regional geological structural event, which occurred during the last geological era, and resulted in the formation of the Jordan Rift Valley.

The selection of this study area was based on its significance in view of its relatively high population and relatively intensive socio-economic development. Consequently, the availability of water in this area is important to meet the increasing water demand for the various socio-economic development activities.

2.1.1 Al-Auja Catchment Area

The surface catchment area of Wadi Al Auja is located in the central and eastern part of the study area, and comprises about 134 Km^2. The catchment area has a variable slope ranging between 10% in the west, to 8% in the middle and the eastern part of the area, (Figure 2.1). The surface catchment area boundaries determined manually by moving with the highest points around the wadi system. The flow quantities are described in chapter 4.

Wadi Al Auja drains this area to the east towards the Jordan Valley. It is an ephemeral stream in its upper part, where flood flows occur after heavy rain storms. Al Auja spring issued, from certified limestone rocks, near its downstream end to form a perennial base-flow in its lower reach. However, most of the spring water is diverted for irrigation in Al Auja town in the Jordan Valley plain, and partly for domestic water supplies for Israeli settlements. Pumping from nearby Israeli wells significantly reduces the spring flow rate, and the spring may dry up completely as early as the month of June as shown in (figure 2.3)

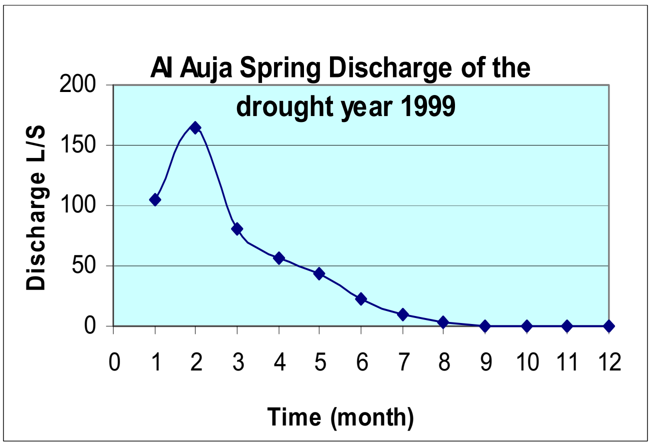

Figure 2.3: Auja Spring Hydrograph in drought year 1999

2.1.2 Ein Samia well field

Ein Samia well field is located within Al-Auja catchment area, Figure 2.1, along a down faulted zone trending in a SSW- NNE direction. Two step faults exist in this area, with the wells located in the down thrown blocks of these faults. Significant drop in the piezometric surface of the lower aquifer indicate that these faults act as barrier or at least a resistant boundaries for the generally eastward groundwater flow.

This well field has eight wells, two of them are for Israeli uses and the rest are operated by the Jerusalem Water Undertaking, JWU. The average annual production from this well field, the JWU wells, is about 3.3 MCM, (PWA, 2002). The produced water from this well field is supplied to the cities of Ramallah and Al Bireh for municipal use.

2.2 Topography and Climate

Elevations in the mountainous area range from 600 to 950 meters above sea level, yielding a relief of more than 1,300 meters between the mountain peaks and the adjacent Dead Sea level (PWA, 2004).

The surface water divide, at the eastern end of the study area, trends approximately north-south, and runs parallel to the axis of the mountain chain. Surface water in the study area, drains eastward or infiltrates to recharge the groundwater aquifers, which also flows eastward towards the Jordan Rift Valley.

The West Bank has a Mediterranean climate characterized by two distinct seasons: a rainy season (winter), from October to May, and a dry, hot season (summer). Temperature and relative humidity are affected by the geomorphologic conditions of the West Bank such as the elevation and distance from the coast. The summer relative humidity is generally below 50%. In winter, however, these parameters are more variable.

The average rainy days per season is about 50 (days). The average annual rainfall varies between 100 mm near the Jordan Valley coast line, to 700 mm on the mountainous areas (Figure 2.4). But in West Bank Generally the Rainfall is higher in the northern part of the West Bank, (600 to 800 mm/yr), than its southern part, where it ranges from 300 to 500 mm/yr,

Evaporation is high in the dry and hot summer season. The average annual potential evapotranspiration in the study area ranges from 2,300 mm at the Dead Sea to approximately 2,000 mm in the mountains (ARIJ, 2000). Potential evapotranspiration rates in the West Bank generally increase from west to east.

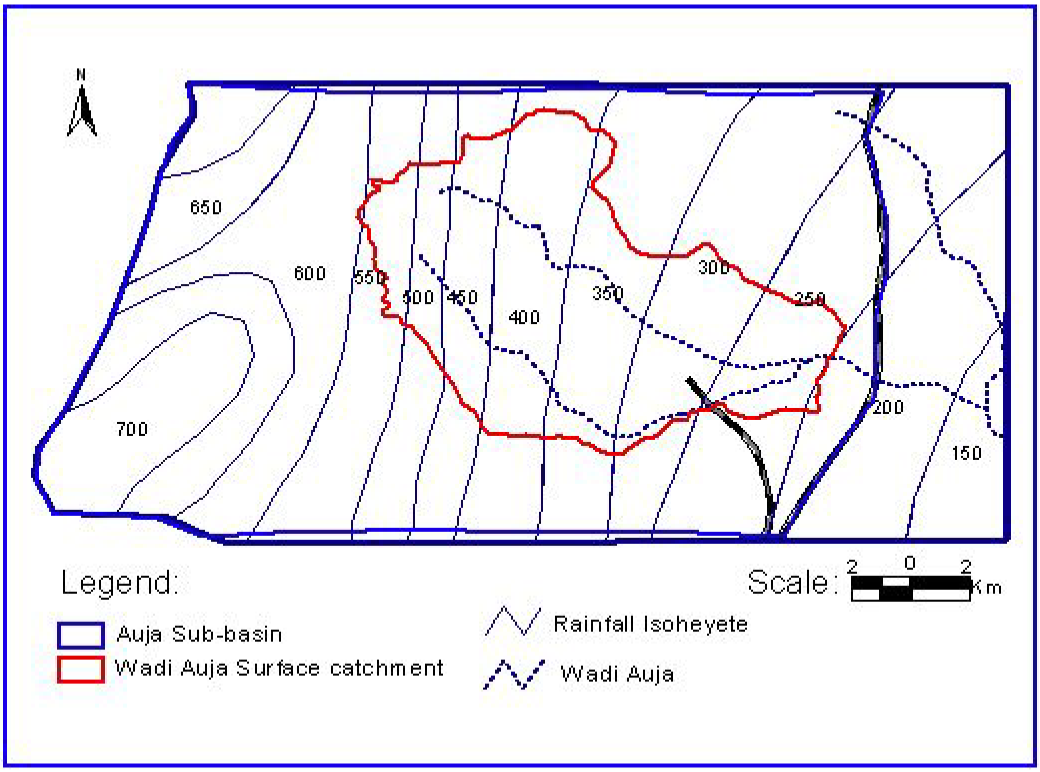

Figure 2.4: Average annual rainfall over Auja Study Areas1970-2002

2.3 Hydrogeological Units and Aquifer Systems

The groundwater domain in the study area is part of the well known Eastern Groundwater basin of the West Bank. It is bounded by the major groundwater divide from the west, and the Jordan valley major fault from the east.

The hydrogeological (Hydrostratigraphic) features of the geological formations prevailing in the study area (figure 2.5), the geological formations based on the physical properties as permeability may be classified into aquifers and Aquiclude. A formation, which store water and transmits it to a well or spring in significant quantity is classified as an aquifer. On the other hand, a formation which stores water, and has a low transmitting capacity, and that yields insignificant quantity of water to a well or spring is classified as an Aquiclude.

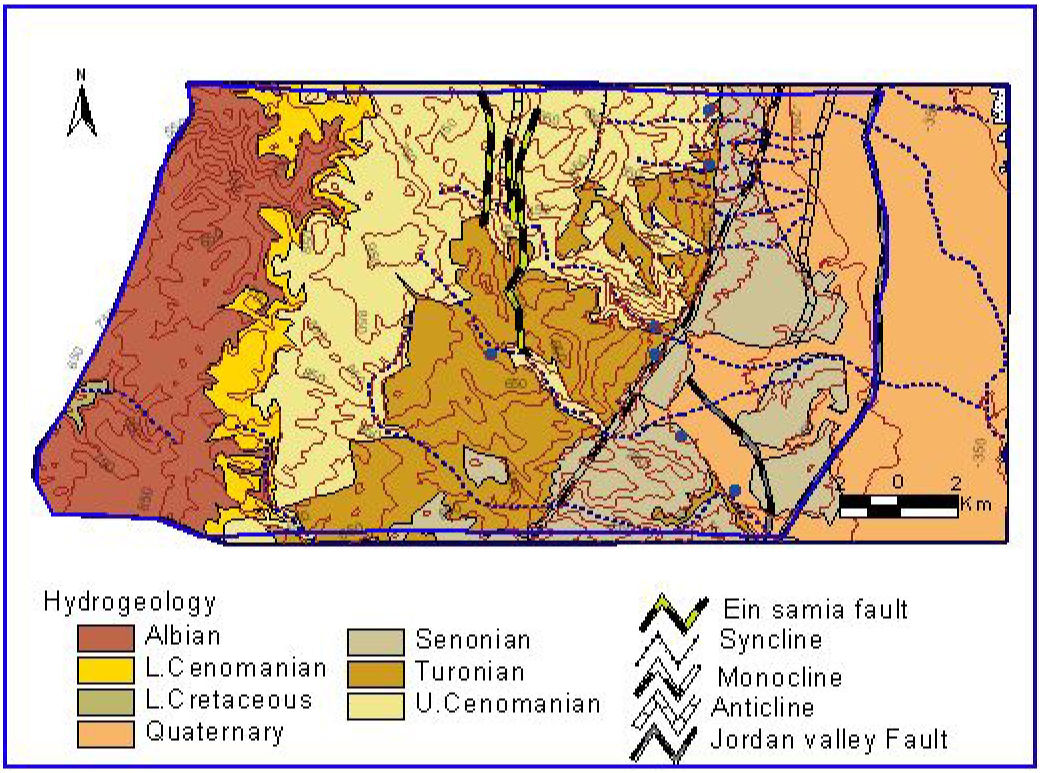

Figure 2.5: Major Hydrostratigraphic Units outcrop in the Study Area (PWA database)

The hydrogeologic units in the study area would be as follows (from bottom to top) (Aliewi, 1996):

a) The lower Beit Kahil Formation (Lower Cenomanian)

lower part of Beit Kahil Formationn (Kafira Formation to Israeli terminology): limestone, well- bedded, fi ne crystalline, highly karstic, sometimes dolomitic in the upper part. Its thickness ranges from 120 to 180m.

upper part of the Lower Beit Kahil Formation (Giv'at Ye'arim formation): dolomite, massively bedded fine–coarse crystalline, hard fractured and karstic, its thickness ranges from 40 to 90 m.

b) The upper Beit Kahil Formation (Lower Cenomanian)

Lower Part of Upper Beit Kahil (Soreq Formation): dolomite, fine crystalline, sometimes soft, inter bedded with thin marly layers, Thickness is between 60 to 130.

Upper part of Upper beit Kahil Formation (kesalon Formation): dolomite and limestone, massively bedded to cliff formation, usually coarse crystalline, rich in reefal phenomena, its thickness ranges from20 to 35 m.

c) Yatta Formation (Lower Cenomanian)

The Lower Part of Yatta Formation (beit Me'ir): dolomite and chalky limestone, fine-medium crystalline, with marly intercalations. Its thickness ranges from 40 to 150.

The Upper Part of Yatta Formation (moza Formation): marl, clay and marly limestone, usually highly enriched with fossilized fauna. Its thickness ranges from 10m to 60m.

d) Hebron Formation (Upper Cenomanian)

This formation is called Aminadav in the Israeli terminology: dolomite, massive, sometimes cliff-forming, hard, medium- coarse crystalline, highky karstic, its thickness varies from 60m to 150 m.

e) Bethlehem Formation (Upper Cenomanian)

The Lower Part of Bethlehem Formation (kefar sha'ul Formation): limeston and dolomite, soft, with marl, rich in faunal remains. Its thickness ranges from 20 m to 50 m.

The Upper Part of Bethlehem Formation (Weradim Formation): dolomite, massive, sometimes cliff- forming, coarse crystalline, limestone lenses, well bedded. its thickness ranges from 25m to 100 m.

f) Jerusalem Formation (Turonian)

This formation is Bina in Israeli terminology, its devided into three subformation;the lower part consist of limestone and dolomite, the middle part consist of limestone, massive to cliffforming, coarse crystalline, and the upper part mainly consists of limestone and fine crystalline.Its thickness ranges from 30m to 120m.

g) Abu Dis Formation (Senonian)

This Formation is Mount scopus Groupe in the Israeli terminology, this formation consist of chalky-marl succe ssions, with brechoid flint layers. its thickness reaches to 500m.

h) The alluvial deposit (Alluvium)

This Layer constitutes a fair to good aquifer in the Jordan valley. It has a variable thickness ranging from Zero to 100 m.

The vertical distribution of the formations is shown in the cross section in (figure 2.6). And the Hydrogeological sequence, according to age is shown in (figure 2.7).

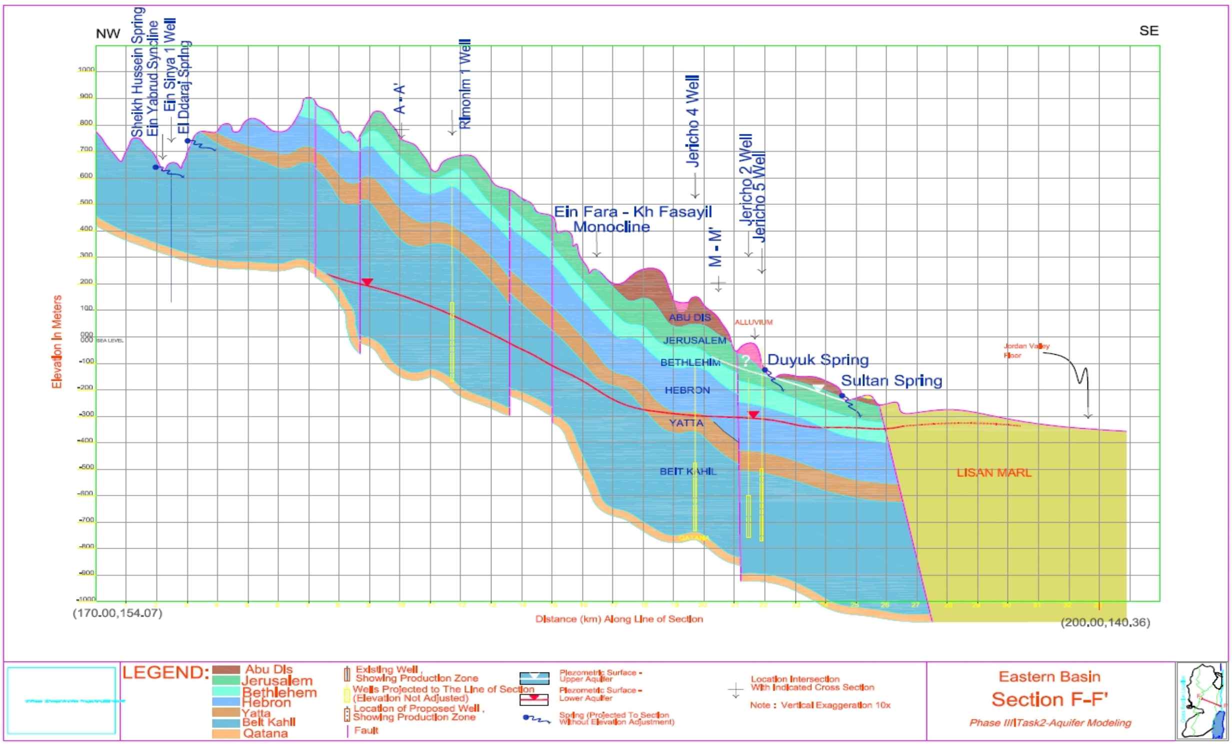

Figure 2.6: Hydrogeological cross section in the study Area (CH2MHILL, 2002)

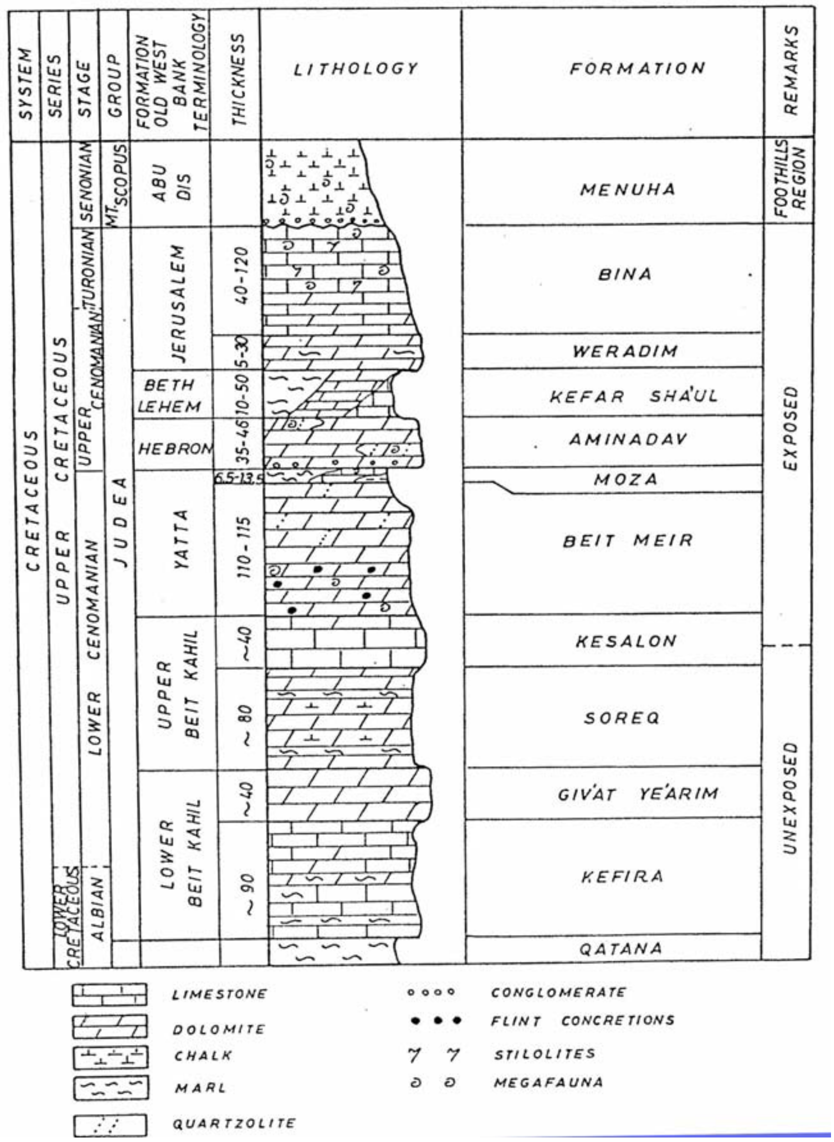

Figure 2.7: Hydrostratigraphic/ Hydrogeological Sequence in the Study Area, (Tahal, 1990).

2.4 Population in the study area

The population in the study area is concentrated in and around the twin Cities of Ramallah and Al Bireh, with a total population for the two cities of 45,989 people. This constitutes about 31% of the total population in the study area, which was about 133,800 people in the year in 1997(PCBS, 1997).

There are 44 population centers in the study area, with population ranging from 500 to 25,000 people for each (Annex 2.1).

2.5 Population Projection

A number of political, social, and economic factors affect the population growth in Palestine. An appreciation of these factors should be considered in assigning population growth rates for projecting the future population, as well as of the growth of the Palestinian population centers. The projection growth rate of 3.5% has been used and is shown in (Figure 2.8).

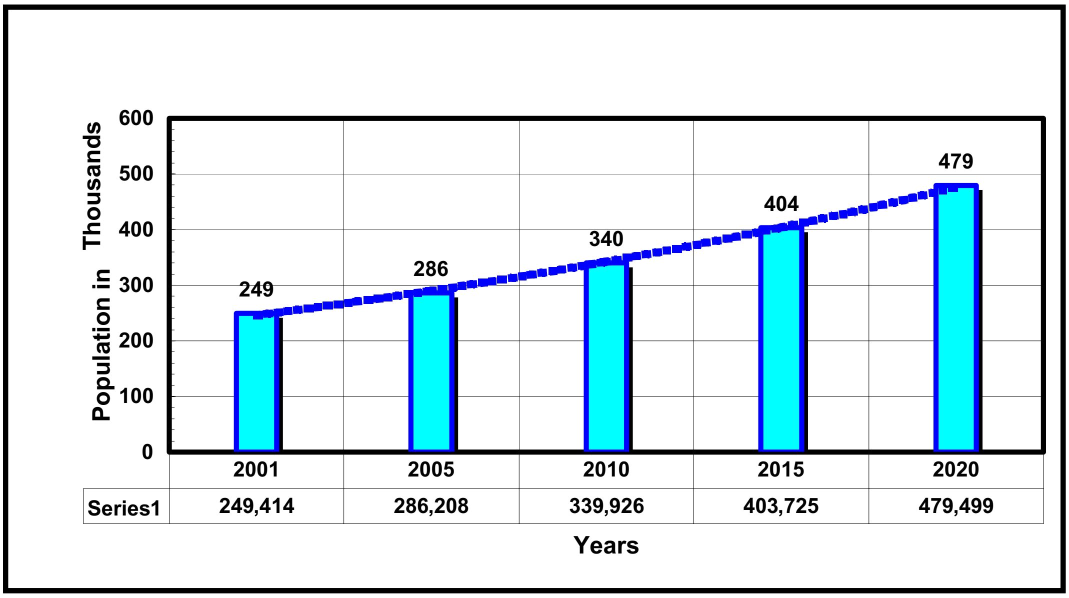

Figure 2.8: Population projection for the Study area (Result of analysis)

2.6 Urbanization

The level of urbanization in the population centers may be judged based on their social and economic characteristics, the level of planning, and the availability of infrastructures. Accordingly, most of the population centers within the study area can be mostly classified as rural.

The main urbanized center, in the study area is in the Ramallah and Al Bireh twin cities, which contain water distribution systems, sewerage networks, and two wastewater treatment plants.

2.7 An overview of the current water situation

2.7.1 Existing Water Supply Systems

The Jerusalem Water Undertaking (JWU) controls, operates, and manages the distribution system in Ramallah and Al Bireh districts, which are the largest water consumers in the study area, using about 90% of the total area water supply. JWU provides all the municipal water needs for domestic, commercial, and industrial purposes in this urban area, through a 700-km long water distribution network, ranging in diameter from ½ to 16 inches, (PWA, 2002).

The water supply sources for this district are from local groundwater wells – Ein Samia well field supplying about 16.5%, about 2 MCM/yr., and 83.5% from Mokorot Water Supply Company which equal around 10 MCM/yr (PWA, 2002).

On the other hand, the water supply sources for the rural areas are from either local wells or springs or both. The total domestic rural water supply in the study area is calculated about 9.78MCM/yr, out of which (0.28) MCM/yr. is from local groundwater wells, and (9.5) MCM/yr. from springs.
In addition, cisterns, for rainwater collection, are widely spread in the rural areas. The number of cisterns, quantity of the collected water in these

cisterns, is unknown. The collected rainwater is used for domestic and gardening purposes.

The percent of population served by piped water in the study area ranges from 75% for Ramallah and Al Bireh, to less than 5 % for the rural areas, (PWA, 2002).

2.7.2 Current Water Supply and Water Use

Groundwater has been the main water supply source for all water uses in the study area as well as for the West Bank. Water supply for the Palestinians is primarily provided by abstraction from Palestinian controlled wells and springs, in addition to supply from Mokorot, and a small amount of water supply from rainwater harvesting projects, by collection cisterns.

All the production wells in the mountain areas, tap either the upper or lower limestone aquifer, and are mostly used for municipal water supplies. However, most of the wells in the Jordan Valley area tap the shallow alluvial aquifer, and are mostly used for irrigation, and to smaller extent for domestic water supplies.

Presently there are 28 production wells, (13 alluvial aquifer, 3 upper aquifer, and 12 lower aquifer), and more than 16 springs in the study area, controlled by the Palestinians. The total abstraction in the year 2000 was 33.94 MCM, out of which 12.44 from the wells, and 21.5 MCM from springs, (PWA, 2002). See Table 2.1.

Table 2.1: Water supply in the study area; by source and type of use, (year 2002), (PWA, 2002).

Water Use	Spring M^3/Yr	Wells M^3/Yr	Mokorot (Wells)M^3/Yr	Total Mcm/Yr
Domestic	11017	2764508	7853690	10.63
Agriculture	12000000	1287270	0	12.84
Agriculture & Dom.	9478118	535594	0	10.01
Total	21,489,135	4,587,372	7,853,690	33.48

The types of water use in the West Bank include: municipal and industrial (M&I), and agricultural. The M&I uses include domestic and non-domestic. The domestic uses include the water furnished to residential houses. The non-domestic uses include public, commercial, and light industries supplied from the distribution network.

The public water use includes that used for public buildings i.e. city halls, public gardens, jails and schools, as well as public service such as fire fighting.

Agricultural water use in the study area is estimated at 12.84 MCM in the year 2000, Out of which, about 12.0 MCM/yr, are from springs, most of which is from Al Auja spring. Some springs are used for domestic purposes by tankers. Irrigation water supply in this area is also provided from 13 private wells tapping the alluvium aquifer, (PWA, 2002).

2.7.3 Future Water Demand Projection

A major and an important factor in water resources planning and management is the assessment of the future water demand. There are different methods available for such assessment. The choice of method depends; to a large extend, on the type of the available data.

When adequate and accurate records on the historical water supplies are not available, the population statistics and population growth rate can give reasonable estimates of the future water demand. However, a base-line data on some population census, and actual water supply and consumption are required. This approach has been used in this study. The 1997 population Census and water supply and consumption records have been used for projecting the future water demand until the year 2020.

The gross per capita water consumption in the year 2001 was 117 l/c/d,(CH2MHILL, 2001). This reflects the unsatisfactory and inadequate water supply situation in the West Bank. The total water use in the study area is about 10.6 MCM/yr, (PWA, 2002).

As the individual water consumption for the Palestinians is low, the basis of demand projection for the West Bank should include specific target level for domestic consumption, and agricultural expansion. These targets are assumed as follows, (CH2MHILL, 2001):

- Domestic consumption will achieve an average of 150 liters per capita per day (l/c/d), gross, by the year 2020, which means an annual increase of about 2 l/c/d per year.
- Agriculture expansion will grow incrementally at a rate of 3 percent per year from 2001 through 2020.
- Reduction of system losses from 40% to 25% by the target date.
- An allowance for the public demand is taken as 6% and 8% for the present and 8% and 12%, for the year 2020 respectively, of the total municipal water use in the rural and urban communities respectively .
- The industrial water use for small industries supplied from the water supply network. Allowance for these needs is about 5% at present and is expected to increase to 10% by the year 2020.

The baseline values for the 1997 water supply and population, in the study, area have been used to establish the starting per capita consumption. Since the 1997 water consumption rate included both the industrial and the public water supply portion of the total municipal water demand, these demands are assumed included in the projected future water demand.

Taking these factors into considerations, the gross municipal water demand for Ramallah Governorate in the year 2020 would be about 26 MCM, which is two and a half times the 2001 supply. (Figure 2.9) present the results of the demand projections based on the above assumptions. The gross per capita water demand will increase from 117 to 150 l/c/d, while the net per capita consumption would rise from 73 to 100 l/c/d.

In addition any expansion in the agricultural sector should be based on water savings and increase in water use efficiency in the agricultural sector. If 3% annual increase in irrigation water demand is assumed, the agricultural water demand will be (18) MCM in the year 2020, (CH2MHILL, 2001).

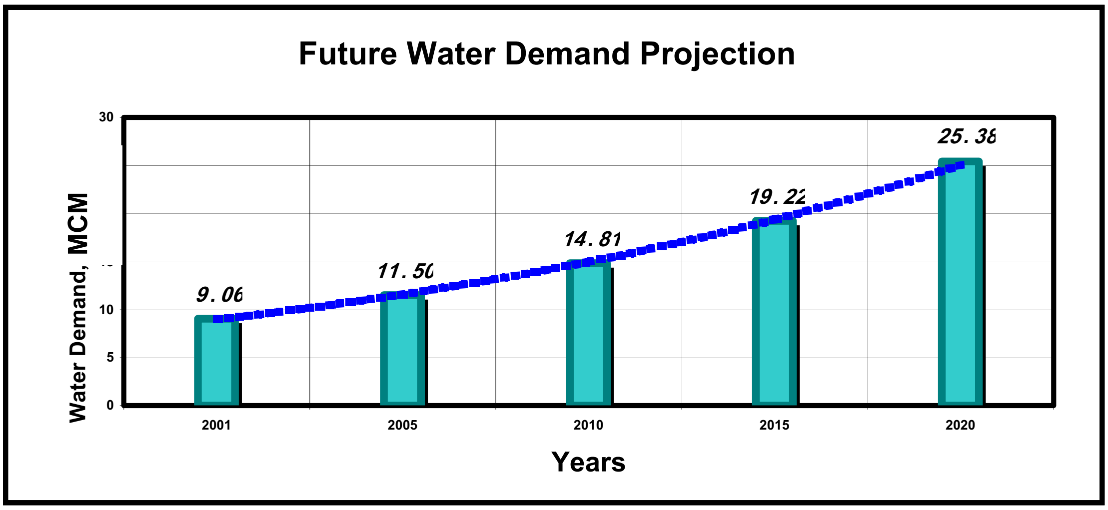

Figure 2.9: Future Water Demand Projection

Chapter 3

Assessment of surface water resources

3.1 Introduction

The surface and grounds water resources in the study area as it is for the West Bank are generated from the local rainfall. The study area does not receive water from outside its boundary contributes to adjacent areas (based on the non flow boundary assumption). Rainfall in the study area is the highest over the West Bank which reaching to about 700 mm/yr. Surface water resources in the study area consists of two components: stream flow which is generated from springs (base-flow) and flood flow in the winter. The flood flow is the direct surface Runoff generated and collected in stream channels after rainfall events, and ceases some time after that. Stream flow (Base-flow) on the other hand, originates from groundwater discharges on the ground surface in the form of springs, and flowing in a stream channel. For renewable groundwater aquifers, such groundwater originates from rainwater infiltration through permeable ground surfaces. Base flow represents the rejected groundwater recharge, in surplus of the storage capacities of the groundwater reservoirs.

Rainfall is significant to aquifer recharge within and outside the study area. However, direct utilization of rainfall is limited to soil storage, which supplies the rain-fed agriculture fall in the mountain area, and to collection in cisterns, particularly in the rural, areas for limited domestic water uses.

Surface Runoff is rather small in the mountain areas, where infiltration to recharge the groundwater aquifers through the fractured and karstified limestone mountainous terrain predominates. Surface Runoff becomes more significant on the eastern slopes where it contributes to the flood flow in the eastern drainage area, such as for Wadi Al Auja.

Base flow on the other hand is represented by the groundwater discharge through Al Auja springs and a number of other smaller springs. Flood flow is not yet developed or directly utilized in the study area, as it is the case for all the Wadis in the West Bank. However, springs' flow constitutes an important water source for domestic and irrigation water uses.

3.2 Assessment of Rainfall

Rainfall in the study area as any where in West Bank considered the soul of water resource in the area. The rainfall is the source of replenish Ground water resource in West Bank Aquifer System and it is the source of surface water generation which flow in the wadi system due the effective rainfall.

3.2.1 Average annual rainfall

For Al Auja study area the rainfall varies widely from very low quantities approximately about 100 mm in the Jordan Valley, to 650 mm in Ramallah mountain area. The average areal rainfall over the study area is estimated as 388 mm/yr. (Figure 3.1).

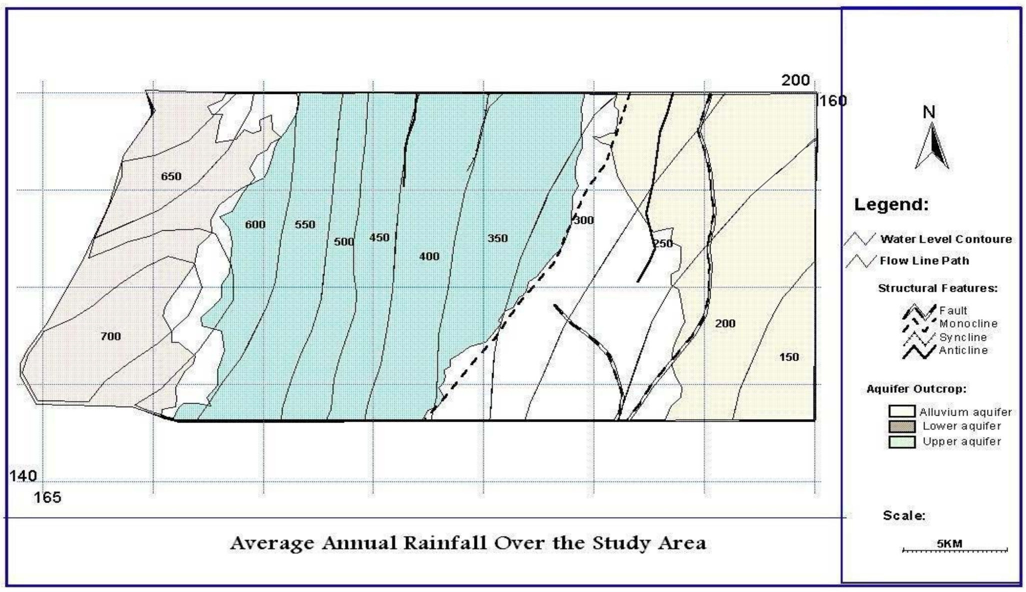

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Figure 3.1: Average Annual Rainfall over the Study Area.

The number of rainy days per rainy season ranges from 43 days in the mountainous areas to 25 days in the Jordan Valley. (Table 3.1) shows the annual variations in precipitation and rainy days at study area stations

Table 3.1: Average Annual Rainfall and Rainy Days in the study area

No.	Station name	Station ID	Average Rainfall (mm)	Average rainy days
1	Birzeit	" 0000003"	552.0	44.5
2	WBWD*	" 0000008"	684.0	42.3
3	Alhashymya	"0242230"	609.3	43.7
4	Sinjil	"0241550"	696.2	43.1
5	Atara	"0241650"	541.4	40.6
6	Deir Dibwan	"0242100"	428.7	37.9

*West Bank Water Department

3.2.2 Analysis of Daily Rainfall Data

Daily rainfall records for six stations, within the study area, were collected from the data bank of the PWA. Information on these rainfall stations is given in (Table 3.2).

Table 3.2: Rainfall Stations in the Study Area

No.	Station ID	Station Name	X- km	Y- km	Location	Average Annual Rainfall
1	0000003	Birzeit	169.00	153.00	BirZeit	557
2	0000008	WBWD	170.17	150.89	AlBira	669
3	0241550	Sinjil	175.00	160.20	Sinjil	578
4	0241630	Atara	169.00	157.00	'Atara	680
5	0242100	Deir Dibwan	176.00	146.50	Deir Dibwan	465
6	0242230	Alhashymya	169.00	145.50	Al Bira	636

The Palestine Meteorological Department and PWA collected daily rainfall data manually, initially by WBWD, then by PWA. Rainfall records are available since 1950's. The Data for the six rainfall stations located in the study area are Available in PWA Data Bank.

Rainfall statistics were obtained to show the degree of variability in daily rainfall. The minimum, maximum and the average of daily rainfall and rainy days were calculated for each station, as shown in annex 3.1-3.6. The daily rainfall at this station ranges from 1.07 mm to 50.1mm, and has an average of 11.32 mm. The average number of rainy days at this station is 38 days per year. (Table 3.3) summarizes the results for the six stations.

Table 3.3: Summary of the statistical analysis results for Rainfall data at the six stations.

Station ID	Station name	Annual Average Rainfall (mm/yr	Average number rainy days	Average Max.rainy day (mm)	Average Min. rainy day (mm)	Average Ave. rainy day (mm)
" 0000003"	Birzeit	552.0	44.5	55.5	1.1	12.5
" 0000008"	WBWD	684.0	42.3	83.0	1.1	16.1
"0242230"	Alhashymya	609.3	43.7	69.7	1.2	13.9
"0241550"	Sinjil	696.2	43.1	70.1	1.6	16.3
"0241650"	Atara	541.4	40.6	12.0	1.4	13.4
"0242100"	Deir Dibwan	428.7	37.9	50.1	1.1	11.3

In addition to the daily variations, there are significant annual variations in rainfall. (Figure 3.2) shows the hydrograph of annual rainfall for Deir Dibwan rainfall station (the representative Station as will be mentioned). The long-term average annual rainfall for Deir Dibwan station is calculated at 432 mm/yr, and the standard deviation is 163.

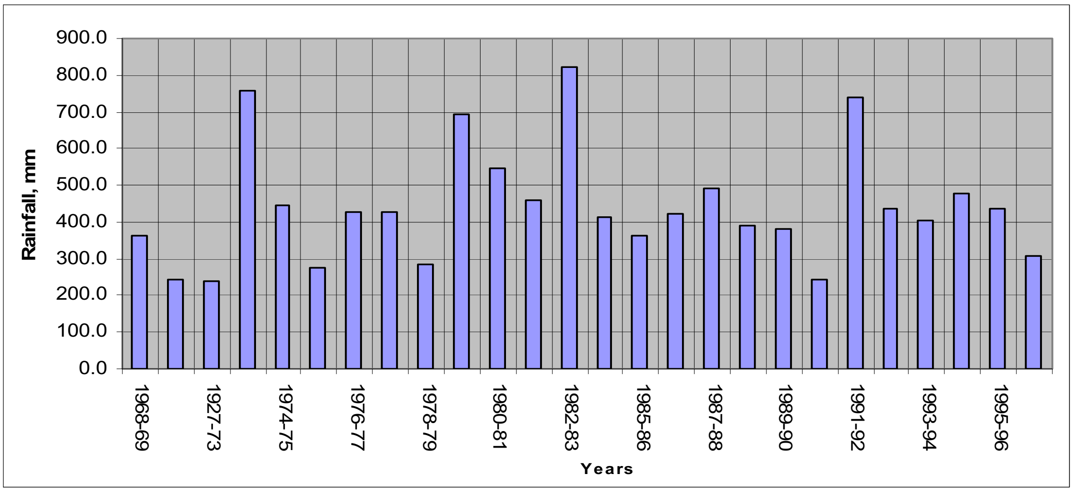

Figure 3.2: Annual Rainfall Variations for Deir Dibwan Station

3.2.3 Calculation of Areal Rainfall

The areal rainfall for both the Auja Sub- basin (study area), and for the surface water catchment area of Wadi Al Auja were calculated using, for each case, Isoheyetal method of estimation of areal Rainfall Figures 3.3. Results of the calculation were, 388, and 366.7 mm/yr for the Auja Sub-basin (study area) and the Auja Surface catchments area, using the Isoheyetal method respectively, (Table 3.4). These figures are the closest to the average annual rainfall of Deir Dibwan rainfall station, which is 428.7 mm/yr. Consequently the Deir Dibwan rainfall could be a good indicator for the area rainfall over the study area, as well as over Al Auja catchment area, and can be used for quick and approximate assessment of the daily, storm, and annual area rainfall for the areas. An adjustment factor can be applied to Deir Dibwan rainfall to obtain the average area or catchment rainfall, this factor will be multiplied by each rainfall storm which Obtained from Deir Dibwan Station. These Factors are (388/428.7=0.9) for the Auja Sub-basin and (366.7/428.7=0.86) for Auja catchments Area.

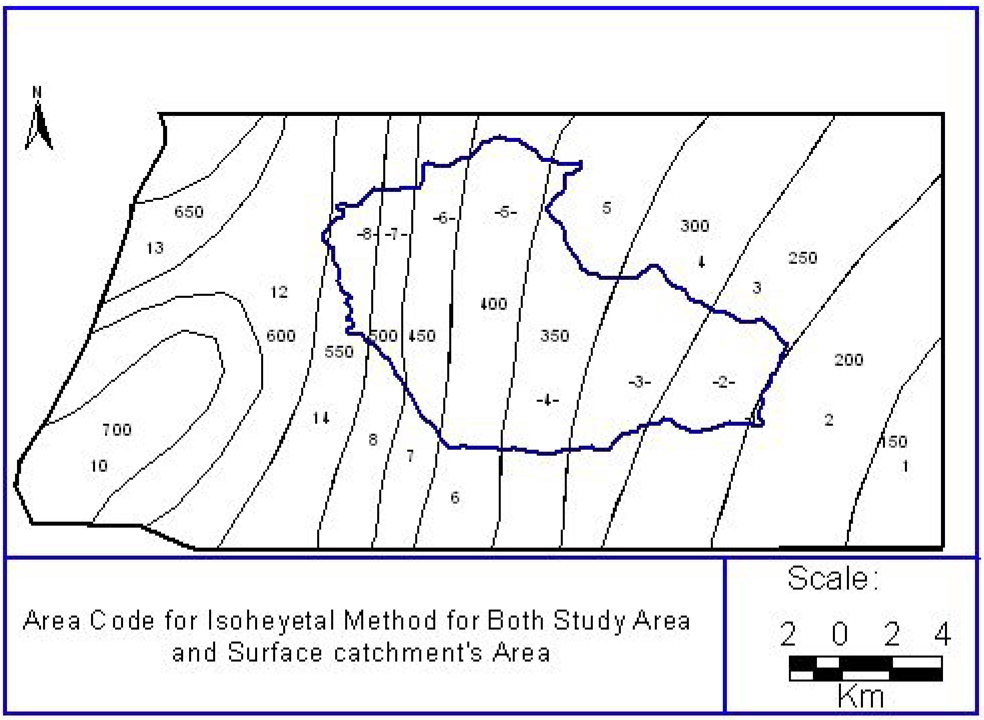

Figure 3.3: Area Code for Isoheyetal Method for Both; Study Area and Surface Catchment's' Area

Table 3.4: Areal rainfall calculation for the Auja Sub-Basin (Study Area) and Auja Surface catchments by Isoheyetal method

Auja Sub- Basin Area- Rainfall Analysis by Isoheyetal					
Isoheyet no.	**Rainfall (mm)**	**Area (km2)**	**%Area**	**Weighted Rainfall (mm)**	**Total Rainfall (MCM/Yr)**
1	130	9	1.45	2	**214.95**
2	150	36	6.52	10	
3	200	74	13.41	27	
4	250	68	12.32	31	
5	300	58	10.51	32	
6	350	53	9.60	34	
7	400	39	7.07	28	
8	450	28	5.07	23	
9	500	32	5.80	29	
10	550	43	7.79	43	
11	600	53	9.60	58	
12	650	16	2.90	19	
13	650	34	6.16	40	
14	670	11	1.81	12	
	Total	**554**	**100**	**388**	

Wadi Auja Surface Catchment Area -Rainfall Calculation By Isoheyetal Method					
Isoheyet no.	**Rainfall (mm)**	**Area (km2)**	**%Area**	**Weighted Rainfall (mm)**	**Total Rainfall (MCM/Yr)**
1	200	2	1.5	3.0	**48.4**
2	250	21	15.9	39.8	
3	300	22	16.7	50.0	
4	350	29	22.0	76.9	
5	400	28	21.2	84.8	
6	450	12	9.1	40.9	
7	500	11	8.3	41.7	
8	550	7	5.3	29.2	
	Total	**132**	**100**	**366.7**	

3.2.4 Storm Data Analysis

The compilation and analysis of storm rainfall data depends firstly on data screening approach, i.e. the full historical series of daily rainfall data for Deir Dibwan station were screened storm by storm, in order to separate the successive storms. A criterion was set for this purpose, so that, if the records were in five successive days and the 4th day had less than one millimeter/day, this day was considered as a separator between the two successive storms, and so fourth (CIDA, 2004). That is to say, the one-millimeter/day rain showers preceding or following a given storm were ignored. After the daily rainfall records were compiled storm-by-storm, the duration and the total rainfall, net from the preceding and following showers, for each storm were calculated, and the rainfall intensity and number of rainy days were determined. The Average number of storm per year, and average storm days and intensity were calculated and shown in (Table 3.5) and shown in detailed in (Annex 3.7). These individual storm rainfall data formed the bases for estimating the surface Runoff from rainfall data. This approach is preferred as compared with other methods which use the daily rainfall data, and much more accurate than using the annual rainfall data.

Table 3.5: Summary of Rainfall Storm Statistics for Stations in the Study Area.

Ser. no.	Station ID	Number of years	Average no of Storm/year.	Average Storm duration days	Average Storm intensity (I) (mm/d)
1	" 0000003"	1971-87	21	4.00	12.41
2	" 0000008"	1974-89	23	3.5	16.18
3	"0242230"	1967-97	19	4	13.94
4	"0241550"	1961-97	22	2.16	16.15
5	"0241630"	1967-95	17	3.9	13.34
6	"0242100"	1968-97	20	3.7	11.33

3.2.5 Frequency Analysis of Rainfall

The frequency of exceedance was calculated for the annual rainfall data for Deir Dibwan Station, The Weibull formula was used to calculate the probability of exceedance as follows:

$$P(X) = \frac{m}{n+1}$$

Where,

P(X): is the probability of exceedance

m: is the order (rank) of annual rainfall or Runoff when annual Values are arranged in descending order. (i.e. m = 1 for the largest observed value).

n: is the number of observations.

The return period (Tr.) in years is then obtained in table 3.6 as the reciprocal of P(x), and plotted on the log scale against annual rainfall on the arithmetic scale, (Figure 3.4). A linear relationship, in the following form can be obtained

$$R = a + b * \log Tr.$$

Where:

R is the annual rainfall in mm; Tr. is the return period in years.

a & b are constants, determined for our case as 320 & 300 which are the Y intercept and the slope respectively. The estimation equation becomes:

R= 320+ 300*Log Tr.

Table 3.6: Rainfall Frequency Analysis for the Index Rainfall Station

Hydrological year	Annual Rainfall (mm)	Rank (m)	probability		Rainy Days	Rainfall statistics		
			P (x)= (m)/(n+1)	Tr.(years) =1/P(x)		Max day	Min day	Ave day
1968	177.6	27	0.96	1.04	28	17.5	1.0	6.3
1968-1969	364.6	20	0.71	1.40	37	37.0	1.0	9.9
1969-1970	245.3	24	0.86	1.17	30	32.4	1.0	8.2
1972-1973	241	26	0.93	1.08	35	21.3	1.0	6.9
1973-1974	756.5	2	0.07	14.00	46	5.5	1.3	16.4
1974-1975	447.3	9	0.32	3.11	33	45.3	1.0	13.6
1975-1976	277.3	23	0.82	1.22	35	29.1	1.3	7.9
1976-1977	427.5	12	0.43	2.33	38	39.7	1.1	11.3
1977-1978	426	13	0.46	2.15	31	63.5	1.0	13.7
1978-1979	286.8	22	0.79	1.27	24	65.5	1.0	12.0
1979-1980	694.2	4	0.14	7.00	52	92.5	1.1	13.4
1980-1981	546.7	5	0.18	5.60	41	125	1	13.3
1981-1982	461.4	8	0.29	3.50	50	73.2	1	9.2
1982-1983	820	1	0.04	28.00	47	63	1.1	17.4
1984-1985	411.8	15	0.54	1.87	30	52.5	1	13.7
1985-1986	365	19	0.68	1.47	37	56.8	1	9.9
1986-1987	424.6	14	0.50	2.00	51	37.9	1.1	8.3
1987-1988	490.2	6	0.21	4.67	56	38.5	1.3	8.8
1988-1989	390.8	17	0.61	1.65	35	33.1	1	11.2
1989-1990	380	18	0.64	1.56	33	53.6	1.2	11.5
1990-1991	243.6	25	0.89	1.12	32	31	1	7.6
1991-1992	740.8	3	0.11	9.33	45	61.4	1.3	16.5
1992-1993	437.6	10	0.36	2.80	28	80	1	15.6
1993-1994	401.8	16	0.57	1.75	37	45	1	10.9
1994-1995	478.1	7	0.25	4.00	47	48	1	10.2
1995-1996	435.8	11	0.39	2.55	43	49	1	10.1
1996-1997	306.3	21	0.75	1.33	21	55	1.2	14.6
Average	**432.5**	**n=27**		**Average**	**37.9**	**50.1**	**1.1**	**11.4**

The rainfall for higher return periods can be obtained using this relationship, or by using the following general distribution equation, (Benjamin and Cornell, 1970):

$$\mathbf{R = R_{Ave} + s^{2} \cdot Z}$$

Where R_{Ave} is the average of rainfall for the sample, s^2, is the standard deviation, and Z is a tabulated value in the statistical references depending on (T_{r}.) the return period for which the rainfall needs to be estimated, the calculation shown in Table 3.7. & figure 3.5

Table 3.7: calculation of rainfall for higher Tr. by using normal distribution

Normal Distribution:			
Base Equations, F(O(n))=1-1/Tr			
Z from statistics table (n) =M+z.S(x)			
Estimation of Rainfall			
Tr.(yr)	F(Q(n))	Z	Q(n) mm
50	0.98	2.054	768.33
100	0.99	2.326	812.80
200	0.995	2.576	853.67
500	0.998	2.9	906.65
1000	0.999	3.1	939.35
2000	0.9995	3.344	979.24
5000	0.9998	3.649	1029.11
10000	0.9999	3.719	1040.55

The calculation results of this section are summarized in Table 3.8, and the detail analysis and calculation for Mean and standard deviation are shown in annex 3.8.

Table 3.8: Comparison between Graphical and Analytical Methods for Estimated Rainfall Frequency Estimation

	Rainfall frequency estimation	
Tr.	R (Graphical)	R (Analytical)
50	830	768.3
100	910	812.8
200	980	853.7
500	1100	906.6
1000	1180	939.3

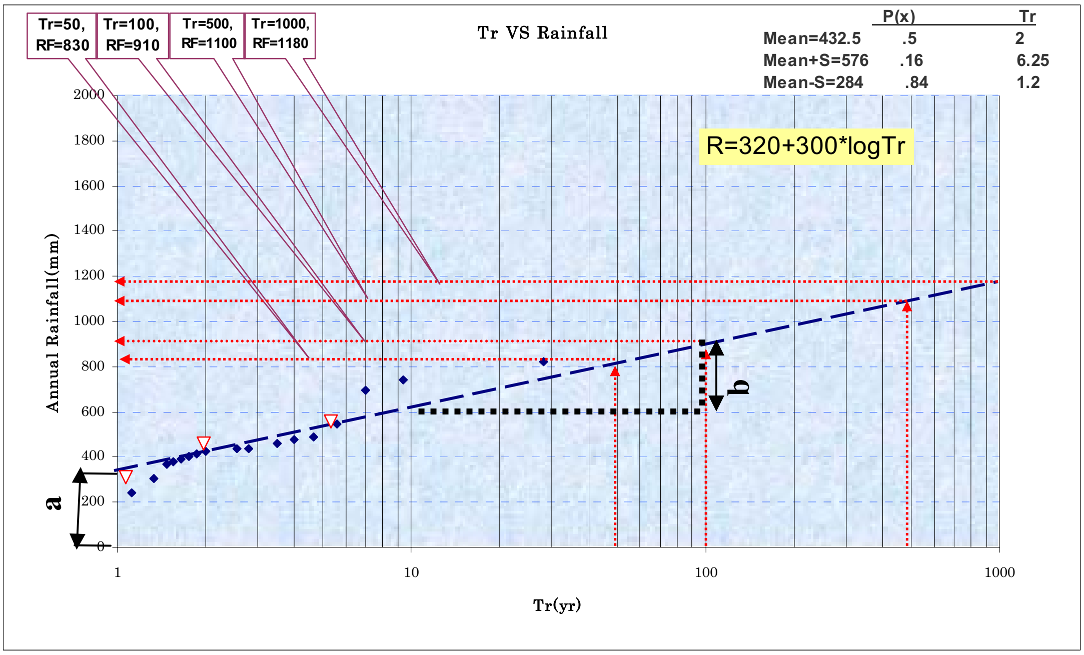

Figure 3.4: The Lognormal Distribution Curve for Rainfall at Deir Dibwan Station.

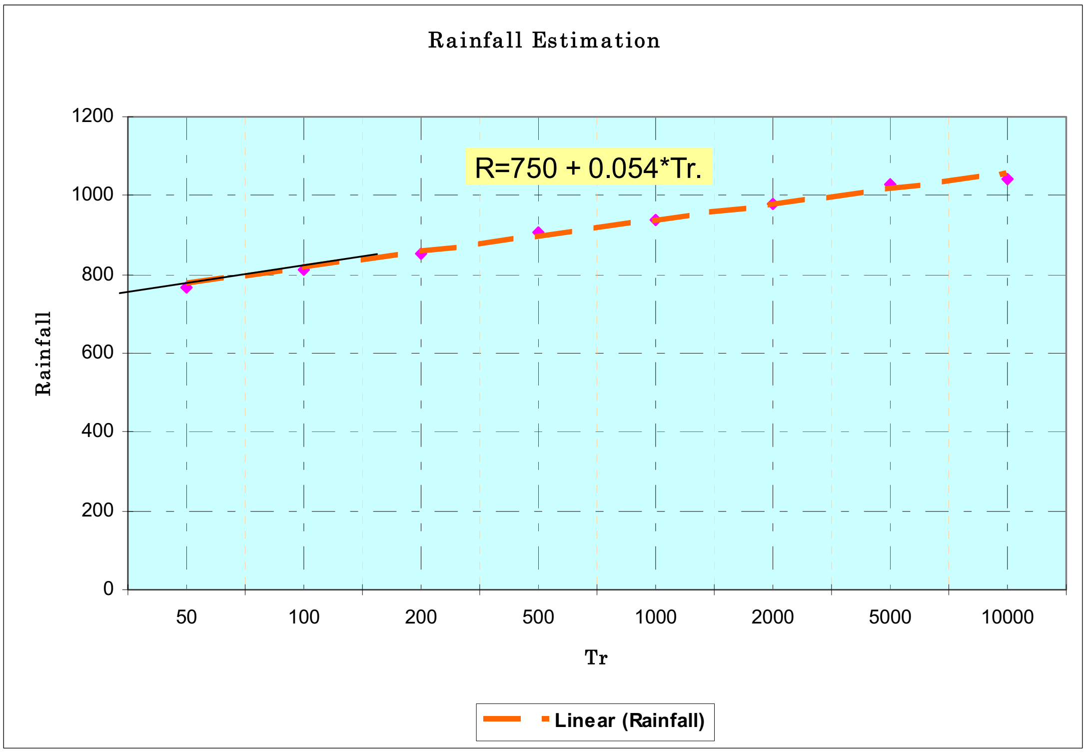

Figure 3.5: Normal Distribution Curve for Rainfall at Deir Dibwan Station.

3.3 Assessment of Flood Flow

3.3.1 General

In absence of automatic rainfall stations in the study area or in its surroundings, the only available rainfall readings would be the daily values. This is a constraint for more detailed analysis. For the study area, there are 6 adjacent stations with daily rainfall readings only; and in the absence of measured flood flow records in the study area, and particularly for Al Auja surface water catchment, a detailed rainfall and Runoff hydrograph can not be established. Therefore the storm-by-storm approach has been adopted and applied to estimate the surface Runoff from precipitation data.

Deir Dibwan station has been selected as the index stations, which best represent the area rainfall for the study area and for Al Auja catchment. This is justified by the closeness of its long-term average annual rainfall to the area rainfall. This station is also close to the center of the study area, and to the centric of Wadi Al-Auja catchment area.

Having this representation established satisfactorily, the Deir Dibwan historical rainfall records could be utilized to represent the area rainfall for the study area and the catchment area. A small adjustment to the station data was done in order to transfer the data to the centric of the catchment area and the Auja sub-basin the (study area) These adjustments were done by multiplying each rainfall records in Deir Dibwan Station by the following Factors: (388/428.7=0.9) for the Auja Sub-basin, and (366.7/428.7=0.86) for Auja catchments Area.

The adjusted storm rainfall data for the historical records of the index station could then be utilized for estimating the surface Runoff for each rainfall storm with the appropriate method. In this study, the U.S. Soil Conservation Service method,(SCS), described in the following section has been used to convert the storm rainfall data into surface Runoff data.

This procedure has enabled to generate a full surface Runoff data for the full period of rainfall records.

3.3.2 The SCS Method

In the absence of sufficient and adequate measured surface Runoff data, estimation using indirect methods would be required. A number of methods are available. The empirical method derived by the U.S. Soil Conservation Services (SCS) is adopted for this study. Because the study area not only un-gagged catchment and no detail rainfall data but also this method is applicable and more accurate than other method as rational method (Q=CIA). The Soil Conservation Service determined that the entire country could be represented by just four dimensionless rainfall distributions of 24-hour duration. Each distribution is expressed as a mass curve indicating what fraction of the total 24-hour precipitation has fallen at any time.

This method is widely applied in the U.S.A. and many other countries under various hydrological conditions. It is also known as the surface Runoff curve number method. Soil Conservation Service National Engineering Handbook Section 4: Hydrology (NEH-4) (USDA, 1985). The first version of the handbook was printed in1954, with subsequent revisions in 1956, 1964, 1965, 1971, 1972, 1985, and 1993 (Ponce and Hawkins 1996).

Rainfall excess (Runoff) varies with many factors centered on the catchment and storm characteristics. The initial part of storm water is either evaporated, or adsorbed by the vegetal cover and other rock surfaces, or absorbed by the soil to satisfy its moisture deficit or retained in surface depressions.

When these total losses or abstractions are fully satisfied, they approach a potential or ultimate saturation value (S'). Then subsurface Runoff (infiltration and percolation) and surface Runoff starts. If infiltration approximates zero, then the surface Runoff will be equivalent to the precipitation rate. If a value for the average infiltration rate is given, it can be subtracted from the precipitation rate to get the surface Runoff rate.

Rainfall excess (Q) and watershed storage (S) can be derived from:

Q = P - S .... (1)

Where: P the rainfall. Units for all parameters should be the same, and millimeters are used in this study. The watershed storage (S), in this equation, includes both the initial abstraction and infiltration. Initial abstraction has an upper limit when it becomes satisfied, while infiltration would continue at an ultimate rate depending on the transmission capacity of the subsoil and the under lying rock formations (Hawkins, 1980).

.

At saturation, the rate of rainfall excess equals the rainfall intensity, and a proportional relationship can be developed:

S / S’ = Q / P ………………………………………………(2)

Where S: Watershed storage at any time (mm)

S': Watershed storage at saturation (mm)

P: Precipitation at any time (mm)

Q: Rainfall excess (mm)

Substituting from equation (1) in equation (2) will yield:

(P – Q)/ S’ = Q / P, or $Q = P^2 / (P + S')$ ....………………(3)

The SCS method considers the potential (maximum) watershed storage of rain water as a function of the soil type, using more than 3000 soil types, four hydrologic soil groups were obtained. Runoff curves were developed for each hydrologic group to estimate (S'), the maximum potential storage. A number (CN) was assigned for each curve which is used in the following equation:

S' = (25400/CN) - 254………………………................................ (4)

Where S' is in mm, and CN is the curve number.

For Wadi Al Auja catchment, where small rural built-up areas exist in its upper catchment, and according to an empirical formula developed by the SCS, the initial abstraction (Ia) considered as 0.2 S’ (Ponce and Hawkins, 1996). The factor (0.2) decreases for urbanized areas.

Subtracting the initial abstraction (Ia) from Precipitation (P) in equation (3) and subtracting 0.2 S' for the initial abstraction, will yield:

$$Q = \frac{(P - Ia)^2}{(P - Ia + S')} ....(5)$$

With P > Ia, S'> Ia, and F (infiltration = P-Ia-Q)

then,

$$Q = \frac{(P - Ia)^2}{(P + 0.8S)} ....(6)$$

This is for the case Ia. = 0.2 S'.

Knowing the curve number, Equations 4, 5 and 6 can be used to calculate the surface Runoff.

3.3.3 Application of the SCS Method to the Study Area

In order to apply the SCS method to estimate the Runoff, and in the absence of measured surface Runoff data, the following procedure was done:

3.3.3.1 Estimation of the Curve Number (CN)

Because of the expected variability of the catchment surface with regard to its infiltration and transmission capacities, as well as its potential retention storage S’, especially for large catchment areas, no single value can be simply picked up from tables for the curve number of a catchment. Instead, a weighted average curve number needs to be calculated.

For this purpose, the study area and catchment area were subdivided into a number of smaller areas or zones, based on the type of land uses, with each zone representing one type of land use. Further subdivisions may be used, particularly for the cultivated areas, based on the type of land treatment, such as the agricultural practices.

A combined land use and soil association map was prepared, Figure 3.6. The various zones of land use, and the soil conditions were used as a background for the land use classes, to be considered in determining the curve number for each land use area or zones.

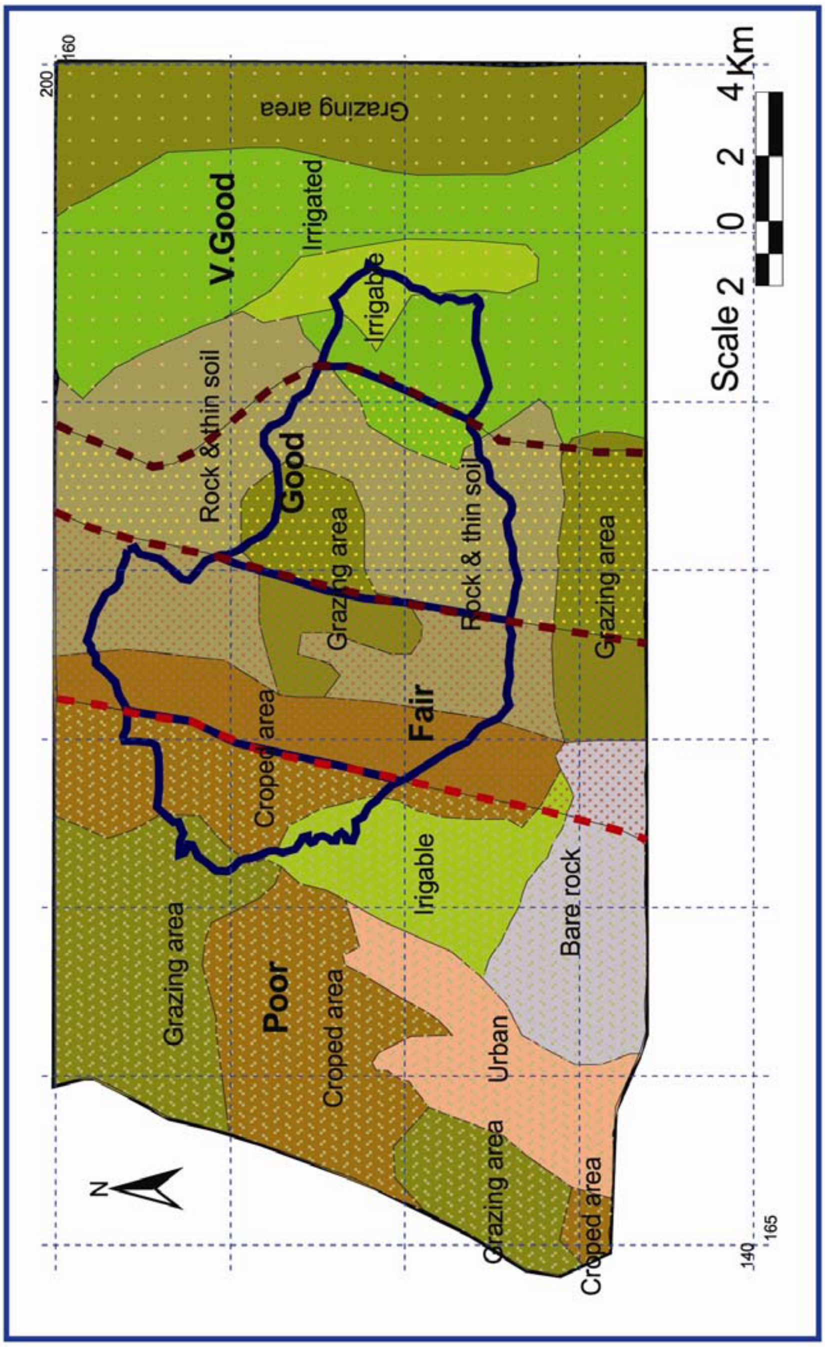

Figure 3.6: Land Use and Soil Association for the Study Area, Digitized by Using Arc view GIS from Land Use Map based on (ARIJ 2000) and (MOPIC 1998).

3.3.3.2 Land Use

Land use within the Auja study area varies according to many factors; among them are the population distribution, types of living and human activities, climatic regions, topography and land slope, and soil and rock cover.

For the purpose of hydrological analysis, and particularly for surface Runoff estimation from rainfall data, the study area was subdivided into different categories based on two criteria:

The first classification was based on the type of land use, where five land use classes were identified in the mountainous region: cropped, grazing, urbanized, range land, and irrigable areas. On the eastern slopes towards the Jordan Valley, the land use classes include: rocky, thin soil cover, grazing area, grazing and irrigated. The irrigated areas are limited to the flat areas in the Jordan Valley. The class and their respective area for the Ramallah-Auja study Area are given in (Table 3.9)

Table 3.9: Land Use Zones in the Study Area, (Analyzed By GIS)

Serial no.	Land use	AREA Km^2
1	Bare rock	31
2	Cropped area	100
3	Urban	28
4	Irrigated	102
5	Irrigable	38
6	Rock & thin soil	110
7	Grazing area	146

The second classification was based on the type of soil association, and particularly the soil hydraulic properties: namely the soil infiltration capacity, and the soil water holding capacity. In other words, this classification was based on the soil cover potential to generate surface Runoff. The study area was, accordingly, divided into four classes: very good, good, fair, and poor. The very good class refers to the highest Runoff potential.

Generally, the relatively thick soil, mostly Terra Rossa type, the fractured limestone rock conditions, and the relatively flat topography in the mountain plateau area, favors good rainwater infiltration and percolation, and consequently a poor Runoff- generation potential.

On the other hand the soil, geologic formations, and soil cover conditions on the eastern slopes and in the flat Jordan Valley area, are relatively thin and less pervious; and the topography is generally steeper except in the rather flat valley floor. In addition, the vegetal cover is relatively poor. All these conditions would result in less surface infiltration capacity, and consequently higher Runoff potential (MOPIC, 1998).

The classifications described above are taking into consideration and the study area classified into four zones using GIS program as shown on the maps given in (Figure 3.7) and (Table 3.10).

Table 3.10: Soil Classification with Respect to runoff- generating Potential

Ser. No	HYDROLOGIC	AREA Km^2
1	Poor	201
2	Fair	91
3	Good	82
4	V. Good	180

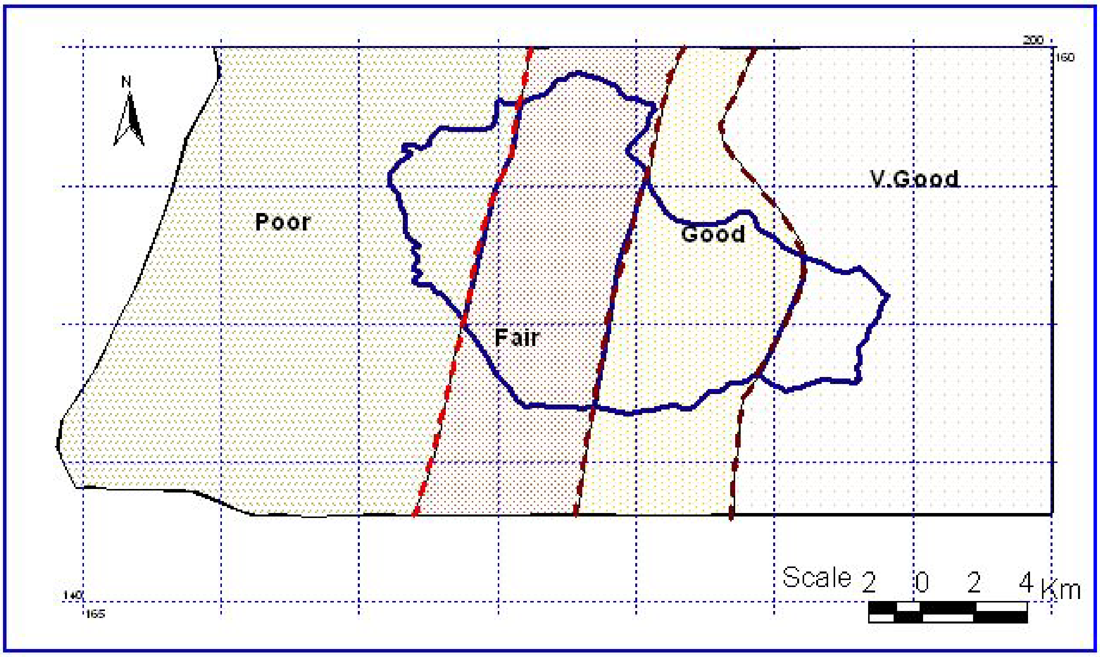

Figure 3.7: Soil Association Map for the Study Area with respect to runoff-generating potential.

3.3.3.3 Hydrologic conditions

The stud area is characterized by a lot of hydrological variation reflecting:

- *The spatial variations in topography, geology, soil conditions, land use, and the vegetation cover,*
- *And the short and long term temporal variations in the hydro meteorological parameters.*

Based on the organic content of the soil, as well as the soil moisture conditions, storm characteristics (Loague and Abrams, 2001), and the temperature prevailing during each storm, the hydrologic condition for each area was determined as poor, fair or good. Poor hydrological conditions refer to lower potential for generation of surface Runoff.

The rainy season was divided into three time zones, each having special rainfall characteristics with regard to its potential to generate surface Runoff. This potential is judged based on the hydrologic condition. Accordingly, the following hydrological conditions have been assigned, again based on the rainfall potential to generate Runoff:

- *Poor for the months: Oct. and November.*
- *Good for the months of Dec., Jan. and Feb.*
- *Fair for the months of March, April and May.*

3.3.3.4 Determination of Hydrological Soil Group

The first step for Runoff calculation from rainfall data is to determine the hydrological soil group, (A, B, C or D). Hydrological soil group “D”, has the highest Runoff potential. This is a very important step in influencing surface Runoff estimates, and has to be done on good understanding of the soil conditions.

The basic properties considered in this process are the infiltration and transmission capacities of the soil. The infiltration capacity depends on the soil composition, texture, and hydraulic properties. Mishra and Singh, 1999 Reported that the highest infiltration rates were found for deep silt loam soils. The transmission capacity of the infiltrating water depends on the sub-soil hydraulic conditions. A given soil type overlying a porous permeable rock or geological formation, would have a continuous infiltration, by maintaining a continuous downward transmission of the infiltrating water.

Following the above steps the curve number can be determined for each land use class.

The area represented by each land use class or zone was calculated. The curve number for each of these areas was determined and the weighted average curve number for each of the study area and the catchment were calculated.

3.3.3.5 Adoption of Runoff curve Number for the Study Area

Based on through and in-depth assessment of the soil and hydrologic condition of the Study area (Annex 3.9) has been adapted to the study area to determine the respective curve number to land use and hydrologic condition for varies area.

Then each area (different land use and hydrologic condition) are coded as shown in (figure 3.8) to calculate the weighted Curve Number for both Auja study area and the surface catchment's area for wadi Al Auja, as shown in (tables 3.11 & 3.12).

Example for weighting the curve number:

For the range zone, soil association very good (B1) and rainfall potential good; CN=60, Area=41 km. For cropped zone, soil association very good (B1) and rainfall potential good also CN=50, area =40 km, then

$$CN\ weighted = (CN1*A1+CN2*A2)/(A1+A2) = (60*41+50*40)/81 = 55.06$$

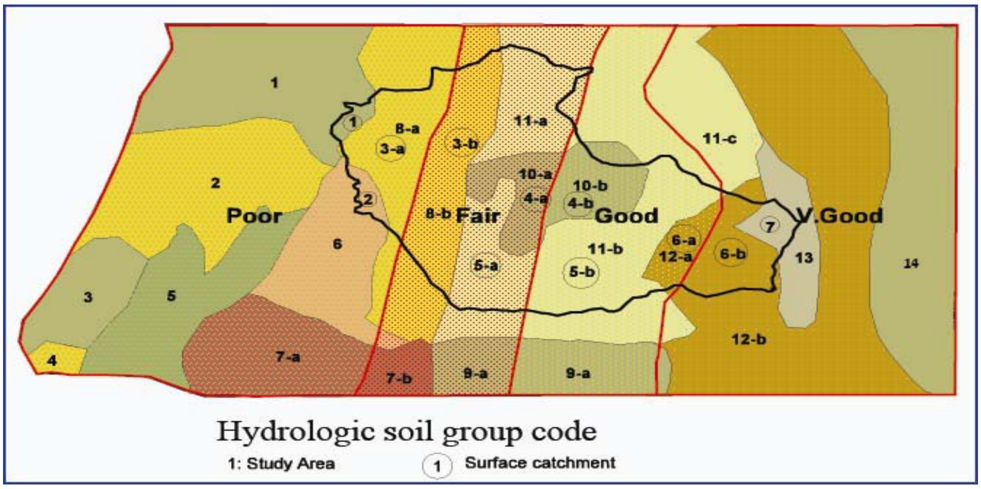

Figure 3.8: Hydrologic soil group coding.

Table 3.11: Calculation of the Hydrologic Soil Group and Weighted Curve Number for the Study Area

SCS Method for Runoff calculation:	Land	Soil	Hydrologic	CN			Area (km2.)		% Area	CN Weighted		
no	Use	Associa.	Soil Group	Good	Fair	Poor	Total	Sub-area		Good	Fair	Poor
1	Range	v.g.	B1	60	55	50	41		0.074	4.440	4.070	3.700
2	Cropped	v.g.	B1	50	45	40	40		0.072	3.610	3.249	2.888
3	Range	v.g.	B1	60	55	50	15		0.027	1.625	1.489	1.354
4	Cropped	v.g.	B1	55	45	35	3		0.005	0.298	0.244	0.190
5	Residential	v.g.	B1	75	70	65	28		0.051	3.791	3.538	3.285
6	Irrigable	v.g.	B1	55	50	45	25		0.045	2.482	2.256	2.031
7-a	Bare Rock	v.g.	B1	25	20	15	31	26	0.056	1.399	1.119	0.839
7-b	"	g	B1	30	25	20		5	0.000	0.000	0.000	0.000
8-a	Gropped	v.g.	B1	50	45	40	56	29	0.101	5.054	4.549	4.043
8-b	"	g	B2	55	50	45		28	0.000	0.000	0.000	0.000
9-a	Range	g	B2	65	60	55	23	8	0.042	2.699	2.491	2.283
9-b	"	f	C	70	65	60		15	0.000	0.000	0.000	0.000
10-a	Range	g	B2	65	60	55	21	10	0.038	2.464	2.274	2.085
10-b		f	C	70	65	60		11	0.000	0.000	0.000	0.000
11-a	Thin soil	g	B2	40	35	30	108	40	0.195	7.798	6.823	5.848
11-b	on rock	f	C	45	40	35		53	0.000	0.000	0.000	0.000
11-c	"	p	D	50	45	40		15	0.000	0.000	0.000	0.000
12-a	Irrigated	f	C	55	45	35	101	5	0.182	10.027	8.204	6.381
12-b	"	p	C	60	50	40		96	0.000	0.000	0.000	0.000
13	Irrigable	p	C	60	55	50	14		0.025	1.516	1.390	1.264
14	Range	p	D	70	65	60	48		0.087	6.065	5.632	5.199
						Total	554.0	341.0	1.0	53.3	47.3	41.4

Table 3.12: Calculation of the Hydrologic Soil Group and Weighted Curve Number for the surface catchment's area.

SCS Method for Runoff calculation:												
no	**Land**	**Soil**	**Hydrologic**	**CN**			**Area (sq.km.)**		**% Area**	**CN Weighted**		
	Use	**Associa.**	**Soil Gr.**	**Good**	**Fair**	**Poor**	**Total**	**Sub-area**		**Good**	**Fair**	**Poor**
1	Range	v	B1	66	51	42	3	3	0.023	1.500	1.159	0.955
2	Irrigable	v	B1	62	48	34	2	2	0.015	0.939	0.727	0.515
3-a	Gropped	v	B1	60	48	36	36	18	0.136	8.182	6.545	4.909
3-b	"	g	B2	75	66	50		18	0.136	10.227	9.000	6.818
4-a	Range	g	B2	79	69	61	19	9	0.068	5.386	4.705	4.159
4-b		f	C	86	79	74		10	0.076	6.515	5.985	5.606
5-a	Thin soil	g	B2	30	35	40	52	14	0.106	3.182	3.712	4.242
5-b	on rock	f	C	46	51	60		38	0.288	13.242	14.682	17.273
6-a	Irrigated	f	C	55	45	35	17	4.5	0.034	1.875	1.534	1.193
6-b	"	p	C	60	50	40		12.5	0.095	5.682	4.735	3.788
7	Irrigable	p	C	74	65	56	3	3	0.023	1.682	1.477	1.273
							132	**132**	**1.0**	**58.4**	**54.3**	**50.7**

3.3.3.6 Calculation of Surface Runoff

Using the calculated weighted average curve number for the entire area under consideration, and considering minor adjustment of this number for each storm conditions, particularly for the temperature and antecedent soil water conditions at the time of the storm, the initial abstraction for the area is calculated using **equations number (4) and (6)**:

Those equations are constructed in formula model by using certain format of excel sheet to calculate the surface Runoff and the direct infiltration for both study area and surface catchment's area. The individual daily storm are taken as model input with constrain to eliminate the value were **P-Ia+S'<=0**.
(Annex 3.10-a, and 3.10-b) shows the detailed calculation sheets of the application of CN method for Al Auja study area and surface catchment's area to estimate Runoff and Infiltration components.

Example:
For rainfall event in March the total storm water (P) =114.5 mm, so rainfall potential is fair, then CN=47.3 from table 3.11.
So, S' = (25400/CN) – 254 = (25400/47.3)-254=283, and I.a=0.2*S'=56.6.

Then Q= $(P-0.2S')^2$/ P + 0.8 S' =9.83and Infiltration=P-I.a-Q=48.83.

Runoff coefficient= (Q/P)*100 %=(9.83/114.5)*100%= 8.58

Infiltration coefficient= (Infiltration/ P)*100 %=(48.83/114.5)*100%=42.6%

By summing up the Runoff values for all storms within, the historical monthly and annual surface water Runoff for the study area can be calculated. (Tables 3.11 and 3.12) give such final results for the study area and for Al Auja catchment area. From the calculations, the average **annual Runoff for Al Auja Study Area and Auja catchment Area were calculated as 10.27 and 2.7 MCM/yr respectively**. (Annex 3.10-a, and 3.10-b) shows the detailed calculation sheets of the Runoff components.

Table 3.13: Estimated Historical Annual Surface Runoff for the Study Area:

Hydro-logical Year	Annual Rainfall (mm)	Total Annual Runoff (mm)	Total Annual (MCM)	Hydro-logical Year	Annual Rainfall (mm)	Total Annual Runoff (mm)	Total Annual Runoff (MCM)
1968-1969	364.6	14.06	7.79	1984-1985	411.8	7.52	4.16
1969-1970	245.3	1.54	0.85	1985-1986	365	14.39	7.97
1972-1973	240	4.14	2.29	1986-1987	424.6	11.23	6.22
1973-1974	756.5	56.65	31.39	1987-1988	490.2	11.93	6.61
1974-1975	447.3	8.76	4.85	1988-1989	390.8	4.08	2.26
1975-1976	277.3	3.32	1.84	1989-1990	380	16.04	8.89
1976-1977	427.5	6.79	3.76	1990-1991	243.6	4.30	2.38
1977-1978	426	5.72	3.17	1991-1992	740.8	66.04	36.59
1978-1979	286.8	3.05	1.69	1992-1993	437.6	35.76	19.81
1979-1980	694.2	18.43	10.21	1993-1994	401.8	12.99	7.20
1980-1981	546.7	54.70	30.30	1994-1995	478.1	10.39	5.76
1981-1982	461.4	8.84	4.90	1995-1996	435.8	13.34	7.39
1982-1983	820	81.71	45.27	1996-1997	306.3	6.13	3.39
				Average.	**442.3**	**18.5**	**10.27**

Table 3.14: Estimated Historical Annual Runoff for Surface Catchment Area

Hydro-logical Year	Annual Rainfall (mm)	Total Annual Runoff (mm)	Total Annual (MCM)	Hydro-logical Year	Annual Rainfall (mm)	Total Annual Runoff (mm)	Total Annual Runoff (MCM)
1968-69	364.6	16.5	2.18	1984-85	411.8	11.5	1.52
1969-70	245.3	32.6	4.30	1985-86	365.0	3.2	0.42
1927-73	241.0	4.9	0.64	1986-87	424.6	6.3	0.83
1973-74	756.5	67.0	8.85	1987-88	490.2	2.7	0.36
1974-75	447.3	3.3	0.44	1988-89	390.8	6.4	0.85
1975-76	277.3	0.0	0.00	1989-90	380.0	13.4	1.76
1976-77	427.5	4.9	0.65	1990-91	243.6	2.9	0.38
1977-78	426.0	5.6	0.74	1991-92	740.8	83.0	10.96
1978-79	286.8	7.2	0.95	1992-93	437.6	33.4	4.41
1979-80	694.2	32.5	4.29	1993-94	401.8	1.0	0.13
1980-81	546.7	53.7	7.09	1994-95	478.1	15.1	2.00
1981-82	461.4	6.5	0.85	1995-96	435.8	12.3	1.63
1982-83	820.0	91.2	12.04	1996-97	306.3	10.5	1.39
				Average	**442.3**	**20.3**	**2.7**

3.3.3.7 Calculation of Runoff Coefficients

The Runoff coefficient (C) represents the percentage for rainfall, which appears as surface Runoff. Values for the period of analysis have been calculated for each storm. Average values for the entire storm have been calculated for both Ramallah-Auja study area and Auja catchment Area.

The historical rainfall data for each rain storm, each month, and for each year, can be used with the respective calculated surface Runoff to calculate the storm, monthly, and annual Runoff coefficient. The average storm and annual Runoff coefficients are given in (Tables 3.15, & 3.16). The storm-by-storm Runoff coefficients are given in (Annex 3.11). **The average storm and annual Runoff coefficients, for the study area are 6.68, 3.5 %, and for the catchment area are 4.2, 3.9 % respectively**.

The lower values for Auja catchment area may confirm the occurrence of karst feature that are demonstrated by the flow characteristics of Auja spring

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Table 3.15: Calculated Annual Runoff Coefficient for the Auja Study Area

Hydro-logical Year	Annual Rainfall mm	Total Annual Runoff mm	Annual Runoff Coefficient%	Hydro-logical Year	Annual Rainfall mm	Total Annual Runoff mm	Annual Runoff Coefficient%
1968-1969	364.6	14.06	3.86	1984-1985	411.8	7.52	1.83
1969-1970	245.3	1.54	0.63	1985-1986	365	14.39	3.94
1972-1973	240	4.14	1.72	1986-1987	424.6	11.23	2.64
1973-1974	756.5	56.65	7.49	1987-1988	490.2	11.93	2.43
1974-1975	447.3	8.76	1.96	1988-1989	390.8	4.08	1.04
1975-1976	277.3	3.32	1.2	1989-1990	380	16.04	4.22
1976-1977	427.5	6.79	1.59	1990-1991	243.6	4.3	1.76
1977-1978	426	5.72	1.34	1991-1992	740.8	66.04	8.91
1978-1979	286.8	3.05	1.06	1992-1993	437.6	35.76	8.17
1979-1980	694.2	18.43	2.66	1993-1994	401.8	12.99	3.23
1980-1981	546.7	54.7	10.01	1994-1995	478.1	10.39	2.17
1981-1982	461.4	8.84	1.92	1995-1996	435.8	13.34	3.06
1982-1983	820	81.71	9.96	1996-1997	306.3	6.13	2
				Average	**442.3**	**18.5**	**3.49**

Table 3.16: Calculated Annual Runoff Coefficient for Auja Catchment Area

Hydro-logical Year	Annual Rainfall mm	Total Annual Runoff mm	Annual Runoff Coefficient%	Hydro-logical Year	Annual Rainfall mm	Total Annual Runoff mm	Annual Runoff Coefficient%
1968-69	364.6	16.5	4.53	1984-85	411.8	11.5	2.79
1969-70	245.3	32.6	13.29	1985-86	365.0	3.2	0.88
1927-73	241.0	4.9	2.02	1986-87	424.6	6.3	1.49
1973-74	756.5	67.0	8.86	1987-88	490.2	2.7	0.55
1974-75	447.3	3.3	0.74	1988-89	390.8	6.4	1.65
1975-76	277.3	0.0	0.00	1989-90	380.0	13.4	3.51
1976-77	427.5	4.9	1.15	1990-91	243.6	2.9	1.19
1977-78	426.0	5.6	1.31	1991-92	740.8	83.0	11.20
1978-79	286.8	7.2	2.50	1992-93	437.6	33.4	7.63
1979-80	694.2	32.5	4.68	1993-94	401.8	1.0	0.24
1980-81	546.7	53.7	9.83	1994-95	478.1	15.1	3.17
1981-82	461.4	6.5	1.40	1995-96	435.8	12.3	2.83
1982-83	820.0	91.2	11.13	1996-97	306.3	10.5	3.43
				Ave.	**442.3**	**20.3**	**3.9**

3.4 Assessment of Spring Flow

3.4.1 Springs Discharge

There are 15 springs in the study area representing the lower and the upper aquifer systems. The average total annual discharge from these springs is approximately 16 MCM/year. Palestinians control the Majority of these springs. Springs' data are available in the PWA database, which includes information on discharge and water quality data, (Annex 3.12)

These springs are distributed in two main areas in the study area, namely, the mountain foothills, and the Ramallah Mountains, (Figure 3.9).

These springs periodically monitored in term of discharge and quality at interval of 1, 2, and 3 months depending on the flow characteristics and the spring significance.

These springs are classified with respect to the water use and the aquifer they issue from as given in (Table 3.17).

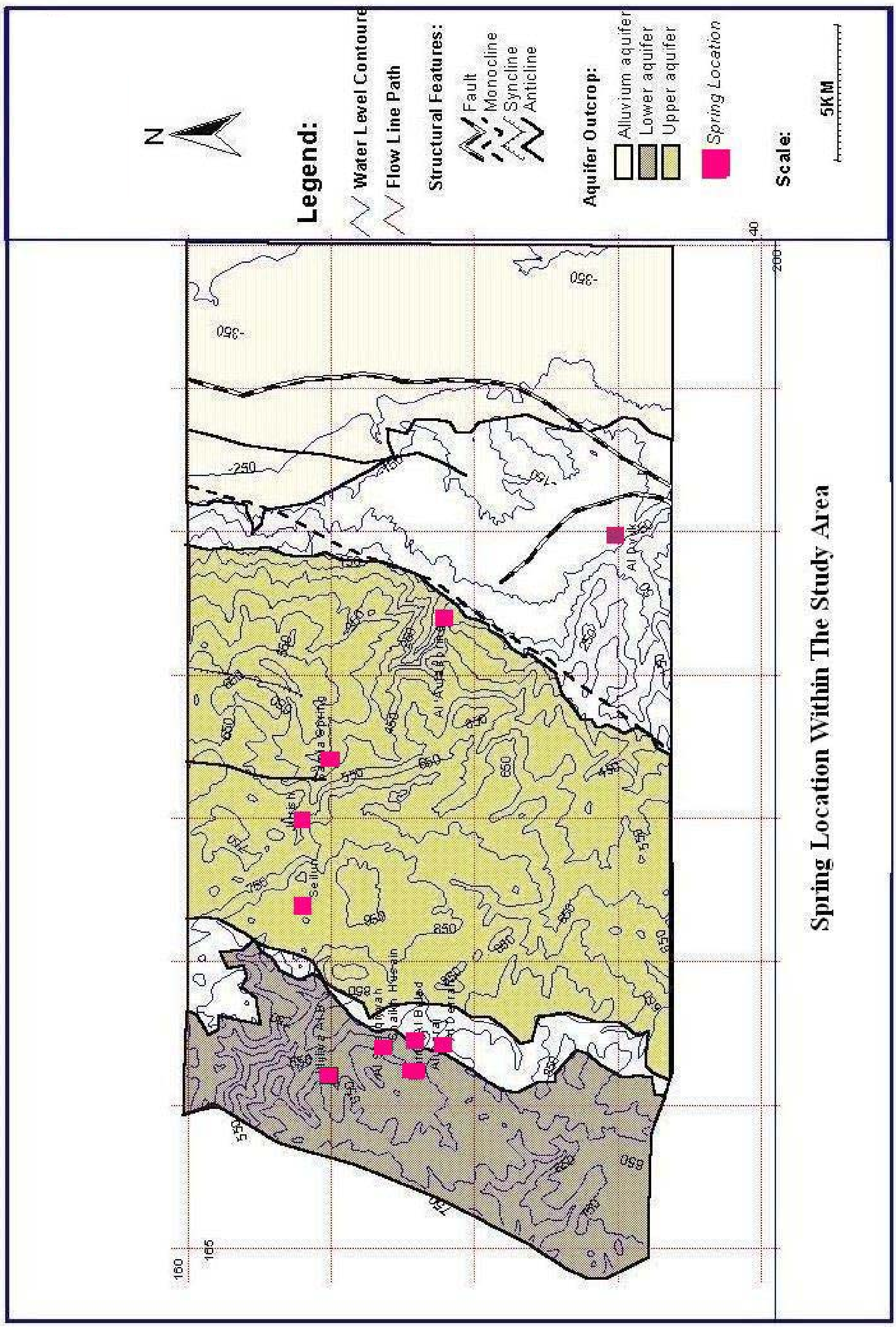

Figure 3.9: Springs' Locations in the Study Area

Table 3.17: Data on the springs in the Study Area

Spring ID	X-km	Y-km	Z-m ASL	Spring Name	Feeding Aquifer	Average discharge C.M./yr	Water Use
AC/060	190.05	144.66	-115	Al Dyuk	UA	4437737	**DA**
AC/060A	190.04	144.72	-110	Al Nwai'mah	UA	2424324	**A**
AC/060B	190	144.8	-110	Al Shusah	UA	550397	**A**
AR/020	186.75	151.42	20	Al 'Auja	LA	8526493	**A**
AR/021	181.55	155.25	425	Samia	\	-	**X**
BA/090	180.03	155.8	740	Jurish	\	3293	**D**
BA/095	176.8	155.6	690	Seilun	\	6365	**D**
BA/106	170.5	155.4		Jilijliya Al Ba	\	1357	**D**
BA/126	171.6	151.2	750	Al Kabeerah	LA	6786	**A**
BA/127	171.6	151.05	760	Al Derrah	LA	6480	**A**
BA/128	171.55	151.05	750	Al Mgharah	LA	16588	**A**
BA/129	171.6	151.15	740	Al Daraj	LA	5286	**A**
BA/130	171.95	153.25	630	Al Sharqiyya	LA	4504	**A**
BA/132	171.85	153.3	640	Shaikh Husa	LA	6876	**A**
BA/135A	170.55	152.2	645	Jifna Al Bala	LA	23306	**DA**

A: Agriculture, D: Domestic, DA: Both, X: Dry, UA: Upper Aquifer, And LA: Lower Aquifer

3.4.2 Spring Flow Recession Analysis

The term recession refers to the decline of outflow from a system in response to the absence of inflow, and is known to follow an exponential decay law. Application in groundwater hydrology deals with the recession characteristics of the base flow component of a stream hydrograph and the declining trend of groundwater levels in wells, and spring discharge in the absence of recharge. There are three features or a flow representing the withdrawal of ground water from an aquifer or a groundwater basin.

In case we dealing with a stream, the total hydrograph should be separated by an approximate method, to its flood and base flow components, then the recession analysis can be performed on the base flow component only

For base flow or spring flow recession, (Buttler, 1957), suggested the following formula to calculate the discharge at any time after the peak discharge time:

$$\mathbf{Q = Q_p / 10^{(t/kr)}} \qquad (1)$$

Where:

$\mathbf{Q_p}$: is the peak discharge.

$\mathbf{Q_t}$: is the discharge at time, t units after Qp.

$\mathbf{K_r}$: is the recession factor.

t: time interval after the zero time, which is the time of peak flow..

T and Kr should have the same time units.

The total potential storage, Q_{tp} in the supplying aquifer, is defined as the total volume of ground water that would be discharged during an entire recession if complete depletion where to take place uninterruptedly, and without any addition to the aquifer from any external source, and it is determined by evaluating Equation (1) between the two times, zero and infinity, which results in the following equation:

$$\mathbf{Q_{tp} = Kr * Q0/2.3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(2)}$$

During such an un-interrupted recession cycle, the remaining base flow storage, Qr, after any time from the peak time, or at the end of the recession cycle, can be determined from the following equation:

$$\mathbf{Qr = Q_{tp} / 10^{(t/kr)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(3)}$$

Or it can be calculated by subtracting the total actual ground water discharge at any time, from the total potential discharge.

The recession technique has been applied to some important springs in the study area. The calculated recession parameters are given in (table 3.18); also shown in (Figure 3.10). The recession period for each spring has been taken from the time of peak for each spring and for the given year of record, till the end of November of that hydrological year.

The recession technique has been also used for calculating the groundwater recharge to the supplying aquifer(s), by subtracting the remaining base flow discharge at the end of the recession cycle of the proceeding year, from the total potential base flow storage for the following year.

The results of the base flow recession analysis which include the total potential discharge for the recession period, the remaining base flow storage at the end of November, and recharge to the supplying aquifer are given in (Annexes 3.12 & 3.13).

Example for Auja Spring:

K=38.5 months, Discharge period=11 months, $Q_{.peak}$=700 l/s

$Q_{.tp}$= $Q_{.peak}$ *K/2.3= ((700l/s*(60*60*24*30)*38.5 month)/2.3)/10^9

$Q_{.tp}$ =30.37 MCM.

Remaining base Storage = $Q_{.tp}$ /10^ (t/K) =30.37/10^ (9/38.5)=17.73MCM

Spring Name:				**Al Auja**
Spring Code:				**AR/020**
Recession Factor =month				**38.5**
Peak Discharge =L/S				**700**
Discharge Period/Cycle (t) = MONTH				**9**
	(1)	(2)=(1)*60*60*24*30/10^6	(3)= $Q_{.tp}$*1000-(2)	
Time (month)	**Spring Discharge (L/s)**	**Cumulative Discharge (MCM)*1000**	**Remaining Storage (MCM)*1000**	
March.	659.4	1709.07	28662.41	
April.	621.1	3318.92	27052.56	
May	585.0	4835.31	25536.17	
June	551.1	6263.66	24107.82	
July	519.1	7609.10	22762.38	
Aug.	488.9	8876.43	21495.05	
Sept.	460.6	10070.18	20301.30	
Oct.	433.8	11194.63	19176.85	
Nov.	408.6	12253.80	18117.67	
Total potential Storage =(MCM)				**30.37**
Total Discharge For The Period =(MCM)= $Q_{.tp}$- Remaining base flow				**12.25**
Remaining Base flow Storage/End Of Nov.=(MCM)				**18.11**
Recharge By The End Of Nov.=(MCM)*1000=remaining base flow-remaining base Storage				**388.04**

Table 3.19: Results of the spring flow recession analysis

Spring ID	Spring Name	Recession factor	Peak Discharge. L/s	Discharge period/cycle month	Total Potential Storage (CM)	Total Discharge. For the period (CM)	Remaining Base Flow Storage (CM)	Recharge By The end of Nov. (CM)
AC/060	Al-Duke	53.3	190	11	11400000	4220000	7200000	97330
AR/020	Al-Auja	38.5	700	9	30370000	12250000	18400000	388040
BA/127	Al-Derah	11.67	0.35	8	4600	3300	1300	351.86
BA/111	Ajjul	8.3 -24	4.8-2.8	9	69160	45540	23520	0
BA/126	Kabeerah	9.6	0.75	8	8110	6120	1990	800
BA/129	Al-Daraj	10	0.55	8	6200	4630	1570	580
BA/132	Al-Shaikh	10	1.2	10	13520	10810	2710	1360
BA/135A	Jifna	31.8	3.8	10	136180	67580	66010	2590
BA/138	Hammrah	4.17	3	9	14090	10480	3620	3520
BA/164	Delbah	2.8 -5	65, 32	9	213160	160800	52400	2760
BA/128	magarah	14	0.95	9	14980	10640	4350	940
BA/130	Al-Sakya	52.2	0.19	10	11170	3890	7280	90
BA/152	Al-`alaq	8.22	1.9	10	17770	14500	3280	2170
				Sum.	**42278940**	**16808290**	**25766040**	**500446.36**

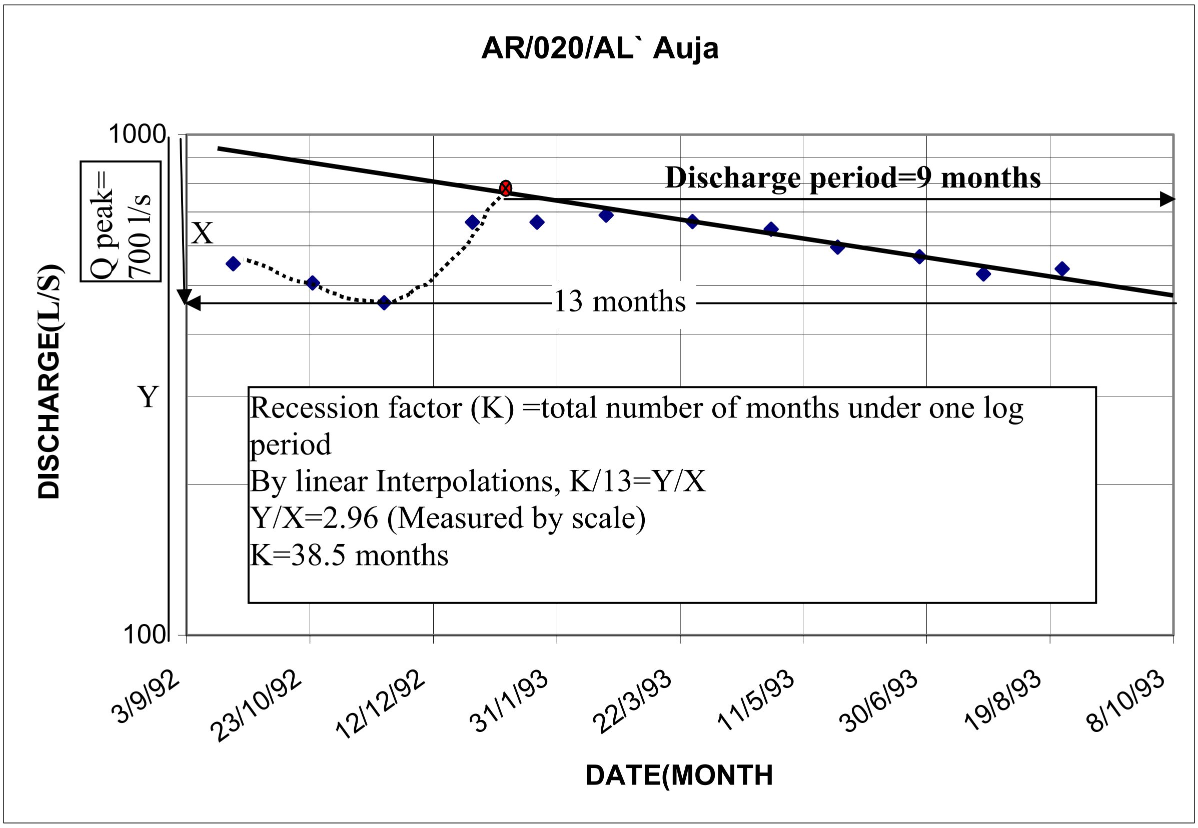

Figure 3.10: Flow Recession for Al Auja Spring

Chapter 4

GROUND WATER RESOURCES EVALUATION

4.1 Groundwater Role and Importance

Ground water, including wells and springs' sources, is considered the main water supply source for the study area, for domestic and agriculture uses. Consequently, it should be carefully developed and managed, in an efficient and sustainable manner, particularly with respect to its protection from depletion and over drafting of the aquifer system. This importance for the groundwater is due to its availability, almost everywhere in the West Bank, in different quantities, and mostly in suitable quality. In addition, there is no other alternative water source, which is economically and physically viable and available to meet the current water demands, and to a large extent, the future water demands.

In this chapter, we will focus on the occurrence and movement of the ground water resources in the study area to assess and evaluate the vital resources from quantity point view, Because of the expansion of ground water resources development based on good understanding of ground water potential, properties, and aquifer behavioral responses to man actions related to ground water developments.

4.2 Hydraulic Characteristics of Aquifers

Knowledge of aquifer properties is essential to water resource evaluation, at least at the initial stage of development. At an advanced stage of resource development, i.e. at the stage of resource management, additional data of different nature would be needed. This data pertains and to the aquifer response to development, in terms of water level changes, which reflect changes in storage, as well as water quality data.

There are different ways to estimate such properties. However, the bases of these methods and the stochastic nature and large variability of these properties are major sources of uncertainty in the estimated values. Regionalization of aquifer properties should be practiced with great care. As stated before, the rock permeability and porosity of the limestone mountain aquifer systems are of *secondary* origin caused by joints, fractures, and karst features. These features create large spatial variations, both vertically and horizontally, in the aquifer properties that limit the validity of data regionalization. In addition, they would result in non-darcian, non-laminar or fissure flow, and consequently limit the accuracy of applying many of the conventional techniques for groundwater evaluation. However, the groundwater flow on a macro or regional scale may replicate laminar flow, similar to the flow in the porous media. This may not be the case on a local scale, if karst features are well developed.

Aquifer heterogeneity in such fractured aquifers is related to various factors such as depth of penetration of wells, geologic structures, geologic facies changes, and the degree of karstification.

Some data on the aquifers hydraulic conductivity, transmissivity, and storitivity are available in the PWA database and are given in Tables (4.1, 4.2). The transmissivity for the Lower Aquifer ranges from 59 m^2/day to 250m^2/day; while for the Upper Aquifer, it ranges from 1200 m^2/day (Jericho) to more than 1600 m^2/day (Ein Samia) (CDM, 1998).

Table 4.1: Hydraulic Properties for the Upper Aquifer (CDM, 1998)

Upper Aquifer	**X (Km)**	**Y (Km)**	**ID**	**Q/S (m^3 /h/m)**	**T (m^2 /d)**
Ein Samia 3A	181.75	154.90	18-15/03A	34	1685
Jericho No.1*	190.90	149.80	19-14/101	4	1280

Table 4.2: Hydraulic Properties for the Lower Aquifer (CDM, 1998)

Lower Aquifer	X (km)	Y (km)	ID	Q/S (m^3/h/m)	T (m^2/d)
Ein Samia no.5	181.55	155.30	18-15/006	1.6	59
Ein Samia no.6	182.28	155.85	18-15/006	0.7	N
Fasayil no.8	188.69	158.75	18-16/009	N	216
Jericho no.5	188.26	146.83	18-14/003	N	227
Kochav hashahar	182.10	153.00	18-15/007	N	120

4.3 Groundwater Flow

The groundwater flow, rate and direction, are usually controlled by four main factors: geological, hydrogeological, hydrological, and topographical. The combined effect of these factors in the study area is the creation of three aquifer systems and eastward direction of groundwater flow in all these systems. The driving force for groundwater flow is the hydraulic gradient, and the aquifer hydraulic conductivity. Therefore, determining the aquifer hydraulic properties, measuring groundwater levels, and mapping its configuration are the main keys for determining the direction and rate of the groundwater flow in an aquifer.

4.3.1 Groundwater Levels and their surface configuration

The current groundwater configuration has been mapped for the study area using the limited available water level data. It is clear that the groundwater flow in the study area is generally from the main groundwater divide, west of Ramallah, towards the Jordan Valley in the east.

The main recharge areas for the Lower and Upper Aquifers are in Ramallah mountain area, while the Jordan Rift Valley and the Dead Sea represent the main discharge area for all the aquifer systems. The configuration of the water table for the upper, and the piezometric surface of the lower aquifer are shown in Figures 4.1,& 4.2,. The flow path lines show the groundwater flow patterns for the three aquifers.

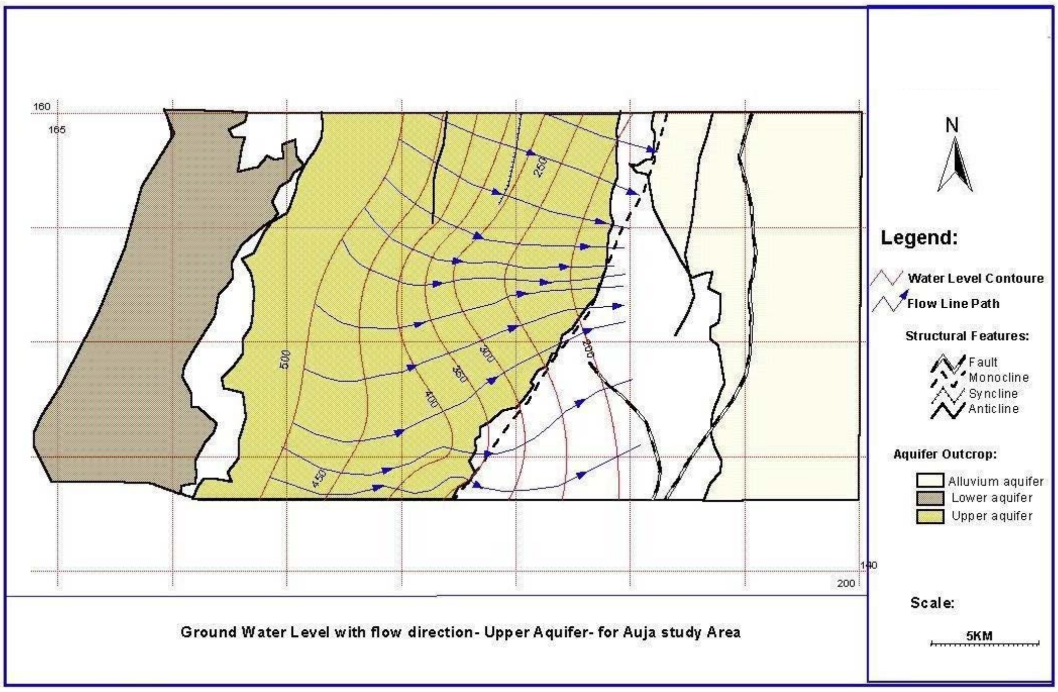

Figure 4.1: Ground Water Level for Upper Aquifer

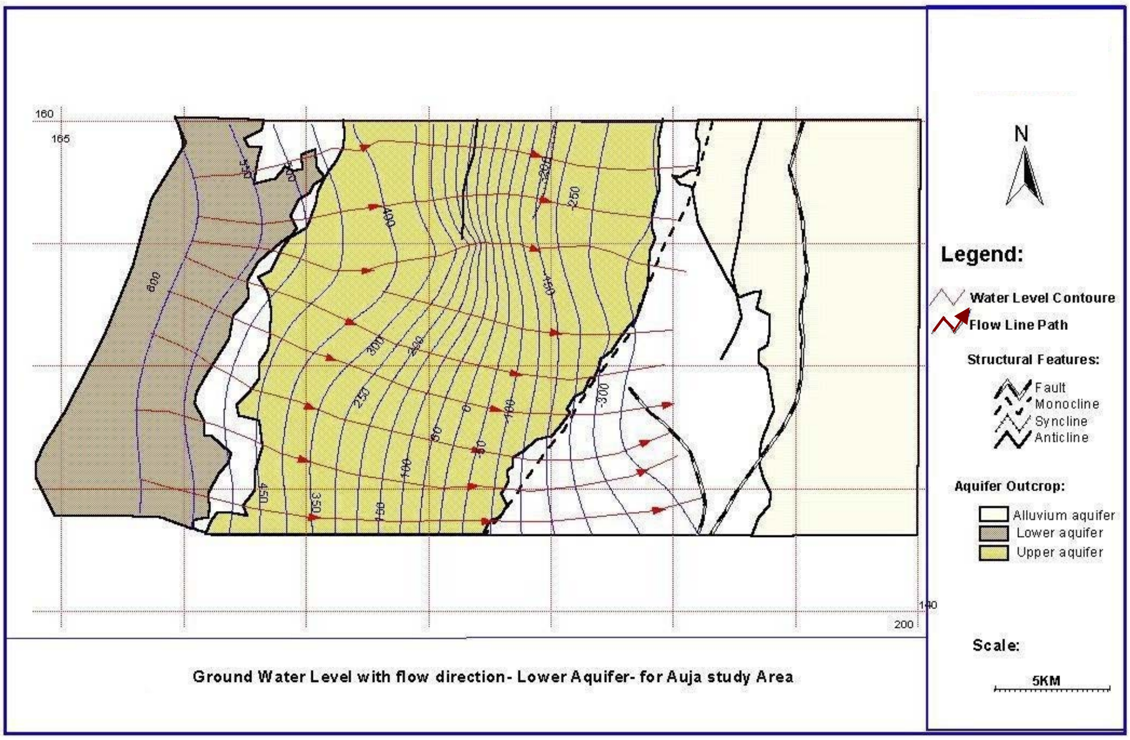

Figure 4.2: Ground Water piezometric head for Lower Aquifer

4.3.2 Hydraulic Gradients

The average hydraulic gradients for the aquifers have been calculated from these maps directly by finding the head difference between the contour line divide by the length where these line sprayed, and are given in the following Table 4.3.

Table 4.3: Hydraulic Gradient for the Main Aquifers in the Study Area (Calculated by GIS)

Aquifer	Hydraulic Gradient
Upper	.025
Lower	.049
Alluvium	.001

The maps show that the hydraulic gradients are not uniforms a long the flow domain in the study area. The hydraulic gradient of aquifers is controlled by the prevailing hydrogeological conditions, such as the aquifer hydraulic conductivity and the rate of flow, geological structures, and the topography. Man-made factors also affect the groundwater surface configurations. Most importantly, groundwater pumping, dams' construction, drainage works, etc.

Significant head differences have been noticed between the Upper and Lower Aquifers at several locations. Vertical flow patterns are complex as gradients change from one location to another. These changes are not well defined due to lack of dedicated observation wells. As a result, the transition zone between the aquifer recharge and discharge areas are not clearly defined. In some areas, the Upper Aquifer is perched, whereas in other areas, the Upper and Lower Aquifers are hydraulically connected, (CH2MHIL, 2000).

As seen in water level contour maps, the hydraulic gradient is affected by the existing faults such as in Ein Samia well field. The hydraulic gradient Increases dramatically across the existing faults, which give an indication that these faults act as resistance boundaries for the ground water flow, particularly in the lower aquifer. That is also clear by the lack of change in the hydraulic gradient across such faults, for both the Upper and lowers Aquifers.

On the other hand, flow continuity of flow from Alluvial Aquifer to the Jordan River and the Dead Sea implies that the major rift faults do not act as complete barriers to groundwater flow (CH2MHIL, 2000, Jericho Model). In all areas major springs reuse along the western shore of the Dead Sea along the major fault zone, such as Al-Fashkha spring. This fault zones act as vertical conduit for the deep artesian aquifer, which brings the ground water to the ground surface, these fault zones also facilitate mixing of water rising from different aquifers.

4.4 Groundwater Recharge

The outcrop areas of the Cinomanian and Turonian rocks constitute the recharge areas for the main aquifer systems within the study area as well as for the study area. These recharge areas, are located in the outcrop areas along the axis of The Hebron-Ramallah Anticline, where the rainfall is relatively high. Although the water table of the Upper and Lower Aquifers in this mountain area may be several hundred meters below ground surface in the main recharge areas, fracturing and karst features facilitate the deep vertical downward movement of the infiltrating water.

Several attempts had been done to estimate the recharge to the eastern basin aquifers. All were based on assumed or estimated infiltration rates from rainfall, which ranged from 20-45% by Rofe &Raffety (1963), 20% by (Scarpa, 1994). In general, a range from 5-30% may be acceptable in semi-arid regions, (CDM, 1998). Based on these previous studies total recharge were estimated for the study area and it was range from 24-36 MCM/yr.

By applying the soil conservation service method in the study area; as mentioned earlier in this thesis, the total direct rainfall recharge was estimated for the study area for all the years from 1968-till 1997. The results are shown in the annex 4.1 and 4.2, for both the study area and the surface catchment's area.

The total Average direct infiltration in the study area is about 30 MCM/yr, which is about 11% of the average annual volume of rainfall. The average infiltration in Al Auja catchment area is about 9 MCM/yr, which is about 15% of the average annual volume of rainfall.

These estimated recharge coefficients range from one third to half of the previous estimates. They are believed to be more accurate, as they were based on analysis of the storm rainfall data rather than the daily or the annual rainfall data.

Recharge to the alluvial aquifer system in the Jordan Valley occurs through stream-bed infiltration of flood and base flow along Wadi Al Auja stream channel. Recharge to the alluvial aquifer also occurs from subsurface under-flow from the mountain aquifers across fault plains, as well as from return-flow from irrigation water (CH2MHIL, 2000, Jericho Model).

4.5 Groundwater Discharge

The natural ground water discharge from the three aquifer systems in the study area occurs through contact and fault springs, seeps and evapotranspiration along the Jordan River flood plain and the Dead Sea.

Artificial discharge from these aquifers takes place through wells abstraction. The average annual abstraction from the wells in the study area is about 12.7MCM/yr and the average annual discharge through springs in the study area is about 16 MCM/yr and the subsurface flow to Fassayel area in the Jordan Valley 10 MCM/yr, (PWA, 2002). (annex 4.3). Thus the total measurable aquifers' discharge is 28.7 MCM/yr. It is difficult to measure the seepage and evapotranspiration components of the natural discharge. However, the total outflow from the lower aquifer, within the study area has been calculated by the Darcy's equation Q=T*I*L (Darcy,1856), where T, Average tramsmisivity120 m^2/d (CDM, 1998), I, hydraulic gradient 0.05, calculated and L, length of water level contour line shown in figure 4.2 which equal 22 km, as 48.2 MCM/yr.

The annual discharges from the upper and lower aquifers in the study area are presented in (Table 4.4). The discharge includes both the Palestinian and Israeli controlled wells and the springs Table (4.4)

Table 4.4: Aquifer Discharge in the Study Area

Source	**Annual Rate MCM/yr**
Spring discharge	16
Subsurface flow to Al Auja Fassayel area in the Jordan Valley	10
Wells abstraction	12.7
Total Discharge	**38.7**

4.6 Estimating the Sustainable Yield of well field.

Using the historical well data, the abstraction and water level records were plotted versus time, Figure 4.4 show an example of determining the equilibrium condition. The optimum discharge for well has been determined from these graphs, by observing the well abstraction rate for the periods when the pumping groundwater levels were stabilized. The results are summarized in Table 4.5 below. On the other hand, pumping from the other wells exceeds the optimum rate, and equilibrium condition could not be maintained i.e. the water level continues to drop over years.

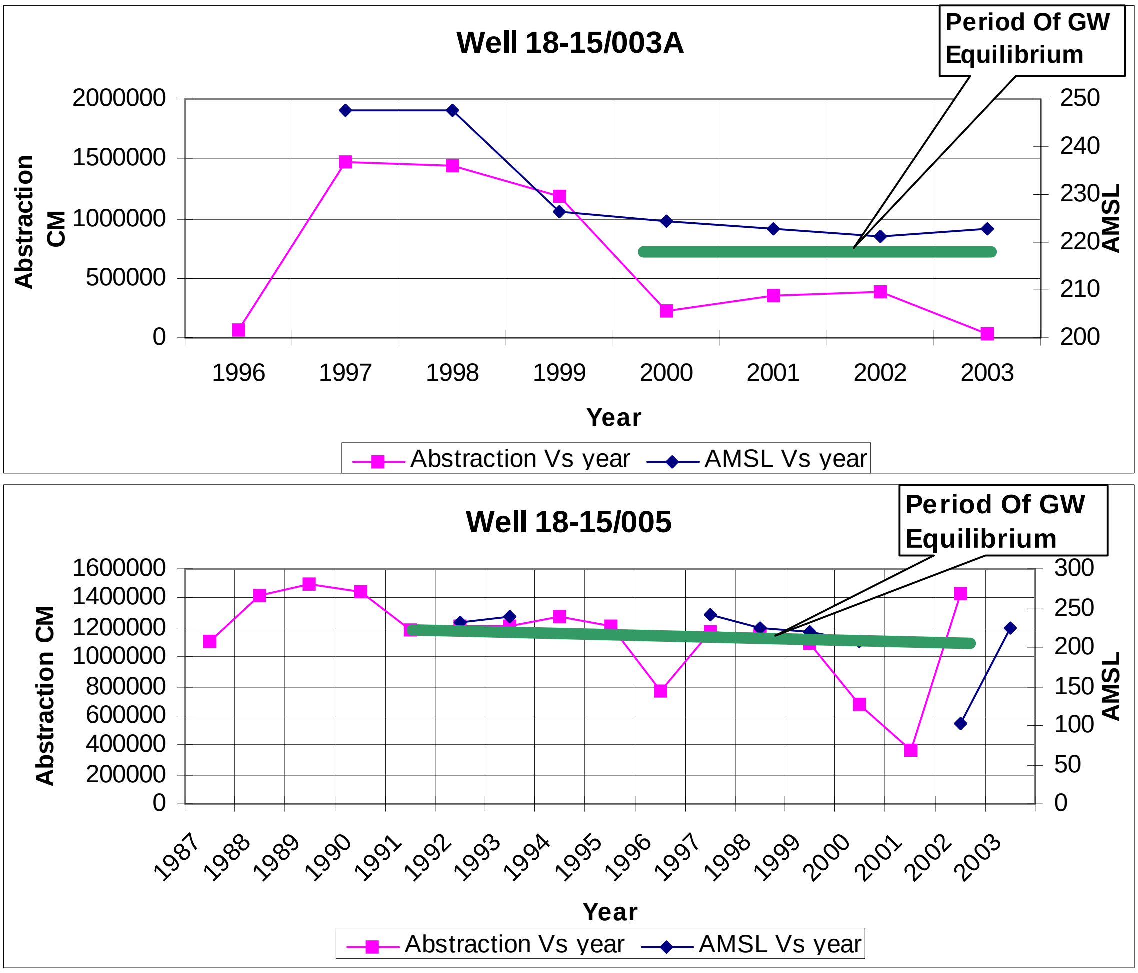

Figure 4.4: Equilibrium conditions indicated by stabilized water level

Table 4.5: Optimum Water Levels with Optimum Pumping Rates For Selected Wells in the Study Area

Well ID	Aquifer	Avg. well abstraction	Optimum abstraction	
			Q	H
18-14/001	LC	1435057.8	1200000	-250
18-14/002	LC	1491364.3	1200000	-296
18-14/003	LC	1502577.2	1000000	309
18-15/001	UC	599021.7	400000	400
18-15/003	UC	256365.2	250000	300
18-15/003A	LC	644027.6	409000	222
18-15/005	LC	1070506.9	800000	150
18-15/006	LC	123421.2	100000	60
18-15/007	LC	150888.2	220000	120
18-15/008	LC	127079.5	800000-1000000	-280
18-15/010	LC	1478817.6	1500000	-280
18-15/011	LC	689245.5	400000-50000	-280
18-15/012	LC	942529.5	1100000	-260
19-15/005	ALL.	100583.5	75000	-307
19-15/010	ALL.	69621.0	80000	-309
19-15/015	ALL.	307815.6	400000	-306
19-15/023	ALL.	87116.7	50000	-303
19-16/006	ALL.	36130.4	40000	-294

4.7 The Impact of the current development on aquifers, and the concept of sustainable aquifer yield

4.7.1 Discussion

Any groundwater quantity abstracted from an aquifer would be compensated from one or more of the following sources:

- Increased groundwater recharge/ flow towards the well or well field caused by the increased hydraulic gradient resulting from the draw down associated with pumping.
- Reduced groundwater flow/discharge in the down stream areas as a result of the interception of the flow by the pumping wells, or,
- Reduction of the groundwater storage in the aquifer.

Normally, these three components work together with different contributions from well to another, and from aquifer to another. In the absence of recharge the last two factors dominate. Reduction in the water level of an aquifer means reduction in storage, and would lead to aquifer overdraft on the long term. On the other hand, reduction in the downstream lateral flow will cut the aquifer discharge in the downstream areas. This would affect the downstream springs, seeps, and wells.

Some drop in the water level is inevitable to pump water and to create the required hydraulic gradient, which would maintain flow towards the pumping well(s). This is called developmental overdraft, and is acceptable. Such water level decline would be recovered when pumping stops. However, if such decline continues and persists after daily or seasonal pumping, such draw down would indicate a permanent overdraft, and this situation requires particular attention and special investigation.

4.7.2 Ein Samia Well Field:

The main fault, in Ain Samia well field area is acting as a barrier in some locations other it acts as a resistant boundary for the eastward groundwater flow. This situation is demonstrated in the field by three observations:

- Head difference of more than 100 m, between wells located east and west of the fault plane, being higher to the west, (Tahal, 1995a).
- Distortion in the flow pattern, with diversion of flow to the north and to the south towards the ends of the impermeable boundary zone.
- Reduction in the wells' yielding capacities, with the wells' yield reduced from about 200m3/hr for the upstream wells, to 40 – 70 m3/hr for the downstream wells, east of the fault.
- The drop in head across the fault plane in the Ein Samia area, applies only to the lower aquifer. The heads in the Upper Aquifer are about 200m higher than in the Lower Aquifer.
- The historical water level data in the Ein Samia well field show a continuous water level decline due to increased abstraction from the Palestinians and the nearby Israeli wells. Drawdown trends for Ein Samia wells can be shown in the following figure 4.5.

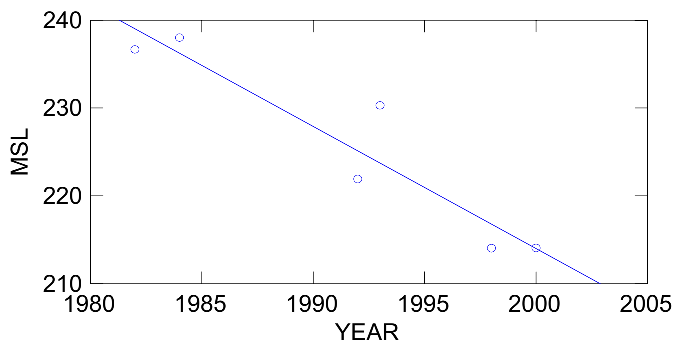

Figure 4.5: Trend of water level Variations in Ein Samia Well Field

4.7.3 Is there an overdraft condition in the well field?

It is obvious that there is a state of imbalance in the existing wells and well fields, with pumping exceeding the aquifer capacity within this particular area.

Although the conducted studies give estimate of annual recharge which is much higher than the current pumping rates from all wells, however, the signs of overdraft are clear in the Ein Samia well fields as shown in previous figure. The following chapter will try to conduct an optimization of production from Ein Samia Well field.

Chapter 5

Sustainable Yield of Ein Samia Wellfield

5.1 Optimization of the Production from well fields

The production capacities of the existing water supply well fields in Ein Samia have been steadily declining during the past few years, resulting in failure to meet water demands, and costly pumps replacement and drilling new substitute wells.

In addition, a continuous and a steady decline in the static and the pumping groundwater levels, in most of the well fields, have also been observed. This, in its turn, has also resulted in additional maintenance and replacement costs.

These observations are strong indications that the current pumping rates and/or patterns are far from being sustainable or safe on the long run.

5.1.1 Ein Samia Well Field Situation

The increased summer production from these well fields, very often, exceeded their safe and sustainable yield. This is indicated from the excessive, continues decline in both the static and the pumping water levels. The pumping water level in deep wells, tapping confined aquifers, was allowed to drop bellow the top of confining layer of the aquifer, and to the maximum possible draw-down in unconfined Aquifer.

Hydraulically speaking, such a practice is a real depletion process of the confined aquifer. The long-term adverse effects would be significant and irreversible/ irrecoverable loss of the aquifer hydraulic properties of the confined aquifer, and consequently a permanent reduction in wells' yields, and the aquifer yield in general.

The risk involved in such practice is real and serious, and would include economic and physical losses, in addition to their social impact due to the lack of alternative water supply sources to meet the demand.

5.1.2 Need for action

To determine and assess the optimum and sustainable yield of the lower aquifer in Ein Samia well field. This is the sum of the optimum yields of the individual wells when all are operated together. In response to this request, a well field optimization study has been carried out using an analytical mathematical model, the TWODAN, prepared by Charlie Fitts, University of Minnesota 1991/1992.

The optimization criteria has been set to prevent the dynamic water level in each well from declining below a pre-set level, which has been chosen as the top of the confined aquifer (Lower Aquifer).

5.1.3 The TWODAN Model

TWODAN is a computer program for modeling two-dimensional groundwater flow using analytical solutions. The program is capable of super positioning large number of analytic solutions to model diverse and irregular boundary conditions, and wide range of problems. Regional flow may be modeled in the horizontal and the vertical direction. The program is prepared by Chares R. Fits. The analytic solutions and “The Analytic Element Method” approach described by (Strack, 1989) form the basis for the TWODAN program. The principle advantages of this method over conventional numerical methods are its simple input, accuracy, speed, lack of a fixed grid, and direct graphical output. TWODAN has a menu-based graphical user interface that is quite intuitive.

The model can solve two-layer aquifer problems. However, the water bearing formation in this case is considered as single layer aquifer to be applicable with analytical modeling abilities.

The input to the model consists of the following:

1- Aquifer properties, including:

- Bottom elevation,
- Aquifer thickness,
- Aquifer hydraulic conductivity,
- Aquifer storage coefficient,
- Aquifer boundaries.

2- Groundwater flow parameters:

- The hydraulic gradient,
- Groundwater through flow, which equals the hydraulic gradient times the hydraulic conductivity.

3- Wells' data:

- Transient and steady state wells, and springs: Location, type of well, pumping rate, time of starting pumping, and pumping period for the transient wells
- Top of aquifer elevation in each steady state well, optimization criteria.

4- Boundary conditions, barriers, heterogeneities, and line sinks.

5- A reference head, which is a point within the modeled area with a known head. This will be used by the model to adjust the water levels at all other point with reference to this point. Therefore, it should be as far as possible from the pumping wells.

The model output would be in terms of heads or potentials at different points, which can be presented as contour maps and hydrographs. The discharge from wells, springs, line sinks, or at any point within the model area can be directly calculated.

5.2 Optimization of the Production from Ein Samia Water Supply Well-Field

5.2.1 The model area

Ein Samia well field is located between the eastern coordinates 176000, 186000, and the northern coordinates, 150000, 160000.

5.2.2 The physical setting of the aquifer

Two wells in the Ein Samia well Field are supplied by the upper aquifer, while four wells tap the lower aquifer. This model study will consider simulating the lower aquifer only, (Figure 5.1).

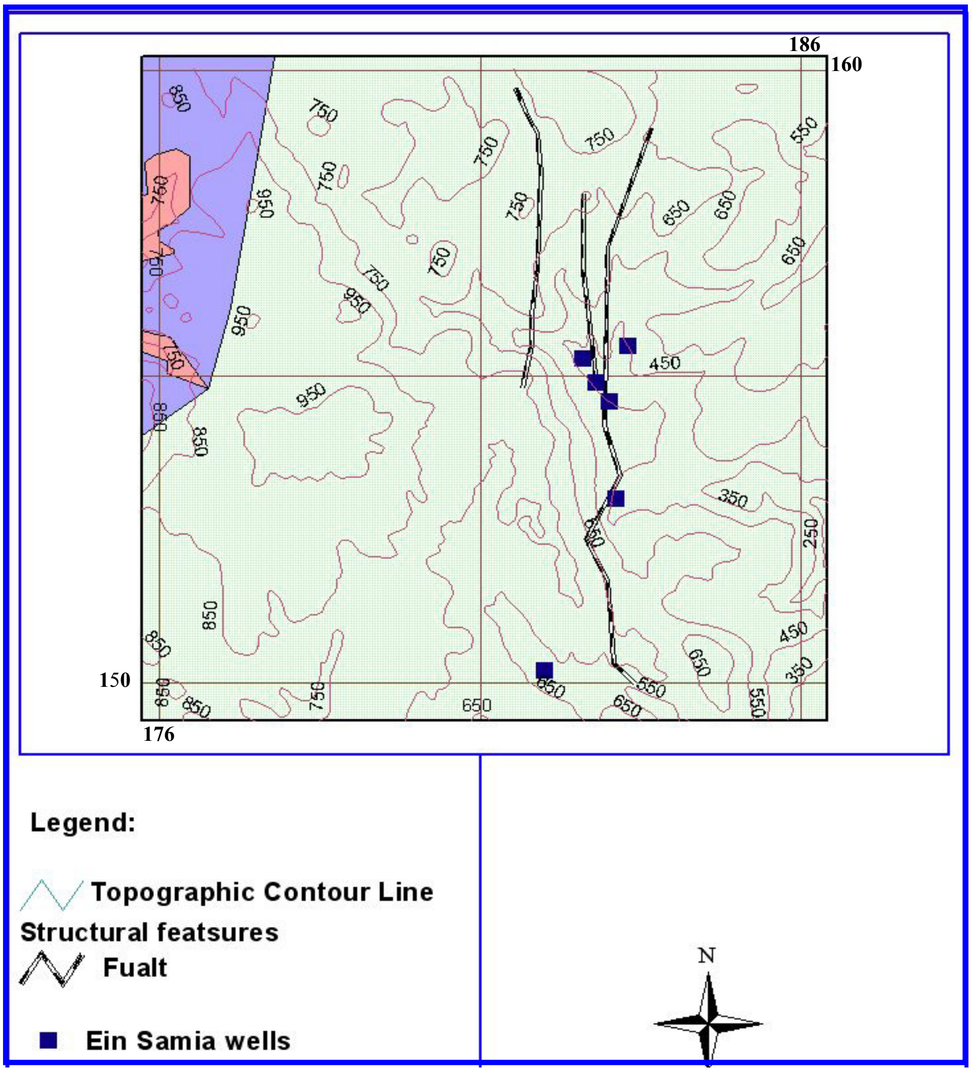

Figure 5.1: Well Locations and the Main Samia Fault, Ein Samia Well Field.

Information obtained from the drilled wells, indicates that the average aquifer thickness within this area is about 350 meters, and the elevation of the aquifer base within the well field area ranges from 100 to 200below the mean sea level. An average value of 180 meter below mean sea level (m.b.m.s.l.) has been considered for the well field area.

Groundwater in the lower aquifer, in this area, occurs under confined conditions as indicated from the big head difference for the two aquifers, being about 200 meters higher for the upper aquifer.

The lower aquifer outcrops on the western part along the Ramallah anticline axis zone, and gently dips eastward towards the Jordan Valley. The geological structures prevailing in the area have significant effect on to the aquifer properties, such as the hydraulic gradient and the aquifer hydraulic conductivity, and wells' productivity. The major geological structures in the study area is the Samia fault, and the Ramallah anticline, to the east of the well field, which forms the main recharge area for the lower aquifer, Figure 5.1. This fault seem to act as a significant barrier to groundwater flow, as indicated from the increased gradient observed in the water levels, which reaches an average of 100 meters difference across the fault plane. In addition, wells productivity is much higher in the upstream side (west).

5.2.3 Boundary Conditions

The boundary conditions applied to the model area included the following:

1. No flow boundaries along the west east flow lines at the northern and southern borders of the well field area. These boundaries were selected at far enough distance from the well field to avoid there effect on the calculated wells water levels.
2. Specified head boundary for the eastern border was chosen with head of -50 m below mean sea level.
3. The Samia fault within the well field was represented as a barrier to groundwater flow.

4. An inflow boundary with specified head boundary of 350 m above mean sea level at the western border of the model area to represent a calculated through-flow into the aquifer.

5.2.4 Aquifer Hydraulic Properties

Data on aquifer hydraulic conductivity in the study area is available only for few wells, mostly on the wells specific capacities. These values for the aquifer hydraulic conductivity obtained from pumping tests, again represent the local conditions of the aquifer, which are within the radius of influence of the pumped wells. However, the regional values may significantly differ from these localized values. The regional values are best obtained during the aquifer modeling process through the steady state calibration process. The regional average of the aquifer hydraulic conductivity was obtained from the model calibration as 0.5 m/day. Considering an aquifer thickness of 350 meters (Rofe and Raffety, 1963), the average aquifer transmissivity about 175 m^2./day. No data was available on the aquifer storage coefficient, and a value of 0.001 was obtained for the aquifer storage coefficient during the model calibration (Trial and error), using the historical wells' abstraction and groundwater levels

5.2.5 Groundwater Levels, Gradient, and Flow

Groundwater level data is available for the wells in the study area, (Figure 5.2), in the previous chapter, shows the present configurations of the piezometric surface of the lower aquifer. The map indicates that the groundwater flow direction in the study area is generally to the east, towards the Jordan Valley.

The water level contour map indicates an average gradient for the piezometric surface of about 2.5 %. This value is important for initiating the TWODAN model in estimating the groundwater through flow into the upstream boundary of the model area.

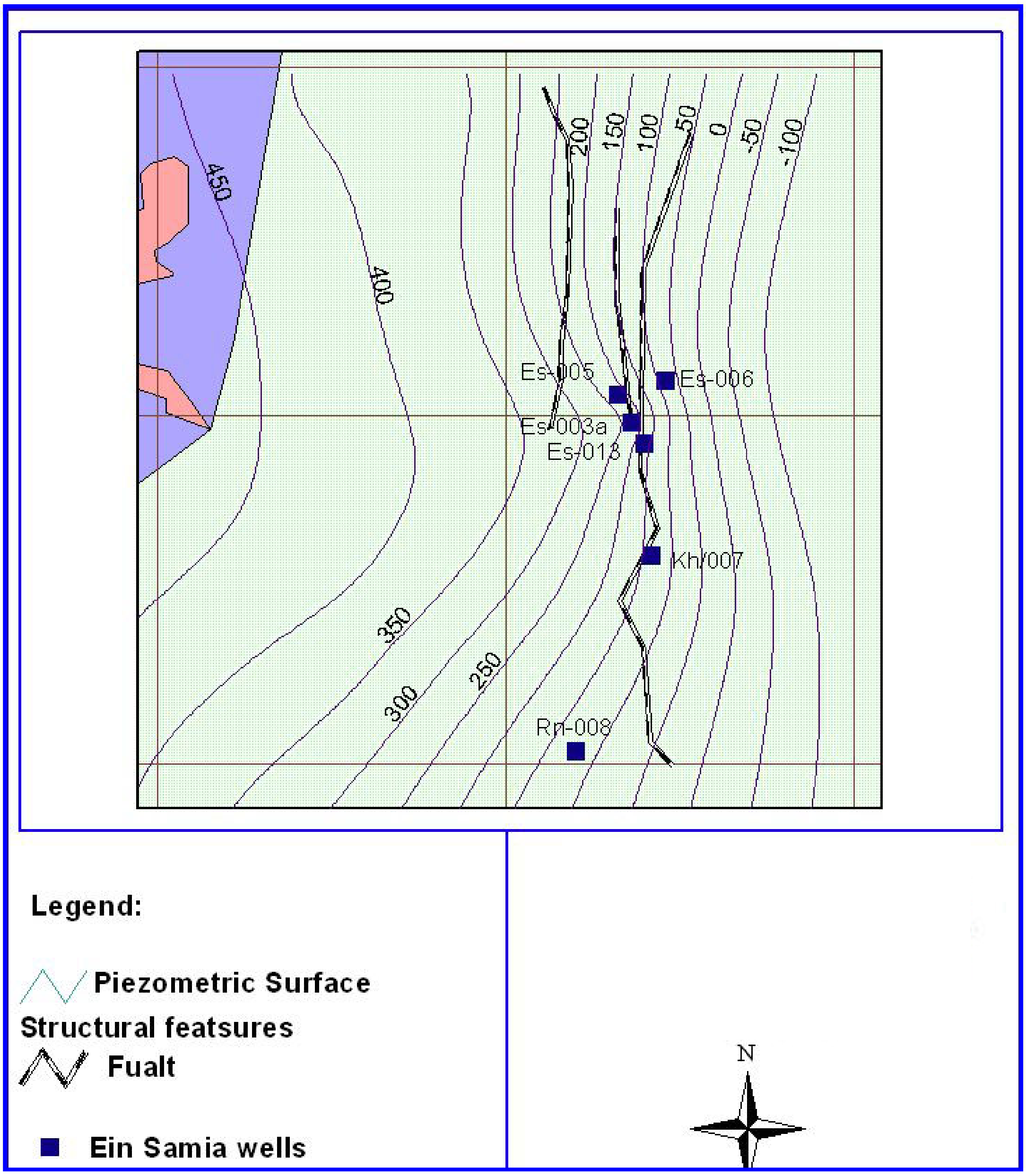

Figure 5.2: Current Groundwater Level Configuration, Ein Samia Well Field 2003.

5.2.6 Historical groundwater abstraction from the well field

The historical groundwater pumping from wells in the Ein Samia well field are given in (table 5.1). The date when pumping started from the oldest well has been set as the zero time for the transient simulation. Pumping periods for all wells were then calculated in days from this date, all in days. Average daily pumping rate was calculated for each pumping well, assuming 365 pumping days per year and 20 hours a day, and uniform pumping rate throughout.

5.2.7 Simulation of the Water Level Configuration and Flow Conditions

The following flow conditions have been simulated by the model:

1. The current pumping and non-pumping flow conditions.
2. The steady state conditions.
3. The pre-development flow conditions.
4. The current transient conditions, using the historical pumping schedule from all wells.
5. The long-term pumping conditions for the adopted optimization criteria.

Adjustment of the aquifer hydraulic conductivity and storage coefficient was necessary for simulating the steady state and the transient state respectively, until the model computed water level contour map conforms to the prepared water level contour map.

A considerable match was obtained at the following values:

- Hydraulic conductivity 0.5 m/day,
- Storage coefficient 0.001
- Hydraulic gradient .025
- Through-flow entering the well field from the western boundary 4.1 m^3/day per meter width of the aquifer perpendicular to the groundwater flow direction.

Once the computed current water level configuration was obtained satisfactorily, the transient state for any pumping scenario is tested, and the pumping water levels and flow conditions can be determined for each case.

The transient state condition; In the absence of adequate historical groundwater level data to develop the steady state flow configurations, the transient flow condition has first been obtained from the existing groundwater level, (Figure 5.2). The hydraulic gradient, aquifer hydraulic conductivity and groundwater through flow obtained from this map have been used, as a start, to simulate the pre-development as well as the future conditions. The most appropriate value obtained, from the modeling process, for the aquifer hydraulic conductivity, which was 0.5 m/day the average hydraulic gradient was obtained as 2.5 %.

The steady state conditions/ the pre-development conditions: The pre-development water level configuration has been obtained from the simulated transient, current water level configurations, as obtained in the previous step, and by converting the existing pumping wells into injection wells, using the same pumping rates and durations, and by backward calculations. The resulting water level contour map is shown in (Figure 5.3).

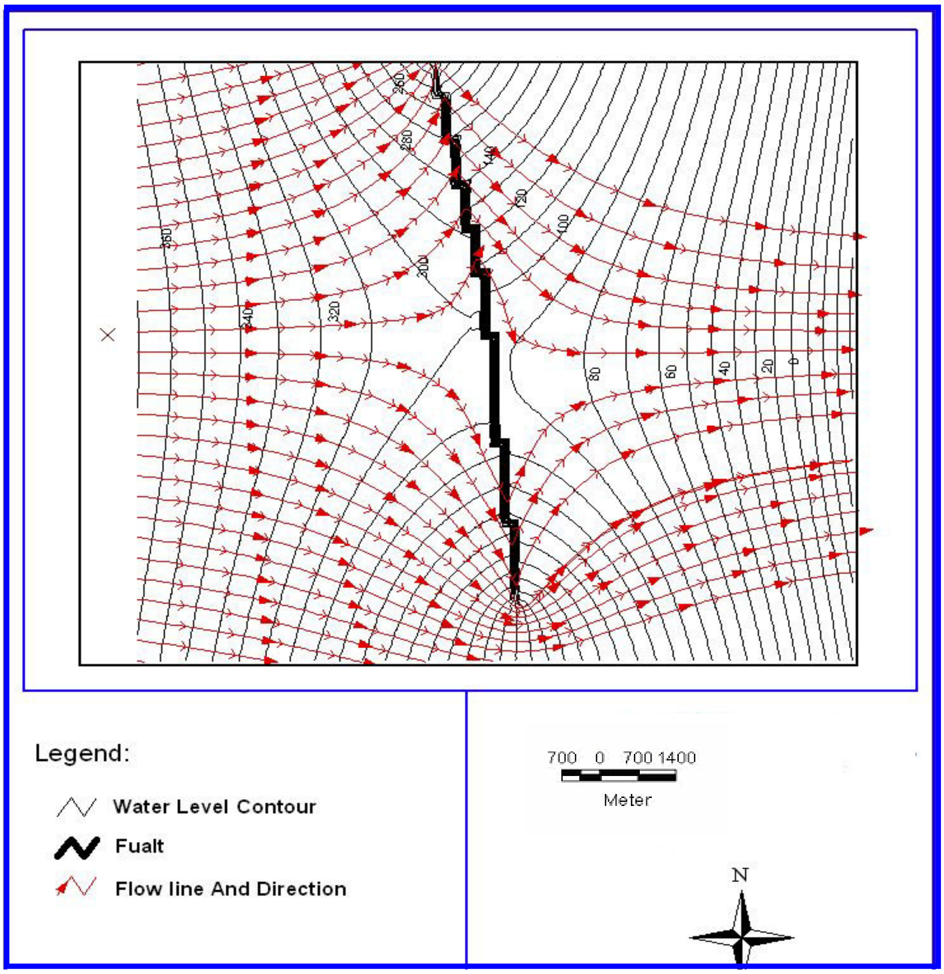

Figure 5.3: Steady State Water Level Configuration, Ein Samia Well Field

Determining the long-term sustainable pumping Rate, The conditions under the optimum pumping rates of the existing wells have been obtained by converting the pumping wells into steady-state wells, and applying some optimization criteria, which are referred to as the maximum allowable pumping water level. The maximum allowable pumping water levels for the artesian wells were set close to the top of the artesian aquifer as much as possible. However, the confinement effect on the water level was not clear for some wells like wells number 3A & 6, and the pumping level, in such cases, was allowed to drop just above the top of the confining layer. The resulting water level contour map is shown in (Figure 5.4), and the determined wells' yields are given in Table 5.1.

Table 5.1: Historical Pumping and the Long-Term Yield for lower aquifer, Ein Samia Well field.

Serial Number	Well ID	Date Pumping Started Year	Time Pumping Started Days	Length of Pumping Period-Days	Historical Average Pumping Rate C.M./day	Lowest Allowable Pumping Level M.a.m.s.l.	Sustainable Pumping Rate C.M./day
3A	18-15/003A	1996	0	2555	2500	240	2200
5	18-15/005	1996	0	2555	2400	240	2400
6	18-15/006	1996	0	2555	400	63	800
7	18-15/007	1999	1100	1455	1750	60	800
13	18-15/013	2003	2555	0	1850	244	1600
				Total	8900		7800

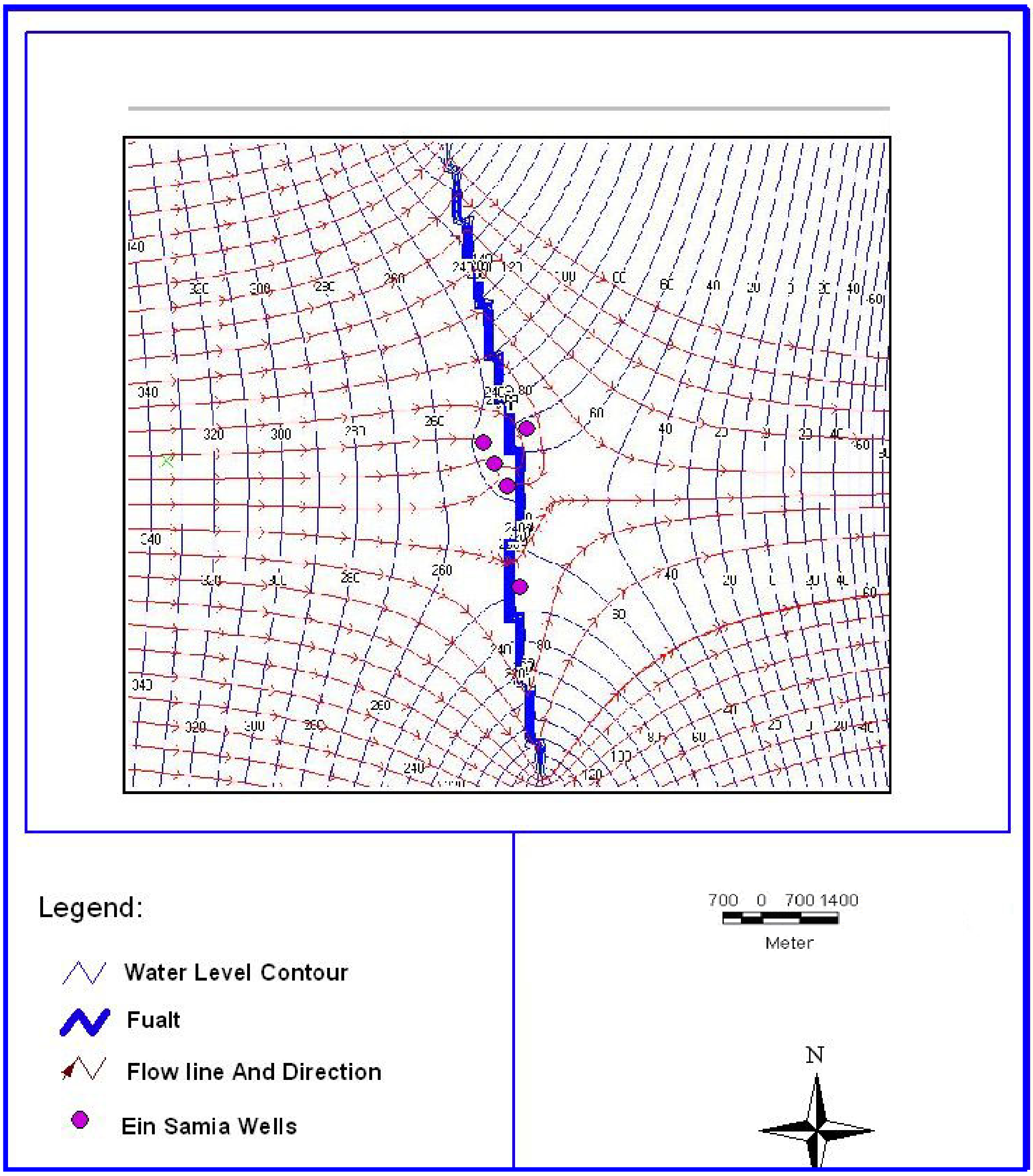

Figure 5.4: Water Level Configuration Under Optimized Abstraction, Ein Samia Well Field

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6 Conclusion and recommendations

6.1 Conclusion

The Water Resources in Auja Study areas both surface and sub- surface need further attentions and required some sound management for the both surface and ground water resources to be used in proper way to have the maximum direct benefits for the people in this important area in West Bank in term of socio economic development which mainly depend on water availability. The following table summarizes the quantity of water resources in the study areas.

Water resources in the Study Area	Annual Rate MCM/yr
Rainfall	214.9
Run-off (Auja Sub-basin)	10.27
Runoff (Surface Catchments-included within The Auja Sub-basin)	2.70
Direct Recharge(DR)	30
Total potential Storage of the Upper & Lower Aquifer (TPS)	42.3
Indirect recharge= (TPS-DR)	12.3
Discharge from spring	16
Discharge from Wells abstraction	12.7
Discharge from Subsurface flow to Al Auja Fassayel area in the Jordan Valley	10
Evapotranspiration and loses	166

For the lower aquifer in Ein Samia Well field the total Water can be abstracted in sustainable manner to avoid the aquifer over drafting from five wells is 7800 M^3/ day which equal to 2.84 MCM/yr that mean abstraction from these 5 well should decreased from 8900 M^3/day to 7800M3/day (3.24 to 2.84 MCM/yr).

Regarding to the Rainfall – Runoff analysis; the average rain fall in the study area is 367 mm/yr, the average rainy days per year is 42 days/yr, average storms per year is 20.3 storm/yr, the average storm duration is 3.5 days, and the average storm intensity 13.9 mm/day. Also the study found that the average storm runoff coefficient is 6.7%, and the average annual runoff coefficient is 3.5% of the average annual Rainfall within the study area.

The recession analysis for the 13 springs in the study area gave that the total potential storage for the Upper and Lower Aquifer is 42.3 MCM/yr, total discharge for giving period is around 16.8 MCM/yr, remaining base flow storage in the Aquifer system is 25.8 MCM/yr, and the recharge by the end of November (the amount of water that aquifer can feed the springs in the study area) is 0.5 MCM/yr.

6.2 Recommendations

It is very important to develop new additional water resource projects in the study area such as:

- Pilot project of flood water harvesting for enhanced agricultural production and groundwater recharge in Wadi Auja, the study show that 2.7 MCM/yr flood water in winter season, this amount can be stored in bonds or dams to be used in irrigations and increasing the recharge occurrence. Rainwater harvesting for agriculture and artificial recharge to fight the aquifer quality deteriorations is an important option in the study area. The best venue for doing this would be through implementing a pilot project. Such pilot project would identify the most appropriate techniques and designs for extending such technology all over the country, and will be useful at the regional level.

- Managing Springs Sustainably: Need for support wells and rehabilitation: The springs in the study area are important water sources for both domestic and agricultural water supplies. There are about 15 springs in the study are supplying about 16 MCM/yr of fresh water. most of these springs are partially used by people in the area without control this springs from losses. It is very important to construct a closed reservoirs and closed channel to distribute springs water for the beneficiaries to avoid the losses in this important source.

- Well field management and production optimization: Due to lack of adequate data on groundwater levels and well abstraction, the ground water modeling done in this study for the Ein Samia well fields should be followed up by an adequate and intensive monitoring program. The program should include data loggers on pumping and observation wells in each well field, and water meters should be installed and well maintained on all wells. The results of one year of intensive monitoring would be of great value for updating and calibrating the developed model. Exactly what should be done in the study area like what SUSMAQ project did in the Nattuf Catchments in Western Aquifer Basin.

- It is important that the determined pumping rates for the wells not to be exceeded what the model will give us to avoid problems related to over drafting and dramatic water level decline in the aquifer system within the study area. In Auja study area as we can increase the ground water abstraction from Both Upper and Lower Aquifer system from 12.7 MCM/yr to 25.7 MCM/yr but by increasing the number of pumping wells not by increasing pumping from the existing ones because as we saw in the result of the analytical model for Ein Samia Well field that we should Decrease the abstraction from this well field.

References

- Aliewi, A, 1996. Ein Samia Well field: Test-Pumping, well development and evaluation of potential well locations using aerial photography.
- ANTEA, 1998.Well development study of the eastern aquifer basin, Volume 1: Interim report
- ARIJ, 2000. An Atlas of Palestine, West Bank and Gaza, January.

  ASCE, 925-937.
- Ba`ba', M., 1996. Hydrogeological Investigations in the Eastern Basin of the West Bank. M.Sc. Thesis
- Bashir, B., 2003. Rainfall-Runoff Analysis and the Synthetic Unit Hydrograph for wadi Far`a Catchment. M.Sc. Thesis.
- Benjamin and Cornell, 1970. Frequency analysis and statistical hydrology, Hydrology for engineering.
- Butler, S, 1957. Engineering Hydrology, Prentice Hall, Inc., Englewood Cliffs.
- CH2MHIL, 2000. GWM, Task 7, Jericho model, Final Draft report.
- CH2MHILL, 1999. *Master Planning frame work for Palestinian Water Resource Development*. Task 9. December.
- CH2MHILL, 2002. *Physical setting and Refrence Data for the Eastern and Northeastern Basin.* Volume 1. Updated report.
- CH2MHILL, 2001. West bank integrated water resource management plan, final report.
- CIDA, 2004, Water Resources Assessment In Selected Area in West Bank, Final report

- DARCY, 1856. The public fountains of the city of Dijon by Henri Darcy, 1856, English Translation by Patricia Bobeck. Published by Kendall/Hunt Publishing Company ISBN 0-7575-0540-6.
- DORSCH Consalt/ Universal DAR, 1998. *Rejonal Planew for West Bank Governorates. Water and Wastewater*. Final Report.
- Fitts, C.R., 1997. Analytic Modeling of Impermeable and Resistant Barriers, Ground Water, 35(2), 312-317.
- Hawkins, R.H., 1980. "Infiltration and Curve Numbers: Some Pragmatic and Theoretic
- Loague, K., and Abrams, R.H. (2001). "Stochastic-Conceptual Analysis of Near-Surface Hydrological Response." Hydrological Processes, 15(14): 2715-2728.
- M/ Morganti & CDM 1998. *Study of the Sustanable yeild of the Eastern Aquifer Basin*. Task 18. Final report.
- Mishra, S.K., and Singh, V.P. (1999). "Another Look at SCS-CN Method." Journal of Hydrologic Engineering, ASCE, 4(3): 257-264.
- Mockus, V., 1972. National Engineering Handbook, Hydrology, Estimation of Direct Runoff from Storm Rainfall. Augest
- Moe, H., 1998.The potential for storm water harvesting in the eastern surface catchment of the west bank.
- MOPIC, 1998. Agricultural land and land use in West Bank governorates, the emergency plan to protect the natural resources. January.
- Palestinian water Authority (PWA); CDM/ Morganti, 1997. *Comprehensive Planning Frame work for Palestinian Water Resource Development*. Task 4. Volume 3. July.
- PCBS, 1997. Local community survey, main finding.

- Ponce, V.M., and Hawkins, R.H. (1996). "Runoff Curve Number: Has It Reached
- Program of Assistance to the Palestinian people (UNDP); Palestinian National Authority Ministry of Agriculture; Food and Agriculture Organization (FAO), 1999. *Agricultural Natural Resource*. October.
- PWA, 1998, Background Information Study About The PWA Role in Water resources Development, Ramallah
- PWA, 2002.Water supply and data base, unpublished report.
- Relationships." Proceedings of the Symposium on Watershed Management,
- Rofe & Raffety, 1963. Consulting Engineers of Westminster, London. *Jerusalem and District Water Supply*. Geological and hydrological Report.
- Scarpa, 1994.Estimation of Annual Recharge in Judea and Sameria, Final Report.
- Strack, 1989. Groundwater Mechanics, Prentice-Hall
- Tahal,1990. Water Well Sittings for Ramallah, The study is carried out by E. Shachnai, Final Report
- UNDP, 1997. *Coseptual Master Plane for Sewerage Management at Rammalh District*. Final Report. Febreuary.
- (USDA,1985). SCS National Engineering Handbook. Section 4: Hydrology, Chapter 4. Soil Conservation Service, U.S. Department of Agriculture, Washington D.C.

ANNEXES

Annex 2.1: Population Distribution in the Study Area (PCBS, 1997)

No	LOCALITY_Name	X_CENT	Y_CENT	Elevation	TOTAL AREA	Pop-Total 1997
1	'Abwein	169.155	160.045	650	16.21	2431
2	Turmus'ayya	177.070	160.345	660	17.61	3147
3	Sinjil	175.265	159.860	800	14.19	3934
4	Jilijliya	172.065	159.420	750	0.01	723
5	Al Mughayyir	182.710	158.505	650	14.56	1705
6	Khirbet Abu Falah	178.725	157.835	750	8.19	2901
9	Al Mazra'a ash Sharqiya	175.969	156.440	940	16.33	3660
11	'Atara	169.405	156.210	820	9.55	1662
12	'Ein Samiya	181.698	155.303	500	0.00	124
13	Kafr Malik	179.330	155.100	780	52.20	2126
14	Silwad	175.000	153.760	880	18.88	1531
17	Yabrud	173.140	153.600	790	2.50	487
18	Bir Zeit	168.605	152.965	800	14.09	4686
19	'Ein Siniya	171.790	153.040	640	2.79	533
20	Silwad Camp	175.057	152.485	850	0.00	300
21	Deir Jarir	177.865	152.559	900	33.16	3044
22	Jifna	170.370	152.075	655	6.02	961
23	Dura al Qar'	171.570	151.715	730	4.17	1938
24	At Tayba	178.510	151.218	860	20.23	1504
25	Al Jalazun Camp	170.320	150.680	780	0.00	6144
26	Abu Qash	167.697	150.745	770	4.75	1106
27	'Ein Yabrud	173.715	150.590	820	11.49	2516
28	Surda	169.500	149.475	830	3.73	1006
29	Rammun	178.325	149.010	750	30.04	2271
30	Beitin	172.765	148.465	860	5.00	2159
31	Deir Dibwan	175.015	146.315	770	73.33	4901
32	Al Bira	170.295	146.435	870	22.05	27972
34	Ramallah	168.814	145.919	850	14.71	18017
35	Burqa	174.155	144.880	730	6.00	1639
36	Beituniya	166.365	144.690	820	23.37	9391
37	Al Am'ari Camp	169.160	144.468	750	0.00	4046
38	Qaddura Camp	169.597	144.663	850	0.00	1102
39	Fasayil	192.045	159.155	-250	44.25	650
40	Al 'Auja	193.635	150.570	-230	106.95	2896
41	An Nuwei'ma	192.380	144.225	-140	52.62	841
42	'Ein ad Duyuk al Foqa	190.815	143.821	-150	21.33	588
43	'Ein as Sultan Camp	192.125	142.735	-200	0.00	1470
44	Kafr 'Aqab	171.425	142.465	800	5.47	7715
	Total					**133827**

Annex 3.1: The daily rainfall Statistics for Birzeit Station

Code:0000003/BirZeit			Duration=11/8/71-3/30/1989		
			Daily Rainfall Statistics		
Hyd-year	Annual RF	Rainy Days	Max day	Min day	Ave day
1971-1972	541.9	54	49.0	1.0	10.0
1972-1973	458.5	38	56.0	1.0	12.1
1973-1974	865.0	54	73.0	1.0	16.0
1974-1975	684.5	53	44.0	1.0	12.9
1975-1976	391.7	46	27.0	1.0	8.5
1976-1977	441.0	45	28.0	1.0	9.8
1977-1978	460.5	37	38.0	1.0	12.4
1978-1979	401.5	44	65.0	1.0	9.1
1979-1980	801.5	57	135.0	1.0	14.1
1980-1981	594.5	41	73.0	1.0	14.5
1981-1982	489.9	42	50.0	1.5	11.7
1982-1983	706.1	55	45.0	1.0	12.8
1983-1984	412.4	34	52.0	1.8	12.1
1984-1985	572.6	31	58.0	1.0	18.5
1985-1986	359.7	34	47.0	1.0	10.6
1986-1987	574.0	52	66.0	1.0	11.0
1987-1988	691.0	45	55.0	1.0	15.4
1988-1989	490.2	39	38.0	1.0	12.6
Ave=	**552.0**	**44.5**	**55.5**	**1.1**	**12.5**

Annex 3.2: The daily rainfall Statistics for Atara Station

PMD_Code:0241630/`Atara			Duration=11/15/67-11/24/1995		
			Daily Rainfall Statistics		
Hyd-year	Total Annual RF	Rainy Days	Max day	Min day	Ave day
1967-1978	608.3	40	0.0	2.0	15.2
1968-1969	739.5	41	0.0	2.2	18.0
1980-1981	580.9	45	120.0	1.0	12.9
1981-1982	605.4	49	0.0	1.2	12.4
1982-1983	809	51	0.0	1.8	15.9
1983-1984	585.8	38	0.0	1.0	15.4
1984-1985	587.4	36	0.0	1.3	16.3
1986-1987	471.6	54	0.0	1.0	8.7
1987-1988	338.2	44	0.0	1.0	7.7
1995	88	8	0.0	1.0	11.0
Avg.	541.4	40.60	12.00	1.35	13.35

Annex 3.3: The daily rainfall Statistics for WBWD Station

Code:0000008/WBWD			Duration=11/18/74-3/30/1989		
Hyd-year	Total Annual RF	Rainy Days	Daily Rainfall Statistics		
			Max day	Min day	Ave day
1974-1975	586.6	34	62.4	1.4	17.3
1975-1976	498.0	49	43.1	1.5	10.2
1976-1977	533.6	44	54.0	1.1	12.1
1977-1978	586.1	33	74.9	1.1	17.8
1978-1979	439.5	29	79.1	1.5	15.2
1979-1980	881.2	44	101.4	1.0	20.0
1980-1981	824.6	43	142.0	1.2	19.2
1981-1982	757.0	48	96.8	1.2	15.8
1982-1983	1319.8	59	106.7	1.5	22.4
1983-1984	556.9	33	97.2	1.0	16.9
1984-1985	612.3	37	86.1	1.0	16.5
1985-1986	453.8	38	74.5	1.1	11.9
1986-1987	762.9	52	92.0	1.0	14.7
1987-1988	859.8	58	66.2	1.0	14.8
1988-1989	604.8	40	54.6	1.0	15.1
1989-1990	617.2	43	78.5	1.0	14.4
1990-1991	524.3	39	66.5	1.0	13.4
1991-1992	1475.3	56	113.8	1.2	26.3
1992-1993	934.5	41	102.7	1.2	22.8
1993-1994	634.1	43	95.0	1.3	14.7
1994-1995	768.3	46	69.3	1.3	16.7
1995-1996	637.2	46	73.1	1.2	13.9
1996-1997	708.9	48	82.0	1.1	14.8
1997-1998	699.0	53	82.3	1.1	13.2
1998-1999	312.2	37	101.3	1.0	8.4
1999-2000	554.8	34	121.4	1.2	16.3
2000-2001	491.7	39	44.7	1.0	12.6
2001-2002	615.3	31	64.3	1.0	19.8
2002-2003	587.3	29	80.3	1.0	20.3
Ave=	**684.0**	**42.3**	**83.0**	**1.1**	**16.1**

Annex 3.4: The daily rainfall Statistics for Alhashymia Station

Code:0242230/Alhashymya			Duration=10/10/67- 15/5/1997		
			Daily Rainfall Statistics		
Hyd-year	Total Annual RF	Rainy Days	Max day	Min day	Ave day
1967-1968	643.7	51	87.0	1.4	12.6
1968-1969	711	48	62.0	1.0	14.8
1970-1971	675	52	80.0	1.0	13.0
1971-1972	700.4	53	54.0	1.0	13.2
1972-1973	453.1	37	48.0	1.8	12.2
1973-1974	934.6	49	60.6	1.0	19.1
1974-1975	581.9	35	50.0	1.0	16.6
1975-1976	477.6	43	44.0	1.2	11.1
1976-1977	534.4	42	50.0	1.0	12.7
1977-1978	570.8	39	75.5	1.0	14.6
1978-1979	523	32	91.0	2.5	16.3
1979-1980	841.2	53	135.0	1.0	15.9
1980-1981	706	40	116.0	1.0	17.7
1981-1982	485.2	48	44.0	1.0	10.1
1982-1983	988.7	61	90.0	1.0	16.2
1983-1984	322.5	31	90.0	1.0	10.4
1984-1985	315.2	27	28.5	1.0	11.7
1985-1986	447	38	67.5	1.0	11.8
1986-1987	739	55	84.0	1.0	13.4
1987-1988	499.5	43	48.0	1.0	11.6
1992-1993	690.4	38	96.0	1.5	18.2
1993-1994	506.1	37	51.0	1.5	13.7
1994-1995	722.6	44	57.6	1.2	16.4
1995-1996	563.4	49	63.7	1.3	11.5
1996-1997	601.1	48	68.4	1.1	12.5
Ave=	**609.3**	**43.7**	**69.7**	**1.2**	**13.9**

Annex 3.5: The daily rainfall Statistics for Sinjil Station

PMD_Code:0241550/Sinjil			Duration=10/27/61-9/28/1997		
			Daily Rainfall Statistics		
Hyd-year	**Total Annual RF**	**Rainy Days**	**Max day**	**Min day**	**Ave day**
1961-1962	660.0	35	107.2	1.4	18.9
1962-1963	384	27	71.0	1.4	14.2
1963-1964	887	49	60.2	1.5	18.1
1964-1965	768	52	64.5	1.0	14.8
1965-1966	532	38	75.7	1.0	14.0
1966-1967	1052.1	54	78.2	1.0	19.5
1967-1968	609.7	52	51.0	1.0	11.7
1968-1969	826.4	54	70.2	1.0	15.3
1969-1970	553	44	52.2	1.1	12.6
1970-1971	804.6	55	97.8	1.0	14.6
1971-1972	680	56	48.3	1.0	12.1
1972-1973	498.9	42	39.6	1.0	11.9
1973-1974	1106	52	68.1	2.3	21.3
1974-1975	648.4	43	62.0	1.0	15.1
1975-1976	587.1	49	47.3	1.0	12.0
1976-1977	625.3	53	64.5	1.0	11.8
1977-1978	673	39	63.2	1.0	17.3
1978-1979	526.9	37	65.4	1.3	14.2
1979-1980	997.6	55	141.1	1.0	18.1
1980-1981	848	43	125	1.0	19.7
1981-1982	707.2	49	100	1.0	14.4
1982-1983	898.2	48	87	1.0	18.7
1983-1984	619	37	75	2.0	16.7
1984-1985	503.2	27	45	2.0	18.6
1985-1986	507	31	60	3.0	16.4
1986-1987	662	46	80	2.0	14.4
1987-1988	773	48	55	1.0	16.1
1988-1989	587	38	50	2.0	15.4
1989-1990	545	31	106	1.0	17.6
1990-1991	1097	52	65	4.0	21.1
1991-1992	765	34	82	3.0	22.5
1992-1993	568	31	45	3.0	18.3
1994-1995	717	36	60	2.0	19.9
1995-1996	570	37	40	2.0	15.4
1996-1997	581	35	50	3.0	16.6
Avg.	**696.2**	**43.11**	**70.07**	**1.57**	**16.27**

Annex 3.6: The daily rainfall Statistics for Dir Dibwan Station

PMD_Code:0242100/Deir Dibwan			Duration=1/11/68-2/26/1997		
			Daily Rainfall Statistics		
Hyd-year	Total Annual RF	Rainy Days	Max day	Min day	Ave day
1968	176.2	28	17.5	1.0	6.3
1968-1969	357.9	37	37.0	1.0	9.7
1969-1970	241.9	30	32.4	1.0	8.1
1972-1973	240	35	21.3	1.0	6.9
1973-1974	754.4	46	5.5	1.3	16.4
1974-1975	448.6	33	45.3	1.0	13.6
1975-1976	273.9	35	29.1	1.3	7.8
1976-1977	422.9	38	39.7	1.1	11.1
1977-1978	425	31	63.5	1.0	13.7
1978-1979	285.5	24	65.5	1.0	11.9
1979-1980	689.9	52	92.5	1.1	13.3
1980-1981	544.1	41	125	1	13.3
1981-1982	459.6	50	73.2	1	9.2
1982-1983	787.8	47	63	1.1	16.8
1984-1985	407.9	30	52.5	1	13.6
1985-1986	362.5	37	56.8	1	9.8
1986-1987	424.5	51	37.9	1.1	8.3
1987-1988	484.6	56	38.5	1.3	8.7
1988-1989	387	35	33.1	1	11.1
1989-1990	374.2	33	53.6	1.2	11.3
1990-1991	239.2	32	31	1	7.5
1991-1992	738.1	45	61.4	1.3	16.4
1992-1993	434.9	28	80	1	15.5
1993-1994	399.7	37	45	1	10.8
1994-1995	475.8	47	48	1	10.1
1995-1996	432.9	43	49	1	10.1
1996-1997	305.6	21	55	1.2	14.6
Avg.	428.7	37.85	50.1	1.1	11.3

Annex 3.7: Historical Storms, Duration and Intensity for Dir Dibwan station

PMD_name Deir Dibwan		Duration=1/11/68-2/26/1997		
PMD_Code:0241100		Rainfall mm/d	Duration day	RF Intensity mm/d
Date ended	RainFall			
1/11/1968	1.0	1	1	1.0
1/17/1968	17.5	42.8	3	14.3
1/22/1968	4.1	4.1	1	4.1
1/24/1968	5.3	5.3	1	5.3
2/1/1968	4.7	31.5	5	6.3
2/7/1968	2.3	2.3	1	2.3
2/9/1968	2.0	2	1	2.0
2/14/1968	15.3	15.3	1	15.3
2/21/1968	6.0	14.6	2	7.3
3/1/1968	1.8	1.8	1	1.8
3/5/1968	1.6	1.6	1	1.6
3/28/1968	4.5	14.0	2	7.0
3/31/1968	5.2	7.9	2	3.9
4/25/1968	9.0	13.5	3	4.5
4/27/1968	13.2	13.2	1	13.2
5/2/1968	2.4	2.4	1	2.4
5/4/1968	2.9	2.9	1	2.9
Total Annual Rainfall(mm)		176.2	28	
10/26/1968	5.7	5.7	1	5.7
11/1/1968	3.0	16.5	2	8.3
11/14/1968	1.3	1.3	1	1.3
11/25/1968	2.4	10.2	2	5.1
12/8/1968	11.4	55.7	3	18.6
12/15/1968	25.3	31.2	2	15.6
12/26/1968	3.3	13.0	2	6.5
1/8/1969	1.0	3.4	2	1.7
1/13/1969	4.9	10.6	2	5.3
1/19/1969	1.0	3.1	2	1.5
1/22/1969	9.8	9.8	1	9.8
1/26/1969	5.1	19.9	3	6.6
1/29/1969	2.7	15.7	2	7.9
2/8/1969	14.7	23.3	2	11.7
3/10/1969	2.8	2.8	1	2.8
3/23/1969	14.7	127.2	6	21.2
4/9/1969	1.5	1.5	1	1.5
4/16/1969	4.8	7.0	2	3.5
Total Annual Rainfall(mm)		357.9	37	
10/9/1969	3.8	3.8	1	3.8
10/20/1969	5.4	5.4	1	5.4
11/1/1969	9.6	9.6	1	9.6
12/15/1969	1.0	1	1	1.0
12/19/1969	2.4	2.4	1	2.4
12/24/1969	7.0	7	1	7.0
12/27/1969	2.9	2.9	1	2.9
12/31/1969	5.2	5.2	1	5.2
1/1/1970	14.1	14.1	1	14.1
1/14/1970	4.2	4.2	1	4.2

PMD_name Deir Dibwan		Duration=1/11/68-2/26/1997		
PMD_Code:0241100		Rainfall mm/d	Duration day	RF Intensity mm/d
Date ended	RainFall			
1/19/1970	2.5	2.5	1	2.5
1/22/1970	32.4	50.9	2	25.5
1/26/1970	8.6	20.5	3	6.8
2/5/1970	3.5	3.5	1	3.5
2/23/1970	5.6	29.8	3	9.9
3/12/1970	2.1	26.8	5	5.4
3/18/1970	1.7	1.7	1	1.7
3/22/1970	19.8	26.4	2	13.2
4/19/1970	11.7	23.7	2	11.8
Total Annual Rainfall(mm)		241.4	30	
11/3/1972	2.0	2	1	2.0
11/24/1972	16.5	16.5	1	16.5
11/29/1972	1.8	12.0	3	4.0
12/4/1972	4.7	10.2	2	5.1
12/21/1972	1.5	20.9	4	5.2
1/16/1973	15.3	79.5	5	15.9
1/22/1973	5.5	11.0	2	5.5
1/27/1973	4.5	4.5	1	4.5
1/31/1973	4.5	11.0	2	5.5
2/4/1973	1.0	1	1	1.0
2/8/1973	4.5	4.5	1	4.5
2/23/1973	8.0	15.5	2	7.8
3/3/1973	10.4	16.9	2	8.4
3/7/1973	6.5	23.3	3	7.8
3/21/1973	5.5	5.5	1	5.5
4/8/1973	1.5	3.2	2	1.6
5/8/1973	1.0	2.5	2	1.3
Total Annual Rainfall(mm)		240.0	35	
11/1/1973	2.5	8.7	2	4.3
11/13/1973	5.0	16.0	3	5.3
11/23/1973	4.3	39.3	2	19.7
12/7/1973	9.2	9.2	1	9.2
12/9/1973	6.8	6.8	1	6.8
12/17/1973	6.6	31.9	2	15.9
1/10/1974	2.0	72.0	5	14.4
1/17/1974	50.7	179.1	5	35.8
1/23/1974	13.4	108.9	5	21.8
1/26/1974	3.8	3.8	1	3.8
1/31/1974	37.4	42.6	2	21.3
2/13/1974	4.0	63.0	4	15.8
2/24/1974	9.6	9.6	1	9.6
2/28/1974	54.3	64.3	2	32.1
3/2/1974	28.8	47.3	2	23.6
3/13/1974	2.3	2.3	1	2.3
3/15/1974	2.6	2.6	1	2.6
3/17/1974	2.6	2.6	1	2.6
3/19/1974	2.3	2.3	1	2.3

Annex 3.7: Historical Storms, Duration and Intensity for Dir Dibwan station/ Cont.

PMD_name Deir Dibwan		Duration=1/11/68-2/26/1997			PMD_name Deir Dibwan		Duration=1/11/68-2/26/1997		
PMD_Code:0241100		Total Rainfall mm/d	Duration day	Rainfall Intensity mm/d	PMD_Code:0241100		Total Rainfall mm/d	Duration day	Rainfall Intensity mm/d
Date ended	RainFall				Date ended	RainFall			
4/5/1974	5.5	5.5	1	5.5	12/9/1976	2.2	2.2	1	2.2
4/10/1974	18.9	36.6	3	12.2	12/28/1976	4.1	4.1	1	4.1
Total Annual Rainfall(mm)		754.4	46		1/6/1977	3.2	34.7	5	6.9
11/18/1974	4.5	4.5	1	4.5	1/16/1977	2.5	13.6	2	6.8
11/24/1974	10.7	50.4	4	12.6	1/22/1977	7.5	57.1	4	14.3
12/6/1974	1.7	32.3	3	10.8	1/28/1977	14.4	14.4	1	14.4
12/8/1974	10.4	10.4	1	10.4	2/9/1977	1.8	46.0	4	11.5
12/11/1974	7.8	28.9	2	14.5	3/5/1977	10.1	86.1	4	21.5
12/18/1974	5.3	5.3	1	5.3	3/10/1977	1.3	16.3	2	8.1
12/21/1974	1.0	5.8	2	2.9	3/18/1977	1.1	10.8	2	5.4
1/11/1975	7.5	28.5	2	14.3	4/5/1977	3.5	6.7	2	3.4
1/28/1975	8.5	19.8	3	6.6	4/14/1977	8.5	23.0	3	7.7
2/3/1975	9.0	46.5	3	15.5	4/23/1977	32.4	35.3	2	17.7
2/7/1975	4.1	9.7	2	4.8	Total Annual Rainfall(mm)		422.9	38	
2/10/1975	21.6	66.5	2	33.3	10/17/1977	11.0	23.5	2	11.8
2/21/1975	14.6	58.7	2	29.3	10/21/1977	4.5	4.5	1	4.5
2/28/1975	13.3	13.3	1	13.3	11/17/1977	17.0	17	1	17.0
3/2/1975	1.8	47.1	2	23.5	12/6/1977	2.8	2.8	1	2.8
3/18/1975	1.7	20.9	2	10.5	12/9/1977	4.5	4.5	1	4.5
Total Annual Rainfall(mm)		448.6	33		12/12/1977	12.7	12.7	1	12.7
11/10/1975	7.4	7.4	1	7.4	12/14/1977	18.0	18	1	18.0
11/26/1975	6.4	8.8	2	4.4	12/17/1977	14.3	77.8	2	38.9
11/30/1975	14.3	14.3	1	14.3	12/22/1977	8.2	45.7	2	22.8
12/10/1975	2.1	30.1	3	10.0	1/3/1978	31.0	31	1	31.0
12/17/1975	5.0	12.5	3	4.2	1/9/1978	4.5	4.5	1	4.5
12/21/1975	7.0	7	1	7.0	1/27/1978	4.0	4	1	4.0
12/22/1975	2.6	2.6	1	2.6	2/10/1978	7.0	12	2	6.0
12/26/1975	7.7	7.7	1	7.7	2/17/1978	13.3	20.6	2	10.3
12/31/1975	5.8	8.8	2	4.4	2/19/1978	1.0	1	1	1.0
1/5/1976	4.6	4.6	1	4.6	2/23/1978	20.7	29.2	3	9.7
1/11/1976	4.4	4.4	1	4.4	3/5/1978	2.0	2	1	2.0
1/14/1976	28.0	28	1	28.0	3/13/1978	39.0	68.0	3	22.7
1/20/1976	2.4	2.4	1	2.4	3/24/1978	2.5	30.7	2	15.4
1/23/1976	17.7	17.7	1	17.7	3/30/1978	2.5	2.5	1	2.5
1/30/1976	4.3	12.5	2	6.3	4/24/1978	13.0	13	1	13.0
3/5/1976	2.6	2.6	1	2.6	Total Annual Rainfall(mm)		425.000002	31	
3/8/1976	3.0	3	1	3.0	10/3/1978	6.4	81.5	3	27.2
3/14/1976	2.4	43.2	4	10.8	10/9/1978	2.7	6.1	2	3.1
3/16/1976	10.4	10.4	1	10.4	10/12/1978	11.4	11.4	1	11.4
3/21/1976	29.1	29.1	1	29.1	10/16/1978	1.4	1.4	1	1.4
4/6/1976	3.7	13.0	3	4.3	10/18/1978	4.0	4	1	4.0
4/12/1976	2.5	2.5	1	2.5	1/4/1979	10.4	10.4	1	10.4
4/18/1976	1.3	1.3	1	1.3	1/9/1979	17.2	64.2	2	32.1
Total Annual Rainfall(mm)		273.9	35		1/23/1979	6.2	31.1	3	10.4
10/25/1976	1.9	3.6	2	1.8	2/7/1979	6.2	6.2	1	6.2
11/28/1976	20.5	52.1	2	26.1	2/10/1979	2.2	8.6	2	4.3
12/1/1976	16.9	16.9	1	16.9	3/9/1979	2.7	45.0	3	15.0

Annex 3.7: Historical Storms, Duration and Intensity for Dir Dibwan station/ Cont.

PMD_name Deir Dibwan		Duration=1/11/68-2/26/1997			PMD_name Deir Dibwan		Duration=1/11/68-2/26/1997		
PMD_Code:0241100		Total Rainfall mm/d	Duration day	Rainfall Intensity mm/d	PMD_Code:0241100		Total Rainfall mm/d	Duratio n day	Rainfall Intensity mm/d
Date ended	Rainfall				Date ended	RainFall			
3/13/1979	1.0	1	1	1.0	3/27/1981	2.0	50.5	3	16.8
3/26/1979	2.1	6.1	2	3.0	4/4/1981	3.0	3	1	3.0
4/13/1979	8.5	8.5	1	8.5	4/7/1981	1.5	1.5	1	1.5
Total Annual Rainfall(mm)		285.5	24		4/11/1981	1.2	1.2	1	1.2
10/5/1979	3.0	19.1	3	6.4	4/15/1981	6.5	6.5	1	6.5
10/22/1979	10.6	10.6	1	10.6	Total Annual Rainfall(mm)		544.099998	41	
11/2/1979	3.8	8.1	2	4.1	10/12/1981	2.2	2.2	1	2.2
11/7/1979	1.1	1.1	1	1.1	11/4/1981	13.2	13.2	1	13.2
11/30/1979	5.0	159.8	3	53.3	11/12/1981	28.3	28.2	1	28.2
12/6/1979	45.7	57.7	2	28.9	11/20/1981	2.0	19.3	4	4.8
12/14/1979	33.5	39.3	2	19.7	11/28/1981	8.5	8.5	1	8.5
12/19/1979	15.6	15.6	1	15.6	12/24/1981	13.0	13	1	13.0
12/28/1979	2.7	45.6	4	11.4	12/27/1981	1.5	1.5	1	1.5
1/6/1980	6.2	47.7	2	23.8	12/29/1981	1.0	1	1	1.0
1/14/1980	6.5	12.6	3	4.2	1/5/1982	2.7	78.9	5	15.8
1/17/1980	1.6	1.6	1	1.6	1/14/1982	25.0	34.5	2	17.3
1/25/1980	1.7	27.5	4	6.9	1/17/1982	1.8	1.8	1	1.8
1/29/1980	1.1	4.3	2	2.2	1/20/1982	3.7	3.7	1	3.7
2/5/1980	19.7	19.7	1	19.7	1/23/1982	8.1	11.9	2	6.0
2/9/1980	1.4	1.4	1	1.4	1/27/1982	4.5	4.5	1	4.5
2/18/1980	2.1	74.6	6	12.4	2/4/1982	2.0	2	1	2.0
2/26/1980	1.3	17.7	4	4.4	2/6/1982	8.7	8.7	1	8.7
2/29/1980	1.5	7.5	2	3.8	2/10/1982	5.2	16.9	2	8.4
3/3/1980	5.5	88.5	3	29.5	2/28/1982	3.6	22.1	4	5.5
3/18/1980	17.2	17.2	1	17.2	3/1/1982	73.2	73.2	1	73.2
4/2/1980	2.3	2.3	1	2.3	3/6/1982	2.6	24.4	4	6.1
4/14/1980	8.1	8.1	1	8.1	3/10/1982	17.6	29.7	3	9.9
4/16/1980	2.3	2.3	1	2.3	3/13/1982	11.0	11	1	11.0
Total Annual Rainfall(mm)		689.9	52		3/17/1982	1.8	1.8	1	1.8
11/20/1980	1.5	1.5	1	1.5	3/27/1982	3.9	38.8	4	9.7
11/26/1980	1.8	1.8	1	1.8	4/4/1982	3.2	3.2	1	3.2
12/13/1980	25.4	191.9	4	48.0	4/26/1982	2.1	3.2	2	1.6
12/26/1980	26.3	33.7	3	11.2	5/12/1982	1.0	2.4	2	1.2
12/29/1980	3.0	4.0	2	2.0	Total Annual Rainfall(mm)		459.6	50	
1/4/1981	12.5	44.7	3	14.9	10/23/1982	14.2	14.2	1	14.2
1/12/1981	15.7	34.3	2	17.2	10/26/1982	3.7	27.2	2	13.6
1/16/1981	5.9	5.9	1	5.9	11/23/1982	14.2	14.2	1	14.2
1/27/1981	7.2	25.3	3	8.4	11/26/1982	3.7	13.0	2	6.5
2/1/1981	14.5	46.6	2	23.3	12/6/1982	2.1	35.3	3	11.8
2/5/1981	9.6	11.4	2	5.7	12/13/1982	12.5	12.5	1	12.5
2/8/1981	8.0	8	1	8.0	12/29/1982	8.5	8.5	1	8.5
2/16/1981	8.4	12.4	2	6.2	12/31/1982	15.0	15	1	15.0
2/18/1981	2.0	2	1	2.0	1/5/1983	2.1	13.6	5	2.7
2/25/1981	2.1	22.1	2	11.0	1/15/1983	1.2	42.5	3	14.2
2/28/1981	7.8	7.8	1	7.8	1/19/1983	33.0	43.0	2	21.5
3/2/1981	6.5	26.5	2	13.3	1/25/1983	1.7	76.4	3	25.5
3/10/1981	1.5	1.5	1	1.5	2/4/1983	9.1	45.4	4	11.4

Annex 3.7: Historical Storms, Duration and Intensity for Dir Dibwan station/ Cont.

PMD_name Deir Dibwan		Duration=1/11/68-2/26/1997			PMD_name Deir Dibwan		Duration=1/11/68-2/26/1997		
PMD_Code:0241100		Total Rainfall mm/d	Duration day	Rainfall Intensity mm/d	PMD_Code:0241100		Total Rainfall mm/d	Duration day	Rainfall Intensity mm/d
Date ended	Rainfall				Date ended	RainFall			
2/6/1983	7.9	7.9	1	7.9	11/11/1986	3.5	3.5	1	3.5
2/21/1983	15.0	231.5	6	38.6	11/18/1986	5.1	6.1	2	3.0
2/26/1983	11.8	35.1	3	11.7	12/1/1986	3.4	23.4	4	5.9
3/6/1983	1.2	109.2	3	36.4	12/9/1986	3.2	3.2	1	3.2
3/15/1983	5.5	8.8	2	4.4	12/14/1986	2.3	11.7	2	5.8
3/22/1983	10.5	34.5	3	11.5	12/19/1986	18.6	22.2	2	11.1
Total Annual Rainfall(mm)		787.8	47		12/30/1986	2.0	16.4	2	8.2
10/18/1984	11.6	37.2	3	12.4	1/3/1987	2.7	10.3	3	3.4
11/7/1984	1.2	1.2	1	1.2	1/6/1987	15.5	45.9	2	22.9
11/12/1984	1.6	2.0	2	1.0	1/26/1987	1.9	26.1	5	5.2
11/18/1984	1.2	25.0	2	12.5	2/3/1987	4.0	4.0	1	4.0
12/4/1984	4.0	4	1	4.0	2/9/1987	10.9	10.9	1	10.9
12/9/1984	3.3	3.3	1	3.3	2/27/1987	1.2	7.6	3	2.5
12/13/1984	36.5	36.5	1	36.5	3/5/1987	6.0	6	1	6.0
12/23/1984	2.5	2.5	1	2.5	3/9/1987	2.8	7.5	3	2.5
1/14/1985	5.1	5.1	1	5.1	3/14/1987	2.7	39.7	3	13.2
1/18/1985	1.9	1.9	1	1.9	3/16/1987	1.1	1.1	1	1.1
1/21/1985	11.4	11.4	1	11.4	3/18/1987	2.9	2.9	1	2.9
2/2/1985	28.0	58.4	2	29.2	3/26/1987	4.9	12.0	3	4.0
2/5/1985	2.8	13.4	2	6.7	4/3/1987	1.3	1.3	1	1.3
2/15/1985	42.2	68.4	2	34.2	Total Annual Rainfall(mm)		424.500001	51	
2/17/1985	2.6	2.6	1	2.6	10/18/1987	11.5	16.1	2	8.0
2/20/1985	2.1	2.1	1	2.1	10/24/1987	7.5	17.9	4	4.5
2/26/1985	19.0	91.0	3	30.3	10/30/1987	1.0	4.1	3	1.4
3/23/1985	2.0	21.9	2	10.9	11/6/1987	5.8	5.8	1	5.8
4/23/1985	1.0	20.0	2	10.0	12/6/1987	7.0	27.4	3	9.1
Total Annual Rainfall(mm)		407.9	30		12/13/1987	2.1	12.6	2	6.3
10/19/1985	31.5	31.5	1	31.5	12/21/1987	3.4	25.4	3	8.5
11/17/1985	10.5	10.5	1	10.5	12/25/1987	4.8	64.8	3	21.6
11/29/1985	4.3	4.3	1	4.3	12/29/1987	5.7	5.7	1	5.7
12/3/1985	2.6	3.9	3	1.3	1/4/1988	22.2	26.8	2	13.4
12/19/1985	14.3	27.8	3	9.3	1/6/1988	2.5	2.5	1	2.5
12/27/1985	4.5	21.6	3	7.2	1/12/1988	3.7	3.7	1	3.7
1/3/1986	3.5	3.5	1	3.5	1/18/1988	1.8	30.6	4	7.7
1/12/1986	9.3	27.1	2	13.5	1/25/1988	13.9	15.3	2	7.6
1/15/1986	10.0	33.3	2	16.6	2/2/1988	15.2	40.2	2	20.1
1/19/1986	4.4	20.1	2	10.0	2/13/1988	3.2	3.2	1	3.2
2/6/1986	2.6	22.3	3	7.4	2/18/1988	1.4	36.0	4	9.0
2/9/1986	15.9	29.3	2	14.6	2/24/1988	3.7	56.5	4	14.1
2/15/1986	4.2	72.0	3	24.0	3/3/1988	36.4	36.4	1	36.4
2/24/1986	1.8	1.8	1	1.8	3/8/1988	2.2	23.5	3	7.8
4/2/1986	1.5	25.2	5	5.0	3/11/1988	3.2	3.2	1	3.2
4/7/1986	3.2	3.2	1	3.2	3/13/1988	2.7	2.7	1	2.7
5/4/1986	3.9	25.1	3	8.4	3/21/1988	1.5	14.0	3	4.7
Total Annual Rainfall(mm)		362.5	37		3/26/1988	1.5	1.5	1	1.5
10/3/1986	4.0	35.0	3	11.7	4/16/1988	5.5	5.5	1	5.5
11/2/1986	19.2	20.9	2	10.5	4/24/1988	1.9	3.2	2	1.6
11/9/1986	35.0	106.8	4	26.7	Total Annual Rainfall(mm)		484.6	56	

Annex 3.7: Historical Storms, Duration and Intensity for Dir Dibwan station/ Cont.

PMD_name Deir Dibwan		Duration=1/11/68-2/26/1997			PMD_name Deir Dibwan		Duration=1/11/68-2/26/1997		
PMD_Code:0241100		Total Rainfall mm/d	Duration day	Rainfall Intensity mm/d	PMD_Code:0241100		Total Rainfall mm/d	Duration day	Rainfall Intensity mm/d
Date ended	RainFall				Date ended	Rainfall			
10/17/1988	10.1	10.1	1	10.1	2/16/1991	9.2	9.2	1	9.2
10/30/1988	1.9	1.9	1	1.9	2/27/1991	2.4	11.2	3	3.7
11/11/1988	8.1	15.7	2	7.9	3/5/1991	12.6	13.7	2	6.9
11/19/1988	3.1	28.0	2	14.0	3/7/1991	1.2	1.2	1	1.2
11/27/1988	1.1	1.1	1	1.1	3/24/1991	1.3	52.9	4	13.2
12/6/1988	2.7	2.7	1	2.7	4/9/1991	3.8	3.8	1	3.8
12/14/1988	3.2	12.7	2	6.4	4/30/1991	1.2	1.2	1	1.2
12/19/1988	33.1	60.8	2	30.4	Total Annual Rainfall(mm)		239.3	32	
12/26/1988	27.5	79.3	3	26.4	10/14/1991	17.0	17	1	17.0
1/3/1989	1.0	9.3	2	4.7	10/25/1991	1.0	1	1	1.0
1/10/1989	7.2	15.1	4	3.8	11/3/1991	5.1	19.6	2	9.8
1/15/1989	15.3	15.3	1	15.3	12/4/1991	13.8	167.5	6	27.9
1/21/1989	8.1	20.6	2	10.3	12/14/1991	3.1	78.0	4	19.5
1/27/1989	5.1	5.1	1	5.1	12/19/1991	2.1	3.4	2	1.7
2/1/1989	1.3	1.3	1	1.3	12/24/1991	7.1	7.1	1	7.1
2/12/1989	9.8	35.9	3	12.0	12/27/1991	35.2	35.2	1	35.2
2/17/1989	1.6	1.6	1	1.6	12/31/1991	38.1	47.4	2	23.7
3/9/1989	3.4	3.4	1	3.4	2/4/1992	49.6	120.7	4	30.2
3/15/1989	15.4	59.4	3	19.8	2/12/1992	1.5	90.8	7	13.0
3/28/1989	7.7	7.7	1	7.7	2/20/1992	3.5	6.1	2	3.0
Total Annual Rainfall(mm)		387	35		2/27/1992	5.0	103.0	5	20.6
10/17/1989	8.0	8	1	8.0	2/29/1992	2.1	2.1	1	2.1
11/6/1989	8.2	8.2	1	8.2	3/4/1992	6.4	6.4	1	6.4
11/17/1989	4.5	39.4	5	7.9	3/14/1992	1.8	1.8	1	1.8
11/29/1989	18.1	18.1	1	18.1	3/22/1992	21.2	26.7	2	13.4
1/5/1990	3.0	107.5	3	35.8	4/16/1992	2.5	2.5	1	2.5
1/16/1990	2.7	5.3	2	2.6	4/21/1992	1.8	1.8	1	1.8
1/23/1990	1.4	10.4	3	3.5	Total Annual Rainfall(mm)		738.100001	45	
1/26/1990	26.5	28.4	2	14.2	11/21/1992	33.1	33.1	1	33.1
2/1/1990	5.6	5.6	1	5.6	11/24/1992	5.3	47.2	2	23.6
2/6/1990	2.2	3.6	2	1.8	12/4/1992	1.0	21.1	3	7.0
2/10/1990	7.2	10.2	2	5.1	12/7/1992	7.5	7.5	1	7.5
2/14/1990	22.6	22.6	1	22.6	12/12/1992	7.4	7.4	1	7.4
2/18/1990	3.0	4.2	2	2.1	12/16/1992	65.0	153.2	3	51.1
3/1/1990	18.5	18.5	1	18.5	12/24/1992	21.3	48.0	2	24.0
3/13/1990	2.2	41.5	3	13.8	2/3/1993	4.2	25.9	3	8.6
4/2/1990	13.0	42.7	3	14.2	2/13/1993	2.6	49.4	6	8.2
Total Annual Rainfall(mm)		374.2	33		3/4/1993	6.5	6.5	1	6.5
11/10/1990	1.5	13.8	3	4.6	3/6/1993	5.0	5	1	5.0
12/25/1990	1.0	1.0	1	1.0	3/11/1993	19.2	20.4	2	10.2
1/4/1991	2.0	17.4	2	8.7	5/5/1993	6.0	10.2	2	5.1
1/20/1991	1.3	1.3	1	1.3	Total Annual Rainfall(mm)		434.9	28	
1/22/1991	4.0	4	1	4.0	10/21/1993	5.5	5.5	1	5.5
1/25/1991	7.9	24.4	2	12.2	11/2/1993	5.0	12.0	3	4.0
2/3/1991	2.8	70.3	6	11.7	11/11/1993	9.5	17.1	2	8.5
2/8/1991	3.4	13.9	3	4.6	11/14/1993	6.3	6.3	1	6.3

Annex 3.7: Historical Storms, Duration and Intensity for Dir Dibwan station/ Cont

PMD_name Deir Dibwan		Duration=1/11/68-2/26/1997		
PMD_Code:0241100		Total Rainfall mm/d	Duration day	Rainfall Intensity mm/d
Date ended	Rainfall			
11/26/1993	1.5	1.5	1	1.5
12/13/1993	18.2	18.2	1	18.2
12/22/1993	6.0	6	1	6.0
1/1/1994	3.0	3	1	3.0
1/4/1994	33.0	33	1	33.0
1/16/1994	5.5	25.8	3	8.6
1/22/1994	9.8	9.8	1	9.8
1/25/1994	7.8	22.6	2	11.3
1/28/1994	3.5	3.5	1	3.5
2/2/1994	1.0	56.2	3	18.7
2/11/1994	15.6	15.6	1	15.6
2/13/1994	2.9	2.9	1	2.9
2/24/1994	10.7	27.0	3	9.0
2/27/1994	17.8	25.2	2	12.6
3/7/1994	4.0	37.0	3	12.3
3/13/1994	27.0	57.3	4	14.3
4/1/1994	14.2	14.2	1	14.2
Total Annual Rainfall(mm)		399.7	37	
11/2/1994	4.4	4.4	1	4.4
11/5/1994	6.5	7.5	2	3.8
11/7/1994	22.1	22.1	1	22.1
11/17/1994	5.3	24.7	4	6.2
11/30/1994	1.0	92.8	8	11.6
12/5/1994	5.3	76.8	4	19.2
12/12/1994	1.0	1	1	1.0
12/20/1994	2.8	86.8	5	17.4
12/30/1994	2.5	6.0	2	3.0
1/18/1995	8.4	22.4	2	11.2
2/8/1995	13.5	56.5	6	9.4
2/15/1995	9.0	9	1	9.0
2/22/1995	7.2	8.4	2	4.2
3/16/1995	9.8	12.4	2	6.2
3/25/1995	18.1	26.4	2	13.2
4/3/1995	3.2	16.2	3	5.4
4/18/1995	2.4	2.4	1	2.4
Total Annual Rainfall(mm)		475.8	47	
11/1/1995	15.8	15.8	1	15.8
11/7/1995	2.7	2.7	1	2.7
11/10/1995	1.8	2.8	2	1.4
11/24/1995	5.0	45.7	3	15.2
12/4/1995	5.5	5.5	1	5.5
12/6/1995	1.1	1.1	1	1.1
12/13/1995	1.5	20.3	5	4.1
12/16/1995	2.0	2	1	2.0
1/3/1996	2.5	2.5	1	2.5
1/7/1996	1.0	37.1	3	12.4
1/10/1996	3.0	3	1	3.0

PMD_name Deir Dibwan		Duration=1/11/68-2/26/1997		
PMD_Code:0241100		Total Rainfall mm/d	Duration day	Rainfall Intensity mm/d
Date ended	Rainfall			
1/19/1996	6.5	94.2	4	23.6
1/24/1996	10.8	18.5	4	4.6
2/2/1996	3.0	9.5	2	4.8
2/4/1996	4.1	4.1	1	4.1
2/10/1996	11.0	11	1	11.0
2/14/1996	4.0	4	1	4.0
2/20/1996	1.0	6.0	2	3.0
3/2/1996	1.0	1.0	1	1.0
3/7/1996	38.8	71.8	2	35.9
3/26/1996	9.3	74.3	5	14.9
Total Annual Rainfall(mm)		432.9	43	
10/12/1996	1.1	1.1	1	1.1
10/25/1996	6.4	6.4	1	6.4
10/29/1996	6.0	7.3	2	3.6
11/18/1996	1.7	6.3	2	3.1
1/13/1997	5.0	5	1	5.0
1/16/1997	24.0	65.5	2	32.8
1/23/1997	9.5	64.5	2	32.3
1/26/1997	10.5	10.5	1	10.5
1/30/1997	10.0	10	1	10.0
2/4/1997	9.2	42.7	2	21.3
2/26/1997	1.3	86.3	6	14.4
Total Annual Rainfall(mm)		305.6	21	

Annex 3.8: Rain fall Statistical Analysis for the Index Rainfall Station

Hydrologic year	Annual Rainfall	Rainy Days	$(Xi-M)^2$
1968	177.6	28	74092.8
1968-1969	364.6	37	7259.0
1969-1970	245.3	30	41820.2
1972-1973	241	35	43597.4
1973-1974	756.5	46	94064.9
1974-1975	447.3	33	6.2
1975-1976	277.3	35	29756.2
1976-1977	427.5	38	497.3
1977-1978	426	31	566.4
1978-1979	286.8	24	26569.0
1979-1980	694.2	52	59731.4
1980-1981	546.7	41	9389.6
1981-1982	461.4	50	134.6
1982-1983	820	47	137048.0
1984-1985	411.8	30	1444.0
1985-1986	365	37	7191.0
1986-1987	424.6	51	635.0
1987-1988	490.2	56	1632.2
1988-1989	390.8	35	3481.0
1989-1990	380	33	4872.0
1990-1991	243.6	32	42518.4
1991-1992	740.8	45	84681.0
1992-1993	437.6	28	148.8
1993-1994	401.8	37	2304.0
1994-1995	478.1	47	800.9
1995-1996	435.8	43	196.0
1996-1997	306.3	21	20592.3
M	**432.5**	**37.9**	**695030**
S(x)	**163.499**		

Annex 3.9: Runoff Curve Number for the Study Area

Runoff Curve Numbers For Hydrologic Soil for the Study Area							
(Based on SCS classification with some adjustments for local conditions)							
No.	**Land Use**	**Treatment or Practices**	**Hydrologic condition**	**Hydrologic soil Group**			
				A	**B**	**C**	**D**
1	**Cropped area Dry farms**	Straight row & cons. Tillage, mountain area	*Poor*	60	75	80	83
			Fair	48	66	74	80
			Good	36	50	65	74
		Contoured & Cons. Tillage, upper hill slopes	*Poor*	65	77	84	88
			Fair	52	64	78	81
			Good	40	56	70	76
		Terraced & Cons. Tillage, Low hill slopes	*Poor*	63	74	82	85
			Fair	52	64	76	80
			Good	38	58	68	78
2	**Range Land**		*Poor*	66	79	86	89
			Fair	51	69	79	84
			Good	42	61	74	80
3	**Irrigated**		*Poor*	40	50	60	70
			Fair	30	40	50	60
			Good	20	30	40	50
4	**Irrigable**		*Poor*	62	74	80	84
			Fair	48	65	74	81
			Good	34	56	68	77
5	**Bare rock**		*Aquifer outcrop*	25	25	25	35
			Aquiclude outcrop	96	96	96	96
			Quaries	15	15	15	15
6	**Rock & Thin soil**		*Aquifer outcrop*	30	35	40	45
			Aquiclude outcrop	72	76	86	88
				68	72	82	84
				62	68	78	78
7	**Residential Areas**	High Density, Imperv. area: 50-75%		82	87	90	92
		Med. Density, Imperv. Area: 20-30%…Poor		76	84	88	90
		Fair		73	78	84	88
		Good		64	68	74	80
		Low Density, Imperv. Area: 15-20%		65	68	80	86
Notes:	**Temporal classification**						
	Poor: Oct., Nov.						
	Good: Dec., Jan., Feb.						
	Fair: March, April, May.						

Annex 3.10-A: Application of US.-SCS Method on the Study Area

Study area index rainfall station			1/11/1968-2/26/1997		Storm				
Date	Rainfall	Rainfall mm/d	Adjusted Rainfall mm/d =388/428.7=0.9	CN	S(mm)	Ia.(mm)	Infiltration P-Ia-Q	Q(mm)	Runoff factor
1/17/1968	17.5	42.8	38.5	53.3	222.5	44.5	0.0	0.17	0.43
2/1/1968	4.7	31.5	28.4	53.3	222.5	44.5	0.0	1.27	4.46
Total Annual Rainfall(mm)		74.3	66.9				0.00	1.43	2.45
12/8/1968	11.4	55.7	50.1	53.3	222.5	44.5	5.5	0.14	0.28
12/15/1968	25.3	31.2	28.1	53.3	222.5	44.5		1.31	4.66
2/8/1969	14.7	23.3	21.0	53.3	222.5	44.5		2.78	13.28
3/23/1969	14.7	127.2	114.5	47.3	283.0	56.6	48.1	9.83	8.58
Total Annual Rainfall(mm)		237.4	213.7				53.53	14.06	6.70
1/22/1970	32.4	50.9	45.8	53.3	222.5	44.5	1.3	0.01	0.02
2/23/1970	5.6	29.8	26.8	53.3	222.5	44.5		1.53	5.70
Total Annual Rainfall(mm)		80.7	72.6				1.29	1.54	2.86
1/16/1973	15.3	79.5	71.5	53.3	222.5	44.5	24.1	2.93	4.09
12/17/1973	6.6	31.9	28.7	53.3	222.5	44.5		1.21	4.21
Total Annual Rainfall(mm)		111.4	100.3				24.11	4.14	4.15
1/10/1974	2.0	72.0	64.8	53.3	222.5	44.5	18.6	1.70	2.62
1/17/1974	50.7	179.1	161.2	53.3	222.5	44.5	76.5	40.13	24.90
1/23/1974	13.4	108.9	98.0	53.3	222.5	44.5	43.1	10.37	10.58
1/31/1974	37.4	42.6	38.3	53.3	222.5	44.5		0.18	0.46
2/13/1974	4.0	63.0	56.7	53.3	222.5	44.5	11.6	0.63	1.12
2/28/1974	54.3	64.3	57.9	53.3	222.5	44.5	12.6	0.76	1.31
3/2/1974	28.8	47.3	42.6	47.3	283.0	56.6		0.73	1.72
4/10/1974	18.9	36.6	32.9	47.3	283.0	56.6		2.16	6.55
Total Annual Rainfall(mm)		613.8	552.4				162.4	56.65	6.16
11/24/1974	10.7	50.4	45.4	41.4	359.5	71.9		2.12	4.67
12/6/1974	1.7	32.3	29.1	53.3	222.5	44.5		1.15	3.96
12/11/1974	7.8	28.9	26.0	53.3	222.5	44.5		1.68	6.45
1/11/1975	7.5	28.5	25.7	53.3	222.5	44.5		1.75	6.81
2/3/1975	9.0	46.5	41.9	53.3	222.5	44.5		0.03	0.08
2/10/1975	21.6	66.5	59.9	53.3	222.5	44.5	14.4	0.99	1.65
2/21/1975	14.6	58.7	52.8	53.3	222.5	44.5	8.0	0.30	0.57
3/2/1975	1.8	47.1	42.4	47.3	283.0	56.6		0.75	1.77
Total Annual Rainfall(mm)		358.9	323.0				22.4	8.76	3.24
12/10/1975	2.1	30.1	27.1	53.3	222.5	44.5		1.48	5.46
1/14/1976	28.0	28	25.2	53.3	222.5	44.5		1.83	7.28
3/14/1976	2.4	43.2	38.9	57	191.6	38.3	0.6	0.00	0.00
Total Annual Rainfall(mm)		101.3	91.2				0.6	3.32	4.25
11/28/1976	20.5	52.1	46.9	41.4	359.5	71.9		1.87	3.99
1/6/1977	3.2	34.7	31.2	53.3	222.5	44.5		0.84	2.70
1/22/1977	7.5	57.1	51.4	53.3	222.5	44.5	6.7	0.21	0.40
2/9/1977	1.8	46.0	41.4	53.3	222.5	44.5		0.04	0.11
3/5/1977	10.1	86.1	77.5	47.3	283.0	56.6	19.5	1.44	1.85
4/23/1977	32.4	35.3	31.8	47.3	283.0	56.6	0.0	2.39	7.52
Total Annual Rainfall(mm)		311.3	280.2				26.1	6.79	2.76
12/17/1977	14.3	77.8	70.0	53.3	222.5	44.5	22.9	2.62	3.75
12/22/1977	8.2	45.7	41.1	53.3	222.5	44.5		0.05	0.13
1/3/1978	31.0	31	27.9	53.3	222.5	44.5		1.34	4.80
2/23/1978	20.7	29.2	26.3	53.3	222.5	44.5		1.63	6.19
3/13/1978	39.0	68.0	61.2	47.3	283.0	56.6	4.5	0.07	0.12
Total Annual Rainfall(mm)		251.7	226.5				27.4	5.7	3.00
10/3/1978	6.4	81.5	73.4	41.4	359.5	71.9	1.4	0.01	0.01
1/9/1979	17.2	64.2	57.8	53.3	222.5	44.5	12.5	0.75	1.29

Annex 3.10-A: Application of US-SCS Method on the Study Area/Cont.

study area index rainfall station			1/11/1968-2/26/1997					Storm	
							Infiltration		
Date	Rainfall	Rainfall mm/d	Adjusted Rainfall mm/d =388/428.7=0.9	CN	S(mm)	Ia(mm)	P-Ia-Q	Q(mm)	Runoff factor
1/23/1979	6.2	31.1	28.0	53.3	222.5	44.5		1.32	4.73
3/9/1979	2.7	45.0	40.5	47.3	283.0	56.6		0.97	2.40
Total Annual Rainfall(mm)		221.8	199.6				14.0	3.0	2.11
11/30/1979	5.0	159.8	143.8	41.4	359.5	71.9	59.9	11.99	8.33
12/6/1979	45.7	57.7	51.9	53.3	222.5	44.5	7.2	0.24	0.46
12/14/1979	33.5	39.3	35.4	53.3	222.5	44.5		0.39	1.11
12/28/1979	2.7	45.6	41.0	53.3	222.5	44.5		0.05	0.13
1/6/1980	6.2	47.7	42.9	53.3	222.5	44.5		0.01	0.03
1/25/1980	1.7	27.5	24.8	53.3	222.5	44.5		1.93	7.78
2/18/1980	2.1	74.6	67.1	53.3	222.5	44.5	20.5	2.09	3.11
3/3/1980	5.5	88.5	79.7	47.3	283.0	56.6	21.3	1.74	2.18
Total Annual Rainfall(mm)		540.7	486.6				109.0	18.4	2.89
12/13/1980	25.4	191.9	172.7	53.3	222.5	44.5	81.3	46.86	27.13
12/26/1980	26.3	33.7	30.3	53.3	222.5	44.5		0.96	3.18
1/4/1981	12.5	44.7	40.2	53.3	222.5	44.5		0.08	0.21
1/12/1981	15.7	34.3	30.9	53.3	222.5	44.5		0.89	2.88
1/27/1981	7.2	25.3	22.8	53.3	222.5	44.5		2.35	10.34
2/1/1981	14.5	46.6	41.9	53.3	222.5	44.5		0.03	0.07
2/25/1981	2.1	22.1	19.9	53.3	222.5	44.5		3.06	15.40
3/27/1981	2.0	50.5	45.5	47.3	283.0	56.6		0.46	1.01
Total Annual Rainfall(mm)		449.1	404.2				81.3	54.7	7.53
1/5/1982	2.7	78.9	71.0	53.3	222.5	44.5	23.7	2.82	3.97
1/14/1982	25.0	34.5	31.1	53.3	222.5	44.5		0.87	2.79
2/28/1982	3.6	22.1	19.9	53.3	222.5	44.5		3.06	15.40
3/1/1982	73.2	73.2	65.9	47.3	283.0	56.6	9.0	0.29	0.45
3/27/1982	3.9	38.8	34.9	47.3	283.0	56.6		1.80	5.15
Total Annual Rainfall(mm)		247.5	222.8				32.7	8.8	5.55
12/6/1982	2.1	35.3	31.8	53.3	222.5	44.5		0.77	2.43
1/15/1983	1.2	42.5	38.2	53.3	222.5	44.5		0.18	0.47
1/19/1983	33.0	43.0	38.7	53.3	222.5	44.5		0.16	0.40
1/25/1983	1.7	76.4	68.8	53.3	222.5	44.5	21.9	2.38	3.47
2/4/1983	9.1	45.4	40.9	53.3	222.5	44.5		0.06	0.15
2/21/1983	15.0	231.5	208.4	53.3	222.5	44.5	94.4	69.47	33.34
2/26/1983	11.8	35.1	31.6	53.3	222.5	44.5		0.80	2.52
3/6/1983	1.2	109.2	98.3	47.3	283.0	56.6	36.3	5.35	5.44
3/22/1983	10.5	34.5	31.1	47.3	283.0	56.6		2.54	8.17
Total Annual Rainfall(mm)		652.9	587.6				152.6	81.7	6.27
12/13/1984	36.5	36.5	32.9	53.3	222.5	44.5		0.64	1.96
2/2/1985	28.0	58.4	52.6	53.3	222.5	44.5	7.8	0.28	0.53
2/15/1985	42.2	68.4	61.6	53.3	222.5	44.5	15.8	1.21	1.97
2/26/1985	19.0	91.0	81.9	53.3	222.5	44.5	32.0	5.38	6.57
Total Annual Rainfall(mm)		254.3	228.9				55.6	7.5	2.76
12/19/1985	14.3	27.8	25.0	53.3	222.5	44.5		1.87	7.48
12/27/1985	4.5	21.6	19.4	53.3	222.5	44.5		3.18	16.37
1/12/1986	9.3	27.1	24.4	53.3	222.5	44.5		2.00	8.20
1/15/1986	10.0	33.3	30.0	53.3	222.5	44.5		1.02	3.39
2/6/1986	2.6	22.3	20.1	53.3	222.5	44.5		3.01	15.02
2/9/1986	15.9	29.3	26.4	53.3	222.5	44.5		1.61	6.10
2/15/1986	4.2	72.0	64.8	53.3	222.5	44.5	18.6	1.70	2.62
Total Annual Rainfall(mm)		233.4	210.1				18.6	14.4	8.45
11/9/1986	35.0	106.8	96.1	41.4	359.5	71.9	22.7	1.53	1.59
12/1/1986	3.4	23.4	21.1	53.3	222.5	44.5		2.76	13.11

Annex 3.10-A: Application of US-SCS Method on the Study Area/Cont.

study area index rainfall station			1/11/1968-2/26/1997				Storm		
			Adjusted Rainfall mm/d	CN	S(mm)	Ia(mm)	Infiltration		Runoff factor
Date	Rainfall	Rainfall mm/d	=388/428.7=0.9				P-Ia-Q	Q(mm)	
12/19/1986	18.6	22.2	20.0	53.3	222.5	44.5		3.04	15.21
1/6/1987	15.5	45.9	41.3	53.3	222.5	44.5		0.05	0.11
1/26/1987	1.9	26.1	23.5	53.3	222.5	44.5		2.19	9.33
3/14/1987	2.7	39.7	35.7	47.3	283.0	56.6		1.66	4.65
Total Annual Rainfall(mm)		264.1	237.7				22.7	11.2	7.33
12/6/1987	7.0	27.4	24.7	53.3	222.5	44.5		1.94	7.88
12/21/1987	3.4	25.4	22.9	53.3	222.5	44.5		2.33	10.21
12/25/1987	4.8	64.8	58.3	53.3	222.5	44.5	13.0	0.81	1.38
1/4/1988	22.2	26.8	24.1	53.3	222.5	44.5		2.06	8.53
1/18/1988	1.8	30.6	27.5	53.3	222.5	44.5		1.40	5.09
2/2/1988	15.2	40.2	36.2	53.3	222.5	44.5		0.32	0.90
2/18/1988	1.4	36.0	32.4	53.3	222.5	44.5		0.70	2.15
2/24/1988	3.7	56.5	50.9	53.3	222.5	44.5	6.2	0.18	0.35
3/3/1988	36.4	36.4	32.8	47.3	283.0	56.6		2.19	6.69
Total Annual Rainfall(mm)		344.1	309.7				19.2	11.9	4.80
12/19/1988	33.1	60.8	54.7	53.3	222.5	44.5	9.8	0.45	0.82
12/26/1988	27.5	79.3	71.4	53.3	222.5	44.5	24.0	2.89	4.05
2/12/1989	9.8	35.9	32.3	53.3	222.5	44.5		0.71	2.19
3/15/1989	15.4	59.4	53.5	47.3	283.0	56.6		0.04	0.07
Total Annual Rainfall(mm)		235.4	211.9				33.7	4.1	1.78
1/5/1990	3.0	107.5	96.8	53.3	222.5	44.5	42.3	9.93	10.27
1/26/1990	26.5	28.4	25.6	53.3	222.5	44.5		1.76	6.90
2/14/1990	22.6	22.6	20.3	53.3	222.5	44.5		2.94	14.48
3/13/1990	2.2	41.5	37.3	47.3	283.0	56.6		1.40	3.76
Total Annual Rainfall(mm)		200.0	180.0				42.3	16.0	8.85
1/25/1991	7.9	24.4	22.0	53.3	222.5	44.5		2.54	11.58
2/3/1991	2.8	70.3	63.3	53.3	222.5	44.5	17.3	1.46	2.31
3/24/1991	1.3	52.9	47.6	47.3	283.0	56.6		0.29	0.62
Total Annual Rainfall(mm)		147.6	132.8				17.3	4.3	4.83
12/4/1991	13.8	167.5	150.8	53.3	222.5	44.5	71.9	34.33	22.77
12/14/1991	3.1	78.0	70.2	53.3	222.5	44.5	23.0	2.66	3.79
12/27/1991	35.2	35.2	31.7	53.3	222.5	44.5		0.78	2.48
12/31/1991	38.1	47.4	42.7	53.3	222.5	44.5		0.02	0.04
2/4/1992	49.6	120.7	108.6	53.3	222.5	44.5	49.8	14.34	13.20
2/12/1992	1.5	90.8	81.7	53.3	222.5	44.5	31.9	5.33	6.52
2/27/1992	5.0	103.0	92.7	53.3	222.5	44.5	39.6	8.58	9.25
Total Annual Rainfall(mm)		642.6	578.3				216.2	66.0	8.29
11/24/1992	5.3	47.2	42.5	41.4	359.5	71.9		2.62	6.17
12/4/1992	1.0	21.1	19.0	53.3	222.5	44.5		3.31	17.41
12/16/1992	65.0	153.2	137.9	53.3	222.5	44.5	65.8	27.60	20.01
12/24/1992	21.3	48.0	43.2	53.3	222.5	44.5		0.01	0.02
2/3/1993	4.2	25.9	23.3	53.3	222.5	44.5		2.23	9.58
2/13/1993	2.6	49.4	44.5	53.3	222.5	44.5	0.0	0.00	0.00
Total Annual Rainfall(mm)		344.8	310.3				65.7	35.8	8.86
1/4/1994	33.0	33	29.7	53.3	222.5	44.5		1.06	3.55
1/16/1994	5.5	25.8	23.2	53.3	222.5	44.5		2.25	9.70
1/25/1994	7.8	22.6	20.3	53.3	222.5	44.5		2.94	14.48
2/2/1994	1.0	56.2	50.6	53.3	222.5	44.5	5.9	0.16	0.32
2/24/1994	10.7	27.0	24.3	53.3	222.5	44.5		2.02	8.31
2/27/1994	17.8	25.2	22.7	53.3	222.5	44.5		2.37	10.47
3/7/1994	4.0	37.0	33.3	47.3	283.0	56.6		2.09	6.28
3/13/1994	27.0	57.3	51.6	47.3	283.0	56.6		0.09	0.18

Annex 3.10-A: Application of US-SCS Method on the Study Area/Cont.

study area index rainfall station			1/11/1968-2/26/1997					Storm		
			Adjusted Rainfall mm/d				Infiltration		Runoff factor	
Date	Rainfall	Rainfall mm/d	=388/428.7=0.9	CN	S(mm)	Ia(mm)	P-Ia-Q	Q(mm)		
Total Annual Rainfall(mm)		284.1	255.7				5.9	13.0	6.66	
11/30/1994	1.0	92.8	83.5	41.4	359.5	71.9	11.3	0.36	0.44	
12/5/1994	5.3	76.8	69.1	53.3	222.5	44.5	22.2	2.45	3.55	
12/20/1994	2.8	86.8	78.1	53.3	222.5	44.5	29.2	4.41	5.65	
1/18/1995	8.4	22.4	20.2	53.3	222.5	44.5		2.99	14.84	
2/8/1995	13.5	56.5	50.9	53.3	222.5	44.5	6.2	0.18	0.35	
Total Annual Rainfall(mm)		335.3	301.8				68.8	10.4	4.96	
11/24/1995	5.0	45.7	41.1	41.4	359.5	71.9		2.88	7.00	
1/7/1996	1.0	37.1	33.4	53.3	222.5	44.5		0.58	1.75	
1/19/1996	6.5	94.2	84.8	53.3	222.5	44.5	34.1	6.17	7.28	
3/7/1996	38.8	71.8	64.6	53.3	222.5	44.5	18.4	1.67	2.58	
3/26/1996	9.3	74.3	66.9	53.3	222.5	44.5	20.3	2.04	3.05	
Total Annual Rainfall(mm)		323.1	290.8				72.9	13.3	4.33	
1/16/1997	24.0	65.5	59.0	53.3	222.5	44.5	13.6	0.88	1.49	
1/23/1997	9.5	64.5	58.1	53.3	222.5	44.5	12.8	0.78	1.34	
2/4/1997	9.2	42.7	38.4	53.3	222.5	44.5		0.17	0.44	
2/26/1997	1.3	86.3	77.7	53.3	222.5	44.5	28.9	4.30	5.54	
Total Annual Rainfall(mm)		259	233.1				55.2	6.1	2.20	

Annex 3.10-B: Application of US-SCS Method on the Catchment Area

surface catchment index rainfall station		D=	1/11/1968-2/26/1997				Infiltration	Storm	
Date	Rainfall	Rainfall mm/d	Adjusted Rainfall mm/d =366.7/428.7=0.86	CN	S(mm)	Ia(mm)	P-Ia-Q	Q(mm)	Runoff factor
1/11/1968	1.0	1	0.86	58.4	180.9	36.2			
1/17/1968	17.5	42.8	36.81	58.4	180.9	36.2	0.63	0.00	0.01
Total Annual Rainfall(mm)		176.2	151.53				0.6344	0.0022	
12/8/1968	11.4	55.7	47.90	58.41	180.9	36.2	11.02	0.71	1
3/23/1969	14.7	127.2	109.39	54.26	214.1	42.8	50.78	15.79	14
Total Annual Rainfall(mm)		357.9	307.79				61.7970	16.5023	8
1/22/1970	32.4	50.9	43.77	58.41	180.9	36.2	7.30	0.31	1
Total Annual Rainfall(mm)		241.4	207.60				119.8738	32.5967	1
1/16/1973	15.3	79.5	68.37	58.41	180.9	36.2	27.33	4.87	7
Total Annual Rainfall(mm)		240.0	206.40				27.3325	4.8661	7
1/10/1974	2.0	72.0	61.92	58.41	180.9	36.2	22.54	3.21	5
1/17/1974	50.7	179.1	154.03	58.41	180.9	36.2	71.36	46.50	30
1/23/1974	13.4	108.9	93.65	58.41	180.9	36.2	43.62	13.86	15
1/31/1974	37.4	42.6	36.64	58.41	180.9	36.2	0.46	0.00	0
2/13/1974	4.0	63.0	54.18	58.41	180.9	36.2	16.38	1.63	3
2/28/1974	54.3	64.3	55.30	58.41	180.9	36.2	17.30	1.83	3
Total Annual Rainfall(mm)		754.4	648.78				171.6530	67.0326	9
2/3/1975	9.0	46.5	39.99	58.41	180.9	36.2	3.74	0.08	0
2/10/1975	21.6	66.5	57.19	58.41	180.9	36.2	18.83	2.19	4
2/21/1975	14.6	58.7	50.48	58.41	180.9	36.2	13.26	1.05	2
Total Annual Rainfall(mm)		448.6	385.80				35.8311	3.3167	2
Total Annual Rainfall(mm)		273.9	235.55					0.0000	
1/22/1977	7.5	57.1	49.11	58.41	180.9	36.2	12.07	0.86	2
2/9/1977	1.8	46.0	39.56	58.41	180.9	36.2	3.33	0.06	0
3/5/1977	10.1	86.1	74.05	54.26	214.1	42.8	27.25	3.97	5
Total Annual Rainfall(mm)		422.9	363.69				42.6467	4.8991	2
12/17/1977	14.3	77.8	66.91	58.41	180.9	36.2	26.27	4.46	7
12/22/1977	8.2	45.7	39.30	58.41	180.9	36.2	3.08	0.05	0
3/13/1978	39.0	68.0	58.48	54.26	214.1	42.8	14.59	1.07	2
Total Annual Rainfall(mm)		425	365.50				43.9389	5.5850	3
10/3/1978	6.4	81.5	70.09	58.41	180.9	36.2	28.56	5.36	8
1/9/1979	17.2	64.2	55.21	58.41	180.9	36.2	17.23	1.81	3
Total Annual Rainfall(mm)		285.5	245.53				45.7889	7.1703	5
11/30/1979	5.0	159.8	137.43	50.73	246.7	49.3	64.91	23.18	17
12/6/1979	45.7	57.7	49.62	58.41	180.9	36.2	12.52	0.93	2
12/28/1979	2.7	45.6	39.22	58.41	180.9	36.2	2.99	0.05	0
1/6/1980	6.2	47.7	41.02	58.41	180.9	36.2	4.72	0.13	0
2/18/1980	2.1	74.6	64.16	58.41	180.9	36.2	24.23	3.75	6
3/3/1980	5.5	88.5	76.11	54.26	214.1	42.8	28.81	4.48	6
Total Annual Rainfall(mm)		689.9	593.31				138.1915	32.5156	5
12/13/1980	25.4	191.9	165.03	58.41	180.9	36.2	75.25	53.61	32
1/4/1981	12.5	44.7	38.44	58.41	180.9	36.2	2.24	0.03	0
2/1/1981	14.5	46.6	40.08	58.41	180.9	36.2	3.82	0.08	0
3/27/1981	2.0	50.5	43.43	54.26	214.1	42.8	0.60	0.00	0
Total Annual Rainfall(mm)		544.1	467.93				81.9173	53.7272	8
1/5/1982	2.7	78.9	67.85	58.41	180.9	36.2	26.96	4.72	7

Annex 3.10-B: Application of US-SCS Method on the Catchment Area/cont.

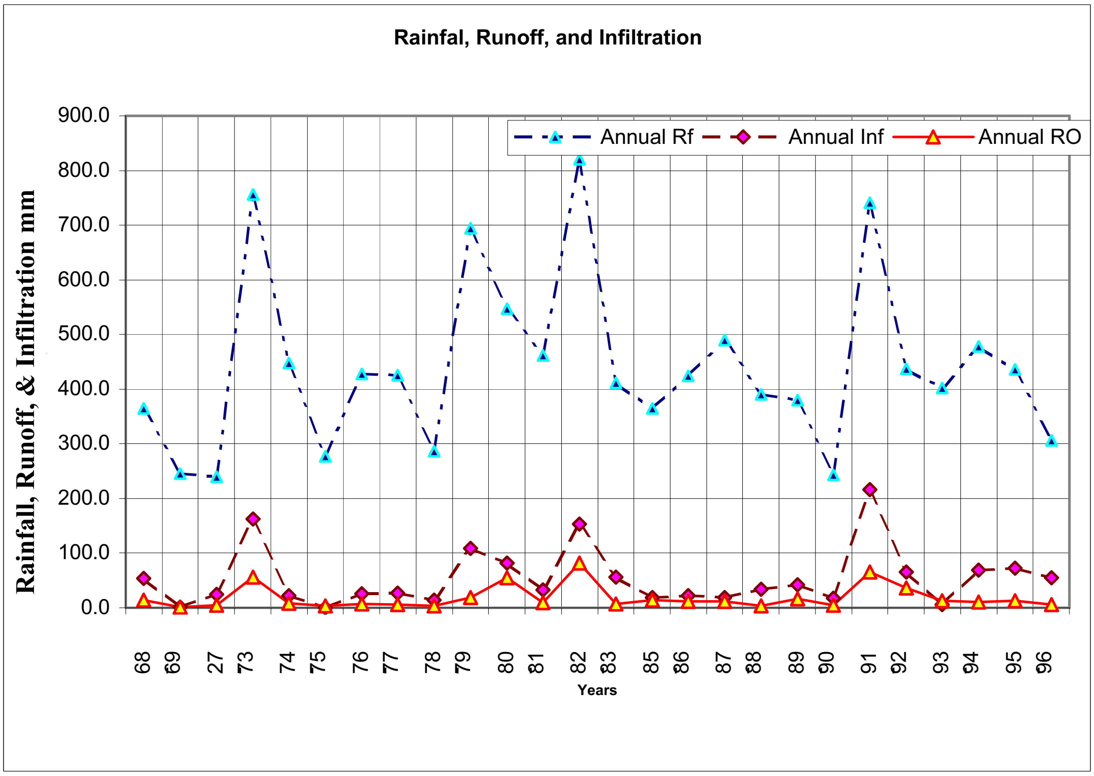
surface catchment index rainfall station		D=	1/11/1968-2/26/1997				Infiltration	Storm	
Date	Rainfall	Rainfall mm/d	Adjusted Rainfall mm/d =366.7/428.7=0.86	CN	S(mm)	Ia(mm)	P-Ia-Q	Q(mm)	Runoff factor
3/1/1982	73.2	73.2	62.95	54.26	214.1	42.8	18.40	1.73	3
Total Annual Rainfall(mm)		459.6	395.26				45.3588	6.4525	5
1/15/1983	1.2	42.5	36.55	58.41	180.9	36.2	0.38	0.00	0
1/19/1983	33.0	43.0	36.98	58.41	180.9	36.2	0.80	0.00	0
1/25/1983	1.7	76.4	65.70	58.41	180.9	36.2	25.39	4.15	6
2/4/1983	9.1	45.4	39.04	58.41	180.9	36.2	2.83	0.04	0
2/21/1983	15.0	231.5	199.09	58.41	180.9	36.2	85.71	77.21	39
3/6/1983	1.2	109.2	93.91	54.26	214.1	42.8	41.25	9.84	10
Total Annual Rainfall(mm)		787.8	677.51				156.3545	91.2452	9
2/2/1985	28.0	58.4	50.22	58.41	180.9	36.2	13.04	1.01	2
2/15/1985	42.2	68.4	58.82	58.41	180.9	36.2	20.13	2.52	4
2/26/1985	19.0	91.0	78.26	58.41	180.9	36.2	34.14	7.95	10
Total Annual Rainfall(mm)		407.9	350.79				67.3135	11.4803	5
2/15/1986	4.2	72.0	61.92	58.41	180.9	36.2	22.54	3.21	5
Total Annual Rainfall(mm)		362.5	311.75				22.5396	3.2090	5
11/9/1986	35.0	106.8	91.85	50.73	246.7	49.3	36.26	6.25	7
1/6/1987	15.5	45.9	39.47	58.41	180.9	36.2	3.24	0.06	0
Total Annual Rainfall(mm)		424.5	365.07				39.5048	6.3078	3
12/25/1987	4.8	64.8	55.73	58.41	180.9	36.2	17.65	1.91	3
2/24/1988	3.7	56.5	48.59	58.41	180.9	36.2	11.62	0.80	2
Total Annual Rainfall(mm)		484.6	416.76				29.2689	2.7063	3
12/19/1988	33.1	60.8	52.29	58.41	180.9	36.2	14.80	1.32	3
12/26/1988	27.5	79.3	68.20	58.41	180.9	36.2	27.21	4.82	7
3/15/1989	15.4	59.4	51.08	54.26	214.1	42.8	7.95	0.31	1
Total Annual Rainfall(mm)		387	332.82				49.9602	6.4437	3
1/5/1990	3.0	107.5	92.45	58.41	180.9	36.2	42.92	13.36	14
Total Annual Rainfall(mm)		374.2	321.81				42.9222	13.3564	14
2/3/1991	2.8	70.3	60.46	58.41	180.9	36.2	21.41	2.88	5
3/24/1991	1.3	52.9	45.49	54.26	214.1	42.8	2.64	0.03	0
Total Annual Rainfall(mm)		239.3	205.80				24.0491	2.9081	2
12/4/1991	13.8	167.5	144.05	58.41	180.9	36.2	67.57	40.31	28
12/14/1991	3.1	78.0	67.08	58.41	180.9	36.2	26.40	4.51	7
12/31/1991	38.1	47.4	40.76	58.41	180.9	36.2	4.48	0.11	0
2/4/1992	49.6	120.7	103.80	58.41	180.9	36.2	49.22	18.41	18
2/12/1992	1.5	90.8	78.09	58.41	180.9	36.2	34.03	7.89	10
2/27/1992	5.0	103.0	88.58	58.41	180.9	36.2	40.63	11.77	13
Total Annual Rainfall(mm)		738.1	634.77				222.3358	82.9998	13
12/16/1992	65.0	153.2	131.75	58.41	180.9	36.2	62.53	33.05	25
12/24/1992	21.3	48.0	41.28	58.41	180.9	36.2	4.97	0.14	0
2/13/1993	2.6	49.4	42.48	58.41	180.9	36.2	6.10	0.21	1
Total Annual Rainfall(mm)		434.9	374.01				73.6008	33.4010	9
2/2/1994	1.0	56.2	48.33	58.41	180.9	36.2	11.39	0.77	2
3/13/1994	27.0	57.3	49.28	54.26	214.1	42.8	6.27	0.19	0
Total Annual Rainfall(mm)		399.7	343.74				17.6603	0.9550	1
11/30/1994	1.0	92.8	79.81	50.73	246.7	49.3	27.12	3.35	4
12/5/1994	5.3	76.8	66.05	58.41	180.9	36.2	25.64	4.24	6
12/20/1994	2.8	86.8	74.65	58.41	180.9	36.2	31.73	6.75	9
2/8/1995	13.5	56.5	48.59	58.41	180.9	36.2	11.62	0.80	2

Annex 3.10-B: Application of US-SCS Method on the Catchment Area/cont.

surface catchment index rainfall station		D=	1/11/1968-2/26/1997				Infiltration	Storm	
Date	Rainfall	Rainfall mm/d	Adjusted Rainfall mm/d =366.7/428.7=0.86	CN	S(mm)	Ia(mm)	P-Ia-Q	Q(mm)	Runoff factor
Total Annual Rainfall(mm)		475.8	409.19				96.1086	15.1332	5
1/19/1996	6.5	94.2	81.01	58.41	180.9	36.2	35.93	8.91	11
3/7/1996	38.8	71.8	61.75	54.26	214.1	42.8	17.39	1.54	2
3/26/1996	9.3	74.3	63.90	54.26	214.1	42.8	19.19	1.89	3
Total Annual Rainfall(mm)		432.9	372.29				72.5060	12.3340	5
1/16/1997	24.0	65.5	56.33	58.41	180.9	36.2	18.14	2.02	4
1/23/1997	9.5	64.5	55.47	58.41	180.9	36.2	17.44	1.86	3
2/4/1997	9.2	42.7	36.72	58.41	180.9	36.2	0.55	0.00	0
2/26/1997	1.3	86.3	74.22	58.41	180.9	36.2	31.43	6.61	9
Total Annual Rainfall(mm)		305.6	262.82				67.5577	10.4967	4

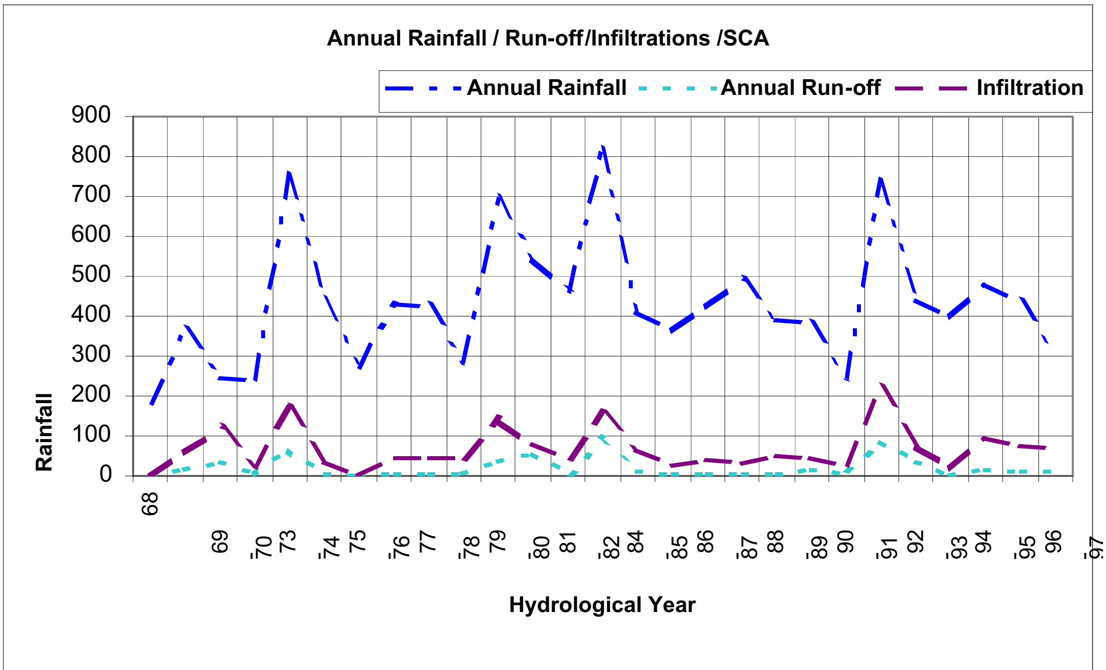
Annex 3.11-A: Calculation of Runoff Coefficient and Infiltration Rate from the Rainfall for the Study Area

Date	Annual Rainfall- mm			Adjusted Rainfall mm	Infiltration			Storm Runoff.			Annual
					mm	MCM	% of Rainfall	mm	MCM	Storm Runoff Coefficient %	Runoff coefficient %
1968-69	364.6	264	237	214	53.5	29.7	14.7	14.06	7.8	6.58	3.86
1969-70	245.3	90	81	73	1.3	0.7	0.5	1.54	0.9	2.11	0.63
1927-73	240	88	79	73	24.1	13.4	10.0	4.14	2.3	5.70	1.72
1973-74	756.5	682	614	552	162.4	90.0	21.5	56.65	31.4	10.26	7.49
1974-75	447.3	399	359	323	22.4	12.4	5.0	8.76	4.9	2.71	1.96
1975-76	277.3	113	101	91	0.6	0.3	0.2	3.32	1.8	3.64	1.20
1976-77	427.5	346	311	280	26.1	14.5	6.1	6.79	3.8	2.42	1.59
1977-78	426	280	252	227	27.4	15.2	6.4	5.72	3.2	2.52	1.34
1978-79	286.8	246	222	200	14.0	7.7	4.9	3.05	1.7	1.53	1.06
1979-80	694.2	601	541	487	109.0	60.4	15.7	18.43	10.2	3.79	2.66
1980-81	546.7	499	449	404	81.3	45.1	14.9	54.70	30.3	13.53	10.01
1981-82	461.4	275	248	223	32.7	18.1	7.1	8.84	4.9	3.97	1.92
1982-83	820	725	653	588	152.6	84.5	18.6	81.71	45.3	13.91	9.96
1984-85	411.8	283	254	229	55.6	30.8	13.5	7.52	4.2	3.28	1.83
1985-86	365	259	233	210	18.6	10.3	5.1	14.39	8.0	6.85	3.94
1986-87	424.6	293	264	238	22.7	12.6	5.3	11.23	6.2	4.72	2.64
1987-88	490.2	382	344	310	19.2	10.6	3.9	11.93	6.6	3.85	2.43
1988-89	390.8	262	235	212	33.7	18.7	8.6	4.08	2.3	1.93	1.04
1989-90	380	222	200	180	42.3	23.4	11.1	16.04	8.9	8.91	4.22
1990-91	243.6	164	148	133	17.3	9.6	7.1	4.30	2.4	3.23	1.76
1991-92	740.8	714	643	578	216.2	119.8	29.2	66.04	36.6	11.42	8.91
1992-93	437.6	383	345	310	65.7	36.4	15.0	35.76	19.8	11.52	8.17
1993-94	401.8	316	284	256	5.9	3.3	1.5	12.99	7.2	5.08	3.23
1994-95	478.1	373	335	302	68.8	38.1	14.4	10.39	5.8	3.44	2.17
1995-96	435.8	359	323	291	72.9	40.4	16.7	13.34	7.4	4.59	3.06
1996-97	306.3	288	259	233	55.2	30.6	18.0	6.13	3.4	2.63	2.00
Ave.	**442.3**			**277.5**	**53.9**	**29.9**	**10.6**	**18.5**	**10.3**	**6.68**	**3.5**



Annex 3.11-B: Calculation of Runoff Coefficient and Infiltration Rate from the Rainfall for Catchment's Area

Hydrologic Year	Annual Rainfall mm	Adjusted Rainfall mm	Infiltration			Storm Runoff.			Annual
			mm	MCM	% of Rainfall	mm	MCM	Storm Runoff Coefficient %	Runoff coefficient %
1968-69	364.6	328.1	61.80	8.16	16.95	16.5	2.18	5.03	4.53
1969-70	245.3	220.8	119.87	15.82	48.87	32.6	4.30	14.77	13.29
1927-73	241.0	216.9	27.33	3.61	11.34	4.9	0.64	2.24	2.02
1973-74	756.5	680.8	171.65	22.66	22.69	67.0	8.85	9.85	8.86
1974-75	447.3	402.6	35.83	4.73	8.01	3.3	0.44	0.82	0.74
1975-76	277.3	249.6	0.00	0.00	0.00	0.0	0.00	0.00	0.00
1976-77	427.5	384.8	42.65	5.63	9.98	4.9	0.65	1.27	1.15
1977-78	426.0	383.4	43.94	5.80	10.31	5.6	0.74	1.46	1.31
1978-79	286.8	258.1	45.79	6.04	15.97	7.2	0.95	2.78	2.50
1979-80	694.2	624.8	138.19	18.24	19.91	32.5	4.29	5.20	4.68
1980-81	546.7	492.0	81.92	10.81	14.98	53.7	7.09	10.92	9.83
1981-82	461.4	415.3	45.36	5.99	9.83	6.5	0.85	1.55	1.40
1982-83	820.0	738.0	156.35	20.64	19.07	91.2	12.04	12.36	11.13
1984-85	411.8	370.6	67.31	8.89	16.35	11.5	1.52	3.10	2.79
1985-86	365.0	328.5	22.54	2.98	6.18	3.2	0.42	0.98	0.88
1986-87	424.6	382.1	39.50	5.21	9.30	6.3	0.83	1.65	1.49
1987-88	490.2	441.2	29.27	3.86	5.97	2.7	0.36	0.61	0.55
1988-89	390.8	351.7	49.96	6.59	12.78	6.4	0.85	1.83	1.65
1989-90	380.0	342.0	42.92	5.67	11.30	13.4	1.76	3.91	3.51
1990-91	243.6	219.2	24.05	3.17	9.87	2.9	0.38	1.33	1.19
1991-92	740.8	666.7	222.34	29.35	30.01	83.0	10.96	12.45	11.20
1992-93	437.6	393.8	73.60	9.72	16.82	33.4	4.41	8.48	7.63
1993-94	401.8	361.6	17.66	2.33	4.40	1.0	0.13	0.26	0.24
1994-95	478.1	430.3	96.11	12.69	20.10	15.1	2.00	3.52	3.17
1995-96	435.8	392.2	72.51	9.57	16.64	12.3	1.63	3.14	2.83
1996-97	306.3	275.7	67.56	8.92	22.06	10.5	1.39	3.81	3.43
	442.3	**398.1**	**69.1**	**9.1**	**15.0**	**20.3**	**2.7**	**4.4**	**3.9**



Annex 3.12: Spring Recession analysis

	Recession factor		Peack Flow					
Spring I.D	Kr1(mon.)	Kr2(mon.)	Qi(l/s)1	Qi(l/s)2	Ti.	Duration Till Nov.	$Q_{.tp}$ MCM*1000	Remaining Base Storage (MCM)*1000
AC/060	53.3		190.00		Dec./92	11	11412.689	7095.924
AR/020	38.5		700.00		feb./93	9	30371.478	17729.631
BA/111	**8.3**	**24**	**4.80**	**2.80**	Feb./93	9	69.161	68.982
BA/126	9.6		0.75		mar./88	8	8.114	1.191
BA127	11.7		0.35		Apri./93	8	4.603	0.950
BA/128	14.0		0.95		Feb./93	9	14.989	3.411
BA129	10.0		0.55		mar./93	8	6.198	0.982
BA/130	52.2		0.19		Jan./93	10	11.177	7.191
BA/132	10.0		1.20		Jan./93	10	13.523	1.352
BA/135A	31.8		3.80		Jan./92	10	136.181	66.016
BA/138	4.2		3.00		Feb./00	9	14.098	0.098
BA/152	8.3		1.90		Jan./93	10	17.772	1.109
BA/164	**2.8**	**5**	**65.00**	**32.00**	Feb./93	9	213.164	49.642

Annex 3.13-: Spring Base Flow Recession Results

Spring Name:				Al Dyuk
Spring Code:				Ac/060
Recession Factor =				53.3
Peak Discharge =L/S				190.00
Discharge Period/Cycle = MONTH				11
R.P.S/Past Year (MCM)				
Time (month)	Spring Discharge (L/s)	Camul Disch (MCM)*100	Remaining Storage (MCM)*100	
Jan.	182.0	471.7	10941.0	
Feb.	174.3	923.4	10489.3	
March.	166.9	1356.0	10056.7	
April.	159.8	1770.3	9642.4	
May	153.1	2167.1	9245.6	
June	146.6	2547.2	8865.5	
July	140.4	2911.1	8501.6	
Aug.	134.5	3259.7	8153.0	
Sept.	128.8	3593.5	7819.2	
Oct.	123.3	3913.2	7499.5	
Nov.	118.1	4219.4	7193.3	
Total potential Storage =(MCM)				11.40
Total Discharge For The Period =(MCM)				4.22
Rem.Baseflow Storage/End Of Nov.=(MCM				7.20
B. Rech. By The End Of Nov.=(MCM)*1000				97.33

Spring Name:				Al`Auja
Spring Code:				AR/020
Recession Factor =				38.5
Peak Discharge =L/S				700
Discharge Period/Cycle = MONTH				9
R.P.S/Past Year (MCM)				
Time (month)	Spring Discharge (L/s)	Camul Disch (MCM)*100	Remaining Storage (MCM)*100	
Jan.				
Feb.				
March.	659.4	1709.07	28662.41	
April.	621.1	3318.92	27052.56	
May	585.0	4835.31	25536.17	
June	551.1	6263.66	24107.82	
July	519.1	7609.10	22762.38	
Aug.	488.9	8876.43	21495.05	
Sept.	460.6	10070.18	20301.30	
Oct.	433.8	11194.63	19176.85	
Nov.	408.6	12253.80	18117.67	
Total potential Storage =(MCM)				30.37
Total Discharge For The Period =(MCM)				12.25
Rem.Baseflow Storage/End Of Nov.=(MCN				18.11
B. Recharge By The End Of Nov.=(MCM)*1				388.04

Spring Name:				Ajjul
Spring Code:				BA/111
Recession Factor =				8.3,24
Peak Discharge =L/S				4.8,2.8
Discharge Period/Cycle = MONTH				9
R.P.S/Past Year (MCM)				
Time (month)	Spring Discharge (L/s)	Camul Disch (MCM)*100	Remaining Storage (MCM)*100	
Jan.				
Feb.				
March.	3.6	9.43	59.73	
April.	2.8	16.57	52.59	
May	2.1	21.98	47.18	
June	1.9	26.93	42.23	
July	1.7	31.42	37.74	
Aug.	1.6	35.50	33.66	
Sept.	1.4	39.21	29.95	
Oct.	1.3	42.58	26.58	
Nov.	1.2	45.64	23.52	
Total potential Storage =(CM)				69160.0
Total Discharge For The Period =(CM)				45640.0
Rem.Baseflow Storage/End Of Nov.=(CM)				23520.0
B. Recharge By The End Of Nov.=(CM)				0.0

Spring Name:				Al Kabeera
Spring Code:				BA/126
Recession Factor =				9.6
Peak Discharge =L/S				0.75
Discharge Period/Cycle = MONTH				8
R.P.S/Past Year (MCM)				
Time (month)	Spring Discharge (L/s)	Camul Disch (MCM)(100	Remaining Storage (MCM)*100	
Jan.				
Feb.				
March.				
April.	0.590	1.53	6.58	
May	0.464	2.73	5.38	
June	0.365	3.68	4.43	
July	0.287	4.42	3.69	
Aug.	0.226	5.01	3.10	
Sept.	0.178	5.47	2.64	
Oct.	0.140	5.83	2.28	
Nov.	0.110	6.12	1.99	
Total potential Storage =(CM)				8110.0
Total Discharge For The Period =(CM)				6120.0
Rem.Baseflow Storage/End Of Nov.=(CM)				1990.0
B. Recharge By The End Of Nov.=(CM)				800.0

Annex 3.13: Spring Base Flow Recession Results/Cont.

Spring Name:				AShaikh
Spring Code:				BA/132
Recession Factor =				10
Peak Discharge =L/S				1.2
Discharge Period/Cycle = MONTH				10
R.P.S/Past Year (MCM)				
Time (month)	Spring Discharge (L/s)	Camul Disch (MCM)*100	Remaining Storage (MCM)*100	
Jan.				
Feb.	0.953	2.47	11.05	
March.	0.757	4.43	9.09	
April.	0.601	5.99	7.53	
May	0.478	7.23	6.29	
June	0.379	8.21	5.31	
July	0.301	9.00	4.53	
Aug.	0.239	9.62	3.91	
Sept.	0.190	10.11	3.41	
Oct.	0.151	10.50	3.02	
Nov.	0.120	10.81	2.71	
Total potential Storage =(CM)				13520.0
Total Discharge For The Period =(CM)				10810.0
Rem.Baseflow Storage/End Of Nov.=(CM)				2710.0
B. Recharge By The End Of Nov.=(CM)				1360.0

Spring Name:				Jifna balad
Spring Code:				BA/135A
Recession Factor =				31.8
Peak Discharge =L/S				3.8
Discharge Period/Cycle = MONTH				10
R.P.S/Past Year (MCM)				
Time (month)	Spring Discharge (L/s)	Camul Disch (MCM)(100	Remaining Storage (MCM)*100	
Jan.				
Feb.	3.53	9.16	127.02	
March.	3.29	17.68	118.50	
April.	3.06	25.61	110.57	
May	2.84	32.98	103.20	
June	2.65	39.84	96.34	
July	2.46	46.22	89.96	
Aug.	2.29	52.15	84.03	
Sept.	2.13	57.67	78.51	
Oct.	1.98	62.80	73.38	
Nov.	1.84	67.58	68.60	
Total potential Storage =(CM)				136180.0
Total Discharge For The Period =(CM)				67580.0
Rem.Baseflow Storage/End Of Nov.=(CM)				66010.0
B. Recharge By The End Of Nov.=(CM)				2590.0

Spring Name:				Delbah
Spring Code:				BA/164
Recession Factor =				2.8,5
Peak Discharge =L/S				65,32
Discharge Period/Cycle = MONTH				9
R.P.S/Past Year (MCM)				
Time (month)	Spring Discharge (L/s)	Camul Disch (MCM)*100	Remaining Storage (MCM)*100	
Jan.				
Feb.				
March.	28.561	74.0	139.13	
April.	12.550	106.6	106.61	
May	8.038	127.4	85.77	
June	5.072	140.5	72.63	
July	3.200	148.8	64.33	
Aug.	2.019	154.1	59.10	
Sept.	1.274	157.4	55.80	
Oct.	0.804	159.5	53.71	
Nov.	0.507	160.8	52.40	
Total potential Storage =(CM)				213160.0
Total Discharge For The Period =(CM)				160800.0
Rem.Baseflow Storage/End Of Nov.=(CM)				52400.0
B. Recharge By The End Of Nov.=(CM)				2760.0

Spring Name:				Al maghara
Spring Code:				BA/128
Recession Factor =				14
Peak Discharge =L/S				0.95
Discharge Period/Cycle = MONTH				9
R.P.S/Past Year (MCM)				
Time (month)	Spring Discharge (L/s)	Camul Disch (MCM)*100	Remaining Storage (MCM)*100	
Jan.				
Feb.				
March.	0.806	2.09	12.90	
April.	0.684	3.86	11.13	
May	0.580	5.36	9.62	
June	0.492	6.64	8.35	
July	0.417	7.72	7.27	
Aug.	0.354	8.64	6.35	
Sept.	0.300	9.42	5.57	
Oct.	0.255	10.08	4.91	
Nov.	0.216	10.64	4.35	
Total potential Storage =(CM)				14980.0
Total Discharge For The Period =(CM)				10640.0
Rem.Baseflow Storage/End Of Nov.=(CM)				4350.0
B. Recharge By The End Of Nov.=(CM)				940.0

Annex 3.13: Spring Base Flow Recession Results/Cont.

Spring Name:				Al Derah
Spring Code:				BA127
Recession Factor =				11.67
Peak Discharge =L/S				0.35
Discharge Period/Cycle = MONTH				8
R.P.S/Past Year (MCM)				
Time (month)	Spring Discharge (L/s)	Camul Disch (MCM)*100	Remaining Storage (MCM)*100	
Jan.				
Feb.				
March.				
April.	0.287	0.745	3.858	
May	0.236	1.356	3.247	
June	0.194	1.858	2.745	
July	0.159	2.270	2.333	
Aug.	0.131	2.608	1.995	
Sept.	0.107	2.886	1.717	
Oct.	0.088	3.114	1.489	
Nov.	0.072	3.301	1.302	
Total potential Storage =(CM)				4600.0
Total Discharge For The Period =(CM)				3300.0
Rem.Baseflow Storage/End Of Nov.=(CM)				1300.0
B. Recharge By The End Of Nov.=(CM)				351.86

Spring Name:				Al`alaq
Spring Code:				BA/152
Recession Factor =				8.33
Peak Discharge =L/S				1.9
Discharge Period/Cycle = MONTH				10
R.P.S/Past Year (MCM)				
Time (month)	Spring Discharge (L/s)	Camul Disch (MCM)*100	Remaining Storage (MCM)*100	
Jan.				
Feb.	1.441	3.74	14.04	
March.	1.093	6.57	11.20	
April.	0.829	8.72	9.05	
May	0.629	10.35	7.42	
June	0.477	11.58	6.19	
July	0.362	12.52	5.25	
Aug.	0.274	13.23	4.54	
Sept.	0.208	13.77	4.00	
Oct.	0.158	14.18	3.59	
Nov.	0.120	14.49	3.28	
Total potential Storage =(CM)				17770.0
Total Discharge For The Period =(CM)				14500.0
Rem.Baseflow Storage/End Of Nov.=(CM)				3280.0
B. Recharge By The End Of Nov.=(CM)				2170.0

Spring Name:				A Daraj
Spring Code:				BA129
Recession Factor =				10
Peak Discharge =L/S				0.55
Discharge Period/Cycle = MONTH				8
R.P.S/Past Year (MCM)				
Time (month)	Spring Discharge (L/s)	Camul Disch (MCM)*100	Remaining Storage (MCM)*100	
Jan.				
Feb.				
March.				
April.	0.437	1.13	5.07	
May	0.347	2.03	4.17	
June	0.276	2.75	3.45	
July	0.219	3.31	2.88	
Aug.	0.174	3.76	2.43	
Sept.	0.138	4.12	2.08	
Oct.	0.110	4.41	1.79	
Nov.	0.087	4.63	1.57	
Total potential Storage =(CM)				6200.0
Total Discharge For The Period =(CM)				4630.0
Rem.Baseflow Storage/End Of Nov.=(CM)				1570.0
B. Recharge By The End Of Nov.=(CM)				580.0

Spring Name:				AShaqiyya
Spring Code:				BA/130
Recession Factor =				52.2
Peak Discharge =L/S				0.19
Discharge Period/Cycle = MONTH				10
R.P.S/Past Year (MCM)				
Time (month)	Spring Discharge (L/s)	Camul Disch (MCM)*100	Remaining Storage (MCM)*100	
Jan.				
Feb.	0.182	0.47	10.71	
March.	0.174	0.92	10.26	
April.	0.166	1.35	9.82	
May	0.159	1.77	9.41	
June	0.152	2.16	9.02	
July	0.146	2.54	8.64	
Aug.	0.140	2.90	8.28	
Sept.	0.134	3.25	7.93	
Oct.	0.128	3.58	7.60	
Nov.	0.122	3.89	7.28	
Total potential Storage =(CM)				11170.0
Total Discharge For The Period =(CM)				3890.0
Rem.Baseflow Storage/End Of Nov.=(CM)				7280.0
B. Recharge By The End Of Nov.=(CM)				90.0

Annex 4.1: Estimated historical Infiltration Recharge in Auja Sub-basin

Hydrologic year	Infiltration			Hydrologic year	Infiltration		
	mm	MCM	%from Rainfall		mm	MCM	%from Rainfall
1968-69	53.5	29.7	14.7	1984-85	55.6	30.8	13.5
1969-70	1.3	0.7	0.5	1985-86	18.6	10.3	5.1
1927-73	24.1	13.4	10.0	1986-87	22.7	12.6	5.3
1973-74	162.4	90.0	21.5	1987-88	19.2	10.6	3.9
1974-75	22.4	12.4	5.0	1988-89	33.7	18.7	8.6
1975-76	0.6	0.3	0.2	1989-90	42.3	23.4	11.1
1976-77	26.1	14.5	6.1	1990-91	17.3	9.6	7.1
1977-78	27.4	15.2	6.4	1991-92	216.2	119.8	29.2
1978-79	14.0	7.7	4.9	1992-93	65.7	36.4	15.0
1979-80	109.0	60.4	15.7	1993-94	5.9	3.3	1.5
1980-81	81.3	45.1	14.9	1994-95	68.8	38.1	14.4
1981-82	32.7	18.1	7.1	1995-96	72.9	40.4	16.7
1982-83	152.6	84.5	18.6	1996-97	55.2	30.6	18.0
			Ave		**53.9**	**29.9**	**10.6**

Annex 4.2: Estimated historical Infiltration Recharge in Auja Surface Catchment

Hydrologic year	Infiltration			Hydrologic year	Infiltration		
	mm	MCM	%from Rainfall		mm	MCM	%from Rainfall
1968-69	61.8	8.2	16.9	1984-85	67.3	8.9	16.3
1969-70	119.9	15.8	48.9	1985-86	22.5	3.0	6.2
1927-73	27.3	3.6	11.3	1986-87	39.5	5.2	9.3
1973-74	171.7	22.7	22.7	1987-88	29.3	3.9	6.0
1974-75	35.8	4.7	8.0	1988-89	50.0	6.6	12.8
1975-76	0.0	0.0	0.0	1989-90	42.9	5.7	11.3
1976-77	42.6	5.6	10.0	1990-91	24.0	3.2	9.9
1977-78	43.9	5.8	10.3	1991-92	222.3	29.3	30.0
1978-79	45.8	6.0	16.0	1992-93	73.6	9.7	16.8
1979-80	138.2	18.2	19.9	1993-94	17.7	2.3	4.4
1980-81	81.9	10.8	15.0	1994-95	96.1	12.7	20.1
1981-82	45.4	6.0	9.8	1995-96	72.5	9.6	16.6
1982-83	156.4	20.6	19.1	1996-97	67.6	8.9	22.1
			Ave.		**66.5**	**8.8**	**14.4**

Annex 4.3-A: Aquifer Discharge through Wells' Abstraction

Well ID	X	Y	Z	Well Name	Aquifer	Abs-(CM)
18-14/001	186.74	149.55	62	Na'ran No.4	LA	1435057.8
18-14/002	189.52	145.15	-97	Jericho No.4	LA	1491364.3
18-14/003	188.26	146.83	-40.16	Jericho No.5	LA	1502577.2
18-15/001	181.45	155.25	446	Ein Samia No. 1	UA	599021.72
18-15/003	182.1	154	495	Ein Samia No. 3	UA	256365.17
18-15/003A	181.75	154.9	417	Ein Samia No. 3a	LA	644027.63
18-15/005	181.55	155.25	440	Ein Samia No. 5	LA	1070506.9
18-15/006	182.25	155.45	432	Ein Samia No. 6	LA	123421.2
18-15/007	182.1	153	430	Kuchav Hashahar	LA	150888.17
18-15/008	181	150.2	585	Reemuneem No.1	LA	127079.5
18-15/009	188.65	158.73	39.42	Fasayil No.8	LA	895379.17
18-15/010	189.12	156.73	9	Fasayil No.9	LA	1478817.6
18-15/011	187.36	151.15	-20	Na'ran No.2	LA	689245.48
18-15/012	186.95	150.1	95	Na'ran No.3	LA	942529.52
18-15/013	181.955	154.569	413	'Ein Samia No. 7	LA	327531
19-14/001	195.91	149.99	-268	private	Alluvium	131370.85
19-15/005	194.75	150.44	-242.04	private	Alluvium	100583.52
19-15/007	194.87	150.76	-250	private	Alluvium	71709.692
19-15/010	194.51	151.1	-247.216	private	Alluvium	69621
19-15/011	194.75	151	-251	private	Alluvium	107516.64
19-15/012	194.59	150.94	-248	private	Alluvium	81396.069
19-15/015	196.15	151.14	-277.8	private	Alluvium	307815.56
19-15/023	196.02	150.09	-273.211	private	Alluvium	87116.654
19-16/006	191.74	160	-240	Sumsam Nemer	Alluvium	36130.357
					Total	12,727,073

Annex 4.3-B: Aquifer Discharge through Spring Discharge

Spring ID	X	Y	Z	Spring Nam	Aquifer	Average Discharge C.M./yr
AC/060	190.05	144.66	-115	Al Dyuk	UC	4437737
AC/060A	190.04	144.72	-110	Al Nwai'mah	UC	2424324
AC/060B	190	144.8	-110	Al Shusah	UC	550397
AR/020	186.75	151.42	20	Al 'Auja	LC	8526493
AR/021	181.55	155.25	425	Samia	\	-
BA/090	180.03	155.8	740	Jurish	\	3293
BA/095	176.8	155.6	690	Seilun	\	6365
BA/106	170.5	155.4		Jilijliya Al Balac	\	1357
BA/126	171.6	151.2	750	Al Kabeerah	LC	6786
BA/127	171.6	151.05	760	Al Derrah	LC	6480
BA/128	171.55	151.05	750	Al Mgharah	LC	16588
BA/129	171.6	151.15	740	Al Daraj	LC	5286
BA/130	171.95	153.25	630	Al Sharqiyyah	LC	4504
BA/132	171.85	153.3	640	Shaikh Husain	LC	6876
BA/135A	170.55	152.2	645	Jifna Al Balad	LC	23306

لقياس كميات الجريان في الاودية نتيجة تدفق الينابيع،و التي يعتبر احد مصادر المياه السطحية في المنطقة، و لتقدير القدرة القصوي للخزان الجوفي لحفظ المياه و كميات المياه المتبقية في الخزان مع بداية السنة المائية الجديدة (الكساد) تم تحليل التدفق في الينابيع بطريقة تقديرفترة ركود التدفق من الينابيع الرئيسية ، والنتيجة كانت 42 و25.7 مليون متر مكعب في السنة على التوالي.

اما نتائج النموذج الرياضي بطريقة العرض التحليليي لتخمين كميات الضخ المتلى من المياه الجوفيّة للطبقة الجوفية السفلى في حقل ابار عين سامية. كان الضخ المثالي من الابار الموجودة حسب نتائج التحليل الرياضي المحوسب 7800 م 3 / يوم والذي يساوي 2.84 مليون متر مكعب/سنة، و يعني ذلك تخفيض كميات الضخ من 8900 م 3 / يوم إلى 7800 م 3 / يوم (3.24 إلى 2.84 مليون متر مكعب /سنة).

الملخّص

تقييم مصادر المياه في منطقة العوجا (المصبّ السطحي و الجوفي) كان القضية الرئيسية للدراسة في هذا البحث، من ناحية علاقة المطر و التدفق السطحي ، تدفق الينابيع ودراسة طاقة التخزين الجوفي للخزانات المغذية لهذه الينابيع (Spring Recession Analysis)، و ادارة الضخ و الانتاج المستديم لمصدر المياه المنزلي من الطبقة الجوفية السفلى لحوض عين سامية.

إنّ إختيار هذه المنطقة للدراسة مستند على أهميه فيما يتعلق بتجمع السكان، وبسبب حالة تزويد المياه الحرجة في هذه المنطقة المركزية، علاوةً على ذلك تكمن أهمية هذه المنطقة بأنها تمثل وتقع بشكل كلي ضمن الحوض المائي الجوفي الشرقي، الذي يعتبر الأكثر أهمية لإمداد المياه للفلسطينيين في المناطق الوسطى والجنوبية.

تحليل الامطار في الضفة الغربية يعاني من نقص في الدراسات الفعلية في منطقة المصبّات و الاحواض المائية الرئيسية لتخمين كميات الجريان السطحي والتغذية الجوفية. بينما تعتمد كلّ الدراسات على بعض القياسات لتدفق الوديان الرئيسية في الضفة الغربية وتعمّم هذه القيم على الوديان الاخرى تبعا لبعض النظرات التجريبية والتقديرات، و ذلك لعدم توفر نظام رصد شامل في منطقة الدراسة لقياس الامطار على الفترات القصيرة، لكن محطات المطر الحالية تؤخذ قرآتها بشكل يومي . لذلك كانت (Soil Conservation Surface) الانسب للتطبيق للدراسة و قياس علاقة المطر بالجريان السطحي ولإيجاد معامل التدفق، والتغذية الجوفية لمنطقة العوجا، ولتخمين الكمية السنوية للفيضان التي تحدث في وادي العوجا.

إنّ الأهداف الرئيسية للدراسة (1) لإجراء تقييم شامل لمنطقة المصب السطحي لوادي العوجا يتضمّن: تقييم مصادر المياه السطحيّة:علاقة المطر و الجريان السطحي بإستعمال (Soil Conservation Surface)، (2) تقييم مصادر المياه الجوفيّة ضمن الحوض الجوفي في منطقة العوجا: من حيث التغذية للخزان الجوفي، حركة المياه الجوفية، و الاستخراج سواء من الابار او الينابيع، (3) تقييم إنتاج المياه الجوفيّة من الطبقة الجوفية السفلى في حقل آبار عين سامية ، الذي يقع ضمن منطقة الدراسة و الذي يعتبر الاهم من حيث التزويد في منطقة الدراسة بإستعمال أداة العرض التحليلية ثنائية الأبعاد (Twodan Model).

وجدت الدراسة ان متوسط معامل الجريان السطحي من أي حدث مطري هو 6.7 %، ومتوسط معامل الجريان السطحي السنوي من المعدل السنوي العام للمطر 3.5 % ، حيث قدرت كميات الفيضان الكليّ في منطقة العوجا ومصب وادي العوجا 10.27و 2.70 مليون متر مكعب في السنة على التوالي. اما بالنسبة للتغذية المائية للخزان الجوفي في منطقة العوجا فكان حوالي 30 مليون متر مكعب في السنة و الذي يساوي إلى 11-15 % من معدل المطر السنوي.

تقييم مصادر المياه في مصب الحوض الجوفي والسطحي في منطقة العوجا الضفة الغربية- فلسطين

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كلية الدراسات العليا

معهد الدراسات المائية

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